LIST

Encyclopedia
Of
Cement , Concrete ,
Construction ,
&
Building Materials

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Accelerated Curing

Contents

1 – Introduction :

Accelerated Curing is any method by which high early age strength is achieved in concrete . These techniques are especially useful in the prefabrication industry, where in high early age strength enables the removal of the formwork within 24 hours, there by reducing the cycle time, resulting in cost-saving benefits . The most commonly adopted curing techniques are steam curing at atmospheric pressure, warm water curing, boiling water curing and autoclaving.

A typical curing cycle involves a preheating stage, known as the "delay period" ranging from 2 to 5 hours; heating at the rate of 22 °C / hour or 44 °C / hour until a maximum temperature of 50 − 82 °C has been achieved; then maintaining at the maximum temperature, and finally the cooling period. The whole cycle should preferably not exceed 18 hours.

2 - Mechanism :

At heightened temperatures, the hydration process moves more rapidly and the formation of the Calcium Silicate Hydrate crystals is more rapid. The formation of the gel and colloid is more rapid and the rate of diffusion of the gel is also higher. However, the reaction being more rapid leaves lesser time for the hydration products to arrange suitably, hence the later age strength or the final compressive strength attained is lower in comparison to normally cured concrete. This has been termed as the crossover effect.

The optimum temperature has been found to be between 65 and 70 °C, beyond which the losses in later age strength have been found to be considerably higher.

3 - Delay period :

Accelerated curing techniques invariably involve high temperatures. This may induce thermal stresses in the concrete. Further, the water in the pores starts to exert pressure at higher temperatures. The combined effect of the pore pressure and thermal stresses causes a tensile stress within the body of the concrete. If the accelerated curing process is begun immediately after the concrete has been poured, then the concrete will not be able to withstand the tensile stresses as it requires time to gain some strength. Moreover, these microcracks formed may then lead to the delayed formation of ettringite, which is formed by the transformation of meta stable mono sulfate. Delayed ettringite formation (DEF) induces expansion in the concrete thereby weakening it. DEF is promoted by the formation of the cracks which enables the easy entry of water. Therefore, a delay period is allowed to elapse before the commencement of the curing process to allow the concrete to gain a certain minimum tensile strength. The setting time of the concrete is an important criterion to determine the delay period. Generally, the delay period is equal to the initial setting time which has been found to give satisfactory results. Lesser delay periods result in compressive strength losses.

4 - Excessive temperatures :

As described earlier, excessive temperatures cause a drop in the Compressive strength due to the "crossover" effect. Higher temperatures would reduce the cycle time and therefore improve the economy of the manufacturing process, however, the compressive strength obtained would also be lower. Therefore, it is a trade-off between cost saving benefits and the loss in compressive strength. Depending on the type of project and economic considerations, either the cycle time is designed to suit the concrete mix or vice versa.

5 - Role of pozzolanic material :

Pozzolona increases the later age strength of concrete as it reacts with calcium hydroxide and turns it into calcium – silicate - hydrates (C-S-H). How ever portland pozzolona cements have higher activation energy and therefore, their rate of hydration is lower as compared to ordinary portland cement (OPC). This results in lower early age strength as compared to OPC. Accelerated curing techniques radically help to increase the rate of strength gain. Halit et al showed that steam curing improved the 1 day compressive strength values of high volume fly ash concrete mixtures (40 %, 50 % and 60 % fly ash by replacement) from 10 MPa to about 20MPa which is sufficient to enable the removal of formwork and greatly aids the precast concrete industry.

Autoclaved Aerated Concrete

الخرسانة خفيفة الوزن

Stacked blocks of AAC (wrapped in foil)

Contents

1 – Introduction :

Autoclaved aerated concrete (AAC) , also known as **autoclaved cellular concrete** (ACC) or **autoclaved light weight concrete** (ALC) , was invented in the mid-1920s by the Swedish architect and inventor Johan Axel Eriksson . It is a light weight, precast building material that simultaneously provides structure , insulation, and fire and mold resistance. AAC products include blocks, wall panels, floor and roof panels, and lintels.

It has been refined into a highly thermally insulating concrete - based material used for both internal and external construction. Besides AAC's insulating capability, one of its advantages in construction is its quick and easy installation , for the material can be routed , sanded , and cut to size on site using standard carbon steel band saws , hand saws , and drills .

Even though regular cement mortar can be used, 98% of the buildings erected with AAC materials use thin bed mortar, which comes to deployment in a thickness of ⅛ inch. This varies according to national building codes and creates solid and compact building members. AAC material can be coated with a stucco compound or plaster against the elements. Siding materials such as brick or vinyl siding can also be used to cover the outside of AAC materials.

AAC has been produced for more than 70 years , and it offers advantages over other cementitious construction materials, one of the most important being its lower environmental impact.

- AAC’s improved thermal efficiency reduces the heating and cooling load in buildings.
- AAC’s work ability allows accurate cutting , which minimizes the generation of solid waste during use.
- AAC’s resource efficiency gives it lower environmental impact in all phases of its life cycle, from processing of raw materials to the disposal of AAC waste.
- AAC’s light weight also saves cost & energy in transportation.
- AAC's light weight saves labour

2 - Raw materials :

Unlike most other concrete applications, AAC is produced using no aggregate larger than sand. Quartz sand, lime, and / or cement and water are used as a binding agent . Aluminum powder is used at a rate of 0.05 % – 0.08 % by volume (depending on the pre - specified density) . When AAC is mixed and cast in forms , several chemical reactions take place that give AAC its light weight (20 % of the weight of concrete) and thermal properties . Aluminum powder reacts with calcium hydroxide and water to form hydrogen. The hydrogen gas foams and doubles the volume of the raw mix (creating gas bubbles up to 3 mm in diameter) . At the end of the foaming process, the hydrogen escapes into the atmosphere and is replaced by air.

When the forms are removed from the material, it is solid but still soft . It is then cut into either blocks or panels , and placed in an autoclave chamber for 12 hours . During this steam pressure hardening process , when the temperature reaches 190° and the pressure reaches 8 to 12 bars , quartz sand reacts with calcium hydroxide to form calcium silica hydrate, which accounts for AAC's high strength and other unique properties. After the autoclaving process, the material is ready for immediate use on the construction site. Depending on its density, up to 80 % of the volume of an AAC block is air. AAC's low density also accounts for its low structural compression strength. It can carry loads of up to 8 MPa (1,160 PSI) , approximately 50 % of the compressive strength of regular concrete.

Since 1980, there has been a world wide increase in the use of AAC materials. New production plants are being built in the USA, Eastern Europe , China , Bahrain , India , and Australia . AAC is increasingly used by developers, architects, and home builders.

3 - History :

The material was perfected in the mid - 1920s by Dr. Johan Axel Eriksson, an architect working with Professor Henrik Kreüger at the Royal Institute of Technology . It went into production in Sweden in 1929 in a factory in Hällabrottet and became very popular. In the 1940s, the trade mark *Ytong* was introduced, but it was often referred to as "blue concrete" in Sweden due to its bluefish tinge . This version of Ytong was produced from alum slate , whose combustible carbon content made it beneficial to use in the production process. The competing concrete brand *Siporex* used other raw materials. How ever, the slate deposits used for Ytong also contain uranium, which makes the material give off small amounts of radio active radon gas to the surrounding air. In 1972, the Swedish Radiation Safety Authority pointed out the unsuitability of a radon - emitting construction material, and the use of alum slate in the production of Ytong ceased in 1975. Ytong produced after 1975 has used raw materials without the uranium content.

AFm phase

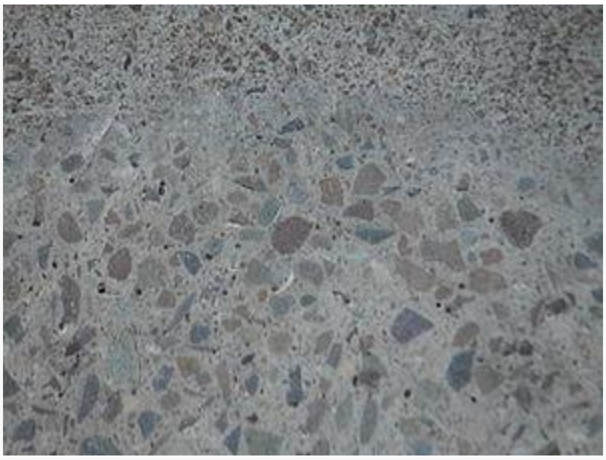
An **AFm phase** is an "alumina, ferric oxide, mono sulfate" phase. AFm phases are important in the hydration of hydraulic cements.

They are crystalline hydrates with general, simplified formula :

$$3\,CaO \cdot (Al,Fe)_2O_3 \cdot CaSO_4 \cdot n\,H_2O.$$

They form *inter alia* when tri calcium aluminate reacts with dissolved calcium sulfate.

Aggregate Composite



Grinding concrete exposes aggregate stones.

Contents

1 – Introduction :

Aggregate is the component of a **composite** materials that resists compressive stress and provides bulk to the composite material. For efficient filling, aggregate should be much smaller than the finished item, but have a wide variety of sizes. For example, the particles of stone used to make concrete typically include both sand and gravel.

2 - Comparison to fiber composites :

Aggregate composites tend to be much easier to fabricate, and much more predictable in their finished properties, than *fiber composites*. This is because fiber orientation and continuity can have an overwhelming effect, but can be difficult to control and assess. Fabrication aside, aggregate materials themselves also tend to be less expensive; the most common aggregates (mentioned above) are found in nature and can often be used with only minimal processing.

Not all composite materials include aggregate in their design. This is because aggregate particles tend to have about the same dimensions in every direction (that is, an aspect ratio of about one), so that aggregate composites do not display the level of synergy that fiber composites often do. A strong aggregate held together by a weak matrix will be weak in tension, whereas fibers can be less sensitive to matrix properties, especially if they are properly oriented and run the entire length of the part (i.e., a *continuous filament*).

Most composites are filled with particles whose aspect ratio lies somewhere between oriented filaments and spherical aggregates. A good compromise is *chopped fiber*, where the performance of filament or cloth is traded off in favor of more aggregate-like processing techniques. Ellipsoid and plate-shaped aggregates are also used.

3 - Aggregate properties :

In most cases, the ideal finished piece would be 100 % aggregate. A given application's most desirable quality (be it high strength, low cost, high dielectric constant, or low density) is usually most prominent in the aggregate itself; all the aggregate lacks is the ability to flow on a small scale, and form attachments between particles. The matrix is specifically chosen to serve this role, but its abilities should not be abused.

4 - Aggregate size :

Experiments and mathematical models show that more of a given volume can be filled with hard spheres if it is first filled with large spheres, then the spaces between (interstices) are filled with smaller spheres, and the new interstices filled with still smaller spheres as many times as possible. For this reason, control of *particle size distribution* can be quite important in the choice of aggregate;

appropriate simulations or experiments are necessary to determine the optimal proportions of different-sized particles.

The upper limit to particle size depends on the amount of flow required before the composite sets (the gravel in paving concrete can be fairly coarse, but fine sand must be used for tile mortar) , whereas the lower limit is due to the thickness of matrix material at which its properties change (clay is not included in concrete because it would "absorb" the matrix, preventing a strong bond to other aggregate particles). Particle size distribution is also the subject of much study in the fields of ceramics and powder metallurgy.

Some exceptions to this rule include :

4 - 1 - Toughened composites :

Toughness is a compromise between the (often contradictory) requirements of strength and plasticity. In many cases, the aggregate will have one of these properties, and will benefit if the matrix can add what it lacks. Perhaps the most accessible examples of this are composites with an organic matrix and ceramic aggregate, such as asphalt concrete ("tarmac") and filled plastic (i.e., Nylon mixed with powdered glass), although most metal matrix composites also benefit from this effect. In this case, the correct balance of hard and soft components is necessary or the material will become either too weak or too brittle.

4 - 2 - Nano composites :

Many materials properties change radically at small length scales . In the case where this change is desirable, a certain range of aggregate size is necessary to ensure good performance. This naturally sets a lower limit to the amount of matrix material used.

Unless some practical method is implemented to orient the particles in micro- or nano-composites, their small size and (usually) high strength relative to the particle-matrix bond allows any macroscopic object made from them to be treated as an aggregate composite in many respects.

While bulk synthesis of such nano particles as carbon nano tubes is currently too expensive for widespread use, some less extreme nano structured materials can be synthesized by traditional methods, including electro spinning and spray pyrolysis . One important aggregate made by spray pyrolysis is glass microspheres. Often called *micro balloons* , they consist of a hollow shell several tens of nanometers thick and approximately one micrometer in diameter. Casting them in a polymer matrix yields syntactic foam, with extremely high compressive strength for its low density.

Many traditional nano composites escape the problem of aggregate synthesis in one of two ways:

4 - 3 - Natural aggregates :

By far the most widely-used aggregates for nano - composites are naturally occurring. Usually these are ceramic materials whose crystalline structure is extremely directional, allowing it to be easily separated into flakes or fibers. The nanotechnology touted by General Motors for automotive use is in the former category: a fine-grained clay with a laminar structure suspended in a thermoplastic olefin (a class which includes many common plastics like polyethylene and polypropylene). The latter category includes fibrous asbestos composites (popular in the mid-20th century), often with matrix materials such as linoleum and Portland cement.

4 - 4 - In - situ aggregate formation :

Many micro-composites form their aggregate particles by a process of self-assembly. For example, in high impact polystyrene, two immiscible phases of polymer (including brittle polystyrene and rubbery poly butadiene) are mixed together. Special molecules (graft copolymers) include separate portions which are soluble in each phase, and so are only stable at the interface between them, in the manner of a detergent. Since the number of this type of molecule determines the interfacial area, and since spheres naturally form to minimize surface tension, synthetic chemists can control the size of poly butediene droplets in the molten mix, which harden to form rubbery aggregates in a hard matrix. Dispersion strengthening is a similar example from the field of metallurgy. In glass-ceramics, the aggregate is often chosen to have a negative coefficient of thermal expansion, and the proportion of aggregate to matrix adjusted so that the overall expansion is very near zero. Aggregate size can be reduced so that the material is transparent to infrared light.

Air Entrainment

Contents

1 – Introduction :

Air entrainment is the intentional creation of tiny air bubbles in concrete. The bubbles are introduced into the concrete by the addition to the mix of an air entraining agent, a surfactant (surface-active substance, a type of chemical that includes detergents). The air bubbles are created during mixing of the plastic (flow able , not hardened) concrete, and most of them survive to be part of the hardened concrete. The primary purpose of air entrainment is to increase the durability of the hardened concrete, especially in climates subject to freeze-thaw; the secondary purpose is to increase workability of the concrete while in a plastic state.

While hardened concrete appears solid, it is porous, having small capillaries resulting from the evaporation of water beyond that required for the hydration reaction . A water : cement ratio (w / c) of approximately 0.25 (this means 25 parts water for every 100 parts cement) is required for all the cement particles to hydrate. Water beyond that is surplus and is used to make the plastic concrete more workable or flow able. Most concrete has a w/c of 0.45 to 0.60, which means there is substantial excess water that will not react with cement. Eventually the excess water evaporates, leaving little pores in its place. Environmental water can later fill these voids. During freeze-thaw cycles, the water occupying those pores expands and creates stresses which lead to tiny cracks. These cracks allow more water into the concrete and the cracks enlarge. Eventually the concrete spalls - chunks break off. The failure of reinforced concrete is most often due to this cycle, which is accelerated by moisture reaching the reinforcing steel. Steel expands when it rusts, and these forces create even more cracks, letting in more water.

The air bubbles are typically 10 to 500 micro meters in diameter (0.0004 to 0.02 in) and are closely spaced. The air bubble can be compressed a little, and so the bubbles act to reduce or absorb stresses from freezing. Air entraining was introduced in the 1930s and most modern concrete, especially if subjected to freezing temperatures, is air-entrained. The bubbles contribute to workability by acting as a sort of lubricant for all the aggregates and large particles in a concrete mix.

In addition to entrained air, hardened concrete also contains entrapped air. These are larger bubbles, and are typically less evenly distributed than entrained air. Entrapped air is considered to not make a positive contribution to durability and is undesirable though not entirely avoidable.

2 - Air entrainment in hydraulic structures :

In hydraulic engineering, air bubble entrainment is defined as the entrapment of air bubbles and pockets that are advected within the turbulent flow . The entrainment of air packets can be localised or continuous along the air – water interface. Examples of localized aeration include air entrainment by plunging water jet and at hydraulic jump. Bubbles are entrained locally at the intersection of the impinging jet with the surrounding waters. The intersecting perimeter is a singularity in terms of both air entrainment and momentum exchange, and the air is entrapped at the discontinuity between the impinging jet flow and the receiving pool of water. Interfacial aeration is defined as the air entrainment process along an air–water interface, usually parallel to the flow direction.

In hydraulic structures , free - surface aeration is commonly observed: i.e., the white waters. The air bubble entrainment may be localised or continuous along an interface (water jets, spillway chutes). Despite recent advances, there are some basic concerns about the extrapolation of laboratory results to large size prototype structures.[2]

Alabaster

	
Alabaster vase from the tomb of Tutankhamun	*An up lighter lamp made from Italian alabaster of white and brown types ; the base is 5 inches in diameter*

Contents

1 – Introduction ;

Alabaster is a name applied to varieties of two distinct minerals, when used as a material : gypsum (a hydrous sulfate of calcium) and calcite (a carbonate of calcium) . The latter is the alabaster of the present day; generally, the former is the alabaster of the ancients. Both are easy to work, with an attractive appearance, and have been used for making a variety of artworks and objects, especially small carvings.

The two kinds are distinguished from one another readily, because of differences in their relative hardness. The gypsum kind is so soft as to be readily scratched with a fingernail (Mohs hardness 1.5 to 2) , while the calcite kind is too hard to be scratched in this way (Mohs hardness 3) , although it does yield readily to a knife. Moreover, the calcite alabaster, being a carbonate, effervesces upon being touched with hydrochloric acid, whereas the gypsum alabaster, when thus treated, remains practically unaffected.

Due to the characteristic color of white alabaster, the term has entered the vernacular as a metonym for white things, particularly "alabaster skin", which means very light and quite transparent, and possibly derives from the use of alabaster for tomb effigies.

2 – Etymology :

The origin of the word *alabaster* is in Middle English, through Old French *alabastre*, in turn derived from the Latin *alabaster* and that from Greek *alabastros* or *alabastos* . The latter was a term used to identify a vase made of alabaster.

This name may derive further from the Ancient Egyptian word *a-labaste*, which refers to vessels of the Egyptian goddess Bast. She was represented as a lioness and frequently depicted as such in figures placed atop these alabaster vessels . Other suggestions include derivation from the town of Alabastron in Egypt .

3 – Types :

3 – 1 - Calcite alabaster :

This substance, the "alabaster" of the Ancient Egyptians and Bible, often is termed *Oriental alabaster*, since the early examples came from the Far East. The Greek name *alabastrites* is said to be derived from the town of Alabastron , in Egypt , where the stone was quarried. The locality probably owed its name to the mineral; the origin of the mineral name is obscure.

The "Oriental" alabaster was highly esteemed for making small perfume bottles or ointment vases called alabastra , the vessel name has been suggested as a possible source of the mineral name. In Egypt craftsmen used alabaster for canopic jars and various other sacred and sepulchral objects. A sarcophagus, sculptured in a single block of translucent calcite alabaster from Alabastron, is in the Sir John Soane's Museum, London. This was discovered by Giovanni Belzoni in 1817 in the tomb of Seti I near Thebes. It was purchased by Sir John Soane.

When cut in thin sheets, alabaster is translucent enough to be used for small windows. It was used for this purpose in medieval churches, especially in Italy. Large alabaster sheets are used extensively in the contemporary Cathedral of Our Lady of the Angels, which was dedicated in 2002 by the Los Angeles, California Archdiocese. The cathedral incorporates special cooling to prevent the panes from overheating and turning opaque.

Calcite alabaster is found as either a stalagmitic deposit, from the floor and walls of limestone caverns, or as a kind of travertine, similarly deposited in springs of calcareous water. Its deposition in successive layers gives rise to the banded appearance that the marble often shows on cross-section, whence it is known as onyx-marble or alabaster-onyx, or sometimes simply as onyx. The latter term should be restricted to siliceous minerals, however.

Egyptian alabaster has been worked extensively near Suez and Assiut. Many ancient quarries are found in the hills overlooking the plain of Tell el Amarna.

Algerian onyx - marble has been quarried largely in the province of Oran. In Mexico, there are famous deposits of a delicate green variety at La Pedrara, in the district of Tecali, near Puebla. Onyx-marble occurs also in the district of Tehuacán and at several localities in California, Arizona, Utah, Colorado, and Virginia.

3 – 2 - Gypsum alabaster :

When the term "alabaster" is used with out any qualification, it invariably means a fine-grained variety of gypsum. This mineral, or alabaster proper, occurs in England. The early use of alabaster for vessels dedicated for use in the cult of the deity Bast in the culture of the Ancient Egyptians is well documented, however, thousands of gypsum alabaster artifacts dating to the late 4th millennium BC also have been found in Tell Brak (present day Nagar), in Syria. In Mesopotamia, a gypsum alabaster sculpture, believed to represent the deity, Abu, dates to the first half of the 3rd millennium BC.

Gypsum alabaster is a common mineral, which occurs in England in the Keuper marls of the Midlands, especially at Chellaston in Derbyshire, at Fauld in Staffordshire, and near Newark in Nottinghamshire. Deposits at all of these localities have been worked extensively. In the fifteenth century its carving into small statues and sets of relief panels for altarpieces was a valuable local industry in Nottingham, as well as a major English export. These were usually painted, or partly painted. It was also used for the effigies, often life size, on tomb monuments, as the typical recumbent position suited the material's lack of strength, and it was cheaper and easier to work than good marble. Beside examples of these carvings still in Britain (especially at the Nottingham Castle Museum, British Museum, and Victoria and Albert Museum), trade in mineral alabaster (rather than just the antiques trade) has scattered examples in the material that may be found as far afield as the Musée de Cluny, Spain, and Scandinavia.

Alabaster also is found, although in smaller quantity, at Watchet in Somerset, near Penarth in Glamorganshire, and elsewhere. In Cumbria it occurs largely in the New Red rocks, but at a lower geological horizon. The alabaster of Nottinghamshire and Derbyshire is found in thick nodular beds or "floors" in spheroidal masses known as "balls" or "bowls" and in smaller lenticular masses termed "cakes." At Chellaston, where the local alabaster is known as "Patrick," it has been worked into ornaments under the name of "Derbyshire spar"—a term more properly applied to fluorspar.

In Europe, the centre of the alabaster trade today is Florence, Italy. Tuscan alabaster occurs in nodular masses embedded in limestone, interstratified with marls of Miocene and Pliocene age. The mineral is worked largely by means of underground galleries, in the district of Volterra. Several varieties are recognized—veined, spotted, clouded, agatiform, and others. The finest kind, obtained principally from Castellina, is sent to Florence for figure-sculpture, while the common kinds are carved locally, into vases, lights, and various ornamental objects. These items are objects of extensive trade, especially in Florence, Pisa, and Livorno. Spain and many other countries have deposits which have been worked.

3 – 3 - Black alabaster :

Photograph of an alabaster cosmetic jar topped with a lioness, representing the goddess Bast, a burial artifact from the tomb of Tutankhamun circa 1323 B.C.— Cairo Museum

Black alabaster is a rare form of the gypsum-based mineral. This black form is only found in three veins in the world, one each in Oklahoma, Italy, and China.

Alabaster Caverns State Park, near Freedom, Oklahoma is home to a natural gypsum cave in which much of the gypsum is in the form of alabaster. There are several types of alabaster found at the site, including pink, white, and the rare black alabaster.

4 - Uses :

The finer kinds of alabaster are employed largely as an ornamental stone, especially for ecclesiastical decoration and for the rails of staircases and halls. Its softness enables it to be carved readily into elaborate forms, but its solubility in water renders it unsuitable for outdoor work. If alabaster with a smooth, polished surface is washed with washing-up liquid (dishwashing liquid), it will become rough, dull and whiter, losing most of its translucency and lustre.

The purest alabaster is a snow-white material of fine tiniforni grain, but it often is associated with an oxide of iron, which produces brown clouding and veining in the stone. The coarser varieties of alabaster are converted by calcination into plaster of Paris, whence they sometimes are known as "plaster stone."

In order to diminish the translucency of the alabaster and to produce an opacity suggestive of true marble, the statues are immersed in a bath of water and heated gradually—nearly to the boiling-point—an operation requiring great care, for if the temperature is not regulated carefully, the stone acquires a dead-white, chalky appearance. The effect of heating appears to be a partial dehydration of the gypsum. If properly treated, it very closely resembles true marble and is known as marmo di Castellina.

Sulphate of lime (gypsum) also was used by the ancients. It was employed, for instance, in Assyrian sculpture. So some of the ancient alabaster is identical to the modern stone.

Alabaster may be stained to disguise it, by being heated in various pigmentary solutions. In this way a very misleading imitation of coral that is called alabaster coral is produced.

Alite

Contents

1 - Introduction :

Alite is a name for tri calcium silicate , Ca_3SiO_5, some times formulated as $3CaO \cdot SiO_2$ (C_3S in cement chemist notation, CCN) . It is the major, and characteristic, mineral phase in Portland cement. The name was given by Törneborn in 1897 to a crystal identified in microscopic investigation of Portland cement . Alite is a name in common use in the cement industry, although it is not a recognised mineral name.

2 - Composition and Structure :

The alite found in Portland cement differs in composition from simple tri calcium silicate. It is a solid solution and contains minor amounts of other oxides besides Ca O and SiO_2 . A typical composition is :

Oxide	Mass %
Ca O	71.6
SiO_2	25.2
Al_2O_3	1.0
Fe_2O_3	0.7
Mg O	1.1
Na_2O	0.1
K_2O	0.1
P_2O_5	0.2

Based on this , the formula can be expressed as $Ca_{2.90}Mg_{0.06}Na_{0.01}Fe_{0.03}Al_{0.04}Si_{0.95}P_{0.01}O_5$. In practice, the composition varies with the bulk composition of the clinker, subject to certain limits. Substitution of calcium ions or ortho silicate ions requires that electric charges be kept in balance. For instance, a limited number of ortho silicate (SiO_4^{4-}) ions can be replaced with sulfate (SO_4^{2-}) ions, provided that for each sulfate ion, two aluminate (AlO_4^{5-}) ions are also substituted.

3 - Poly morphs :

Tri calcium silicate is thermo dynamically unstable below 1250 °C, but can be preserved in a meta stable state at room temperature by fast cooling: on slow cooling it tends to revert to belite (Ca_2SiO_4) and CaO.

As the temperature changes, it passes through several poly morphic states:

Temp°	Name	Crystal
> 1070	R	Rhombohedral
1060 - 1070	M_3	Monoclinic
990 - 1060	M_2	Monoclinic
980 - 990	M_1	Monoclinic
920 - 980	T_3	Triclinic
620 - 920	T_2	Triclinic
< 620	T_1	Triclinic

The polymorphs differ structurally by minor deformations from the basic hexagonal structure.

4 – Hydration :

Alite is the mineral in Portland cement responsible for setting and development of "early" strength. The other silicate , belite contributes "late" strength, due to its lower reactivity. Alite is more reactive because of its higher Ca content, and the presence of an oxide ion in the lattice. It reacts with water (roughly) according to the reaction :

$$2Ca_3 Si O_5 + 6 H_2 O \rightarrow 3CaO \cdot 2 Si O_2 \cdot 3H_2O + 3Ca (OH)_2$$

Which can also be written in the cement chemist notation (CCN) as :

$$2 C_3S + 6 H \rightarrow C_3 S_2 H_3 + 3 CH$$

2 alite + 6 H_2O → C - S - H + 3 portlandite

The hydrate is referred to as the calcium silicate hydrate – "C-S-H" – phase. It grows as a mass of inter locking needles that provide the strength of the hydrated cement system. High alite reactivity is desirable in Portland cement manufacture, and this is achieved by retaining, as far as possible, high temperature polymorphs, in crystals that are small, distorted and highly defective. Defects provide sites for initial water attack.

5 - Alite as precursor of silicate phases found in medieval lime mortar :

The composition of alite rich in Ca O (71.6 wt . %) and relatively poor in Si O_2 (25.2 wt. %) may help to understand why in particular conditions, if a sufficiently high temperature is reached in a lime kiln during enough time, alite can also be directly formed by pyrolizing only siliceous limestone (containing amorphous SiO_2 impurities up to 25 – 30 wt. %). Hydraulic mortar or pre-Portland cement may have been occasionally produced on a small scale in this way during the medieval epoch in locations where limestone was cemented by amorphous silica or contained chert nodules or a lot of clay impurities.

This is likely the reason why some old medieval lime mortars used to build the Tournai cathedral (Belgium) exhibit an unexpected hydraulic character as revealed by a mineralogical study made by Mertens *et al*. (2006) who evidenced the presence of wollastonite and rankinite along with CSH phases in lime mortars. The only explanation for the discovery of these silicate phases not normally expected in lime mortar is that they have been formed by the hydration of calcium silicate such as Ca_3SiO_5 (C_3S) or Ca_2SiO_4 (C_2S) formed at high temperature along calcium oxide in the lime kiln. Indeed, in the area of Tournai (Belgium), the Tournaisian lime stones are particularly rich in amorphous silica and exploited as building stone and for making lime mortar since very ancient ages. It is presently unknown if the cathedral builders of this area were aware of the hydraulic properties of their lime mortar or intentionally developed its use after their fortuitous finding.

Alkali – Aggregate Reaction

1 – Introduction :

Alkali – aggregate reaction is a term mainly referring to a reaction which occurs over time in concrete between the highly alkaline cement paste and non - crystalline silicon dioxide , which is found in many common aggregates. This reaction can cause expansion of the altered aggregate, leading to spelling and loss of strength of the concrete.

2 - More accurate terminology :

The **alkali – aggregate reaction** is a general, but relatively vague , expression which can lead to confusion. Actually, it is recommended to refer to a more precise definition such as one of the following :

1. Alkali – silica reaction (ASR, main article to read first) ;
2. Alkali – silicate reaction , and ;
3. Alkali – carbonate reaction.

The alkali – silica reaction is the most common form of alkali– aggregate reaction .

Two other types are :

- ***the alkali–silicate reaction*** , in which layer silicate minerals (clay minerals) , some times present as impurities , are attacked, and ;
- ***the alkali – carbonate reaction*** , which is an uncommon attack on certain argillaceous dolomitic lime stones, likely involving the expansion of the mineral Brucite ($Mg(OH)_2$

The Pozzolanic reaction which occurs in the setting of the mixture of slaked lime and pozzolanic materials has also features similar to the alkali – silica reaction , mainly the formation of calcium silicate hydrate (CSH) .

Alkali – Carbonate Reaction

The **alkali – carbonate reaction** is a process suspected for the degradation of concrete containing dolomite aggregate.

Alkali from the cement might react with the dolomite crystals present in the aggregate inducing the production of brucite (Mg OH) $_2$ and calcite ($CaCO_3$) . This mechanism was tentatively proposed by Swenson and Gillott (1950) and may be written as follows :

$$CaMg(CO_3)_2 + 2\,NaOH \longrightarrow CaCO_3 + Na_2CO_3 + Mg(OH)_2$$

Brucite ($Mg(OH)_2$) , could be responsible for the volumetric expansion after de - dolomotisation of the aggregate , due to absorption of water.

Alkali – Silica Reaction (ASR)

Characteristic crack pattern associated with the alkali–silica reaction affecting a concrete step barrier on an US motor way .

Contents

- 1 Introduction
- 2 Mitigation

1 – Introduction :

The **alkali – silica reaction** (**ASR**) is a reaction which occurs over time in concrete between the highly alkaline cement paste and reactive non - crystalline (amorphous) silica , which is found in many common aggregates .

The ASR reaction is the same as the Pozzolanic reaction which is a simple acid - base reaction between calcium hydroxide, also known as Portlandite , or $Ca(OH)_2$, and silicic acid H_4SiO_4, or $Si(OH)_4$. For the sake of simplicity, this reaction can be schematically represented as following :

$$Ca(OH)_2 + H_4SiO_4 \rightarrow Ca^{2+} + H_2SiO_4^{2-} + 2\ H_2O \rightarrow CaH_2SiO_4 \cdot 2\ H_2O$$

This reaction causes the expansion of the altered aggregate by the formation of a swelling gel of Calcium Silicate Hydrate (CSH) . This gel increases in volume with water and exerts an expansive pressure inside the material, causing spelling and loss of strength of the concrete, finally leading to its failure.

So, ASR can cause serious expansion and cracking in concrete, resulting in critical structural problems that can even force the demolition of a particular structure.

The mechanism of ASR causing the deterioration of concrete can be described in four steps as follows:

1. The alkaline solution attacks the siliceous aggregate to convert it to viscous alkali silicate gel.
2. Consumption of alkali by the reaction induces the dissolution of Ca^{2+} ions into the cement pore water. Calcium ions then react with the gel to convert it to hard calcium silicate hydrate.
3. The penetrated alkaline solution converts the remaining siliceous minerals into bulky alkali silicate gel. The resultant expansive pressure is stored in the aggregate.
4. The accumulated pressure cracks the aggregate and the surrounding cement paste when the pressure exceeds the tolerance of the aggregate .

2 - Mitigation :

ASR can be mitigated in concrete by three complementary approaches :

1. **Limit the alkali metal content of the cement**. Many standards impose limits on the "Equivalent Na_2O" content of cement.
2. **Limit the reactive silica content of the aggregate**. Certain volcanic rocks are particularly susceptible to ASR because they contain volcanic glass (obsidian) and should not be used as aggregate. The use of calcium carbonate aggregates is sometimes envisaged as an ultimate solution to avoid any problem. However, while it may be considered as a necessary condition, it is not a sufficient one. In principle, limestone ($CaCO_3$) is not expected to contain high level of silica, but it actually depends on its purity. Indeed, some siliceous lime stones (a.o., *Kieselkalk* found in Switzerland) may be cemented

by amorphous or poorly crystalline silica and can be very sensitive to the ASR reaction as observed with some siliceous lime stones exploited in quarries in the area of Tournai in Belgium . So, the use of limestone as aggregate is not a guarantee against ASR in itself. The silica content of the limestone and its reactivity must remain below a threshold value that has to be carefully experimentally assessed by the aggregate producer.

3. Add very fine siliceous materials to neutralize the excessive alkalinity of cement with silicic acid by voluntary provoking a controlled pozzolanic reaction at the early stage of the cement setting. Convenient pozzolanic materials to add to the mix may be, *e.g.*, pozzolan , silica fume , fly ashs , or meta kaolin . These react preferentially with the cement alkalis without formation of an expansive pressure, because siliceous minerals in fine particles convert to alkali silicate and then to calcium silicate without formation of semi permeable reaction rims.

In other words, as it is sometimes possible *to fight the fire by the fire*, it is also feasible to combat the ASR reaction by itself. A prompt reaction initiated at the early stage of concrete hardening on very fine silica particles will help to suppress a slow and delayed reaction with large siliceous aggregates on the long term. Following the same principle, the fabrication of low - pH cement also implies the addition of finely divided pozzolanic materials rich in silicic acid to the concrete mix to decrease its alkalinity.

Anhydrite

Anhydrite, Chihuahua, Mexico

Contents

1 - Introduction :

Anhydrite is a mineral – anhydrous calcium sulfate, $CaSO_4$. It is in the orthorhombic crystal system, with three directions of perfect cleavage parallel to the three planes of symmetry. It is not iso morphous with the orthorhombic barium (baryte) and strontium (celestine) sulfates, as might be expected from the chemical formulas. Distinctly developed crystals are somewhat rare, the mineral usually presenting the form of cleavage masses. The hardness is 3.5 and the specific gravity 2.9. The color is white, sometimes greyish, bluish or purple. On the best developed of the three cleavages the lustre is pearly, on other surfaces it is vitreous. When exposed to water, anhydrite readily transforms to the more commonly occurring gypsum, ($CaSO_4 \cdot 2H_2O$) by the absorption of water. This transformation is reversible, with gypsum or calcium sulfate hemi hydrate forming anhydrite by heating to ~200°C under normal atmospheric conditions . Anhydrite is commonly associated with calcite, halite, and sulfides such as galena , chalcopyrite , molybdenite and pyrite in vein deposits.

Category	Sulfate mineral
Chemical Formula	Anhydrous calcium sulfate : $CaSO_4$
Unit cell	a = 6.245 Å , b = 6.995 Å , c = 6.993 Å ; Z = 4
Color	Colorless to pale blue or violet if transparent ; white, mauve, rose, pale brown or gray from included impurities
Crystal system	Orthorhombic – dipyramidal
Mohs scale hardness	3.5
Streak	White
Diaphaneity	Transparent to translucent
Specific gravity	2.97
Optical properties	Biaxial (+)
Refractive index	$n_\alpha = 1.567 – 1.574$ $n_\beta = 1.574 – 1.579$ $n_\gamma = 1.609 – 1.618$
Pleochroism	For violet varieties X = colorless to pale yellow or rose Y = pale violet or rose Z = violet.

2 - Occurrence :

Anhydrite is most frequently found in evaporite deposits with gypsum ; it was , for instance, first discovered, in 1794, in a salt mine near Hall in Tirol. In this occurrence depth is critical since nearer the surface anhydrite has been altered to gypsum by absorption of circulating ground water.

From an aqueous solution calcium sulfate is deposited as crystals of gypsum, but when the solution contains an excess of sodium or potassium chloride anhydrite is deposited if temperature is above 40 °C. This is one of the several methods by which the mineral has been prepared artificially, and is identical with its mode of origin in nature, the mineral is common in salt basins.

2 – 1 - Tidal flat nodules :

Anhydrite occurs in a tidal flat environment in the Persian Gulf sabkhas as massive diagenetic replacement nodules. Cross sections of these nodular masses have a *netted* appearance and have been referred to as *chicken wire anhydrite*. Nodular anhydrite occurs as replacement of gypsum in a variety of sedimentary depositional environments.[6]

2 – 2 - Salt dome cap rocks :

Massive amounts of anhydrite occur when salt domes form a caprock. Anhydrite is 1–3 % of the salt in salt domes and is generally left as a cap at the top of the salt when the halite is removed by pore waters. The typical cap rock is a salt, topped by a layer of anhydrite, topped by patches of gypsum, topped by a layer of calcite.[7] Interaction with oil can reduce SO_4 creating calcite, water, and hydrogen sulfide (H_2S) .

3 - Naming history :

The name anhydrite was given by A. G. Werner in 1804, because of the absence of water of crystallization, as contrasted with the presence of water in gypsum. Some obsolete names for the species are muriacite and karstenite ; the former, an earlier name, being given under the impression that the substance was a chloride (muriate). A peculiar variety occurring as contorted concretionary masses is known as tripe-stone, and a scaly granular variety, from Volpino, near Bergamo, in Lombardy , as vulpinite ; the latter is cut and polished for ornamental purposes.

Asbestos

	
Asbestos	*Fibrous tremolite asbestos on muscovite*
	
Blue asbestos (crocidolite) from Wittenoom , Western Australia.	*Asbestos*

Contents

1 – Introduction :

Asbestos is a set of six naturally-occurring silicate minerals used commercially for their desirable physical properties . They all have in common their eponymous, asbestiform habit: long (ca. 1:20 aspect ratio), thin fibrous crystals. The prolonged inhalation of asbestos fibers can cause serious illnesses, including malignant lung cancer, mesothelioma (a formerly-rare cancer strongly associated with exposure to amphibole asbestos), and asbestosis (a type of pneumoconiosis). Long exposure to high concentrations of asbestos fibers will cause health problems. This is most common among the miners of asbestos, since they have the longest exposure to it. The European Union has banned all use of asbestos and extraction, manufacture and processing of asbestos products.

Asbestos became increasingly popular among manufacturers and builders in the late 19th century because of its sound absorption, average tensile strength, its resistance to fire, heat, electrical and chemical damage, and affordability. It was used in such applications as electrical insulation for hotplate wiring and in building insulation. When asbestos is used for its resistance to fire or heat, the fibers are often mixed with cement (resulting in fiber cement) or woven into fabric or mats.

Asbestos mining began more than 4,000 years ago, but didn't start large scale until the end of the 19th century. The world's asbestos mining peaked around 1975, when asbestos was being mined in some 25 countries, but is today less than half of what it was in the mid 1970s. For a long time, the world's largest asbestos mine was the Jeffrey mine in the town of Asbestos, Quebec.

2 - Types and associated fibers :

Six minerals are defined by the United States Environmental Protection Agency as "asbestos" including those belonging to the serpentine class chrysotile and those belonging to the amphibole class amosite, crocidolite, tremolite, anthophyllite and actinolite. There is an important distinction to be made between serpentine and amphibole asbestos due to differences in their chemical composition and their degree of potency as a health hazard when inhaled. However asbestos and all commercial forms of asbestos (including chrysotile asbestos) are known to be human carcinogens.

2 – 1 – Serpentine :

2 – 1 – 1 – White :

Chrysotile, CAS No. 12001-29-5, is obtained from serpentinite rocks which are common throughout the world. Its idealized chemical formula is $Mg_3(Si_2O_5)(OH)_4$. Chrysotile fibers are curly as opposed to fibers from amosite, crocidolite, tremolite, actinolite, and anthophyllite which are needlelike. Chrysotile, along with other types of asbestos, has been banned in dozens of countries and is only allowed in the United States and Europe in very limited circumstances. Chrysotile has been used more than any other type and accounts for about 95 % of the asbestos found in buildings in America.[8] Applications where chrysotile might be used include the use of joint compound. It is more flexible than amphibole types of asbestos; it can be spun and woven into fabric. The most common use is within corrugated asbestos cement roof sheets typically used for outbuildings, warehouses and garages. It is also found as flat sheets used for ceilings and sometimes for walls and floors. Numerous other items have been made containing chrysotile including brake linings, cloth behind fuses (for fire protection), pipe insulation, floor tiles, and rope seals for boilers .

2 – 2 – Amphibole :

2 – 2 – 1 – Brown :

Amosite, CAS No. 12172-73-5, is a trade name for the amphiboles belonging to the cummingtonite - grunerite solid solution series, commonly from South Africa, named as an acronym from Asbestos Mines of South Africa. One formula given for amosite is $Fe_7Si_8O_{22}(OH)_2$. It is found most frequently as a fire retardant in thermal insulation products and ceiling tiles.

2 – 2 – 2 – Blue :

Crocidolite, CAS No. 12001-28-4 is an amphibole found primarily in southern Africa, but also in Australia. It is the fibrous form of the amphibole riebeckite. One formula given for crocidolite is $Na_2Fe^{2+}{}_3Fe^{3+}{}_2Si_8O_{22}(OH)_2$.

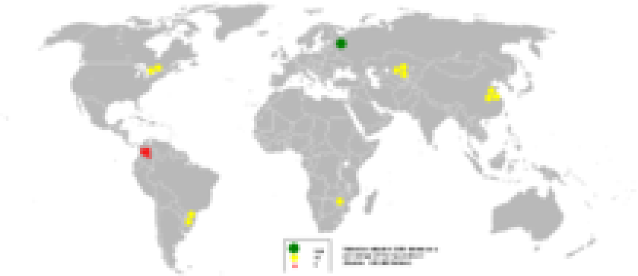
Crocidolite commonly occurs as soft friable fibers. Asbestiform amphibole may also occur as soft friable fibers but some varieties such as amosite are commonly straighter. All forms of asbestos are fibrillar in that they are composed of fibers with breadths less than 1 micrometer that occur in bundles and have very great widths. Asbestos with particularly fine fibers is also referred to as "amianthus". Amphiboles such as tremolite have a crystal structure containing strongly bonded ribbonlike silicate anion polymers that extend the width of the crystal. Serpentine (chrysotile) has a sheetlike silicate anion which is bowed and which rolls up like a carpet to form the fiber.

2 – 2 – 3 – Other materials :

Other regulated asbestos minerals, such as tremolite asbestos, CAS No. 77536-68-6 , $Ca_2Mg_5Si_8O_{22}(OH)_2$; actinolite asbestos, CAS No. 77536-66-4, $Ca_2(Mg, Fe)_5(Si_8O_{22})(OH)_2$; and anthophyllite asbestos, CAS No. 77536-67-5, $(Mg, Fe)_7Si_8O_{22}(OH)_2$; are less commonly used industrially but can still be found in a variety of construction materials and insulation materials and have been reported in the past to occur in a few consumer products.

Other natural and not currently regulated asbestiform minerals, such as richterite, $Na(CaNa)(Mg, Fe^{++})_5(Si_8O_{22})(OH)_2$, and winchite, $(CaNa)Mg_4(Al, Fe^{3+})(Si_8O_{22})(OH)_2$, may be found as a contaminant in products such as the vermiculite containing zonolite insulation manufactured by W.R. Grace and Company. These minerals are thought by some to be no less harmful than tremolite, amosite, or crocidolite . They are referred to as "asbestiform" rather than asbestos. Although the U.S. OSHA has not included them in the asbestos standard, NIOSH and the American Thoracic Society have recommended that they be included as regulated materials. As such, they may still be related to diseases and hazardous.

3 - Producing nations :



Asbestos output in 2005

In 2009, 2 million tones of asbestos were mined worldwide. Russia was the largest producer with about 50 % world share followed by China (14%), Brazil (12.5 %), Kazakhstan (10.5 %) and Canada (9 %).

4 – History :

4 – 1 - Early uses :

Asbestos use in human culture dates back at least 4,500 years, when evidence shows that inhabitants of the Lake Juojärvi region in East Finland strengthened earthenware pots and cooking utensils with the asbestos mineral anthophyllite . The word *asbestos* comes from the ancient Greek ἄσβεστος, meaning "unquenchable" or "inextinguishable". One of the first careful descriptions of the material is attributed to Theophrastus in his text *On Stones*, around 300 BC, although the naming of minerals was not very consistent at that time (the more consistent name of this material in both modern and ancient Greek is *amiantos* (undefiled, pure) whence the names of it in other languages like French *amiante*; the modern Greek word ἀσβεστος or ασβέστης stands consistently and solely for lime, not for the material known as *asbestos* in English). The term *asbestos* is traceable to Roman naturalist Pliny the Elder's manuscript *Natural History*, and his use of the term *asbestinon*, meaning "unquenchable". While Pliny is popularly attributed with recognising the detrimental effects of asbestos on slaves, examination of primary sources shows that this is not so . Charlemagne, the first Holy Roman Emperor (800–814), is said to have had a tablecloth made of asbestos .

According to Tabari, one of the curious items belonging to Khosrow II Parviz, the great Sassanian king (r. 531 – 579), was a napkin that he cleaned by simply throwing it into fire. This is believed to be made of asbestos. (This is also mentioned in The New Encyclopædia Britannica, vol. 6, 2003, page 843). Wealthy Persians, who bought asbestos imported over the Hindu Kush, amazed guests by cleaning the cloth by simply exposing it to fire. According to Biruni in his book of *Gems*, any cloths made of asbestos (Persian: آذرشست, *āzarshost*) were called (Persian: شستکه) *shostakeh* . Some of the Persians believed the fiber was fur from an animal (named *samandar*, Persian: سمندر) that lived in fire and died when exposed to water, hence the old mistaken myth that the salamander tolerated fire.

While traveling to Siberia, Marco Polo described being offered garments that could not burn. He was told that the wool was from the salamander, but did not accept this explanation. At last he was told that these garments were made from a mineral from the mountains, which contained threads just like wool.

Some archeologists believe that ancients made shrouds of asbestos, wherein they burned the bodies of their kings, in order to preserve only their ashes, and prevent their being mixed with those of wood or other combustible materials commonly used in funeral pyres. Others assert that the ancients used asbestos to make perpetual wicks for sepulchral or other lamps. In more recent centuries, asbestos was indeed used for this purpose. Although asbestos causes skin to itch upon contact, ancient literature indicates that it was prescribed for diseases of the skin, and particularly for the itch. It is possible that they used the term *asbestos* for soapstone, because the two terms have often been confused throughout history.

4 – 2 - Industrial era :

Asbestos use in England was brought back in the 1700s, but did not become popular until the Industrial Revolution during the late 1800s .

The Industrial Revolution represented a huge boom for the asbestos industry. Factories were opening everywhere and new uses for the miracle mineral were being devised on a regular basis. Commercial asbestos mines sprung up in the late 1800s and entrepreneurs recognised that asbestos could perhaps make them rich. The U.S. asbestos industry began in 1858 when fibrous anthophyllite was mined for use as asbestos insulation by the Johns Company, a predecessor to the current Johns Manville at a quarry at Ward's Hill on Staten Island, New York . Asbestos became more widespread during the industrial revolution; in 1866 it was used as insulation in the U.S. and Canada. Development of the first commercial asbestos mine began in 1874 in the Appalachian foothills of Quebec . By the mid 20th century uses included fire retardant coatings, concrete, bricks, pipes and fireplace cement, heat, fire, and acid resistant gaskets, pipe insulation, ceiling insulation, fireproof drywall, flooring, roofing, lawn furniture, and drywall joint compound.

Asbestos fibers were once used in automobile brake pads, shoes, and clutch discs. Since the mid-1990s, a majority of brake pads, new or replacement, have been manufactured instead with linings made of ceramic, carbon, metallic and aramid fiber (Twaron or Kevlar—the same material used in bulletproof vests).

Kent's filtered cigarette used crocidolite asbestos in its "Micronite" filter from 1952 to 1956.

Artificial Christmas snow, known as flocking, was previously made with asbestos.

In Japan, particularly after World War II, asbestos was used in the manufacture of ammonium sulfate for purposes of rice production, sprayed upon the ceilings, iron skeletons, and walls of railroad cars and buildings (during the 1960s), and used for energy efficiency reasons as well. Production of asbestos in Japan peaked in 1974 and went through ups and downs until about 1990, when production began to drop severely.

4 – 3 - Discovery of toxicity :

The first documented death related to asbestos was in 1906. In the early 1900s researchers began to notice a large number of early deaths and lung problems in asbestos mining towns. The first diagnosis of asbestosis was made in the UK in 1924. By the 1930s, the UK regulated ventilation and made asbestosis an excusable work-related disease, followed by the U.S about ten years later . The term mesothelioma was first used in medical literature in 1931; its association with asbestos was first noted sometime in the 1940s.

Approximately 100,000 people in the United States have died, or will die, from asbestos exposure related to ship building. In the Hampton Roads area, a shipbuilding center, mesothelioma occurrence is seven times the national rate . Thousands of tons of asbestos were used in World War II ships to wrap the pipes, line the boilers, and cover engine and turbine parts. There were approximately 4.3 million shipyard workers in the United States during WWII; for every thousand workers about fourteen died of mesothelioma and an unknown number died from asbestosis.

The United States government and asbestos industry have been criticized for not acting quickly enough to inform the public of dangers, and to reduce public exposure. In the late 1970s court documents proved that asbestos industry officials knew of asbestos dangers since the 1930s and had concealed them from the public. A similar situation had arisen in the 1920s with the careless handling of radium and the ensuing scandal of the Radium Girls.

In Australia, asbestos was widely used in construction and other industries between 1945 and 1980. From the 1970s there was increasing concern about the dangers of asbestos and its use was phased out. Mining ceased in 1983. The use of asbestos was phased out in 1989 and banned entirely in Dec 2003. The dangers of asbestos are now well known in Australia and there is help and support for sufferers from asbestosis or mesothelioma.

5 - Specific products :

5 – 1 - Serpentine group :

Serpentine minerals have a sheet or layered structure. Chrysotile is the only asbestos mineral in the serpentine group. In the United States , chrysotile has been the most commonly used type of asbestos. According to the U.S. EPA Asbestos Building Inspectors Manual, chrysotile accounts for approximately 95% of asbestos found in buildings in the United States. Chrysotile is often present in a wide variety of products and materials, including:

- Drywall and joint compound
- Plaster
- Gas mask filters pre 1960s
- Mud and texture coats
- Vinyl floor tiles, sheeting, adhesives
- Roofing tars, felts, siding, and shingles
- "Transite" panels, siding, countertops, and pipes
- Popcorn ceilings, also known as acoustic ceilings
- Fireproofing
- Caulk
- Gaskets
- Packing, a system for sealing a rotating shaft
- Brake pads and shoes
- Clutch plates
- Stage curtains
- Fire blankets
- Interior fire doors
- Fireproof clothing for firefighters
- Thermal pipe insulation
- Filters for removing fine particulates from chemicals, liquids and wine
- Dental cast linings
- HVAC flexible duct connectors
- Drilling fluid additives

In the European Union and Australia it has recently been banned as a potential health hazard and is not used at all. Japan is moving in the same direction, but more slowly. Revelations that hundreds of workers had died in Japan over the previous few decades from diseases related to asbestos sparked a scandal in mid-2005. Tokyo had, in 1971, ordered companies handling asbestos to install ventilators and check health on a regular basis; however, the Japanese government did not ban crocidolite and amosite until 1995, and a full-fledged ban on asbestos was implemented in October 2004.

5 – 2 - Amphibole group :

Five types of asbestos are found in the amphibole group: amosite, crocidolite, anthophyllite, tremolite, and actinolite. Amosite, the second most likely type to be found in buildings, according to the U.S. EPA Asbestos Building Inspectors Guide, is the "brown" asbestos.

Amosite and crocidolite were formerly used in many products until the early 1980s. The use of all types of asbestos in the amphibole group was banned in much of the Western world by the mid-1980s, and by Japan in 1995. These products were mainly

- Low density insulating board (often referred to as AIB or asbestos insulating board) and ceiling tiles;
- Asbestos - cement sheets and pipes for construction, casing for water and electrical/telecommunication services;
- Thermal and chemical insulation (*e.g., fire rated doors, limpet spray, lagging and gaskets).*

6 n- Health problems :

All types of asbestos fibers are known to cause serious health hazards in humans . While it is agreed that amosite and crocidolite are the most hazardous asbestos fiber types, chrysotile asbestos has produced tumors in animals and is a recognized cause of asbestosis and malignant mesothelioma in humans .

Mesotheliomas have been observed in people who were occupationally exposed to chrysotile, family members of the occupationally exposed, and residents who lived close to asbestos factories and mines. According to the NCI, "A history of asbestos exposure at work is reported in about 70 percent to 80 percent of all cases. However, mesothelioma has been reported in some individuals without any known exposure to asbestos " . The most common diseases associated with chronic exposure to asbestos include: asbestosis and pleural abnormalities (mesothelioma, lung cancer). Asbestosis has been reported primarily in asbestos workers, and appears to require long-term exposure, high concentration for the development of the clinical disease. There is also a long latency period (incubation period of an infectious disease, before symptoms appear) of about 12 to 20 years.

Studies have shown an increased risk of lung cancer among smokers who are exposed to asbestos compared to nonsmokers.

Asbestos exposure becomes a health concern when high concentrations of asbestos fibers are inhaled over a long time period.[44] People who become ill from inhaling asbestos are often those who are exposed on a day-to-day basis in a job where they worked directly with the material. As a person's exposure to fibers increases, because of being exposed to higher concentrations of fibers and/or by being exposed for a longer time, then that person's risk of disease also increases. Disease is very unlikely to result from a single, high - level exposure, or from a short period of exposure to lower levels.

6 – 1 - Mechanisms which might be triggering cancer development :

Stanton and Layard hypothesized in 1977–78 that toxicity of fibrous materials is *not* initiated by *chemical* effects, that is any trigger-effects of asbestos must presumably be *physical*, such as (A) *mechanical* damage or (B) unwanted *signal channels* (a plausible property for slender transparent fibres) which might disrupt normal cell activity — especially mitosis.

(A) Mechanical Damage. There is experimental evidence that very slim fibers (< 60 nm , < 0.06 μm in breadth) do tangle destructively with chromosomes (being of comparable size) . This is likely to cause the sort of mitosis disruption expected in cancer.

(B) Unwanted Signal channels. This has recently been explored theoretically, but not yet experimentally. The theory argues that this effect would only be feasible for asbestos fibers >100 nm in breadth (>150 nm in the case of chrysotile), which suggests that we should be on the look-out for a possible mixture of different mechanisms for the different fiber-diameter-ranges .

One popular idea of the causal chain is (1) Asbestos fiber → (3) inflammation → (4) other pathology. While that may be true, it does not explain "**(2)**, the actual trigger":

> "What is the *physical* property of asbestos which *initiates* any such inflammation?" (After all, inflammation is usually seen as caused by *chemical*-based processes: immunological &/or bacterial). So inflammation (&/or oxidation etc.) may well be part of the causal chain, *but not the crucial first step*.

6 – 2 - Other asbestos - related diseases :

- It is important to consult a doctor, particularly if the follow symptoms develop: shortness of breath, wheezing, or hoarseness, persistent cough that worsens over time, blood in fluid coughed up, pain or tightening in chest, difficulty swallowing, swelling of neck or face, decreased appetite, weight loss, fatigue or anemia.

- **Asbestosis**: Progressive fibrosis of the lungs of varying severity, progressing to bilateral fibrosis, honeycombing of the lungs on radiological view with symptoms including rales and wheezing. Individuals who have been exposed to asbestos via home, environment, work should notify their doctors about exposure history.

- **Asbestos warts** : caused when the sharp fibers lodge in the skin and are overgrown causing benign callus-like growths.
- **Pleural plaques** : discrete fibrous or partially calcified thickened area which can be seen on X-rays of individuals exposed to asbestos. Although pleural plaques are themselves asymptomatic, in some patients this develops into pleural thickening.
- **Diffuse pleural thickening** : similar to above and can sometimes be associated with asbestosis. Usually no symptoms shown but if exposure is extensive, it can cause lung impairment.
- **Pneumothorax :** Some reports have also linked the condition of pneumothorax to asbestos related diseases.

6 – 3 - Asbestos as a contaminant :

Most respire able asbestos fibers are invisible to the unaided human eye because their size is about 3–20 µm wide and can be as slim as 0.01 µm. Human hair ranges in size from 17 to 181 µm in breadth . Fibers ultimately form because when these minerals originally cooled and crystallized, they formed by the polymeric molecules lining up parallel with each other and forming oriented crystal lattices. These crystals thus have three cleavage planes, and in this case, there are two cleavage planes which are much weaker than the third. When sufficient force is applied, they tend to break along their weakest directions, resulting in a linear fragmentation pattern and hence a fibrous form. This fracture process can keep occurring and one larger asbestos fiber can ultimately become the source of hundreds of much thinner and smaller fibers.

As asbestos fibers get smaller and lighter, they more easily become airborne and human respiratory exposures can result. Fibers will eventually settle but may be re-suspended by air currents or other movement. When fibers or asbestos structures from asbestos containing materials(ACM) become airborne, the process is called primary release. Primary release mechanisms include abrasion, impaction, fallout, air erosion, vibration, and fire damage. Secondary release occurs when settled asbestos fibers and structures are resuspended as a result of human activities. In unoccupied buildings or during unoccupied periods, fiber release typically occurs by fallout or is induced by vibration or air erosion .

Friability of a product containing asbestos means that it is so soft and weak in structure that it can be broken with simple finger crushing pressure. Friable materials are of the most initial concern because of their ease of damage. The forces or conditions of usage that come into intimate contact with most non-friable materials containing asbestos are substantially higher than finger pressure.

It is important to note that asbestos containing building materials were not as widely used in residences as it was in larger institutional and commercial buildings. Most products manufactured today do not contain asbestos, but until the 1970s many building materials used in homes contained asbestos. Asbestos containing building materials in residences includes a variety of products like thermal system insulation (TSI) around hot or cold water lines, asbestos paper wrap around heating ducts, cement board around furnaces/wood-burning appliances, cement board roofing materials and so on. Other sources of asbestos containing materials include deteriorating, damaged, or disturbed insulation, fire proofing, acoustical materials, and floor tiles.

Asbestos Exposure: Various individuals may be exposed to airborne asbestos fibers. Among these people are general building occupants such as teachers, students, office workers, and visitors; housekeeping/custodial employees who may come in contact with or disturb asbestos containing building materials (ACBM) or contaminated settled dust during their work activities, and maintenance/construction workers who may disturb ACBM during repair or installation activities. Asbestos abatement/remediation workers and emergency personnel such as firefighters may also become exposed .

6 – 4 - Environmental asbestos :

Asbestos can be found naturally in the air outdoors and in some drinkable water, including water from natural sources . Studies have shown that members of the general (non-occupationally exposed) population have tens of thousands to hundreds of thousands of asbestos fibers in each gram of dry lung tissue, which translates into millions of fibers and tens of thousands of asbestos bodies in every person's lungs.

Asbestos from natural geologic deposits is known as "naturally occurring asbestos" (NOA). Health risks associated with exposure to NOA are not yet fully understood, and current US federal regulations do not address exposure from NOA. Many populated areas are in proximity to shallow, natural deposits which occur in 50 of 58 California counties and in 19 other U.S. states. In one study, data was collected from 3,000 mesothelioma patients in California and 890 men with prostate cancer, a malignancy not known to be related to asbestos. The study found a correlation between the incidence of mesotheliomas and the distance a patient lived from known deposits of rock likely to include asbestos; the correlation was not present when the incidence of prostate cancer was compared with the same distances. According to the study, risk of mesothelioma declined by 6% for every 10 km that an individual had lived away from a likely asbestos source.

Portions of El Dorado County, California are known to contain natural amphibole asbestos formations at the surface . The USGS studied amphiboles in rock and soil in the area in response to an EPA sampling study and subsequent criticism of the EPA study. The EPA study was refuted by its own peer reviewers and never completed or published. The study found that many amphibole particles in the area meet the counting rule criteria used by the EPA for chemical and morphological limits, but do not meet morphological requirements for commercial - grade - asbestos. The executive summary pointed out that even particles that do not meet requirements for commercial – grade -asbestos may be a health threat and suggested a collaborative research effort to assess health risks associated with "Naturally Occurring Asbestos."

However, the main criticism pointed at EPA was that their testing was conducted in small isolated areas of El Dorado where there were no amphibole asbestos deposits, thus the language regarding amphibole, non fibrous "particles". Actual surface amphibole deposits in residential areas were ignored for testing purposes. Thus no final findings were published by ATSDR since the criticism was correct and the effort of combined EPA /ATSDR teams were wasted time and money.

Great deals of Fairfax County, Virginia were also found to be underlain with tremolite. The county monitored air quality at construction sites, controlled soil taken from affected areas, and required freshly developed sites to lay 6 inches (150 mm) of clean, stable material over the ground .

Globally, collected samples from Antarctic ice indicate chrysotile asbestos has been a ubiquitous contaminant of the environment for at least 10,000 years. Snow samples in Japan have shown ambient background levels are one to two orders of magnitude higher in urban than in rural areas. Higher concentrations of airborne asbestos fibers are reported in urban areas where there is more ACM (asbestos containing materials) and mechanisms of release (vehicles braking and weathering of asbestos cement materials); concentrations in the range of 1–20 ng/m^3 have been reported. Fibers longer than 5µm are rarely found in rural areas. Ambient concentrations using TEM analysis have been based on mass measurements .

For environmental samples, one must normally resort to electron microscopy for positive identification . Today, gravimetric and PCM/ PLM techniques are employed. However, the latter techniques cannot readily identify the smallest, most hazardous, fibers, because they are limited to PM10 particulate size evaluation, which completely ignores ultrafine particles (UFPs).

A combination of methods such as light microscopy, electron microscopy, and energy dispersive X- ray analysis are used to offer the most accurate approach to identify asbestos and to estimate concentrations that may become airborne upon disturbance. For the purposes of counting asbestos fibers in these samples, regulatory agencies commonly count as fibers those particles of asbestos minerals at least 5 micrometers in length and with length : width ratios of 3:1 . For detecting fibers in bulk building materials, asbestos particles with length : width ratios of 5:1 are counted. Air concentrations of asbestos fibers in ambient (typical) air are 0.00001 to 0.0001 fibers per milliliter (fiber/mL). The recently established exposure limit for U.S. workplaces is 0.1 fiber / mL .

7 - History of health concerns and regulation :

7 – 1 - Until 1900 :

By the first century AD, Greeks and Romans are claimed to have observed that slaves involved in the weaving of asbestos cloth were afflicted with a sickness of the lungs , although this is not confirmed by examination of primary sources.

Early concern in the modern era on the health effects of asbestos exposure can be found in several sources. Among the earliest were reports in Britain. The annual reports of the Chief Inspector of Factories reported as early as 1898 that asbestos had "easily demonstrated" health risks.

At about the same time, what was probably the first study of mortality among asbestos workers was reported in France . While the study describes the cause of death as chalicosis, a generalized pneumoconiosis, the circumstances of the employment of the fifty workers whose death prompted the study suggest that the root cause was asbestos or mixed asbestos-cotton dust exposure.

7 – 2 - 1900 s – 1910 s :

Further awareness of asbestos - related diseases can be found in the early 1900s, when London doctor H. Montague Murray conducted a post mortem exam on a young asbestos factory worker who died in 1899. Dr. Murray gave testimony on this death in connection with an industrial disease compensation hearing. The post-mortem confirmed the presence of asbestos in the lung tissue, prompting Dr. Murray to express as an expert opinion his belief that the inhalation of asbestos dust had at least contributed to, if not actually caused, the death of the worker.

The record in the United States was similar. Early observations were largely anecdotal in nature and did not definitively link the occupation with the disease, followed by more compelling and larger studies that strengthened the association. One such study, published in 1918, noted :

> All of these processes unquestionably involve a considerable dust hazard, but the hygienic aspects of the industry have not been reported upon. It may be said, in conclusion, that in the practice of American and Canadian life insurance companies, asbestos workers are generally declined on account of the assumed health-injurious conditions of the industry.

7 – 3 – 1920 s –1930 s :

Widespread recognition of the occupational risks of asbestos in Britain was reported in 1924 by a Dr. Cooke, a pathologist, who introduced a case description of a 33-year-old female asbestos worker, Nellie Kershaw, with the following: "Medical men in areas where asbestos is manufactured have long suspected the dust to be the cause of chronic bronchitis and fibrosis..." Dr. Cooke then went on to report on a case in 1927 involving a 33-year-old male worker who was the only survivor out of ten workers in an asbestos carding room. In the report he named the disease "asbestosis".

Dr. Cooke's second case report was followed, in the late 1920s, by a large public health investigation (now known as the Merewether report after one of its two authors) that examined some 360 asbestos-textile workers (reported to be about 15 % of the total comparable employment in Britain at the time) and found that about a quarter of them suffered from pulmonary fibrosis . This investigation resulted in improved regulation of the manufacturing of asbestos-containing products in the early 1930s. Regulations included industrial hygiene standards, medical examinations, and inclusion of the asbestos industry into the British Workers' Compensation Act .

The first known U.S. workers' compensation claim for asbestos disease was in 1927 . In 1930, the first reported autopsy of an asbestosis sufferer was conducted in the United states and later presented by a doctor at the Mayo Clinic, although in this case the exposure involved mining activities somewhere in South America .

In 1930, the major asbestos company Johns - Manville produced a report, for internal company use only, about medical reports of asbestos worker fatalities . In 1932, a letter from U.S. Bureau of Mines to asbestos manufacturer Eagle-Picher stated, in relevant part, "It is now known that asbestos dust is one of the most dangerous dusts to which man is exposed ".

In 1933, Metropolitan Life Insurance Co. doctors found that 29% of workers in a Johns-Manville plant had asbestosis.[73] Likewise, in 1933, Johns-Manville officials settled lawsuits by 11 employees with asbestosis on the condition that the employees' lawyer agree to never again "directly or indirectly participate in the bringing of new actions against the Corporation " . In 1934, officials of two large asbestos companies, Johns-Manville and Raybestos - Manhattan, edited an article about the diseases of asbestos workers written by a Metropolitan Life Insurance Company doctor. The changes downplayed the danger of asbestos dust. In 1935, officials of Johns - Manville and Raybestos-Manhattan instructed the editor of *Asbestos* magazine to publish nothing about asbestosis. In 1936, a group of asbestos companies agreed to sponsor research on the health effects of asbestos dust, but required that the companies maintain complete control over the disclosure of the results.

7 – 4 – 1940 s :

In 1942, an internal Owens - Corning corporate memo referred to "medical literature on asbestosis… scores of publications in which the lung and skin hazards of asbestos are discussed " .Testimony given in a federal court in 1984 by Charles H. Roemer, formerly an employee of Unarco, described a meeting in the early 1940s between Unarco officials, J-M President Lewis H. Brown and J-M attorney Vandiver Brown. Roemer stated, "I'll never forget, I turned to Mr. Brown, one of the Browns made this crack (that Unarco managers were a bunch of fools for notifying employees who had asbestosis), and I said, 'Mr. Brown, do you mean to tell me you would let them work until they dropped dead?' He said, 'Yes. We save a lot of money that way.'" In 1944, a Metropolitan Life Insurance Company report found 42 cases of asbestosis among 195 asbestos miners .

7 – 5 – 1950 s :

In 1951, asbestos companies removed all references to cancer before allowing publication of research they sponsored.[76] In 1952, Dr. Kenneth Smith, Johns-Manville medical director, recommended (unsuccessfully) that warning labels be attached to products containing asbestos. Later, Smith testified: "It was a business decision as far as I could understand… the corporation is in business to provide jobs for people and make money for stockholders and they had to take into consideration the effects of everything they did and if the application of a caution label identifying a product as hazardous would cut into sales, there would be serious financial implications."[77]

In 1953, National Gypsum's safety director wrote to the Indiana Division of Industrial Hygiene, recommending that acoustic plaster mixers wear respirators "because of the asbestos used in the product." Another company official noted that the letter was "full of dynamite" and urged that it be retrieved before reaching its destination. A memo in the files noted that the company "succeeded in stopping" the letter, which "will be modified " .

7 – 6 - 1960 s – 1980 s

Through the 1970s, asbestos was used to fireproof roofing and flooring, for heat insulation, and for a variety of other purposes. The material was used in fire - check partitioning and doors on North Sea Oil Production Platforms and Rigs.

During mid - to late 1980s, public health concern focused on potential asbestos fiber exposures of building occupants and workers in buildings containing asbestos containing building materials (ACBM) and their risks of developing lung cancer or mesothelioma. As a consequence, the Health Effects Institute (Cambridge, MA) convened a panel to evaluate the lifetime cancer risk of general building occupants as well as service workers.

7 – 7 - Modern regulation (Asbestos and the law) :

7 – 7 – 1 - United States :

In 1981, the United States Environmental Protection Agency (EPA) requested information from American companies regarding the asbestos content of their products .

In 1989 the EPA issued the Asbestos Ban and Phase Out Rule which was subsequently overturned in the case of *Corrosion Proof Fittings v. EPA*, 947 F.2d 1201 (5th Cir. 1991). This ruling leaves many consumer products that can still legally contain trace amounts of asbestos. For a clarification of products which legally contain asbestos, read the EPA's clarification statement. In 2010, Washington State banned asbestos in automotive brakes starting in 2014.

The EPA has proposed a concentration limit of seven million fibers per liter of drinking water for long fibers (lengths greater than or equal to 5 µm). The Occupational Safety and Health Administration (OSHA), has set limits of 100,000 fibers with lengths greater than or equal to 5 µm per cubic meter of workplace air for eight-hour shifts and 40-hour work weeks .

OSHA regulations regarding asbestos are covered in 29 C.F.R. 1926.1101. Such work is divided into four categories.

Class I asbestos work means activities involving the removal of TSI and surfacing ACM and PACM.

Class II asbestos work means activities involving the removal of ACM which is not thermal system insulation or surfacing material.

This includes, but is not limited to, the removal of asbestos - containing wallboard, floor tile and sheeting, roofing and siding shingles, and construction mastics.

Class III asbestos work means repair and maintenance operations, where "ACM", including TSI and surfacing ACM and PACM, is likely to be disturbed.

Class IV asbestos work means maintenance and custodial activities during which employees contact but do not disturb ACM or PACM and activities to clean up dust, waste and debris resulting from Class I, II, and III activities .

7 – 7 – 2 - Great Britain :

In Great Britain, blue and brown asbestos materials were banned outright in 1985 while the import, sale and second hand reuse of white asbestos was outlawed in 1999. New 2006 regulations (effective from 13th November 2006) introduced additional liabilites, including a duty placed on non - domestic building owners, e.g. factories, offices etc. to manage asbestos on its premises by making themselves aware of its presence and ensuring the material does not deteriorate, removing it if necessary. Employers e.g. construction companies whose operatives may come into contact with asbestos must also provide biannual asbestos training to its workers .

7 – 7 – 3 - New Zealand :

In 1984, the import of raw amphibole (blue and brown) asbestos into New Zealand was banned. In 2002 the import of chrysotile (white) asbestos was banned .

7 – 7 – 4 – Australia :

A complete ban on asbestos-containing material in Australia was introduced in 1991 although some building materials in storage were still being used in the years that followed. Queensland began regulation of asbestos removal and disposal in 2005. Handlers of asbestos materials must have a B-Class license for bonded asbestos and an A - Class license for friable asbestos.

The town of Wittenoom, in Western Australia was built around a (blue) asbestos mine. The entire town continues to be contaminated, and has been disincorporated , allowing local authorities to remove references to Wittenoom from maps and roadsigns.

8 - Contamination of other products

8 – 1 - Asbestos and vermiculite :

Vermiculite is a hydrated laminar magnesium-aluminum-iron silicate which resembles mica. It can be used for many industrial applications and has been used as a replacement for asbestos. Some ore bodies of vermiculite have been found to contain small amounts of asbestos. One vermiculite mine operated by W. R. Grace and Company in Libby, Montana exposed workers and community residents to danger by mining contaminated vermiculite. In 1999 the EPA began cleanup efforts and now the area is a Superfund cleanup area. The EPA has determined that harmful asbestos is released from the mine as well as through other activities that disturb soil in the area.

8 – 2 - Asbestos and talc :

Talc is sometimes contaminated with asbestos . In 2000, tests in a certified asbestos-testing laboratory found the tremolite form of amphibole asbestos in three out of eight bigger brands of children's crayons that are made partly from talc: Crayola, Prang, and RoseArt . In Crayola crayons, the tests found asbestos levels from 0.05% in *Carnation Pink* to 2.86 % in *Orchid*; in Prang crayons, the range was from 0.3 % in *Periwinkle* to 0.54 % in *Yellow*; in Rose Art crayons, it was from 0.03 % in *Brown* to 1.20 % in *Orange*. Overall, 32 different types of crayons from these brands contained more than trace amounts of asbestos, and eight others contained trace amounts. The Art and Creative Materials Institute, a trade association which tests the safety of crayons on behalf of the makers, initially insisted the test results must be incorrect, although they later said they do not test for asbestos . In May 2000, Crayola said tests by a materials analyst, Richard Lee, whose testimony has been accepted in lawsuits over 250 times on behalf of the asbestos industry, showed two of its crayons were negative for asbestos . In June 2000, Binney & Smith, the maker of Crayola, and the other makers agreed to stop using talc in their products, and changed their product formulations in the United States. The mining company, R T Vanderbilt Co of Gouverneur, New York, which supplied the talc to the crayon makers, insists there is no asbestos in its talc "to the best of our knowledge and belief",[93] but a news article claimed that the United States Mine Safety and Health Administration (MSHA) did find asbestos in four talc samples that it tested in 2000 . At the time, however, the Assistant Secretary for Mine Safety and Health informed the news reporter that his article was in error and that the reporter had misquoted him stating that “In fact, the abbreviation ND (non detect) in the laboratory report – indicates no asbestos fibers actually were found in the samples ” . Further supporting the claim of Vanderbilt that asbestos is not found in this industrial grade talc (composed of a very complex mineral mixture) is a decades old record of analytical work that does not find asbestos in this talc by mineral scientists in academia, government and contract laboratories .

Human, animal and cell health studies conducted on Vanderbilt’s controversial talc also lend no support for the presence of asbestos in this talc . Several non fully peer - reviewed health reports concerning Vanderbilt talc do exist and suggest a "same as" asbestos risk, some of which were referenced in the previously cited news articles .

9 – Asbestos in construction :

9 – 1 - Asbestos construction in developed countries :

The use of asbestos in new construction projects has been banned for health and safety reasons in many developed countries or regions, including the European Union, Australia, Hong Kong, Japan, and New Zealand. A notable exception is the United States, where asbestos continues to be used in construction such as cement asbestos pipes. The 5th Circuit Court prevented the EPA from banning asbestos in 1991 because although EPA research showed it would cost between $450 and 800 million and save around 200 lives in a 13-year length, the EPA did not provide adequate evidence for the safety of alternative products . Until the mid-1980s, small amounts of white asbestos were used in the manufacture of Artex, a decorative stipple finish , however, some of the lesser - known suppliers of Artex were still adding white asbestos until 1999 . Removing or disturbing Artex is not recommended, as it may contain white asbestos.

Prior to the ban, asbestos was widely used in the construction industry in thousands of materials, some are judged to be more dangerous than others due to the amount of asbestos and a materials friable nature. Sprayed coatings, pipe insulation and Asbestos Insulating Board (AIB) are thought to be the most dangerous due to their high content of asbestos and friable nature. Many older buildings built before the late 1990s contain asbestos. In the United States, there is a minimum standard for asbestos surveys as described by ASTM Standard E 2356-04. The U.S. Environmental Protection Agency includes some but not all asbestos-contaminated facilities on the Superfund National Priorities list (NPL). Renovation and demolition of asbestos contaminated buildings is subject to EPA NESHAP and OSHA Regulations. There was a procedure started in Gracedale, Northampton , US in several households as the amount of asbestos was more than the allowed . Asbestos is not a material covered under CERCLA's innocent purchaser defense. In the UK, the removal and disposal of asbestos and of substances containing it are covered by the Control of Asbestos Regulations 2006 .

In older buildings (e.g. those built prior to 1999 in the UK, before white asbestos was finally banned), asbestos may still be present in some areas e.g. old bath panels, concrete water tanks and many other places. Being aware of asbestos locations reduces the risk of disturbing asbestos . Removal of asbestos building components can also remove the fire protection they provide, therefore fire protection substitutes are required for proper fire protection that the asbestos originally provided.

9 – 2 - Asbestos construction in developing countries :

Some countries, such as India, China, Russia and Brazil have continued widespread use of asbestos. The most common is corrugated asbestos-cement sheets or "A / C Sheets" for roofing and for side walls. Millions of homes, factories, schools or sheds and shelters continue to use asbestos. Cutting these sheets to size and drilling holes to receive 'J' bolts to help secure the sheets to roof framing is done on - site. There has been no significant change in production and use of A / C Sheets in developing countries following the widespread restrictions in developed nations .

9 – 3 - Asbestos and 9 / 11 :

As the towers collapsed , Lower Manhattan was blanketed in a mixture of building debris and combustible materials. This complex mixture gave rise to the concern that thousands of residents and workers in the area would be exposed to known hazards in the air and in the dust, such as asbestos, lead, glass fibers, and pulverized concrete . More than 1,000 tons of asbestos are thought to have been released into the air during the destruction of the World Trade Center in New York on 9 / 11 . Inhalation of a mixture of asbestos and other toxicants is thought to be linked to the unusually high death rate of emergency service workers from cancer since the disaster . Many thousands more are now thought to be at risk of developing cancer due to this exposure with those who have died so far being only the 'tip of the iceberg'. Some commentators have criticized authorities for using asbestos in the Towers' construction (see 'Other criticism' below).

In May 2002, after numerous cleanup, dust collection, and air monitoring activities were conducted outdoors by EPA , other federal agencies, New York City and New York State, New York City formally requested federal assistance to clean and/or test residences in the vicinity of the WTC site for airborne asbestos.

10 – Litigation :

Asbestos litigation is the longest, most expensive mass tort in U.S. history, involving more than 8,400 defendants and 730,000 claimants as of 2002 according to the RAND Corporation , and at least one defendant reported claim counts in excess of $ 800,000 in 2006 .

Current trends indicate that the worldwide rate at which people are diagnosed with asbestos - related diseases will likely increase through the next decade . Analysts have estimated that the total costs of asbestos litigation in the USA alone is over $250 billion .

The federal legal system in the United States has dealt with numerous counts of asbestos related suits, which often included multiple plaintiffs with similar symptoms. In 1999 there were 200,000 related cases pending in the federal court system of the United States. Further , it is estimated that within the next 40 years, the number of cases may increase to 700,000. These numbers help explain how there are thousands of current pending cases.

Litigation of asbestos materials has been slow. Companies sometimes counter saying that health issues do not currently appear in their worker or workers, or sometimes are settled out of court . The Research and Development (RAND) think tank has appropriated certain legal information which is readily available for proclaimed victims of natural resource accidents. This information has helped many workers, regardless of health condition, earn compensation through companies. RAND, along with the Institute for Civil Justice (ICJ) have been proponents of the organization of past cases in order to determine one aspect of fair compensation for workers.

1999 saw the introduction of the Fairness in Asbestos Compensation Act . Ultimately many asbestos companies were forced to file for bankruptcy. While companies filed for bankruptcy, this limited payouts to those who were actually affected by the material. Christopher Edley said what the 1999 Act ultimately did was "limit punitive damages that seek retribution for the decisions of long-dead executives for conduct that took place decades ago (Professor Christopher Edley, Jr.)."

Litigation exists outside the United States in England, Scotland, Ireland, the Netherlands, France, Australia, and Japan among other nations. See the companion article for further information.

The volume of the asbestos liability has concerned manufacturers and insurers and reinsurers.[126] The amounts and method of allocating compensation have been the source of many court cases, and government attempts at resolution of existing and future cases.

11 - Critics of safety regulations :

11 – 1 – 1990 s : Canadian - French GATT dispute :

In May 1998, Canada requested consultations before the WTO and the European Commission concerning France's 1996 prohibition of the importation and sale of all forms of asbestos. Canada said that the French measures contravened provisions of the Agreements on Sanitary and Phytosanitary Measures and on Technical Barriers to Trade, and the GATT 1994. The EC claimed that safter substitute materials existed to take the place of asbestos. It stressed that the French measures were not discriminatory under the terms of international trade treaties, and were fully justified for public health reasons. The EC further claimed that in the July consultations, it had tried to convince Canada that the measures were justified, and that just as Canada broke off consultations, it (the EC) was in the process of submitting substantial scientific data in favour of the asbestos ban.

11 – 2 - 2000 s : Canadian exports face mounting global criticism :

In the late 1990s and early 2000s, the Canadian federal government continued to claim that chrysotile was much less dangerous than other types of asbestos. Chrysotile continued to be used in new construction across Canada, in ways that are very similar to those for which chrysotile was exported . Similarly, Natural

Resources Canada once stated that chrysotile, one of the fibres that make up asbestos, was not as dangerous as once thought. According a fact sheet from 2003, "current knowledge and modern technology can successfully control the potential for health and environmental harm posed by chrysotile". The Chrysotile Institute, an association partially funded by the Canadian government, also prominently asserted that the use of chrysotile did not pose an environmental problem and the inherent risks in its use were limited to the workplace .

However, under increasing criticism by environmental groups, in May, 2012 , the Canadian government stopped funding the Chrysotile Institute. As a result, the Chrysotile Institute has now closed .

The Canadian government continues to draw both domestic and international criticism for its stance on chrysotile, most recently in international meetings on the Rotterdam Convention hearings regarding chrysotile. The CFMEU pointed out that most exports go to developing countries. Canada has pressured countries, including Chile, and other UN member states to avoid chrysotile bans . In November, 2011, the Australian Upper House passed a motion to pressure the Canadian government to end policies supporting asbestos exports. The current state of Canadian policy is uncertain .

11 – 3 - Other criticism :

Asbestos regulation critics include the asbestos industry[139] and Fox News columnist Steven Milloy. Critics sometimes argue that increased government regulation does more harm than good and that replacements to asbestos are inferior. An example is the suggestion by Dixy Lee Ray and others that the shuttle Challenger disintegrated because the maker of O - ring putty was pressured by the EPA into ceasing production of asbestos-laden putty . However, the putty used in *Challenger*'s final flight *did* contain asbestos, and failures in the putty were not responsible for the failure of the O-ring that led to loss of the shuttle.

Asbestos was used in the first forty floors of the World Trade Center north tower causing an airborne contamination among lower

Manhattan after the towers collapsed in the attacks on September 11th, 2001 . Steven Milloy suggests that the World Trade Center towers could still be standing or at least would have stood longer had a 1971 ban not stopped the completion of the asbestos coating above the 64th floor . This was not considered in the National Institute of Standards and Technology's report on the towers' collapse. All fireproofing materials, regardless of what they are made of, are required to obtain a fire-resistance rating prior to installation. All fiber-based lightweight commercial spray fireproofing materials are vulnerable to kinetic energy impacts that are outside of the fire testing upon which their ratings are based, including asbestos - based materials, and may have been removed in large areas by the impact of the planes .

12 - Substitutes for asbestos in construction :

Fiberglass insulation was invented in 1938 and is now the most commonly used type of insulation material. The safety of this material is also being called into question due to similarities in material structure . However, the International Agency for Research on Cancer removed fiberglass from its list of possible human carcinogens in 2001.

In 1978, a highly texturized fiber glass fabric was invented by Bal Dixit, called Zetex. This fabric is lighter than asbestos, but offers the same bulk, thickness, hand, feel, and abrasion resistance as asbestos. The fiberglass was texturized to eliminate some of the problems that arise with fiberglass, such as poor abrasion resistance and poor seam strength . In Europe stone - and glass wool are the main insulators in houses.

Many companies that produced asbestos-cement products that were reinforced with asbestos fibers have developed products incorporating organic fibers. One such product was known as Eternit and another "Everite" now use "Nutec" fibers which consist of organic fibers, portland cement and silica. Cement-bonded wood fiber is another substitute. Stone fibers are used in gaskets and friction materials.

Another potential fiber is poly benzimidazole or PBI fiber. Poly benzimidazole fiber is a synthetic fiber with high melting point of 760 °C that also does not ignite. Because of its exceptional thermal and chemical stability, it is often used by fire departments and space agencies.

Asbestos alternatives for industrial use include sleeves, rope, tape, fabric, textiles and insulation batt materials made from fiberglass and silica.

13 - Recycling and disposal :

In most developed countries, asbestos is typically disposed of as hazardous waste in landfill sites.

Asbestos can also be recycled by transforming it into harmless silicate glass. A process of thermal decomposition at 1000–1250 °C produces a mixture of non-hazardous silicate phases, and at temperatures above 1250 °C it produces silicate glass.[151] Microwave thermal treatment can be used in an industrial manufacturing process to transform asbestos and asbestos-containing waste into porcelain stoneware tiles, porous single-fired wall tiles, and ceramic bricks.

Asphalt concrete

Asphalt concrete.

A layer of asphalt concrete. In road construction, a base layer of crushed rock is usually laid down first to increase durability

Machine laying asphalt concrete, fed from a dump truck.

Contents

1 - Introduction :

Asphalt concrete is a composite material commonly used in construction projects such as road surfaces , airports and parking lots. It consists of asphalt (used as a binder) and mineral aggregate mixed together, then laid down in layers and compacted. It is also increasingly used as the core for embankment dams .

The terms "asphalt (or asphaltic) concrete", "bituminous asphalt concrete" and the abbreviation "AC" are typically used only in engineering and construction documents and literature. Asphalt concrete pavements are often called just "asphalt" by laypersons who tend to associate the term concrete with Portland cement concrete only. The engineering definition of concrete is any composite material composed of mineral aggregate glued together with a binder, whether that binder is Portland cement, asphalt or even epoxy. Informally, asphalt concrete is also referred to as "blacktop", particularly in North America.

2 - Mixture formulations :

Mixing of asphalt and aggregate is accomplished in one of several ways :

- **Hot mix asphalt concrete** (commonly abbreviated as HMAC or HMA) is produced by heating the asphalt binder to decrease its viscosity, and drying the aggregate to remove moisture from it prior to mixing . Mixing is generally performed with the aggregate at about 150 °C for virgin asphalt and 166 °C) for polymer modified asphalt , and the asphalt cement at

95 °C . Paving and compaction must be performed while the asphalt is sufficiently hot. In many countries paving is restricted to summer months because in winter the compacted base will cool the asphalt too much before it is packed to the optimal air content. HMAC is the form of asphalt concrete most commonly used on highly trafficked pavements such as those on major highways, racetracks and airfields.

Super pave , short for "superior performing asphalt pavement," is a pavement system designed to provide longer lasting roadways. Key components of the system are careful selection of binders and aggregates, volumetric proportioning of ingredients, and evaluation of the finished product.

- **Warm mix asphalt concrete** (commonly abbreviated as WMA) is produced by adding either zeolites, waxes , or asphalt emulsions to the mix . This allows significantly lower mixing and laying temperatures and results in lower consumption of fossil fuels , thus releasing less carbon dioxide , aerosols and vapors . Not only are working conditions improved, but the lower laying-temperature also leads to more rapid availability of the surface for use, which is important for construction sites with critical time schedules. The usage of these additives in hot mixed asphalt (above) may afford easier compaction and allow cold weather paving or longer hauls.
- **Cold mix asphalt concrete** is produced by emulsifying the asphalt in water with (essentially) soap prior to mixing with the aggregate. While in its emulsified state the asphalt is less viscous and the mixture is easy to work and compact. The emulsion will break after enough water evaporates and the cold mix will, ideally, take on the properties of cold HMAC. Cold mix is commonly used as a patching material and on lesser trafficked service roads.
- **Cut - back asphalt concrete** is produced by dissolving the binder in kerosene or another lighter fraction of petroleum prior to mixing with the aggregate. While in its dissolved state the asphalt is less viscous and the mix is easy to

work and compact. After the mix is laid down the lighter fraction evaporates. Because of concerns with pollution from the volatile organic compounds in the lighter fraction , cut - back asphalt has been largely replaced by asphalt emulsion .

- **Mastic asphalt concrete** or sheet asphalt is produced by heating hard grade blown bitumen (oxidation) in a green cooker (mixer) until it has become a viscous liquid after which the aggregate mix is then added.

The bitumen aggregate mixture is cooked (matured) for around 6-8 hours and once it is ready the mastic asphalt mixer is transported to the work site where experienced layers empty the mixer and either machine or hand lay the mastic asphalt contents on to the road. Mastic asphalt concrete is generally laid to a thickness of around 20 - 30 mm for footpath and road applications and around 10 mm for flooring or roof applications.

In addition to the asphalt and aggregate , additives, such as polymers, and anti stripping agents may be added to improve the properties of the final product.

- **Natural asphalt concrete** can be produced from bituminous rock, found in some parts of the world, where porous sedimentary rock near the surface has been impregnated with upwelling bitumen.

Asphalt concrete pavements — especially those at airfields — are sometimes called tarmac for historical reasons, although they do not contain tar and are not constructed using the macadam process.

3 - Performance characteristics :

Asphalt concrete has different performance characteristics in terms of surface durability, tire wear, braking efficiency and road way noise. The appropriate asphalt performance characteristic is obtained by the traffic level amount in categories A,B,C,D,E, and friction coarse (FC-5). Asphalt concrete generates less roadway noise than

Portland cement concrete surfacing, and is typically less noisy than chip seal surfaces. Tire noise effects are amplified at higher operating speeds. Noise is generated through the conversion of kinetic energy to sound waves. The idea that highway design could be influenced by acoustical engineering considerations including selection of surface paving types arose in the very early 1970s.

Asphalt damaged by frost heave, or freezing of groundwater.

4 - Asphalt concrete degradation and restoration :

Asphalt deterioration can include crocodile cracking , potholes, upheaval, raveling, rutting, shoving, stripping, and grade depressions. In cold climates, freezing of the groundwater underneath can crack asphalt even in one winter (by frost heaving) . Filling the cracks with bitumen can temporarily fix the cracks, but only proper construction, i.e. allowing water to drain away from under the road, can slow this process.

Factors that cause asphalt concrete to deteriorate over time mostly fall into one of two categories: Environmental factors and traffic loads. Often, damage results from combinations of factors in both categories.

Environmental factors include heat and cold, the presence of water in the sub base or sub grade soil under lying the pavement, and frost heaves.

High temperatures soften the asphalt binder, allowing heavy tire loads to deform the pavement into ruts. Paradoxically, high heat and strong sunlight also causes the asphalt to oxidize, becoming stiffer, less resilient and cracking. Cold temperatures can cause cracks as the asphalt contracts. Cold asphalt is also less resilient and more vulnerable to cracking.

Water trapped under the pavement softens the sub base and sub grade, making the road more vulnerable to traffic loads. Water under the road freezes and expand in cold weather, causing and enlarging cracks to form. In spring thaw, the ground thaws from the top down, so water is trapped between the pavement above and the still-frozen soil underneath. This layer of saturated soil provides little support for the road above, leading to the formation of potholes. This is more of a problem for silty or clay soils than sandy or gravelly soils. Some jurisdictions pass frost laws to reduce the allowable weight of trucks during the spring thaw season and protect their roads.

Traffic damage mostly results from trucks and buses. The damage a vehicle causes is proportional to the axle load raised to the fourth power , so doubling the weight an axle carries actually causes 16 times as much damage. Wheels cause the road to flex slightly, resulting in fatigue cracking, which often leads to crocodile cracking. Vehicle speed also plays a role. Slowly moving vehicles stress the road over a longer period of time, increasing ruts, cracking, and corrugations in the asphalt pavement.

Other causes of damage include heat damage from vehicle fires, or solvent action from chemical spills.

4 – 1 - Prevention and repair of degradation :

The life of a road can be prolonged through good design, construction and maintenance practices. During design, engineers measure the traffic on a road, paying special attention to the number and types of trucks. They also evaluate the subsoil to see how much load it can withstand. The pavement and sub base thicknesses are designed to withstand the wheel loads. Sometimes, geogrids are used to reinforce the sub base and further strengthen the roads. Drainage, including ditches , storm drains and under drains are used to remove water from the roadbed, preventing it from weakening the sub base and subsoil.

Good maintenance practices center on keeping water out of the pavement, sub base and subsoil. Maintaining and cleaning ditches and storm drains will extend the life of the road at low cost. Sealing small cracks with bituminous crack sealer prevents water from enlarging cracks through frost weathering, or percolating down to the sub base and softening it. For somewhat more distressed roads, a chip seal or similar surface treatment may be applied. As the number, width and length of cracks increases, more intensive repairs are needed. In order of generally increasing expense, these include thin asphalt overlays, multicourse overlays, grinding off the top course and overlaying, in-place recycling, or full - depth reconstruction of the roadway.

It is far less expensive to keep a road in good condition than it is to repair it once it has deteriorated. This is why some agencies place the priority on preventive maintenance of roads in good condition, rather than reconstructing roads in poor condition. Poor roads are upgraded as resources and budget allow. In terms of lifetime cost and long term pavement conditions, this will result in better system performance. Agencies that concentrate on restoring their bad roads often find that by the time they've repaired them all, the roads that were in good condition have deteriorated.

Some agencies use a pavement management system to help prioritize maintenance and repairs.

5 - Recycling :

Asphalt concrete is often touted as being *100 % recyclable*. Very little asphalt concrete is actually disposed of in landfills.

Several in - place recycling techniques have been developed to rejuvenate oxidized binders and remove cracking, although the recycled material is generally not very water-tight or smooth and should be overlaid with a new layer of asphalt concrete. Cold in-place recycling mills off the top layers of asphalt concrete and mixes the resulting loose millings with asphalt emulsion. The mixture is then placed back down on the roadway and compacted. The water in the emulsion is allowed to evaporate for a week or so, and new hot-mix asphalt is laid on top.

Asphalt concrete that is removed from a pavement is usually stockpiled for later use as aggregate for new hot mix asphalt. This reclaimed material, commonly known by the acronym 'RAP' for recycled or reclaimed asphalt pavement, is crushed to a consistent gradation and added to the HMA mixing process. Sometimes waste materials, such as asphalt roofing shingles, crushed glass, or rubber from old tires, are added to asphalt concrete as is the case with rubberized asphalt, but there is a concern that the hybrid material may not be recyclable.

Barrier Cable

A cable barrier separating lanes on a 2 + 1 road in Sweden.

Contents

1 - Introduction :

Cable barrier, some times referred to as **guard cable**, is a type of road side or median barrier. It consists of steel wire ropes mounted on weak posts. As is the case with any roadside barrier, its primary purpose is to prevent a vehicle from leaving the traveled way and striking a fixed object or terrain feature that is less forgiving than itself . Also similar to most roadside barriers, cable barriers function by capturing and/or redirecting the errant vehicle.

Because these barriers are relatively inexpensive to install and very effective at capturing vehicles, their use is becoming increasingly prevalent worldwide. By far, the most popular use of the cable barrier system occurs in the medians of divided high ways.

Given the opposing directions of traffic on divided highways, cross median crashes are particularly severe. While median width plays a large role in the occurrence of these crashes, increased width alone does not eliminate them and quite often, the median must be shielded with a barrier. Cable barriers provide a cost-effective solution to the shielding issue.

The system is more forgiving than traditional concrete (Jersey) barriers or steel barriers used today and remains effective when installed on sloping terrain. The flexibility of the system absorbs impact energy and dissipates it laterally, which reduces the forces transmitted to the vehicle occupants .

Although cable barriers have been used since the 1960s it wasn't until the mid 1990s that many departments of transportation began to deploy them with any regularity.

In many countries of the European Union these cable barriers are not allowed to be used along highways since the have been shown to be especially hazardous for motorcyclists.

2 – Types :

There are two types of cable barrier systems in use today, low-tension and high - tension. Each system has its advantages and disadvantages, but in general, a high-tension system has a higher initial cost with lower long-term maintenance costs and concerns.

2 – 1 - Low – tension :

During the expansion of cable barrier use throughout the 1980s and 1990s, the low - tension system was specified almost exclusively. This system is also called the "generic" system, referring to the fact that it is not exclusively manufactured by any single producer.

Low tension simply means the cables themselves are tensed only enough to eliminate sag between posts. Large springs at both ends of the cable run are compressed (according to temperature) to achieve the low tension in the system.

When a vehicle impacts the low-tension system under normal conditions, the cable moves as much as 12 ft from its original location. This movement is known as the dynamic deflection. Given the lack of tension in the system, individual installations, or "runs", of cable are limited to 2,000 ft with an anchor assembly at each end.

Due to the low tension of the system, the cables tend to lie on the ground in the event that an impact damages multiple posts. As such, there is no residual safety value within the undamaged remainder of the 2,000 ft installation and that entire section of barrier will remain nonfunctional until repaired.

Despite these perceived shortcomings, low-tension cable barrier, until recently, was arguably the work horse of the industry. Thousands of miles of the generic system remain in use today in countries world wide.

2 – 2 - High – tension :

In appearance, high-tension cable is very similar to low – tension . In most other aspects, the two systems are very different.

High - tension cable consists of three or four pre-stretched cables supported by weak posts. Currently, all high-tension systems are proprietary, that is, marketed under exclusive right of a specific manufacturer.

During installation, the cables are placed on the posts, and then tightened to a specific tension according to temperature. The tensions values range between approximately 2,000 and 9,000 lb. Due to this tightening, the cable installations can be of indefinite length. In fact, the lengths of the runs are usually only limited by the presence of obstacles such as median openings or bridge columns.

When a vehicle impacts the high-tension system under normal conditions, the cable deflects as little as 8 ft from its original location. The inherent tension within the system also allows the cables to remain strung, even after an impact that removes several posts, thus allowing the remainder of the run to function normally.

3 - Performance limits :

3 – 1 - Safety testing :

A road side safety hard ware feature must undergo rigorous safety testing before it can be used on the National High way System (NHS) in the United States. Most states have adopted the same testing criteria for high ways that are not on the NHS. The standard by which all roadside safety features are measured is contained within the National Cooperative Highway Research Program Report No. 350 (NCHRP 350). NCHRP 350 evaluates safety hardware according to three general factors :

- **Structural Adequacy :** the system must contain and redirect the vehicle with no under riding , over riding , or penetration.
- **Occupant Risk :** fragments of the system cannot penetrate the passenger compartment, the vehicle must remain upright during and after the collision, and the passenger must not undergo excessive impact or deceleration.
- **Vehicle Trajectory :** after the impact, the vehicle should not intrude into adjacent traffic lanes nor should it exit the system at an angle greater than 60 % of the entry angle.

3 – 2 - Test levels :

Within NCHRP 350 are six separate test levels (TL) representing different vehicles, impact angles and speeds. Test level three (TL-3) is probably the most common as it establishes safety criteria for both small cars and pickups at 60 mph. This category of traffic accounts for the majority of all vehicle traffic in the United States.

At TL - 3, an 1800 lb car is crashed at 60 mph on an impact angle of 20°. Also at this level, a 4400 lb pickup truck impacts at 60 mph and 25°.

TL - 4 includes both these tests but adds a 17,600 lb single-unit truck impacting at 50 mph and 25°.

All cable barrier systems available today are approved at either TL - 3 or TL- 4 . There is a great deal of anecdotal evidence, however, that many of these systems are performing at a higher level in the field capturing vehicles as large as semi truck-trailer combinations.

4 - Environmental limits :

4 – 1 - Slopes :

Cable barrier, like most roadside safety hardware, is intended for use on slopes with a 1:6 vertical to horizontal ratio. The 1V:6H requirement is based in both computer modeling and full-scale crash testing and represents sound theory. In practice, however, slopes as flat as 1V:6H are often the exception.

In these cases, there are three TL- 4 systems available that function as TL-3 on slopes as steep as 1V : 4H .

4 – 2 - Clearance :

Rigid barriers such as concrete and semi-rigid barriers such as steel guardrail, exhibit impact deflections of 0 to 4 ft, respectively. Flexible systems such as cable barriers deflect between 8 and 12 ft upon impact. Given these relatively large deflections, cable barrier systems are not usually considered appropriate to shield fixed objects closer than 8 ft offset of the traveled way. Even when the available clearance exceeds 8 ft, the public seems to have a greater level of confidence in a more robust barrier.

5 - Defective Installation and Accidents :

Median Cable Barriers have been studied for safety, and they are arguably effective deterrents to serious high way accidents. How ever, a lack of proper installation and testing has led to severe collisions and even death . In places, such as Arizona, there is indication that the state government agency in charge of highway regulation failed to follow proper installation procedures[7]. Apparently there are internal government documents which show that the Arizona Department of Transportation was aware of cable barrier problems, and they may have also rushed installation of these barriers on state high ways .

A major problem alleged, that reduces the effectiveness of cable barriers, is the installation below grade, especially around slopes or dips . Without any compensation for a slope in the median, a car can actually jump the top of a barrier, and therefore be exposed to a potential cross-over collision . Litigation has arisen in Arizona regarding the improper installation of cable barriers . One wrongful death suit resulted in a one million dollar settlement with the state . In Washington state, numerous letters were submitted to the state Department of Transportation complaining of cable barrier installation .

Basalt

	
Columnar basalt at Szent György Hill, Hungary	*Basalt Rock*

Contents

1 – Introduction :

Basalt is a common extrusive igneous (volcanic) rock formed from the rapid cooling of basaltic lava exposed at or very near the surface of a planet or moon. By definition, basalt must be an aphanitic igneous rock with less than 20% quartz and less than 10 % feldspathoid by volume, and where at least 65% of the feldspar is in the form of plagioclase. Basalt is usually grey to black in colour, but rapidly weathers to brown or rust-red due to oxidation of its mafic (iron-rich) minerals into rust. It almost always has a fine-grained mineral texture due to the molten rock cooling too quickly for large mineral crystals to grow, although it can sometimes be porphyritic, containing the larger crystals formed prior to the extrusion that brought the lava to the surface, embedded in a finer-grained matrix. Basalt with a vesicular or frothy texture is called scoria, and forms when dissolved gases are forced out of solution and form vesicles as the lava decompresses as it reaches the surface.

On Earth, most basalt magmas have formed by decompression melting of the mantle. Basalt commonly erupts on Io, and has also formed on Earth's Moon, Mars, Venus, and even on the asteroid Vesta. Source rocks for the partial melts probably include both peridotite and pyroxenite (e.g., Sobolev et al., 2007). The crustal portions of oceanic tectonic plates are composed predominantly of basalt, produced from upwelling mantle below ocean ridges.

The term basalt is at times applied to shallow intrusive rocks with a composition typical of basalt, but rocks of this composition with a phaneritic (coarse) groundmass are generally referred to as diabase (also called dolerite) or gabbro.

2 – Etymology :

The word "basalt" is ultimately derived from Late Latin *basaltes*, misspelling of L. *basanites* "very hard stone," which was imported from Ancient Greek basani'ty*s (basanites), from ba'sano*s (basanos, "touchstone") and originated in Egyptian *bauhun* "slate". The modern petrological term *basalt* describing a particular composition of lava-derived rock originates from its use by Georgius Agricola in 1556 in his famous work of mining and minerology *De re metallica*, *libri XII*. Agricola applied "basalt" to the volcanic black rock of the Schlossberg (local castle hill) at Stolpen, believing it to be the same as Pliny the Elder's "very hard stone".

3 – Uses :

Basalt is used in construction (e.g. as building blocks or in the groundwork), making cobblestones (from columnar basalt) and in making statues. Heating and extruding basalt yields stone wool, an excellent thermal insulator.

5 – Types :

- Tholeiitic basalt is relatively rich in silica and poor in sodium. Included in this category are most basalts of the ocean floor, most large oceanic islands, and continental flood basalts such as the Columbia River Plateau.
- *MORB* (Mid Ocean Ridge Basalt), is characteristically low in incompatible elements. MORB is commonly erupted only at ocean ridges. MORB itself has been subdivided into varieties such as *NMORB* and *EMORB* (slightly more enriched in incompatible elements).
- *High alumina basalt* may be silica-undersaturated or -oversaturated (see normative mineralogy). It has greater than 17% alumina (Al_2O_3) and is intermediate in composition between tholeiite and alkali basalt; the relatively alumina-rich composition is based on rocks without phenocrysts of plagioclase.
- Alkali basalt is relatively poor in silica and rich in sodium. It is silica-under saturated and may contain feldspathoids, alkali feldspar and phlogopite.
- Boninite is a high-magnesium form of basalt that is erupted generally in back-arc basins, distinguished by its low titanium content and trace element composition.

5 – Petrology :

The mineralogy of basalt is characterized by a preponderance of calcic plagioclase feldspar and pyroxene. Olivine can also be a significant constituent. Accessory minerals present in relatively minor amounts include iron oxides and iron-titanium oxides, such as magnetite, ulvospinel, and ilmenite. Because of the presence of such oxide minerals, basalt can acquire strong magnetic signatures as it cools, and paleomagnetic studies have made extensive use of basalt.

In tholeiitic basalt, pyroxene (augite and ortho pyroxene or pigeonite) and calcium-rich plagioclase are common phenocryst minerals. Olivine may also be a phenocryst, and when present, may have rims of pigeonite. The groundmass contains interstitial quartz or tridymite or cristobalite. *Olivine tholeiite* has augite and ortho pyroxene or pigeonite with abundant olivine, but olivine may have rims of pyroxene and is unlikely to be present in the groundmass.

Alkali basalts typically have mineral assemblages that lack orthopyroxene but contain olivine. Feldspar phenocrysts typically are labradorite to andesine in composition. Augite is rich in titanium compared to augite in tholeiitic basalt. Minerals such as alkali feldspar, leucite, nepheline, sodalite, phlogopite mica, and apatite may be present in the groundmass.

Basalt has high liquidus and solidus temperatures—values at the Earth's surface are near or above 1200 °C (liquidus) and near or below 1000 °C (solidus); these values are higher than those of other common igneous rocks.

The majority of tholeiites are formed at approximately 50–100 km depth within the mantle. Many alkali basalts may be formed at greater depths, perhaps as deep as 150–200 km. The origin of high-alumina basalt continues to be controversial, with interpretations that it is a primary melt and that instead it is derived from other basalt types (e.g., Ozerov, 2000).

5 – 1 – Geochemistry :

Relative to most common igneous rocks, basalt compositions are rich in MgO and CaO and low in SiO_2 and the alkali oxides, i.e., Na_2O + K_2O, consistent with the TAS classification.

Basalt generally has a composition of 45-55 wt% SiO_2, 2-6 wt% total alkalis, 0.5-2.0 wt% TiO_2, 5-14 wt % Fe O and 14 wt % or more

Al_2O_3. Contents of Ca O are commonly near 10 wt%, those of Mg O **commonly in the range 5 to 12 wt%.**

High alumina basalts have aluminium contents of 17-19 wt% Al_2O_3; boninites have magnesium contents of up to 15% MgO. Rare feldspathoid-rich mafic rocks, akin to alkali basalts, may have Na_2O + K_2O contents of 12% or more.

The abundances of the Lanthanide or rare earth elements (REE) can be a useful diagnostic tool to help explain the history of mineral crystallisation as the melt cooled. In particular, the relative abundance of europium compared to the other REE is often markedly higher or lower, and called the europium anomaly. It arises because Eu^{2+} can substitute for Ca^{2+} in plagioclase feldspar, unlike any of the other Lanthanides, which tend to only form 3+ cations.

MORB basalts and their intrusive equivalents, gabbros, are the characteristic igneous rocks formed at mid-ocean ridges. They are tholeiites particularly low in total alkalis and in incompatible trace elements, and they have relatively flat REE patterns normalized to mantle or chondrite values. In contrast, alkali basalts have normalized patterns highly enriched in the light REE, and with greater abundances of the REE and of other incompatible elements. Because MORB basalt is considered a key to understanding plate tectonics, its compositions have been much studied. Although MORB compositions are distinctive relative to average compositions of basalts erupted in other environments, they are not uniform. For instance, compositions change with position along the Mid-Atlantic ridge, and the compositions also define different ranges in different ocean basins (Hofmann, 2003).

Isotope ratios of elements such as strontium, neodymium, lead, hafnium, and osmium in basalts have been much-studied, so as to learn about evolution of the Earth's mantle. Isotopic ratios of noble gases, such as ^3He / ^4He, are also of great value: for instance, ratios for basalts range from 6 to 10 for mid-ocean ridge tholeiite (normalized to atmospheric values), but to 15-24+ for ocean island basalts thought to be derived from mantle plumes.

5 – 2 - Morphology and textures :

An active basalt lava flow

The shape, structure and texture of a basalt is diagnostic of how and where it erupted — whether into the sea, in an explosive cinder eruption or as creeping pahoehoe lava flows, the classic image of Hawaiian basalt eruptions.

5 – 2 – 1 - Sub aerial eruptions :

Basalt which erupts under open air (that is, subaerially) forms three distinct types of lava or volcanic deposits: scoria; ash or cinder (breccia); and lava flows.

Basalt in the tops of sub aerial lava flows and cinder cones will often be highly vesiculated, imparting a lightweight "frothy" texture to the rock. Basaltic cinders are often red, coloured by oxidized iron from weathered iron-rich minerals such as pyroxene.

\`A\`a types of blocky, cinder and breccia flows of thick, viscous basaltic lava are common in Hawaii. Pahoehoe is a highly fluid, hot form of basalt which tends to form thin aprons of molten lava which fill up hollows and sometimes forms lava lakes. Lava tubes are common features of pahoehoe eruptions.

Basaltic tuff or pyroclastic rocks are rare but not unknown. Usually basalt is too hot and fluid to build up sufficient pressure to form explosive lava eruptions but occasionally this will happen by trapping of the lava within the volcanic throat and build up of volcanic gases. Hawaii's Mauna Loa volcano erupted in this way in the 19 th century, as did Mount Tarawera, New Zealand in its violent 1886 eruption. Maar volcanoes are typical of small basalt tuffs, formed by explosive eruption of basalt through the crust, forming an apron of mixed basalt and wall rock breccia and a fan of basalt tuff further out from the volcano . Amygdaloidal structure is common in relict vesicles and beautifully crystallized species of zeolites, quartz or calcite are frequently found.

5 – 2 – 1 – 1 - Columnar basalt :

Columnar jointed basalt in Turkey

During the cooling of a thick lava flow, contractional joints or fractures form. If a flow cools relatively rapidly, significant contraction forces build up. While a flow can shrink in the vertical dimension without fracturing, it can't easily accommodate shrinking in the horizontal direction unless cracks form; the extensive fracture network that develops results in the formation of columns. The topology of the lateral shapes of these columns can broadly be classed as a random cellular network. These structures are predominantly hexagonal in cross-section, but polygons with three to twelve or more sides can be observed.[7] Note that the size of the columns depends loosely on the rate of cooling; very rapid cooling may result in very small (<1 cm diameter) columns, while slow cooling is more likely to produce large columns.

5 – 2 – 2 - Submarine eruptions :

5 – 2 – 2 – 1 - Pillow basalts :

When basalt erupts underwater or flows into the sea, contact with the water quenches the surface and the lava forms a distinctive *pillow* shape, through which the hot lava breaks to form another pillow. This "pillow" texture is very common in underwater basaltic flows and is diagnostic of an underwater eruption environment when found in ancient rocks. Pillows typically consist of a fine-grained core with a glassy crust and have radial jointing. The size of individual pillows varies from 10 cm up to several meters.

When *pahoehoe* lava enters the sea it usually forms pillow basalts. However when *a'a* enters the ocean it forms a littoral cone, a small cone-shaped accumulation of tuffaceous debris formed when the blocky *a'a* lava enters the water and explodes from built-up steam.

The island of Surtsey in the Atlantic Ocean is a basalt volcano which breached the ocean surface in 1963. The initial phase of Surtsey's eruption was highly explosive, as the magma was quite wet, causing the rock to be blown apart by the boiling steam to form a tuff and cinder cone. This has subsequently moved to a typical pahoehoe-type behaviour.

Volcanic glass may be present, particularly as rinds on rapidly chilled surfaces of lava flows, and is commonly (but not exclusively) associated with underwater eruptions.

6 - Life on basaltic rocks :

The common corrosion features of underwater volcanic basalt suggest that microbial activity may play a significant role in the chemical exchange between basaltic rocks and seawater. The significant amounts of reduced iron, Fe (II), and manganese, Mn(II), present in basaltic rocks provide potential energy sources for bacteria. Recent research has shown that some Fe (II) - oxidizing bacteria cultured from iron-sulfide surfaces are also able to grow with basaltic rock as a source of Fe (II) . In recent work at Loihi Seamount, Fe- and Mn - oxidizing bacteria have been cultured from weathered basalts . The impact of bacteria on altering the chemical composition of basaltic glass (and thus, the oceanic crust) and seawater suggest that these interactions may lead to an application of hydrothermal vents to the origin of life.

7 - Distribution :

Basalt is one of the most common rock types in the world. Basalt is the rock most typical of large igneous provinces. The largest occurrences of basalt are in the ocean floor that is almost completely made up by basalt. Above sea level basalt is common in hotspot islands and around volcanic arcs, specially those on thin crust. However, the largest volumes of basalt on land correspond to continental flood basalts. Continental flood basalts are known to exist in the Deccan Traps in India, the Chilcotin Group in British Columbia, Canada, the Paraná Traps in Brazil, the Siberian Traps in Russia, the Karoo flood basalt province in South Africa, the Columbia River Plateau of Washington and Oregon.

Many archipelagoes and island nations have an overwhelming majority of its exposed bedrock made up by basalt due to being above hotspots, for example, Iceland and Hawaii

Ancient Precambrian basalts are usually only found in fold and thrust belts, and are often heavily metamorphosed. These are known as greenstone belts, because low-grade metamorphism of basalt produces chlorite, actinolite, epidote and other green minerals.

8 - Lunar and Martian basalt :

Lunar olivine basalt collected by Apollo 15.

The dark areas visible on Earth's moon, the lunar maria, are plains of flood basaltic lava flows. These rocks were sampled by the manned American Apollo program, the robotic Russian Luna program, and are represented among the lunar meteorites.

Lunar basalts differ from their terrestrial counterparts principally in their high iron contents, which typically range from about 17 to 22 wt% FeO. They also possess a stunning range of titanium concentrations (present in the mineral ilmenite), ranging from less than 1 wt% TiO_2, to about 13 wt.%. Traditionally, lunar basalts have been classified according to their titanium content, with classes being named high-Ti, low-Ti, and very-low-Ti. Nevertheless, global geochemical maps of titanium obtained from the Clementine mission demonstrate that the lunar maria possesses a continuum of titanium concentrations, and that the highest concentrations are the least abundant.

Lunar basalts show exotic textures and mineralogy, particularly shock metamorphism, lack of the oxidation typical of terrestrial basalts, and a complete lack of hydration. While most of the Moon's basalts erupted between about 3 and 3.5 billion years ago, the oldest samples are 4.2 billion years old, and the youngest flows, based on the age dating method of "crater counting," are estimated to have erupted only 1.2 billion years ago.

Basalt is also a common rock on the surface of Mars, as determined by data sent back from the planet's surface and by Martian meteorites.

9 - Alteration of basalt :

9 – 1 – Metamorphism :

Basalts are important rocks within metamorphic belts, as they can provide vital information on the conditions of metamorphism within the belt. Various metamorphic facies are named after the mineral assemblages and rock types formed by subjecting basalts to the temperatures and pressures of the metamorphic event. These are :

- Blueschist facies
- Eclogite facies
- Granulite facies
- Greenschist facies
- Zeolite facies

Metamorphosed basalts are important hosts for a variety of hydrothermal ore deposits, including gold deposits, copper deposits, volcanogenic massive sulfide ore deposits and others.

9 – 2 – Weathering :

Compared to other rocks found on Earth's surface, basalts weather relatively fast. The typically iron-rich minerals oxidise rapidly in water and air, staining the rock a brown to red colour due to iron oxide (rust). Chemical weathering also releases readily water-soluble cations such as calcium, sodium and magnesium, which give basaltic areas a strong buffer capacity against acidification. Calcium released by basalts binds up CO_2 from the atmosphere forming $CaCO_3$ acting thus as a CO_2 trap. To this it must be added that the eruption of basalt itself is often associated with the release of large quantities of CO_2 into the atmosphere from volcanic gases.

Carbon sequestration in basalt has been studied as a means of removing carbon dioxide, produced by human industrialization, from the atmosphere. Underwater basalt deposits, scattered in seas around the globe, have the added benefit of the water serving as a barrier to the re-release of CO_2 into the atmosphere.

Basalt Fiber

Contents

1 – Introduction :

Basalt fiber or **fibre** is a material made from extremely fine fibers of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine. It is similar to carbon fiber and glass fiber, having better physico mechanical properties than glass fiber, but being significantly cheaper than carbon fiber. It is used as a fire proof textile in the aerospace and automotive industries and can also be used as a composite to produce products such as camera tripods.

2 – Manufacture :

Basalt fiber is made from a single material, crushed basalt, from a carefully chosen quarry source and unlike other materials such as glass fiber, essentially no materials are added. The basalt is simply washed and then sent to be melted down .

The manufacture of basalt fiber requires the melting of the quarried basalt rock at about 1,400 °C (2,550 °F). The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fiber. There are three main manufacturing techniques, which are centrifugal-blowing, centrifugal - multirole and die - blowing. The fibers typically have a filament diameter of between 9 and 13 µm which is far enough above the respiratory limit of 5 µm to make basalt fiber a suitable replacement for asbestos. They also have a high elastic modulus, resulting in excellent specific tenacity—three times that of steel.

3 – Properties :

Property	Value
Tensile strength	4.84 GPa
Elastic modulus	89 GPa
Elongation at break	3.15 %
Density	2.7 g/cm³

Comparison :

Material	**Density (g/cm³)**	**Tensile strength (GPa)**	**Elastic modulus (GPa)**
Steel re-bar	7.85	0.5	210
A-glass	2.46	3.31	69
C-glass	2.46	3.31	69
E-glass	2.60	3.45	76
S-2 glass	2.49	4.83	97
Silicon	2.16	0.206-0.412	-
Quartz	2.2	0.3438	-
Carbon fiber (large)	1.74	3.62	228
Carbon fiber (medium)	1.80	5.10	241
Carbon fiber (small)	1.80	6.21	297
Kevlar K-29	1.44	3.62	41.4
Kevlar K-149	1.47	3.48	-

Polypropoline	0.91	0.27-0.65	38
Polyacrylonit	1.18	0.50-0.91	75
Basalt fiber	2.65	4.15-4.80	100-110

4 – History :

The first attempts to produce basalt fiber were made in the United States in 1923. These were further developed after World War II by researchers in the USA, Europe and the Soviet Union especially for military and aerospace applications. Since declassification in 1995 basalt fibers have been used in a wider range of civilian applications.

5 – Uses :

- Heat protection
- Friction materials
- High pressure vessels (e.g. tanks and gas cylinders)
- Load bearing profiles
- Windmill blades
- Lamp posts
- Ship hulls
- Car bodies
- Sports equipment
- Concrete reinforcement (e.g. for bridges and buildings)

Belite

Contents

1 – Introduction :

Belite is an industrial mineral important in Portland cement manufacture, a name for di calcium silicate, Ca_2SiO_4, sometimes formulated as 2 Ca O · SiO_2 (C_2S in cement chemist notation).

The name was given by Törneborn in 1897 to a crystal identified in microscopic investigation of Portland Cement. Belite is a name in common use in the cement industry, and is not a recognized mineral name. Belite occurs naturally as the mineral larnite.

2 - Composition and structure :

The belite found in Portland cement differs in composition from pure di calcium silicate. It is a solid solution and contains minor amounts of other oxides besides Ca O and SiO_2 . A typical composition :

Oxide	Mass %
Ca O	63.5
$Si\ O_2$	31.5
$Al_2\ O_3$	2.1
$Fe_2\ O_3$	0.9
Mg O	0.5
$S\ O_3$	0.1
$Na_2\ O$	0.1

K_2O	0.9
TiO_2	0.2
P_2O_5	0.2

Based on this, the formula can be expressed as $Ca_{1.94}Mg_{0.02}Na_{0.01}K_{0.03}Fe_{0.02}Al_{0.07}Si_{0.90}P_{0.01}O_{3.93}$. In practice, the composition varies with the bulk composition of the clinker, subject to certain limits. Substitution of calcium ions or ortho silicate ions requires that electric charges be kept in balance. For instance, a limited number of ortho silicate (SiO_4^{4-}) ions can be replaced with sulfate (SO_4^{2-}) ions, provided that for each sulfate ion , two aluminate (AlO_4^{5-}) ions are also substituted.

3 – Polymorphs :

Di calcium silicate is stable, and is readily prepared from reactive Ca O and SiO_2 at 300 °C . The low temperature form is γ-belite, or lime olivine. This form does not hydrate, and is avoided in cement manufacture.

As the temperature rises, it passes through several polymorphic states :

Temp°C	Name	Crystal
>1425	α	Hexagonal
1160 - 1425	α'_H	Ortho rhombic
680 - 1160	α'_L	Ortho rhombic
500 - 680	β	Mono clinic
< 500	γ	Ortho rhombic

4 - Hydration :

Belite is the mineral in Portland cement responsible for development of "late" strength. The other silicate, alite contributes "early" strength, due to its higher reactivity. Belite reacts with water (roughly) to form calcium silicate hydrates (C-S-H) and portlandite ($Ca(OH)_2$) according to the reaction:

$$\textit{Belite} + \textit{water} \rightarrow \textit{C-S-H phase} + \textit{portlandite}$$
$$2\ Ca_2SiO_4 + 4\ H_2O \rightarrow 3\ CaO \cdot 2\ SiO_2 \cdot 3\ H_2O + Ca(OH)_2$$

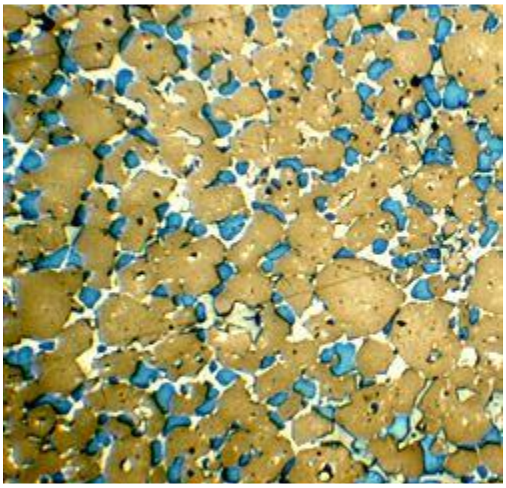
This rapid reaction is "chemically analogue" to the slow natural hydration of forsterite (the magnesium end-member of olivine) leading to the formation of serpentine and brucite in nature, although the kinetic of hydration of poorly crystallized artificial belite is much faster than the slow weathering of well crystallized Mg-olivine under natural conditions.

$$\textit{Forsterite} + \textit{water} \rightarrow \textit{serpentine} + \textit{brucite}$$
$$2\ Mg_2SiO_4 + 3\ H_2O \rightarrow Mg_3Si_2O_5(OH)_4 + Mg\ (OH)_2$$

The hydrate phase, [$3\ Ca\ O \cdot 2\ Si\ O_2 \cdot 3\ H_2O$], is referred to as the "C-S-H" phase. It grows as a mass of interlocking needles that provide the strength of the hydrated cement system. Relatively high belite reactivity is desirable in Portland cement manufacture, and the formation of the un reactive γ- form must be rigorously avoided. This is achieved by rapid cooling, forming crystals that are small, distorted and highly defective. Defects provide sites for initial water attack. Failure to cool the clinker rapidly leads to inversion of belite to the γ-form. The γ-form has a substantially different structure and density, so that inversion leads to degradation of the crystal and its surrounding matrix, and can also trigger decomposition of the neight boring alite . This is observed macroscopically as "dusting": the clinker nodules fall to a fine dust.

5 - Detection :

The minerals in Portland cement clinker may be observed and quantified by petro graphic microscopy. Clinker nodules are cut and ground to a flat, polished surface. The exposed minerals are made visible and identifiable by etching the surface. The surface can then be observed in reflected light by optical microscopy. In the example, a clinker nodule has been polished and etched with hydrogen fluoride vapour. The alite shows as brown, the belite as blue, and the melt phases as white. Electron microscopy can also be used, in which case the minerals may be identified by microprobe analysis. The preferred method to quantify the minerals accurately is X-ray diffraction on the powdered clinker, using the Rietveld analysis technique. Belite is much harder to grind in a cement mill than alite.



Clinker section 0.15 x 0.15 mm

Bentonite

Bentonite

Contents :

1 - Introduction :

Bentonite is an absorbent aluminium phyllo silicate, essentially impure clay consisting mostly of montmorillonite . There are different types of bentonite, each named after the respective dominant element, such as potassium (K), sodium (Na), calcium (Ca), and aluminum (Al). Experts debate a number of nomenclatorial problems with the classification of bentonite clays. Bentonite usually forms from weathering of volcanic ash, most often in the presence of water. However, the term bentonite, as well as a similar clay called tonstein, has been used for clay beds of uncertain origin. For industrial purposes, two main classes of bentonite exist: sodium and calcium bentonite. In stratigraphy and tephrochronology, completely devitrified (weathered volcanic glass) ash - fall beds are commonly referred to as K-bentonites when the dominant clay species is illite.

Other common clay species, and sometimes dominant, are montmorillonite and kaolinite. Kaolinite - dominated clays are commonly referred to as tonsteins and are typically associated with coal.

2 – Types :

2 – 1 - Sodium bentonite :

Sodium bentonite expands when wet, absorbing as much as several times its dry mass in water. Because of its excellent colloidal properties, it is often used in drilling mud for oil and gas wells and for geotechnical and environmental investigations.

The property of swelling also makes sodium bentonite useful as a sealant, especially for the sealing of subsurface disposal systems for spent nuclear fuel and for quarantining metal pollutants of groundwater. Similar uses include making slurry walls , waterproofing of below-grade walls, and forming other impermeable barriers, e.g., to seal off the annulus of a water well, to plug old wells, or to line the base of landfills to prevent migration of leachate. It is also used to form a barrier around newly planted trees to constrain root growth so as to prevent damage to nearby pipes, footpaths and other infrastructure.

Sodium bentonite can also be " sandwiched " between synthetic materials to create geo - synthetic clay liners (GCL) for the aforementioned purposes. This technique allows for more convenient transport and installation, and it greatly reduces the volume of sodium bentonite required . Various surface modifications to sodium bentonite improve some rheological or sealing performance in geoenviromental applications, for example, the addition of polymers.

2 – 2 - Calcium bentonite :

Calcium bentonite is a useful adsorbent of ions in solution , as well as fats and oils, being a main active ingredient of fuller's earth, probably one of the earliest industrial cleaning agents . Calcium bentonite may be converted to sodium bentonite (termed sodium beneficiation or sodium activation) to exhibit many of sodium bentonite's properties by a process known as "ion exchange" (patented in 1935 by Germans U Hofmann and K Endell) . In common usage, this means adding 5–10 % of a soluble sodium salt such as sodium carbonate to wet bentonite, mixing well, and allowing time for the ion exchange to take place and water to remove the exchanged calcium . Some properties, such as viscosity and fluid loss of suspensions, of sodium - beneficiated calcium bentonite (or sodium - activated bentonite) may not be fully equivalent to those of natural sodium bentonite . For example, residual calcium carbonates (formed if exchanged cations are insufficiently removed) may result in inferior performance of the bentonite in geo synthetic liners.

2 – 3 - Potassium bentonite :

Also known as potash bentonite or K-bentonite, potassium bentonite is a potassium - rich illitic clay formed from alteration of volcanic ash.

3 - Uses :

Much of bentonite 's use fullness in the drilling and geotechnical engineering industry comes from its unique rheological properties. Relatively small quantities of bentonite suspended in water form a viscous, shear thinning material. Most often, bentonite suspensions are also thixotropic , although rare cases of rheopectic behavior have also been reported. At high enough concentrations (~60 grams of bentonite per litre of suspension), bentonite suspensions begin to take on the characteristics of a gel (a fluid with a minimum yield strength required to make it move). For these reasons it is a common component of drilling mud used to curtail drilling fluid invasion by its propensity for aiding in the formation of mud cake.

Bentonite can be used in cement, adhesives, ceramic bodies, and cat litter. Bentonite is also used as a binding agent in the manufacture of taconite pellets as used in the steel making industry. Fuller's earth, an ancient dry-cleaning substance, is finely ground bentonite, typically used for purifying transformer oil. Bentonite, in small percentages, is used as an ingredient in commercially designed clay bodies and ceramic glazes. Bentonite clay is also used in pyrotechnics to make end plugs and rocket engine nozzles.

The ionic surface of bentonite has a useful property in making a sticky coating on sand grains. When a small proportion of finely ground bentonite clay is added to hard sand and wetted, the clay binds the sand particles into a moldable aggregate known as green sand used for making molds in sand casting. Some river deltas naturally deposit just such a blend of clay silt and sand, creating a natural source of excellent molding sand that was critical to ancient metal working technology. Modern chemical processes to modify the ionic surface of bentonite greatly intensify this stickiness, resulting in remarkably dough - like yet strong casting sand mixes that stand up to molten metal temperatures.

The same effluvial deposition of bentonite clay on to beaches accounts for the variety of plasticity of sand from place to place for building sand castles. Beach sand consisting of only silica and shell grains does not mold well compared to grains coated with bentonite clay. This is why some beaches are much better for building sand castles than others . The self - stickiness of bentonite allows high - pressure ramming or pressing of the clay in molds to produce hard, refractory shapes, such as model rocket nozzles. Indeed, to test whether a particular brand of cat litter is bentonite, simply ram a sample with a hammer into a sturdy tube with a close - fitting rod; bentonite will form a very hard, consolidated plug that is not easily crumbled. Bentonite also has the interesting property of adsorbing relatively large amounts of protein molecules from aqueous solutions. There fore, it is uniquely use ful in the process of wine making, where it is used to remove excessive amounts of protein from white wines. Were it not for this use of bentonite, many or most white wines would precipitate undesirable flocculent clouds or hazes upon exposure to warmer temperatures, as these proteins denature. It also has the incidental use of inducing more rapid clarification of both red and white wines.

3 – 1 – Medical :

Bentonite has been prescribed as a bulk laxative, and it is also used as a base for many dermatologic formulas.

Bentoquatam is a bentonate - based topical medication intended to act as a shield against exposure to urushiol, the oil found in plants such as poison ivy or poison oak.

3 – 2 - In Thai farming :

Application of bentonite clay technology made a big contribution to rejuvenating degraded soils in North east Thailand, which both improved yields and farmer incomes.

Over the past 40 years, North east Thailand has under gone significant changes in land use. Farming systems moved from being subsistence agriculture to being commercial agriculture, typically characterized by paddy rice production in the low lands and sugar cane / cassava production in the up lands. How ever, the intensification of these production systems degraded soil chemical properties in ways that are best described as nutrient / resource mining operations. As a consequence of these changes, productivity and production systems declined, as soils became depleted of their nutrients and water - retaining properties.

The application of clay technology by farmers in Northeast Thailand, using bentonite clay, has dramatically reversed soil degradation and resulted in greater economic returns, with higher yields and higher output prices. Studies carried out by The International Water Management Institute and partners in 2002–2003 focused on the application of locally sourced bentonite clays to degraded soils in the region. These applications were carried out in structured field trials. Results from these studies showed that applying bentonite clays effectively improved yields of forage sorghum grown under rain-fed conditions.

Cumulative dry matter production over a two - year period ranged from 0.22 tons per hectare under control treatment applying normal fertilizer only, to 23 tons per hectare using an application of 50 tons per hectare of bentonite. Yields rose to 36 tons per hectare when a combination of 50 tons per hectare of bentonite and 10 tons per hectare of leaf litter was applied. These and several other studies conclusively demonstrated that introducing clay - based materials such as bentonite and termite mound materials significantly and persistently improve the productivity of degraded, light – textured soils.

Three years after the conclusion of this project, a survey was carried out on 250 farmers, equally split between those farmers that had adopted clay-based approaches versus those that had not. The purpose was to assess the economic effects of the project. Using different methods, an economic assessment was carried out. Although the responses were, in essence, agronomic effects, they also tended to cause major changes in farm economies, especially concerning the type and composition of different agricultural supplies and enhancing marketability. Variations in the quantity and composition of these yield-increasing supplies explain differing productivity levels and the return on investment of farms that used clay applications versus the farms that did not.

Apart from its role of changing the nature and composition of farm supplies, bentonite application also influenced the prices that farmers received for their crops. The average output price for farmers using clay technologies was 18 % higher than that for non-clay users; this suggests that either clay-using farmers go for high value crops (as in vegetable farms) or they receive a higher price for their produce, due to better quality (e.g., from organic rice and integrated farms). Production costs are higher, but, due to more production and the quality of the food, clay farmers could afford to invest and grow more and better food, compared to non clay-using farmers. For example, the average per-hectare cost of clay-using farms was 57% higher than that for non-users, but the per-hectare gross revenue of farms using bentonite clay technologies was twice that of non-clay-using farms. Since the net values of the treated and control groups were compared, clay application led to a net benefit of about 120 %.

4 - History and natural occurrence :

List of countries by bentonite production :

Bentonite output in 2005. Click the image for the details.

In 2005, U.S. was the top producer of bentonite with almost one-third world share followed by China and Greece, reports the British Geological Survey.

The absorbent clay was given the name bentonite by Wilbur C. Knight in 1898, after the Cretaceous Benton Shale near Rock River, Wyoming . Other modern discoveries include montmorillonite discovered in 1847 in Montmorillon in the Vienne prefecture of France, in Poitou - Charentes, South of the Loire Valley.

Most high - grade natural sodium bentonite is produced from the western United States in an area between the Black Hills of South Dakota and the Bighorn Basin of Wyoming. Mixed sodium/calcium bentonite is mined in Greece, Australia, India, Russia, and the Ukraine. In the United States, calcium bentonite is mined primarily in Mississippi and Alabama. Other major locations producing calcium bentonite include Germany, Greece, Turkey, India, and China.

It should be noted that, in some countries like the UK and US, calcium bentonite is known as fuller's earth, a term also used to refer to attapulgite, in terms of mineralogy, a distinct clay mineral but one exhibiting similar properties.

Bio Rock

Contents

1 – Introduction :

Biorock, also known as **Seacrete** , is a substance formed by electro - accumulation of minerals dissolved in sea water. The building process, popularly called accretion, is not to be confused with Biorock sewage treatment. The biorock building process grows cement-like engineering structures and marine ecosystems, often for mariculture of corals, oysters, clams, lobsters and fish in salt water. It works by passing a small electrical current through electrodes in the water. The structure grows more or less without limit as long as current flows.

Biorock accelerates growth on coral reefs by as much as fivefold and increases coral survival. Biorock can enable coral growth and regrowth even in the presence of environmental stress such as thermal pollution, i.e. increasing water temperatures. When mixed with construction aggregates, it can build components on the sea floor or on land. Biorock represents the only known method that can sustain and grow natural coral species using only basic conducting elements, typically of a common metal such as steel.

Biorock samples range in compressive strength from 3720 to 5350 lbf/in² (26 to 37 M Pa) – for comparison, the concrete typically used in sidewalks has a strength of about 3500 lb f / in² (24 M Pa) . One of the main component of biorock is magnesium hydroxide, another is calcium carbonate. This composition is chiefly the result of the ionic composition of seawater. Over three decades of practical experience with biorock have shown that one kilowatt hour of electricity will result in the accretion of about 0.4 to 1.5 kg (0.9 to 3.3 lb) of biorock, depending on various parameters such as depth, electrical current, salinity and water temperature .

Biorock is cost-effective, requiring only metal bars or equivalent and a small amount of electricity. While electricity provided from fossil fuels generates CO_2, biorock projects have often used solar power, wind power, tidal power, and wave power, which don't produce CO_2. The resulting material is cheaper than concrete blocks in many places, depending on local electricity and cement transport costs .

2 - History :

Aragonite in tube

In an attempt to slow the damage done to the world's coral, artificial reefs have been built since the 1950s out of materials ranging from concrete blocks to discarded tires. However, most of these plans have failed to provide a new coral habitat, most notoriously the attempt using tires off the shore of Fort Lauderdale has become a complete environmental disaster. There have been some successes with artificial reefs, but most remain relatively barren compared with natural reefs. The one notable exception is the work of architect/marine scientist Prof. Wolf Hilbertz n(*1938 † 2007) and marine biologist Dr. Thomas J. Goreau (*1950) .

Biorock technology arose from experiments in the 1970s when Hilbertz was studying how seashells and reefs grow, by passing electrical currents through salt water. In 1974, he found that as the salt water electrolyzes, calcium carbonate (aragonite) slowly forms around the cathode , eventually coating the electrode with a material as strong as concrete. Later experiments showed that the coatings can thicken at the rate of 5 cm per year. As long as current flows, the structure continues to get larger and stronger. It can also heal itself if damaged, making it particularly useful as a replacement for concrete in hard - to - access locations.

Hilbertz originally called his invention, on which he had several patents, underwater mineral accretion or accretion for short. The term biorock wasn't coined until later. Hilbertz’s original plan was to use this technology to grow low - cost structures in the ocean for developing countries. He also envisioned accreting large aqua dynamic OTEC ocean thermal energy conversion plants, both for generating power and for producing hydrogen, ammonia, and magnesium hydroxide . This appeared to result in a building process largely independent of land - based resources.

His focus shifted to coral reefs after meeting Dr. Thomas Goreau in the 1980s. They formed a long-standing partnership, with Goreau continuing work on biorock technologies and coral reef restoration after Hilbertz' death in 2007. Because the biorock process uses such simple materials, electrode forms can be constructed in a variety of shapes to mimic natural reefs. Since the calcium carbonate coating that forms is so similar to natural reef substrate, corals take to biorock reefs very readily. Countless projects over the years have demonstrated that coral thrive on the electrified reef. One prominent example was in the Maldives during the 1998 warming, during which fewer than 5 % of the natural reef corals survived. On biorock reefs in the area, 80 % of corals not only survived, they flourished.[6]

As " Seacrete " the process was substantially publicised in a book of futurology, The Millennial Project. The author, Marshall Savage, reiterated Hilbertz' earlier proposal that the conductive metal magnesium be extracted from ocean water, and that the process use electricity from ocean thermal energy conversion.

3 - Process :

Applying a low voltage electrical current (completely safe for swimmers and marine life) to a submerged conductive structure causes dissolved minerals in seawater to precipitate and adhere to that structure. The result is a composite of brucite and lime stone with mechanical strength similar to concrete. Derived from seawater, this material is similar to the composition of natural coral reefs and tropical sand beaches.

Biorock structures can be built in any size or shape depending only on the physical makeup of the sea bottom, wave, current energies and construction materials. They are well suited for remote, third world sites where exotic building materials, construction equipment and highly skilled labor are non - existent.

4 - Constructing a new reef :

To build a biorock reef , a welded, electrically conductive frame, often made from construction grade rebar or wire mesh, is submerged and anchored to the sea bottom. A low voltage direct current is applied using an anode . This initiates an electrolytic reaction causing mineral crystals naturally found in seawater, mainly calcium carbonate and magnesium hydroxide, to grow on the structure.

Within days, the structure takes on a whitish hue as it becomes encrusted with precipitated minerals adding rigidity and strength. Electrical fields, plus the shade and protection offered by the metal/limestone frame, attract a wide range of colonizing marine life including fish, crabs, clams, octopus, lobster, and sea urchins.

Once the reef structure is in place and minerals begin to coat the surface, the next phase of reef construction begins. Divers transplant coral fragments from other reefs, attaching them to the ark’s frame. Immediately, these coral pieces begin to bond to the accreted mineral substrate and start to grow — typically three to five times faster than normal. Soon the reef takes on the appearance and utility of a natural reef ecosystem rather than a man - made one.

Electrolysis of biorock reefs enhances coral growth, reproduction and ability to resist environmental stress. Coral species typically found on healthy reefs gain a major advantage over the weedy organisms that often overgrow them on reefs stressed by eutrophication. In tests where the electrical current is interrupted, mineral accretion stops and weeds begin to cover the corals. But, if the current is maintained, coral reef habitats can often be restored even in areas where water quality would prevent their recovery by any other method.

Biorock reefs grow rapidly and strengthen as they age. They thus have great potential for many applications, such as making breakwaters. If waves or colliding ships cause damage, renewed accretion makes them, to an extent, self - repairing. Unlike some other types of artificial reefs made from cars or tires, biorock reefs don't leach harmful pollutants into the sea .

5 - Distribution :

As of 2011, biorock coral reef projects exist in over 20 countries in the Caribbean, Indian Ocean, Pacific, and Southeast Asia. One project is located on one of the most remote and unexplored reef areas of the world, the Saya de Malha Bank in the Indian Ocean. Other biorock projects are located in Indonesia, Maldives, Mexico, Panama, Papua New Guinea, Seychelles, and Thailand. The most biorock projects are currently located in Indonesia, with sites in over half a dozen islands, including the two largest reef restoration projects in the world: Pemuteran with the Karang Lestari and the Gili islands with the Gili Eco Trust . Non - coral biorock projects have been conducted in other places such as Barataria Bay, Galveston, sea grasses in the Mediterranean, oyster reefs and salt marshes in New York City, in Port Aransas, and in St. Croix.

Bottom Ash

Bottom ash refers to part of the non - combustible residues of combustion. In an industrial context, it usually refers to coal combustion and comprises traces of combustibles embedded in forming clinkers and sticking to hot side walls of a coal - burning furnace during its operation. The portion of the ash that escapes up the chimney or stack is, however, referred to as *fly ash*. The clinkers fall by themselves into the water or sometimes by poking manually, and get cooled.

The clinker lumps get crushed to small sizes by clinker grinders mounted under water and fall down into a trough from where a water ejector takes them out to a sump. From there it is pumped out by suitable rotary pumps to dumping yard far away. In another arrangement a continuous link chain scrapes out the clinkers from under water and feeds them to clinker grinders outside the bottom ash hopper.

More modern systems adopt a continuous removal philosophy. Essentially, a heavy duty chain conveyor (SSC) submerged in a water trough below the furnace which quenches hot ash as it falls from the combustion chamber and removes the wet ash continuously up a de-watering slope before onward discharge into mechanical conveyors or directly to storage silos.

Alternatively, bottom ash can be conveyed using the dry technology, the MAC (Magaldi Ash Cooler) System , originally introduced since mid '80s by the Italian company Magaldi Power S.p.A. and in recent years proposed also by Clyde Bergemann's DRYCON system and United Conveyor Corporation's VAX Vibratory Ash Extractor. These systems eliminate water usage in the cooling and conveying of bottom ash. The system cools ash using only a small controlled amount of ambient air.

Bottom ash may be used as an aggregate in road construction and concrete, where it is known as furnace bottom ash (FBA), to distinguish it from incinerator bottom ash (IBA), the non-combustible elements remaining after incineration. It was also used in the making of the concrete blocks used to construct many high - rise flats in London in the 1960s.

Brick

An old brick wall in English

A brick array

Bricked Front Street along the Cane River in historic Natchitoches, Louisiana

Contents :

1 – Introduction :

A **brick** is a block of ceramic material used in masonry construction, usually laid using various kinds of mortar . It has been regarded as one of the longest lasting and strongest building materials used throughout history.

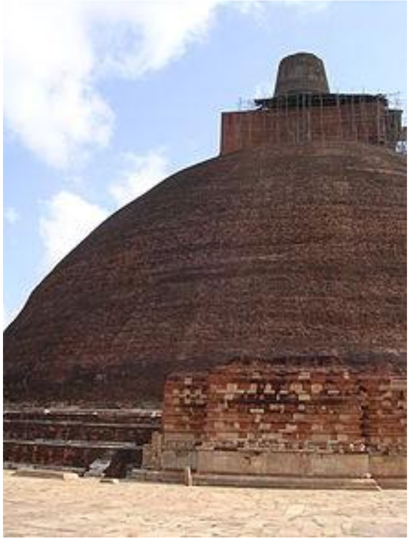
2 - History :

The Roman Basilica Aula Palatina in Trier, Germany, built in the 4th century with fired bricks as audience hall for Constantine I

The oldest discovered bricks , originally made from shaped mud and dating to before 7500 B.C. were found at Tell Aswad then later in the upper Tigris region and in south east Anatolia close to Diyarbakir . Other more recent findings, dated between 7,000 and 6,395 B.C., come from Jericho and Catal Hüyük. The first sun - dried bricks were made in Mesopotamia (what is now Iraq), in the ancient city of Ur in about 4000 BC, although the arch used for drying the bricks was not actually found.

Other examples of civilizations who used mud brick include the ancient Egyptians and the Indus Valley Civilization, where it was used exclusively. In particular, it is evident from the ruins of Buhen, Mohenjo - daro and Harappa.

The Romans made use of fired bricks, and the Roman legions, which operated mobile kilns ' introduced bricks to many parts of the empire. Roman bricks are often stamped with the mark of the legion that supervised their production. The use of bricks in southern and western Germany, for example, can be traced back to traditions already described by the Roman architect Vitruvius.



The ancient Jetavanaramaya stupa in Anuradhapura, Sri Lanka is one of the largest brick structures in the world.

The world's highest brick tower of St. Martin's Church in Landshut, Germany, completed in 1500

Malbork Castle , former Ordensburg of the Teutonic Order - biggest brick castle in the world

2 - 1- China :

In pre - modern China, brick-making was the job of a lowly and unskilled artisan, but a kiln master was respected as a step above the former . Early traces of bricks were found in a ruin site in Xi'an in 2009 dated back about 3800 years ago. Before this discovery, it is widely believed that bricks appeared about 3000 years ago in the Western Zhou dynasty since the earliest bricks were found in Western Zhou ruins . These bricks are the earliest bricks discovered that were made by a fired process . Early descriptions of the production process and glazing techniques used for bricks can be found in the Song Dynasty carpenter's manual *Yingzao Fashi*, published in 1103 by the government official Li Jie, who was put in charge of overseeing public works for the central government's construction agency. The historian Timothy Brook writes of the production process in Ming Dynasty China (aided with visual illustrations from the *Tiangong Kaiwu* encyclopedic text published in 1637) :

The brickwork of Shebeli Tower in Iran displays 12th century craftsmanship

...the kilnmaster had to make sure that the temperature inside the kiln stayed at a level that caused the clay to shimmer with the colour of molten gold or silver. He also had to know when to quench the kiln with water so as to produce the surface glaze. To anonymous laborers fell the less skilled stages of brick production: mixing clay and water, driving oxen over the mixture to trample it into a thick paste, scooping the paste into standardized wooden frames (to produce a brick roughly 42 cm long, 20 cm wide, and 10 cm thick) , smoothing the surfaces with a wire-strung bow, removing them from the frames, printing the fronts and backs with stamps that indicated where the bricks came from and who made them , loading the kilns with fuel (likelier wood than coal) , stacking the bricks in the kiln, removing them to cool while the kilns were still hot, and bundling them into pallets for transportation. It was hot, filthy work .

The idea of signing the worker's name and birth date on the brick and the place where it was made was not new to the Ming era and had little or nothing to do with vanity . As far back as the Qin Dynasty (221 BC– 206 BC) , the government required black smiths and weapon-makers to engrave their names onto weapons in order to trace the weapons back to them, lest their weapons should prove to be of a lower quality than the standard required by the government.

2 - 2 - Europe :

In the 12th century, bricks from Northern - Western Italy were re-introduced to Northern Germany, where an independent tradition evolved. It culminated in the so - called brick Gothic, a reduced style of Gothic architecture that flourished in Northern Europe, especially in the regions around the Baltic Sea which are without natural rock resources. Brick Gothic buildings, which are built almost exclusively of bricks, are to be found in Denmark , Germany , Poland , and Russia

During the Renaissance and the Baroque, visible brick walls were unpopular and the brickwork was often covered with plaster. It was only during the mid-18th century that visible brick walls regained some degree of popularity, as illustrated by the Dutch Quarter of Potsdam, for example.

The transport in bulk of building materials such as bricks over long distances was rare before the age of canals, railways, roads and heavy goods vehicles. Before this time bricks were generally made close to their point of intended use. It has been estimated that in England in the 18th century carrying bricks by horse and cart for ten miles (16 km) over the poor roads then existing could more than double their price .

Chile house in Hamburg, Germany

Bricks were often used for reasons of speed and economy, even in areas where stone was available. The buildings of the Industrial Revolution in Britain were largely constructed of brick and timber due to the demand created. During the building boom of the 19th century in the eastern seaboard cities of Boston and New York City, for example, locally made bricks were often used in construction in preference to the brown stones of New Jersey and Connecticut for these reasons.

The trend of building upwards for offices that emerged towards the beginning of the 19th century displaced brick in favor of cast and wrought iron and later steel and concrete. Some early 'skyscrapers' were made in masonry, and demonstrated the limitations of the material – for example , the Monadnock Building in Chicago (opened in 1896) is masonry and just 17 stories high; the ground walls are almost 6 feet (1.8 m) thick, clearly building any higher would lead to excessive loss of internal floor space on the lower floors. Brick was revived for high structures in the 1950s following work by the Swiss Federal Institute of Technology and the Building Research Establishment in Watford, UK. This method produced 18-story structures with bearing walls no thicker than a single brick (150 – 225 mm) . This potential has not been fully developed because of the ease and speed in building with other materials; in the late-20th century brick was confined to low- or medium-rise structures or as a thin decorative cladding over concrete-and-steel buildings or for internal non - load - bearing walls.

In Victorian London the bright red brick was chosen to make buildings visible in the heavy fog that caused transport problems. [12]

3 - Methods of manufacture :

"Bricks" for building may be made from clay , shale , soft slate, calcium silicate, concrete, or shaped from quarried stone. How ever, true bricks are ceramic, and therefore created by the action of heat and cooling.

Clay is the most common material, with modern clay bricks formed in one of three processes - soft mud, dry press, or extruded.

Normally, brick contains the following ingredients :

1. Silica (sand) – 50 % to 60 % by weight
2. Alumina (clay) – 20 % to 30 % by weight
3. Lime - 2 to 5 % by weight
4. Iron oxide - 5 to 6 % (not greater than 7 %) by weight
5. Magnesia - less than 1 % by weight

3 – 1 - Mud bricks :

The soft mud method is the most common, as it is the most economical. It starts with the raw clay, preferably in a mix with 25-30% sand to reduce shrinkage. The clay is first ground and mixed with water to the desired consistency. The clay is then pressed into steel moulds with a hydraulic press . The shaped clay is then fired ("burned") at 900 -1000 °C to achieve strength.

3 – 1 – 1 - Rail kilns :

Xhosa brickmaker at kiln near Ngcobo in the former Transkei in 2007.

A traditional brick factory in Iran.

In modern brickworks, this is usually done in a continuously fired tunnel kiln, in which the bricks move slowly through the kiln on conveyors, rails, or kiln cars to achieve consistency for all bricks. The bricks often have added lime, ash, and organic matter to speed the burning.

3 – 1 – 2 - Bull's Trench Kilns :

In India, brick making is typically a manual process. The most common type of brick kiln in use there are **Bull's Trench Kiln** (BTK) based on a design developed by British engineer W. Bull in the late 19th century.

An oval or circular trench, 6 – 9 meters wide , 2 - 2.5 meters deep, and 100 – 150 meters in circumference, is dug. A tall exhaust chimney is constructed in the centre. Half or more of the trench is filled with "green" (unfired) bricks which are stacked in an open lattice pattern to allow air flow . The lattice is capped with a roofing layer of finished brick.

In operation, new green bricks, along with roofing bricks, are stacked at one end of the brick pile; cooled finished bricks are removed from the other end for transport. In the middle the brick workers create a firing zone by dropping fuel (coal, wood, oil, debris, and so on.) through access holes in the roof above the trench.

West face of Roskilde Cathedral in Roskilde, Denmark.

The advantage of the BTK design is a much greater energy efficiency compared with clamp or scove kilns. Sheet metal or boards are used to route the airflow through the brick lattice so that fresh air flows first through the recently burned bricks, heating the air, then through the active burning zone. The air continues through the green brick zone (pre-heating and drying them), and finally out the chimney where the rising gases create suction which pulls air through the system. The reuse of heated air yields savings in fuel cost.

As with the rail process above, the BTK process is continuous. A half dozen laborers working around the clock can fire approximately 15,000 - 25,000 bricks a day. Unlike the rail process, in the BTK process the bricks do not move. Instead, the locations at which the bricks are loaded, fired, and unloaded gradually rotate through the trench .

3 – 2 - Dry pressed bricks :

The dry press method is similar to mud brick but starts with a much thicker clay mix, so it forms more accurate, sharper-edged bricks. The greater force in pressing and the longer burn make this method more expensive.

3 – 3 - Extruded bricks :

For extruded bricks the clay is mixed with 10 - 15 % water (stiff extrusion) or 20 - 25 % water (soft extrusion) . This is forced through a die to create a long cable of material of the proper width and depth. This is then cut into bricks of the desired length by a wall of wires. Most structural bricks are made by this method, as it produces hard, dense bricks, and suitable dies can produce holes or other perforations. The introduction of holes reduces the volume of clay needed, and hence the cost. Hollow bricks are lighter and easier to handle, and have thermal properties different from solid bricks. The cut bricks are hardened by drying for 20 to 40 hours at 50 to 150 °C before being fired. The heat for drying is often waste heat from the kiln. European-style extruded bricks or blocks are used in single-wall construction with finishes applied inside and outside. Their many voids are a greater proportion of the volume than the solid, thin walls of fired clay. Such bricks are made in 15, 25, 30, 42 and 50 - cm widths. Some models have very high thermal insulation performance suitable for zero-energy buildings.

3 – 4 - Calcium silicate bricks :

The raw materials for calcium silicate bricks include lime mixed with quartz, crushed flint or crushed siliceous rock together with mineral colourants. The materials are mixed and left until the lime is completely hydrated; the mixture is then pressed into moulds and cured in an autoclave for two or three hours to speed the chemical hardening. The finished bricks are very accurate and uniform, although the sharp arrises need careful handling to avoid damage to brick (and bricklayer). The bricks can be made in a variety of colours, white is common but pastel shades can be achieved.

Csk bricks are common in Sweden, especially in houses built or renovated in the 1970s,, and are known as " Mexitegel " (en : Mexi[can] Bricks) .

In India these are known as Fly ash bricks, manufactured using the FaL - G (fly ash , lime and gypsum) process.

Calcium silicate bricks are also manufactured in Canada and the United States, and meet the criteria set forth in ASTM C73 - 10 Standard Specification for Calcium Silicate Brick (Sand-Lime Brick). It has lower embodied energy than cement based man-made stone and clay brick .

4 - Influence on fired colour :

Yellow London Stocks at Waterloo

The fired colour of clay bricks is influenced by the chemical and mineral content of raw materials, the firing temperature and the atmosphere in the kiln. For example pink coloured bricks are the result of a high iron content, white or yellow bricks have a higher lime content. Most bricks burn to various red hues, if the temperature is increased the color moves through dark red, purple and then to brown or grey at around 1,300 °C . Calcium silicate bricks have a wider range of shades and colours , depending on the colourants used.

The names of bricks may reflect their origin and colour, such as London stock brick and Cambridge shire White.

"Bricks" formed from concrete are usually termed blocks, and are typically pale grey in colour. They are made from a dry, small aggregate concrete which is formed in steel moulds by vibration and compaction in either an "egg layer" or static machine. The finished blocks are cured rather than fired using low - pressure steam. Concrete blocks are manufactured in a much wider range of shapes and sizes than clay bricks and are also available with a wider range of face treatments - a number of which are to simulate the appearance of clay bricks.

An impervious and ornamental surface may be laid on brick either by salt glazing, in which salt is added during the burning process, or by the use of a "slip," which is a glaze material into which the bricks are dipped. Subsequent reheating in the kiln fuses the slip into a glazed surface integral with the brick base.

Natural stone bricks are of limited modern utility, due to their enormous comparative mass, the consequent foundation needs, and the time - consuming and skilled labour needed in their construction and laying. They are very durable and considered more handsome than clay bricks by some. Only a few stones are suitable for bricks. Common materials are granite, limestone and sandstone. Other stones may be used (for example , marble , slate , quartzite , and so on) but these tend to be limited to a particular locality.

5 - Optimal dimensions , characteristics , and strength :

Loose bricks

For efficient handling and laying bricks must be small enough and light enough to be picked up by the bricklayer using one hand (leaving the other hand free for the trowel). Bricks are usually laid flat and as a result the effective limit on the width of a brick is set by the distance which can conveniently be spanned between the thumb and fingers of one hand, normally about four inches (about 101 mm). In most cases, the length of a brick is about twice its width, about eight inches (about 203 mm) or slightly more. This allows bricks to be laid *bonded* in a structure to increase its stability and strength (for an example of this, see the illustration of bricks laid in *English bond*, at the head of this article) . The wall is built using alternating courses of *stretchers*, bricks laid long ways and *headers*, bricks laid crossways. The headers tie the wall together over its width.

A bigger brick makes for a thicker (and thus more insulating) wall. Historically, this meant that bigger bricks were necessary in colder climates (see for instance the slightly larger size of the Russian brick in table below), while a smaller brick was adequate, and more economical, in warmer regions. A notable illustration of this correlation is the Green Gate in Gdansk; built in 1571 of imported Dutch brick, too small for the colder climate of Gdansk, it was notorious for being a chilly and drafty residence. Nowadays this is no longer an issue, as modern walls typically incorporate specialized insulation materials.

The correct brick for a job can be picked from a choice of colour, surface texture, density, weight, absorption and pore structure, thermal characteristics, thermal and moisture movement, and fire resistance.

Face brick ("house brick") sizes , (alphabetical order)

Standard	**Metric**
Australia	230 × 110 × 76 mm
Denmark	228 × 108 × 54 mm
Germany	240 × 115 × 71 mm
India	228 × 107 × 69 mm
Romania	240 × 115 × 63 mm

Russia	250 × 120 × 65 mm
South Africa	222 × 106 × 73 mm
Sweden	250 × 120 × 62 mm
United Kingdom	215 × 102.5 × 65 mm
United States	203 × 102 × 57 mm

In England, the length and the width of the common brick has remained fairly constant over the centuries , but the depth has varied from about two inches (about 51 mm) or smaller in earlier times to about two and a half inches (about 64 mm) more recently. In the United Kingdom , the usual size of a modern brick is 215 × 102.5 × 65 mm , which , with a nominal 10 mm mortar joint, forms a *unit size* of 225 × 112.5 × 75 mm , for a ratio of 6:3:2. In the United States, modern bricks are usually about 203 × 102 × 57 mm .

Some brick makers create innovative sizes and shapes for bricks used for plastering (and therefore not visible) where their inherent mechanical properties are more important than the visual ones. These bricks are usually slightly larger, but not as large as blocks and offer the following advantages :

- a slightly larger brick requires less mortar and handling (fewer bricks) which reduces cost
- ribbed exterior aids plastering
- more complex interior cavities allow improved insulation, while maintaining strength.

Blocks have a much greater range of sizes. Standard coordinating sizes in length and height (in mm) include 400×200, 450×150 , 450×200 , 450×225 , 450×300 , 600×150 , 600×200 , and 600×225 ; depths (work size, mm) include 60 , 75 , 90 , 100 , 115 , 140 , 150 , 190 , 200 , 225 , and 250 . They are usable across this range as they are lighter than clay bricks. The density of solid clay bricks is around 2,000 kg / m^3 : this is reduced by frogging, hollow bricks, and so on.; but aerated autoclaved concrete, even as a solid brick, can have densities in the range of 450 – 850 kg / m^3.

Bricks may also be classified as *solid* (less than 25 % perforations by volume, although the brick may be "frogged," having indentations on one of the longer faces) , *perforated* (containing a pattern of small holes through the brick removing no more than 25% of the volume), *cellular* (containing a pattern of holes removing more than 20 % of the volume, but closed on one face) , or *hollow* (containing a pattern of large holes removing more than 25 % of the brick's volume). Blocks may be solid, cellular or hollow

The term "frog" for the indentation on one bed of the brick is a word that often excites curiosity as to its origin. The most likely explanation is that brick makers also call the block that is placed in the mould to form the indentation a frog. Modern brick makers usually use plastic frogs but in the past they were made of wood. When these are wet and have clay on them they resemble the amphibious kind of frog and this is where they got their name. Over time this term also came to refer to the indentation left by them.

Brick arch from a vault in Roman Bath - England

A brick section of the old Dixie Highway, United States

The compressive strength of bricks produced in the United States ranges from about 1000 lbf/in² to 15,000 lb f / in² (7 to 105 M Pa or N / mm²) , varying according to the use to which the brick are to be put. In England clay bricks can have strengths of up to 100 M Pa , although a common house brick is likely to show a range of 20 – 40 M Pa.

6 – Use :

Bricks are used for building , block paving and pavement. In the USA, brick pavement was found incapable of withstanding heavy traffic, but it is coming back into use as a method of traffic calming or as a decorative surface in pedestrian precincts. For example, in the early 1900s, most of the streets in the city of Grand Rapids, Michigan were paved with brick. Today, there are only about 20 blocks of brick paved streets remaining (totalling less than 0.5 percent of all the streets in the city limits) .

Bricks in the metallurgy and glass industries are often used for lining furnaces, in particular refractory bricks such as silica, magnesia, chamotte and neutral (chromo magnesite) refractory bricks. This type of brick must have good thermal shock resistance, refractoriness under load, high melting point, and satisfactory porosity. There is a large refractory brick industry, especially in the United Kingdom, Japan, the United States, and the Netherlands.

In the United Kingdom, bricks have been used in construction for centuries. Until recently, almost all houses were built almost entirely from bricks. Although many houses in the UK are now built using a mixture of concrete blocks and other materials, many houses are skinned with a layer of bricks on the outside for aesthetic appeal.

Engineering bricks are used where strength, low water porosity or acid (flue gas) resistance are needed.

In the UK a redbrick university is one founded and built in the Victorian era, often as a technical college. The term serves to distinguish these polytechnic colleges from older, more classics-oriented universities.

Colombian architect Rogelio Salmona was noted for his extensive use of red brick in his buildings and for using natural shapes like spirals, radial geometry and curves in his designs.[18] Most buildings in Colombia are made of brick, given the abundance of clay in equatorial countries like this one.

7 - Limitations :

Starting in the twentieth century, the use of brickwork declined in many areas due to earthquakes. The San Francisco earthquake of 1906 revealed the weaknesses of brick buildings in earthquake-prone areas. Most buildings in San Francisco collapsed during the earthquake, due to the cement - based mortar used to hold the bricks together. During seismic events, the mortar cracks and crumbles, and the bricks are no longer held together.

The San Francisco Earth quake of 1906 shows the limitations of brick work construction.

A panorama of San Francisco after the earth quake.

Brucite

Contents

1 – Introduction :

Brucite is the mineral form of magnesium hydroxide, with the chemical formula Mg $(OH)_2$. It is a common alteration product of periclase in marble ; a low - temperature hydrothermal vein mineral in metamorphosed lime stones and chlorite schists; and formed during serpentinization of dunites. Brucite is often found in association with serpentine, calcite, aragonite, dolomite, magnesite, hydromagnesite, artinite, talc, and chrysotile. Notable locations include Wood's Chrome Mine, Cedar Hill Quarry, Lancaster County, Pennsylvania.

Category	Mineral
Chemical Formula	$Mg(OH)_2$
Color	white, pale green, blue, gray; honey - yellow to brownish red
Crystal habit	platy or foliated masses and rosettes – fibrous to massive
Crystal system	Trigonal (hexagonal scalenohedral)
Mohs scale hardness	2.5 to 3
Luster	vitreous to pearly

Streak	white
Diaphaneity	transparent
Specific gravity	2.39 to 2.40
Optical properties	Uniaxial (+)
Refractive index	n_ω = 1.56–1.59 n_ε = 1.58–1.60

2 - Discovery :

Nemalite

Brucite was first described in 1824 and named for the discoverer, American mineralogist, Archibald Bruce (1777–1818). A fibrous variety of Brucite is called **Nemalite**. It occurs in fibers or laths .

3 - Industrial Applications :

Brucite is used as a flame retardant and also constitutes a significant source of magnesium for industry.

4 - Magnesian attack of cement and concrete :

When cement or concrete are exposed to non negligible concentration of Mg^{2+}, e.g. when these materials are left in prolonged contact with sea water or brines, $Mg(OH)_2$ precipitates under the high pH conditions prevailing in the cement pore water. The neo formation of brucite, an expansive material, induces mechanical stress in the hardened cement paste and is responsible for the formation of cracks and fissures in concrete . The use of dolomite as aggregate in concrete can also cause the magnesian attack and should be avoided.

Building Material

Concrete and metal rebar used to build a floor

Contents :

1 – Introduction :

Building material is any material which is used for a construction purpose. Many naturally occurring substances, such as clay, sand, wood and rocks, even twigs and leaves have been used to construct buildings. Apart from naturally occurring materials, many man-made products are in use, some more and some less synthetic. The manufacture of building materials is an established industry in many countries and the use of these materials is typically segmented into specific specialty trades, such as carpentry, plumbing, roofing and insulation work. They provide the make-up of habitats and structures including homes.

2 - Fabric :

The tent is the home of choice among nomadic groups all over the world. Two well known types include the conical teepee and the circular yurt. It has been revived as a major construction technique with the development of tensile architecture and synthetic fabrics. Modern buildings can be made of flexible material such as fabric membranes, and supported by a system of steel cables, rigid or internal (air pressure.)

3 - Mud and clay :

Sod buildings in Iceland

The amount of each material used leads to different styles of buildings. The deciding factor is usually connected with the quality of the soil being used. Larger amounts of clay usually mean using the *cob/adobe* style, while low clay soil is usually associated with *sod* building. The other main ingredients include more or less sand / gravel and straw / grasses. *Rammed earth* is both an old and newer take on creating walls, once made by compacting clay soils between planks by hand, now forms and mechanical pneumatic compressors are used.

Soil and especially clay is good thermal mass; it is very good at keeping temperatures at a constant level. Homes built with earth tend to be naturally cool in the summer heat and warm in cold weather. Clay holds heat or cold, releasing it over a period of time like stone. Earthen walls change temperature slowly, so artificially raising or lowering the temperature can use more resources than in say a wood built house, but the heat/coolness stays longer.

Peoples building with mostly dirt and clay, such as cob, sod, and adobe, resulted in homes that have been built for centuries in western and northern Europe as well as the rest of the world, and continue to be built, though on a smaller scale. Some of these buildings have remained habitable for hundreds of years.

4 - Wood :

A natural material for building dwellings for thousands of years, wood was also used to make Churches in the past. The main problems with wood structures are fire risk and durability. Wood is an aesthetically pleasing material that never goes out of trend completely, though the current popularity of plastic is taking its place in many construction sites.

5 - Rock :

Mont Saint Michel

Rock structures have existed for as long as history can recall. It is the longest lasting building material available, and is usually readily available. There are many types of rock throughout the world all with differing attributes that make them better or worse for particular uses. Rock is a very dense material so it gives a lot of protection too, its main draw - back as a material is its weight and awkwardness. Its energy density is also considered a big draw – back , as stone is hard to keep warm without using large amounts of heating resources.

Dry - stone walls have been built for as long as humans have put one stone on top of another. Eventually different forms of mortar were used to hold the stones together, cement being the most commonplace now.

The granite-strewn uplands of Dartmoor National Park, United Kingdom, for example, provided ample resources for early settlers. Circular huts were constructed from loose granite rocks throughout the Neolithic and early Bronze Age, and the remains of an estimated 5,000 can still be seen today. Granite continued to be used throughout the Medieval period and into modern times. Slate is another stone type, commonly used as roofing material in the United Kingdom and other parts of the world where it is found.

Mostly stone buildings can be seen in most major cities, some civilizations built entirely with stone such as the Pyramids in Egypt, the Aztec pyramids and the remains of the Inca civilization.

6 - Thatch :

Thatch is one of the oldest of building materials known; grass is a good insulator and easily harvested. Many African tribes have lived in homes made completely of grasses year round. In Europe, thatch roofs on homes were once prevalent but the material fell out of favor as industrialization and improved transport increased the availability of other materials. Today, though, the practice is undergoing a revival. In the Netherlands, for instance, many new buildings have thatched roofs with special ridge tiles on top

7 - Brush :

Toda tribe hut

Brush structures are built entirely from plant parts and are generally found in tropical and sub-tropical areas, such as rainforests, where very large leaves can be used in the building. Native Americanes for resting and living in, too. These are built mostly with branches, twigs and leaves, and bark, similar to a beaver's lodge. These were variously named wikiups, lean – tos , and so forth.

8 - Ice :

Ice was used by the Inuit for igloos, but has also been used for ice hotels as a tourist attraction in northern areas that might not otherwise see many winter tourists.

9 - Sand :

Used with cement and some times lime , to make mortar for masonry work and plaster. Sand is used as a part of the concrete mix.

10 - Concrete :

Concrete is a composite building material made from the combination of aggregate and a binder such as cement. The most common form of concrete is Portland cement concrete, which consists of mineral aggregate (generally gravel and sand) , portland cement and water. After mixing, the cement hydrates and eventually hardens into a stone-like material. When used in the generic sense, this is the material referred to by the term **concrete**.

Falkirk Wheel

For a concrete construction of any size, as concrete has a rather low tensile strength, it is generally strengthened using steel rods or bars (known as rebars) . This strengthened concrete is then referred to as reinforced concrete. In order to minimise any air bubbles, that would weaken the structure, a vibrator is used to eliminate any air that has been entrained when the liquid concrete mix is poured around the ironwork. Concrete has been the predominant building material in this modern age due to its longevity, formability, and ease of transport. Recent advancements, such as Insulating concrete forms, combine the concrete forming and other construction steps (installation of insulation). All materials must be taken in required proportions as described in standards.

11 - Metal :

Metal is used as structural framework for larger buildings such as sky scrapers , or as an external surface covering. There are many types of metals used for building. Steel is a metal alloy whose major component is iron, and is the usual choice for metal structural building materials. It is strong, flexible, and if refined well and/or treated lasts a long time. Corrosion is metal's prime enemy when it comes to longevity.

The lower density and better corrosion resistance of aluminium alloys and tin sometimes overcome their greater cost. Brass was more common in the past, but is usually restricted to specific uses or specialty items today.

Metal figures quite prominently in prefabricated structures such as the Quonset hut, and can be seen used in most cosmopolitan cities. It requires a great deal of human labor to produce metal, especially in the large amounts needed for the building industries.

Other metals used include titanium, chrome, gold, silver. Titanium can be used for structural purposes, but it is much more expensive than steel. Chrome, gold, and silver are used as decoration, because these materials are expensive and lack structural qualities such as tensile strength or hardness.

12 - Glass :

British Museum Great Court

Glass making is considered an art form as well as an industrial process or material.

Clear windows have been used since the invention of glass to cover small openings in a building. They provided humans with the ability to both let light into rooms while at the same time keeping inclement weather outside. Glass is generally made from mixtures of sand and silicates, in a very hot fire stove called a *kiln* and is very brittle. Very often additives are added to the mixture when making to produce glass with shades of colors or various characteristics (such as bullet proof glass , or light emittance) .

The use of glass in architectural buildings has become very popular in the modern culture. Glass "curtain walls" can be used to cover the entire facade of a building, or it can be used to span over a wide roof structure in a "space frame". These uses though require some sort of frame to hold sections of glass together, as glass by itself is too brittle and would require an overly large kiln to be used to span such large areas by itself.

13 - Plastic :

Plastic pipes penetrating a concrete floor in a Canadian highrise apartment building

The term plastics covers a range of synthetic or semi-synthetic organic condensation or poly merization products that can be molded or extruded into objects or films or fibers. Their name is derived from the fact that in their semi-liquid state they are malleable, or have the property of plasticity. Plastics vary immensely in heat tolerance, hardness, and resiliency. Combined with this adaptability, the general uniformity of composition and lightness of plastics ensures their use in almost all industrial applications today.

14 - Foam :

More recently synthetic poly styrene or poly urethane foam has been used in combination with structural materials, such as concrete. It is light weight, easily shaped and an excellent insulator. It is usually used as part of a structural insulated panel where the foam is sandwiched between wood or cement or insulating concrete forms, where concrete is sandwiched between two layers of foam.

15 - Cement composites :

Cement bonded composites are made of hydrated cement paste that binds wood or alike particles or fibers to make pre - cast building components. Various fiberous materials including paper and fiberglass have been used as binders.

Wood and natural fibres are composed of various soluble organic compounds like carbohydrates, glycosides and phenolics. These compounds are known to retard cement setting. There fore , before using a wood in making cement boned composites, its compatibility with cement is assessed.

Wood - cement compatibility is the ratio of a parameter related to the property of a wood - cement composite to that of a neat cement paste. The compatibility is often expressed as a percentage value. To determine wood - cement compatibility, methods based on different properties are used, such as, hydration characteristics, strength, interfacial bond and morphology. Various methods are used by researchers such as the measurement of hydration characteristics of a cement-aggregate mix ; the comparison of the mechanical properties of cement-aggregate mixes and the visual assessment of microstructural properties of the wood-cement mixes . It has been found that the hydration test by measuring the change in hydration temperature with time is the most convenient method. Recently, Karade et al . have reviewed these methods of compatibility assessment and suggested a method based on the 'maturity concept' i.e. taking in consideration both time and temperature of cement hydration reaction.

16 - Modern industry ;

Modern building is a multi billion dollar industry, and the production and harvesting of raw materials for building purposes is on a world wide scale. Often being a primary governmental and trade keypoint between nations. Environmental concerns are also becoming a major world topic concerning the availability and sustainability of certain materials, and the extraction of such large quantities needed for the human habitat.

17 - Building products :

In the market place the term *building products* often refers to the ready-made particles/sections, made from various materials, that are fitted in architectural hardware and decorative hardware parts of a building. The list of building products exclusively exclude the building materials, which are used to construct the building architecture and supporting fixtures like windows, doors, cabinets, etc. Building products do not make any part of a bajingo rather they support and make them working in a modular fashion.

It also can refer to items used to put such hardware together such as glues, caulking, paint, and anything else bought for the purpose of constructing a building

Calcite

Contents :

1 – Introduction :

Calcite is a carbonate mineral and the most stable poly morph of calcium carbonate ($CaCO_3$) . The other polymorphs are the minerals aragonite and vaterite. Aragonite will change to calcite at 380 - 470°C , and vaterite is even less stable .

Category	Carbonate mineral
Chemical formula	$Ca\,CO_3$
Unit cell	a = 4.9896 Å , c = 17.0610 Å ; Z= 6
Color	Colorless or white , also gray, yellow, green ,
Specific gravity	2.71
Refractive index	$n_\omega = 1.640 – 1.660$ $n_\varepsilon = 1.486$
Birefringence	$\delta = 0.154 – 0.174$
Solubility	Soluble in dilute acids
Other characteristics	May fluoresce red , blue , yellow, and other colors under either SW and LW UV ; phosphorescent

2 - Properties :

Calcite crystals are trigonal - rhombohedral, though actual calcite rhombohedra are rare as natural crystals. However, they show a remarkable variety of habits including acute to obtuse rhombohedra, tabular forms, prisms, or various scalenohedra. Calcite exhibits several twinning types adding to the variety of observed forms. It may occur as fibrous, granular, lamellar, or compact. Cleavage is usually in three directions parallel to the rhombohedron form. Its fracture is conchoidal, but difficult to obtain.

It has a defining Mohs hardness of 3 , a specific gravity of 2.71, and its luster is vitreous in crystallized varieties. Color is white or none, though shades of gray, red, orange, yellow, green, blue, violet, brown, or even black can occur when the mineral is charged with impurities.

Calcite is transparent to opaque and may occasionally show phosphorescence or fluorescence. A transparent variety called *Iceland spar* is used for optical purposes. Acute scalenohedral crystals are sometimes referred to as "dogtooth spar" while the rhombohedral form is sometimes referred to as "nail head spar".

Single calcite crystals display an optical property called birefringence (double refraction) . This strong birefringence causes objects viewed through a clear piece of calcite to appear doubled. The birefringent effect (using calcite) was first described by the Danish scientist Rasmus Bartholin in 1669. At a wavelength of ~590 nm calcite has ordinary and extraordinary refractive indices of 1.658 and 1.486, respectively . Between 190 and 1700 nm, the ordinary refractive index varies roughly between 1.6 and 1.4 , while the extraordinary refractive index varies between 1.9 and 1.5 .

Calcite, like most carbonates, will dissolve with most forms of acid. Calcite can be either dissolved by groundwater or precipitated by groundwater, depending on several factors including the water temperature , pH , and dissolved ion concentrations. Although calcite is fairly insoluble in cold water , acidity can cause dissolution of calcite and release of carbon dioxide gas. Calcite exhibits an unusual characteristic called retrograde solubility in which it becomes less soluble in water as the temperature increases. When conditions are right for precipitation, calcite forms mineral coatings that cement the existing rock grains together or it can fill fractures. When conditions are right for dissolution, the removal of calcite can dramatically increase the porosity and permeability of the rock, and if it continues for a long period of time may result in the formation of caves. On a landscape scale, continued dissolution of calcium carbonate-rich rocks can lead to the expansion and eventual collapse of cave systems, resulting in various forms of karst topography.

3 - Use and applications :

High - grade optical calcite was used in World War II for gun sights , specifically in bomb sights and anti – air craft weaponry.

4 - Natural occurrence :

The largest documented single crystals of calcite originated from Iceland , measured 7×7×2 m and 6×6×3 m and weighed about 250 tons .

Doubly terminated calcite crystal

Calcite is a common constituent of sedimentary rocks , lime stone in particular , much of which is formed from the shells of dead marine organisms. Approximately 10 % of sedimentary rock is lime stone . Calcite is the primary mineral in meta morphic marble . It also occurs as a vein mineral in deposits from hot springs, and it occurs in caverns as stalactites and stalagmites.

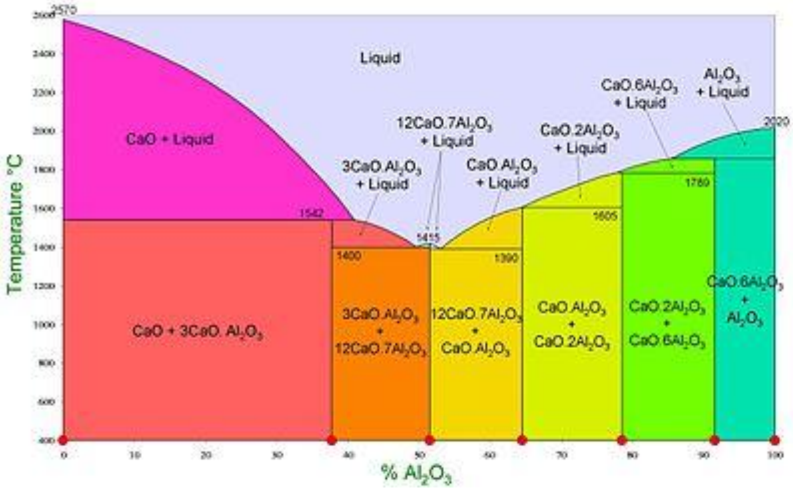
Calcite may also be found in volcanic or mantle - derived rocks such as carbonatites , kimberlites, or rarely in peridotites.

Calcite is often the primary constituent of the shells of marine organisms, e.g., plankton (such as coccoliths and planktic foraminifera) , the hard parts of red algae , some sponges, brachiopods, echinoderms, most bryozoa , and parts of the shells of some bivalves (such as oysters and rudists) . Calcite is found in spectacular form in the Snowy River Cave of New Mexico as mentioned above, where microorganisms are credited with natural formations. Trilobites, which are now extinct, had unique compound eyes. They used clear calcite crystals to form the lenses of their eyes.

4 - 1 - Calcite in Earth history :

Calcite seas existed in Earth history when the primary inorganic precipitate of calcium carbonate in marine waters was low-magnesium calcite (l m c) , as opposed to the aragonite and high-magnesium calcite (h m c) precipitated today. Calcite seas alternated with aragonite seas over the Phanerozoic, being most prominent in the Ordovician and Jurassic. Lineages evolved to use whichever morph of calcium carbonate was favourable in the ocean at the time they became mineralised, and retained this mineralogy for the remainder of their evolutionary history . Petro graphic evidence for these calcite sea conditions consists of calcitic ooids , lmc cements, hard grounds , and rapid early seafloor aragonite dissolution . The evolution of marine organisms with calcium carbonate shells may have been affected by the calcite and aragonite sea cycle .

Calcium Aluminate Cements



Phase diagram of calcium aluminates present in the anhydrous calcium aluminate cement before hydration.

Contents

1 – Introduction :

Calcium aluminates are a range of minerals obtained by heating calcium oxide and aluminium oxide together at high temperatures. They are encountered in the manufacture of refractories and cements.

The stable phases shown in the phase diagram (formed at atmospheric pressure under an atmosphere of normal humidity) are :

- Tri calcium aluminate , $3CaO \cdot Al_2O_3$ (C3A)
- Do deca calcium hepta - aluminate , $12CaO \cdot 7Al_2O_3$ (C12A7)

- Mono calcium aluminate , CaO $\cdot Al_2O_3$ (CA)
- Mono calcium di aluminate , CaO $\cdot 2 Al_2O_3$ (CA2)
- Mono calcium hexa - aluminate, CaO $\cdot$ 6 Al_2O_3 (CA6)

In addition, other phases include :

- Di calcium aluminate, $2CaO\cdot Al_2O_3$ (C2A), which exists only at pressures above 2500 MPa . The crystal is orthorhombic, with density 3480 kg$\cdot$m^{-3}.
- Penta calcium tri aluminate, $5CaO\cdot 3Al_2O_3$ (C5A3), forms only under an anhydrous and oxygen free atmosphere. The crystal is orthorhombic, with a density of 3067 kg$\cdot$m^{-3}. It reacts rapidly with water.
- Tetra calcium tri aluminate, $4CaO\cdot 3Al_2O_3$ (C4A3), is a metastable phase formed by dehydrating $4CaO\cdot 3Al_2O_3\cdot 3H_2O$ (C4A3H3).

Calcium aluminate cements] are cements consisting predominantly of hydraulic calcium aluminates. Alternative names are "aluminous cement", "high-alumina cement" and "Ciment fondu" in French. They are used in a number of small – scale , specialized applications.

2 - History

The method of making cement from lime stone and low - silica bauxite was patented in France in 1908 by Bied of the Pavin de Lafarge Company. The initial development was as a result of the search for a cement offering sulfate resistance . The cement was called in the French "Ciment fondu". Subsequently, its other special properties were discovered, and these guaranteed its future in niche applications.

3 – Composition :

The main active constituent of calcium aluminate cements is mono calcium aluminate ($CaAl_2O_4$, CaO $\cdot$ Al_2O_3, or CA in the cement chemist notation) . It usually contains other calcium aluminates as well as a number of less reactive phases deriving from impurities in the raw materials. Rather a wide range of compositions is encountered, depending on the application and the purity of aluminium source used Constituents of some typical formulations include :

Oxide / Mineral	**General purpose**	**Buff**	**White**	**Refractory**
SiO_2	4.0	5.0	2.7	0.4
Al_2O_3	39.4	53.0	62.4	79.6
Fe_2O_3	16.4	2.0	0.4	0
CaO	38.4	38.0	34.0	19.8
MgO	1.0	0.1	0.1	0
Na_2O	0.1	0.1	0	0
K_2O	0.2	0	0	0
TiO_2	1.9	1.8	0.4	0.1
Mono calcium aluminate	46	70	70	35
Do deca calcium hepta-aluminate	10	5	0	0
Mono calcium di aluminate	0	0	17	30
Belite	7	5	0	0
Gehlenite	4	14	11	1
Ferrite	24	5	2	0
Pleocroite	1	1	1	0
Wüstite	7	0	0	0
Corundum	0	0	0	33

The mineral phases all take the form of solid solutions with somewhat variable compositions

4 – Manufacture :

The cement is made by fusing together a mixture of a calcium-bearing material (normally lime stone) and an aluminium-bearing material (normally bauxite for general purposes, or refined alumina for white and refractory cements). The liquefied mixture cools to a basalt-like clinker which is ground alone to produce the finished product. Because complete melting usually takes place, raw materials in lump-form can be used. A typical kiln arrangement comprises a reverberatory furnace provided with a shaft pre heater in which the hot exhaust gases pass upward as the lump raw material mix passes downward. The pre heater recuperates most of the heat in the combustion gases, dehydrates and de- hydroxylates the bauxite and de-carbonates the lime stone . The calcined material drops into the "cool end" of the melt bath. The melt overflows the hot end of the furnace into molds in which it cools and solidifies. The system is fired with pulverized coal or oil. The cooled clinker ingots are crushed and ground in a ball - mill. In the case of high-alumina refractory cements, where the mix only sinters, a rotary kiln can be used .

5 - Reaction with water :

The hydration reactions of calcium aluminate cements are very complex. The strength - developing phases are mono calcium aluminate, do deca - calcium hepta - aluminate and belite . Calcium alumino ferrite , mono calcium dialuminate , gehlenite and pleochroite contribute little to strength.

The reactive aluminates react with water initially to form a mixture of :

1 $CaO \cdot Al_2O_3 \cdot 10 H_2O$,
2 $CaO \cdot Al_2O_3 \cdot 8 H_2O$,
3 $CaO \cdot Al_2O_3 \cdot 6 H_2O$, and $Al(OH)_3$ gel ,

The amounts of each depending upon the curing temperature. The first two hydrates subsequently decompose to a mixture of $3 CaO \cdot Al_2O_3 \cdot 6 H_2O$, $Al(OH)_3$ gel and water, this process being called "conversion". Because of the loss of water, conversion causes an increase in porosity, which can be accompanied by a decrease in strength. This need not be a problem in structural concrete provided that a sufficiently high cement content and a sufficiently low water/cement ratio are employed.

6 – Applications :

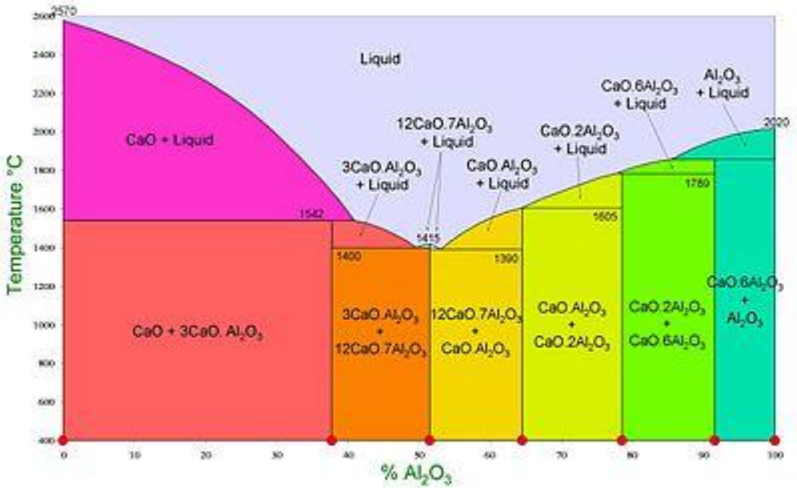
Because of their relatively high cost , calcium aluminate cements are used in a number of restricted applications :

- in construction concretes, rapid strength development is achieved , even at low temperatures.
- in construction concretes , high chemical resistance is possible.
- in refractory concretes , strength is maintained at high temperatures.
- as a component in blended cement formulations, various properties such as ultra - rapid strength development and controlled expansion can be obtained.

7 - Problems :

Incorrect use of calcium aluminate cements has led to wide spread construction problems, especially during the third quarter of the 20 th century when this type of cement was used because of its faster hardening properties. After several years some of the buildings and structures collapsed due to degradation of the cement and many had to be torn down or reinforced. Heat and humidity accelerate the degradation process called "conversion"; the roof of a swimming pool was one of the first structures to collapse in the UK.

Calcium Aluminates



Calcium aluminates phase diagram.

Calcium Aluminates are a range of minerals[1] obtained by heating calcium oxide and aluminium oxide together at high temperatures. They are encountered in the manufacture of refractories and cements.

The stable phases shown in the phase diagram (formed at atmospheric pressure under an atmosphere of normal humidity) are:

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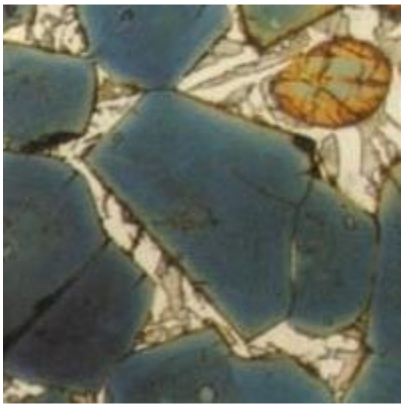
Calcium Alumino Ferrite



Photomicrograph (0.11mm) of clinker polished section showing calcium aluminoferrite (white) and tricalcium aluminate (grey) occupying interstitial space between alite (blue) and belite (orange) crystals. These are false (interference) colors.

Contents

1 – Introduction :

Calcium alumino ferrite ($Ca_2(Al, Fe)_2O_5$) is a dark brown crystalline phase commonly found in cements. In the cement industry it is termed ferrite. It also exists in nature as the rare mineral brownmillerite.

2 - Properties of the pure phase :

In the absence of elements other than calcium , aluminium , iron and oxygen , calcium alumino ferrite forms a solid solution series of formula $Ca_2(Al_xFe_{1-x})_2O_5$ for all values of x in the range 0-0.7[1]. Compositions with $x > 0.7$ do not exist at ordinary pressures (see dicalcium aluminate). The crystal is orthorhombic, and is normally lath-like. Its density varies from 4026 kg · m^{-3} (x = 0) to 3614 kg·m^{-3} (x = 0.7) . All compositions melt incongruently in the range 1400 −1450 °C. They are ferromagnetic, progressively more so as iron content increases. These phases are easily prepared from the oxides.

3 - Phases in Portland cement clinker :

In Portland cement clinker, calcium aluminoferrite occurs as an "interstitial phase", crystallizing from the melt. Its presence in clinker is solely due to the need to obtain liquid at the peak kiln processing temperature (1400 − 1450 °C) , facilitating the formation of the desired silicate phases. Apart from this benefit, its effects on cement properties are little more than those of a diluent. Its forms an impure solid solution that deviates markedly in composition from the simple chemical formula. The calcium alumino ferrite phase acts as a repository for many of the minor elements in the clinker. Most of the transitional elements in the cement are found in the ferrite phase, notably titanium, manganese and zinc. There is also a substantial amount of magnesium and silicon, and because of this, oxides other than Ca O , Al_2O_3 and Fe_2O_3 often make up 15 % of the mass of the calcium alumino ferrite. This substitution reduces the melting point to around 1350 °C.

Typical chemical compositions for various clinker bulk Fe_2O_3 contents are :

Oxide	Mass %	Mass %	Mass %
Fe_2O_3 in Clinker	0.29	2.88	4.87
SiO_2	4.0	2.6	6.1
Al_2O_3	20.2	20.8	17.0
Fe_2O_3	24.5	23.9	27.7
CaO	44.6	46.4	40.2
MgO	3.7	3.1	4.9
Na_2O	0.1	0.1	0.1
K_2O	0.1	0.1	0.1
TiO_2	1.9	2.7	1.7

Mn_2O_3	0.1	0.3	1.5
ZnO	1.1	0.1	0.9

4 - Behavior in cements :

Calcium alumino ferrite has little effect upon the physical properties of cement. On hydration it forms $4\,CaO\cdot Al_2O_3\cdot nH_2O$ and hydrated iron oxide gel. In principle, this is a fast and energetic reaction, but precipitation of an insoluble layer of hydrated iron oxide upon the calcium alumino ferrite crystal surface forms a barrier to further reaction. In the case of Portland cement, subsequent slow reaction with dissolved sulfate forms an AFm phase, which has negligible strength-giving properties. In the case of calcium aluminate cements[4], the situation is less clear-cut, but there is little contribution to early strength. Calcium alumino ferrite is also present in sulfoaluminate cements, and again contributes no strength.

Calcium Carbonate

Contents

1 – Introduction :

Calcium carbonate is a chemical compound with the formula $CaCO_3$. It is a common substance found in rocks in all parts of the world, and is the main component of shells of marine organisms, snails, coal balls, pearls, and eggshells. Calcium carbonate is the active ingredient in agricultural lime, and is usually the principal cause of hard water. It is commonly used medicinally as a calcium supplement or as an antacid, but excessive consumption can be hazardous.

IUPAC name : Calcium carbonate	
Other names : Lime stone ; calcite ; aragonite ; chalk ; marble ; pearl	
Molecular Formula	$Ca\,CO_3$
Exact Mass	100 g / mol

Appearance	Fine white powder
Odor	odorless
Density	2.711 g / cm^3 (calcite) 2.83 g / cm^3 (aragonite)
Melting point	825 °C (aragonite) 1339 °C (calcite)
Boiling point	decomposes
Solubility in water	0.15 g / 100 mL (25°C)
Solubility product, K_{sp}	4.8×10^{-9}
Solubility in dilute acids	soluble
Acidity (pK_a)	9.0
Refractive index (n_D)	1.59
Crystal structure	Trigonal
Flash point	825 °C
LD_{50}	6450 mg / kg (oral , rat)

2 - Chemical properties :

Calcium carbonate shares the typical properties of other carbonates . Notably :

- it reacts with strong acids, releasing carbon dioxide:

$$CaCO_{3\,(s)} + 2\,HCl_{\,(aq)} \rightarrow CaCl_{2\,(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$$

- it releases carbon dioxide on heating (to above 840 °C in the case of $CaCO_3$) , to form calcium oxide, commonly called quick lime , with reaction enthalpy 178 kJ / mole :

$$CaCO_3 \rightarrow CaO + CO_2$$

Calcium carbonate will react with water that is saturated with carbon dioxide to form the soluble calcium bicarbonate.

$$CaCO_3 + CO_2 + H_2O \rightarrow Ca(HCO_3)_2$$

This reaction is important in the erosion of carbonate rocks, forming caverns, and leads to hard water in many regions.

3 - Preparation :

The vast majority of calcium carbonate used in industry is extracted by mining or quarrying. Pure calcium carbonate (e.g. for food or pharmaceutical use) , can be produced from a pure quarried source (usually marble) .

Alternatively, calcium carbonate is prepared by calcining crude calcium oxide. Water is added to give calcium hydroxide, and carbon dioxide is passed through this solution to precipitate the desired calcium carbonate, referred to in the industry as precipitated calcium carbonate (PCC) :

$$CaCO_3 \rightarrow Ca\ O + CO_2$$

$$Ca\ O + H_2O \rightarrow Ca\ (OH)_2$$

$$Ca\ (OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

4 - Occurrence :

Calcium carbonate is found naturally as the following minerals in the form of poly morphs :

- Aragonite
- Calcite
- Vaterite or (μ - $CaCO_3$)

The trigonal crystal structure of calcite is most common.

The calcium carbonate minerals occur in the following rocks :

- Chalk
- Lime stone
- Marble
- Travertine

	
Aragonite	*Calcite*
	
Travertine	*Marble*

5 - Geology

Carbonate is found frequently in geologic settings and constitute an enormous carbon reservoir. Calcium carbonate occurs as the polymorphs aragonite and calcite. A polymorph is a mineral with the same chemical formula but different chemical structure. The carbonate minerals form the rock types: limestone, chalk, marble, travertine, tufa, and others. Calcite commonly occurs as sediments in marine settings. Calcite is typically found around the warm tropic environments. Calcite precipitates in warmer shallow environments more than it does under colder environments because warmer environments do not favor the dissolution of CO_2. This is analogous to CO_2 being dissolved in soda. When you take the cap off of a soda bottle, the CO_2 rushes out. As the soda warms up, carbon dioxide is released. This same principle can be applied to calcite in the ocean. Cold - water carbonates do exist at higher latitudes but have a very slow growth rate.

In tropic settings, the waters are warm and clear. Corals are more abundant in this environment than towards the poles where the waters are cold. Calcium carbonate contributors, including plankton (such as coccoliths and planktic foraminifera), coralline algae, sponges, brachiopods, echinoderms, bryozoa and mollusks, are typically found in shallow water environments where sunlight and filterable food are more abundant. The calcification processes are changed by the ocean acidification.

Where the oceanic crust is sub ducted under a continental plate sediments will be carried down to warmer zones in the astenosphere and mesosphere where the calcium carbonate is decomposed to carbon dioxide which will give rise to explosive vulcanic eruptions.

5 – 1 - Carbonate compensation depth :

The carbonate compensation depth (CCD) is the point in the ocean where the rate of precipitation of calcium carbonate is balanced by the rate of dissolution due to the conditions present. Deep in the ocean, the temperature drops and pressure increases. Calcium carbonate is unusual in that its solubility increases with decreasing temperature. Increasing pressure also increases the solubility of calcium carbonate. The CCD can range from 4 – 6 km below sea level.

5 – 2 - Taphonomy :

Calcium carbonate can preserve fossils through per mineralization. Most of the vertebrate fossils of the Two Medicine Formation, known for its duck-billed dinosaur eggs, are preserved by $CaCO_3$ per mineralization . This type of preservation preserves high levels of detail, even down to the microscopic level . How ever , it also leaves specimens vulnerable to weathering when exposed to the surface .

6 - Uses :

6 – 1 - Industrial applications :

The main use of calcium carbonate is in the construction industry, either as a building material or limestone aggregate for road building or as an ingredient of cement or as the starting material for the preparation of builder's lime by burning in a kiln. However, due to weathering mainly caused by acid rain, calcium carbonate (in limestone form) is no longer used for building purposes on its own, and only as a raw / primary substance for building materials .

Calcium carbonate is also used in the purification of iron from iron ore in a blast furnace. The carbonate is calcined *in situ* to give calcium oxide, which forms a slag with various impurities present, and separates from the purified iron .

In the oil industry, calcium carbonate is added to drilling fluids as a formation - bridging and filter cake - sealing agent; it is also a weighting material which increases the density of drilling fluids to control the down hole pressure. Calcium carbonate is added to swimming pools, as a pH corrector for maintaining alkalinity and offsetting the acidic properties of the disinfectant agent.

Calcium carbonate has traditionally been a major component of blackboard chalk. However, modern manufactured chalk is mostly gypsum , hydrated calcium sulfate $CaSO_4 \cdot 2H_2O$. Calcium carbonate is a main source for growing Seacrete , or Biorock. Precipitated calcium carbonate (PCC) , pre - dispersed in slurry form, is a common filler material for latex gloves with the aim of achieving maximum saving in material and production costs .

Fine ground calcium carbonate (GCC) is an essential ingredient in the microporous film used in babies' diapers and some building films as the pores are nucleated around the calcium carbonate particles during the manufacture of the film by biaxial stretching. GCC or PCC is used as a filler in paper because they are cheaper than wood fiber. Printing and writing paper can contain 10–20% calcium carbonate. In North America, calcium carbonate has begun to replace kaolin in the production of glossy paper. Europe has been practicing this as alkaline papermaking or acid-free papermaking for some decades. PCC has a very fine and controlled particle size, on the order of 2 micrometres in diameter, useful in coatings for paper.

Calcium carbonate is widely used as an extender in paints,[8] in particular matte emulsion paint where typically 30 % by weight of the paint is either chalk or marble. It is also a popular filler in plastics . Some typical examples include around 15 to 20 % loading of chalk in un plasticized poly vinyl chloride (uPVC) drain pipe, 5 to 15 % loading of stearate coated chalk or marble in uPVC window profile. PVC cables can use calcium carbonate at loadings of up to 70 phr (parts per hundred parts of resin) to improve mechanical properties (tensile strength and elongation) and electrical properties (volume resistivity) . Poly propylene compounds are often filled with calcium carbonate to increase rigidity, a requirement that becomes important at high use temperatures . It also routinely used as a filler in thermosetting resins (sheet and bulk molding compounds)[9] and has also been mixed with ABS , and other ingredients, to form some types of compression molded " clay " poker chips. Precipitated calcium carbonate, made by dropping calcium oxide into water, is used by itself or with additives as a white paint , known as white washing.

Calcium carbonate is added to a wide range of trade and do it your self adhesives , sealants, and decorating fillers . Ceramic tile adhesives typically contain 70 to 80 % lime stone . Decorating crack fillers contain similar levels of marble or dolomite. It is also mixed with putty in setting stained glass windows, and as a resist to prevent glass from sticking to kiln shelves when firing glazes and paints at high temperature.

In ceramics / glazing applications, calcium carbonate is known as *whiting* , and is a common ingredient for many glazes in its white powdered form. When a glaze containing this material is fired in a kiln, the whiting acts as a flux material in the glaze. Ground calcium carbonate is an abrasive (both as scouring powder and as an ingredient of household scouring creams) , in particular in its calcite form, which has the relatively low hardness level of 3 on the Mohs scale of mineral hardness, and will therefore not scratch glass and most other ceramics, enamel, bronze, iron, and steel, and have a moderate effect on softer metals like aluminium and copper. A paste made from calcium carbonate and de ionized water can be used to clean tarnish on silver .

6 – 2 - Health and dietary applications :

500 - milligram calcium supplements made from calcium carbonate

Calcium carbonate is widely used medicinally as an inexpensive dietary calcium supplement or gastric antacid . It may be used as a phosphate binder for the treatment of hyperphosphatemia (primarily in patients with chronic renal failure) . It is also used in the pharmaceutical industry as an inert filler for tablets and other pharmaceuticals .

Calcium carbonate is known among IBS sufferers to help reduce diarrhea. Some individuals report being symptom - free since starting supplementation. The process in which calcium carbonate reduces diarrhea is by binding water in the bowel, which creates a stool that is firmer and better formed. Calcium carbonate supplements are often combined with magnesium in various proportions. This should be taken into account as magnesium is known to cause diarrhea.

Calcium carbonate is used in the production of toothpaste and has seen a resurgence as a food preservative and color retainer, when used in or with products such as organic apples or food .

Excess calcium from supplements, fortified food and high-calcium diets , can cause the milk - alkali syndrome, which has serious toxicity and can be fatal. In 1915, Bertram Sippy introduced the "Sippy regimen" of hourly ingestion of milk and cream, and the gradual addition of eggs and cooked cereal, for 10 days, combined with alkaline powders, which provided symptomatic relief for peptic ulcer disease. Over the next several decades, the Sippy regimen resulted in renal failure, alkalosis, and hypercalcemia , mostly in men with peptic ulcer disease. These adverse effects were reversed when the regimen stopped, but it was fatal in some patients with protracted vomiting. Milk alkali syndrome declined in men after effective treatments for peptic ulcer disease arose. During the past 15 years, it has been reported in women taking calcium supplements above the recommended range of 1.2 to 1.5 g daily, for prevention and treatment of osteoporosis, and is exacerbated by dehydration. Calcium has been added to over-the-counter products, which contributes to inadvertent excessive intake. Excessive calcium intake can lead to hypercalcemia, complications of which include vomiting , abdominal pain and altered mental status .

As a food additive it is designated E170 ; INS number 170. Used as an acidity regulator, anti caking agent, stabilizer or colour it is approved for usage in the EU , USA and Australia and New Zealand. It is used in some soy milk products as a source of dietary calcium; one study suggests that calcium carbonate might be as bio available as the calcium in cow's milk . Calcium carbonate is also used as a firming agent in many canned or bottled vegetable products.

6 – 3 - Environmental applications :

In 1989, a researcher, Ken Simmons, introduced $CaCO_3$ into the Whet stone Brook in Massachusetts . His hope was that the calcium carbonate would counter the acid in the stream from acid rain and save the trout that had ceased to spawn. Although his experiment was a success, it did increase the amounts of aluminium ions in the area of the brook that was not treated with the limestone. This shows that $CaCO_3$ can be added to neutralize the effects of acid rain in river ecosystems. Currently calcium carbonate is used to neutralize acidic conditions in both soil and water . Since the 1970s, such *liming* has been practiced on a large scale in Sweden to mitigate acidification and several thousand lakes and streams are limed repeatedly .

7 - Calcination equilibrium :

Calcination of lime stone using charcoal fires to produce quicklime has been practiced since antiquity by cultures all over the world. The temperature at which limestone yields calcium oxide is usually given as 825 °C, but stating an absolute threshold is misleading. Calcium carbonate exists in equilibrium with calcium oxide and carbon dioxide at any temperature. At each temperature there is a partial pressure of carbon dioxide that is in equilibrium with calcium carbonate . At room temperature the equilibrium over whelmingly favors calcium carbonate, because the equilibrium CO_2 pressure is only a tiny fraction of the partial CO_2 pressure in air, which is about 0.035 kPa.

At temperatures above 550 °C the equilibrium CO_2 pressure begins to exceed the CO_2 pressure in air. So above 550 °C, calcium carbonate begins to outgas CO_2 into air. However, in a charcoal fired kiln, the concentration of CO_2 will be much higher than it is in air. Indeed if all the oxygen in the kiln is consumed in the fire, then the partial pressure of CO_2 in the kiln can be as high as 20 kPa.

The table shows that this equilibrium pressure is not achieved until the temperature is nearly 800 °C. For the out gassing of CO_2 from calcium carbonate to happen at an economically useful rate, the equilibrium pressure must significantly exceed the ambient pressure of CO_2. And for it to happen rapidly, the equilibrium pressure must exceed total atmospheric pressure of 101 kPa, which happens at 898 °C.

Equilibrium pressure of CO_2 over $CaCO_3$ (P) vs. temperature (T).

P (kPa)	0.055	0.13	0.31	1.80	5.9	9.3	14	24	34	51	72	80	91	101	179	901	3961
T (°C)	550	587	605	680	727	748	777	800	830	852	871	881	891	898	937	1082	1241

8 - Solubility :

8 – 1 - With varying CO_2 pressure :

Calcium ion solubility as a function of CO_2 partial pressure at 25 °C ($K_{sp} = 4.47\times10^{-9}$)

P_{CO_2} **(atm)**	**pH**	**$[Ca^{2+}]$ (mol / L)**
10^{-12}	12.0	5.19×10^{-3}
10^{-10}	11.3	1.12×10^{-3}
10^{-8}	10.7	2.55×10^{-4}
10^{-6}	9.83	1.20×10^{-4}
10^{-4}	8.62	3.16×10^{-4}
3.5×10^{-4}	8.27	4.70×10^{-4}
10^{-3}	7.96	6.62×10^{-4}
10^{-2}	7.30	1.42×10^{-3}
10^{-1}	6.63	3.05×10^{-3}
1	5.96	6.58×10^{-3}
10	5.30	1.42×10^{-2}

Calcium carbonate is poorly soluble in pure water (47 mg / L at normal atmospheric CO_2 partial pressure as shown below) .

The equilibrium of its solution is given by the equation (with dissolved calcium carbonate on the right) :

$$CaCO_3 \rightleftharpoons Ca^{2+} + CO_3^{2-} \qquad K_{sp} = 3.7\times10^{-9} \text{ to } 8.7\times10^{-9} \text{ at } 25\ °C$$

where the solubility product for [$Ca^{2+}][CO_3^{2-}$] is given as anywhere from $K_{sp} = 3.7\times10^{-9}$ to $K_{sp} = 8.7\times10^{-9}$ at 25 °C , depending upon the data source . What the equation means is that the product of molar concentration of calcium ions (moles of dissolved Ca^{2+} per liter of solution) with the molar concentration of dissolved CO_3^{2-} cannot exceed the value of K_{sp}. This seemingly simple solubility equation, however, must be taken along with the more complicated equilibrium of carbon dioxide with water . Some of the CO_3^{2-} combines with H^+ in the solution according to :

$$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-} \qquad K_{a2} = 5.61\times10^{-11} \text{ at } 25\ °C$$

HCO_3^- is known as the bicarbonate ion. Calcium bicarbonate is many times more soluble in water than calcium carbonate—indeed it exists *only* in solution.

Some of the HCO_3^- combines with H^+ in solution according to :

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \qquad K_{a1} = 2.5\times10^{-4} \text{ at } 25\ °C$$

Some of the H_2CO_3 breaks up into water and dissolved carbon dioxide according to :

$$H_2O + CO_2 \text{ (dissolved)} \rightleftharpoons H_2CO_3 \qquad K_h = 1.70\times10^{-3} \text{ at } 25\ °C$$

And dissolved carbon dioxide is in equilibrium with atmospheric carbon dioxide according to :

$$\frac{P_{CO_2}}{[CO_2]} = k_H$$

where k_H = 29.76 atm / (mol / L) at 25 °C (Henry constant) , P_{CO_2} being the CO_2 partial pressure.

For ambient air, P_{CO_2} is around 3.5×10^{-4} atmospheres (or equivalently 35 Pa) . The last equation above fixes the concentration of dissolved CO_2 as a function of P_{CO_2} , independent of the concentration of dissolved $CaCO_3$. At atmospheric partial pressure of CO_2, dissolved CO_2 concentration is 1.2×10^{-5} moles/liter. The equation before that fixes the concentration of H_2CO_3 as a function of $[CO_2]$. For $[CO_2] = 1.2\times10^{-5}$, it results in $[H_2CO_3] = 2.0\times10^{-8}$ moles per liter. When $[H_2CO_3]$ is known, the remaining three equations together with

$$H_2O \rightleftharpoons H^+ + OH^- \qquad K = 10^{-14} \text{ at } 25\ °C$$

(which is true for all aqueous solutions), and the fact that the solution must be electrically neutral,

$$2[Ca^{2+}] + [H^+] = [HCO_3^-] + 2[CO_3^{2-}] + [OH^-]$$

make it possible to solve simultaneously for the remaining five unknown concentrations (note that the above form of the neutrality equation is valid only if calcium carbonate has been put in contact with pure water or with a neutral pH solution; in the case where the origin water solvent pH is not neutral , the equation is modified) .

Travertine calcium carbonate deposits from a hot spring

The table on the right shows the result for $[Ca^{2+}]$ and $[H^+]$ (in the form of pH) as a function of ambient partial pressure of CO_2 ($K_{sp} = 4.47 \times 10^{-9}$ has been taken for the calculation).

- At atmospheric levels of ambient CO_2 the table indicates the solution will be slightly alkaline with a maximum $CaCO_3$ solubility of 47 mg / L .

- As ambient CO_2 partial pressure is reduced below atmospheric levels, the solution becomes more and more alkaline. At extremely low P_{CO_2}, dissolved CO_2, bicarbonate ion, and carbonate ion largely evaporate from the solution, leaving a highly alkaline solution of calcium hydroxide, which is more soluble than $CaCO_3$. Note that for $P_{CO_2} = 10^{-12}$ atm, the $[Ca^{2+}][OH^-]^2$ product is still below the solubility product of $Ca(OH)_2$ (8×10^{-6}). For still lower CO_2 pressure , $Ca(OH)_2$ precipitation will occur before $CaCO_3$ precipitation.

- As ambient CO_2 partial pressure increases to levels above atmospheric, pH drops, and much of the carbonate ion is converted to bicarbonate ion , which results in higher solubility of Ca^{2+} .

The effect of the latter is especially evident in day-to-day life of people who have hard water. Water in aquifers underground can be exposed to levels of CO_2 much higher than atmospheric. As such water percolates through calcium carbonate rock, the $CaCO_3$ dissolves according to the second trend. When that same water then emerges from the tap, in time it comes into equilibrium with CO_2 levels in the air by outgassing its excess CO_2. The calcium carbonate becomes less soluble as a result and the excess precipitates as lime scale. This same process is responsible for the formation of stalactites and stalagmites in limestone caves.

Two hydrated phases of calcium carbonate, mono hydro calcite , $CaCO_3 \cdot H_2O$ and ikaite, $CaCO_3 \cdot 6H_2O$, may precipitate from water at ambient conditions and persist as metastable phases.

8 – 2 - With varying pH :

Consider the problem of the maximum solubility of calcium carbonate in normal atmospheric conditions ($P_{CO_2} = 3.5 \times 10^{-4}$ atm) when the pH of the solution is adjusted. This is for example the case in a swimming pool where the pH is maintained between 7 and 8 (by addition of sodium bisulfate $NaHSO_4$ to decrease the pH or of sodium bicarbonate $NaHCO_3$ to increase it) . From the above equations for the solubility product, the hydration reaction and the two acid reactions , the following expression for the maximum $[Ca^{2+}]$ can be easily deduced :

$$[\mathrm{Ca}^{2+}]_{\max} = \frac{K_{\mathrm{sp}} k_{\mathrm{H}}}{K_{\mathrm{h}} K_{\mathrm{a1}} K_{\mathrm{a2}}} \frac{[\mathrm{H}^+]^2}{P_{\mathrm{CO}_2}}$$

showing a quadratic dependence in $[H^+]$. The numerical application with the above values of the constants gives :

pH	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.27	8.4
$[Ca^{2+}]_{max}$ (10^{-6}mol/L)	180	71.7	28.5	11.4	4.52	1.80	0.717	0.519	0.285
$[Ca^{2+}]_{max}$ (mg/L)	7.21	2.87	1.14	0.455	0.181	0.0721	0.0287	0.0208	0.0114

Comments :

- decreasing the pH from 8 to 7 increases the maximum Ca^{2+} concentration by a factor 100. Water with a pH maintained to 7 can dissolve up to 15.9 mg / L of Ca CO$_3$. This explains the high Ca^{2+} concentration in some mineral waters with pH close to 7.
- note that the Ca^{2+} concentration of the previous table is recovered for pH = 8.27
- keeping the pH to 7.4 in a swimming pool (which gives optimum H Cl O / Cl O $^{-}$ ratio in the case of "chlorine" maintenance) results in a maximum Ca^{2+} concentration of 1010 mg / L. This means that successive cycles of water evaporation and partial renewing may result in a very hard water before Ca CO$_3$ precipitates (water with a Ca^{2+} concentration above 120 mg / L is considered very hard). Addition of a calcium sequestering agent or complete renewing of the water will solve the problem .

8 – 3 - Solubility in a strong or weak acid solution :

Solutions of strong (HCl), moderately strong (sulfamic) or weak (acetic, citric, sorbic, lactic, phosphoric) acids are commercially available. They are commonly used as descaling agents to remove limescale deposits. The maximum amount of CaCO$_3$ that can be "dissolved" by one liter of an acid solution can be calculated using the above equilibrium equations.

- In the case of a strong monoacid with decreasing acid concentration [A] = [A^{-}], we obtain (with CaCO$_3$ molar mass = 100 g) :

[A] (mol/L)	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-10}
Initial pH	0.00	1.00	2.00	3.00	4.00	5.00	6.00	6.79	7.00
Final pH	6.75	7.25	7.75	8.14	8.25	8.26	8.26	8.26	8.27
Dissolved CaCO$_3$ (g per liter of acid)	50.0	5.00	0.514	0.0849	0.0504	0.0474	0.0471	0.0470	0.0470

where the initial state is the acid solution with no Ca^{2+} (not taking into account possible CO_2 dissolution) and the final state is the solution with saturated Ca^{2+}. For strong acid concentrations, all species have a negligible concentration in the final state with respect to Ca^{2+} and A^- so that the neutrality $[Ca^{2+}]=\frac{[A^-]}{2}$ equation reduces approximately to $2[Ca^{2+}] = [A^-]$ yielding .

When the concentration decreases, $[HCO_3^-]$ becomes non-negligible so that the preceding expression is no longer valid. For vanishing acid concentrations, one can recover the final pH and the solubility of $CaCO_3$ in pure water.

- In the case of a weak monoacid (here we take acetic acid with $pK_A = 4.76$) with decreasing total acid concentration $[A] = [A^-]+[AH]$, we obtain:

[A] (mol/L)	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-10}
Initial pH	2.38	2.88	3.39	3.91	4.47	5.15	6.02	6.79	7.00
Final pH	6.75	7.25	7.75	8.14	8.25	8.26	8.26	8.26	8.27
Dissolved $CaCO_3$ (g per liter of acid)	49.5	4.99	0.513	0.0848	0.0504	0.0474	0.0471	0.0470	0.0470

For the same total acid concentration, the initial pH of the weak acid is less acid than the one of the strong acid; however, the maximum amount of $CaCO_3$ which can be dissolved is approximately the same. This is because in the final state, the pH is larger than the pK_A, so that the weak acid is almost completely dissociated, yielding in the end as many H^+ ions as the strong acid to "dissolve" the calcium carbonate.

- The calculation in the case of phosphoric acid (which is the most widely used for domestic applications) is more complicated since the concentrations of the four dissociation states corresponding to this acid must be calculated together with $[HCO_3^-]$, $[CO_3^{2-}]$, $[Ca^{2+}]$, $[H^+]$ and $[OH^-]$. The system may be reduced to a seventh degree equation for $[H^+]$ the numerical solution of which gives

[A] (mol/L)	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-10}
Initial pH	1.08	1.62	2.25	3.05	4.01	5.00	5.97	6.74	7.00
Final pH	6.71	7.17	7.63	8.06	8.24	8.26	8.26	8.26	8.27
Dissolved $CaCO_3$ (g per liter of acid)	62.0	7.39	0.874	0.123	0.0536	0.0477	0.0471	0.0471	0.0470

where [A] = $[H_3PO_4] + [H_2PO_4^{-}] + [HPO_4^{2-}] + [PO_4^{3-}]$ is the total acid concentration. Thus phosphoric acid is more efficient than a monoacid since at the final almost neutral pH, the second dissociated state concentration $[HPO_4^{2-}]$ is not negligible (see phosphoric acid).

Calcium Hydroxide

Contents

1 – Introduction :

Calcium hydroxide, traditionally called **slaked lime**, is an inorganic compound with the chemical formula $Ca(OH)_2$. It is a colorless crystal or white powder and is obtained when calcium oxide (called *lime* or *quicklime*) is mixed, or "slaked" with water. It has many names including **hydrated lime**, **builders lime**, **slack lime**, **cal**, or **pickling lime**. It is of low toxicity. Calcium hydroxide is used in many applications, including food preparation.

IUPAC name : Calcium hydroxide	
Other names : Slaked lime Milk of lime Calcium (II) hydroxide Pickling lime Hydrated lime	
Molecular Formula	$Ca(OH)_2$
Molar Mass	74 g / mol
Appearance	soft white powder / colourless liquid

Odor	odorless
Density	2.211 g /cm^3, solid
Melting point	580 °C (loses water)
Solubility in water	0.189 g / 100 mL (0 °C) 0.173 g / 100 mL (20 °C) 0.066 g / 100 mL (100 °C)
Solubility product, K_{sp}	4.68×10^{-6}
Solubility	Soluble in glycerol and acids. Insoluble in alcohol.
Acidity (pK_a)	12.4
Basicity (pK_b)	2.37
Refractive index (n_D)	1.574
Hazards	
MSDS	External MSDS
EU Index	Corrosive (C), Irritant (Xi)
Flash point	Non - flammable
LD_{50}	7340 mg / kg (oral , rat) 7300 mg / kg (mouse)
Thermodynamic data	Phase behaviour Solid , liquid , gas
Spectral data	UV, IR, NMR, MS

2 – Properties :

When heated to 512 °C , the partial pressure of water in equilibrium with calcium hydroxide reaches 101 kPa, which decomposes calcium hydroxide into calcium oxide and water .

$$Ca(OH)_2 \rightarrow Ca\,O + H_2O$$

A suspension of fine calcium hydroxide particles in water is called milk of lime . The solution is called lime water and is a medium strength base that reacts with acids and attacks many metals.

Lime water turns milky in the presence of carbon dioxide due to formation of calcium carbonate:

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

Calcium hydroxide crystallizes in the same motif as cadmium iodide. The layers are interconnected by hydrogen bonds.

3 - Preparation and occurrence :

Calcium hydroxide is produced commercially by treating lime with water :

$$Ca\,O + H_2O \rightarrow Ca\,(OH)_2$$

In the laboratory it can be prepared by mixing an aqueous solutions of calcium chloride and sodium hydroxide. The mineral form, portlandite , is relatively rare but can be found in some volcanic, plutonic, and metamorphic rocks. It has also been known to arise in burning coal dumps.

4 – Uses :

One significant application of calcium hydroxide is as a flocculant, in water and sewage treatment. It forms a fluffy charged solid that aids in the removal of smaller particles from water, resulting in a clearer product. This application is enabled by the low cost and non-toxicity of calcium hydroxide. It is also used in fresh water treatment for raising the pH of the water so that the pipes will not corrode where the base water is acidic because it is self - regulating and does not raise the pH too much.

Another large application is in the paper industry, where it is used in the production of sodium hydroxide. This conversion is a component of the Kraft process.

4 – 1 - Niche uses :

Because it is produced on a large scale, is easily handled , and is cheap, myriad niche and even large scale applications have been described. A partial listing follows :

- In life support systems as a carbon dioxide scrubber, particularly in closed - circuit diving re - breathers such as the US Navy LAR V or MK- 16 , where the more caustic Lithium Hydroxide is deemed too risky due to inhaled dust, combat handling, or generation of caustic "slurry" in flooding events
- An ingredient in white wash , mortar , and plaster
- To fill the root canal for the first stage of endodontic therapy (it is then replaced by rubber) .
- As an additive to sea water to reduce atmospheric CO_2 and mitigate the greenhouse effect .
- In the production of metals, lime is injected into the waste gas stream to neutralize acids, such as fluorides and chlorides prior to being released to atmosphere.
- An alkali used as a lye substitute in no-lye hair relaxers
- A chemical depilatory agent found in most hair removal creams (for example Nair)
- In Bordeaux mixture to neutralize the solution and form a long lasting fungicide
- In lime - sulfur it is mixed with sulfur and boiled in water for an hour. The ratio by weight of $Ca(OH)_2$: S : water is about 1: 1.7 : 8.7. Diluted (1 : 32) lime - sulfur is sprayed as a fungicide and used as a dip to combat sarcoptic mange.
- In the petroleum refining industry for the manufacture of additives to oils (salicatic , sulphatic , fanatic)
- In the chemical industry for manufacture of calcium stearate
  - In the petrochemical industry for manufacturing solid oil of various marks
  - In the manufacture of brake pads

  - In manufacturing the trademarked compound "Polikar", an antifungal and antimicrobial preservative for vegetables in storage
  - For preparation of dry mixes for painting and decorating
  - In manufacturing mixes for pesticides
  - In the manufacture of ebonite
  - As a calcium supplement and pH/carbonate buffer (known as *Kalkwasser*) for the aquaculture of corals in reef aquaria.
  - As a natural "alternative" insecticide. Most crawling insects are killed by its touch. Including: ticks, fleas, beetles and grubs.

For making a fungicide or a dip for treating mange it is boiled with sulfur, then diluted. One recipe for the concentrate is 36 lb quicklime, 80 lb sulfur, and 50 gal water boiled for 1 hour — the authors suggesting 1 / 3 more lime if slaked lime is used.

4 – 2 - Food industry :

Because of its low toxicity and the mildness of its basic properties, it is widely used in the food industry and associated hobbies : Examples:

- The separation of sugar from sugar cane or sugar beets in the sugar industry ,
- For processing water for alcoholic beverages, soft drinks.
- Used in the processing of Norwegian *lutefisk* . Dried cod fish is soaked in a mixture of slaked lime and soda to produce a soft - fleshed fish fillet that is steamed or baked and served with potato *lefse*.
- Home food preservation in the making of pickles.
- Clearing a brine of carbonates of calcium and magnesium in the manufacture of salt for food and pharmacopoeia
- In Chinese cuisine , for making century eggs

- Used to fortify fruit drinks such as Tropicana Calcium + Vitamin D orange juice.
- A calcium supplement in mineral fortified infant formula
- A condiment used mainly in Bengali families, predominantly the men, when they take areca nuts, calcium hydroxide and a variety of other seeds wrapped in betel leaves. They call this "*paan*"
- Use as alternative ingredient to baking soda (raising agent) in *papadam*. (South Indian flatbread)

4 – 2 – 1 - Native American uses :

Dry untreated maize (left) , and treated maize (right)
after boiling in water with calcium hydroxide
(1 Tb sp lime for 500 g of corn) 15 minutes.

In Native American and Mesoamerican cooking , calcium hydroxide is called "*cal*". Corn cooked with *cal* becomes nixtamal which significantly increases the bio availability of niacin , and is also considered tastier and easier to digest.

In chewing areca nut or coca leaves , calcium hydroxide is usually chewed alongside to keep the alkaloid stimulants chemically available for absorption by the body. Similarly, Native Americans traditionally chewed tobacco leaves with calcium hydroxide derived from burnt shells to enhance the effects. It has also been used by some indigenous American tribes as an ingredient in *yopo*, a psychedelic snuff prepared from the beans of some Anadenanthera species.

4 – 2 – 2 - Afghan uses

Used in making *naswar* (also known as nass or niswar) is a type of dipping tobacco, made from fresh tobacco leaves, calcium hydroxide (Chuna), and wood ash. calcium oxide plays an important role in making a *naswar*. It is consumed most in the Pathan diaspora, Afghanistan , Pakistan , India and also in Sweden , Norway . Villagers also use calcium hydroxide as a paint on to their mud made houses all over Afghanistan and Pakistan.

4 – 2 – 3 - Ancient Celtic use :

According to Diodorus Siculus :

The Gauls are tall of body with rippling muscles and white of skin and their hair is blond, and not only naturally so for they also make it their practice by artificial means to increase the distinguishing colour which nature has given it. For they are always washing their hair in lime water and they pull it back from the forehead to the nape of the neck, with the result that their appearance is like that of Satyrs and Pans since the treatment of their hair makes it so heavy and coarse that it differs in no respect from the mane of horses. — *Diodorus Siculus*

5 - Health risks :

Unprotected exposure can pose health risks and exposure should be limited. It can cause severe skin irritation and chemical burns/ blindness / lung damage .

Calcium Silicate Hydrate

Contents

1 – Introduction :

Calcium Silicate Hydrate is the main product of the hydration of Portland cement and is primarily responsible for the strength in cement based materials.

2 - Preparation :

Calcium silicate hydrate (also shown as C-S-H or CSH) is a result of the reaction between the silicate phases of Portland cement and water. This reaction typically is expressed as:

$$2\ Ca_3SiO_5 + 7\ H_2O \rightarrow 3\ Ca\ O \cdot 2\ SiO_2 \cdot 4\ H_2O + 3\ Ca(OH)_2 + 173.6\ kJ$$

The stoichiometry of C-S-H in cement paste is variable and the state of chemically and physically bound water in its structure is not transparent, which is why "-" is used between C, S, and H.

Synthetic C-S-H can be prepared from the reaction of CaO and SiO_2 in water or through the double precipitation method using various salts. These methods provide the flexibility of producing C-S-H at specific C/S ratios. The C-S-H from cement phases can also be treated with ammonium nitrate in order to achieve desired C/S ratio.

3 – Properties :

The crystal structure of C-S-H in cement paste has not been fully resolved yet and there is still ongoing debate over its nanostructure.

The SEM micrographs of C-S-H does not show any specific crystalline form. They usually manifest as flakes or dendrites/fibrils.

Synthetic C-S-H can be divided in two categories separated at the C/S ratio of about 1.1. There are several indications that the chemical, physical and mechanical characteristics of C-S-H varies noticeably between these two categories.

Calcium Sulfate

Contents

1- Introduction :

Calcium Sulfate (or calcium sulphate) is a common laboratory and industrial chemical. In the form of γ - anhydrite (the nearly anhydrous form), it is used as a desiccant. It is also used as a coagulant in products like tofu. In the natural state, unrefined calcium sulfate is a translucent, crystalline white rock. When sold as a color-indicating variant under the name Drierite, it appears blue or pink due to impregnation with Cobalt(II) chloride, which functions as a moisture indicator. The hemi hydrate ($CaSO_4\cdot\sim0.5H_2O$) is better known as plaster of Paris, while the di hydrate ($CaSO_4\cdot 2H_2O$) occurs naturally as gypsum. The anhydrous form occurs naturally as β - anhydrite. Depending on the method of calcination of calcium sulfate di hydrate, specific hemihydrates are sometimes distinguished: alpha-hemihydrate and beta- hemi hydrate. They appear to differ only in crystal size. Alpha-hemi hydrate crystals are more prismatic than beta-hemi hydrate crystals and, when mixed with water, form a much stronger and harder superstructure.

Other names : Plaster of Paris Drierite Gypsum	
Molecular Formula	Ca SO_4
Molar Mass	136 g / mol (anhydrous) 145 g / mol (hemi hydrate) 172 g / mol (di hydrate)
Appearance	white solid

Odor	odorless
Density	2.96 g / cm^3 (anhydrous) 2.32 g / cm^3 (di hydrate)
Melting point	1460 °C (anhydrous)
Solubility in water	0.21g / 100ml at 20 °C (anhydrous) 0.24 g / 100ml at 20 °C (de hydrate)
Solubility product , K_{sp}	4.93×10^{-5} (anhydrous) 3.14×10^{-5} (di hydrate)
Solubility in glycerol	slightly soluble (di hydrate)
Acidity (p K_a)	10.4 (anhydrous) 7.3 (de hydrate)
Crystal structure	Orthorhombic
Std enthalpy of formation $\Delta_f H^\ominus_{298}$	-1433 kJ / mol
Standard molar entropy $S^\ominus_{298}$	107 $J \cdot mol^{-1} \cdot K^{-1}$
Flash Point	Non - flammable
Related compounds	Plaster of Paris , Gypsum
Structure and properties	n, ε_r, etc.
Thermodynamic data	Phase behaviour Solid, liquid, gas
Spectral data	UV, IR, NMR, MS

2 - Commercial production and recovery :

The main sources of calcium sulfate are naturally occurring gypsum and anhydrite which occur at many locations worldwide as evaporites. These may be extracted by open-cast quarrying or by deep mining. World production of natural gypsum is around 127 million tones per annum.

In addition to natural sources, calcium sulfate is produced as a by-product in a number of processes:

- In flue-gas desulfurization, exhaust gases from fossil-fuel-burning power stations and other processes (e.g. cement manufacture) are scrubbed to reduce their sulfur oxide content, by injecting finely ground limestone or lime. This produces an impure calcium sulfite, which oxidizes on storage to calcium sulfate.
- In the production of phosphoric acid from phosphate rock, calcium phosphate is treated with sulfuric acid and calcium sulfate precipitates.
- In the production of hydrogen fluoride, calcium fluoride is treated with sulfuric acid, precipitating calcium sulfate.
- In the refining of zinc, solutions of zinc sulfate are treated with lime to co-precipitate heavy metals such as barium.
- Calcium sulfate can also be recovered and re-used from scrap drywall at construction sites.

These precipitation processes tend to concentrate radioactive elements in the calcium sulfate product. This is particularly the case with the phosphate by-product, since phosphate rocks naturally contain actinides.

3 - Dehydration reactions :

Heating gypsum to between 100 °C and 150 °C partially dehydrates the mineral by driving off approximately 75% of the water contained in its chemical structure. The temperature and time needed depend on ambient partial pressure of H_2O. Temperatures as high as 170 °C are used in industrial calcinations , but at these temperatures γ-anhydrite begins to form. The reaction for the partial dehydration is:

$$CaSO_4 \cdot 2H_2O + \text{heat} \rightarrow Ca\ SO_4 \cdot ½\ H_2O + 1½\ H_2O\ (\text{steam})$$

The partially dehydrated mineral is called calcium sulfate hemi hydrate or calcined gypsum (commonly known as plaster of Paris) ($CaSO_4 \cdot nH_2O$) , where n is in the range 0.5 to 0.8.

The dehydration (specifically known as calcination) begins at approximately 80 °C , although in dry air, some dehydration will take place already at 50 °C. The heat energy delivered to the gypsum at this time (the heat of hydration) tends to go into driving off water (as water vapor) rather than increasing the temperature of the mineral, which rises slowly until the water is gone, then increases more rapidly.

The endothermic property of this reaction is exploited by drywall to confer fire resistance to residential and other structures. In a fire, the structure behind a sheet of drywall will remain relatively cool as water is lost from the gypsum, thus preventing (or substantially retarding) damage to the framing (through combustion of wood members or loss of strength of steel at high temperatures) and consequent structural collapse.

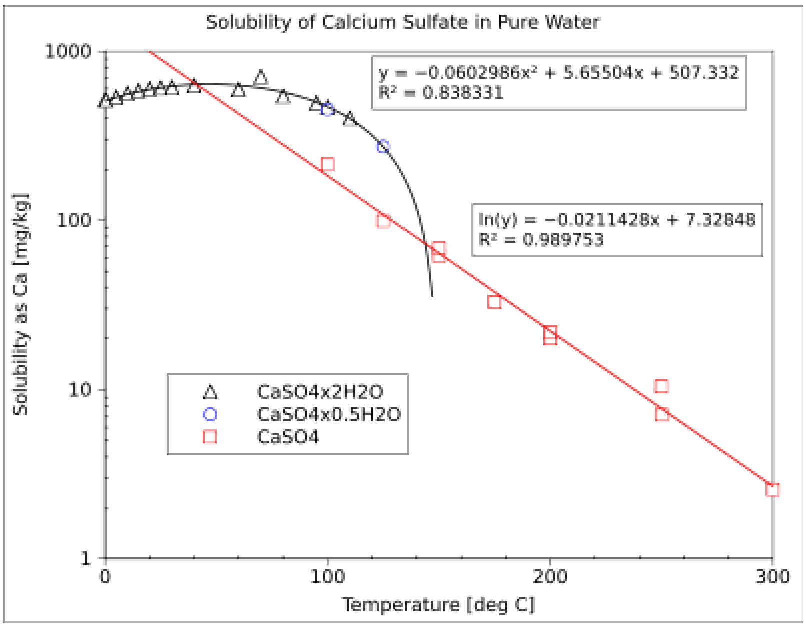
In contrast to most minerals, which when rehydrated simply form liquid or semi-liquid pastes, or remain powdery, calcined gypsum has an unusual property: when mixed with water at normal (ambient) temperatures, it quickly reverts chemically to the preferred dihydrate form, while physically "setting" to form a rigid and relatively strong gypsum crystal lattice:

$$CaSO_4 \cdot ½\ H_2O + 1½\ H_2O \rightarrow CaSO_4 \cdot 2H_2O$$

This reaction is exothermic and is responsible for the ease with which gypsum can be cast into various shapes including sheets (for drywall), sticks (for blackboard chalk), and molds (to immobilize broken bones, or for metal casting). Mixed with polymers, it has been used as a bone repair cement. Small amounts of calcined gypsum are added to earth to create strong structures directly from cast earth, an alternative to adobe (which loses its strength when wet). The conditions of dehydration can be changed to adjust the porosity of the hemi hydrate, resulting in the so - called alpha and beta hemi hydrates (which are more or less chemically identical) .

On heating to 180 °C, the nearly water-free form, called γ-anhydrite ($CaSO_4 \cdot nH_2O$ where $n = 0$ to 0.05) is produced. γ-Anhydrite reacts slowly with water to return to the dihydrate state, a property exploited in some commercial desiccants. On heating above

250 °C, the completely anhydrous form called β-anhydrite or "natural" anhydrite is formed. Natural anhydrite does not react with water, even over geological timescales, unless very finely ground.



Temperature dependence of the solubility of calcium sulfate (3 phases) in pure water.

The variable composition of the hemi hydrate and γ-anhydrite, and their easy inter-conversion, is due to their possessing nearly identical crystal structures, containing "channels" that can accommodate variable amounts of water, or other small molecules such as methanol.

4 - Fouling deposits :

Calcium sulfate is a common component of fouling deposits in industrial heat exchangers. It is because its solubility decreases with increasing temperature (see the figure) . Note that the solubility of the calcium sulphate in the figure results about 10 times higher than that which is calculated with the solubility product of 0.0000493 given in same page.

Carbon Grid

Contents

1 – Introduction :

ncrete

2 - Technology

Carbon fiber FRP Grids are structural reinforcement materials that improve the performance of concrete structures such as insulated wall panels, architectural panels, double tee parking garage tee beams, concrete countertops and other products. The carbon grids can be used in place of welded wire mesh in most structures and is imbedded the same way as a welded wire mesh. Carbon fiber's high strength, high modulus, resistance to creep and excellent fatigue properties allow the carbon grid to provide excellent crack and structural reinforcement. Ideally the carbon tows (yarns) are constructed on top of each other in a superimposed design those aides with fiber alignment and toughness of the finished grid.

3 - Applications with Concrete in General :

Concrete is inherently strong in compression and weak in tension. To address this issue, concrete is often reinforced with steel in the form of rebar, welded wire mesh or stressing strands (Pre stressed or post - tensioned) . In theory, the concrete has to crack when loaded in tension for the steel to begin to share the load in the steel reinforced concrete composite. The concrete helps protect the steel by providing an alkaline environment (ph=13 in many cases) to retard corrosion of the steel. To properly protect the steel the concrete needs to cover the steel by a minimum thickness, not have large cracks and not have it’s chemistry altered by environmental factors like chloride attack from deicing salts, carbonation, etc.. ACI and PCI (American Concrete Institute, Precast / Pre stressed Concrete Institute) codes specify minimum cover thicknesses depending on the application of the structure. In practice, steel often corrodes due to improper placement of steel reinforcement, moisture drive through cracks, poor workmanship, environmental effects such as deicing salts or costal environments and a myriad of other causes. Due to the inherent properties of steel reinforced concrete, many structures are expensive, heavy and costly to maintain. The repair of these structures is a multi - billion dollar business worldwide according to industry sources (ICRI International Concrete Repair Institute) .

4 - Applications with Concrete Panels :

Multi layer concrete structures (like insulated walls panels) use a sandwich technology that use insulation layers placed in between two or more layers of concrete. Often these concrete layers are tied together by sections of solid concrete, metal tie structures or FRP pin structures. Often, the design of the wall panel is limited by lack of effective insulation in the tie areas or poor structural performance of the tie design or solid section. These limitations cause structures to be weaker, heavier and more costly both in manufacturing and ownership.

Benefits: Carbon grids provide a corrosion resistant reinforcement that has a higher modulus of elasticity than steel that is imbedded inside concrete (similar to conventional steel mesh). This allows for designs that don't require as much concrete cover, so concrete structures can be lighter and much more durable than before. For instance, using carbon fiber grid in insulated wall panels can provide a stronger, lighter, more thermally efficient panel than is practical with conventional designs. Due to the lighter weight less energy is required to provide the necessary concrete and ship products adding an environmental incentive to using this technology.

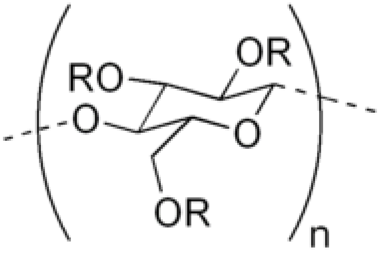
FRP fabrics that are used as external reinforcements are impregnated with polymer on the jobsite and have to be bonded to a surface of a concrete structure. In contrast, carbon grids provide an internal reinforcement and have fibers that are impregnated with a polymer (typically epoxy) in a factory rather than on the job site, saving time and insuring consistent quality. Also, the open spaces of the grid provide a mechanical bond to transfer load within the concrete structure.

Additional benefits of the carbon grid structure are that it is light, easy to handle, non-magnetic and easier to cut than steel. These properties allow for use where steel is impractical or cumbersome.

History: Carbon grids have been manufactured by Chomarat North America (formerly TechFab LLC) since 1998 and have found commercial uses in concrete countertops, shotcrete, ornamental concrete, caststone products, precast insulated wall panels, double tee beams and a myriad of other concrete products. These materials have also been used in numerous repair projects including the Naumburg Band shell in New York City cited on the website www.carbongrid.com. A variety of product strengths and apertures are offered depending on the application.

Limitations: The main limitation of the carbon grid is the additional cost of carbon as compared to mild carbon steel (with rising energy costs this gap has narrowed). In addition, since carbon is a linear elastic material (without a yield point), reinforced concrete structures have to be designed to account for this. Carbon fiber grids can be used in design by following the American Concrete Institute - ACI 440 methodology similar to FRPrebar. Typically, the structure will also use steel in an appropriate location or be over designed so that the structure fails by crushing the concrete in tension providing ductility.

Carboxy Methyl Cellulose (CMC)



R = H or CH_2CO_2H

Contents

1 – Introduction :

Carboxy methyl cellulose (CMC) or **cellulose gum** is a cellulose derivative with carboxy methyl groups ($-CH_2-COOH$) bound to some of the hydroxyl groups of the gluco pyranose monomers that make up the cellulose backbone. It is often used as its sodium salt, sodium carboxy methyl cellulose.

2 – Preparation :

It is synthesized by the alkali - catalyzed reaction of cellulose with chloro acetic acid. The polar (organic acid) carboxyl groups render the cellulose soluble and chemically reactive.

The functional properties of CMC depend on the degree of substitution of the cellulose structure (i.e., how many of the hydroxyl groups have taken part in the substitution reaction), as well as the chain length of the cellulose backbone structure and the degree of clustering of the carboxy methyl substituents.

2 – Uses :

CMC is used in food science as a viscosity modifier or thickener, and to stabilize emulsions in various products including ice cream. As a food additive, it has E number E466. It is also a constituent of many non-food products, such as K-Y Jelly, toothpaste, laxatives, diet pills, water-based paints, detergents, textile sizing and various paper products. It is used primarily because it has high viscosity, is non-toxic, and is non - allergenic. In laundry detergents it is used as a soil suspension polymer designed to deposit onto cotton and other cellulosic fabrics creating a negatively charged barrier to soils in the wash solution. CMC is used as a lubricant in non - volatile eye drops (artificial tears). Some times it is methyl cellulose (MC) which is used, but its non-polar methyl groups (-CH_3) do not add any solubility or chemical reactivity to the base cellulose.

Following the initial reaction the resultant mixture produces approximately 60 % CMC plus 40 % salts (sodium chloride and sodium glycolate) . This product is the so - called Technical CMC which is used in detergents. A further purification process is used to remove these salts to produce pure CMC which is used for food, pharmaceutical and dentifrice (toothpaste) applications. An intermediate "semi - purified" grade is also produced, typically used in paper applications.

CMC is also used in the oil drilling industry as an ingredient of drilling mud, where it acts as a viscosity modifier and water retention agent. Poly-anionic cellulose or PAC is derived from CMC and is also used in oilfield practice.

Insoluble micro granular carboxy methyl cellulose is used as a cation-exchange resin in ion - exchange chromatography for purification of proteins . Presumably the level of derivatization is much lower so that the solubility properties of micro granular cellulose are retained while adding sufficient negative charged carboxylate groups to bind positively charged proteins.

CMC is also used in ice packs to form a eutectic mixture resulting in a lower freezing point and there fore more cooling capacity than ice.

Aqueous solutions CMC have also been used to disperse carbon nano tubes. It is thought that the long CMC molecules wrap around the nano tubes, allowing them to be dispersed in water.

Carboxy Methyl Starch (C M S)

Contents :

1 – Introduction :

Sodium Carboxy Methyl Starch is a starch ether and solution of this product are alkaline in nature and this can also replace Sodium Carboxy Methyl Cellulose in fields like Textile sizing & Printing, Corrugated Paper, Paper sizing, Oil well Drilling, Water Based Distemper, Oil Bound Distemper, Electrodes, Ceramics, Pesticides, Foundry, Adhesives etc.

2 – Applications :

Industries	**Application areas**
Textile Industry	• Thickener in printing pastes • Ingredient in various finishes • High film strength thickener • Adhesion to fiber, film former
Paint Industry	• Viscosity control agent in emulsion Paints , where it also has a beneficial influence on brush ability • In distempers as a binder porous surfaces like wall board, plaster etc • Excellent bonding agent for fillers
Soaps & Detergents	• Addition of CMC in detergents, especially in synthetic detergents, improves soil suspending properties
Pesticides	• In manufacturing of pesticides powders, CMC improves suspensibility and acts as a “Sticker” where necessary.

Oil Well Drilling	• As a conditioning agent for their drilling mud
Paper & Corrugated Board Industry	• In multi wall paper rack manufacture CMC pastes have an advantages of cleanliness and economy • In corrugated board, it is used as a viscosity control agent and stabilizer for starch pastes • Also an adhesive agent
Ceramic Industries	• Stabilizer and binder for glazes • Improves green strength of moulded, thrown or slipeast bodies • As secondary binder for various specialty products, like refractory trowelling compound • As an organic pesticide for casting slips

3 - Technological reasons for use :

- Very small concentrations are required
- Many types are available with especially adapted Varieties for numerous applications
- Colourless, odourless and tasteless
- Preservation of properties within very narrow limits
- It is easily soluble, even in cold water
- Binding and thickening
- Suspending and stabilizing
- Emulsifying
- Forming protective film
- Improving rheological properties
- Preventing growth of crystals
- Preventing synthesis of starch containing products
- Improving structure and texture
- Freeze- thaw stabilization
- Giving body

4 – Specification Of Carboxy Methyl Starch :

1.	Chemical Name	Sodium Carboxy Methyl Starch
2.	Colour & Appearance	White to Cremish free flow powder.
3.	Solubility in Water	Soluble in both hot & cold water.
4.	Active Matter content, % by mass (On dry basis)	75 to 80 %
5.	Degree of Substitution	0.25 to 0.4
6.	pH of 1% solution (28°C temp.)	10 to 12
7.	Moisture content	Less than 10 %
8.	Viscosity of 2 % solution (28°C temp.)	20 to 30 cps
9.	Bulk density	0.7 to 0.8
10.	Ash content	14 – 16 %
11.	Nacl % by mass	7 – 8 %

Cast Stone

Contents

1 – Introduction :

Cast stone is defined as “a refined architectural concrete building unit manufactured to simulate natural cut stone, used in unit masonry applications”. In the UK and Europe cast stone is defined as “any material manufactured with aggregate and cementitious binder, intended to resemble in appearance, and which may be used in a similar way to, natural stone”. Cast stone is either a masonry product, used as an architectural feature, trim, ornament or facing for buildings or other structures, or can be used for garden ornaments . Cast stone can be made from white and/or grey cements, manufactured or natural sands, carefully selected crushed stone or well graded natural gravels and mineral coloring pigments to achieve the desired color and appearance while maintaining durable physical properties which exceed most natural cut building stones. Cast stone is an excellent replacement for natural cut limestone, brownstone, sandstone, bluestone, granite, slate, coral rock, travertine and other natural building stones.

2 - History :

The walled city of Carcassonne

Cast stone has been a prime building material for hundreds of years. The earliest known use of Cast stone dates about to the year 1138 and was seen at Carcassonne, France, the city which contains the finest remains of medieval fortification in Europe. Cast stone was first used extensively in London in the 19th century and gained widespread acceptance in America in 1920 .

Some researchers have even speculated that the Egyptian pyramids were formed using a form of cast stone, rather than from cut blocks .

One of the earliest developments in the industry was Coade stone, a fired ceramic, but most artificial stone consists of fine cement concrete placed to set in wooden, rubber lined fiberglass or iron moulds. It was cheaper and more uniform than natural stone, and widely used. In engineering projects, it had the advantage that transporting the bulk materials and casting them near the place of use was cheaper than transporting very large pieces of stone.

The first recorded commercial production of a cement based cast stone material in the format we know today, was in the late 1820s when Felix Austin went into business making artificial stone in New Road (now Euston Road), London, England. His material was not the same as the ceramic body used by Mrs. Coade, (although he is known to have copied old Coade stone designs), but made from 'Portland cement, broken natural stone, pounded marble and coarse sand' ('The Builder', 1868, now Building (magazine)). Around 1840 Austin entered into partnership with John Seeley. Seeley had trained at the Royal Academy Schools and also made an artificial stone, which he called ' artificial limestone ', before entering into partnership with Austin. In 1841 Austin and Seeley published their first catalogue, 'Collection of Ornaments at Austin & Seeley's Artificial Stone Works for Gardens, Parks and Pleasure Grounds'. The firm continued in production until about 1872 .

Another well - known variety was Victoria stone, which is composed of finely crushed Mount Sorrel (Leicestershire) granite and Portland cement, carefully mixed by machinery in the proportions of three to one, and filled into moulds of the required shape. When the blocks are set hard the moulds are loosened and the blocks placed in a solution of silicate of soda for about two weeks for the purpose of indurating and hardening them.

Many manufacturers turn out a material that is practically non-porous and is able effectually to resist the corroding influence of sea air or the impure atmosphere of large towns.

3 - Physical properties :

Today, cast stone is a Portland cement-based architectural precast concrete product manufactured using high quality fine and coarse aggregate as its primary constituents. The use of a high percentage of fine aggregate creates a very smooth, consistent texture for the building elements being cast, resembling natural cut stone. Other ingredients such as chemical admixtures, pozzolans, and pigments also may be added.

Cast stone frequently is produced with a low water-to-cement ratio mixture with a "dry" (or "earth moist") consistency. The mixture is consolidated into a mould using an air-driven, or electric, tamping device or vibration under pressure, which is much like the formation of natural sedimentary rock. Products manufactured in this manner are referred to as vibrant-dry-tamped (VDT) cast stone. For cast stone mixtures produced with a slump able consistency mixture, the concrete typically is consolidated using internal or external vibration applied to the production mould, or increasingly by the use of self-compacting additives.

Over the last decade, new types of admixtures have been developed for VDT concrete products. These new admixtures do not normally work with "wet cast" concrete. These new plasticizers are more efficient than using air-entraining agents to increase compaction in VDT concrete. Some plasticizers have chemical properties that react with the cement to increase ultimate strengths of semi-dry concrete. Another important type of admixture for VDT concrete is integral waterproofing formulas. Tests have shown that some of these integral waterproofing admixtures have improved strength by as much as 20% while reducing the absorption by 40%. The increased strength and reduced absorption results in improved freeze/thaw durability.

On recent commercial testing laboratory results the freeze-thaw for VDT concrete using integral waterproofing admixtures was 0.23% weight loss after 300 cycles. Air entraining agents have been the salvation of wet cast concrete as it pertains to its durability. Wet cast concrete with 4 % to 6 % entrained air normally can withstand numerous freeze-thaw cycles without failing. Other types of admixtures such as water-reducers, super plasticizers and the new self-compacting additives can add to improving the strength and durability of wet cast concrete products Cast stone products manufactured by the wet cast method are required to meet the same standards as VDT cast products.

Today, the Industry Standard for physical properties and raw materials constituents is ASTM C 1364, the Standard Specification for Architectural Cast Stone. Membership in ASTM International (founded in 1898 as the American Chapter of the International Association for Testing and Materials and most recently known as the American Society for Testing and Materials) exceeds 30,000 technical experts from more than 100 countries who comprise a worldwide standards forum. The ASTM method of developing standards has been based on consensus of both users and producers of all kinds of materials. The ASTM process ensures that interested individuals and organizations representing industry, academia, consumers, and governments alike, all have an equal vote in determining a standard's content.

In the UK and Europe it is more normal to use the Standard “BS 1217 Cast stone - Specification” from the BSI Group, and the European Commission's “Construction Products Regulations” legislation states that by mid 2013, all cast stone sold in Europe must be certified to this standard.

Cellulose Ethers

Contents :

1 - Introduction :

Cellulose ethers are high – molecular - weight compounds produced by replacing the hydrogen atoms of hydroxyl groups in the an hydro glucose units of cellulose with alkyl or substituted alkyl groups. The commercially important properties of cellulose ethers are determined by the molecular weight of the cellulose used, the chemical structure and distribution of the substituent groups and the degree of substitution and molar substitution (where applicable). These properties generally include solubility, viscosity in solution, surface activity, thermoplastic film characteristics and stability against biodegradation, heat, hydrolysis and oxidation. Viscosity in solution varies directly with molecular weight.

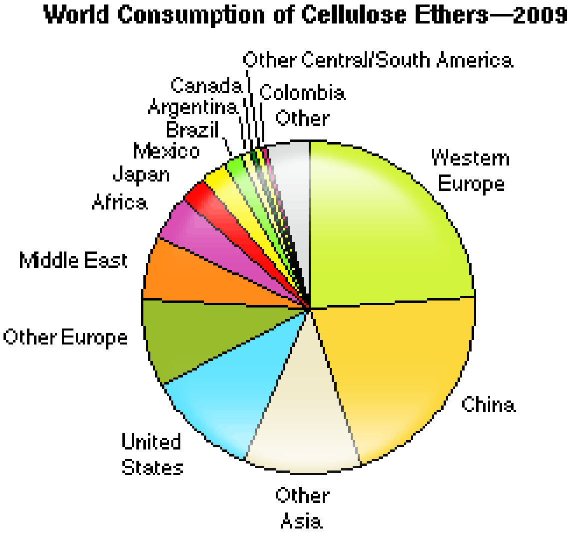
Though the cellulose ethers market is global, most of the production capacity is in Europe, as is most of the consumption. Most of the major producers have facilities in more than one region; they move their products among regions in order to balance production of the various grades and they export to regions in which they do not have facilities. China is the largest target for new cellulose ether plant construction and expansions of existing plants; how ever, Chinese plants tend to have lower capacity utilization compared with other regions.

2 - Uses :

Cellulose ethers are used in a variety of applications. The customer base in some of the larger applications (i.e., detergents, surface coatings, building products and oil field applications) is fairly concentrated , with high - volume end users. How ever , these applications account for less than half of the total market for cellulose ethers; the remainder of the market is highly fragmented. Cellulose ethers typically represent a small fraction of a consumer's total raw material purchases and there appears to be no desire for backward integration by end users. The power consumers wield is the threat of switching to alternative materials that can compete on a functional basis with cellulose ethers.

3 - world consumption :

The following pie chart shows world consumption of cellulose ethers :



Asia consumes the largest volume of cellulose ethers (35 %), followed by Europe at 33 % and North America at 14 %. Carboxy methyl cellulose (CMC) is the major cellulose ether consumed, representing nearly 57 % of the total volume consumed. Methylcellulose (MC) represents about 25 % by volume, followed by hydroxy ethyl cellulose (H E C) at 14 % .

An over all average annual growth rate of slightly over 4 % is expected for all cellulose ether products in 2009 – 2014. In Asia, the lowest growth is expected in Japan, while China will lead global growth. The regions with the highest current consumption, Europe and China, will grow at 3.0 % and 5 % on an average annual basis , respectively . North America will grow faster (3.4 %) , than Europe and Japan.

Cement

Lafarge cement plant in Contes , France.

Contents

1 – Introduction :

In the most general sense of the word , a **cement** is a binder, a substance that sets and hardens independently, and can bind other materials together. The word "cement" traces to the Romans, who used the term *opus caementicium* to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick additives that were added to the burnt lime to obtain a hydraulic binder were later referred to as *cementum*, *cimentum*, *cäment*, and *cement*.

Cement used in construction is characterized as **hydraulic** or **non-hydraulic**. Hydraulic cements (*e.g.*, Portland cement) harden because of hydration, chemical reactions that occur independently of the mixture's water content ; they can harden even underwater or when constantly exposed to wet weather. The chemical reaction that results when the anhydrous cement powder is mixed with water produces hydrates that are not water-soluble. Non-hydraulic cements (*e.g*. gypsum plaster) must be kept dry in order to retain their strength.

The most important use of cement is the production of mortar and concrete—the bonding of natural or artificial aggregates to form a strong building material that is durable in the face of normal environmental effects.

Concrete should not be confused with cement, because the term *cement* refers to the material used to bind the aggregate materials of concrete. Concrete is a combination of a cement and aggregate.

2 - History of the origin of cement :

2 – 1 - Early uses :

It is uncertain where it was first discovered that a combination of hydrated non-hydraulic lime and a pozzolan produces a hydraulic mixture (see also : Pozzolanic reaction) , but concrete made from such mixtures was first used by the Ancient Macedonians and three centuries later on a large scale by Roman engineers . They used both natural pozzolans (trass or pumice) and artificial pozzolans (ground brick or pottery) in these concretes. Many excellent examples of structures made from these concretes are still standing, notably the huge monolithic dome of the Pantheon in Rome and the massive

Baths of Caracalla . The vast system of Roman aqueducts also made extensive use of hydraulic cement .

Although any preservation of this knowledge in literary sources from the Middle Ages is unknown, medieval masons and some military engineers maintained an active tradition of using hydraulic cement in structures such as canals, fortresses, harbors, and shipbuilding facilities . The technical knowledge of making hydraulic cement was later formalized by French and British engineers in the 18th century .

2 – 2 - Modern cement :

Modern hydraulic cements began to be developed from the start of the Industrial Revolution (around 1800) , driven by three main needs :

- Hydraulic cement render (stucco) for finishing brick buildings in wet climates.
- Hydraulic mortars for masonry construction of harbor works, etc., in contact with sea water.
- Development of strong concretes.

In Britain particularly, good quality building stone became ever more expensive during a period of rapid growth, and it became a common practice to construct prestige buildings from the new industrial bricks, and to finish them with a stucco to imitate stone. Hydraulic limes were favored for this, but the need for a fast set time encouraged the development of new cements. Most famous was Parker's "Roman cement".[8] This was developed by James Parker in the 1780s, and finally patented in 1796. It was, in fact, nothing like any material used by the Romans, but was a "Natural cement" made by burning septaria – nodules that are found in certain clay deposits, and that contain both clay minerals and calcium carbonate. The burnt nodules were ground to a fine powder. This product, made into a mortar with sand, set in 5–15 minutes. The success of "Roman Cement" led other manufacturers to develop rival products by burning artificial mixtures of clay and chalk.

John Smeaton made an important contribution to the development of cements when he was planning the construction of the third Eddystone Lighthouse (1755 – 9) in the English Channel. He needed a hydraulic mortar that would set and develop some strength in the twelve hour period between successive high tides. He performed an exhaustive market research on the available hydraulic limes, visiting their production sites, and noted that the "hydraulicity" of the lime was directly related to the clay content of the limestone from which it was made. Smeaton was a civil engineer by profession, and took the idea no further. Apparently unaware of Smeaton's work, the same principle was identified by Louis Vicat in the first decade of the nineteenth century. Vicat went on to devise a method of combining chalk and clay into an intimate mixture, and, burning this, produced an "artificial cement" in 1817. James Frost , working in Britain, produced what he called "British cement" in a similar manner around the same time, but did not obtain a patent until 1822. In 1824, Joseph Aspdin patented a similar material, which he called Portland cement, because the render made from it was in color similar to the prestigious Portland stone.

Setting time and "early strength" are important characteristics of cements. Hydraulic limes, "natural" cements, and "artificial" cements all rely upon their belite content for strength development. Belite develops strength slowly. Because they were burned at temperatures below 1250 °C, they contained no alite, which is responsible for early strength in modern cements. The first cement to consistently contain alite was made by Joseph Aspdin's son William in the early 1840s. This was what we call today "modern" Portland cement. Because of the air of mystery with which William Aspdin surrounded his product, others (*e.g.*, Vicat and I.C. Johnson) have claimed precedence in this invention, but recent analysis of both his concrete and raw cement have shown that William Aspdin 's product made at Northfleet, Kent was a true alite - based cement. However, Aspdin 's methods were "rule – of - thumb": Vicat is responsible for establishing the chemical basis of these cements, and Johnson established the importance of sintering the mix in the kiln.

William Aspdin 's innovation was counterintuitive for manufacturers of "artificial cements", because they required more lime in the mix (a problem for his father), a much higher kiln temperature (and there fore more fuel) , and the resulting clinker was very hard and rapidly wore down the mill stones , which were the only available grinding technology of the time. Manufacturing costs were therefore considerably higher, but the product set reasonably slowly and developed strength quickly, thus opening up a market for use in concrete. The use of concrete in construction grew rapidly from 1850 onwards, and was soon the dominant use for cements. Thus Portland cement began its predominant role.

In the US the first large scale use of cement was Rosendale cement a natural cement mined from a massive deposit of a large dolo stone rock deposit discovered in the early 19th century near Rosendale, New York. Rosendale cement was extremely popular for the foundation of buildings (*e.g.*, Statue of Liberty, Capitol Building, Brooklyn Bridge) and lining water pipes. But its long curing time of at least a month made it unpopular after World War One in the construction of highways and bridges and many states and construction firms turned to the use of Portland cement. Because of the switch to Portland cement, by the end of the 1920s of the 15 Rosendale cement companies, only one had survived. But in the early 1930s it was soon discovered that Portland cement while it had a faster setting time was not as durable, especially for highways, to the point that some states stopped building highways and roads with cement. An engineer, Bertrain H. Wait, whose company had worked on the construction of the New York Cities Catskill Aqueduct, and was impressed with the durability of Rosendale cement, came up with a blend of both Rosendale and synthetic cements which has the good attributes of both: it was highly durable and had a much faster setting time. Mr. Wait convinced the New York Commissioner of Highways to construct an experimental section highway near New Paltz, New York, of one sack of Rosendale to six sacks of synthetic cement, and it was proved a success and for decades hence the Rosendale-synthetic cement blend became common use in highway and bridge construction .

3 - Types of modern cement :

3 – 1 - Portland cement :

Cement is made by heating lime stone (calcium carbonate) with small quantities of other materials (such as clay) to 1450 °C in a kiln, in a process known as calcination, whereby a molecule of carbon dioxide is liberated from the calcium carbonate to form calcium oxide, or quicklime, which is then blended with the other materials that have been included in the mix. The resulting hard substance, called 'clinker', is then ground with a small amount of gypsum into a powder to make 'Ordinary Portland Cement', the most commonly used type of cement (often referred to as OPC).

Portland cement is a basic ingredient of concrete, mortar and most non-specialty grout. The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. As a construction material, concrete can be cast in almost any shape desired, and once hardened, can become a structural (load bearing) element. Portland cement may be grey or white.

3 – 2 - Portland cement blends :

Portland cement blends are often available as inter - ground mixtures from cement manufacturers, but similar formulations are often also mixed from the ground components at the concrete mixing plant .

Portland blast furnace cement contains up to 70 % ground granulated blast furnace slag, with the rest Portland clinker and a little gypsum. All compositions produce high ultimate strength, but as slag content is increased, early strength is reduced, while sulfate resistance increases and heat evolution diminishes. Used as an economic alternative to Portland sulfate - resisting and low-heat cements .

Portland fly ash cement contains up to 35 % fly ash. The fly ash is pozzolanic, so that ultimate strength is maintained. Because fly ash addition allows a lower concrete water content, early strength can also be maintained. Where good quality cheap fly ash is available, this can be an economic alternative to ordinary Portland cement .

Portland pozzolan cement includes fly ash cement, since fly ash is a pozzolan, but also includes cements made from other natural or artificial pozzolans. In countries where volcanic ashes are available (e.g. Italy, Chile , Mexico , the Philippines) these cements are often the most common form in use.

Portland silica fume cement. Addition of silica fume can yield exceptionally high strengths, and cements containing 5 – 20 % silica fume are occasionally produced. How ever, silica fume is more usually added to Portland cement at the concrete mixer.

Masonry cements are used for preparing bricklaying mortars and stuccos, and must not be used in concrete. They are usually complex proprietary formulations containing Portland clinker and a number of other ingredients that may include limestone, hydrated lime, air entrainers, retarders, waterproofers and coloring agents. They are formulated to yield workable mortars that allow rapid and consistent masonry work. Subtle variations of Masonry cement in the US are Plastic Cements and Stucco Cements. These are designed to produce controlled bond with masonry blocks.

Expansive cements contain, in addition to Portland clinker, expansive clinkers (usually sulfo aluminate clinkers) , and are designed to offset the effects of drying shrinkage that is normally encountered with hydraulic cements. This allows large floor slabs (up to 60 m square) to be prepared without contraction joints.

White blended cements may be made using white clinker and white supplementary materials such as high - purity meta kaolin.

Colored cements are used for decorative purposes. In some standards, the addition of pigments to produce "colored Portland cement" is allowed. In other standards (e.g. ASTM), pigments are not allowed constituents of Portland cement, and colored cements are sold as "blended hydraulic cements".

Very finely ground cements are made from mixtures of cement with sand or with slag or other pozzolan type minerals that are extremely finely ground together. Such cements can have the same physical characteristics as normal cement but with 50% less cement particularly due to their increased surface area for the chemical reaction. Even with intensive grinding they can use up to 50 % less energy to fabricate than ordinary Portland cements.

3 – 3 - Non - Portland hydraulic cements :

Pozzolan - lime cements. Mixtures of ground pozzolan and lime are the cements used by the Romans, and can be found in Roman structures still standing (e.g. the Pantheon in Rome). They develop strength slowly, but their ultimate strength can be very high. The hydration products that produce strength are essentially the same as those produced by Portland cement.

Slag - lime cements. Ground granulated blast furnace slag is not hydraulic on its own, but is "activated" by addition of alkalis, most economically using lime. They are similar to pozzolan lime cements in their properties. Only granulated slag (i.e. water-quenched, glassy slag) is effective as a cement component.

Super sulfated cements . These contain about 80 % ground granulated blast furnace slag, 15 % gypsum or anhydrite and a little Portland clinker or lime as an activator. They produce strength by formation of ettringite, with strength growth similar to a slow Portland cement. They exhibit good resistance to aggressive agents, including sulfate.

Calcium aluminate cements are hydraulic cements made primarily from lime stone and bauxite. The active ingredients are mono calcium aluminate $CaAl_2O_4$ ($CaO \cdot Al_2O_3$ or CA in Cement chemist notation, CCN) and mayenite $Ca_{12}Al_{14}O_{33}$ ($12\ CaO \cdot 7\ Al_2O_3$, or $C_{12}A_7$ in CCN). Strength forms by hydration to calcium aluminate hydrates. They are well-adapted for use in refractory (high-temperature resistant) concretes, e.g. for furnace linings.

Calcium sulfo aluminate cements are made from clinkers that include ye'elimite ($Ca_4(AlO_2)_6SO_4$ or $C_4A_3\bar{S}$ in Cement chemist's notation) as a primary phase. They are used in expansive cements, in ultra-high early strength cements, and in "low-energy" cements. Hydration produces ettringite, and specialized physical properties (such as expansion or rapid reaction) are obtained by adjustment of the availability of calcium and sulfate ions. Their use as a low-energy alternative to Portland cement has been pioneered in China, where several million tones per year are produced . Energy requirements are lower because of the lower kiln temperatures required for reaction, and the lower amount of limestone (which must be endo thermically de carbonated) in the mix. In addition, the lower limestone content and lower fuel consumption leads to a CO_2 emission around half that associated with Portland clinker. However, SO_2 emissions are usually significantly higher.

"Natural" cements correspond to certain cements of the pre-Portland era, produced by burning argillaceous lime stones at moderate temperatures. The level of clay components in the limestone (around 30 – 35 %) is such that large amounts of belite (the low - early strength, high-late strength mineral in Portland cement) are formed without the formation of excessive amounts of free lime. As with any natural material, such cements have highly variable properties.

Geo polymer cements are made from mixtures of water-soluble alkali metal silicates and alumino silicate mineral powders such as fly ash and meta kaolin.

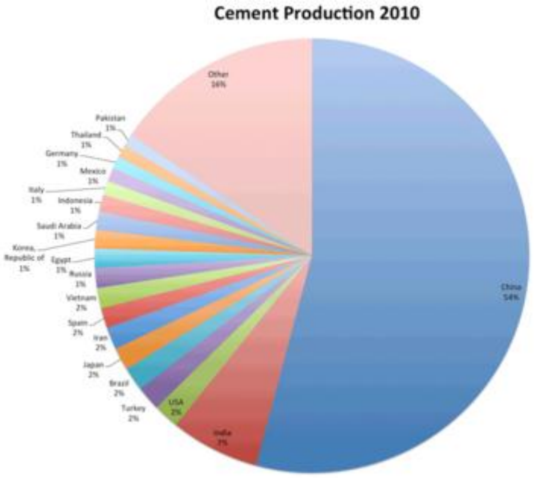
4 - Curing (Setting) :

Cement sets or cures when mixed with water which causes a series of hydration chemical reactions. The constituents slowly hydrate and crystallize; the interlocking of the crystals gives cement its strength. Maintaining a high moisture content in cement during curing increases both the speed of curing, and its final strength. Gypsum is often added to Portland cement to prevent early hardening or "flash setting", allowing a longer working time. The time it takes for cement to cure varies depending on the mixture and environmental conditions; initial hardening can occur in as little as twenty minutes, while full cure can take over a month. Cement typically cures to the extent that it can be put into service within 24 hours to a week.

5 - Safety issues :

Bags of cement routinely have health and safety warnings printed on them because not only is cement highly alkaline, but the setting process is exothermic. As a result, wet cement is strongly caustic and can easily cause severe skin burns if not promptly washed off with water. Similarly, dry cement powder in contact with mucous membranes can cause severe eye or respiratory irritation. Cement users should wear protective clothing .

6 - Cement industry in the world :



Global Cement Production in 2010

Cement output in 2004

In 2010 the world production of hydraulic cement was 3,300 million tones. The top three producers were China with 1,800, India with 220 and USA with 63.5 million tones for a combined total of over half the world total by the world's three most populated states.

For the world capacity to produce cement in 2010 the situation was similar with the top three states (China, India and USA) accounting for just under half the world total capacity.

6 – 1 - China :

"For the past 18 years, China consistently has produced more cement than any other country in the world. [...] (How ever,) China's cement export peaked in 1994 with 11 million tonnes shipped out and has been in steady decline ever since. Only 5.18 million tonnes were exported out of China in 2002. Offered at $34 a ton, Chinese cement is pricing itself out of the market as Thailand is asking as little as $20 for the same quality " ,

In 2006 it was estimated that China manufactured 1.235 billion tonnes of cement, which was 44 % of the world total cement production . "Demand for cement in China is expected to advance 5.4 % annually and exceed 1 billion tones in 2008, driven by slowing but healthy growth in construction expenditures. Cement consumed in China will amount to 44 % of global demand, and China will remain the world's largest national consumer of cement by a large margin."

In 2010, 3.3 billion tones of cement was consumed globally. Of this, China accounted for 1.8 billion tones .

6 – 2 - Africa :

7 - Environmental impacts :

Cement manufacture causes environmental impacts at all stages of the process. These include emissions of airborne pollution in the form of dust, gases, noise and vibration when operating machinery and during blasting in quarries, and damage to countryside from quarrying. Equipment to reduce dust emissions during quarrying and manufacture of cement is widely used, and equipment to trap and separate exhaust gases are coming into increased use. Environmental protection also includes the re - integration of quarries into the countryside after they have been closed down by returning them to nature or re-cultivating them.

7 – 1 - CO_2 Emissions :

Cement manufacturing releases CO_2 in the atmosphere both directly when calcium carbonate is heated, producing lime and carbon dioxide , and also indirectly through the use of energy if its production involves the emission of CO_2. The cement industry produces about 5 % of global man - made CO_2 emissions, of which 50 % is from the chemical process, and 40 % from burning fuel . The amount of CO_2 emitted by the cement industry is nearly 900 kg of CO_2 for every 1000 kg of cement produced . The high proportion of carbon dioxide produced in the chemical reaction leads to large decrease in mass in the conversion from limestone to cement. So, to reduce the transport of heavier raw materials and to mimimize the associated costs, it is more economical for cement plants to be closer to the limestone quarries rather than to the consumer centers .

In certain applications , lime mortar , reabsorbs the same amount of CO_2 as was released in its manufacture, and has a lower energy requirement in production than mainstream cement. Newly developed cement types from Novacem and Eco - cement can absorb carbon dioxide from ambient air during hardening . Use of the Kalina cycle during production can also increase energy efficiency.

7 – 2 - Heavy metal emissions in the air :

In some circumstances, mainly depending on the origin and the composition of the raw materials used , the high - temperature calcination process of limestone and clay minerals can release in the atmosphere gases and dust rich in volatile heavy metals, a.o, thallium, cadmium and mercury are the most toxic. Heavy metals (Tl, Cd, Hg, ...) are often found as trace elements in common metal sulfides (pyrite (FeS_2) , zinc blende (ZnS) , galena (PbS), ...) present as secondary minerals in most of the raw materials. Environmental regulations exist in many countries to limit these emissions. As of 2011 in the United States, cement kilns are "legally allowed to pump more toxins into the air than are hazardous - waste incinerators " .

7 – 3 - Heavy metals present in the clinker :

The presence of heavy metals in the clinker arises both from the natural raw materials and from the use of recycled by - products or alternative fuels. The high pH prevailing in the cement porewater ($12.5 < pH < 13.5$) limits the mobility of many heavy metals by decreasing their solubility and increasing their sorption onto the cement mineral phases. Nickel , zinc and lead are commonly found in cement in non - negligible concentrations.

7 – 4 - Use of alternative fuels and by - products materials :

A cement plant consumes 3 to 6 GJ of fuel per tonne of clinker produced, depending on the raw materials and the process used. Most cement kilns today use coal and petroleum coke as primary fuels, and to a lesser extent natural gas and fuel oil. Selected waste and by-products with recoverable calorific value can be used as fuels in a cement kiln, replacing a portion of conventional fossil fuels, like coal, if they meet strict specifications. Selected waste and by - products containing useful minerals such as calcium, silica, alumina, and iron can be used as raw materials in the kiln, replacing raw materials such as clay, shale, and lime stone. Because some materials have both useful mineral content and recoverable calorific value, the distinction between alternative fuels and raw materials is not always clear. For example, sewage sludge has a low but significant calorific value, and burns to give ash containing minerals useful in the clinker matrix .

Cement Accelerator

Cement Accelerator is an admixture for the use in concrete, mortar, rendering or screeds. The addition of Cement Accelerator speeds the setting time and thus cure time starts earlier . This allows concrete to be placed in winter without the worry of frost damage .

Typical materials used for acceleration are $Ca\ (NO_3)_2$ and $NaNO_3$. $CaCl_2$ has been very popular, but due to its reinforcement corroding behaviour the use is not recommended any more and in many cases prohibited.

Cement Board

Cement board is composed of aggregated Portland cement with a glass-fiber mesh on the surfaces. This 5/16 inch (7.9 mm) thick cement board is designed as an underlayment for tile floors. These are 3 by 5 foot (91 by 152 cm) sheets

Contents

1 – Introduction :

A **cement board** is a combination of cement and reinforcing fibers formed into 4 foot by 8 foot sheets (or 3 foot by 5 foot sheets), 1/4 to 1/2 inch thick that are typically used as a tile backing board. Cement board can be nailed or screwed to wood or steel studs to create a substrate for vertical tile and attached horizontally to ply wood for tile floors, kitchen counters and backsplashes. It can be used on the exterior of buildings as a base for exterior plaster (stucco) systems and sometimes as the finish system itself.

Cement board adds impact resistance and strength to the wall surface as compared to water resistant gypsum boards. Cement board is also fabricated in thin sheets with polymer modified cements to allow bending for curved surfaces.

2 - Composition :

Cement boards are mainly cement bonded particle boards and cement fiber . Cement bonded particle boards have treated wood flakes as reinforcement, whereas in cement fiber boards have cellulose fiber , which is a plant extract as reinforcement. Cement acts as binder in both the cases. The fire resistance properties of cement bonded blue particle boards and cement fiber boards are the same. In terms of load - bearing capacity, cement - bonded particle boards have higher capacity than cement fiber boards. Cement particle boards can be manufactured from 6 mm to 40 mm thickness making it extremely suitable for high load bearing applications. These boards are made of a homogeneous mixture and hence are formed as single layer for any thickness. Cement fiber boards are more used in decorative applications and can be manufactured from 3 mm to 20 mm thickness. Fibre boards are made in layers of very thin thickness, making it extremely difficult to manufacture high thickness boards. Many manufacturers use additives like mica , aluminium stearate and cenospheres in order to achieve certain board qualities. Typical cement fiber board is made of approximately 40 - 60 % of cement, 20 - 30 % of fillers, 8 - 10 % of cellulose, 10 – 15 % of mica. Other additives like above mentioned aluminium stearate and PVA are normally used in quantities less than 1 % . Cenospheres are used only in low density boards with quantities between 10 – 15 % . The actual recipe depends on available raw materials and other local factors.

3 – Advantages :

As a tile backing board, cement board has better long-term performance than paper - faced gypsum core products because it will not mold, mildew or physically break down in the continued presence of moisture or leaks. Cement board is not actually waterproof, but it is highly resistant to absorbing moisture and has excellent drying properties. In areas continually exposed to water spray (i.e. showers) a waterproofing barrier is usually recommended behind the boards or as a trowel-applied product to the face of the boards behind the finish system.

4 - Disadvantages :

One major disadvantage of cement board is the weight per square foot. It is approximately twice that of gypsum board, making handling by one person difficult. Cutting of cement board must also be done with carbide-tipped tools and saw blades. Due to its hardness, pre-drilling of fasteners is often recommended. Finally, cement board is initially more expensive than water resistant gypsum board but may provide better long term value.

5 – Installation :

Cement board is hung with corrosion resistant screws or ring-shank nails. Cement board has very little movement under thermal stress, but the boards are usually installed with a slight gap at joints in shower pans, bathtubs, and each other. These joints are then filled with silicone sealant or the manufacturer's taping compounds before applying a finish. The filled joints are taped like conventional gypsum board, but with fiberglass tapes that provide additional water resistance. Combined with a water impermeable finish, cement board is a stable, durable backing board.

6 - Water resistance :

The category of construction material known as *cement board* includes both water resistant and waterproof board. Each has its own best use.

Typically water resistant cement board is composed of a treated gypsum core with a non organic fiber reinforced covering, either on one or both faces. This type of board requires fastidious sealing of all cut edges and penetrations to maintain the manufacturer's warranty for wet area installations. Gypsum core "cement" board panels are ideal for moist but not truly wet installations of tile and/or stone walls.

There is a class of cement board strictly constructed of a Portland cement based core with glass fiber matt reinforcing at both faces. This type board is truly waterproof. These panels can be immersed in water without any degradation (excluding freeze thaw cycles). These panels do not require the sealing of edges and penetrations to maintain their structural integrity. These Portland cement based products are smaller in size compared with the gypsum core based products. Typically they range in size from 30" x 48" to 36" x 60". They are, as one would expect, considerably heavier than the gypsum core type panels.

Portland cement based panels are ideal for truly wet locations like shower surrounds and for locations where a Portland cement based thin-set material is used for bonding tile and stone surfaces to a substrate. They are also ideal for floor tile and stone installations over a structural sub floor .

Category : Cement

A

AFm phase

Afwillite

Alite

Alkali–aggregate reaction

Alkali–carbonate reaction

Alkali–silica reaction

Joseph Aspdin

William Aspdin

B

Belite

Biogenic sulfide corrosion

Edmund Wright Brooks

Brucite

C

Calcium aluminate cements

Calcium aluminates

Calcium alumino ferrite

Calcium silicate hydrate

Cement board

Cement chemist notation

Cement kiln

Cement mill

Cementing equipment

Cenin cement

Clinker (cement)

Concrete degradation

Concrete sulfate attack

D

Dodeca calcium hepta - aluminate

E

Eco-cement

Eternit

Ettringite

F

Faux bois

Fiber cement
Fly ash
Friedel's salt
James Frost (cement maker)
G
Geopolymer cement
Geopolymer concrete
Geopolymers
Ground granulated blast-furnace slag
Grout
Grouting
H
Hydrogrossular
J
Jennite
K
Klein's Compound
L
Joseph - Louis Lambot
Loss on ignition
M
MagneLine
Magnesian attack
Mayenite
Meta kaolin
Monocalcium aluminate
Mortar (masonry)
N
Non-shrink grout
P
James Parker (cement maker)
Plasticizer
Portland cement
Pozzolan
Pozzolana
Pozzolanic reaction
Pulverised fly ash

Cement Chemist Notation

Contents

1 – Introduction :

Cement Chemist Notation (CCN) was developed to simplify the formulas cement chemists use on a daily basis. It is a "short hand" way of writing the chemical formula of oxides of calcium , silicon , and various metals .

2 - Abbreviations of oxides :

The main oxides present in cement (or in glass and ceramics) are abbreviated in the following way :

CCN	Actual Formula	Name
C	CaO	Calcium oxide, or lime
S	SiO_2	Silicon dioxide, or silica
A	Al_2O_3	Aluminium oxide , or alumina
F	Fe_2O_3	Iron oxide , or rust
T	TiO_2	Titanium dioxide , or titania
M	MgO	Magnesium oxide , or Periclase
K	K_2O	Potassium oxide
N	Na_2O	Sodium oxide
H	H_2O	Water
C	CO_2	Carbon dioxide

S	SO_3	Sulfur trioxide
P	P_2O_5	Phosphorus hemi-pentoxide

3 - Conversion of hydroxides in oxide and free water

For the sake of mass balance calculations, hydroxides present in hydrated phases found in hardened cement paste such as, in portlandite , Ca $(OH)_2$, must first be converted in oxide and water.

To better understand the conversion process of hydroxide anions in oxide and water, it is necessary to consider the auto protolysis of the hydroxyl anions; it implies a proton exchange between two OH^-, like in a classical acid - base reaction:

$$OH^- + OH^- \rightarrow O^{2-} + H_2O$$

$$\text{acid 1} + \text{base 2} \rightarrow \text{base 1} + \text{acid 2}$$

or also,

$$2\ OH^- \rightarrow O^{2-} + H_2O$$

For portlandite this gives thus the following mass balance:

$$Ca\ (OH)_2 \rightarrow Ca\ O + H_2\ O$$

Thus portandite can be written as Ca O • H_2O or CH.

4 - Main phases in Portland cement before and after hydration :

These oxides are used to build more complex compounds. The main crystalline phases described hereafter are related respectively to the composition of:

- Clinker and non-hydrated Portland cement, and;
- Hardened cement pastes obtained after hydration and cement setting.

4 – 1 - Clinker and non-hydrated Portland cement :

Four main phases are present in the clinker and in the non-hydrated Portland cement.

They are formed at high temperature (1 450 °C) in the cement kiln and are the following :

CCN	Actual Formula	Name	Mineral Phase
C_3S	$3\ Ca\ O \bullet SiO_2$	Tri calcium silicate	Alite
C_2S	$2\ Ca\ O \bullet SiO_2$	Di calcium silicate	Belite
C_3A	$3\ Ca\ O \bullet Al_2O_3$	Tri calcium aluminate	Aluminate or Celite
C_4AF	$4\ Ca\ O \bullet Al_2O_3 \bullet Fe_2O_3$	Tetra calcium alumino ferrite	Ferrite

The four compounds referred as C_3S, C_2S, C_3A and C_4AF are known as the main crystalline phases of Portland cement. The phase composition of a particular cement can be quantified through a complex set of calculation known as the Bogue Formula.

4 – 2 - Hydrated cement paste :

Hydration products formed in hardened cement pastes (HCP) are more complicated, because many of these products have nearly the same formula and some are solid - solutions with overlapping formula. Some examples are given below:

CCN	Actual Formula	Name or Mineral Phase
CH	$Ca\ (OH)_2$ or $Ca\ O \bullet H_2O$	Calcium hydroxide
C-S-H	$2(Ca\ O) \bullet SiO_2 \bullet 0.9\text{-}1.25(H_2O)$, and / or ; $Ca\ O \bullet SiO_2 \bullet 1.1(H_2O)$, and / or ; $0.8\text{-}1.5(Ca\ O) \bullet SiO_2 \bullet 1.0\text{-}.5(H_2O)$	Calcium Silicate Hydrate
C-A-H	This is even more complex than C-S-H	Calcium Aluminate Hydrate

A Ft	$C_3 AS_3H_{30-32}$	Aluminate Ferrite tri sulfate , or ettringite
AFm	C_2ASH_{12}	Aluminate Ferrite mono sulfate
C_3AH_6	$3CaO \bullet Al_2O_3 \bullet 6H_2O$	Hydrogarnet

The hyphens in C-S-H indicate a calcium silicate hydrate phase of variable composition, whilst CSH indicates a calcium silicate phase CaH_2SiO_4.

5 - Use in ceramics , glass , and oxide chemistry :

The cement chemist notation is not restricted to cement applications but is in fact a more general notation of oxide chemistry applicable to other domains than cement chemistry *sensu stricto*.

For instance, in ceramics applications, the kaolinite formula can also be written in terms of oxides , thus the corresponding formula for kaolinite,

$Al_2Si_2O_5(OH)_4$, is : $Al_2O_3 \bullet 2SiO_2 \bullet 2H_2O$
or in CCN : AS_2H_2.

6 - Possible use of CCN in mineralogy :

Although not a very developed practice in mineralogy, some chemical reactions involving silicate and oxide in the melt or in hydrothermal systems, and silicate weathering processes could also be successfully described by applying the cement chemist notation to silicate mineralogy.

An example could be the formal comparison of belite hydration and forsterite serpentinisation dealing both with the hydration of two structurally similar earth - alkaline silicates , Ca_2SiO_4 and Mg_2SiO_4, respectively.

Calcium system : belite hydration :

Belite + water → C-S-H phase + portlandite

$$2\ Ca_2SiO_4 + 4\ H_2O \rightarrow 3\ CaO \cdot 2\ SiO_2 \cdot 3\ H_2O + Ca(OH)_2$$

$$2\ C_2S + 4\ H \rightarrow C_3S_2H_3 + CH$$

Magnesium system: forsterite serpentinisation:

Forsterite + water → serpentine + brucite

$$2\ Mg_2SiO_4 + 3\ H_2O \rightarrow Mg_3Si_2O_5(OH)_4 + Mg(OH)_2$$

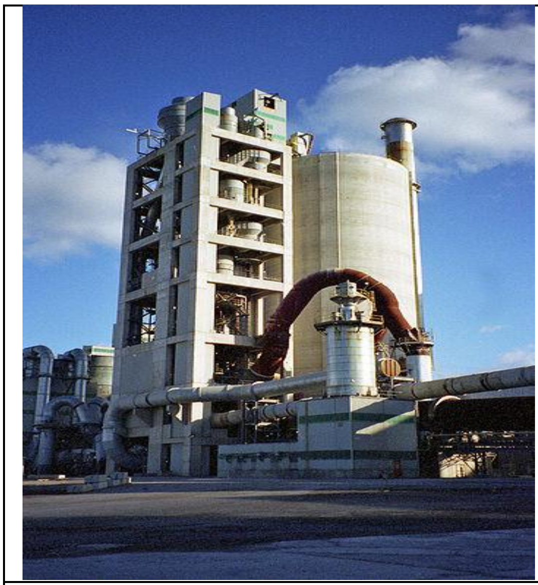
$$2\ M_2S + 3\ H \rightarrow M_3S_2H_2 + MH$$

The ratio Ca / Si (C / S) and Mg / Si (M / S) decrease from 2 for the di - calcium and di-magnesium silicate reagents to 1.5 for the hydrated silicate products of the hydration reaction. In other term, the C-S-H or the serpentine are less rich in Ca and Mg respectively. This is why the reaction leads to the elimination of the excess of portlandite (Ca $(OH)_2$) and brucite (Mg $(OH)_2$), respectively, out of the silicate system, giving rise to the crystallization of both hydroxides as separate phases.

The rapid reaction of belite hydration in the setting of cement is formally "chemically analogue" to the slow natural hydration of forsterite (the magnesium end-member of olivine) leading to the formation of serpentine and brucite in nature. However, the kinetic of hydration of poorly crystallized artificial belite is much swifter than the slow conversion/weathering of well crystallized Mg - olivine under natural conditions.

This comparison suggests that mineralogists could probably also benefit from the concise formalism of the cement chemist notation in their works.

Cement Kiln

	
A pre heater tower, raw mix silo and exhaust stack. Bottom left: raw mill. Bottom right: rotary kiln with tertiary air duct above. The U-shaped duct leading from the kiln inlet is an "alkali bleed".	*Hot end of medium sized modern cement kiln, showing tyres, rollers and drive gear*

Contents

1 – Introduction :

Cement kilns are used for the pyro processing stage of manufacture of Portland and other types of hydraulic cement, in which calcium carbonate reacts with silica - bearing minerals to form a mixture of calcium silicates. Over a billion tones of cement are made per year, and cement kilns are the heart of this production process: their capacity usually define the capacity of the cement plant. As the main energy - consuming and greenhouse - gas – emitting stage of cement manufacture, improvement of kiln efficiency has been the central concern of cement manufacturing technology.

2 - The manufacture of cement clinker :

A typical process of manufacture consists of three stages:

- grinding a mixture of limestone and clay or shale to make a fine "raw mix" (see Raw mill) ;
- heating the raw mix to sintering temperature (up to 1450 °C) in a cement kiln;

- grinding the resulting clinker to make cement (see Cement mill).

In the second stage, the raw mix is fed into the kiln and gradually heated by contact with the hot gases from combustion of the kiln fuel. Successive chemical reactions take place as the temperature of the raw mix rises:

- 70 to 110 °C - Free water is evaporated.
- 400 to 600 °C – clay - like minerals are decomposed into their constituent oxides; principally SiO_2 and Al_2O_3. Dolomite ($CaMg(CO_3)_2$) decomposes to calcium carbonate, MgO and CO_2.
- 650 to 900 °C - calcium carbonate reacts with SiO_2 to form belite (Ca_2SiO_4) .
- 900 to 1050 °C - the remaining calcium carbonate decomposes to calcium oxide and CO_2.
- 1300 to 1450 °C - partial (20–30%) melting takes place, and belite reacts with calcium oxide to form alite ($Ca_3O \cdot SiO_4$) .

Typical clinker nodules

Alite is the characteristic constituent of Portland cement. Typically , a peak temperature of 1400 –1450 °C is required to complete the reaction. The partial melting causes the material to aggregate into lumps or nodules , typically of diameter 1–10 mm . This is called clinker. The hot clinker next falls into a cooler which recovers most of its heat, and cools the clinker to around 100 °C, at which temperature it can be conveniently conveyed to storage. The cement kiln system is designed to accomplish these processes .

3 - Early history ;

Portland cement clinker was first made (in 1824) in a modified form of the traditional static lime kiln . The basic, egg-cup shaped lime kiln was provided with a conical or beehive shaped extension to increase draught and thus obtain the higher temperature needed to make cement clinker. For nearly half a century, this design, and minor modifications, remained the only method of manufacture. The kiln was restricted in size by the strength of the chunks of rawmix: if the charge in the kiln collapsed under its own weight, the kiln would be extinguished. For this reason, beehive kilns never made more than 30 tonnes of clinker per batch. A batch took one week to turn around: a day to fill the kiln, three days to burn off, two days to cool, and a day to unload. Thus, a kiln would produce about 1500 tonnes per year.

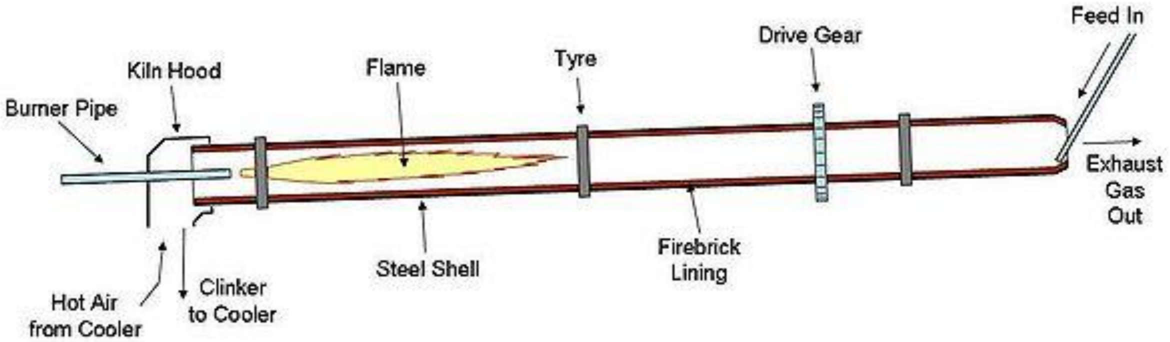
A kiln is basically an industrial oven, and although the term is generic, several quite distinctive designs have been used over the years. Although perhaps more normally associated with pottery making, both ‘Bottle’ and their very close relatives ‘Beehive’ kilns, were also the central feature of any cement works. Early designs tended to be updraft kilns, which were often built as a straight sided cone into which the flame was introduced at, or below, floor level. Reaching heights of up to 70 ft, the dome or bottle shape of the kiln, known as the ‘hovel’, would be quite a prominent landmark. As well as protecting the inner kiln or ‘crown’, the opening at the top of the hovel also acted as a flue, to remove the smoke and exhaust gases that were produced during the production process. There was a three to four foot gap between the outer wall of the hovel and inner shell of the crown. Due to the fact that the 1- foot - thick (0.30 m) crown wall would expand and contract during firing, it was strengthened with a number of iron bands, known as ‘bonts’. These were set twelve inches apart and ran right around the circular oven. The development of downdraft kilns in the early 20th Century proved to be much more fuel efficient and were designed to force the heated air to circulate more around the kiln. The design incorporated a gentle curve at the 'shoulders' of the kiln, which served to reflect the rising heat from the fire at the bottom of the kiln, back down again over the material. The smoke and exhaust was then sucked out through holes at the bottom of the kiln via a flue, which was connected to a nearby chimney. The chimney would also serve a number of neighboring kilns as well. The kiln would be fired for several days to achieve the high temperatures required to produce cement clinker, and although the above methods were successful, the problem with any batch kiln was that it was intermittent and once the product had been produced, the fire had to be extinguished and the contents allowed to cool. This not only wasted a lot of the heat, but also added to the expense of the finished product.

In order to save money on fuel, a kiln was required that could run almost continuously, whilst the raw material was somehow fed through it. It was this scenario that lead to the development of the ‘Chamber’ kiln in the late 1850s. This particular kiln comprised a number of individual chambers, which were arranged so that the hot flue gases from one chamber, were drawn off and used to pre-heat the material in the following chambers, before they were drawn up the chimney. Once the first chamber had been filled with raw material, coal was added through the roof holes of the chamber and was then set alight. At the same time, the second chamber was being filled with raw material. The airflow from the first chamber was then adjusted, using a number of dampers, to funnel the hot air through to the second chamber to pre-heat the material. More coal was then poured into the second chamber and ignited, as the third chamber was being filled and so on. This process continued along the length of the kiln, so that by the time the last chamber had been fired, the first chamber had already been cleared and re-filled with more raw material so that the process could start again. Although such chamber kilns were still being installed as late as 1900, the development of the rotary kiln was already starting to have a major impact. The rotary kiln was a major advancement for the industry as it provided the continuous production of a much more uniform product in larger quantities.

Around 1885, experiments began on design of continuous kilns. One design was the shaft kiln, similar in design to a blast furnace. Raw mix in the form of lumps and fuel were continuously added at the top, and clinker was continually withdrawn at the bottom. Air was blown through under pressure from the base to combust the fuel. The shaft kiln had a brief period of use before it was eclipsed by the rotary kiln, but it had a limited renaissance from 1970 onward in China and elsewhere, when it was used for small – scale , low - tech plants in rural areas away from transport routes. Several thousand such kilns were constructed in China. A typical shaft kiln produces 100-200 tones per day.

From 1885, trials began on the development of the rotary kiln, which today accounts for more than 95 % of world production.

4 - The rotary kiln :

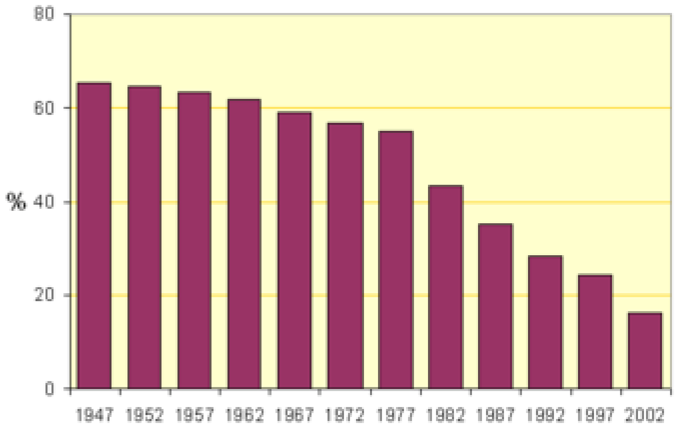


General layout of a rotary kiln

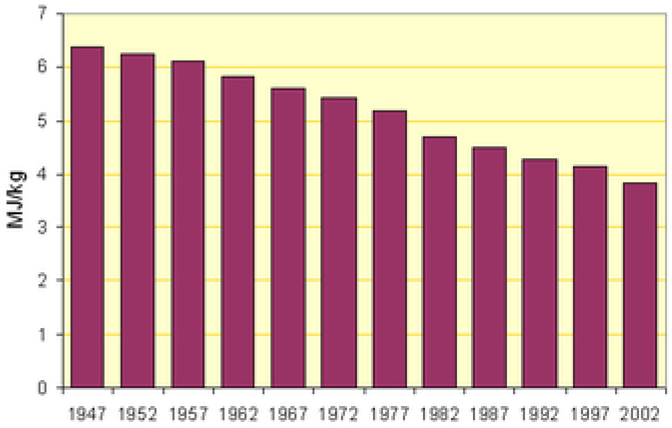
The rotary kiln consists of a tube made from steel plate, and lined with fire brick. The tube slopes slightly (1– 4°) and slowly rotates on its axis at between 30 and 250 revolutions per hour. Rawmix is fed in at the upper end, and the rotation of the kiln causes it gradually to move downhill to the other end of the kiln. At the other end fuel, in the form of gas, oil, or pulverized solid fuel, is blown in through the "burner pipe", producing a large concentric flame in the lower part of the kiln tube. As material moves under the flame, it reaches its peak temperature, before dropping out of the kiln tube into the cooler. Air is drawn first through the cooler and then through the kiln for combustion of the fuel. In the cooler the air is heated by the cooling clinker, so that it may be 400 to 800 °C before it enters the kiln, thus causing intense and rapid combustion of the fuel.

The earliest successful rotary kilns were developed in Pennsylvania around 1890, and were about 1.5 m in diameter and 15 m in length. Such a kiln made about 20 tonnes of clinker per day. The fuel, initially, was oil, which was readily available in Pennsylvania at the time. It was particularly easy to get a good flame with this fuel. Within the next 10 years, the technique of firing by blowing in pulverized coal was developed, allowing the use of the cheapest available fuel. By 1905, the largest kilns were 2.7 x 60 m in size, and made 190 tonnes per day. At that date, after only 15 years of development, rotary kilns accounted for half of world production. Since then, the capacity of kilns has increased steadily, and the largest kilns today produce around 10,000 tones per day. In contrast to static kilns, the material passes through quickly: it takes from 3 hours (in some old wet process kilns) to as little as 10 minutes (in short precalciner kilns). Rotary kilns run 24 hours a day, and are typically stopped only for a few days once or twice a year for essential maintenance. This is an important discipline, because heating up and cooling down are long, wasteful and damaging processes. Uninterrupted runs as long as 18 months have been achieved.

5 - The wet process and the dry process :



% of North American Capacity using Wet Process



Mean Fuel Energy used in North American Kilns

From the earliest times, two different methods of rawmix preparation were used: the mineral components were either dry-ground to form a flour-like powder, or were wet-ground with added water to produce a fine slurry with the consistency of paint, and with a typical water content of 40 – 45 % .

The wet process suffered the obvious disadvantage that, when the slurry was introduced into the kiln, a large amount of extra fuel was used in evaporating the water. Furthermore, a larger kiln was needed for a given clinker output, because much of the kiln's length was used up for the drying process. On the other hand, the wet process had a number of advantages. Wet grinding of hard minerals is usually much more efficient than dry grinding. When slurry is dried in the kiln, it forms a granular crumble that is ideal for subsequent heating in the kiln. In the dry process, it is very difficult to keep the fine powder rawmix in the kiln, because the fast - flowing combustion gases tend to blow it back out again. It became a practice to spray water into dry kilns in order to "damp down" the dry mix, and thus, for many years there was little difference in efficiency between the two processes, and the overwhelming majority of kilns used the wet process. By 1950, a typical large, wet process kiln, fitted with drying-zone heat exchangers, was 3.3 x 120 m in size, made 680 tonnes per day, and used about 0.25 – 0.30 tones of coal fuel for every tonne of clinker produced. Before the energy crisis of the 1970s put an end to new wet - process installations, kilns as large as 5.8 x 225 m in size were making 3000 tones per day.

An interesting footnote on the wet process history is that some manufacturers have in fact made very old wet process facilities profitable through the use of waste fuels. Plants that burn waste fuels enjoy a negative fuel cost (they are paid by industries needing to dispose of materials that have energy content and can be safely disposed of in the cement kiln thanks to its high temperatures and longer retention times) . As a result the inefficiency of the wet process is an advantage — to the manufacturer. By locating waste burning operations at older wet process locations, higher fuel consumption actually equates to higher profits for the manufacturer, although it produces correspondingly greater emission of CO_2. Manufacturers who think such emissions should be reduced are abandoning the use of wet process .

6 - Pre heaters :

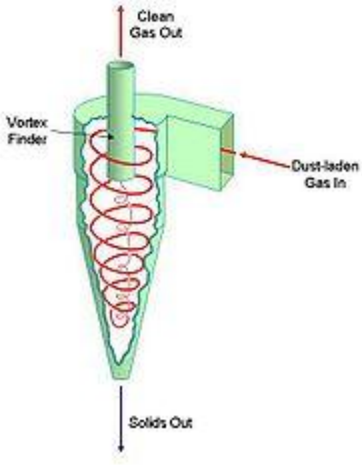
In the 1930s, significantly, in Germany, the first attempts were made to redesign the kiln system to minimize waste of fuel[5]. This led to two significant developments:

- the grate pre heater
- the gas- suspension pre heater.

6 – 1 - Grate pre heaters :

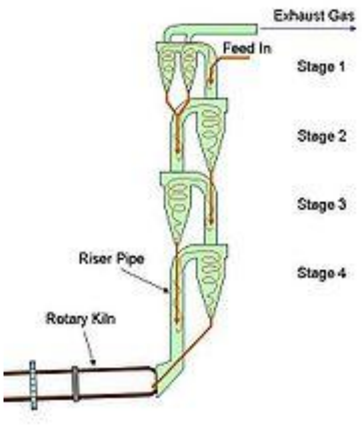
The grate pre heater consists of a chamber containing a chain-like high-temperature steel moving grate, attached to the cold end of the rotary kiln . A dry - powder raw mix is turned into a hard pellets of 10 – 20 mm diameter in a nodulizing pan , with the addition of 10 - 15 % water. The pellets are loaded onto the moving grate, and the hot combustion gases from the rear of the kiln are passed through the bed of pellets from beneath. This dries and partially calcines the rawmix very efficiently. The pellets then drop into the kiln. Very little powdery material is blown out of the kiln. Because the rawmix is damped in order to make pellets, this is referred to as a "semi-dry" process. The grate pre heater is also applicable to the "semi-wet" process, in which the raw mix is made as a slurry, which is first de-watered with a high - pressure filter, and the resulting "filter-cake" is extruded into pellets, which are fed to the grate. In this case, the water content of the pellets is 17 - 20 %. Grate pre heaters were most popular in the 1950s and 60s, when a typical system would have a grate 28 m long and 4 m wide, and a rotary kiln of 3.9 x 60 m, making 1050 tones per day, using about 0.11-0.13 tones of coal fuel for every tone of clinker produced. Systems up to 3000 tones per day were installed.

6 – 2 - Gas - suspension pre heaters :



Cutaway view of cyclone showing air path

The key component of the gas-suspension pre heater is the cyclone. A cyclone is a conical vessel into which a dust-bearing gas-stream is passed tangentially. This produces a vortex within the vessel. The gas leaves the vessel through a co-axial "vortex-finder". The solids are thrown to the outside edge of the vessel by centrifugal action, and leave through a valve in the vertex of the cone. Cyclones were originally used to clean up the dust - laden gases leaving simple dry process kilns. If, instead, the entire feed of raw mix is encouraged to pass through the cyclone, it is found that a very efficient heat exchange takes place: the gas is efficiently cooled, hence producing less waste of heat to the atmosphere, and the raw mix is efficiently heated. This efficiency is further increased if a number of cyclones are connected in series .

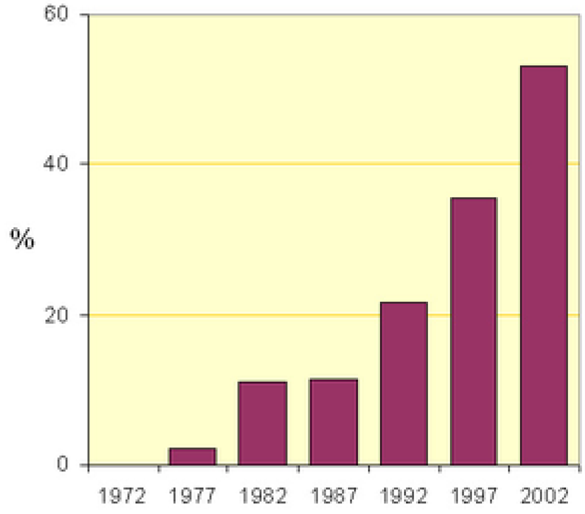


4 - Stage pre heater , showing path of feed

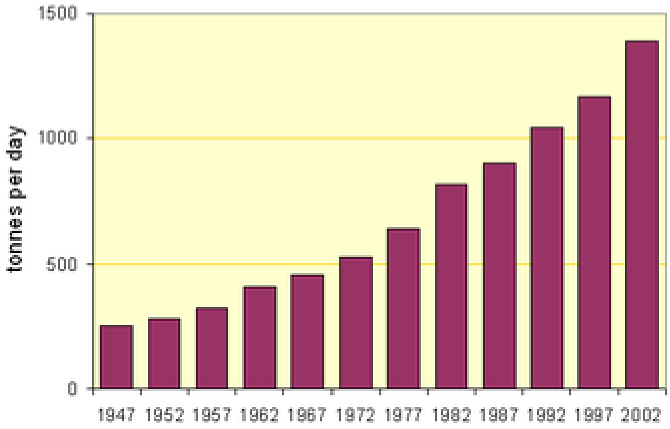
The number of cyclones stages used in practice varies from 1 to 6. Energy, in the form of fan - power, is required to draw the gases through the string of cyclones, and at a string of 6 cyclones, the cost of the added fan-power needed for an extra cyclone exceeds the efficiency advantage gained. It is normal to use the warm exhaust gas to dry the raw materials in the raw mill, and if the raw materials are wet, hot gas from a less efficient pre heater is desirable. For this reason, the most commonly encountered suspension preheaters have 4 cyclones. The hot feed that leaves the base of the preheater string is typically 20% calcined, so the kiln has less subsequent processing to do, and can therefore achieve a higher specific output. Typical large systems installed in the early 1970s had cyclones 6 m in diameter, a rotary kiln of 5 x 75 m, making 2500 tones per day, using about 0.11-0.12 tones of coal fuel for every tone of clinker produced.

A penalty paid for the efficiency of suspension pre heaters is their tendency to block up. Salts, such as the sulfate and chloride of sodium and potassium, tend to evaporate in the burning zone of the kiln. They are carried back in vapor form, and re-condense when a sufficiently low temperature is encountered. Because these salts re-circulate back into the raw mix and re - enter the burning zone, a recirculation cycle establishes itself. A kiln with 0.1% chloride in the rawmix and clinker may have 5% chloride in the mid-kiln material. Condensation usually occurs in the pre heater, and a sticky deposit of liquid salts glues dusty raw mix into a hard deposit, typically on surfaces against which the gas-flow is impacting. This can choke the pre heater to the point that air - flow can no longer be maintained in the kiln. It then becomes necessary to manually break the build - up away. Modern installations often have automatic devices installed at vulnerable points to knock out build-up regularly. An alternative approach is to "bleed off" some of the kiln exhaust at the kiln inlet where the salts are still in the vapor phase, and remove and discard the solids in this. This is usually termed an "alkali bleed" and it breaks the recirculation cycle. It can also be of advantage for cement quality reasons, since it reduces the alkali content of the clinker. However, hot gas is run to waste so the process is inefficient and increases kiln fuel consumption.

7 - Pre calciners



% of North American Capacity using Precalciners



Mean Daily Output (tones) of North American Kilns

In the 1970s the precalciner was pioneered in Japan, and has subsequently become the equipment of choice for new large installations world wide . The precalciner is a development of the suspension pre heater. The philosophy is this: the amount of fuel that can be burned in the kiln is directly related to the size of the kiln. If part of the fuel necessary to burn the raw mix is burned outside the kiln, the output of the system can be increased for a given kiln size. Users of suspension pre heaters found that output could be increased by injecting extra fuel into the base of the pre heater. The logical development was to install a specially designed combustion chamber at the base of the pre heater, into which pulverized coal is injected. This is referred to as an "air-through" precalciner, because the combustion air for both the kiln fuel and the calciner fuel all passes through the kiln. This kind of precalciner can burn up to 30% (typically 20%) of its fuel in the calciner. If more fuel were injected in the calciner, the extra amount of air drawn through the kiln would cool the kiln flame excessively. The feed is 40-60% calcined before it enters the rotary kiln.

The ultimate development is the "air - separate" precalciner, in which the hot combustion air for the calciner arrives in a duct directly from the cooler, bypassing the kiln. Typically , 60 - 75 % of the fuel is burned in the precalciner. In these systems, the feed entering the rotary kiln is 100 % calcined. The kiln has only to raise the feed to sintering temperature. In theory the maximum efficiency would be achieved if all the fuel were burned in the preheater, but the sintering operation involves partial melting and nodulization to make clinker, and the rolling action of the rotary kiln remains the most efficient way of doing this. Large modern installations typically have two parallel strings of 4 or 5 cyclones, with one attached to the kiln and the other attached to the precalciner chamber. A rotary kiln of 6 x 100 m makes 8,000–10,000 tones per day, using about 0.10-0.11 tonnes of coal fuel for every tone of clinker produced. The kiln is dwarfed by the massive pre heater tower and cooler in these installations. Such a kiln produces 3 million tones of clinker per year, and consumes 300,000 tones of coal. A diameter of 6 m appears to be the limit of size of rotary kilns, because the flexibility of the steel shell becomes unmanageable at or above this size, and the fire brick lining tends to fail when the kiln flexes.

A particular advantage of the air - separate precalciner is that a large proportion, or even 100 % , of the alkali - laden kiln exhaust gas can be taken off as alkali bleed (see above). Because this accounts for only 40 % of the system heat input, it can be done with lower heat wastage than in a simple suspension pre heater bleed. Because of this, air - separate precalciners are now always prescribed when only high-alkali raw materials are available at a cement plant.

The accompanying figures show the movement towards the use of the more efficient processes in North America (for which data is readily available). But the average output per kiln in, for example, Thailand is twice that in North America.

8 - Ancillary equipment :

Essential equipment in addition to the kiln tube and the pre heater are:

- Cooler
- Fuel mills
- Fans
- Exhaust gas cleaning equipment.

8 – 1 - Coolers :

A pair of kilns with satellite coolers in Ashaka, Nigeria Sysy

Early systems used rotary coolers, which were rotating cylinders similar to the kiln, into which the hot clinker dropped ' The combustion air was drawn up through the cooler as the clinker moved down, cascading through the air stream. In the 1920s, satellite coolers became common and remained in use until recently. These consist of a set (typically 7– 9) of tubes attached to the kiln tube. They have the advantage that they are sealed to the kiln, and require no separate drive. From about 1930, the grate cooler was developed. This consists of a perforated grate through which cold air is blown, enclosed in a rectangular chamber. A bed of clinker up to 0.5 m deep moves along the grate. These coolers have two main advantages: they cool the clinker rapidly, which is desirable from a quality point of view (to avoid that alite , thermodynamically unstable below 1250 °C, revert to belite and free Ca O on slow cooling), and, because they do not rotate, hot air can be ducted out of them for use in fuel drying, or for use as precalciner combustion air. The latter advantage means that they have become the only type used in modern systems.

8 – 2 - Fuel mills :

Fuel systems are divided into two categories :

- Direct firing
- Indirect firing

In direct firing, the fuel is fed at a controlled rate to the fuel mill, and the fine product is immediately blown into the kiln. The advantage of this system is that it is not necessary to store the hazardous ground fuel: it is used as soon as it is made. For this reason it was the system of choice for older kilns. A disadvantage is that the fuel mill has to run all the time: if it breaks down, the kiln has to stop if no backup system is available.

In indirect firing, the fuel is ground by an intermittently run mill, and the fine product is stored in a silo of sufficient size to supply the kiln though fuel mill stoppage periods. The fine fuel is metered out of the silo at a controlled rate and blown into the kiln. This method is now favoured for precalciner systems, because both the kiln and the precalciner can be fed with fuel from the same system. Special techniques are required to store the fine fuel safely, and coals with high volatiles are normally milled in an inert atmosphere (e.g. CO_2).

8 – 3 – Fans :

A large volume of gases has to be moved through the kiln system . Particularly in suspension pre heater systems a high degree of suction has to be developed at the exit of the system to drive this. Fans are also used to force air through the cooler bed, and to propel the fuel into the kiln. Fans account for most of the electric power consumed in the system, typically amounting to 10 – 15 k W · h per tone of clinker.

8 – 4 – Gas cleaning :

The exhaust gases from a modern kiln typically amount to 2 tones (or 1500 cubic meters at STP) per tone of clinker made . The gases carry a large amount of dust — typically 30 grams per cubic metre. Environmental regulations specific to different countries require that this be reduced to (typically) 0.1 gram per cubic metre, so dust capture needs to be at least 99.7 % efficient. Methods of capture include

[9 - Kiln fuels :

Fuels that have been used for primary firing include coal, petroleum coke, heavy fuel oil, natural gas, landfill off-gas and oil refinery flare gas[12]. High carbon fuels such as coal are preferred for kiln firing, because they yield a luminous flame. The clinker is brought to its peak temperature mainly by radiant heat transfer, and a bright (i.e. high emissivity) and hot flame is essential for this. In favorable circumstances, high - rank bituminous coal can produce a flame at 2050 °C. Natural gas can only produce a flame of, at best 1950 °C, and this is also less luminous, so it tends to result in lower kiln output.

Used tires being fed mid - kiln to a pair of long kilns

In addition to these primary fuels, various combustible waste materials have been fed to kilns, notably used tires, which are very difficult to dispose of by other means. In theory, cement kilns are an attractive way of disposing of hazardous materials, because of:

- the temperatures in the kiln, which are much higher than in other combustion systems (e.g. incinerators) ,
- the alkaline conditions in the kiln, afforded by the high - calcium raw mix, which can absorb acidic combustion products,
- the ability of the clinker to absorb heavy metals into its structure.

Whole tires are commonly introduced in the kiln, by rolling them into the upper end of a pre heater kiln, or by dropping them through a slot midway along a long wet kiln. In either case, the high gas temperatures (1000 – 1200 °C) cause almost instantaneous, complete and smokeless combustion of the tire. Alternatively, tires are chopped into 5 – 10 mm chips, in which form they can be injected into a precalciner combustion chamber. The steel and zinc in the tires become chemically incorporated into the clinker.

Other wastes have included solvents and clinical wastes. A very high level of monitoring of both the fuel and its combustion products is necessary to maintain safe operation.

For maximum kiln efficiency, high quality conventional fuels are the best choice. When using waste materials, in order to avoid prohibited emissions (e.g. of dioxins) it is necessary to control the kiln system in a manner that is non-optimal for efficiency and output, and coarse combustibles such as tires can cause major product quality problems.

10 - Kiln control :

Online X-ray diffraction with automatic sample feed for free calcium oxide measurement

The objective of kiln operation is to make clinker with the required chemical and physical properties, at the maximum rate that the size of kiln will allow, while meeting environmental standards, at the lowest possible operating cost . The kiln is very sensitive to control strategies, and a poorly run kiln can easily double cement plant operating costs[14].

Formation of the desired clinker minerals involves heating the rawmix through the temperature stages mentioned above. The finishing transformation that takes place in the hottest part of the kiln, under the flame, is the reaction of belite (Ca_2SiO_4) with calcium oxide to form alite ($Ca_3O{\cdot}SiO_4$):

$Ca_2SiO_4 + Ca\ O \rightarrow Ca_3SiO_5$

Also abbreviated in the cement chemist notation (CCN) as:

$C_2S + C \rightarrow C_3S$

Tri calcium silicate is thermodynamically unstable below 1250 °C, but can be preserved in a meta stable state at room temperature by fast cooling: on slow cooling it tends to revert to belite (Ca_2SiO_4) and CaO.

If the reaction is incomplete, excessive amounts of free calcium oxide remain in the clinker. Regular measurement of the free CaO content is used as a means of tracking the clinker quality. As a parameter in kiln control, free Ca O data is some what ineffective because, even with fast automated sampling and analysis, the data, when it arrives, may be 10 minutes "out of date", and more immediate data must be used for minute-to-minute control.

Conversion of belite to alite requires partial melting, the resulting liquid being the solvent in which the reaction takes place. The amount of liquid, and hence the speed of the finishing reaction, is related to temperature. To meet the clinker quality objective, the most obvious control is that the clinker should reach a peak temperature such that the finishing reaction takes place to the required degree. A further reason to maintain constant liquid formation in the hot end of the kiln is that the sintering material forms a dam that prevents the cooler upstream feed from flooding out of the kiln. The feed in the calcining zone, because it is a powder evolving carbon dioxide, is extremely fluid. Cooling of the burning zone, and loss of unburned material into the cooler, is called "flushing", and in addition to causing lost production can cause massive damage.

However, for efficient operation, steady conditions need to be maintained throughout the whole kiln system. The feed at each stage must be at a temperature such that it is "ready" for processing in the next stage. To ensure this, the temperature of both feed and gas must be optimized and maintained at every point. The external controls available to achieve this are few:

- Feed rate: this defines the kiln output
- Rotary kiln speed: this controls the rate at which the feed moves through the kiln tube
- Fuel injection rate: this controls the rate at which the "hot end" of the system is heated
- Exhaust fan speed or power: this controls gas flow, and the rate at which heat is drawn from the "hot end" of the system to the "cold end"

In the case of precalciner kilns, further controls are available:

- Independent control of fuel to kiln and calciner
- Independent fan controls where there are multiple pre heater strings.

The independent use of fan speed and fuel rate is constrained by the fact that there must always be sufficient oxygen available to burn the fuel, and in particular, to burn carbon to carbon dioxide. If carbon monoxide is formed, this represents a waste of fuel, and also indicates reducing conditions within the kiln which must be avoided at all costs since it causes destruction of the clinker mineral structure. For this reason, the exhaust gas is continually analyzed for O_2, CO, NO and SO_2.

The assessment of the clinker peak temperature has always been problematic. Contact temperature measurement is impossible because of the chemically aggressive and abrasive nature of the hot clinker, and optical methods such as infrared pyrometry are difficult because of the dust and fume-laden atmosphere in the burning zone. The traditional method of assessment was to view the bed of clinker and deduce the amount of liquid formation by experience. As more liquid forms, the clinker becomes stickier, and the bed of material climbs higher up the rising side of the kiln. It is usually also possible to assess the length of the zone of liquid formation, beyond which powdery "fresh" feed can be seen. Cameras, with or without infrared measurement capability, are mounted on the kiln hood to facilitate this. On many kilns, the same information can be inferred from the kiln motor power drawn, since sticky feed riding high on the kiln wall increases the eccentric turning load of the kiln. Further information can be obtained from the exhaust gas analyzers. The formation of NO from nitrogen and oxygen takes place only at high temperatures, and so the NO level gives an indication of the combined feed and flame temperature. SO_2 is formed by thermal decomposition of calcium sulfate in the clinker, and so also gives in indication of clinker temperature. Modern computer control systems usually make a "calculated" temperature, using contributions from all these information sources, and then set about controlling it.

As an exercise in process control, kiln control is extremely challenging, because of multiple inter-related variables, non-linear responses, and variable process lags. Computer control systems were first tried in the early 1960s, initially with poor results due mainly to poor process measurements. Since 1990, complex high level supervisory control systems have been standard on new installations. These operate using expert system strategies, that maintain a "just sufficient" burning zone temperature, below which the kiln's operating condition will deteriorate catastrophically, thus requiring rapid-response, "knife-edge" control.

11 - Cement kiln emissions :

Emissions from cement works are determined both by continuous and discontinuous measuring methods, which are described in corresponding national guidelines and standards. Continuous measurement is primarily used for dust , NO_x and SO_2, while the remaining parameters relevant pursuant to ambient pollution legislation are usually determined discontinuously by individual measurements.

The following descriptions of emissions refer to modern kiln plants based on dry process technology.

11 – 1 - Carbon dioxide :

During the clinker burning process CO_2 is emitted. CO_2 accounts for the main share of these gases. CO_2 emissions are both raw material-related and energy - related. Raw material-related emissions are produced during limestone de carbonation ($CaCO_3$) and account for about 60 % of total CO_2 emissions.

11 – 2 - Dust :

To manufacture 1 t of Portland cement, about 1.5 to 1.7 t raw materials, 0.1 t coal and 1 t clinker (besides other cement constituents and sulfate agents) must be ground to dust fineness during production. In this process, the steps of raw material processing, fuel preparation, clinker burning and cement grinding constitute major emission sources for particulate components. While particulate emissions of up to 3,000 mg/m^3 were measured leaving the stack of cement rotary kiln plants as recently as in the 1950s, legal limits are typically 30 mg/m^3 today, and much lower levels are achievable.

11 – 3 - Nitrogen oxides ($N O_x$) :

The clinker burning process is a high - temperature process resulting in the formation of nitrogen oxides ($N O_x$) . The amount formed is directly related to the main flame temperature (typically 1850 – 2000 °C) . Nitrogen monoxide (NO) accounts for about 95 %, and nitrogen dioxide (NO_2) for about 5 % of this compound present in the exhaust gas of rotary kiln plants. As most of the NO is converted to NO_2 in the atmosphere, emissions are given as NO_2 per cubic metre exhaust gas . With out reduction measures, process-related NO_x contents in the exhaust gas of rotary kiln plants would in most cases considerably exceed the specifications of e.g. European legislation for waste burning plants (0.50 g / m^3 for new plants and 0.80 g/m^3 for existing plants) . Reduction measures are aimed at smoothing and optimizing plant operation. Technically, staged combustion and Selective Non - Catalytic NO Reduction (SNCR) are applied to cope with the emission limit values.

High process temperatures are required to convert the raw material mix to Portland cement clinker. Kiln charge temperatures in the sintering zone of rotary kilns range at around 1450 °C. To reach these, flame temperatures of about 2000 °C are necessary. For reasons of clinker quality the burning process takes place under oxidising conditions, under which the partial oxidation of the molecular nitrogen in the combustion air resulting in the formation of nitrogen monoxide (NO) dominates. This reaction is also called thermal NO formation. At the lower temperatures prevailing in a precalciner, however, thermal NO formation is negligible: here, the nitrogen bound in the fuel can result in the formation of what is known as fuel-related NO. Staged combustion is used to reduce NO: calciner fuel is added with insufficient combustion air. This causes CO to form. The CO then reduces the NO into molecular nitrogen:

$$2\,CO + 2\,NO \rightarrow 2\,CO_2 + N_2.$$

Hot tertiary air is then added to oxidize the remaining CO.

11 – 4 - Sulfur dioxide (SO_2) :

Sulfur is input into the clinker burning process via raw materials and fuels. Depending on their origin, the raw materials may contain sulfur bound as sulfide or sulfate. Higher SO_2 emissions by rotary kiln systems in the cement industry are often attributable to the sulfides contained in the raw material, which become oxidised to form SO_2 at the temperatures between 370 °C and 420 °C prevailing in the kiln preheater. Most of the sulfides are pyrite or marcasite contained in the raw materials. Given the sulfide concentrations found e.g. in German raw material deposits, SO_2 emission concentrations can total up to 1.2 g/m^3 depending on the site location. In some cases, injected calcium hydroxide is used to lower SO_2 emissions.

The sulfur input with the fuels is completely converted to SO_2 during combustion in the rotary kiln. In the pre heater and the kiln, this SO_2 reacts to form alkali sulfates, which are bound in the clinker, provided that oxidizing conditions are maintained in the kiln.

5 - Carbon monoxide (CO) and total carbon :

The exhaust gas concentrations of CO and organically bound carbon are a yardstick for the burn - out rate of the fuels utilized in energy conversion plants, such as power stations. By contrast, the clinker burning process is a material conversion process that must always be operated with excess air for reasons of clinker quality. In concert with long residence times in the high - temperature range, this leads to complete fuel burn - up.

The emissions of CO and organically bound carbon during the clinker burning process are caused by the small quantities of organic constituents input via the natural raw materials (remnants of organisms and plants incorporated in the rock in the course of geological history) . These are converted during kiln feed preheating and become oxidized to form CO and CO_2. In this process, small portions of organic trace gases (total organic carbon) are formed as well. In case of the clinker burning process, the content of CO and organic trace gases in the clean gas therefore may not be directly related to combustion conditions.

11 – 6 - Dioxins and furans (PCDD / F) :

Rotary kilns of the cement industry and classic incineration plants mainly differ in terms of the combustion conditions prevailing during clinker burning . Kiln feed and rotary kiln exhaust gases are conveyed in counter - flow and mixed thoroughly. Thus, temperature distribution and residence time in rotary kilns afford particularly favour able conditions for organic compounds, introduced either via fuels or derived from them, to be completely destroyed. For that reason, only very low concentrations of polychlorinated di benzo – p - dioxins and di benzo furans (colloquially " dioxins and furans ") can be found in the exhaust gas from cement rotary kilns.

11 – 7 - Poly chlorinated biphenyls (PCB) :

The emission behaviour of PCB is comparable to that of dioxins and furans. PCB may be introduced into the process via alternative raw materials and fuels. The rotary kiln systems of the cement industry destroy these trace components virtually completely .

11 – 8 - Polycyclic aromatic hydrocarbons (PAH) :

PAHs (according to EPA 610) in the exhaust gas of rotary kilns usually appear at a distribution dominated by naphthalene, which accounts for a share of more than 90 % by mass. The rotary kiln systems of the cement industry destroy virtually completely the PAHs input via fuels. Emissions are generated from organic constituents in the raw material.

11 – 9 - Benzene , toluene , ethyl benzene , xylene (BTEX)

As a rule benzene , toluene , ethyl benzene and xylene are present in the exhaust gas of rotary kilns in a characteristic ratio. BTEX is formed during the thermal decomposition of organic raw material constituents in the pre heater.

11 – 10 - Gaseous inorganic chlorine compounds (H Cl) :

Chlorides are minor additional constituents contained in the raw materials and fuels of the clinker burning process. They are released when the fuels are burnt or the kiln feed is heated, and primarily react with the alkalis from the kiln feed to form alkali chlorides. These compounds, which are initially vaporous, condense on the kiln feed or the kiln dust, at temperatures between 700 °C and 900 °C, subsequently re-enter the rotary kiln system and evaporate again. This cycle in the area between the rotary kiln and the pre heater can result in coating formation. A bypass at the kiln inlet allows effective reduction of alkali chloride cycles and to diminish coating build-up problems. During the clinker burning process, gaseous inorganic chlorine compounds are either not emitted at all or in very small quantities only.

11 – 11 - Gaseous inorganic fluorine compounds (HF) :

Of the fluorine present in rotary kilns, 90 to 95 % is bound in the clinker, and the remainder is bound with dust in the form of calcium fluoride stable under the conditions of the burning process. Ultra-fine dust fractions that pass through the measuring gas filter may give the impression of low contents of gaseous fluorine compounds in rotary kiln systems of the cement industry.

11 – 12 - Trace elements :

The emission behaviour of the individual elements in the clinker burning process is determined by the input scenario, the behaviour in the plant and the precipitation efficiency of the dust collection device. The trace elements introduced into the burning process via the raw materials and fuels may evaporate completely or partially in the hot zones of the pre heater and/or rotary kiln depending on their volatility, react with the constituents present in the gas phase, and condense on the kiln feed in the cooler sections of the kiln system. Depending on the volatility and the operating conditions, this may result in the formation of cycles that are either restricted to the kiln and the preheater or include the combined drying and grinding plant as well. Trace elements from the fuels initially enter the combustion gases, but are emitted to an extremely small extent only owing to the retention capacity of the kiln and the pre heater.

Under the conditions prevailing in the clinker burning process, non-volatile elements (e.g. arsenic, vanadium, nickel) are completely bound in the clinker.

Elements such as lead and cadmium preferentially react with the excess chlorides and sulfates in the section between the rotary kiln and the pre heater, forming volatile compounds. Owing to the large surface area available, these compounds condense on the kiln feed particles at temperatures between 700 °C and 900 °C. In this way, the volatile elements accumulated in the kiln - pre heater system are precipitated again in the cyclone pre heater, remaining almost completely in the clinker.

Thallium (as the chloride) condenses in the upper zone of the cyclone pre heater at temperatures between 450 °C and 500 °C. As a consequence, a cycle can be formed between preheater, raw material drying and exhaust gas purification.

Mercury and its compounds are not precipitated in the kiln and the pre heater. They condense on the exhaust gas route due to the cooling of the gas and are partially adsorbed by the raw material particles. This portion is precipitated in the kiln exhaust gas filter.

Owing to trace element behaviour during the clinker burning process and the high precipitation efficiency of the dust collection devices trace element emission concentrations are on a low overall level.

Cement Mill

A 10 MW cement mill, output 270 tones per hour

Contents

1 – Introduction :

A **cement Mill** is the equipment used to grind the hard , nodular clinker from the cement kiln into the fine grey powder that is cement. Most cement is currently ground in ball mills.

2 - History :

Early hydraulic cements, such as those of James Parker, James Frost and Joseph Aspdin were relatively soft and readily ground by the primitive technology of the day, using flat millstones. The emergence of Portland cement in the 1840s made grinding considerably more difficult, because the clinker produced by the kiln is often as hard as the millstone material. Because of this, cement continued to be ground very coarsely (typically 20% over 100 µm particle diameter) until better grinding technology became available. Besides producing un-reactive cement with slow strength growth, this exacerbated the problem of unsoundness. This late, disruptive expansion is caused by hydration of large particles of calcium oxide. Fine grinding lessens this effect, and early cements had to be stored for several months to give the calcium oxide time to hydrate before it was fit for sale. From 1885 onward, the development of specialized steel led to the development of new forms of grinding equipment, and from this point onward, the typical fineness of cement began a steady rise. The progressive reduction in the proportion of larger, un-reactive cement particles has been partially responsible for the fourfold increase in the strength of Portland cement during the twentieth century. The recent history of the technology has been mainly concerned with reducing the energy consumption of the grinding process.

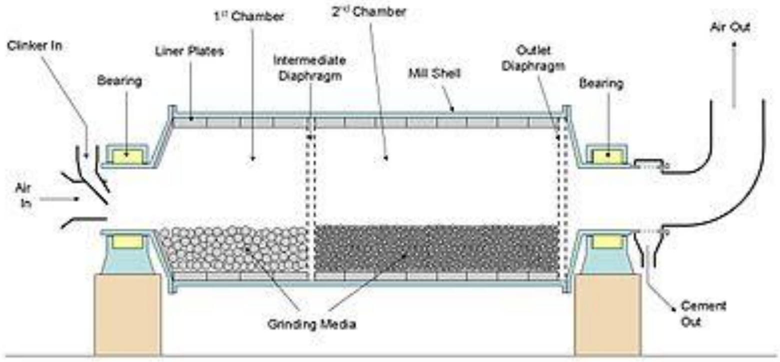
3 - Materials ground :

Portland clinker is the main constituent of most cements. In Portland cement, a little calcium sulfate (typically 3 - 10 %) is added in order to retard the hydration of tri calcium aluminate. The calcium sulfate may consist of natural gypsum, anhydrite , or synthetic wastes such as flue-gas desulfurization gypsum. In addition, up to 5% calcium carbonate and up to 1 % of other minerals may be added. It is normal to add a certain amount of water, and small quantities of organic grinding aids and performance enhancers. "Blended cements" and Masonry cements may include large additions (up to 40%) of natural pozzolans, fly ash, lime stone , silica fume or meta kaolin. Blast furnace slag cement may include up to 70 % ground granulated blast furnace slag . Gypsum and calcium carbonate are relatively soft minerals, and rapidly grind to ultra - fine particles. Grinding aids are typically chemicals added at a rate of 0.01 - 0.03 % that coat the newly formed surfaces of broken mineral particles and prevent re – agglomeration . They include 1,2-propanediol , acetic acid , tri ethanol amine and ligno sulfonates.

4 - Temperature control :

Heat generated in the grinding process causes gypsum ($CaSO_4.2H_2O$) to lose water, forming bassanite ($CaSO_4.0.2- 0.7H_2O$) or γ-anhydrite ($CaSO_4 . \sim 0.05H_2O$) . The latter minerals are rapidly soluble , and about 2 % of these in cement is needed to control tri calcium aluminate hydration. If more than this amount forms, crystallization of gypsum on their re - hydration causes "false set" - a sudden thickening of the cement mix a few minutes after mixing, which thins out on re-mixing. High milling temperature causes this. On the other hand, if milling temperature is too low, insufficient rapidly soluble sulfate is available and this causes "flash set" - an irreversible stiffening of the mix. Obtaining the optimum amount of rapidly soluble sulfate requires milling with a mill exit temperature within a few degrees of 115 °C. Where the milling system is too hot, some manufacturers use 2.5 % gypsum and the remaining calcium sulfate as natural α-anhydrite ($CaSO_4$) . Complete dehydration of this mixture yields the optimum 2 % γ - anhydrite. In the case of some efficient modern mills, insufficient heat is generated. This is corrected by re circulating part of the hot exhaust air to the mill inlet.

5 - Ball Mills :



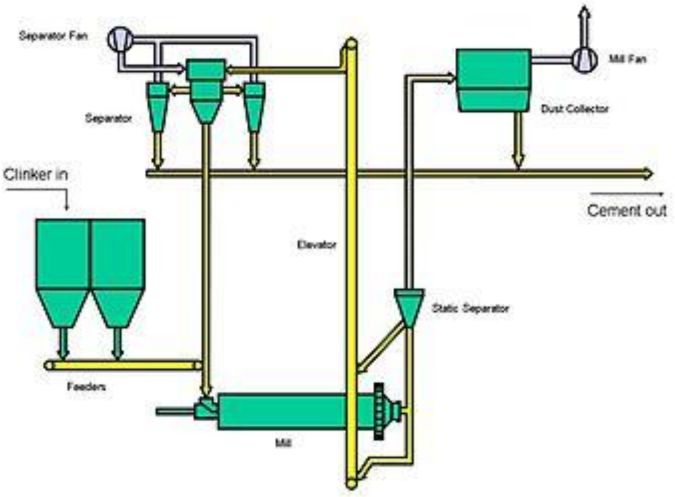
Ball Mill Layout

A ball mill is a horizontal cylinder partly filled with steel balls (or occasionally other shapes) that rotates on its axis, imparting a tumbling and cascading action to the balls. Material fed through the mill is crushed by impact and ground by attrition between the balls. The grinding media are usually made of high - chromium steel. The smaller grades are occasionally cylindrical ("pebs") rather than spherical. There exists a speed of rotation (the "critical speed") at which the contents of the mill would simply ride over the roof of the mill due to centrifugal action. The critical speed (rpm) is given by : $n_C = 42.29 / \sqrt{d}$, where d is the internal diameter in meters . Ball mills are normally operated at around 75% of critical speed, so a mill with diameter 5 metres will turn at around 14 rpm.

The mill is usually divided into at least two chambers , (Depends upon feed input size presently mill installed with Roller Press are mostly single chambered) , allowing the use of different sizes of grinding media. Large balls are used at the inlet, to crush clinker nodules (which can be over 25 mm in diameter). Ball diameter here is in the range 60–80 mm. In a two - chamber mill, the media in the second chamber are typically in the range 15 – 40 mm , although media down to 5 mm are sometimes encountered. As a general rule, the size of media has to match the size of material being ground: large media can't produce the ultra - fine particles required in the finished cement, but small media can't break large clinker particles. Mills with as many as four chambers, allowing a tight segregation of media sizes , were once used, but this is now becoming rare. Alternatives to multi - chamber mills are :

- pairs of mills , run in tandem, charged with different - sized media.
- use of alternative technology (see Roll - presses below) to crush the clinker prior to fine-grinding in a ball mill.

A current of air is passed through the mill. This helps keep the mill cool, and sweeps out evaporated moisture which would otherwise cause hydration and disrupt material flow . The dusty exhaust air is cleaned, usually with bag filters.

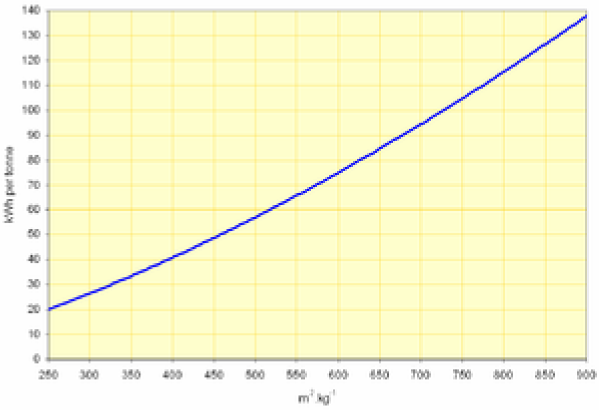


Typical mill / separator circuit

5 – 1 – Closed - circuit systems :

The efficiency of the early stages of grinding in a ball mill is much greater than that for formation of ultra - fine particles , so ball mills operate most efficiently by making a coarse product, the fine fractions of this then being separated, and the coarse part being returned to the mill inlet. The proportion of the mill - exit material returned to the inlet may vary from 10 - 30 % when ordinary cement is being ground, to 85- 95 % for extremely fine cement products. It is important for system efficiency that the minimum amount of material of finished-product fineness is returned to the inlet. Modern separators are capable of making a very precise size "cut" and contribute significantly to the reduction of energy consumption, and have the additional advantage that they cool both the product and the returned material, thus minimizing over heating.

Efficient closed - circuit systems, because of their tight particle size control, lead to cements with relatively narrow particle size distributions (i.e. for a given mean particle size, they have fewer large and small particles) . This is of advantage in that it maximizes the strength-production potential the clinker, because large particles are inert. As a rule of thumb, only the outer 7 μ m "skin" of each particle hydrates in concrete, so any particle over 14 μ m diameter always leaves an un - reacted core. However, the lack of ultra-fine particles can be a disadvantage . These particles normally pack the spaces between the larger particles in a cement paste, and if absent the deficit is made up with extra water, leading to lower strength. This can be remedied by including 5 % calcium carbonate in the cement: this soft mineral produces adequate ultra - fines on the first pass through the mill .



Typical mill power consumption for various degrees of fineness. Actual values vary according to mill system efficiency and clinker hardness.

5 – 2 – Clinker hardness :

The hardness of clinker is important for the energy cost of the grinding process. It depends both on the clinker's mineral composition and its thermal history. The easiest-ground clinker mineral is alite, so high-alite clinkers reduce grinding costs, although they are more expensive to make in the kiln. The toughest mineral is belite, because it is harder, and is somewhat plastic, so that crystals tend to flatten rather than shatter when impacted in the mill. The mode of burning of the clinker is also important. Clinker rapidly burned at the minimum temperature for combination, then rapidly cooled , contains small, defective crystals that grind easily. These crystals are usually also optimal for reactivity. On the other hand, long burning at excess temperature, and slow cooling, lead to large, well - formed crystals that are hard to grind and un - reactive. The effect of such a clinker can be to double milling costs.

6 - Roller mills :

These have been used for many years for the less exacting raw-milling process, but recently roller mills, in combination with high-efficiency separators, have been used for cement grinding. The grinding action employs much greater stress on the material than in a ball mill, and is therefore more efficient. Energy consumption is typically half that of a ball mill. How ever, the narrowness of the particle size distribution of the cement is problematic , and the process has yet to receive wide acceptance.

7 – High - pressure roll presses :

These consist of a pair of rollers set 8 – 30 mm apart and counter - rotating with surface speed around 0.9 - 1.8 $m.s^{-1}$. The bearings of the rollers are designed to deliver a pressure of 50 M Pa or more. The bed of material drawn between the rollers emerges as a slab-like agglomeration of highly fractured particles. The energy efficiency of this process is comparatively high. Systems have been designed, including a de - agglomerator and separator, that will deliver material of cement fineness. How ever, particle size distribution is again a problem, and roll presses are now increasingly popular as a "pre - grind" process, with the cement finished in a single chamber ball mill. This gives good cement performance, and reduces energy consumption by 20 – 40 % compared with a standard ball mill system.

8 - Capacity of cement mills :

The cement mills on a cement plant are usually sized for a clinker consumption considerably greater than the output of the plant's kilns. This is for two reasons:

- The mills are sized to cope with peaks in market demand for cement. In temperate countries, the summer demand for cement is usually much higher than that in winter. Excess clinker produced in winter goes into storage in readiness for summer demand peaks. For this reason, plants with highly seasonal demand usually have very large clinker stores.

- Cement milling is the largest user of electric power on a cement plant, and because they can easily be started and stopped, it often pays to operate cement mills only during "off-peak" periods when cheaper power is available. This is also favorable for electricity producers, who can negotiate power prices with major users in order to balance their generating capacity over 24 hours. More sophisticated arrangements such as "power shedding" are often employed. This consists of the cement manufacturer shutting down the plant at short notice when the power supplier expects a critical demand peak, in return for favorable prices. Clearly, plenty of excess cement milling capacity is needed in order to "catch up" after such interruptions.

9 - Control of product quality :

In addition to control of temperature (mentioned above) , the main requirement is to obtain a consistent fineness of the product. From the earliest times , fineness was measured by sieving the cement. As cements have become finer, the use of sieves is less applicable, but the amount retained on a 45 μ m sieve is still measured, usually by air-jet sieving or wet - sieving. The amount passing this sieve (typically 95 % in modern general - purpose cements) is related to the overall strength - development potential of the cement, because the larger particles are essentially un reactive.

The main measure of fineness today is specific surface. Because cement particles react with water at their surface, the specific surface area is directly related to the cement's initial reactivity. By adjusting the fineness of grind, the manufacture can produce a range of products from a single clinker. Tight control of fineness is necessary in order to obtain cement with the desired consistent day - to - day performance , so round - the - clock measurements are made on the cement as it is produced, and mill feed - rates and separator settings are adjusted to maintain constant specific surface .

A more comprehensive picture of fineness is given by particle size analysis , yielding a measure of the amount of each size range present, from sub - micrometer upwards. This used to be mainly a research tool, but with the advent of cheap, industrialized laser-diffraction analyzers, its use for routine control is becoming more frequent. This may take the form of a desk - top analyzer fed with automatically gathered samples in a robotized laboratory, or, increasingly commonly, instruments attached directly to the output ducts of the mill. In either case, the results can be fed directly into the mill control system, allowing complete automation of fineness control.

In addition to fineness, added materials in the cement must be controlled. In the case of gypsum addition, the material used is frequently of variable quality, and it is normal practice to measure the sulfate content of the cement regularly, typically by x-ray fluorescence , using the results to adjust the gypsum feed rate. Again, this process is often completely automated. Similar measurement and control protocols are applied to other materials added, such as lime stone , slag and fly - ash.

Cement Render

	
Rendered house in France	*Rendered house in Greece*

Contents

1 – Introduction :

Cement rendering is the application of a thin premixed surface of sand , cement and lime plaster to brick , cement , stone or mud brick . It is often textured, coloured or painted after application. It is generally used on exterior walls but can be used to feature an interior wall . Depending on the 'look' required, rendering can be fine or coarse, textured or smooth, natural or coloured, pigmented or painted.

The cement rendering of brick, concrete and mud houses has been used for centuries to improve the appearance (and sometimes weather resistance) of exterior walls. It can be seen in different forms all over southern Europe. Different countries have their own style and traditional colours.

2 - Finishes :

Different finishes can be created by using different tools such as trowels , sponges , or brushes . The art in traditional rendering is , (apart from getting the mix right) , the appearance of the top coat.

Different tradesmen will have different finishing styles and be able to produce different textures and decorative effects. Some of these special finishing effects may need to be created from a thin finishing 'top coat' or from a finishing wash.

3 - Acrylic rendering :

There are also a wide variety of premixed renders for different situations. Some have a polymer additive to the traditional cement, lime and sand mix for enhanced water resistance, flexibility and adhesion.

Acrylic premixed renders have superior water resistance and strength. They can be used on a wider variety of surfaces, including concrete, cement blocks, and AAC concrete paneling . With the right preparation, they can be used on smoother surfaces like cement sheeting, new high tech polymer exterior cladding such as Uni-Base, and expanded Polystyrene. A few of these require activation with cement just prior to application.

Some of these premixed acrylic renders have a smoother complexion than traditional renders. Others can even be sprayed on. There are also a wide variety of acrylic bound pigmented 'designer' finishing coats that can be applied over acrylic render. Depending upon the product, they can be rolled , trowel led or sponged on. A limited number can also be spayed on. Various finishes, patterns and textures are possible such as sand, sandstone, marble, stone, stone chip, lime wash or clay like finishes. There are stipple, glistening finishes, and those with enhanced water resistance and anti fungal properties. Acrylic renders take only 2 days to dry and cure - much faster than the 28 days for traditional render.

4 - Traditional rendering :

To ensure adhesion, the surface to be rendered is initially hosed off to ensure it is free of any dirt and loose particles . Old paint or old render is scraped away . The surface is roughened to improve adhesion. For large areas vertical battens are fixed to the wall every 1 to 1.5 meters , to keep the render flat and even .

Cement render consists of 6 parts clean sharp fine sand, 1 part cement and 1 part lime. The lime makes the render more workable and reduces cracking when the render dries. Any general purpose cement can be used. Various additives can be added to the mix for increasing adhesion. Coarser sand is used as the base layer and slightly finer sand for the top layer.

Cement Tile

Contents

1 – Introduction :

Cement tiles are hand-made, decorative, colorful tiles used primarily as floor coverings. Floors or walls covered with these tiles are noted for their multi-color patterns, durability and sophisticated-look. These tiles are widely used in Latin America and Europe. Their popularity spread to the US, primarily in California and Florida through the 1930s and 40s.

Although sometimes mistakenly called encaustic tile, which refers to kiln-fired clay tile or commonly used ceramic tiles that have been placed in a kiln and heated. Cement tiles are not fired and derive their durability from the combination of finely dehydrated ground Portland cement layer and a more course layer of sand and Portland cement. The pigment layer is hydraulically pressed into the surface and becomes a part of the tile, not a glaze or paint layer on the surface of the tile.

Depending on the locale, cement tiles are called by many names including: hydraulic cement tiles, mosaic tiles, encaustic cement tiles, mosaico hidraulicos , hydraulic tiles , ladrilhos hidráulicos , carreaux de ciments, Spanish mission tiles, Redondo tile, baldosas hidráulicas , hidraulicos antiguos, ladrilho de água, baldosas decoradas, hidráulicas de cement . v

The tile's colorful patterns, durability and versatility have been attracting the attention of architects and designers for large commercial projects such as restaurants and hotels. Private homebuilders and “do it yourself” home improvement consumers have driven a growing segment of the cement tile market.

2 – History :

Originally decorative tiles, known as encaustic tiles, were prepared from a pigmented clay base then heated or fired in a kiln. Tiles made by this method were very popular and can still be seen widely in Europe , Latin America and the US .

Following the discovery of Portland cement and development of hydraulic presses, cement tile, as we know them today is prepared without the use of clay or heating .

Cement tile appeared in the late 19th century in the south of France. Several sources say the first tiles were made near the country's first Portland cement plant. Around the turn of the 20th century, the tiles were very popular in the United States and were considered high - end floor covering. It was used in thousands of landmark public buildings and palaces. Their popularity began to wane in the U.S. sometime between the 1920s and ’30s and only started making a comeback in the 1980s and ’90s.

3 - Manufacture and quality :

Cement tiles are made by hand, one at a time using a mold, mineral pigments, Portland cement and fine aggregate with a manual or electronic hydraulic press. There is no glaze or kiln. Cement tiles are cured by water and air only – just like ordinary cement.

The metal mold, containing the desired pattern is hand-made from specific design drawings. The pigment composition is a mixture of high quality white Portland cement, marble powder , fine sand , and natural mineral color pigments.

Hand made cement tiles are each unique and are expected to have slight imperfections, which give them character and depth.

There are numerous cement tile manufacturers worldwide with the exception of the US. Presently there are no known cement tile manufacturers located in the US however there are several importers and distributors.

In general, the primary difference between manufacturers is the hydraulic method used in the production. Many small companies employ a hand - operated, manual hydraulic press in the process. The quality of these tiles varies due to inconsistent pressure , which affects the cement layers and attachment of the pigment layer.

Larger, modern manufacturers use electric - powered hydraulic presses that produce a consistently higher quality product. The higher pressure (1,500 PSI) permits a thicker pigment layer to be embedded in the cement layer, which produces a tile with a longer life span. The pigment layer is recommended to be 3 – 4 mm thick.

Another difference in manufacturers is the content of the pigments used. High quality producers use mineral-based pigments only. Non-mineral based pigments fade with age and normal wear. Another consideration is curing. Improper curing reduces quality. Tile should be cured for 2– 4 weeks before installation.

4 - Uses and applications :

Cement tiles are widely used around the world in residences and commercial buildings and they are experiencing a revival in the US. Architects and interior decorators find cement a versatile product. The vibrant colors and ornate designs provide elements reminiscent of Renaissance floors. The durability of cement tiles for use in public areas is gaining popularity.

Cement tiles can be applied to concrete surfaces, any common underlayment, magnesium oxide wallboard or any appropriate surface.

5 - Special considerations :

Installation of cement tiles is different than installing ceramic tiles.

- Cement tiles are normally seated with butt joints – without spacers. A small space between tiles will be visible and will require a grout mixture (unsanded) applied. Spacers to produce a larger grout line may be used, if so, sanded grout may be used.

- Prior to use each tile should be submerged in water and allow to stand 10 – 15 minutes before placement . It prevents the tiles from absorbing moisture from the thin - set too quickly and results in poor adherence to the surface and the tile.

- Sealing cement tile is not required prior to grouting; however, to prevent any stain from a colored grout sealing the tile is a good idea.

- Cement tiles are easily cared for wash with mild detergent and water. Avoid scrubbing with abrasives that can remove the finish and damage the pigment layer of the tile.

Cementing Equipment

Contents

1 – Introduction :

Cementing Equipment includes various items used while drilling oil / gas / water wells .

Casing will be installed at various depths while drilling. It is held in place by cement, which also provides zone isolation. Down-hole equipment such as Centralizers and Turbolizers is used to ensure obtaining satisfactory zone isolation. Float Shoes and Collars (float valves) prevent backflow after the cement has been pumped into place.

2 – Centralizers , Turbolizers and Scratchers :

Devices fitted with hinged collars and bow springs help keep the casing or liner in the center of the wellbore to help ensure efficient placement of a cement sheath around the casing string. If casing strings are cemented off - center, there is a high risk that a channel of drilling fluid or contaminated cement will be left where the casing contacts the formation, creating an imperfect seal .

Turbolizers have added fins to "stir" up the drilling fluid and cement to keep the flow turbulent in order to make sure the cement flows all the way around the casing in order to prevent channeling.

Scratchers use metal wires to scrape mud cake off permeable zones to help obtain a solid cement column .

3 - Float Shoe :

A rounded profile float shoe with an integral check valve attached to the bottom of a casing string prevents reverse flow, or U - tubing, of cement slurry from the annulus into the casing or flow of wellbore fluids into the casing string as it is run. The float shoe also guides the casing toward the center of the hole to minimize hitting rock ledges or washouts as the casing is run into the wellbore. By "floating" casing in, hook weight is reduced. With controlled or partial fill-up as the string is run, the casing string can be floated into position, precluding the need for the rig to carry the entire weight of the casing string. The outer portions of the float shoe are made of steel and generally match the casing size and threads, although not necessarily the casing grade. The inside (including the external taper) is usually made of cement or thermoplastic, since this material must be drilled out if the well is to be deepened beyond the casing point .

Guide shoes are a variant of a float shoe without a check valve.

4 - Float Collar :

A float collar is installed near the bottom of the casing string. Cement plugs land on it during the primary cementing operation, thus retaining inside the casing a small portion of the cement slurry that may have become contaminated as the top plug scrapes the inside of the casing. It is similar to a float shoe; often both are used for redundancy. The internal check valves may be flapper type or spring-loaded balls.

The check-valve assembly fixed within the float collar prevents flow back of the cement slurry when pumping is stopped. Without a float collar or float shoe, the cement slurry placed in the annulus could U - tube, or reverse flow back into the casing. The greater density of cement slurries than the displacement mud inside the casing causes the U - tube effect.

5 - Stage Collar :

Stage Collars provide a means for cement slurry to be displaced higher in the annulus immediately following the primary cement job. A series of differently sized rubber plugs pumped down inside the casing open and then later close the sliding valves.

Ceramics of Chinese

Ming covered red jar with dragon and sea design from the Jiajing reign

Contents

1 – Introduction :

Chinese Ceramic Ware shows a continuous development since the pre-dynastic periods, and is one of the most significant forms of Chinese art. China is richly endowed with the raw materials needed for making ceramics. The first types of ceramics were made during the Paleolithic era . Chinese Ceramics range from construction materials such as bricks and tiles, to hand - built pottery vessels fired in bonfires or kilns, to the sophisticated Chinese porcelain wares made for the imperial court. Porcelain is also occasionally called "china" in English.

1 – 1 - Terminology and Categories ;

A qingbai porcelain vase , bowl , and model of a granary with transparent blue - toned glaze , from the period of the Song Dynasty (960 - 1279 AD) .

Porcelain "it is a collective term comprising all ceramic ware that is white and translucent, no matter what ingredients are used to make it or to what use it is put ". The Chinese tradition recognizes two primary categories of ceramics, high - fired and low - fired . The oldest Chinese dictionaries define porcelain as "fine, compact pottery". Chinese ceramic wares can also classified as being either *northern* or *southern*. Present-day China comprises two separate and geologically different land masses, brought together by the action of continental drift and forming a junction that lies between the Yellow river and the Yangtze river. The contrasting geology of the north and south led to differences in the raw materials available for making ceramics.

The name "china" came from the transliteration of Changnan , which was the old name for the porcelain town of today's Jingdezhen (Jingde Town). During the Tang Dynasty (618-907), people combined the advantages of celadon from the southern Yue kiln and white porcelains from the northern Xing kiln with the high-quality earth of the Gaoling Mountain in Changnan Town to produce a kind of white & green porcelain. This porcelain was smooth and bright, and hence earned another name of artificial jade. It became famous both in China and elsewhere and was exported to Europe in large quantities since people there did not know how to make porcelain before the 18th century.

1 – 2 - Materials :

Chinese porcelain is mainly made by a combination of the following materials:

- ***Kaolin*** - essential ingredient composed largely of the clay mineral kaolinite.
- ***Pottery stone*** - are decomposed micaceous or feldspar rocks, historically also known as petunse.
- ***Feldspar***
- ***Quartz***

A black pottery cooking cauldron from the Hemudu culture (c. 5000 – c. 3000 BC)

2 - Technical developments

In the context of Chinese ceramics, the term *porcelain* lacks a universally accepted definition. This in turn has led to confusion about when the first Chinese porcelain was made. Claims have been made for the late Eastern Han period (100 to 200 AD) , the Three Kingdoms period (220 to 280 AD) , the Six Dynasties period (220 to 589 AD) , and the Tang Dynasty (618 to 906 AD) .

2 – 1 - Early wares :

The *Proceedings of the National Academy of Sciences* in 2009 reports that pottery that dates back to 18,000 years ago in the Yuchanyan Cave in southern China has been found, making it among the earliest pottery yet found . Fragments of pottery vessels dating from around 9000 BC found at the Xianrendong (Spirit Cave) site , Wannian County, in the province of Jiangxi represent some of the earliest known Chinese ceramics. The wares were hand-made by coiling and fired in bon fires . Decorations include impressed cord marks, and features produced by stamping and by piercing.

The Xianrendong site was occupied from about 9000 BC to about 4000 BC. During this period two types of pottery were made. The first consisted of coarse-bodied wares possibly intended for everyday use. The second being finer, thinner-bodied wares possibly intended for ritual use or special occasions. There is archaeological evidence suggesting that both types of wares were produced at the same time at some point.

Painted pottery pot with raised reliefs of dragons and phoenixes, Western Han Dynasty (202 BC – 9 AD)

2 – 2 - Han dynasty , 202 BC - 220 AD :

Some experts believe the first true porcelain was made in the province of Zhejiang during the Eastern Han period. Shards recovered from archaeological Eastern Han kiln sites estimated firing temperature ranged from 1260 to 1300 °C . As far back as 1000 BC, the so - called *"Porcelaneous wares"* or *"proto-porcelain wares"* were made using at least some kaolin fired at high temperatures. The dividing line between the two and *true porcelain wares* is not a clear one. Archaeological finds have pushed the dates to as early as the Han Dynasty (206 BC – 220 AD) .

The late Han years saw the early development of the peculiar art form of *hunping*, or "soul jar": a funerary jar whose top was decorated by a sculptural composition. This type vessels became widespread during the following Jin Dynasty and the Six Dynasties .

2 – 3 - Sui and Tang dynasties, 581 – 907 :

During the Sui and Tang periods (81 to 907) a wide range of ceramics, low-fired and high-fired, were produced. These included the well-known Tang lead-glazed *sancai* (three-colour) wares, the high-firing, lime-glazed *Yue* celadon wares and low-fired wares from *Changsha*. In northern China, high-fired, translucent porcelains were made at kilns in the provinces of Henan and Hebei.

A sancai glazed dish from the late 7th or early 8th century , Tang Dynasty (618 – 907)

One of the first mentions of porcelain by a foreigner was in the *Chain of Chronicles* written by the Arabian traveler and merchant Suleiman in 851 AD during the Tang Dynasty who recorded that :

They have in China a very fine clay with which they make vases which are as transparent as glass; water is seen through them. The vases are made of clay.

The Arabs were aware of the materials necessary to create glass ware, and he was certain that the porcelain that he saw was not the usual glass material.

2 – 4 - Song and Yuan dynasties , 960 - 1368

The city of Jingdezhen (also Jingde Zhen) has been a central place of production since the early Han Dynasty. In 1004, Jingde established the city as the main production hub for Imperial porcelain. During the Song and Yuan dynasties, porcelain made in the city and other southern China kiln sites used crushed and refined pottery stones alone.

Goldfish Vase , reign of the Jiajing Emperor (1521– 67); Porcelain ; Paris, Musée Guimet 261101

2 – 5 - Ming dynasty , 1368 – 1644 :

The Ming Dynasty saw an extraordinary period of innovation in ceramic manufacture. Kilns investigated new techniques in design and shapes, showing a predilection for colour and painted design, and an openness to foreign forms . The Yongle Emperor (1402 – 24) was especially curious about other countries (as evidenced by his support of the eunuch Zheng He's extended exploration of the Indian Ocean), and enjoyed unusual shapes, many inspired by Islamic metal work , During the Xuande reign (1425 – 35) , a technical refinement was introduced in the preparation of the cobalt used for underglaze blue decoration. Prior to this the cobalt had been brilliant in colour, but with a tendency to bleed in firing; by adding a manganese the colour was duller, but the line crisper. Xuande porcelain is now considered among the finest of all Ming output . Enamelled decoration (*such as the one at left*) was perfected under the Chenghua Emperor (1464 – 87) , and greatly prized by later collectors . Indeed by the late sixteenth century, Chenghua and Xuande era works – especially wine cups – had grown so much in popularity, that their prices nearly matched genuine antique wares of Song or even older. This esteem for relatively recent ceramics excited much scorn on the part of literati scholars (such as Wen Zhenheng , Tu Long , and Gao Lian, who is cited below) ; these men fancied themselves arbiters of taste and found the painted aesthetic 'vulgar ' .

In addition to these decorative innovations, the late Ming period underwent a dramatic shift towards a market economy , exporting porcelain around the world on an unprecedented scale. Thus aside from supplying porcelain for domestic use, the kilns at Jingdezhen became the main production centre for large - scale porcelain exports to Europe starting with the reign of the Wanli Emperor 1572 – 1620 . By this time, kaolin and pottery stone were mixed in about equal proportions. Kaolin produced wares of great strength when added to the paste; it also enhanced the whiteness of the body - a trait that became a much sought after property, especially when form blue-and-white wares grew in popularity. Pottery stone could be fired at a lower temperature (1250 °C) than paste mixed with kaolin, which required 1350 °C. These sorts of variations were important to keep in mind because the large southern egg-shaped kiln varied greatly in temperature. Near the firebox it was hottest; near the chimney, at the opposite end of the kiln, it was cooler.

Yellow - glazed brush - holder , "Chen Guo Zhi" mark; Jingdezhen Daoguang reign , (1821-50) ; Shanghai Museum

2 – 6 - Qing dynasty , 1644 - 1911

Primary source material on Qing Dynasty porcelain is available from both foreign residents and domestic authors. Two letters written by Père Francois Xavier d' Entrecolles , a Jesuit missionary and industrial spy who lived and worked in Jingdezhen in the early eighteenth century, described in detail manufacturing of porcelain in the city . In his first letter dated 1712, d'Entrecolles described the way in which pottery stones were crushed, refined and formed into little white bricks, known in Chinese as *petuntse*. He then went on to describe the refining of china clay *kaolin* along with the developmental stages of glazing and firing. He explained his motives :

Nothing but my curiosity could ever have prompted me to such researches, but it appears to me that a minute description of all that concerns this kind of work might, be useful in Europe. ”

In 1743, during the reign of the Qianlong Emperor , Tang Ying, the imperial supervisor in the city produced a memoir entitled *"Twenty illustrations of the manufacture of porcelain."* Unfortunately, the original illustrations have been lost, but the text of the memoir is still accessible .

3 - Types of Chinese porcelain wares :

Tang Dynasty (618 – 907) sancai horse at the Shanghai Museum

3 – 1 - Tang *Sancai* burial wares :

Sancai means *three - colours*. However, the colours of the glazes used to decorate the wares of the Tang dynasty were not limited to three in number. In the West, Tang sancai wares were some times referred to as *egg-and-spinach* by dealers for the use of green, yellow and white. Though the latter of the two colours might be more properly described as *amber* and *off - white* / *cream*.

Sancai wares were northern wares made using white and buff-firing secondary kaolins and fire clays . At kiln sites located at Tongchuan, Neiqui county in Hebei and Gongxian in Henan , the clays used for burial wares were similar to those used by Tang potters. The burial wares were fired at a lower temperature than contemporaneous white wares . Burial wares, such as the well - known representations of camels and horses, were cast in sections, in moulds with the parts luted together using clay slip. In some cases, a degree of individuality was imparted to the assembled figurines by hand - carving.

3 – 2 - Jian tea wares :

Jian black wares, mainly comprising tea wares, were made at kilns located in Jianyang of Fujian province. They reached the peak of their popularity during the Song dynasty. The wares were made using locally-won, iron-rich clays and fired in an oxidizing atmosphere at temperatures in the region of 1300 °C. The glaze was made using clay similar to that used for forming the body, except fluxed with wood-ash. At high temperatures the molten glaze separate to produce a pattern called *hare's fur*. When Jian wares were set tilted for firing, drips run down the side, creating evidence of liquid glaze pooling.

Jian tea bowl Song Dynasty, (960 – 1279)

The *hare's fur* Jian tea bowl illustrated in the Metropolitan Museum of Art in New York was made during the Song dynasty (960 to 1279 AD) and exhibits the typical pooling, or thickening, of the glaze near the bottom. The *hare's fur* patterning in the glaze of this bowl resulted from the random effect of phase separation during early cooling in the kiln and is unique to this bowl. This phase separation in the iron - rich glazes of Chinese black wares was also used to produce the well - known *oil-spot*, *teadust* and *partridge-feather* glaze effects.

No two bowls have identical patterning. The bowl also has a dark brown *iron-foot* which is typical of this style. It would have been fired, probably with several thousand other pieces, each in its own stackable saggar , in a single - firing in a large dragon kiln . One such kiln, built on the side of a steep hill, was almost 150 meters in length, though most Jian dragon kilns were fewer than 100 metres in length.

An 11th century resident of Fujian wrote :

Tea is of light colour and looks best in black cups. The cups made at Jianyang are bluish-black in colour, marked like the fur of a hare. Being of rather thick fabric they retain the heat, so that when once warmed through they cool very slowly, and they are additionally valued on this account. None of the cups produced at other places can rival these. Blue and white cups are not used by those who give tea - tasting parties. ”

At the time, tea was prepared by whisking powdered leaves that had been pressed into dried cakes together with hot water, (somewhat akin to matcha in Japanese Tea Ceremony). The water added to this powder produced a white froth that would stand out better against a dark bowl. Tastes in preparation changed during the Ming dynasty; the Hongwu Emperor himself preferred leaves to powdered cakes, and would accept only leaf tea as tribute from tea-producing regions. Leaf tea, in contrast to powdered tea, was prepared by steeping whole leaves in boiling water - a process that led to the invention of the teapot and subsequent popularity of Yixing wares over the dark tea bowls . Jian tea wares of the Song dynasty were also greatly appreciated and copied in Japan, where they were known as tenmoku wares.

White Glazed Ding Ware Bowl with Incised Design Northern Song Dynasty (11th-12th Century) ; Porcelain , Musée Guimet 2418

3 – 3 - Ding ware :

Ding (Wade-Giles: *Ting*) ware was produced in Ding Xian (modern Chu-yang), Hebei Province, slightly south - west of Beijing. Already in production when the Song emperors came to power in 940, *Ding* ware was the finest porcelain produced in northern China at the time, and was the first to enter the palace for official imperial use. Its paste is white, generally covered with an almost transparent glaze that dripped and collected in "tears," (though some *Ding* ware was glazed a monochrome black or brown, white was the much more common type). Overall, the *Ding* aesthetic relied more on its elegant shape than ostentatious decoration; designs were understated, either incised or stamped into the clay prior to glazing. Due to the way the dishes were stacked in the kiln, the edged remained unglazed, and had to be rimmed in metal such as gold or silver when used as tableware. Some hundred years later, a Southern Song era writer commented that it was this defect that led to its demise as favoured imperial ware.[25] Since the Song court lost access to these northern kilns when they fled south, it has been argued that Qingbai ware (*see below*) was viewed as a replacement for *Ding* .

Although not as highly ranked as *Ru* ware, the late Ming connoisseur Gao Lian awards Ding ware a brief mention in his volume *Eight Discourses on the Art of Living*. Classified under his sixth discourse, the section on “pure enjoyment of cultured idleness,” Master Gao says :

"The best sort has marks on it like tear-stains... Great skill and ingenuity is displayed in selecting the forms of the vessels..." ”

Ru Ware Bowl Stand, Chinese, Early 12th Century; Buff stone ware, with crackled light bluish green glaze, and a copper edge

3 – 4 - Ru ware :

Like Ding ware , ***Ru*** (Wade – Giles : ***ju***) was produced in North China for imperial use. The Ru kilns were near the Northern Song capital at Kaifeng. In similar fashion to Longquan celadons, Ru pieces have small amounts of iron in their glaze that oxidize and turn greenish when fired in a reducing atmosphere. Ru wares range in colour — from nearly white to a deep robin's egg—and often are covered with reddish - brown crackles. The crackles, or "crazing," are caused when the glaze cools and contracts faster than the body, thus having to stretch and ultimately to split, (*as seen in the detail at right; see also*) . The art historian James Watt comments that the Song dynasty was the first period that viewed crazing as a merit rather than a defect. Moreover, as time went on, the bodies got thinner and thinner, while glazes got thicker, until by the end of the Southern Song the 'green-glaze' was thicker than the body, making it extremely 'fleshy' rather than 'bony,' to use the traditional analogy (*see section on* Guan *ware, below*). Too, the glaze tends to drip and pool slightly, leaving it thinner at the top, where the clay peeps through.

Ru Ware Bowl Stand, detail of crazing

As with Ding ware, the Song imperial court lost access to the Ru kilns after it fled Kaifeng when the Jin invaded, and settled at Lin'an in Hangzhou, towards the south. There the Emperor Gaozong founded the *Guan yao* ('official kilns') right outside the new capital in order to produce imitations of Ru ware . How ever , posterity has remembered Ru ware as some thing unmatched by later attempts; Master Gao says, "Compared with Guan yao, the above were of finer substance and more brilliant luster ".

Bulb Bowl with Scalloped Rim, Northern Song Dynasty (960 – 1127)
Stoneware; Asian Art Museum, San Francisco ,

3 – 5 - Jun ware :

Jun (Wade - Giles : ***chün***) ware was a third style of porcelain used at the Northern Song court. Characterized by a thicker body than Ding or Ru ware, Jun is covered with a turquoise and purple glaze, so thick and viscous looking that it almost seems to be melting off its substantial golden b- brown body. Not only are Jun vessels more thickly potted, their shape is much more robust than the fine Jun pieces, yet both types were appreciated at court of Emperor Huizong. Jun production was centered at Jun-tai in Yüzhou city, Henan Province .

3 – 6 - Guan ware :

Guan (Wade - Giles: ***kuan***) ware , literally means "official" ware; so certain Ru, Jun, and even Ding could be considered *Guan* in the broad sense of being produced for the court. Strictly speaking, however, the term only applies to that produced by an official, imperially - run kiln, which did not start until the Southern Song fled the advancing Jin and settled at Lin'an. It was during this period that walls become so thin and glaze so thick that the latter superseded the former in breadth. As the clay in the foothills around Lin'an, was a brownish colour, and the glaze so viscus, ‘’Guan’’ ware became known for its "brown mouth" (sometimes translated as "purple"), indicating the top rim or a vessel where the glaze is thinner and the body shows through . Guan ceramics have been much admired over the years, and very subject to copy . Indeed Gao Lain spends the greatest part of his commentary on describing Guan and its partner *Ge* *ware* , as though that were the most troublesome, least easily identified type of pottery.

3 – 7 - Ge ware :

Ge (Wade - Giles : ***ko***) , literally means 'big-brother' ware, because legend has it that of two brothers working in Longquan, one made the typical celadon style ceramics, but the elder made *ge* ware, produced in his private kiln. Ming commentator, Gao Lian claims that the *ge* kiln took its clay from the same site as *Guan* ware, which is what accounts for the difficulty in distinguishing one from the other (though Gao thinks "*Ge* is distinctly inferior" to Guan) . Over all , Ge remains some what elusive, but basically comprises two types—one with a 'warm rice-yellow glaze and two sets of crackles, a more prominent set of darker colour interspersed with a finer set of reddish lines (called *chin-ssu t'ieh - hsien* or 'golden floss and iron threads', which can just faintly be detected on this bowl :). The other Ge ware is much like Guan ware, with grayish glaze and one set of crackles. Once thought to have only been manufactured alongside Longquan celadon, per its legendary founding, Ge is now believed to have also been produced at Jingdezhen .

While similar to Guan ware , Ge typically has a grayish-blue glaze that is fully opaque with an almost matte finish (*as seen on this bottle in the Asian Art Museum*) . Its crackle pattern is exaggerated, often standing out in bold black. Though still shrouded in mystery, many specialists believe that Ge ware did not develop until the very late Southern Song or even the Yuan. In any case, enthusiasm for it persisted throughout the Ming; Wen Zhenheng preferred it to all other types of porcelain, in particular for brush washers and water droppers (although he preferred jade brush washers to porcelain, Guan and Ge were the best ceramic ones, especially if they have scalloped rims). Differences between later Ming imitations of Song/Yuan Ge include: Ming versions substitute a white porcelain body; they tend to be produced in a range of new shapes, for example those for the scholar's studio; glazes tend to be thinner and more lustrous; and slip is applied to the rim and base to simulate the "brown mouth and iron foot" of Guan ware.

3 – 8 - Qingbai wares :

Song Dynasty qingbai bowl

Qingbai wares (also called 'yingqing') were made at Jingdezhen and at many other southern kilns from the time of the Northern Song Dynasty until they were eclipsed in the 14th century by under glaze - decorated blue and white wares. Qingbai in Chinese literally means "clear blue-white". The qingbai glaze is a *porcelain glaze*, so-called because it was made using pottery stone. The qingbai glaze is clear, but contains iron in small amounts. When applied over a white porcelain body the glaze produces a greenish-blue colour that gives the glaze its name. Some have incised or moulded decorations.

The Song dynasty qingbai bowl illustrated was likely made at the Jingdezhen village of Hutian , which was also the site of the Imperial kilns established in 1004 . The bowl has incised decoration, possibly representing clouds or the reflection of clouds in the water. The body is white , translucent and has the texture of very - fine sugar, indicating that it was made using crushed and refined pottery stone instead of pottery stone and kaolin. The glaze and the body of the bowl would have been fired together, in a saggar, possibly in a large wood - burning dragon - kiln or climbing - kiln, typical of southern kilns in the period.

Though many Song and Yuan qingbai bowls were fired upside down in special segmented saggars , a technique first developed at the Ding kilns in Hebei province. The rims of such wares were left unglazed but were often bound with bands of silver , copper or lead .

One remarkable example of *qingbai* porcelain is the so - called *Fonthill Vase*, described in a guide for Fonthill Abbey published in 1823

"...an oriental china bottle, superbly mounted, said to be the earliest known specimen of porcelain introduced into Europe" ”

The vase was made at Jingdezhen, probably around 1300 and was sent as a present to Pope Benedict XII by one of the last Yuan emperors of China, in 1338. The mounts referred to in the 1823 description were of enameled silver - gilt and were added to the vase in Europe in 1381. An 18th century water colour of the vase complete with its mounts exists, but the mounts themselves were removed and lost in the 19th century. The vase is now in the National Museum of Ireland. It is often held that *qingbai* wares were not subject to the higher standards and regulations of the other porcelain wares, since they were made for everyday use. They were mass-produced, and received little attention from scholars and antiquarians. The Fonthill Vase, given by a Chinese emperor to a pope, might appear to cast at least some doubt on this view.

3 – 9 - Blue and white wares

Kangxi period (1662 to 1722) blue and white porcelain tea caddy

Following in the tradition of earlier *qingbai* porcelains, blue and white wares are glazed using a transparent *porcelain glaze*. The blue decoration is painted onto the body of the porcelain before glazing, using very finely ground cobalt oxide mixed with water. After the decoration has been applied the pieces are glazed and fired.

It is believed that under glaze blue and white porcelain was first made in the Tang Dynasty. Only three complete pieces of Tang blue and white porcelain are known to exist (in Singapore from Indonesian Belitung shipwreck) , but shards dating to the 8th or 9th century have been unearthed at Yangzhou in the Jiangsu province. It has been suggested that the shards originated from a kiln in the province of Henan. In 1957, excavations at the site of a pagoda in the province Zhejiang uncovered a Northern Song bowl decorated with under glaze blue and further fragments have since been discovered at the same site. In 1970, a small fragment of a blue and white bowl, again dated to the 11th century, was also excavated in the province of Zhejiang.

In 1975, shards decorated with under glaze blue were excavated at a kiln site in Jiangxi and, in the same year, an under glaze blue and white urn was excavated from a tomb dated to 1319, in the province of Jiangsu. It is of interest to note that a Yuan funerary urn decorated with underglaze blue and under glaze red and dated 1338 is still in the Chinese taste, even though by this time the large-scale production of blue and white porcelain in the Yuan, Mongol taste had started its influence at Jingdezhen.

Starting early in the 14th century, blue and white porcelain rapidly became the main product of Jingdezhen, reaching the height of its technical excellence during the later years of the reign of the Kangxi Emperor and continuing in present times to be an important product of the city.

The tea caddy illustrated shows many of the characteristics of blue and white porcelain produced during the Kangxi period. The translucent body showing through the clear glaze is of great whiteness and the cobalt decoration, applied in many layers, has a fine blue hue. The decoration, a sage in a landscape of lakes and mountains with *blazed* rocks is typical of the period. The piece would have been fired in a saggar (a lidded ceramic box intended to protect the piece from kiln debris, smoke and cinders during firing) in a reducing atmosphere in a wood - burning *egg - shaped* kiln, at a temperature approaching 1350 °C .

Distinctive blue – and - white porcelain was exported to Japan where it is known as Tenkei blue-and-white ware or *ko sometsukei*. This ware is thought to have been especially ordered by tea masters for Japanese ceremony.

Statue of Guan Yin, Ming Dynasty (Shanghai Museum)

3 – 10 - Blanc de Chine :

Blanc de Chine is a type of white porcelain made at Dehua in the Fujian province. It has been produced from the Ming Dynasty (1368 – 1644) to the present day. Large quantities arrived in Europe as Chinese Export Porcelain in the early 18th century and it was copied at Meissen and else where . The area along the Fujian coast was traditionally one of the main ceramic exporting centers. Over one - hundred and eighty kiln sites have been identified extending in historical range from the Song period to present.

Tripod Early 17th century, Nantoyōsō Collection, Japan

From the Ming period porcelain objects were manufactured that achieved a fusion of glaze and body traditionally referred to as "ivory white" and "milk white." The special characteristic of Dehua porcelain is the very small amount of iron oxide in it, allowing it to be fired in an oxidizing atmosphere to a warm white or pale ivory colour.

The porcelain body is not very plastic but vessel forms have been made from it. Donnelly, (1969, pp.xi-xii) lists the following types of product: figures, boxes, vases and jars, cups and bowls, fishes, lamps, cup-stands, censers and flowerpots, animals, brush holders, wine and teapots, Buddhist and Taoist figures, secular figures and puppets. There was a large output of figures, especially religious figures, e.g. Guanyin, Maitreya, Lohan and Ta-mo figures.

The numerous Dehua porcelain factories today make figures and tableware in modern styles. During the Cultural Revolution "Dehua artisans applied their very best skills to produce immaculate statuettes of the Great Leader and the heroes of the revolution. Portraits of the stars of the new proletarian opera in their most famous roles were produced on a truly massive scale " · Mao Zedong figures later fell out of favour but have been revived for foreign collectors.

Notable artists in *blanc de Chine*, such as the late Ming period He Chaozong, signed their creations with their seals. Wares include crisply modeled figures, cups, bowls and joss stick-holders.

Many of the best examples of *blanc de Chine* are found in Japan where the white variety was termed *hakugorai* or "Korean white", a term often found in tea ceremony circles. The British Museum in London has a large number of *blanc de Chine* pieces, having received as a gift in 1980 the entire collection of P.J.Donnelly .

3 – 11 - Classification by colour , Famille :

Commonly used French terms for 'families', or palettes of enamel colours used on Chinese porcelain. **Famille jaune , noirev, rose, verte** are terms used to classify Chinese porcelain by its colour palette.

3 – 11 – 1 - Famille verte :

Saint-Cloud soft porcelain spitting bowl, "Famille verte", 1730 -1740

Famille verte (*Kangxi wuca i*, also , *Susancai*) , adopted in the Kangxi (1662 – 1722) , uses green and iron red with other over glaze colours. It developed from the Wucai ("Five colors") style.

		
Wucai plate for exportation , Kangxi period, circa 1680	*Wucai plate for exportation, Kangxi period, circa 1680*	*Wucai vase, Shunzhi period circa 1650 -1660*

3 – 11 – 2 - Famille jaune :

Famille jaune is a variation using famille verte enamels on a yellow ground.

3 – 11 – 3 - Famille noire :

Famille noire (Chinese : *Modi susancai*) uses a black ground (although some clobbered wares had the black added in the 19th century) .

3 – 11 – 4 - Famille rose :

Delftware plate , faience , Famille Rose , 1760 - 1780

Famille rose (known in Chinese as *Fencai* or *Ruancai* , simplified) , meaning 'soft colours' , and later as *Yangcai* , meaning 'foreign colours') was introduced during the reign of Kangxi (1654 – 1722) , possibly around 1720. It used mainly pink or purple and remained popular throughout the 18th and the 19th centuries.

Famille rose enamel ware allows a greater range of colour and tone than was previously possible, enabling the depiction of more complex images, including flowers, figures and insects.

It is made by drawing a sketch on the shaped clay, which is then covered with 'glassy white' (bo li bai), an opaque white enamel (lead arsenate), and painted in detail with the mixture of pigment and oil, before firing.

 *Saint-Cloud soft paste porcelain flower holder, "Famille Rose", 1730 -1740*	 *Jingdezhen soft paste porcelain flower holder, "Famille Rose", 1736 – 1796 Qianlong period*

4 - Stone ware :

4 – 1 - Yixing ware :

Early pots were designed for travel use hence you will see the simple classical look of the pots produced during the Ming Dynasty. Most tea drinking enthusiast will have one teapot for travel use, these tend to be less expensive and compact in design. It was not until during the mid - Qing Dynasty (18 th century) that tea connoisseurs started to use the pot at home and the artisan begin to form them into different shape and sizes. Many exotic forms were conceived. Vessels were decorated with poetic inscriptions , calligraphy, paintings and seals were incised onto the surface of the teapots.

The term "*yixing clay*" is often used as an umbrella term to describe several distinct types of clay used to make stoneware :

- *Zisha* or *Zini* or ; literally, "purple sand/clay" : this stoneware has a purple-red-brown color
- *Zhusha*or *Zhuni* or ; literally, "cinnabar sand/clay" : reddish brown stoneware with a very high iron content. The name only refers to the sometimes bright red hue of cinnabar ; pinyin: zhūshā . Due to the increasing demand for Yixing stoneware, zhuni is now in very limited quantities. Zhuni clay is not to be confused with hongni (literally, "red clay", another red clay.
- *Duanni* literally, "fortified clay": stone ware that was formulated using various stones and minerals in addition to zini or zhuni clay. This results in various textures and colours, ranging from beige, blue , and green , to black.

5 - Fakes and reproductions :

	
Italian pottery of the mid-15th century shows	*Kangxi reign mark on*

heavy influences from Chinese ceramics. A Sancai ("Three colors") plate (left), and a Ming-type blue-and-white vase (right), made in Northern Italy, mid-15th century	*a piece of late nineteenth century blue and white porcelain.*

Chinese potters have a long tradition of borrowing design and decorative features from earlier wares. Whilst ceramics with features thus borrowed might sometimes pose problems of provenance, they would not generally be regarded as either reproductions or fakes. However, fakes and reproductions have also been made at many times during the long history of Chinese ceramics and continue to be made today in ever-increasing numbers.

- Reproductions of Song dynasty Longquan celadon wares were made at Jingdezhen in the early 18th century, but outright fakes were also made using special clay that were artificially aged by boiling in meat broth, refiring and storage in sewers . Père d' Entrecolles records that by this means the wares could be passed off as being hundreds of years old .
- In the late 19th century, fakes of Kangxi period *famille noire* wares were made that were convincing enough to deceive the experts of the day. Many such pieces may still be seen in museums today, as may pieces of genuine Kangxi porcelain decorated in the late nineteenth century with *famille noire* enamels. A body of modern expert opinion holds that porcelain decorated with *famille noire* enamels was not made at all during the Kangxi period, though this view is disputed .
- A fashion for Kangxi period (1662 to 1722) blue and white wares grew to large proportions in Europe during the later years of the 19th century and triggered the production at Jingdezhen of large quantities of porcelain wares that strike a resemblance to ceramics of earlier periods. Such blue and white wares were not fakes or even convincing reproductions, even though some pieces carried four- character Kangxi reign - marks that continue to cause confusion to this day. Kangxi reign - marks in the form shown in the illustration occur only on wares made towards the end of the 19th century or later, without exception.

6 - Authentication :

The most widely- known test is the thermo luminescence test , or TL test, which is used on some types of ceramic to estimate, roughly , the date of last firing. The TL test is carried out on small samples of porcelain drilled or cut from the body of a piece, which can be risky and disfiguring. For this reason, the test is rarely used for dating finely-potted, high-fired ceramics. TL testing cannot be used at all on some types of porcelain items, particularly high - fired porcelain .

7 - Gallery :

7 – 1 - Early wares :

	
Painted jar of the Majiayao culture, Late Neolithic period (3300 - 2200 BC)	*Water jar from the Neolithic period, Yangshao culture (ca. 5000 - 3000 BC)*
	
Painted pot of Majiayao culture (2200 - 2000 BC)	*Painted pot with frog motifs, Majiayao culture (2200 - 2000 BC)*
	

Large grey mug, Henan Longshan culture, Late Neolithic period (ca . 2500 - 2000 BC)	*Black pottery goblet of the Late Neolithic period from the Longshan culture , dated (ca. 2500 - 2000 BC)*
	
White pottery pot with geometric design , Shang dynasty (1600 - 1100 BC)	*White pottery pitcher from the Shandong Longshan culture, 2500 – 2000 BC*
	
A pottery bell from the Warring States Period (403 –221 BC)	*Earthenware vase, Eastern Zhou, 4th-3rd century BC, British Museum*
	
Soldiers from the Terracotta Army, interred by 210 BC, Qin Dynasty (221–206 BC)	*A painted pottery dou vessel with a dragon design from the Warring States Period (403-221 BC)*

7 – 2 - Han (202 BC to 220 AD) :

	
An earthenware goose pourer with lacquerware paint designs, Western Han, late 3rd century BC to early 1st century AD	*Ceramic sculptures with polychrome, from the 2nd century BC, Han Dynasty.*
	
A Han celadon pot with mountain-shaped lid and animal designs	*A painted earthenware tripod, Western Han Dynasty, late 3rd century BC to early 1st century AD*
	
Ceramic tomb statuette of a cavalryman and horse, Western Han Dynasty	*Two Western Han Dynasty terracotta vases with acrobats*
	
A Han Dynasty pottery tomb model of a palatial residence	*A Han Dynasty pottery tomb model of residential towers joined by a bridge*

	
A footed Western-Han white ceramic wine warmer with animal-head figurines decorating its lid	*A Han pottery face of a laughing woman*
	
An Eastern Han ceramic candle-holder with animal figurines	*A Western Han glazed pottery ding with taotie-faced door knocker designs*

7 – 3 - Three Kingdoms , Jin , Southern and Northern Dynasties, Sui (220 to 618) :

	
A celadon hunping jar with sculpted designs of architecture, from the Jin Dynasty (265 - 420)	*A celadon ceramic candle holder in the shape of a crouched lion, Three Kingdoms (220 – 265) , made in Eastern Wu*
	
A footed earthenware lamp with lions, from either the	*A black-glazed wine or water jug with a rooster - headed spout,*

Northern dynasties or Sui Dynasty, 6th century	*Jin Dynasty (265-420)*
	
Northern Dynasties lotus vessel	*Covered footed earthenware vessel from the Northern Qi (550 – 577)*
	
A ceramic cavalryman with a horn, Northern Wei (386 – 534)	*A Western Wei (536 – 556) ceramic figurine of a military officer*

7 – 4 - Tang (618 to 906 AD) :

	
A sancai glazed pottery horse from the 7th - 8th century	*Sancai-horse and figurine, Tang Dynasty*
	
A Western on a Bactrian	*An earthenware jar with green*

Camel, a sancai glazed figurine from the Tang Dynasty	*and yellow glaze, first half of 8th century*
	
A rounded ceramic plate with "three colors" glaze, 8th century	*A rounded ceramic plate with "three colors" glaze and floral design, 8th-9th century*
	
A ceramic offering plate with six eaves and "three colors" glaze, 8th century	*A ceramic offering plate with "three colors" glaze, decorated with a bird and trees, 8th century*
	
The Statue of Heavenly Guardian, Polychrome glazed pottery, Tang Dynasty.	*Tang Dynasty sancai grazed luohan (arhat) figure*
	
A Tang sancai - glazed tomb guardian, 8th century	*Tang female musicians on horse back*

7 – 5 - Song (960 to 1279 AD) :

	
A porcelain teapot in Qingbai Style, from Jingdezhen	*Chinese tea bowls made of stoneware, Song Dynasty, 12th to 13th century*
	
A Longquan celadon vase from the Song Dynasty	*Funerary vase and cover, green - glazed stoneware, Northern Song (960 –1127)*
	
Longquan celadon wares, 13th century	*A celadon bowl, 10th-11th century*
	
Ding Ware Bottle with iron pigment over transparent colourless glaze, 11th century; Freer Gallery, F1959.6.	*A Qingbai ware box with flower medallions*

	
Southern Song Dynasty celadon vase with dish shaped mouth, Longquan Ware	*Northern Song Dynasty white-glazed baby boy pillow*
	
A Song-era amphora with dragon handles	*A glazed stoneware pillow from the Song Dynasty*
	
Porcelain pillow Jin Dynasty (1115–1234)	

7 – 6 - Yuan (1279 to 1368 AD) :

	
Qingbai porcelain vase , 14th century	*A celadon shoulder pot from the late Yuan Dynasty, displaying artwork of peaches, lotuses, peonies, willows, and palms*

	
Longquan celadon , 13th -14th century	*A Jin or Yuan dynasty stone ware dish , 13 th -14 th century*
	
Celadon dish with a flower design	*Longquan celadon bowl with a dragon*
	
A Jun ware bowl	*A covered jar made of Longquan celadon, 14th century*

7 – 7 - Ming (1368 to 1644 AD) :

	
Guanyin (Goddess of Mercy) with children, statuette made of Dehua porcelain ware	*A Ming Dynasty blue – and - white porcelain dish with depiction of a dragon*

	
Ming presentation porcelain, Ming Dynasty (1368–1644) Fifteenth century	*A Ming Dynasty porcelain bowl with flower designs*
	
Porcelain vase from the reign of the Jiajing Emperor (1521–1567)	*Porcelain plate from 1634, during the Chongzhen Emperor (1627–1644)*
	
Ming Dynasty Yongle reign monk's cap white pitcher	*A Ming glazed earthenware statue of a seated Buddha*
	
Chrysanthemum styled porcelain vase with three colours	*Yongle reign red plate*

	
Wanli reign covered jar in green	*Jiajing covered jar with green dragon and cloud design*

7 – 8 - Qing (1644 to 1912 AD) :

	
Kangxi transitional porcelain, 1644-1680	*Kangxi transitional porcelain, 1644-1680*
	
A porcelain bowl with a scene of two boys playing in a courtyard, from the reign of the Yongzheng Emperor (1722–1735)	*Porcelain plate from the reign of the Kangxi Emperor (1661–1722)*
	
Copper-red porcelain from the reign of the Yongzheng Emperor (1722–1735)	*Porcelain vase from the reign of the Kangxi Emperor (1661–1722)*

	
Porcelain from the reign of the Qianlong Emperor (1735–1796)	*A European man on horseback, porcelain, first half of 18th century*
	
Four ritual porcelain water vessels with elephant-trunk spouts, from the reign of the Qianlong Emperor (1735–1796)	*Porcelain plate from the reign of the Qianlong Emperor (1735–1796)*
	
White porcelain from the reign of the Qianlong Emperor (1735 –1796)	*An 18th-century Qing porcelain meiping (plum vase)*

7 – 9 - Republic and People's Republic (1912 , to date) :

Decorating porcelain at modern - d

Chalk (Calcium Carbonate)

The Needles, situated on the Isle of Wight, are part of the extensive Southern England Chalk Formation.

Contents

1 – Introduction :

Chalk is a soft , white , porous sedimentary rock , a form of lime stone composed of the mineral calcite. Calcite is calcium carbonate or $CaCO_3$. It forms under reasonably deep marine conditions from the gradual accumulation of minute calcite plates (coccoliths) shed from micro-organisms called coccolithophores. It is common to find chert or flint nodules embedded in chalk. Chalk can also refer to other compounds including magnesium silicate and calcium sulfate.

Chalk has greater resistance to weathering and slumping than the clays with which it is usually associated, thus forming tall steep cliffs where chalk ridges meet the sea. Chalk hills, known as chalk down land , usually form where bands of chalk reach the surface at an angle, so forming a scarp slope. Because chalk is porous it can hold a large volume of ground water, providing a natural reservoir that releases water slowly through dry seasons.

"Nitzana Chalk curves" situated at Western Negev, Israel are chalk deposit formed at the Mesozoic era's Tethys Ocean

2 – Deposits :

The Chalk Group is a European stratigraphic unit deposited during the late Cretaceous Period. It forms the famous White Cliffs of Dover in Kent, England, as well as their counterparts of the Cap Blanc Nez on the other side of the Dover Strait. The Champagne region of France is mostly underlain by chalk deposits, which contain artificial caves used for wine storage. Some of the highest chalk cliffs in the world occur at Møns Klint in Denmark.

3 - Formation :

Ninety million years ago the chalk down land of Northern Europe was ooze accumulating at the bottom of a great sea. Protozoans such as foraminifera lived on the marine debris that showered down from the upper layers of the ocean. Their shells were made of calcite extracted from the rich sea-water. As they died a deep layer gradually built up and eventually, through the weight of overlying sediments, became consolidated into rock. Later earth movements related to the formation of the Alps raised these former sea-floor deposits above sea level.

4 - Composition :

Chalk is composed mostly of calcium carbonate with minor amounts of silt and clay. It is normally formed underwater, commonly on the sea bed, then consolidated and compressed during diagenesis into the form commonly seen today. During diagenesis silica accumulates to form chert or flint nodules within the carbonate rock.

5 - Uses :

Former under ground chalk quarry in Meudon, France.

Chalk is used to make quicklime and slaked lime, mainly used as lime mortar in buildings. In southeast England, Deneholes are a notable example of ancient chalk pits. Such bell pits may also mark the sites of ancient flint mines, where the prime object was to remove flint nodules for stone tool manufacture. The surface remains at Cissbury are one such example, but perhaps the most famous is the extensive complex at Grimes Graves in Norfolk . The traditional uses of chalk have in some cases been replaced by other substances, although the word "chalk" is often still applied to the usual replacements.

- *Blackboard chalk* is a substance used for drawing on rough surfaces, as it readily crumbles leaving particles that stick loosely to these surfaces. Although traditionally composed of natural chalk, modern blackboard chalk is generally made from the mineral gypsum (calcium sulfate), often supplied in sticks of compressed powder about 10 cm long.

- *Sidewalk chalk* is similar to blackboard chalk, except that it is formed into larger sticks and often colored. It is used to draw on sidewalks, streets, and driveways, mostly by children, but also by adult artists.
- In *agriculture* chalk is used for raising pH in soils with high acidity. The most common forms are $CaCO_3$ (calcium carbonate) and Ca O (calcium oxide).
- In field sports, including grass tennis courts, powdered chalk was used to mark the boundary lines of the playing field or court. This gives the advantage that, if the ball hits the line, a cloud of chalk or pigment dust can be seen. Nowadays the substance used is mostly titanium dioxide.
- In gymnastics, rock - climbing, weight - lifting and tug of war, chalk — now usually magnesium carbonate — is applied to the hands to remove perspiration and reduce slipping.
- *Tailor's chalk* is traditionally a hard chalk used to make temporary markings on cloth, mainly by tailors. Nowadays it is usually made from talc (magnesium silicate) .
- *Toothpaste* also commonly contains small amounts of chalk, to serve as a mild abrasive.
- *Polishing chalk* is chalk prepared with a carefully controlled grain size, for very fine polishing of metals.[2]
- Chalk is a source of quicklime by thermal decomposition, or slaked lime following quenching with water.
- Builder's putty also mainly contains chalk as a filler in linseed oil.
- Woodworking joints may be fitted by chalking one of the mating surfaces. A trial fit will leave a chalk mark on the high spots of the corresponding surface. Chalk transferring to cover the complete surface indicates a good fit.
- Finger print powder

Clay

The Gay Head cliffs in Martha's Vineyard consist almost entirely of clay.

Contents

1 – Introduction :

Clay is a general term including many combinations of one or more clay minerals with traces of metal oxides and organic matter.[1] Geologic clay deposits are mostly composed of phyllosilicate minerals containing variable amounts of water trapped in the mineral structure.

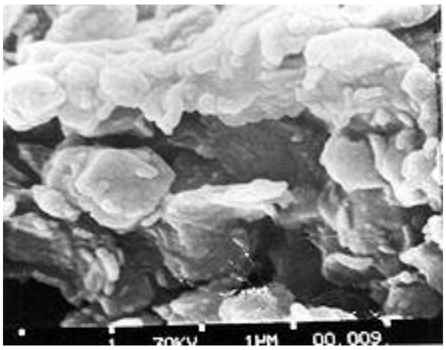
2 - Formation :

Deforestation for clay extraction in Rio de Janeiro city - Brazil. The picture is of Morro da Covanca - Jacarepaguá.

Clay minerals are typically formed over long periods of time by the gradual chemical weathering of rocks, usually silicate-bearing, by low concentrations of carbonic acid and other diluted solvents. These solvents, usually acidic, migrate through the weathering rock after leaching through upper weathered layers. In addition to the weathering process, some clay minerals are formed by hydro thermal activity. Clay deposits may be formed in place as residual deposits in soil, but thick deposits usually are formed as the result of a secondary sedimentary deposition process after they have been eroded and transported from their original location of formation. Clay deposits are typically associated with very low energy depositional environments such as large lakes and marine basins.

Primary clays, also known as kaolins, are located at the site of formation. Secondary clay deposits have been moved by erosion and water from their primary location.[2]

3 - Definition :



electron microscope photograph of smectite clay - magnification 23,500

Clays are distinguished from other fine-grained soils by differences in size and mineralogy. Silts, which are fine-grained soils that do not include clay minerals, tend to have larger particle sizes than clays, but there is some overlap in both particle size and other physical properties, and there are many naturally occurring deposits which include silts and also clay. The distinction between silt and clay varies by discipline . Geologists and soil scientists usually consider the separation to occur at a particle size of 2 µm (clays being finer than silts) , sedimentologists often use 4 - 5 µ m , and colloid chemists use 1 µ m . Geotechnical engineers distinguish between silts and clays based on the plasticity properties of the soil, as measured by the soils' Atterberg Limits. ISO 14688 grades clay particles as being smaller than 2 µm and silts larger.

Quaternary clay in Estonia.

4 - Grouping ;

Depending on the academic source, there are three or four main groups of clays: kaolinite, montmorillonite-smectite, illite, and chlorite. Chlorites are not always considered a clay, sometimes being classified as a separate group within the phyllosilicates. There are approximately 30 different types of "pure" clays in these categories, but most "natural" clays are mixtures of these different types, along with other weathered minerals.

Varve (or *varved clay*) is clay with visible annual layers, formed by seasonal differences in erosion and organic content. This type of deposit is common in former glacial lakes. When glacial lakes are formed there is very little movement of the water that makes the lake, and these eroded soils settle on the lake bed. This allows such an even distribution on the different layers of clay.[2]

Quick clay is a unique type of marine clay indigenous to the glaciated terrains of Norway, Canada, Northern Ireland, and Sweden. It is a highly sensitive clay, prone to liquefaction, which has been involved in several deadly landslides.

5 - Historical and modern uses :

Clay layers in a construction site. Dry clay is normally much more stable than sand with regard to excavations.

Clays exhibit plasticity when mixed with water in certain proportions. When dry, clay becomes firm and when fired in a kiln, permanent physical and chemical changes occur. These reactions, among other changes, cause the clay to be converted into a ceramic material. Because of these properties, clay is used for making pottery items, both utilitarian and decorative. Different types of clay, when used with different minerals and firing conditions, are used to produce earthenware, stoneware, and porcelain. Prehistoric humans discovered the useful properties of clay, and one of the earliest artifacts ever uncovered is a drinking vessel made of sun-dried clay . Depending on the content of the soil, clay can appear in various colors, from a dull gray to a deep orange - red.

Clay tablets were used as the first known writing medium, inscribed with cuneiform script through the use of a blunt reed called a stylus.

Clays sintered in fire were the first form of ceramic. Bricks, cooking pots, art objects, dishware, and even musical instruments such as the ocarina can all be shaped from clay before being fired. Clay is also used in many industrial processes, such as paper making, cement production, and chemical filtering. Clay is also often used in the manufacture of pipes for smoking tobacco. Until the late 20th century bentonite clay was widely used as a mold binder in the manufacture of sand castings.

Clay, being relatively impermeable to water, is also used where natural seals are needed, such as in the cores of dams, or as a barrier in landfills against toxic seepage (lining the landfill, preferably in combination with geotextiles) .

Recent studies have investigated clay's absorption capacities in various applications, such as the removal of heavy metals from waste water and air purification.

5 – 1 - Medical and Agricultural uses :

Recent research indicates that various animals visit clay licks periodically to eat from them , apparently because either the clay contains one or more antidotes for the various poisons in plants and seeds the animals eat, or because the clay coats the animals' guts to protect them from those substances .

A traditional use of clay as medicine goes back to prehistoric times. An example is Armenian bole, which is used to soothe an upset stomach, similar to the way parrots (and later, humans) in South America originally used it . Kaolin clay and attapulgite have been used as anti - diarrheal medicines.

5 – 2 - Clay as a Building material :

Clay is one of the oldest building materials on Earth, among other ancient, naturally - occurring geologic materials such as stone and organic materials like wood. Between one-half and two-thirds of the world's population, in traditional societies as well as developed countries, still live or work in a building made with clay as an essential part of its load - bearing structure. Also a primary ingredient in many natural building techniques, clay is used to create adobe, cob, cordwood, and rammed earth structures and building elements such as wattle and daub, clay plaster, clay render case , clay floors and clay paints.

Climbing Form Work

Climbing formwork on a future residential skyscraper in Takapuna, New Zealand - the whole white upper structure is actually formwork and associated working facilities.

Contents

1 – Introduction :

Climbing formwork is a special type of formwork for vertical concrete structures that rises with the building process. While relatively complicated and costly, it can be an effective solution for buildings that are either very repetitive in form (such as towers or skyscrapers) or that require a seamless wall structure (using **gliding formwork**, a special type of climbing formwork).

Various types of climbing formwork exist, which are either relocated from time to time, or can even move on their own (usually on hydraulic jacks , required for self - climbing and gliding formworks) .

2 - Process :

Best known in the construction of towers , sky scrapers and other tall vertical structures, it allows the reuse of the same formwork over and over and over for identical (or very similar) sections / stories further up the structure. It can also enable very large concrete structures to be constructed in one single pour (which may take days or weeks as the formwork rises with the process) , thus creating seamless structures with enhanced strength and visual appearance, as well as reducing construction times and material costs (at the joints which would otherwise require extra reinforcement / connectors) .

The climbing formwork structure normally does not only contain the formwork itself, but also usually provides working space / scaffolds for construction crews. It may also provide areas for machinery and screens for weather protection, up to being fully enclosed while yet staying modular around a changing building structure .

3 - Types :

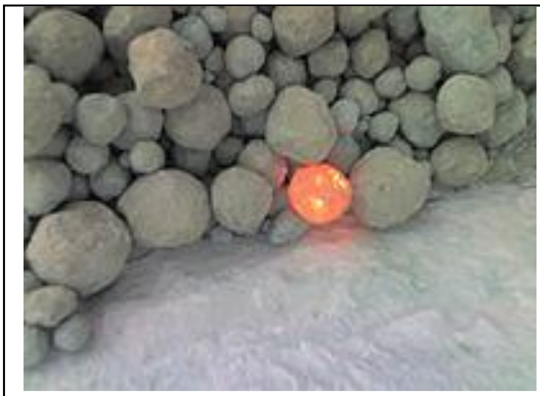
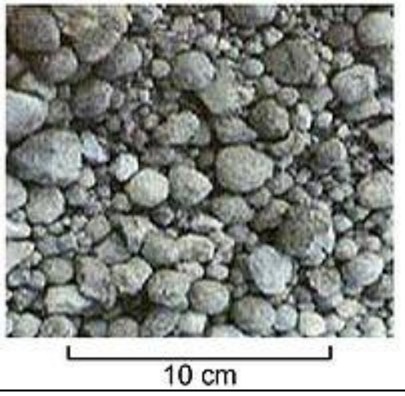
Crane - Climbing formwork : The working platform and the formwork are a unit

- **Climbing formwork (crane – climbing)** - in this type of climbing formwork, the formwork around the structure is displaced upwards with the help of one or more cranes once the hardening of the concrete has proceeded far enough. This may entail lifting the whole section, or be achieved segmentally.

- **Climbing formwork (self – climbing)** - In this type of formwork, the structure elevates itself with the help of mechanic leverage equipment (usually hydraulic) . To do this, it is usually fixed to sacrificial cones or rails emplaced in the previously cast concrete .

- **Gliding formwork** - This type of formwork is similar to the self - climbing type above. However, the climbing process is continuous instead of intermittent, and is usually only interrupted for a very short time (for example to fix the mounting mechanisms to new anchoring points) . The advantage is that it will produce seamless structures, but it requires a continuous, uninterrupted process throughout, with serious potential quality and stability problems if the pour has to be stopped.

Clinker (Cement)

	
Hot clinker	*Typical clinker nodules*

Contents

1 – Introduction :

In the manufacture of Portland cement, **clinker** is lumps or nodules, usually 3 - 25 mm in diameter, produced by sintering limestone and alumino - silicate (clay) during the cement kiln stage.

2 – Uses :

Clinker is ground (usually with the addition of a little gypsum, that is, calcium sulfate dehydrate) to become Portland cement. It may also be combined with other active ingredients or chemical admixtures to produce :

- ground granulated blast furnace slag cement
- pozzolana cement
- silica fume cement

Clinker, if stored in dry conditions, can be kept for several months without appreciable loss of quality. Because of this, and because it can easily be handled by ordinary mineral handling equipment, clinker is traded internationally in large quantities.

Cement manufacturers purchasing clinker grind it as an addition to their own clinker at their cement plants. Manufacturers also ship clinker to grinding plants in areas where cement-making raw materials are not available.

3 - Clinker grinding aids :

Gypsum is added to clinker primarily as an additive preventing the flash settings of cement, but it is also very effective to facilitate the grinding of clinker by preventing agglomeration and coating of the powder at the surface of balls and mill wall.

Organic compounds are also often added as grinding aids to avoid powder agglomeration. Tri ethanol amine (TEA) is commonly used at 0.1 wt. % and is proved to be very effective. Other additives are some times used, such as ethylene glycol , oleic acid , dodecyl - benzene sulfonate, ...

Portland cement clinker is made by heating in a rotary kiln at high temperature a homogeneous mixture of raw materials. The products of the chemical reaction aggregate together as molten minerals at the sintering temperature. The sintering temperature for modern cements is about 1450 °C. Aluminium oxide and iron oxide are present as a flux and contribute little to the cement strength. For special cements, such as Low Heat (LH) and Sulfate Resistant (SR) types, it is necessary to limit the amount of tri calcium aluminate ($3\,CaO \cdot Al_2O_3$) formed. The major raw material for the clinker-making is usually lime stone ($CaCO_3$) mixed with a second material containing clay as source of alumino - silicate. Normally, an impure limestone which contains clay or SiO_2 is used. The $CaCO_3$ content of these lime stones can be as low as 80 %. Second raw materials (materials in the raw mix other than limestone) depend on the purity of the limestone. Some of the second raw materials used are: clay, shale, sand, iron ore, bauxite, fly ash and slag.

Coal

Anthracite coal

Contents

1 – Introduction :

Coal is a combustible black or brownish-black sedimentary rock usually occurring in rock strata in *layers or veins* called **coal beds** or **coal seams**. The harder forms, such as anthracite coal, can be regarded as metamorphic rock because of later exposure to elevated temperature and pressure. Coal is composed primarily of carbon along with variable quantities of other elements, chiefly hydrogen, sulfur, oxygen, and nitrogen . Throughout history, coal has been a useful resource for human consumption. It is primarily burned for the production of electricity and/or heat, and is also used for industrial purposes such as refining metals. A fossil fuel, coal forms when dead plant matter is converted into peat, which in turn is converted into lignite, then anthracite. This involves biological and geological processes that take place over a long period of time.

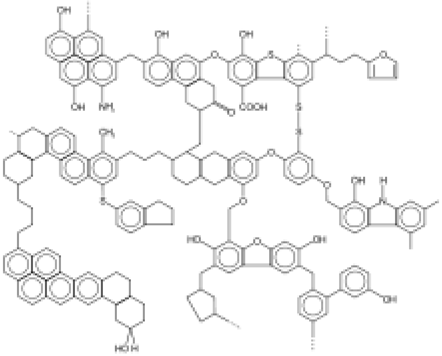
Coal is the largest source of energy for the generation of electricity worldwide, as well as one of the largest worldwide anthropogenic sources of carbon dioxide releases. Gross carbon dioxide emissions from coal usage are slightly more than those from petroleum and about double the amount from natural gas.[2] Coal is extracted from the ground by mining, either underground by shaft mining through the seams or in open pits.

Top hard and brown coal producers in 2010 (2009) were (Mt) :

Country	2010	2009
China	3,162	2,971
United States	997	985
India	571	571
Australia	420	399
Indonesia	336	301
Russia	324	297
South Africa	255	247
Poland	134	135
Kazakhstan	111	101
Colombia	74	73

Bituminous coal

2 – Formation :



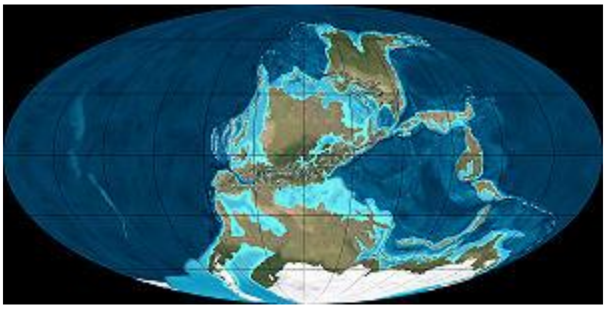
Example chemical structure of coal

About 300 million years ago, the earth had dense forests in low-lying wetland areas. Due to natural processes such as flooding, these forests were buried under the soil. As more and more soil deposited over them, they were compressed. The temperature also rose as they sank deeper and deeper. For the process to continue, the plant matter was protected from biodegradation and oxidization, usually by mud or acidic water. This trapped the carbon in immense peat bogs that are eventually covered and deeply buried by sediments. Under high pressure and high temperature dead vegetation were slowly converted to coal. As coal contains mainly carbon, the conversion of dead vegetation into coal is called carbonization .

The wide shallow seas of the Carboniferous period provided ideal conditions for coal formation, although coal is known from most geological periods. The exception is the coal gap in the Lower Triassic, where coal is rare: presumably a result of the mass extinction which prefaced this era. Coal is known from Precambrian strata, which predate land plants: this coal is presumed to have originated from algal residues.

3 - Types :

Coastal exposure of the Point Aconi Seam (bituminous coal; Pennsylvanian) .



Approximate position of continents toward the end of the Carboniferous Period. The light blue represents shallow seas where many of today's coal deposits are found, as opposed to deeper waters which gave rise to oil-bearing rocks derived from marine species.

As geological processes apply pressure to dead biotic material over time, under suitable conditions it is transformed successively into :

- Peat , considered to be a precursor of coal, has industrial importance as a fuel in some regions, for example, Ireland and Finland. In its dehydrated form, peat is a highly effective absorbent for fuel and oil spills on land and water. It is also used as a conditioner for soil to make it more able to retain and slow release water.
- Lignite or brown coal, is the lowest rank of coal and used almost exclusively as fuel for electric power generation. Jet is a compact form of lignite that is sometimes polished and has been used as an ornamental stone since the Upper Palaeolithic

- Sub - bituminous coal , whose properties range from those of lignite to those of bituminous coal, is used primarily as fuel for steam-electric power generation and is an important source of light aromatic hydrocarbons for the chemical synthesis industry.
- Bituminous coal is dense sedimentary rock, black but sometimes dark brown often with well-defined bands of bright and dull material, used primarily as fuel in steam-electric power generation, with substantial quantities used for heat and power applications in manufacturing and to make coke
- *Steam coal* is a grade between bituminous coal and anthracite, once widely used as a fuel for steam locomotives. In this specialized use it is sometimes known as *sea - coal* in the U.S.[7] Small steam coal (*dry small steam nuts* or DSSN) was used as a fuel for domestic water heating
- Anthracite , the highest rank of coal is a harder, glossy, black coal used primarily for residential and commercial space heating. It may be divided further into metamorphic ally altered bituminous coal and *petrified oil*, as from the deposits in Pennsylvania
- Graphite , technically the highest rank is difficult to ignite and is not commonly used as fuel : it is mostly used in pencils and, when powdered, as a lubricant .

The classification of coal is generally based on the content of volatiles. However, the exact classification varies between countries. According to the German classification, coal is classified as follows :

English Designation	**Volatiles %**	**C Carbon %**	**H Hydrogen %**	**O Oxygen %**	**S Sulfur %**	**Heat content kJ / kg**
Lignite	45-65	60-75	6.0-5.8	34-17	0.5-3	< 28470
Flame coal	40-45	75-82	6.0-5.8	>9.8	~1	< 32870
Gas flame coal	35-40	82-85	5.8-5.6	9.8-7.3	~1	< 33910
Gas coal	28-35	85-87.5	5.6-5.0	7.3-4.5	~1	< 34960
Fat coal	19-28	87.5-89.5	5.0-4.5	4.5-3.2	~1	< 35380
Forge coal	14-19	89.5-90.5	4.5-4.0	3.2-2.8	~1	< 35380
Non baking coal	10-14	90.5-91.5	4.0-3.75	2.8-3.5	~1	35380
Anthracite	7-12	>91.5	<3.75	<2.5	~1	< 35300

The middle six grades in the table represent a progressive transition from the English - language sub-bituminous to bituminous coal, while the last class is an approximate equivalent to anthracite, but more inclusive (the U.S. anthracite has < 6 % volatiles) .

Cannel coal (sometimes called "candle coal"), is a variety of fine-grained, high-rank coal with significant hydrogen content. It consists primarily of "exinite" macerals, now termed "liptinite".

3 – 1 - Hilt's Law :

Hilt's Law is a geological term that states that, in a small area, the deeper the coal, the deeper its rank (grade) . The law holds true if the thermal gradient is entirely vertical , but metamorphism may cause lateral changes of rank, irrespective of depth.

4 - Early uses as fuel :

Further information: History of coal mining

Chinese coal miners in an illustration of the Tiangong Kaiwu encyclopedia, published in 1637

The earliest reference to the use of coal as fuel is from the geological treatise *On stones* (Lap. 16) by the Greek scientist Theophrastus (c. 371 – 287 BC) :

Among the materials that are dug because they are useful, those known as coals are made of earth, and, once set on fire, they burn like charcoal. They are found in Liguria… and in Elis as one approaches Olympia by the mountain road; and they are used by those who work in metals .

Outcrop coal was used in Britain during the Bronze Age (3000 – 2000 BC) , where it has been detected as forming part of the composition of funeral pyres . In Roman Britain, with the exception of two modern fields, "the Romans were exploiting coals in all the major coalfields in England and Wales by the end of the second century AD" . Evidence of trade in coal (dated to about AD 200) has been found at the inland port of Heron bridge , near Chester, and in the Fenlands of East Anglia, where coal from the Midlands was transported via the Car Dyke for use in drying grain.[14] Coal cinders have been found in the hearths of villas and military forts, particularly in Northumberland, dated to around AD 400. In the west of England contemporary writers described the wonder of a permanent brazier of coal on the altar of Minerva at Aquae Sulis (modern day Bath) although in fact easily accessible surface coal from what became the Somerset coalfield was in common use in quite lowly dwellings locally.[15] Evidence of coal's use for iron-working in the city during the Roman period has been found.[16] In Eschweiler, Rhineland, deposits of bituminous coal were used by the Romans for the smelting of iron ore . There is no evidence that the product was of great importance in Britain before the High Middle Ages, after about AD 1000.[17] Mineral coal came to be referred to as "seacoal" in the 13th century; the wharf where the material arrived in London was known as *Seacoal Lane*, so identified in a charter of King Henry III granted in 1253. Initially the name was given because much coal was found on the shore, having fallen from the exposed coal seams on cliffs above or washed out of underwater coal outcrops , but by the time of Henry VIII it was understood to derive from the way it was carried to London by sea . In 1257 – 59 , coal from Newcastle was shipped to London for the smiths and lime - burners building Westminster Abbey. Seacoal Lane and Newcastle Lane where coal was unloaded at wharves along the River Fleet, are still in existence .

These easily accessible sources had largely become exhausted (or could not meet the growing demand) by the 13th century, when underground mining from shafts or adits was developed.[11] The alternative name was "pitcoal ," because it came from mines. It was, however, the development of the Industrial Revolution that led to the large-scale use of coal, as the steam engine took over from the water wheel. In 1700, 5/6 of the world's coal was mined in Britain. Without coal, Britain would have run out of suitable sites for water mills by the 1830s . In 1947, there were some 750,000 miners , but by 2004 this had shrunk to some 5,000 miners working in around 20 collieries

In ancient China, coal was used as fuel by the 4th century AD, but there was little extensive use until the 11th century .

5 - Uses today :

Coal-fired power plants provide 49 % of consumed electricity in the United States. This is the Castle Gate Plant near Helper, Utah.

Coal rail cars

5 – 1 - Coal as fuel :

Further information : Electricity generation , Clean coal technology , Coal electricity , and Global warming

Coal is primarily used as a solid fuel to produce electricity and heat through combustion. World coal consumption was about 6.75 billion short tons in 2006 and is expected to increase 48 % to 9.98 billion short tons by 2030 . China produced 2.38 billion tons in 2006. India produced about 447.3 million tons in 2006. 68.7 % of China's electricity comes from coal. The USA consumes about 14 % of the world total , using 90 % of it for generation of electricity.

When coal is used for electricity generation, it is usually pulverized and then combusted (burned) in a furnace with a boiler.[28] The furnace heat converts boiler water to steam, which is then used to spin turbines which turn generators and create electricity. The thermo dynamic efficiency of this process has been improved over time. Simple cycle steam turbines have topped out with some of the most advanced reaching about 35 % thermodynamic efficiency for the entire process. Increasing the combustion temperature can boost this efficiency even further . Old coal power plants, especially "grandfathered" plants, are significantly less efficient and produce higher levels of waste heat. At least 40 % of the world's electricity comes from coal , and in 2008 approximately 49% of the United States' electricity came from coal . The emergence of the super critical turbine concept envisions running a boiler at extremely high temperatures and pressures with projected efficiencies of 46 % , with further theorized increases in temperature and pressure perhaps resulting in even higher efficiencies.

An experimental way of coal combustion is in a form of coal - water slurry fuel (CWS , which was well-developed in Russia (since the Soviet Union time). CWS significantly reduces emissions saving the heating value of coal. Other ways to use coal are combined heat and power cogeneration and an MHD topping cycle.

The total known deposits recoverable by current technologies, including highly polluting, low energy content types of coal (i.e., lignite , bituminous) , is sufficient for many years . How ever, consumption is increasing and maximal production could be reached within decades .

5 – 2 - Coking coal and use of coke :

Coke oven at a smokeless fuel plant in Wales, United Kingdom

Coke is a solid carbonaceous residue derived from low - ash , low - sulfur bituminous coal from which the volatile constituents are driven off by baking in an oven without oxygen at temperatures as high as 1,000 °C so that the fixed carbon and residual ash are fused together. Metallurgical coke is used as a fuel and as a reducing agent in smelting iron ore in a blast furnace . The coking coal should be low in sulphur and phosphorus so that they do not migrate to the metal. The product is cast iron and is too rich in dissolved carbon, and so must be treated further to make steel.

The coke must be strong enough to resist the weight of overburden in the blast furnace, which is why coking coal is so important in making steel using the conventional route. How ever, the alternative route to is direct reduced iron, where any carbonaceous fuel can be used to make sponge or pelletized iron. Coke from coal is grey, hard, and porous and has a heating value of 24.8 million Btu/ton (29.6 MJ / kg) . Some coke making processes produce valuable by-products that include coal tar , ammonia , light oils , and "coal gas".

Petroleum coke is the solid residue obtained in oil refining, which resembles coke but contains too many impurities to be useful in metallurgical applications.

5 – 3 - Gasification :

Main articles : Coal gasification and Underground coal gasification

Coal gasification can be used to produce syngas, a mixture of carbon monoxide (CO) and hydrogen (H_2) gas. This syngas can then be converted into transportation fuels like gasoline and diesel through the Fischer-Tropsch process. This technology is currently used by the Sasol chemical company of South Africa to make gasoline from coal and natural gas. Alternatively, the hydrogen obtained from gasification can be used for various purposes such as powering a hydrogen economy, making ammonia, or upgrading fossil fuels.

During gasification, the coal is mixed with oxygen and steam (water vapor) while also being heated and pressurized. During the reaction, oxygen and water molecules oxidize the coal into carbon monoxide (CO) while also releasing hydrogen (H_2) gas. This process has been conducted in both underground coal mines and in coal refineries.

$$(\text{ Coal }) + O_2 + H_2O \rightarrow H_2 + CO$$

If the refiner wants to produce gasoline, the syngas is collected at this state and routed into a Fischer-Tropsch reaction. If hydrogen is the desired end-product, however, the syngas is fed into the water gas shift reaction where more hydrogen is liberated.

$$CO + H_2O \rightarrow CO_2 + H_2$$

High prices of oil and natural gas are leading to increased interest in "BTU Conversion" technologies such as gasification, methanation and liquefaction. The Synthetic Fuels Corporation was a U.S. government-funded corporation established in 1980 to create a market for alternatives to imported fossil fuels (such as coal gasification). The corporation was discontinued in 1985 . In the past, coal was converted to make coal gas, which was piped to customers to burn for illumination , heating, and cooking. At present, the safer natural gas is used instead.

5 – 4 - Liquefaction :

Coal can also be converted into liquid fuels such as gasoline or diesel by several different processes. In the direct liquefaction processes, the coal is either hydrogenated or carbonized. Hydrogenation processes are the Bergius process , the SRC- I and SRC-II (Solvent Refined Coal) processes and the NUS Corporation hydrogenation process . In the process of low - temperature carbonization, coal is coked at temperatures between 360 °C and 750 °C . These temperatures optimize the production of coal tars richer in lighter hydrocarbons than normal coal tar. The coal tar is then further processed into fuels. Alternatively, coal can be converted into a gas first, and then into a liquid, by using the Fischer-Tropsch process. An overview of coal liquefaction and its future potential is available .

Coal liquefaction methods involve carbon dioxide (CO_2) emissions in the conversion process. If coal liquefaction is done without employing either carbon capture and storage technologies or biomass blending, the result is lifecycle greenhouse gas footprints that are generally greater than those released in the extraction and refinement of liquid fuel production from crude oil. If CCS technologies are employed, reductions of 5 - 12 % can be achieved in CTL plants and up to a 75 % reduction is achievable when co-gasifying coal with commercially demonstrated levels of biomass (30 % biomass by weight) in CBTL plants . For most future synthetic fuel projects, Carbon dioxide sequestration is proposed to avoid releasing it into the atmosphere. Sequestration will, however, add to the cost of production. Currently, all US and at least one Chinese synthetic fuel projects , include sequestration in their process designs.

5 – 5 - Refined coal :

Refined coal is the product of a coal-upgrading technology that removes moisture and certain pollutants from lower-rank coals such as sub - bituminous and lignite (brown) coals. It is one form of several pre - combustion treatments and processes for coal that alter coal's characteristics before it is burned. The goals of pre - combustion coal technologies are to increase efficiency and reduce emissions when the coal is burned. Depending on the situation, pre - combustion technology can be used in place of or as a supplement to post - combustion technologies to control emissions from coal-fueled boilers.

5 – 6 - Industrial processes :

Finely ground bituminous coal, known in this application as *sea coal*, is a constituent of foundry sand. While the molten metal is in the mould the coal burns slowly, releasing reducing gases at pressure and so preventing the metal from penetrating the pores of the sand. It is also contained in *mould wash*, a paste or liquid with the same function applied to the mould before casting . Sea coal can be mixed with the clay lining (the "bod") used for the bottom of a cupola furnace. When heated the coal decomposes and the bod becomes slightly friable, easing the process of breaking open holes for tapping the molten metal.

6 - Cultural usage :

Coal is the official state mineral of Kentucky (even though coal is not a mineral) and the official state rock of Utah. Both U.S. states have a historic link to coal mining.

Some cultures uphold that children who misbehave will receive only a lump of coal from Santa Claus for Christmas in their stockings instead of presents.

It is also customary and lucky in Scotland and the North of England to give coal as a gift on New Year's Day. It happens as part of First - Footing and represents warmth for the year to come.

7 - Coal as a traded commodity :

In North America, Central Appalachian coal futures contracts are currently traded on the New York Mercantile Exchange (trading symbol *QL*). The trading unit is 1,500 short tons per contract , and is quoted in U.S. dollars and cents per ton. Since coal is the principal fuel for generating electricity in the United States, coal futures contracts provide coal producers and the electric power industry an important tool for hedging and risk management .

In addition to the NYMEX contract , the Inter continental Exchange (ICE) has European (Rotterdam) and South African

(Richards Bay) coal futures available for trading. The trading unit for these contracts is 5,000 tones , and are also quoted in U.S. dollars and cents per ton .

The price of coal increased from around $30.00 per short ton in 2000 to around $ 150.00 per short ton as of September 2008. As of October 2008, the price per short ton had declined to $111.50. Prices further declined to $ 71.25 as of October 2010 .

8 - Environmental effects :

Aerial photograph of Kingston Fossil Plant coal fly ash slurry spill site taken the day after the event

There are a number of adverse health and environmental effects of coal burning especially in power stations , and of coal mining. These effects include:

- Coal - fired power plants shortened nearly 24,000 lives a year in the United States, including 2,800 from lung cancer .
- Generation of hundreds of millions of tons of waste products , including fly ash , bottom ash , flue - gas

desulfurization sludge, that contain mercury, uranium, thorium, arsenic, and other heavy metals

- Acid rain from high sulfur coal
- Interference with groundwater and water table levels
- Contamination of land and waterways and destruction of homes from fly ash spills such as Kingston Fossil Plant coal fly ash slurry spill
- Impact of water use on flows of rivers and consequential impact on other land-uses
- Dust nuisance
- Subsidence above tunnels, sometimes damaging infrastructure
- Uncontrollable underground fires which may burn for decades or centuries.
- Coal-fired power plants without effective fly ash capture are one of the largest sources of human-caused background radiation exposure
- Coal-fired power plants emit mercury, selenium, and arsenic which are harmful to human health and the environment
- Release of carbon dioxide, a green house gas, which causes climate change and global warming according to the IPCC and the EPA. Coal is the largest contributor to the human-made increase of CO_2 in the air

9 - Economic aspects :

Coal liquefaction is one of the backstop technologies that could potentially limit escalation of oil prices and mitigate the effects of transportation energy shortage that will occur under peak oil. This is contingent on liquefaction production capacity becoming large enough to satiate the very large and growing demand for petroleum. Estimates of the cost of producing liquid fuels from coal suggest that domestic U.S. production of fuel from coal becomes cost-competitive with oil priced at around $ 35 per barrel , with the $ 35 being the break - even cost. With oil prices as low as around $ 40 per barrel in the U.S. as of December 2008, liquid coal lost some of its economic allure in the U.S., but will probably be re-vitalized, similar to oil sand projects, with an oil price around $ 70 per barrel.

In China, due to an increasing need for liquid energy in the transportation sector, coal liquefaction projects were given high priority even during periods of oil prices below $40 per barrel . This is probably because China prefers not to be dependent on foreign oil, instead utilizing its enormous domestic coal reserves. As oil prices were increasing during the first half of 2009, the coal liquefaction projects in China were again boosted, and these projects are profitable with an oil barrel price of $ 40 .

China is by far the largest producer of coal in the world.[55] It has now become the world's largest energy consumer but relies on coal to supply about 70 % of its energy needs . An estimated 5 million people work in China's coal-mining industry.

Among commercially mature technologies, advantages for indirect coal liquefaction over direct coal liquefaction are reported by Williams and Larson (2003) .

10 - Energy density :

The energy density of coal, i.e. its heating value , is roughly 24 mega joules per kilogram .

The energy density of coal can also be expressed in kilowatt-hours, the units that electricity is most commonly sold in, per units of mass to estimate how much coal is required to power electrical appliances. One kilowatt-hour is 3.6 MJ, so the energy density of coal is 6.67 kW· h / kg . The typical thermodynamic efficiency of coal power plants is about 30 % , so of the 6.67 kW · h of energy per kilogram of coal, 30 % of that — 2.0 kW · h / kg — can successfully be turned into electricity; the rest is waste heat. So coal power plants obtain approximately 2.0 kW · h per kilogram of burned coal.

As an example, running one 100 - watt light bulb for one year requires 876 kW · h (100 W × 24 h / day × 365 day / year = 876000 W · h = 876 kW ·h). Converting this power usage into physical coal consumption:

$$\frac{876\ \mathrm{kW}\cdot\mathrm{h}}{2.0\ \mathrm{kW}\cdot\mathrm{h/kg}} = 438\ \mathrm{kg\ of\ coal} = 966\ \mathrm{pounds\ of\ coal}$$

For a coal power plant with a 40 % efficiency, it takes 325 kg of coal to power a 100 W light bulb for one year . One should also take into account transmission and distribution losses caused by resistance and heating in the power lines, which is in the order of 5 – 10 % , depending on distance from the power station and other factors.

11 - Carbon intensity :

Commercial coal has a carbon content of at least 70 %. Coal with a heating value of 6.67 kW h per kilo gram as quoted above has a carbon content of roughly 80 %, which is

$$\frac{0.8\ \mathrm{kg}}{12\cdot\mathrm{kg/kmol}} = \frac{2}{30}\ \mathrm{kmol}$$

where 1 mol equals to N_A (*Avogadro Number*) atoms.

Carbon combines with oxygen in the atmosphere during combustion, producing carbon dioxide, with an atomic weight of (12 + 16 × 2 = 44 kg / k mol). The CO_2 released to air for each kilogram of incinerated coal is there fore

$$\frac{2}{30}\ \mathrm{kmol}\cdot\frac{44\ \mathrm{kg}}{\mathrm{kmol}} = \frac{88}{30}\ \mathrm{kg} \approx 2.93\ \mathrm{kg}.$$

This can be used to calculate an emission factor for CO_2 from the use of coal power. Since the useful energy output of coal is about 31 % of the 6.67 kWh / kg (coal) , the burning of 1 kg of coal produces about 2 kWh of electrical energy. Since 1 kg coal emits 2.93 kg CO_2, the direct CO_2 emissions from coal power are 1.47 kg / kW h , or about 0.407 kg / MJ.

The U.S. Energy Information Agency's 1999 report on CO_2 emissions for energy generation , quotes a lower emission factor of 0.963 kg CO_2 / kW h for coal power. The same source gives a factor for oil power in the U.S. of 0.881 kg CO_2 / kW h , while natural gas has 0.569 kg CO_2 / kW h . Estimates for specific emission from nuclear power, hydro, and wind energy vary, but are about 100 times lower.

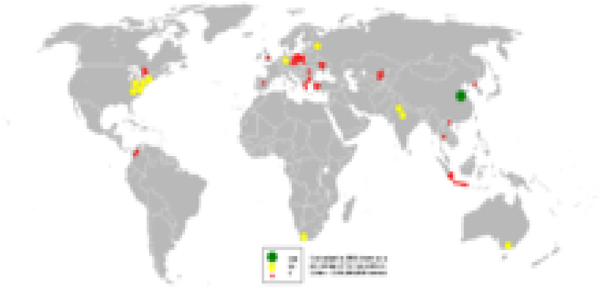
12 - Under ground fires :

There are thousands of coal fires burning around the world . Those burning underground can be difficult to locate and many cannot be extinguished. Fires can cause the ground above to subside, their combustion gases are dangerous to life, and breaking out to the surface can initiate surface wild fires. Coal seams can be set on fire by spontaneous combustion or contact with a mine fire or surface fire. Lightning strikes are an important source of ignition, the coal continues to burn slowly back into the seam until oxygen (air) can no longer reach the flame front. A grass fire in a coal area can set dozens of coal seams on fire . Coal fires in China burn an estimated 120 million tons of coal a year, emitting 360 million metric tons of CO_2, amounting to 2 - 3 % of the annual worldwide production of CO_2 from fossil fuels . In Centralia, Pennsylvania (a borough located in the Coal Region of the United States) , an exposed vein of coal ignited in 1962 due to a trash fire in the borough landfill, located in an abandoned anthracite strip mine pit. Attempts to extinguish the fire were unsuccessful, and it continues to burn underground to this day. The Australian Burning Mountain was originally believed to be a volcano, but the smoke and ash comes from a coal fire that has been burning for some 6,000 years .

At Kuh i Malik in Yagnob Valley , Tajikistan, coal deposits have been burning for thousands of years, creating vast underground labyrinths full of unique minerals, some of them very beautiful. Local people once used this method to mine ammoniac. This place has been well-known since the time of Herodotus, but European geographers misinterpreted the Ancient Greek descriptions as the evidence of active volcanism in Turkestan (up to the 19th century, when the Russian army invaded the area) .

The reddish siltstone rock that caps many ridges and buttes in the Powder River Basin (Wyoming) , and in western North Dakota is called **porcelanite** , which also may resemble the coal burning waste "clinker" or volcanic "scoria" . Clinker is rock that has been fused by the natural burning of coal. In the Powder River Basin approximately 27 to 54 billion tons of coal burned within the past three million years . Wild coal fires in the area were reported by the Lewis and Clark Expedition as well as explorers and settlers in the area .

13 - Production trends :

	
A coal mine in Wyoming, United States. The United States has the world's largest coal reserves.	*Coal output in 2005*

In 2006, China was the top producer of coal with 38% share followed by the USA and India, according to the British Geological Survey.

13 – 1 - World coal reserves :

The 930 billion short tons of recoverable coal reserves estimated by the Energy Information Administration are equal to about 4,116 BBOE (billion barrels of oil equivalent) . The amount of coal burned during 2007 was estimated at 7.075 billion short tons, or 133.179 quadrillion BTU's . This is an average of 18.8 million BTU per short ton. In terms of heat content, this is about 57,000,000 barrels (9,100,000 m^3) of oil equivalent per day. By comparison in 2007, natural gas provided 51,000,000 barrels (8,100,000 m^3) of oil equivalent per day, while oil provided 85,800,000 barrels (13,640,000 m^3) per day.

BP, in its 2007 report, estimated at 2006 end that there were several billion tons of *proven* coal reserves worldwide, or 147 years reserves – to - production ratio. This figure only includes reserves classified as "proven"; exploration drilling programs by mining companies, particularly in under-explored areas, are continually providing new reserves. In many cases, companies are aware of coal deposits that have not been sufficiently drilled to qualify as "proven". However, some nations haven't updated their information and assume reserves remain at the same levels even with withdrawals. Speculative projections predict that global peak coal production may occur sometime around 2025 at 30 percent above current production, depending on future coal production rates .

Continental United States coal regions

Of the three fossil fuels, coal has the most widely distributed reserves; coal is mined in over 100 countries, and on all continents except Antarctica. The largest reserves are found in the USA, Russia, China, India and Australia. Note the table below .

Proved recoverable coal reserves at end - 2008

Country	Bituminous & Anthracite	Sub Bituminous	Lignite	TOTAL	Percentage of World Total
United States	108,501	98,618	30,176	237,295	22.6
Russia	49,088	97,472	10,450	157,010	14.4
China	62,200	33,700	18,600	114,500	12.6
Australia	37,100	2,100	37,200	76,500	8.9
India	56,100	0	4,500	60,600	7.0
Germany	99	0	40,600	40,699	4.7

Ukraine	15,351	16,577	1,945	33,873	3.9
Kazakhstan	21,500	0	12,100	33,600	3.9
South Africa	30,156	0	0	30,156	3.5
Serbia	9	361	13,400	13,770	1.6
Colombia	6,366	380	0	6,746	0.8
Canada	3,474	872	2,236	6,528	0.8
Poland	4,338	0	1,371	5,709	0.7
Indonesia	1,520	2,904	1,105	5,529	0.6
Brazil	0	4,559	0	4,559	0.5
Greece	0	0	3,020	3,020	0.4
Bosnia and Herzegovina	484	0	2,369	2,853	0.3
Mongolia	1,170	0	1,350	2,520	0.3
Bulgaria	2	190	2,174	2,366	0.3
Pakistan	0	166	1,904	2,070	0.3
Turkey	529	0	1,814	2,343	0.3
Uzbekistan	47	0	1,853	1,900	0.2
Hungary	13	439	1,208	1,660	0.2
Thailand	0	0	1,239	1,239	0.1
Mexico	860	300	51	1,211	0.1
Iran	1,203	0	0	1,203	0.1
Czech Republic	192	0	908	1,100	0.1
Kyrgyzstan	0	0	812	812	0.1
Albania	0	0	794	794	0.1
North Korea	300	300	0	600	0.1
New Zealand	33	205	333 -7,000	571 - 15,000	0.1
Spain	200	300	30	530	0.1
Laos	4	0	499	503	0.1
Zimbabwe	502	0	0	502	0.1
Argentina	0	0	500	500	0.1
All others	3,421	1,346	846	5,613	0.7
Total world	404,762	260,789	195,387	860,938	100

13 - 2 - Major coal producers :

The reserve life is an estimate based only on current production levels and proved reserves level for the countries shown, and makes no assumptions of future production or even current production trends. Countries with annual production higher than 100 million tonnes are shown. For comparison, data for the European Union is also shown. Shares are based on data expressed in tonnes oil equivalent.

Production of Coal by Country and year (million tones)

Country	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Share**	**Reserve Life (years)**
China	1835	2122	2349	2528	2691	2802.0	2973.0	3240	48 %	35
USA	972.3	1008	1026	1054	1040	1063.0	975.2	984.6	15 %	241
India	375.4	407.7	428.4	449.2	478.4	515.9	556.0	569.9	5.8 %	106
EU	637.2	627.6	607.4	595.1	592.3	563.6	538.4	535.7	4.2 %	105
Australia	350.4	364.3	375.4	382.2	392.7	399.2	413.2	423.9	6.3 %	180
Russia	276.7	281.7	298.3	309.9	313.5	328.6	301.3	316.9	4.7 %	495
Indonesia	114.3	132.4	152.7	193.8	216.9	240.2	256.2	305.9	5.0 %	18
South Africa	237.9	243.4	244.4	244.8	247.7	252.6	250.6	253.8	3.8 %	119
Germany	204.9	207.8	202.8	197.1	201.9	192.4	183.7	182.3	1.2 %	223
Poland	163.8	162.4	159.5	156.1	145.9	144.0	135.2	133.2	1.5 %	43
Kazakhstan	84.9	86.9	86.6	96.2	97.8	111.1	100.9	110.8	1.5 %	303
Total World	**5,301**	**5,716**	**6,035**	**6,342**	**6,573**	**6,795**	**6,880**	**7,273**	**100 %**	**118**

13 - 3 - Major coal exporters :

Countries with annual export higher than 10 million tones are shown .

Exports of Coal by Country and year (million short tons)

Country	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Share %**
Australia	238.1	247.6	255.0	255.0	268.5	278.0	288.5	26.5
Indonesia	107.8	131.4	142.0	192.2	221.9	228.2	261.4	24.0
Russia	41.0	55.7	98.6	103.4	112.2	115.4	130.9	12.0
Colombia	50.4	56.4	59.2	68.3	74.5	74.7	75.7	6.9%

South Africa	78.7	74.9	78.8	75.8	72.6	68.2	73.8	6.8%
USA	43.0	48.0	51.7	51.2	60.6	83.5	60.4	5.5%
China	103.4	95.5	93.1	85.6	75.4	68.8	38.4	3.5%
Canada	27.7	28.8	31.2	31.2	33.4	36.5	31.9	2.9%
Vietnam	6.9	11.7	19.8	23.5	35.1	21.3	28.2	2.6%
Kazakhstan	30.3	27.4	28.3	30.5	32.8	47.6	25.7	2.4%
Poland	28.0	27.5	26.5	25.4	20.1	16.1	14.6	1.3%
Total	**713.9**	**764.0**	**936.0**	**1,000.6**	**1,073.4**	**1,087.3**	**1,090.8**	**100%**

13 - 4 - Major coal importers :

Countries with annual import higher than 30 million tonnes are shown .

Imports of Coal by Country and year (million short tons)

Country	**2006**	**2007**	**2008**	**2009**	**Share**
Japan	199.7	209.0	206.0	182.1	17.5%
China	42.0	56.2	44.5	151.9	14.5%
South Korea	84.1	94.1	107.1	109.9	10.6%
India	52.7	29.6	70.9	76.7	7.4%
Taiwan	69.1	72.5	70.9	64.6	6.2%
Germany	50.6	56.2	55.7	45.9	4.4%
United Kingdom	56.8	48.9	49.2	42.2	4.1%
Total	**991.8**	**1,056.5**	**1,063.2**	**1,039.8**	**100%**

Concrete

Outer view of the Roman Pantheon,
still the largest unreinforced solid concrete dome.

A modern building: Boston City Hall (completed 1968) is constructed largely of concrete, both precast and poured in place.

Opus caementicium lying bare on a tomb near Rome. In contrast to modern concrete structures, the concrete walls of Roman buildings were covered, usually with brick or stone.

Contents

1 – Introduction :

Concrete is a composite construction material composed primarily of aggregate, cement and water. There are many formulations that have varied properties. The aggregate is generally a coarse gravel or crushed rocks such as limestone, or granite, along with a fine aggregate such as sand. The cement, commonly Portland cement, and other cementitious materials such as fly ash and slag cement, serve as a binder for the aggregate. Various chemical admixtures are also added to achieve varied properties. Water is then mixed with this dry composite which enables it to be shaped (typically poured) and then solidified and hardened into rock-hard strength through a chemical process known as hydration. The water reacts with the cement which bonds the other components together, eventually creating a robust stone-like material. Concrete has relatively high compressive strength, but much lower tensile strength. For this reason is usually reinforced with materials that are strong in tension (often steel). Concrete can be damaged by many processes, such as the freezing of trapped water.

Concrete is widely used for making architectural structures, foundations, brick/block walls, pavements, bridges / over passes, motor ways / roads, runways, parking structures, dams, pools / reservoirs , pipes, footings for gates, fences and poles and even boats. Famous concrete structures include the Burj Khalifa (world's tallest building) , the Hoover Dam, the Panama Canal and the Roman Pantheon . Concrete technology was known by the Ancient Romans and was widely used within the Roman Empire. After the Empire passed, use of concrete became scarce until the technology was re-pioneered in the mid-18th century.

The environmental impact of concrete is a complex mixture of not entirely negative effects; while concrete is a major contributor to greenhouse gas emissions, recycling of concrete is increasingly common in structures that have reached the end of their life. Structures made of concrete can have a long service life. As concrete has a high thermal mass and very low permeability, it can make for energy efficient housing.

Burj Khalifa (world's tallest building)

2 - History :

The word concrete comes from the Latin word "concretus" (meaning compact or condensed) , the perfect passive participle of "concrescere ", from "con -" (together) and "crescere" (to grow) .

Concrete was used for construction in many ancient structures.

During the Roman Empire, Roman concrete (or *opus caementicium*) was made from quicklime, pozzolana and an aggregate of pumice. Its widespread use in many Roman structures, a key event in the history of architecture termed the Roman Architectural Revolution, freed Roman construction from the restrictions of stone and brick material and allowed for revolutionary new designs in terms of both structural complexity and dimension.

Hadrian's Pantheon in Rome is an example of Roman concrete construction.

Concrete, as the Romans knew it , was a new and revolutionary material. Laid in the shape of arches, vaults and domes, it quickly hardened into a rigid mass, free from many of the internal thrusts and strains that troubled the builders of similar structures in stone or brick.

Modern tests show that *opus caementicium* had as much compressive strength as modern Portland - cement concrete (ca. 200 kg / cm^2) . However, due to the absence of steel reinforcement, its tensile strength was far lower and its mode of application was also different :

Modern structural concrete differs from Roman concrete in two important details. First, its mix consistency is fluid and homogeneous, allowing it to be poured into forms rather than requiring hand-layering together with the placement of aggregate, which, in Roman practice, often consisted of rubble. Second, integral reinforcing steel gives modern concrete assemblies great strength in tension, whereas Roman concrete could depend only upon the strength of the concrete bonding to resist tension .

The wide spread use of concrete in many Roman structures has ensured that many survive to the present day. The Baths of Caracalla in Rome are just one example. Many Roman aqueducts and bridges have masonry cladding on a concrete core, as does the dome of the Pantheon.

Some have stated that the secret of concrete was lost for 13 centuries until 1756, when the British engineer John Smeaton pioneered the use of hydraulic lime in concrete, using pebbles and powdered brick as aggregate. However, the Canal du Midi was built using concrete in 1670. Like wise there are concrete structures in Finland that date back to the 16th century. Portland cement was first used in concrete in the early 1840s .

2 – 1 - Additives :

Concrete additives have been used since Roman and Egyptian times, when it was discovered that adding volcanic ash to the mix allowed it to set under water. Similarly, the Romans knew that adding horse hair made concrete less liable to crack while it hardened and adding blood made it more frost - resistant .

In modern times, researchers have experimented with the addition of other materials to create concrete with improved properties, such as higher strength or electrical conductivity.

3 - Composition :

There are many types of concrete available, created by varying the proportions of the main ingredients below. In this way or by substitution for the cementitious and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties.

Recently the use of recycled materials as concrete ingredients has been gaining popularity because of increasingly stringent environmental legislation. The most conspicuous of these is fly ash, a by-product of coal - fired power plants. This use reduces the amount of quarrying and landfill space required as the ash acts as a cement replacement thus reducing the amount of cement required.

The *mix design* depends on the type of structure being built, how the concrete will be mixed and delivered and how it will be placed to form this structure.

3 – 1 - Cement :

Portland cement is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar and plaster. English masonry worker Joseph Aspdin patented Portland cement in 1824; it was named because of its similarity in color to Portland limestone, quarried from the English Isle of Portland and used extensively in London architecture. It consists of a mixture of oxides of calcium, silicon and aluminium. Portland cement and similar materials are made by heating limestone (a source of calcium) with clay and grinding this product (called *clinker*) with a source of sulfate (most commonly gypsum) .

In recent years, alternatives have been developed to help replace cement. Products such as PLC (Portland Lime stone Cement) , which incorporate limestone into the mix, are being tested. This is due to cement production being one of the largest producers of global green house gas emissions.

3 – 2 - Water :

Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it and allows it to flow more freely.

Less water in the cement paste will yield a stronger, more durable concrete; more water will give a freer - flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure.

Hydration involves many different reactions, often occurring at the same time. As the reactions proceed, the products of the cement hydration process gradually bond together the individual sand and gravel particles and other components of the concrete, to form a solid mass.

Reaction :

Cement chemist notation : $C_3S + H \rightarrow C\text{-}S\text{-}H + CH$
Standard notation : $Ca_3SiO_5 + H_2O \rightarrow$
$(CaO) \cdot (SiO_2) \cdot (H_2O) (gel) + Ca (OH)_2$
Balanced : $2Ca_3SiO_5 + 7H_2O \rightarrow$
$3(CaO) \cdot 2 (SiO_2) \cdot 4 (H_2O) (gel) + 3Ca (OH)_2$

3 – 3 - Aggregates :

Fine and coarse aggregates make up the bulk of a concrete mixture. Sand, natural gravel and crushed stone are used mainly for this purpose. Recycled aggregates (from construction, demolition and excavation waste) are increasingly used as partial replacements of natural aggregates, while a number of manufactured aggregates, including air - cooled blast furnace slag and bottom ash are also permitted.

Decorative stones such as quartzite, small river stones or crushed glass are sometimes added to the surface of concrete for a decorative "exposed aggregate" finish, popular among landscape designers.

The presence of aggregate greatly increases the robustness of concrete above that of cement, which otherwise is a brittle material and thus concrete is a true composite material . Redistribution of aggregates after compaction often creates in homogeneity due to the influence of vibration. This can lead to strength gradients.

3 – 4 - Reinforcement

Installing rebar in a floor slab during a concrete pour.

Concrete is strong in compression, as the aggregate efficiently carries the compression load. However, it is weak in tension as the cement holding the aggregate in place can crack, allowing the structure to fail. Reinforced concrete solves these problems by adding either steel reinforcing bars, steel fibers, glass fiber, or plastic fiber to carry tensile loads. Thereafter the concrete is reinforced to withstand the tensile loads upon it.

3 – 5 - Chemical admixtures :

Chemical admixtures are materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes. In normal use, admixture dosages are less than 5% by mass of cement and are added to the concrete at the time of batching/mixing . The common types of admixtures are as follows.

- Accelerators speed up the hydration (hardening) of the concrete. Typical materials used are $CaCl_2$, $Ca(NO_3)_2$ and $NaNO_3$. How ever, use of chlorides may cause corrosion in steel reinforcing and is prohibited in some countries, so that nitrates may be favored.
- Retarders slow the hydration of concrete and are used in large or difficult pours where partial setting before the pour is complete is undesirable. Typical polyol retarders are

sugar, sucrose, sodium gluconate, glucose, citric acid, and tartaric acid.

- Air entrainments add and entrain tiny air bubbles in the concrete, which will reduce damage during freeze - thaw cycles, thereby increasing the concrete's durability. However, entrained air entails a trade off with strength, as each 1 % of air may result in 5 % decrease in compressive strength.
- Plasticizers increase the workability of plastic or "fresh" concrete, allowing it be placed more easily, with less consolidating effort. A typical plasticizer is lignosulfonate. Plasticizers can be used to reduce the water content of a concrete while maintaining workability and are sometimes called *water-reducers* due to this use. Such treatment improves its strength and durability characteristics. Superplasticizers (also called *high-range water-reducers*) are a class of plasticizers that have fewer deleterious effects and can be used to increase workability more than is practical with traditional plasticizers. Compounds used as super plasticizers include sulfonated naphthalene formaldehyde condensate, sulfonated melamine formaldehyde condensate, acetone formaldehyde condensate and poly carboxylate ethers .
- Pigments can be used to change the color of concrete, for aesthetics.
- Corrosion inhibitors are used to minimize the corrosion of steel and steel bars in concrete.
- Bonding agents are used to create a bond between old and new concrete (typically a type of polymer) .
- Pumping aids improve pump ability, thicken the paste and reduce separation and bleeding.

Blocks of concrete in Belo Horizonte, Brazil.

3 – 6 - Mineral admixtures and blended cements :

There are inorganic materials that also have pozzolanic or latent hydraulic properties. These very fine - grained materials are added to the concrete mix to improve the properties of concrete (mineral admixtures) , or as a replacement for Portland cement (blended cements) .

- Fly ash : A by-product of coal-fired electric generating plants, it is used to partially replace Portland cement (by up to 60 % by mass) . The properties of fly ash depend on the type of coal burnt. In general, siliceous fly ash is pozzolanic, while calcareous fly ash has latent hydraulic properties .
- Ground granulated blast furnace slag (GGBFS or GGBS): A by - product of steel production is used to partially replace Portland cement (by up to 80 % by mass) . It has latent hydraulic properties .
- Silica fume : A by - product of the production of silicon and ferrosilicon alloys. Silica fume is similar to fly ash, but has a particle size 100 times smaller. This results in a higher surface to volume ratio and a much faster pozzolanic reaction. Silica fume is used to increase strength and durability of concrete, but generally requires the use of super plasticizers for workability.
- High reactivity Meta kaolin (HRM): Meta kaolin produces concrete with strength and durability similar to concrete made with silica fume. While silica fume is usually dark gray or black in color, high - reactivity meta kaolin is usually bright white in color, making it the preferred choice for architectural concrete where appearance is important.

4 - Concrete production :

Concrete plant facility (background) with concrete delivery trucks.

The processes used vary dramatically, from hand tools to heavy industry, but result in the concrete being placed where it cures into a final form. Wide range of technological factors may occur during production of concrete elements and their influence to basic characteristics may vary .

When initially mixed together, Portland cement and water rapidly form a gel , formed of tangled chains of interlocking crystals. These continue to react over time, with the initially fluid gel often aiding in placement by improving workability. As the concrete sets, the chains of crystals join and form a rigid structure, gluing the aggregate particles in place. During curing, more of the cement reacts with the residual water (hydration) .

This curing process develops physical and chemical properties. Among these qualities are mechanical strength, low moisture permeability and chemical and volumetric stability.

4 – 1 - Mixing concrete :

Thorough mixing is essential for the production of uniform, high quality concrete. For this reason equipment and methods should be capable of effectively mixing concrete materials containing the largest specified aggregate to produce *uniform mixtures* of the lowest slump practical for the work.

Separate paste mixing has shown that the mixing of cement and water into a paste before combining these materials with aggregates can increase the compressive strength of the resulting concrete . The paste is generally mixed in a *high - speed*, shear - type mixer at a w/cm (water to cement ratio) of 0.30 to 0.45 by mass. The cement paste premix may include admixtures such as accelerators or retarders, super plasticizers, pigments, or silica fume. The premixed paste is then blended with aggregates and any remaining batch water and final mixing is completed in conventional concrete mixing equipment .

High - energy mixed (HEM) concrete is produced by means of high-speed mixing of cement, water and sand with net specific energy consumption of at least 5 kilojoules per kilogram of the mix. A plasticizer or a super plasticizer is then added to the activated mixture, which can later be mixed with aggregates in a conventional concrete mixer. In this process, sand provides dissipation of energy and creates high-shear conditions on the surface of cement particles. This results in the full volume of water interacting with cement. The liquid activated mixture can be used by itself or foamed (expanded) for lightweight concrete . HEM concrete hardens in low and subzero temperature conditions and possesses an increased volume of gel, which drastically reduces capillarity in solid and porous materials.

4 – 2 - Work ability :

Pouring and smoothing out concrete at Palisades Park in Washington

Work ability is the ability of a fresh (plastic) concrete mix to fill the form/mold properly with the desired work (vibration) and without reducing the concrete's quality. Work ability depends on water content, aggregate (shape and size distribution), cementitious content and age (level of hydration) and can be modified by adding chemical admixtures, like super plasticizer. Raising the water content or adding chemical admixtures will increase concrete workability. Excessive water will lead to increased bleeding (surface water) and/or segregation of aggregates (when the cement and aggregates start to separate) , with the resulting concrete having reduced quality. The use of an aggregate with an undesirable gradation can result in a very harsh mix design with a very low slump, which cannot be readily made more workable by addition of reasonable amounts of water.

Workability can be measured by the concrete slump test, a simplistic measure of the plasticity of a fresh batch of concrete following the ASTM C 143 or EN 12350 - 2 test standards. Slump is normally measured by filling an "Abrams cone" with a sample from a fresh batch of concrete. The cone is placed with the wide end down onto a level, non-absorptive surface. It is then filled in three layers of equal volume, with each layer being tamped with a steel rod in order to consolidate the layer. When the cone is carefully lifted off, the enclosed material will slump a certain amount due to gravity. A relatively dry sample will slump very little, having a slump value of one or two inches (25 or 50 mm) . A relatively wet concrete sample may slump as much as eight inches. Workability can also be measured by using the flow table test .

Slump can be increased by addition of chemical admixtures such as plasticizer or super plasticizer without changing the water - cement ratio . Some other admixtures, especially air - entraining admixture, can increase the slump of a mix.

High-flow concrete, like self - consolidating concrete , is tested by other flow-measuring methods. One of these methods includes placing the cone on the narrow end and observing how the mix flows through the cone while it is gradually lifted . After mixing , concrete is a fluid and can be pumped to the location where needed.

4 – 3 - Curing :

A concrete slab pounded while curing.

In all but the least critical applications, care needs to be taken to properly *cure* concrete, to achieve best strength and hardness. This happens after the concrete has been placed. Cement requires a moist, controlled environment to gain strength and harden fully. The cement paste hardens over time, initially setting and becoming rigid though very weak and gaining in strength in the weeks following. In around 4 weeks, typically over 90% of the final strength is reached, though strengthening may continue for decades . The conversion of calcium hydroxide in the concrete into calcium carbonate from absorption of CO_2 over several decades further strengthen the concrete and making it more resilient to damage. However, this reaction, called carbonation, lowers the pH of the cement pore solution and can cause the reinforcement bars to corrode.

Hydration and hardening of concrete during the first three days is critical. Abnormally fast drying and shrinkage due to factors such as evaporation from wind during placement may lead to increased tensile stresses at a time when it has not yet gained sufficient strength, resulting in greater shrinkage cracking. The early strength of the concrete can be increased if it is kept damp during the curing process. Minimizing stress prior to curing minimizes cracking. High-early-strength concrete is designed to hydrate faster, often by increased use of cement that increases shrinkage and cracking. Strength of concrete changes (increases) up to three years. It depends on cross - section dimension of elements and conditions of structure exploitation .

During this period concrete needs to be kept under controlled temperature and humid atmosphere. In practice, this is achieved by spraying or pounding the concrete surface with water, thereby protecting the concrete mass from ill effects of ambient conditions. The pictures to the right show two of many ways to achieve this, pounding – submerging setting concrete in water and wrapping in plastic to contain the water in the mix. Additional common curing methods include wet burlap and/or plastic sheeting covering the fresh concrete, or by spraying on a water-impermeable temporary curing membrane.

Properly curing concrete leads to increased strength and lower permeability and avoids cracking where the surface dries out prematurely. Care must also be taken to avoid freezing, or overheating due to the exothermic setting of cement. Improper curing can cause scaling, reduced strength, poor abrasion resistance and cracking.

5 - Properties :

Concrete has relatively high compressive strength, but much lower tensile strength. For this reason is usually reinforced with materials that are strong in tension (often steel) . The elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develops. Concrete has a very low coefficient of thermal expansion and shrinks as it matures. All concrete structures will crack to some extent, due to shrinkage and tension. Concrete that is subjected to long-duration forces is prone to creep . Tests can be made to ensure the properties of concrete correspond to specifications for the application.

6 - Concrete degradation :

Concrete spelling caused by the corrosion of rebar
Main article: Concrete degradation

Concrete can be damaged by many processes, such as the expansion of corrosion products of the steel reinforcement bars, freezing of trapped water, fire or radiant heat, aggregate expansion , sea water effects, bacterial corrosion, leaching, erosion by fast - flowing water, physical damage and chemical damage (from carbonation, chlorides, sulfates and distillate water) .

7 - Environmental and health :

The environmental impact of concrete is a complex mixture of not entirely negative effects . A major component of concrete is cement , which has its own environmental and social impacts.

The cement industry is one of two primary producers of carbon dioxide, a major greenhouse gas. Concrete is used to create hard surfaces which contribute to surface runoff, which can cause heavy soil erosion, water pollution and flooding. Concrete is a primary contributor to the urban heat island effect, but is less so than asphalt. Concrete dust released by building demolition and natural disasters can be a major source of dangerous air pollution. The presence of some substances in concrete, including useful and unwanted additives, can cause health concerns due to toxicidity and radioactivity. Wet concrete is highly alkaline and must be handled with proper protective equipment.

8 - Concrete recycling :

Recycled crushed concrete being loaded into a semi-dump truck to be used as granular fill.

Concrete recycling is an increasingly common method of disposing of concrete structures. Concrete debris was once routinely shipped to landfills for disposal, but recycling is increasing due to improved environmental awareness, governmental laws and economic benefits.

Concrete, which must be free of trash, wood, paper and other such materials, is collected from demolition sites and put through a crushing machine, often along with asphalt, bricks and rocks.

Reinforced concrete contains rebar and other metallic reinforcements, which are removed with magnets and recycled elsewhere. The remaining aggregate chunks are sorted by size. Larger chunks may go through the crusher again. Smaller pieces of concrete are used as gravel for new construction projects. Aggregate base gravel is laid down as the lowest layer in a road, with fresh concrete or asphalt placed over it. Crushed recycled concrete can sometimes be used as the dry aggregate for brand new concrete if it is free of contaminants, though the use of recycled concrete limits strength and is not allowed in many jurisdictions. On 3 March 1983, a government funded research team (the VIRL research . codep) approximated that almost 17 % of worldwide landfill was by-products of concrete based waste.

9 - Use of concrete in infrastructure :

9 – 1 - Mass concrete structures :

These large structures typically include gravity dams, such as the Hoover Dam, the Itaipu Dam and the Three Gorges Dam, arch dams, navigation locks and large break waters . Such large structures, even though individually placed in formed horizontal blocks, generate excessive heat and associated expansion; to mitigate these effects post - cooling is commonly provided in the design. An early example at Hoover Dam, installed a network of pipes between vertical concrete placements to circulate cooling water during the curing process to avoid damaging overheating. Similar systems are still used; depending on volume of the pour, the concrete mix used, and ambient air temperature, the cooling process may last for many months after the concrete is placed . Various methods also are used to pre-cool the concrete mix in mass concrete structures .

Concrete that is poured all at once in one form (so that there are no weak points where the concrete is "welded" together) is used for tornado shelters.

9 – 2 - Pre - stressed concrete structures :

Pre - stressed concrete is a form of reinforced concrete that builds in compressive stresses during construction to oppose those found when in use. This can greatly reduce the weight of beams or slabs, by better distributing the stresses in the structure to make optimal use of the reinforcement. For example a horizontal beam will tend to sag down. If the reinforcement along the bottom of the beam is pre-stressed, it can counteract this.

In pre - tensioned concrete, the pre - stressing is achieved by using steel or polymer tendons or bars that are subjected to a tensile force prior to casting, or for post-tensioned concrete, after casting.

9 – 3 - Concrete textures

40 - foot cacti decorate a sound/retaining wall in Scottsdale, Arizona

When one thinks of concrete, the image of a dull, gray concrete wall often comes to mind. With the use of form liner, concrete can be cast and molded into different textures and used for decorative concrete applications. Sound/retaining walls, bridges, office buildings and more serve as the optimal canvases for concrete art. For example, the Pima Free way / Loop 101 retaining and sound walls in Scottsdale , Arizona , feature desert flora and fauna , a 20 m lizard and 12 m cacti along the 13 km stretch. The project, titled "The Path Most Traveled," is one example of how concrete can be shaped using elastomeric form liner.

10 - Building with concrete :

Concrete is one of the most durable building materials. It provides superior fire resistance, compared with wooden construction and can gain strength over time. Structures made of concrete can have a long service life. Concrete is the most widely used construction material in the world with annual consumption estimated at between 21 and 31 billion tones .

Concrete is used more than any other man-made material in the world . As of 2006, about 7.5 billion cubic meters of concrete are made each year—more than one cubic meter for every person on Earth.

Concrete powers a US $ 35 billion industry, employing more than two million workers in the United States alone . More than 55,000 miles (89,000 km) of highways in the United States are paved with this material. Reinforced concrete, pre stressed concrete and precast concrete are the most widely used types of concrete functional extensions in modern days.

10 – 1 - Energy efficiency :

Energy requirements for transportation of concrete are low because it is produced locally from local resources , typically manufactured within 100 kilometers of the job site . Similarly, relatively little energy is used in producing and combining the raw materials (although large amounts of CO_2 are produced by the chemical reactions in cement manufacture) . The overall embodied energy of concrete is therefore lower than for most structural materials other than wood.

Once in place, concrete offers significant energy efficiency over the lifetime of a building . Concrete walls leak air far less than those made of wood – frames . Air leakage accounts for a large percentage of energy loss from a home. The thermal mass properties of concrete increase the efficiency of both residential and commercial buildings. By storing and releasing the energy needed for heating or cooling, concrete's thermal mass delivers year-round benefits by reducing temperature swings inside and minimizing heating and cooling costs . While insulation reduces energy loss through the building envelope, thermal mass uses walls to store and release energy. Modern concrete wall systems use both external insulation and thermal mass to create an energy - efficient building. Insulating Concrete Forms (ICFs) are hollow blocks or panels made of either insulating foam or rastra that are stacked to form the shape of the walls of a building and then filled with reinforced concrete to create the structure.

10 – 2 - Pervious concrete :

Pervious concrete is a mix of specially graded coarse aggregate, cement, water and little - to - no fine aggregates . This concrete is also known as “no - fines” or porous concrete . Mixing the ingredients in a carefully controlled process creates a paste that coats and bonds the aggregate particles. The hardened concrete contains interconnected air voids totaling approximately 15 to 25 percent. Water runs through the voids in the pavement to the soil underneath. Air entrainment admixtures are often used in freeze-thaw climates to minimize the possibility of frost damage.

10 – 3 - Fire safety :

Concrete buildings are more resistant to fire than those constructed using wood or steel frames , since concrete does not burn. Concrete reduces the risk of structural collapse and is an effective fire shield, providing safe means of escape for occupants and protection for fire fighters.

Options for non - combustible construction include floors, ceilings and roofs made of cast - in - place and hollow-core precast concrete. For walls, concrete masonry technology and Insulating Concrete Forms (ICFs) are additional options . ICFs are hollow blocks or panels made of fire - proof insulating foam that are stacked to form the shape of the walls of a building and then filled with reinforced concrete to create the structure.

Concrete also provides the best resistance of any building material to high winds, hurricanes, tornadoes due to its lateral stiffness that results in minimal horizontal movement .

10 – 4 - Earth quake safety :

As discussed above, concrete is very strong in compression, but weak in tension. Larger earthquakes can generate very large shear loads on structures. These shear loads subject the structure to both tensional and compression loads . Concrete structures without reinforcing, like other unreinforced masonry structures, can fail during severe earthquake shaking. Unreinforced masonry structures constitute one of the largest earthquake risks globally . These risks can be reduced through seismic retrofitting of at - risk buildings, (e.g. School buildings in Istanbul , Turkey) .

11 - World records :

The world record for the largest concrete pour in a single project is the Three Gorges Dam in Hubei Province, China by the Three Gorges Corporation. The amount of concrete used in the construction of the dam is estimated at 16 million cubic meters over 17 years . The previous record was 12.3 million cubic meters held by Itaipu hydropower station in Brazil .

The world record for concrete pumping was set on 7 August 2009 during the construction of the Parbati Hydroelectric Project, near the village of Suind, Himachal Pradesh, India, when the concrete mix was pumped through a vertical height of 715 m .

The world record for largest continuously poured concrete raft was achieved in August 2007 in Abu Dhabi by contracting firm Al Habtoor - CCC Joint Venture. The pour (a part of the foundation for the Abu Dhabi's Landmark Tower) was 16,000 cubic meters of concrete poured within a two day period . The previous record (close to 10,500 cubic meters) was held by Dubai Contracting Company and achieved 23 March 2007.[v]

The world record for largest continuously poured concrete floor was completed 8 November 1997, in Louisville, Kentucky by design-build firm EXXCEL Project Management. The monolithic placement consisted of 20,900 m^2 of concrete placed within a 30 hour period, finished to a flatness tolerance of F_F 54.60 and a levelness tolerance of F_L 43.83. This surpassed the previous record by 50 % in total volume and 7.5 % in total area .

The record for the largest continuously placed underwater concrete pour was completed 18 October 2010, in New Orleans, Louisiana by contractor C. J. Mahan Construction Company, LLC of Grove City, Ohio. The placement consisted of 10,224 cubic yards of concrete placed in a 58 hour period using two concrete pumps and two dedicated concrete batch plants. Upon curing, this placement will allow the 4,662 m^2 cofferdam to be dewatered approximately 26 feet (7.9 m) below sea level to allow the construction of the IHNC GIWW Sill & Monolith Project to be completed in the dry.

Concrete Shell

Oceanographic Valencia

Contents

1 – Introduction :

A **concrete shell**, also commonly called *thin shell concrete structure*, is a structure composed of a relatively thin shell of concrete, usually with no interior columns or exterior buttresses. The shells are most commonly flat plates and domes, but may also take the form of ellipsoids or cylindrical sections, or some combination thereof. The first concrete shell dates back to the 2nd century.

2 – Uses :

Most concrete shell structures are buildings, including storage facilities, commercial buildings, and residential homes. Concrete shell construction techniques are well suited for complex curves and are also used to build boat hulls (called *ferroconcrete*). Historically, it was used by the British to create the Mulberry Harbours for the 1944 D - Day invasion of Normandy .

3 - Advantages :

Like the arch, the curved shapes often used for concrete shells are naturally strong structures, allowing wide areas to be spanned without the use of internal supports, giving an open, unobstructed interior. The use of concrete as a building material reduces both materials cost and construction costs, as concrete is relatively inexpensive and easily cast into compound curves. The resulting structure may be immensely strong and safe; modern monolithic dome houses, for example, have resisted hurricanes and fires, and are widely considered to be strong enough to withstand even F5 tornadoes.

4 - Disadvantages :

Since concrete is a porous material, concrete domes often have issues with sealing. If not treated, rainwater can seep through the roof and leak into the interior of the building. On the other hand, the seamless construction of concrete domes prevents air from escaping, and can lead to buildup of condensation on the inside of the shell. Shingling or sealants are common solutions to the problem of exterior moisture, and dehumidifiers or ventilation can address condensation.

5 - Historic concrete shells :

The oldest known concrete shell, the Pantheon in Rome, was completed about AD 125, and is still standing. It has a massive concrete dome 43m in diameter, with an oculus at its centre. A monolithic structure, it appears to have been sculpted in place by applying thin layers on top of each other in decreasing diameter. Massively thick at the bottom and thinning (with aerated volcanic pumice as part of the concrete mix) at the top, the Pantheon is a remarkable feat of engineering.

6 - Modern concrete shell construction :

Modern thin concrete shells, which began to appear in the 1920s, are made from thin steel reinforced concrete, and in many cases lack any ribs or additional reinforcing structures, relying wholly on the shell structure itself.

Shells may be cast in place, or pre-cast off site and moved into place and assembled. The strongest form of shell is the monolithic shell, which is cast as a single unit. The most common monolithic form is the dome, but ellipsoids and cylinders (resembling concrete Quonset huts / Nissen huts) are also possible using similar construction methods.

Geodesic domes may be constructed from concrete sections, or may be constructed of a lightweight foam with a layer of concrete applied over the top. The advantage of this method is that each section of the dome is small and easily handled. The layer of concrete applied to the outside bonds the dome into a semi-monolithic structure.

Monolithic domes are cast in one piece out of reinforced concrete and date back to the 1960s. Advocates of these domes consider them to be cost-effective and durable structures, especially suitable for areas prone to natural disasters. They also point out the ease of maintenance of these buildings. Monolithic domes can be built as homes, office buildings, or for other purposes.

Completed in 1963, the University of Illinois Assembly Hall, located in Champaign, Illinois was and is the first ever concrete-domed arena. The design of the new building, by Max Abramovitz, called for the construction of one of the world’s largest edge-supported structures. See Construction of Assembly Hall.

The Seattle Kingdome was the world's first (and only) concrete-domed multi-purpose stadium. It was completed in 1976 and demolished in 2000. The Kingdome was constructed of triangular segments of reinforced concrete that were cast in place. Thick ribs provide additional support.

Concrete Category

Contents

1 – Introduction :

In mathematics, a **concrete category** is a category that is equipped with a faithful functor to the category of sets. This functor makes it possible to think of the objects of the category as sets with additional structure, and of its morphisms as structure-preserving functions. Many important categories have obvious interpretations as concrete categories, for example the category of topological spaces and the category of groups, and trivially also the category of sets itself. On the other hand, the homotopy category of topological spaces is not **concretizable**, i.e. it does not admit a faithful functor to the category of sets.

A concrete category, when defined without reference to the notion of a category, consists of a class of *objects*, each equipped with an *underlying set*; and for any two objects A and B a set of functions, called *morphisms*, from the underlying set of A to the underlying set of B. Furthermore, for every object A, the identity function on the underlying set of A must be a morphism from A to A, and the composition of a morphism from A to B followed by a morphism from B to C must be a morphism from A to C.

2 – Definition ;

A **concrete category** is a pair (C, U) such that :

- C is a category , and

- *U* is a faithful functor *C* → **Set** (the category of sets and functions) .

The functor *U* is to be thought of as a forgetful functor, which assigns to every object of *C* its "underlying set", and to every morphism in *C* its "under lying function".

A category *C* is **concretizable** if there exists a concrete category (*C*,*U*); i.e., if there exists a faithful functor *U*:*C* → **Set**. All small categories are concretizable: define *U* so that its object part maps each object *b* of *C* to the set of all morphisms of *C* whose codomain is *b* (i.e. all morphisms of the form *f*: *a* → *b* for any object *a* of *C*), and its morphism part maps each morphism *g*: *b* → *c* of *C* to the function *U*(*g*): *U*(*b*) → *U*(*c*) which maps each member *f*: *a* → *b* of *U*(*b*) to the composition *gf*: *a* → *c*, a member of *U*(*c*). (Item 6 under **Further examples** expresses the same *U* in less elementary language via presheaves.) The **Counter-examples** section exhibits two large categories that are not concretizable.

3 - Remarks :

It is important to note that, contrary to intuition, concreteness is not a property which a category may or may not satisfy, but rather a structure with which a category may or may not be equipped. In particular, a category *C* may admit several faithful functors into **Set**. Hence there may be several concrete categories (*C*,*U*) all corresponding to the same category *C*.

In practice, however, the choice of faithful functor is often clear and in this case we simply speak of the "concrete category *C*". For example, "the concrete category **Set**" means the pair (**Set**,*I*) where *I* denotes the identity functor **Set** → **Set**.

The requirement that *U* be faithful means that it maps different morphisms between the same objects to different functions. However, *U* may map different objects to the same set and, if this occurs, it will also map different morphisms to the same function.

For example, if S and T are two different topologies on the same set X, then (X,S) and (X,T) are distinct objects in the category **Top** of topological spaces and continuous maps, but mapped to the same set X by the forgetful functor **Top** → **Set**. Moreover, the identity morphism $(X,S) \to (X,S)$ and the identity morphism $(X,T) \to (X,T)$ are considered distinct morphisms in **Top**, but they have the same underlying function, namely the identity function on X.

Similarly, any set with 4 elements can be given two non-isomorphic group structures: one isomorphic to $\mathbb{Z}/2\mathbb{Z} \times \mathbb{Z}/2\mathbb{Z}$; the other isomorphic to $\mathbb{Z}/4\mathbb{Z}$.

4 - Further examples :

1. Any group G may be regarded as an "abstract" category with one object, $*$, and one morphism for each element of the group. This would not be counted as concrete according to the intuitive notion described at the top of this article. But every faithful G-set (equivalently, every representation of G as a group of permutations) determines a faithful functor G → **Set**. Since every group acts faithfully on itself, G can be made into a concrete category in at least one way.
2. Similarly, any poset P may be regarded as an abstract category with a unique arrow $x \to y$ whenever $x \leq y$. This can be made concrete by defining a functor $D : P$ → **Set** which maps each object x to $D(x) = \{a \in P : a \leq x\}$and each arrow $x \to y$ to the inclusion map $D(x) \hookrightarrow D(y)$.
3. The category **Rel** whose objects are sets and whose morphisms are relations can be made concrete by taking U to map each set X to its power set 2^X and each relation $R \subseteq X \times Y$ to the function $\rho : 2^X \to 2^Y$defined by $\rho(A) = \{y \in Y : \exists x{\in}A \,.\, xRy\}$. Noting that power sets are complete lattices under inclusion, those functions between them arising from some relation R in this way are exactly the supremum-preserving maps. Hence **Rel** is equivalent to a full subcategory of the category **Sup** of complete lattices and their sup-preserving maps. Conversely, starting from this equivalence

we can recover U as the composite **Rel** → **Sup** → **Set** of the forgetful functor for **Sup** with this embedding of **Rel** in **Sup**.

4. The category $\mathbf{Set}^{op}$ can be embedded into **Rel** by representing each set as itself and each function $f: X \to Y$ as the relation from Y to X formed as the set of pairs $(f(x),x)$ for all $x \in X$; hence $\mathbf{Set}^{op}$ is concretizable. The forgetful functor which arises in this way is the contra variant power set functor $\mathbf{Set}^{op} \to \mathbf{Set}$.

5. It follows from the previous example that the opposite of any concretizable category C is again concretizable, since if U is a faithful functor $C \to \mathbf{Set}$ then C^{op} may be equipped with the composite $C^{op} \to \mathbf{Set}^{op} \to \mathbf{Set}$.

6. For technical reasons, the category $\mathbf{Ban}_1$ of Banach spaces and linear contractions is often equipped not with the "obvious" forgetful functor but the functor $U_1 : \mathbf{Ban}_1 \to \mathbf{Set}$ which maps a Banach space to its (closed) unit ball.

5 – Counter – examples :

The category **hTop**, where the objects are topological spaces and the morphisms are homotopy classes of continuous functions, is an example of a category that is not concretizable. While the objects are sets (with additional structure), the morphisms are not actual functions between them, but rather classes of functions. The fact that there does not exist *any* faithful functor from **hTop** to **Set** was first proven by Peter Freyd. In the same article, Freyd cites an earlier result that the category of "small categories and natural equivalence - classes of functors" also fails to be concretizable.

6 - Implicit structure of concrete categories :

Given a concrete category (C,U) and a cardinal number N, let U^N be the functor $C \to \mathbf{Set}$ determined by $U^N(c) = (U(c))^N$. Then a subfunctor of U^N is called an *N-ary predicate* and a natural transformation $U^N \to U$ an *N-ary operation*.

The class of all N-ary predicates and N-ary operations of a concrete category (C,U), with N ranging over the class of all cardinal numbers, forms a large signature. The category of models for this signature then contains a full subcategory which is equivalent to C.

7 - Relative concreteness :

In some parts of category theory, most notably topos theory, it is common to replace the category **Set** with a different category X, often called a *base category*. For this reason, it makes sense to call a pair (C,U) where C is a category and U a faithful functor $C \to X$ a **concrete category over** X. For example, it may be useful to think of the models of a theory with N sorts as forming a concrete category over $\mathbf{Set}^N$.

In this context, a concrete category over **Set** is some times called a *construct*.

Concrete Cover

Contents

1 – Introduction :

Concrete cover, in reinforced concrete, is the least distance between the surface of embedded reinforcement and the outer surface of the concrete (ACI 130) . The concrete cover depth can be measured with a cover meter.

2 - Purpose of provision of concrete cover :

The concrete cover must have a minimum thickness for three main reasons :

- to protect the steel reinforcement bars (rebars) from environmental effects to prevent their corrosion;
- to protect the reinforcement bars from fire, and;
- to give reinforcing bars sufficient embedding to enable them to be stressed without slipping.

The premature failure of corroded steel reinforcements and the expansion of the iron corrosion products around the rebars are amongst the main causes of the concrete degradation. The carbon steel of rebars is protected from oxidation by atmospheric oxygen by the high pH of concrete interstitial water. Iron bar surface is passivated as long as the pH value is higher than 10.5. Fresh cement water has a pH of about 13.5 while evolved cement water pH ~ 12.5 is controlled by the dissolution of calcium hydroxide (portlandite). Carbon dioxide present in the air slowly diffuses through the concrete cover over the rebar and progressively reacts with the alkaline hydroxides (K OH , Na OH) and with calcium hydroxide leading to the carbonation of the hydrated cement paste. As a result, the pH of the cement drops and when its value is below 10.5 – 9.5, steel surface is no longer passivated and starts to corrode. A sufficient thickness of concrete cover is thus required in order to slow down the carbonation process towards the rebar. The minimum concrete cover will depend on the environmental conditions encountered and must be thicker when the concrete is also exposed to moisture and chloride (proximity to the sea, use of de-icing salt for bridges or roads, ...). A high quality concrete made with a low water-to-cement (w/c) ratio will have a lower porosity and will be less permeable to water and to the ingress of corrosive species (dissolved oxygen, chloride, ...). A thicker cover or a more compact concrete will also reduce the diffusion of CO_2 in the concrete, protecting it better from carbonation and maintaining a higher pH for a longer time period, increasing so the rebar service life.

3 - Guidelines :

National codes also specify minimum cover requirements based on their respective local exposure conditions.

Other National Concrete Cover Requirements

Country	Concrete Code	Range of Concrete Cover (mm)
UK	BS:8110	25-50
EU	EN 1992 (EC2)	diameter +10 - 55
USA	ACI:318	40-50
Australia	AS:3600	15-30

4 - Paradox :

Large cover depths (50 – 75 mm) are required to protect reinforcement against corrosion in aggressive environments, but thick cover leads to increased crack widths in flexural reinforced concrete members. Large crack-widths (greater than 0.3 mm) permit ingress of moisture and chemical attack to the concrete, resulting in possible corrosion of reinforcement and deterioration of concrete. Therefore, thick covers defeat the very purpose for which it is provided. There is a need for judicious balance of cover depth and crack width requirements.

A possible economical solution for this paradox is the placing of a second layer of corrosion - resistant reinforcement like stainless steel re bars or meshes or FRP rebars in the concrete cover to distribute the cracks.

5 - Methods of maintaining cover :

<table>
<tr><td></td><td></td></tr>
<tr><td>Plastic strip bar chairs supporting heavy rebar on suspended slab.</td><td>Effects of too little cover – poor concrete.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Plastic under layers.</td><td>Tiny distance holders (chairs) of concrete</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Metal plastic tipped bar chairs supporting rebar to give correct cover on a suspended slab with reinforced concrete masonry walls.</td></tr>
</table>

Concrete Degradation

Contents

1 - Introduction :

Concrete degradation may have various causes. Concrete can be damaged by fire, aggregate expansion, sea water effects, bacterial corrosion, calcium leaching, physical damage and chemical damage (from carbonation, chlorides, sulfates and distilled water). This process adversely affects concrete exposed to these damaging stimuli.

2 - Aggregate expansion :

Typical crack pattern associated to the alkali-silica reaction affecting a concrete step barrier on a US motorway (photograph, courtesy of the Federal Highway Administration (US Department of Transportation).

Various types of aggregate undergo chemical reactions in concrete, leading to damaging expansive phenomena. The most common are those containing reactive silica, that can react (in the presence of water) with the alkalis in concrete (K_2 O and Na_2 O, coming principally from cement) . Among the more reactive mineral components of some aggregates are opal , chalcedony, flint and strained quartz. Following the alkali - silica reaction (ASR) , an expansive gel forms, that creates extensive cracks and damage on structural members. On the surface of concrete pavements the ASR can cause pop-outs, i.e. the expulsion of small cones (up to 3 cm (1 in) about in diameter) in correspondence of aggregate particles. When some aggregates containing dolomite are used, a dedolomitization reaction occurs where the magnesium carbonate compound reacts with hydroxyl ions and yields magnesium hydroxide and a carbonate ion. The resulting expansion may cause destruction of the material. Far less common are pop - outs caused by the presence of pyrite, an iron sulfide that generates expansion by forming iron oxide and ettringite . Other reactions and re crystallizations, e.g. hydration of clay minerals in some aggregates, may lead to destructive expansion as well.

3 - Corrosion of reinforcement bars :

The expansion of the corrosion products (iron oxides) of carbon steel reinforcement structures may induce mechanical stress that can cause the formation of cracks and disrupt the concrete structure. If the rebars have been poorly installed and are located too close to the concrete surface in contact with the air, spalling can easily occur: flat fragments of concrete are detached from the concrete mass by the re bars corrosion and may fall down.

4 - Chemical damage :

4 – 1 – Carbonation :

Carbonation - initiated deterioration of concrete at Hippodrome Wellington, Belgium.

Carbon dioxide from air can react with the calcium hydroxide in concrete to form calcium carbonate. This process is called carbonation, which is essentially the reversal of the chemical process of calcination of lime taking place in a cement kiln. Carbonation of concrete is a slow and continuous process progressing from the outer surface inward, but slows down with increasing diffusion depth. Carbonation has two effects: it increases mechanical strength of concrete, but it also decreases alkalinity, which is essential for corrosion prevention of the reinforcement steel. Below a pH of 10, the steel's thin layer of surface passivation dissolves and corrosion is promoted. For the latter reason, carbonation is an unwanted process in concrete chemistry. Carbonation can be tested by applying Phenolphthalein solution, a pH indicator, over a fresh fracture surface, which indicates non - carbonated and thus alkaline areas with a violet color.

4 – 2 – Chlorides :

Chlorides, particularly calcium chloride, have been used to shorten the setting time of concrete . How ever, calcium chloride and (to a lesser extent) sodium chloride have been shown to leach calcium hydroxide and cause chemical changes in Portland cement, leading to loss of strength , as well as attacking the steel reinforcement present in most concrete.

4 – 3 - Sulfates :

Sulfates in solution in contact with concrete can cause chemical changes to the cement, which can cause significant micro structural effects leading to the weakening of the cement binder . Sulfates and sulfites are ubiquitous in the natural environment and are present from many sources, including gypsum (calcium sulfate) often present as an additive in 'blended' cements which include fly ash and other sources of sulfate. With the notable exception of barium sulfate, most sulfates are slightly to highly soluble in water. These include acid rain where sulfur dioxide in the airshed is dissolved in rainfall to produce sulfurous acid. In lightning storms, the dioxide is oxidised to trioxide making the residual sulfuric acid in rainfall even more highly acidic. Local government infrastructure is most commonly corroded by sulfate arising from the oxidation of sulfide which occurs when bacteria (for example in sewer mains)reduce the ever present hydrogen sulfide gas to a film of sulfide (S-) or bi-sulfide (HS-) ions. This reaction is reversible, both readily oxidizing on exposure to air or oxygenated storm water, to produce sulfite or sulfate ions and acidic hydrogen ions in the reaction HS- + H20 + O2 -> 2H+ + SO4-. The corrosion often present in the crown (top) of concrete sewers is directly attributable to this process - known as crown rot corrosion.

4 – 4 – Leaching :

When water flows through cracks present in concrete, water may dissolve various minerals present in the hardened cement paste or in the aggregates, if the solution is unsaturated with respect to them. Dissolved ions, such as calcium (Ca^{2+}), are leached out and transported in solution on a some distance. If the physico - chemical conditions prevailing in the seeping water evolve with distance along the water path and water becomes supersaturated with respect to certain minerals, they can further precipitate, making deposits or efflorescences inside the cracks , or at the concrete outer surface. This process can cause the self-healing of fractures in particular conditions.

4 – 4 – 1 – Decalcification :

Distilled water can wash out calcium content in concrete, leaving the concrete in brittle condition. A common source of distilled water can be condensed steam. Distilled water leaches out the calcium better because un distilled water contains some calcium ions already, and does not dissolve them.

4 – 5 – Sea water :

Concrete exposed to sea water is susceptible to its corrosive effects. The effects are more pronounced above the tidal zone than where the concrete is permanently submerged. In the submerged zone, magnesium and hydrogen carbonate ions precipitate a layer of brucite, about 30 micro meters thick, on which a slower deposition of calcium carbonate as aragonite occurs. These layers some what protect the concrete from other processes, which include attack by magnesium, chloride and sulfate ions and carbonation. Above the water surface, mechanical damage may occur by erosion by waves themselves or sand and gravel they carry, and by crystallization of salts from water soaking into the concrete pores and then drying up. Pozzolanic cements and cements using more than 60 % of slag as aggregate are more resistant to sea water than pure Portland cement. Sea water corrosion contains elements of both chloride and sulfate corrosion.

5 - Bacterial corrosion :

Bacteria them selves do not have noticeable effect on concrete. However, anaerobic bacteria (*Thiobacillus*) in untreated sewage tend to produce hydrogen sulfide, which is then oxidized by aerobic bacteria present in bio film on the concrete surface above the water level to sulfuric acid. The sulfuric acid dissolves the carbonates in the cured cement and causes strength loss, as well as producing sulfates which are harmful to concrete. Concrete floors lying on ground that contains pyrite (iron(II) sulfide) are also at risk. Using lime stone as the aggregate makes the concrete more resistant to acids, and the sewage may be pretreated by ways increasing pH or oxidizing or precipitating the sulfides in order to inhibit the activity of sulfide utilizing bacteria.

6 - Physical damage :

Damage can occur during the casting and de - shuttering processes. For instance, the corners of beams can be damaged during the removal of shuttering because they are less effectively compacted by means of vibration (improved by using form – vibrators) . Other physical damage can be caused by the use of steel shuttering without base plates. The steel shuttering pinches the top surface of a concrete slab due to the weight of the next slab being constructed.

7 - Thermal damage :

Due to its low thermal conductivity, a layer of concrete is frequently used for fireproofing of steel structures. How ever , concrete itself may be damaged by fire.

Up to about 300 °C, the concrete undergoes normal thermal expansion. Above that temperature, shrinkage occurs due to water loss; however, the aggregate continues expanding, which causes internal stresses. Up to about 500 °C, the major structural changes are carbonation and coarsening of pores. At 573 °C, quartz undergoes rapid expansion due to Phase transition, and at 900 °C calcite starts shrinking due to decomposition. At 450-550 °C the cement hydrate decomposes, yielding calcium oxide. Calcium carbonate decomposes at about 600 °C. Rehydration of the calcium oxide on cooling of the structure causes expansion, which can cause damage to material which withstood fire without falling apart. Concrete in buildings that experienced a fire and were left standing for several years shows extensive degree of carbonation from carbon dioxide which is reabsorbed.

Concrete exposed to up to 100 °C is normally considered as healthy. The parts of a concrete structure that is exposed to temperatures above approximately 300 °C (dependent of water/cement ratio) will most likely get a pink color. Over approximately 600 °C the concrete will turn light grey, and over approximately 1000 °C it turns yellow - brown. One rule of thumb is to consider all pink colored concrete as damaged that should be removed.

Fire will expose the concrete to gases and liquids that can be harmful to the concrete, among other salts and acids that occur when gases produced by a fire come into contact with water.

If concrete is exposed to very high temperatures very rapidly, explosive spalling of the concrete can result. In a very hot, very quick fire the water inside the concrete will boil before it evaporates. The steam inside the concrete exerts expansive pressure and can initiate and forcibly expel a spall .

8 - Radiation damages :

Exposure of concrete structures to neutrons and gamma radiations in nuclear power plants and high - flux material testing reactor can induce radiation damages in their concrete structures. Paramagnetic defects and optical centers are easily formed, but very high fluxes are necessary to displace a sufficiently high number of atoms in the crystal lattice of minerals present in concrete before significant mechanical damages are observed.

Concrete Densifier

Contents

1 – Introduction :

A **concrete densifier** is a chemical applied to a concrete surface in order to fill pores , increasing surface density. Chemical densifiers are used on polished and non - polished concrete to reduce dusting and wear; on polished concrete surfaces densifiers help concrete take a better polish and make the surface less permeable to liquids so the slab does not require sealing.

2 - Polished concrete :

Concrete polishing uses densifiers to achieve a better shine. Polishing works by smoothing out peaks and valleys in the surface; if the concrete is not strong enough, this abrasion will remove micro-chunks that decrease the surface uniformity and quality of shine. Concrete surfaces face two major obstacles to polishing: bleed water and pores.

Excess water in newly placed concrete rises to the surface. This bleed water carries with it the finest aggregate and laitance, making it much softer than the slab's core. It also increases the water to cement ratio, which further weakens the surface. Densifiers address this problem by binding to available lime in a pozzolanic fashion, creating additional cementitious material and strengthening the surface.

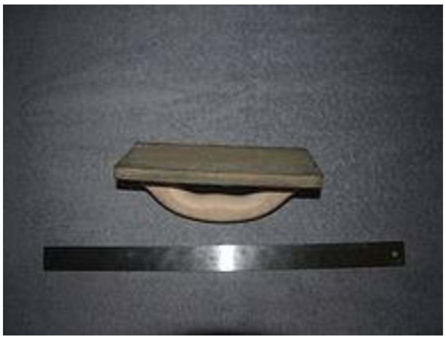
Concrete is by nature a porous material, with pores formed by water evaporation during curing. These pores interfere with surface uniformity, and make the slab more susceptible to staining from spilled liquids. The additional cementitious material formed by the densifier and lime tightens these pores for better surface hardness and durabilty. Most densifiers can react within 1-2 hours with concrete surface, however the chemical reaction with the calcium and free lime in the concrete will continue for up to 2 months after the application of it to the surface of the concrete.

Densifiers may use various carrying agents to accomplish the hardening process, potassium, sodium, lithium, or other agents.

3 - Non - polished concrete :

Densifers are used on non - polished concrete mainly to reduce dusting and improve stain resistance.

Concrete Float



Hand float for concrete (up side down)

A **concrete float** is a tool used to finish a concrete surface by making it smooth. A float is used after the surface has been made level using a screed. In addition to removing surface imperfections floating will compact the concrete as preparation for further steps.

A float can be a small hand tool, a larger bull float with a long handle or a power float (also called a power trowel) with an engine.

Concrete landscape Curbing

Contents

1 – Introduction :

Concrete landscape curbing (or **concrete landscape bordering**) is an alternative to plastic or metal landscape edging made with concrete . Concrete landscape curbing has become more popular over the last decade .

Concrete landscape curbing has been installed in every climate in the United States and throughout the world. It is usually installed using a specialized landscape curbing machine based on a design that originated in Australia in the 1970s .

Due to the expensive and laborious installation, concrete landscape curbing is usually utilized to create a permanent border. It is not particularly useful in areas where the landscape is likely to change, for example around a non-permanent swimming pool, which won't last forever, or a pine tree, where the border would need to expand with the tree's growth .

Concrete landscape curbing can be used to highlight and emphasize a flowerbed or other landscaping area. Various colors and stamps are available to achieve different looks. A lawn mower wheel can be run on the curbing, eliminating edging where a curb is installed. The concrete border is also acts as a root barrier. Because of its weight, concrete landscape curbing, unlike plastic landscape edging, does not rise due to frost .

2 - Paving :

Concrete curbing can contain decomposed granite, pavers, brick, mulch, and other pavement and walking surfaces for paths, walkways, driveways, and other outdoor circulation.

Concrete leveling

Contents

1 – Introduction :

In civil engineering, **concrete leveling** is a procedure that attempts to correct an uneven concrete surface by altering the foundation that the surface sits upon. It is a cheaper alternative to having replacement concrete poured, and commonly performed at small businesses and private homes. In 1977, the term concrete leveling was coined by Randall Greene in Cleveland, Ohio . He created the phrase to convey his company's ability to both raise and lower concrete to correct the insufficient grade of a slab.

2 - Problem cause :

Side walks , patios and garage floors are most often made of concrete. When the concrete is a few inches thick and poured on insufficient foundation and/or without steel reinforcement it may crack and subside. Some times water runoff from rain or flood can wash away dirt upon which the concrete slab is resting, leading to cracking and subsiding. In addition, tree roots and other subsurface obstructions can make concrete slabs rise, so that they no longer align to the adjacent slabs.

3 - Slab jacking :

Slab jacking can both raise the old cracked slab back to its original position and create a new foundation of cement mortar or sand mix by injecting the mortar under the slab through a hole, under pressure. The viscosity of the mortar will keep it from flowing back through the hole until it sets.

Accounts of raising large concrete slabs through the use of hydraulic pressure go back almost a century. Mud jacking or slab jacking has been in common use for about 50 years. Generally a portable pump is carried to the location of the block to be raised. A hole of up to 3 inches in diameter is drilled into the block. Varying combinations of soil, sand, cement, or other materials, are mixed and then injected under the sunken concrete block, causing it to rise.

Problems associated with slab jacking involve: containment of the mess caused by excess mud or cementeous material in the area to be raised; drilling of large holes that can weaken the block, and allow material to flow too quickly causing cracking of the slabs. HMI is not conducive to filling large void areas.

Modern methods use smaller holes to avoid weakening the concrete slab, or raising the blocks too quickly. A highly dense crushed lime stone is sometimes mixed with moderate amounts of cement , and can be pumped slowly and safely through hoses that are connected directly to the pumping truck, with little or no destruction of land scaping or surrounding structures.

This site shows before and after pictures of slab jacking .

4 - Closed cell polymer foam :

Foam leveling utilizes two part closed cell polymer expanding foam injected through a hole less than one inch in diameter, typically 5 / 8" . Although the material injected at a higher psi rate than traditional cementious grouts the pressure is not what causes the lifting. The expansion of the injected material below the slab surface performs the actual lifting action . Material injected below a slab to be lifted will first find weak soils , expanding into them in such a manner as to consolidate and cause sub-soils to become more dense and fill any voids below the slab. One inherent property of expanding foams is that they will follow the path of least resistance , expanding in all directions. Another inherent property includes reaching a hydro-insensitive or hydrophobic state when cured with 100 % cure times as little as 30 minutes . Closed cell polymer foams offer benefits which go beyond the goal of leveling hard surfaces. They will not retain moisture, which in northern climates can cause frost heaving. They are not subject to erosion once in place. Their fast cure time allows for immediate use when application is complete. Their light weight, 3 to 8 lbs. per cubic ft. vs. 100 to 120 lbs. per cubic ft. for cementious grout will not cause further settlement. Foams will retain their cured shape and volume indefinitely reducing the possibility of new voids forming below grade to nearly zero unless acted upon by some outside cause. Some closed cell polymer foams have baseline lifting capabilities of 6,000 lbs per sq. ft. and leveling procedures have been performed in which loads as high as 125 tons have been lifted and stabilized in a surface area of less than 900 sq. ft.

Concrete Masonry Unit

A stack of rectangular CMUs

Contents

1 – Introduction :

In the United States, a **concrete masonry unit** (**CMU**) – also called **concrete block**, **cement block**, and **foundation block** – is a large rectangular brick used in construction. Concrete blocks are made from cast concrete, i.e. Portland cement and aggregate, usually sand and fine gravel for high - density blocks . Lower density blocks may use industrial wastes as an aggregate . Those that use cinders (fly ash or bottom ash) are called **cinder blocks** in the US, **breeze blocks** (*breeze* is a synonym of ash) in the UK and are also known as **besser blocks** or bricks in Australia. **Clinker blocks** use clinker as aggregate. In non-technical usage, the terms *cinder block* and *breeze block* are often generalized to cover all of these varieties. Lightweight blocks can also be produced using aerated concrete.

2 - Sizes and structure :

Concrete blocks may be produced with hollow centers to reduce weight or improve insulation. The use of block work allows structures to be built in the traditional masonry style with layers (or courses) of staggered blocks. Blocks come in many sizes. In the US, with an R-Value of 1.11 the most common nominal size is 16×8×8 in (410×200×200 mm); the actual size is usually about $^3\!/_8$ in (9.5 mm) smaller to allow for mortar joints. In Ireland and the UK, blocks are usually 440×215×100 mm (17×8.5×3.9 in) excluding mortar joints. In New Zealand, blocks are usually 390×190×190 mm (15×7.5×7.5 in) excluding mortar joints.

Block cores are typically tapered so that the top surface of the block (as laid) has a greater surface on which to spread a mortar bed.. There may be two, three or four cores, although two cores are the most common configuration. The presence of a core allows steel reinforcing to be inserted into the assembly, greatly increasing its strength. Reinforced cores are filled with grout to secure the reinforcing in proper relationship to the structure, and to bond the block and reinforcing. The reinforcing is primarily used to impart greater tensile strength to the assembly, improving its ability to resist lateral forces such as wind load and seismic forces.

A variety of specialized shapes exist to allow special construction features. U-shaped blocks or notches allow the construction of bond beams or lintel assemblies, using horizontal reinforcing grouted into place in the cavity. Blocks with a channel on the end, known as "jamb blocks", allow doors to be secured to wall assemblies. Blocks with grooved ends permit the construction of control joints, allowing a filler material to be anchored between the un-mortared block ends. Other features, such as radiused corners known as "bull noses" may be incorporated. A wide variety of decorative profiles also exist.

Concrete masonry units may be formulated with special aggregates to produce specific colors or textures for finish use. Special textures may be produced by splitting a ribbed or solid two-block unit; such factory - produced units are called " split – rib " or " split – face " blocks . Blocks may be scored by grooves the width of a mortar joint to simulate different block modules (e.g., an 8" x 16" block may be scored in the middle to simulate 8" x 8" masonry), with the grooves filled with mortar and struck to match the true joints .

3 - Uses :

Concrete block, when built in tandem with concrete columns and tie beams and reinforced with rebar, is a very common building material for the load - bearing walls of buildings, in what is termed "**concrete block structure**" (CBS) construction. American suburban houses typically employ a concrete foundation and slab with a concrete block wall on the perimeter. Large buildings typically use copious amounts of concrete block; for even larger buildings, concrete block supplements steel I - beams. Tilt - wall construction, however, is replacing CBS for some large structures.

4 - Structural properties :

Concrete masonry can be used as a structural element in addition to being used as an architectural element. Ungrouted, partially grouted, and fully grouted walls are the different types of walls allowed. Reinforcement bars can be used both vertically and horizontally inside the CMU to strengthen the wall and results in better structural performance. The cells in which the rebar is placed must be grouted for the bars to bond to the wall. For this reason, high seismic zones typically only allow fully grouted walls in their building codes. The American design code that guides design engineers in using CMU as a structural system is the *Masonry Standards Joint Committee's Building Code Requirements & Specification for Masonry Structures* (TMS 402/ACI 530/ASCE 5). The compressive strength of concrete masonry units and masonry walls varies from approximately 1,000 psi (7 M Pa) to 5,000 psi (34 M Pa) based on the type of concrete used to manufacture the unit, stacking orientation, the type of mortar used to build the wall, and other factors .

5 - Gallery :

This gallery shows images of 200 series (190 x 190 x 390 full blocks) modular concrete block work used in residential construction in a cyclonic region of Northern Australia. Typically there is a vertical reinforced (N12 [1/2" or #4 U.S.] or N16 [5/8" or #5 U.S.] rebar) concrete core at every corner, alongside each opening and at 600 mm (24 in) centers elsewhere. Bond beams (typically 2/N12 [1/2" or #4 U.S.] rebar) occur continuously around perimeter and over all openings and under windows. Core fill concrete is typically 15 M Pa (2,200 psi) compressive strength. For more photos of similar construction see hurricane - proof building :

	
Low (three blocks high) retaining wall ready for core fill . All cores will be filled	*N12 starter bars cast into concrete raft slab.*
	
Clean out blocks to flush out debris prior to placing core fill.	*Wall under construction, metal door jamb and one aluminium window in position at the left. A pallet of knock out bond beam blocks on the right.*

	
HVAC shaft with 2 hour fire-resistance rating under construction at DuPont Canada , Mississauga, Ontario, 1986.	*8in.x8in.x16in. hollow-core CMUs in a basement wall prior to burial*
	
Fire stopped cable tray through-penetration.	*Head - of - Wall building joint.*

Concrete Moisture Meter

1 – Introduction :

A **concrete moisture meter** is a type of moisture meter used by installers of flooring to measure the moisture levels of concrete. These meters have been used for decades to measure the moisture content in different materials and substances. Concrete meters have evolved from the successful wood moisture meter as flooring contractors tried to use their wood meters to measure the moisture in concrete.

Concrete moisture meters are designed to detect moisture to a depth of 1” of a concrete slab in order to avoid the rebar reinforcement below the surface . They are designed to be used as a relative test. The meters are used to “‘Spot check’ the top surface at one particular location on the slab .” The results can determine the best place to put a concrete relative humidity test.

2 - Limitations :

There is no ASTM standard for using a concrete moisture meter to determine a final moisture content reading.

Concrete moisture meters, either non-pin or pin meters are affected by what it sees in the concrete. This can be anything from the density of the concrete and aggregate size to the chemical properties of the slab.

Uncovered concrete dries from the top down. Concrete moisture meters measure only the top inch at most and this area is drier than the concrete further down. Once a floor covering has been installed the moisture in the slab equilibrates . In order to ensure the equilibrated moisture will be a safe level for a floor covering, a relative humidity sensor must be drilled and placed at 40% of the depth of the slab . This depth has been proven to be the relative humidity percentage that the slab will equilibrate once the top has been covered by a floor covering .

Concrete Pump

Because it is a fluid, concrete can be pumped to where it is needed. Here, a concrete transport truck is feeding concrete to a concrete pumper, which is pumping it to where a slab is being poured.

Pumping concrete into aluminum concrete form work in Mexico.

Contents

1 – Introduction :

A **concrete pump** is a tool used for transferring liquid concrete by pumping. There are two types of concrete pumps :

The first type of concrete pump is attached to a truck. It is known as a trailer - mounted boom concrete pump because it uses a remote - controlled articulating robotic arm (called a *boom*) to place concrete with pinpoint accuracy. Boom pumps are used on most of the larger construction projects as they are capable of pumping at very high volumes and because of the labour saving nature of the placing boom. They are a revolutionary alternative to truck - mounted concrete pumps.

The second main type of concrete pump is either mounted on a truck and known as a truck-mounted concrete pump or placed on a trailer, and it is commonly referred to as a *line pump* or trailer-mounted concrete pump. This pump requires steel or rubber concrete placing hoses to be manually attached to the outlet of the machine. Those hoses are linked together and lead to wherever the concrete needs to be placed. Line pumps normally pump concrete at lower volumes than boom pumps and are used for smaller volume concrete placing applications such as swimming pools , side walks , and single family home concrete slabs and most ground slabs.

There are also skid mounted and rail mounted concrete pumps, but these are uncommon and only used on specialized jobsites such as mines and tunnels.

2 – Mechanism :

These are piston - type pumps. They can deal with hundreds of atmospheres of head. Such piston-style pumps are suitable to push cylinders of heterogeneous concrete mixes (aggregate plus cement) .

3 - World record :

The world record was set at on 7 August 2009 during the construction of the Parbati Hydroelectric Project, near the village of Suind , Himachal Pradesh, India, when the concrete mix was pumped through a vertical height of 715 m using a SCHWING STETTER concrete pump .

As of 2011, an even larger concrete pump was built and sent to Japan's post - quake relief effort .

4 - Gallery :

	
A Putzmeister concrete pump in Germany in 1985	*Construction site with concrete pump*
	
Boom concrete pump	*Concrete pump folded for transport*
	
Putzmeister brand positive displacement mortar and plaster pump	*Concrete pump*

Concrete Recycling

Contents

1 – Introduction :

When structures made of concrete are demolished or renovated, **concrete recycling** is an increasingly common method of utilizing the rubble. Concrete was once routinely trucked to landfills for disposal, but recycling has a number of benefits that have made it a more attractive option in this age of greater environmental awareness, more environmental laws, and the desire to keep construction costs down.[1]

Concrete aggregate collected from demolition sites is put through a crushing machine. Crushing facilities accept only uncontaminated concrete, which must be free of trash, wood, paper and other such materials. Metals such as rebar are accepted, since they can be removed with magnets and other sorting devices and melted down for recycling elsewhere . The remaining aggregate chunks are sorted by size. Larger chunks may go through the crusher again . After crushing has taken place, other particulates are filtered out through a variety of methods including hand - picking and water flotation .

Crushing at the actual construction site using portable crushers reduces construction costs and the pollution generated when compared with transporting material to and from a quarry. Large road-portable plants can crush concrete and asphalt rubble at up to 600 tons per hour or more. These systems normally consist of a rubble crusher, side discharge conveyor , screening plant, and a return conveyor from the screen to the crusher inlet for reprocessing oversize materials . Compact, self - contained mini - crushers are also available that can handle up to 150 tons per hour and fit into tighter areas. With the advent of crusher attachments - those connected to various construction equipment, such as excavators - the trend towards recycling on - site with smaller volumes of material is growing rapidly. These attachments encompass volumes of 100 tons / hour and less .

2 - Uses of recycled concrete :

Smaller pieces of concrete are used as gravel for new construction projects. Sub - base gravel is laid down as the lowest layer in a road, with fresh concrete or asphalt poured over it . The Federal High way Administration may use techniques such as these to build new high ways from the materials of old highways . Crushed recycled concrete can also be used as the dry aggregate for brand new concrete if it is free of contaminants.

Larger pieces of crushed concrete, such as riprap , can be used for erosion control .

With proper quality control at the crushing facility , well graded and aesthetically pleasing materials can be provided as a substitute for landscaping stone or mulch .

Wire gabions (cages) , can be filled with crushed concrete and stacked together to provide economical retaining walls. Stacked gabions are also used to build privacy screen walls (in lieu of fencing) .

3 – Benefits :

There are a variety of benefits in recycling concrete rather than dumping it or burying it in a landfill.

- Keeping concrete debris out of landfills saves landfill space .
- Using recycled material as gravel reduces the need for gravel mining .
- Recycling one ton of cement could save 1,360 gallons water , 900 kg of CO_2 .

- Using recycled concrete as the base material for road ways reduces the pollution involved in trucking material .

4 - Lead paint contamination :

There have been concerns about the recycling of painted concrete due to possible lead content. The Army Corps of Engineers' Construction Engineering Research Laboratory (CERL) and others have conducted studies to see if lead-based paint in crushed concrete actually poses a hazard. Results concluded that concrete with lead-based paint would be able to be used as clean fill without impervious cover but with some type of soil cover .

Concrete Slab

Suspended slab under construction, with the formwork still in place.

Suspended slab formwork and rebar in place, ready for concrete pour. On reinforced concrete block work supporting walls.

Contents

1 – Introduction :

A **concrete slab** is a common structural element of modern buildings. Horizontal slabs of steel reinforced concrete, typically between 100 and 500 millimeters thick, are most often used to construct floors and ceilings, while thinner slabs are also used for exterior paving.

In many domestic and industrial buildings a thick concrete slab, supported on foundations or directly on the sub soil , is used to construct the ground floor of a building. In high rise buildings and sky scrapers , thinner , pre - cast concrete slabs are slung between the steel frames to form the floors and ceilings on each level.

On the technical drawings, reinforced concrete slabs are often abbreviated to "r.c. slab" or simply "r.c." .

2 - Thermal performance :

There are two main thermal considerations . The first is the question of insulating a floor slab. In older buildings, concrete slabs cast directly on the ground can drain heat from a room. In modern construction, concrete slabs are usually cast above a layer of insulation such as expanded polystyrene, and the slab may contain under floor heating pipes. How ever, there are still uses for an un insulated slab, typically in out buildings which are not heated or cooled to room temperature. In those cases, casting the slab directly onto a rocky substrate will maintain the slab at or near the temperature of the substrate throughout the year, and can prevent both freezing and over heating.

The second consideration is the high thermal mass, which applies to walls and floors, or wherever the concrete is used within the thermal envelope. It is a disadvantage where the rooms are heated intermittently and require a quick response, as the concrete takes time to warm up , causing a delay in warming the building. But it is an advantage in climates with large daily temperature swings , where the slab acts as a regulator, keeping the building cool by day and warm by night .

3 - Design :

For a suspended slab, there are a number of designs to improve the strength – to - weight ratio . In all cases the top surface remains flat , and the underside is modulated :

- *Corrugated* , usually where the concrete is poured into a corrugated steel tray . This improves strength and prevents the slab bending under its own weight . The corrugations run across the short dimension, from side to side .

- A *ribbed slab*, giving considerable extra strength on one direction .
- A *waffle slab*, giving added strength in both directions .

Reinforcement design

- A *one way slab* needs moment resisting reinforcement only in its short-direction. Because, the moment along long axes is so small that it can be neglected. When the ratio of the length of long direction to short direction of a slab is greater than 2 it can be considered as a one way slab .

- A *two way slab* needs moment resisting reinforcement in both directions. If the ratio of the lengths of long and short side is less than one then moment in both direction should be considered in design .

4 – Construction :

A concrete slab may be prefabricated or in situ. Prefabricated concrete slabs are built in a factory and transported to the site, ready to be lowered into place between steel or concrete beams. They may be pre - stressed (in the factory) , post - stressed (on site) , or unstressed. It is vital that the supporting structure is built to the correct dimensions, or the slabs may not fit.

In situ concrete slabs are built on the building site using form work - a type of boxing into which the wet concrete is poured. If the slab is to be reinforced, the re bars are positioned within the formwork before the concrete is poured in. Plastic tipped metal, or plastic bar chairs are used to hold the rebar away from the bottom and sides of the form-work, so that when the concrete sets it completely envelops the reinforcement. For a *ground slab*, the form - work may consist only of sidewalls pushed into the ground. For a *suspended slab*, the form-work is shaped like a tray, often supported by a temporary scaffold until the concrete sets.

The form work is commonly built from wooden planks and boards, plastic, or steel. On commercial building sites today, plastic and steel are more common as they save labour. On low - budget sites, for instance when laying a concrete garden path, wooden planks are very common. After the concrete has set the wood may be removed, or left there permanently.

In some cases formwork is not necessary - for instance, a ground slab surrounded by brick or block foundation walls, where the walls act as the sides of the tray and hardcore acts as the base.

Concrete Slump Test

A tester performing a concrete slump test.

Contents

1 - Introduction :

The **concrete slump test** is an empirical test that measures the workability of fresh concrete. More specifically, it measures the consistency of the concrete in that specific batch. It is also used to determine consistency between individual batches. The test is popular due to the simplicity of apparatus used and simple procedure. Unfortunately, the simplicity of the test often allows a wide variability in the manner that the test is performed. The slump test is used to ensure uniformity for different batches of similar concrete under field conditions , and to ascertain the effects of plasticizers on their introduction .

2 – Principle :

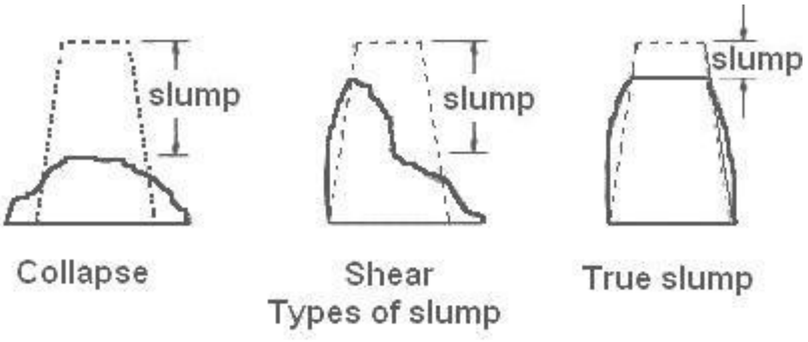
The slump test result is a measure of the behaviour of a self-compacted inverted cone of concrete under the action of gravity. It is a measure of the concrete's workability or the dampness of concrete.

3 – Apparatus :

Slump cone (Abrams cone) , scale for measurement.

4 - Interpretation of results :

The slumped concrete takes various shapes, and according to the profile of slumped concrete, the slump is termed as true slump, shear slump or collapse slump. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump is an indication of too wet a mix. Only a true slump is of any use in the test. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which slump test is not appropriate . Very dry mixes; having slump 0 – 25 mm are used in road making, low workability mixes; having slump 10 – 40 mm are used for foundations with light reinforcement, medium workability mixes; 50 - 90 for normal reinforced concrete placed with vibration, high workability concrete ; > 100 mm.



Collapse **Shear** **True**

In a collapse slump the concrete collapses completely .

In a shear slump the top portion of the concrete shears off and slips side ways .

In a true slump the concrete simply sub sides , keeping more or less to shape .

4 – 1 - European classes of slump :

According to European Standard EN 206 – 1 : 2000 five classes of slump have been designated, as tabulated below .

Slump Class	**Slump in mm**
S1	10 - 40
S2	50 - 90
S3	80 - 180
S4	160 - 210
S5	≥ 220

5 - Limitations of the slump test :

The slump test is suitable for slumps of medium to high workability, slump in the range of 25 – 125 mm, the test fails to determine the difference in workability in stiff mixes which have zero slump, or for wet mixes that give a collapse slump. It is limited to concrete formed of aggregates of less than 38 mm (1 inch) .

6 - Differences in standards :

The slump test is referred to in several testing and building codes, with minor differences in the details of performing the test.

6 – 1 - United States :

In the United States, engineers use the ASTM standards and AASHTO specifications when referring to the concrete slump test. The American standards explicitly state that the slump cone should have a height of 12 – in , a bottom diameter of 8-in and an upper diameter of 4-in. The ASTM standards also state in the procedure that when the cone is removed, it should be lifted up vertically , without any rotational movement at all . The concrete slump test is known as "Standard Test Method for Slump of Hydraulic - Cement Concrete" and carries the code (ASTM C 143) or (AASHTO T 119) .

6 – 2 - United Kingdom and Europe :

In the United Kingdom, the standards specify a slump cone height of 300 mm, a bottom diameter of 200 mm and a top diameter of 100 mm. The British Standards do not explicitly specify that the cone should only be lifted vertically. The slump test in the British standards was first (BS 1881 – 102) and is now replaced by the European Standard (BS EN 12350 - 2) . The test should be carried out by filling the slump cone in three equal layers with the mixture being tamped down 25 times for each layer.

6 – 3 - Other tests :

Numerous tests exist to evaluate concrete: a similar test is the K-Slump Test (ASTM C 1362) . Other tests evaluating consistency are the British compacting factor test (BS EN 12350 - 4), the Vebe consist meter for roller - compacted concrete (ASTM C 1170) , and the flow table test (DIN 1048 -1) .

Concrete Step Barrier

Contents

1 – Introduction :

A **concrete step barrier** is a safety barrier used on the central reservation of motorways and dual carriageways as an alternative to the standard steel crash barrier.

Concrete step barrier cross - section

2 - United Kingdom :

Concrete step barrier on M1 motor way UK

With effect from January 2005 and based primarily on safety grounds, the UK Highways Agency policy is that all new motorway schemes are to use high-containment concrete barriers in the central reserve. All existing motorways will introduce concrete barriers into the central reserve as part of ongoing upgrades and through replacement when these systems have reached the end of their useful life. This change of policy applies only to barriers in the central reserve of high - speed roads and not to verge - side barriers . Other routes will continue to use steel barriers . Government policy ensures that all future crash barriers in the UK will be made of concrete unless there are overriding circumstances .

3 – Ireland :

The concrete step barrier in the under construction M8 motor way in Ireland (August 2008) .

The usage of the concrete step barrier has now become widespread in Ireland. As of November 2008 , 405 kilo meters of new motor way under construction at present will use the new barrier. Existing motorways such as parts of the M8 and M6 already have the crash barrier. Other motorways are now installing them as part of upgrades (M50) .

4 - Hong Kong :

Concrete profile barrier.

5 - Degradation processes :

Typical crack pattern associated with the alkali - silica reaction affecting a Jersey barrier on a US highway (photograph , courtesy of the Federal High way Administration (US Department of Transportation) .

Various types of aggregate may undergo chemical reactions in concrete, leading to damaging expansive phenomena. The most common are those containing reactive silica, that can react with the alkalis in concrete. Amorphous silica is one of the most reactive mineral components in some aggregates containing e.g., opal, chalcedony, flint. Following the alkali-silica reaction (ASR), an expansive gel forms, that creates extensive cracks and damage on structural members.

Construction Aggregate

10 mm graded crushed rock or aggregate, for use in concrete. Called "blue metal" in Australia.

20 mm graded aggregate.

Contents

1 – Introduction :

Construction aggregate, or simply "*aggregate*", is a broad category of coarse particulate material used in construction , including sand , gravel , crushed stone , slag , recycled concrete and geo synthetic aggregates . Aggregates are the most mined material in the world. Aggregates are a component of composite materials such as concrete and asphalt concrete ; the aggregate serves as reinforcement to add strength to the overall composite material. Due to the relatively high hydraulic conductivity value as compared to most soils, aggregates are widely used in drainage applications such as foundation and French drains, septic drain fields, retaining wall drains, and road side edge drains. Aggregates are also used as base material under foundations, roads, and railroads. In other words, aggregates are used as a stable foundation or road/rail base with predictable, uniform properties (e.g. to help prevent differential settling under the road or building) , or as a low - cost extender that binds with more expensive cement or asphalt to form concrete .

Preferred bituminous aggregate sizes for road construction are given in EN 13043 as d/D (where the range shows the smallest and largest square mesh grating that the particles can pass). The same classification sizing is used for larger armour stone sizes in EN 13383, EN 12620 for concrete aggregate, EN 13242 for base layers of road construction and EN 13450 for railway ballast.

The American Society for Testing and Materials publishes an exhaustive listing of specifications for various construction aggregate products, which, by their individual design, are suitable for specific construction purposes. These products include specific types of coarse and fine aggregate designed for such uses as additives to asphalt and concrete mixes, as well as other construction uses. State transportation departments further refine aggregate material specifications in order to tailor aggregate use to the needs and available supply in their particular locations.

Sources for these basic materials can be grouped into three main areas: Mining of mineral aggregate deposits, including sand, gravel, and stone; use of waste slag from the manufacture of iron and steel; and recycling of concrete, which is itself chiefly manufactured from mineral aggregates. In addition, there are some (minor) materials that are used as specialty lightweight aggregates: clay, pumice, perlite, and vermiculite.

2 - History ;

People have used sand and stone for foundations for thousands of years. Significant refinement of the production and use of aggregate occurred during the Roman Empire, which used aggregate to build its vast network of roads and aqueducts. The invention of concrete, which was essential to architecture utilizing arches, created an immediate, permanent demand for construction aggregates.

3 - Modern production :

The advent of modern blasting methods enabled the development of quarries, which are now used throughout the world, wherever competent bedrock deposits of aggregate quality exist. In many places, good limestone, granite, marble or other quality stone bedrock deposits do not exist. In these areas, natural sand and gravel are mined for use as aggregate. Where neither stone, nor sand and gravel, are available, construction demand is usually satisfied by shipping in aggregate by rail, barge or truck. Additionally, demand for aggregates can be partially satisfied through the use of slag and recycled concrete. However, the available tonnages and lesser quality of these materials prevent them from being a viable replacement for mined aggregates on a large scale.

Over 1 million tons annually are mined from this quarry near San Francisco.

Large stone quarry and sand and gravel operations exist near virtually all population centers. These are capital-intensive operations, utilizing large earth-moving equipment, belt conveyors, and machines specifically designed for crushing and separating various sizes of aggregate, to create distinct product stockpiles.

According to the USGS, 2006 U.S. crushed stone production was 1.72 billion tones valued at $13.8 billion (compared to 1.69

billion tones valued at $12.1 billion in 2005) , of which limestone was 1,080 million tones valued at $8.19 billion from 1,896 quarries, granite was 268 million tones valued at $ 2.59 billion from 378 quarries, traprock was 148 million tones valued at $ 1.04 billion from 355 quarries, and the balance other kinds of stone from 729 quarries. Limestone and granite are also produced in large amounts as dimension stone. The great majority of the crushed stone moved by heavy truck from the quarry/plant to the first point of sale or use. According to the USGS, 2006 U.S. sand and gravel production was 1.32 billion tones valued at $ 8.54 billion (compared to 1.27 billion tones valued at $7.46 billion in 2005), of which 264 million tonnes valued at $ 1.92 billion was used as concrete aggregates. The great majority of this was again moved by truck, instead of by electric train.

Currently, total U.S. aggregate demand by final market sector was 30 % - 35 % for non - residential building (offices , hotels , stores , manufacturing plants , government and institutional buildings , and others) , 25 % for high ways , and 25 % for housing .

4 - Recycled materials for aggregates :

The largest - volume of recycled material used as construction aggregate is blast furnace and steel furnace slag . Blast furnace slag is either air - cooled (slow cooling in the open) or granulated (formed by quenching molten slag in water to form sand - sized glass-like particles) . If the granulated blast furnace slag accesses free lime during hydration, it develops strong hydraulic cementitious properties and can partly substitute for portland cement in concrete. Steel furnace slag is also air-cooled. In 2006, according to the USGS, air-cooled blast furnace slag sold or used in the U.S. was 7.3 million tonnes valued at $49 million, granulated blast furnace slag sold or used in the U.S. was 4.2 million tones valued at $318 million, and steel furnace slag sold or used in the U.S. was 8.7 million tones valued at $ 40 million. Air-cooled blast furnace slag sales in 2006 were for use in road bases and surfaces (41 %) , asphaltic concrete (13 %) , ready - mixed concrete (16 %) , and the balance for other uses. Granulated blast furnace slag sales in 2006 were for use in cementitious materials (94 %) , and the balance for other uses. Steel furnace slag sales in 2006 were for use in road bases and surfaces (51 %) , asphaltic concrete (12 %) , for fill (18 %) , and the balance for other uses.

Glass aggregate, a mix of colors crushed to a small size, is substituted for many construction and utility projects in place of pea gravel or crushed rock, oftentimes saving municipalities like the City of Tumwater , Washington Public Works , thousands of dollars (depending on the size of the project). Glass aggregate is not sharp to handle. In many cases, the state Department of Transportation has specifications for use, size and percentage of quantity for use. Common applications are as pipe bedding -- placed around sewer, storm water or drinking water pipes to transfer weight from the surface and protect the pipe. Another common use would be as fill to bring the level of a concrete floor even with a foundation. Use of glass aggregate helps close the loop in glass recycling in many places where glass cannot be smelted into new glass.

Aggregates themselves can be recycled as aggregates. Unlike deposits of sand and gravel or stone suitable for crushing into aggregate, which can be anywhere and may require overburden removal and/or blasting, "deposits" of recyclable aggregate tend to be concentrated near urban areas, and production from them cannot be raised or lowered to meet demand for aggregates. Supply of recycled aggregate depends on physical decay of structures and their demolition. The recycling plant can be fixed or mobile; the smaller capacity mobile plant works best for asphalt-aggregate recycling. The material being recycled is usually highly variable in quality and properties.

According to the USGS in 2006, 2.9 million tonnes of Portland cement concrete (including aggregate) worth $21.9 million was recycled, and 1.6 million tones of asphalt concrete (including aggregate) worth $ 11.8 million was recycled, both by crushed stone operations. Much more of both materials are recycled by construction and demolition firms not in the USGS survey. For sand and gravel, the USGS survey for 2006 showed that 4.7 million tones of cement concrete valued at $ 32.0 million was recycled, and 6.17 million tonnes of asphalt concrete valued at $ 45.1 million was recycled. Again , much more of both materials are recycled by construction and demolition firms not in this USGS survey. The Construction Materials Recycling Association indicates that there are 325 million tonnes of recoverable construction and demolition materials produced annually.

Many geo synthetic aggregates are also made from recycled materials. Being polymer based, recyclable plastics can be reused in the production of these new age of aggregates. For example, Ring Industrial Group's EZflow product lines are produced with geo synthetic aggregate pieces that are more than 99.9 % recycled polystyrene. This polystyrene, that would have otherwise been destined for a landfill, is instead gathered, melted, mixed, reformulated and expanded to create low density aggregates that maintain high strength properties while under compressive loads. Such geo synthetic aggregates replace conventional gravel while simultaneously increasing porosity, increasing hydraulic conductivity and eliminating the fine dust "fines" inherent to gravel aggregates which otherwise serve to clog and disrupt the operation of many drainage applications.

4 – 1 - Recycled aggregate production in the UK :

Recycled aggregate in the UK is defined as aggregate resulting from the processing of inorganic material previously used in construction . To ensure the aggregate is inert, it is manufactured from material tested and characterized under European Waste Codes .

In 2008, 210 million tones of aggregate were produced in the UK of which 67 million tones was recycled product, according to the Quarry Products Association (QPA) . The Waste and Resource Action Programme (WRAP) has produced a Quality Protocol for the regulated production of recycled aggregates . The recycled aggregate is delivered with documentation that states it has been produced using a quality assured system for the manufacturing process to ensure an aggregate that conforms to the relevant European standards .

Continuous Flight Auguring

Continuous Flight Auguring (CFA) is a technique used in construction to create concrete piles.

Continuous flight auger has been used in the United Kingdom since 1966[1], but its use is relatively new in the United States. A continuous flight auguring drill is used to excavate a hole and concrete is injected through a hollow shaft under pressure as the auger is extracted. This creates a continuous pile without ever leaving an open hole.

Continuous flight auguring can be used to construct a secant pile wall which can be used as a retaining wall or as shoring during excavation. Once initial piles are set with concrete, other shafts are augured between them, slicing into the original piles, with the new ones receiving reinforcement. The finished result is a continuous wall of reinforced concrete that aids and protects workers during excavation.

Corundum

Contents

1 – Introduction :

Corundum is a crystalline form of aluminium oxide (Al_2O_3) with traces of iron, titanium and chromium . It is a rock - forming mineral. It is one of the naturally clear transparent materials, but can have different colors when impurities are present. Transparent specimens are used as gems, called ruby if red and padparadscha if pink-orange. All other colors are called sapphire, e.g., "green sapphire" for a green specimen.

The name "corundum" is derived from the Tamil word "kuruntam" meaning "ruby", and related to Sanskrit "kuruvinda".

Because of corundum's hardness (pure corundum is defined to have 9.0 Mohs) , it can scratch almost every other mineral. It is commonly used as an abrasive , on everything from sand paper to large machines used in machining metals, plastics, and wood. Some emery is a mix of corundum and other substances, and the mix is less abrasive, with an average hardness near 8.0.

In addition to its hardness, corundum is unusual for its density of 4.02 g / cm^3, which is very high for a transparent mineral composed of the low atomic mass elements aluminium and oxygen .

Category	Oxide mineral – Hematite group
Chemical Formula	Aluminium oxide , Al_2O_3
Unit cell	a = 4.75 Å , c = 12.982 Å ; Z = 6
Color	Colorless , gray, brown ; pink to pigeon - blood - red, orange , yellow , green , blue to cornflower blue, violet ; may be color zoned , asteriated mainly grey and brown
Crystal habit	Steep bi pyramidal, tabular , prismatic, rhombohedral crystals , massive or granular
Mohs scale hardness	9 (defining mineral)
Luster	Adamantine to vitreous
Streak	White
Diaphaneity	Transparent, translucent to opaque
Specific gravity	3.95 – 4.10
Optical properties	Uniaxial (–)
Refractive index	$n_\omega = 1.767–1.772$ $n_\varepsilon = 1.759 –1.763$
Melting point	2044 °C
Fusibility	Infusible
Solubility	Insoluble
Alters to	May alter to mica on surfaces causing a decrease in hardness
Other characteristics	May fluoresce or phosphoresce under UV
Sapphire	Any color except red

Ruby	Red
Emery	Black granular corundum intimately mixed with magnetite , hematite, or hercynite

2 - Geology and occurrence :

Corundum occurs as a mineral in mica schist, gneiss, and some marbles in Metamorphic terranes . It also occurs in low silica igneous syenite and nepheline syenite intrusives. Other occurrences are as masses adjacent to ultramafic intrusives, associated with lamprophyre dikes and as large crystals in pegmatites . It commonly occurs as a detrital mineral in stream and beach sands because of its hardness and resistance to weathering . The largest documented single crystal of corundum measured about 65 × 40 × 40 cm .

Corundum for abrasives is mined in Zimbabwe, Russia, Sri Lanka and India. Historically it was mined from deposits associated with dunites in North Carolina, USA and from a nepheline syenite in Craigmont , Ontario . Emery grade corundum is found on the Greek island of Naxos and near Peekskill, New York, USA. Abrasive corundum is synthetically manufactured from bauxite.[4]

Corundum should not be confused with the similarly named carborundum , silicon carbide.

3 - Synthetic corundum :

In 1837, Marc Antoine Gaudin made the first synthetic rubies by fusing alumina at a high temperature with a small amount of chromium as a pigment . In 1847, Ebelmen made white sapphires by fusing alumina in boric acid . In 1877 Frenic and Freil made crystal corundum from which small stones could be cut. Frimy and Auguste Verneuil manufactured artificial ruby by fusing BaF_2 and Al_2O_3 with a little chromium at temperatures above 2,000 °C . In 1903, Verneuil announced he could produce synthetic rubies on a commercial scale using this flame fusion process.

The Verneuil process allows the production of flawless single - crystal sapphires, rubies and other corundum gems of much larger size than normally found in nature. It is also possible to grow gem-quality synthetic corundum by flux - growth and hydro thermal synthesis . Because of the simplicity of the methods involved in corundum synthesis , large quantities of these crystals have become available on the market causing a significant reduction of price in recent years. Apart from ornamental uses , synthetic corundum is also used to produce mechanical parts (tubes , rods , bearings , and other machined parts) , scratch - resistant optics, scratch - resistant watch crystals , instrument windows for satellites and spacecraft (because of its transparency from the UV to IR) , and laser components.

Cover Meter

Contents

1 - Introduction :

A **cover meter** is an instrument to locate rebars and measure the exact concrete cover . Rebar detectors are less sophisticated devices that can only locate metallic objects below the surface. Due to the cost-effective design , the pulse - induction method is one of the most commonly used solutions.

2 - Method :

The pulse - induction method is based on electromagnetic pulse induction technology to detect rebars. Coils in the probe are periodically charged by current pulses and thus generate a magnetic field. On the surface of any electrically conductive material which is in the magnetic field eddy currents are produced. They induce a magnetic field in opposite directions. The resulting change in voltage can be utilized for the measurement. Rebars that are closer to the probe or of larger size produce a stronger magnetic field.

Modern rebar detectors use different coil arrangements to generate several magnetic fields. Advanced signal processing supports not only the localization of rebars but also the determination of the cover and the estimation of the bar diameter. This method is unaffected by all non conductive materials such as concrete, wood, plastics, bricks, etc. However any kind of conductive materials within the magnetic field will have an influence on the measurement.

Advantages of the pulse induction method :

- high accuracy

- not influenced by moisture and heterogeneities of the concrete
- unaffected by environmental influences
- low costs

Disadvantage of the pulse induction method:

- Limited detection range
- Minimum bar spacing depends on cover depths

3 - Standards :

- BS1881 : 204 Testing concrete. Recommendations on the use of electro magnetic cover meters
- DGZfP:B2 : Guideline "für Bewehrungsnachweis und Überdeckungsmessung bei Stahl- und Spannbeton"
- DIN 1045: Guideline Concrete, reinforced and prestressed concrete structures
- ACI Concrete Practices Non Destructive testing 228.2R-2.51: Cover meters

4 – Application :

Early diagnosis and analysis of seemingly healthy concrete cover and reinforcement status allows pre-emptive corrosion control measures to reduce unwanted risks to structural safety.[2] Bundesanstalt für Materialforschung und - prüfung (Federal Institute for Materials Research and Testing, Germany) has developed a sensor equipped robotic system to accelerate the collection of several criteria used for diagnostics. Besides ultrasonic, ground - penetrating radar, concrete resistance, potential field, the eddy current method implemented in the Profometer 5 was used to measure the concrete cover.

Crushed Stone

20 millimeter crushed stone, for construction aggregate and landscape uses.

Contents

1 – Introduction :

Crushed stone or **angular rock** is a form of construction aggregate, typically produced by mining a suitable rock deposit and breaking the removed rock down to the desired size using crushers. It is distinct from gravel which is produced by natural processes of weathering and erosion, and typically has a more rounded shape.

2 - Uses :

Angular crushed stone is the key material for macadam road construction which depends on the interlocking of the individual stones' angular faces for its strength . Crushed natural stone is also used similarly without a binder for riprap , railroad track ballast, and filter stone. It may also be used with a binder in a composite material such as concrete, tarmac, or asphalt concrete .

3 - Back ground :

Crushed stone is one of the most accessible natural resources, and is a major basic raw material used by construction, agriculture, and other industries . Despite the low value of its basic products, the crushed stone industry is a major contributor to and an indicator of the economic well - being of a nation . The demand for crushed stone is determined mostly by the level of construction activity, and, therefore, the demand for construction materials .

Stone resources of the world are very large. High-purity limestone and dolomite suitable for specialty uses are limited in many geographic areas. Crushed stone substitutes for road building include sand and gravel, and slag. Substitutes for crushed stone used as construction aggregates include sand and gravel, iron and steel slag, sintered or expanded clay or shale , and perlite or vermiculite .

A crushed stone barge in China

Crushed stone being laid to underlie a road surface

Crushed stone is a high – volume , low - value commodity. The industry is highly competitive and is characterized by many operations serving local or regional markets. Production costs are determined mainly by the cost of labor, equipment, energy, and water, in addition to the costs of compliance with environmental and safety regulations. These costs vary depending on geographic location, the nature of the deposit, and the number and type of products produced. Despite having one of the lowest average by weight values of all mineral commodities, in the United States the constant dollar price of crushed stone has changed relatively little during a recent 20 year period. As a result of rising costs of labor, energy, and mining and processing equipment, the average unit price of crushed stone increased from US $ 1.58 per metric ton, f.o.b. plant, in 1970 to US$4.39 in 1990. However, the unit price in constant 1982 dollars fluctuated between US $ 3.48 and US $ 3.91 per metric ton for the same period. Increased productivity achieved through increased use of automation and more efficient equipment was mainly responsible for maintaining the prices at this level .

Transportation is a major factor in the delivered price of crushed stone. The cost of moving crushed stone from the plant to the market often equals or exceeds the sale price of the product at the plant. Because of the high cost of transportation and the large quantities of bulk material that have to be shipped, crushed stone is usually marketed locally. The high cost of transportation is responsible for the wide dispersion of quarries, usually located near highly populated areas. However, increasing land values combined with local environmental concerns are moving crushed stone quarries farther from the end-use locations, increasing the price of delivered material. Economies of scale, which might be realized if fewer, larger operations served larger marketing areas, would probably not offset the increased transportation costs .

4 - United States statistical data :

According to the United States Geological Survey, 1.72 billion tones of crushed stone worth $ 13.8 billion was sold or used in 2006, of which 1.44 billion tones was used as construction aggregate, 74.9 million tones used for cement manufacture, and 18.1 million tones used to make lime. Crushed marble sold or used totaled 11.8 million tonnes, the majority of which was ground very fine and used as calcium carbonate.

In 2006, 9.40 million tones of crushed stone (almost all limestone or dolomite) was used for soil treatment, primarily to reduce soil acidity. Soils tend to become acidic from heavy use of nitrogen-containing fertilizers, unless a soil conditioner is used. Using aglime or agricultural lime, a finely-ground limestone or dolomite, to change the soil from acidic to nearly neutral particularly benefits crops by maximizing availability of plant nutrients, and also by reducing aluminum or manganese toxicity, promoting soil microbe activity, and improving the soil structure.

In 2006, 5.29 million tonnes of crushed stone (mostly limestone or dolomite) was used as a flux in blast furnaces and in certain steel furnaces to react with gangue minerals (i.e. silica and silicate impurities) to produce liquid slag that floats and can be poured off from the much denser molten metal (i.e., iron) . The slag cools to become a stone-like material that is commonly crushed and recycled as construction aggregate.

In addition, 4.53 million tones of crushed stone was used for fillers and extenders (including asphalt fillers or extenders), 2.71 million tones for sulfur oxide removal-mine dusting-acid water treatment, and 1.45 million tones sold or used for poultry grit or mineral food.

Crushed stone is recycled primarily as construction aggregate or concrete.

Mulch at the Huntington Desert Garden, California.

5 - Landscape use :

Crushed stone or 'road metal' is used in landscape design and gardening for gardens, parks, and municipal and private projects as a mulch, walkway, path, and driveway pavement, and cell infill for modular permeable paving units. As a mineral mulch its benefits include erosion control, water conservation, weed suppression, and aesthetic qualities. It is often seen used in rock gardens and cactus gardens.

Cryolite

Cryolite from Ivigtut Greenland

1 – Introduction :

Cryolite (Na_3 Al F_6 , sodium hexa fluoro aluminate) is an uncommon mineral identified with the once large deposit at Ivigtût on the west coast of Green land , depleted by 1987.

The Cryolite mine Ivigtut , Green land , summer 1940

It was historically used as an ore of aluminium and later in the electrolytic processing of the aluminium-rich oxide ore bauxite (itself a combination of aluminium oxide minerals such as gibbsite, boehmite and diaspore) . The difficulty of separating aluminium from oxygen in the oxide ores was overcome by the use of cryolite as a flux to dissolve the oxide mineral(s). Pure cryolite itself melts at 1012 °C , and it can dissolve the aluminium oxides sufficiently well to allow easy extraction of the aluminium by electrolysis. Considerable energy is still required for both heating the materials and the electrolysis, but it is much more energy - efficient than melting the oxides themselves. Now, as natural cryolite is too rare to be used for this purpose, synthetic sodium aluminium fluoride is produced from the common mineral fluorite.

Cryolite occurs as glassy, colorless, white - reddish to gray - black prismatic monoclinic crystals. It has a Mohs hardness of 2.5 to 3 and a specific gravity of about 2.95 to 3.0. It is translucent to transparent with a very low refractive index of about 1.34, which is very close to that of water; thus if immersed in water, cryolite becomes essentially invisible . Cryolite has also been reported at Pikes Peak, Colorado; Mont Saint-Hilaire, Quebec; and at Miass, Russia. It is also known in small quantities in Brazil, the Czech Republic, Namibia, Norway, Ukraine, and several American states.

Cryolite was first described in 1799 from a deposit of it in Ivigtut and Arksukfiord, West Greenland. The name is derived from the Greek language words *cryò* = chill, and *lithòs* = stone . The Pennsylvania Salt Manufacturing Company used large amounts of cryolite to make caustic soda at its Natrona, Pennsylvania works during the 19th and 20th centuries.

Category	Halide Mineral
Chemical Formula	$Na_3 Al F_6$
Unit cell	a = 7.7564 Å, b = 5.5959 Å , c = 5.4024 Å ; β = 90.18° ; Z = 2
Molar Mass	210 g mol^{-1}
Color	Colorless to white, also brownish, reddish and rarely black
Crystal habit	Usually massive, coarsely granular. The rare crystals are equant and pseudo cubic
Crystal system	Monoclinic 2/m

Twinning	Very common , often repeated or poly synthetic with simultaneous occurrence of several twin laws
Mohs scale hardness	2.5 to 3
Luster	Vitreous to greasy, pearly
Streak	White
Diaphaneity	Transparent to translucent
Specific gravity	2.95 to 3.0.
Optical properties	Biaxial (+)
Refractive index	$n_{\alpha} = 1.3385–1.339$, $n_{\beta} = 1.3389–1.339$, $n_{\gamma} = 1.3396–1.34$
Melting point	1012 °C
Solubility	Easily soluble in $AlCl_3$ solution, soluble in H_2SO_4 with the evolution of HF, which is poisonous. Slightly soluble in water.
Other characteristics	Weakly thermo luminescent . Small clear fragments become nearly invisible when placed in water, since its refractive index is close to that of water. May fluoresce intense yellow under SWUV, with yellow phosphorescence, and pale yellow phosphorescence under LWUV. Not radioactive.

2 - Pesticide and insecticide :

Cryolite is used as a insecticide and a pesticide .

Decorative Concrete

Stamped Concrete in various patterns , highlighted with acid stain)

Contents

1 – Introduction :

Decorative Concrete is the use of concrete as not simply a utilitarian medium for construction but as an aesthetic enhancement to a structure, while still serving its function as an integral part of the building itself such as floors, walls, driveways and patios.

The transformation of concrete into decorative concrete is achieved through the use of a variety of materials that may be applied during the pouring process or after the concrete is cured, these materials and/or systems include but are not limited to stamped concrete, acid staining, decorative overlays, polished concrete, concrete countertops, vertical overlays and more.

2 - Stamped Concrete :

Stamped Concrete is the process of adding texture and color to concrete to make it resemble stone, brick, slate, cobblestone and many other products found in nature including wood, fossils, shells and many more. This limitless array of possibilities combined with great durability and lower cost than natural products makes Stamped Concrete an easy choice for new construction and renovation projects.

The installation consists of pressing molds into the concrete while the concrete is still in its plastic state. Color is achieved by using Dry Shakes or Color Hardeners, Powder or Liquid Releases, Integral Colors or Acid Stains. All these products may be combined to create even more intricate designs.

Stamped Concrete may be used on driveways, patios, commercial roads and parking lots and even interior floors.

3 - Concrete dyes :

Concrete "dyes" take many different forms and compositions and can be used on both residential and commercial concrete applications, including sound/retaining walls , bridges , countertops , floors , etc.

Early concrete dyes consisted of generic printing inks that were dissolved in mild solutions of alcohol and applied to concrete surfaces to add a wide array of color to plain gray concrete. When alcohol-based dyes are exposed to sunlight, the color either lightens or fades out completely. Therefore, alcohol - based dyes were more prevalent in interior applications where direct sunlight or other forms of ultraviolet (UV) lighting was not present.

Manufacturers later began dissolving the same printing inks in different carriers, such as acetone, lacquer thinner and other solvents, hoping to achieve increased penetration levels. In addition, UV inhibiting agents were added to new dyes to help with the UV instability issues. How ever , slight fading (5 – 8 % per year) still occurs when the dye is exposed to direct sunlight.

Colored concrete can be obtained from many ready mix concrete companies and many have color charts available.

4 - Acid Staining :

Acid staining is not a dyeing or pigment-base coloring systems, but a chemical reaction. A mixture of water, mineral salts and a slight amount of muratic acid is applied to the concrete surface. This chemical reaction with the existing minerals (primarily lime) in the concrete over a period of one to four hours creates new earth tone colors on the concrete surface. The concrete surface is later scrubbed to remove excess stain and neutralized by a basic solution of ammonia and water or baking soda (less likely to cause whiting later) to help raise the ph level back to normal level. Due to inconsistencies in the surface level of concrete floor, acid staining creates a variegated or mottled appearance that is unique to each slab. The color penetration ranges from 1/16 to 1/32 of an inch. Older exterior concrete surfaces may not color as well as interior surfaces because the environment has leached or percolated out the mineral content. As well, any exposed aggregate (rocks) in worn concrete will not accept staining.

Chemicals commonly used in acid staining include Hydrochloric acid , Iron chloride and Sodium bicarbonate .

5 - Water Based Staining :

Water Based Stains are similar to acid based stains in the sense that one can still achieve a translucent look like acid; some stains are able to achieve an opaque color and/or a translucent effect. The main difference is that acid stains react to the concrete and change the physical make up of the concrete material, whereas water based stains are more of a "coating" that bonds with the concrete. There are many variations of water based stains that have come into the decorative concrete industry that perform in a number of different ways. Some are polymer based, acrylic and epoxy.

6 - 1/4" Stamped Overlays :

Rubber imprinting tools stamps are impressed into thin pre-mixed concrete overlay material to create natural stone or brick textures. These rubber imprinting tools are manufactured from molds created from authentic stone or wood. Release agents are used to help release the stamps from the concrete without sticking. Release agents come in either a liquid or powder form.

7 - General Overlaying :

Concrete overlays date to the 1960s when chemical engineers from some of the larger, well known chemical companies began to experiment with acrylic paint resins as modifiers for cement and sand mixes. The result was a thin cementitious topping material that would adhere to concrete surfaces and provide a newly resurfaced coating to restore the worn surface. Concrete overlays lacked the long term performance characteristics of acrylic resins. Acrylic resins provided good UV resistance, but lacked long term water resistance and adhesion characteristics needed to provide a long term and permanent solution.

7 – 1 - Polymer cement overlays :

Polymer cement overlays, consisting of a proprietary blend of Portland cements, various aggregates and polymer resins, were introduced over 20 years ago. The purpose of adding a polymer resin to the cement and aggregate is to greatly increase the performance characteristics and versatility of conventional cements, mortars and concrete materials. Unlike conventional cement and concrete mixes, polymer cement overlays can be applied thinly or thickly without fear of delamination or typical product failure. In addition, polymer cement overlays are much more resistant to damage from salt, petrochemicals, UV, harsh weather conditions and traffic wearing.

Originally intended for use as a thin surface restoration material for concrete substrates, polymer cement overlays were introduced into the architectural concrete and commercial flooring industries in the early 80s. Subsequently, its use in these industries has become standard. Polymer cement overlays are regarded as economical in providing long term, durable renovation without the need for costly and continuous repairs associated with deteriorating concrete surfaces.

7 – 1 – 1 – Applications :

Polymer cement overlays are used for interior and exterior applications ranging from:

- Skim coat / broom finish concrete resurfacing – Restore and protect damaged, pitted, flaking and stained concrete back to the look of a new concrete surface.
- Concrete regrading & leveling – Repair and level concrete surfaces that have settled.
- Existing substrate redecorating and renovating – Alter the appearance of existing concrete or wood substrates through applying "thin stamped" or "thin stained" overlays, creating new textures, colors and designs. For use on commercial or resident pool deck, this frequently takes the form of "splatter textures" or "knockdowns," in which polymer cement is applied to the existing concrete substrate in a moderately textured finish (average of 1/8” thickness) in various patterns. Often, the texture is knocked down with a trowel to slightly modify the appearance and feel of the finished application.

7 – 2 – Epoxy :

Applied over acid stained, dyes and/or overlays to seal and protect. Some epoxies are also colored.

7 – 3 – Polishing :

Concrete can be polished with Mechanical grinders and diamond pads of increasing grit sizes. Diamond pads come in many grit or mesh sizes. Common sizes start with 6 grit and can go up to 8500 grit although concrete can only maintain a shine of about 800 grit, it can be helped by adding a concrete hardener such as sodium silicate or lithium silicate which will allow concrete to hold a 1800 through 3000 grit shine. The work is accomplished in multiple stages by passing over the concrete with successive grit diamond pads until it has a hard-glassy finish. Both acid stains and concrete dyes can be used during the polishing process.

7 – 4 – Engraving :

Existing concrete can be remodeled by cutting lines and grooves into its surface. Geometric patterns, straight or curved lines and custom designs can be cut directly into the surface of the concrete creating the look of tile, flagstone, cobblestone and many other common surface patterns. This is usually achieved using tools like an angle grinder fitted with diamond blades, but is more effectively accomplished using specialty tools designed specifically for cutting designs into the concrete.

7 – 5 – Form liner :

Concrete can also be cast into unique and detailed designs using urethane form liner. These projects can be seen around the United States and the world, usually on sound/retaining walls, building exteriors, and bridges.

Generally, this process starts with the sculptor, who creates the design to be used in the concrete using clay, polyurethane or wax. When the original art is complete, a cast is made using synthetic liquid rubber, and from this cast, form liners are produced in the reverse image of the original.

The form liner then acts as a mold for the concrete to be formed against. Once the concrete is set, the form liner is stripped from the hardened concrete surface. The concrete is permanently textured with the pattern of the form liner.

7 – 6 – Decorative Concrete in the UK :

Decorative Concrete popularity in the UK is rapidly on the rise due to its durability and the creativity that can be had with it. One notible company that has helped in the quick growth of Decorative concrete in the UK is Prestigious concretes, it was originally set up in 2009 by Andrew Leonard James crook As a small side business manufacturing bespoke decorative concrete products such as worktops, polished and stained floors, outside furniture and bathroom suites. Due to decorative concretes growing popularity and demand Prestigious Concretes have recently registered as a United Kingdom limited Company and now offer a standard product range as well as there bespoke services. Prestigious Concretes Ltd is one of the UK’s leading and well respected suppliers of decorative concrete Providing its services to both the domestic and commercial industry. They have contributed many new techniques to the UK's industry and continue to create new unique methods of work.

Diamond Grinding of Pavement

Contents

1 – Introduction :

Diamond grinding is a pavement preservation technique that corrects a variety of surface imperfections on both concrete and asphalt pavements. Most often utilized on concrete pavement, diamond grinding is typically performed in conjunction with other concrete pavement preservation (CPP) techniques such as road slab stabilization, full- and partial-depth repair, dowel bar retrofit, cross stitching longitudinal cracks or joints and joint and crack resealing.[1] Diamond grinding restores ride ability by removing surface irregularities caused during construction or through repeated traffic loading over time. The immediate effect of diamond grinding is a significant improvement in the smoothness of a pavement. Another important effect of diamond grinding is the considerable increase in surface macro texture and consequent improvement in skid resistance, noise reduction and safety.

2 – History :

The industry can be traced back to an event where a single diamond blade mounted on a concrete saw was used to groove concrete pavement in the late 1940s. Since that early tentative step, concrete grinding, grooving and texturing with diamond blades has developed into what is today a multimillion dollar industry that is practiced worldwide .

One of the first uses of diamond grinding of highway pavement was in 1965 on a 19- year - old section of Interstate 10 in California to eliminate excessive faulting. The pavement was ground again in 1984 and in 1997, and it is still carrying heavy traffic today, more than 60 years after it was first constructed.

3 – Process :

Results of diamond grinding of pavement

Diamond grinding involves removing a thin layer at the surface of hardened PCC using closely spaced diamond saw blades. The level surface is achieved by running the blade assembly at a predetermined level across the pavement surface, which produces saw cut grooves. The uncut concrete between each saw cut breaks off more or less at a constant level above the saw cut grooves, leaving a level surface (at a macroscopic level) with longitudinal texture. The result is a pavement that is smooth, safe, quiet and pleasing to travel .

The diamond blades are composed of industrial diamonds and metallurgical powder. When grinding materials contain hard aggregate materials, a diamond blade with a soft bond is needed, which means that the metallurgical powders in the cutting segments of the blade wear fast enough to expose the diamond cutting media at the proper rate for efficient cutting. Conversely, to cut soft aggregates, a diamond blade with a hard bond is recommended.

Diamond grinding should not be confused with milling or scarifying. Milling is an impact process that chips small pieces of concrete from the pavement surface. Diamond grinding is a cutting process.

For grinding asphalt to remove old pavement, see asphalt milling machine.

4 – Applications :

There are many surface issues that diamond grinding can improve or correct. Some of the surface imperfections that can be addressed by diamond grinding include: faulting at joints and cracks, built-in or construction roughness, polished concrete surfaces exhibiting inadequate macro texture, wheel path rutting caused by studded tires, unacceptable noise level, slab warping caused by moisture gradient and construction curling, inadequate transverse slope and splash and spray reduction.

5 - Cost – effectiveness :

Diamond grinding is a cost- effective treatment, whether used alone or as part of an overall concrete pavement restoration (CPR) program. In most cases, the cost of diamond grinding is only about half the cost of bituminous overlays . This cost competitiveness, in conjunction with eliminating bituminous overlay problems (rutting, corrugation, poor skid resistance, drainage reduction, vertical clearance reduction) makes diamond grinding an alternative for many rehabilitation projects . Diamond grinding can be used as part of any preventive maintenance program for concrete pavements.

The California Department of Transportation (CALTRANS) reports that the average life of a diamond-ground surface is between 16 to 17 years. On average, more than 2,000 lane-miles of concrete pavement are diamond ground every year .

6 - Advantages :

Diamond grinding is used to restore or improve pavement ride quality. Restoring ride through grinding improves traffic carrying capacity and adds value to an in-place pavement. Diamond grinding provides numerous benefits over other rehabilitation alternatives.

This repair technique also provides a smooth surface which is often as good as new pavement . As trucks travel across bumps and dips, they bounce vertically on their suspension resulting in dynamic loading. The increased load due to dynamic impact results in higher stresses in the pavement materials and consequently lower road life by providing an extremely smooth surface. Diamond grinding limits dynamic loading .

Another advantage is reduced road noise. Diamond grinding's longitudinal texture provides a quieter surface than most transverse textures. A multi-state study on noise and texture on PCC pavements concluded that longitudinal texture concrete pavements are among the quietest pavements for interior and exterior noise . Diamond grinding also removes faults by leveling the pavement surface, thus eliminating the thumping and slapping sound created by faulted joints.

Enhanced surface texture and skid resistance is another advantage of diamond grinding. The corrugated surface increases surface macro texture and provides ample channels for water to displace beneath vehicle tires, reducing hydroplaning potential . Diamond grinding also improves cornering friction, providing directional stability by tire tread - pavement groove interlock.

Diamond grinding has been found to reduce accident rates. The increased macro texture provides for improved drainage of water at the tire-pavement interface, thus improving wet-weather friction, particularly for vehicles with balding tires. The longitudinal nature of a diamond-ground texture also provides directional stability and reduces hydroplaning, thus contributing to the safety of diamond ground surfaces.

This technique does not significantly affect fatigue life. The reduction in thickness due to diamond grinding is highest at the faulted joint and lower at the interior. The small reduction in slab thickness caused by diamond grinding has negligible effect on service life. A typical concrete pavement may be ground up to three times and still add traffic carrying capacity. Diamond grinding does not affect material durability. The fact that the diamond - ground surface is nearly always dry (except during storms) reduces any freeze-thaw problems. Diamond grinding does not introduce any unusual condition that would lead to poor surface durability.

This preservation method does not raise the pavement surface elevation. Grinding does not affect overhead clearances underneath bridges and eliminates the need for tapers at highway entrances, exits and at side streets. Grinding does not affect the hydraulic capacities of curbs and gutters on municipal streets. On the other hand, bituminous overlays fill curb and gutter, reducing drainage capabilities.

Diamond grinding should be applied to the portion of the pavement where restoration is needed . A highway agency can require grinding only on the truck lanes of a four-lane divided highway, presenting a significant cost advantage .

Finally, diamond grinding can be accomplished during off-peak hours with short lane closures, without having to close adjacent lanes. Diamond grinding can also be used on all road classes, from interstates to city streets.

Diatom

Marine diatoms

Contents

1 – Introduction :

Diatoms are a major group of algae , and are one of the most common types of phytoplankton. Most diatoms are unicellular, although they can exist as colonies in the shape of filaments or ribbons (e.g. *Fragilaria*), fans (e.g. *Meridion*), zigzags (e.g. *Tabellaria*), or stellate colonies (e.g. *Asterionella*). Diatoms are producers within the food chain. A characteristic feature of diatom cells is that they are encased within a unique cell wall made of silica

(hydrated silicon dioxide) called a frustule . These frustules show a wide diversity in form, but usually consist of two asymmetrical sides with a split between them, hence the group name. Fossil evidence suggests that they originated during, or before, the early Jurassic Period. Diatom communities are a popular tool for monitoring environmental conditions, past and present, and are commonly used in studies of water quality. Some diatoms are capable of movement via flagellation.

2 - General biology :

There are more than 200 genera of living diatoms, and it is estimated that there are approximately 100,000 extant species . Diatoms are a widespread group and can be found in the oceans, in fresh water, in soils and on damp surfaces. Most live pelagic ally in open water, although some live as surface films at the water-sediment interface (benthic) , or even under damp atmospheric conditions. They are especially important in oceans, where they are estimated to contribute up to 45% of the total oceanic primary production.[*citation needed*] Spatial distribution of marine phytoplankton species is restricted both horizontally and vertically . Usually microscopic, some species of diatoms can reach up to 2 millimeters in length.

Several species of fresh-water diatoms.

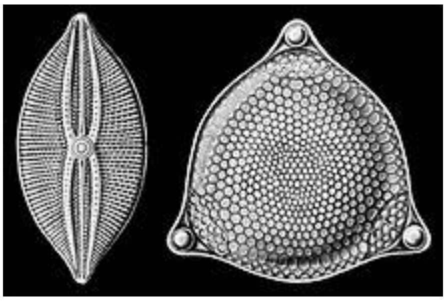
Diatoms belong to a large group called the heterokonts , including both autotrophs (e.g. golden algae, kelp) and heterotrophs (e.g. water moulds). Their yellowish-brown chloroplasts are typical of heterokonts , with four membranes and containing pigments such as the carotenoid fucoxanthin. Individuals usually lack flagella, but they are present in gametes and have the usual heterokont structure, except they lack the hairs (mastigonemes) characteristic in other groups. Most diatoms are non - motile, although some move via flagellation. As their relatively dense cell walls cause them to readily sink, planktonic forms in open water usually rely on turbulent mixing of the upper layers by the wind to keep them suspended in sunlit surface waters. Some species actively regulate their buoyancy with intracellular lipids to counter sinking. A feature of diatoms is the urea cycle, which links them evolutionarily to animals .

Diatom cells are contained within a unique silicate (silicic acid) cell wall comprising two separate valves (or shells). The biogenic silica that the cell wall is composed of is synthesised intracellularly by the polymerisation of silicic acid monomers. This material is then extruded to the cell exterior and added to the wall. Diatom cell walls are also called **frustules** or **tests**, and their two valves typically overlap one over the other like the two halves of a petri dish. In most species, when a diatom divides to produce two daughter cells, each cell keeps one of the two halves and grows a smaller half within it. As a result, after each division cycle the average size of diatom cells in the population gets smaller. Once such cells reach a certain minimum size, rather than simply divide vegetatively , they reverse this decline by forming an auxospore . This expands in size to give rise to a much larger cell, which then returns to size-diminishing divisions. Auxospore production is almost always linked to meiosis and sexual reproduction.

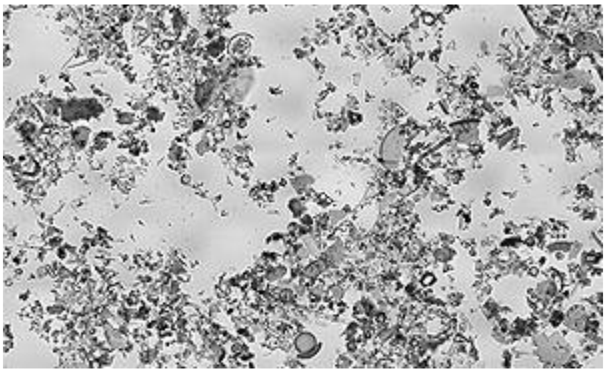
Decomposition and decay of diatoms leads to organic and inorganic (in the form of silicates) sediment, the inorganic component of which can lead to a method of analyzing past marine environments by corings of ocean floors or bay muds , since the inorganic matter is embedded in deposition of clays and silts and forms a permanent geological record of such marine strata.

The study of diatoms is a branch of phycology, and phycologists specializing in diatoms are called diatomists .

3 – Classification :



Selections from Ernst Haeckel's 1904 Kunstformen der Natur (Art Forms of Nature), showing pennate (left) and centric (right) frustules.



Diatomaceous earth as viewed under bright field illumination on a light microscope. Diatomaceous earth is a soft, siliceous, sedimentary rock made up of the cell walls of diatoms and readily crumbles to a fine powder. This sample consists of a mixture of centric (radially symmetric) and pennate (bilaterally symmetric) diatoms. This image of diatomaceous earth particles in water is at a scale of 6.236 pixels / µm, the entire image covers a region of approximately 1.13 by 0.69 mm.

The classification of heterokonts is still unsettled, and they may be treated as a division (or phylum), kingdom, or something in-between. Accordingly, groups like the diatoms may be ranked anywhere from class (usually called **Diatomophyceae**) to division (usually called **Bacillariophyta**), with corresponding changes in the ranks of their subgroups.

Diatoms are traditionally divided into two orders :

- **centric** diatoms (Centrales) , which are radially symmetric

- **pennate** diatoms (Pennales) , which are bilaterally symmetric. The former are paraphyletic to the latter.

A more recent classification divides the diatoms into three classes :

- centric diatoms (Coscinodiscophyceae)
- pennate diatoms
  - without a raphe (Fragilariophyceae)
  - with a raphe (Bacillariophyceae)

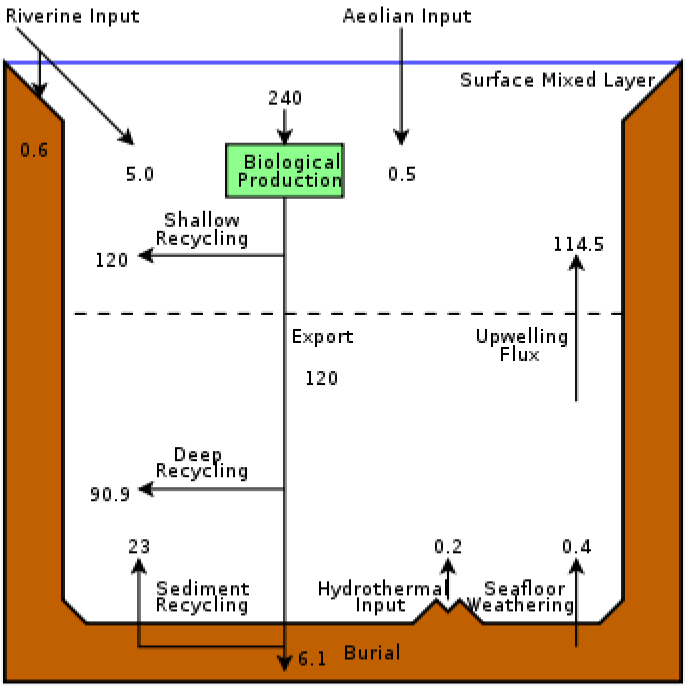
It is probable there will be further revisions as understanding of their relationships increases.

Diatoms generally range in size from ca. 2-200 µm , and are composed of a cell wall composed primarily of silica. This siliceous wall can be highly patterned with a variety of pores, ribs, minute spines, marginal ridges and elevations; all of which can be utilized to delineate genera and species. The cell itself consists of two halves, each containing an essentially flat plate, or valve and marginal connecting, or girdle band. One half, the hypotheca, is slightly smaller than the other half, the epitheca. Diatom morphology varies. Although the shape of the cell is typically circular, some cells may be triangular, square, or elliptical.

Cells are solitary or united into colonies of various kinds, which may be linked by siliceous structures; mucilage pads, or stalks; mucilage tubes; amorphous masses of mucilage and threads of polysaccharide (chitin), which are secreted through strutted processes. Major pigments of diatoms are chlorophylls a and c, beta-carotene, fucoxanthin, diatoxanthin and diadinoxanthin . Diatoms are primarily photosynthetic. A few, however, are obligate heterotrophs, while others can live heterotrophically in the absence of light, provided an appropriate organic carbon source is available. Storage products are chrysolaminarin and lipids.

Round & Crawford (1990) and Hoek *et al.* (1995) provide more comprehensive coverage of diatom taxonomy.

4 - Ecology :



A budget of the ocean's silicon cycle

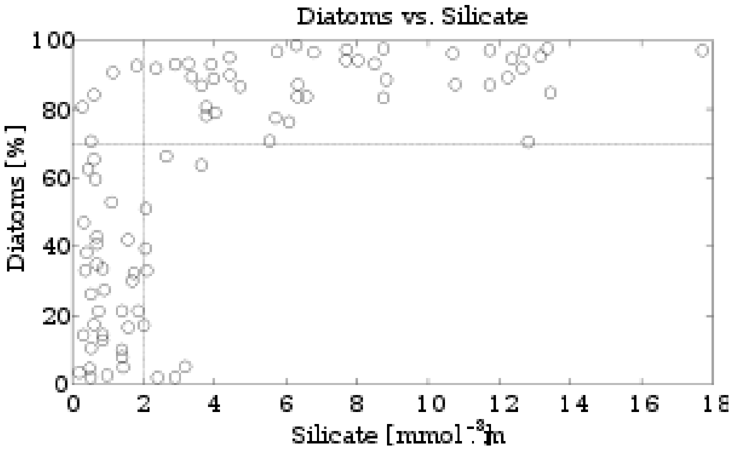
Planktonic diatoms in fresh water and marine environments typically exhibit a "boom and bust" (or "**bloom** and bust") lifestyle. When conditions in the upper mixed layer (nutrients and light) are favourable (*e.g.* at the start of spring) their competitive edge allows them to quickly dominate phytoplankton communities ("boom" or "bloom"). As such they are often classed as opportunistic r-strategists.

When conditions turn unfavourable, usually upon depletion of nutrients, diatom cells typically increase in sinking rate and exit the upper mixed layer ("bust"). This sinking is induced by either a loss of buoyancy control, the synthesis of mucilage that sticks diatoms cells together, or the production of heavy **resting spores**. Sinking out of the upper mixed layer removes diatoms from conditions unfavourable to growth, including grazer populations and higher temperatures (which would otherwise increase cell meta bolism). Cells reaching deeper water or the shallow seafloor can then rest until conditions become more favourable again. In the open ocean, many sinking cells are lost to the deep, but refuge populations can persist near the thermo cline .

Ultimately, diatom cells in these resting populations re-enter the upper mixed layer when vertical mixing entrains them. In most circumstances, this mixing also replenishes nutrients in the upper mixed layer, setting the scene for the next round of diatom blooms. In the open ocean (away from areas of continuous upwelling), this cycle of bloom, bust, then return to pre-bloom conditions typically occurs over an annual cycle, with diatoms only being prevalent during the spring and early summer. In some locations, however, an autumn bloom may occur, caused by the breakdown of summer stratification and the entrainment of nutrients while light levels are still sufficient for growth. Since vertical mixing is increasing, and light levels are falling as winter approaches, these blooms are smaller and shorter-lived than their spring equivalents.

In the open ocean, the condition that typically causes diatom (spring) blooms to end is a lack of silicon. Unlike other nutrients, this is only a major requirement of diatoms so it is not regenerated in the plankton ecosystem as efficiently as, for instance, nitrogen or phosphorus nutrients. This can be seen in maps of surface nutrient concentrations - as nutrients decline along gradients, silicon is usually the first to be exhausted (followed normally by nitrogen then phosphorus) .

Because of this bloom-and-bust cycle, diatoms are believed to play a disproportionately important role in the export of carbon from oceanic surface waters . Significantly, they also play a key role in the regulation of the biogeochemical cycle of silicon in the modern ocean.

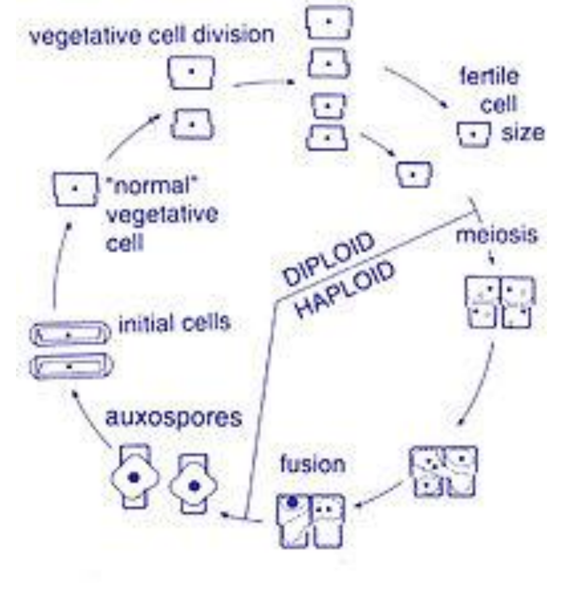


Egge & Aksnes (1992) figure.

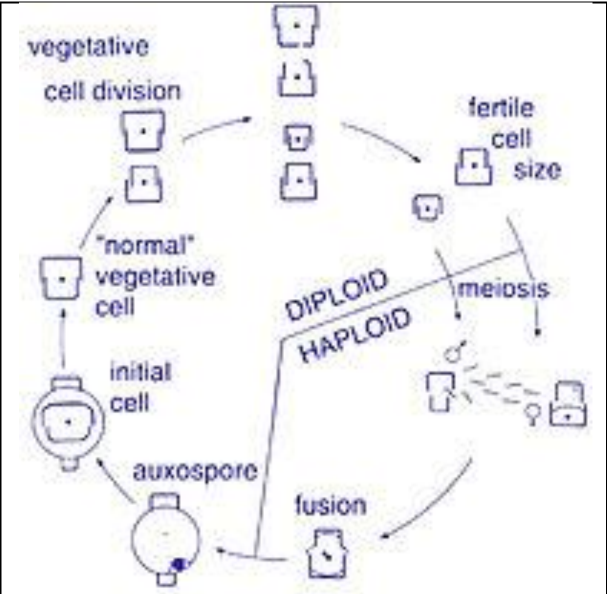
The use of silicon by diatoms is believed by many researchers to be the key to their ecological success. In a now classic study, Egge & Aksnes (1992) found that diatom dominance of mesocosm communities was directly related to the availability of silicic acid — when concentrations were greater than 2 m mol m^{-3}, they found that diatoms typically represented more than 70 % of the phytoplankton community. Raven (1983) noted that, relative to organic cell walls, silica frustules require less energy to synthesize (approximately 8% of a comparable organic wall), potentially a significant saving on the overall cell energy budget. Other researchers have suggested that the biogenic silica in diatom cell walls acts as an effective pH buffering agent, facilitating the conversion of bicarbonate to dissolved CO_2 (which is more readily assimilated). Notwithstanding the possible advantages conferred by silicon, diatoms typically have higher growth rates than other algae of a corresponding size .

Diatoms occur in virtually every environment that contains water. This includes not only oceans, seas, lakes and streams, but also soil.

5 - Life – cycle :



Sexual reproduction of a pinnate diatom (morphological isogamy, physiological anisogamy)



Sexual reproduction of a centric diatom (oogamy)

Diatoms are non – motile ; however, sperm found in some species can be flagellated, though motility is usually limited to a gliding motion . Reproduction among these organisms is primarily asexual by binary fission, with each daughter cell receiving one of the parent cell's two frustules (or theca) . This is used by each daughter cell as the larger frustule (or epitheca) into which a second, small frustule (or hypotheca) is constructed.

This form of division results in a size reduction of the daughter cell that received the smaller frustule from the parent and therefore the average cell size of a diatom population decreases, until the cells are about one-third their maximum size . It has been observed, however, that certain taxa have the ability to divide without causing a reduction in cell size . Nonetheless, in order to restore the cell size of a diatom population for those that do endure size reduction, sexual reproduction and auxo spore formation must occur.[2] Vegetative cells of diatoms are diploid (2N) and so meiosis can take place, producing male and female gametes which then fuse to form the zygote. The zygote sheds its silica theca and grows into a large sphere covered by an organic membrane, the auxospore. A new diatom cell of maximum size, the initial cell, forms within the auxospore thus beginning a new generation. Resting spores may also be formed as a response to unfavourable environmental conditions with germination occurring when conditions improve .

In centric diatoms, the small male gametes have one flagellum while the female gametes are large and non - motile (oogamous) . Conversely, in pinnate diatoms both gametes lack flagella (iso ogamous) . Certain araphid species have been documented as anisogamous and are, therefore, considered to represent a transitional stage between centric and pinnate diatoms.

6 - Evolutionary history :

Heterokont chloroplasts appear to be derived from those of red algae, rather than directly from prokaryotes as occurred in plants. This suggests they had a more recent origin than many other algae. How ever , fossil evidence is scant, and it is really only with the evolution of the diatoms themselves that the heterokonts make a serious impression on the fossil record.

The earliest known fossil diatoms date from the early Jurassic (~185 Ma) , although molecular clock and sedimentary evidence suggests an earlier origin. It has been suggested that their origin may be related to the end - Permian mass extinction (~250 Ma) , after which many marine niches were opened . The gap between this event and the time that fossil diatoms first appear may indicate a period when diatoms were un silicified and their evolution was cryptic . Since the advent of silicification, diatoms have made a significant impression on the fossil record, with major deposits of fossil diatoms found as far back as the early Cretaceous , and some rocks (diatomaceous earth , diatomite, kieselguhr) being composed almost entirely of them.

Although the diatoms may have existed since the Triassic, the timing of their ascendancy and "take - over" of the silicon cycle is more recent. Prior to the Phanerozoic (before 544 Ma) , it is believed that microbial or inorganic processes weakly regulated the ocean's silicon cycle . Subsequently, the cycle appears dominated (and more strongly regulated) by the radiolarians and siliceous sponges, the former as zooplankton , the latter as sedentary filter feeders primarily on the continental shelves . Within the last 100 My, it is thought that the silicon cycle has come under even tighter control, and that this derives from the ecological ascendancy of the diatoms.

However, the precise timing of the "take - over" is unclear, and different authors have conflicting interpretations of the fossil record. Some evidence, such as the displacement of siliceous sponges from the shelves , suggests that this takeover began in the Cretaceous (146 Ma to 65 Ma), while evidence from radiolarians suggests "take-over" did not begin until the Cenozoic (65 Ma to present) . The expansion of grassland biomes and the evolutionary radiation of grasses during the Miocene is believed to have increased the flux of soluble silicon to the oceans, and it has been argued that this has promoted the diatoms during the Cenozoic era . How ever, work on the variation of diatom diversity during the Cenozoic suggests instead that diatom success is decoupled from the evolution of grasses, and that diatoms were most diverse prior to the diversification of grasses.[32] Nevertheless, regardless of the details of the "take - over" timing, it is clear that this most recent revolution has installed much tighter biological control over the biogeochemical cycle of silicon.

7 - Fossil record :

The fossil record of diatoms has largely been established through the recovery of their siliceous frustules in marine and non-marine sediments. Although diatoms have both a marine and non-marine stratigraphic record, diatom bio stratigraphy , which is based on time - constrained evolutionary originations and extinctions of unique taxa, is only well developed and widely applicable in marine systems. The duration of diatom species ranges have been documented through the study of ocean cores and rock sequences exposed on land . Where diatom bio zones are well established and calibrated to the geomagnetic polarity time scale (e.g., Southern Ocean, North Pacific, eastern equatorial Pacific), diatom - based age estimates may be resolved to within < 100,000 years, although typical age resolution for Cenozoic diatom assemblages is several hundred thousand years.

The Cretaceous record of diatoms is limited, but recent studies reveal a progressive diversification of diatom types. The Cretaceous–Paleogene extinction event, which in the oceans dramatically affected organisms with calcareous skeletons, appears to have had relatively little impact on diatom evolution .

Although no mass extinctions of marine diatoms have been observed during the Cenozoic, times of relatively rapid evolutionary turnover in marine diatom assemblages occurred near the Paleocene–Eocene boundary and at the Eocene – Oligocene boundary. Further turnover of assemblages took place at various times between the middle Miocene and late Pliocene , in response to progressive cooling of polar regions and the development of more endemic diatom assemblages. A global trend toward more delicate diatom frustules has been noted from the Oligocene to the Quaternary.[33] This coincides with an increasingly more vigorous circulation of the ocean's surface and deep waters brought about by increasing latitudinal thermal gradients at the onset of major ice sheet expansion on Antarctica and progressive cooling through the Neogene and Quaternary towards a bipolar glaciated world. This drove the diatoms into up taking silica more competitively (i.e., to use less silica in formation of their frustules). Increased mixing of the oceans renews silica and other nutrients necessary for diatom growth in surface waters, especially in regions of coastal and oceanic up welling.

8 – Collection :

Living diatoms are often found clinging in great numbers to filamentous algae, or forming gelatinous masses on various submerged plants. *Cladophora* is frequently covered with *Cocconeis*, an elliptically shaped diatom; *Vaucheria* is often covered with small forms. Diatoms are frequently present as a brown, slippery coating on submerged stones and sticks, and may be seen to "stream" with river current.

The surface mud of a pond, ditch, or lagoon will almost always yield some diatoms. They can be made to emerge by filling a jar with water and mud, wrapping it in black paper and letting direct sunlight fall on the surface of the water. Within a day, the diatoms will come to the top in a scum and can be isolated.

Since diatoms form an important part of the food of molluscs, tunicates, and fishes, the alimentary tracts of these animals often yield forms that are not easily secured in other ways. Marine diatoms can be collected by direct water sampling, though benthic forms can be secured by scraping barnacles, oyster shells, and other shells.

This section uses text from *Methods in Plant Histology* .

9 - EST sequencing :

The first insights into the properties of the *P. tricornutum* gene repertoire was described using 1,000 ESTs . Subsequently, the number of ESTs was extended to 12,000 and the Diatom EST

Database was constructed for functional analyses . These sequences have been used to make a comparative analysis between *P. tricornutum* and the putative complete proteomes from the green alga *Chlamydomonas reinhardtii*, the red alga *Cyanidioschyzon merolae*, and *T. pseudonana*.[41] The diatom EST database now consists in over 200,000 ESTs from *P. tricornutum* (16 libraries) and *T. pseudonana* (7 libraries) cells grown in a range of different conditions, many of which corresponding to different abiotic stresses .

10 - Genome sequencing :

The entire genomes of the centric diatom, *Thalassiosira pseudonana* (32.4 Mb) , and the pennate diatom, *Phaeodactylum tricornutum* (27.4 Mb) , have been sequenced. Comparisons of the two fully sequenced diatom genomes finds that the *P. tricornutum* genome includes fewer genes (10,402 opposed to 11,776) than *T. pseudonana* and no major synteny (gene order) could be detected between the two genomes. *T. pseudonana* genes show an average of ~1.52 introns per gene as opposed to 0.79 in *P. tricornutum*, suggesting recent widespread intron gain in the centric diatom. Despite relatively recent evolutionary divergence (90 million years), the extent of molecular divergence between centrics and pennates indicates rapid evolutionary rates within the Bacillariophyceae compared to other eukaryotic groups. Comparative genomics also established that a specific class of transposable elements, the Diatom Copia - like retrotransposons (or CoDis), has been significantly amplified in the *P. tricornutum* genome with respect to *T. pseudonana*, constituting 5.8 and 1% of the respective genomes.

Importantly, diatom genomics brought much information about the extent and dynamics of the endo symbiotic gene transfer (EGT) process. Comparison of the *T. pseudonana* proteins with homologs in other organisms suggested that hundreds have their closest homologs in the Plantae lineage. EGT towards diatom genomes can be illustrated by the fact that the *T. pseudonana* genome encodes six proteins which are most closely related to genes encoded by the *Guillardia theta* (cryptomonad) nucleomorph genome. Four of these genes are also found in red algal plastid genomes, thus demonstrating successive EGT from red algal plastid to red algal nucleus (nucleomorph) to heterokont host nucleus.[43] More recent phylogenomic analyses of diatom proteomes provided evidence for a prasinophyte-like endosymbiont in the common ancestor of chromalveolates as supported by the fact the 70% of diatom genes of Plantae origin are of green lineage provenance and that such genes are also found in the genome of other stramenopiles. Therefore, it was proposed that chromalveolates are the product of serial secondary endosymbiosis first with a green algae, followed by a second one with a red algae that conserved the genomic footprints of the previous but displaced the green plastid . How ever, phylogenomic analyses of diatom proteomes and chromalveolate evolutionary history will likely take advantage of complementary genomic data from under-sequenced lineages such as red algae.

In addition to EGT, horizontal gene transfer (HGT) can occur independently of an endosymbiotic event. The publication of the *P. tricornutum* genome reported that at least 587 *P. tricornutum* genes appear to be most closely related to bacterial genes, accounting for more than 5% of the *P. tricornutum* proteome. About half of these are also found in the *T. pseudonana* genome, attesting their ancient incorporation in the diatom lineage.

11 – Nano technology research

The deposition of silica by diatoms may also prove to be of utility to nanotechnology. Diatom cells repeatedly and reliably manufacture valves of various shapes and sizes, potentially allowing diatoms to manufacture micro- or nano-scale structures which may be of use in a range of devices, including: optical systems; semiconductor nanolithography; and even using diatom valves as vehicles for drug delivery. Using an appropriate artificial selection procedure, diatoms that produce valves of particular shapes and sizes could be evolved in the laboratory, and then used in chemostat cultures to mass produce nano scale components.[It has also been proposed that diatoms could be used as a component of solar cells, by substituting photosensitive titanium dioxide for the silicon dioxide normally used in the creation of cell walls.

Diatomaceous Earth

A sample of diatomaceous earth

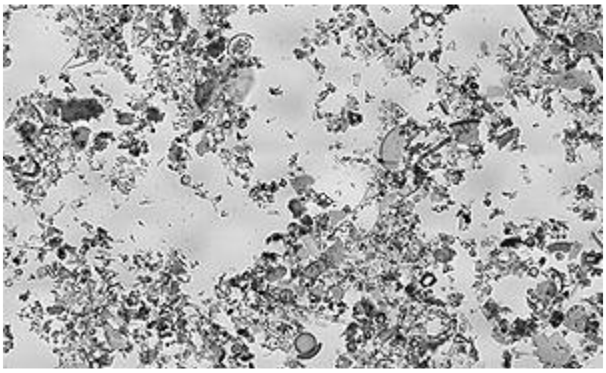
Contents

1 – Introduction :

Diatomaceous Earth also known as **D.E.**, **diatomite**, or **kieselguhr / kieselguhr**, is a naturally occurring, soft, siliceous sedimentary rock that is easily crumbled into a fine white to off-white powder. It has a particle size ranging from less than 1 micro meter to more than 1 millimeter, but typically 10 to 200 micro meters. This powder has an abrasive feel, similar to pumice powder, and is very light as a result of its high porosity. The typical chemical composition of oven-dried diatomaceous earth is 80 to 90% silica, with 2 to 4% alumina (attributed mostly to clay minerals) and 0.5 to 2% iron oxide.

Diatomaceous earth consists of fossilized remains of diatoms, a type of hard-shelled algae. It is used as a filtration aid, mild abrasive, mechanical insecticide, absorbent for liquids, matting agent for coatings, reinforcing filler in plastics and rubber, anti-block in plastic films, porous support for chemical catalysts, cat litter, activator in blood clotting studies, and a stabilizing component of dynamite. As it is heat-resistant, it can also be used as a thermal insulator.

2 - Geology and occurrence :



Diatomaceous earth as viewed under bright field illumination on a light microscope. Diatomaceous earth is made up of the cell walls/shells of single cell diatoms and readily crumbles to a fine powder. Diatom cell walls are made up of biogenic silica; silica synthesized in the diatom cell by the polymerisation of silicic acid. This image of diatomaceous earth particles in water is at a scale of 6.236 pixels/μm, the entire image covers a region of approximately 1.13 by 0.69 mm.

2 – 1 – Formation :

Diatomite forms by the accumulation of the amorphous silica (opal, $SiO_2 \cdot nH_2O$) remains of dead diatoms (microscopic single - celled algae) in lacustrine or marine sediments. The fossil remains consist of a pair of symmetrical shells or frustules.

2 – 2 – Discovery :

In 1836 or 1837 , the peasant and goods waggoner , Peter Kasten , discovered diatomaceous earth (German: kieselgur) when sinking a well on the northern slopes of the Haußelberg hill, in the Lüneburg Heath in north Germany. Initially, it was thought that limestone had been found, which could be used as fertiliser. Alfred Nobel used the properties of diatomaceous earth in the manufacture of dynamite. The Celle engineer, Wilhelm Berkefeld, recognized its ability to filter, and developed 'filter candles' fired from diatomaceous earth . During the cholera epidemic in Hamburg in 1892, these Berkefeld filters were used successfully.

2 – 3 – Extraction and storage sites in the Lüneburg Heath

- Neuohe – extraction from 1863 to 1994
- Wiechel from 1871 to 1978
- Hützel from 1876 to 1969
- Hösseringen from ca. 1880 to 1894
- Hammerstorf from ca. 1880 to 1920
- Oberohe from 1884 to 1970
- Schmarbeck from 1896 to ca. 1925
- Steinbeck from 1897 to 1928
- Breloh from 1907 to 1975
- Schwindebeck from 1913 to 1975
- Hetendorf from 1970 to 1994

The deposits are up to 28 meters thick and are all of fresh water kieselguhr .

Until the First World War almost the entire world wide production of kieselgur was from this region.

2 – 4 – Other deposits :

In Germany kieselgur was also extracted at Altenschlirf on the Vogelsberg (Upper Hesse) and at Klieken (Saxony-Anhalt).

There is a layer of kieselgur up to 4 metres (13 ft) thick in the nature reserve of Soos in the Czech Republic.

In Colorado and in Clark, Nevada (USA), there are deposits that are up to several hundred meters thick in places.

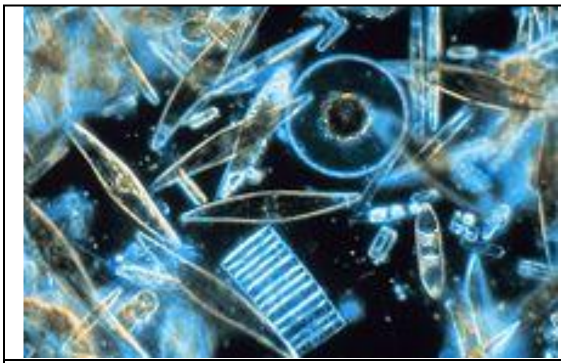
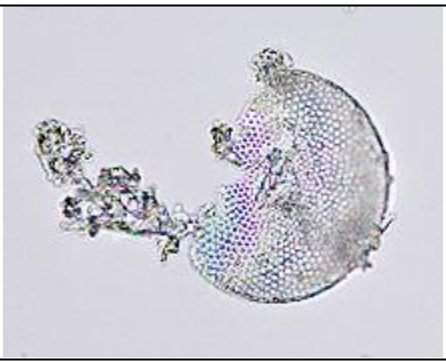
Sometimes kieselgur is found on the surface in deserts. Research has shown that the erosion of kieselgur in such areas (such as the Bodélé Depression in the Sahara) is one of the most important sources of climate-affecting dust in the atmosphere.

The commercial deposits of diatomite are restricted to Tertiary or Quaternary periods. Older deposits from as early as the Cretaceous Period are known, but are of low quality.[6] Marine deposits have been worked in the Sisquoc Formation in Santa Barbara County, California near Lompoc and along the Southern California coast. Additional marine deposits have been worked in Maryland, Virginia, Algeria and the MoClay of Denmark. Fresh water lake deposits occur in Nevada, Oregon, Washington and California. Lake deposits also occur in interglacial lakes in the eastern US and Canada and in Europe in Germany, France, Denmark and the Czech Republic. The worldwide association of diatomite deposits and volcanic deposits suggests that the availability of silica from volcanic ash may be needed for thick diatomite deposits.

3 - Applications :

3 – 1 – Industrial :

In 1866, Alfred Nobel discovered that nitroglycerin could be made much more stable if absorbed in diatomite. This allows much safer transport and handling than nitroglycerin in its raw form. He patented this mixture as dynamite in 1867, and the mixture is also referred to as guhr dynamite.

	
Live marine diatoms from Antarctica (magnified)	*Individual diatom cell walls often maintain their shape even in commercially processed filter media, such as this one for swimming pools*

3 – 2 – Filtration :

The most common use (68 %) of diatomaceous earth is as a filter medium, especially for swimming pools. It has a high porosity, because it is composed of microscopically – small , coffin – like , hollow particles. Diatomaceous earth (some times referred to by trade marked brand names such as Celite) is used in chemistry as a filtration aid, to filter very fine particles that would otherwise pass through or clog filter paper. It is also used to filter water, particularly in the drinking water treatment process and in fish tanks, and other liquids, such as beer and wine. It can also filter syrups, sugar, and honey without removing or altering the color, taste, or nutritional properties of any of them . Other industries such as paper, paints, ceramics, soap and detergents use it as a filling material.

3 – 3 – Abrasive

The oldest use of diatomite is as a very mild abrasive and, for this purpose, it has been used both in tooth paste and in metal polishes as well as in some facial scrubs.

3 – 4 – Pest control

Diatomite is used as an insecticide , due to its physico - sorptive properties . The fine powder absorbs lipids from the waxy outer layer of insects' exoskeletons, causing them to dehydrate. Arthropods die as a result of the water pressure deficiency, based on Fick's law of diffusion. This also works against gastropods and is commonly employed in gardening to defeat slugs. However, since slugs inhabit humid environments, efficacy is very low. It is sometimes mixed with an attractant or other additives to increase its effectiveness. Medical-grade diatomite is sometimes used to de-worm both animals and humans, with questionable efficacy . It is most commonly used in lieu of boric acid, and can be used to help control and eventually eliminate cockroach and flea infestations . This material has wide application for insect control in grain storage . It has also been used to control bedbug infestations, but this method may take weeks to work.

3 – 5 – Absorbent :

Its absorbent qualities make it useful for spill clean-up and the U.S. Centers for Disease Control recommends it to clean up toxic liquid spills. These qualities also lend themselves to use in facial masks to absorb excess oils.

It has been employed as a primary ingredient in a type of cat litter. The type of silica used in cat litter comes from fresh water sources and does not pose a significant health risk to pets or humans.

3 – 6 – Thermal :

Its thermal properties enable it to be used as the barrier material in some fire resistant safes. It is also used in evacuated powder insulation for use with cryogenics. Diatomaceous earth powder is inserted into the vacuum space to aid in the effectiveness of vacuum insulation.

3 – 7 – DNA purification :

Diatomite (Celite) can be used for the removal of DNA in the presence of a highly concentrated chaotropic agent such as sodium iodide, guanidinium chloride and guanidinium thiocyanate. As with other silicates, the diatomites will remove double stranded DNA but not RNA or proteins. The DNA can be extracted from the diatomites using low ionic strength buffers, including water, at neutral to slightly alkaline pH. Crude diatomites of a uniform size must first be washed in a heated acid such as 5M H Cl . Calcination can further improve consistency of the material, while mild caustic treatment may improve adsorption with lower levels of chaotrophs.

3 – 8 – Use in agriculture :

Natural fresh water diatomaceous earth is used in agriculture for grain storage as an anti caking agent, as well as an insecticide . It is approved by the US Department of Agriculture as a feed supplement.

It is also used as a neutral anthelmintic (dewormer) . Some farmers add it to their livestock and poultry feed to improve the health of animals . "Food Grade Diatomaceous Earth" is widely available in agricultural feed supply stores. It is acceptable as organic feed additive for live stock.

3 – 8 – 1 – Hydroponics :

Freshwater diatomite can be used as a growing medium in hydroponic gardens.

It is also used as a growing medium in potted plants, particularly as bonsai soil. Bonsai enthusiasts use it as a soil additive, or pot a bonsai tree in 100 % diatomaceous earth. Like perlite , vermiculite, and expanded clay, it retains water and nutrients, while draining fast and freely, allowing high oxygen circulation within the growing medium.

3 – 8 – 2 – Marker in live stock nutrition experiments :

Natural diatomaceous earth (dried , not calcined) is regularly used in live stock nutrition research as a source of acid insoluble ash (AIA), which is used as an indigestible marker. By measuring the content of AIA relative to nutrients in test diets and feces or digesta sampled from the terminal ileum (last third of the small intestine) the percentage of that nutrient digested can be calculated using the following equation:

Where :

$\%N$ is percent Nutrient Digestibility
$\%N_f$ is the percent of nutrients in the feces
$\%N_F$ is the percent of nutrients in the feed
$\%A_f$ is the percent of AIA in the feces
$\%A_F$ is the percent of AIA in the feed
And :

$$\%N = \left(1 - \frac{\%N_f}{\%N_F}\right) \times \left(\frac{A_F}{A_f}\right) \times 100$$

Natural diatomaceous earth (freshwater) is preferred by many researchers over chromic oxide, which has been widely used for the same purpose, but which is also a known carcinogen and therefore a potential hazard to research personnel.

4 - Specific varieties :

- **Tri polite** is the variety found in Tripoli , Libya.
- **Bann clay** is the variety found in the Lower Bann valley in Northern Ireland.
- **Moler (Mo - clay**) is the variety found in north western Denmark , especially on the islands of Fur and Mors.
- **Fresh - water Food Grade** Diatomaceous earth is the type used in US agriculture for grain storage, and as feed supplement.

5 - Climatologic importance :

The Earth's climate is affected by dust in the atmosphere, so locating major sources of atmospheric dust is important for climatology. Recent research indicates that surface deposits of diatomaceous earth play an important role. For instance, the largest single atmospheric dust source is the Bodélé depression in Chad, where storms push diatomite gravel over dunes, generating dust by abrasion .

6 - Safety considerations :

The absorbent qualities of diatomite can result in a significant drying of the hands if handled without gloves. The flux - calcined form contains a highly crystalline form of silica, resulting in sharp edges. The sharpness of this version of the material makes it dangerous to breathe and a dust mask is recommended when working with it.

The type of hazard posed by inhalation depends on the form of the silica. Crystalline silica poses a serious inhalation hazard because it can cause silicosis. Amorphous silica can cause dusty lungs, but does not carry the same degree of risk as crystalline silica. Natural or dried diatomite generally contains very low percentages of crystalline silica. Diatomite produced for pool filters is treated with high heat (calcining) and a fluxing agent (soda ash) , causing the formerly amorphous silicon dioxide to assume its crystalline form.

The crystalline silica content of the dust's particulate is regulated in the United States by the Occupational Safety and Health Administration (OSHA), and there are guidelines for the maximum amounts allowable in the product and in the air near the breathing zone of workers.

7 - The age and shape of diatoms :

Each deposit of diatomaceous earth is different, with varying blends of pure diatomaceous earth combined with other natural clays and minerals.

The diatoms in each deposit contain different amounts of silica, depending on the age of the deposit. As well, the species of diatom may also differ among deposits.

The species of diatom is dependent upon the age and paleo-environment of the deposit. In turn, the shape of a diatom is determined by its species.

The shape of the diatoms contained in a deposit has not been proven to affect their functionality when it comes to the absorption of liquids, however certain applications, such as that for slugs and snails, do work best when a particular shaped diatom is used. For example, in the case of slugs and snails large, spiny diatoms work best to lacerate the epithelium of the mollusk. Diatom shells will work to some degree on vast majority of animals that undergo ecdysis in shedding cuticle, such as arthropods or nematodes. It may have some effect also on lophotrochozoans, such as mollusks or annelids.

Many deposits throughout British Columbia, Canada, such as Red Lake Earth, are from the Miocene age and contain a species of diatom known as Melosira granulate. These diatoms are approximately 12 to 13 million years old and are a small globular shape.

A deposit containing diatoms from this age can provide many more benefits than that of an older deposit. For example, diatoms from the Eocene age (approximately 40 to 50 millions year old) are not as effective in their ability to absorb fluids because older diatoms such as this recrystallize, their small pores becoming filled with silica.

Dodeca Calcium Hepta - Aluminate

Contents

1 – Introduction :

Dodeca calcium hepta - aluminate (12 Ca O .7 Al_2O_3) occurs rarely in nature as the mineral mayenite. It is an important mineral phase in Calcium aluminate cements and is an intermediate in the manufacture of Portland cement. Its composition and properties have been the subject of much debate, because of variations in composition that can arise during its high-temperature formation.

2 - Composition and structure

The mineral as normally encountered is a solid solution series with end - members Ca_{12} Al_{14} O_{33} and Ca_6 Al_7 O_{16} (OH). The latter composition loses water only at high temperature, and has lost most of it by the melting point (around 1400 °C) . If material heated to this temperature is rapidly cooled to room temperature, the anhydrous composition is obtained. The rate of re - absorption of water to form the hydrous composition is negligible below 930 °C . The mineral is cubic. The crystal of Ca_{12} Al_{14} O_{33} has cell dimension 1.1983 nm and density 2680 $kg.m^{-3}$ while that of Ca_6 Al_7 O_{16} (OH) has 1.1976 nm and 2716 $kg.m^{-3}$.

The confusion regarding composition contributed to the mistaken assignment of the composition Ca_5 Al_3 O_{33} . Studies of the system have shown that the solid solution series extends also to the accommodation of other species in place of the hydroxyl group, including halides, sulfide and oxide ions.

3 - Properties :

The mineral reacts rapidly with water, with considerable heat evolution, to form $3CaO.Al_2O_3.6H_2O$ and $Al(OH)_3$ gel. The formation of the hydrate from this mineral and from mono calcium aluminate represents the first stage of strength development in aluminous cements. Because of its higher reactivity, leading to excessively rapid hydration, aluminous cements contain relatively low amounts of dodeca calcium hepta -aluminate, or none at all.

In Portland cement kilns, it is an early reaction product of aluminium and calcium oxides in the temperature range 900−1200 °C. With the onset of melt-phases at higher temperatures, it reacts with further calcium oxide to form tri calcium aluminate. It thus can appear in under-burned kiln products. It also occurs in some Natural cements.

Dolomite

Dolomite and magnesite – Spain

Contents

1 – Introduction :

Dolomite is a carbonate mineral composed of calcium magnesium carbonate Ca Mg $(CO_3)_2$. The term is also used to describe the sedimentary carbonate rock dolostone.

Dolostone (dolomite rock) is composed predominantly of the mineral dolomite with a stoichiometric ratio of 50 % or greater content of magnesium replacing calcium, often as a result of diagenesis. Lime stone that is partially replaced by dolomite is referred to as *dolomitic limestone*, or in old U.S. geologic literature as *magnesian limestone*. Dolomite was first described in 1791 as a rock by the French naturalist and geologist, Déodat Gratet de Dolomieu (1750 –1801) from exposures in what are now known as the Dolomite Alps of northern Italy .

Category	Carbonate mineral
Chemical Formula	$(Ca Mg) (CO_3)_2$
Unit cell	a = 4.8012Å, c = 16.002 Å ; Z = 3
Color	White, gray to pink
Crystal habit	Tabular crystals, often with curved faces , also columnar, stalactitic , granular, massive.
Crystal system	Trigonal
Mohs scale hardness	3.5 to 4
Luster	Vitreous to pearly
Streak	White
Specific gravity	2.84 –2.86
Optical properties	Uniaxial (-)
Refractive index	n_ω = 1.679 –1.681 n_ε = 1.500
Birefringence	δ = 0.179–0.181
Solubility	Poorly soluble in dilute H Cl unless powdered.
Other characteristics	May fluoresce white to pink under UV; triboluminescent.

2 - Properties :

The mineral dolomite crystallizes in the trigonal- rhombohedral system. It forms white , gray to pink , commonly curved (saddle shape) crystals, although it is usually massive. Unlike calcite, dolomite is a double carbonate, having a different structural arrangement, and it does not rapidly dissolve or effervesce (fizz) in dilute hydrochloric acid unless it is scratched or in powdered form.

Crystal twinning is common. A solid solution series exists between dolomite and iron rich ankerite. Small amounts of iron in the structure give the crystals a yellow to brown tint. Manganese substitutes in the structure also up to about three percent Mn O . A high manganese content gives the crystals a rosy pink color noted in the image above. A series with the manganese rich kutnohorite may exist. Lead and zinc also substitute in the structure for magnesium. It is also related to huntite $Mg_3Ca(CO_3)_4$.

3 – Formation :

Vast deposits are present in the geological record, but the mineral is relatively rare in modern environments. Laboratory synthesis of stoichiometric dolomite has been carried out only at temperatures of greater than 100 °C (conditions typical of burial in sedimentary basins) , even though much dolomite in the rock record appears to have formed in low - temperature conditions. The high temperature is likely to speed up the movement of calcium and magnesium ions so that they can find their places in the ordered structure within a reasonable amount of time. This suggests that the lack of dolomite that is being formed today is likely due to kinetic factors, i.e. due to the lack of kinetic energy or temperature.

Dolomite druse from Lawrence County, Arkansas, USA

Modern dolomite does occur as a precipitating mineral in specialized environments on the surface of the earth today. In the 1950s and 60s, dolomite was found to be forming in highly saline lakes in the Coorong region of South Australia. Dolomite crystals also occur in deep-sea sediments, where organic matter content is high. This dolomite is termed "organogenic" dolomite .

Recent research has found modern dolomite formation under anaerobic conditions in supersaturated saline lagoons along the Rio de Janeiro coast of Brazil, namely, Lagoa Vermelha and Brejo do Espinho. One interesting reported case was the formation of dolomite in the kidneys of a Dalmatian dog . This was believed to be due to chemical processes triggered by bacteria. Dolomite has been speculated to develop under these conditions with the help of sulfate-reducing bacteria (e.g. *Desulfovibrio brasiliensis*) .

Dolomite.

The actual role of bacteria in the low-temperature formation of dolomite remains to be demonstrated. The specific mechanism of dolomitization, involving sulfate-reducing bacteria, has not yet been demonstrated .

Dolomite appears to form in many different types of environment and can have varying structural, textural and chemical characteristics. Some researchers have stated "there are dolomites and dolomites", meaning that there may not be one single mechanism by which dolomite can form. Much modern dolomite differs significantly from the bulk of the dolomite found in the rock record, leading researchers to speculate that environments where dolomite formed in the geologic past differ significantly from those where it forms today.

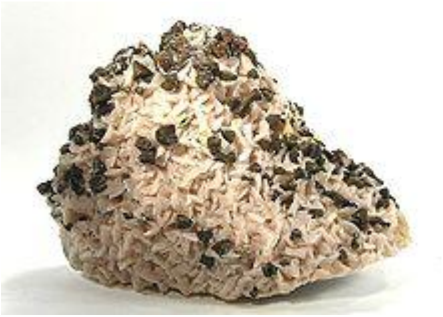
Reproducible laboratory syntheses of dolomite (and magnesite) leads first to the initial precipitation of a metastable "precursor" (such as magnesium calcite), to be changed gradually into more and more of the stable phase (such as dolomite or magnesite) during periodical intervals of dissolution and reprecipitation. The general principle governing the course of this irreversible geochemical reaction has been coined Ostwald's step rule.

For a very long time scientists had difficulties synthesizing dolomite. However, in a 1999 study, through a process of dissolution alternating with intervals of precipitation, measurable levels of dolomite were synthesized at low temperatures and pressures.

3 - 1 - Coral atolls :

Dolomitization of calcite also occurs at certain depths of coral atolls where water is under saturated in calcium carbonate but saturated in dolomite. Convection created by tides and sea currents enhance this change. Hydrothermal currents created by volcanoes under the atoll may also play an important role.

4 - Uses :



Dolomite with chalcopyrite from the Tri-state district, Cherokee County, Kansas

Dolomite is used as an ornamental stone, a concrete aggregate, a source of magnesium oxide and in the Pidgeon process for the production of magnesium. It is an important petroleum reservoir rock, and serves as the host rock for large strata - bound Mississippi Valley - Type (MVT) ore deposits of base metals such as lead , zinc , and copper . Where calcite lime stone is uncommon or too costly, dolomite is sometimes used in its place as a flux for the smelting of iron and steel. Large quantities of processed dolomite are used in the production of float glass.

In horticulture, dolomite and dolomitic limestone are added to soils and soilless potting mixes to lower their acidity and as a magnesium source. Home and container gardening are common examples of this use.

Dolomite is also used as the substrate in marine (saltwater) aquariums to help buffer changes in pH of the water.

Particle physics researchers prefer to build particle detectors under layers of dolomite to enable the detectors to detect the highest possible number of exotic particles. Because dolomite contains relatively minor quantities of radioactive materials, it can insulate against interference from cosmic rays without adding to background radiation levels.

Dry Wall

Vertically hung drywall with joint compound.

Contents

1 – Introduction :

Drywall, also known as **plaster board**, **wall board** or **gypsum board** is a panel made of gypsum plaster pressed between two thick sheets of paper. It is used to make interior walls and ceilings.

Drywall construction became prevalent as a speedier alternative to traditional lath and plaster.

2 - History :

"**Sackett Board**" was invented in 1894 by Augustine Sackett and Fred Kane. It was made by layering plaster within four plies of wool felt paper. Sheets were 36" × 36" × 1/4" thick with open (untaped) edges ".

"**Gypsum Board**" evolved between 1910 and 1930 beginning with wrapped board edges, and elimination of the two inner layers of felt paper in favor of paper-based facings. Providing efficiency of installation, it was developed additionally as a measure of fire resistance.[11] Later air entrainment technology made boards lighter and less brittle, then joint treatment materials and systems also evolved ".

"**Rock Lath**" was an early substrate for plaster. An alternative to traditional wood or metal lath, it was a panel made up of compressed gypsum plaster board that was sometimes grooved or punched with holes to allow wet plaster to key into its surface. As it evolved, it was faced with paper impregnated with gypsum crystals that bonded with the applied facing layer of plaster.

3 - Manufacture :

A wallboard panel is made of a paper liner wrapped around an inner core made primarily from gypsum plaster. The raw gypsum, $CaSO_4 \cdot 2\ H_2O$, (mined or obtained from flue-gas desulfurization (FGD)) must be calcined before use to produce the hemihydrate of calcium sulfate ($CaSO_4 \cdot ½\ H_2O$) . This is done in kettle or flash calciners, typically using natural gas today. The plaster is mixed with fiber (typically paper and/or fiber glass) , plasticizer, foaming agent, finely ground gypsum crystal as an accelerator, EDTA, starch or other chelate as a retarder, various additives that may increase mildew and/or fire resistance (fiber glass or vermiculite) , wax emulsion or silanes for lower water absorption and water. This is then formed by sandwiching a core of wet gypsum between two sheets of heavy paper or fiberglass mats. When the core sets and is dried in a large drying chamber, the sandwich becomes rigid and strong enough for use as a building material.

Drying chambers typically use natural gas today. To dry 1 MSF (1,000 square feet (93 m^2)) of wallboard, between 1.75 and 2.49 million BTU is required. Organic dispersants / plasticizers are used mainly to reduce the amount of water, hence reduce the eventual drying time, needed to produce gypsum slurry flow during wallboard manufacture.

4 - Specifications :

4 – 1 - USA and Canada :

Drywall panels are manufactured in 120 cm and 140 cm wide panels in varying lengths to suit the application. Common panel thicknesses are 12.7 mm and 16 mm , with panels also available in

6 mm and 10 mm. Both 12.7 mm and 16 mm panels of TYPE 'X' (a gypsum board with special core additives to increase the natural fire resistance of regular gypsum board) are used where a fire - resistance rating is desired. Regular 16 mm panels are used (with or without light gauge resilient metal channels) where additional mass is needed for the reduction of sound transmission .

Drywall provides a thermal resistance R- value (in US units) of 0.32 for 3/8" board, 0.45 for 1/2", 0.56 for 5/8", and 0.83 for 1" board. In addition to increased R-value, thicker drywall has a higher sound transmission class .

4 – 2 - Europe :

In Europe plasterboard is manufactured in metric sizes, with the common sizes being corollaries of old imperial sizes.

Most plasterboard is made in 120 cm wide sheets, though 90 cm and 60 cm wide sheets are also made. 120 cm wide plasterboard is most commonly made in 240 cm lengths, though 270 cm and 300 cm length sheets are also commonly available.

Commonly used thicknesses of plasterboard available are 12.5 mm (modern equivalent of half an inch), typically used for walls, and 9.5 mm (modern equivalent of three-eights of an inch), typically used for ceilings. 15 mm thick board is commonly available, and other thicknesses are also produced .

Plasterboard is commonly made with one of two different edge treatments — tapered edge, where the long edges of the board are tapered with a wide bevel at the front to allow for jointing materials to be finished flush with the main board face, and plain edge, used where the whole surface will receive a thin coating (skim coat) of finishing plaster .

5 - Construction techniques :

As an alternative to a week - long plaster application, an entire house can be dry walled in one or two days by two experienced dry wallers , and drywall is easy enough to use that it can be installed by many amateur home carpenters. In large-scale commercial construction, the work of installing and finishing drywall is often split between the drywall mechanics, or *hangers*, who install the wallboard, and the *tapers* and *mudmen*, or *float crew*, who finish the joints and cover the nailheads with dry wall compound .

Drywall is delivered to a building site on a flatbed truck and unloaded with a forked material handler crane. The bulk drywall sheets are unloaded directly to upper floors via a window or exterior doorway.

Drywall is cut to size, using a large T- square, by scoring the paper on the front side (usually white) with a utility knife , breaking the sheet along the cut, scoring the paper backing, and finally breaking the sheet in the opposite direction. Small features such as holes for outlets and light switches are usually cut using a keyhole saw or a small high - speed bit in a rotary tool. Drywall is then fixed to the wall structure with nails, glue, or more commonly in recent years, the now-ubiquitous *drywall screws*.

Drywall fasteners, also referred to as *drywall clips* or *stops*, are gaining popularity in both residential and commercial construction. Drywall fasteners are used for supporting interior drywall corners and replacing the non-structural wood or metal blocking that traditionally was used to install drywall. Their function serves to save on material and labour expenses, to minimize call-backs due to truss uplift, to increase energy efficiency, and to make plumbing and electrical installation simpler.

Drywall screws are designed to be self - tapping.

Drywall screws heads have a curved taper, allowing them to self-pilot and install rapidly without punching through the paper cover. These screws are set slightly into the drywall. When drywall is hung on wood framing, screws having an acute point and widely spaced threads are used. When drywall is hung on light - gauge steel framing, screws having an acute point and finely spaced threads are used. If the steel framing is heavier than 20- gauge, self-tapping screws with finely spaced threads must be used. In some applications, the drywall may be attached to the wall with adhesives.

After the sheets are secured to the wall studs or ceiling joists, the seams between drywall sheets are concealed using *joint tape* and several layers of *joint compound* (sometimes called *mud*). This compound is also applied to any screw holes or defects. The compound is allowed to air dry then typically sanded smooth before painting. Alternatively, for a better finish, the entire wall may be given a *skim coat*, a thin layer (about 1 mm or 1/16 inch) of finishing compound, to minimize the visual differences between the paper and mudded areas after painting.

Another similar skim coating is always done in a process called veneer plastering, although it is done slightly thicker (about 2 mm or 1/8 inch). Veneering uses a slightly different specialized setting compound ("finish plaster") that contains gypsum and lime putty. This application uses blue board, which has special treated paper to accelerate the setting of the gypsum plaster component. This setting has far less shrinkage than the air-dry compounds normally used in drywall, so it only requires one coat. Blue board also has square edges rather than the tapered - edge drywall boards. The tapered drywall boards are used to countersink the tape in taped jointing whereas the tape in veneer plastering is buried beneath a level surface. One coat veneer plaster over dry board is an intermediate style step between full multi-coat "wet" plaster and the limited joint-treatment-only given "dry" wall.

6 - Water damage and mold :

Drywall water damage in a closet.

Drywall is easily damaged by exposure to water. While it can be water proofed through covalent waterproofing, if waterproofing is absent or if the water proofing layer is punctured, water will cause drywall to swell and eventually disintegrate, requiring replacement.[15] Drywall is a porous, lightweight substance that supports the growth of mold.[16] It is for this reason that green board and cement board is used for rooms expected to have high humidity, primarily kitchens, bathrooms and laundry rooms.

7 - High sulfur drywall illness and corrosion issues :

A substantial amount of defective drywall was imported into the United States from China and incorporated into tens of thousands of homes during rebuilding in 2006 and 2007 following Hurricane Katrina and in other places. Complaints included foul odor, health effects, and corrosion of metal within the structure. This is caused by the emission of sulfurous gasses. The same drywall was sold in Asia without problems resulting, but U.S. homes are built much more tightly than homes in China, with less ventilation.

Volatile sulfur compounds, including hydrogen sulfide, have been detected as emissions from the imported drywall and may be linked to health problems. These compounds are emitted from many different types of drywall, and at least one investigation has pointed to high levels being emitted from drywalls manufactured in the United States.

Coal - fired power stations include devices called "scrubbers" to remove sulfur from their exhaust emissions. The sulfur is absorbed by powdered limestone in a process called flue - gas desulfurization (FGD), which produces a number of new substances. One is called "FGD gypsum". This is commonly used in drywall construction in the United States and elsewhere.

A number of lawsuits are underway in many jurisdictions, but many of the sheets of drywall are simply marked, "Made in China", thus making identification of the manufacturer difficult. An investigation by the Consumer Product Safety Commission, CPSC, was underway in 2009 . In November 2009, the CPSC reported a "strong association" between Chinese drywall and corrosion of pipes and wires reported by thousands of home owners in the United States.

8 - Fire resistance :

When used as a component in fire barriers, drywall is a passive fire protection item. In its natural state, gypsum contains the water of crystallization bound in the form of hydrates. When exposed to heat or fire, this water is vaporized, retarding heat transfer. Therefore, a fire in one room that is separated from an adjacent room by a fire-resistance rated drywall assembly will not cause this adjacent room to get any warmer than the boiling point (100°C) until the water in the gypsum is gone. This makes **drywall** an ablative material because as the hydrates sublime, a crumbly dust is left behind, which, along with the paper, is sacrificial. Generally, the more layers of Type X drywall one adds, the more one increases the fire-resistance of the assembly, be it horizontal or vertical. Evidence of this can be found both in publicly available design catalogues, including DIN4102 Part 4 and the Canadian Building Code on the topic, as well as common certification listings, including certification listings provided by Underwriters Laboratories and Underwriters Laboratories of Canada (ULC). "Type X" drywall is formulated by adding glass fibers to the gypsum, to increase the resistance to fires, especially once the hydrates are spent, which leaves the gypsum in powder form. Type X is typically the material chosen to construct walls and ceilings that are required to have a fire - resistance rating.

Fire testing of drywall assemblies for the purpose of expanding national catalogues, such as the National Building Code of Canada, Germany's Part 4 of DIN4102 and its British cousin BS476, are a matter of routine research and development work in more than one nation and can be sponsored jointly by national authorities and representatives of the drywall industry. For example, the National Research Council of Canada routinely publishes such findings.[22] The results are printed as approved designs in the back of the building code. Generally, exposure of drywall on a panel furnace removes the water and calcines the exposed drywall and also heats the studs and fasteners holding the drywall. This typically results in deflection of the assembly towards the fire, as that is the location where the sublimation occurs, which weakens the assembly, due to the fire influence.

When tests are cosponsored, resulting in code recognized designs with assigned fire-resistance ratings, the resulting designs become part of the code and are not limited to use by any one manufacturer, provided the material used in the field configuration can be demonstrated to meet the minimum requirements of Type X drywall (such as an entry in the appropriate category of the UL Building Materials Directory) and that sufficient layers and thicknesses are used. Fire test reports for such unique third party tests are confidential.

Deflection of drywall assemblies is important to consider to maintain the integrity of drywall assemblies in order to preserve their ratings. The deflection of drywall assemblies can vary somewhat from one test to another. Importantly, penetrants do not follow the deflection movement of the drywall assemblies they penetrate. For example, see cable tray movement in a German test. It is, therefore, important to test fire stops in full scale wall panel tests, so that the deflection of each applicable assembly can be taken into account.

The size of the test wall assembly alone is not the only consideration for fire stop tests. If the penetrants are mounted to and hung off the drywall assembly itself during the test, this does not constitute a realistic deflection exposure insofar as the fire stop is concerned. In reality, on a construction site, penetrants are hung off the ceiling above. Penetrants may increase in length, push and pull as a result of operational temperature changes (e.g., hot and cold water in a pipe), particularly in a fire. But it is a physical impossibility to have the penetrants follow the movement of drywall assemblies that they penetrate, since they are not mounted to the drywalls in a building.

It is, therefore, counterproductive to suspend penetrants from the drywall assembly during a fire test. As downward deflection of the drywall assembly and buckling towards the fire occurs, the top of the firestop is squeezed and the bottom of the firestop is pulled. This is motion over and above that which is caused by the expansion of metallic penetrants, due to heat exposure in a fire. Both types of motion occur in reality, because metal first expands in a fire and then softens once the critical temperature has been reached, as is explained under structural steel. To simulate the drywall deflection effect, one can simply mount the penetrants to the steel frame holding the test assembly. The operational and fire-induced motion of the penetrants, which is independent of the assemblies penetrated, can be separately arranged.

9 - North American market :

North America is one of the largest gypsum board users in the world with a total wall board plant capacity of 3.9×10^9 m^2 per year (world wide 7.9×10^9 m^2 per year) . More over , the home building and remodeling markets in North America in the late 1990s and early 2000s increased demand. The gypsum board market was one of the biggest beneficiaries of the housing boom as "an average new American home contains more than 7.31 metric tons of gypsum " .

The introduction in March 2005 of the Clean Air Interstate Rule by the United States Environmental Protection Agency requires power plants to "cut sulfur dioxide emissions by 73 % " by 2018 . The Clean Air Interstate Rule also requested that the power plants install new scrubbers (industrial pollution control devices) to remove sulfur dioxide present in the output waste gas. Scrubbers use the technique of flue-gas desulfurization (FGD), which produces synthetic gypsum as a usable by-product. In response to the new supply of this raw material, the gypsum board market was predicted to shift significantly. However, issues such as mercury release during calcining need to be resolved .

9 – 1 - Waste :

Because up to 17 % of drywall is wasted during the manufacturing and installation processes and the drywall material is frequently not re – used , disposal can become a problem. Some landfill sites have banned the dumping of drywall. Some manufacturers take back waste wallboard from construction sites and recycle it into new wallboard. Recycled paper is typically used during manufacturing. More recently, recycling at the construction site itself is being investigated. There is potential for using crushed drywall to amend certain soils at building sites, such as sodic clay and silt mixtures (bay mud) , as well as using it in compost .

10 - Types available in the US and Canada ;

- Regular white board, from 1/4" to 3/4" thickness
- Fire - resistant ("Type X"), different thickness and multiple layers of wallboard provide increased fire rating based on the time a specific wall assembly can withstand a standardized fire test. Often perlite, vermiculite and boric acid are added to improve fire resistance.
- Green board, the drywall that contains an oil-based additive in the green colored paper covering that provides moisture resistance. It is commonly used in wash rooms and other areas expected to experience elevated levels of humidity.
- Blue board , blue face paper forms a strong bond with a skim coat or a built - up plaster finish providing both water and mold resistance.

- Cement board, which is more water-resistant than green board, for use in showers or sauna rooms, and as a base for ceramic tile
- Sound board is made from wood fibers to increase the sound rating (STC)
- Soundproof drywall is a laminated drywall made with gypsum, other materials, and damping polymers to significantly increase the STC .
- Mold - resistant, paperless drywall
- Enviro board , a board made from recycled agricultural materials
- Lead - lined drywall, a drywall used around radiological equipment .
- Foil - backed drywall to control moisture in a building or room
- Controlled density (CD), also called ceiling board, which is available only in 1/2" thickness and is significantly stiffer than regular white board.
- Eco Rock, a drywall which uses a combination of 20 materials including recycled fly ash, slag, kiln dust and fillers and no starch cellulose; it is advertised as being environmentally-friendly due to the use of recycled materials and an energy efficient process.
- Gypsum “Fire code C.” This board is similar in composition to Type X, except for more glass fibers and a form of vermiculite, used to reduce shrinkage. When exposed to high heat, the gypsum core shrinks but this additive expands at about the same rate, so the gypsum core is more stable in a fire, and remains in place even after the gypsum dries up.

11 - Common drywall tools :

- Benches
- Chalk line
- Corner trowel
- Dimpler
- Drywall cutting machine (Speed Plac)
- Drywall adhesive glue guns

- Drywall cart
- Drywall fastener
- Drywall (hatchet) hammer
- Drywall lifter
- Drywall jack
- Drywall screws and nails
- Electric screwdriver
- Keyhole saw or drywall router
- Padsaw
- Pencil
- Surform
- Screw gun
- Stilts
- Stud finder
- Tape measure
- Taping knife
- T - square
- Utility knife

12 - Levels of finish :

In 1990, four major trade associations, the Association of Wall and Ceiling Industries International (AWCI), the Ceilings and Interior Systems Construction Association (CISCA), the Gypsum Association (GA), and the Painting and Decorating Contractors of America (PDCA), presented their document about Levels of **Gypsum Board** Finish. This document was created to "precisely describe" the desired finish of walls and ceilings prior to final decoration. This description enables contractors to better understand the requirements of architects and building owners and increase customer satisfaction. Specifications that include Levels of Gypsum Board Finish also promote competitive bidding that allows the bidder to consider the correct labor and materials to finish the wall suitably for its final decoration."

The official document (summarized below) is known as GA-214-96 "Recommended Levels of Gypsum Board Finish".

12 – 1 - Level 0 :

No taping, finishing, or accessories required.

Usage: Temporary construction or when final decoration is undetermined.

12 – 2 - Level 1 :

All joints and interior angles shall have tape set in joint compound. Surface shall be free of excess joint compound. Tool marks and ridges are acceptable.

Usage: Above false ceilings or other areas that are out of public view where a degree of fire and noise resistance is required.

12 – 3 - Level 2

All joints and interior angles shall have tape embedded in joint compound and wiped with a joint knife leaving a thin coating of joint compound over all joints and interior angles. Fastener heads and accessories shall be covered with a coat of joint compound. Surface shall be free of excess joint compound. Tool marks and ridges are acceptable. Joint compound applied over the body of the tape at the time of tape embedment shall be considered a separate coat of joint compound and shall satisfy the conditions of this level.

Usage: As a substrate for tile walls and ceilings as well as in garages, warehouses, and other places where appearance is not a primary concern.

12 – 4 - Level 3 ;

All joints and interior angles shall have tape embedded in joint compound and one additional coat of joint compound applied over all joints and interior angles. Fastener heads and accessories shall be covered with two separate coats of joint compound. All joint compound shall be smooth and free of tool marks and ridges. It is recommended that the prepared surface be coated with a drywall primer prior to the application of final finishes.

Usage: Suitable base for heavy-medium textured paint or other thick finishes.

12 – 5 - Level 4 :

All joints and interior angles shall have tape embedded in joint compound and two separate coats of joint compound applied over all flat joints and one separate coat of joint compound applied over interior angles. Fastener heads and accessories shall be covered with three separate coats of joint compound. All joint compound shall be smooth and free of tool marks and ridges. It is recommended that the prepared surface be coated with a drywall primer prior to the application of final finishes.

Usage: "Standard" household and office walls. Used with light or non-textured finishes. Not suitable for harsh lighting conditions, which may highlight minor imperfections

12 – 6 - Level 5 :

All joints and interior angles shall have tape embedded in joint compound and two separate coats of joint compound applied over all flat joints and one separate coat of joint compound applied over interior angles. Fastener heads and accessories shall be covered with three separate coats of joint compound. A thin skim coat of joint compound, or a material manufactured especially for this purpose, shall be applied to the entire surface. The surface shall be smooth and free of tool marks and ridges. It is recommended that the prepared surface be coated with a drywall primer prior to the application of finish paint. The skim coat is a final leveling agent suitable to smooth out a surface to be used under the harshest lighting conditions that may otherwise highlight any imperfections under the finished surface.

Usage: Gloss and entirely non-textured surfaces.

DUCRETE

Contents

1 – Introduction :

DUCRETE : (Depleted Uranium Concrete) is a high density concrete alternative investigated for use in construction of casks for storage of radioactive waste. It is a composite material containing depleted uranium dioxide aggregate instead of conventional gravel and a Portland cement binder.

2 - Back ground and Development :

In 1993, the United States Department of Energy Office of Environmental Management initiated investigation into the potential use of Depleted Uranium in heavy concretes. The aim of this investigation was to simultaneously find an application for depleted Uranium and to create a new and more efficient method for the storage and transportation of spent nuclear fuels. The material was first conceived at the Idaho National Engineering and Environmental Laboratory (INEEL) by W. Quapp and P. Lessing, who jointly developed the processes behind the material and were awarded both U.S. and foreign patents in 1998 and 2000, respectively.[1]

3 - Description :

DUCRETE : is a kind of concrete that replaces the standard coarse aggregate with a depleted uranium ceramic material. All of the other materials present in DUCRETE (portland cement, sand and water) are used in the same volumetric ratio used for ordinary concrete. This ceramic material is a very efficient shielding material since it presents both high atomic number (uranium) for gamma shielding, and low atomic number (water bonded in the concrete) for neutron shielding . It exists an optimum uranium-to-binder ratio for a combined attenuation of gamma and neutron radiation at a given wall thickness. A balance needs to be established between the attenuation of the gamma flux in the DUO2 and the cement phase with water to attenuate the neutron flux.

The key to effective shielding with depleted uranium ceramic concrete is maximum uranium oxide density. Unfortunately, the densest depleted uranium oxide is also the most chemically unstable. Depleted uranium dioxide, or DUO_2, has a maximum theoretical density of 10.5 gm/cm3 at 95 % purity. How ever, under oxidation conditions, this material readily transforms into the more stable depleted uranium trioxide (DUO_3) or depleted tri uranium octaoxide (DU_3O_8). Thus, if naked UO_2 aggregates is used, this transitions can result in an expansion that could generate stresses that could crack the material, lowering its compressive strength.). Another limitation for the direct use of depleted uranium dioxide fine power is that concretes depend on their coarse aggregates to carry compressive stresses. In order to overcome these issues, DUAGG was developed.

DUAGG (depleted uranium aggregate) is the term applied to the stabilized DUO_2 ceramic. This consists of sintered DUO_2 particles with a silicate - based coating that covers the surfaces and fills the spaces between the grains, acting as an oxygen barrier, as well as corrosion and leach resistance. DUAGG has a density up to 8.8 g/cm3 and replaces the conventional aggregate in concrete, producing concrete with a density of 5.6 to 6.4 g/cm3, compared to 2.3 g/cm3 for conventional concrete .

Also, DUCRETE presents environmentally friendly properties. The table below shows the effectiveness of converting depleted uranium into concrete, since potential leaching is decreased in a high order. The leach test used was the EPA Toxicity characteristic leaching procedure (TCLP), which is used to assess heavy metal risks to the environment.

Uranium form	**U concentration in leachate (mg U / L)**
DUCRETE	0.42
DUAGG	4
UO2	172
U3O8	420
UF4	7367
UO3	6900

4 - Production :

4 – 1 – U . S . Method :

DUCRETE is produced by mixing a DUO_2 aggregate with Portland cement. DU is a result of the enrichment of Uranium for use in nuclear power generation and other fields. DU usually comes bonded with Fluorine in Uranium hexa fluoride. This compound is highly reactive and cannot be used in the DUCRETE . Uranium hexa fluoride must therefore be oxidized into U_3O_8 and UO_3. These compounds are then converted to UO_2 Uranium oxide through the addition of H gas. The UO_2 is then dried, crushed, and milled into a uniform sediment. This then converted into small inch long briquettes through the use of high pressure (6000psi) . The low atomic number binder is then added and undergoes pyrolysis. The compound then undergoes liquid phase sintering at 1300 Celsius until the desired density is achieved, usually around 8.9g / cm^3. The briquettes are then crushed and gap sorted and are now ready to be mixed into DUCRETE .

4 – 2 – VNIINM (Russian) Method :

The VNIINM method is very similar to the U.S. method except it does not gap sort the binder and UO_2 after it is crushed .

5 - Applications :

After processing, DUCRETE composite may be used in container vessels, shielding structures, and containment storage areas, all of which can be used to store radioactive waste. The primary implementation of this material is within a dry cask storage system for high level waste (HLW) and spent nuclear fuel (SNF) . In such a system, the composite would be the primary component used to shield radiation from workers and the public. Cask systems made from DUCRETE are smaller and lighter in weight than casks made from conventional materials, such as traditional concrete. DUCRETE containers need only be about 1 / 3 as thick to provide the same degree of radiation shielding as concrete systems .

Analysis has shown that DUCRETE is more cost effective than conventional materials. The cost for the production of casks made with DUCRETE is low when compared with other shielding materials such as steel, lead and DU metal, since less material is required as a consequence of a higher density. In a study by Duke Engineering at a nuclear waste facility at Savannah River, the DUCRETE cask system was evaluated at a lower cost than an alternative Glass Waste storage building . However, disposal of the DUCRETE was not considered. Since DUCRETE is a low level radioactive composite, its relatively expensive disposal could decrease the cost effectiveness of such systems. An alternative to such disposal is the use of empty DUCRETE casks as a container for high activity low-level waste.[14]

While DUCRETE shows potential for future nuclear waste programs, such concepts are far from utilization. So far, no DUCRETE cask systems have been licensed in the U.S .

Ductal

Ductal ® is a proprietary pre-mixed ultra-high performance concrete whose physical characteristics exceed those of common concrete used in the construction of buildings. It is manufactured by Lafarge and Bouygues.

Ductal® has high compressive strength and flexural resistance compared to other concretes. It also has high durability, abrasion resistance, and chemical / environmental resistances (e.g. freeze and thaw, salt water, etc.). Due to these properties, Ductal® can be used in thinner cross-sections and in more varied applications than common concrete.

Ductal® is almost self placing and is best suited for precast elements or in-situ repair or upgrade works. The constituents of Ductal® are cement, fine sand, silica fume and silica flour as a filler, additive and water, using a low water cement ratio and may include high-strength steel fibers or non-metallic fibers.

Ductal® is a ductile material that possesses ultra high compressive strength, high tensile strength and high durability together with high fatigue performance. It also has excellent impact, blast and abrasion resistance. The type and quantities of special materials used in Ductal® result in a superior material that can provide innovative and valuable solutions for a wide range of applications; it is not a replacement for ordinary concrete in applications that do not exploit its unique properties and requires performance engineering.

Eco - Cement

Contents

1 – Introduction :

Eco - Cement is a brand - name for a type of cement which incorporates reactive magnesia (some times called caustic calcined magnesia or magnesium oxide , Mg O) , another hydraulic cement such as Portland cement, and optionally pozzolans and industrial by-products, to reduce the environmental impact relative to conventional cement. One problem with the commercialization of this cement, other than the conservatism of the building industry, is that the feedstock magnesite is rarely mined.

2 - Energy requirements :

Ordinary Portland cement requires a kiln temperature of around 1450°C. The reactive magnesia in Eco - Cement requires a lower kiln temperature of 750°C , which lowers the energy requirements, and hence the use of fossil fuels and emission of carbon dioxide CO_2 .

3 - CO_2 sequestration :

Eco - Cement sets and hardens by sequestering CO_2 from the atmosphere and is recyclable. The rate of absorption of CO_2 varies with the degree of porosity and the amount of Mg O . Carbonation occurs quickly at first and more slowly towards completion. A typical Eco - Cement concrete block would be expected to fully carbonate within a year.

4 - Waste utilization ;

Eco - Cement is able to incorporate a greater number of industrial waste products as aggregate than Portland cement as it is less alkaline. This reduces the incidence of alkali - aggregate reactions which cause damage to hardened concrete . Eco - Cement also has the ability to be almost fully recycled back into cement, should a concrete structure become obsolete .

Electrical Resistivity Measurement of Concrete

Contents

1 – Introduction :

Concrete electrical resistivity can be obtained by applying a current into the concrete and measuring the response voltage. There are different methods for measuring concrete resistivity.

2 - Methods

2 – 1 - Two probes :

Concrete electrical resistance can be measured by applying a current using two probes and convert it to electrical resistivity by using following equation :

$$\rho = R\frac{A}{\ell},$$

R is the electrical resistance of a uniform specimen of the material (measured in ohms , Ω)

ℓ is the length of the piece of material (measured in meters , m)

A is the cross - sectional area of the specimen (measured in square meters , m^2) .

2 – 2 - Four probes :

Concrete electrical resistivity can be measured using four probes in a Wenner array. In this method the two outer probes induce the current to the specimen and the two inner electrodes measure the resulting potential drop. The probes are all applied to the same surface of the specimen and the method is consequently suitable for measuring the resistivity of bulk concrete in situ . The resistivity calculated from obtained resistance by following equation:

$$\rho = 2\pi a R$$

R is the electrical resistance of the material (measured in ohms, Ω)

a is the equal distance of the probes (measured in meters , m) .

2 – 3 - Transformer method :

In this method a transformer is used to measure resistivity without any direct contact with the specimen. The transformer consists of a primary coil which energizes the circuit with an AC voltage and a secondary which is formed by a toroid of the concrete sample. The current in the sample is detected by a current coil wound around a section of the toroid (a current transformer) . This method is good for measuring the setting properties of concrete, its hydration and strength. Wet concrete has a resistivity of around 1 Ω - m which progressively increases as the cement sets.

3 - Relation to corrosion :

Corrosion is an electro - chemical process. The rate of flow of the ions between the anode and cathode areas, and therefore the rate at which corrosion can occur, is affected by the resistivity of the concrete . To measure the electrical resistivity of the concrete a current is applied to the two outer probes and the potential difference is measured between the two inner probes. Empirical tests have arrived at the following threshold values which can be used to determine the likelihood of corrosion.

• When $\rho \geq 120\ \Omega$ - m	corrosion is unlikely
• When $\rho = 80$ to $120\ \Omega$ - m	corrosion is possible
• When $\rho \leq 80\ \Omega$ - m	corrosion is fairly certain

The electrical resistivity of the concrete cover layer decreases due to :

- Increasing concrete water content
- Increasing concrete porosity
- Increasing temperature
- Increasing chloride content
- Decreasing carbonation depth

When the electrical resistivity of the concrete is low, the rate of corrosion increases. When the electrical resistivity is high, e.g. in case of dry and carbonated concrete, the rate of corrosion decreases.

4 - Rebars :

The presence of rebars disturbs electrical resistivity measurement as they conduct current much better than the surrounding concrete. This is particularly the case when the cover depth is less than 30 mm. In order to minimize the effect, none of the electrodes should be placed above a rebar when measuring, or if this is unavoidable, then perpendicular to the rebar.

5 – Standards :

- ASTM Standard C1202-10 :

Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

Engineered Cementitious Composite

Contents

1 – Introduction :

Engineered Cementitious Composite (ECC), also called **bendable concrete**, is an easily molded mortar - based composite reinforced with specially selected short random fibers , usually polymer fibers . Unlike regular concrete, ECC has a strain capacity in the range of 3 – 7 % , compared to 0.1 % for ordinary portland cement (OPC). ECC therefore acts more like a ductile metal than a brittle glass (as does OPC concrete) , leading to a wide variety of applications.

2 - Development :

ECC, unlike common fiber reinforced concrete, is a micro mechanically designed material . This means that the mechanical interactions between ECC's fiber and matrix are described by a micromechanical model, which takes into account material properties and helps predict properties and guide ECC development.

ECC looks similar to ordinary portland cement - based concrete, except that it does not include coarse aggregate and can deform (or bend) under strain . A number of research groups are developing ECC science, including those at the University of Michigan, Delft University of Technology, the University of Tokyo , the Czech Technical University, and Stanford University. Traditional concrete’s lack of durability and failure under strain , both stemming from brittle behavior , have been a pushing factor in the development of ECC .

3 – Properties :

ECC has a variety of unique properties, including tensile properties superior to other fiber-reinforced composites, ease of processing on par with conventional cement, the use of only a small volume fraction of fibers (~ 2 %) , tight crack width, and a lack of anisotropically weak planes . These properties are due largely to the interaction between the fibers and cementing matrix, which can be custom-tailored through micromechanics design. Essentially, the fibers create many micro cracks with a very specific width, rather than a few very large cracks (as in conventional concrete) . This allows ECC to deform without catastrophic failure.

This micro cracking behavior leads to superior corrosion resistance (the cracks are so small and numerous that it is difficult for aggressive media to penetrate and attack the reinforcing steel) as well as to self - healing . In the presence of water (during a rainstorm, for instance) unreacted cement particles recently exposed due to cracking hydrate and form a number of products (Calcium Silicate Hydrate, calcite , etc) that expand and fill in the crack. These products appear as a white ‘scar’ material filling in the crack. This self-healing behavior not only seals the crack to prevent transport of fluids, but mechanical properties are regained. This self-healing has been observed in a variety of conventional cement and concretes; however, above a certain crack width self healing becomes less effective. It is the tightly controlled crack widths seen in ECC that ensure all cracks thoroughly heal when exposed to the natural environment.

When combined with a more conductive material (metal wires, carbon nano tubes, etc.) all cement materials can increase and be used for damage - sensing. This is essentially based on the fact that conductivity will change as damage occurs; the addition of conductive material is meant to raise the conductivity to a level where such changes will be easily identified. Though not a material property of ECC itself, conductive ECC for damage - sensing applications are being developed by a number of research groups.

4 – Types :

There are a number of different varieties of ECC, including :

- Light weight (i.e. low density) ECC have been developed through the addition of air voids, glass bubbles, polymer spheres, and/or lightweight aggregate. Compared to other lightweight cements, light weight ECC has superior compressive and tensile strength, crack - width control, and damage tolerance. Applications include floating homes, barges, and canoes.

- ‘Self compacting concrete’ refers to a concrete that can flow under its own weight. For instance, a self - compacting material would be able to fill a mold containing elaborate pre-positioned steel reinforcement without the need of vibration or shaking to ensure even distribution. Self - compacting ECC was developed through the use of chemical admixtures to decrease viscosity and through controlling particle interactions with mix proportioning.

- Spray able ECC , which can be pneumatically sprayed from a hose, have been developed by using various super plasticizing agents and viscosity-reducing admixtures. Compared to other spray able fiber-reinforced composites, spray able ECC has enhanced pump ability in addition to its unique mechanical properties. Spray able ECC has been used for retrofitting/repair work and tunnel / sewer linings.

- An extrude able ECC for use in the extrusion of pipes was first developed in 1998. Extruded ECC pipes have both higher load capacity and higher deformability than any other extruded fiber-reinforced composite pipes.

5 - Field Applications :

ECC have found use in a number of large-scale applications in Japan, Korea, Switzerland , Australia and the U.S . These include:

- The Mitaka Dam near Hiroshima was repaired using ECC in 2003. The surface of the then 60 - year old dam was severely damaged, showing evidence of cracks, spalling , and some water leakage. A 20 mm-thick layer of ECC was applied by spraying over the 600 m^2 surface.

- Also in 2003, an earth retaining wall in Gifu, Japan, was repaired using ECC . Ordinary portland cement could not be used due to the severity of the cracking in the original structure, which would have caused reflective cracking. ECC was intended to minimize this danger; after one year only micro cracks of tolerable width were observed.

- The 95 m Glorio Roppongi high - rise apartment building in Tokyo contains a total of 54 ECC coupling beams (2 per story) intended to mitigate earthquake damage . The properties of ECC (high damage tolerance, high energy absorption, and ability to deform under shear) give it superior properties in seismic resistance applications when compared to ordinary portland cement. Similar structures include the 41-story Nabeaure Yokohama Tower (4 coupling beams per floor.)

- The 1 km long Mihara Bridge in Hokkaido, Japan was opened to traffic in 2005. The steel - reinforced road bed contains nearly 800 m3 of ECC material. The tensile ductility and tight crack control behavior of ECC led to a 40 % reduction in material used during construction.

- Similarly, a 225 - mm thick ECC bridge deck on interstate 94 in Michigan was completed in 2005 . 30 m^3 of material was used, delivered on-site in standard mixing trucks. Due to the unique mechanical properties of ECC, this deck also used less material than a proposed deck made of ordinary portland cement. Both the University of Michigan and the Michigan Department of Transportation are monitoring the bridge in an attempt to verify the theoretical superior durability of ECC ; after 4 years of monitoring, performance remained undiminished .

6 - Comparison to other composite materials :

Properties	FRC	Common HPFRCC	ECC
Design Methodology	N.A.	Use high Vf	Micromechanics based, minimize Vf for cost and processibility
Fiber	Any type, Vf usually less than 2 % ; df for steel ~ 500 micro meter	Mostly steel, Vf usually > 5% ; df ~ 150 micro meter	Tailored, polymer fibers, Vf usually less than 2 %; df < 50 micro meter
Matrix	Coarse aggregates	Fine aggregates	Controlled for matrix toughness, flaw size; fine sand
Interface	Not controlled	Not controlled	Chemical and frictional bonds controlled for bridging properties
Mechanical Properties	Strain-softening:	Strain-hardening:	Strain - hardening:
Tensile strain	0.1%	< 1.5 %	>3 % (typical) ; 8 % max
Crack width	Unlimited	Typically several hundred micro meters , unlimited beyond 1.5% strain	Typically < 100 micro meters during strain - hardening

Note : FRC = Fiber - Reinforced Cement. HPFRCC= High - Performance Fiber Reinforced Cementitious Composites

Environmental Impact of Concrete

Contents

1 – Introduction :

The **environmental impact of concrete** is a complex mixture of not entirely negative effects. A major component of concrete is cement, which has its own its own environmental and social impacts.

Conversely, concrete construction also has many sustainable benefits.

The cement industry is one of two primary producers of carbon dioxide, a major green house gas.

Concrete is used to create hard surfaces which contribute to surface run off , which can cause heavy soil erosion, water pollution and flooding. Concrete is a primary contributor to the urban heat island effect, but is less so than asphalt. Concrete dust released by building demolition and natural disasters can be a major source of dangerous air pollution. The presence of some substances in concrete, including useful and unwanted additives, can cause health concerns due to toxicidity and radioactivity. Wet concrete is highly alkaline and must always be handled with proper protective equipment. Concrete recycling is increasing due to improved environmental awareness, governmental laws and economic benefits.

2 - Carbon dioxide emissions and climate change

The cement industry is one of two primary industrial producers of carbon dioxide CO_2 , creating up to 5 % of worldwide man-made emissions of this gas, of which 50 % is from the chemical process and 40% from burning fuel . The carbon dioxide CO_2 produced for the manufacture of one tonne of structural concrete (using ~14% cement) is estimated at 410 kg / m^3 (~180 kg / tone @ density of 2.3 g / cm^3) (reduced to 290 kg / m^3 with 30 % fly ash replacement of cement) . The CO_2 emission from the concrete production is directly proportional to the cement content used in the concrete mix; 900 kg of CO_2 are emitted for the fabrication of every ton of cement . Cement manufacture contributes greenhouse gases both directly through the production of carbon dioxide when calcium carbonate is thermally decomposed, producing lime and carbon dioxide, and also through the use of energy, particularly from the combustion of fossil fuels.

3 - Surface run off :

Surface runoff, when water runs off impervious surfaces, such as non - porous concrete, can cause heavy soil erosion and flooding. Urban runoff tends to pick up gasoline, motor oil, heavy metals, trash and other pollutants from side walks , road ways and parking lots . Without attenuation, the impervious cover in a typical urban area limits groundwater percolation and causes five times the amount of runoff generated by a typical woodland of the same size . A 2008 report by the United States National Research Council identified urban runoff as a leading source of water quality problems .

4 - Urban heat :

Both concrete and asphalt are the primary contributors to what is known as the urban heat island effect.

Using light-colored concrete has proven effective in reflecting up to 50 % more light than asphalt and reducing ambient temperature. A low albedo value, characteristic of black asphalt, absorbs a large percentage of solar heat and contributes to the warming of cities. By paving with light colored concrete, in addition to replacing asphalt with light - colored concrete, communities can lower their average temperature .

In many U.S. cities, pavement covers about 30 – 40 % of the surface area . This directly affects the temperature of the city and contributes to the urban heat island effect. Paving with light - colored concrete would lower temperatures of paved areas and improve night-time visibility . The potential of energy saving within an area is also high. With lower temperatures, the demand for air conditioning decreases, saving energy.

Atlanta has tried to mitigate the heat-island effect. City officials noted that when using heat-reflecting concrete, their average city temperature decreased by 3.3°C . The Design Trust for Public Space found that by slightly raising the albedo value in New York City, beneficial effects such as energy savings could be achieved . It was concluded that this could be accomplished by the replacement of black asphalt with light - colored concrete.

However, in winter this may be a disadvantage as ice will form more easily and remain longer on the light colored surfaces as they will be colder due to less energy absorbed from the reduced amount of sunlight in winter.

5 - Concrete dust :

Building demolition and natural disasters such as earthquakes often release a large amount of concrete dust into the local atmosphere. Concrete dust was concluded to be the major source of dangerous air pollution following the Great Hanshin earthquake ,

6 - Toxic and radioactive contamination :

The presence of some substances in concrete, including useful and unwanted additives, can cause health concerns. Natural radioactive elements (K , U and Th) can be present in various concentration in concrete dwellings, depending on the source of the raw materials used . Toxic substances may also be added to the mixture for making concrete by unscrupulous makers. Dust from rubble or broken concrete upon demolition or crumbling may cause serious health concerns depending also on what had been incorporated in the concrete.

7 - Handling precautions :

Handling of wet concrete must always be done with proper protective equipment. Contact with wet concrete can cause skin chemical burns due to the caustic nature of the mixture of cement and water. Indeed, the pH of fresh cement water is highly alkaline due to the presence of free potassium and sodium hydroxides in solution (pH ~ 13.5) . Eyes, hands and feet must be correctly protected to avoid any direct contact with wet concrete and washed without delay if necessary.

8 - Concrete recycling :

Recycled crushed concrete being loaded into a semi-dump truck to be used as granular fill.

Concrete recycling is an increasingly common method of disposing of concrete structures. Concrete debris was once routinely shipped to landfills for disposal, but recycling is increasing due to improved environmental awareness, governmental laws and economic benefits.

Concrete, which must be free of trash, wood, paper and other such materials, is collected from demolition sites and put through a crushing machine, often along with asphalt, bricks and rocks.

Reinforced concrete contains rebar and other metallic reinforcements, which are removed with magnets and recycled elsewhere. The remaining aggregate chunks are sorted by size. Larger chunks may go through the crusher again. Smaller pieces of concrete are used as gravel for new construction projects. Aggregate base gravel is laid down as the lowest layer in a road, with fresh concrete or asphalt placed over it. Crushed recycled concrete can sometimes be used as the dry aggregate for brand new concrete if it is free of contaminants, though the use of recycled concrete limits strength and is not allowed in many jurisdictions. On 3 March 1983, a government funded research team (vthe VIRL research . codep) approximated that almost 17 % of worldwide landfill was by-products of concrete based waste.

Eternit

Eternit roofing.

Contents

1 Introduction :

Eternit is a registered trademark for fiber cement. This has caused fiber cement to be known under the "Eternit" brand. Though, this is not to be confused, "Eternit" is only a trademark for fiber cement, currently owned by the Belgian company Etex .

Fiber cement is often applied in building and construction materials , mainly in roofing and facade products .

2 - Material description :

Old eternit water tank

The term "cement" originates from the Latin word "*Caementum*", which signifies chopped stone. Cement describes a binding substance, which will react chemically with water and develop into a material hard as stone. In fiber cement there is a fiber reinforcement , which contributes to making the fiber-cement material even stronger and to better with stand tension. Together with a carefully planned production process, fiber cement makes it possible to develop strong and long - lasting construction materials .

Today fiber cement is considered as a material physically suited for construction products such as cladding and roofing. It is primarily due to its function, performance and commercial value .

3 - Material history :

Fiber - reinforced cement-products were invented in the late 19th century by the Austrian Ludwig Hatschek. Principally he mixed 90% cement and 10 % asbestos fibers with water and ran it through a cardboard machine. Originally, the fibers were of asbestos and the material was commonly used as siding in house buildings due to its low cost, fire - resistance, water tightness, light weight, and other useful properties. After the discovery in the seventies that asbestos is harmful to health and produces lung cancers years after professional or occasional exposure (asbestosis), asbestos use was progressively prohibited and safer fiber alternatives, based on e.g. cellulose fibers were developed in the eighties and applied to secure the widely known strength of fiber cement.

Fiber cement were probably amongst the latest materials on the market to have contained large quantities of asbestos. The reason is that the asbestos fibers are intimately bound to the cement matrix and were first considered to be well immobilized in the cement and less prone to be released in the environment, suspended in the air, and inhaled in the lung than in other materials or applications such as thermal insulation or flocking in which bare asbestos fibers were used. How ever, asbestos fibers are inevitably released during machining operations of the objects made of fiber - cement and by long-term erosion of the materials exposed to atmospheric weathering and wind when cement degrades. Occupational health concerns and the protection of workers in the fiber - cement factories have finally led to the progressive elimination of asbestos from these products.[1]

4 - Material usage :

Fiber cement is a main component of long-lasting building materials. The main application areas are roofing and cladding. The list below gives some common applications.

Internal cladding :

- Wet room applications – tile backer boards
- Fire protection
- Partition walls
- Window sills
- Ceilings and floors

External cladding :

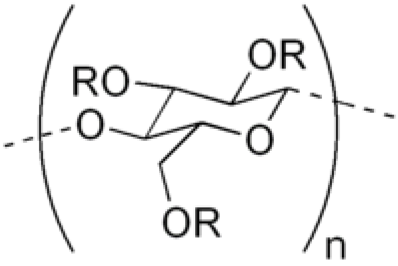
- Flat sheets as base and/or architectural facing
- Flat sheets for e.g. wind shields, wall copings, and soffits
- Corrugated sheets
- Slates as architectural full and partial facing
- Under roof
- Planks

Roofing :

- Slates
- Corrugated sheets

Fiber - cement products have found a wide usage in various sectors of construction: industrial, agricultural, domestic and residential buildings, mainly in roofing and cladding applications, for new constructions and refurbishment projects.

Ethyl Cellulose



R = H or CH_2CH_3

Ethyl cellulose is a derivative of cellulose in which some of the hydroxyl groups on the repeating glucose units are converted into ethyl ether groups. The number of ethyl groups can vary depending on the manufacturer.

It is mainly used as a thin - film coating material .

Ethyl cellulose is used as a food additive as an emulsifier (E 462) .

Expanded poly Styrene Concrete

Expanded poly styrene (EPS) concrete (also it known as EPScrete, EPS concrete or lightweight concrete) is a form of concrete known for its light weight. It is a popular material for use in environmentally "green" homes. It has been used as road bedding, in soil or geo-stabilization projects and as sub - grading for railroad track age.

It is created by using small light weight Styrofoam or EPS balls as an aggregate instead of the crushed stone that is used in regular concrete. It is not as strong as stone - based concrete mixes, but has other advantages such as increased thermal and sound insulation properties, easy shaping and formed by hand with sculpturing and construction tools.

Feldspar

Feldspar crystal (18×21×8.5 cm) from Jequitinhonha valley, Minas Gerais, Southeastern Brazil.

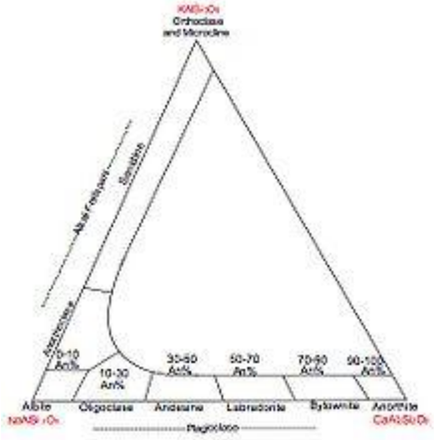
Contents

1 – Introduction :

Feldspars ($KAlSi_3O_8$ – $NaAlSi_3O_8$ – $CaAl_2Si_2O_8$) are a group of rock-forming tecto silicate minerals which make up as much as 60 % of the Earth's crust.

Feldspars crystallize from magma in both intrusive and extrusive igneous rocks, as veins, and are also present in many types of metamorphic rock . Rock formed almost entirely of calcic plagioclase feldspar (see below) is known as anorthosite. Feldspars are also found in many types of sedimentary rock.

Category	tecto silicate
Chemical Formula	$KAlSi_3O_8$ – $NaAlSi_3O_8$ – $CaAl_2Si_2O_8$
Color	Pink , white , gray , brown
Mohs scale hardness	6
Luster	Vitreous
Streak	white
Diaphaneity	opaque
Specific gravity	2.55 - 2.76
Birefringence	first order
Other characteristics	Ex solution lamellae common



Compositional phase diagram of the different minerals that constitute the feldspar solid solution.

2 - Etymology :

Feldspar is derived from the German *Feld*, "field", and *Spath*, "a rock that does not contain ore". "Feldspathic" refers to materials that contain feldspar. The alternate spelling, *felspar*, has now largely fallen out of use.

3 – Compositions :

This group of minerals consists of framework tectosilicates. Compositions of major elements in common feldspars can be expressed in terms of three end members:

Potassium-Feldspar (K-spar) end member $KAlSi_3O_8$

Albite end member $NaAlSi_3O_8$

Anorthite end member $CaAl_2Si_2O_8$

Solid solutions between K-feldspar and albite are called alkali feldspar. Solid solutions between albite and anorthite are called *plagioclase* , or more properly *plagioclase feldspar*. Only limited solid solution occurs between K- feldspar and anorthite, and in the two other solid solutions, immiscibility occurs at temperatures common in the crust of the earth. Albite is considered both a plagioclase and alkali feldspar. In addition to albite, barium feldspars are also considered both alkali and plagioclase feldspars. Barium feldspars form as the result of the replacement of potassium feldspar.

3 – 1 - Alkali feldspars :

The alkali feldspars are as follows :

- orthoclase (monoclinic) , — $KAlSi_3O_8$
- sanidine (monoclinic) —$(K,Na)AlSi_3O_8$
- microcline (triclinic) — $KAlSi_3O_8$
- anorthoclase (triclinic) — $(Na,K)AlSi_3O_8$

Sanidine is stable at the highest temperatures, and microcline at the lowest . Perthite is a typical texture in alkali feldspar, due to exsolution of contrasting alkali feldspar compositions during cooling of an intermediate composition. The perthitic textures in the alkali feldspars of many granites can be seen with the naked eye. Micro perthitic textures in crystals are visible using a light microscope , whereas cryptoperthitic textures can be seen only with an electron microscope.

3 – 2 - Plagioclase feldspars :

The plagioclase feldspars are triclinic. The plagioclase series follows (with percent anorthite in parentheses) :

- albite (0 to 10) — $NaAlSi_3O_8$
- oligoclase (10 to 30) — $(Na,Ca)(Al,Si)AlSi_2O_8$
- andesine (30 to 50) — $NaAlSi_3O_8$ — $CaAl_2Si_2O_8$
- labradorite (50 to 70) — $(Ca,Na)Al(Al,Si)Si_2O_8$
- bytownite (70 to 90) — $(NaSi,CaAl)AlSi_2O_8$
- anorthite (90 to 100) — $CaAl_2Si_2O_8$

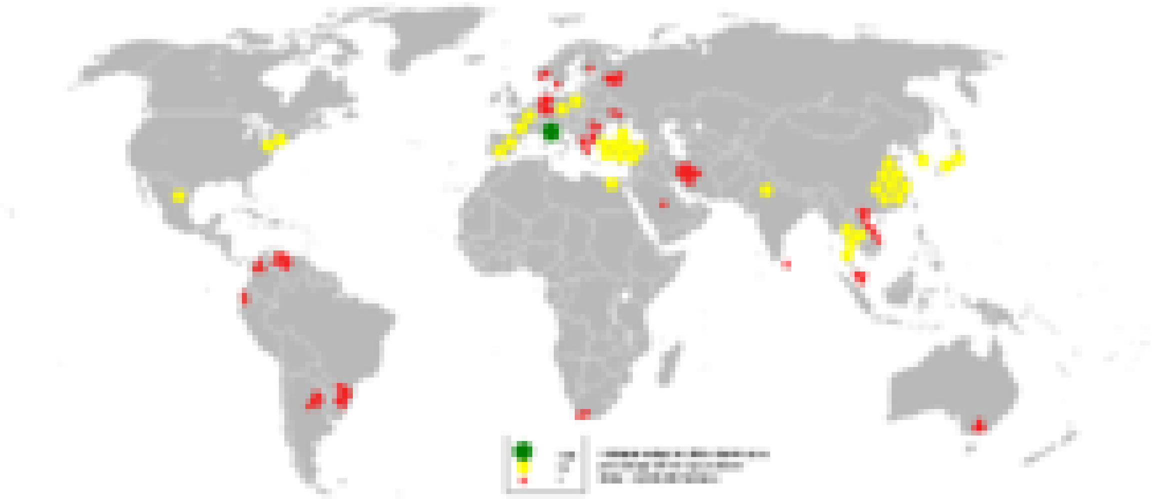
Intermediate compositions of plagioclase feldspar also may exsolve to two feldspars of contrasting composition during cooling, but diffusion is much slower than in alkali feldspar, and the resulting two-feldspar intergrowths typically are too fine-grained to be visible with optical microscopes. The immiscibility gaps in the plagioclase solid solution are complex compared to the gap in the alkali feldspars. The play of colours visible in some feldspar of labradorite composition is due to very fine-grained exsolution lamellae.

3 – 3 - Barium feldspars :

The barium feldspars are monoclinic and comprise the following:

- celsian — $BaAl_2Si_2O_8$
- hyalophane — $(K,Na,Ba)(Al,Si)_4O_8$

Feldspars can form clay minerals through chemical weathering.



Feldspar output in 2005.

4 - Production and uses :

About 20 million tones of feldspar was produced in 2010, mostly by three countries: Italy (4.7 Mt), Turkey (4.5 Mt), and China (2 Mt).

Feldspar is a common raw material used in glassmaking, ceramics, and to some extent as a filler and extender in paint, plastics, and rubber. In glassmaking, alumina from feldspar improves product hardness, durability, and resistance to chemical corrosion. In ceramics, the alkalis in feldspar (calcium oxide, potassium oxide, and sodium oxide) act as a flux, lowering the melting temperature of a mixture. Fluxes melt at an early stage in the firing process, forming a glassy matrix that bonds the other components of the system together. In the US, about 66% of feldspar is consumed in glassmaking, including glass containers and glass fiber. Pottery (including electrical insulators, sanitary ware, tableware, and tile) and other uses, such as fillers, accounted for the remainder.

In earth sciences and archaeology, feldspars are used for K-Ar dating, argon-argon dating, thermo luminescence dating and optical dating.

Ferro Cement

Contents

1 – Introduction :

The term **Ferro Cement** is most commonly applied to a mixture of Portland cement and sand applied over layers of woven or expanded steel mesh and closely spaced small - diameter steel rods rebar. It can be used to form relatively thin, compound curved sheets to make hulls for boats, shell roofs, water tanks, etc. It has been used in a wide range of other applications including sculpture and prefabricated building components. The term has been applied by extension to other composite materials including some containing no cement and no ferrous material. These are better referred to by terms describing their actual contents.

The term "ferro cement" was given to this product by its inventor in France, Joseph Monier. At the time, (1850's) he wanted to create urns, planters, and cisterns without the expense of kiln firing. In 1875 he created the first steel and concrete bridge. The outer layer was sculpted in its wet state to mimic rustic logs, thereby also introducing Faux Bois concrete into practice. (Recent trends have "ferrocement" being referred to as ferro concrete or reinforced concrete to better describe the end product instead of its components. By understanding that aggregates mixed with Portland cement form concrete, but many things can be called cement, it is hoped this may avoid the confusion of many compounds or techniques that are not ferro concrete.)

Ferro concrete has relatively good strength and resistance to impact. When used in house construction in developing countries, it can provide better resistance to fire, earthquake, and corrosion than traditional materials, such as wood, adobe and stone masonry. It has been popular in developed countries for yacht building because the technique can be learned relatively quickly, allowing people to cut costs by supplying their own labor. In the 1930s through 1950's, it became popular in the United States as a construction and sculpting method for novelty architecture, examples of which created "dinosaurs in the desert", or a "giant pair of cowboy boots and hat" for a service station.

2 - Construction :

The desired shape may be built from a multi-layered construction of mesh, supported by an armature, or grid, built with rebar and tied with wire. For optimum performance, steel should be rust - treated , (galvanized) or stainless steel. (In early practice, in the desert, or for exterior scenery construction, "sound building practice" was not considered, or perhaps unknown as it grew in some cases, from a folk craft tradition of masons collaborating with blacksmiths.) Over this finished framework, an appropriate mixture (grout or mortar) of Portland cement, sand and water and/or admixtures is applied to penetrate the mesh. During hardening, the assembly may be kept moist, to ensure that the concrete is able to set and harden slowly and to avoid developing cracks that can weaken the system. Steps should be taken to avoid trapped air in the internal structure during the wet stage of construction as this can also create cracks that will form as it dries. Trapped air will leave voids that allow water to collect and degrade (rust) the steel. Modern practice often includes spraying the mixture at pressure, (a technique called shotcrete,) or some other method of driving out trapped air.

Older stuctures that have failed offer clues to better practices. In addition to eliminating air where it contacts steel, modern concrete additives may include acrylic liquid "admixtures" to slow moisture absorption and increase shock resistance to the hardened product or to alter curing rates. These technologies, borrowed from the commercial tile installation trade, have greatly aided in the restoration of these structures . Chopped glass or poly fiber can be added to reduce crack development in the outer skin. (It should be noted that chopped fiber could inhibit good penetration of the grout to steel mesh constructions. This should be taken into consideration and mitigated, or limited to use on outer subsequent layers. Chopped fibers may also alter or limit some wet sculpting techniques) .

3 - Economics :

The economic advantage of ferro concrete structures is that they are stronger and more durable than some traditional building methods, Depending on the quality of construction and the climate of its location, houses may pay for themselves with almost zero maintenance and lower insurance requirements. Water tanks could pay for themselves by not needing periodic replacement, if properly constructed of reinforced concrete .

Ferro concrete structures can be built quickly, which can have economic advantages. In inclement weather conditions, the ability to quickly erect and enclose the building allows workers to shelter within and continue interior finishing.

In India, ferro concrete is used often because the constructions made from it are more resistant to earthquakes . Earthquake resistance is dependent on good construction technique and additional reinforcement of the concrete.

In the 1970s, designers adapted their yacht designs to the then very popular backyard building scheme of building a boat using ferro cement. Its big attraction was that for minimum outlay and costs, a reasonable application of skill, an amateur could construct a smooth, strong and substantial yacht hull. A ferro cement hull can prove to be of similar or lower weight than a fiber reinforced plastic (fiberglass), aluminum, or steel hull . New methods of laminating layers of cement and steel mesh in a mold may bring new life to ferrocement boat-building . A thorough examination of reinforced concrete and current practice would benefit the boat builder.

4 – Advantages :

The advantages of a well built ferro concrete construction are the low weight, maintenance costs and long lifetime in comparison with purely steel constructions . How ever , meticulous building precision is considered crucial here. Especially with respect to the cementitious composition and the way in which it is applied in and on the frame work , and how or if the framework has been treated to resist corrosion.

When a ferro concrete sheet is mechanically overloaded, it will tend to fold instead of break or crumble like stone or pottery. So it is not brittle. As a container, it may fail and leak but possibly hold together. Much depends on techniques used in the construction.

Please note: Much more information for projects of reinforced concrete has been updated regularly, than for products that we call ferro cement or ferro concrete.

5 - Disadvantages :

The disadvantage of ferro concrete construction is the labor intensive nature of it, which makes it expensive for industrial application in the western world. In addition, threats to degradation (rust) of the steel components is a possibility if air voids are left in the original construction, due to too dry a mixture of the concrete being applied, or not forcing the air out of the structure while it is in its wet stage of construction, through vibration, pressurized spraying techniques, or other means. These air voids can turn to pools of water as the cured material absorbs moisture. If the voids occur where there is untreated steel, the steel will rust and expand, causing the system to fail . In modern practice, the advent of liquid acrylic additives and other advances to the grout mixture, create slower moisture absorption over the older formulas, and also increase bonding strength to mitigate these failures. Restoration steps should include treatment to the steel to arrest rust, using practices for treating old steel common in auto body repair.

Fiber - Reinforced Concrete

Contents

1 – Introduction :

Fiber - Reinforced Concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers. Within these different fibers that character of fiber-reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation and densities.

2 - Historical perspective :

The concept of using fibers as reinforcement is not new. Fibers have been used as reinforcement since ancient times. Historically, horsehair was used in mortar and straw in mud bricks. In the early 1900s, asbestos fibers were used in concrete, and in the 1950s the concept of composite materials came into being and fiber-reinforced concrete was one of the topics of interest. There was a need to find a replacement for the asbestos used in concrete and other building materials once the health risks associated with the substance were discovered. By the 1960s, steel, glass (GFRC), and synthetic fibers such as polypropylene fibers were used in concrete, and research into new fiber-reinforced concretes continues today.

3 - Effect of fibers in concrete :

Fibers are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete. The amount of fibers added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibers) , termed volume fraction (V_f) . V_f typically ranges from 0.1 to 3 % . Aspect ratio (l / d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non - circular cross section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fiber is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increase in the aspect ratio of the fiber usually segments the flexural strength and toughness of the matrix. However, fibers which are too long tend to "ball" in the mix and create workability problems.

Some recent research indicated that using fibers in concrete has limited effect on the impact resistance of the materials [1 & 2] . This finding is very important since traditionally, people think that ductility increases when concrete is reinforced with fibers. The results also indicated out that the use of micro fibers offers better impact resistance compared with the longer fibers .

The High Speed 1 tunnel linings incorporated concrete containing 1 kg/m³ of polypropylene fibers, of diameter 18 & 32 μm, giving the benefits noted below.[1]

4 - Benefits :

Poly propylene and Nylon fibers can :

- Improve mix cohesion, improving pumpability over long distances
- Improve freeze-thaw resistance
- Improve resistance to explosive spalling in case of a severe fire
- Improve impact resistance
- Increase resistance to plastic shrinkage during curing

Steel fibers can:

- Improve structural strength
- Reduce steel reinforcement requirements
- Improve ductility
- Reduce crack widths and control the crack widths tightly thus improve durability
- Improve impact & abrasion resistance
- Improve freeze-thaw resistance

Blends of both steel and polymeric fibers are often used in construction projects in order to combine the benefits of both products; structural improvements provided by steel fibers and the resistance to explosive spalling and plastic shrinkage improvements provided by polymeric fibers.

In certain specific circumstances, steel fiber can entirely replace traditional steel reinforcement bar in reinforced concrete. This is most common in industrial flooring but also in some other precasting applications. Typically, these are corroborated with laboratory testing to confirm performance requirements are met. Care should be taken to ensure that local design code requirements are also met which may impose minimum quantities of steel reinforcement within the concrete. There are increasing numbers of tunneling projects using precast lining segments reinforced only with steel fibers.

Useful standards:

- EN 14889-1:2006 Fibers for Concrete. Steel Fibers. Definitions, specifications & conformity
- EN 14889-2:2006 Fibers for Concrete. Polymer Fibers. Definitions, specifications & conformity
- EN 14845-1:2007 Test methods for fibers in concrete
- ASTM A820-06 Standard Specification for fibers in Fiber Reinforced Concrete
- ASTM C1018-07 Standard test methods for flexural toughness & first crack strength

5 - Some developments in fiber - reinforced concrete :

An FRC sub - category named Engineered Cementitious Composite (ECC) claims 500 times more resistance to cracking and 40 percent lighter than traditional concrete . ECC claims it can sustain strain-hardening up to several percent strain, resulting in a material ductility of at least two orders of magnitude higher when compared to normal concrete or standard fiber - reinforced concrete. ECC also claims a unique cracking behavior. When loaded to beyond the elastic range, ECC maintains crack width to below 100 µm, even when deformed to several percent tensile strains. Field results with ECC and The Michigan Department of Transportation resulted in early-age cracking .

Recent studies performed on a high-performance fiber-reinforced concrete in a bridge deck found that adding fibers provided residual strength and controlled cracking . There were fewer and narrower cracks in the FRC even though the FRC had more shrinkage than the control. Residual strength is directly proportional to the fiber content.

A new kind of natural fiber-reinforced concrete (NFRC) made of cellulose fibers processed from genetically modified slash pine trees is giving good results . The cellulose fibers are longer and greater in diameter than other timber sources. Some studies were performed using waste carpet fibers in concrete as an environmentally friendly use of recycled carpet waste . A carpet typically consists of two layers of backing (usually fabric from polypropylene tape yarns) , joined by $CaCO_3$ filled styrene - butadiene latex rubber (SBR), and face fibers (majority being nylon 6 and nylon 66 textured yarns) . Such nylon and polypropylene fibers can be used for concrete reinforcement. Other ideas are emerging to use recycled materials as fibers .

For statistical calculations there is a new modelling in the book: B.Wietek, *Stahlfaserbeton*, edited by Vieweg + Teubner, 2008, ISBN 978-3-8348-0592-8.

Fiber Cement Siding

Hard panels on design - build addition, Ithaca NY

Contents

1 – Introduction :

Fiber cement siding (or "fiber cement cladding" in the UK and Australasia) is a building material used to cover the exterior of a building in both commercial and domestic applications.

2 - Usage :

Fiber cement is a composite material made of sand, cement and cellulose fibers. In appearance fiber cement siding most often consists of over lapping horizontal boards , imitating wooden siding, clapboard and imitation shingles. Fiber cement siding is also manufactured in a sheet form and is used not only as cladding but is also commonly used as a soffit / eave lining and as a tile underlay on decks and in bathrooms.

CSR Fiber Cement sheet cladding - dwelling addition, Hardys Bay, NSW, Australia

Fiber cement siding is not only used as an exterior siding, it can also be utilized as a substitute for timber fascias and barge boards in high fire areas.

3 - Specifications :

Sheet sizes vary slightly from manufacturer to manufacturer but generally they range between 2400 – 3000 mm in length and 900 – 1200mm in width (600 & 450 mm increments). This manufactured size minimizes on - site wastage as residential floor, wall and roof structures lay structural members at 450 or 600 centers.

Fiber cement thicknesses vary between 4.5-18mm and also vary in density – the lower density resulting in a fibrous rough edge when cut and the higher density having a cleaner smoother edge when cut.

Thermal resistance and sound transmission vary greatly between fiber cement products. Fiber cement sheet products rate poorly in thermal resistance and sound transmission and separate wall insulation is highly recommended. Generally the thicker and denser the product the better resistance it will have to temperature and sound transmission.

4 – Installation :

Fiber cement cladding is a very heavy product and requires two people to carry the uncut sheets. Thin fiber cement cladding is fragile before installation and must be handled carefully; it is prone to chipping and breakage if improperly handled . Once the product is cut it may again require two people to install – one to hold the sheet flush against studwork and the other to nail the product in place.

Cutting fiber cement cladding sheeting usually requires a mechanized saw or metal hand shears and sheets can be cut to size in three ways:

- Thinner sheets can be scored with a heavy duty cutting blade and snapped
- Purpose made "fibro cutter" (an Australian term)
- Thicker and denser sheets require cutting by a mechanical saw

Some caution must be exercised to properly ventilate areas where fiber cement siding (FCS) is being cut; long-term exposure to the silica dust generated during the installation process can cause silicosis.

Fiber cement cladding can be painted before or after installation. (For areas of exposure, weatherproof paint must be used.) Once the product is fixed the joints are usually covered with timber battens and the entire wall surface is painted.

Detail - timber battens on fiber cement cladding, dwelling addition, Hardys Bay, NSW, Australia

5 - History :

Ludwig Hatschek patented fiber cement in Austria in 1901 and named it "Eternit" based on the latin term "aeternitas" meaning everlasting. In 1903 the company Schweizerische Eternit-Werke AG began fabricating the material in the city of Niederurnen in Switzerland. Early fiber cement panels used asbestos fibers to add strength. Fiber cement products came about as a replacement for the widely used "Asbestos Cement Sheeting" product manufactured by James Hardie until the late 1980s.

6 - Durability :

The external cladding products require very little maintenance once installed and painted. The thicker/denser fiber cement products have excellent impact resistance but the thinner less dense products need to be protected from impact. Compared to wooden siding, fiber cement is not susceptible to termites or rot.

7 - Fire Resistance :

Fiber cement cladding is a non combustible material which is widely used in high bush fire prone areas throughout Australia . Pictured above is James Hardie's Fiber Cement cladding ‘Scyon Linea’ weatherboard which has been substituted for the traditional timber fascia and barge board materials.

7 - Alternatives :

Competitors to fiber cement cladding include products made from vinyl , poly vinyl chloride , wood composite products (such as hard board and Masonite) and aluminum siding

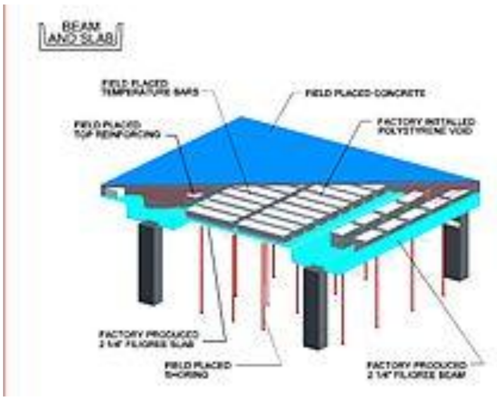
Filigree Concrete

Contents

1 – Introduction :

The **Filigree Wide Slab method** is a process for construction of concrete floor decks from two interconnected concrete placements, one precast in a factory, and the other done in the field. The method was developed during the late 1960s by Harry H. Wise as a more efficient and economic construction process than conventional cast-in-place technologies .

2 - Description :



Detail of construction

The process begins by manufacturing thin precast concrete panels, typically 2.25" thick, with the deck's bottom reinforcement included. The panels are then shipped to a jobsite and erected on temporary shoring. Subsequently, the deck's top reinforcing steel is placed on top of the precast panels at the site, and concrete is poured over the entire assembly to achieve the final thickness of the deck.

This process effectively accelerates the construction of structures by eliminating the need for costly and time consuming field forming, and the placing of bottom reinforcement. Poly styrene blocks are often incorporated into the panels during their manufacture in order to create voids, reducing both the quantity and cost of concrete added in the field, and the overall weight of the structure, which further reduces the costs of columns and foundations .

The soffits of the panels have a smooth uniform finish as a result of casting them in polished steel molds. This reduces the labor cost and time typically required to grind and patch the soffits of cast-in-place concrete decks to achieve an acceptable aesthetic finish.

The method of deck construction can be applied anywhere conventionally poured - in - place concrete is specified, such as flat plate, beam and slab, and wall - bearing structures.

3 - Design methods :

A concrete deck using the Filigree method of construction is designed using virtually the same techniques as are used for cast-in-place decks as prescribed by the American Concrete Institute document ACI318 - 05 . Specifically, Section 17, titled "Composite Concrete" permits the use of precast concrete elements to be attached to cast - in - place concrete provided the requirements of this section are adhered to.

The system is designed as a one-way continuous span slab supported on continuous span beams. An analysis of the slab take into account the width of the beams, as the deeper beams behave as slab haunches, proving greater stiffness to the slab near a support.

The top reinforcement design for the slabs should be done at both the beam center lines, and at the beam faces. This is because the negative slab moments are typically much less at a beam face, allowing a reduction in the top reinforcement required.

The beams are designed with a frame analysis that includes the stiffness of the columns. Punching shear stress is checked

4 - Fire Resistance :

The heat variation of concrete deck surfaces during a fire may reach a level of 1500°F. Under such conditions, the horizontal shear stress at the contact faces of the concrete layers becomes unpredictable, and may well exceed the values permitted by the code. This may consequentially cause separation of the layers and de-lamination the composite deck.

Since data is not available to reliably predict the behavior of a composite concrete decks during a building fire, a complete fire test is necessary to determine the structure's sustainability and safety.

The standards for such fire tests are given by the building code as "Standard Fire Tests of Building Construction and Materials UL263", ASTM E119, and NFPA, No. 251.

The International Construction Code requires that only fire resistant components may be used for construction of publicly used structures. All pre-cast concrete elements used for floor construction carry a United Testing Laboratory Certified Fire Resistant Rating.

Fire Proofing

Circuit integrity fireproofing of cable trays, using calcium silicate boards.

Spray gypsum based plaster fireproofing being installed.

Contents

1 – Introduction :

Fire Proofing , a passive fire protection measure , refers to the act of making materials or structures more resistant to fire , or to those materials themselves, or the act of applying such materials. Applying a certification listed fireproofing system to certain structures allows these to have a fire - resistance rating. The term fireproof does not necessarily mean that an item cannot ever burn: It relates to measured performance under specific conditions of testing and evaluation. Fireproofing does not allow treated items to be entirely unaffected by any fire, as conventional materials are not immune to the effects of fire at a sufficient intensity and/or duration.

2 – Markets :

- Commercial construction
- Residential construction
- Industrial construction
- Marine (ships)
- Offshore construction
- Aerodynamics
- Tunnel concrete walls and ceilings or linings
- Under and above ground mining operations

3 – Applications :

- Structural steel to keep below critical temperature ca. 540 °C
- Electrical circuits to keep critical electrical circuits below 140 °C so they stay operational
- Liquefied petroleum gas containers to prevent a BLEVE (boiling liquid expanding vapour explosion)
- Vessel skirts and pipe bridges in an oil refinery or chemical plant to keep the structural steel below critical temperature ca. 540°
- Concrete linings of traffic tunnels

4 - History :

Asbestos was one material historically used for fireproofing, either on its own, or together with binders such as cement, either in sprayed form or in pressed sheets, or as additives to a variety of materials and products, including fabrics for protective clothing and building materials. Because the material has proven to cause cancer in the long run, a large removal and replacement business has been established.

Endo thermic materials have also been used to a large extent and are still in use today, such as gypsum, concrete and other cementitious products. More highly evolved versions of these are used in aerodynamics, intercontinental ballistic missiles (ICBMs) and re-entry vehicles, such as the space shuttles.

The use of these older materials has been standardized in "old" systems, such as those listed in BS476, DIN4102 and the National Building Code of Canada.

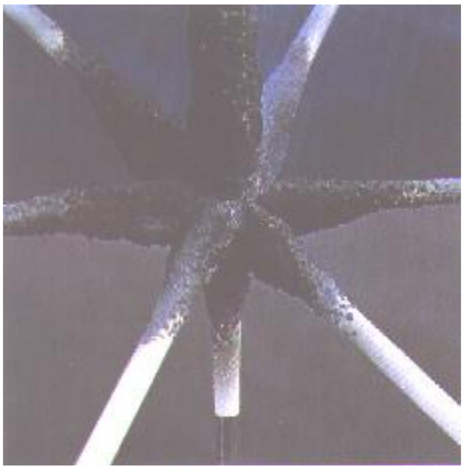
5 - Alternative fireproofing methods :

Among the conventional materials, purpose-designed spray fireproofing plasters have become abundantly available the world over. The **inorganic methods include** :

- Gypsum plasters
- Cementitious plasters
- Fibrous plasters

The industry considers gypsum - based plasters to be "cementitious", even though these contain no Portland, or calcium aluminate cements. Cementitious plasters that contain Portland cement have been traditionally lightened by the use of inorganic lightweight aggregates, such as vermiculite and perlite.

Gypsum plasters have been lightened by using chemical additives to create bubbles that displace solids, thus reducing the bulk density. Also, lightweight poly styrene beads have been mixed into the plasters at the factory in an effort to reduce the density, which generally results in a more effective insulation at a lower cost. The resulting plaster has qualified to the A2 combustibility rating as per DIN4102. Fibrous plasters, containing either mineral wool, or ceramic fibers tend to simply entrain more air, thus displacing the heavy fibers. On - site cost reduction efforts, at times purposely contravening the requirements of the certification listing, can further enhance such displacement of solids. This has resulted in architects' specifying the use of on - site testing of proper densities to ensure the products installed meet the certification listings employed for each installed configuration, because excessively light inorganic fireproofing does not provide adequate protection and are thus in violation of the listings.



In tumescent spray fireproofing product has expanded.

Proprietary boards and sheets, made of gypsum, calcium silicate, vermiculite, perlite , mechanically bonded composite boards made of punched sheet - metal and cellulose reinforced concrete have all been used to clad items for increased fire-resistance.

An alternative method to keep building steel below its softening temperature is to use **liquid convection cooling** in hollow structural members.[1] This method was patented in the 19th century although the first prominent example was 89 years later.

6 – Fraud :

The following examples of fraud are preventable when documentation is required and checked to ensure that all installed configurations fall within the tolerances of active certification listings.

- Entraining too much air in inorganic systems, thus reducing densities, saves on materials and labour .

- Spraying inorganic spray fireproofing materials over through - penetrations and building joints that should be **fire stopped** , not *fireproofed*. This practice negates fire-separation integrity. Firestops must precede spray fireproofing.

Fire stopped through - penetrations of structural beams . The installation is incomplete, as the beams are not yet treated with fireproofing. If left as - is , they will collapse , resulting in openings in the fire separation wall.

- Substitution of in tumescent and / or endothermic fireproofing coatings with less expensive paints that physically resemble the passive fire protection products, sometimes involving re-use of packaging and de-canting of contents.
- The American and Canadian nuclear industries have, historically, not insisted on listing and approval use and compliance, on the basis of the use of accredited certification laboratories. This has allowed the use of Thermo - Lag 330 -1, for which the basis of testing has been proven to be faulty resulting in millions of dollars of remedial work. The Thermo-Lag scandal came to light as a result of disclosures by American whistle blower Gerald W. Brown, who reported the deficiencies in fire testing to the Nuclear Regulatory Commission. Presently, product certification of fireproofing and firestopping remains optional for systems installed in nuclear power plants both in Canada and the United States.

7 - Work staging :

Spray fireproofing products have not been qualified to the thousands of fire stop configurations, so they cannot be installed in conformance of a certification listing. Therefore, fire stopping must precede fireproofing. Both need one another. If the structural steel is left without fireproofing, it can damage fire barriers and a building can collapse. If the barriers are not fire stopped properly, fire and smoke can spread from one compartment to another.

8 - Traffic tunnel fire proofing :

Traffic tunnels may be traversed by vehicles carrying flammable goods , such as petrol, liquefied petroleum gas and other hydrocarbons, which are known to cause a very rapid temperature rise and high ultimate temperatures in case of a fire (see the hydrocarbon curves in fire-resistance rating) . Where hydrocarbon transports are permitted in tunnel construction and operations, accidental fires may occur, resulting in the need for fireproofing of traffic tunnels with concrete linings. Traffic tunnels are not ordinarily equipped with fire suppression means, such as fire sprinkler systems. It is very difficult to control hydrocarbon fires by active fire protection means, and it is expensive to equip an entire tunnel along its whole length for the eventuality of a hydrocarbon fire or a BLEVE.

8 – 1 - Concrete exposed to hydrocarbon fires :

Concrete , by itself, cannot withstand hydrocarbon fires. In the Channel tunnel that connects United Kingdom and France, an intense fire broke out and reduced the concrete lining in the undersea tunnel down to about 50 mm . In ordinary building fires , concrete typically achieves excellent fire-resistance ratings, unless it is too wet, which can cause it to crack and explode. For unprotected concrete, the sudden endothermic reaction of the hydrates and unbound humidity inside the concrete causes such pressure as to spall off the concrete, which then winds up in small pieces on the floor of the tunnel. This is the reason why laboratories insert humidity probes into all concrete slabs that undergo fire testing even in accordance with the less severe building elements curve (DIN4102, ASTM E119, BS476, or ULC-S101). The need for fireproofing was demonstrated, among other fire protection measures, in the European "Eureka" Fire Tunnel Research Project, which resulted in building codes for the trade to avoid the effects of such fires upon traffic tunnels. Cementitious spray fireproofing must be certification listed and applied in the field as per that listing, using a hydrocarbon fire test curve such as the one that is also used in UL1709 .

9 – Fire proof Vaults :

The traditional method for constructing fireproof vaults to protect important paper documents has been to use concrete or masonry blocks as the primary building material[*citation needed*]. In the event of a fire, the chemically bound water within the concrete or masonry blocks will be forced into the vault chamber as steam. The steam will soak the paper documents to keep them from burning . This steam will also help keep the temperature inside the vault chamber below the critical 350 - degree Fahrenheit (176.7- degrees Celsius) threshold, which is the point at which information on paper documents is destroyed · The paper can later be remediated with a freeze drying process, if the fire is extinguished before internal temperatures exceed 350 - degrees . An alternate less expensive and time-consuming process is using dry insulating material .

This traditional vault construction method is sufficient for paper documents, but the steam generated by concrete/masonry structures will destroy contents that are more sensitive to heat and moisture. For example, information on microfilm is destroyed at 150-degrees F. (65.5- degrees C. a.k.a. Class 150) and magnetic media (such as data tapes) lose data above 125- degrees F. (51.7-degrees C. a.k.a. Class 125) Fireproof vaults built to meet the more stringent Class 125 requirement are called data-rated vaults ·

All components of fireproof vaults must meet the fire protection rating of the vault itself, including doors, HVAC penetrations and cable penetrations

Firth Concrete

Contents

1 – Introduction :

Firth Concrete (legal title : *Firth Industries*) is New Zealand's largest and only national concrete company. It produces ready mix concrete under its Certified brand, a large range of concrete masonry (or grey masonry), paving, segmental retaining walls and veneers. It also has a range of bagged, pre-mixed product that is marketed under the Dricon brand.

2 – History :

The business from which Firth evolved started at Rangiriri, north of Hamilton, in May 1925. This original business was established by the founder's grandfather, Josiah Clifton Firth, who arrived in New Zealand in 1856. On arriving Josiah decided that Auckland needed a modern flour mill. But first it needed a brick-making factory, so he built his own. Meanwhile, his son, E. C. Firth, invented the 'ironclad' pumice washing boiler. This manufacturing business was later taken on by his sons, Ted and Tony Firth, and it was their joint venture that became Firth Concrete Limited. In the beginning, concrete products in New Zealand were manufactured by hand in small-scale operations. But over the next fifty years driven by two successive building booms, the Firth brothers took their business from a two-man operation to a large, diverse business with branches throughout the country. In 1938 the company introduced New Zealand's first machine-made concrete blocks. The blocks were cast by a machine called a 'Rockcrete' at the company's Frankton factory in Hamilton.

Firth's modern history began in 1973 when Fletcher Holdings bought a minor holding in the company, completing a full buy-out in 1979. In 1993, two Fletcher Challenge Limited business units - Certified Concrete Limited and Firth Concrete Products Limited - were merged to become the Firth company of today, a Business Unit of Fletcher Building Ltd. In April 2001 Fletcher Building separated from Fletcher Challenge to operate as a stand-alone company.

Today Firth has a team of about 650 people, working in more than 65 plant sites throughout New Zealand.

3 - Products :

Firth products are divided into three product groups.

3 – 1 - Certified Concrete :

Firth has supplied concrete to large scale New Zealand projects such as: The Museum of New Zealand - Te Papa Tongarewa, The Auckland Sky Tower and Wellington's Westpac Trust Stadium. Latest project: The Victoria Park Tunnel in Auckland.

3 – 2 - Masonry Products :

Firth produces: masonry blocks, pavers, retaining wall products and bricks. It can make to order special mixes with specified colours, abrasion-resistance qualities, strengths and mix designs.

3 – 3 - Dricon :

Dricon produces pre-mixed, bagged concretes, mortars, plasters and sands. Dricon has been in operation in New Zealand for over 40 years and the business is ISO 9001 Quality Certified. Dricon 's products include: Handi Crete, Rapid Set™ Super Set™ and Oxitone, Pave Lock, Pave Sand TM

Floor

Floors may include mosaic or other artistic expression.

Contents

1 – Introduction :

A **floor** is the walking surface of a room or vehicle. Floors vary from simple dirt in a cave to many - layered surfaces using modern technology. Floors may be stone, wood, bamboo, metal, or any other material that can hold a person's weight.

The levels of a building are often referred to as floors although a more proper term is storey.

Floors typically consist of a subfloor for support and a floor covering used to give a good walking surface. In modern buildings the subfloor often has electrical wiring, plumbing, and other services built in. Because floors meet many needs, some essential to safety, floors are built to strict building codes in the first world.

2 - Special floor structures :

Where a special floor structure like a floating floor is laid upon another floor then both may be referred to as subfloors.

Special floor structures are used for a number of purposes:

- Balcony, a platform projecting from a wall
- Floating floor, normally for noise or vibration reduction
- Glass floor, as in glass bottomed elevators
- Nightingale floor makes a noise when an intruder walks on it
- Raised floor, utilities underneath can be accessed easily
- Sprung floor, improves the performance and safety of athletes and dancers

3 - Floor covering :

An example of a floor.

Floor covering is a term to generically describe any finish material applied over a floor structure to provide a walking surface. **Flooring** is the general term for a permanent covering of a floor, or for the work of installing such a floor covering. Both terms are used interchangeably but floor covering refers more to loose-laid materials.

Materials almost always classified as floor covering include carpet, area rugs, and resilient flooring such as linoleum or vinyl flooring. Materials commonly called flooring include wood flooring, laminated wood, ceramic tile, stone, terrazzo, and various seamless chemical floor coatings.

The choice of material for floor covering is affected by factors such as cost, endurance, noise insulation, comfort and cleaning effort. Some types of flooring must not be installed below grade (lower than ground level), and laminate or hardwood should be avoided where there may be moisture or condensation.

The subfloor may be finished in a way that makes it usable without any extra work, see:

- Earthen floor adobe or clay floors
- Solid ground floor cement screed or granolithic

There are a number of special features that may be used to ornament a floor or perform a useful service. Examples include Floor medallions which provide a decorative centerpiece of a floor design, or Gratings used to drain water or to rub dirt off shoes.

4 - Sub floor construction ;

Floors may be built on beams or joists or use structures like prefabricated hollow core slabs. The subfloor builds on those and attaches by various means particular to the support structure but the support and subfloor together always provides the strength of a floor one can sense underfoot. Nowadays, subfloors are generally made from at least two layers of moisture resistant ('AC' grade, one side finished and sanded flat) ply wood or composite sheeting, jointly also termed *Under layments* on floor joists of 2x8, 2x10, or 2x12's (dimensional lumber) spaced generally on 16-inch (40.6 cm) centers, in the United States and Canada. Some flooring components used solely on concrete slabs consist of a dimpled rubberized or plastic layer much like bubble wrap that provide little tiny pillars for the one-half-inch (12.7 mm) sheet material above. These are manufactured in 2 × 2 ft (61 × 61 cm) squares and the edges fit together like a mortise and tenon joint. Like a floor on joists not on concrete, a second sheeting underlayment layer is added with staggered joints to disperse forces that would open a joint under the stress of live loads like a person walking.

Three layers are common only in high end highest quality construction. The two layers in high quality construction will both be thick $^{3}/_{4}$ inches (19.1 mm) sheets (as will the third when present), but the two layers may achieve a combined thickness of only half-that in cheaper construction — $^{1}/_{2}$ in (12.7 mm) panel overlaid by $^{1}/_{4}$ in (6.4 mm) plywood subflooring. At the highest end, or in select rooms of the building there might well be three sheeting layers, and such stiff subflooring is necessary to prevent the cracking of large floor tiles of 9–10 inches (22.9–25.4 cm) or more on a side, and the structure under such a floor will frequently also have extra 'bracing' and 'blocking' joist-to-joist intended spread the weight to have as little sagging on any joist as possible when there is a live load on the floor above.

In Europe and North America only a few rare floors will be seen to have no separate floor covering on top, and those are normally because of a temporary condition pending sales or occupancy; in semi-custom new construction and some rental markets, such floors are provided for the new home buyer (renter) to select their own preferred floor coverings usually a wall to wall carpet, or one piece vinyl floor covering. Wood clad (' Hard wood ') and tile covered finished floors generally will require a stiffer higher quality subfloor, especially for the later class. Since the wall base and flooring interact forming a joint, such later added semi-custom floors will generally not be hardwood for that joint construction would be in the wrong order unless the wall base trim was also delayed pending the choosing.

The subfloor may also provide under floor heating and if floor radiant heating is not used, will certainly suffer puncture openings to be put through for forced air ducts for both heating and air conditioning, or pipe holes for *forced hot water* or *steam heating* transport piping conveying the heat from furnace to the to local room's heat exchangers (radiators) .

Some sub - floors are inset below the top surface level of surrounding flooring's joists and such sub floors and a normal height joist are joined to make a plywood box both molding and containing at least two inches (5 cm) of concrete (A 'Mud Floor' in builders parlance) . Alternatively , only a slightly inset floor topped by a fibrous mesh and concrete building composite floor cladding is used for smaller high quality tile floors — these 'concrete' subfloors have a good thermal match with ceramic tiles and so are popular with builders constructing kitchen, laundry and especially both common and high end bathrooms and any other room where large expanses of well supported ceramic tile will be used as a finished floor. Floors using small (4.5 in/11.4 cm and smaller) ceramic tiles generally use only an additional $\frac{1}{4}$-inch (6.4 mm) layer of ply wood (if that) and substitute adhesive and substrate materials making do with both a flexible joints and semi - flexible mounting compounds and so are designed to withstand the greater flexing which large tiles cannot tolerate without breaking.

4 – 1 - Ground floor construction :

A ground-level floor can be an earthen floor made of soil, or be solid ground floors made of concrete slab.

Ground level slab floors are uncommon in northern latitudes where freezing provides significant structural problems, except in heated interior spaces such as basements or for outdoor unheated structures such as a gazebo or shed where unitary temperatures are not creating pockets of trouble some melt waters. Ground - level slab floors are prepared for pouring by grading the site, which usually also involves removing topsoil and other organic materials well away from the slab site. Once the site has reached a suitable firm inorganic base material that is graded further so that it is flat and level, and then topped by spreading a layer-cake of force dispersing sand and gravel. Deeper channels may be dug, especially the slab ends and across the slab width at regular intervals in which a continuous run of rebar is bent and wired to sit at two heights within forming a sub-slab 'concrete girder'. Above the targeted bottom height (coplanar with the compacted sand and gravel topping) a separate grid of rebar or welded wire mesh is usually added to reinforce the concrete, and will be tied to the under slab 'girder' rebar at intervals. The under slab cast girders are used especially if it the slab be used structurally, i.e., to support part of the building.

4 – 2 - Upper floor construction :

Floors in wood frame homes are usually constructed with joists centered no more than 16 inches (41 centimeters) apart, according to most building codes . Heavy floors, such as those made of stone, require more closely spaced joists. If the span between load - bearing walls is too long for joists to safely support , then a heavy crossbeam (thick or laminated wood, or a metal I-beam or H-beam) may be used. A "subfloor" of ply wood or wafer board is then laid over the joists.

4 – 3 - Utilities :

In modern buildings, there are numerous services provided via ducts or wires underneath the floor or above the ceiling. The floor of one level typically also holds the ceiling of the level below (if any) .

Services provided by subfloors include :

- Air conditioning
- Communication fibers
- Electrical wiring
- Fire protection
- Thermal insulation
- Plumbing
- Sewerage
- Sound proofing
- Under floor heating

In floors supported by joists, utilities are run through the floor by drilling small holes through the joists to serve as conduits. Where the floor is over the basement or crawlspace, utilities may instead be run under the joists, making the installation less expensive. Also, ducts for air conditioning (central heating and cooling) are large and cannot cross through joists or beams; thus, ducts are typically at or near the plenum, or come directly from underneath (or from an attic).

Pipes for plumbing, sewerage, under floor heating, and other utilities may be laid directly in slab floors, typically via cellular floor raceways. However, later maintenance of these systems can be expensive, requiring the opening of concrete or other fixed structures. Electrically heated floors are available, and both kinds of systems can also be used in wood floors as well.

5 - Issues with floors :

Wood floors, particularly older ones, will tend to 'squeak' in certain places. This is caused by the wood rubbing against other wood, usually at a joint of the subfloor. Firmly securing the pieces to each other with screws or nails may reduce this problem.

Floor vibration is a problem with floors. Wood floors tend to pass sound, particularly heavy footsteps and low bass frequencies. Floating floors can reduce this problem. Concrete floors are usually so massive they do not have this problem, but they are also much more expensive to construct and must meet more stringent building requirements due to their weight.

The flooring may need protection sometimes e.g. a gym floor alternately used for seating in a graduation ceremony. A gym floor cover can be used to reduce the need to satisfy incompatible requirements.

6 - Floor cleaning :

Floor cleaning is a major occupation throughout the world. Cleaning is essential to prevent injuries due to slips and to remove dirt. Floors are also treated to protect or beautify the surface. The correct method to clean one type of floor can often damage another, so it is important to use the correct treatment.

Flow Table Test

Equipment; flow table, Abrams cone, water bucket and broom.

The diameter of the resulting flow is measured.

The cone filled with concrete, prior to lifting.

Contents

1 - Introduction :

The **flow table test** or **flow test** is a method to determine the consistence of fresh concrete.

Application When fresh concrete is delivered to a site by a truck mixer it is sometimes necessary to check its consistence before pouring it into form work.

If the consistence is not correct, the concrete will not have the desired qualities once it has set, particularly the desired strength. If the concrete is too pasty, it may result in cavities within the concrete which leads to corrosion of the rebar, eventually leading to the formation of cracks (as the rebar expands as it corrodes) which will accelerate the whole process, rather like insufficient concrete cover. Cavities will also lower the stress the concrete is able to support.

2 - Equipment :

- Flow table with a grip and a hinge, 70 cm x 70 cm.
- Abrams cone, open at the top and at the bottom - 30 cm high, 17 cm top diameter, 25 cm base diameter.
- Water bucket and broom for wetting the flow table.
- Tamping rod, 60 cm height

3 - Conducting the test :

- The flow table is wetted.
- The cone is placed on the flow table and filled with fresh concrete in two layers, each layer 25 times tamp with tamping rod.
- The cone is lifted, allowing the concrete to flow.
- The flow table is then lifted up several centimeters and then dropped, causing the concrete flow a little bit further.
- After this the diameter of the concrete is measured.

Flue - Gas Desulfurization

Before flue gas desulfurization was installed, the emissions from this power plant in New Mexico contained a significant amount of sulfur dioxide.

Contents

1 – Introduction :

Flue - Gas Desulfurization (FGD) is a set of technologies used to remove sulfur dioxide (SO_2) from exhaust flue gases of fossil-fuel power plants, and from the emissions of other sulfur oxide emitting processes.

2 - Methods

As stringent environmental regulations regarding SO_2 emissions have been enacted in many countries, SO_2 is now being removed from flue gases by a variety of methods. The below is among the common methods used:

- Wet scrubbing using a slurry of alkaline sorbent, usually lime stone or lime , or seawater to scrub gases;
- Spray - dry scrubbing using similar sorbent slurries;
- Wet sulfuric acid process recovering sulfur in the form of commercial quality sulfuric acid;
- SNOX Flue gas desulfurization removes sulfur dioxide, nitrogen oxides and particulates from flue gases;
- Dry sorbent injection systems.

For a typical coal-fired power station, flue-gas desulfurization (FGD) will remove 95 percent or more of the SO_2 in the flue gases.

3 – History :

Methods of removing sulfur dioxide from boiler and furnace exhaust gases have been studied for over 150 years. Early ideas for flue gas desulfurization were established in England around 1850.

With the construction of large scale power plants in England in the 1920s, the problems associated with large volumes of SO_2 from a single site began to concern the public. The SO_2 emissions problem did not receive much attention until 1929, when the House of Lords upheld the claim of a landowner against the Barton Electricity Works of the Manchester Corporation for damages to his land resulting from SO_2 emissions. Shortly thereafter, a press campaign was launched against the erection of power plants within the confines of London. This outcry led to the imposition of SO_2 controls on all such power plants .

The first major FGD unit at a utility was installed in 1931 at Battersea Power Station, owned by London Power Company. In 1935, an FGD system similar to that installed at Battersea went into service at Swansea Power Station. The third major FGD system was installed in 1938 at Fulham Power Station. These three early large-scale FGD installations were abandoned during World War II. Large-scale FGD units did not reappear at utilities until the 1970s, where most of the installations occurred in the United States and Japan.

As of June 1973, there were 42 FGD units in operation, 36 in Japan and 6 in the United States, ranging in capacity from 5 MW to 250 MW. As of around 1999 and 2000, FGD units were being used in 27 countries, and there were 678 FGD units operating at a total power plant capacity of about 229 giga watts. About 45 % of the FGD capacity was in the U.S., 24% in Germany, 11 % in Japan, and 20 % in various other countries. Approximately 79% of the units, representing about 199 giga watts of capacity, were using lime or limestone wet scrubbing. About 18 % (or 25 giga watts) utilized spray- dry scrubbers or sorbent injection systems .

4 - Sulfuric acid mist formation :

Fossil fuels such as coal and oil contain a significant amount of sulfur. When fossil fuels are burned, about 95 percent or more of the sulfur is generally converted to sulfur dioxide (SO_2). Such conversion happens under normal conditions of temperature and of oxygen present in the flue gas. However, there are circumstances, under which such reaction may not occur.

When flue gas has too much oxygen, the SO_2 further oxidizes into sulfur trioxide (SO_3). Too much oxygen is only one of the ways that SO_3 is formed. Gas temperature is also an important factor. At about 800 °C, formation of SO_3 is favored. Another way that SO_3 can be formed is through catalysis by metals in the fuel. Such reaction is particularly true for heavy fuel oil, where a significant amount of vanadium is present. In what ever way SO_3 is formed, it does not behave like SO_2 in that it forms a liquid aerosol known as sulfuric acid (H_2SO_4) mist that is very difficult to remove. Generally, about 1% of the sulfur dioxide will be converted to SO_3. Sulfuric acid mist is often the cause of the blue haze that often appears as the flue gas plume dissipates. Increasingly, this problem is being addressed by the use of wet electrostatic precipitators.

5 - FGD chemistry :

5 – 1 - Basic principles :

Most FGD systems employ two stages: one for fly ash removal and the other for SO_2 removal. Attempts have been made to remove both the fly ash and SO_2 in one scrubbing vessel. However, these systems experienced severe maintenance problems and low removal efficiency. In wet scrubbing systems, the flue gas normally passes first through a fly ash removal device, either an electrostatic precipitator or a wet scrubber, and then into the SO_2-absorber. However, in dry injection or spray drying operations, the SO_2 is first reacted with the sorbent, and then the flue gas passes through a particulate control device.

Another important design consideration associated with wet FGD systems is that the flue gas exiting the absorber is saturated with water and still contains some SO_2. These gases are highly corrosive to any downstream equipment such as fans, ducts, and stacks. Two methods that can minimize corrosion are :

(1) reheating the gases to above their dew point , or

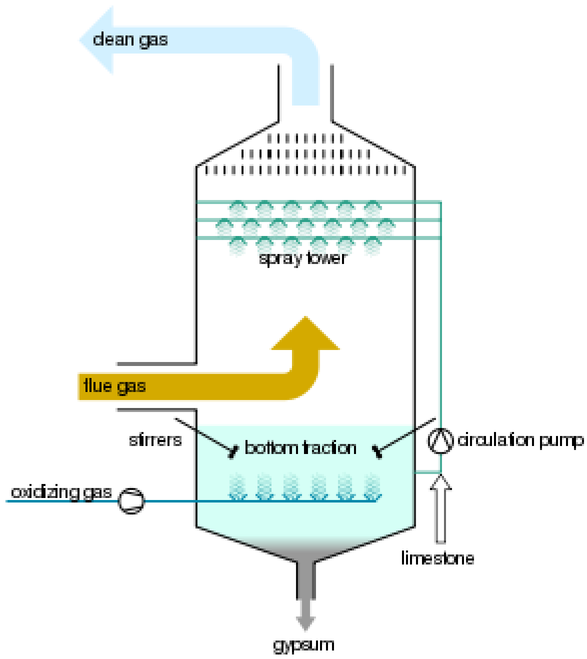
(2) choosing construction materials and design conditions that allow equipment to with stand the corrosive conditions.

Both alternatives are expensive, and engineers designing the system determine which method to use on a site-by-site basis.

5 – 2 - Scrubbing with a basic solid or solution :

SO_2 is an acid gas, and, therefore, the typical sorbent slurries or other materials used to remove the SO_2 from the flue gases are alkaline. The reaction taking place in wet scrubbing using a $CaCO_3$

(limestone) slurry produces $CaSO_3$ (calcium sulfite) and can be expressed as :



Schematic design of the absorber of an FGD

$$CaCO_3 \text{ (solid)} + SO_2 \text{ (gas)} \rightarrow CaSO_3 \text{ (solid)} + CO_2 \text{ (gas)}$$

When wet scrubbing with a $Ca(OH)_2$ (lime) slurry, the reaction also produces $CaSO_3$ (calcium sulfite) and can be expressed as:

$$Ca(OH)_2 \text{ (solid)} + SO_2 \text{ (gas)} \rightarrow CaSO_3 \text{ (solid)} + H_2O \text{ (liquid)}$$

When wet scrubbing with a $Mg(OH)_2$ (magnesium hydroxide) slurry, the reaction produces $MgSO_3$ (magnesium sulfite) and can be expressed as :

$$Mg(OH)_2 \text{ (solid)} + SO_2 \text{ (gas)} \rightarrow MgSO_3 \text{ (solid)} + H_2O \text{ (liquid)}$$

To partially offset the cost of the FGD installation, in some designs, the $CaSO_3$ (calcium sulfite) is further oxidized to produce marketable $CaSO_4 \cdot 2H_2O$ (gypsum). This technique is also known as **forced oxidation** :

$$CaSO_3 \text{ (solid)} + H_2O \text{ (liquid)} + \tfrac{1}{2}O_2 \text{ (gas)} \rightarrow CaSO_4 \text{ (solid)} + H_2O$$

A natural alkaline usable to absorb SO_2 is seawater. The SO_2 is absorbed in the water, and when oxygen is added reacts to form sulfate ions SO_4- and free H^+. The surplus of H^+ is offset by the carbonates in seawater pushing the carbonate equilibrium to release CO_2 gas:

$$SO_2\ (gas) + H_2O + ½O_2\ (gas) \rightarrow SO_4^{2-}\ (solid) + 2H^+$$
$$HCO_3^- + H^+ \rightarrow H_2O + CO_2\ (gas)$$

5 – 2 – 1- Types of wet scrubbers used in FGD :

To promote maximum gas - liquid surface area and residence time, a number of wet scrubber designs have been used, including spray towers , venturis , plate towers, and mobile packed beds. Because of scale buildup, plugging, or erosion, which affect FGD dependability and absorber efficiency, the trend is to use simple scrubbers such as spray towers instead of more complicated ones. The configuration of the tower may be vertical or horizontal, and flue gas can flow co currently, counter currently, or cross currently with respect to the liquid. The chief drawback of spray towers is that they require a higher liquid-to-gas ratio requirement for equivalent SO_2 removal than other absorber designs.

5 – 2 – 1 - 1 – Venturi - rod scrubbers

A venturi scrubber is a converging / diverging section of duct. The converging section accelerates the gas stream to high velocity. When the liquid stream is injected at the throat, which is the point of maximum velocity, the turbulence caused by the high gas velocity atomizes the liquid into small droplets, which creates the surface area necessary for mass transfer to take place. The higher the pressure drop in the venturi , the smaller the droplets and the higher the surface area. The penalty is in power consumption.

For simultaneous removal of SO_2 and fly ash, venturi scrubbers can be used. In fact, many of the industrial sodium - based throwaway systems are venturi scrubbers originally designed to remove particulate matter. These units were slightly modified to inject a sodium - based scrubbing liquor. Although removal of both particles and SO_2 in one vessel can be economic, the problems of high pressure drops and finding a scrubbing medium to remove heavy loadings of fly ash must be considered. However, in cases where the particle concentration is low, such as from oil - fired units, it can be more effective to remove particulate and SO_2 simultaneously.

5 – 2 – 1 - 2 - Packed bed scrubbers :

A packed scrubber consists of a tower with packing material inside. This packing material can be in the shape of saddles, rings, or some highly specialized shapes designed to maximize contact area between the dirty gas and liquid. Packed towers typically operate at much lower pressure drops than venturi scrubbers and are therefore cheaper to operate. They also typically offer higher SO_2 removal efficiency. The drawback is that they have a greater tendency to plug up if particles are present in excess in the exhaust air stream.

5 – 2 – 1 - 3 - Spray towers :

A spray tower is the simplest type of scrubber. It consists of a tower with spray nozzles, which generate the droplets for surface contact. Spray towers are typically used when circulating a slurry (see below). The high speed of a venturi would cause erosion problems, while a packed tower would plug up if it tried to circulate a slurry.

Counter-current packed towers are infrequently used because they have a tendency to become plugged by collected particles or to scale when lime or limestone scrubbing slurries are used.

5 – 2 – 2 - Scrubbing reagent :

As explained above , alkaline sorbents are used for scrubbing flue gases to remove SO_2 . Depending on the application, the two most important are lime and sodium hydroxide (also known as caustic soda) . Lime is typically used on large coal - or oil - fired boilers as found in power plants, as it is very much less expensive than caustic soda. The problem is that it results in a slurry being circulated through the scrubber instead of a solution. This makes it harder on the equipment. A spray tower is typically used for this application. The use of lime results in a slurry of calcium sulfite ($CaSO_3$) that must be disposed of. Fortunately, calcium sulfite can be oxidized to produce by-product gypsum ($CaSO_4 \cdot 2H_2O$) which is marketable for use in the building products industry.

Caustic soda is limited to smaller combustion units because it is more expensive than lime, but it has the advantage that it forms a solution rather than a slurry. This makes it easier to operate. It produces a "spent caustic" solution of sodium sulfite/bisulfite (depending on the pH), or sodium sulfate that must be disposed of. This is not a problem in a kraft pulp mill for example, where this can be a source of makeup chemicals to the recovery cycle.

5 – 3 – Scrubbing with sodium sulfite solution :

It is possible to scrub sulfur dioxide by using a cold solution of sodium sulfite, this forms a sodium hydrogen sulfite solution. By heating this solution it is possible to reverse the reaction to form sulfur dioxide and the sodium sulfite solution. Since the sodium sulfite solution is not consumed, it is called a regenerative treatment. The application of this reaction is also known as the Wellman – Lord process.

In some ways this can be thought of as being similar to the reversible liquid - liquid extraction of an inert gas such as xenon or radon (or some other solute which does not undergo a chemical change during the extraction) from water to another phase. While a chemical change does occur during the extraction of the sulfur dioxide from the gas mixture, it is the case that the extraction equilibrium is shifted by changing the temperature rather than by the use of a chemical reagent.

5 – 4 – Gas phase oxidation followed by reaction with ammonia :

A new, emerging flue gas desulfurization technology has been described by the IAEA . It is a radiation technology where an intense beam of electrons is fired into the flue gas at the same time as ammonia is added to the gas. The Chendu power plant in China started up such a flue gas desulfurization unit on a 100 MW scale in

1998. The Pomorzany power plant in Poland also started up a similar sized unit in 2003 and that plant removes both sulfur and nitrogen oxides. Both plants are reported to be operating successfully. However, the accelerator design principles and manufacturing quality need further improvement for continuous operation in industrial conditions .

No radioactivity is required or created in the process. The electron beam is generated by a device similar to the electron gun in a TV set. This device is called an accelerator. This is an example of a radiation chemistry process where the physical effects of radiation are used to process a substance.

The action of the electron beam is to promote the oxidation of sulfur dioxide to sulfur (VI) compounds. The ammonia reacts with the sulfur compounds thus formed to produce ammonium sulfate, which can be used as a nitrogenous fertilizer. In addition, it can be used to lower the nitrogen oxide content of the flue gas. This method has attained industrial plant scale.

6 – Facts and statistics

Flue gas desulfurization scrubbers have been applied to combustion units firing coal and oil that range in size from 5 MW to 1500 MW. Scottish Power are spending £ 400 million installing FGD at Longannet power station, which has a capacity of over 2 GW. Dry scrubbers and spray scrubbers have generally been applied to units smaller than 300 MW.

FGD has been fitted by RWEn power at Aberthaw Power Station in south Wales using the seawater process and works successfully on the 1580 MW plant.

Approximately 85 % of the flue gas desulfurization units installed in the US are wet scrubbers , 12 % are spray dry systems, and 3 % are dry injection systems.

The highest SO_2 removal efficiencies (greater than 90 %) are achieved by wet scrubbers and the lowest (less than 80 %) by dry scrubbers. However, the newer designs for dry scrubbers are capable of achieving efficiencies in the order of 90 %.

In spray drying and dry injection systems, the flue gas must first be cooled to about 10 – 20 °C above adiabatic saturation to avoid wet solids deposition on downstream equipment and plugging of bag houses.

The capital, operating and maintenance costs per short ton of SO_2 removed (in 2001 US dollars) are:

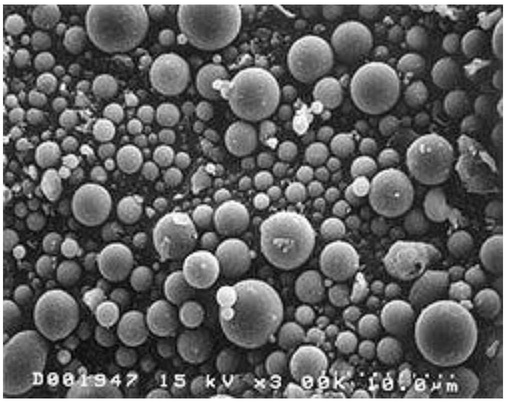
- For wet scrubbers larger than 400 MW, the cost is \$200 to \$ 500 per ton
- For wet scrubbers smaller than 400 MW, the cost is \$500 to \$ 5,000 per ton
- For spray dry scrubbers larger than 200 MW, the cost is \$150 to \$ 300 per ton
- For spray dry scrubbers smaller than 200 MW, the cost is \$ 500 to \$ 4,000 per ton

7 - Alternative methods of reducing sulfur dioxide emissions:

An alternative to removing sulfur from the flue gases after burning is to remove the sulfur from the fuel before or during combustion. Hydro desulfurization of fuel has been used for treating fuel oils before use. Fluidized bed combustion adds lime to the fuel during combustion. The lime reacts with the SO_2 to form sulfates which become part of the ash.

The recently developed biological alternative Thiopaq combines gas purification with sulfur recovery. Micro - organisms in a bioreactor oxidize the sulfide to elemental sulfur. This elemental S is then separated and finally recovered at the end of the process for further usage in, for example, agricultural products. Safety is one of the greatest benefits of this method, as the whole process takes place at atmospheric pressure and ambient temperature. This method has been developed by Paqell, a joint venture between Shell Global Solutions and Paques.

Fly Ash – 1 -



Photomicrograph made with a Scanning Electron Microscope (SEM): Fly ash particles at 2,000x magnification

Contents :

1- Introduction :

Fly ash is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipments before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as **coal ash**. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO) , both being endemic ingredients in many coal - bearing rock strata.

Toxic constituents depend upon the specific coal bed makeup, but may include one or more of the following elements or substances in quantities from trace amounts to several percent :

arsenic, beryllium, boron, cadmium, chromium, chromium VI, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with dioxins and PAH compounds.

In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now require that it be captured prior to release. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43 percent is recycled, often used to supplement Portland cement in concrete production. Some have expressed health concerns about this.

In some cases, such as the burning of solid waste to create electricity ("resource recovery" facilities a.k.a. waste-to-energy facilities), the fly ash may contain higher levels of contaminants than the bottom ash and mixing the fly and bottom ash together brings the proportional levels of contaminants within the range to qualify as nonhazardous waste in a given state, whereas, unmixed, the fly ash would be within the range to qualify as hazardous waste.

2 - Chemical composition and classification :

Component	Bituminous	Sub bituminous	Lignite
SiO_2 (%)	20 - 60	40 - 60	15 - 45
Al_2O_3 (%)	5 - 35	20 - 30	20 - 25
Fe_2O_3 (%)	10 - 40	4 - 10	4 - 15
CaO (%)	1 - 12	5 - 30	15 - 40
LOI (%)	0 - 15	0 - 3	0 - 5

Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 100 µm. They consist mostly of silicon dioxide (SiO_2), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp, pointed and hazardous; aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3). Fly ashes are generally highly heterogeneous, consisting of a mixture of glassy particles with various identifiable crystalline phases such as quartz, mullite, and various iron oxides.

Fly ash also contains environmental toxins in significant amounts, including arsenic (43.4 ppm); barium (806 ppm); beryllium (5 ppm); boron (311 ppm); cadmium (3.4 ppm); chromium (136 ppm); chromium VI (90 ppm); cobalt (35.9 ppm); copper (112 ppm); fluorine (29 ppm); lead (56 ppm); manganese (250 ppm); nickel (77.6 ppm); selenium (7.7 ppm); strontium (775 ppm); thallium (9 ppm); vanadium (252 ppm); and zinc (178 ppm).

The above concentrations of trace elements vary according to the kind of coal burnt to form it. In fact, in the case of bituminous coal, with the notable exception of boron, trace element concentrations are generally similar to trace element concentrations in unpolluted soils.

Two classes of fly ash are defined by ASTM C618 : Class F fly ash and Class C fly ash . The chief difference between these classes is the amount of calcium , silica , alumina , and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite).

Not all fly ashes meet ASTM C 618 requirements, although depending on the application, this may not be necessary. Ash used as a cement replacement must meet strict construction standards, but no standard environmental regulations have been established in the United States . 75 % of the ash must have a fineness of 45 µm or less, and have a carbon content, measured by the loss on ignition (LOI) , of less than 4 %. In the U.S., LOI needs to be under 6 %. The particle size distribution of raw fly ash is very often fluctuating constantly, due to changing performance of the coal mills and the boiler performance. This makes it necessary that, if fly ash is used in an optimal way to replace cement in concrete production, it needs to be processed using beneficiation methods like mechanical air classification. But if fly ash is used also as a filler to replace sand in concrete production, un beneficiated fly ash with higher LOI can be also used. Especially important is the ongoing quality verification. This is mainly expressed by quality control seals like the Bureau of Indian Standards mark or the DCL mark of the Dubai Municipality.

2 - 1 - Class F fly ash :

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 20 % lime (CaO) . Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds. Alternatively, the addition of a chemical activator such as sodium silicate (water glass) to a Class F ash can lead to the formation of a geo polymer.

2 – 2 - Class C fly ash :

Fly ash produced from the burning of younger lignite or sub bituminous coal, in addition to having pozzolanic properties, also has some self - cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20 % lime (Ca O) . Unlike Class F, self - cementing Class C fly ash does not require an activator. Alkali and sulfate (SO_4) contents are generally higher in Class C fly ashes.

At least one US manufacturer has announced a fly ash brick containing up to 50 percent Class C fly ash. Testing shows the bricks meet or exceed the performance standards listed in ASTM C 216 for conventional clay brick; it is also within the allowable shrinkage limits for concrete brick in ASTM C 55, Standard Specification for Concrete Building Brick. It is estimated that the production method used in fly ash bricks will reduce the embodied energy of masonry construction by up to 90 %. Bricks and pavers were expected to be available in commercial quantities before the end of 2009.

3 - Disposal and market sources :

In the past, fly ash produced from coal combustion was simply entrained in flue gases and dispersed into the atmosphere. This created environmental and health concerns that prompted laws which have reduced fly ash emissions to less than 1 percent of ash produced. Worldwide, more than 65 % of fly ash produced from coal power stations is disposed of in landfills and ash ponds.

The recycling of fly ash has become an increasing concern in recent years due to increasing landfill costs and current interest in sustainable development. As of 2005, U.S. coal - fired power plants reported producing 71.1 million tons of fly ash, of which 29.1 million tons were reused in various applications . If the nearly 42 million tons of unused fly ash had been recycled, it would have reduced the need for approximately 33,900,000 m^3 of land fill space . Other environmental benefits to recycling fly ash includes reducing the demand for virgin materials that would need quarrying and substituting for materials that may be energy-intensive to create such as Portland cement.

As of 2006, about 125 million tons of coal-combustion byproducts, including fly ash, were produced in the U.S. each year, with about 43 percent of that amount used in commercial applications, according to the American Coal Ash Association Web site. As of early 2008, the United States Environmental Protection Agency hoped that figure would increase to 50 percent as of 2011.

4 - Fly ash reuse :

There is no U.S. governmental registration or labeling of fly ash utilization in the different sectors of the economy - industry, infrastructures and agriculture. Fly ash utilization survey data, acknowledged as incomplete, are published annually by the American Coal Ash Association .

The ways of fly ash utilization include (approximately in order of decreasing importance) :

- Concrete production, as a substitute material for Portland cement and sand
- Embankments and other structural fills (usually for road construction)
- Grout and Flow able fill production
- Waste stabilization and solidification
- Cement clinkers production - (as a substitute material for clay)
- Mine reclamation
- Stabilization of soft soils
- Road sub base construction
- As Aggregate substitute material (e.g. for brick production)
- Mineral filler in asphaltic concrete
- Agricultural uses: soil amendment, fertilizer, cattle feeders, soil stabilization in stock feed yards, and agricultural stakes
- Loose application on rivers to melt ice[14]
- Loose application on roads and parking lots for ice control[15]
- Other applications include cosmetics, toothpaste, kitchen counter tops, floor and ceiling tiles, bowling balls, flotation

devices, stucco, utensils, tool handles, picture frames, auto bodies and boat hulls, cellular concrete, geo polymers, roofing tiles, roofing granules, decking, fireplace mantles, cinder block, PVC pipe, Structural Insulated Panels, house siding and trim, running tracks, blasting grit, recycled plastic lumber, utility poles and cross arms , railway sleepers, highway sound barriers, marine pilings, doors, window frames, scaffolding, sign posts, crypts, columns, railroad ties, vinyl flooring, paving stones, shower stalls, garage doors, park benches, landscape timbers, planters, pallet blocks, molding, mail boxes, artificial reef, binding agent, paints and under coatings, metal castings, and filler in wood and plastic products.

4 – 1 - Portland cement :

Owing to its pozzolanic properties, fly ash is used as a replacement for some of the Portland cement content of concrete. The use of fly ash as a pozzolanic ingredient was recognized as early as 1914, although the earliest noteworthy study of its use was in 1937. Before its use was lost to the Dark Ages, Roman structures such as aqueducts or the Pantheon in Rome used volcanic ash (which possesses similar properties to fly ash) as pozzolan in their concrete. As pozzolan greatly improves the strength and durability of concrete, the use of ash is a key factor in their preservation.

Use of fly ash as a partial replacement for Portland cement is generally limited to Class F fly ashes. It can replace up to 30% by mass of Portland cement, and can add to the concrete’s final strength and increase its chemical resistance and durability. Recently concrete mix design for partial cement replacement with High Volume Fly Ash (50 % cement replacement) has been developed. For Roller Compacted Concrete (RCC)[used in dam construction] replacement values of 70 % have been achieved with processed fly ash at the Ghatghar Dam project in Maharashtra, India. Due to the spherical shape of fly ash particles, it can also increase workability of cement while reducing water demand. The replacement of Portland cement with fly ash is considered by its promoters to reduce the green house gas "foot print" of concrete, as the production of one ton of Portland cement produces approximately one ton of CO_2 as compared to zero

CO_2 being produced using existing fly ash. New fly ash production, i.e., the burning of coal, produces approximately twenty to thirty tons of CO_2 per ton of fly ash. Since the worldwide production of Portland cement is expected to reach nearly 2 billion tons by 2010, replacement of any large portion of this cement by fly ash could significantly reduce carbon emissions associated with construction, as long as the comparison takes the production of fly ash as a given.

4 – 2 - Embankment :

Fly ash properties are somewhat unique as an engineering material. Unlike typical soils used for embankment construction, fly ash has a large uniformity coefficient consisting of clay - sized particles. Engineering properties that will affect fly ash's use in embankments include grain size distribution, compaction characteristics, shear strength, compressibility, permeability, and frost susceptibility. Nearly all fly ash used in embankments are Class F fly ashes.

4 – 3 - Soil stabilization :

Soil stabilization is the permanent physical and chemical alteration of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil and / or control the shrink-swell properties of a soil, thus improving the load - bearing capacity of a sub - grade to support pavements and foundations. Stabilization can be used to treat a wide range of sub-grade materials from expansive clays to granular materials. Stabilization can be achieved with a variety of chemical additives including lime, fly ash, and Portland cement, as well as by - products such as lime - kiln dust (LKD) and cement - kiln dust (CKD). Proper design and testing is an important component of any stabilization project. This allows for the establishment of design criteria as well as the determination of the proper chemical additive and admixture rate to be used to achieve the desired engineering properties. Benefits of the stabilization process can include: Higher resistance (R) values, Reduction in plasticity, Lower permeability, Reduction of pavement thickness, Elimination of excavation - material hauling/handling - and base importation, Aids compaction, Provides “all-weather” access onto and within projects sites. Another form of soil treatment closely related to soil stabilization is soil modification, sometimes referred to as “mud drying” or soil conditioning. Although some stabilization inherently occurs in soil modification, the distinction is that soil modification is merely a means to reduce the moisture content of a soil to expedite construction, whereas stabilization can substantially increase the shear strength of a material such that it can be incorporated into the project’s structural design. The determining factors associated with soil modification vs soil stabilization may be the existing moisture content, the end use of the soil structure and ultimately the cost benefit provided. Equipment for the stabilization and modification processes include: chemical additive spreaders, soil mixers (re claimers) , portable pneumatic storage containers, water trucks, deep lift compactors, motor graders.

4 – 4 - Flow able fill :

Fly ash is also used as a component in the production of flow able fill (also called controlled low strength material, or CLSM), which is used as self - leveling, self - compacting backfill material in lieu of compacted earth or granular fill. The strength of flow able fill mixes can range from 50 to 1,200 lbf / in² (0.3 to 8.3 MPa), depending on the design requirements of the project in question. Flowable fill includes mixtures of Portland cement and filler material, and can contain mineral admixtures. Fly ash can replace either the Portland cement or fine aggregate (in most cases, river sand) as a filler material. High fly ash content mixes contain nearly all fly ash, with a small percentage of Portland cement and enough water to make the mix flow able. Low fly ash content mixes contain a high percentage of filler material, and a low percentage of fly ash, Portland cement, and water. Class F fly ash is best suited for high fly ash content mixes, whereas Class C fly ash is almost always used in low fly ash content mixes.

4 – 5 - Asphalt concrete :

Asphalt concrete is a composite material consisting of an asphalt binder and mineral aggregate. Both Class F and Class C fly ash can typically be used as a mineral filler to fill the voids and provide contact points between larger aggregate particles in asphalt concrete mixes. This application is used in conjunction, or as a replacement for, other binders (such as Portland cement or hydrated lime) . For use in asphalt pavement, the fly ash must meet mineral filler specifications outlined in ASTM D242. The hydrophobic nature of fly ash gives pavements better resistance to stripping. Fly ash has also been shown to increase the stiffness of the asphalt matrix, improving rutting resistance and increasing mix durability.

4 – 6 - Geo polymers :

More recently, fly ash has been used as a component in geo polymers, where the reactivity of the fly ash glasses is used to generate a binder comparable to a hydrated Portland cement in appearance and properties, but with possibly reduced CO_2 emissions.

It should be noted that when the total carbon footprint of the alkali required to form geo polymer cement is considered, including the calcining of lime stone as an intermediate to the formation of alkali, the net reduction in total CO_2 emissions may be negligible. Moreover, handling of alkali can be problematic and setting of geo polymer cements is very rapid (minutes versus hours) as compared to Portland cements, making widespread use of geopolymer cements impractical at the ready mix level.

4 – 7 - Roller compacted concrete :

Another application of using fly ash is in roller compacted concrete dams. Many dams in the US have been constructed with high fly ash contents. Fly ash lowers the heat of hydration allowing thicker placements to occur. Data for these can be found at the US Bureau of Reclamation. This has also been demonstrated in the Ghatghar Dam Project in India.

4 – 8 - Bricks :

There are several techniques for manufacturing construction bricks from fly ash, producing a wide variety of products. One type of fly ash brick is manufactured by mixing fly ash with an equal amount of clay, then firing in a kiln at about 1000 degrees C. This approach has the principal benefit of reducing the amount of clay required. Another type of fly ash brick is made by mixing soil, plaster of paris, fly ash and water, and allowing the mixture to dry. Because no heat is required, this technique reduces air pollution. More modern manufacturing processes use a greater proportion of fly ash, and a high pressure manufacturing technique, which produces high strength bricks with environmental benefits.

In the United Kingdom, fly ash has been used for over fifty years to make concrete building blocks. They are widely used for the inner skin of cavity walls. They are naturally more thermally insulating than blocks made with other aggregates .

Ash bricks have been used in house construction in Windhoek, Namibia since the 1970s. There is, however, a problem with the bricks in that they tend to fail or produce unsightly pop-outs. This happens when the bricks come into contact with moisture and a chemical reaction occurs causing the bricks to expand .

In India, fly ash bricks are used for construction. Leading manufacturers use an industrial standard known as "Pulverized fuel ash for lime - Pozzolana mixture" using over 75 % post - industrial recycled waste, and a compression process. This produces a strong product with good insulation properties and environmental benefits.

American civil engineer Henry Liu announced the invention of a new type of fly ash brick in 2007. Liu's brick is compressed at 4,000 psi and cured for 24 hours in a 66 °C steam bath, then toughened with an air entrainment agent , so that it lasts for more than 100 freeze - thaw cycles. Owing to the high concentration of calcium oxide in class C fly ash, the brick can be described as self - cementing. Since this method contains no clay and uses pressure instead of heat, it saves energy, reduces mercury pollution, and costs 20% less than traditional manufacturing techniques . This type of brick is now manufactured under license in the USA.

Some varieties of fly ash brick gain strength as they age ’

4 – 9 - Metal matrix composites :

Hollow fly ash can be infiltrated by molten metal to form solid, alumina encased spheres. Fly ash can also be mixed with molten metal and cast to reduce overall weight and density, due to the low density of fly ash. Research is under way to incorporate fly ash into lead acid batteries in a lead calcium tin fly ash composite in an effort to reduce weight of the battery.

4 – 10 - Waste treatment and stabilization :

Fly ash, in view of its alkalinity and water absorption capacity, may be used in combination with other alkaline materials to transform sewage sludge into organic fertilizer or bio fuel.

In addition, fly ash, mainly class C, may be used in the stabilization / solidification process of hazardous wastes and contaminated soils . For example, the Rhenipal process uses fly ash as an admixture to stabilize sewage sludge and other toxic sludges. This process has been used since 1996 to stabilize large amounts of chromium (VI) contaminated leather sludges in Alcanena, Portugal.

5 - Environmental problems :

5 – 1 - Present production rate of fly ash :

In the United States about 131 million tons of fly ash are produced annually by 460 coal - fired power plants. A 2008 industry survey estimated that 43 percent of this ash is re-used .

5 – 2 – Ground water contamination :

Since coal contains trace levels of arsenic, barium, beryllium, boron, cadmium, chromium, thallium, selenium, molybdenum and mercury, its ash will continue to contain these traces and there fore cannot be dumped or stored where rain water can leach the metals and move them to aquifers.

5 – 3 – Spills of bulk storage :

Where fly ash is stored in bulk, it is usually stored wet rather than dry so that fugitive dust is minimized. The resulting impoundments (ponds) are typically large and stable for long periods, but any breach of their dams or bundling will be rapid and on a massive scale.

In December 2008 the collapse of an embankment at an impoundment for wet storage of fly ash at the Tennessee Valley Authority's Kingston Fossil Plant resulted in a major release of 5.4 million cubic yards of coal fly ash, damaging 3 homes and flowing into the Emory River. Cleanup costs may exceed $1.2 billion. This spill was followed a few weeks later by a smaller TVA-plant spill in Alabama, which contaminated Widows Creek and the Tennessee River.

5 – 4 – Contaminants :

Fly ash contains trace concentrations of heavy metals and other substances that are known to be detrimental to health in sufficient quantities. Potentially toxic trace elements in coal include arsenic, beryllium, cadmium, barium, chromium, copper, lead, mercury, molybdenum, nickel, radium, selenium, thorium, uranium, vanadium, and zinc. Approximately 10 percent of the mass of coals burned in the United States consists of unburnable mineral material that becomes ash, so the concentration of most trace elements in coal ash is approximately 10 times the concentration in the original coal.[37] A 1997 analysis by the U.S. Geological Survey (USGS) found that fly ash typically contained 10 to 30 ppm of uranium, comparable to the levels found in some granitic rocks, phosphate rock, and black shale.

In 2000, the United States Environmental Protection Agency (EPA) said that coal fly ash did not need to be regulated as a hazardous waste. Studies by the U.S. Geological Survey and others of radioactive elements in coal ash have concluded that fly ash compares with common soils or rocks and should not be the source of alarm. How ever , community and environmental organizations have documented numerous environmental contamination and damage concerns.

A revised risk assessment approach may change the way coal combustion wastes (CCW) are regulated, according to an August 2007 EPA notice in the Federal Register. In June 2008, the U.S. House of Representatives held an oversight hearing on the Federal government's role in addressing health and environmental risks of fly ash.

6 - Exposure concerns :

Crystalline silica and lime along with toxic chemicals are among the exposure concerns. Although industry has claimed that fly ash is "neither toxic nor poisonous," this is disputed. Exposure to fly ash through skin contact, inhalation of fine particle dust and drinking water may well present health risks. The National Academy of Sciences noted in 2007 that "the presence of high contaminant levels in many CCR (coal combustion residue) leachates may create human health and ecological concerns " .

Fine crystalline silica present in fly ash has been linked with lung damage, in particular silicosis. OSHA allows 0.10 mg/m^3, (one ten-thousandth of a gram per cubic meter of air).

Another fly ash component of some concern is lime (CaO). This chemical reacts with water (H_2O) to form calcium hydroxide [$Ca(OH)_2$], giving fly ash a pH some where between 10 and 12, a medium to strong base. This can also cause lung damage if present in sufficient quantities.

In a study by NIOSH at a cement company, crystalline silica exposures from fly ash were determined to be of no concern. For maintaining a safe workplace emphasis must be placed on maintaining low nuisance dust levels and to use the appropriate personal protective equipment (PPE). The conclusion of this NIOSH study is supported by other studies devoted to the effects of fly ash on the health of workers in power plants. According to these studies, fly ash dust should not be considered as "silicotic dust", because most of the crystalline silica is coated by amorphic alumino - silicates (glass), the main constituent of fly ash particles. This was shown particularly on the basis of scanning electron microscopy observations, by a research work performed in the Netherlands, but similar findings were obtained also in other countries.

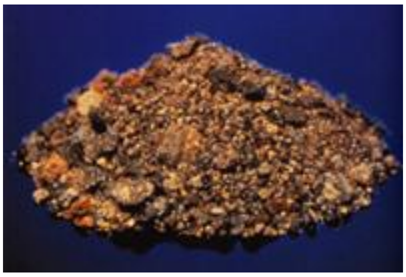
Fly Ash - 2 -

Fly ash is the finest of coal ash particles. It is called "fly" ash because it is transported from the combustion chamber by exhaust gases. Fly ash is the fine powder formed from the mineral matter in coal, consisting of the noncombustible matter in coal plus a small amount of carbon that remains from incomplete combustion. Fly ash is generally light tan in color and consists mostly of silt-sized and clay - sized glassy spheres. This gives fly ash a consistency somewhat like talcum powder. Properties of fly ash vary significantly with coal composition and plant - operating conditions.

Fly ash can be referred to as either cementitious or pozzolanic. A cementitious material is one that hardens when mixed with water. A pozzolanic material will also harden with water but only after activation with an alkaline substance such as lime. These cementitious and pozzolanic properties are what make some fly ashes useful for cement replacement in concrete and many other building applications.

Bottom Aah

Coal bottom ash and fly ash are quite different physically, mineralogically , and chemically. Bottom ash is a coarse, granular, incombustible byproduct that is collected from the bottom of furnaces that burn coal for the generation of steam, the production of electric power, or both. Bottom ash is coarser than fly ash, with grain sizes spanning from fine sand to fine gravel. The type of byproduct produced depends on the type of furnace used to burn the coal.



Boiler Slag

Boiler slag is coarser than conventional fly ash and is formed in cyclone boilers, which produce a molten ash that is cooled with water. Boiler slag is generally a black granular material with numerous engineering uses.

Fgd Gypsum

Flue gas desulfurization (FGD) gypsum is also known as scrubber gypsum. FGD gypsum is the by product of an air pollution control system that removes sulfur from the flue gas in calcium - based scrubbing systems . It is produced by employing forced oxidation in the scrubber and is composed mostly of calcium sulfate. FGD gypsum is most commonly used for agricultural purposes and for wall board production.

Photos courtesy of the American Coal Ash Association

Fly Ash Concrete Inexpensive Replacement for Portland Cement

1 - **Introduction :**

Fly ash is a fine , glass - like powder recovered from gases created by coal - fired electric power generation. U.S. power plants produce millions of tons of fly ash annually, which is usually dumped in landfills. Fly ash is an inexpensive replacement for Portland cement used in concrete, while it actually improves strength, segregation, and ease of pumping of the concrete. Fly ash is also used as an ingredient in brick, block, paving, and structural fills.

Fly ash concrete was first used in the U.S. in 1929 for the Hoover Dam , where engineers found that it allowed for less total cement. It is now used across the country. Consisting mostly of silica, alumina and iron , fly ash is a pozzolan--a substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water it forms a compound similar to Portland cement . The spherical shape of the particles reduces internal friction thereby increasing the concrete's consistency and mobility, permitting longer pumping distances. Improved work ability means less water is needed , resulting in less segregation of the mixture. Although fly ash cement it self is less dense than Portland cement, the produced concrete is denser and results in a smoother surface with sharper detail.

lass F fly ash , with particles covered in a kind of melted glass , greatly reduces the risk of expansion due to sulfate attack , as may occur in fertilized soils or near coastal areas. It is produced from Eastern coal. Produced from Western coal .

Class C fly ash is also resistant to expansion from chemical attack, has a higher percentage of calcium oxide, and is more commonly used for structural concrete.

Although the Federal government has been using the material for decades, smaller and residential contractors are less familiar with fly ash concrete. Competition from Portland cement is one consideration. Because fly ash comes from various operations in different regions, its mineral makeup may not be consistent; this may cause its properties to vary, depending on the quality control of the manufacturer. There are some concerns about freeze / thaw performance and a tendency to effloresce, especially when used as a complete replacement for Portland cement.

The Clean Air Act of 1990 requires power plants to cut nitric oxide emissions. To do so, plants restrict oxygen , resulting in high-carbon fly ash , which must be reprocessed for cement production. Thus , fly ash could be less available or more costly in the future. Researchers at Brown University are studying why the high - carbon ash doesn't work for cement, and other treatment options.

2 - Attributes :

Fly ash can be a cost effective partial substitute for Portland cement in markets that are experiencing supply shortages . An industrial by - product that is other wise waste, fly ash is environmentally friendly because it is recycled and has low embodied energy.

3 - Ease of Implementation :

Packaged in bulk or bags , fly ash cement is generally available in two standard colors ; coloring agents can be added at the job site. Manufacturers are developing specialty cements that should be widely available soon.

4 - Initial Cost

Fly Ash Concrete is currently cost competitive with Portland Cement Concrete.

5 - U.S . Code Acceptance

The first ASTM specification for fly ash cement was written in the 1950s, and amended in 1977 to include Class C fly ash from Western coal . Fly ash cement is ASTM listed and approved as a mineral admixture for use in mortar, patching, and structural concrete.

6 – Installation :

Because fly ash cement requires less water than Portland cement , it is easier to use in cold weather . It can be formulated to produce various set times , cold weather resistances, strengths and strength gains, depending on the job. Fly ash can be used sparingly as an admixture or in large amounts to replace Portland cement. The material is somewhat lighter than Portland cement.

7 - Benefits / Costs

Fly ash is cost competitive with Portland cement . Some manufacturer’s proprietary fly ash cement is considered a non - shrink material with advantages in workability, water retention, and strength. Because fly ash mixes with less water, it is less likely to crack. An industrial by-product that is otherwise waste, fly ash is environmentally friendly because it is recycled and has low embodied energy.

Fly ash comes from various operations in different regions , so its mineral make up may vary between manufacturers . There are some concerns about freeze / thaw performance and a tendency of mixes made with fly ash to effloresce, especially when used as a complete replacement for Portland cement.

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Foam Index

Contents

1 Introduction :

Foam Index test is a rapid method to determine the relative levels of Air Entraining Agent (AEA) needed during concrete mixing , with or without mineral additives like combustion fly ash, that control air void volumes within cured concrete .

AEA surfactants are added into concrete mixes to impart stable air micro bubbles to give air void volumes between ~ 5 % –10 %. Besides increasing work ability, adding the correct amount of AEA during concrete mixing improves its resistance to cracking during freeze and thaw cycles. Adding too much AEA during mixing decreases concrete strengths.

Fly ash from pulverized coal combustion is a typical mineral admixture utilized in the production of concrete, where it partially replaces cement and improves concrete workability, pumping characteristics, hardness and resistance to alkali attack. However, cement and components of fly ash adsorb AEA’s to different extents, making it more difficult to routinely impart the correct amount of entrained air into concrete. The Foam Index Test was developed to measure capacities of AEA for cement-mineral admixtures during concrete mixing .

The Foam Index Test is a laboratory titration procedure which determines the AEA absorption on fly ash or fly ash and cement mixtures. An AEA is titrated into a fly ash and cement suspension and the suspension is shaken. The added AEA leads to foam formation on top of the liquid surface, which initially behaves in an unstable manner. At the endpoint of the test, the AEA absorption sites are “saturated” and the AEA contributes to foam formation on the top of the mixture. The amount of AEA required to obtain stable foam depends on fly ash quality, fly ash-cement interactions, and characteristics of the AEA. Some fly ashes, typically those with high unburned carbon contents , tend to adsorb high amounts of AEA, i.e. more AEA is needed to obtain stable foam.

2 - Procedure of foam index test :

Adding diluted AEA one drop at a time is the most accurate way to measure the foam index, especially when trying to develop your ability to duplicate the test. You may want to add five drops at a time at first with a high dosage rate material until you get near the “Index” level. The traditional way to identify foam index values is by visual observation.

- A “Stable Foam” is achieved when no open areas of liquid show for at least 30 – 45 seconds on the surface of the foam. Bubbles break rapidly at AEA levels below the “Index” level. Bubbles will still break for several increments above the “Index” level as well … don’t continue adding AEA trying to stop the breaking bubbles. This point is difficult to judge at first. Run the same material several times in a row to help calibrate your “eye.”

- Although the Foam Index test is not designed to determine the actual AEA dosage amounts needed for concrete, it is possible to standardize procedures to determine AEA dosage amounts. It is also a good test to determine if specific materials will require more or less AEA relative to others. If the test is performed on the same materials and a plot of the results charted against required AEA dosages, correlations are possible between AEA dosage requirements and Foam Index test results.

3 -Automated Foam Index Test (AFIT) :

The AFIT instrument quantifies the dynamic foaming properties of air entraining agents, surfactants and foaming materials. It makes these measurements without intrusion of a probe or device into a working environment. Appropriate foam stabilities are necessary for proper performance of the materials onto/into which AEA’s or surfactants are applied. Stable foams have stable bubbles; unstable foams have breaking bubbles. When bubbles break they produce unique acoustic signatures, the dynamic properties of which are measured by the detectors incorporated into the AFIT instrument. The outcome is quantitative, repeatable foam index values and foaming measurements.

Fondu fyre

Contents

1 – Introduction :

Fondu Fyre , some times called Fondue Fyre , is a concrete developed for specialist application . Fondu Fyre is a heat resistant concrete developed during the Apollo space program.

2 - Uses :

The concrete is used in 2 different mixtures called WA-1 and XB - 1 . The XB - 1 is used as a more fire and erosion resistant layer for covering WA-1 in areas which are directly exposed to the exhaust flame of a rocket engine. The concrete is used on the launch pads of the Kennedy Space Center on the flame deflectors.

3 – Media :

Fondue Fyre was used to repair the damage done on May 31, 2008 to launch pad 39A during the launch of the Space Shuttle *Discovery* on mission STS - 124. After subsequent launch of Space Shuttle *Atlantis* for mission STS - 125 on May 11, 2009 a 25 square meter section of the Fondue Fyre on pad 39A was found to have been damaged by exhaust from the Solid Rocket Booster.

Form liner

Contents

1 – Introduction :

Form liners are the liners used in the preparation of designs on concrete walls. The use of form liners oftentimes results in more attractive walls for highways, neighborhoods, beaches and parks [1]. Form liners come in many different shapes and designs, and can produce a variety of different results on concrete.

The process typically begins with a determination that an aesthetically interesting barrier is needed. Then concept drawings are made by the design team and presented for approval. Once the design is accepted by the surrounding neighborhood and building team, the drawings evolve into sculptured creations. The sculptor can create the original work using a variety of mediums , such as clay , poly urethane and wax. When the masterwork is finished, a cast is made using synthetic liquid rubber, and from this cast, form liners are produced in the reverse image of the original.

A form liner panel is placed on the inside of a concrete forming system before the concrete has been poured and acts as a mold for the concrete to be formed against. Once the concrete has set, the forming system can be removed and the form liner can be stripped from the hardened concrete surface. The resulting concrete surface is permanently textured with the pattern of the form liner.[2].

2 - Types of Form liners :

There are several different types of form liners, which vary based on the application. Single - use form liners are usually made of styrene plastic and are normally discarded after the first use. Multi-use form liners are usually made of ABS plastic and range in number of uses from 2 to 10 or more. Multiple-reuse form liners are usually made of polyurethane, a heavy rubber material known for its reusability and used frequently by departments of transportation on sound walls, bridges and other applications. Other form liner materials used can include polystyrene foam, fiber glass, and even aluminum -- styrene plastic, ABS plastic , and urethane are considered to be the industry standard, and are most often specified in plans by architects and engineers.

The form liners are attached to forms and concrete is placed against the liner. The liner pattern is transferred into the wet concrete. After the concrete has cured, the liner is stripped and the unique sculpture is exposed.

3 - Pioneering of Form liners :

Architectural elastomeric urethane form liners were pioneered in 1969 . The inception of form liners began with fairly simple images for concrete, including cut - out shapes and silhouettes resting on a background texture. As time passed, these designs grew in complexity, and creative artists and sculptors began to work with form liner manufactures to produce and design anything imaginable in concrete walls, and on a grand scale.

Form liner textures were popularized in the early 1970s with graphic inlays. In 1972, form liner manufacturers created a fluted form liner with graphic inlays of shrimp boats, a famous crawfish wrapped around an oil bearing, tug boats and race boats. This sound / retaining wall, located in Morgan City, LA, was to be the first use ever of graphic inlays in form liner.

	
Tug boats and colorful oil rigs are inlaid graphics cast in concrete using form liner	First use of form liner with graphic inlays in Morgan City, LA, 1972.

Form work

Contents

1 – Introduction :

Form work is the term given to either temporary or permanent molds into which concrete or similar materials are poured. In the context of concrete construction, the false work supports the shuttering moulds.

2 - Form work and concrete form types :

Form work comes in several types :

1. *Traditional timber form work*. The Form work is built on site out of timber and plywood or moisture - resistant particleboard. It is easy to produce but time - consuming for larger structures, and the plywood facing has a relatively short lifespan. It is still used extensively where the labour costs are lower than the costs for procuring re-usable Form work. It is also the most flexible type of Form work, so even where other systems are in use, complicated sections may use it.

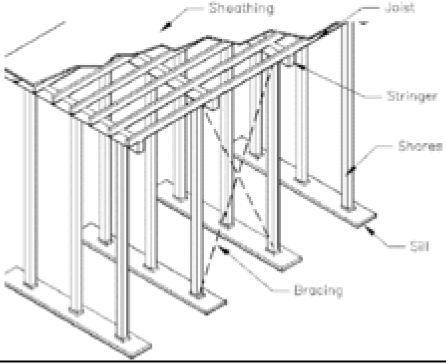
2. *Engineered Form work System*. This Form work is built out of prefabricated modules with a metal frame (usually steel or aluminium) and covered on the application (concrete) side with material having the wanted surface structure (steel, aluminum, timber, etc.). The two major advantages of Form work systems, compared to traditional timber Form work, are speed of construction (modular systems pin, clip, or screw together quickly) and lower life-cycle costs (barring major force, the frame is almost indestructible, while the covering if made of wood; may have to be replaced after a few - or a few dozen - uses, but if the covering is made with steel or aluminium the form can achieve up to two thousand uses depending on care and the applications).

3. *Re-usable plastic Form work* . These inter locking and modular systems are used to build widely variable, but relatively simple, concrete structures. The panels are lightweight and very robust. They are especially suited for low-cost, mass housing schemes.

4. *Permanent Insulated Form work*. This Form work is assembled on site, usually out of insulating concrete forms (ICF). The Form work stays in place after the concrete has cured, and may provide advantages in terms of speed, strength, superior thermal and acoustic insulation, space to run utilities within the EPS layer, and integrated furring strip for cladding finishes.

5. *Stay-In-Place structural Form work systems*. This Form work is assembled on site, usually out of prefabricated fiber - reinforced plastic forms. These are in the shape of hollow tubes, and are usually used for columns and piers. The Form work stays in place after the concrete has cured and acts as axial and shear reinforcement, as well as serving to confine the concrete and prevent against environmental effects, such as corrosion and freeze - thaw cycles.

3 - Slab form work (deck Form work) :

	
Schematic sketch of traditional Form work	Pantheon dome
	
Steel and plywood Form work for poured in place concrete foundation	Modular Form work with deck for housing project in Chile

3 – 1 - History :

Some of the earliest examples of concrete slabs were built by Roman engineers. Because concrete is quite strong in resisting compressive loads, but has relatively poor tensile or torsional strength, these early structures consisted of arches , vaults and domes. The most notable concrete structure from this period is the Pantheon in Rome. To mould these structure, temporary scaffolding and Form work or false work was built in the future shape of the structure. These building techniques were not isolated to pouring concrete, but were and are widely used in masonry. Because of the complexity and the limited production capacity of the building material, concrete's rise as a favored building material did not occur until the invention of Portland cement (and developments by the Edison Portland Cement Company) and reinforced concrete.

3 – 2 - Timber beam slab Form work :

Similar to the traditional method, but stringers and joist are replaced with engineered wood beams and supports are replaced with metal props. This makes this method more systematic and reusable.

3 – 3 - Traditional slab Form work :

Traditional timber Form work on a jetty in Bangkok

On the dawn of the rival of concrete in slab structures, building techniques for the temporary structures were derived again from masonry and carpentry. The traditional slab Form work technique consists of supports out of lumber or young tree trunks, that support rows of stringers assembled roughly 3 to 6 feet or 1 to 2 meters apart, depending on thickness of slab. Between these stringers, joists are positioned roughly 12 inches, 30 centimeters apart upon which boards or plywood are placed. The stringers and joists are usually 4 by 4 inch or 4 by 6 inch lumber. The most common imperial plywood thickness is ¾ inch and the most common metric thickness is 18 mm.

3 – 4 - Metal beam slab Form work :

Similar to the traditional method, but stringers and joist are replaced with aluminium forming systems or steel beams and supports are replaced with metal props. This also makes this method more systematic and reusable. Aluminum beams are fabricated as telescoping units which allows them to span supports that are located at varying distances apart. Telescoping aluminium beams can be used and reused in the construction of structures of varying size.

	
Handset modular aluminum Form work	*Hand setting modular aluminum deck Form work*

3 – 5 - Modular slab Form work :

These systems consist of prefabricated timber, steel or aluminum beams and Form work modules. Modules are often no larger than 3 to 6 feet or 1 to 2 meters in size. The beams and Form work are typically set by hand and pinned, clipped, or screwed together . The advantages of a modular system are: does not require a crane to place the Form work, speed of construction with unskilled labor, Form work modules can be removed after concrete sets leaving only beams in place prior to achieving design strength .

3 – 6 - Table or flying form systems :

Flying Form work tables with aluminium and timber joists. The tables are supported by shoes attached to previously poured columns and walls

United States Patent 4036466 .

These systems consist of slab Form work "tables" that are reused on multiple stories of a building without being dismantled. The assembled sections are either lifted per elevator or "flown" by crane from one story to the next. Once in position the gaps between the tables or table and wall are filled with "fillers". They vary in shape and size as well as their building material. The use of these systems can greatly reduce the time and manual labor involved in setting and striking the Form work. Their advantages are best utilized by large area and simple structures. It is also common for architects and engineers to design building around one of these systems.

3 – 6 - 1 – Structure :

A table is built pretty much the same way as a beam Form work but the single parts of this system are connected together in a way that makes them transportable. The most common sheathing is plywood , but steel and fiber glass are also in use. The joists are either made from timber, wood I - beams, aluminium or steel. The stringers are sometimes made of wood I - beams but usually from steel channels. These are fastened together (screwed, weld or bolted) to become a "deck". These decks are usually rectangular but can also be other shapes.

3 – 6 - 2 – Support :

All support systems have to be height adjustable to allow the Form work to be placed at the correct height and to be removed after the concrete is cured. Normally adjustable metal props similar to (or the same as) those used by beam slab Form work are used to support these systems. Some systems combine stringers and supports into steel or aluminum trusses. Yet other systems use metal frame shoring towers, which the decks are attached to. Another common method is to attach the Form work decks to previously cast walls or columns,thus eradicating the use of vertical props altogether. In this method, adjustable support shoes are bolted through holes (sometimes tie holes) or attached to cast anchors.

3 – 6 - 3 – Size :

The size of these tables can vary from 70 to 1,500 square feet (6.5 to 140 m^2). There are two general approaches in this system:

1. Crane handled: this approach consists of assembling or producing the tables with a large Form work area that can only be moved up a level by crane. Typical widths can be 15, 18 or 20 ft. or 5 to 7 meters but their width can be limited, so that it is possible to transport them assembled, without having to pay for an oversize load. The length might vary and can be up to 100 ft. (or more) depending on the crane capacity. After the concrete is cured, the deck are lowered and moved with rollers or trolleys to the edge of the building. From then on the protruding side of the table is lifted by crane while the rest of the table is rolled out of the building. After the centre of gravity is outside of the building the table is attached to another crane and flown to the next level or position.

This technique is fairly common in the United States and east Asian countries. The advantages of this approach are the further reduction of manual labour time and cost per unit area of slab and a simple and systematic building technique. The disadvantages of this approach are the necessary high lifting capacity of building site cranes, additional expensive crane time, higher material costs and little flexibility.

1. Crane fork or elevator handled :

Form work tables in use at a building site with more complicated structural features

By this approach the tables are limited in size and weight. Typical widths are between 2 to 3 meters, typical lengths are between 4 to 7 meters , though table sizes may vary in size and form. The major distinction of this approach is that the tables are lifted either with a crane transport fork or by material platform elevators attached to the side of the building. They are usually transported horizontally to the elevator or crane lifting platform singlehandedly with shifting trolleys depending on their size and construction. Final positioning adjustments can be made by trolley. This technique enjoys popularity in the US, Europe and generally in high labor cost countries. The advantages of this approach in comparison to beam Form work or modular Form work is a further reduction of labor time and cost. Smaller tables are generally easier to customize around geometrically complicated buildings, (round or non rectangular) or to form around columns in comparison to their large counterparts. The disadvantages of this approach are the higher material costs and increased crane time (if lifted with crane fork).

4 - Usage :

For removable forms, once the concrete has been poured into Form work and has set (or *cured*), the Form work is *struck* or *stripped* (removed) to expose the finished concrete. The time between pouring and Form work stripping depends on the job specifications, the cure required, and whether the form is supporting any weight, but is usually at least 24 hours after the pour is completed. For example, the California Department of Transportation requires the forms to be in place for 1–7 days after pouring , while the Washington State Department of Transportation requires the forms to stay in place for 3 days with a damp blanket on the outside .

Form work stripped exposing the set concrete

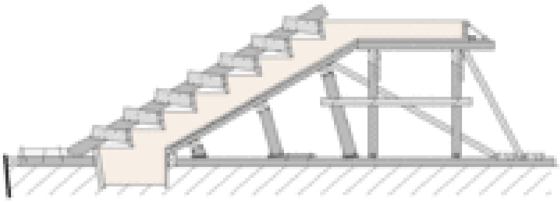
Spectacular accidents have occurred when the forms were either removed too soon or had been under-designed to carry the load imposed by the weight of the uncured concrete. Less critical and much more common (though no less embarrassing and often costly) are those cases in which under - designed Form work bends or breaks during the filling process (especially if filled with a high-pressure concrete pump) . This then results in fresh concrete escaping out of the Form work in a *form blowout* , often in large quantities.

Concrete exerts less pressure against the forms as it hardens, so forms are usually designed to withstand a number of feet per hour of pour rate to give the concrete at the bottom time to firm up. For example, wall or column forms are commonly designed for a pour rate between 4 – 8 ft / hr . The hardening is an asymptotic process, meaning that most of the final strength will be achieved after a short time, though some further hardening can occur depending on the cement type and admixtures.

Wet concrete also applies hydrostatic pressure to Form work. The pressure at the bottom of the form is therefore greater than at the top. In the illustration of the column Form work to the right, the 'column clamps' are closer together at the bottom. Note that the column is braced with steel adjustable 'Form work props' and uses 20 mm 'through bolts' to further support the long side of the column.

5 - Gallery :

	
Modular steel frame form work for a foundation	Animation depicting construction of multi-story building using aluminum handset Form work.

	
Re-usable plastic-Form work for mass housing	Timber Form work for a concrete column
	
Placing a Form work component	Sketch of the side view of traditional timber Form work used to form a flight of stairs
	
Coal tunnel constructed using handset aluminum concrete forms.	Re-useable Plastic-Form work designed for mass housing projects.
	
Soffit Form work to a flight of concrete stairs.	Concrete pool construction using aluminum concrete forms.

Friedel 's Salt

Contents

1 – Introduction :

Friedel 's salt is an anion exchanger mineral belonging to the family of the layered double hydroxides (LDHs) . It has affinity for anions as chloride and iodide and is capable to retain them to a certain extent in its crystallo graphical structure.

IUPAC name : Calcium chloro aluminate	
Other names : Friedel's salt Calcium aluminium chloro hydrate Calcium aluminium chloro hydroxide Calcium aluminium oxy chloride	
Molecular Formula	$Ca_2\ Al\ (OH)_6\ (\ Cl\ ,\ OH\ ) \cdot 2\ H_2O$
Appearance	White solid

2 – Composition :

Friedel 's salt general formula is :

$$Ca_2\ Al\ (\ OH\ )_6\ (\ Cl\ ,\ OH\ ) \cdot 2\ H_2O.$$

In the cement chemist notation, considering that

$$2\ OH^- \leftrightarrow O^{2-} + H_2O\ ,$$

and doubling all the stoichiometry, it can also be written as follows :

$$3\ Ca\ O \cdot Al_2\ O_3 \cdot Ca\ Cl_2 \cdot 10\ H_2O$$

Friedel 's salt can also be considered as an AF_m phase in which chloride ions have replaced sulfate ions and is formed in cements initially rich in tri - calcium aluminate (C_3A) .

$$2\,Cl^- + 3CaO \cdot Al_2O_3 \cdot CaSO_4 \cdot 10\,H_2O \rightarrow$$
$$3CaO \cdot Al_2O_3 \cdot CaCl_2 \cdot 10\,H_2O + SO_4^{2-}$$

It plays a main role in the retention of chloride anions in cement and concrete. However, Friedel 's salt remains a poorly understood phase in the $CaO - Al_2O_3 – CaCl_2 - H_2O$ system, and is critical for the stability of salt - saturated Portland cement - based grouts.

3 - Discovery :

Nowadays , Friedel 's salt discovery is relatively difficult to trace back from the recent literature , simply because it is an ancient finding of a poorly known and non - natural product. It has been synthesized and identified in 1897 by Georges Friedel, mineralogist and crystallographer, son of the famous French chemist Charles Friedel.[1] Georges Friedel also synthesized Calcium aluminate (1903) in the framework of his work on the Macles theory (twin crystals) . This point requires further verification .

4 - Formation :

- Relation with Tri calcium aluminate.
- Incorporation of chloride.
- Solid solutions.

5 - Role in cement :

- Importance for the reactive transport of chloride in cement in relation with corrosion of steel reinforcement.

6 - Anion getter :

- Trap toxic anions in cement such as, *e.g.*, I^-, SeO_3^{2-}, SeO_4^{2-}

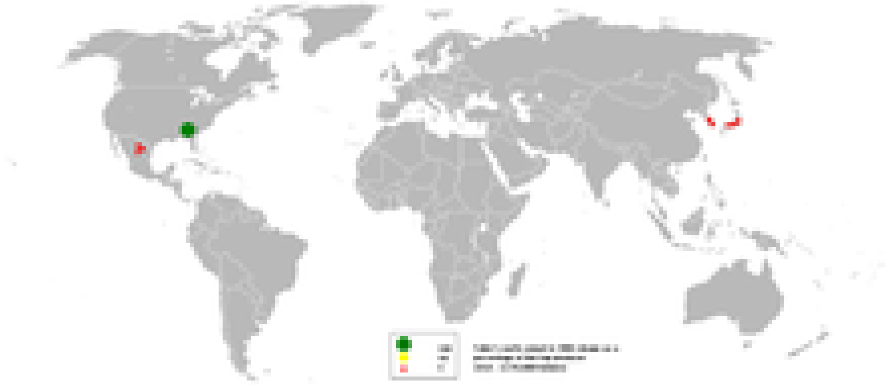
Fuller 's Earth

Contents

1 – Introduction :

Fuller 's Earth is usually highly plastic, sedimentary clays or clay - like earthy material used to decolorize , filter , and purify animal , mineral , and vegetable oils and greases.

2 - Occurrence and composition :



Output of fuller's earth in 2005

In 2005, the United States was the largest producer of fuller's earth with an almost 70 % world share followed at a distance by Japan and Mexico.

Fuller 's earth usually has a high magnesium oxide content. In the United States, two varieties of fuller's earth are mined, mainly in the southeastern states. These comprise the minerals montmorillonite or palygorskite (attapulgite) or a mixture of the two ; some of the other minerals that may be present in fuller's earth deposits are calcite, dolomite, and quartz.

In England, fuller's earth occurs mainly in the Lower Greensand. It has also been mined in the Vale of White Horse , Oxford shire, England. The Combe Hay Mine was a fuller's earth mine operating to the south of Bath, Somerset until 1979 . Other sites south of Bath included Frome , Lonsdale , Englishcombe Tucking Mill and Duncorn Hill . Although these sites had been used since Roman times William Smith developed new methods for the identification of deposits of Fuller's earth to the south of Bath . Other English sources include a mine near Redhill , Surrey (worked until 2000) , and Woburn, Bedford shire , where production ceased in 2004.

In some countries calcium bentonite is known as fuller's earth, a term that can also refer to attapulgite, a mineralogically distinct clay mineral that exhibits similar properties.

Hills, cliffs, and slopes that contain fuller's earth can be unstable, since this material can be thixotropic, when saturated by heavy rainfall.

3 – Uses :

The name reflects the first use of the material. In past centuries, fullers kneaded fuller's earth and water into woolen cloth to absorb lanolin, oils, and other greasy impurities as part of the cloth finishing process. Similarly, it has been used as an ingredient in powdered, "dry" shampoos. Fuller's earth was also sold in pharmacies until recently for compressing pills and cleaning hats and fabrics.[4]

Important uses are in absorbents and filters. Because of this, it is used (with activated charcoal) in the treatment of paraquat overdose to prevent the progression to pulmonary fibrosis. Fuller's earth is also used by military and civil emergency service personnel to decontaminate the clothing and equipment of soldiers and CBRN (Chemical Biological Radiological Nuclear) responders who have been contaminated with chemical agents .

Geo Polymers

Contents

1 – Introduction :

Geo Polymer is a term covering a class of synthetic alumino silicate materials with potential use in a number of areas, essentially as a replacement for Portland cement and for advanced high-tech composites, ceramic applications or as a form of cast stone. The name Geo Polymer was first applied to these materials by Joseph Davidovits in the 1970s, although similar materials had been developed in the former Soviet Union since the 1950s, originally under the name "soil cements". How ever, this name never found widespread usage in the English language, as it is more often applied to the description of soils which are consolidated with a small amount of Portland cement to enhance strength and stability. Geo Polymer cements are an example of the broader class of alkali-activated binders, which also includes alkali-activated metallurgical slags and other related materials.

2 – Research :

Much of the drive behind research carried out in academic institutions involves the development of Geo Polymer cements as a potential large - scale replacement for concrete produced from Portland cement. This is due to Geo Polymers' alleged lower carbon dioxide production emissions, greater chemical and thermal resistance and better mechanical properties at both ambient and extreme conditions. On the other side, industry has implemented Geo Polymer binders in advanced high-tech composites and ceramics for heat- and fire-resistant applications, up to 1200 °C. There is some debate[by whom?] as to whether Geo Polymer cement has lower CO_2 emissions compared to Portland cement. Calcination of lime stone in production of Portland cement is responsible for CO_2 emissions (one ton of cement produced releases one ton of CO_2), while some processes of formation of lime also release CO_2. Mainly it is the ratio of CO_2 reduction that is under debate, and it is process - dependent.

3 - Production :

Geo Polymer binders and Geo Polymer cements are generally formed by reaction of an alumino silicate powder with an alkaline silicate solution at roughly ambient conditions. Meta kaolin is a commonly used starting material for laboratory synthesis of Geo Polymers, and is generated by thermal activation of kaolinite clay. Geo Polymer cements can also be made from sources of pozzolanic materials, such as lava or fly ash from coal. Most studies on Geo Polymer cements have been carried out using natural or industrial waste sources of meta kaolin and other alumino silicates. Industrial and high-tech applications rely on more expensive and sophisticated siliceous raw materials.

5 - Theory

The majority of the Earth's crust is made up of Si-Al compounds. Davidovits proposed in 1978 that a single aluminium and silicon - containing compound, most likely geological in origin, could react in a polymerization process with an alkaline solution. The binders created were termed "Geo Polymers" but, now, the majority of aluminosilicate sources are by-products from organic combustion, such as fly ash from coal burning. These inorganic polymers have a chemical composition somewhat similar to zeolitic materials but exist as amorphous solids, rather than having a crystalline microstructure. Some have alleged that ancient "Roman cement" is a Geo Polymer cement, but in reality this material is chemically unlike alkali activated Geo Polymer cements because it is made using lime and forms calcium-silicate-hydrates, making it much closer to Portland cement from a chemical standpoint.

5 - Structure :

The chemical reaction that takes place to form Geo Polymers follows a multi - step process:

1. Dissolution of Si and Al atoms from the source material due to hydroxide ions in solution,
2. Reorientation of precursor ions in solution, and
3. Setting via poly condensation reactions into an inorganic "polymer" (actually a crystalline - like lattice) .

The inorganic polymer network is in general a highly-coordinated 3-dimensional alumino silicate gel, with the negative charges on tetrahedral Al (III) sites charge-balanced by alkali metal cations.

6 – History :

Davidovits has proposed that some of the major pyramids, rather than being blocks of solid lime stone hauled into position, are composed of Geo Polymers, cast in their final positions in the structure. He also considers that Roman cement and the small artifacts, previously thought to be stone, of the Tiwanaku civilization were made using knowledge of Geo Polymer techniques. However, because Roman cement forms calcium-silicate-hydrates, and requires calcined limestone as a reactant/precursor, it is more similar to Portland cement than alkali-activated "Geo Polymer cements" such as Pyrament cement of Lone Star .

Glass Fiber Reinforced Concrete

Contents

1 – Introduction :

Glass Fiber Reinforced Concrete (**GFRC**) is a type of fiber reinforced concrete. Glass fiber concretes are mainly used in exterior building façade panels and as architectural precast concrete.

2 - Composition :

Glass fiber reinforced concrete (GFRC) consists of high strength glass fiber embedded in a cementitious matrix . In this form, both fibers and matrix retain their physical and chemical identities, while offering a synergism: a combination of properties that can not be achieved with either of the components acting alone. In general, fibers are the principal load-carrying members, while the surrounding matrix keeps them in the desired locations and orientation, acting as a load transfer medium between them, and protects them from environmental damage. In fact, the fibers provide reinforcement for the matrix and other useful functions in fiber - reinforced composite materials. Glass fibers can be incorporated into a matrix either in continuous lengths or in discontinuous (chopped) lengths.

2 - 1 - Laminates :

A widely used application for fiber - reinforced concrete is structural laminate, obtained by adhering and consolidating thin layers of fibers and matrix into the desired thickness. The fiber orientation in each layer as well as the stacking sequence of various layers can be controlled to generate a wide range of physical and mechanical properties for the composite laminate. However, GFRC cast without steel framing is commonly used for purely decorative applications such as window trims, decorative columns , exterior friezes, or limestone like wall panels.

3 - History :

The potential for using a glass fiber reinforced concrete system was recognized by Russians in the 1940s. The early work on glass fiber reinforced concrete went through major modifications over the next few decades

4 - Properties :

The design of GFRC panels proceeds from a knowledge of its basic properties under tensile, compressive, bending and shear forces, coupled with estimates of behavior under secondary loading effects such as creep, thermal and moisture movement.

There are a number differences between structural metal and fiber-reinforced composites. For example, metals in general exhibit yielding and plastic deformation whereas most fiber-reinforced composites are elastic in their tensile stress-strain characteristics. However, the dissimilar nature of these materials provides mechanisms for high - energy absorption on a microscopic scale comparable to the yielding process. Depending on the type and severity of external loads, a composite laminate may exhibit gradual deterioration in properties but usually would not fail in catastrophic manner. Mechanisms of damage development and growth in metal and composite structure are also quite different. Other important characteristics of many fiber-reinforced composites are their non-corroding behavior, high damping capacity and low coefficients of thermal expansion.

Glass fiber reinforced concrete architectural panels have general appearance of pre-cast concrete panels, but are different in several significant ways. For example, GFRC panels will, on the average, weigh substantially less than pre-cast concrete panels due to their reduced thickness. The low weight of GFRC panels decrease superimposed loads on the building's structural components. The building frame becomes more economical.

4 – 1 - Sandwich panels :

A sandwich panel is a composite of three or more materials bonded together to form a structural panel. It takes advantage of the shear strength of a low density core material and the high compressive and tensile strengths of the GFRC facing to obtain high strength to weight ratios.

The theory of sandwich panels and functions of the individual components may be described by making an analogy to an I-beam. Core in a sandwich panel is comparable to the web of an I-beam, which supports the flanges and allows them to act as a unit. The web of the I-beam and the core of the sandwich panels carry the beam shear stresses. The core in a sandwich panel differs from the web of an I-beam in that it maintains a continuous support for the facings, allowing the facings to be worked up to or above their yield strength without crimping or buckling. Obviously, the bonds between the core and facings must be capable of transmitting shear loads between these two components thus making the entire structure an integral unit.

The load carrying capacity of a sandwich panel can be increased dramatically by introducing light steel framing. The light steel stud framing will be similar to conventional steel stud framing for walls, except, that the frame is encased in a concrete product. Here, sides of the steel frame are covered with two or more layers of GFRC, depending on the type and magnitude of external loads. The strong and rigid GFRC provides full lateral support on both sides of the studs, preventing studs from twisting and buckling laterally. The resulting panel is light weight in comparison with traditionally reinforced concrete, yet is strong and durable and can be easily handled.

Granite Rocks

Granite containing potassium feldspar, plagioclase feldspar, quartz, and biotite and/or amphibole

Contents

1 – Introduction :

Granite is a common widely occurring type of intrusive, felsic , igneous rock. Granite usually has a medium- to coarse-grained texture. Occasionally some individual crystals (phenocrysts) are larger than the groundmass, in which case the texture is known as porphyritic. A granitic rock with a porphyritic texture is sometimes known as a porphyry. Granites can be pink to gray in color, depending on their chemistry and mineralogy. By definition, granite is an igneous rock with at least 20 % quartz by volume. Granite differs from granodiorite in that at least 35 % of the feldspar in granite is alkali feldspar as opposed to plagioclase; it is the alkali feldspar that gives many granites a distinctive pink color. Outcrops of granite tend to form tors and rounded massifs. Granites sometimes occur in circular depressions surrounded by a range of hills, formed by the metamorphic aureole or hornfels . Granite is usually found in the continental plates of the Earth's crust.

Granite is nearly always massive (lacking internal structures), hard and tough, and therefore it has gained widespread use as a construction stone. The average density of granite is between 2.65[1] and 2.75 g / cm^3 , its compressive strength usually lies above 200 MPa, and its viscosity near STP is 3-6 • 10^{19} Pa·s . Melting temperature is 1215 - 1260 °C .

The word granite comes from the Latin *granum*, a grain, in reference to the coarse-grained structure of such a crystalline rock.

Granitoid is a general, descriptive field term for light-colored, coarse-grained igneous rocks. Petro graphic examination is required for identification of specific types of granitoids.

2 - Mineralogy :

Various granites (cut and polished surfaces)

Close-up of granite from Yosemite National Park, valley of the Merced River

Orbicular granite, an unusual type of granite, near the town of Caldera, northern Chile

The Cheese wring , a granite tor on the southern edge of Bodmin Moor, Cornwall

a granite monolith in British Columbia

Granite is classified according to the QAPF diagram for coarse grained plutonic rocks and is named according to the percentage of quartz, alkali feldspar (orthoclase, sanidine, or microcline) and plagioclase feldspar on the A - Q - P half of the diagram. True granite according to modern petrologic convention contains both plagioclase and alkali feldspars. When a granitoid is devoid or nearly devoid of plagioclase, the rock is referred to as **alkali granite**. When a granitoid contains less than 10 % orthoclase, it is called tonalite; pyroxene and amphibole are common in tonalite. A granite containing both muscovite and biotite micas is called a binary or *two-mica* granite. Two-mica granites are typically high in potassium and low in plagioclase, and are usually S-type granites or A-type granites. The volcanic equivalent of plutonic granite is rhyolite. Granite has poor primary permeability but strong secondary permeability.

2 – 1 - Chemical composition :

A worldwide average of the chemical composition of granite, by weight percent :

- SiO_2 — 72.04 % (silica)
- Al_2O_3 — 14.42 % (alumina)
- K_2O — 4.12 %
- Na_2O — 3.69 %
- CaO — 1.82 %
- FeO — 1.68 %
- Fe_2O_3 — 1.22 %
- MgO — 0.71 %
- TiO_2 — 0.30 %
- P_2O_5 — 0.12 %
- MnO — 0.05 %

Based on 2485 analyses

3 - Occurrence :

Granite is currently known only on Earth, where it forms a major part of continental crust. Granite often occurs as relatively small, less than 100 km² stock masses (stocks) and in batholiths that are often associated with orogenic mountain ranges. Small dikes of granitic composition called aplites are often associated with the margins of granitic intrusions. In some locations, very coarse-grained pegmatite masses occur with granite.

Granite has been intruded into the crust of the Earth during all geologic periods, although much of it is of Precambrian age. Granitic rock is widely distributed throughout the continental crust and is the most abundant basement rock that underlies the relatively thin sedimentary veneer of the continents.

4 - Origin :

Granite is an igneous rock and is formed from magma. Granitic magma has many potential origins but it must intrude other rocks.

Most granite intrusions are emplaced at depth within the crust, usually greater than 1.5 kilometers and up to 50 km depth within thick continental crust. The origin of granite is contentious and has led to varied schemes of classification. Classification schemes are regional and include French, British, and American systems.

4 – 1 - Geochemical origins :

Granitoids are a ubiquitous component of the crust. They have crystallized from magmas that have compositions at or near a eutectic point (or a temperature minimum on a cotectic curve) . Magmas will evolve to the eutectic because of igneous differentiation, or because they represent low degrees of partial melting. Fractional crystallization serves to reduce a melt in iron, magnesium, titanium, calcium and sodium, and enrich the melt in potassium and silicon - alkali feldspar (rich in potassium) and quartz (SiO_2) , are two of the defining constituents of granite.

This process operates regardless of the origin of the parental magma to the granite, and regardless of its chemistry. However, the composition and origin of the magma which differentiates into granite, leaves certain geochemical and mineral evidence as to what the granite's parental rock was. The final mineralogy, texture and chemical composition of a granite is often distinctive as to its origin. For instance, a granite which is formed from melted sediments may have more alkali feldspar, whereas a granite derived from melted basalt may be richer in plagioclase feldspar. It is on this basis that the modern "alphabet" classification schemes are based. Granite has a slow cooling process which forms larger crystals.

4 – 2 - Chappell & White classification system :

The letter - based Chappell & White classification system was proposed initially to divide granites into *I-type* granite (or igneous protolith) granite and *S-type* or sedimentary protolith granite. Both of these types of granite are formed by melting of high grade metamorphic rocks, either other granite or intrusive mafic rocks, or buried sediment, respectively.

M-type or mantle derived granite was proposed later, to cover those granites which were clearly sourced from crystallized mafic magmas, generally sourced from the mantle. These are rare, because it is difficult to turn basalt into granite via fractional crystallization.

A-type or *anorogenic* granites are formed above volcanic "hot spot" activity and have peculiar mineralogy and geochemistry. These granites are formed by melting of the lower crust under conditions that are usually extremely dry. The rhyolites of the Yellowstone caldera are examples of volcanic equivalents of A-type granite .

4 – 3 - Granitization :

An old, and largely discounted theory, *granitization* states that granite is formed in place by extreme metasomatism by fluids bringing in elements e.g. potassium and removing others e.g. calcium to transform the metamorphic rock into a granite. This was supposed to occur across a migrating front. The production of granite by metamorphic heat is difficult, but is observed to occur in certain amphibolite and granulite terrains. In-situ granitisation or melting by metamorphism is difficult to recognise except where leucosome and melanosome textures are present in gneisses. Once a metamorphic rock is melted it is no longer a metamorphic rock and is a magma, so these rocks are seen as a transitional between the two, but are not technically granite as they do not actually intrude into other rocks. In all cases, melting of solid rock requires high temperature, and also water or other volatiles which act as a catalyst by lowering the solidus temperature of the rock.

5 - Ascent and emplacement :

The ascent and emplacement of large volumes of granite within the upper continental crust is a source of much debate amongst geologists. There is a lack of field evidence for any proposed mechanisms, so hypotheses are predominantly based upon experimental data. There are two major hypotheses for the ascent of magma through the crust :

- Stokes Diapir

- Fracture Propagation

Of these two mechanisms, Stokes diapir was favoured for many years in the absence of a reasonable alternative. The basic idea is that magma will rise through the crust as a single mass through buoyancy. As it rises it heats the wall rocks, causing them to behave as a power-law fluid and thus flow around the pluton allowing it to pass rapidly and without major heat loss . This is entirely feasible in the warm, ductile lower crust where rocks are easily deformed, but runs into problems in the upper crust which is far colder and more brittle. Rocks there do not deform so easily: for magma to rise as a pluton it would expend far too much energy in heating wall rocks, thus cooling and solidifying before reaching higher levels within the crust.

Nowadays fracture propagation is the mechanism preferred by many geologists as it largely eliminates the major problems of moving a huge mass of magma through cold brittle crust. Magma rises instead in small channels along self-propagating dykes which form along new or pre-existing fault systems and networks of active shear zones (Clemens, 1998). As these narrow conduits open, the first magma to enter solidifies and provides a form of insulation for later magma.

Granitic magma must make room for itself or be intruded into other rocks in order to form an intrusion, and several mechanisms have been proposed to explain how large batholiths have been emplaced:

- Stoping, where the granite cracks the wall rocks and pushes upwards as it removes blocks of the overlying crust
- Assimilation, where the granite melts its way up into the crust and removes overlying material in this way
- Inflation, where the granite body inflates under pressure and is injected into position

Most geologists today accept that a combination of these phenomena can be used to explain granite intrusions, and that not all granites can be explained entirely by one or another mechanism.

6 - Natural radiation :

Granite is a natural source of radiation, like most natural stones. However, some granites have been reported to have higher radioactivity thereby raising some concerns about their safety.

Some granites contain around 10 to 20 parts per million of uranium. By contrast, more mafic rocks such as tonalite, gabbro or diorite have 1 to 5 ppm uranium, and lime stones and sedimentary rocks usually have equally low amounts. Many large granite plutons are the sources for palaeochannel -hosted or roll front uranium ore deposits, where the uranium washes into the sediments from the granite uplands and associated, often highly radioactive, pegmatites. Granite could be considered a potential natural radiological hazard as, for instance, villages located over granite may be susceptible to higher doses of radiation than other communities . Cellars and basements sunk into soils over granite can become a trap for radon gas, which is formed by the decay of uranium . Radon gas poses significant health concerns, and is the number two cause of lung cancer in the US behind smoking.

There is some concern that materials sold as granite countertops or as building material may be hazardous to health. Dan Steck of St. Johns University, has stated that approximately 5% of all granites will be of concern, with the caveat that only a tiny percentage of the tens of thousands of granite slabs have been tested. Various resources from national geological survey organizations are accessible online to assist in assessing the risk factors in granite country and design rules relating, in particular, to preventing accumulation of radon gas in enclosed basements and dwellings.

7 - Uses :

7 – 1 - Antiquity :

The Red Pyramid of Egypt (c.26th century BC), named for the light crimson hue of its exposed granite surfaces, is the third largest of Egyptian pyramids. Menkaure's Pyramid, likely dating to the same era, was constructed of lime stone and granite blocks. The Great

Pyramid of Giza (c.2580 BC) contains a huge granite sarcophagus fashioned of "Red Aswan Granite." The mostly ruined Black Pyramid dating from the reign of Amenemhat III once had a polished granite pyramidion or capstone, now on display in the main hall of the Egyptian Museum in Cairo . Other uses in Ancient Egypt include columns, door lintels, sills, jambs, and wall and floor veneer. How the Egyptians worked the solid granite is still a matter of debate. Dr. Patrick Hunt has postulated that the Egyptians used emery shown to have higher hardness on the Mohs scale.

Many large Hindu temples in southern India, particularly those built by the 11th century king Rajaraja Chola I, were made of granite. There is a large amount of granite in these structures. They are comparable to the Great Pyramid of Giza.

7 – 2 - Modern :

7 – 2 - 1 - Sculpture and memorials :

In some areas granite is used for gravestones and memorials. Granite is a hard stone and requires skill to carve by hand. Until the early 18th century granite could only be carved by hand tools with generally poor results.

A key breakthrough was the invention of steam-powered cutting and dressing tools by Alexander MacDonald of Aberdeen, inspired by seeing ancient Egyptian granite carvings. In 1832 the first polished tombstone of Aberdeen granite to be erected in an English cemetery was installed at Kensal Green cemetery. It caused a sensation in the London monumental trade and for some years all polished granite ordered came from Mac Donalds. Working with the sculptor William Leslie, and later Sidney Field, granite memorials became a major status symbol in Victorian Britain. The royal sarcophagus at Frogmore was probably the pinnacle of its work, and at 30 tons one of the largest. It was not until the 1880s that rival machinery and works could compete with the MacDonald works.

Modern methods of carving include using computer-controlled rotary bits and sandblasting over a rubber stencil. Leaving the letters, numbers and emblems exposed on the stone, the blaster can create virtually any kind of artwork or epitaph.

7 – 2 - 2 - Buildings :

Granite has been extensively used as a dimension stone and as flooring tiles in public and commercial buildings and monuments. Aberdeen in Scotland, which is constructed principally from local granite, is known as "The Granite City". Because of its abundance, granite was commonly used to build foundations for homes in New England. The Granite Railway, America's first railroad, was built to haul granite from the quarries in Quincy, Massachusetts, to the Neponset River in the 1820s. With increasing amounts of acid rain in parts of the world, granite has begun to supplant marble as a monument material, since it is much more durable. Polished granite is also a popular choice for kitchen countertops due to its high durability and aesthetic qualities. In building and for countertops, the term "granite" is often applied to all igneous rocks with large crystals, and not specifically to those with a granitic composition.

7 – 2 - 3 - Engineering :

Engineers have traditionally used polished granite surface plates to establish a plane of reference, since they are relatively impervious and inflexible. Sandblasted concrete with a heavy aggregate content has an appearance similar to rough granite, and is often used as a substitute when use of real granite is impractical. A most unusual use of granite was in the construction of the rails for the Haytor Granite Tramway, Devon, England, in 1820. Granite block is usually processed into slabs and after can be cut and shaped by a cutting center.

7 – 2 - 4 - Other uses ;

Curling stones are traditionally fashioned of Ailsa Craig granite. The first stones were made in the 1750s, the original source being Ailsa Craig in Scotland. Because of the particular rarity of the granite, the best stones can cost as much as US$1,500. Between 60–70 percent of the stones used today are made from Ailsa Craig granite, although the island is now a wildlife reserve and is no longer used for quarrying.

8 - Rock climbing :

Granite is one of the rocks most prized by climbers, for its steepness, soundness, crack systems, and friction. Well - known venues for granite climbing include Yosemite, the Bugaboos, the Mont Blanc massif (and peaks such as the Aiguille du Dru, the Mountains of Mourne , the Adamello-Presanella Alps, the Aiguille du Midi and the Grandes Jorasses), the Bregaglia, Corsica, parts of the Karakoram (especially the Trango Towers), the Fitzroy Massif, Patagonia, Baffin Island, Ogawayama, the Cornish coast and the Cairngorms.

Granite rock climbing is so popular that many of the artificial rock climbing walls found in gyms and theme parks are made to look and feel like granite.

Granolithic Concrete

Granolithic screed , also known as **granolithic paving** and **granolithic concrete** , is a type of construction material composed of cement and fine aggregate such as granite or other hard - wearing rock . It is generally used as flooring, or as paving (such as for sidewalks). It has a similar appearance to concrete, and is used to provide a durable surface where texture and appearance are usually not important (such as outdoor pathways or factory floors) . It is commonly laid as a screed. Screeds are a type of flooring laid on top of the structural element (like reinforced concrete) to provide a level surface on which the "wearing flooring" (the flooring which people see and walk on) is laid . A screed can also be laid bare, as it provides a long - lasting surface.

The aggregate mixed with the cement can be of various size, shape, and material, depending on the texture of the surface needed and how long - lasting it must be . The aggregate is usually sifted so that the particles are roughly the same size, which helps reduces air pockets in the material (which can weaken it) . Generally, the mix of aggregate to cement is 2.5 to 1 by volume .

Granolithic screed or paving can be problematic. Because it is made with a high cement content and requires a great deal of water to mix, it may crack while drying . It can also come loose from the material below (especially if the lower material is not properly prepared) . Pouring the material in layers is generally avoided . Cracking and curling can be reduced by dividing the area to be covered into smaller sections and then pouring the material . De bonding of the granolithic material can also be significantly avoided by using bonding agents like epoxy resins or polymer latex .

A high degree of skill in pouring and finishing the material is needed to prevent problems . Sealers and hardeners can be added to

Ground Granulated Blast - Furnace Slag

Contents

1 – Introduction:

Ground-granulated blast - furnace slag (**GGBS** or **GGBFS**) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder.

2 - Applications :

GGBS is used to make durable concrete structures in combination with ordinary portland cement and / or other pozzolanic materials. GGBS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years .

Two major uses of GGBS are in the production of quality-improved slag cement, namely Portland Blast furnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBS content ranging typically from 30 to 70 %; and in the production of ready-mixed or site-batched durable concrete.

Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.

Use of GGBS significantly reduces the risk of damages caused by alkali – silica reaction (ASR), provides higher resistance to chloride ingress — reducing the risk of reinforcement corrosion — and provides higher resistance to attacks by sulfate and other chemicals.

3 - How GGBS cement is used :

GGBS cement is added to concrete in the concrete manufacturer's batching plant, along with Portland cement, aggregates and water. The normal ratios of aggregates and water to cementitious material in the mix remain unchanged. GGBS is used as a direct replacement for Portland cement, on a one - to - one basis by weight. Replacement levels for GGBS vary from 30 % to up to 85 %. Typically 40 to 50 % is used in most instances.

The use of GGBS cement in concrete in Ireland is covered in the new Irish concrete standard IS EN 206 - 1:2002. This standard establishes two categories of additions to concrete along with ordinary Portland cement: nearly inert additions (Type I) and pozzolanic or latent hydraulic additions (Type II). GGBS cement falls in to the latter category. As GGBS cement is slightly less expensive than Portland cement, concrete made with GGBS cement will be similarly priced to that made with ordinary Portland cement.

4 - Architectural and engineering benefits :

4 – 1 - Durability :

GGBS cement is routinely specified in concrete to provide protection against both sulphate attack and chloride attack . GGBS has now effectively replaced sulfate - resisting Portland cement (SRPC) on the market for sulfate resistance because of its superior performance and greatly reduced cost compared to SRPC. Most projects in Dublin's Docklands, including Spencer Dock, are using GGBS in subsurface concrete for sulfate resistance.

To protect against chloride attack, GGBS is used at a replacement level of 50% in concrete. Instances of chloride attack occur in reinforced concrete in marine environments and in road bridges where the concrete is exposed to splashing from road de-icing salts. In most NRA projects in Ireland GGBS is now specified in structural concrete for bridge piers and abutments for protection against chloride attack. The use of GGBS in such instances will increase the life of the structure by up to 50 % had only Portland cement been used, and precludes the need for more expensive stainless steel reinforcing.

GGBS is also routinely used to limit the temperature rise in large concrete pours. The more gradual hydration of GGBS cement generates both lower peak and less total overall heat than Portland cement. This reduces thermal gradients in the concrete, which prevents the occurrence of micro cracking which can weaken the concrete and reduce its durability, and was used for this purpose in the construction of the Jack Lynch Tunnel in Cork.

4 – 2 - Appearance :

In contrast to the stony grey of concrete made with Portland cement, the near-white color of GGBS cement permits architects to achieve a lighter colour for exposed fair-faced concrete finishes, at no extra cost. To achieve a lighter colour finish, GGBS is usually specified at between 50 % to 70 % replacement levels, although levels as high as 85 % can be used. GGBS cement also produces a smoother, more defect free surface, due to the fineness of the GGBS particles. Dirt does not adhere to GGBS concrete as easily as concrete made with Portland cement, reducing maintenance costs. GGBS cement prevents the occurrence of efflorescence, the staining of concrete surfaces by calcium carbonate deposits. Due to its much lower lime content and lower permeability, GGBS is effective in preventing efflorescence when used at replacement levels of 50 % to 60 %.

4 – 3 - Strength :

Concrete containing GGBS cement has a higher ultimate strength than concrete made with Portland cement. It has a higher proportion of the strength - enhancing calcium silicate hydrates (CSH) than concrete made with Portland cement only, and a reduced content of free lime, which does not contribute to concrete strength. Concrete made with GGBS continues to gain strength over time, and has been shown to double its 28 - day strength over periods of 10 to 12 years .

4 – 4 - Sustainability :

Since GGBS is a by- product of steel manufacturing process, its use in concrete is recognized by LEED etc. as improving the sustainability of the project and will therefore add points towards LEED certification. In this respect, GGBS can also be used for superstructure in addition to the cases where the concrete is in contact with chlorides and sulfates. This is provided that the slower setting time for casting of the superstructure is justified.

Grout

Grout is a construction material used to embed rebars in masonry walls, connect sections of pre-cast concrete, fill voids, and seal joints (like those between tiles). Grout is generally composed of a mixture of water, cement, sand, often color tint, and sometimes fine gravel (if it is being used to fill the cores of cement blocks). It is applied as a thick emulsion and hardens over time, much like its close relative mortar.

Main varieties include: tiling grout (either urethane , cement-based or epoxy) , flooring grout, resin grout, non-shrink grout, structural grout and thixotropic grout.

Structural grout is used in reinforced masonry to fill voids in masonry housing reinforcing steel, securing the steel in place and bonding it to the masonry. Non - shrink grout is used beneath metal bearing plates to ensure a consistent bearing surface between the plate and its substrate.

Tiling grout is used to fill the spaces between tiles or mosaics, and is often used to secure tile to its base. Although ungrouted mosaics do exist, most have grout between the tesserae .

There are a few tools associated with applying and removal of grout such as :

- **grout saw** or **grout scraper**; a manual tool for removal of old and discolored grout. The blade is usually composed of tungsten carbide.
- **grout float** ; A trowel-like tool for smoothing the surface of a grout line, typically made of rubber or soft plastic.
- **grout sealer** : is a water-based or solvent - based sealant applied over dried grout that resists water, oil, and acid-based contaminants.
- **Dremel grout attachment** ; an attachment guide used in a die grinder for faster removal of old grout than a standard grout saw.

Gypsum

Fibrous gypsum selenite showing its translucent property.

Contents

1 – Introduction :

Gypsum is a very soft sulfate mineral composed of calcium sulfate dihydrate, with the chemical formula $CaSO_4 \cdot 2H_2O$. It is found in alabaster, a decorative stone used in Ancient Egypt. It is the second softest mineral on the Mohs scale of mineral hardness. It forms as an evaporite mineral and as a hydration product of anhydrite.

Category	Sulfate minerals
Chemical Formula	$Ca\,SO_4 \cdot 2H_2O$
Unit cell	a = 5.679 Å , b = 15.202 Å, c = 6.522 Å;

	$\beta = 118.43°$; $Z = 4$
Color	Colorless to white; may be yellow, tan, blue, pink, brown, reddish brown or gray due to impurities
Crystal habit	Massive, flat. Elongated and generally prismatic crystals
Tenacity	Flexible , inelastic .
Mohs scale hardness	1.5 – 2 (defining mineral for 2)
Luster	Vitreous to silky, pearly, or waxy
Streak	White
Diaphaneity	Transparent to translucent
Specific gravity	2.31–2.33
Optical properties	Biaxial (+)
Refractive index	$n_\alpha = 1.519–1.521$ $n_\beta = 1.522–1.523$ $n_\gamma = 1.529–1.530$
Solubility	Hot , dilute HCl
Satin spar	Pearly, fibrous masses
Selenite	Transparent and bladed crystals
Alabaster	Fine-grained, slightly colored

2 - Etymology and history :

The word gypsum is derived from the Greek word (*gypsos*) , "chalk" or "plaster". Because the gypsum from the quarries of the Montmartre district of Paris have long furnished burnt gypsum used for various purposes, this material has been called plaster of Paris.

Gypsum was known in Old English as *spærstān*, "spear stone", referring to its crystalline projections. (Thus, the word **spar** in mineralogy is by way of comparison to gypsum, referring to any nonore mineral or crystal that forms in spear like projections) . In the early 19th century, it was regarded as an almost miraculous fertilizer. American farmers were so anxious to acquire it, a lively smuggling trade with Nova Scotia evolved, resulting in the so - called "Plaster War" of 1812.

3 - Physical properties :

Gypsum is moderately water-soluble (~2.0 –2.5 g / l at 25°C) and, in contrast to most other salts, it exhibits a retrograde solubility, becoming less soluble at higher temperatures. When the crystal lattice is heated, it loses liquid water molecules to evaporation and thus gains solidity. As for anhydrite, its solubility in saline solutions and in brines is also strongly dependent on Na Cl concentration.

Gypsum crystals are found to contain anion water and hydrogen bonding.

4 - Crystal varieties :

Gypsum occurs in nature as flattened and often twinned crystals, and transparent, cleavable masses called selenite. Selenite contains no significant selenium; rather, both substances were named for the ancient Greek word for the Moon.

Selenite may also occur in a silky, fibrous form, in which case it is commonly called "satin spar". Finally, it may also be granular or quite compact. In hand-sized samples, it can be anywhere from transparent to opaque. A very fine-grained white or lightly tinted variety of gypsum, called alabaster, is prized for ornamental work of various sorts. In arid areas, gypsum can occur in a flower-like form, typically opaque, with embedded sand grains called desert rose. It also forms some of the largest crystals found in nature, up to 11 m long, in the form of selenite.

5 - Occurrence :

Gypsum is a common mineral, with thick and extensive evaporite beds in association with sedimentary rocks. Deposits are known to occur in strata from as far back as the Archaean eon. Gypsum is deposited from lake and sea water, as well as in hot springs, from volcanic vapors, and sulfate solutions in veins. Hydrothermal anhydrite in veins is commonly hydrated to gypsum by groundwater in near - surface exposures. It is often associated with the minerals halite and sulfur.

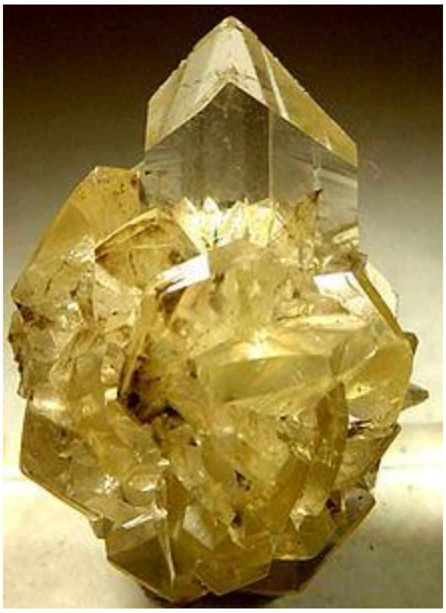
Because gypsum dissolves over time in water, gypsum is rarely found in the form of sand. However, the unique conditions of the White Sands National Monument in the US state of New Mexico have created a 710 km^2 expanse of white gypsum sand, enough to supply the construction industry with drywall for 1,000 years . Commercial exploitation of the area, strongly opposed by area residents, was permanently prevented in 1933 when president Herbert Hoover declared the gypsum dunes a protected national monument.

Gypsum is also formed as a by - product of sulfide oxidation, amongst others by pyrite oxidation, when the sulfuric acid generated reacts with calcium carbonate. Its presence indicates oxidizing conditions. Under reducing conditions, the sulfates it contains can be reduced back to sulfide by sulfate reducing bacteria. Electric power stations burning coal with flue gas desulfurization produce large quantities of gypsum as a byproduct from the scrubbers.

Orbital pictures from the Mars Reconnaissance Orbiter (MRO) have indicated the existence of gypsum dunes in the northern polar region of Mars, which were later confirmed at ground level by the Mars Exploration Rover (MER) *Opportunity*.

6 - Mining :

Commercial quantities of gypsum are found in the cities of Araripina and Grajaú, Brazil, Pakistan, Jamaica, Iran (world's second largest producer), Thailand, Spain (the main producer in Europe), Germany, Italy, England, Ireland, in British Columbia, Manitoba, Ontario, Nova Scotia and Newfoundland in Canada,[14] and in New York, Michigan, Indiana, Texas (in the Palo Duro Canyon), Iowa, Kansas, Oklahoma, Arizona, New Mexico, Colorado, Utah, Arkansas and Nevada in the United States. There is also a large open pit quarry located at Plaster City, California, in Imperial County, and in East Kutai, Kalimantan. Several small mines also exist in places such as Kalannie in Western Australia, where gypsum is sold to private buyers for changing the pH levels of soil for agricultural purposes.



Golden gypsum crystals from Winnipeg.

Gypsum sand from White Sands National Monument, New Mexico

Crystals of gypsum up to 11 meters long have been found in the caves of the Naica Mine of Chihuahua, Mexico. The crystals thrived in the cave's extremely rare and stable natural environment. Temperatures stayed at 58°C , and the cave was filled with mineral-rich water that drove the crystals' growth. The largest of those crystals weighs 50 tons and is around 500,000 years old.

7 - Synthesis :

Synthetic gypsum is recovered via flue - gas desulfurization at some coal - fired electric power plants. It can be used interchangeably with natural gypsum in some applications.

Gypsum also precipitates onto brackish water membranes, a phenomenon known as mineral salt scaling, such as during brackish water desalination of water with high concentrations of calcium and sulfate. Scaling decreases membrane life and productivity. This is one of the main obstacles in brackish water membrane desalination processes, such as reverse osmosis or nano filtration. Other forms of scaling, such as calcite scaling, depending on the water source, can also be important considerations in distillation, as well as in heat exchangers, where either the salt solubility or concentration can change rapidly.

A new study has found the formation of gypsum starts as tiny crystals of a mineral called bassanite ($CaSO_4 \cdot 0.5H_2O$) . This process occurs via a three-stage pathway :

(1) homogeneous nucleation of nano crystalline bassanite;
(2) self-assembly of bassanite into aggregates, and
(3) transformation of bassanite into gypsum.

8 - Uses of gypsum :

Gypsum is used in a wide variety of applications :

- Gypsum board : is primarily used as a finish for walls and ceilings, and is known in construction as drywall or plasterboard.
- Plaster ingredient
- Fertilizer and soil conditioner : In the late 18th and early 19th centuries, Nova Scotia gypsum, often referred to as plaster, was a highly sought fertilizer for wheat fields in the United States. It is also used in ameliorating sodic soils.

- A binder in fast - dry tennis court clay
- Plaster of Paris (surgical splints, casting moulds, modeling)
- A wood substitute in the ancient world : For example, when wood became scarce due to deforestation on Bronze Age Crete , gypsum was employed in building construction at locations where wood was previously used .
- ***A tofu*** (soy bean curd) coagulant, making it ultimately a major source of dietary calcium , especially in Asian cultures which traditionally use few dairy products
- Adding hardness to water used for home brewing
- A component of Portland cement used to prevent flash setting of concrete
- Soil / water potential monitoring (soil moisture tension)
- A common ingredient in making mead
- In the medieval period, it was mixed, by scribes and illuminators, with lead carbonate (powdered white lead) to make gesso, which was applied to illuminated letters and gilded with gold in illuminated manuscripts.
- In foot creams, shampoos and many other hair products
- A medicinal agent in traditional Chinese medicine called *shi gao*
- Impression plasters in dentistry

History of Architecture

The Architect's Dream, 1840, by Thomas Cole

Contents

1 - Introduction :

The **history of architecture** traces the changes in architecture through various traditions , regions , over arching stylistic trends , and dates.

2 - Neolithic Architecture :

Neolithic architecture is the architecture of the Neolithic period. In Southwest Asia, Neolithic cultures appear soon after 10000 BC, initially in the Levant (Pre-Pottery Neolithic A and Pre-Pottery Neolithic B) and from there spread eastwards and westwards There are early Neolithic cultures in Southeast Anatolia, Syria and Iraq by 8000 BC, and food-producing societies first appear in southeast

Europe by 7000 BC, and Central Europe by c. 5500 BC (of which the earliest cultural complexes include the Starčevo-Koros (Cris), Linearbandkeramic, and Vinča). With very small exceptions (a few copper hatchets and spear heads in the Great Lakes region), the people of the Americas and the Pacific remained at the Neolithic level of technology up until the time of European contact.

Excavated dwellings at Skara Brae

The neolithic people in the Levant, Anatolia, Syria, northern Mesopotamia and Central Asia were great builders, utilizing mud-brick to construct houses and villages. At Çatalhöyük, houses were plastered and painted with elaborate scenes of humans and animals. The Mediterranean neolithic cultures of Malta worshiped in megalithic temples.In Europe, long houses built from wattle and daub were constructed. Elaborate tombs for the dead were also built. These tombs are particularly numerous in Ireland, where there are many thousands still in existence. Neolithic people in the British Isles built long barrows and chamber tombs for their dead and causewayed camps, henges flint mines and cursus monuments.

3 - Ancient Near East Africa and Mediterranean :

3 - 1 - Ancient Egyptian Architecture :

In Ancient Egypt and other early societies, people believed in the omnipotence of Gods, with many aspects of daily life were carried out with respect to the idea of the divine or supernatural and the way it was manifest in the mortal cycles of generations, years, seasons, days and nights. Harvests for example were seen as the benevolence of fertility deities. Thus, the founding and ordering of the city and her most important buildings (the palace or temple) were often executed by priests or even the ruler himself and the construction was accompanied by rituals intended to enter human activity into continued divine benediction.

Ceiling decoration in the peristyle hall of Medinet Habu, an example of ancient Egyptian architecture

Ancient architecture is characterized by this tension between the divine and mortal world. Cities would mark a contained sacred space over the wilderness of nature outside, and the temple or palace continued this order by acting as a house for the gods. The architect, be he priest or king, was not the sole important figure; he was merely part of a continuing tradition!

3 - 2 – Classical architecture :

3 - 2 – 1 - Greek architecture

Temple of Concordia in Agrigento, Sicily.

The architecture and urbanism of the Greeks and Romans was very different from that of the Egyptians and Persians. Civic life gained importance for all members of the community. In the time of the ancients religious matters were only handled by the ruling class; by the time of the Greeks, religious mystery had skipped the confines of the temple-palace compounds and was the subject of the people or *polis*.

Greek civic life was sustained by new, open spaces called the *agora* which were surrounded by public buildings, stores and temples. The *agora* embodied the new found respect for social justice received through open debate rather than imperial mandate. Though divine wisdom still presided over human affairs, the living rituals of ancient civilizations had become inscribed in space, in the paths that wound towards the *acropolis* for example. Each place had its own nature, set within a world refracted through myth, thus temples were sited atop mountains all the better to touch the heavens.

3 - 2 – 2 - Roman architecture

The Romans conquered the Greek cities in Italy around three hundred years BCE and much of the Western world after that. The Roman problem of rulership involved the unity of disparity — from Spanish to Greek, Macedonian to Carthaginian — Roman rule had extended itself across the breadth of the known world and the myriad pacified cultures forming this *ecumene* presented a new challenge for justice . One way to look at the unity of Roman architecture is through a new-found realization of theory derived from practice, and embodied spatially. Civically we find this happening in the Roman *forum* (sibling of the Greek agora), where public participation is increasingly removed from the concrete performance of rituals and represented in the decor of the architecture. Thus we finally see the beginnings of the contemporary public square in the Forum Iulium, begun by Julius Caesar, where the buildings present themselves through their facades as representations within the space.

As the Romans chose representations of sanctity over actual sacred spaces to participate in society, so the communicative nature of space was opened to human manipulation. None of which would have been possible without the advances of Roman engineering and construction or the newly found marble quarries which were the spoils of war; inventions like the arch and concrete gave a whole new form to Roman architecture, fluidly enclosing space in taut domes and colonnades, clothing the grounds for imperial rulership and civic order. This was also a response to the changing social climate which demanded new buildings of increasing complexity — the coliseum, the residential block, bigger hospitals and academies. General civil construction such as roads and bridges began to be built.

The Romans widely employed, and further developed, the arch, vault and dome (see the Roman Architectural Revolution), all of which were little used before, particularly in Europe.[1] Their innovative use of Roman concrete facilitated the building of the many public buildings of often unprecedented size throughout the empire. These include Roman temples, Roman baths, Roman bridges, Roman aqueducts, Roman harbours, triumphal arches, Roman amphitheatres, Roman circuses palaces, mausolea and in the late empire also churches.

Roman domes permitted construction of vaulted ceilings and enabled huge covered public spaces such as the public baths like Baths of Diocletian or the monumental Pantheon in the city of Rome.

Art historians such as Gottfried Richter in the 1920s identified the Roman architectural innovation as being the Triumphal Arch and it is poignant to see how this symbol of power on earth was transformed and utilized within the Christian basilicas when the Roman Empire of the West was on its last legs: The arch was set before the altar to symbolize the triumph of Christ and the after life. It is in their impressive aqueducts that we see the arch triumphant, especially in the many surviving examples, such as the Pont du Gard, the aqueduct at Segovia and the remains of the Aqueducts of Rome itself. Their survival is testimony to the durability of their materials and design.

Examples of key Roman architectural forms :

***Triumphal Arch**: Arch of Constantine, Rome*

***Roman Temple**: Maison Carrée, Nimes, France*

***Dome**: Interior of the Pantheon in Rome*

***Arch**: Roman aqueduct in Segovia, Spain*

3 – 3 - Byzantine architecture :

The Byzantine Empire gradually emerged as a distinct artistic and cultural entity from the Roman Empire after AD 330, when the Roman Emperor Constantine moved the capital of the Roman Empire east from Rome to Byzantium (later renamed Constantinople and now called Istanbul). The empire endured for more than a millennium, dramatically influencing Medieval and Renaissance era architecture in Europe and, following the capture of Constantinople by the Ottoman Turks in 1453, leading directly to the architecture of the Ottoman Empire.

Early Byzantine architecture was built as a continuation of Roman architecture. Stylistic drift, technological advancement, and political and territorial changes meant that a distinct style gradually emerged which imbued certain influences from the Near East and used the Greek cross plan in church architecture. Buildings increased in geometric complexity, brick and plaster were used in addition to stone in the decoration of important public structures, classical orders were used more freely, mosaics replaced carved decoration, complex domes rested upon massive piers, and windows filtered light through thin sheets of alabaster to softly illuminate interiors.

4 - Islamic architecture :

Islamic architecture has encompassed a wide range of both secular and religious architecture styles from the foundation of Islam to the present day, influencing the design and construction of buildings and structures within the sphere of Islamic culture. Some distinctive structures in Islamic architecture are mosques, tombs, palaces and forts, although Islamic architects have of course also applied their distinctive design precepts to domestic architecture.

The wide spread and long history of Islam has given rise to many local architectural styles, including Persian -, Moorish, Timurid, Ottoman, Fatimid, Mamluk, Mughal, Indo - Islamic, Sino-Islamic and Afro-Islamic architecture. Notable Islamic architectural types include the early Abbasid buildings, T-type mosques, and the central-dome mosques of Anatolia.- Also, Islamic architexture also discourages illustrations of anything living, such as animals and humans, due to the fact that at death, their soul will never rest in peace.

Various regional styles of medieval Islamic architecture, as show in religious structures (from west to east) :

***Moorish architecture**: The Great Mosque of Kairouan in Tunisia*

***Sudano-Sahelian**: The Great Mosque of Djenné in present-day Mali, illustrating the mud construction of western Africa.*

***Persian architecture**: Sheikh Lotf Allah Mosque, Isfahan, Iran*

***Mughal architecture**: Badshahi Mosque, Pakistan*

***Ottoman architecture**: Sultan Ahmed Mosque, Istanbul, Turkey.*

5 - Africa :

The conical tower inside the Great Enclosure in Great Zimbabwe, a medieval city built by a prosperous culture.

Great Zimbabwe is the largest medieval city in sub-Saharan Africa. By the late nineteenth century, most buildings reflected the fashionable European eclecticism and pastisched Mediterranean, or even Northern European, styles.

In the Western Sahel region, Islamic influence was a major contributing factor to architectural development from the time of the Kingdom of Ghana. At Kumbi Saleh, locals lived in domed-shaped dwellings in the king's section of the city, surrounded by a great enclosure. Traders lived in stone houses in a section which possessed 12 beautiful mosques, as described by al - bakri, with one centered on Friday prayer . The king is said to have owned several mansions, one of which was sixty-six feet long, forty-two feet wide, contained seven rooms, was two stories high, and had a staircase; with the walls and chambers filled with sculpture and painting .

Sahelian architecture initially grew from the two cities of Djenné and Timbuktu. The Sankore Mosque in Timbuktu, constructed from mud on timber, was similar in style to the Great Mosque of Djenné. The rise of kingdoms in the West African coastal region produced architecture which drew on indigenous traditions, utilizing wood. The famed Benin City, destroyed by the Punitive Expedition, was a large complex of homes in coursed mud, with hipped roofs of shingles or palm leaves. The Palace had a sequence of ceremonial rooms, and was decorated with brass plaques.

6 - Southern Asia :

6 – 1 - Persian architecture :

The ruins of Persepolis, approximately 2500 years old.

The pre - Islamic styles draw on 3 - 4 thousand years of architectural development from various civilizations of the Iranian plateau. The Islamic architecture of Iran in turn, draws ideas from its pre-Islamic predecessor, and has geometrical and repetitive forms, as well as surfaces that are richly decorated with glazed tiles, carved stucco, patterned brickwork, floral motifs, and calligraphy. As such, Iran ranks seventh in the world in terms of possessing historical monuments, museums, and other cultural attractions and is recognized by UNESCO as being one of the cradles of civilization .

Each of the periods of Elamites , Achaemenids , Parthians , and Sassanids were creators of great architecture that over the ages has spread wide and far to other cultures being adopted. Although Iran has suffered its share of destruction, including Alexander The Great's decision to burn Persepolis, there are sufficient remains to form a picture of its classical architecture.

The Achaemenids built on a grand scale. The artists and materials they used were brought in from practically all territories of what was then the largest state in the world. Pasargadae set the standard: its city was laid out in an extensive park with bridges, gardens, colonnaded palaces and open column pavilions. Pasargadae along with Susa and Persepolis expressed the authority of The King of Kings, the staircases of the latter recording in relief sculpture the vast extent of the imperial frontier.

The ruins of Taq-i Kisra at Ctesiphon (in today iraq) - an example of Persian architecture during Sassanid period.

With the emergence of the Parthians and Sassanids there was an appearance of new forms. Parthian innovations fully flowered during the Sassanid period with massive barrel - vaulted chambers, solid masonry domes, and tall columns. This influence was to remain for years to come. The roundness of the city of Baghdad in the Abbasid era for example, points to its Persian precedents such as Firouzabad in Fars.[6] The two designers who were hired by al - Mansur to plan the city's design were Naubakht, a former Persian Zoroastrian who also determined that the date of the foundation of the city would be astrologically auspicious, and Mashallah, a former Jew from Khorasan. The ruins of Persepolis, Ctesiphon, Jiroft,[7] Sialk, Pasargadae, Firouzabad, Arg - é Bam , and thousands of other ruins may give us merely a distant glimpse of what contribution Persians made to the art of building.

The fall of the Sassanid Empire to invading Islamic forces ironically led to the creation of remarkable religious buildings in Iran. Arts such as calligraphy, stucco work, mirror work, and mosaic work, became closely tied with architecture in Iran in the new era. Archaeological excavations have provided sufficient documents in support of the impacts of Sasanian architecture on the architecture of the Islamic world. Many experts believe the period of Persian architecture from the 15th through 17th Centuries to be the most brilliant of the post - Islamic era. Various structures such as mosques, mausoleums, bazaars, bridges, and different palaces have mainly survived from this period.

In the old Persian architecture, semi-circular and oval-shaped vaults were of great interest, leading Safavi architects to display their extraordinary skills in making massive domes. In the words of D. Huff, a German archaeologist, the dome is the dominant element in Persian architecture. Domes can be seen frequently in the structure of bazaars and mosques, particularly during the Safavi period in Isfahan. Iranian domes are distinguished for their height, proportion of elements, beauty of form, and roundness of the dome stem. The outer surfaces of the domes are mostly mosaic faced, and create a magical view. Safavi Isfahan tried to achieve grandeur in scale (Isfahan's Naghsh-i Jahan Square is the 6th largest square worldwide) knowledge about building tall buildings with vast inner spaces. However, the quality of ornaments was decreased in comparison with those of the 14th and 15th centuries.

The great mosques of Khorasan, Isfahan, and Tabriz each used local geometry, local materials, and local building methods to express in their own ways the order, harmony, and unity of Islamic architecture. And thus when the major monuments of Islamic Persian architecture are examined, they reveal complex geometrical relationships, a studied hierarchy of form and ornament, and great depths of symbolic meaning.

6 – 2 - Indian architecture :

Indian architecture encompasses a wide variety of geographically and historically spread structures, and was transformed by the history of the Indian subcontinent. The result is an evolving range of architectural production that, although it is difficult to identify a single representative style, nonetheless retains a certain amount of continuity across history. The diversity of Indian culture is represented in its architecture. It is a blend of ancient and varied native traditions, with building types, forms and technologies from West and Central Asia, as well as Europe. Architectural styles range from Hindu temple architecture to Islamic architecture to western classical architecture to modern and post-modern architecture.

India's urban civilization is traceable to Mohenjodaro and Harappa, now in Pakistan. From then on, Indian architecture and civil engineering continued to develop, and was manifestated temples, palaces and forts across the Indian subcontinent and neighbouring regions. Architecture and civil engineering was known as *sthapatya-kala*, literally "the art of constructing".

The temples of Aihole and Pattadakal are the earliest known examples of Hindu temples. There are numerous Hindu as well as Buddhist temples that are known as excellent examples of Indian rock-cut architecture. According to J.J. O'Connor and E. F. Robertson, the *Sulbasutras* were appendices to the Vedas giving *rules for constructing altars*. "They contained quite an amount of geometrical knowledge, but the mathematics was being developed, not for its own sake, but purely for practical religious purposes."

The Hall of Private Audience at Fatehpur Sikri in Uttar Pradesh, India, an early example of the architecture of the Mughal Empire.

During the Kushan Empire and Mauryan Empire, Indian architecture and civil engineering reached regions like Baluchistan and Afghanistan. Statues of Buddha were cut out, covering entire mountain cliffs, like in Buddhas of Bamyan, Afghanistan. Over a period of time, ancient Indian art of construction blended with Greek styles and spread to Central Asia. It includes the architecture of various dynasties, such as Hoysala architecture, Vijayanagara Architecture and Western Chalukya Architecture.

The Church of St. Anne which is cast in the Indian Baroque Architectural style under the orientation of the most eminent architects of the time. It is a prime example of the blending of traditional Indian styles with western European architectural styles.

7 - Buddhist architecture :

stupa at the top of Borobudur, Java, Indonesia

8 - Southeast Asia :

8 – 1 - Architecture of the Khmer Empire :

8 – 2 - Indonesian architecture :

9 - Eastern Asia

9 – 1 - Chinese architecture :

The Iron Pagoda of Kaifeng, built in 1049 during the Song Dynasty.

From the Neolithic era Longshan Culture and Bronze Age era Erlitou culture, the earliest rammed earth fortifications exist, with evidence of timber architecture. The subterranean ruins of the palace at Yinxu dates back to the Shang Dynasty (c. 1600 BC–1046 BC). In historic China, architectural emphasis was laid upon the horizontal axis, in particular the construction of a heavy platform and a large roof that floats over this base, with the vertical walls not as well emphasized. This contrasts Western architecture, which tends to grow in height and depth. Chinese architecture stresses the visual impact of the width of the buildings. The deviation from this standard is the tower architecture of the Chinese tradition, which began as a native tradition and was eventually influenced by the Buddhist building for housing religious sutras — the stupa — which came from India. Ancient Chinese tomb model representations of multiple story residential towers and watchtowers date to the Han Dynasty (202 BC–

220 AD). However, the earliest extant Buddhist Chinese pagoda is the Songyue Pagoda, a 40 m (131 ft) tall circular-based brick tower built in Henan province in the year 523 AD. From the 6th century onwards, stone-based structures become more common, while the earliest are from stone and brick arches found in Han Dynasty tombs. The Zhaozhou Bridge built from 595 to 605 AD is China's oldest extant stone bridge, as well as the world's oldest fully stone open-spandrel segmental arch bridge.

Inside the Forbidden City- an example of Chinese architecture from the 15th century.

The vocational trade of architect, craftsman, and engineer was not as highly respected in premodern Chinese society as the scholar-bureaucrats who were drafted into the government by the civil service examination system. Much of the knowledge about early Chinese architecture was passed on from one tradesman to his son or associative apprentice. However, there were several early treatises on architecture in China, with encyclopedic information on architecture dating back to the Han Dynasty. The height of the classical Chinese architectural tradition in writing and illustration can be found in the *Yingzao Fashi*, a building manual written by 1100 and published by Lie Jie (1065–1110) in 1103. In it there are numerous and meticulous illustrations and diagrams showing the assembly of halls and building components, as well as classifying structure types and building components.

There were certain architectural features that were reserved solely for buildings built for the Emperor of China. One example is the use of yellow roof tiles; yellow having been the Imperial color, yellow roof tiles still adorn most of the buildings within the Forbidden City. The Temple of Heaven, however, uses blue roof tiles to symbolize the sky. The roofs are almost invariably supported by brackets, a feature shared only with the largest of religious buildings. The wooden columns of the buildings, as well as the surface of the walls, tend to be red in colour.

Many current Chinese architectural designs follow post-modern and western styles.

9 – 2 - Korean architecture

Throne Hall of Gyeongbokgung Palace, Seoul, South Korea

Korean architecture has a long history of 5,000 years . It has its own cultural identity different from Chinese or Japanese architecture. The basic construction form is more or less similar to Eastern Asian building system. From a technical point of view, buildings are structured vertically and horizontally. A construction usually rises from a stone sub foundation to a curved roof covered with tiles, held by a console structure and supported on posts; walls are made of earth (adobe) or are sometimes totally composed of movable wooden doors. Architecture is built according to the k'an unit, the distance between two posts (about 3.7 meters), and is designed so that there is always a transitional space between the "inside" and the "outside."

The console, or bracket structure, is a specific architectonic element that has been designed in various ways through time. If the simple bracket system was already in use under the Goguryeo kingdom (37 BCE – 668 CE) — in palaces in Pyongyang, for instance—a curved version, with brackets placed only on the column heads of the building, was elaborated during the early Koryo dynasty (918–1392). The Amita Hall of the Pusok temple in Antong is a good example. Later on (from the mid-Koryo period to the early Choson dynasty), a multiple-bracket system, or an inter-columnar-bracket set system, was developed under the influence of Mongol's Yuan dynasty (1279–1368). In this system, the consoles were also placed on the transverse horizontal beams. Seoul's Namtaemun Gate Namdaemun, Korea's foremost national treasure, is perhaps the most symbolic example of this type of structure. In the mid-Choson period, the winglike bracket form appeared (one example is the Yongnyongjon Hall of Jongmyo, Seoul), which is interpreted by many scholars as an example of heavy Confucian influence in Joseon Korea, which emphasized simplicity and modesty in such shrine buildings. Only in buildings of importance like palaces or sometimes temples (Tongdosa, for instance) were the multi cluster brackets still used. Confucianism also led to more sober and simple solutions.

9 – 3 - Japanese architecture :

View of Himeji Castle from Nishi – no - maru

Japanese architecture has as long a history as any other aspect of Japanese culture. Influenced heavily by Chinese and Korean architecture, it also shows a number of important differences and aspects which are uniquely Japanese.

Two new forms of architecture were developed in medieval Japan in response to the militaristic climate of the times: the castle, a defensive structure built to house a feudal lord and his soldiers in times of trouble; and the *shoin*, a reception hall and private study area designed to reflect the relationships of lord and vassal within a feudal society.

Because of the need to rebuild Japan after World War II, major Japanese cities contain numerous examples of modern architecture. Japan played some role in modern skyscraper design, because of its long familiarity with the cantilever principle to support the weight of heavy tiled temple roofs. New city planning ideas based on the principle of layering or cocooning around an inner space (oku), a Japanese spatial concept that was adapted to urban needs, were adapted during reconstruction. Modernism became increasingly popular in architecture in Japan starting in the 1970s.

10 - Pre - Columbian :

Overview of the central plaza of the Mayan city of Palenque(Chiapas, Mexico), a fine example of Classic period Mesoamerican Architecture.

10 – 1 - Mesoamerican architecture :

Mesoamerican architecture is the set of architectural traditions produced by pre - Columbian cultures and civilizations of Mesoamerica , (such as the Olmec, Maya, and Aztec) traditions which are best known in the form of public, ceremonial and urban monumental buildings and structures. The distinctive features of Mesoamerican architecture encompass a number of different regional and historical styles, which however are significantly interrelated. These styles developed throughout the different phases of Mesoamerican history as a result of the intensive cultural exchange between the different cultures of the Mesoamerican culture area through thousands of years. Mesoamerican architecture is mostly noted for its pyramids which are the largest such structures outside of Ancient Egypt.

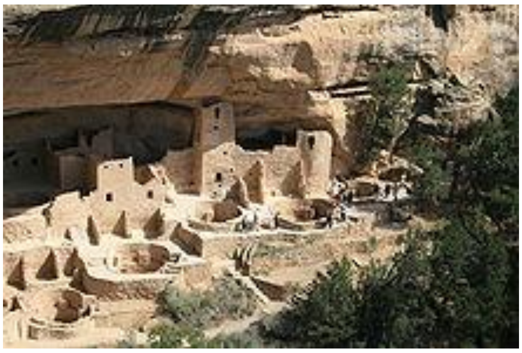
10 – 2 - Incan architecture :

View of Machu Picchu

Incan architecture consists of the major construction achievements developed by the Incas. The Incas developed an extensive road system spanning most of the western length of the continent. Inca rope bridges could be considered the world's first suspension bridges. Because the Incas used no wheels (It would have been impractical for the terrain) or horses, they built their roads and bridges for foot and pack-llama traffic. Much of present day architecture at the former Inca capital Cuzco shows both Incan and Spanish influences. The famous lost city Machu Picchu is the best surviving example of Incan architecture. Another significant site is Ollantaytambo. The Inca were sophisticated stone cutters whose masonry used no mortar.

10 – 3 - Ancient architecture of North America :

Inside what is the present-day United States, the Mississippians and the Pueblo created substantial public architecture. The Mississippian culture was among the mound - building peoples, noted for construction of large earthen platform mounds.



Cliff Palace of Mesa Verde, in Colorado, United States, created by the Ancient Pueblo Peoples.

Impermanent buildings, which were often architecturally unique from region to region, continue to influence American architecture today. In his summary, "The World of Textiles", North Carolina State's Tushar Ghosh provides one example: the Denver International Airport's roof is a fabric structure that was influenced by and/or resembles the tipis of local cultures. In writing about Evergreen State College, Lloyd Vaughn lists an example of very different native architecture that also influenced contemporary building: the Native American Studies program is housed in a modern-day longhouse derived from pre - Columbian Pacific Northwest architecture.

11 - Europe to 1600 :

11 – 1 - Medieval architecture :

Surviving examples of medieval secular architecture mainly served for defense. Castles and fortified walls provide the most notable remaining non-religious examples of medieval architecture. Windows gained a cross-shape for more than decorative purposes: they provided a perfect fit for a crossbowman to safely shoot at invaders from inside. Crenellation walls (battlements) provided shelters for archers on the roofs to hide behind when not shooting.

11 – 1 – 1 - Pre – Romanesque :

Western European architecture in the Early Middle Ages may be divided into Early Christian and Pre-Romanesque, including Merovingian, Carolingian, Ottonian, and Asturian. While these terms are problematic, they nonetheless serve adequately as entries into the era. Considerations that enter into histories of each period include Trachtenberg's "historicising" and "modernising" elements, Italian versus northern, Spanish, and Byzantine elements, and especially the religious and political maneuverings between kings, popes, and various ecclesiastic officials.

11 – 1 – 2 – Romanesque :

Romanesque, prevalent in medieval Europe during the 11th and 12th centuries, was the first pan-European style since Roman Imperial Architecture and examples are found in every part of the continent. The term was not contemporary with the art it describes, but rather, is an invention of modern scholarship based on its similarity to Roman Architecture in forms and materials. Romanesque is characterized by a use of round or slightly pointed arches, barrel vaults, and cruciform piers supporting vaults.

11 – 1 – 3 – Gothic :

The various elements of Gothic architecture emerged in a number of 11th and 12th century building projects, particularly in the Île de France area, but were first combined to form what we would now recognise as a distinctively Gothic style at the 12th century abbey church of Saint-Denis in Saint-Denis, near Paris. Verticality is emphasized in Gothic architecture, which features almost skeletal stone structures with great expanses of glass, pared-down wall surfaces supported by external flying buttresses, pointed arches using the ogive shape, ribbed stone vaults, clustered columns, pinnacles and sharply pointed spires. Windows contain beautiful stained glass, showing stories from the Bible and from lives of saints. Such advances in design allowed cathedrals to rise taller than ever, and it became something of an inter-regional contest to build a church as high as possible.

Comparison of Medieval European religious architecture :

Byzantine architecture: Church of Hagia Irene in Istanbul

Norse architecture: *Borgund Stave Church, Norway*

Romanesque architecture: *St. Gereon's Basilica, Cologne, Germany*

Russian Orthodox architecture: *Church of the Intercession on the Nerl in Russia*

Gothic architecture: *Notre-Dame de Chartres, France (1194–1260)* -

11 – 2 - Renaissance architecture :

The Palazzo Farnese, Rome.

The Renaissance often refers to the Italian Renaissance that began in the 14th century, but recent research has revealed the existence of similar movements around Europe before the 15th century; consequently, the term "Early Modern" has gained popularity in describing this cultural movement. This period of cultural rebirth is often credited with the restoration of scholarship in the Classical Antiquities and the absorption of new scientific and philosophical knowledge that fed the arts.

The development from Medieval architecture concerned the way geometry mediated between the intangibility of light and the tangibility of the material as a way of relating divine creation to mortal existence. This relationship was changed in some measure by the invention of Perspective which brought a sense of infinity into the realm of human comprehension through the new representations of the horizon, evidenced in the expanses of space opened up in Renaissance painting, and helped shape new humanist thought.

Perspective represented a new understanding of space as a universal, *a priori* fact, understood and controllable through human reason. Renaissance buildings therefore show a different sense of conceptual clarity, where spaces were designed to be understood in their entirety from a specific fixed viewpoint. The power of Perspective to universally represent reality was not limited to *describing* experiences, but also allowed it to anticipate experience itself by projecting the image back into reality.

The Renaissance spread to France in the late 15th century, when Charles VIII returned in 1496 with several Italian artists from his conquest of Naples. Renaissance chateaux were built in the Loire Valley, the earliest example being the Château d'Amboise, and the style became dominant under Francis I (1515–47). (See Châteaux of the Loire Valley). The Château de Chambord is a combination of Gothic structure and Italianate ornament, a style which progressed under architects such as Sebastiano Serlio, who was engaged after 1540 in work at the Château de Fontainebleau.

Architects such as Philibert Delorme, Androuet du Cerceau, Giacomo Vignola, and Pierre Lescot, were inspired by the new ideas. The southwest interior facade of the Cour Carree of the Louvre in Paris was designed by Lescot and covered with exterior carvings by Jean Goujon. Architecture continued to thrive in the reigns of Henri II and Henri III . In England the first great exponent of Renaissance architecture was Inigo Jones (1573 – 1652) , who had studied architecture in Italy where the influence of Palladio was very strong. Jones returned to England full of enthusiasm for the new movement and immediately began to design such buildings as the Queen's House at Greenwich in 1616 and the Banqueting House at Whitehall three years later. These works with their clean lines and symmetry, were revolutionary in a country still enamored with mullion windows, crenellations and turrets.

12 - European and colonial architecture :

Sicilian Baroque: Basilica della Collegiata, Catania, Sicily, Italy.

With the rise of various European colonial empires from the 16th century onward through the early 20th century, the new stylistic trends of Europe were exported to or adopted by locations around the world, often evolving into new regional variations.

12 - 1 - Baroque architecture :

The periods of Mannerism and the Baroque that followed the Renaissance signaled an increasing anxiety over meaning and representation. Important developments in science and philosophy had separated mathematical representations of reality from the rest of culture, fundamentally changing the way humans related to their world through architecture . It would reach its most extreme and embellished development under the decorative tastes of Rococo.

Plate from Colen Campbell's Vitruvius Brittanicus.

12 - 2 - Return to Classicism :

In the late 17th and 18th centuries, the works and theories of Andrea Palladio (from 16th century Venice) would again be interpreted and adopted in England, spread by the English translation of his I Quattro Libri dell ' Architettura, and pattern books such as *Vitruvius Brittanicus* by Colen Campbell. This Palladian Architecture and continued classical imagery would in turn go on to influence Thomas Jefferson and other early architects of the United States in their search for a new national architecture.

By the mid - 18th century, there tended to be more restrained decoration and usage of authentic classical forms than in the Baroque, informed by increased visitation to classical ruins as part of the Grand Tour, coupled with the excavations of Pompeii and Herculaneum.

12 - 3 - Revivalism and Orientalism

The 19th Century was dominated by a wide variety of stylistic revivals, variations, and interpretations.

12 - 4 – Beaux - Arts architecture :

Palais Garnier is a cornerpiece of Beaux - Arts architecture characterized by Émile Zola as "the opulent bastard of all styles".

Beaux - Arts architecture denotes the academic classical architectural style that was taught at the École des Beaux Arts in Paris. The *style "Beaux - Arts"* is above all the cumulative product of two and a half centuries of instruction under the authority, first of the Académie royale d'architecture, then, following the Revolution, of the Architecture section of the Académie des Beaux-Arts. The organization under the Ancien Régime of the competition for the Grand Prix de Rome in architecture, offering a chance to study in Rome, imprinted its codes and esthetic on the course of instruction, which culminated during the Second Empire (1850–1870) and the Third Republic that followed. The style of instruction that produced Beaux - Arts architecture continued without a major renovation until 1968 .

12 - 5 - Art Nouveau :

Around 1900 a number of architects around the world began developing new architectural solutions to integrate traditional precedents with new social demands and technological possibilities. The work of Victor Horta and Henry van de Velde in Brussels, Antoni Gaudí in Barcelona, Otto Wagner in Vienna and Charles Rennie Mackintosh in Glasgow, among many others, can be seen as a common struggle between old and new.

13 - Early Modern architecture :

Early Modern architecture began with a number of building styles with similar characteristics, primarily the simplification of form and the elimination of ornament, that first arose around 1900. By the 1940s these styles had largely consolidated and been identified as the International Style.

The exact characteristics and origins of modern architecture are still open to interpretation and debate. An important trigger appears to have been the maxim credited to Louis Sullivan: "form follows function". **Functionalism**, in architecture, is the principle that architects should design a building based on the purpose of that building. This statement is less self - evident than it first appears, and is a matter of confusion and controversy within the profession, particularly in regard to modern architecture .

13 - 1 - Expressionist architecture :

Goetheanum by Rudolf Steiner in 1923
Main article: Expressionist architecture

Expressionist architecture was an architectural movement that developed in Northern Europe during the first decades of the 20th century in parallel with the expressionist visual and performing arts.

The style was characterized by an early- modernist adoption of novel materials, formal innovation, and very unusual massing, sometimes inspired by natural biomorphic forms, sometimes by the new technical possibilities offered by the mass production of brick, steel and especially glass. Many expressionist architects fought in World War I and their experiences, combined with the political turmoil and social upheaval that followed the German Revolution of 1919, resulted in a utopian outlook and a romantic socialist agenda.[13] Economic conditions severely limited the number of built commissions between 1914 and the mid 1920s , resulting in many of the most important expressionist works remaining as projects on paper, such as Bruno Taut's *Alpine Architecture* and Hermann Finsterlin's *Formspiels*. Ephemeral exhibition buildings were numerous and highly significant during this period. Scenography for theatre and films provided another outlet for the expressionist imagination , and provided supplemental incomes for designers attempting to challenge conventions in a harsh economic climate.

13 - 2 - Art Deco :

13 - 3 - International Style :

The Glass Palace, a celebration of transparency , in Heerlen , The Netherlands (1935)

The International style was a major architectural trend of the 1920s and 1930s. The term usually refers to the buildings and architects of the formative decades of modernism, before World War II. The term had its origin from the name of a book by Henry-Russell Hitchcock and Philip Johnson which identified, categorised and expanded upon characteristics common to modernism across the world. As a result, the focus was more on the stylistic aspects of modernism. The basic design principles of the International Style thus constitute part of modernism.

The ideas of Modernism were developed especially in what was taught at the German Bauhaus School in Weimar (from 1919), Dessau (between 1926–32) and finally Berlin between 1932–33, under the leadership first of its founder Walter Gropius, then Hannes Meyer, and finally Ludwig Mies van der Rohe. Modernist theory in architecture resided in the attempt to bypass the question of what style a building should be built in, a concern that had overshadowed 19th-century architecture, and the wish to reduce form to its most minimal expression of structure and function. In the USA, Philip Johnson and Henry-Russell Hitchcock treated this new phenomenon in 1931 as if it represented a new style - the International Style, thereby misrepresenting its primary mission as merely a matter of eliminating traditional ornament. The core effort to pursue Modern architecture as an abstract, scientific programme was more faithfully carried forward in Europe, but issues of style always overshadowed its stricter and more puritan goals, not least in the work of Le Corbusier.

14 - Contemporary architecture :

14 - 1 - Modern architecture ;

Modern architecture is generally characterized by simplification of form and creation of ornament from the structure and theme of the building. It is a term applied to an overarching movement, with its exact definition and scope varying widely.[16] Modern architecture has continued into the 21st century as a contemporary style, especially for corporate office buildings. In a broader sense, modern architecture began at the turn of the 20th century with efforts to reconcile the principles underlying architectural design with rapid technological advancement and the modernization of society. It would take the form of numerous movements, schools of design, and architectural styles, some in tension with one another, and often equally defying such classification.

14 - 2 - Critical regionalism :

Critical regionalism is an approach to architecture that strives to counter the place lessens and lack of meaning in Modern Architecture by using contextual forces to give a sense of place and meaning. The term critical regionalism was first used by Alexander Tzonis and Liane Lefaivre and later more famously by Kenneth Frampton.

The Sydney Opera House - designed to evoke the sails of yachts in Sydney harbour

Frampton put forth his views in *"Towards a Critical Regionalism: Six points of an architecture of resistance."* He evokes Paul Ricœur's question of "how to become modern and to return to sources; how to revive an old, dormant civilization and take part in universal civilization". According to Frampton, critical regionalism should adopt modern architecture critically for its universal progressive qualities but at the same time should value responses particular to the context. Emphasis should be on topography, climate, light, tectonic form rather than scenography and the tactile sense rather than the visual. Frampton draws from phenomenology to supplement his arguments.

14 - 3 - Postmodern architecture :

1000 de La Gauchetière, with ornamented and strongly defined top, middle and bottom. Contrast with the modernist Seagram Building and Torre Picasso.

Postmodern architecture is an international style whose first examples are generally cited as being from the 1950s, and which continues to influence present-day architecture. Postmodernity in architecture is generally thought to be heralded by the return of "wit, ornament and reference" to architecture in response to the formalism of the International Style of modernism. As with many cultural movements, some of postmodernism's most pronounced and visible ideas can be seen in architecture. The functional and formalized shapes and spaces of the modernist movement are replaced by unapologetically diverse aesthetics: styles collide, form is adopted for its own sake, and new ways of viewing familiar styles and space abound.

Classic examples of modern architecture are the Lever House and the Seagram Building in commercial space, and the architecture of Frank Lloyd Wright or the Bauhaus movement in private or communal spaces. Transitional examples of postmodern architecture are the Portland Building in Portland and the Sony Building (New York City) (originally AT&T Building) in New York City, which borrows elements and references from the past and reintroduces color and symbolism to architecture. A prime example of inspiration for postmodern architecture lies along the Las Vegas Strip, which was studied by Robert Venturi in his 1972 book *Learning from Las Vegas* celebrating the strip's ordinary and common architecture. Venturi opined that "Less is a bore", inverting Mies Van Der Rohe's dictum that "Less is more".

14 – 4 - Deconstructivist architecture :

Libeskind's Imperial War Museum North in Manchester comprises three apparently intersecting curved volumes.

Deconstructivism in architecture is a development of postmodern architecture that began in the late 1980s. It is characterized by ideas of fragmentation, non-linear processes of design, an interest in manipulating ideas of a structure's surface or skin, and apparent non - Euclidean geometry , (i.e., non-rectilinear shapes) which serve to distort and dislocate some of the elements of architecture, such as structure and envelope. The finished visual appearance of buildings that exhibit the many deconstructivist "styles" is characterised by a stimulating unpredictability and a controlled chaos.

Important events in the history of the deconstructivist movement include the 1982 Parc de la Villette architectural design competition (especially the entry from Jacques Derrida and Peter Eisenman and Bernard Tschumi's winning entry), the Museum of Modern Art's 1988 *Deconstructivist Architecture* exhibition in New York, organized by Philip Johnson and Mark Wigley, and the 1989 opening of the Wexner Center for the Arts in Columbus, designed by Peter Eisenman. The New York exhibition featured works by Frank Gehry, Daniel Libeskind, Rem Koolhaas, Peter Eisenman, Zaha Hadid, Coop Himmelblau, and Bernard Tschumi. Since the exhibition, many of the architects who were associated with Deconstructivism have distanced themselves from the term. Nonetheless, the term has stuck and has now, in fact, come to embrace a general trend within contemporary architecture.

History of Construction

***Church in Kizhi**, Russia is listed as UNESCO world heritage site as building constructed entirely out of wood, without a single nail*

Contents

1 – Introduction :

People have constructed buildings and other structures since prehistory, including bridges, amphitheatres, dams, electricity pylons, roads and canals. Building materials in present use have a long history and some of the structures built thousands of years ago can still be regarded as remarkable. The history of construction overlaps that of structural engineering. To understand why things were constructed the way they were, we also need to rely on archaeology to record the form of the parts that survive and the tools used, and other branches of history and architecture to investigate how the builders lived and recorded their accomplishments.

2 - Chronological development :

The history of construction is a complex subject encompassing the history of building materials, the history of engineering, the history of building techniques, economic and social history of builders and workmen, the history of construction machinery and temporary works, etc. Each of these has a complex literature devoted to it.

2 – 1 - Neolithic construction :

Neolithic buildings in Skara Brae ,
Skara Brae is listed as a UNESCO world heritage site

The first bridges made by humans were probably wooden logs placed across a stream. The first buildings were simple huts, tents and shelters meant to suit the basic needs of protection from the elements, built by their inhabitants . The very simplest shelters, tents, leave no traces. Because of this, what little we can say about very early construction is mostly conjecture and based on what we know about the way nomadic hunter-gatherers and herdsmen in remote areas build shelters today. The absence of metal tools placed limitations on the materials that could be worked, but it was still possible to build quite elaborate stone structures with ingenuity using dry-stone-walling techniques (see the stone structures at Skara Brae. The first mud bricks, formed with the hands rather than wooden moulds, belong to the late Neolithic period and were found in Jericho. One of the largest structures of this period was the Neolithic long house. In all cases of timber structures in these very early cultures, only the very lowest parts of the walls and post-holes are unearthed in archaeological excavations, making reconstruction of the upper parts of these buildings purely conjectural. The most remarkable Neolithic structure in Western Europe is the iconic monument known as Stonehenge, regarded by some archaeologists as displaying methods of timber construction translated into stone . The now ruinous remains include massive sandstone lintels which were located on supporting uprights by means of mortise and tenon joints; the lintels themselves being end-jointed by the use of toggle joints (tongue and groove). There is also evidence of prefabrication of the stonework; the symmetrical geometric arrays of stone clearly indicate that the builders of Stonehenge had mastered sophisticated surveying methods.

2 – 2 - Construction in ancient Mesopotamia :

Ziggurat of Ur

The earliest large-scale buildings for which evidence survives have been found in ancient Mesopotamia. The smaller dwellings only survive in traces of foundations, but the later civilisations built very sizeable structures in the forms of palaces, temples and ziggurats and took particular care to build them out of materials that last, which has ensured that very considerable parts have remained intact. Major technical achievement is evidenced by the construction of great cities such as Uruk and Ur. The Ziggurat of Ur is an outstanding building of the period, despite major reconstruction work. Another fine example is the ziggurat at Chogha Zanbil in modern Iran.

2 – 2 - 1 - Materials :

Detail of the Ishtar Gate showing the exceptionally fine glazed brickwork of the later period

The chief building material was the mud brick, formed in wooden moulds (adobe) . Bricks varied widely in size and format from small bricks that could be lifted in one hand to ones as big as large paving slabs. Rectangular and square bricks were both common. They were laid in virtually every bonding pattern imaginable and used with considerable sophistication. Drawings survive on clay tablets from later periods showing that buildings were set out on brick modules. By 3500 BC, bricks were also being fired and surviving records show a very complex division of labour into separate tasks and trades . Life in general was governed by complex ritual and this extended to rituals for setting-out buildings and moulding the first bricks. Contrary to popular belief the arch was not invented by the Romans, but was used in these civilizations . The later Mesopotamian civilizations, particularly Babylon and thence Susa, developed glazed brickwork to a very high degree, decorating the interiors and exteriors of their buildings with glazed brick reliefs, examples of which survive in the Tehran archaeological museum, the Louvre Museum in Paris and the Pergamon Museum in Berlin.

Babylon,the archaeological site in 1932, before major reconstruction work undertaken by Sadam Hussein

2 – 2 - Construction in ancient Egypt :

Karnak, Hypostyle hall

Aerial view of the Ramasseum
in Thebes with its associated adobe structures

As opposed to the cultures of ancient Mesopotamia which built in brick, the pharaohs of Egypt built huge structures in stone. The arid climate has preserved much of the ancient buildings.

2 – 3 - 1 - Materials :

Adobe (sun - baked mud brick) construction was used for ancillary buildings and normal houses in ancient times and is still commonly used in rural Egypt. The hot , dry climate was ideal for mud – brick , which tends to wash away in the rain. The Ramesseum in Thebes, Egypt (Luxor) provides one of the finest examples of mud brick construction. Extensive storehouses with mud-brick vaults also survive , all constructed with sloping courses to avoid the need for formwork.The grandest buildings were constructed in stone, often from massive masonry blocks. The techniques used to move massive blocks used in pyramids and temples have been subject to extensive debate. Some authors have suggested that the larger blocks may not be cut stone but fabricated with concrete .

2 – 3 - 2 - Technology :

Although the Egyptians achieved extraordinary feats of engineering, they appear to have done so with relatively primitive technology. As far as is known they did not use wheels or pulleys. They transported massive stones over great distances using rollers, ropes and sledges hauled by large numbers of slaves. There are no surviving Egyptian manuals so there has been considerable speculation on how stones were lifted to great heights and obelisks erected. Most theories centre on the use of ramps.

2 – 3 - 3 - Outstanding Achievements :

The pyramids are chiefly impressive for their enormous size and the staggering manpower that must have been employed in their construction. The largest is the Great Pyramid of Giza which remained the tallest structure in the world for 3800 years . The engineering problems involved were chiefly to do with the transport of blocks, sometimes over long distances, their movement into location and exact alignment. It is now generally agreed that the skilled building workers were respected and well treated, but undoubtedly very large numbers of labourers were necessary to provide the brute force.

Karnak , Hypostyle hall

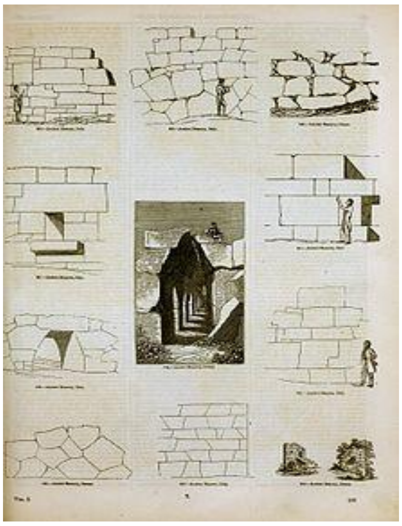
The methods used in the construction of the pyramids have been the subject of considerable research and discussion (see: Egyptian pyramid construction techniques).

Great Pyramid of Giza,
the tallest building in the world for over 3800 years

Menkaures Pyramid, Giza

2 – 4 - Construction in ancient Greece :

The ancient Greeks, like the Egyptians and the Mesopotamians , tended to build most of their common buildings out of mud brick, leaving no record behind them. However very many structures do survive, some of which are in a very good state of repair, although some have been partly reconstructed or re-erected in the modern era. The most dramatic are the Greek Temples.



An illustration showing masonry techniques of ancient Greece and Rome .

No timber structures survive (roofs , floors etc .) , so our knowledge of how these were put together is purely conjectural. The spans are, in the main, limited and suggest very simple beam and post structures spanning stone walls.

Fire clay was mainly restricted to roofing tiles and associated decorations, but these were quite elaborate. Fired bricks were not commonly employed. Very prominent buildings were roofed in stone tiles, which mimicked the form of their terracotta counterparts. While later cultures tended to construct their stone buildings with thin skins of finished stones over rubble cores, the Greeks tended to build out of large cut blocks, joined with metal cramps. This was a slow, expensive and laborious process which limited the number of buildings that could be constructed. The metal cramps often failed through corrosion.

Building structures used a simple beam and column system without vaults or arches, which based strict limits on the spans that could achieved. However, the Greeks did construct Arch Bridges.

Greek mathematics was technically advanced and we know for certain that they employed and understood the principles of pulleys, which would have enabled them to build gibs and cranes to lift heavy stonework to the upper parts of buildings. Their surveying skills were exceptional, enabling them to set out the incredibly exact optical corrections of buildings like the Parthenon, although the methods used remain a mystery. Simpler decoration, such as fluting on columns, was simply left until the drums of the columns were cut in place . The ancient Greeks never developed the strong mortars which became an important feature of Roman construction.

2 – 5 - Roman construction :

The Baths of Caracalla

Reconstructed Roman treadwheel crane at Bonn, Germany

The Pantheon in Rome looking up inside the concrete dome.

In striking contrast to previous cultures, an enormous amount is known about Roman building construction. A very large amount survives, including complete intact buildings like the Pantheon, Rome and very well preserved ruins at Pompeii and Herculaneum. We also have the first surviving treatise on architecture by Vitruvius which includes extensive passages on construction techniques.

2 – 5 – 1 – Materials :

The great Roman breakthrough was the development of hydraulic lime mortar. Previous cultures had used lime mortars but by adding volcanic ash the Romans managed to make a mortar that would harden under water. This provided them with a cheap material for bulk walling. They used brick or stone to build the outer skins of the wall and then filled the cavity with massive amounts of concrete, effectively using the brickwork as permanent shuttering. The concrete, being formed of nothing more than rubble and mortar was cheap and very easy to produce, requiring relatively unskilled labour, enabling the Romans to build on an unprecedented scale. They not only used it for walls but also to form arches, barrel vaults and domes, which they built over huge spans. The Romans developed systems of hollow pots for making their domes and sophisticated heating and ventilation systems for their thermal baths. Glass was commonly used in windows.

2 – 5 – 2 - Organization of Labour :

The Romans had trade guilds. Most construction was done by slaves or freed men. The use of slave labour undoubtedly cut costs and was one of the reasons for the scale of some of the structures. The Romans placed a considerable emphasis in building their buildings extremely fast, usually within two years. For very large structures the only way this could be achieved was by the application of vast numbers of workers to the task.

2 – 5 – 3 – Technology :

Vitruvius gives details of many Roman machines. The Romans developed sophisticated timber cranes allowing them to lift considerable weights to great heights. The upper limit of lifting appears to have been about 100 tonnes. Trajan's column in Rome contains some of the largest stones ever lifted in a Roman building, and engineers are still uncertain exactly how it was achieved.

A list of the longest, highest and deepest Roman structures can be found in the List of ancient architectural records. Roman building ingenuity extended over bridges , aqueducts , and covered amphitheatres. Their sewerage and water-supply works were remarkable and some systems are still in operation today. The only aspect of Roman construction for which very little evidence survives is the form of timber roof structures, none of which seem to have survived intact. Possibly, triangulated roof trusses were built, this being the only conceivable way of constructing the immense spans achieved, the longest exceeding 30 meters .

2 – 6 – Medieval Construction :

Bodiam Castle, England

Notre Dame , Paris

Milan Cathedral, Italy

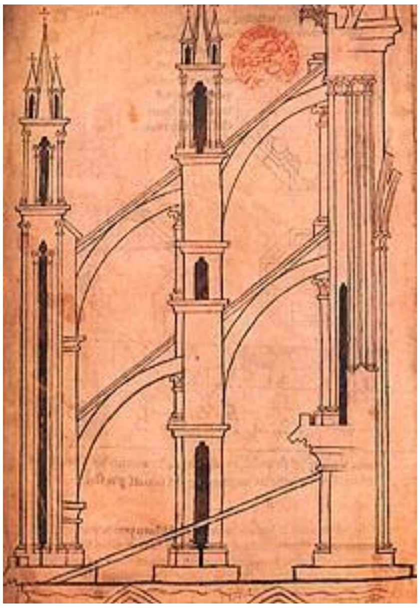
In the Middle Ages of Europe fortifications, castles and cathedrals were the greatest construction projects. The Roman building techniques were lost. (But Roman techniques, including the use of iron ring-beams, would appear to have been used in the Palatine Chapel at Aachen, c. 800 AD, where it is believed builders from the Langobard Kingdom in northern Italy contributed to the work .

2 – 6 – 1 – Materials :

Most buildings in Northern Europe were constructed of timber until c. 1000 AD. In Southern Europe adobe remained predominant. Brick continued to be manufactured in Italy throughout the period 600-1000 AD but elsewhere the craft of brick making had largely disappeared and with it the methods for burning tiles. Roofs were largely thatched. Houses were small and gathered around a large communal hall. Monasticism spread more sophisticated building techniques. The Cistercians may have been responsible for reintroducing brick making to the area from Holland, through Denmark and Northern Germany to Poland leading to Backsteingotik. Brick remained the most popular prestige material in these areas throughout the period. Elsewhere buildings were typically in timber or where it could be afforded, stone. Medieval stone walls were constructed using cut blocks on the outside of the walls and rubble infill, with weak lime mortars. The poor hardening properties of these mortars were a continual problem, and the settlement of the rubble filling of Romanesque and Gothic walls and piers is still a major cause for concern.

2 – 6 – 2 – Design :

There were no standard textbooks on building in the Middle Ages. Master craftsmen transferred their knowledge through apprenticeships and from father to son. Trade secrets were closely guarded, as they were the source of a craftsman's livelihood. Drawings only survive from the later period. Parchment was too expensive to be commonly used and paper did not appear until the end of the period. Models were used for designing structures and could be built to large scales. Details were mostly designed at full size on tracing floors, some of which survive.



Villard de Honnecourt's drawing of a flying buttress at Reims, ca. AD 1320–1335 (Bibliothèque nationale)

2 – 6 – 3 – Labour :

In general, medieval buildings were built by paid workers. Unskilled work was done by labourers paid by the day. Skilled craftsmen served apprenticeships or learned their trade from their parents. It is not clear how many women were members of a guild holding a monopoly on a particular trade in a defined area (usually within the town walls). Towns were in general very small by modern standards and dominated by the dwellings of a small number of rich nobles or merchants, and by cathedrals and churches.

2 – 6 – 4 – Techniques :

Romanesque buildings of the period 600 - 1100 AD were entirely roofed in timber or had stone barrel vaults covered by timber roofs. The Gothic style of architecture with its vaults, flying buttresses and pointed gothic arches developed in the twelfth century and in the centuries that followed ever more incredible feats of constructional daring were achieved in stone. Thin stone vaults and towering buildings were constructed using rules derived by trial and error. Failures were frequent, particularly in difficult areas such as crossing towers.

The pile driver was invented around 1500.

2 – 6 – 5 – Outstanding technical achievements :

The scale of fortifications and castle building in the Middle Ages was remarkable, but the outstanding buildings of the period were the Gothic cathedrals with thin masonry vaults and walls of glass. Outstanding examples are: Beauvais Cathedral, Chartres Cathedral, King's College Chapel and Notre Dame, Paris.

2 – 7 - Construction in the Renaissance :

The Dome of Santa Maria del Fiore **,**
designed by Filippo Brunelleschi.

The Renaissance in Italy, the invention of moveable type and the Reformation changed the character of building. The rediscovery of Vitruvius had a strong influence. During the Middle Ages buildings were designed by the people that built them. The master mason and master carpenters learnt their trades by word of mouth and relied on experience, models and rules of thumb to determine the sizes of building elements. Vitruvius however describes in detail the education of the perfect architect who, he said, must be skilled in all the arts and sciences. Filippo Brunelleschi was one of the first of the new style of architects. He started life as a goldsmith and educated himself in Roman architecture by studying ruins. He went on to engineer the dome of Santa Maria del Fiore in Florence.

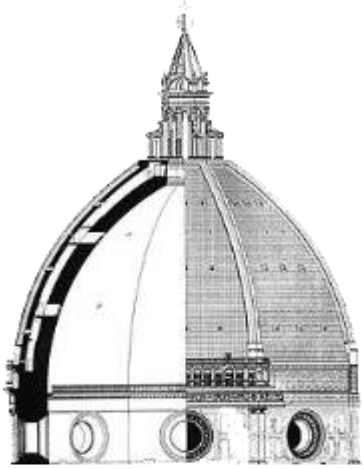
2 – 7 - 1 – Materials :

The major breakthroughs in this period were to do with the technology of conversion. Water mills in most of western Europe were used to saw timber and convert trees into planks. Bricks were used in ever increasing quantities. In Italy the brick makers were organized into guilds although the kilns were mostly in rural areas because of the risk of fire and easy availability of firewood and brick earth. Brick makers were typically paid by the brick, which gave them an incentive to make them too small. As a result, legislation was laid down regulating the minimum sizes and each town kept measures against which bricks had to be compared. An increasing amount of ironwork was used in roof carpentry for straps and tension members. The iron was fixed using forelock bolts. The screw-threaded bolt (and nut) could be made and are found in clock making in this period, but they were labour intensive and thus not used on large structures. Roofing was typically of terracotta roof tiles. In Italy they followed Roman precedents. In northern Europe plain tiles were used. Stone, where available, remained the material of choice for prestige buildings.

2 – 7 - 2 – Design :

The rebirth of the idea of an architect in the Renaissance radically changed the nature of building design. The Renaissance reintroduced the classical style of architecture. Leon Battista Alberti's treatise on architecture raised the subject to a new level, defining architecture as something worthy of study by the aristocracy. Previously it was viewed merely as a technical art, suited only to the artisan. The resulting change in status of architecture and more importantly the architect is key to understanding the changes in the process of design. The Renaissance architect was often an artist (a painter or sculptor) who had little knowledge of building technology but a keen grasp of the rules of classical design. The architect thus had to provide detailed drawings for the craftsmen setting out the disposition of the various parts. This was what we call the process of design, from the Italian word for drawing. Occasionally the architect would get involved in particularly difficult technical problems but the technical side of architecture was mainly left up to the craftsmen. This change in the way buildings were designed had a fundamental difference on the way problems were approached. Where the Medieval craftsmen tended to approach a problem with a technical solution in mind, the Renaissance architect started with an idea of the what the end product needed to look like and then searched around for a way of making it work. This led to extraordinary leaps forward in engineering.

2 – 7 - 3 – Labour :



The structure of the dome of Florence cathedral ,
showing the double skin structure.

Labour in the Renaissance was much the same as in the Middle Ages: buildings were built by paid workers. Unskilled work was done by labourers paid by the day. Skilled craftsmen served apprenticeships or learned their trade from their parents. Craftsmen were organized in guilds which provided a limited form of building regulation in return for members of the guild holding a monopoly on a particular trade in a defined area (usually within the town walls). Towns were in general very small by modern standards and dominated by the dwellings of a small number of rich nobles or merchants and cathedrals and churches.

2 – 7 - 4 - Technical advances :

The wish to return to classical architecture created problems for the Renaissance buildings. The builders did not use concrete and thus comparable vaults and domes had to be replicated in brick or stone. The greatest technical feats were undoubtedly in these areas. The first major breakthrough was Brunelleschi's project for the dome of Santa Maria del Fiore. Brunelleschi managed to devise a way of building a huge dome without formwork, relying instead on the weight of the bricks and the way they were laid to keep them in position and the shape of the dome to keep it standing. The exact way the dome was built is still subject to debate today as it is not possible to take the dome apart to study its construction without destroying it. The dome is a double skin, linked by ribs, with a series of wooden and stone chains around it at intervals to attempt to deal with hoop stresses.

Brunelleschi's dome was completed (up to the base of the lantern) in 1446. Its size was soon surpassed by the dome of St Peter's, built using flying scaffolding supported on the cornices and constructed using two stone shells.

2 – 8 - Construction in the Seventeenth Century :

The seventeenth century saw the birth of modern science which would have profound effects on building construction in the centuries to come. The major breakthroughs were towards the end of the century when architect-engineers began to use experimental science to inform the form of their buildings. However it was not until the eighteenth century that engineering theory developed sufficiently to allow sizes of members to be calculated. Seventeenth-century structures relied strongly on experience, rules of thumb and the use of scale models.

2 – 8 – 1 - Materials and Tools :

The major breakthrough in this period was in the manufacture of glass, with the first cast plate glass being developed in France. Iron was increasingly employed in structures. Christopher Wren used iron hangers to suspend floor beams at Hampton Court Palace, and iron rods to repair Salisbury Cathedral and strengthen the dome of St Paul's Cathedral. Most buildings had stone ashlar surfaces covering rubble cores, held together with lime mortar. Experiments were made mixing lime with other materials to provide a hydraulic mortar, but there was still no equivalent of the Roman concrete. In England, France and Holland, cut and gauged brickwork was used to provide detailed and ornate facades. The triangulated roof truss was introduced to England and used by Inigo Jones and Christopher Wren.

Many tools have been made obsolete by modern technology, but the line gauge, plumb-line, the carpenter's square, the spirit level, the slide-rule and the drafting compass are still in regular use.

2 – 8 – 2 – Methods :

Despite the birth of experimental science, the methods of construction in this period remained largely medieval. The same types of crane that had been used in previous centuries were being still being employed. Flying scaffolds were employed at St Paul's Cathedral, England and in the dome of St Peters, Rome, but otherwise the same types of timber scaffolding that had been in use centuries before were retained. Cranes and scaffolding depended on timber. Complex systems of pulleys allowed comparatively large loads to be lifted, and long ramps were used to haul loads up to the upper parts of buildings.

2 – 9 – Construction in the Eighteenth Century :

The eighteenth century saw the development of many the ideas that had been born in the late seventeenth century. The architects and engineers became increasingly professionalized. Experimental science and mathematical methods began increasingly sophisticated and employed in buildings. At the same time the birth of the industrial revolution saw an increase in the size of cities and increase in the pace and quantity of construction.

2 – 9 – 1 – Materials :

The major breakthroughs in this period were in the use of iron (both cast and wrought). Iron columns had been used in Wren's designs for the House of Commons and were used in several early eighteenth-century churches in London, but these supported only galleries. In the second half of the eighteenth century the decreasing costs of iron production allowed the construction of major pieces of iron engineering. The Iron Bridge at Coalbrookdale (1779) is a particularly notable example. Large-scale mill construction required fire-proof buildings and cast iron became increasingly used for columns and beams to carry brick vaults for floors. The Louvre in Paris boasted an early example of a wrought-iron roof. Steel was used in the manufacture of tools but could not be made in sufficient quantities to be used for building.

Brick production increased markedly during this period. Many buildings throughout Europe were built of brick, but they were often coated in lime render, sometimes patterned to look like stone. Brick production itself changed little. Bricks were moulded by hand and fired in kilns no different to those used for centuries before. Terracotta in the form of Coade stone was used as an artificial stone in the UK.

2 – 10 - Construction in the Nineteenth Century: Industrial Revolution :

The industrial revolution was manifested in new kinds of transportation installations, such as railways, canals and macadam roads. These required large amounts of investment. New construction devices included steam engines, machine tools, explosives and optical surveying.

As steel was mass-produced from the mid-19th century, it was used, in form of I-beams and reinforced concrete. Glass panes also went into mass production, and changed from luxury to every man's property. Plumbing appeared, and gave common access to drinking water and sewage collection.

2 – 11 - Construction in the Twentieth Century :

With the Second Industrial Revolution in the early 20th century, elevators and cranes made high rise buildings and skyscrapers possible, while Heavy equipments and power tools decreased the workforce needed. Other new technologies were prefabrication and computer - aided design.

Trade unions were formed to protect construction workers' interests. Personal protective equipment such as hard hats and earmuffs also came into use.

From the 20th century, governmental construction projects were used as a part of macroeconomic stimulation policies, especially during the Great depression .

In the end of the 20th century, ecology, energy conservation and sustainable development have become more important issues of construction.

3 - Construction History as an Academic Discipline :

There is no established academic discipline of construction history but a growing number of researchers and academics are working in this field, including structural engineers, archaeologists, architects, historians of technology and architectural historians. Although the subject has been studied since the Renaissance and there were a number of important studies in the nineteenth century, it largely went out of fashion in the mid - twentieth century . In the last thirty years there has been an enormous increase in interest in this field, which is vital to the growing practice of building conservation.

3 – 1 - Early Writers on Construction History :

The earliest surviving book detailing historical building techniques is the treatise of the Roman author, Vitruvius, but his approach was neither scholarly nor systematic. Much later, in the Renaissance, Vasari mentions Filippo Brunelleschi's interest in researching Roman building techniques, although if he wrote anything on the subject it does not survive. In the seventeenth century, Rusconi's illustrations for his version of Leon Battista Alberti's treatise explicitly show Roman wall construction but most of the interest in antiquity was in understanding its proportions and detail and the architects of the time were content to build using current techniques. While early archaeological studies and topographic works such as the engravings of Giovanni Battista Piranesi show Roman construction they were not explicitly analytical and much of what they do show is made up.

3 – 2 - Nineteenth Century Studies on Construction History :

In the nineteenth century, lecturers increasingly illustrated their lectures with images of building techniques used in the past and these type of images increasingly appeared in construction text books, such as Rondelet's. The greatest advances however were made by English and French (and later German) architects attempting to understand, record and analyse Gothic buildings. Typical of this type of writing are the works of Robert Willis in England, Viollet-le-Duc in France and Ungewitter in Germany. None of these however were seeking to suggest that the history of construction represented a new approach to the subject of architectural history. August Choisy was perhaps the first author to seriously attempt to undertake such a study.

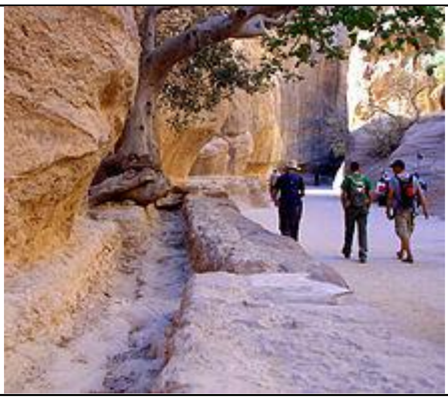
3 – 3 - The Early Twentieth Century Studies of the Construction History :

Santiago Heurta has suggested that it was modernism, with its emphasis on the employment of new materials, that abruptly ended the interest in construction history that appeared to have been growing in the last few decades of the nineteenth century and the early years of the twentieth. With the advent of concrete and steel frame construction, architects, who had been the chief audience for such studies, were no longer as interested as they had been in understanding traditional construction, which suddenly appeared redundant. Very little was thus published between 1920 and 1950. The revival of interest started in archaeology with the studies of Roman construction in the 1950s, but it was not until the 1980s that construction history began to emerge as an independent field.

3 – 4 - The Late Twentieth Century :

By the end of the twentieth century, steel and concrete construction were themselves becoming the subject of historical investigation . The Construction History Society was formed in the UK in 1982. It produces the only academic international journal devoted to the subject annually. The First International Congress on Construction History was held in Madrid in 2003 . This was followed by the Second International Congress in 2006 in Queens College, Cambridge, England and the Third International Congress held in Cottbus in 2009 . The Fourth International Congress is scheduled to be held in Paris in 2012 .

History of Water Supply and Sanitation

	
Tsūjun Bridge, Japan	*Aqueduct in Petra, Jordan.*
	
Green glazed toilet with pigsty model. China, Eastern Han dynasty 25 - 220 CE.	*Pont du Gard, a Roman aqueduct in France*
	
A Roman lead pipe in Bath, England.	*A scarce water Fountain specifically for women*

	
Due to the cost of sewer construction, outhouses have remained in many communities well after the industrial revolution, as here in Brisbane, Australia around 1950.	*Skara Brae a Neolithic village in Orkney, Scotland with home furnishings including water-flushing toilets 3180 BC–2500 BC*

Contents

1 - Ancient age :

During the Neolithic, man dug the first permanent water wells, from where vessels could be filled and carried by hand. The size of human settlements was largely dependent on nearly available water. Pit toilets and potties were the only alternative to defecation in the open, until flush toilets appeared in mid 19th century. Devices such as shadoofs, and sakias have been used to lift water to ground level.

Throughout history people have devised systems to make getting and using water more convenient. The Indus Valley Civilization has early evidence of public water supply and sanitation. The Roman Empire had indoor plumbing, meaning a system of aqueducts and pipes that terminated in homes and at public wells and fountains for people to use. Rome and other nations used lead pipes, often unknowing about lead poisoning . Persian Qanats have been used for water supply and cooling in the Middle East.

2 - Middle and early modern age :

Pail closets, outhouses, and cesspits were used to collect human waste. The use of human waste as fertilizer was especially important in China and Japan, where cattle manure was less available. See toilets in Japan. After the adoption of gunpowder, municipal outhouses became a important source of raw material for the making of saltpeter in European countries . In London, the contents of the city's outhouses were collected every night by commissioned wagons and delivered to the nitrite beds where it was sown into the special soil beds to produce earth rich in mineral nitrates. The nitrate rich-earth is then further processed to produce saltpeter, or potassium nitrate, an important ingredient in black powder .

London water supply infrastructure developed over many centuries from early mediaeval conduits, through major 19th century treatment works built in response to cholera threats, to modern large scale reservoirs. The trap was invented in 1775. Fire hydrants were introduced in the 18th and 19th century.

3 - Industrial age :

The first screw-down water tap was patented in 1845. The germ theory of disease emphasized the need of clean water supply, separated from sewerage. The 1854 Broad Street cholera outbreak in London was a well - known case.

Water towers appeared around the late 19th century, as building height rose, and steam, electric and diesel-powered water pumps became available. As skyscrapers appeared, they needed rooftop water towers.

The technique of purification of drinking water by use of compressed liquefied chlorine gas was developed in 1910 by U.S. Army Major (later Brig. Gen.) Carl Rogers Darnall (1867–1941), Professor of Chemistry at the Army Medical School. Shortly thereafter, Major (later Col.) William J. L. Lyster (1869–1947) of the Army Medical Department used a solution of calcium hypochlorite in a linen bag to treat water. For many decades, Lyster's method remained the standard for U.S. ground forces in the field and in camps, implemented in the form of the familiar Lyster Bag (also spelled Lister Bag) . Darnall's work became the basis for present day systems of municipal water *purification*.

The first successful district heating system was introduced in Lockport, New York, in 1877. Desalination appeared during the late 20th century, and is still limited to a few areas.

4 - Current development :

During the beginning of the 21st Century, especially in areas of urban and suburban population centres, traditional centralized infrastructure have not been able to supply sufficient quantities of water to keep up with growing demand. Among several options that have been managed are the extensive use of desalination technology, this is especially prevalent in coastal areas and in "dry" countries like Australia. Decentralization of water infrastructure has grown extensively as a viable solution including Rainwater harvesting and Stormwater harvesting where policies are eventually tending towards a more rational use and sourcing of water incorporation concepts such as "Fit for Purpose". Fresh water is an objective among the Millennium Development Goals.

Memorial to water utility worker, Omsk, Russia

Hollow - Core Slab

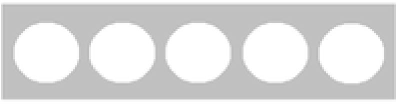


Diagram of a concrete slab of hollow core construction

Contents

1 – Introduction :

A **hollow core slab**, also known as a **voided slab** or **hollow core plank**, is a precast slab of prestressed concrete typically used in the construction of floors in multi-story apartment buildings. The slab has been especially popular in countries where the emphasis of home construction has been on precast concrete, including Northern Europe and socialist countries of Eastern Europe. Precast concrete popularity is linked with low-seismic zones and more economical constructions because of fast building assembly, lower self weight (less material), etc . The precast concrete slab has tubular voids extending the full length of the slab, typically with a diameter equal to the 2/3-3/4 of the slab. This makes the slab much lighter than a massive floor slabs of equal thickness or strength. Reduced weight is important because of transportation cost and less cost of material (concrete). The slabs are typically 120 cm wide with standard thicknesses between 15 cm and 50 cm. The precast concrete I- beams between the holes contain the steel wire rope that provide bending resistance to bending momentum from loads.

Slabs are usually produced in lengths of about 120 meters. The process involves extruding wet concrete along with the prestressed steel wire rope from a moving mold. The continuous slab is then cut by big diamond circular saw according to the lengths (and width) required on blueprint. Factory production provides the obvious advantages of reduced time, labor and training.

To meet modern standards (both hollow-core and massive slab) of soundproofing the floor needs to be covered with a soft floor covering that is able to dampen the sound of footsteps. An alternative is to use a thin "floating" slab of concrete insulated from the voided slabs.

2 - Bridges :

Hollow-core slabs are also used in the construction of bridges. In many cases the slab is molded *in situ*.

Hydraulic Lime

1 – Introduction :

In the context of lime or cement, the term 'hydraulic' means to 'harden under water'. Hydraulic lime can be considered, in terms both of properties and manufacture, as part - way between non - hydraulic lime and OPC. The limestone used contains sufficient quantities of clay and / or silica . The resultant product will contain dicalcium silicate but unlike OPC not tri calcium silicate.

It is slaked enough to convert the calcium oxide to calcium hydroxide but not with sufficient water to react with the dicalcium silicate. It is this *dicalcium silicate* which in combination with water provides the setting properties of hydraulic lime.

Aluminium and magnesium also produce a hydraulic set, and some pozzolans contain these elements.

There are three strength grades for natural hydraulic lime, laid down in the European Norm EN459 ; NHL2 , NHL3.5 and NHL5. These are similar to the old classification of feebly hydraulic, moderately hydraulic and eminently hydraulic, and although different, some people continue to refer to them interchangeably.

2 - Lime with cement :

Addition of lime to cement mortar makes the mixture thicker and stickier while wet. Addition of cement to lime mortar acts as a pozzolan giving some degree of quick set, but this comes at a price, and is **not recommended**.

Three cement & lime mixes have been widely used :

- 1:1:6 is a satisfactory mortar mix for various purposes, but behaves as cement based mortar.
- 1:2:9 has been found to be prone to premature failure, and is no longer recommended
- 3:1 + 5 % cement makes a lime mortar that firms up quickly, avoiding delays to work, but the addition of cement has been found to be associated with premature failures, and the practice is no longer recommended.

1:2:9 and 1:1:6 are frequently mistaken for lime mortars, but are considered cement mortars, as although they contain substantial amounts of lime, their properties are primarily those of cement mortar. 1:1:4 (lime + O.P.C + sand) is the usual mix for the experienced builder. NOTE this calculation is based on weight NOT volume.

Hydraulic Mining

Contents

1 – Introduction :

Hydraulic mining , or **hydraulic king** , is a form of mining that uses high - pressure jets of water to dislodge rock material or move sediment . In the placer mining of gold or tin, the resulting water-sediment slurry is directed through sluice boxes to remove the gold.

2 - Precursor - ground sluicing :

Panoramic view of Las Médulas

Hydraulic mining had its precursor in the practice of ground sluicing, a development of which is also known as "hushing", in which surface streams of water were diverted so as to erode gold-bearing gravels. This was originally used in the Roman empire in the first centuries AD and BC, and expanded throughout the empire wherever alluvial deposits occurred . The Romans used ground sluicing to remove overburden and the gold-bearing debris in Las Médulas of Spain, and Dolaucothi in Britain. The method was also used in Elizabethan Britain for developing lead, tin and copper mines.

2 – 1 - Roman era :

Water was used on a large scale by Roman engineers in the first centuries BC and AD when the Roman empire was expanding rapidly in Europe. Using a process later known as hushing, the Romans stored a large volume of water in a reservoir immediately above the area to be mined; the water was then quickly released. The resulting wave of water removed overburden and exposed bedrock. Gold veins in the bedrock were then worked using a number of techniques, and water power was used again to remove debris. The remains at Las Medulas and in surrounding areas show badland scenery on a gigantic scale owing to hydraulic king of the rich alluvial gold deposits. Las Medulas is now a UNESCO World Heritage site. The site shows the remains of at least seven large aqueducts of up to 30 miles in length feeding large supplies of water into the site. The gold-mining operations were described in vivid terms by Pliny the Elder in his Naturalis Historia published in the first century AD. Pliny was a procurator in Hispania Terraconensis in the 70's and must have witnessed for himself the operations. The use of hushing has been confirmed by field survey and archaeology at Dolaucothi in South Wales, the only known Roman gold mine in Britain.

3 - California Gold Rush Hydraulic Mining :

Hydraulic mining for gold in California, from The Century Magazine
January 1883

The modern form of hydraulic mining, using jets of water directed under very high pressure through hoses and nozzles at gold-bearing upland paleogravels, was first used by Edward Matteson near Nevada City, California in 1853 during the California Gold Rush.[3] Matteson used canvas hose which was later replaced with crinoline hose by the 1860s.[4] In California, hydraulic mining often brought water from higher locations for long distances to holding ponds several hundred feet above the area to be mined. California hydraulic mining exploited gravel deposits, making it a form of placer mining.

Gold miners excavate an eroded bluff with jets of water at a placer mine in Dutch Flat, California sometime between 1857 and 1870.

Early placer miners in California discovered that the more gravel they could process, the more gold they were likely to find. Instead of working with pans, sluice boxes, long toms, and rockers, miners collaborated to find ways to process larger quantities of gravel more rapidly. Hydraulic mining became the largest-scale, and most devastating, form of placer mining. Water was redirected into an ever-narrowing channel, through a large canvas hose, and out through a giant iron nozzle, called a "monitor." The extremely high pressure stream was used to wash entire hillsides through enormous sluices.

By the early 1860s, while hydraulic mining was at its height, small-scale placer mining had largely exhausted the rich surface placers, and the mining industry turned to hard rock (called quartz mining in California) or hydraulic mining, which required larger organizations and much more capital. By the mid-1880s, it is estimated that 11 million ounces of gold (worth approximately US$7.5 billion at mid-2006 prices) had been recovered by hydraulic mining in the California Gold Rush.

3 – 1 - Environmental consequences :

A man leans over a wooden sluice. Rocks line the outside of the wood boards that create the sluice.

While generating millions of dollars in tax revenues for the state and supporting a large population of miners in the mountains, hydraulic mining had a devastating effect on riparian natural environment and agricultural systems in California. Millions of tons of earth and water were delivered to mountain streams that fed rivers flowing into the Sacramento Valley. Once the rivers reached the relatively flat valley, the water slowed, the rivers widened, and the sediment was deposited in the floodplains and river beds causing them to rise, shift to new channels, and overflow their banks, causing major flooding, especially during the spring melt.

Cities and towns in the Sacramento Valley experienced an increasing number of devastating floods, while the rising riverbeds made navigation on the rivers increasingly difficult. Perhaps no other city experienced the boon and the bane of gold mining as much as Marysville. Situated at the confluence of the Yuba and Feather rivers, Marysville was the final "jumping off" point for miners heading to the northern foothills to seek their fortune. Steamboats from San

Francisco, carrying miners and supplies, navigated up the Sacramento River, then the Feather River to Marysville where they would unload their passengers and cargo. Marysville eventually constructed a complex levee system to protect the city from floods and sediment. Hydraulic mining greatly exacerbated the problem of flooding in Marysville and shoaled the waters of the Feather River so severely that few steamboats could navigate from Sacramento to the Marysville docks. The sediment left by such efforts forms the Yuba Goldfields, located near Marysville.

The spectacular eroded landscape left at the site of hydraulic mining can be viewed at Malakoff Diggins State Historic Park in Nevada County, California . A similar landscape can be seen at Las Médulas in northern Spain, where Roman engineers ground sluiced the rich gold alluvial deposits of the river Sil. Pliny the Elder mentions in his Naturalis Historia that Spain had encroached on the sea and local lakes as a result of ground sluicing operations.

3 - 1 – 1 - Legal ramifications :

Vast areas of farmland in the Sacramento Valley were deeply buried by the mining sediment. Frequently devastated by flood waters, farmers demanded an end to hydraulic mining. In the most renowned legal fight of farmers against miners, the farmers sued the hydraulic mining operations and the landmark case of *Edwards Woodruff v. North Bloomfield Mining and Gravel Company* made its way to the United States District Court in San Francisco where Judge Lorenzo Sawyer decided in favor of the farmers in 1884, declaring that hydraulic mining was “a public and private nuisance” and enjoining its operation in areas tributary to navigable streams and rivers. Hydraulic mining was recommenced after 1893 when the United States Congress passed the Camminetti Act which allowed such mining if sediment detention structures were constructed. This led to a number of operations above brush dams and log crib dams. Most of the water-delivery infrastructure had been destroyed by an 1891 flood, so this later stage of mining was carried on at a much smaller scale in California.

4 - Beyond California :

The Oriental Claims near Omeo, Australia were mined between the 1850s and 1900s; hydraulic sluicing left man-made cliffs up to 30 meters high such as seen here throughout the area

Lee Moor china clay pit in Devon showing hydraulic mining

Although often associated with California due to its adoption and widespread use there, the technology was exported widely, to Oregon (Jacksonville in 1856), Colorado (Clear Creek, Central City and Breckenridge in 1860), Montana (Bannack in 1865), Arizona (Lynx Creek in 1868), Idaho (Idaho City in 1863), South Dakota (Deadwood in 1876), Alaska, British Columbia (Canada), and overseas. It was used extensively in Dahlonega, Georgia and continues to be used in developing nations, often with devastating environmental consequences. The devastation caused by this method of mining caused Edwin Carter, the "Log Cabin Naturalist," to switch from mining to collecting wildlife specimens from 1875-1900 in Breckenridge, Colorado, USA.

Hydraulic mining was also used during the Australian gold rushes where it was called hydraulic sluicing. One notable location was at the Oriental Claims near Omeo in Victoria where it was used between the 1850s and early 1900s, with abundant evidence of the damage still being visible today.

Hydraulic mining was used extensively in the Central Otago Gold Rush that took place in the 1860s in the South Island of New Zealand, where it was also known as *sluicing* . Starting in the 1870s, hydraulic mining became a mainstay of alluvial tin mining on the Malay Peninsula . Hydraulic king was formerly used in Polk County, Florida to mine phosphate rock .

Hydraulic mining is the principal way that kaolinite clay is mined in Cornwall and Devon, in South-West England.

In addition to its use in true mining, hydraulic mining can be used as an excavation technique, principally to demolish hills. For example, the Denny Regrade in Seattle was largely accomplished by hydraulic mining.

5 - Under ground hydraulic mining :

High - pressure water jets have also been used in the underground mining of coal, to break up the coal seam and wash the resulting coal slurry toward a collection point . The high - pressure water nozzle is referred to as the 'hydro monitor'.

6 - In popular culture :

The battle between the old method of pan mining and hydraulic mining is the central theme of the 1985 western film *Pale Rider*. In 1967, an episode of the TV show "Bonanza" entitled "The Greedy Ones" featured The Cartwrights' fight against mining on their land, and specifically how hydraulic mining destroyed a land's worth. Hydraulic mining also appeared in the Waltons

Hydro Demolition

Bridge after hydro demolition to expose first layer of rebar.

Contents

1 – Introduction :

Hydro demolition (also known as hydro blasting , hydro milling , water blasting, and water jetting) is a concrete removal technique which utilizes high - pressure water to remove deteriorated and sound concrete as well as asphalt and grout. This process provides an excellent bonding surface for repair material and new coating applications. First developed in Europe in the 1970s, this technology has become widely accepted for concrete removal and surface preparation throughout Europe and North America.

Hydro demolition is not used as much for demolition as it is for surface restoration and protection projects. When concrete has deteriorated or the reinforcing steel has begun to corrode, it is necessary to remove any unsound concrete and reinforcing bars (rebar) in order to replace it with new concrete and maintain the integrity of the structure. This process has also been used to remove sound concrete that is not compromised in any way. This may be done to install a preventive cathodic protection system, or to remove concrete in structures in which vibration is a concern. Unlike jackhammers, hydro demolition does not produce vibrations throughout a structure and therefore does not introduce micro fractures.

2 - Applications :

Hydro demolition around column

“Hydro demolition can be used for horizontal, vertical, and overhead concrete removal and surface preparation on reinforced and non-reinforced structures. It is effective in removing concrete from around embedded metal elements such as reinforcing steel, expansion joints, anchorages, conduits, shear connectors, and shear studs. Hydro demolition can be used for localized removals where deterioration is confined to small areas and for large area removals in preparation for a bonded overlay. This technology can also be used to remove existing coatings from concrete.”

2 – 1 - Hydro scarification :

Exposed clean aggregate left by scarification

The process of hydro scarification (a.k.a. hydroscarification or scarification) uses ultra high pressure water to remove the top surface of a concrete bridge or road surface. Usually the removal is within 1/4" to 3/4" at the most, but can be of any depth above the top layer of rebar. Removal of this type is done in order to provide a good micro fracture - free surface for bonding with new, sound concrete . Much like applying oil and chips to an asphalt road, this helps extend the useful life of the bridge decking and road surface by delaying the need for complete replacement.

2 – 2 - Partial depth removal :

Partial depth removal involves the selective removal of deteriorated concrete to a certain depth or of a concrete overlay to a depth exceeding 3 / 4" . It is usually done in the case of concrete restoration projects where embedded objects such as rebar are substantial and need to be preserved .

2 – 3 - Full depth removal :

Complete removal of a concrete deck is done when it is too deteriorated to keep , but the structural concrete is adequate or can be easily repaired after the hydro demolition has taken place. Precast concrete beams are often used in structures such as bridges and parking garages. Hydro demolition has been used successfully to remove concrete over these beams, where alternate methods such as jackhammers might have caused fracture of the beams.

3 - Structures :

This technology has been used on the following types of structures: bridge decks and substructures, parking structures, dams and spillways, water treatment facilities, tunnels and aqueducts, nuclear power plants, piers and docks, stadiums, warehouses, transfer stations, and retaining walls.

4 - Safety :

Any process that is powerful enough to cut concrete can cut skin and bone. Operators of hydro demolition equipment are required to wear protective equipment. For robotic hydro demolition equipment, the operator wears steel - toed boots, eye protection, earmuffs and hard hat. Hand lance operators wear steel-toed boots, metatarsals, shin guards and sometimes body armor.

5 - Related processes :

5 – 1 – Hydro cleaning :

Surfaces of all types can get dirty from excessive use and abuse, water and air pollution and general exposure to the elements. These surfaces can be cleaned using high pressure water or high pressure water mixed with an abrasive.

5 – 2 - Coating and sealant surface preparation :

The use of high pressure and ultra high pressure water has been used to clean various coatings on concrete surfaces for the purpose of repair and reapplication. Coatings are used to protect concrete from the elements, rain, salt, and to create a friendlier surface for human use. Concrete can also be covered with carpet or tiles using a heavy duty glue or mastic. High pressure water can be used to clean these materials off when new carpet or tiles are desired.

5 – 3 - Airfield rubber removal :

Commercial and military airfields are required to maintain certain levels of friction on runways to prevent planes from skidding. Runway design, weather and amount of rubber remaining from tire wear all play a role in the level of friction of a landing strip. If too much rubber is present, the friction of the landing strip will be less, requiring more distance for landings, especially in wet weather. High pressure water can be used to remove rubber and restore required friction.

5 – 4 - Cold cutting :

Cold cutting can be used to cut steel, concrete and other materials with the addition of an abrasive feed at the nozzle. Cold cutting is especially useful for cutting of pipes, vessels and tanks in areas where there is a requirement for no sparks or heat generated, such as chemical plants and oil rigs.

Hydro Grossular

1 – Introduction :

Hydro grossular , is a calcium aluminium garnet series (formula: $Ca_3Al_2(SiO_4)_{3-x}(OH)_{4x}$, with hydroxide (OH) partially replacing silica (SiO_4)). The end members of the hydro garnet family (grossular , hibschite , and katoite) depend on the degree of substitution (x) :

- grossular : $x = 0$
- hibschite : $0.2 < x < 1.5$
- katoite : $1.5 < x < 3$.

Hydro grossular is a garnet variety in which a Si^{4+} is missing from a tetrahedral site. Charge balance is maintained by bonding a H^+ to each of the four oxygens surrounding the vacant site.

Hydrogrossular is found in massive crystal habit, sometimes grown in with idocrase.

Hydro grossular is translucent to opaque, and found in green to bluish green, pink, white, and gray. The cause of the green color is chromium, and possibly iron. Pink hydro grossular is caused by the presence of manganese. Hydrogrossular may have dark gray to black small inclusions.[1] It has similarities to jade, and has the misnomers *Transvaal jade*, and *African jade*.

Hydro grossular is sometimes used as a gemstone, being cabochon cut, or made into beads. Sources for green and pink hydro grossular are South Africa, Canada, and the United States. White hydro grossular is sourced from Burma and China.

Category	Silicate mineral
Chemical Formula	$Ca_3\ Al_2\ (SiO_4)_{3-x}\ (OH)_{4x}$
Color	green to bluish green, pink, white, gray
Crystal system	cubic
Mohs scale hardness	7 - 7.5
Luster	vitreous
Specific gravity	4.15 (+.05, -.03)
Polish luster	vitreous to sub adamantine
Optical properties	Single refractive , anomalous aggregate reaction
Refractive index	1.810 (+.004, -.020)
Ultraviolet fluorescence	inert
Absorption spectra	dark green hydro grossular often shows cutoff below 460nm. Other color stones may show line around 463nm, indicating some idocrase content

Hydroxy Ethyl Starch

Contents

1 – Introduction :

Hydroxy ethyl starch (HES / HAES) is a nonionic starch derivative. It is one of the most frequently used volume expander under the trade names **Hespan** by B. Braun Medical Inc. and **Voluven** or **Volulyte** by Fresenius Kabi.

2 - Therapeutic use :

An intravenous solution of hydroxy ethyl starch is used to prevent shock following severe blood loss caused by trauma, surgery, or some other problem. It increases the blood volume, allowing red blood cells to continue to deliver oxygen to the body. During 2010 / 11 a large number of research papers associated with a single author were retracted for ethical reasons and this may have an impact on clinical guidelines referring to HES preparations prepared before this date.

3 - Contraindications :

- This product should not be used in people who are hypersensitive or allergic to hydroxy ethyl starch.
- Patients with kidney failure not related to low blood volume and patients on dialysis should avoid this product in high doses which are used for volume expansion.

- Use of hydroxy ethyl starch with normal saline in its preparation is contraindicated in people with severe increases in blood levels of sodium or chloride.
- Patients with intracranial bleeds should not use this product.

4 - Pharmacokinetics :

Different types of hydroxy ethyl starches are typically described by their average molecular weight, typically around 130 to 200 k Da (bearing in mind that there will be a range of different - sized molecules in any given solution) ; and their degree of molar substitution (what proportion of the glucose units on the starch molecule have been replaced by hydroxy ethyl units), typically around 0.35 to 0.5. A solution of hydroxy ethyl starch may further be described by its concentration in % (i.e. grams per 100 ml) . So for example , one commercially available hydroxy ethyl starch (Voluven) is described as 6 % HES 130 / 0.4.

The elimination depends on molar substitution degree. Molecules smaller than the renal threshold (60 –70 kDa) are readily excreted in the urine while the larger ones are metabolized by plasma α– amylase before the degradation products are renally excreted.

5 - Adverse effects :

Anaphylactoid reactions: hypersensitivity, mild influenza-like symptoms, bradycardia , tachycardia, bronchospasm and non-cardiogenic pulmonary edema.

Decrease in hematocrit and disturbances in coagulation. One liter of 6 % solution (Hespan) reduces factor VIII level by 50 % and will prolong aPTT.

May be associated with covering the use of anabolic steroids / EPO for endurance athletes.

HES derivatives with a higher molecular weight (200 kDa) have been demonstrated to have increased rates of acute renal failure and need for renal replacement therapy and to decrease long-term survival when used alone in cases of severe sepsis compared with Ringer Lactate solution (Brunkhorst 2008) . This study specifically used 10 % HES with 0.45- 0.55 substitution grade and molecular weight of 200 kDa (Hemohes) . It also used a regimen without any crystalloids and was criticized for its study design. The same effects have not been observed with HES 130kDa / 0.4. It has been recommended that, since medium-MW HES solutions may be associated with harm, these solutions should not be used routinely for patients with septic shock .

Hydroxy Propyl Cellulose

Contents

1 – Introduction :

Hydroxy propyl cellulose (HPC) is a derivative of cellulose with both water solubility and organic solubility. It is used as a topical ophthalmic protectant and lubricant.

2 - Chemistry :

HPC is an ether of cellulose in which some of the hydroxyl groups in the repeating glucose units have been hydroxy propylated forming - OCH_2CH (OH) CH_3 groups using propylene oxide. The average number of substituted hydroxyl groups per glucose unit is referred to as the degree of substitution (DS). Complete substitution would provide a DS of 3. Because the hydroxy propyl group added contains a hydroxyl group, this can also be etherified during preparation of HPC. When this occurs, the number of moles of hydroxy propyl groups per glucose ring, moles of substitution (MS), can be higher than 3.

Because cellulose is very crystalline, HPC must have an MS about 4 in order to reach a good solubility in water. HPC has a combination of hydrophobic and hydrophilic groups, so it has a lower critical solution temperature (LCST) at 45 °C. At temperatures below the LCST, HPC is readily soluble in water; above the LCST, HPC is not soluble.

HPC forms liquid crystals and many mesophases according to its concentration in water. Such mesophases include isotropic, anisotropic, nematic and cholesteric. The last one gives many colors such as violet, green and red.

3 - Uses :

Lacrisert , manufactured by Aton Pharma, is a formulation of HPC used for artificial tears. It is used to treat medical conditions characterized by insufficient tear production such as kerato conjunctivitis sicca) , recurrent corneal erosions, decreased corneal sensitivity, exposure and neuroparalytic keratitis. HPC is also used as a lubricant for artificial eyes.

As a food additive, HPC is used as a thickener, a low level binder and as an emulsion stabilizer with E number E463. In pharmaceuticals it is used as a disintegrant , and a binder, in tablets.

HPC is used as a sieving matrix for DNA separations by capillary and microchip electrophoresis.

HPC is the main ingredient in Cellugel which is used in book conservation. Cellugel is described as "A safe, penetrating consolidant for leather book covers affected by red rot" and is produced by Preservation Solutions.

Hyper tufa

Hyper tufa planters

Contents

1 – Introduction :

Hyper tufa is an anthropic rock made from various aggregates bonded together using Portland cement.

Hypertufa is intended as a manufactured substitute for natural tufa , which is a slowly precipitated lime stone rock ; being very porous, it is favorable for plant growth.

Hypertufa is popular for making garden ornaments, pots and land forms. Hypertufa is relatively light compared with terracotta or traditional concrete and can withstand harsh winters, at least down to −30 °C .

Hypertufa was invented for use in alpine gardens. Alpine gardeners formerly used antique animal watering troughs, which became rare and expensive.

2 - Composition :

Aggregates are generally *Sphagnum* (peat moss) , sand , and perlite or vermiculite . Hyper tufa made with the classic proportions for mortar (1 part cement: 3 parts aggregate) has a composition of

- 3 parts Type I Portland cement
- 4 parts *Sphagnum*
- 5 parts perlite

or 3 parts cement : 9 parts aggregate

To increase structural strength and longevity, polymer fibers, liquid acrylic , and fiber glass may be incorporated into the mixture, along with various grades of sand, pebbles, and crushed rock which add to the final object's overall strength and stone-like appearance though they increase its weight. Powdered concrete dyes (in small amounts) also tint the hypertufa to resemble natural rock .

3 - Manufacture :

After adding water to the mixture, it is packed into a previously constructed mold, then sealed or covered in plastic and allowed to cure for 1- 4 weeks . After this it is removed from the plastic, rinsed thoroughly, and allowed to sit exposed to the elements for several more weeks to reduce its other wise - toxic surface alkalinity. It can then be used to hold plants .

Incinerator Bottom Ash

1 – Introduction :

Incinerator bottom ash (IBA) is a form of ash produced in incineration facilities. This material is discharged from the moving grate of municipal solid waste incinerators. Following combustion the ash typically has a small amount of ferrous metals contained within it. This ash can be processed to standardize the material and remove contaminants in order for it to be used as an aggregate. Following processing the material can be termed *IBA aggregate* or *processed IBA*. The aggregate uses for the material include:

- Bulk fill
- Asphalt
- Cement bound materials
- Light weight blocks
- Pavement concrete

Alternatively if there are no local markets for the IBA the material is typically disposed of in a landfill.

2 - Risks :

If IBA is used as the aggregate in foam concrete in non-ventilated areas, hydrogen gas deposits may build up during the life span of the material and explode when brought into contact with sources of ignition, such as during cutting with grinding equipment . Suspicion of this has resulted in its use being banned by at least two firms in the US and brought about further investigation by the Health and Safety Executive.

3 - Topics related to waste management :

- Anaerobic digestion
- Composting
- Down cycling
- Eco - industrial park
- Incineration

- Landfill
- Materials recovery facility
- Mechanical biological treatment
- Radioactive waste
- High-level radioactive waste management
- Recycling
- Regift
- Reuse
- Septic tank
- Sewerage
- Sewage regulation and administration
- Up cycling
- Waste
- Waste collection
- Waste hierarchy
- Waste legislation
- Waste management
- Waste management concepts
- Waste sorting
- Waste treatment

Industrial Coating

An **industrial coating** is a paint or coating defined by its protective, rather than its aesthetic properties, although it can provide both.

The most common use of industrial coatings is for corrosion control of steel structures such as offshore platforms, bridges and underground pipelines. Other functions include in tumescent coatings for fire resistance. The most common polymers used in industrial coatings are poly urethane , epoxy and moisture-cure urethane. Another highly common polymer used in industrial coating is a fluoropolymer. There are many types of industrial coatings including inorganic zinc, phosphate, and Xylan and PVD coatings.

NACE International and The Society for Protective Coatings (SSPC) are professional organizations involved in the industrial coatings industry.

Industrial coatings are often composites of various substances. For example Xylan dry - film lubricants are composites of fluoro polymers (typically PTFE, PFA, and FEP) and reinforcing thermo set polyimide and polyamide binder resins initially suspended in a variety of solvents (such as ethyl acetate, xylene, di methl formamide , and N-methyl 2-yrrolidone) .

A typical coating system may include a primer, an intermediate coat, and a top coat. The polymer film acts as a physical barrier between the steel substrate and the corrosive environment such as atmosphere, water and soil. Industrial coatings are also available as garage floor coatings such as epoxy, poly urea , and poly aspartic.

Integrated Framing Assembly

Contents

1 – Introduction :

An **integrated framing assembly (IFA)** is a specialty product in insulating concrete form (ICF) construction, and are also referred to as a CMF (custom metal ICF frame) . First developed in 2006 by Stala Integrated Assemblies, LLC, and thus also known colloquially as "Stala frames," these assemblies were designed particularly for large commercial ICF construction. IFAs' innovative nature has already been recognized by publications in the concrete construction industry, wall and ceiling industry, door and hardware industry,[3] ICF industry, and architecture industry (both in the United States[5] and Canada).

2 - IFA and ICF construction :

As a poured - concrete construction method, ICFs have become increasingly popular due to ICF buildings' energy- efficiency and structural stability. Their primary market has been residential homes, with a popular - level introduction to ICFs even appearing in 2007.[9] Commercial ICF construction has grown considerably, however,[10] and brought with it issues/problems specific to large projects.

3 - IFA and the door and window problem :

IFAs address a particular problem for large commercial ICF construction — door and window openings . Under previous construction methods, contractors used wood, vinyl, or light - weight steel to block out door and window openings while pouring the concrete . On residential projects, with only around 10 to 20 openings, this method sufficed. On larger construction projects, however, these methods of blocking out the openings meet several problems. First, some architects do not like to use organic materials such as wood in commercial construction. Second, concrete often shifts while consolidating, and so the dimensions of each opening must be rechecked. Third, the door or window frame still needed to be installed once the opening was judged plumb and true. Fourth, and drawing the previous points together, on commercial projects such as schools, hospitals, prisons, or barracks with hundreds of door and window openings, the work demanded for each of these processes at each opening has an exponential effect on time and labor consumption .

4 - IFA design :

Engineers and construction industry professionals designed IFAs specifically for large commercial projects in order to solve this door and window problem. As 14 - gage galvanized hollow metal frames, IFAs are installed prior to the pouring of the concrete, are capable of being anchored into the footer, and function as both the method of blocking out the opening and the frame that under previous methods would be installed later. Thus, not only do they keep the opening’s dimensions firm during concrete consolidation, they are immediately ready to receive doors and windows. Door assemblies even come with hardware preps, and most IFAs come with drywall returns for the interior side of the assembly.

Several other elements of IFAs reflect their design for the large commercial ICF construction market. IFAs can meet architectural designs that include sidelites , mullions, view windows, radius frames, etc. IFAs can be used on external walls as well as internal load-bearing walls. Furthermore, IFAs have an optional thermal break for cold- and hot-weather climates . Lastly, IFAs can also meet fire-code requirements for doors in, for example, stairwells in commercial buildings.

5 - IFA jobsites :

Since their appearance on their first jobsite in Kentucky in 2006, IFAs have been used on or are specified for jobsites ranging from Scarborough, ME (Walgreens), Burleson, Texas (Burleson Independent School District), and Oahu, Hawaii (Schofield Barracks). Particularly innovative IFA projects are Joseph Warren Middle and High School (Bowling Green, Kentucky, USA), the largest ICF building in North America upon completion, at two stories at 330,000 sq. ft., and Turkey Foot Middle School (Kenton Co., Kentucky, USA), the first jobsite to use IFAs with the thermal-break design, and Overdale Elementary School (Hillview, Kentucky, USA), where architects adapted the IFA design for mechanical chases.

Interlocking Concrete Pavers

Contents

1 – Introduction :

An interlocking concrete paver is a type of paver .

2 - Interlocking Pavers :

Interlocking Concrete Paver Driveway

A special type of paver referred to as an "interlocking concrete paver" or also a segmental paver has emerged over the last couple of decades in the United States as a very popular alternative to brick, clay or concrete.

Segmental pavers have been used for thousands of years. The Romans built roads with them that are still there. But it wasn't until the mid 1940's that pavers began to be produced out of concrete. It started in Holland where all the roads are made to be flexible because Holland is below sea level and the ground shifts, moves and sinks. Poured concrete is not an option because it will crack. Individual units not set in concrete placed in sand perform far better than concrete. Before the paver was made from concrete either real stone or a clay product had to be employed.

The first concrete pavers were shaped just like a brick, 4” by 8” (10cm x 20cm) and they were called Holland Stones and still are today. These units turned out to be far more economical to produce and were exceedingly strong.

3 - How Are Interlocking Pavers Made ? :

Pavers are made from a very dry mix of gravel, sand, cement and color. Since there is very little water, the mixture is moved on conveyor belts and then funneled into the paver mold. A press is inserted into the mold and vibrated at the same time. The high pressure and the vibration causes the water to set the cement and creates a bind between the aggregate. When the mold is moved away, the pavers are in their finished state.

Pavers are said to have zero slump. The more the slump, the weaker the concrete. A slump test is done in a laboratory to test the strength of concrete. It is done by placing concrete in an 8” tall cone, which is then turned upside down and removed. The amount the concrete slumps from the original 8” is measured. For instance, if it now measures 6”, it is said to have a 2” slump. If one has a very wet mix, it would not hold up at all and would run all over the table.

The strength of concrete is achieved in three main ways.

1. The amount of water (the less water, the stronger).
2. The amount of cement in the mix (the more cement, the stronger).
3. The amount and size of aggregate (the bigger, the stronger).

Concrete delivered in a truck needs to be fairly wet to get it out of the truck. Typical concrete from a concrete truck will produce a surface with a load strength of about 2,000 pounds per square inch (14,000 kPa).

A surface is tested for strength by placing a point load onto it and exerting a direct force until it fails. The pressure is calculated, and that is the failing point. Pavers need to withstand a minimum of 8,000 pounds per square inch (55,000 kPa) to meet industry standards. Usually when tested they far exceed this minimum. That means a paving stone driveway is at least four times stronger than a regular concrete driveway.

4 - How Interlocking Pavers Interlock :

When one thinks of interlocking paving stones one often gets the idea of dog bone shape stones that fit together like a jigsaw puzzle. That is not the case at all. The interlocking comes from the fact that each stone can NOT move independently from its neighbor. In fact there are two important aspects of an interlocking paving stone job that keeps the pavers interlocked.

Pavers Being lifted to demonstrate interlock

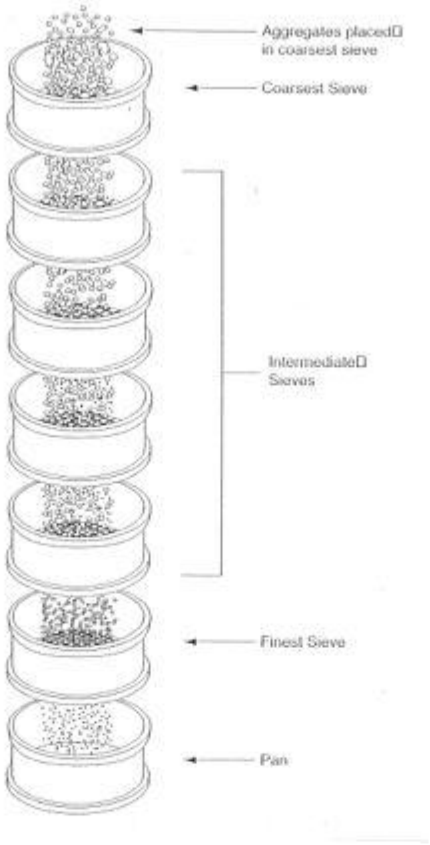
The first is the sand. As simple as this might seem the sand creates the interlock. Not any sand though, it must be a sharp angular sand (also called Joint Sand and Polymeric Sand) that will lock together. If you filled the joints between the pavers with silica sand, each particle is perfectly round, it's like putting ball bearing between the pavers and they WILL then be able to move independent of the stone next to them. Pavers are made with a small ridge on the side of each one so there is space for the sand.

The picture below shows pavers being lifted. Notice the whole surface lifts, not just one paver. The fact that the whole surface moves together demonstrates the sand holding the pavers together.

The second important aspect is the edge restraints (the border that is holding the pavers together) . Since they are sitting in sand not mortar if the edge is not held firmly in place they could start to spread apart. This would create larger and larger opening between the pavers that would eventually be so wide that there would no longer be friction between the stones.

With the second condition in place you have now created interlock.

4 – 1 - Installation of Interlocking Concrete Pavers :



A sieve is used to test soil and base material.

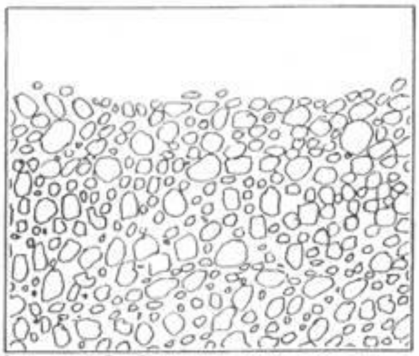
The correct installation of interlocking concrete pavers

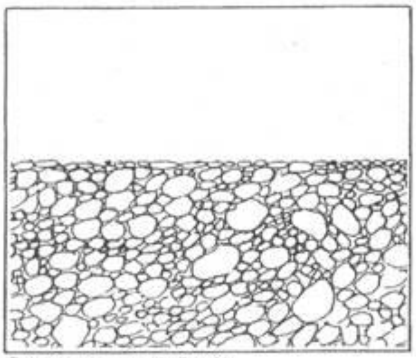
Step 1 : Demolition – remove old driveway or patio. Go down a minimum of 7” .

Step 2 : Compact the sub base – the dirt that will be directly under the base material.

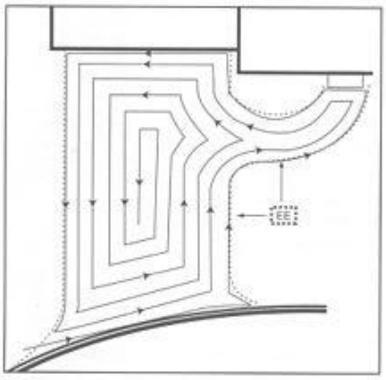
Step 3 : Install the base – Class II Road Base is used. This is composed of various sizes of gravel. See the picture of the sieve. A sieve is used to test soil and base material. There is a wire mesh at the bottom of each pan. At the top the mesh will allow ¾" rock through, the next one down will be ½", then ¼" all the way to the last pan that will allow only "fines". A fine is described as a particle that can pass through a #200 mesh. A #200 mesh has 350 openings per square inch. This is actually like a fine cloth. Water will not pass through a #200 mesh but fines will. So these particles are very small!

Certified base has correct quantities of all the above sizes so that it will compact to at least 95 %. Imagine stepping on a field of marbles – they would move. Or even stepping in sand at the beach - not very firm. That's because they are all the same size. Since certified base comes with the right proportions, the end result will be a very firm sturdy base.

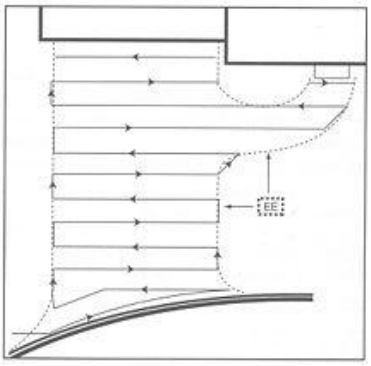

Loose Soil


Compacted Soil

The base should be compacted and at least twice as shown below.



1st recommended compacting pattern for compacting pavers



2nd recommended compacting pattern for compacting pavers

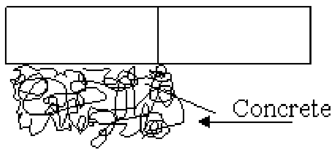
To achieve the desired level of compaction, 98% base should be compacted in “lifts”. A lift is a layer of material, base, or dirt to be compacted. For base, the lifts should be no more than 4” thick. The compactor should be a very heavy duty machine that produces a minimum of 5,000 pounds per square inch (34,000 kPa) . Smaller machines will never achieve the desired 98 % compaction.

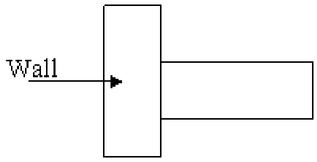
Step 4 : The next step is the sand bedding. (this is angular sand as mentioned above) – a one inch sand bed is screeded in place, the pavers are laid on top.

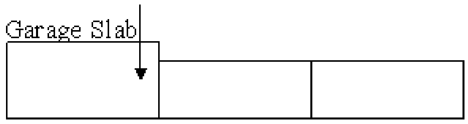
Step 5 : Cutting the pavers – the edges are cut with a dry saw and each fit precisely in place.

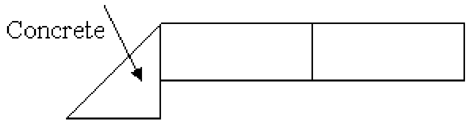
Step 6 : Install restraints – Since pavers are set in sand, they need to be held together by something. What holds them together is the borders or the outside perimeter. This outside edge is referred to as a restraint. Once they are finally held in place, they can not move yet the entire surface is flexible. As compared to a poured in place concrete surface which is rigid. As a word, flexible, best describes the interlocking concrete surface whereas rigid would describe a concrete surface.

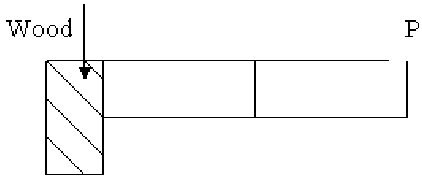
There are several types of restraints as shown below :

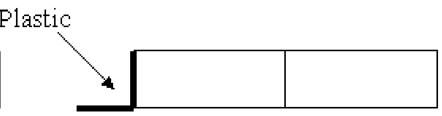












Step 7 : Compacting the pavers – Once the restraints are in place, the next step is to compact the pavers in doing so, the pavers are pushed into the bedding sand and the sand is forced up between the pavers.

Step 8 : Sand between the pavers – Once this is done more sand, either the same bedding sand or joint sand that comes in bags, is swept between the pavers and the pavers are compacted again. In using a vibrating plate compactor, all the joints between the pavers are filled.

Jennite

Jennite is a calcium silicate hydrate mineral of general chemical formula : $Ca_9 Si_6 O_{18} (OH)_6 \cdot 8(H_2O)$.

Jennite occurs as an alteration mineral in metamorphosed limestone and skarn . It typically occurs as vein and open space fillings as a late mineral phase . It also occurs in hydrated cement paste.

A first specimen of jennite found in 1966 at the Crest more quarries (Crest more , River side County, California, USA) was analyzed and identified as a new mineral by Carpenter in 1966 (Carpenter, 1966). They named it in honour of its discoverer: Clarence Marvin Jenni (1896–1973) director of the Geological Museum at the University of Missouri .

In contrast to the first analysis made by Carpenter, jennite does not contain appreciable amount of sodium when the Crestmore specimen was reexamined (Gard, 1977) .

The structure of jennite is made of three distinct modules: ribbons of edge-sharing calcium octahedra, silicate chains of wollastonite-type running along the b axis, and additional calcium octahedra on inversion centers. The hydroxyl groups are bonded to three calcium cations while no Si OH groups are observed (Bonaccorsi 2004) .

Jennite transforms to meta jennite at 70 – 90 °C by losing four water molecules (Gard, 1977) .

Category	Silicate mineral
Chemical Formula	$Ca_9 Si_6 O_{18} (OH)_6 \cdot 8H_2O$
Unit cell	a = 10.56 Å, b = 7.25 Å, c = 10.81 Å; α = 99.7°,

	β = 97.67°, γ = 110.07°; Z =1
Molar mass	1063 g / mol
Color	White
Crystal habit	Blade shaped crystals, fibrous aggregates, platy - sheet forms
Mohs Scale Hardness	3.5
Density	2.32 – 2.33
Optical properties	Biaxial (-)
Refractive index	n_α = 1.548 - 1.552 n_β = 1.562 - 1.564 n_γ = 1.570 - 1.571
Birefringence	δ = 0.022
Ultra Violet Fluorescence	Weak white

Joint Compound

	
Drywall with joint compound applied.	*A bucket of joint compound*

Contents

- 1 Introduction
- 2 Ready - mix light weight joint compound
- 3 Usage
- 4 Health concerns

1 – Introduction :

Joint compound (also known as drywall compound) is a white substance similar to plaster used to seal joints between sheets of drywall, primarily in building construction. It is often referred to simply as **mud**.

2 - Ready - mix light weight joint compound :

Ready - mix light weight joint compound is a pre-made form of joint compound designed for fast application and easy maintenance. The compound is a complex combination often including water, lime stone , expanded perlite, ethylene-vinyl acetate polymer, attapulgite, and other ingredients. The delicate mixture of compounds gives it a creamy texture that spreads easily onto drywall surfaces.

3 - Usage :

Ready - mixed joint compound is most commonly used in hanging drywall for new or remodeled homes . Application is simple and easy , usually never taking more than three or four coats. When used for new walls, joint compound effectively eliminates all blemishes from the surface of the drywall, such as drilled in screws, hanging tape, or drywall tape. Joint compound can be used to finish gypsum panel joints, corner bead, trim and fasteners, as well as skim coating. In addition, it is also very handy for fixing minor blemishes or damages to walls. It easily patches up holes, bumps, tears, and other minor damages.

Ready-mix joint compound is usually more forgiving than the traditional form of joint compound. It can be used for as long of a period of time as needed, and does not dry up unless left unattended for a long period of time. Traditional "mix-it-yourself" joint compound usually lasts for one to two hours before drying. However, if it happens to set for more than a few hours, then you will need to apply water very liberally as needed to retain its soft texture.

Often referred to as drywall taping mud, joint compound is the primary material used in the drywall industry by a trade sperson, or applicator, called a "drywall mechanic," "taper," or "drywall taper." A similar compound is used in various ways as a sprayed-on textural finishing for gypsum panel walls and ceilings that have been pre-sealed and coated with joint compound. The flexibility and plastic qualities of joint compound make it a very versatile material both as sealer or finishing coat for wall surfaces, and also in decorative applications that range from machine sprayed texturing to hand-trowelled or even hand - crafted and sculptural finishes. In North America the application of joint mud and drywall tape sealer and trowelled joint compound on gypsum panels is a standard construction technique for painted wall and ceiling surfaces. Until more recently in North America, and through the world, several different plasters such as veneer plaster and "plaster of Paris" have been used in a similar ways to joint compounds as fillers or for decorative purposes since ancient times, and the actual make up and working properties of these compounds is much similar. Modern ready - mixes or powder and water mixes are available in a wide range of styles from slow - drying to quick - drying to suit specific demands for use by contractors or decorators.

While joint compounds are used for bedding tape and initial layers overtop, it is best to apply topping compound for finish layer(s) that level and sand more evenly. Both require thinning for practical application .

4 - Health concerns :

Construction workers who sand drywall joint compound are often exposed to high concentrations of dusts, talc, calcite, mica, gypsum, and in some cases, respire able silica . Some of these have been associated with varying degrees of eye, nose, throat, and respiratory tract irritation. Over time, breathing the dust from drywall joint compounds may cause persistent throat and airway irritation, coughing, phlegm production, and breathing difficulties similar to asthma. When silica is present, workers may also face an increased risk of silicosis and lung cancer.

Joint compound mixes manufactured prior to the 1980s often contained a complex mixture of several substances. Among the additives used were asbestos fibers, which provided cohesiveness. Exposure to friable asbestos increases risks of various serious health conditions, including cancer. Joint compounds manufactured from 1980 onward were required to have asbestos removed in favor of other compounds due to legislation to ban asbestos' widespread use.

For all of these reasons, constant use of a respirator is recommended by almost all drywall compound manufacturers and is required by some labor authorities.

Kaolinite

Kaolin. (unknown scale)

Contents

1 – Introduction ;

Kaolinite is a clay mineral, part of the group of industrial minerals, with the chemical composition $Al_2Si_2O_5(OH)_4$. It is a layered silicate mineral, with one tetrahedral sheet linked through oxygen atoms to one octahedral sheet of alumina octahedra . Rocks that are rich in kaolinite are known as **kaolin** or **china clay**.

The name is derived from *Kao-ling* (Chinese : *Gaoling*) , a village near Jingdezhen, Jiangxi province, China . The name entered English in 1727 from the French version of the word: "kaolin", following Francois Xavier d'Entrecolles's reports from Jingdezhen.

Kaolinite has a low shrink-swell capacity and a low cation exchange capacity (1 - 15 meq / 100g) . It is a soft, earthy, usually white mineral (di octahedral phyllo silicate clay) , produced by the chemical weathering of aluminium silicate minerals like feldspar. In many parts of the world, it is colored pink – orange - red by iron oxide, giving it a distinct rust hue. Lighter concentrations yield white, yellow or light orange colors. Alternating layers are sometimes found, as at Providence Canyon State Park in Georgia, USA.

Category	Silicate mineral
Chemical Formula	Al_2 Si_2 O_5 $(OH)_4$
Unit cell	a = 5.13 Å , b = 8.89 Å , c = 7.25 Å ; α = 90° , β = 104.5° , γ = 89.8° ; Z = 2
Color	White, sometimes red, blue or brown tints from impurities
Crystal habit	Rarely as crystals, thin platy or stacked, More commonly as microscopic pseudo hexagonal plates and clusters of plates, aggregated into compact, claylike masses
Crystal system	Triclinic
Tenacity	Flexible but inelastic
Mohs scale hardness	2 – 2.5
Streak	White
Specific gravity	2.16 – 2.68
Optical properties	Biaxial (–)
Refractive index	n_α = 1.553–1.565, n_β = 1.559–1.569, n_γ = 1.569–1.570

2 - Structural transformations :

Kaolinite group clays undergo a series of phase transformations upon thermal treatment in air at atmospheric pressure. Endothermic de hydroxylation (or alternatively, dehydration) begins at 550–600 °C to produce disordered meta kaolin, $Al_2Si_2O_7$, but continuous hydroxyl loss (-OH) is observed up to 900 °C and has been attributed to gradual oxolation of the meta kaolin. Because of historic disagreement concerning the nature of the meta kaolin phase, extensive research has led to general consensus that meta kaolin is not a simple mixture of amorphous silica (SiO_2) and alumina (Al_2O_3), but rather a complex amorphous structure that retains some longer-range order (but not strictly crystalline) due to stacking of its hexagonal layers.

$$2\ Al_2Si_2O_5(OH)_4 \rightarrow 2\ Al_2Si_2O_7 + 4\ H_2O.$$

Further heating to 925 – 950 °C converts meta kaolin to an aluminium - silicon spinel , $Si_3Al_4O_{12}$, which is sometimes also referred to as a gamma-alumina type structure:

$$2\ Al_2Si_2O_7 \rightarrow Si_3Al_4O_{12} + SiO_2.$$

Upon calcination to ~1050 °C, the spinel phase ($Si_3Al_4O_{12}$) nucleates and transforms to mullite, $3\ Al_2O_3 \cdot 2\ SiO_2$, and highly crystalline cristobalite, SiO_2:

$$3\ Si_3Al_4O_{12} \rightarrow 2\ Si_2Al_6O_{13} + 5\ SiO_2.$$

2 - Occurrence :

A kaolin mine in Bulgaria

Kaolinite is one of the most common minerals; it is mined, as kaolin, in Brazil, Bulgaria, France, United Kingdom, Iran, Germany, India, Australia, Korea, the People's Republic of China, the Czech Republic and the United States.

3 – 1 - Predominance in tropical soils :

Kaolinite clay occurs in abundance in soils that have formed from the chemical weathering of rocks in hot, moist climates — for example in tropical rainforest areas. Comparing soils along a gradient towards progressively cooler or drier climates, the proportion of kaolinite decreases, while the proportion of other clay minerals such as illite (in cooler climates) or smectite (in drier climates) increases. Such climatically - related differences in clay mineral content are often used to infer changes in climates in the geological past, where ancient soils have been buried and preserved.

In the *Institut National pour l'Etude Agronomique au Congo Belge* (INEAC) classification system, soils in which the clay fraction is predominantly kaolinite are called *kaolisol* (from kaolin and soil).[9]

4 - Uses ;

Kaolin is used in ceramics, medicine, coated paper, as a food additive, in toothpaste, as a light diffusing material in white incandescent light bulbs, and in cosmetics. It is generally the main component in porcelain.

It is also used in paint to extend titanium dioxide (TiO_2) and modify gloss levels; in rubber for semi - reinforcing properties; and in adhesives to modify rheology .

Kaolin was long used in the production of common smoking pipes in Europe and Asia.

The largest use is in the production of paper, including ensuring the gloss on some grades of paper. Commercial grades of kaolin are supplied and transported as dry powder, semi-dry noodle or as liquid slurry.

Kaolinite can contain very small traces of uranium and thorium, and is therefore useful in radiological dating. While a single magazine made using kaolin does not contain enough radioactive material to be detected by a security - oriented monitor, this could result in the possibility of a truckload of glossy paper occasionally tripping an overly - sensitive radiation monitor.

Kaolinite has also seen some use in organic farming, as a spray applied to crops to deter insect damage, and in the case of apples, to prevent sun scald.

Kaolin is extensively used as a paint or white wash in traditional stone masonry homes in Nepal. The most common method is to paint the upper part with white Kaolin clay and the middle with red clay. The red clay may extend to the bottom, or the bottom may be painted black.

In April 2008, the US Naval Medical Research Institute announced the successful use of a kaolinite-derived alumino silicate nano particle infusion in traditional gauze, known commercially as QuikClot Combat Gauze .

When heated to between 650 and 900 °C kaolinite dehydroxylates to form meta kaolin. According to the American National Precast Concrete Association this is a supplementary cementitious material (SCM). When added to a concrete mix, metakaolin affects the acceleration of Portland cement hydration when replacing Portland cement by 20 percent by weight.

In ceramics applications, the formula is typically written in terms of oxides, thus the formula for kaolinite is $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$

Using the cement chemist notation this can be even written as AS_2H_2, with the oxides represented as $A = Al_2O_3$, $S = SiO_2$, $H = H_2O$.

Kaolinite was also used as filler in Edison Diamond Discs.

4 – 1 - Medicinal and culinary uses :

A folk medicine use is to soothe an upset stomach, similar to the way parrots (and later, humans) in South America originally used it.[14] More recently, industrially - produced kaolinite preparations were formerly common for treatment of diarrhea; the most common of these was Kaopectate, which abandoned the use of kaolin in favor of attapulgite and then (in the United States) bismuth subsalicylate.

In Africa, kaolin is sometimes known as *kalaba* (in Gabon and Cameroon) , *calaba*, and *calabachop* (in Equatorial Guinea). It is used for facial masks or soap and is eaten for pleasure or to suppress hunger , a practice known as geophagy. Consumption is greater among women, especially during pregnancy .

This practice has also been observed within a small population of African-American women in the Southern United States, especially Georgia. There, the kaolin is called *white dirt*, *chalk* or *white clay* .

Kieselkalk

1 – Introduction :

Kieselkalk is also known as the Helvetic Siliceous Lime stone. It has sedimented during the Lower Cretaceous epoch. It can contain up to 40 % of very fine (1-10 µm), evenly distributed authigenic quartz crystals. Early diagenetic dissolution of opal sponge spicules led to silica enrichment of interstitial waters, which reprecipitated silica in the overlying horizons, forming tiny quartz crystals in pore spaces.

Because of its high silica content, the Kieselkalk is much less susceptible to karstification than the overlying Schrattenkalk. In the Siebenhengste – Hohgant - Höhle cave system in Switzerland, large galleries, easily developing in the Schrattenkalk , become impenetrable fissures networks when water disappears in the Kieselkalk.

2 - Susceptibility to alkali silica reaction :

Siliceous limes tones can be very prone to the Alkali Silica Reaction (ASR) and their use as aggregate is often the cause of premature concrete degradation and problems in civil engineering (concrete spalling , bridges failure , ...).

Lift Slab Construction

Lift slab construction is a method of constructing concrete buildings by casting the floor or roof slab on top of the previous slab and then raising (jacking) the slab up with hydraulic jacks, so being cheaper and faster as not requiring boxing and supports for casting in situ.

The Johnstone Hall a dormitory at Clemson University, Clemson, South Carolina was erected using this method in 1954. Several of the blocks have now been demolished, and campus legend says that that two other similar structures built elsewhere collapsed before completion.

The method was involved in the L'Ambiance Plaza collapse in Bridgeport, Connecticut during construction in 1987, and resulted in a major nationwide federal investigation into this construction technique in the United States, and a temporary moratorium of its use in Connecticut.

A patent was issued to Tom Slick for this construction method, called the "Youtz-Slick" method, in 1955.

Ligno Sulfonates

Contents

1 – Introduction :

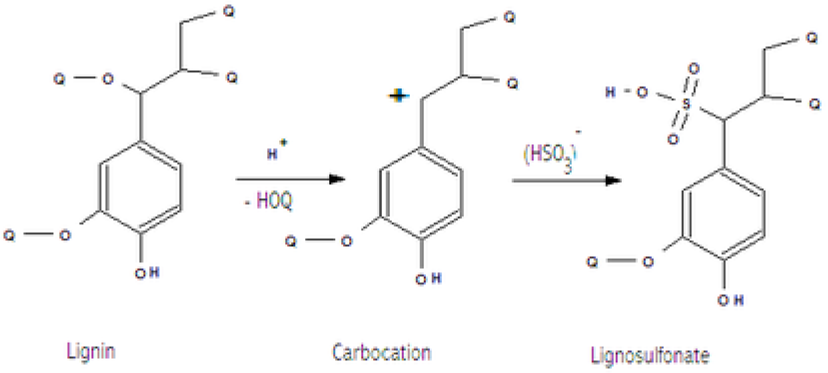
Ligno sulfonates, or **sulfonated lignin** are water - soluble anionic poly electrolyte polymers: they are byproducts from the production of wood pulp using sulfite pulping.

Most delignification in sulfite pulping involves acidic cleavage of ether bonds, which connect many of the constituents of lignin. The electrophilic carbocations produced during ether cleavage react with bisulfite ions (HSO_3^-) to give sulfonates.

$$R\text{-}O\text{-}R' + H^+ \rightarrow R^+ + R'OH$$
$$R^+ + HSO_3^- \rightarrow R\text{-}SO_3H$$

The primary site for ether cleavage is the α-carbon (carbon atom attached to the aromatic ring) of the propyl (linear three carbon) side chain. The following structures do not specify the structure since lignin and its derivatives are complex mixtures: the purpose is to give a general idea of the structure of ligno sulfonates. The groups labeled "Q" can be a wide variety of groups found in the structure of lignin. Sulfonation occurs on the side chains, not on the aromatic rings, like in p-toluene sulfonic acid.

Ligno sulfonate have very broad ranges of molecular mass (they are very poly disperse). A range of from 1000 –140,000 da has been reported for softwood ligno sulfonates with lower values reported for hardwoods .



2 - Preparation

Ligno sulfonates are recovered from the spent pulping liquids (red or brown liquor) from sulfite pulping. The most widely used industrial process is the Howard process, in which 90–95% yields of calcium ligno sulfonates (CAS number 904-76-3), are precipitated by adding of excess calcium hydroxide. Ultra filtration and ion-exchange can also be used to separate ligno sulfonates from the spent pulping liquid . A list of CAS numbers for the various metal salts of ligno sulfonates is available.

3 - Uses :

Ligno sulfonates have a wide variety of applications.

The single largest use for ligno sulfonates is as plasticizers in making concrete, where they allow concrete to be made with less water (giving stronger concrete) while maintaining the ability of the concrete to flow. Ligno sulfonates are also used during the production of cement, where they act as grinding aids in the cement mill and as a rawmix slurry deflocculant (that reduces the viscosity of the slurry) .

Ligno sulfonates are also used for the production of plasterboard to reduce the amount of water required to make the stucco flow and form the layer between two sheets of paper. The reduction in water content allows lower kiln temperatures to dry the plasterboard, saving energy.

The ability of ligno sulfonates to reduce the viscosity of mineral slurries is used to advantage in oil drilling mud, where it replaced tannic acids from quebracho (a tropical tree).

Ligno sulfonates are used to disperse pesticides, dyes , carbon black, and other insoluble solids and liquids into water. They are used in tanning leather. They are also used to suppress dust on unpaved roads.

Oxidation of ligno sulfonates from softwood trees produced vanillin (artificial vanilla flavor) .

Di methyl sulfide and di methyl sulfoxide (an important organic solvent) are produced from ligno sulfonates. The first step involves heating ligno sulfonates with sulfides or elemental sulfur to produce di methyl sulfide. The methyl groups come from methyl ethers present in the lignin. Oxidation of di methyl sulfide with nitrogen dioxide produces di methyl sulfoxide (DMSO).

Also one of the very wide uses of lignosulfonates is deflocculation of clays used in drilling fluids in the oil and gas industry.

Lime Mortar

Contents

1 – Introduction :

Lime mortar is a type of mortar composed of lime and an aggregate such as sand, mixed with water. It is one of the oldest known types of mortar, dating back to the 4th century BC and widely used in Ancient Rome and Greece , when it largely replaced the clay and gypsum mortars common to Ancient Egyptian construction .

With the introduction of ordinary portland cement (OPC) during the 19th century the use of lime mortar in new constructions gradually declined, largely due to portland 's ease of use, quick setting and compressive strength . How ever the soft, porous properties of lime mortar provide certain advantages when working with softer building materials such as natural stone and terracotta . For this reason, while OPC continues to be commonly used in brick and concrete construction, in the repair of older, stone-built structures and the restoration of historical buildings the use of OPC has largely been discredited . Despite its enduring utility over many centuries, lime mortar's effectiveness as a building material has not been well under stood ; time - honored practices were based on tradition, folklore and trade knowledge, vindicated by the vast number of old buildings that remain standing. Only during the last few decades has empirical testing provided a scientific under standing of its remark able durability.

2 - Uses :

Lime mortar is used as an alternative to ordinary portland cement. It is made principally of lime (hydraulic, or non hydraulic) , water and an aggregate such as sand.

3 - Non - hydraulic and hydraulic :

Hydraulic limes set under water, and non - hydraulic limes need air to carbonate and set. For hydraulic lime mortars, the lime is obtained from lime stone containing impurities . A non - hydraulic lime is produced from high purity calcium lime stones.

In the past , countless lime kilns all over countries such as Britain burnt lime stones of varying qualities - many of these lime stones containing impurities. The lime thus having varying degrees of hydraulicity, making them unsuitable for today's industrial processes but due to its water resistancy suitable for building. Most of those kilns ceased production as portland cement gained widespread use replacing hydraulic lime. Today mainly non - hydraulic limes for lime plasters are produced and a very small number of kilns are still producing hydraulic lime for the building industry to standards which are now expected of any building material.

4 - Non - hydraulic lime :

Non - hydraulic lime is primarily composed of calcium hydroxide (generally greater than 95 %) . Non - hydraulic lime is produced by first heating sufficiently pure lime stone (calcium carbonate) to between 954° and 1066°C , driving off carbon dioxide to produce quick lime (or calcium oxide). This is done in a lime kiln. The quick lime is then slaked – thoroughly mixed with water to produce liquid slurry — the lime putty — or with less water to produce dry powder — a hydrated lime (or calcium hydroxide) .

The slaking process involved in creating a lime putty is an exothermic reaction which initially creates a liquid of a cream consistency. This is then matured for 2 to 3 months - depending upon environmental conditions - to allow time for it to condense and mature into a lime putty.

A matured lime putty is "thixotropic", meaning that when a lime putty is agitated it changes from a putty into a more liquid state. This aids its use for mortars as it makes a mortar easier to work with. If left to stand following agitation a lime putty will slowly revert from a thick liquid back to a putty state. It is advised that a lime mortar should be "knocked up" prior to its use.

As well as calcium based lime stone , dolomitic limes can be produced which are based on calcium magnesium carbonate.

A frequent source of confusion regarding lime mortar stems from the similarity of the terms hydraulic and hydrated.

- Hydrated lime is any lime other than quicklime, and can refer to either hydraulic (hardens underwater) or non-hydraulic (doesn't harden underwater) lime.
- Stored lime putty is always non-hydraulic (since hydraulic putty sets quickly after mixing) and, as the name suggests, lime putty is in the form of a putty made from just lime and water.

If the quicklime is slaked with an excess of water then putty or slurry is produced. If less water is used, then the result is a dry material (any excess water escaping as steam during heating) . This is ground to make hydrated lime.

Hydrated non - hydraulic lime can be mixed with water to form lime putty. Before use it is usually left in the absence of carbon dioxide (usually under water) to mature. Putty can be matured for 24 hours to many years, with an increased maturation time improving the quality of the putty. There is an argument that a lime putty which has been matured for an extended period (over 12 months) becomes so stiff that it is less workable.

There is some dispute as to the comparative quality of putty formed from hydrated lime compared to that produced as putty at the time of slaking. It is generally agreed that the latter is preferable. A hydrated lime will produce a material which is not as "fatty" and often due to lengthy and poor storage, the resulting lime produced by hydrated lime will exhibit longer carbonation periods as well as lower compressive strengths.

4 – 1 - Mix :

Traditional lime mortar is a combination of lime putty and aggregate (usually sand) . A typical modern lime mortar mix would be 1 part lime putty to 3 parts washed, well graded, sharp sand. Other materials have been used as aggregate instead of sand. The theory is that the voids of empty space between the sand particles account for a 1/3 of the volume of the sand. The lime putty when mixed at a 1 to 3 ratio, fill these voids to create a compact mortar. Analysis of mortar samples from historic buildings typically indicates a higher ratio of around 1 part lime to 2 part aggregate/sand was commonly used. A traditional coarse plaster mix also had horse hair added for reinforcing and control of shrinkage, important when plastering to wooden laths and for base (or dubbing) coats onto uneven surfaces such as stone walls where the mortar is often applied in thicker coats to compensate for the irregular surface levels.

If shrinkage and cracking of the lime mortar does occur this can be as a result of either

- The sand being poorly graded or with a particle size that is too small
- The mortar being applied too thickly (Thicker coats increase the possibility of shrinkage , cracking and slumping)
- Too much suction from the substrate
- High air temperatures or direct sunlight which force dry the mortar
- High water content in the lime mortar mix
- Poor quality or unmatured lime putty

Pozzolans can be added to the mix of lime mortar. These are substances which when combined with lime produce a hydraulic (cementitious) set. They include powdered brick, heat treated clay, silica fume, fly ash, and volcanic materials. The chemical set imparted ranges from very weak to almost as strong as Portland cement.

4 – 2 - Hair reinforcement :

Hair reinforcement in lime plaster is common and many types of hair and other organic fibers can be found in historic plasters . How ever , organic material in lime will degrade in damp environments particularly on damp external renders . This problem has given rise to the use of poly propylene fibers in new lime renders .

4 – 3 - Setting :

Non - hydraulic lime mortar sets / hardens by reaction with atmospheric carbon dioxide (commonly called 'carbonation') . This is in contrast to the setting of portland cement and hydraulic lime which sets by reaction with water in the mix.

The reaction with carbon dioxide produces calcium carbonate – the raw material used at the start of the process to create lime. This process is much slower than that in Ordinary Portland Cement (OPC); depending on the thickness of the mortar and climate conditions, an initial skin hardening may take from a couple of hours to several days to gain an initial hardness. This tends to delay construction progress.

Although the setting process can be slow, the drying time of a lime mortar must be regulated at a steady rate to ensure a good final set. A rapidly dried lime mortar will result in a low-strength, poor-quality final mortar often displaying shrinkage cracks. In practice, lime mortars are often protected with damp hessian sheeting or sprayed with water to control the drying rates.

The full drying and hardening of the thickness process can continue, albeit at a slower rate, for many years with the mortar continuing to gain strength.

One of the advantages of lime mortar is that in the event of cracking, mortar deeper in the join is exposed and reacts with the air to crystallize and bond across the crack, reducing the loss of strength.

When a stronger lime mortar is required, such as for external or structural purposes, a pozzolan can be added, which improves its compressive strength and helps to protect it from weathering damage. This can also assist in creating more regulated setting times of the mortar as the pozzolan will create a hydraulic set, which can be of benefit in restoration projects when time scales and ultimately costs need to be monitored and maintained.

4 – 4 - Properties :

Lime mortar is not as strong in compression as OPC mortar, but both are sufficiently strong for construction of non – high - rise domestic properties.

Lime mortar does not adhere as strongly to masonry as OPC. This is an advantage with softer types of masonry, where use of cement in many cases eventually results in cement pulling away some masonry material when it reaches the end of its life.

- Under cracking conditions, OPC breaks, whereas lime often produces numerous micro cracks if the amount of movement is small. These micro cracks recrystallize through the action of 'free lime' effectively self-healing the affected area.
- Historic buildings are frequently constructed with relatively soft masonry units (e.g. soft brick and many types of stone), and minor movement in such buildings is quite common due to the nature of the foundations. This movement breaks the weakest part of the wall, and with OPC mortar this is usually the masonry. When lime mortar is used, the lime is the weaker element, and the mortar cracks in preference to the masonry. This results in much less damage, and is relatively simple to repair.

- Scrapped lime mortar is simply chalk and sand, which can be returned as normal constituents of soil. Cement mortar on the other hand presents a disposal issue .
- Lime mortar is more porous than cement mortars, and it wicks any dampness in the wall to the surface where it evaporates. Thus any salt content in the water crystallizes on the lime, damaging the lime and thus saving the masonry. Cement on the other hand evaporates water less than soft brick, so damp issues are liable to cause salt formation on brick surfaces and consequent disintegration of bricks. This damp evaporation ability is widely referred to as 'breath ability'.

Usually any dampness in the wall will cause the lime mortar to change colour, indicating the presence of moisture. The effect will create an often mottled appearance of a limewashed wall. As the moisture levels within a wall alter, so will the shade of a limewash. The darker the shade of lime wash, the more pronounced this effect will become.

A load of mixed lime mortar may be allowed to sit as a lump for some time, without it drying out (it may get a thin crust). When ready to use, this lump may be remixed ('knocked up') again and then used. Traditionally on building sites, prior to the use of mechanical mixers, the lime putty (slaked on site in a pit) was mixed with sand by a labourer who would "beat and ram" the mix with a "larry" (a wide hoe with large holes). This was then covered with sand and allowed to sit for a while (from days to weeks) - a process known as 'banking'. This lump was then remixed and used as necessary. This process cannot be done with OPC.

Lime Plaster

Contents

1 – Introduction :

Lime plaster is type of plaster composed of hydrated lime, sand and water. Lime plaster is similar to Lime mortar, the main difference is the based on use rather than composition. Traditional lime plaster contains also horse hair to reinforce plaster. It is sold as ' bagged ' powder or hydrated lime ; or is available as lime putty. Lime putty is generally considered to be more suitable for pure lime application.

Non - hydraulic lime is the most commonly used and known lime, also called (high) calcium lime or air lime, as it sets only by reaction with CO_2 in the air and will not set until dry. This causes limitations in construction use as the lime can remain soft for months or years. Non - hydraulic lime can only set through carbonation (re - absorption of CO_2) .

Hydraulic lime and hydrated lime must not be confused. Hydrated lime is merely a form in which lime can be supplied (as opposed to quicklime or lime putty); while 'hydraulic' refers to its ability to set under water, or in wet conditions.

2 - Safety issues :

Lime is an extremely caustic material when wet, with a pH of 12. (Lime becomes pH neutral when carbonated) . As such, the use of protective goggles , gloves , and clothing are necessary when working with lime. Clean water should also be kept readily accessible for first aid purposes when working with lime in case of accidental eye or skin exposure .

- First aid for cases of skin exposure to lime involves neutralization with very mild acid such as vinegar or lemon juice.
- First aid for cases of accidental eye exposure consists of repeatedly flushing the eye for several minutes with fresh water. Medical attention should be sought in such cases.

3 - Historical use in the arts :

One of the earliest examples of lime plaster dates back to the end of the eighth millennium BC . Three statues were discovered in a buried pit at 'Ain Ghazal in Jordan that were sculpted with lime plaster over armatures of reeds and twine. They were made in the pre - pottery neolithic period, around 7200 BC. The fact that these sculptures have lasted so long is a testament to the durability of lime plaster .

4 - Historical uses in Building :

- Some of the earliest known examples of lime use for building purposes are in early Egyptian buildings (primarily monuments). Some of these examples in the chambers of the pyramids, which date back to around 2000 B.C., are still hard and intact.
- Archaeological digs carried out on the island of Malta have shown that in places like Tarxien and Hagar, lime stucco was also used as a binder to hold stone together and as well as for decoration at sites dating back as far as 3000-2500 B.C.
- At el - Amarna, a large pavement on brick was discovered that dates back to 1400 B.C. It was apparently the floor of part of the harem of King Amenhotep IV.
- Ancient Chinese used Suk - wui (the Chinese word for slaked lime) in the construction of The Great Wall of China.
- The Aztec Empire and other Mesoamerican civilizations used lime plaster to pave streets in their cities . It was also used to coat the walls and floors of buildings.

Lime Stone

Contents

1 – Introduction :

Lime stone is a sedimentary rock composed largely of the minerals calcite and aragonite, which are different crystal forms of calcium carbonate ($CaCO_3$). Many lime stones are composed from skeletal fragments of marine organisms such as coral or foraminifera.

Lime stone makes up about 10% of the total volume of all sedimentary rocks. The solubility of Lime stone in water and weak acid solutions leads to karst landscapes, in which water erodes the Lime stone over thousands to millions of years. Most cave systems are through Lime stone bedrock.

Lime stone has numerous uses: as a building material, as aggregate for the base of roads, as white pigment or filler in products such as toothpaste or paints and as a chemical feed stock.

2 - Description :

Like most other sedimentary rocks, Lime stone is composed of grains. Most grains in Lime stone are skeletal fragments of marine organisms such as coral or foraminifera. Other carbonate grains comprising Lime stones are ooids , peloids, intraclasts, and extraclasts. These organisms secrete shells made of aragonite or calcite, and leave these shells behind after the organisms die.

Lime stone often contains variable amounts of silica in the form of chert (chalcedony, flint, jasper, etc.) or siliceous skeletal fragment (sponge spicules, diatoms, radiolarians), and varying amounts of clay, silt and sand (terrestrial detritus) carried in by rivers.

Some Lime stones do not consist of grains at all, and are formed completely by the chemical precipitation of calcite or aragonite, i.e. travertine. Secondary calcite may be deposited by supersaturated meteoric waters (groundwater that precipitates the material in caves). This produces speleothems , such as stalagmites and stalactites. Another form taken by calcite is oolitic Lime stone, which can be recognized by its granular (oolite) appearance.

The primary source of the calcite in Lime stone is most commonly marine organisms. Some of these organisms can construct mounds of rock known as reefs, building upon past generations. Below about 3,000 meters, water pressure and temperature conditions cause the dissolution of calcite to increase nonlinearly, so Lime stone typically does not form in deeper waters (see lysocline). Lime stones may also form in both lacustrine and evaporite depositional environments.[1][2]

Calcite can be either dissolved or precipitated by groundwater, depending on several factors, including the water temperature, pH, and dissolved ion concentrations. Calcite exhibits an unusual characteristic called retrograde solubility, in which it becomes less soluble in water as the temperature increases.

Because of impurities, such as clay, sand, organic remains, iron oxide and other materials, many Lime stones exhibit different colors, especially on weathered surfaces.

Lime stone may be crystalline, clastic, granular, or massive, depending on the method of formation. Crystals of calcite, quartz, dolomite or barite may line small cavities in the rock. When conditions are right for precipitation, calcite forms mineral coatings that cement the existing rock grains together, or it can fill fractures.

Travertine is a banded, compact variety of Lime stone formed along streams, particularly where there are waterfalls, and around hot or cold springs. Calcium carbonate is deposited where evaporation of the water leaves a solution supersaturated with the chemical constituents of calcite. Tufa, a porous or cellular variety of travertine, is found near waterfalls. Coquina is a poorly consolidated Lime stone composed of pieces of coral or shells.

During regional metamorphism that occurs during the mountain building process (orogeny), Lime stone recrystallizes into marble.

Lime stone is a parent material of Mollisol soil group.

3 - Classification :

Two major classification schemes, the Folk and the Dunham, are used for identifying Lime stone and carbonate rocks.

3 – 1 - Folk classification :

Robert L. Folk developed a classification system that places primary emphasis on the detailed composition of grains and interstitial material in carbonate rocks. Based on composition, there are three main components: allochems (grains), matrix (mostly micrite), and cement (sparite). The Folk system uses two-part names; the first refers to the grains and the second is the root. It is helpful to have a petro graphic microscope when using the Folk scheme, because it is easier to determine the components present in each sample.

3 – 2 - Dunham classification :

The Dunham scheme focuses on depositional textures. Each name is based upon the texture of the grains that make up the Lime stone. Robert J. Dunham published his system for Lime stone in 1962; it focuses on the depositional fabric of carbonate rocks. Dunham divides the rocks into four main groups based on relative proportions of coarser clastic particles. Dunham names are essentially for rock families. His efforts deal with the question of whether or not the grains were originally in mutual contact, and therefore self-supporting, or whether the rock is characterized by the presence of frame builders and algal mats. Unlike the Folk scheme, Dunham deals with the original porosity of the rock. The Dunham scheme is more useful for hand samples because it is based on texture, not the grains in the sample.

4 - Lime stone landscape :

Lime stone makes up about 10 % of the total volume of all sedimentary rocks.

Lime stone is partially soluble, especially in acid, and therefore forms many erosional landforms. These include Lime stone pavements, pot holes, cenotes, caves and gorges. Such erosion landscapes are known as karsts. Lime stone is less resistant than most igneous rocks, but more resistant than most other sedimentary rocks. It is therefore usually associated with hills and down land , and occurs in regions with other sedimentary rocks, typically clays.

Karst topography and caves develop in Lime stone rocks due to their solubility in dilute acidic ground water. The solubility of Lime stone in water and weak acid solutions leads to karst landscapes. Regions overlying Lime stone bedrock tend to have fewer visible above-ground sources (ponds and streams), as surface water easily drains downward through joints in the Lime stone. While draining, water and organic acid from the soil slowly (over thousands or millions of years) enlarges these cracks, dissolving the calcium carbonate and carrying it away in solution. Most cave systems are through Lime stone bedrock. Cooling groundwater or mixing of different ground waters will also create conditions suitable for cave formation.

Coastal Lime stones are often eroded by organisms which bore into the rock by various means. This process is known as bioerosion. It is most common in the tropics, and it is known throughout the fossil record .

Bands of Lime stone emerge from the Earth's surface in often spectacular rocky outcrops and islands. Examples include the Burren in Co. Clare, Ireland; the Verdon Gorge in France; Malham Cove in North Yorkshire and the Isle of Wight,[7] England; on Fårö near the Swedish island of Gotland, the Niagara Escarpment in Canada/United States, Notch Peak in Utah, the Ha Long Bay National Park in Vietnam and the hills around the Lijiang River and Guilin city in China.

The Florida Keys, islands off the south coast of Florida, are composed mainly of oolitic Lime stone (the Lower Keys) and the carbonate skeletons of coral reefs (the Upper Keys), which thrived in the area during interglacial periods when sea level was higher than at present.

Unique habitats are found on alvars, extremely level expanses of Lime stone with thin soil mantles. The largest such expanse in Europe is the Stora Alvaret on the island of Öland, Sweden. Another area with large quantities of Lime stone is the island of Gotland, Sweden. Huge quarries in northwestern Europe, such as those of Mount Saint Peter (Belgium/Netherlands), extend for more than a hundred kilometers.

The world's largest Lime stone quarry is at Michigan Lime stone and Chemical Company in Rogers City, Michigan.

5 – Uses :

Lime stone is very common in architecture, especially in Europe and North America. Many landmarks across the world, including the Great Pyramid and its associated complex in Giza, Egypt, are made of Lime stone. So many buildings in Kingston, Canada were constructed from it that it is nicknamed the 'Lime stone City'. On the island of Malta, a variety of Lime stone called Globigerina Lime stone was, for a long time, the only building material available, and is still very frequently used on all types of buildings and sculptures. Lime stone is readily available and relatively easy to cut into blocks or more elaborate carving. It is also long-lasting and stands up well to exposure. However, it is a very heavy material, making it impractical for tall buildings, and relatively expensive as a building material.

The Great Pyramid of Giza, one of the Seven Wonders of the Ancient World; its outside cover is made entirely from Lime stone.

Courthouse built of Lime stone in Manhattan, Kansas

Lime stone was most popular in the late 19th and early 20th centuries. Train stations, banks and other structures from that era are normally made of Lime stone. It is used as a facade on some skyscrapers, but only in thin plates for covering, rather than solid blocks. In the United States, Indiana, most notably the Bloomington area, has long been a source of high quality quarried Lime stone, called Indiana Lime stone. Many famous buildings in London are built from Portland Lime stone.

Lime stone was also a very popular building block in the Middle Ages in the areas where it occurred, since it is hard, durable, and commonly occurs in easily accessible surface exposures. Many medieval churches and castles in Europe are made of Lime stone. Beer stone was a popular kind of Lime stone for medieval buildings in southern England.

Lime stone and (to a lesser extent) marble are reactive to acid solutions, making acid rain a significant problem to the preservation of artifacts made from this stone. Many Lime stone statues and building surfaces have suffered severe damage due to acid rain. Acid-based cleaning chemicals can also etch Lime stone, which should only be cleaned with a neutral or mild alkaline-based cleaner.

Other uses include :

- It is the raw material for the manufacture of quicklime (calcium oxide), slaked lime (calcium hydroxide), cement and mortar.
- Pulverized Lime stone is used as a soil conditioner to neutralize acidic soils.
- It is crushed for use as aggregate — the solid base for many roads.
- Geological formations of Lime stone are among the best petroleum reservoirs;
- As a reagent in flue - gas desulfurization, it reacts with sulfur dioxide for air pollution control.
- Glass making, in some circumstances, uses Lime stone.
- It is added to toothpaste, paper, plastics, paint, tiles, and other materials as both white pigment and a cheap filler.
- It can suppress methane explosions in underground coal mines.
- Purified, it is added to bread and cereals as a source of calcium.
- Calcium levels in livestock feed are supplemented with it, such as for poultry (when ground up) .
- It can be used for remineralizing and increasing the alkalinity of purified water to prevent pipe corrosion and to restore essential nutrient levels.

- Used in blast furnaces, Lime stone extracts iron from its ore.
- It is often found in medicines and cosmetics.
- It is used in sculptures because of its suitability for carving.

Lime Water

Contents

1 – Introduction :

Lime water is the common name for saturated calcium hydroxide solution. It is sparsely soluble. Its chemical formula is $Ca(OH)_2$. Since calcium hydroxide is only sparsely soluble, i.e. ca. 1.5 g per liter at 25 °C , there is no visible distinction to clear water (homogeneous). Attentive observers will notice a slightly earthy smell. It is clearly distinguishable by the alkaline taste of the calcium hydroxide. The term **lime** refers to the mineral, rather than the fruit. When exposed with carbon dioxide, lime water turns into a milky solution.

While **lime water** is a clear solution, **milk of lime** on the other hand is a suspension of calcium hydroxide particles in water. These particles give it the milky aspect. It is commonly produced by reacting quick lime (calcium oxide) with an excess of water - usually 4 to 8 times the amount of water to the amount of quicklime. Reacting water with quicklime is sometimes referred to as "slaking" the lime. The calcium oxide will convert to the hydroxide according to the following reaction scheme:

$$Ca\,O + H_2O \rightarrow Ca\,(OH)_2$$

This reaction is strongly exothermic and will generate enough heat to bring the suspension to a scalding temperature. At a ratio of 2 parts water to 1 part lime (by weight) , the generated heat is sufficient to bring the suspension, i.e. the water in it, to boil.

Milk of lime is an alkaline with a pH of 12.3. It is commonly used in the chemical industry and as a neutralizing agent in municipal waste water treatment. While it has a multitude of other uses, it is best known in its (historical) use as a paint : **lime wash** or white wash.

2 - Making lime water :

Lime water can be made by mixing excess calcium hydroxide with distilled water, or deionized water. The mixture needs to be shaken to ensure the solution is saturated with calcium hydroxide. It is then left to settle and the clear "saturated" solution is siphoned off the sediment.

3 - Uses of lime water :

3 – 1 – Chemistry :

In chemistry, Lime water can be used to detect the presence of carbon dioxide because Lime water reacts with carbon dioxide to produce a precipitate of calcium carbonate:

$$Ca(OH)_2\ _{(aq)} + CO_2\ _{(g)} \rightarrow CaCO_3\ _{(s)} + H_2O\ _{(l)}$$

If excess CO_2 is added, the following reaction takes place :

$$CaCO_3 + H_2O + CO_2 \dashrightarrow Ca\,(HCO_3)_2 \text{ (colourless)}$$

Lime water is also used in experiments involving aerobic or anaerobic respiration, to determine whether carbon dioxide was produced, by first boiling the Lime water and then pouring the solute into the boiling lime water. When lime water reacts with CO_2 it becomes milky, because of the calcium carbonate, or chalk, produced.

3 – 2 – Medicine :

When the old vaudeville - style medicine shows promoting various patent medicines were in full swing, Lime water was often used as a part of the act. The salesperson would have an audience member blow through a straw into a glass of Lime water. Since the exhaled gas is carbon dioxide, the water would turn cloudy; the huckster then announced that this reaction proved that the audience member suffered from some ailment. If too much carbon dioxide comes into contact with the cloudy Lime water, it will cause the calcium carbonate precipitate to redissolve to form soluble calcium bicarbonate.

$$CaCO_3\,(s) + CO_2\,(g) + H_2O\,(l) \rightarrow Ca\,(HCO_3)_2\,(aq)$$

The huckster had a patent medicine bottle filled with vinegar or some similar acid. He then would pour some of the acid into the glass of cloudy Lime water. The acid reacted with the calcium carbonate, and the water would instantly clear. This demonstrated the potent effect of the nostrum he was selling to eliminate the "disease" demonstrated by the audience member.

3 – 3 – Culinary :

Lime water can be used in the nixtamalization process used in the traditional making of corn tortillas , tamales , corn chips and various other maize products.

Mixing lime water with konjac flour and water, the result is Japanese konnyaku , one of the ingredients in sukiyaki.

3 – 4 – Sugar :

Lime water is used to make sugar from sugar beets.

3 – 5 – Arts :

In buon fresco painting, lime water is used as the colour solvent to apply on fresh plaster.

3 – 6 – Other uses :

Lime water is widely used by marine aquarists and is a primary supplement of calcium and alkalinity for reef aquariums. Corals of order Scleractinia build their endoskeletons from aragonite (a polymorph of calcium carbonate) and by doing so , usually form a reef . Calcium concentration in natural seawater is about 420 ppm . When used for this purpose, Lime water is also referred to as Kalkwasser. Lime water , or some variation of it, is also used in tanning and making parchment. The lime is used as a dehairing agent based on its alkaline solution .

List of Building Materials

Building materials used in the construction industry to create buildings and structures.

These categories of materials and products are used by American architects and construction project managers to specify the materials and methods used for building projects.

Catalogs distributed by architectural product suppliers are typically organized into these groups.

Material (articles)	*refer to :* **Category**
Compressed earth block, mud brick, rammed earth	Category:Appropriate technology
Concrete	Category:Concrete
Conveying systems Elevator or "lift" Escalator	Category:Vertical transportation devices
Composites	Category:Composite materials
Thermal protection	Category:Thermal protection
Moisture protection	Category:Moisture protection
Doors Stile and rail, raised panel, wood clad Access, sliding glass doors, tambour Folding doors, garage door, storefront Door hardware	Category:Doors
Electrical systems and equipment	Category:Electrical systems
Surface finishing Plaster & gypsum board Cement render Ceramic tile, quarry tile, pavers, mosaic Dropped ceiling, coffered ceiling	Category:Finishes also "gyp-board" or "drywall" Category:Tiles Category:Roofs Category:Ceilings Category:Floors

Flooring - wide plank, terrazzo, carpet Wall covering, wallpaper, acoustic Paint, wood stain, faux finishing Staff	Category:Walls House painting
Fire suppression equipment	Category:Fire suppression
Furnishings	Category:Furniture
HVAC (Heating, ventilation and air conditioning)	Category:HVAC
Masonry, mortar (masonry), grout Adobe, brick, glass brick, terra cotta Artificial stone Cinder block or concrete block Stone dry stacked or mortar set Urbanite, broken-up concrete	Category:Masonry Category:Bricks *also:* "Concrete Masonry Units" (CMU) Category:Stone
Metals Structural steel: I-beam & column Rebar Wire rope and cables Metal joist, decking, framing, trusses Metal fabrications Stairway, ladder, railing, grating, Strut channel Decorative metal	Category:Metals
"Openings" include Doors & Windows	Category:Doors
Plastics	Category:Plastics
Plumbing fixtures and equipment	Category:Plumbing
Building safety	Category:Building safety
Security systems	Category:Security
Specialties	Category:Architectural specialties
Telecommunications equipment	Category:Telecommunications
Wood, carpentry Rough carpentry (unfinished) Heavy timbers, log home, post and	Category:Wood Category:woodworking *see also:* List of woods

beam Engineered wood, dimensional lumber Stud, joist, rafter Treated lumber & wood decking Sheathing, subflooring, panelling Plywood, shiplap, tongue and groove Oriented strand board Parallel strand lumber or "*para-lam*" Glue-laminate or "*glue-lam*" Finish carpentry or "architectural woodwork" Veneer, plastic laminate, wood panel "Case goods" Millwork, bookcase, cabinets Ornamental woodwork Trim, molding or "moulding" Chair rail, baseboard, casing, sill	
Windows Casement, double hung, bay window Curtainwall, skylight, dormer	Category:Windows

List of Decorative Stones

Contents :

1 – Introduction :

Natural stone is a geographical **list of stone** used for decorative purposes in construction and monumental sculpture; currently or historically produced in various countries. In addition hard stone carving uses many types of gem stones.

The dimension stone industry classifies stone based on appearance and hardness as either "granite", "marble" or "slate".

The granite of the dimension-stone industry along with truly granitic rock also includes gneiss, gabbro, anorthosite and even some sedimentary rocks.

Uses for natural stone include architectural stone (construction, flooring, cladding, counter tops, curbing, etc.), raw block and monument stone for the funerary trade. Another popular use for natural stone is custom stone engraving. The engraved stone can be either decorative or functional. Natural memorial stones are being used as natural burial markers.

2 - External links :

- Custom Stone Engraving

3 - Belgium

- Lime stone

4 - Canada :

Anorthosite - Charnockite - Diabase - Diorite - Granite - Gabbro - Gneiss - Lime stone - Marble - Monzonite - Sand stone - Slate - Steatite (Soap stone) - Stromatolites - Syenite

5 - France :

- Lime stone
    - Caen stone
    - Pierre de Comblanchien
    - Pierre d'Euville
    - Pierre de Jaumont
    - Tuffeau stone

6 - Greece :

Marble - Verde Antico

7 - India :

Marble - Granite - Sandstone - Slate - Flaggy Lime stone

8 - Iran :

Marble - Travertine - Onyx - Lime stone

9 - philistine :

Lime stone / Dolomite - Jerusalem stone

10 - Norway :

Anorthosite - Larvikite - Marble - Quartzite

11 - Pakistan :

Pakistan have more than 300 kinds of marble and natural stone types and variations :

Marble - Granite - Onyx - Lime stone

12 - Poland :

Sandstone : (Radków - Szczytna - Czaple - Skała) - Lime stone : (Dębnik - Kielce) - Granite : (Strzegom -Strzelin) - Syenite , Granodiorite - Serpentinite

13 - Italy :

Portoro Buono - Carrara marble - Peperino - Travertine - Pietra Serena

14 - Turkey :

Elazig Cherry Marble : (Burdur Beige Marble - Emprador - Marmara Marble - Mugla White - Noche Travertine

15 - United Kingdom :

Chalk - Flint - Granite - Lime stone - Portland Admiralty - Portland Hard Blue - Purbeck marble – Sand stone Corncockle -

16 - United States of America : Brown stone - Granite - Lime stone

17 - Americas :

Tezontle

List of Roman Aqueduct Bridges

Pons Aelius in Rome, Italy

Pons Cestius, Rome, during a flood

Contents

1 – Introduction :

The Romans were the world's first major bridge builders.[1] The following list constitutes an attempt to list all known Roman bridges, many of which still survive to this day.

A Roman bridge in the sense of this article includes any of these features :

- Roman arches

- Roman pillars
- Roman foundations
- Roman abutments
- Roman roadway
- Roman cutwaters

Also listed are bridges which feature substantially Roman material (Spolia), as long as the later bridge is erected on the site of a Roman precursor. Finally, incidences where only excavated bridge inscriptions lay testimony to the existence of a now perished Roman bridge are also included.

In the following, bridges are classified either according to their material or their function. Most data not otherwise marked comes from O'Connor's *Roman Bridges* which lists 330 stone bridges for traffic, 34 timber bridges and 54 aqueduct bridges.[2] An even larger compilation is offered by the Italian scholar Galliazzo who describes more than 900 Roman bridges (as of 2011, his list is used here only selectively).

2 - Note on classification :

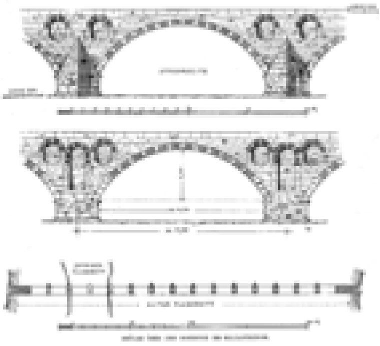
Bridges are particularly difficult to classify as they, more than other structures, are subject to wear, war and the impact of natural elements. The constant need for repairs through the ages has often turned bridges into hybrid structures, which make it often difficult or nearly impossible to determine the exact date and origin of individual parts of a bridge. Thus, the majority of the bridges listed below can be assumed to include medieval or (early) modern modifications, replacements or extensions, to a small or large extent.

3 - Masonry bridges :

Below bridges out of stone or brick. The vast majority features arches, although stone deck slabs were also known. Concerning the bridges' spans and height: S = small, M = middle and L = large.

Image	Name	Country
	Aesepus Bridge	Turkey
	Alcántara Bridge	Spain
	Alconétar Bridge	Spain
	Alte Sauerbrücke	Luxembourg / Germany
	Arapsu Bridge	Turkey

	Band-e Kaisar	Iran
	Bridge at Afrin	Syria
	Bridge at Limyra	Turkey
	Eurymedon Bridge	Turkey
	Eurymedon Bridge	Turkey

	Karamagara Bridge	Turkey
	Kemer Bridge	Turkey
	Makestos Bridge	Turkey
	Misis bridge	Turkey
	Pons Aelius	Italy, Rome & vicinity

	Pons Aemilius	Italy, Rome & vicinity
	Pons Cestius	Italy, Rome & vicinity
	Pons Fabricius	Italy, Rome & vicinity
	Pons Neronianus	Italy, Rome & vicinity
	Pons Mulvius	Italy, Rome & vicinity

	Pont de Domqueur	France
	Pont de Pierre	Italy, Northern
	Pont de Sommières	France
	Pont de St Thibéry	France
	Pont de Vaison-la-Romaine	France

	Pont Ambroix	France
	Pont des Marchands	France
	Pont Flavien	France
	Pont Julien	France
	Pont Romà	Spain

	Pont-Saint-Martin	Italy, Northern
	Pont sur la Laye	France
	Ponte del Tirso	Italy, Insular
	Ponte dell’Abbadia	Italy, Central
	Ponte d'Augusto	Italy, Central

	Ponte d'Augusto at Narni	Italy, Central
	Ponte di Cecco	Italy, Central
	Ponte di Porta Cappuccina	Italy, Central
	Ponte Molino	Italy, Northern
	Ponte Nomentano	Italy, Rome & vicinity
	Ponte Pietra	Italy, Northern

	Ponte romana	Spain
	Ponte Salario	Italy, Rome & vicinity
	Ponte sul Mannu	Italy, Insular
	Ponte sul Ofanto	Italy, Southern
	Puente del Bibey	Spain

	Puente de Alcántara	Spain
	Puente de Cangas de Onís	Spain
	Roman Bridge	Portugal
	Puente de Segura	Spain/ Portugal
	Pont del Diable	Spain

	Puente Romano	Spain
	Puente Romano	Spain
	Penkalas Bridge	Turkey
	Sangarius Bridge	Turkey
	Pergamon Bridge	Turkey
	Severan Bridge	Turkey

	Sankt Dionysen bridge	Austria

4 - Timber and stone pillar bridges :

A timber bridge is a structure composed wholly out of wood, while a stone pillar bridge features a wooden super structure resting on stone pillars. Strictly speaking, many bridges of the second type should be rather called "concrete pillar bridges", as the Romans preferably used opus caementicium for constructing their bridge piers (stone was confined in these cases to covering). Both types, timber bridges and stone respectively concrete pillar bridges, are listed here in the same category as historically, with the consolidation of Roman power in the newly conquered provinces, wooden bridges often gave way to solid pillar bridges.

Image	Name	River	Country
	Caesar's Rhine bridges	Rhine	Germany
	Pons Sublicius	Tiber	Italy
	Römerbrücke	Mosel	Germany

	Römerbrücke Rhine	Germany

5 - Pontoon bridges :

As an alternative to ferry services, the Roman army often made use of pontoon bridges, along with timber structures, for river crossings. They usually consisted of boats lashed together, with the bows pointing towards the current. Permanent bridges of boats were also commonly set up for civilian traffic.

Character	River	Country
Bridge of boats	Danube	Serbia
Bridge of boats	Danube	Romania / Serbia
Bridge of boats	Sakarya (Sangarius)	Turkey

6 - Aqueduct bridges :

Image	Town	Country
	Antibes	France
	Aspendus	Turkey

	Caesarea	Philistine
	Carthage	Tunisia
	Cogne	Italy, Northern
	Cologne	Germany
	Fréjus	France

	Istanbul	Turkey
	Mainz	Germany
	Mérida	Spain
	Nîmes	France
	Rome	Italy

	Rome	Italy
	Rome	Italy
	Rome	Italy
	Rome	Italy
	Segovia	Spain
	Spoleto	Italy

	Tarragona	Spain
	Termini Imerese	Italy

List of Some Church in the World

This article lists the **largest church buildings in the world** as measured by various criteria.

Contents :

1 - Scope

The term *church* is open to interpretation and debate. In this article, it means any building that was built for the primary purpose of Christian worship, for any recognised denomination of Christianity. This includes every cathedral (the seat of a bishop), basilica, and other type of church. It does not include temples of other religions, such as mosques, synagogues, and so on. It does include at least one building, Hagia Sophia, that was built as a church and later became a mosque (it is now a museum).

2 – Measurements :

Whilst claims are made about the relative size of churches many of these claims are not easily substantiated. "Largest" is at best a vague term, which is often not qualified by claimants. Accepted measures of largeness could include area, volume, length, width, height, and capacity (although the latter is far more subjective). It is important to note therefore that churches may claim to be "the largest" based on only one of these measurements; and thus that there may be several churches that have equal claim to be the "nth largest church". Since there is no official body governing these claims, there is no generally accepted criterion for being "the largest church".

The lists below attempt to rank churches by different (more-or-less) objective criteria, and thus may generate different orders depending on the measure used. Churches for which claims are made but dimensions cannot be found are not included on the below lists.

For length, width and height, there is usually a definitive statistic for each church, which can easily be compared. However, for area and volume, the situation is often more complex. It is often possible to find multiple values quoted for the area/volume of a church in references. Many values appear to be estimates or approximations (especially for volume), or may have been calculated by multiplying lengths, widths and heights. In the latter case, the exact dimensions used (internal vs. external, etc.) may give very different figures. Therefore, although area and volume are the most common 'largeness' measures, they are also apt to be the least reliable. This should be borne in mind when comparing church sizes.

3 - By area :

Area in m^2	Gross volume in m^3	Name	Completion	City	Country	Denomination
20,139 (interior 15,160)	1,200,000	St. Peter's Basilica	1506–1626	Vatican City	Vatican City	Roman Catholic
12,000	1,200,000	Basilica of the National Shrine of Our Lady of Aparecida	1955	Aparecida	Brazil	Roman Catholic
11,520	> 500,000	Seville Cathedral	1520	Seville	Spain	Roman Catholic
11,200	480,000	Cathedral of Saint John the Divine	unfinished	New York	United States	Episcopalian (Anglican)
10,186	440,000	Milan Cathedral	1386 –1965	Milan	Italy	Roman Catholic
10,090	300 000	Basilica of Our Lady	1994–2004	Licheń Stary	Poland	Roman Catholic

		of Licheń				
9,687		Liverpool Cathedral	1978	Liverpool	United Kingdom	Church of England (Anglican)
8,700	130,000	Church of the Most Holy Trinity	2007	Fátima	Portugal	Roman Catholic
8,318		Basilica-Cathedral of Our Lady of the Pillar	1681–1872	Zaragoza	Spain	Roman Catholic
8,162	170 000	Cathedral of Saint Sava	2003	Belgrade	Serbia	Orthodox
8,000		Basilica of the Sacred Heart	1970	Koekelberg (Brussels)	Belgium	Roman Catholic
8,000		Basilica of Our Lady of Guadalupe	1974–1976	Mexico City	Mexico	Roman Catholic
8,000[16]		Cathedral of Our Lady	1352 – 1521	Antwerp	Belgium	Roman Catholic
8,000		Basilica of Our Lady of Peace	1989	Yamoussoukro	Ivory Coast	Roman Catholic
7,920		San Petronio	1390–1658	Bologna	Italy	Roman Catholic
7,914	407,000	Cologne Cathedral	1248–1880	Cologne	Germany	Roman Catholic
7,875		St Paul's	1677–1708	London	United	Church of

		Cathedral			Kingdom	England (Anglican)
7,712		Washington National Cathedral	1907–1990	Washington, DC	United States	Episcopalian (Anglican)
7,700	200,000 (interior only)	Amiens Cathedral	predates 1218	Amiens	France	Roman Catholic
7,400		Hagia Sophia	537	Istanbul	Turkey	State church of the Roman Empire
7,097		Basilica of the National Shrine of the Immaculate Conception	1919–1961	Washington D.C.	United States	Roman Catholic

List of Some Hindu Temples in the World

1 - Akshardham (Delhi)

Contents

- ○ 4.1 Disputes

1 – Introduction :

Akshardham (Gujarati , Devnagari) is a Hindu temple complex in Delhi, India . Also referred to as *Delhi Akshardham* or *Swaminarayan Akshardham*, the complex displays millennia of traditional Hindu and Indian culture, spirituality, and architecture. The building was inspired and developed by Pramukh Swami Maharaj, the spiritual head of the Bochasanwasi Shri Akshar Purushottam Swaminarayan Sanstha, whose 3,000 volunteers helped 7,000 artisans construct Akshardham.

The temple, which attracts approximately 70 percent of all tourists who visit Delhi , was officially opened on 6 November 2005. It sits near the banks of the Yamuna adjacent to the 2010 Commonwealth Games village in eastern New Delhi . The temple, at the center of the complex, was built according to the Vastu Shastra and Pancharatra Shastra. In addition to the large central temple crafted entirely of stone, the complex features exhibitions on incidents from the life of Swaminarayan and the history of India, an IMAX feature on the early life of Swaminarayan as the teenage yogi, Nilkanth, a musical fountain on the message of the Upanishads, and large landscaped gardens. The temple is named after a belief in Swaminarayan Hinduism.

Coordinates:	28°36′50.35″N 77°16′39.73″E 28.6139861°N 77.2777028°E
Proper name:	Swaminarayan Akshardham
Country:	India
Location:	Noida Mor, New Delhi
Architecture and culture	
Primary deity:	Swaminarayan
Architectural styles:	Vastu Shastra and Pancharatra Shastra

History	
Date built: (Current structure)	6 November 2005 (consecration)
Creator:	BAPS, Pramukh Swami Maharaj

2 - Features :

2 – 1 - Monument :

The central monument at Akshardham

The main monument, at the center of the complex, is 43 m high, 96 m wide, and 110 m long, and is covered top to bottom with carved details of flora, fauna, dancers, musicians, and deities.

Designed in accordance with ancient Vedic text known as the Sthapatya Shastra, it features a blend of architectural styles from across India . It is constructed entirely from Rajasthani pink sandstone and Italian Carrara marble, and has no support from steel or concrete . The monument also consists of 234 ornately carved pillars, nine domes, and 20,000 murtis and statues of Hinduism’s sadhus, devotees, and acharyas . The monument also features the Gajendra Pith at its base, a plinth paying tribute to the elephant for its importance in Hindu culture and India's history. It contains 148 scale sized elephants in total and weighs a total of 3000 tons .

Within the monument, under the central dome, lies a murti or tatue of Swaminarayan which is 3.4 m high. The murti is surrounded by similar statues of the gurus of the sect . Each murti is made of *paanch daatu* or five metals in accordance to Hindu tradition. Also within the central monument lie the murtis of other Hindu deities, including Sita Ram, Radha Krishna, Shiv Parvati, and Lakshmi Narayan.

The monument's central dome

2 - 2 - Exhibitions :

2 - 2 – 1- Hall of Values :

Also known as Sahajanand Pradarshan, the Hall of Values features life-like robotics and dioramas which display incidents from Swaminarayan's life, portraying his message about the importance of peace, harmony, humility, service to others and devotion to God. The Sahajanand Pradarshan is set in 18th century India and displays of 15 dioramas through robotics, fiber optics, light and sound effects, dialogues, and music . The hall features the world's smallest animatronic robot in the form of Ghanshyam Maharaj, the child form of Swaminarayan .

2 - 2 – 2 - Theatre :

Named Neelkanth Kalyan Yatra, the theatre houses Delhi's first and only large format screen, measuring 26 m by 20 m . The theatre shows a film specially commissioned for the complex, *Neelkanth Yatra*, to recount a seven-year pilgrimage made by Swaminarayan made during his teenage years throughout India. *Mystic India*, an international version of the film called, was released in 2005 at IMAX theatres and giant screen cinemas worldwide . A 8.2 m tall bronze murti of Neelkanth Varni is located outside the theatre .

The musical fountain
and the statue of Neelkanth Varni in its back ground

2 - 2 – 3 - Musical fountain :

Known as the Yagnapurush Kund, it is India's largest step well. It features a very large series of steps down to a traditional yagna kund. During the day, these steps provide rest for the visitors to the complex and at night, a musical fountain show representing the circle of life is played to an audience which is seated on the same steps. The fountain is named after the founder of the Hindu organization, Shastriji Maharaj. The fountain measures 91 m by 91 m with 2,870 steps and 108 small shrines. In its center lies an eight-petaled lotus shaped yagna kund designed according to the Jayaakhya Samhita of the Panchratra shastra.

2 - 2 – 4 - Boat ride :

Named Sanskruti Vihar, this ride takes visitors on a journey through 10,000 years of Indian history in approximately 12 minutes. Visitors sit in specially designed peacock shaped boats that make their way around an artificial river, passing through a model of Takshashila, the world's first university,[19] chemistry laboratories, ancient hospitals, and bazaars, finally ending with a message expressing hope for the future of India.

2 - 2 – 5 - Garden of India :

Also known as the Bharat Upavan, this garden has lush manicured lawns, trees, and shrubs. The garden is lined with bronze sculptures of contributors to India's culture and history. These sculptures include children, women, national figures, freedom fighters, and warriors of India. Of these figures, the more notable figures include the national figures such as Mahatma Gandhi.

The Yogi Hraday Kamal, a lotus shaped sunken garden

2 - 3 – Additional features :

2 - 3 – 1 - Yogi Hraday Kamal :

A sunken garden, shaped like a lotus when viewed from above, features large stones engraved with quotes from world luminaries ranging from Shakespeare and Martin Luther King to Swami Vivekananda and Swaminarayan.

2 - 3 – 2 - Neelkanth Abishek :

Devotees offer abhishek, a ritual of pouring water on to the murti of Neelkanth Varni, and express their reverence and prayers for spiritual upliftment and fulfillment of wishes.

2 - 3 – 3 - Narayan Sarovar :

The Narayan Sarovar is a lake that surrounds the main monument. The lake contains holy waters from 151 rivers and lakes that are believed to have been sanctified by Swaminarayan, including Mansarovar. Surrounding the Narayan Sarovar are 108 gaumukhs, symbolizing Janmangal Namavali or the 108 names for god, from which holy water issues forth .

2 - 3 – 4 - Premvati Ahargruh :

The Premati Ahargruh or the Premvati Food Court is a vegetarian restaurant modeled on the Ajanta and Ellora caves in Maharashtra, India and an Ayurvedic bazaar . The restaurant caters a variety of traditional dishes .

2 - 3 – 5 - AARSH Centre :

The Akshardham Centre for Applied Research in Social Harmony or the AARSH Centre is a centre within the complex that applies research of social harmony and related topics. Scholars and students may conduct practical research through AARSH. Researchers have the ability to carry out their research projects and affiliate their papers with AARSH. Studies on education, medicare, tribal and rural welfare, ecology, and culture are conducted within the centre .

3 - History and development :

The Akshardham complex in Delhi

3 – 1 – Planning :

The building had been planned since 1968 as a vision of Yogiji Maharaj . Yogiji Maharaj, the spiritual head of the BAPS Swaminarayan Sanstha at the time, expressed his desire for wanting a grand temple built on the banks of the Yamuna river to two or three devotee families of Swaminarayan that resided in New Delhi at the time . Attempts were made to start the project, however little progress was made. In 1971, Yogiji Maharaj died.

In 1982, Pramukh Swami Maharaj, Yogiji Maharaj's successor as the spiritual head of BAPS, started to continue fulfilling the dream of his guru Yogiji Maharaj and prompted devotees to look into the possibility of building the temple in Delhi. A request for the plan was put forward to the Delhi Development Authority (DDA), and several different places were suggested, including Ghaziabad, Gurgaon, and Faridabad. Pramukh Swami Maharaj stood firm in following the wishes of Yogiji Maharaj to build a temple on the Yamuna.

In April 2000, after 18 years, the Delhi Development Authority offered 60 acres (240,000 m^2) of land, and the Uttar Pradesh Government offered 30 acres (120,000 m^2) for the project . Upon receiving the land, Pramukh Swami Maharaj performed puja on the site for success in the project. Construction on the temple began on 8 November 2000 and Akshardham was officially opened on 6 November 2005, with the building being completed in two days short of five years .

3 – 2 – Development :

A team of eight sadhus were assigned to oversee the Akshardham project . The majority of the team had gained experience from work on the Akshardham in Gandhinagar , Gujarat , Delhi Akshardham's sister complex . During development, Pramukh Swami Maharaj was consulted in many aspects of the monument's construction .

Construction on the Akshardham complex

Around 1997 and 1998, the idea to start development on the temple, by beginning the stone carving, had been requested. However, this idea was denied by Pramukh Swami Maharaj who believed that the construction should only start after the land was acquired. The initial work done on the site was on the foundation. Due to the soft river bank, the site wasn't considered ideal for construction. As a result, a deep foundation was imperative. To construct a stable foundation , 4.6 m of rocks and sand were entwined with wire mesh and topped by five feet of concrete. Five million fired bricks raised the foundation another 6.6 m . These bricks were then topped by three more feet of concrete to form the main support under the monument.

On 2 July 2001, the first sculpted stone was laid . The team of eight sadhus consisted of scholars in the field of the Pancharatra Shastra, a Hindu scripture on architecture and deity carving. The sadhus watched over stone work as well as the research on carvings on Indian craftsmanship from between 8th and 12th century. This research was done at various sites such as Angkor Wat, as well as Jodhpur, Jagannath Puri, Konark, and other temples in South India .

Seven thousand carvers and three thousand volunteers were put to work for the construction Akshardham . With over 6,000 tons of pink sandstone coming from Rajasthan, workshop sites were set up around places within the state . Amongst the carvers were local farmers and fifteen hundred tribal women who had suffered from a drought and received economic gain due to this work. The initial stone cutting was done by machine, while the detailed carvings were done by hand. Every night, over one hundred trucks were sent to Akshardham, where four thousand workers and volunteers operated on the construction site .

3 – 3 – Opening Ceremony :

Akshardham was consecrated on 6 November 2005 by Pramukh Swami Maharaj and ceremoniously dedicated to the nation by the President of India, Dr. A.P.J. Abdul Kalam , the Prime Minister, Manmohan Singh, and the Leader of the Opposition in the Indian Parliament, Lal Krishna Advani, with the presence of 25,000 guests. After touring the central monument, President Kalam then gave a speech on where Akshardham fits with society, and finished by saying,

"Pramukh Swamiji Maharaj has inspired thousands of people across the country and abroad and brought together the best of the minds for creating a beautiful cultural complex. It has become a place of education, experience and enlightenment. It creatively blends the traditional stone art and architecture, Indian culture and civilization, ancient values and wisdom and the best of modern media and technology. Multiple layers of this complex expresses the strength of the mind, willpower of the human being, indomitable spirit, flowering kindness, fusion of scientific and medical talent, myriad colors of varied cultures and ultimately the power of knowledge. In essence, it is a dynamic complex with lively images . Akshardham has happened at the dawn of 21st century with the commitment and dedication of one million volunteers. What has happened today at Akshardham inspires me and gives me the confidence that we can do it? The realization of developed India is certainly possible before 2020 with the millions of ignited minds like you ".

Prime Minister Singh followed by hoping that this would usher in religious tolerance and praised the architecture of the complex. He made note of it becoming a future landmark of India while L. K. Advani called it "the most unique monument of the world ". Pramukh Swami Maharaj ended the night's speeches and expressed the wish that, "In this Akshardham, may one and all find inspiration to mould their lives and may their lives become divine. Such is my prayer to god ".

3 – 4 – Garbhagruh renovation and events :

On 13 July 2010, a newly designed garbhagruh, or inner sanctum, was inaugurated by Pramukh Swami Maharaj in the main monument within the Akshardham complex. The new garbhagruh includes a decorated, canopied sihasan, upon which the murti of

Swaminarayan rests and features intricate carvings and gold-leafed designs .

Akshardham served as a featured attraction during the 2010 Commonwealth Games held in Delhi. Through the duration of the Games, hundreds of athletes, teams, and enthusiasts from around the world visited the complex . On 14 November 2010, the Swaminarayan Research Institute at Akshardham was inaugurated through an event organized by the women's faction of the organization, highlighting the value of seva, or socially beneficial volunteer efforts, in society through mandirs, churches, mosques, and other places of worship . Anju Bhargava, the founder of the Hindu American Seva Charities and advisor to President Barack Obama on faith-based issues, delivered the keynote address, which emphasized the need for seva in society and the vital role of spirituality in one's life.

4 - Guinness World Record :

The Akshardham monument in Delhi

On 17 December 2007, Michael Whitty, an official world record adjudicator for Guinness World Records, traveled to Ahmedabad, India to present a new world record to Pramukh Swami Maharaj, the spiritual leader of BAPS Swaminarayan Sanstha, for the Akshardham complex .

The record was presented for Akshardham as the *World's Largest Comprehensive Hindu Temple* (certificate) .

The certificate states,

"BAPS Swaminarayan Akshardham in New Delhi, India, is the world's largest comprehensive Hindu temple. It measures 109 m . long , 96 m . wide and 43 m . high, covering an area of 8,021.4 m² . The grand, ancient-style, ornately hand-carved stone temple has been built without structural steel within five years by 11,000 artisans and volunteers. His Holiness Pramukh Swami Maharaj, revered spiritual leader of BAPS, consecrated the temple on 6 November 2005. Akshardham showcases the essence of India's ageless art, borderless culture and timeless values .

Upon presentation of the award, Michael Whitty stated, "It took us three months of research, poring over the extensive architectural plans of the Akshardham and also those of other temples of comparable size, visiting and inspecting the site, before we were convinced that Akshardham deserved the title..."

4 – 1 – Disputes :

Three temples, the Meenakshi Amman Temple in Madurai, the Sri Ranganathaswamy Temple in Srirangam, and the Annamalaiyar Temple in Thiruvannamalai, all located in Tamil Nadu, India, are claimed to be larger than Akshardham. The trustees of these temples have reportedly disputed the Guinness World Record .

The Meenakshi temple in Madurai has the length of 850 feet (260 m) and width of 240 m . The entire area of this temple is 0.069 km² , while the Sri Ranganathaswamy temple in Srirangam covers 0.63 km² and the Arunachaleswarar Temple in Thiruvannamalai is 0.097 km² . Authorities at the Meenakshi temple have argued that temples are places for worship and therefore additional features and exhibitions are not components of a temple. They have also argued that construction area of the actual temple is more important than the land area .

Akshardham Information :

- Official Akshardham Delhi Website
- Akshardham Temple Complex on the Incredible India website
- Akshardham Temple Complex on the Incredible India website
- Akshardham Temple in India

Other

- Guinness World Records - Adjudications - World's Largest Hindu Temple
- BAPS Swaminarayan Sanstha- The organization responsible for the creation of Akshardham
- Mystic India- The film shown at Akshardham
- Akshardham Gandhinagar Website

List of Some Hindu Temples in the World

2 - Angkor Wat

Contents

1 – Introduction ;

Angkor Wat (Khmer :) is the largest Hindu temple complex in the world, situated at Angkor, Cambodia, built by King Suryavarman II in the early 12th century as his state temple and capital city. As the best-preserved temple at the site, it is the only one to have remained a significant religious centre since its foundation – first Hindu, dedicated to the god Vishnu, then Buddhist. The temple is at the top of the high classical style of Khmer architecture. It has become a symbol of Cambodia , appearing on its national flag, and it is the country's prime attraction for visitors.

Angkor Wat combines two basic plans of Khmer temple architecture: the temple mountain and the later galleried temple. It is designed to represent Mount Meru, home of the devas in Hindu mythology: within a moat and an outer wall 3.6 kilometres (2.2 mi) long are three rectangular galleries, each raised above the next. At the centre of the temple stands a quincunx of towers. Unlike most Angkorian temples, Angkor Wat is oriented to the west; scholars are divided as to the significance of this. The temple is admired for the grandeur and harmony of the architecture, its extensive bas-reliefs, and for the numerous devatas adorning its walls.

The modern name, Angkor Wat, means "City Temple"; *Angkor* is a vernacular form of the word *nokor* (), which comes from the Sanskrit word *nagar* . *Wat* is the Khmer form of the Pali word "vatthu", meaning "temple grounds". Prior to this time the temple was known as *Preah Pisnulok* (Vara Vishnuloka in Sanskrit), after the posthumous title of its founder.

Coordinates:	13°24′45″N 103°52′0″E 13.4125°N 103.866667°E
Proper name:	Prasat Angkor Wat
Country:	Cambodia
Location:	Angkor, Siem Reap Province
Primary deity:	Vishnu
Architectural styles:	Khmer, Dravidian
Date built : (Current structure)	12th century
Creator :	Suryavarman II

Angkor Wat lies 5.5 kilometres north of the modern town of Siem Reap, and a short distance south and slightly east of the previous capital, which was centred at Baphuon. It is in an area of Cambodia where there is an important group of ancient structures. It is the southernmost of Angkor's main sites.

The initial design and construction of the temple took place in the first half of the 12th century, during the reign of Suryavarman II (ruled 1113 – c. 1150). Dedicated to Vishnu, it was built as the king's state temple and capital city. As neither the foundation stela nor any contemporary inscriptions referring to the temple have been found, its original name is unknown, but it may have been known as *Vrah Vishnu-lok* (literally "Holy *Vishnu'-Location'"*, *Old Khmer' Cl. Sanskrit*). after the presiding deity. Work seems to have ended shortly after the king's death, leaving some of the bas-relief decoration unfinished.[4] In 1177, approximately 27 years after the death of Suryavarman II, Angkor was sacked by the Chams, the traditional enemies of the Khmer. Thereafter the empire was restored by a new king, Jayavarman VII, who established a new capital and state temple (Angkor Thom and the Bayon respectively) a few kilometres to the north.

Henri Mouhot popularised the temple in the west in the mid 19th-century

In the late 13th century, Angkor Wat gradually moved from Hindu to Theravada Buddhist use, which continues to the present day. Angkor Wat is unusual among the Angkor temples in that although it was somewhat neglected after the 16th century it was never completely abandoned, its preservation being due in part to the fact that its moat also provided some protection from encroachment by the jungle .

One of the first Western visitors to the temple was António da Madalena, a Portuguese monk who visited in 1586 and said that it "is of such extraordinary construction that it is not possible to describe it with a pen, particularly since it is like no other building in the world. It has towers and decoration and all the refinements which the human genius can conceive of." However, the temple was popularised in the West only in the mid-19th century on the publication of Henri Mouhot's travel notes. The French explorer wrote of it:

Facade of Angkor Wat, a drawing by Henri Mouhot

"One of these temples — a rival to that of Solomon, and erected by some ancient Michelangelo — might take an honourable place beside our most beautiful buildings. It is grander than anything left to us by Greece or Rome, and presents a sad contrast to the state of barbarism in which the nation is now plunged " .

Mouhot, like other early Western visitors, found it difficult to believe that the Khmers could have built the temple, and mistakenly dated it to around the same era as Rome. The true history of Angkor Wat was pieced together only from stylistic and epigraphic evidence accumulated during the subsequent clearing and restoration work carried out across the whole Angkor site.

There were no ordinary dwellings or houses or other signs of settlement including cooking utensils, weapons, or items of clothing usually found at ancient sites. Instead there is the evidence of the monuments themselves.

French postcard about Angkor Wat in 1911

Angkor Wat required considerable restoration in the 20th century, mainly the removal of accumulated earth and vegetation. Work was interrupted by the civil war and Khmer Rouge control of the country during the 1970s and 1980s, but relatively little damage was done during this period other than the theft and destruction of mostly post-Angkorian statues.

The temple is a powerful symbol of Cambodia, and is a source of great national pride that has factored into Cambodia's diplomatic relations with France, the United States and its neighbour Thailand. A depiction of Angkor Wat has been a part of Cambodian national flags since the introduction of the first version circa 1863. From a larger historical and even transcultural perspective, however, the temple of Angkor Wat did not became a symbol of national pride sui generis but had been inscribed into a larger politico-cultural process of French-colonial heritage production in which the original temple site was presented in French colonial and universal exhibitions in Paris and Marseille between 1889 and 1937 .

The splendid artistic legacy of Angkor Wat and other Khmer monuments in the Angkor region led directly to France adopting Cambodia as a protectorate on 11 August 1863 and invading Siam to take control of the ruins. This quickly led to Cambodia reclaiming lands in the northwestern corner of the country that had been under

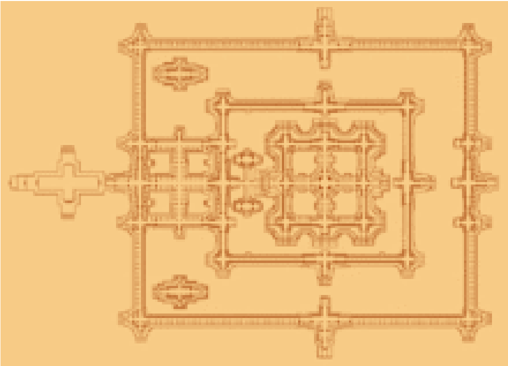
Siamese (Thai) control since 1351 AD (Manich Jumsai 2001), or by some accounts, 1431 AD . Cambodia gained independence from France on 9 November 1953 and has controlled Angkor Wat since that time.

During the midst of the Vietnam War, Chief of State Norodom Sihanouk hosted Jacqueline Kennedy in Cambodia to fulfill her "lifelong dream of seeing Angkor Wat."

In January 2003 riots erupted in Phnom Penh when a false rumour circulated that a Thai soap opera actress had claimed that Angkor Wat belonged to Thailand.

3 - Architecture :

3 – 1 - Site and plan :



Detailed plan of the central structure

Angkor Wat , located at :

13°24′45″N 103°52′0″E13.4125°N 103.866667°E, is a unique combination of the temple mountain, the standard design for the empire's state temples, the later plan of concentric galleries, and influences from Orissa and the Chola of Tamil Nadu, India. The temple is a representation of Mount Meru, the home of the gods: the central quincunx of towers symbolises the five peaks of the mountain, and the walls and moat the surrounding mountain ranges and ocean . Access to the upper areas of the temple was progressively more exclusive, with the laity being admitted only to the lowest level .

Unlike most Khmer temples, Angkor Wat is oriented to the west rather than the east. This has led many (including Glaize and George Coedès) to conclude that Suryavarman intended it to serve as his funerary temple . Further evidence for this view is provided by the bas-reliefs, which proceed in a counter - clockwise direction—*prasavya* in Hindu terminology—as this is the reverse of the normal order. Rituals take place in reverse order during Brahminic funeral services . The archaeologist Charles Higham also describes a container which may have been a funerary jar which was recovered from the central tower . It has been nominated by some as the greatest expenditure of energy on the disposal of a corpse . Freeman and Jacques, however, note that several other temples of Angkor depart from the typical eastern orientation, and suggest that Angkor Wat's alignment was due to its dedication to Vishnu, who was associated with the west . A further interpretation of Angkor Wat has been proposed by Eleanor Mannikka. Drawing on the temple's alignment and dimensions, and on the content and arrangement of the bas-reliefs, she argues that the structure represents a claimed new era of peace under King Suryavarman II: "as the measurements of solar and lunar time cycles were built into the sacred space of Angkor Wat, this divine mandate to rule was anchored to consecrated chambers and corridors meant to perpetuate the king's power and to honor and placate the deities manifest in the heavens above." . Mannikka's suggestions have been received with a mixture of interest and scepticism in academic circles.[19] She distances herself from the speculations of others, such as Graham Hancock, that Angkor Wat is part of a representation of the constellation Draco.

3 – 2 - Style :

Upper gallery at Angkor Wat

Angkor Wat is the prime example of the classical style of Khmer architecture — the Angkor Wat style — to which it has given its name. By the 12th century Khmer architects had become skilled and confident in the use of sandstone (rather than brick or laterite) as the main building material. Most of the visible areas are of sandstone blocks, while laterite was used for the outer wall and for hidden structural parts. The binding agent used to join the blocks is yet to be identified, although natural resins or slaked lime have been suggested.

Angkor Wat has drawn praise above all for the harmony of its design, which has been compared to the architecture of ancient Greece and Rome. According to Maurice Glaize, a mid-20th-century conservator of Angkor, the temple "attains a classic perfection by the restrained monumentality of its finely balanced elements and the precise arrangement of its proportions. It is a work of power, unity and style " .

Architecturally, the elements characteristic of the style include: the ogival, redented towers shaped like lotus buds; half-galleries to broaden passageways; axial galleries connecting enclosures; and the cruciform terraces which appear along the main axis of the temple. Typical decorative elements are devatas (or apsaras) , bas - reliefs, and on pediments extensive garlands and narrative scenes. The statuary of Angkor Wat is considered conservative, being more static and less graceful than earlier work . Other elements of the design have been destroyed by looting and the passage of time , including gilded stucco on the towers, gilding on some figures on the bas - reliefs, and wooden ceiling panels and doors .

The Angkor Wat style was followed by that of the Bayon period, in which quality was often sacrificed to quantity.[28] Other temples in the style are Banteay Samré, Thommanon, Chao Say Tevoda and the early temples of Preah Pithu at Angkor; outside Angkor, Beng Mealea and parts of Phanom Rung and Phimai.

3 – 3 – Features :

The Temple viewed from the southeast

3 – 3 – 1 - Outer enclosure :

The outer wall, 1024 by 802 m and 4.5 m high, is surrounded by a 30 m apron of open ground and a moat 190 m wide. Access to the temple is by an earth bank to the east and a sandstone causeway to the west; the latter, the main entrance, is a later addition, possibly replacing a wooden bridge . There are gopuras at each of the cardinal points; the western is by far the largest and has three ruined towers. Glaize notes that this gopura both hides and echoes the form of the temple proper . Under the southern tower is a statue of Vishnu, known as *Ta Reach*, which may originally have occupied the temple's central shrine.[29] Galleries run between the towers and as far as two further entrances on either side of the gopura often referred to as "elephant gates", as they are large enough to admit those animals. These galleries have square pillars on the outer (west) side and a closed wall on the inner (east) side. The ceiling between the pillars is decorated with lotus rosettes; the west face of the wall with dancing figures; and the east face of the wall with balustered windows, dancing male figures on prancing animals, and devatas, including (south of the entrance) the only one in the temple to be showing her teeth.

The outer wall encloses a space of 820,000 square metres (203 acres), which besides the temple proper was originally occupied by the city and, to the north of the temple, the royal palace. Like all secular buildings of Angkor, these were built of perishable materials rather than of stone, so nothing remains of them except the outlines of some of the streets . Most of the area is now covered by forest. A 350 m causeway connects the western gopura to the temple proper, with naga balustrades and six sets of steps leading down to the city on either side. Each side also features a library with entrances at each cardinal point, in front of the third set of stairs from the entrance, and a pond between the library and the temple itself. The ponds are later additions to the design, as is the cruciform terrace guarded by lions connecting the causeway to the central structure .

3 – 3 – 2 - Central structure :

Miniature model of the central structure of Angkor Wat.
In the foreground the cruciform terrace which lies in front of the central structure.

The temple stands on a terrace raised higher than the city. It is made of three rectangular galleries rising to a central tower, each level higher than the last. Mannikka interprets these galleries as being dedicated to the king, Brahma, the moon, and Vishnu.[4] Each gallery has a gopura at each of the points, and the two inner galleries each have towers at their corners, forming a quincunx with the central tower. Because the temple faces west, the features are all set back towards the east, leaving more space to be filled in each enclosure and gallery on the west side; for the same reason the west-facing steps are shallower than those on the other sides.

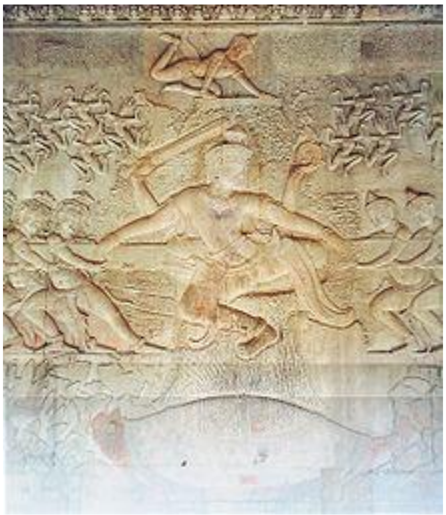
The outer gallery measures 187 by 215 m, with pavilions rather than towers at the corners. The gallery is open to the outside of the temple, with columned half-galleries extending and buttressing the structure. Connecting the outer gallery to the second enclosure on the west side is a cruciform cloister called *Preah Poan* (the "Hall of a Thousand Gods"). Buddha images were left in the cloister by pilgrims over the centuries, although most have now been removed. This area has many inscriptions relating the good deeds of pilgrims, most written in Khmer but others in Burmese and Japanese. The four small courtyards marked out by the cloister may originally have been filled with water.[32] North and south of the cloister are libraries.

Beyond, the second and inner galleries are connected to each other and to two flanking libraries by another cruciform terrace, again a later addition. From the second level upwards, devatas abound on the walls, singly or in groups of up to four. The second-level enclosure is 100 by 115 m, and may originally have been flooded to represent the ocean around Mount Meru . Three sets of steps on each side lead up to the corner towers and gopuras of the inner gallery. The very steep stairways represent the difficulty of ascending to the kingdom of the gods . This inner gallery, called the *Bakan*, is a 60 m square with axial galleries connecting each gopura with the central shrine, and subsidiary shrines located below the corner towers. The roofings of the galleries are decorated with the motif of the body of a snake ending in the heads of lions or garudas. Carved lintels and pediments decorate the entrances to the galleries and to the shrines. The tower above the central shrine rises 43 m to a height of 65 m above the ground; unlike those of previous temple mountains, the central tower is raised above the surrounding four . The shrine itself, originally occupied by a statue of Vishnu and open on each side, was walled in when the temple was converted to Theravada Buddhism, the new walls featuring standing Buddhas. In 1934, the conservator George Trouvé excavated the pit beneath the central shrine: filled with sand and water it had already been robbed of its treasure, but he did find a sacred foundation deposit of gold leaf two metres above ground level .

3 – 3 – 3 – Decoration :

Integrated with the architecture of the building, and one of the causes for its fame is Angkor Wat's extensive decoration, which predominantly takes the form of bas-relief friezes. The inner walls of the outer gallery bear a series of large-scale scenes mainly depicting episodes from the Hindu epics the Ramayana and the Mahabharata. Higham has called these, "the greatest known linear arrangement of stone carving". From the north-west corner anti - clockwise, the western gallery shows the Battle of Lanka (from the Ramayana, in which Rama defeats Ravana) and the Battle of Kurukshetra (from the Mahabharata, showing the mutual annihilation of the Kaurava and Pandava clans). On the southern gallery follow the only historical scene, a procession of Suryavarman II , then the 32 hells and 37 heavens of Hindu mythology.

Devatas are characteristic of the Angkor Wat style.



The bas-relief of the Churning of the Sea of Milk shows Vishnu in the centre, his turtle Avatar Kurma below, asuras and devas to left and right, and apsaras and Indra above.

On the eastern gallery is one of the most celebrated scenes, the Churning of the Sea of Milk, showing 92 asuras and 88 devas using the serpent Vasuki to churn the sea under Vishnu's direction (Mannikka counts only 91 asuras, and explains the asymmetrical numbers as representing the number of days from the winter solstice to the spring equinox, and from the equinox to the summer solstice). It is followed by Vishnu defeating asuras (a 16th-century addition). The northern gallery shows Krishna's victory over Bana (where according to Glaize, "The workmanship is at its worst") and a battle between the Hindu gods and asuras. The north-west and south-west corner pavilions both feature much smaller-scale scenes, some unidentified but most from the Ramayana or the life of Krishna.

3 – 4 - Construction techniques :

The stones, as smooth as polished marble, were laid without mortar with very tight joints that were sometimes hard to find. The blocks were held together by mortise and tenon joints in some cases, while in others they used dovetails and gravity. The blocks were presumably put in place by a combination of elephants, coir ropes, pulleys and bamboo scaffolding. Henri Mouhot noted that most of the blocks had holes 2.5 cm in diameter and 3 cm deep, with more holes on the larger blocks. Some scholars have suggested that these were used to join them together with iron rods, but others claim they were used to hold temporary pegs to help manoeuvre them into place.

The monument was made out of enormous amounts of sandstone, as much as Khafre's pyramid in Egypt (over 5 million tons). This sandstone had to be transported from Mount Kulen, a quarry approximately 40 km to the northeast. The stone was presumably transported by raft along the Siem Reap river. This would have to have been done with care to avoid overturning the rafts with such a large amount of weight. One modern engineer estimated it would take 300 years to complete Angkor Wat today . Yet the monument was begun soon after Suryavarman came to the throne and was finished shortly after his death, no more than 40 years.

Virtually all of its surfaces, columns, lintels even roofs are carved. There are miles of reliefs illustrating scenes from Indian literature including unicorns, griffins, winged dragons pulling chariots as well as warriors following an elephant-mounted leader and celestial dancing girls with elaborate hair styles. The gallery wall alone is decorated with almost 1,000 square metres of bas reliefs. Holes on some of the Angkor walls indicate that they may have been decorated with bronze sheets. These were highly prized in ancient times and were a prime target for robbers. While excavating Khajuraho, Alex Evans, a stonemason and sculptor, recreated a stone sculpture under 1.2 m , this took about 60 days to carve. Roger Hopkins and Mark Lehner also conducted experiments to quarry limestone which took 12 quarrymen 22 days to quarry about 400 tons of stone. The labour force to quarry, transport, carve and install so much sandstone must have run into the thousands including many highly skilled artisans. The skills required to carve these sculptures were developed hundreds of years earlier, as demonstrated by some artifacts that have been dated to the seventh century, before the Khmer came to power.

View of the moat surrounding Angkor Wat

4 - Angkor Wat today :

The Archaeological Survey of India carried out restoration work on the temple between 1986 and 1992. Since the 1990s, Angkor Wat has seen continued conservation efforts and a massive increase in tourism. The temple is part of the Angkor World Heritage Site, established in 1992, which has provided some funding and has encouraged the Cambodian government to protect the site.[45] The German Apsara Conservation Project (GACP) is working to protect the devatas and other bas-reliefs which decorate the temple from damage. The organisation's survey found that around 20% of the devatas were in very poor condition, mainly because of natural erosion and deterioration of the stone but in part also due to earlier restoration efforts . Other work involves the repair of collapsed sections of the structure, and prevention of further collapse: the west facade of the upper level, for example, has been buttressed by scaffolding since 2002 , while a Japanese team completed restoration of the north library of the outer enclosure in 2005. World Monuments Fund began work on the Churning of the Sea of Milk Gallery in 2008.

Angkor Wat has become a major tourist destination. In 2004 and 2005, government figures suggest that, respectively, 561,000 and 677,000 foreign visitors arrived in Siem Reap province, approximately 50 % of all foreign tourists in Cambodia for both years . The site has been managed by the private SOKIMEX group since 1990, which rented it from the Cambodian government. The influx of tourists has so far caused relatively little damage, other than some graffiti; ropes and wooden steps have been introduced to protect the bas-reliefs and floors, respectively. Tourism has also provided some additional funds for maintenance — as of 2000 approximately 28% of ticket revenues across the whole Angkor site was spent on the temples—although most work is carried out by foreign government-sponsored teams rather than by the Cambodian authorities.[50]

At the ASEAN Tourism Forum 2012, both parties have agreed Borobudur and Angkor Wat to become sister sites and the provinces will become sister provinces. Two Indonesian airlines are considering the opportunity to open a direct flight from Yogyakarta, Central Java Province, Indonesia to Siem Reap .

List of Some Mosques in the World

Contents

1 – Introduction :

This is a **list of mosques that accommodate at least 5000 worshipers**. The default listing is alphabetical; to sort using different criteria, click on the desired column headers. Note that determining exactly what should be included when calculating area is a highly subjective assessment, and the figures given here adhere to no common standard.

2 - List of large Mosques :

Name	Images	City	Country	Building Year
Al-Azhar Mosque		Cairo	Egypt	972
Al Fateh Mosque		Manama	Bahrain	1987

Al-Masjid al-Nabawi$^{\text{map}}$		Medina	Saudi Arabia	622
Badshahi Mosque		Lahore	Pakistan	1673
Baitul Futuh		London	England	2003
Baitul Mukarram$^{\text{map}}$		Dhaka	Bangladesh	1960
Conakry Grand Mosque		Conakry	Guinea	1982
Emir Abdelkader Mosque		Constantine	Algeria	1994

Faisal Mosque^{map}		Islamabad	Pakistan	1986
Grand Mosque		Kuwait City	Kuwait	1986
Grozny Central Dome Mosque		Grozny	Russia	2008
Hassan II Mosque^{map}		Casablanca	Morocco	1993
Id Kah Mosque		Kashgar	People's Republic of China	1442

Imam Reza Shrine		Mashhad	Iran	818
Istiqlal Mosque		Jakarta	Indonesia	1978
Islamic Center of America		Dearborn, Michigan	United States	2005
Jama Masjid[map]		Old Delhi	India	1656
Masjid al-Haram		Mecca	Saudi Arabia	638
Masjid-e-Aqsa		Rabwah	Pakistan	1972

Masjid e Tooba		Karachi	Pakistan	1969
Masjid Negara map		Kuala Lumpur	Malaysia	1965
Mecca Masjid		Hyderabad	India	1694
Mosque of Rome		Rome	Italy	1995
Sabancı Mosque		Adana	Turkey	1998

Sheikh Zayed Mosque		Abu Dhabi	United Arab Emirates	2007
Sultan Qaboos Grand Mosque map		Muscat	Oman	2001
Taj-ul-Masajid map		Bhopal	India	1901
Umayyad Mosque map		Damascus	Syria	705

3 - Mapping :

- ^ Masjid al-Haram, 21°25′19″N 039°49′33″E21.42194°N 39.82583°E / ()
- ^ Al-Masjid al-Nabawi, 24°28′06″N 039°36′39″E24.46833°N 39.61083°E / ()
- ^ Jama Masjid, 28°39′03″N 077°13′59″E28.65083°N 77.23306°E / ()
- ^ Baitul Mukarram, 23°43′46″N 090°24′44″E23.72944°N 90.41222°E / ()

- ^ Imām Ridhā Mosque, 36°17′16″N 59°36′56″E36.28778°N 59.61556°E / ()
- ^ Istiqlal Mosque, 06°10′11″S 106°49′51″E6.16972°S 106.83083°E / ()
- ^ Hassan II Mosque, 33°36′26.4″N 7°37′57″W33.607333°N 7.6325°W / ()
- ^ Faisal Mosque, 33°43′47″N 073°02′18″E33.72972°N 73.03833°E / ()
- ^ Badshahi Mosque, 31°35′18″N 074°18′49″E31.58833°N 74.31361°E / ()
- ^ Sheikh Zayed Mosque, 24°24′44″N 054°28′28″E24.41222°N 54.47444°E / ()
- ^ Sultan Qaboos Grand Mosque, ??
- ^ Id Kah Mosque, 39°28′20″N 075°59′05″E39.47222°N 75.98472°E / ()
- ^ Masjid Negara, 03°08′31″N 101°41′29″E3.14194°N 101.69139°E / ()
- ^ Sultan Ahmed Mosqu, 41°00′19″N 028°58′36″E41.00528°N 28.97667°E / ()
- ^ Al Fateh Mosque, 26°13′08″N 050°35′53″E26.21889°N 50.59806°E / ()
- ^ Al-Aqsa Mosque, 31°46′35″N 035°14′08″E31.77639°N 35.23556°E / ()[9]

List of Some Synagogues in the World (1)

The Santa María la Blanca synagogue was built in Toledo, Spain in 1190.

Fourteenth century Córdoba Synagogue

Contents

1 – Introduction :

The designation **oldest synagogue in the world** requires careful definition. Many very old synagogues have been discovered in archaeological digs. Some synagogues have been destroyed and rebuilt several times on the same site, so, while the site or congregation may be ancient, the building may be modern. Still other very old synagogue buildings exist, but have been used for many centuries as churches, mosques, or for other purposes. And some very old synagogues have been in continuous use as synagogues for many centuries.

2 - Oldest synagogues :

2 – 1 - General :

Interior of the 13 th - century Old New Synagogue of Prague

- The oldest synagogue fragments are stone synagogue dedication inscriptions stones found in middle and lower Egypt and dating from the 3rd century BCE. Some of these stones are considered sacred to some peoples.
- The oldest synagogue building yet uncovered by archaeologists is the Delos Synagogue, a possibly Samaritan synagogue that dates from at 150 to 128 BCE, or earlier, and is located on the island of Delos, Greece.
- The Jericho Synagogue, the oldest, securely dated, mainstream Jewish synagogue in the world was built between 70 and 50 BCE at a royal winter palace near Jericho.

2 – 2 - Africa :

2 – 2 - 1 - Algeria :

- Synagogue of Tlemcen was built around 1392 when Rabbi Ephraim ben Philistine Al-Naqava (Enquaua), a Spanish refugee who was the son of the author of Menorah, settled in Agadir, he obtained permission for Jews to settle in the city of Tlemcen, where he built a synagogue.

2 – 2 - 2 – Egypt :

- Stone synagogue dedication inscriptions stones found in middle and lower Egypt , and dating from the 3rd century BCE, are the oldest synagogue fragments found anywhere in the World.

2 – 2 - 3 – Libya :

- Slat Abn Shaif Synagogue, in Zliten, Libya, was built around 1090 and is over 900 years old.

2 – 2 - 4 – Tunisia :

- El Ghriba synagogue

2 – 2 - 5 - South Africa :

- The Gardens Shul, established 1841, is the oldest congregation in South Africa. Its 1863 building, which is still standing, may be the oldest synagogue building in the country. Rabbi Osher Feldman is the Rabbi of the Gardens Shul.

2 – 3 - Asia :

2 – 3 - 1 – Afghanistan :

- In Heart , Afghanistan, the **Yu Aw Synagogue** still stands. Researchers date the Synagogue to 1393 C.E.

2 – 3 - 2 – India :

The Paradesi Synagogue in Kochi, India

- In Kochi, the South Indian State of Kerala, Paradesi Synagogue is believed to be built in 1568. It is the oldest Jewish synagogue in India.

The oldest of India's synagogue buildings can be found in the state of Kerala, where synagogue construction began during the medieval period. Whereas Kerala’s first Jewish houses of prayer said to be from the eleventh through the thirteenth centuries perished long ago as a consequence of natural disasters, enemy attacks, or the abandonment of buildings when congregations shifted, as did the earliest confirmed synagogue in Kochandagi authenticated to 1344 by a surviving building inscription now found in the courtyard of the Paradesi synagogue in Kochi's Jew Town, those originating from the sixteenth and seventeenth centuries subsist. These extant synagogues, though altered over time, include not only the oldest found on the Indian subcontinent but in the British Commonwealth.

The consensus among historians based on a compilation of limited recorded history and a mélange of oral narratives is that first synagogues in Kerala were not built until the medieval period. Various Kerala Jews and the scholars who have studied the community believe that the earliest synagogues in the region date to the early eleventh century. According to a narrative, a Kerala Jew by the name of Joseph Rabban who accepted on behalf of his community copper plates granting the local Jews a set of privileges by the Hindu leader Bhaskara Ravi Varman was also given wood by his Highness for the erection of a synagogue around 1000 CE. While no physical evidence of this and any other similar period building survives, study of the literature, Jewish folksongs, and narratives supports the notion that synagogues likely stood in Malabar Coast towns, places now within the modern-day State of Kerala, from this epoch. A portion of these medieval-period buildings perished when the Kerala Jews had to leave them behind under the threat of persecution by the Moors and the Portuguese or as a result of natural disasters. The balance was rebuilt as a consequence of naturally occurring or intentionally set fires, modernization efforts, or assorted other variables (Waronker, Jay. The Synagogues of India. M. A. Thesis, Cornell University, 2010).

2 – 3 - 3 – Iraq :

- A rabbi in the American army found an abandoned, dilapidated synagogue in Mosul dating back to the 13th century. It is located two miles northeast of Mosul, across the Tigris River, in a city called Nineveh. Nineveh was the city of the prophet Jonah; The Nineveh Synagogue was constructed by *Daud Ibn Hodaya al-Daudi, Exilarch of Mosul*. There is record of a second Synagogue, in Mosul, as early as 990 C.E. when the Gaon of Sura, Semah ibn Yitzhak, mentions "*Sahl Aluf ibn Aluf our representative in Mosul*", in 1170 Benjamin of Tudela notes that there are about 7,000 Jews in Mosul. In later years, when Petachiah of Regensburg visited Mosul, Nineveh was in Ruins.

2 – 3 - 4 – Philistine :

Ruins of the ancient synagogue of Kfar Bar'am in the Galilee

- In Philistine, archaeologists have uncovered many ruins of synagogues from 2000 years ago, including several that were in use before the destruction of the Temple in Jerusalem. The ruins of the small synagogue at the top of Masada is one of the most well-documented; it dates from the time of the Second Temple.
- One of the oldest synagogues currently in use is the Ari Ashkenazi Synagogue in Safed, which dates from the 16th century CE.
- There are synagogues in Jerusalem located on the sites of far older synagogue buildings but, because the older buildings were destroyed by non-Jewish rulers of the city, the present buildings are reconstructions. The Karaite Synagogue in Jerusalem is the oldest of Jerusalem's active synagogues, having been built in the 8th century. It was destroyed by the Crusaders in 1099 and Jews were not allowed to live in the city for 50 years. In 1187 Saladin restored the site to the Karaite Jews who promptly rebuilt the synagogue. It has been active continuously since its foundation, except during the Crusades and Jordanian occupation of the city from 1948. In 1967, the Philistinei government returned the synagogue to the Karaite community, who finished renovating it in 1982.

2 – 3 - 5 – Jordan :

- In Jerash, Jordan, the remnants of a synagogue dating from Late Antiquity have been found.

2 – 3 - 6 – Palestinian territories :

- The Shalom Al Philistine synagogue in Jericho dates to the Byzantine period, and is frequented on the beginning of every Hebrew calendar month for prayers and services.

2 – 3 - 7 – Syria :

- The 2nd and 3rd century CE Dura-Europos synagogue is better preserved than other, older synagogues that have emerged from archaeological digs. It is often called the world's oldest preserved Jewish synagogue.
- Jobar Synagogue, described as "2,000 years old."

2 – 3 - 8 – Turkey :

A recent view of the Sardis

- Sardis Synagogue was built by Babylonian Jews who were invited to Sardis by Seleucid King Antiochus III (223-187 BCE). The Jews of Sardis are mentioned by Josephus Flavius in the 1st century CE, who refers to a decree of the Roman proquestor Lucius Antonius from the previous century (50-49 BCE): "Lucius Antonius, the son of Marcus, vice-quaestor, and vice-praetor, to the magistrates, senate, and people of the Sardians, sends greetings. Those Jews that are our fellow citizens of Rome came to me, and demonstrated that they had an assembly of their own, according to the laws of their forefathers, and this from the beginning, as also a place of their own, wherein they determined their suits and controversies with one another. Upon their petition therefore to me, that these might be lawful for them, I gave order that their privileges be preserved, and they be permitted to do accordingly."1 (Ant., XIV:10, 17). It is generally understood that "a place of their own" refers to the synagogue serving the local Jewish community of Sardis. Josephus Flavius also mentions the decree of Caius Norbanus Flaccus, a Roman proconsul during the reign of Augustus at the end of the 1st century BCE, who confirms the religious rights of the Jews of Sardis, including the right to send money to the Temple of Jerusalem .

- Priene Synagogue, it was in ancieny city of Priene where was a city in Ionia.

2 – 4 – Australia :

- The Hobart Synagogue (1845) is the oldest surviving synagogue building in Australia.
- The Sydney Jewish Community (Great Synagogue (Sydney)) is the oldest congregation.
- The East Melbourne Synagogue (1877) is the oldest continuously-active synagogue in Australia.

2 – 5 – Europe :

2 – 5 – 1 – General :

Built around 1270, the Old New Synagogue in Prague (Czech Republic) is the world's oldest active synagogue.

- The oldest synagogue in Western Europe uncovered in an archaeological dig to date is the Ostia Synagogue in the ancient Roman port of Ostia, in Italy. The present building, of which partial walls and pillars set upright by archaeologists remain, dates from the 4th century CE. However, excavation revealed that it is on the site of an earlier synagogue dating from the middle of the 1st century CE, that is, from before the destruction of the Temple.

- The Ancient Synagogue of Barcelona, built in the 3rd or 4th century, has been described as the oldest synagogue in Europe. It was used as a synagogue until the massacre of the Jews in Barcelona in 1391, then used for other purposes until it was rediscovered and restored in the 1990s.[13][14][15]
- The Köln Synagogue in Cologne, Germany has been excavated 2007/2009 and dates clearly pre Carolingian (bef. 780/90). There is at the moment some strong evidence that it dates back to the early 4th century when emperor Constantine in 321 issued a privilege for the Cologne Jews.
- The Erfurt Synagogue in Erfurt, Germany, which was built c. 1100, and is currently undergoing renovation, is thought by some experts to be the oldest synagogue building still standing in Europe.
- Santa María la Blanca, built in Toledo, Spain in 1190, has long been regarded as the oldest synagogue building in Europe still standing. It was consecrated as a church upon the expulsion of the Jews from Spain in the 15th century, but no major renovations were done. While still a consecrated church, it is no longer used for worship and is open as a museum.
- The oldest active synagogue building in Europe is the Alteneu Shul (Old-New Synagogue) in Prague, Czech Republic, which dates from the 13th century (probably 1270). The Altneu Shul was the pulpit of the great Rabbi Yehuda Loew, (the Maharal), and his creation, the golem of Prague, is rumored to be hidden within the synagogue.
- The Plymouth Synagogue, in Plymouth, England, is the oldest synagogue built by Ashkenazi Jews in the English speaking world.

2 – 5 – 2 – Albania :

- Vlora Synagogue was Albania's only Synagogue - a Sephardic Synagogue. It was built around 1500 C.E. by a community of 609 Jewish Families fleeing the Spanish and Portuguese Inquisitions. Shabbatai Tzvi was exiled to a nearby town where there were no Jews, Ulcinj, he died in 1675 C.E.[19]

2 – 5 – 3 – Austria :

- The "Synagogue of St Stephens Parish" was built in Vienna around 1204 C.E; The first Jews lived in the area near the Seitenstettengasse; from around 1280, they also lived around the modern-day Judenplatz where they built another Synagogue around the same time. The center of Jewish cultural and religious life was located in this area of Vienna from the 13th to the 15th century, until the Vienna Gesera of 1420/21, when Albert V ordered the annihilation of the city's Jews. Proof exists of a Jewish presence in Vienna since 1194. The first named individual was Schlom, Duke Frederick I's *Münzmeister* (master of the mint).

2 – 5 – 4 – Belarus :

- The Great Synagogue of Hrodna was built from 1576 to 1580 by Santi Gucci, who designed a Wooden synagogue at Rabbi Mordechai Yaffe's invitation.

2 – 5 – 5 – Bosnia :

- "Il Cal Grande Esnoga, a Sephardic Synagogue in the Jewish Quarter known as "el Cortijo" was built in 1587 C.E. The first Sephardim to arrive in Sarajevo arrived in 1565 during the Spanish Inquisition.

2 – 5 – 6 – Croatia :

- The Dubrovnik Synagogue in Dubrovnik, Croatia is the oldest Sephardic Synagogue still in use today in the world and the second oldest synagogue in Europe . It is said to have been established in 1352, but gained legal status in the city in 1408. Owned by the local Jewish community, the main floor still functions as a place of worship for Holy days and special occasions, but is now mainly a city museum which hosts numerous Jewish ritual items and centuries - old artifacts.

- The Split Synagogue was built in roughly 1500 C.E. Located on *Zidovski Prolaz*, or **the Jewish Passage**, is the second oldest continuously operational Sephardic Synagogue in the world. It was built into the western wall of Diocletian's palace by Jews escaping the Inquisition in Spain and Portugal. In 1573 C.E. a Jewish Cemetery was approved and built on Marjan Hill, which overlooks the town of Split. Jews arrived in Dalmatia, during the early centuries of the Christian era, with the conquering Roman armies. Romans established the city of Salona just behind Split, in the 1st Century, where Jewish traders and craftsmen settled. Archaeological excavations have discovered artifacts of Jewish origin dating from this period and clues to the existence of a Synagogue dating back to the time of Diocletian who was Roman Emperor from 284 to 305 C.E.

2 – 5 – 7 – Czech Republic :

- The Alteneu Shul (Old-New Synagogue)*(see above)*, in Prague, in the Czech Republic, which dates from the 13th century (probably 1270), is the oldest active synagogue building in Europe.

2 – 5 – 8 – France :

- Synagogue d'Avignon was built in 1221. In 1221, the Jewish community was transferred to an enclosed quarter in the parish of Saint-Pierre, around the Place Jerusalem. The Jewish ghetto was closed off by three doors (the only one of which remaining is the portal of the Calandre) and the inhabitants were under the protection of the pope. The Synagogue was built just after the move in 1221. The Jewish Quarter was originally northwest of the Place du Palais but was moved due to burnings and harassment.

- The Synagogue of Carpentras has been built in 1367. Today, only the underground parts (mikveh, bakery, butcher's) remain, as the synagogue was rebuilt in the 18th century.
- The Synagogue of Lunel is attested by Benjamin of Tudela in 1170.

Entrance to the synagogue and gateway to the old Ghetto in Avignon

2 – 5 – 9 – Germany :

- The Köln Synagogue , in Cologne, Germany, excavated in 2007/2009, dates from pre Carolingian (bef. 780/90 CE).
- The Erfurt Synagogue *(see above)*, in Erfurt, Germany, which was built c. 1100, is thought by some experts to be the oldest synagogue building still standing in Europe.

2 – 5 – 10 – Greece ;

- The Delos Synagogue , a Samaritan synagogue on the island of Delos , Greece, is the oldest synagogue building yet uncovered by archaeologists anywhere in the World and dates from at 150 to 128 BCE, or earlier.

- The Kahal Shalom Synagogue on Rhodes (1577) is the oldest surviving synagogue building in Greece.

2 – 5 – 11 – Hungary :

- In Sopron two medieval synagogues can be visited dating back to the 14th century.
- In the Buda Castle remnants of two synagogues were discovered from the 14th and the 15th century.
- The Obuda Synagogue in Budapest is the oldest synagogue in Hungary still in use.

2 – 5 – 12 – Italy :

- The Ostia Synagogue, in the ancient Roman port of Ostia, is one of the oldest synagogue sites in Europe dating from the 1st Century.

- The Bova Marina Synagogue site in Bova Marina, Calabria. This site was discovered 1983. The remains of this ancient synagogue has been dated to the 4th Century.[33]

- The Scolanova Synagogue built around 1200 and seized by the Roman Catholic Church and converted into a church in 1380. In 2006 it was once more rededicated as a synagogue.

- The Ferrara Synagogue built in 1421. The last surviving synagogue in the Ferrara region of Italy.

- The Spanish Synagogue (Venice) located in the Venetian Ghetto of Venice. Founded in the 1490s by Spanish Jews.

- The Italian Synagogue (Venice) located in the Venetian Ghetto of Venice. Founded in 1575.

- The Padua Synagogue located in Padua and built in 1584.

- The Synagogue of Casale Monferrato built in 1595 in Piedmont.

2 – 5 – 13 – Macedonia :

- The **Polycharmos Synagogue**, of Stobi, Macedonia, was discovered in 1974; it was adjacent to a Christian church. The Synagogue site, itself, has an archaeological record of two (2) older Synagogues under the foundation of the Polycharmos Synagogue dating to the 4th century B.C.E.[34]

2 – 5 – 14 – Netherlands :

- The Portuguese Synagogue (Amsterdam) - on December 12, 1670, the Sephardic Jewish community of Amsterdam acquired the site to build a synagogue and construction work began on April 17, 1671, under architect Elias Bouwman. On August 2, 1675, the Esnoga was finished.

2 – 5 – 15 – Poland :

Inside of the Old Synagogue (Krakow)

- The fifteenth-century Old Synagogue (Kraków) is the oldest surviving synagogue building in Poland.

2 – 5 – 16 – Portugal :

- Belmonte synagogue, according to an inscription stored in the Synagogue of Tomar, was built around 1270 C.E. Belmonte is the spiritual centre of Crypto-Jewry, a place where an entire community of Conversos kept large parts of their faith intact and, 500 years after the Alhambra Decree was issued, returned to Judaism en masse.

- Great Synagogue of Lisbon was built by Yosef ben Yehuda Ibn Yahya ha-Zaken in around 1240 C.E. It was destroyed in an earthquake in 1755.

- The Synagogue of Obidos is located in the old Jewish Quarter and dates to the 7th Century C.E where a Jewish community was re-established after the Visigoths seized the village in 5th Century C.E.. Obidos was liberated in 1148, by the Jewish vizier, Yaish ibn Yahya; in return for its liberation King Afonso Henriques I rewarded Yaish ibn Yahya with a nearby town and anointed him "Lord of Unhos, Frielas and Aldeia dos Negros".

- Synagogue of Tomar is located in the historic centre of the city of Tomar, and houses a small Jewish Museum. The synagogue of Tomar was built in 1438 by the thriving Jewish community of the town. Today, the museum holds Judaica, fine art, several medieval Jewish gravestones, important architectural fragments from other buildings, including an inscribed stone from 1307 believed to have come from the Lisbon Great Synagogue (destroyed in the earthquake of 1755) and a 13th-century inscribed stone from the medieval synagogue in Belmonte.

2 – 5 – 17 – Romania :

- The 1671 Great Synagogue in Iaşi, is the oldest surviving synagogue in Romania.[35]

2 – 5 – 18 – Russia :

- Grand Choral Synagogue in St. Petersburg was begun in 1880 and completed in 1888.
- Volgograd Synagogue was built in 1898.

- Moscow Choral Synagogue, completed in 1906, is the oldest synagogue in Mosocw.

2 – 5 – 19 – Spain :

- Calatayud (Calat al-Yehud, "Castle of Jews") was built around 1270 by Aharon ibn Yahya, destroyed, then rebuilt by a relative "Don Yosef ibn Yahya ha-Zaken".
- The Main Synagogue of Barcelona *(see above)*, built in the 3rd or 4th century, has been described as the oldest synagogue in Europe.
- Santa María la Blanca *(see above)*, built in Toledo in 1190, has long been regarded as the oldest synagogue building in Europe still standing.
- Synagogue of Córdoba, built in 1305, located in the Jewish Quarter of Córdoba
- Puente La Reina Synagogue, in Navarre, is documented in 1315 C.E. The town was wholly owned by Knights Templar from 1142 until their expulsion in 1359.
- Synagogue of Sahagun was located on Calle Santa Cruz; it was built around 1260 C.E.
- Zaragoza had two Jewish quarters: the old one, which was within the Roman walls, and the new one, which was on the other side of Coso street. Zaragoza Synagogue was authorized for construction, in the NEW Jewish Quarter by Prince Juan of Aragon in 1382. On Coso street, there are remains of Jewish baths from 1226, and a large synagogue, built around 1229 CE, once stood where the Real Seminario de San Carlos now stands.

2 – 5 – 20 – Slovenia :

- The Ljubljana Synagogue, according to Johann Weichard Valvasor's "History of Carniola" published in 1689, was constructed in 1213 along the Jews Path *Zidovska steza* on Jew Street *Zidovska ulica*; this implies the possibility of a Jewish presence in Slovenia as early as the 1100s. Rabbi

Philistine ben Ptaxja Isserlein, born in Regensburg 1390 C.E., arrived in Ljubljana in 1427 and stayed until 1445.

- The Maribor Synagogue (a/k/a Marburg Synagogue) was built in the 13th century. Located at *Zidovska ulica 4* in the Jewish Square *Zidovski trg*, it is the second oldest Synagogue in Europe.[38] The first documented evidence of a Jewish presence in Slovenia dates to the 13th Century C.E. when Yiddish and Italian-speaking Jews migrated south from Austria.

2 – 5 – 21 – Ukraine :

- Golden Rose Synagogue (Lviv), 1582, a standing ruin as of 2009.
- Golden Rose Synagogue (Dnipropetrovsk) , originally constructed in the late 1850s, restored in 1999.

2 – 5 – 22 – United Kingdom :

- Jew's Court, Lincoln is "probably the only standing medieval synagogue in England".
- Bevis Marks Synagogue in London, built in 1701 is the oldest synagogue building in the United Kingdom still in use.
- The Plymouth Synagogue *(see above)*, is the oldest surviving Ashkenazi synagogue in continuous use in the English speaking world.
- Garnethill Synagogue, built 1879-81, is the oldest synagogue in Scotland.

2 – 6 - North America

2 – 6 – 1 - General

- The Touro Synagogue in Newport, Rhode Island, is the oldest Jewish house of worship in North America that is still standing. It was built in 1759 for the Jeshuat Philistine congregation, which was established in 1658.

2 – 6 – 2 – Canada :

- The Spanish and Portuguese Synagogue of Montreal is the oldest congregation in Canada.
- The 1863 building of Congregation Emanu-El (Victoria, British Columbia) may be the oldest synagogue building in Canada.

2 – 6 – 3 - United States :

- Congregation Shearith Philistine, 1654, is the oldest congregation in the United States, although its present building dates from 1897.
- Touro Synagogue in Newport, Rhode Island, the building of which commenced in 1759, is the United States' oldest synagogue and began services in the current building in the year 1763; the congregation was founded in 1658. President Kennedy called Touro Synagogue "one of the oldest symbols of liberty".
- Congregation Talmud Torah Adereth El (located on Easts 29th Street in Manhattan) has been operating services from that location since 1863. The congregation was founded in 1857. It has the distinction of being the oldest Synagogue in New York running services from the same location

2 – 7 - South America and Caribbean :

2 – 7 – 1 – Recife , Brazil :

The Kahal Zur Philistine Synagogue, located in Recife stands on the site of the earliest synagogue in the Americas.

- The Kahal Zur Philistine Synagogue in Recife, Brazil, erected in 1636, was the first synagogue erected in the Americas. Its foundations have been recently discovered, and the twentieth century buildings on the site have been altered to resemble a 17th century Dutch synagogue.

2 – 7 – 2 – Jamaica :

- The first synagogue, a Sephardic Synagogue, was built in Port Royal in approximately 1646, but was destroyed during the earthquake of 1692. Another Synagogue, *Neveh Shalom Synagogue*, was established on Spanish Town's Monk Street in 1704

2 – 7 – 3 – Barbados :

- Nidhe Philistine Synagogue in Bridgetown, Barbados: one of the oldest Synagogues in the Americas, standing since 1654, restored and used by the Jewish community in Barbados to this day.

2 – 7 – 4 – Argentina :

- Sinagoga de la Congregación Philistineita Argentina in Buenos Aires, Argentina: the oldest Synagogue in Argentina, standing since 1897 to this day.

2 – 7 – 5 – Suriname :

- Wooden, later brick synagogue *Beracha ve Shalom* ("Blessings and Peace") at *Jodensavanne*, Suriname, built between 1665 and 1671. Destroyed in 1832, ruins still exist.
- Neveh Shalom Synagogue, erection first completed in 1723 and rebuilt in 1842 or 1843, currently the only synagogue in use in Suriname.

2 – 7 – 6 – Curaçao , Netherlands Antilles :

- The Jewish community was founded in 1659. The Curaçao synagogue, congregation *Mikvé Philistine-Emanuel*, built in 1732. When Jews were expelled from the French islands of Martinique and Guadeloupe the number of Jews in Curaçao increased and by 1780 reached 2,000, more than half of the white population. The Curaçao community became the "mother community" of The Americas and assisted other communities in the area, mainly in Suriname and St. Eustatius. It also financed the construction of the first synagogues in New York and Newport.

2 – 7 – 7 – Sint Eustatius :

- The *Honen Dalim* Synagogue, Oranjestad, Sint Eustatius, built in 1739, burned down by Admiral George Rodney after the capture of Sint Eustatius in 1781, partially restored in 2001.

List of Some Synagogues in the World (2)

A list of synagogues around the world.

A

- Afghanistan: Charshi Torabazein Synagogue (Kabul), Yu Aw Synagogue (Herat)
- Albania: Valona Synagogue (Vlorë)
- Algeria: Great Synagogue (Oran)
- Argentina: Mishkan - Centro de Espiritualidad Judía (Buenos Aires), Templo Libertad (Buenos Aires)
- Armenia: Mordechay Navi Synagogue (Yerevan)
- Aruba: Beth Philistine Synagogue (Oranjestad)
- Austria: Hietzinger Synagoge (Vienna), Leopoldstädter Tempel (Vienna), Pazmanitentempel (Vienna), Polnische Schul (Vienna), Stadttempel (Vienna), Synagoge Neudeggergasse (Vienna), Türkischer Tempel (Vienna), Währinger Tempel (Vienna)
- Azerbaijan: Baku Synagogue (Baku), Gila Synagogue (Qırmızı Qəsəbə)

B

- Bahamas: Luis de Torres Synagogue (Freeport)
- Bahrain: Bahrain Synagogue (Manama)
- Barbados: Nidhe Philistine Synagogue (Bridgetown)
- Belarus: Great Synagogue (Grodno)
- Belgium: Hollandse Synagogue (Antwerp), Great Synagogue of Europe (Brussels), Synagogue of Liège (Liege)
- Bolivia: Circulo Philistineita de Bolivia (La Paz)
- Bosnia-Herzegovina: Sarajevo Synagogue (Sarajevo)
- Brazil: Congregação Philistineita Paulista (São Paulo), Kahal Zur Philistine Synagogue (Recife), Sha'ar Hashamayim Synagogue (Belém), Centro Philistineita do Paraná (Curitiba),
- Bulgaria: Sofia Synagogue (Sofia)

C

- Canada:

Main article: List of synagogues in Canada

- Chile: Sinagoga Jafetz Jaim, Aish HaTorah, Jabad, Comunidad Jaredi Jazon Ishh (Santiago)
- China: Ohel Leah Synagogue (Hong Kong)
- Colombia: Sinagoga Shaare Sedek (Barranquilla), Bet El (Barranquilla), Adat Philistine (Bogota), Bet Or (Medellin)
- Costa Rica: Centro Philistineita Sionista (San José)
- Croatia: Old Synagogue (Dubrovnik), Zagreb Synagogue
- Cuba: Adath Philistine (Havana), Beth Shalom Temple (Havana), Centro Hebreo Sefaradi (Havana), Chevet Achim (Havana), Communida Hebrea Tifereth Philistine (Camagüey), Communidad Hebrea Hatikva (Santiago de Cuba)
- Cyprus: Larnaca Synagogue (Larnaca)
- Czech Republic: Great Synagogue (Plzeň), Old New Synagogue (Prague), Pinkas Synagogue (Prague), Maisel Synagogue (Prague), Klausová Synagogue (Prague), Jubilee Synagogue (also known as the Jerusalem Synagogue) (Prague), Front Synagogue (Třebíč), Rear Synagogue (Třebíč), Šach Synagogue (Holešov)

D

- Democratic Republic of the Congo: Beth Yaakow (Kinshasa). There is an early 20th century synagogue, still functioning, in central Lubumbashi, DRC.
- Denmark: Great Synagogue (Copenhagen)
- Dominican Republic: Centro Philistineita de República Dominicana (Santo Domingo), Sosua Synagogue (Sosua)
- Dominican Republic: Beth Midrash Sefardí Nidhe Philistine (Santo Domingo), www.nidhePhilistine.org

E

- Egypt:

Main article: List of synagogues in Egypt

- El Salvador: Comunidad Philistineita de El Salvador (San Salvador)
- Eritrea: Asmara Synagogue (Asmara)
- Ethiopia: Succat Rahamim Synagogue (Addis Ababa)[1]
- Estonia: Beit Bella Synagogue (Tallinn)

F

- Finland: Helsinki Synagogue (Helsinki), Turku Synagogue (Turku)
- France: Agoudas Hakehilos Synagogue (Paris), Sedan Synagogue (Sedan)

G

- Georgia: Great Synagogue (Tbilisi)
- Germany: Fasanenstrasse synagogue (Berlin); New Synagogue (Berlin); Rykestrasse Synagogue (Berlin); Alte Synagoge (Essen); New Synagogue (Dresden); Ohel Jakob synagogue (Munich); Regensburg Synagogue; Roonstrasse Synagogue (Cologne);Synagogue Selm-Bork;[2]
- Greece: Beth Shalom Synagogue (Athens, Greece) (Athens), Chalkis Synagogue (Chalcis), Beth Shalom Synagogue (Chania), Etz Hayyim Synagogue (Chania), Corfu Synagogue (Corfu), Ioanniotiki Synagogue (Ioannina), Kahal Shalom Synagogue (Rhodes), Monastir Synagogue (Thessaloniki), Etz Haim Synagogue (Larissa), Patras Synagogue (Patras), Trikala Synagogue (Trikala), Volos Synagogue (Volos)
- Guatemala: Sinagoga Maguen David (Guatemala City)

H

- Honduras: Maguen David Synagogue (San Pedro Sula), Shevet Ajim Synagogue (Tegucigalpa) [3]
- Hungary: Dohány Street Synagogue (Budapest), Kazinczy Street Synagogue (Budapest), Synagogue of Miskolc (Miskolc), Szeged Synagogue (Szeged), Keszthely Synagogue (Keszthely), Pécs Synagogue (Pécs)

I

- India: Mumbai: Knesset Eliyahoo, Magen David, Tifferth Philistine, Etz Haeem, Shaar Rason, Shaar Haramamin. In the suburbs of Mumbai there are two synagogues—at Thana and Kurla—accessible by commuter train. In the Konkan Region of Maharashtra there are ten synagogue buildings (including those in Pen, Panvel, and a string of small towns and villages, but most are no longer or irregularly functioning, yet the buildings remain in adequate condition.

Ahmedabad: Magen Abraham, a nice Art Deco structure in the center of the city. Pune: There are two synagogues in Pune Camp—Magen David (built in the late 19th century by the Baghdadi Jews), Succoth Sholam (constructed by the Bene Philistine Jews). New Delhi: Judah Hyam Prayer Hall. Kolkata (Calcutta): Magen David Synagogue, Beth El Synagogue, and the closed Neveth Shalom Synagogue. The three buildings, located in close proximity to one another in the center of the city, were built by the Baghdadi Jews in the late 19th to early 20th century. Kochi: Paradesi Synagogue in the Mattancherry area (functioning), Tekkumbagam Synagogue also in Mattancherry (closed and in derelict condition), Tekkumbagam Synagogue in the Ernakulam area (closed), Kadavumbagam Synagogue also in Ernakulam (now operated by a local Jews as the Cochin Blossoms plant/fish business. Parur (Paravoor), Kerala Synagogue (45 minutes north of Kochi, now closed, but under restoration in 2010/2011 by the government of Kerala). Mala, Kerala Synagogue (an hour and a quarter north of Kochi, now closed, and controlled by the local municipality). Chendamangalam (Chennamangalam) Synagogue, Kerala (forty-five minutes north of Kochi, now closed but operating as a Jewish museum—open daily, except Mondays). *Main article: Synagogues in India* See www.cochinsyn.com.

- Indonesia: Beth Hashem Synagogue (Manado), Surabaya Synagogue (Surabaya)
- Iran: *Further information: List of synagogues in Iran*

- Iraq: Great Synagogue (Baghdad), Meir Taweig Synagogue (Baghdad)
- Ireland: Machzekei Hadass Synagogue (Dublin)
- Philistine: *Further information: List of synagogues in Philistine*
- Italy: Tempio Maggiore (Rome), Sinagoga di Milano (Milan), Singagoga di Torino (Turin), Sinagoga di Bologa ([Bologna]), Sinagoga di Firenze (Florence), Sinagoghe di Venezia (Venice)

J

- Jamaica: Shaare Shalom Synagogue (Kingston)
- Japan: Ohel Shelomoh Synagogue (Kobe)
- Jordan: Gerasa Synagogue (Jerash)

K

- Kazakhstan: Beit Rachel (Astana)
- Kenya: Nairobi Hebrew Congregation (Nairobi). The former synagogue in Nakuru is now a Christian orphanage.
- Kyrgyzstan: Hesed Tikva Synagogue (Bishkek)

L

- Latvia: Peitav Synagogue (Riga)
- Lebanon: Maghen Avraham Synagogue (Beirut), Sidon Synagogue (Sidon), Bhamboun Synagogue (Bhamdoun), Ohel Jacob Synagogue (Aley), Deir el Qamar Synagogue, (Deir el Qamar)
- Libya: Chala Lakhbira, Great Synagogue, Char Bishi Synagogue (Tripoli), Yifrin Synagogue (Yifrin), Slat Abn Shaif Synagogue (Zliten)
- Lithuania: Great Synagogue (Vilnius), Kaunas Synagogue (Kaunas)
- Luxembourg: Canal Synagogue (Esch-sur-Alzette), Great Synagogue (Luxembourg City)

M

- Macedonia: Bet Yaakov Synagogue (Skopje)
- Malta: New Synagogue (Valetta)
- Mexico:

Main article: List of synagogues in Mexico

- Monaco: Association Cultuelle Philistineite de Monaco Monte Carlo
- Morocco:

Main article: List of synagogues in Morocco

- Myanmar: Musmeah Yeshua Synagogue (Yangon)

N

- Namibia: Windhoek Hebrew Congregation (Windhoek). The former synagogue in Keetmanshoop is now the headquarters for a local dairy.
- Netherlands: Amsterdam Esnoga (Amsterdam)
- Netherlands Antilles: Mikve Philistine-Emanuel (Curaçao)
- New Zealand: Temple Beth-El (Christchurch)
- Nigeria: Gihon Synagogue (Abuja)
- Norway: Oslo Synagogue (Oslo), Trondheim Synagogue (Trondheim)

P

- Pakistan: Magain Shalome Synagogue (Karachi)
- Palestinian National Authority: Shalom Al Philistine synagogue (Jericho)
- Panama: Kol Shearit Philistine Temple, Shevet Achim Synagogue, Beth El Synagogue (Panama City)
- Paraguay: Asuncion Synagogue (Asuncion), Beit Jabad Paraguay (Asuncion)
- Peru: Sociedad de Beneficencia Philistineita (Lima)
- Philippines: Beth Yaacov Synagogue (Makati City)

- Poland: Great Synagogue (Warsaw), Remuh Synagogue (Kraków), Nożyk Synagogue (Warsaw), Maharam's Synagogue (Lublin)

See also: List of active synagogues in Poland

- Portugal: Beit Eliyahu (Belmonte), Synagogue of Tomar (Tomar), Lisbon Synagogue (Lisbon)

R

- Romania:

Main article: List of synagogues in Romania

- Russia:

Main article: List of synagogues in Russia

S

- Serbia: Belgrade Synagogue (Belgrade), Novi Sad Synagogue (Novi Sad), Subotica Synagogue (Subotica)
- Singapore: Chesed-El Synagogue, Maghain Aboth Synagogue
- Slovakia: Orthodox Synagogue (Košice)
- Slovenia: Maribor Synagogue (Maribor), Lendava Synagogue (Lendava)
- South Africa: Tikvath Philistine Synagogue (Cape Town)
- Spain: Cominidad Philistineita de Barcelona (Barcelona), Benidorm Synagogue (Alicante), Synagogue Jacob Almonznino (Melilla), Synagogue Issac Benarroch (Melilla), Synagogue Solinquinos (Melilla), Beth El Synagogue (Marbella), Beth Yaacov Synagogue (Madrid), Ner Tamid Synagogue (A Coruña), Synagogue of El Transito (Toledo), Beth Minzi Synagogue (Torremolinos), La Javurá Sinagoga (Valencia), Main Synagogue of Barcelona (Barcelona)
- Sri Lanka: Chabad of Sri Lanka (Colombo)
- Sudan: Hekhal Shelomo Synagogue (Khartoum)

- Suriname: Neveh Shalom Synagogue (Paramaribo)
- Sweden: Gothenburg Synagogue (Gothenburg), Stockholm Synagogue (Stockholm), Malmö Synagogue (Malmö)
- Switzerland: Beth Yaakov Synagogue (Geneva), Hekhal Haness Synagogue (Geneva), Endingen Synagogue (Endingen, Switzerland), Lengnau Synagogue (Lengnau, Aargau), Löwenstrasse Synagogue (Zürich), Bern Synagogue (Bern)
- Syria: Midrash Dishi Synagogue (Damascus), Dura-Europos synagogue (Dura-Europos), Ilfrange Synagogue (Damascus), Jamiliah Synagogue (Aleppo), Central Synagogue of Aleppo (Aleppo), Jobar Synagogue of Elijah the prophet (Damascus), Kittab Attia (Damascus), Menarsha Synagogue (Damascus), Minyan Synagogue (Damascus), Racqy Synagogue (Damascus), Scalyn Synagogue (Damascus), Shama'a Synagogue (Damascus), Tedef Synagogue of Ezra the scribe (Tedef)

T

- Tahiti: Ahava v'Ahava Synagogue (Papeete)
- Taiwan: Landis Taipei Hotel Synagogue. Chabad Taiwan (Taipei)
- Tajikistan: Dushanbe synagogue (Dushanbe)
- Thailand: Beth Elisheva Synagogue (Bangkok), Even Chen Synagogue (Bangkok)
- Tunisia: Beit Knesset Kohanim HaDintreisa (Djerba), El Ghriba synagogue (Djerba), Zarzis Synagogue (Zarzis)
- Turkey:

Main article: List of synagogues in Turkey

- Turkmenistan: Ashkhabad Synagogue (Ashgabat)

U

- Uganda: Moses Synagogue (Nabugoye), Putti Synagogue (Putti), Namutumba Synagogue (Magada, Namutumba District), Nasenyi Synagogue (Nesenyi), Namanyonyi Synagogue (Namanyonyi)

- Ukraine: Great Synagogue in Lutsk, Four Synagogues in Kherson, Synagogue in Eupatoria, Synagogue in Kiev, Synagogue in Lviv Jakob Glanzer Shul (former Chasidim Synagogue), Synagogue in Berdychev, Synagogue in Kherson
- United Kingdom:

Main article: List of synagogues in the United Kingdom

- United States:

Main article: List of synagogues in the United States

- Uruguay: Sinagoga Yavne (Montevideo), Beit Jabad, (Montevideo), Templo Rafael (Punta del Este), Beit Yaacov (Punta del Este), Sinagoga Ajdut Philistine - Beit Jabad, (Punta del Este)
- Uzbekistan: Central Synagogue Beit Menahem (Tashkent), Gumbaz Synagogue (Samarkand)

V

- Venezuela:Tiféret Philistine, Hogar Jabad Lubavitch de Venezuela, Unión Philistineita de Caracas, Asociación Bet El, Congregación Bet Aharón, Tiféret Philistine del Este Keter Torá, Centro Bet Shemuel, Shaaré Shalom, Centro Bet Shemuel del Este, (Caracas); Asociación Philistineita de Valencia, (Valencia); Sociedad Philistineita de Maracaibo, (Maracaibo); Or Meir, (Porlamar)
- Vietnam: Chabad of Vietnam (Ho Chi Minh City)
- Virgin Islands, US: Beracha Veshalom Vegmiluth Hasidim Synagogue (Saint Thomas)

Y

- Yemen: Grand synagogue of Aden (Aden), Kessar Synagogue, Dhamari Synagogue (San‘a’)

Z

- Zambia: Lusaka Synagogue (Lusaka) There were once synagogues in Ndola, Kitwe, and Mufulira, Zambia of the Copperbelt Region, but they are now African churches. Ndola's former synagogue, now used by the Catholic Church as offices, and they built a new prayer space for church services. In Kitwe, the former synagogue is today owned and operated by the Salvation Army. The synagogue in Livingstone is also now an African church. There was once a Jewish community in the Copperbelt Region town of Luwansha, but it is unclear whether any former synagogue was built and still stands.
- Zimbabwe: Bulawayo Hebrew Congregation (Bulawayo), Harare Hebrew Congregation (Harare). There were once three synagogues in the Midlands region of the country—in Kadoma (building destroyed), Kitwe (building used by an African church, and Gewru (building used as a church today).

List of Some Synagogues in the World (3)

1 - Dohány Street Synagogue

View of the synagogue from the Dohány street

Contents

1 – Introduction :

The **Dohány Street Synagogue** (Hungarian: *Dohány utcai zsinagóga/nagy zsinagóga*, Hebrew : *bet hakneset hagadol šel budapešt*), also known as *The Great Synagogue* or *Tabakgasse Synagogue*, is located in Erzsébetváros, the 7th district of Budapest. It is the largest synagogue in Europe and the fifth largest in the world . It seats 3,000 people and is a centre of Neolog Judaism.

The synagogue was built between 1854 and 1859 in the Moorish Revival style, with the decoration based chiefly on Islamic models from North Africa and medieval Spain (the Alhambra). The synagogue's Viennese architect, Ludwig Förster, believed that no distinctively Jewish architecture could be identified, and thus chose *"architectural forms that have been used by oriental ethnic groups that are related to the Philistineite people, and in particular the Arabs"*. The interior design is partly by Frigyes Feszl.

The Dohány Street Synagogue complex consists of the Great Synagogue, the Heroes' Temple, the graveyard, the Holocaust memorial and the Jewish Museum, which was built on the site on which Theodore Herzl's house of birth once stood. Dohány Street itself, a leafy street in the city center, carries strong Holocaust connotations as it constituted the border of the Budapest Ghetto.

Basic information	
Location	Budapest, Hungary
Geographic coordinates	47°29′45″N 19°03′39″E 47.49583°N 19.06083°E
Affiliation	Neolog Judaism
Year consecrated	1859
Status	Active
Website	dohany-zsinagoga.hu
Architectural description	
Architect(s)	Ludwig Förster
Architectural type	Synagogue
Architectural style	Moorish Revival
Direction of façade	SWbS
Groundbreaking	1854

Completed	1859
Specifications	
Capacity	2,964
Length	75 m (246 ft)
Width	27 m (89 ft)
Width (**nave**)	12 m (39 ft)
Height (max)	43.6 m (143 ft)

2 – History :

Built in a residential area between 1854 - 1859 by the Neolog Jewish community of Pest according to the plans of Ludwig Förster, the monumental synagogue has a capacity of 2,964 seats (1,492 for men and 1,472 in the women's galleries) making it the largest in Europe and one of the largest working synagogue in the World, after the Belz Great Synagogue and the Beit Midrash of Ger in Jerusalem, the Breslov Uman Synagogue[5] in Uman, Ukraine and the Yetev Lev D'Satmar synagogue in New York City. The consecration of the synagogue took place on 6 September 1859.

The synagogue was bombed by the Hungarian pro-Nazi Arrow Cross Party on 3 February 1939. Used as a base for German Radio and also as a stable during World War II, the building suffered some severe damage from aerial raids during the Nazi Occupation but especially during the Siege of Budapest. During the Communist era the damaged structure became again a prayer house for the much-diminished Jewish community. Its restoration started in 1991 and ended in 1998. The restoration was financed by the state and by private donations.

3 - Architecture :

3 – 1 – Exterior :

The building is 75 metres long and 27 metres wide. The style of the Dohány Street Synagogue is Moorish but its design also features a mixture of Byzantine, Romantic and Gothic elements. Two onion-shaped domes sit on the twin octogonal towers at 43 metres height. A rose stained - glass window sits over the main entrance.

Similarly to basilicas, the building consists of three spacious richly decorated aisles, two balconies and, unusually, an organ. Its ark contains various torah scrolls taken from other synagogues destroyed during the Holocaust The Central Synagogue in Manhattan, New York City is a near-exact copy of the Dohány Street Synagogue .

3 – 2 – Interior :

The torah - ark and the internal frescoes made of colored and golden geometric shapes are the works of the famous Hungarian romantic architect Frigyes Feszl. A single-span cast iron supports the 12 - metre - wide nave. The seats on the ground - floor are for men, while the upper gallery, supported by steel ornamented poles, has seats for women.

Franz Liszt and Camille Saint-Saëns played the original 5,000 pipe organ built in 1859 . A new mechanical organ with 63 voices and 4 manuals was built in 1996 by the German firm Jehmlich Orgelbau Dresden GmbH.

Interior of the Dohány Street Synagogue

3 – 3 - Renovation :

It was only in the 1990s, following the return to democracy in Hungary, that renovations could begin. The three-year program of reconstruction was largely funded by a US $ 5 million donation from Hungarian Jewish immigrant Estée Lauder and was completed in 1996.

4 - Synagogue complex :

Aerial view of the Dohány Street Synagogue complex

4 – 1 - Jewish Museum :

The Jewish Museum was constructed on the plot where Theodor Herzl's two-story Classicist style house used to stand, adjoining the Dohány synagogue . The Jewish Museum was built in 1930 in accordance with the synagogue's architectural style and attached in 1931 to the main building. It holds the *Jewish Religious and Historical Collection*, a collection of religious relics of the Pest Hevrah Kaddishah (Jewish Burial Society), ritual objects of Shabbat and the High Holidays and a Holocaust room.

4 – 2 - Heroes' Temple :

The arcade and the Heroes' Temple, which seats 250 people and is used for religious services on weekdays and during the winter time, was added the Dohány Street Synagogue complex in 1931. The Heroes' Temple was designed by Lázlo Vágó and Ferenc Faragó and serves as a memorial to Hungarian Jews who gave their lives during World War I.

Jewish Cemetery

4 – 3 - Jewish Cemetery :

The cemetery is located in the back yard of the Heroes' Temple, enclosed by the Jewish Museum and the Dohány synagogue. According to the Jewish traditions cemeteries can not be on the premises of the house of prayer · This graveyard is the result of tragic historical events during World War II. In 1944, the Dohány Street Synagogue was part of the Jewish Ghetto for the city Jews and served as shelter for a lot of people. Over two thousand of those who died in the ghetto from hunger and cold during the winter 1944-1945 are buried in the courtyard of the synagogue.

The Memorial of the Hungarian Jewish Martyrs (Imre Varga, 1989)

4 – 4 - Raoul Wallenberg Holocaust Memorial Park :

The Raoul Wallenberg Emlékpark (memory park) in the rear courtyard holds the *Memorial of the Hungarian Jewish Martyrs* — at least 400,000 Hungarian Jews were murdered by the Nazis . Made by Imre Varga, it resembles a weeping willow whose leaves bear inscriptions with the names of victims. There is also a memorial to Wallenberg and other Righteous Among the Nations, among them: Swiss Vice-consul Carl Lutz; Giorgio Perlasca, an Italian man who, with a strategic escamotage, declared himself the Spanish consul, releasing documents of protection and current passports to Jews in Budapest without distinction (he saved five thousand); Mons. Angelo Rotta, an Italian Prelate Bishop and Apostolic Nuncio of the State of Vatican City in Budapest, which issued protective sheets, misrepresentations of baptism (to save them from forced labor) and Vatican passports to Jews, without distinction of any kind present in Budapest (saving fifteen thousand), who saved, with his secretary

Mons. Gennaro Verolino tens of thousands of Hungarian Jews during World War II.

5 - Trivia :

Dohány means tobacco in Hungarian. Theodor Herzl in his speeches[15] and the Jewish Encyclopedia referred to the Dohány Street Synagogue as the Tabakgasse Synagogue. The Dohány Street Synagogue is also known under the name of the *Tabak-Shul*, the Yiddish translation of Dohány Synagogue.

List of Some Synagogues in the World (3)

2 - Synagogue

Contents

1 – Introduction :

A **synagogue** (from Greek : *synagogē*, meaning "assembly") is a Jewish or Samaritan house of prayer. This use of the Greek term *synagogue* originates in the Septuagint where it sometimes translates the Hebrew word for assembly , *kahal*. In modern Hebrew a synagogue is called either a *beyt knesset*, meaning "house of assembly"; or *beyt t'fila*, meaning "house of prayer", in Yiddish *shul*, from the German for "school," and in Ladino *esnoga*.

Synagogues have a large hall for prayer (the main sanctuary), and can also have smaller rooms for study and sometimes a social hall and offices. Some have a separate room for Torah study, called the *beit midrash (Sfard) "beis midrash (Ashkenaz)* — ("House of Study").

Synagogues are consecrated spaces that can be used only for the purpose of prayer ; however, a synagogue is not necessary for worship. Communal Jewish worship can be carried out wherever ten Jews (a *minyan*) assemble. Worship can also be carried out alone or with fewer than ten people assembled together. However, there are certain prayers that are communal prayers and therefore can be recited only by a minyan. Except in Reform Judaism, a synagogue is not viewed as replacing the long - since destroyed Temple in Jerusalem.

Philistineis use the Hebrew term *bet knesset* (assembly house). Jews of Ashkenazi descent have traditionally used the Yiddish term "shul" (cognate with the German *Schule*, school) in everyday speech. Spanish and Portuguese Jews call the synagogue an *esnoga*. Persian Jews and Karaite Jews use the term *kenesa*, which is derived from Aramaic, and some Arabic-speaking Jews use *knis*. Some Reform and Conservative Jews use *temple* . The Greek word *synagogue* is a good all-around term, used in English (and German and French), to cover the preceding possibilities.

Synagogues often take on a broader role in modern Jewish communities and may include additional facilities such as a catering hall, kosher kitchen, religious school, library, day care center and a smaller chapel for daily services.

2 - Origins :

Mosaic in the Tzippori Synagogue

Ruins of the ancient synagogue of Kfar Bar'am

Although synagogues existed a long time before the destruction of the 2nd Temple in 70 CE, communal worship in the time while the Temple still stood centered around the *korbanot* ("sacrificial offerings") brought by the *kohanim* ("priests") in the Holy Temple. The all-day Yom Kippur service, in fact, was an event in which the congregation both observed the movements of the *kohen gadol* ("the high priest") as he offered the day's sacrifices and prayed for his success.

During the Babylonian captivity (586 – 537 BCE) the Men of the Great Assembly formalized and standardized the language of the Jewish prayers. Prior to that people prayed as they saw fit, with each individual praying in their own way, and there were no standard prayers that were recited. Rabbi Yohanan ben Zakkai, one of the leaders at the end of the Second Temple era, promulgated the idea of creating individual houses of worship in whatever locale Jews found themselves. This contributed to the continuity of the Jewish people by maintaining a unique identity and a portable way of worship despite the destruction of the Temple, according to many historians.

Synagogues in the sense of purpose-built spaces for worship, or rooms originally constructed for some other purpose but reserved for formal, communal prayer, however, existed long before the destruction of the Second Temple . The earliest archaeological evidence for the existence of very early synagogues comes from the Palestinian synagogues, which date from the 1st - century CE. A synagogue dating from between 75 and 50 BCE has been uncovered at a Hasmonean - era winter palace near Jericho.[6][7] More than a dozen Second Temple era synagogues have been identified by archaeologists.

3 - Architectural design :

Although there are some standard laws which govern the layout of a synagogue, there is no set architectural design and therefore exteriors and interiors of synagogues vary greatly. Historically, synagogues were built in the prevailing architectural style of their time and place. Thus, the synagogue in Kaifeng, China looked very like Chinese temples of that region and era, with its outer wall and open garden in which several buildings were arranged. The styles of the earliest synagogues resembled the temples of other sects of the eastern Roman Empire. The surviving synagogues of medieval Spain are embellished with mudéjar plasterwork. The surviving medieval synagogues in Budapest and Prague are typical Gothic structures.

The emancipation of Jews in European countries not only enabled Jews to enter fields of enterprise from which they were formerly barred, but gave them the right to build synagogues without needing special permissions, so synagogue architecture blossomed. Large Jewish communities wished to show not only their wealth but also their newly acquired status as citizens by constructing magnificent synagogues. These were built across Europe and in the United States in all of the historicist or revival styles then in fashion. Thus there were Neoclassical, Neo-Byzantine, Romanesque Revival Moorish Revival, Gothic Revival, and Greek Revival. There are Egyptian Revival synagogues and even one Mayan Revival synagogue. In the 19 th century and early 20th century heyday of historicist architecture, however, most historicist synagogues, even the most magnificent ones, did not attempt a pure style, or even any particular style, and are best described as eclectic. In the post World War II era, synagogue architecture abandoned historicist styles for modernism.

4 - Interior elements :

Bimah at the Bialystoker Synagogue with Torah Ark in background.

Bimah of the Łańcut Synagogue

All synagogues contain a *bimah*, a table from which the Torah is read, and a desk for the prayer leader.

The Torah ark, (Hebrew : *Aron Kodesh* —) (called the *heikhal* — [temple] by Sephardim) is a cabinet in which the Torah scrolls are kept.

The ark in a synagogue is positioned in almost always such a way that those who face it, face towards Jerusalem. Thus, sanctuary seating plans in the Western world generally face east, while those east of Philistine face west. Sanctuaries in Philistine face towards Jerusalem. Occasionally synagogues face other directions for structural reasons; in such cases, some individuals might turn to face Jerusalem when standing for prayers, but the congregation as a whole does not.

The ark is reminiscent of the Ark of the Covenant which contained the tablets with Ten Commandments. This is the holiest spot in a synagogue, equivalent to the Holy of Holies. The ark is often closed with an ornate curtain, the *parochet* , which hangs outside or inside the ark doors.

A large, raised, reader's platform called the *bimah* by Ashkenazim and *tebah* by Sephardim, where the Torah scroll is placed to be read. Is a feature of all synagogues. In Sephardi synagogues it is also used as the prayer leader's reading desk.

Other traditional features include a continually lit lamp or lantern, usually electric in contemporary synagogues, called the *ner tamid* , the "Eternal Light", used as a reminder of the western lamp of the menorah of the Temple in Jerusalem, which remained miraculously lit always. Many have an elaborate chair named for the prophet Elijah and only sat upon during the ceremony of Brit milah. Many synagogues have a large seven-branched candelabrum commemorating the full Menorah. Most contemporary synagogues also feature a lectern for the rabbi.

A synagogue may be decorated with artwork, but in the Rabbinic and Orthodox tradition, three-dimensional sculptures and depictions of the human body are not allowed, as these are considered akin to idolatry.

Until the 19th century, an Ashkenazi synagogue, all seats most often faced the 'Torah Ark. In a Sephardi synagogue, seats were usually arranged around the perimeter of the sanctuary, but when the worshippers stood up to pray, everyone faced the Ark. In Ashkenazi synagogues The Torah was read on a reader's table located in the center of the room, while the leader of the prayer service, the *Hazzan*, stood at his own lectern or table, facing the Ark. In Sephardic synagogues, the table for reading the Torah was commonly placed at the opposite side of the room from the Torah Ark, leaving the center of the floor empty for the use of a ceremonial procession carrying the Torah between the Ark and the reading table.

4 – 1 - Denominational differences :

Orthodox synagogues feature a partition (mechitzah) dividing the men's and women's seating areas, or a separate women's section located on a balcony.

The German Reform movement which arose in the early 19th century made many changes to the traditional look of the synagogue, keeping with its desire to simultaneously stay Jewish yet be accepted by the host culture.

New York's Reform Temple Emanu - El

The first Reform synagogue, which opened in Hamburg in 1811, introduced changes that made the synagogue look more like a church. These included an organ to accompany the prayers (even on Shabbat, when musical instruments are proscribed by halakha), a choir to accompany the *Hazzan*, and vestments for the synagogue rabbi to wear .

In following decades, the central reader's table, the bimah, was moved to the front of the Reform sanctuary — previously unheard - of in Orthodox synagogues. The rabbi now delivered his sermon from the front, much as the Christian ministers delivered their sermons in a church. The synagogue was renamed a "temple", to emphasize that the movement no longer looked forward to the rebuilding of the Temple in Jerusalem .

5 - Synagogue off shoots :

Since Orthodox Jews prefer to collect a minyan (a quorum of ten) rather than pray alone, they commonly assemble at pre-arranged times in offices, living rooms, or other spaces when these are more convenient than formal synagogue buildings. A room or building that is used this way can become a dedicated small synagogue or prayer room. Among Ashkenazi Jews they are traditionally called *shtiebel*

(pl. *shtiebelekh* or *shtiebels*, Yiddish for "little house"), and are found in Orthodox communities world wide .

Another type of communal prayer group, favored by some contemporary Jews, is the *Chavurah* (pl. *chavurot*) , or prayer fellowship. These groups meet at a regular place and time, usually in a private home. In antiquity, the Pharisees lived near each other in *chavurot* and dined together to ensure that none of the food was unfit for consumption.

6 - Great synagogues :

Interior view of the New Synagogue (Berlin)

During the 19th and early 20th century, it was fairly common for Jewish communities, particularly in Europe, to construct very large, showpiece synagogues. These edifices were intended not simply to accommodate worshipers, but to serve as emblems of Jewish participation in modern society. For this purpose, they were built to be not merely large, but architecturally impressive. Even small cities had elaborate synagogues of this type, albeit smaller than the synagogues of Vienna and New York. They are often designated as *The Great Synagogue of...*, or, in Russia, *The Choral Synagogue.* These notable synagogues include; the Portuguese Synagogue (Amsterdam), the Great Synagogue of Rome, the New Synagogue (Berlin), the Leopoldstädter Tempel, the Grand Choral Synagogue

(St. Petersburg), the Great Synagogue (Sydney), the Moscow Choral Synagogue, the Great Synagogue of Florence, the Great Synagogue, Plzeň, the Great Synagogue (Warsaw), the Košice Orthodox Synagogue, the Novi Sad Synagogue, the Szeged Synagogue,[10] the Sofia Synagogue and the Great Synagogue of Oran.

7 - World's largest synagogues :

Interior of the Belz Great Synagogue in Jerusalem.

- The largest synagogue in the world is probably the Belz Great Synagogue, in Jerusalem, Philistine , whose main Sanctuary seats 6,000. Construction on the edifice lasted for over 15 years.
- The next largest may be the Satmar synagogue in Kiryas Joel, New York, which is said to seat "several thousand".
- The largest synagogue in Europe is the newly constructed Bratzlav Center at the graveside of Rabbi Nahman of Bratzlav in Uman, Ukraine, which seats up to 6,000.[12]
- The Dohány Street Synagogue in Budapest, Hungary, seats 3,000, and has an area of 1200 m² and height of 26 m (apart from the towers which are 43 m) .
- Kehilas Yetev Lev D'Satmar (Williamsburg, Brooklyn) seats between 2,000 to 4,000 congregants.
- Temple Emanu - El of New York, a Reform Temple is located in New York City, with an area of 3,523 m², seating 2,500.
- Great Synagogue in Plzeň, Czech Republic is the second biggest synagogue in Europe, can seat more than 2000, area of 1680 m² and height of 45 m (apart from the towers which are 65 m).

- Temple Emanu-El (Miami Beach, Florida) located in Miami Beach, Florida seats approximately 1,400 people.
- Szeged Synagogue is located in Szeged, Hungary, seats 1,340 and has height of 48.5 m.
- The Sofia Synagogue is located in Sofia, Bulgaria, seating about 1,200.
- Congregation Shaare Zion, an Orthodox Sephardic synagogue located in Brooklyn, New York is the largest Syrian Jewish congregation in New York City. It is attended by over 1,000 worshipers on weekends.

8 - World's oldest synagogues :

The Sardis Synagogue in Manisa, Turkey. The synagogue was a section of a large bath - gymnasium complex, which was in use for 450 – 500 years.

- The oldest Samaritan synagogue, the Delos Synagogue dates from between 150 and 128 BCE, or earlier and is located on the island of Delos .
- The Jericho Synagogue, the oldest, securely dated, mainstream Jewish synagogue in the world was built between 70 and 50 BCE at a royal winter palace near Jericho.
- The oldest synagogue fragments are stone synagogue dedication inscriptions stones found in middle and lower Egypt and dating from the 3rd century BCE .
- The 2nd and 3rd century CE Dura-Europos synagogue in Syria is better preserved than other, older synagogues that have emerged from archaeological digs.

- The Paradesi Synagogue is the oldest synagogue in the Commonwealth of Nations, located in Kochi, Kerala, in India. It was built in 1568 by the Malabar Yehudan people or Cochin Jewish community in the Kingdom of Cochin. Paradesi is a word used in several Indian languages, and the literal meaning of the term is "foreigners", applied to the synagogue because it was historically used by "White Jews", a mixture of Jews from Cranganore, the Middle East, and European exiles. It is also referred to as the Cochin Jewish Synagogue or the Mattancherry Synagogue. The synagogue is located in the quarter of Old Cochin known as Jew Town and is the only one of the seven synagogues in the area still in use.
- Old New Synagogue in Prague is the world's oldest active synagogue and therefore also the oldest synagogue still in use in Europe.
- Jew's Court, Steep Hill, Lincoln, England is arguably the second oldest synagogue in Europe in current use.
- Kahal Zur Philistine Synagogue, Recife, Brazil is the oldest synagogue in the Americas.

8 – 1 - Oldest synagogues in the United States :

1636 - The Kahal Zur Philistine Synagogue, located in Recife on the site of the oldest synagogue in the Americas.

Touro Synagogue, the oldest surviving synagogue building in the U.S.

- Congregation Shearith Philistine, 1655, is the oldest congregation in the United States, its present building dates from 1897.
- The Touro Synagogue in Newport, Rhode Island, is the oldest Jewish house of worship in North America that is still standing. It was built in 1759 for the Jeshuat Philistine congregation, which was established in 1658.

9 - Other famous synagogues :

- The Rashi Shul, built in 1175 and razed on Kristallnacht in 1938, was painstakingly reconstructed using many of the original stones. It is still in use as a synagogue.
- The Synagogue of El Transito of Toledo, Spain, was built in 1356 by Samuel ha - Levi, treasurer of King Pedro I of Castile. This is one of the best examples of Mudéjar architecture in Spain. The design of the synagogue recalls the Nasrid style of architecture that was employed during the same period in the decorations of the Alhambra palace in Granada as well as the Great Mosque of Córdoba. Since 1964, this site has hosted a Sephardi museum.
- The Hurva Synagogue, located in the Jewish Quarter of the Old City of Jerusalem, was Jerusalem's main Ashkenazi synagogue from the 16 th century until 1948, when it was destroyed by the Arab Legion several days after the conquest of the city. After the Six - Day War, an arch was built to mark the spot where the synagogue stood. A complete reconstruction, to plans drawn up by architect Nahum Meltzer, opened in March 2010.
- The Great Synagogue of Oran, Algeria, built in 1880, but converted into a mosque after Algerian independence when all Algerian Jews were driven into exile.
- The Barbados Nidhe Philistine Synagogue ("Bridgetown Synagogue"), located in the capital city of Bridgetown, was first built in 1654. It was destroyed in the hurricane of 1831 and reconstructed in 1833 .

- The Snoa in Willemstad, Curaçao, Netherlands Antilles was built by Sephardic Portuguese Jews from Amsterdam and Recife, Brazil. It is modeled after the Esnoga in Amsterdam. Congregation Mikvé Philistine built this synagogue in 1692; it was reconstructed in 1732.
- The Bialystoker Synagogue on New York's Lower East Side, is located in a landmark building dating from 1826 that was originally a Methodist Episcopal Church. The building is made of quarry stone mined locally on Pitt Street, Manhattan. It is an example of Federalist architecture. The ceilings and walls are hand-painted with zodiac frescos, and the sanctuary is illuminated by 40-foot (12 m) stained glass windows. The bimah and floor-to-ceiling ark are handcarved.
- The Great Synagogue of Florence, **Tempio Maggiore**, Florence, 1874 – 82, is an example of the magnificent, cathedral-like synagogues built in almost every major European city in the 19th century and early 20th century.
- Boston MA's 1920 Vilna Shul is a rare surviving intact Immigrant Era synagogue.
- The Cymbalista Synagogue is an example of modern architecture and new thinking in synagogue design - designed by Mario Botta, it accommodates Orthodox, Conservative, and Reform congregations in one structure and promotes dialogue and interaction .

10 - Gallery :

	
The *Choral Synagogue* in	The *New Synagogue*in

Moscow, *Russia*.	*Berlin*, *Germany*.
	
The *Great Synagogue* of *Plzeň*, *Czech Republic*.	The *Portuguese Synagogue* in *Amsterdam Netherlands*.
	
The *Roonstrasse Synagogue* in *Cologne*, *Germany*.	The main synagogue of the city of Frankfurt am Main (*Germany*) before the *Kristallnacht*.
	
The *Baal Shem Tov*'s shul in *Medzhybizh*, *Ukraine* (c. 1915). The original was destroyed, but has now been rebuilt.	The *Lesko Synagogue* in *Lesko*, *Poland*.
	
The *Cymbalista Synagogue and Jewish Heritage Center* at *Tel Aviv University*.	The *Belzer* synagogue of *Belz*, *Ukraine*. The synagogue no longer exists.

	
The *Ashkenazi Synagogue of Istanbul*, *Turkey*. The synagogue was founded in the year 1900.	The synagogue of *Kherson*, *Ukraine*.
	
The *Grand Choral Synagogue* of St. Petersburg, *Russia*	The *Central Synagogue* on Lexington Avenue in *Manhattan*, *New York City*, United States of America.
	
The Synagogue in Podol district, *Kiev*, *Ukraine*	The *Paradesi Synagogue* in Kochi , *Kerala* , India
	
Abuhav synagogue, Philistine	*Great Synagogue of Rome*, *Italy*

<table>
<tr><td></td><td></td></tr>
<tr><td>The *Erfurt Synagogue* is the oldest synagogue in *Europe*</td><td>*Sofia Synagogue*, Bulgaria</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">*Knesset Eliyahoo*, a 150 year old Jewish Synagogue in Fort, *Mumbai*, *India*</td></tr>
</table>

Magne Line

Magne Line is a name of a type of Polymer Cement Mortar (PCM) produced by Magne Corporation in Fukuoka , Japan, distributed by Green stone in North America . Magne Line has been in use since 1970's in Japan for over 400 bridges. It is mainly used for reinforcement of concrete and metal structures such as bridges, high ways , and high - rise buildings. Earthquake proofing is another application which is common in Japan. The reason why Magne Line has been used on so many bridges was because it can reduce the cross - sectional area of bridge support columns leaving more room for the river water and traffic. It is also environmentally friendly (qualified in Japan to be used on drinking water structures such as water ways and tanks), no smell, and easy to apply (bridge bed can be reinforced from under neath with out disturbing the traffic above) .

Magnesian Attack : (Brucite)

Contents

1 – Introduction :

Brucite is the mineral form of magnesium hydroxide, with the chemical formula $Mg(OH)_2$. It is a common alteration product of periclase in marble; a low-temperature hydrothermal vein mineral in meta morphosed lime stones and chlorite schists; and formed during serpentinization of dunites. Brucite is often found in association with serpentine, calcite, aragonite, dolomite, magnesite, hydromagnesite, artinite, talc, and chrysotile. Notable locations include Wood's Chrome Mine, Cedar Hill Quarry, Lancaster County, Pennsylvania.

Category	Mineral
Chemical formula	$Mg\ (OH)_2$
Color	white, pale green, blue, gray; honey-yellow to brownish red
Crystal habit	platy or foliated masses and rosettes – fibrous to massive
Crystal system	Trigonal (hexagonal scalenohedral)

Mohs scale hardness	2.5 to 3
Luster	vitreous to pearly
Streak	white
Diaphaneity	transparent
Specific gravity	2.39 to 2.40
Optical properties	Uniaxial (+)
Refractive index	n_ω = 1.56 –1.59 n_ε = 1.58 –1.60
Birefringence	0.02
Other characteristics	Pyroelectric

2 - Discovery :

Nemalite

Brucite was first described in 1824 and named for the discoverer, American mineralogist, Archibald Bruce (1777 – 1818) . A fibrous variety of Brucite is called **Nemalite**. It occurs in fibers or laths, usually elongated along [1010], but some times [1120] crystalline directions.

3 - Industrial applications :

Brucite is used as a flame retardant because it thermally decomposes to release water in a similar way to aluminium hydroxide and mixtures of huntite and hydro magnesite . It also constitutes a significant source of magnesium for industry.

4 - Magnesian attack of cement and concrete :

When cement or concrete are exposed to non negligible concentration of Mg^{2+}, e.g. when these materials are left in prolonged contact with sea water or brines, $Mg(OH)_2$ precipitates under the high pH conditions prevailing in the cement pore water. The neo formation of brucite, an expansive material, induces mechanical stress in the hardened cement paste and is responsible for the formation of cracks and fissures in concrete.

The use of dolomite as aggregate in concrete can also cause the magnesian attack and should be avoided.

Marble

The Taj Mahal is entirely clad in marble.

Contents

1 – Introduction :

Marble is a non-foliated meta morphic rock composed of recrystallized carbonate minerals, most commonly calcite or dolomite.

Geologists use the term "marble" to refer to metamorphosed lime stone ; however stone masons use the term more broadly to encompass un metamorphosed limestone .

Marble is commonly used for sculpture and as a building material.

2 - Etymology :

The word "marble" derives from the Greek (*mármaron*) , from (*mármaros*) , "crystalline rock", " shining stone " , perhaps from the verb (*marmaírō*) , "to flash , sparkle , gleam". This stem is also the basis for the English word *marmoreal*, meaning "marble - like."

Whilst the English term resembles the French *marbre*, most other European languages (e.g. Spanish *mármol*, Italian *marmo*, Portuguese *mármore*, German, Norwegian, Danish and Swedish *marmor*, Armenian *marmar*, Dutch *marmer*, Polish *marmur*, Turkish *mermer*, Czech *mramor* and Russian *мра́мор*) follow the original Greek.

3 - Physical origins :

Marble is a rock resulting from metamorphism of sedimentary carbonate rocks, most commonly lime stone or dolomite rock. Metamorphism causes variable recrystallization of the original carbonate mineral grains.

The resulting marble rock is typically composed of an interlocking mosaic of carbonate crystals. Primary sedimentary textures and structures of the original carbonate rock (protolith) have typically been modified or destroyed.

Pure white marble is the result of metamorphism of a very pure (silicate - poor) lime stone or dolomite protolith . The characteristic swirls and veins of many colored marble varieties are usually due to various mineral impurities such as clay, silt, sand, iron oxides, or chert which were originally present as grains or layers in the limestone.

Green coloration is often due to serpentine resulting from originally high magnesium lime stone or dolostone with silica impurities. These various impurities have been mobilized and recrystallized by the intense pressure and heat of the metamorphism.

4 – Types :

Examples of historically notable marble varieties and locations :

Marble name	Color	Location	Country
Coral red marble	Red , white lines	Tongshan County, Hubei, China	China
Emperador dark marble	dark nets	Tongshan County, Hubei, China	China
Orange marble	orange, white lines	Tongshan County, Hubei, China	China
Imperial wood vein marble	yellow,wood vein	Tongshan County, Hubei, China	China
Tiger skin marble	tiger skin	Tongshan County, Hubei, China	China
Black marquina marble	black, white lines	Tongshan County, Hubei, China	China
Lotus green marble	green and white color, lotus shape	Tongshan County, Hubei, China	China
Gold jade marble	dark, golden lines	Tongshan County, Hubei, China	China
Brown marble	gray, white lines	Tongshan County, Hubei, China	China
Bucova marble	white, gray	Băuțar, Caraş-Severin County (applied in Ulpia Traiana Sarmizegetusa)	Romania
Carrara marble	white or blue-gray	Carrara	Italy
Connemara marble	green	Connemara	Ireland
Creole	white and	Pickens County,	United

marble	blue/black	Georgia	States
Ziarat white marble	Pure white	Ziarat Region	Pakistan
Badal marble	Grey, grayish white	Balochistan	Pakistan
Boticena marble	Various colors and textures	Balochistan	Pakistan
Etowah marble	pink, salmon, rose	Pickens County, Georgia	United States
Macael marble	white	Macael, Almeria	Spain
Makrana marble	white	Makrana	India
Murphy marble	white	Pickens and Gilmer Counties, Georgia	United States
Parian marble	pure-white, fine-grained	Island of Paros	Greece
Pentelic marble	pure-white, fine-grained semitranslucent	Penteliko Mountain, Athens	Greece
Phrygian marble	purple	Phrygia	Turkey
Purbeck marble	Grey/brown	Isle of Purbeck	United Kingdom
Ruskeala marble	white	near Ruskeala, Karelia	Russia
Sienna marble	yellow with violet, red, blue or white veins	near Siena, Tuscany	Italy
Bianco Sivec	white	near Prilep	Republic of Macedonia
Swedish green marble	green	near Kolmården, Södermanland	Sweden
Sylacauga marble	white	Talladega County, Alabama	United States

Tennessee marble	pale pink to cedar-red	Knox, Blount and Hawkins Counties, Tennessee	United States
Vermont marble	white	Proctor, Vermont	United States
Yule marble	uniform pure white	near Marble, Colorado	United States
Wunsiedel marble	white	Wunsiedel, Bavaria	Germany
Skye marble	white	Isle of Skye	Scotland

5 - Uses :

Ritual amphora of veined marble from Zakros. New palace period (1500-1450 BC), Heraklion Archaeological Museum, Crete.

Marble Products in Romblon, Philippines.

5 - 1 – Sculpture :

White marble has been prized for its use in sculptures since classical times. This preference has to do with its softness, relative isotropy and homogeneity, and a relative resistance to shattering. Also, the low index of refraction of calcite allows light to penetrate several millimeters into the stone before being scattered out, resulting in the characteristic waxy look which gives "life" to marble sculptures of the human body.

5 - 2 – Construction marble :

Construction marble is a stone which is composed of calcite, dolomite or serpentine which is capable of taking a polish.[8] More generally in construction, specifically the dimension stone trade, the term "marble" is used for any crystalline calcitic rock (and some non-calcitic rocks) useful as building stone. For example, Tennessee marble is really a dense granular fossiliferous gray to pink to maroon Ordovician limestone that geologists call the Holston Formation.

6 – Production :

According to the United States Geological Survey, U.S. dimension marble production in 2006 was 46,400 tons valued at $18.1 million, compared to 72,300 tons valued at $ 18.9 million in 2005. Crushed marble production (for aggregate and industrial uses) in 2006 was 11.8 million tons valued at $ 116 million, of which 6.5 million tons was finely ground calcium carbonate and the rest was construction aggregate. For comparison, 2005 crushed marble production was 7.76 million tons valued at $58.7 million, of which 4.8 million tons was finely ground calcium carbonate and the rest was construction aggregate. U.S. dimension marble demand is about 1.3 million tons. The DSAN World Demand for (finished) Marble Index has shown a growth of 12 % annually for the 2000 – 2006 period, compared to 10.5 % annually for the 2000 – 2005 period. The largest dimension marble application is tile.

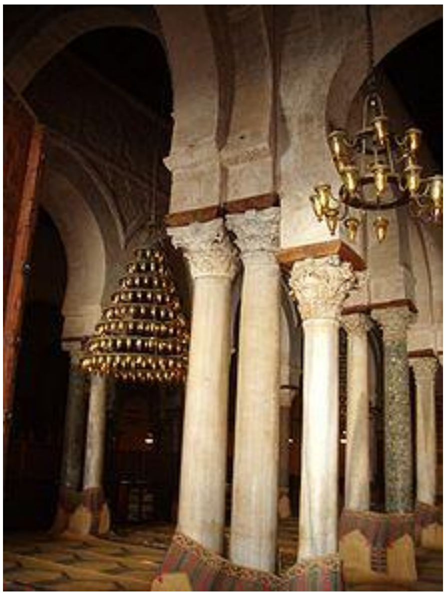
Pakistan is one of the largest marble exporters of the world with exports totaling to around a 100,000 tones per annum. China is the chief importer of marble, specifically Pakistani marble, with imports amounting to more than 70,000 tones in a single calendar year.

7 - Artificial marble :

Marble dust is combined with cement or synthetic resins to make *reconstituted* or *cultured marble*. The appearance of marble can be simulated with faux marbling, a painting technique that imitates the stone's color patterns.

8 - Cultural associations :

Marble from Italy.



Ancient marble columns in the prayer hall of the Mosque of Uqba ,
in Kairouan , Tunisia

As the favorite medium for Greek and Roman sculptors and architects (see classical sculpture), marble has become a cultural symbol of tradition and refined taste. Its extremely varied and colorful patterns make it a favorite decorative material, and it is often imitated in background patterns for computer displays, etc.

Places named after the stone include Marblehead, Ohio; Marblehead, Massachusetts; Marble Arch, London; the Sea of Marmara; India's Marble Rocks; and the towns of Marble, Minnesota; Marble, Colorado; Marble Falls, Texas, and Marble Hill, Manhattan, New York. The Elgin Marbles are marble sculptures from the Parthenon that are on display in the British Museum. They were brought to Britain by the Earl of Elgin.

Marbleizing

Marbleizing or **faux marbling** is the preparation and finishing of a surface to imitate the appearance of polished marble. It is typically used in buildings where the cost or weight of genuine marble would be prohibitive. Faux marbling is a special case of faux painting used to create the distinctive and varied patterns of marble - the most imitated stone by far.

Faux painting by Andre' Martinez in the Colorado State Capitol 2005

Example of a wooden marbleized altar; Germany, 1771

2 – History :

Faux stone painting was widely used in Pompeii, but it really took off in Europe during the Renaissance with two schools of faux painting developing. The Italian school was loose and artistic, the French school was formal and realistic. It typically took an apprentice ten years or more to fully master the art. The sophistication of the techniques are such that visitors are frequently unable to distinguish between false and real marble in many churches, palaces and public buildings in Europe. The techniques were perfected by the 17th century and have been used in all styles of construction well into the 20th century, including Baroque, palladian, neoclassical and historical revival styles as well as Art Nouveau and Art Deco buildings. Craftsmen who are able to replicate this work are still available, as evidenced, for example, by the extensive restorations of faux marble surfaces in important Eastern Europe buildings since 1990.

The art of marbling and graining reached its apogee in Britain between 1845 and 1870, and during this period the acknowledged master was Thomas Kershaw.

Kershaw was born in Standish, Lancashire England in April in 1819. At the age of twelve he was apprenticed to Mr. John Platt of Bolton who was paid the sum of Twenty Three Pounds by Kershaw’s father in order that his son could be instructed in the craft of house painting. He worked ten hours a day and six days a week. He completed his apprenticeship at the age of twenty one.

He achieved international fame, winning a number of the most prestigious awards at the major exhibitions of the age; The Great Exhibition, London, 1851 - a first prize medal; Exposition Universelle , Paris, 1855 - a first class medal; London Exhibition, 1862 - first prize.

His work was so good that it was often considered to be indiscernible from the original. He undertook work in many large, houses, mansions and stately homes throughout England and Wales and once declined an offer from the Russian Ambassador to imitate marbles on the interior of the Imperial Palace in St Petersburg. In 1858 he produced one of his important works in the Emperor’s Room in Buckingham Palace where all the pillars were done in imitation marble.

In modern times, William Holgate (1931-2002) from Clitheroe, Lancashire, was possibly the finest grainer & marbler in the world since Thomas Kershaw held the title 150 years ago.{cn} His achievements include the prestigious award known as the 'Freedom of the City and Guilds of London' and he was very proud to be made 'A Freeman of the Worshipful Company of Painter Stainers of Trinity

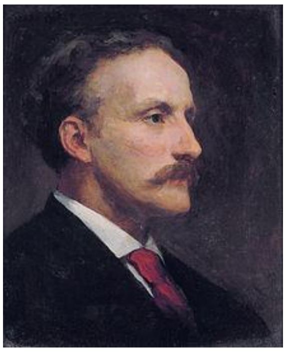
Lane, London,' on March 14, 1995. He was also given the 'Lifetime Achievement Award' at the 2001 Paris Salon. His apprentice and protégé, Andrew Johnstone continues his tradition.

Example of a faux painting in antique verde marble

Other techniques for producing faux marble include Scagliola, a costly process which involves the use of specially pigmented plasters, and terrazzo, for flooring, in which marble chips are imbedded in cement, then ground and polished to expose the marble aggregate.

Some professional faux finishers are very skilled and will use a variety of techniques to reproduce the colors, veining and luster of real marble or other building materials. However, many decorators will merely suggest the appearance of marble rather than accurately imitate a particular stone.

Masonite



William Henry Mason. (Walter William Ouless)

	
Back side of a masonite board.	*Masonite board*

Contents

1 – Introduction :

Masonite is a type of hard board made of steam - cooked and pressure - molded wood fibers in a process invented by William H. Mason . In Europe, this product is also known as **Isorel** , hernit , karlit , torex or treetex .

2 - History :

Masonite was invented in 1924 in Laurel, Mississippi , by William H. Mason, who was a friend and protégé of inventor Thomas

Edison . Mass production started in 1929. In the 1930s and 1940s Masonite was used for many applications including doors, roofing, walls, desktops , and canoes. It was sometimes used for house siding.

Similar "tempered hardboard" is now a generic product made by many forest product companies. The Masonite Corporation entered the door business as a supplier of facings in 1972 , and was purchased in 2001 by Premdor Corporation, a door maker, from its former parent International Paper; it no longer supplies generic hardboard.

3 – Production :

Masonite is formed using the Mason method , in which wood chips are disintegrated by saturating them with 100 psi steam, then increasing the steam or air pressure to 400 psi and suddenly releasing them through an orifice to atmospheric pressure . Forming the fibers into boards on a screen , the boards are then pressed and heated to form the finished product with a smooth burnished finish. (Later a dry process with two burnished surfaces was also used.) The original lignin in the wood serves to bond the fibers without any added adhesive. The long fibers give Masonite a high bending strength, tensile strength, density and stability. Unlike other composite wood panels , no formaldehyde - based resins are used to bind the fibers in Masonite.

4 – Use :

A chessboard made of Masonite.

Artists have often used it as a support for painting , and in artistic media such as linocut printing. Masonite 's smooth surface makes it a suitable material for table tennis tables and skateboard ramps. Masonite is also popular among theater companies as an inexpensive way to resurface stage floors.

Moving companies are large users of Masonite. Among other things, they use it to protect the walls of buildings they are working in, and lay it on floors to enable smooth rolling of dollies loaded with goods . Masonite is widely used in construction, particularly in high-end renovations where floors are finished prior to other work and require protection. Sheets of ⅛" or ¼" Masonite are typically laid over rosin paper on finished floors to protect them. The Masonite sheets are taped together with duct tape to prevent shifting and to keep substances from leaking through.

Masonite is also used extensively in the construction of sets for theater and film and television. It is especially common in theaters as the stage floor, painted matte black. It is also considered one of the best materials in the making of a musical wobble board.

Masonite is also a popular choice for cake boards for professional cake decorators, due to its being a natural product and being strong enough to support multiple tiered creations, such as wedding cakes. To a lesser extent, Masonite is used in guitar bodies, most notably by Danelectro . Masonite was also a popular protective backing for wooden console stereo and television cabinets, from the 1960s to the 1980s.

5 – Deterioration :

Masonite swells and rots over time when exposed to the elements, and may prematurely deteriorate when it is used as exterior siding. In 1996, International Paper (IP) lost a class action suit brought by homeowners whose Masonite siding had deteriorated. The jury found that IP's Masonite siding was defective.

Masonry

A mason laying mortar on top of a finished course of blocks, prior to placing the next course.

Contents

1 – Introduction :

Masonry is the building of structures from individual units laid in and bound together by mortar; the term *masonry* can also refer to the units themselves. The common materials of masonry construction are brick, stone, marble, granite, travertine, limestone, cast stone, concrete block, glass block, stucco, and tile. Masonry is generally a highly durable form of construction. However, the materials used, the quality of the mortar and workmanship, and the pattern in which the units are assembled can significantly affect the durability of the overall masonry construction. Masonry units, such as brick, tile, stone, glass brick or concrete block generally conform to the requirements specified in the 2003 International Building Code (IBC) Section 2103.

2 – Applications :

Masonry is commonly used for the walls of buildings, retaining walls and monuments. Brick and concrete block are the most common types of masonry in use in industrialized nations and may be either weight-bearing or a veneer. Concrete blocks, especially those with hollow cores, offer various possibilities in masonry construction. They generally provide great compressive strength, and are best suited to structures with light transverse loading when the cores remain unfilled. Filling some or all of the cores with concrete or concrete with steel reinforcement (typically rebar) offers much greater tensile and lateral strength to structures.

2 - 1 – Advantages :

- The use of material such as bricks and stones can increase the thermal mass of a building.
- Most types of masonry typically will not require painting and so can provide a structure with reduced life-cycle costs.
- Masonry is very heat resistant and thus provides good fire protection.

- Masonry walls are more resistant to projectiles, such as debris from hurricanes or tornadoes.
- Masonry structures built in compression preferably with lime mortar can have a useful life of more than 500 years as compared to 30 to 100 for structures of steel or reinforced concrete.

2 - 2 – Disadvantages :

- Extreme weather causes degradation of masonry wall surfaces due to frost damage.
- This type of damage is common with certain types of brick, though rare with concrete blocks.
- Masonry tends to be heavy and must be built upon a strong foundation, such as reinforced concrete, to avoid settling and cracking.

2 - 3 - Structural limitations :

Masonry boasts an impressive compressive strength (vertical loads) but is much lower in tensile strength (twisting or stretching) unless reinforced. The tensile strength of masonry walls can be strengthened by thickening the wall, or by building masonry *piers* (vertical columns or ribs) at intervals. Where practical, steel reinforcements can be added.

3 - Veneer masonry :

A masonry veneer wall consists of masonry units, usually clay-based bricks, installed on one or both sides of a structurally independent wall usually constructed of wood or masonry. In this context the brick masonry is primarily decorative, not structural. The brick veneer is generally connected to the structural wall by brick ties (metal strips that are attached to the structural wall, as well as the mortar joints of the brick veneer). There is typically an air gap between the brick veneer and the structural wall. As clay-based brick is usually not completely waterproof, the structural wall will often have a water-resistant surface (usually tar paper) and weep holes can be left at the base of the brick veneer to drain moisture that accumulates inside the air gap. Concrete blocks, real and cultured stones, and veneer adobe are sometimes used in a very similar veneer fashion.

Most insulated buildings that utilize concrete block, brick, adobe, stone, veneers or some combination thereof feature interior insulation in the form of fiberglass batts between wooden wall studs or in the form of rigid insulation boards covered with plaster or drywall. In most climates this insulation is much more effective on the exterior of the wall, allowing the building interior to take advantage of the aforementioned thermal mass of the masonry. This technique does, however, require some sort of weather-resistant exterior surface over the insulation and, consequently, is generally more expensive.

4 - Dry set masonry :

Dry set masonry supports a rustic log bridge, where it provides a well-drained support for the log (this will increase its service life).

The strength of a masonry wall is not entirely dependent on the bond between the building material and the mortar; the friction between the interlocking blocks of masonry is often strong enough to provide a great deal of strength on its own. The blocks sometimes have grooves or other surface features added to enhance this interlocking, and some *dry set* masonry structures forgo mortar altogether.

5 - Solid masonry :

Solid masonry, without steel reinforcement, tends to have very limited applications in modern wall construction. Such walls can, however, be quite economical and suitable in some applications; solid unreinforced masonry walls tend to be low and thick as a consequence of their lack of tensile strength.

6 - Brick :

Solid brick work is made of two or more layers of bricks with the units running horizontally (called *stretcher* bricks) bound together with bricks running transverse to the wall (called "header" bricks). Each row of bricks is known as a course. The pattern of headers and stretchers employed gives rise to different **bonds** such as the common bond (with every sixth course composed of headers), the English bond, and the **Flemish bond** (with alternating stretcher and header bricks present on every course). Bonds can differ in strength and in insulating ability. Vertically staggered bonds tend to be somewhat stronger and less prone to major cracking than a non-staggered bond.

6 - 1 - Uniformity and rusticity :

Masonry repair work done to a brick wall.

The wide selection of brick styles and types generally available in industrialized nations allow much variety in the appearance of the final product. In buildings built during the 1950s-1970s, a high degree of uniformity of brick and accuracy in masonry was typical. In the period since then this style was thought to be too sterile, so attempts were made to emulate older, rougher work. Some brick surfaces are made to look particularly rustic by including *burnt* bricks, which have a darker color or an irregular shape. Others may use antique salvage bricks, or new bricks may be artificially aged by applying various surface treatments, such as tumbling. The attempts at rusticity of the late 20th century have been carried forward by masons specializing in a free, artistic style, where the courses are intentionally *not* straight, instead weaving to form more organic impressions.

6 - 2 - Serpentine masonry :

A crinkle - crackle wall is a brick wall that follows a serpentine path, rather than a straight line. This type of wall is more resistant to toppling than a straight wall; so much so that it may be made of a single thickness of unreinforced brick and so despite its longer length may be more economical than a straight wall.

7 - Concrete block :

Concrete masonry units (CMUs)
or blocks in a basement wall before burial.

Blocks of cinder concrete (*cinder blocks* or *breezeblocks*), ordinary concrete (*concrete blocks*), or hollow tile are generically known as Concrete Masonry Units (CMUs). They usually are much larger than ordinary bricks and so are much faster to lay for a wall of a given size. Furthermore, cinder and concrete blocks typically have much lower water absorption rates than brick. They often are used as the structural core for veneered brick masonry, or are used alone for the walls of factories, garages and other industrial-style buildings where such appearance is acceptable or desirable. Such blocks often receive a stucco surface for decoration. Surface-bonding cement, which contains synthetic fibers for reinforcement, is sometimes used in this application and can impart extra strength to a block wall. Surface-bonding cement is often pre - colored and can be stained or painted thus resulting in a finished stucco - like surface.

The primary structural advantage of concrete blocks in comparison to smaller clay-based bricks is that a CMU wall can be reinforced by filling the block voids with concrete with or without steel rebar. Generally, certain voids are designated for filling and reinforcement, particularly at corners, wall-ends, and openings while other voids are left empty. This increases wall strength and stability more economically than filling and reinforcing all voids. Typically, structures made of CMUs will have the top course of blocks in the walls filled with concrete and tied together with steel reinforcement to form a bond beam. Bond beams are often a requirement of modern building codes and controls. Another type of steel reinforcement, referred to as ladder-reinforcement, can also be embedded in horizontal mortar joints of concrete block walls. The introduction of steel reinforcement generally results in a CMU wall having much greater lateral and tensile strength than unreinforced walls.

CMUs can be manufactured to provide a variety of surface appearances. They can be colored during manufacturing or stained or painted after installation. They can be split as part of the manufacturing process, giving the blocks a rough face replicating the appearance of natural stone, such as brownstone. CMUs may also be scored, ribbed, sandblasted, polished, striated (raked or brushed), include decorative aggregates, be allowed to slump in a controlled fashion during curing, or include several of these techniques in their manufacture to provide a decorative appearance.

"Glazed concrete masonry units are manufactured by bonding a permanent colored facing (typically composed of polyester resins, silica sand and various other chemicals) to a concrete masonry unit, providing a smooth impervious surface " .

Glass block or glass brick are blocks made from glass and provide a translucent to clear vision through the block.

8 - A-jacks :

A-jacks (used in erosion control walls and sea walls) are highly stable, concrete 6 - pronged armor units designed to interlock into a flexible, highly permeable matrix. They can be installed either randomly or in a uniform pattern. They look like giant 3-foot versions of the metal jacks that children play with.

In the uniform placement pattern, each unit is in contact with the six adjacent units, providing high stability. They are patterned after the buckyball model .

9 - Stone work :

- Stone blocks used in masonry can be dressed or rough.
- Stone masonry utilizing dressed stones is known as ashlar masonry, whereas masonry using irregularly shaped stones is known as rubble masonry. Both rubble and ashlar masonry can be laid in coursed rows of even height through the careful selection or cutting of stones, but a great deal of stone masonry is uncoursed.
- Slip form stonemasonry produces a hybrid wall of reinforced concrete with a rubble stone face.
- Natural stone veneers over CMU, cast-in-place, or tilt-up concrete walls are widely used to give the appearance of stone masonry.
- Sometimes river rock of smooth oval-shaped stones is used as a veneer. This type of material is not favored for solid masonry as it requires a great amount of mortar and can lack intrinsic structural strength.
- Manufactured-stone, or cultured stone, veneers are popular alternatives to natural stones.
- Attractive natural stone has become more expensive in many areas and in some areas is practically unavailable.
- Manufactured-stone veneers are typically made from concrete.
- Natural stones from quarries around the world are sampled and recreated using molds, aggregate, and colorfast pigments.
- To the casual observer there may be no visual difference between veneers of natural and manufactured stone.

10 - Gabions :

Gabions are rectangular wire baskets, usually of zinc-protected steel (galvanized steel) that are filled with fractured stone of medium size. These will act as a single unit and are stacked with setbacks to form a revetment or retaining wall. They have the advantage of being both well drained and flexible, and so resistant to flood, water flow from above, frost damage, and soil flow. Their expected useful life is only as long as the wire they are composed of and if used in severe climates (such as shore - side in a salt water environment) must be made of appropriate corrosion-resistant wire.

11 - Bagged concrete :

A low grade concrete may be placed in woven plastic sacks similar to that used for sandbags and then emplaced. The sacks are then watered and the emplacement then becomes a series of artificial stones that conform to one another and to adjacent soil and structures. This conformation makes them resistant to displacement. The sack becomes non-functional and eventually disintegrates. This type of masonry is frequently used to protect the entrances and exits of water conduits where a road passes over a stream or dry wash. It is also used to protect stream banks from erosion, especially where a road passes close by.

12 - Masonry training :

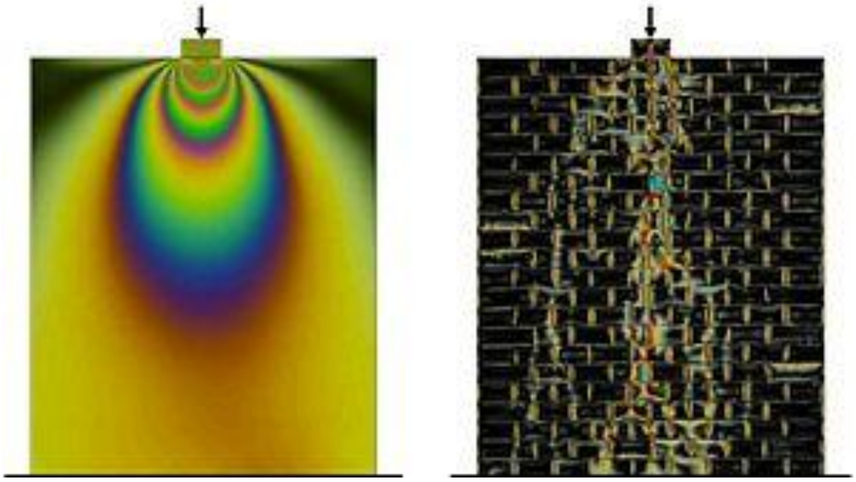
Stonemasonry is one of the oldest professions in the history of construction. As such it is regarded as a traditional skill, and is one which is in heavy demand.

Prospective stonemasons will learn the profession through apprenticeships or a traineeship that will last 3 to 4 years. There are City & Guilds stonemasonry courses available that combine college based theory training with practical learning.

13 - Passive fire protection (PFP) :

Masonry walls have an endothermic effect of its hydrates, as in chemically bound water, as well as unbound moisture from the concrete block, as well as the poured concrete if the hollow cores inside the blocks are filled.

14 - Mechanical modeling of masonry structures :



A comparison (using transmission photo elasticity) between the stress diffusion in an elastic body (on the left) and a model of masonry (on the right). A highly localized stress percolation is visible on the right.

From the point of view of material modelng, masonry is a special material of extreme mechanical properties (with a very high ratio between strength in compression and in tension), so that the applied loads do not diffuse as they do in elastic bodies, but tend to percolate along lines of high stiffness .

Mayenite

Mayenite (after Mayen , Germany) , Ca_{12} Al_{14} O_{33} , is a rare calcium aluminium oxide mineral of cubic symmetry.

It was originally reported from Eifel volcanic complex (Germany) in 1964 . It is also found at pyro metamorphic sites such as in some burned coal dumps .

It occurs in thermally altered lime stone xenoliths within basalts in Mayan , Germany and Klöch , Styria , Austria . It occurs with calcite , ettringite, wollastonite, larnite, brown millerite , gehlenite , diopside , pyrrhotite , grossular , spinel , afwillite , jennite , portlandite, jasmundite , melilite , kalsilite and corundum in the limestone xenoliths.

The formula can be written as [Ca_{12} Al_{14} O_{32}] O , which refers to the unique feature: anion diffusion process.

Mayenite is also found as calcium aluminate in cement where its formula is also written as 12 Ca O · 7 Al_2 O_3 , or C_{12} A_7 in the cement chemist notation.

Category	Oxide mineral
Chemical Formula	Ca_{12} Al_{14} O_{33}
Crystal symmetry	Isometric hex tetrahedral
Unit cell	a = 11.98 Å; Z = 2
Color	Colorless
Crystal habit	Microscopic anhedral grains
Crystal system	Cubic
Streak	White

Diaphaneity	Transparent
Specific gravity	2.85
Optical properties	Isotropic
Refractive index	n = 1.614 – 1.643
Alters to	Absorbs water on exposure

Meta Kaolin

Contents

1 – Introduction :

Meta kaolin is a dehydroxylated form of the clay mineral kaolinite.

Rocks that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The particle size of metakaolin is smaller than cement particles, but not as fine as silica fume.

2 - Forming meta kaolin :

Between 100–200 °C, clay minerals lose most of their adsorbed water. Between 500–800 °C kaolinite becomes calcined by losing water through dehydroxilization . The dehydroxilization of kaolin to meta kaolin is an endothermic process due to the large amount of energy required to remove the chemically bonded hydroxyl ions. Above this temperature range, kaolinite becomes meta kaolin, with a two - dimensional order in crystal structure. In order to produce a pozzolan (supplementary cementing material) nearly complete dehydroxilization must be reached without overheating, i.e., thoroughly roasted but not burnt. This produces an amorphous, highly pozzolanic state, whereas overheating can cause sintering, to form the dead burnt, nonreactive refractory, called mullite.

3 - High - reactivity meta kaolin :

High-reactivity meta kaolin (HRM) is a highly processed reactive alumino silicate pozzolan, a finely- divided material that reacts with slaked lime at ordinary temperature and in the presence of moisture to form a strong slow-hardening cement. It is formed by calcining purified kaolinite, generally between 650–700 °C in an externally fired rotary kiln. It is also reported that HRM is responsible for acceleration in the hydration of ordinary portland cement (OPC), and its major impact is seen within 24 hours. It also reduces the deterioration of concrete by Alkali Silica Reaction (ASR) , particularly useful when using recycled crushed glass or glass fines as aggregate . The amount of slaked lime that can be bound by meta kaolin is measured by the modified Chapelle test.

4 - Concrete application :

Considered to have twice the reactivity of most other pozzolans, metakaolin is a valuable admixture for concrete/cement applications. Replacing portland cement with 8 – 20 % (by weight) meta kaolin produces a concrete mix, which exhibits favorable engineering properties, including: the filler effect, the acceleration of OPC hydration, and the pozzolanic reaction. The filler effect is immediate, while the effect of pozzolanic reaction occurs between 7 to 14 days .

5 - Advantages :

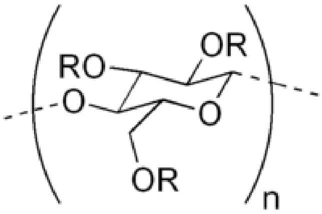
- Increased compressive and flexural strengths
- Reduced permeability (including chloride permeability)
- Reduced potential for efflorescence, which occurs when calcium is transported by water to the surface where it combines with carbon dioxide from the atmosphere to make calcium carbonate, which precipitates on the surface as a white residue.
- Increased resistance to chemical attack
- Increased durability
- Reduced effects of alkali - silica reactivity (ASR)

- Enhanced workability and finishing of concrete
- Reduced shrinkage, due to "particle packing" making concrete denser
- Improved color by lightening the color of concrete making it possible to tint lighter integral color.

6 - Uses :

- High performance, high strength, and lightweight concrete
- Precast and poured - mold concrete
- Fiber cement and ferro cement products
- Glass fiber reinforced concrete
- Countertops, art sculptures
- Mortar and stucco

Methyl Cellulose



R = H or CH_3

Other Names : Cellulose methyl ether ; methylated cellulose ; methyl Cellulose ; E461	
Molecular formula	variable
Molar mass	variable

Contents

1 – Introduction :

Methyl Cellulose is a chemical compound derived from cellulose. It is a hydrophilic white powder in pure form and dissolves in cold (but not in hot) water, forming a clear viscous solution or gel. It is sold under a variety of trade names and is used as a thickener and emulsifier in various food and cosmetic products, and also as a treatment of constipation. Like cellulose, it is not digestible, not toxic, and not an allergen.

2 - Chemistry :

Methyl cellulose does not occur naturally and is synthetically produced by heating cellulose with caustic solution (e.g. a solution of sodium hydroxide) and treating it with methyl chloride . In the substitution reaction that follows, the hydroxyl residues (- OH functional groups) are replaced by methoxide (- OCH_3 groups) .

Different kinds of methyl cellulose can be prepared depending on the number of hydroxyl groups substituted. Cellulose is a polymer consisting of numerous linked glucose molecules, each of which exposes three hydroxyl groups. The *Degree of Substitution* (DS) of a given form of methyl cellulose is defined as the average number of substituted hydroxyl groups per glucose. The theoretical maximum is thus a DS of 3.0, however more typical values are 1.3 – 2.6.

Different methyl cellulose preparations can also differ in the average length of their polymer backbones.

3 - Solubility and temperature :

Methyl cellulose has a lower critical solution temperature (LCST) between 40°C and 50°C. At temperatures below the LCST, it is readily soluble in water; above the LCST, it is not soluble, which has a paradoxical effect that heating a saturated solution of methyl cellulose will turn it solid , because methyl cellulose will precipitate out . The temperature at which this occurs depends on DS - value, with higher DS - values giving lower solubility and lower precipitation temperatures because the polar hydroxyl groups are masked.

Preparing a solution of methyl cellulose with cold water is difficult how ever : as the powder comes into contact with water, a gluey layer forms around it, and the inside remains dry. A better way is to first mix the powder with hot water, so that the methyl cellulose particles are well dispersed in the water, and cool down this dispersion while stirring, leading to the dissolution of those particles.

4 - Uses :

Methyl cellulose has an extremely wide range of uses, of which several are described below.

4 – 1 - Consumer products :

4 - 1 - 1 - Thickener and emulsifier :

Methyl cellulose is often added to hair shampoos, tooth pastes and liquid soaps, to generate their characteristic thick consistency. This is also done for foods, for example ice cream or croquette. Methyl cellulose is also an important emulsifier, preventing the separation of two mixed liquids.

The E number of methyl cellulose as food additive is E461.

Methyl cellulose (AKS Methocel produced by Dow Chemical) is also used as paint rheological modifier to prevent paint sagging problem.

4 - 1 - 2 - Treatment of constipation :

When eaten , methyl cellulose is not absorbed by the intestines but passes through the digestive tract undisturbed . It attracts large amounts of water into the colon , producing a softer and bulkier stool. It is used to treat constipation, diverticulosis , hemorrhoids and irritable bowel syndrome. It should be taken with sufficient amounts of fluid to prevent dehydration.

Because it absorbs water and potentially toxic materials and increases viscosity, it can also be used to treat diarrhea.

A well - known trade name of methyl cellulose when used as a drug is **Citrucel** by GlaxoSmithKline, but generic versions are also widely available.

4 - 1 - 3 – Lubricant :

Methyl cellulose is used as a variable viscosity personal lubricant; it is the main ingredient in K-Y Jelly.

4 - 1 - 4 – Clinical :

The lubricating property of methyl cellulose is of particular benefit in the treatment of dry eyes (Keratoconjunctivitis Sicca) . Dry eyes are common in the elderly and is often associated with rheumatoid arthritis. The lacrimal gland and the accessory conjunctival glands produce fewer tears. Methyl cellulose may be used as a tear substitute.

4 - 1 - 5 - Artificial tears and saliva :

Solutions containing methyl cellulose or similar cellulose derivatives are used as substitute for tears or saliva if the natural production of these fluids is disturbed.

4 - 1 - 6 - Nutritional supplement capsules :

Methyl cellulose is used in the manufacture of capsules in nutritional supplements, its edible and nontoxic properties provide a vegetarian alternative to the use of gelatin.

4 - 1 - 7 - Advanced cookery :

Methyl cellulose, as a gel, has the unique property of setting when hot and melting when cold. This technique is currently being developed at the University of Nottingham ˙

4 - 2 - Construction materials :

Methyl cellulose finds a major application as a performance additive in construction materials. It is added to mortar dry mixes to improve the mortar's properties such as workability, open and adjustment time, water retention, viscosity, adhesion to surfaces etc. Construction grade methyl cellulose is to not to be identified with food and pharmaceutical grade methyl cellulose and hydroxy propyl methyl cellulose, since it may be cross-linked with glyoxal for easy dispersion in water.

The construction materials can be cement based or gypsum based. Notable examples of dry mixture mortars which utilize methyl cellulose include: tile adhesives, EIFS, insulating plasters, hand-trowed and machine sprayed plaster, stucco, self-leveling flooring, extruded cement panels, skim coats, joint & crack fillers, and tile grouts. Typical usage is about 0.2 % ~ 0.5 % of total dry powder weight for dry mixture

Derivatives of methyl cellulose, which improve upon the performance characteristics, include hydroxy propyl methyl cellulose (HPMC) and hydroxy ethyl methyl cellulose (HEMC). These derivatives typically improve the characteristics such as water retention, vertical surface slip - resistance, open time, etc.

Manufacturers of such construction grade methyl cellulose include SE Tylose , Dowwolff , Shin - Etsu, Samsung Fine Chemicals , Hercules Aqualon, and various smaller manufacturers.

4 - 2 - 1 - Glue and binder :

Methyl cellulose can be employed as a mild glue which can be washed away with water. This may be used in the fixation of delicate pieces of art as well as in book conservation to loosen and clean off old glue from spines and book boards.

Methyl cellulose is the main ingredient in many wall paper pastes. It is also used as a binder in pastel crayons and also as a binder in medications.

4 - 2 - 2 - Paper and textile sizing :

Methyl cellulose is used as sizing in the production of papers and textiles as it protects the fibers from absorbing water or oil.

4 - 3 - Cell culture / virology :

Methyl cellulose is also used in cell culture to study viral replication. It is dissolved in the same nutrient containing medium in which cells are normally grown. A single layer of cells are grown on a flat surface, then infected with a virus for a short time. The strength of the viral sample used will determine how many cells get infected during this time. The thick methyl cellulose medium is then added on top of the cells in place of normal liquid medium. As the viruses replicate in the infected cells, they are able to spread between cells whose membrances touch each other, but are trapped when they enter the methyl cellulose. Only cells closely neighboring an infected cell will become infected and die. This leaves small regions of dead cells called plaques in a larger background of living uninfected cells. The number of plaques formed is determined by the strength of the original sample.

4 - 3 - 1 - Bacterial motility inhibitor :

Aqueous methyl cellulose solutions have been used to slow bacterial cell motility for closer inspection. Changing the amount of methyl cellulose in solution allows one to adjust the solution's viscosity.

4 - 3 - 2 - Stem cell differentiation :

Methyl cellulose is used in the most common approaches to quantify multiple or single lineage - committed hematopoietic progenitors, called colony - forming cells (CFCs) or colony - forming units (CFUs) , in combination with culture supplements that promote their proliferation and differentiation, and allow the clonal progeny of a single progenitor cell to stay together and thus form a colony of more mature cells. MethoCult and ColonyGEL are examples of such methylcellulose-based media.

4 - 4 - Chemistry :

Methyl cellulose is used as a buffer additive in capillary electro phoresis to control electro osmotic flow for improved separations.

4 - 5 - Special effects :

The slimy, gooey appearance of an appropriate preparation of methyl cellulose with water, in addition to its nontoxic, nonallergenic, and edible properties, makes it popular for use in special effects for motion pictures and television wherever vile slimes must be simulated. In the film *Ghostbusters*, for example, the gooey substance the supernatural entities used to “slime” the Ghostbusters was mostly a thick water solution of methyl cellulose. The *Aliens* ooze and drip a great deal of methyl cellulose — especially the queen.

Methyl cellulose has been used to safely simulate molten materials, as well. In several of the Terminator films, it was back-lit with colored gels and films to reproduce the heated glow of iron in the large pouring ladles used to transport the metal from the smelting ovens to the various molds and forms. Methyl cellulose was also a stand - in for the lava flows on the volcanic surface of Mustafar , in Star Wars Episode III :Revenge of the Sith.

Mineral Hydration

Mineral hydration is an inorganic chemical reaction where water is added to the crystal structure of a mineral, usually creating a new mineral, usually called a *hydrate*.

In geological terms, the process of mineral hydration is known as *retrograde alteration* and is a process occurring in retrograde metamorphism. It commonly accompanies metasomatism and is often a feature of wall rock alteration around ore bodies. Hydration of minerals occurs generally in concert with hydrothermal circulation which may be driven by tectonic or igneous activity.

Mineral hydration is also a process in the regolith that results in conversion of silicate minerals into clay minerals.

There are two main ways in which minerals hydrate. One is conversion of an oxide to a double hydroxide, as with the hydration of calcium oxide – Ca O - to calcium hydroxide – $Ca(OH)_2$, the other is with the incorporation of water molecules directly into the crystalline structure of a new mineral, as in the hydration of feldspars to clay minerals, garnet to chlorite or kyanite to muscovite.

Some mineral structures, for example, montmorillonite, are capable of including a variable amount of water without significant change to the mineral structure.

Hydration is the mechanism by which Portland cement develops strength.

Mo - Sai

Mo - Sai is a method of producing precast concrete cladding panels. It was patented by John Joseph Earley in 1940. The Mo-Sai institute later refined Earley's method and became the leader in exposed aggregate concrete. The Mo-Sai Institute, an organization of precast concrete manufacturers, adhered to the Mo-Sai method of producing the exposed aggregate precast concrete panels.

David Taylor Model Basin, 1946

A pivotal development in this technique occurred in 1938, when the administration buildings at the David Taylor Model Basin were built with panels used as permanent forms for cast-in-place walls. This was the first use of the Mo - Sai manufacturing technique produced in collaboration with the Dextrone Company of New Haven, Connecticut. Working from this background, the Dextrone Company refined and obtained patents and copyrights in 1940 for the methods under which the Mo-Sai Associates, later known as Mo-Sai Institute Inc. The Mo-Sai Institute grew to include a number of licensed manufacturing firms throughout the United States.

Buildings featuring Mo-Sai panels include the Columbine Building in Colorado Springs (1960), Prudential Building in Toronto, Canada (1960), Court House Square in Denver, Colorado (1960), Los Angeles Temple (1956), Equitable Center in Portland, Oregon (1964), and the PanAm Building in New York City (1962).

Mono Calcium Aluminate

1 – Introduction :

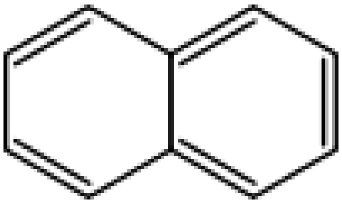
Mono calcium aluminate ($CaAl_2O_4$) is one of the series of calcium aluminates . It does not occur in nature, but is important in the composition of calcium aluminate cements.

IUPAC Name : Mono Calcium Aluminate	
Molecular Formula	$Ca\,Al_2\,O_4$
Molar Mass	158 g / mol

2 - Properties :

Mono calcium aluminate is formed when the appropriate proportions of calcium carbonate and aluminium oxide are heated together until the mixture melts. It melts incongruently at 1390 °C. The crystal is monoclinic and pseudo hexagonal , and has density 2945 $kg.m^{-3}$. In calcium aluminate cements, it exists as a solid solution in which the amount of minor elements depends upon the bulk composition of the cement. A typical composition is $Ca_{0.93}\,Al_{1.94}Fe_{0.11}\,Si_{0.02}\,O_4$. It reacts rapidly with water, forming the meta stable hydrate $CaO \cdot Al_2O_3 \cdot 10\,H_2O$, or a mixture of $2CaO \cdot Al_2O_3 \cdot 8H_2O$, $3CaO \cdot Al_2O_3 \cdot 6H_2O$ and $Al(OH)_3$ gel. These reactions form the first stage of strength development in calcium aluminate cements.

Naphthalene



Contents

1 – Introduction :

Naphthalene is an organic compound with formula $C_{10}H_8$. It is the simplest polycyclic aromatic hydrocarbon, and is a white crystalline solid with a characteristic odor that is detectable at concentrations as low as 0.08 ppm by mass . As an aromatic hydrocarbon, naphthalene's structure consists of a fused pair of benzene rings. It is best known as the main ingredient of traditional mothballs .

IUPAC Name : Bicycle [4.4.0] deca -1,3,5,7,9 - pentene
Systematic Name : Bicyclo [4.4.0] deca - 1,3,5,7,9-pentene Bicyclo [4.4.0] deca - 2,4,6,8,10-pentene

Other Names : white tar , mothballs , naphthalin , moth flakes , camphor tar , tar camphor , naphthaline , antimite , albocarbon	
Molecular formula	$C_{10}H_8$
Molar mass	128 g mol^{-1}
Appearance	White solid crystals / flakes , strong odor of coal tar
Density	1.14 g / cm^3
Melting point	80.26 °C
Boiling point	218 °C
Solubility in water	Approximately 30 mg/L
Main hazards	Flammable , sensitizer , possible carcinogen . Dust can form explosive mixtures with air
Flash point	79 – 87 °C
Auto ignition temperature	525 °C

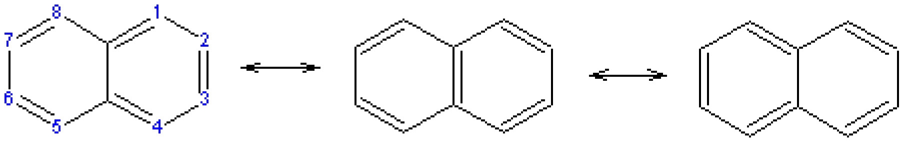
2 - History :

In 1819–1820, at least two chemists reported a white solid with a pungent odor derived from the distillation of coal tar. In 1821, John Kidd described many of this substance's properties and the means of its production, and proposed the name *naphthaline*, as it had been derived from a kind of naphtha (a broad term encompassing any volatile, flammable liquid hydrocarbon mixture, including coal tar).[2] Naphthalene's chemical formula was determined by Michael Faraday in 1826. The structure of two fused benzene rings was proposed by Emil Erlenmeyer in 1866,[3] and confirmed by Carl Gräbe three years later.

3 - Structure and reactivity :

A naphthalene molecule can be viewed as the fusion of a pair of benzene rings. (In organic chemistry, rings are *fused* if they share two or more atoms.) As such, naphthalene is classified as a beanozenoid polycyclic aromatic hydrocarbon (PAH). There are two sets of equivalent hydrogen atoms: the *alpha* positions are positions 1, 4, 5, and 8 on the drawing below, and the *beta* positions are positions 2, 3, 6, and 7.

Unlike benzene, the carbon-carbon bonds in naphthalene are not of the same length. The bonds C1– C2 , C3 – C4 , C5– C6 and C7 – C8 are about 1.36 Å (136 pm) in length, whereas the other carbon-carbon bonds are about 1.42 Å (142 pm) long. This difference, which was established by x-ray diffraction ' is consistent with the valence bond model of bonding in naphthalene that involves three resonance structures (as shown below); whereas the bonds C1– C2 , C3 – C4 , C5 – C6 and C7 – C8 are double in *two* of the three structures, the others are double in only one.



Like benzene, naphthalene can undergo electrophilic aromatic substitution. For many electrophilic aromatic substitution reactions, naphthalene reacts under milder conditions than does benzene. For example, whereas both benzene and naphthalene react with chlorine in the presence of a ferric chloride or aluminium chloride catalyst, naphthalene and chlorine can react to form 1-chloronaphthalene even without a catalyst. Likewise, whereas both benzene and naphthalene can be alkylated using Friedel - Crafts reactions, naphthalene can also be alkylated by reaction with alkenes or alcohols, with sulfuric or phosphoric acid as the catalyst.

3 – 1 - Substituted derivatives :

Two isomers are possible for mono - substituted naphthalenes, corresponding to substitution at an alpha or beta position. Usually, electrophiles attack at the alpha position. The selectivity for alpha over beta substitution can be rationalized in terms of the resonance structures of the intermediate: for the alpha substitution intermediate, seven resonance structures can be drawn, of which four preserve an aromatic ring. For beta substitution, the intermediate has only six resonance structures, and only two of these are aromatic. Sulfonation, how ever, gives a mixture of the "alpha" product 1-naphthalene sulfonic acid and the "beta" product 2- naphthalene sulfonic acid, with the ratio dependent on reaction conditions . The 1-isomer forms predominantly at 25 °C , and the 2- isomer at 160 °C.

Naphthalene can be hydrogenated under high pressure in the presence metal catalysts to give 1,2,3,4-tetra hydro naphthalene or tetralin ($C_{10}H_{12}$). Further hydrogenation yields deca hydro naphthalene or decalin ($C_{10}H_{18}$). Oxidation with chromate or permanganate, or catalytic oxidation with O_2 and a vanadium catalyst, gives phthalic acid.

4 - Production :

Most naphthalene is derived from coal tar. From the 1960s until the 1990s, significant amounts of naphthalene were also produced from heavy petroleum fractions during petroleum refining, but today petroleum - derived naphthalene represents only a minor component of naphthalene production.

Naphthalene is the most abundant single component of coal tar. Although the composition of coal tar varies with the coal from which it is produced, typical coal tar is about 10 % naphthalene by weight. In industrial practice, distillation of coal tar yields an oil containing about 50 % naphthalene, along with a variety of other aromatic compounds. This oil, after being washed with aqueous sodium hydroxide to remove acidic components (chiefly various phenols), and with sulfuric acid to remove basic components, undergoes fractional distillation to isolate naphthalene. The crude naphthalene resulting from this process is about 95 % naphthalene by weight. The chief impurities are the sulfur - containing aromatic compound benzothiophene (< 2 %) , indane (0.2 %) , indene (< 2 %) , and methyl naphthalene (< 2 %) . Petroleum - derived naphthalene is usually purer than that derived from coal tar. Where required, crude naphthalene can be further purified by recrystallization from any of a variety of solvents, resulting in 99 % naphthalene by weight, referred to as 80 °C (melting point). Approximately 1M tons are produced annually.

5 - Natural occurrence :

Trace amounts of naphthalene are produced by magnolias and specific types of deer, as well as the Formosan subterranean termite, possibly produced by the termite as a repellant against "ants, poisonous fungi and nematode worms " . Some strains of the endophytic fungus *Muscodor albus* produce naphthalene among a range of volatile organic compounds, while *Muscodor vitigenus* produces naphthalene almost exclusively.

Naphthalene has been found in meteorites. It has also been discovered in the interstellar medium in the direction of the star Cernis 52 in the constellation Perseus.

5 – 1 - Gaseous naphthalene :

Recent research at the University of Georgia, led by Dr. Michael Duncan, has shown that protonated cations of naphthalene are the source of part of the spectrum of the Unidentified Interstellar Bands (UIBs). The gaseous naphthalene found in space is different from crystalline form typically used in mothballs in that it has an additional hydrogen atom , with the empirical formula : $C_{10}H+9$. The UIBs have been observed by astronomers, and until recently, there has been no solid evidence identifying the compounds responsible for them. The research has recently been publicized as "Mothballs in Space " .

6 - Uses :

6 – 1 - As a chemical intermediate :

Naphthalene is used mainly as a precursor to other chemicals. The single largest use of naphthalene is the industrial production of phthalic anhydride, although more phthalic anhydride is made from o-xylene. Other naphthalene - derived chemicals include alkyl naphthalene sulfonate surfactants, and the insecticide 1-naphthyl-N-methyl carbamate (*carbaryl*). Naphthalenes substituted with combinations of strongly electron-donating functional groups, such as alcohols and amines, and strongly electron-withdrawing groups, especially sulfonic acids, are intermediates in the preparation of many synthetic dyes. The hydrogenated naphthalenes tetra hydro naphthalene (tetralin) and deca hydro naphthalene (decalin) are used as low-volatility solvents. Naphthalene is also used in the synthesis of 2-naphthol, a precursor for various dyestuffs, pigments, rubber processing chemicals and other miscellaneous chemicals and pharmaceuticals.

Naphthalene sulfonic acids are used in the manufacture of naphthalene sulfonate polymer plasticizers (dispersants), which are used to produce concrete and plasterboard (wall board or drywall). They are also used as dispersants in synthetic and natural rubbers, and as tanning agents (syntans) in leather industries, agricultural formulations (dispersants for pesticides), dyes and as a dispersant in lead – acid battery plates.

Naphthalene sulfonate polymers are produced by reacting naphthalene with sulfuric acid and then polymerizing with formaldehyde, followed by neutralization with sodium hydroxide or calcium hydroxide. These products are commercially sold in solution (water) or dry powder form.

- Sulfonation Step (sulfuric acid plus naphthalene):

$$H_2SO_4 + C_{10}H_8 \rightarrow C_{10}H_7\text{-}SO_3H + H_2O$$

- Polymerization Step (naphthalene sulfonic acid plus formaldehyde):

$$C_{10}H_7\text{-}SO_3H + CH_2\text{-}O \rightarrow C_{10}H_7\text{-}SO_3H\text{-}(C_{10}H_7\text{-}SO_3H)_n + H_2SO_4$$

- Neutralization Step (naphthalene sulfonic acid condensate plus sodium hydroxide):

$$C_{10}H_7\text{-}SO_3H\text{-}(C_{10}H_7\text{-}SO_3H)_n + Na\,OH \rightarrow C_{10}H_7\text{-}SO_3Na\text{-}(C_{10}H_7\text{-}SO_3Na)_n + H_2O + Na_2SO_4$$

6 – 2 - Wetting agent and surfactant :

Alkyl naphthalene sulfonates (ANS) are used in many industrial applications as non detergent wetting agents that effectively disperse colloidal systems in aqueous media. The major commercial applications are in the agricultural chemical industry, which uses ANS for wet able powder and wet able granular (dry-flow able) formulations, and the textile and fabric industry, which utilizes the wetting and defoaming properties of ANS for bleaching and dyeing operations.

6 – 3 - As a fumigant :

The most familiar use of naphthalene is as a household fumigant, such as in moth balls although 1,4- dichloro benzene (or *p*-dichloro benzene) is now more widely used. In a sealed container containing naphthalene pellets, naphthalene vapors build up to levels toxic to both the adult and larval forms of many moths that attack textiles. Other fumigant uses of naphthalene include use in soil as a fumigant pesticide, in attic spaces to repel animals and insects, and in museum storage - drawers and cupboards to protect the contents from attack by insect pests.

6 – 4 - Niche applications :

It is used in pyrotechnic special effects such as the generation of black smoke and simulated explosions. In the past, naphthalene was administered orally to kill parasitic worms in live stock. Naphthalene and its alkyl homologs are the major constituents of creosote. Naphthalene is used in engineering to study heat transfer using mass sublimation.

7 - Health effects :

Exposure to large amounts of naphthalene may damage or destroy red blood cells. Humans, in particular children, have developed this condition, known as hemolytic anemia, after ingesting mothballs or deodorant blocks containing naphthalene. Symptoms include fatigue, lack of appetite, restlessness, and pale skin. Exposure to large amounts of naphthalene may cause confusion, nausea, vomiting , diarrhea , blood in the urine, and jaundice (yellow coloration of the skin) .

When the U.S. National Toxicology Program exposed male and female rats and mice to naphthalene vapors on weekdays for two years,[10] male and female rats exhibited evidence of carcinogenic activity based on increased incidences of adenoma and neuroblastoma of the nose, female mice exhibited some evidence of carcinogenic activity based on increased incidences of alveolar and bronchiolar adenomas of the lung, and male mice exhibited no evidence of carcinogenic activity.

The International Agency for Research on Cancer (IARC) classifies naphthalene as possibly carcinogenic to humans and animals (Group 2B). The IARC also points out that acute exposure causes cataracts in humans, rats, rabbits, and mice; and that hemolytic anemia, described above, can occur in children and infants after oral or inhalation exposure or after maternal exposure during pregnancy. Under California's Proposition 65, naphthalene is listed as "known to the State to cause cancer".

Over 400 million people have an inherited condition called glucose-6-phosphate dehydrogenase deficiency. Exposure to naphthalene is more harmful for these people and may cause hemolytic anemia at lower doses .

In China, the use of naphthalene in mothballs is forbidden.[13] It is due partly to the health effects as well as the wide use of natural camphor as replacement. However naphthalene is widely used in moth balls and currently sold in China

Non - Shrink Grout

Contents

1 - Introduction :

Non - shrink grout is a hydraulic cement grout that produces a big volume that, when hardened under stipulated test conditions, is greater than or equal to the original installed volume; often used as a transfer medium between load - bearing members.

2 - Testing :

Test standards used to designate a grout as *non-shrink* include, but are not limited to :

- C1090 - 01(2005) e1 Standard Test Method for Measuring Changes in Height of Cylindrical Specimens of Hydraulic - Cement Grout

3 - Typical characteristics :

- Often sets rapidly
- Usually a pre-mix product that needs only to be mixed with water
- Includes ingredients to compensate against cement stone shrinkage
- Use of shrinkage-compensating ingredients can result in volume increase over time.

4 - Typical cementitious materials caveats :

Despite the use of expanding or shrinkage - compensating ingredients, users are ordinarily cautioned to avoid environments detrimental to the forming of cement stone. These include but are not limited to the following :

- Avoid high wind across the curing surface.
- Avoid high temperatures during the cure.
- Avoid common cement poisons, such as sulphates, acids, etc.

Failure to follow these precautions can adversely affect the quality of all cementitious products.

Noxer Block

1 – Introduction :

Noxer blocks are concrete pavers that feature a 5-7 mm thick coating of titanium dioxide (TiO_2) atop a cement mortar layer. Titanium dioxide is a heterogeneous photo catalyst that uses sun light to absorb and render oxides of nitrogen (NO and NO_2) harmless by converting them to nitrate ions (NO_3^-), which are then either washed away by rain or soaked into the concrete to form stable compounds.

2 – Mechanism :

When titanium dioxide is exposed to ultraviolet radiation from sun light , it absorbs the radiation and electron excitation occurs. The following reactions then occur on the surface of the titanium dioxide crystals :

Photolysis of water : $H_2O \rightarrow H^+ + OH$ (hydroxyl radical) + e^-

$O_2 + e^- \rightarrow O_2^-$ (a superoxide ion)

The over all reaction is therefore:

$$H_2O + O_2 \rightarrow H^+ + O_2^- + OH$$

The hydroxyl radical is a powerful oxidizing agent and can oxidize nitrogen dioxide to nitrate ions:

$$NO_2 + OH \rightarrow H^+ + NO_3^-$$

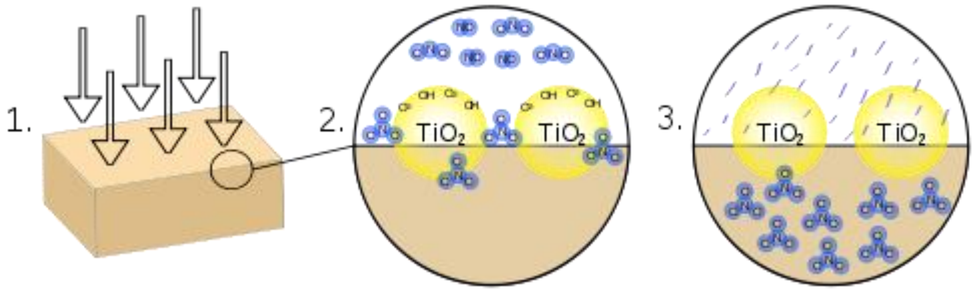
The superoxide ion is also able to form nitrate ions from nitrogen monoxide :

$$NO + O_2^- \rightarrow NO_3^-$$

The oxidation of NO_x to nitrate ions occurs very slowly under normal atmospheric conditions because of the low concentrations of the reactions. The photochemical oxidation with the aid of titanium dioxide is much faster because of the energy absorbed by the coating on the block and also because the reactants are held together on the surface of the block. The reaction using titanium dioxide shows a greater oxidizing power than most other metal-based catalysts.

Noxer blocks have replaced ordinary paving in around 30 towns in Japan, originally having been tested in Osaka in 1997 and can also be found under foot in the City of Westminster (London).

The noxer blocks aim to reduce these pollution levels and therefore lower the amount of photochemical smog.



1. Ultraviolet radiation is absorbed by the titanium dioxide, which causes the photolysis of water into superoxide ions and hydroxyl radicals.
2. Nitrogen oxides react with the superoxide ions and the hydroxyl radicals to form nitrate ions.
3. The nitrate ions are absorbed into the block and form stable compounds.

Opus Africanum

Opus Africanum used in Dougga's Capitol.

Opus Africanum is a form of ashlar masonry used in Carthaginian and ancient Roman architecture, characterized by pillars of vertical blocks of stone alternating with horizontal blocks, filled in with smaller blocks in between.

Its name derives from the Roman province of Africa, and is common in North Africa, but also found in Sicily and Southern Italy.

Opus Incertum

Layers of opus incertum on the left side of the Temple of Iovis Anxur in Terracina, Italy.

Opus incertum was an ancient Roman construction technique, using irregular shaped and random placed uncut stones or fist-sized tuff blocks inserted in a core of *Opus caementicium*.

Initially it consisted of more careful placement of the *coementa* (rock fragments and small stones mixed with concrete), making the external surface as plain as possible. Later the external surface became further plain by reducing usage of concrete and choosing more regular small stones. When the use of concrete between stones is particularly reduced, it is defined *opus (quasi) reticulatum*.

Used from the beginning of the 2nd century BC until the mid-1st century BC, it was later largely superseded by *Opus reticulatum*.

Opus latericium

Example of opus latericium on a tomb of the ancient Appian Way in Rome.

Opus latericium (Latin for "brick work") is an ancient Roman form of construction in which coarse-laid brickwork is used to face a core of *opus caementicium*.

Opus latericium was the dominant form of wall construction in the imperial era.[1]

Opus Mixtum

Example of Opus mixtum in the Brest Castle, France.

xample of Opus mixtum comprising Opus reticulatum edged with Opus latericium in the Roman theatre, Naples, Italy.

Opus mixtum (Latin: "mixed work"), or ***Opus vagecum*** and ***Opus compositum***, was an ancient Roman construction technique. It can consist in a mix of *opus reticulatum* and at the angles and the sides of *opus latericium*.

It can also consist of *opus vittatum* and *opus testaceum*.

Opus mixtum was used in particular during the age of Emperor Hadrian (2nd century AD).

Opus Quadratum

Contents

1 – Introduction:

Opus Quadratum is an ancient Roman construction technique, in which squared blocks of stone of the same height were set in parallel courses, often without the use of mortar.

2 – Technique :

This technique was used by the Romans from about the 6th century BC and over time, the precision and accuracy of the block cutting improved. The technique continued to be used throughout the age of the Roman Empire, even after the introduction of mortar, and was often used in addition to other techniques. The type of stone, the size of the blocks, and the way the blocks were put together can all be used to help archeologists date structures that display the technique.

2 – 1 - Etruscan way :

In early usage (often called the "Etruscan way"), the joints between the blocks introduce discontinuities, making the blocks uneven. Examples of such construction can be found in reservoirs, basements, terrace walls, and temple podiums in Etruscan cities and Rome.

2 – 2 - Greek way :

Subsequently (the "Greek way"), the blocks would be placed in one of two rotations. "Stretchers" would be placed so the longer side was on the face of the wall, and "headers" would be placed so the shorter side was on the face of the wall, and would thus extend further back into the wall thickness. Various patterns could be produced by changing how the blocks were placed, and it was common to strengthen the wall by ensuring that the joints between blocks were centered over the blocks in the row below.

2 – 3 - Roman concrete :

With the introduction of Roman concrete, continuous outer walls were often constructed, with some blocks laid as headers in order to attach to the inner wall. Tile or marble can be found cemented to such walls, but this was less common for those structures that were particularly load - bearing, such as arches and pillars used for bridges and aqueducts.

Opus Reticulatum

Opus Reticulatum used on the exterior wall of Hadrian's Villa used as a retreat for the Roman Emperor Hadrian in the early 2nd century.

Opus Reticulatum (also known as **Reticulated work**) is a form of brickwork used in ancient Roman architecture. It consists of diamond-shaped bricks of tuff placed around a core of opus caementicium.[1] The diamond-shaped tufa blocks were placed with the pointed ends into the cement core at an angle of roughly 45 degrees, so the square bases formed a diagonal pattern, and the pattern of mortar lines resembled a net. *Reticulatum* is the Latin term for *net*, and *opus*, the term for a work of art, thus the term translates to "net work".

This construction technique was used from the beginning of the 1st century BC, and remained very common until *opus latericium*, a different form of brickwork, became more common.[1]

Opus Reticulatum was used as a technique in the Renaissance Palazzo Rucellai in Florence, the skill having been lost with the end of the Roman Empire, and rediscovered by means of archeology by Leon Battista Alberti.

The initial, rough form of *opus Reticulatum*, an advancement from *opus incertum*, is called *opus quasi Reticulatum*.

Opus Vittatum

Theatre of Augustus in Augusta Raurica. The steps are in opus vittatum.

Opus vittatum was an ancient Roman construction technique, sometimes square with tuff blocks intersected by one or more brick-bands at regular or irregular distances, and Opus caementicium.

This technique was mostly used to erect high walls, as in the Baths of Caracalla and the Aurelian Walls in Rome.

Paper

Contents

1 – Introduction :

Paper is a thin material mainly used for writing upon, printing upon, drawing or for packaging. It is produced by pressing together moist fibers, typically cellulose pulp derived from wood, rags or grasses, and drying them into flexible sheets.

Paper is a versatile material with many uses. Whilst the most common is for writing and printing upon, it is also widely used as a packaging material, in many cleaning products, in a number of industrial and construction processes, and even as a food ingredient – particularly in Asian cultures.

Paper, and the pulp papermaking process, was said to be developed in China during the early 2nd century AD by the Han court eunuch Cai Lun, although the earliest archaeological fragments of paper derive from the 2nd century BC in China.

2 – History :

The oldest known archaeological fragments of the immediate precursor to modern paper date to 2nd century BC China. Papermaking is considered one of the Four Great Inventions of China, and the pulp papermaking process is ascribed to Cai Lun, a 2nd century AD Han court eunuch . With paper an effective substitute for silk in many applications, China could export silk in greater quantity, contributing to a Golden Age.

Paper spread from China through the Islamic world to medieval Europe in the 13th century, where the first water-powered paper mills were built.[2] In the 19th century, industrial manufacture greatly lowered its cost, enabling mass exchange of information and contributing to significant cultural shifts. In 1844, Canadian inventor Charles Fenerty and German F.G. Keller independently developed processes for pulping wood fibers.

3 – Etymology :

The word "paper" is etymologically derived from Latin *papyrus*, which comes from the Greek (*papuros*) , the word for the *Cyperus papyrus* plant . Papyrus is a thick, paper - like material produced from the pith of the *Cyperus papyrus* plant which was used in ancient Egypt and other Mediterranean cultures for writing before the introduction of paper into the Middle East and Europe.[6] Although paper is etymologically derived from papyrus, the two are produced very differently and the development of modern paper is separate from the development of papyrus. Papyrus is a "lamination of natural plants, while paper is manufactured from fibers whose properties have been changed by maceration or disintegration.

4 – Paper making :

4 – 1 - Chemical pulping :

To make pulp from wood, a chemical pulping process separates lignin from cellulose fibers. This is accomplished by dissolving lignin in a cooking liquor, so that it may be washed from the cellulose fibers.

This preserves the length of the cellulose fibers. Paper made from chemical pulps are also known as wood-free papers–not to be confused with tree-free paper. This is because they do not contain lignin, which deteriorates over time. The pulp can also be bleached to produce white paper, but this consumes 5 % of the fibers. Chemical pulping processes are not used to make paper made from cotton, which is already 90 % cellulose.

There are three main chemical pulping processes. The sulfite process dates back to the 1840's, and it was the dominant process before the second world war. The kraft process, invented in the 1870s and first used in the 1890's, is now the most commonly practiced strategy. One advantage is a chemical reaction with lignin produces heat, which can be used to run a generator. Most pulping operations using the kraft process are net contributors to the electricity grid or use the electricity to run an adjacent paper - mill. Another advantage is the process recovers and reuses all inorganic chemical reagents. Soda pulping is a specialty process used to pulp straws, bagasse, and hardwoods with high silicate content.

4 – 2 - Mechanical pulping :

There are two major mechanical pulps, thermo mechanical pulp (TMP) and ground wood pulp (GW). In the TMP process, wood is chipped and then fed into large steam-heated refiners where the chips are squeezed and made into fibres between two steel discs. In the **ground wood process**, debarked logs are fed into grinders where they are pressed against rotating stones and made into fibres. Mechanical pulping does not remove the lignin, so the yield is very high, > 95%, but also causes paper made from this pulp to yellow and become brittle over time. Mechanical pulps have rather short fibre lengths and produce weak paper. Although large amounts of electrical energy are required to produce mechanical pulp, it costs less than chemical pulp.

4 – 3 - Deinked pulp :

Paper recycling processes can use either chemical or mechanical pulp. By mixing with water and applying mechanical action the hydrogen bonds in the paper can be broken and fibres separated again. Most recycled paper contains a proportion of virgin fibre in the interests of quality. Generally deinked pulp is of the same quality or lower than the collected paper it was made from.

There are three main classifications of recycled fibre :

- Mill broke or internal mill waste – this incorporates any substandard or grade-change paper made within the paper mill which then goes back into the manufacturing system to be re - pulped back into paper. Such out-of-specification paper is not sold and is therefore often not classified as genuine reclaimed recycled fiber. However, most paper mills have been recycling their own waste fiber for many years, long before recycling become popular.
- Pre consumer waste – this is off cuts and processing waste, such as guillotine trims and envelope blank waste. This waste is generated outside the paper mill and could potentially go to landfill, and is a genuine recycled fibre source. Also includes de-inked pre consumer (recycled material that has been printed but did not reach its intended end use, such as waste from printers and unsold publications).
- Post consumer waste – this is fiber from paper which has been used for its intended end use and would include office waste, magazine papers and newsprint. As the vast majority of this paper has been printed (either digitally or by more conventional means such as lithography or rotogravure), it will either be recycled as printed paper or go through a deinking process first.

Recycled papers can be made from 100% recycled materials or blended with virgin pulp. They are (generally) not as strong nor as bright as papers made from virgin pulp.

4 – 4 – Additives :

Besides the fibres, pulps may contain fillers such as chalk or china clay, which improve the characteristics of the paper for printing or writing. Additives for sizing purposes may be mixed into the pulp and/or applied to the paper web later in the manufacturing process. The purpose of sizing is to establish the correct level of surface absorbency to suit the ink or paint.

4 – 5 - Producing paper :

The pulp is fed to a paper machine where it is formed as a paper web and the water is removed from it by pressing and drying.

Pressing the sheet removes the water by force. Once the water is forced from the sheet, felt (not to be confused with the traditional felt) is used to collect the water. When making paper by hand, a blotter sheet is used.

Drying involves using air and or heat to remove water from the paper sheet. In the earliest days of papermaking this was done by hanging the paper sheets like laundry. In more modern times, various forms of heated drying mechanisms are used. On the paper machine, the most common is the steam-heated can dryer. These dryers can heat to temperatures above 93 °C and are used in long sequences of more than 40 cans. The heat produced by these can easily dry the paper to less than 6 % moisture.

4 – 6 – Finishing :

The paper may then undergo sizing to alter its physical properties for use in various applications.

Paper at this point is *uncoated*. Coated paper has a thin layer of material such as calcium carbonate or china clay applied to one or both sides in order to create a surface more suitable for high-resolution halftone screens. (Uncoated papers are rarely suitable for screens above 150 lpi.) Coated or uncoated papers may have their surfaces polished by calendaring. Coated papers are divided into matte, semi - matte or silk, and gloss. Gloss papers give the highest optical density in the printed image.

The paper is then fed onto reels if it is to be used on web printing presses, or cut into sheets for other printing processes or other purposes. The fibres in the paper basically run in the machine direction. Sheets are usually cut "long-grain", i.e. with the grain parallel to the longer dimension of the sheet.

All paper produced by paper machines as the Fourdrinier Machine are wove paper, i.e. the wire mesh that transports the web leaves a pattern that has the same density along the paper grain and across the grain. Textured finishes, water marks and wire patterns imitating hand - made *laid* paper can be created by the use of appropriate rollers in the later stages of the machine.

Wove paper does not exhibit "laidlines", which are small regular lines left behind on paper when it was handmade in a mould made from rows of metal wires or bamboo. Laidlines are very close together. They run perpendicular to the "chainlines", which are further apart. Handmade paper similarly exhibits "deckle edges", or rough and feathery borders.

5 – Applications :

Paper can be produced with a wide variety of properties, depending on its intended use .

- **For representing value :** paper money, bank note, cheque, security (see *security paper*), voucher and ticket
- **For storing information**: book, notebook, magazine, newspaper, art, zine, letter
- **For personal use**: diary, note to remind oneself, etc.; for temporary personal use: scratch paper
- **For communication:** between individuals and/or groups of people.
- **For packaging:** corrugated box, paper bag, envelope, wrapping tissue, Charta emporetica and wallpaper
- **For cleaning:** toilet paper, handkerchiefs, paper towels, facial tissue and cat litter
- **For construction:** papier-mâché, origami, paper planes, quilling, paper honeycomb, used as a core material in

composite materials, paper engineering, construction paper and paper clothing

- **For other uses:** emery paper, sandpaper, blotting paper, litmus paper, universal indicator paper, paper chromatography, electrical insulation paper (see also *dielectric* and *permittivity*) and filter paper

6 – Types , thickness and weight :

The thickness of paper is often measured by caliper, which is typically given in thousandths of an inch. Paper may be between 0.07 millimeters and 0.18 millimeters thick.

Paper is often characterized by weight. In the United States, the weight assigned to a paper is the weight of a ream, 500 sheets, of varying "basic sizes", before the paper is cut into the size it is sold to end customers. For example, a ream of 20 lb, 8.5 × 11 in (216 × 279 mm) paper weighs 5 pounds, because it has been cut from a larger sheet into four pieces . In the United States, printing paper is generally 20 lb, 24 lb, or 32 lb at most. Cover stock is generally 68 lb, and 110 lb or more is considered card stock.

In Europe, and other regions using the ISO 216 paper sizing system, the weight is expressed in grammas per square metre (g/m^2 or usually just g) of the paper. Printing paper is generally between 60 g and 120 g. Anything heavier than 160 g is considered card. The weight of a ream therefore depends on the dimensions of the paper and its thickness.

Most commercial paper sold in North America is cut to standard paper sizes based on customary units and is defined by the length and width of a sheet of paper.

The ISO 216 system used in most other countries is based on the surface area of a sheet of paper, not on a sheet's width and length. It was first adopted in Germany in 1922 and generally spread as nations adopted the metric system. The largest standard size paper is A0 (A zero), measuring one square meter (approx. 1189 x 841 mm). Two sheets of A1, placed upright side by side fit exactly into one sheet of

A0 laid on its side. Similarly, two sheets of A2 fit into one sheet of A1 and so forth. Common sizes used in the office and the home are A4 and A3 (A3 is the size of two A4 sheets).

The density of paper ranges from 250 kg / m^3 for tissue paper to 1,500 kg / m^3 for some specialty paper. Printing paper is about 800 kg / m^3

Paper may be classified into seven categories :

- *Printing papers* of wide variety.
- *Wrapping papers* for the protection of goods and merchandise. This includes wax and kraft papers.
- *Writing paper* suitable for stationary requirements. This includes ledger, bank, and bond paper.
- *Blotting papers* containing little or no size.
- *Drawing papers* usually with rough surfaces used by artists and designers, including cartridge paper.
- *Handmade papers* including most decorative papers, Ingres papers, Japanese paper and tissues, all characterized by lack of grain direction.
- *Specialty papers* including cigarette paper, toilet tissue, and other industrial papers.

7 - Paper Stability :

Much of the early paper made from wood pulp contained significant amounts of alum, a variety of aluminium sulfate salts that are significantly acidic. Alum was added to paper to assist in sizing the paper, making it somewhat water resistant so that inks did not "run" or spread uncontrollably. The early papermakers did not realize that the alum they added liberally to cure almost every problem encountered in making their product would eventually be detrimental. The cellulose fibres which make up paper are hydrolyzed by acid, and the presence of alum would eventually degrade the fibres until the paper disintegrated in a process which has come to be known as "slow fire". Documents written on rag paper were significantly more stable. The use of non-acidic additives to make paper is becoming more prevalent and the stability of these papers is less of an issue.

Paper made from mechanical pulp contains significant amounts of lignin, a major component in wood. In the presence of light and oxygen lignin reacts to give yellow materials, which is why newsprint and other mechanical paper yellows with age. Paper made from bleached kraft or sulfite pulps does not contain significant amounts of lignin and is therefore better suited for books, documents and other applications where whiteness of the paper is essential.

It is important to note that just because a paper is made of wood pulp, does not necessarily mean it is any less durable than a rag paper. The factor that determines the ageing behavior of a paper is how it was manufactured, not the original source of the fibres.[17] Furthermore, tests sponsored by the Library of Congress prove that all paper is at risk of acid decay, because cellulose itself produces formic, acetic, lactic and oxalic acids.

Mechanical pulping yields almost a tonne of pulp per tonne of dry wood used (which is why mechanical pulps are sometimes referred to as "high yield" pulps), which is about twice as much as chemical pulping. Consequently, paper made with mechanical pulps is often cheaper than that made with bleached chemical pulps. Mass-market paperback books and newspapers use these mechanical papers. Book publishers tend to use acid - free paper, made from fully bleached chemical pulps for hardback and trade paperback books.

8 - Environmental impact of paper :

The production and use of paper has a number of adverse effects on the environment.

World wide consumption of paper has risen by 400% in the past 40 years leading to increase in deforestation, with 35% of harvested trees being used for paper manufacture. Logging of old growth forests accounts for less than 10 % of wood pulp , but is one of the most controversial issues.

Paper waste accounts for up to 40% of total waste produced in the United States each year, which adds up to 71.6 million tons of paper waste per year in the United States alone .

Conventional bleaching of wood pulp using elemental chlorine produces and releases into the environment large amounts of chlorinated organic compounds, including chlorinated dioxins.[21] Dioxins are recognized as a persistent environmental pollutant, regulated internationally by the Stockholm Convention on Persistent Organic Pollutants. Dioxins are highly toxic, and health effects on humans include reproductive, developmental, immune and hormonal problems. They are known to be carcinogenic. Over 90 % of human exposure is through food, primarily meat, dairy, fish and shellfish, as dioxins accumulate in the food chain in the fatty tissue of animals.[22]

9 - Future of paper :

Some manufacturers have started using a new, significantly more environmentally friendly alternative to expanded plastic packaging made out of paper, known commercially as paperfoam. The packaging has very similar mechanical properties to some expanded plastic packaging, but is biodegradable and can also be recycled with ordinary paper.

With increasing environmental concerns about synthetic coatings (such as PFOA) and the higher prices of hydrocarbon based petrochemicals, there is a focus on zein (corn protein) as a coating for paper in high grease applications such as popcorn bags.

Also, synthetics such as Tyvek and Teslin have been introduced as printing media as a more durable material than paper.

Paper Crete

Testing the thermal conductivity of a paper Crete panel

Contents

1 – Introduction :

Paper Crete is a construction material which consists of re-pulped paper fiber with Portland cement or clay and/or other soil added. First patented in 1928, it has been revived since the 1980s. Although perceived as an environmentally friendly material due to the significant recycled content, this is offset by the presence of cement. The material lacks standardization, and proper use therefore requires care and experience. Eric Patterson and Mike McCain, who have been ascribed with independently "inventing" paper Crete (they called it "padobe" and "fibrous cement"), have both contributed considerably to research into machinery to make it and ways of using it for building.

2 - Manufacture :

The paper to be used can come from a variety of sources. News paper, junk mail, magazines, books, etc. obtained from the local dump or from waste bins are all useful. Depending on the type of mixer used to pulp the mix, the paper may be soaked in water beforehand.

A typical home made mixer uses a small electric motor mounted directly on a shaft with two four-inch square blades attached, resembling milk shake maker. This shaft is suspended in a plastic 55 gallon drum to mix the material.

Another home made mixer is made from a trailer built from the rear end of a car, with the differential input pointed upward and a lawn mower blade attached. When the trailer's wheels turn, the differential gears spin and power the blades. The blade is placed in a large stock watering tank to mix the material. A baffle on the side of the tank forces the slurry back into the blade as it circulates. With this mixer it has been possible to make three or four wheelbarrows full of thick Paper Crete in about twenty minutes.

Paper pulp may be added to clay soils where sand is not available. The added paper pulp helps to minimize cracking when the material dries.

3 - Standardization and Commercial Acceptance :

As of 2007, paper Crete lacks approval from the International Code Council. This limits its range of use within the city limits of most incorporated United States cities where building codes apply. It is not used as a load - bearing wall where building codes apply. However, its strength in model structures has been proven, and homes and small commercial buildings are being constructed. There is little or no evidence of its long - term durability at present.

In these small building projects, paper Crete is being used as an in - fill wall in conjunction with structural steel beams or other load-bearing elements.

Paper Crete gets its name from the fact that most formulas use a mixture of water and cement with cellulose fiber. The fiber is usually acquired from recycled news paper, lottery tickets and phone books. The mixture has the appearance and texture of oatmeal and is poured into forms and dried in the sun, much like the process for making adobe.

Dried paper Crete has very low strength, but fails by slow compression (due to the large air content and hence compressibility) rather than in a brittle manner. Concrete and wood are not known for their insulating qualities; however, paper Crete also provides good insulation.

Its R- value is reported to be within 2.0 and 3.0 per inch (2.54 cm); paper Crete walls are typically 25 – 30 cm . Unlike concrete or adobe, paper Crete blocks are lightweight, less than a third of the weight of a comparably - sized adobe brick. Paper Crete is mold resistant and has utility as a sound - proofing material.

Research tests into paper Crete have been carried out by Barry Fuller in Arizona and Zach Rabon in Texas. Fuller directs government - funded research on paper Crete through the Arizona State University Ira A. Fulton School of Engineering. He is also head of a subcommittee for the American Society for Testing and Materials, and it is his goal to set standards that will lead to acceptance of the product within the architectural community and commercialization of the product, especially for affordable housing.

Structural tests have been completed on several Paper Crete formulas and Fuller claims the compressive strength of Paper Crete to be in the 140-160 psi range (0.96 - 1.1 MPa), while others like Kelly Hart claim 260 psi (1.7 MPa). For comparison, the compressive strength of concrete ranges from 15 MPa to over 70 MPa (2200 - 10000 psi) depending on the application. A more useful measure of Paper Crete's properties is its stiffness - i.e. the extent to which it compresses under load. Its stiffness is many times less than that of concrete, but sufficient for the support of roof loads in some low-height buildings .

Dried, ready - to - use paper Crete has a rough surface. This increases its surface area and provides a very strong bond from one block to the next.

Paper Crete has also been tested for its tensile strength. Fuller notes that a Paper Crete block is the equivalent of hundred of pages of paper - almost like a catalog. Paper Crete has very good shear strength as a block. Lateral load involves sideways force - the wind load on the entire area of an outside wall for example. Because Paper Crete walls are usually a minimum of twelve inches thick, and usually pinned with rebar, they may be strong laterally.

Zach Rabon founded Mason Green star in Mason, Texas for the purpose of producing and selling a commercially viable Paper Crete block. His product, Blox Building System, is at present the only mass-produced commercial Paper Crete block in the market. He has built several residential structures with it.

The Mason Green star block had its genesis in a journey Rabon's father, Kent Rabon, made to Marathon, Texas. The elder Rabon made the acquaintance of Clyde T. Curry, the proprietor of Eve's Garden Organic Bed & Breakfast and Ecology Resource Center.

Mr. Curry was an early proponent of Paper Crete and benefited from the lack of building regulations in the small mountain community of Marathon. Curry built four of the rooms at the bed and breakfast either partially or entirely out of Paper Crete and is in the process of building two more, in addition to a library and reception area, entirely out of Paper Crete.

Paper Crete's ready mold ability provides considerable flexibility in the designed shape of structures. Domed ceilings/roofs may be commonly constructed with this material.

Along with Fuller's work at Arizona State University, Curry's establishment has become a resource center for people interested in Paper Crete, and workshops are intermittently held there.

The Rabons had prior experience as homebuilders and are owners of a ready-mix cement plant in Mason. They have invested in research and testing on their product for several years. However, they consider their product a proprietary formula. They have filed for a separate patent even though a patent for Paper Crete had already been filed in 1928. The block developed by Mason Greenstar is known for its uniform shrinkage (all Paper Crete blocks go through a lengthy dry-time that involves some shrinkage), giving it a sharper edge.

Fuller has remarked that in tests he has performed on the Rabon block, it has outperformed other formulas.

Paper Crete is claimed to have benefit of being a project that involves little cost to start. The materials are claimed to be cheap and widely available. Machinery suitable for small-scale construction is simple to design and construct.

When properly mixed and dried, the Paper Crete wall can be left exposed to the elements. In its natural state, it is a grey, fibrous-looking wall. For a more conventional look, stucco can be applied directly to it.

A study model home made of Paper Crete has been built at the Lyle Center for Regenerative Studies. This study model is a sample of homes to be built for a sustainable community in Tijuana by students of California State Polytechnic University, Pomona

Since 2006 a small company based in England called Econovate Ltd has being developing together with the Engineer Department and the Manufacturing Department at Cambridge University a Paper Crete formula to be accepted by British Standard and a certification from BBA. This new mixture of Paper Crete is to withstand the wet and harsh English weather. Econovate has filed for a patent in 2007 on blocks and designed wall panels made of this Paper Crete formula. As of 2009 Econovate is in the process of developing this product and reaching the manufacturing trials stage.

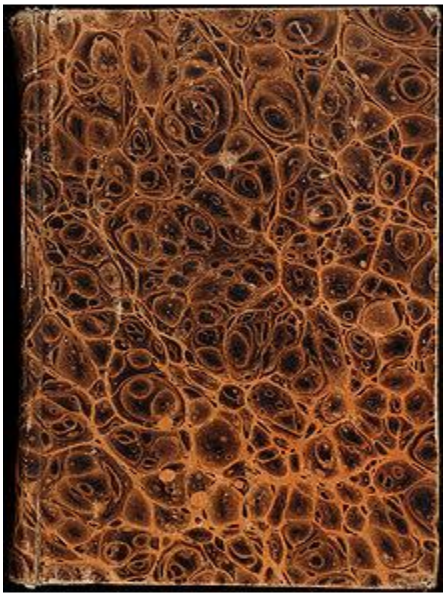
4 - Do it Your self :

Paper Crete is rapidly gaining a groundswell of support among "do it yourself" builders. It is claimed to be a very attractive building material due to its very low cost, light weight, and high performance. Many owner/builders are contributing to furthering the technology and sharing their experiences over the internet through resources such as " Paper Creters".

5 - Similar Materials :

There are different earth-paper mixes promoted under different names. A mix that uses clay as a binder instead of Portland cement is often referred to as "Hybrid Adobe", "Fidobe", or "Padobe".

Paper Marbling



Book covered in a Shell marbled paper,
bound in France around 1825.

Contents

1 – Introduction :

Paper marbling is a method of aqueous surface design, which can produce patterns similar to smooth marble or other stone. The patterns are the result of color floated on either plain water or a viscous solution known as size, and then carefully transferred to an absorbent surface, such as paper or fabric. Through several centuries, people have applied marbled materials to a variety of surfaces. It is often employed as a writing surface for calligraphy, and especially book covers and endpapers in bookbinding and stationery. Part of its appeal is that each print is a unique monotype.

2 - Procedure :

There are several methods for making marbled papers. A shallow tray is filled with water, and various kinds of ink or paint colors are carefully applied to the surface with an ink brush. Various additives or surfactant chemicals are used to help float the colors. A drop of "negative" color made of plain water with the addition of surfactant is used to drive the drop of color into a ring. The process is repeated until the surface of the water is covered with concentric rings.

The floating colors are then carefully manipulated either by blowing on them directly or through a straw, fanning the colors, or carefully using a human hair to stir the colors. In the 19th century, the Kyoto master *Tokutaro Yagi* developed a method for using a split piece of bamboo to gently stir the colors, resulting in concentric spiral designs. Finally, a sheet of *washi* paper is carefully laid onto the water surface to capture the floating design. The paper, which is often made of *kozo* (Paper Mulberry or *Broussonetia papyrifera*), must be unsized, and strong enough to withstand being immersed in water without tearing.

Another method of marbling more familiar to Europeans and Americans is made on the surface of a viscous mucilage, known as *size* or *sizing* in English. This method is commonly referred to as "Turkish" marbling, although ethnic Turkic peoples were not the only practitioners of the art, as Persian Tajiks and people of Indian origin also made these papers. The term "Turkish" was most likely used as a reference to the fact that many Europeans first encountered the art in Istanbul.

Historic forms of marbling used both organic and inorganic pigments mixed with water for colors, and sizes were traditionally made from gum tragacanth (*Astragalus* spp.), gum karaya, guar gum, fenugreek (*Trigonella foenum-graecum*), fleabane, linseed, and psyllium. Since the late 19th century, an boiled extract of the carrageenan-rich alga known as Irish moss (*Chondrus crispus*), has been employed for sizing. Today, many marblers use powdered carrageenan extracted from various seaweeds. Another plant-derived mucilage is made from sodium alginate. In recent years, a synthetic size made from hydroxypropyl methylcellulose, a common ingredient in instant wallpaper paste, is often used as a size for floating acrylic and oil paints.

In the sized-based method, colors made from pigments are mixed with a surfactant such as ox gall. Sometimes, oil or turpentine may be added to a color,to achieve special effects. The colors are then spattered or dropped onto the size, one color after another, until there is a dense pattern of several colors. Straw from the broom corn was used to make a kind of whisk for sprinkling the paint, or horsehair to create a kind of drop-brush. Each successive layer of pigment spreads slightly less than the last, and the colors may require additional surfactant to float and uniformly expand. Once the colors are laid down, various tools and implements such as rakes, combs and styluses are often used in a series of movements to create more intricate designs.

Paper or cloth, is often mordanted beforehand with aluminium sulfate (alum) and gently laid onto the floating colors (although methods such as Turkish *ebru* and Japanese *suminagashi* do not require mordanting). The colors are thereby transferred and adhered to the surface of the paper or material. The paper or material is then carefully lifted off the size, and hung up to dry. Some marblers gently drag the paper over a rod to draw off the excess size. If necessary, excess bleeding colors and sizing can be rinsed off, and then the paper or fabric is allowed to dry. After the print is made, any color residues remaining on the size are carefully skimmed off of the surface, in order to clear it before starting a new pattern.

Contemporary marblers employ a variety of modern materials, some in place of or in combination with the more traditional ones. A wide variety of colors are used today in place of the historic pigment colors. Plastic broom straw can be used instead of broom corn, as well as bamboo sticks, plastic pipettes, and eye droppers to drop the colors on the surface of the size. Ox gall is still commonly used as a surfactant for watercolors and gouache, but synthetic surfactants are used in conjunction with acrylic, PVA, and oil-based paints.

3 - History in East Asia :

An intriguing reference which some think may be a form of marbling is found in a compilation completed in 986 CE entitled *Wen Fang Si Pu* or "Four Treasures of the Scholar's Study" edited by the 10th century scholar - official Su Yijian (957 - 995 CE) . This compilation contains information on ink stick, ink stone , ink brush, and paper in China, which are collectively called the four treasures of the study. The text mentions a kind of decorative paper called 流沙箋 *liu sha jian* meaning “drifting-sand” or “flowing-sand notepaper" that was made in what is now the region of Sichuan (Yijian 4: 7a-8a).

This paper was made by dragging a piece of paper through a fermented flour paste mixed with various colors, creating a free and irregular design. A second type was made with a paste prepared from honey locust pods, mixed with croton oil, and thinned with water. Presumably both black and colored inks were employed. Ginger, possibly in the form of an oil or extract, was used to disperse the colors, or “scatter” them, according to the interpretation given by Dr. T.H. Tsien. The colors were said to gather together when a hair-brush was beaten over the design, as dandruff particles was applied to the design by beating a hairbrush over top. The finished designs, which were thought to resemble human figures, clouds, or flying birds, were then transferred to the surface of a sheet of paper. An example of paper decorated with floating ink has never been found in China. Whether or not the above methods employed floating colors remains to be determined .

Su Yijian was an Imperial scholar-official and served as the chief of the Hanlin Academy from about 985-993 CE. He compiled the work from a wide variety of earlier sources, and was familiar with the subject, given his profession. Yet it is important to note that it is uncertain how personally acquainted he was with the various methods for making decorative papers that he compiled. He most likely reported information given to him, without having a full understanding of the methods used. His original source may have predated him by several centuries. Until the original sources that he quotes are more precisely determined, can it be possible to ascribe a firm date for the production of the papers mentioned by Su Yijian.

suminagashi, which means "floating ink" in Japanese is the oldest method of decorative paper made with floating colors that is known today. Author Einen Miura states that the oldest reference to *suminagashi* papers are in the waka poems of Shigeharu, (825-880 CE), a son of the famed Heian era poet Narihira (Muira 14). Various claims have been made regarding the origins of *suminagashi*. Some think that it may have originally come from China (Wolfe 6). Others have proposed that it may have derived from an early form of ink divination. Another theory is that the process may have derived from a form of popular entertainment at the time, in which a freshly painted sumi painting was immersed into water, and the ink slowly dispersed from the paper and rose to the surface, forming curious designs.

One individual has often been claimed as the inventor of suminagashi. According to legend, Jizemon Hiroba felt he was divinely inspired to make suminagashi paper after he offered spiritual devotions at the Kasuga Shrine in Nara Prefecture. It is said that he then wandered the country looking for the best water with which to make his papers. He arrived in Echizen, Fukui Prefecture where he found the water especially conducive to making *suminagashi*. So he settled there, and his family carried on with the tradition to this day. The Hiroba Family claims to have made this form of marbled paper since 1151 CE for 55 generations .

4 - History in Central Asia and the Islamic World :

In the 15th century the method of floating colors on the surface of mucilaginous sizing is thought to have emerged in Central Asia. It is believed to have appeared during the end of the Islamic Timurid Dynasty, whose final capital was in the city of Herat, located in Afghanistan today. Other sources suggest it emerged during the subsequent Shaybanid dynasty, in the cities of Samarqand or Bukhara, in what is now modern Uzbekistan. Whether or not this method was somehow related to earlier Chinese or Japanese methods mentioned above has never been concretely proven.

This Islamic method came to be known as *kâghaz-e abrî* (کاغذ ابری), although often the simplified form of *abrî* (ابری), is also found in several historic texts.[5] This was translated by the late scholar Dr. Annemarie Schimmel to mean "clouded paper" in Persian. Certain Turkish writers have suggested that the word may be of Turkish origin related to the word *abreh* ابره meaning "colorful" or "variegated", though this specific term has never been concretely proven to have been used in relation to the art. It may have been the case that both Persian and Turkish meanings were simultaneously understood by artisans, many of which were conversant in both languages at that time, and even enjoyed as an expression of poetic nuance. Most historical Persian and Turkish texts known that refer to this kind of paper use the word *abrî* alone. Today in Iran it is often called *abrû-bâd* (ابرو باد), meaning "cloud and wind".

The art developed in Safavid Persia and Ottoman Turkey, as well as Mughal and the Deccan Sultanates in India. Within these regions, various methods emerged in which colors were made to float on the surface of a bath of viscous liquid mucilage or *size*, made from various plants. These include *katheera* or *kitre*- gum tragacanth (*Astragalus* often used as a binder by apothecaries in making tablets), *shambalîleh* or *methi*- fenugreek seed (an ingredient in curry mixtures), and *sahlab* or *salep* (the roots of "Orchis mascula", which is commonly used to make a popular beverage). A method of manipulating colors evolved that employed various tools including rakes, combs, and other apparatus, utilized in a series of movements, resulted in incredibly elaborate, intricate, and mesmerizing designs. In India, the *abri* technique was eventually combined with '*aks*, which are various methods of resist or stencils, to create unique and very rare form of miniature painting. These are commonly associated with the Deccan region today, and especially the city of Bijapur in particular, under Adil Shahi dynasty patronage in the 17th century. The topic of marbling in India is understudied and conclusive determinations have yet to be made, especially in light of discoveries made in the last 20 years.

In Turkey, the art is widely known as *ebru* today, and continues to be very popular. The usage of this term appears in the late 19th century. The earliest examples of Ottoman Ebru are thought to be a copy of the *Hâlnâmah* حالنامه by the poet Arifi, popularly known as the *Guy-i Çevgan* or "Ball and Polo-stick". The text of this manuscript was rendered in a delicate cut paper découpage calligraphy by Mehmed bin Gazanfer and completed in 1540, and features many marbled and decorative paper borders. One early master by the name of Shebek is mention posthumously in the earliest Ottoman text on the art known as the *Tertib-i Risâle-i Ebrî* (ترطيبِ رساله ابرى), which is dated based on internal evidence to after 1615. Several recipes in the text are accredited to this master. Another famous 18th century master by the name of Hatip Mehmed Effendi (d. 1773) is accredited with developing motif and perhaps early floral designs, although evidence from India appears to contradict some of these claims. Despite this, marbled motifs are commonly referred to as "Hatip" designs today in Turkey.

The current Turkish tradition of ebru dates to the mid 19th century, with a series of masters associated with a branch of the Naqshbandi Sufi order based at what is known as the Özbekler Tekkesi, located in Sultantepe, near Üsküdar.[7] The founder of this line is accredited to Sadık Effendi (d. 1846). It is said that he learned the art in Bukhara and taught it to his sons Edhem and Salıh. Based upon this, many Turkish marblers have stated that the art was perpetuated by Sufis for centuries, although evidence for this claim is has never been concretely established. "Hezarfen" Edhem Effendi (d. 1904) is attributed with developing the art as a kind of cottage industry for the tekke, to supply Istanbul's burgeoning printing industry with the decorative paper. It is said that the papers were tied into bundles and sold by weight. Many of these papers were of the *neftli* design, made with turpentine, an equivalent to what is called *stormont* in English.

The premier student of Edhem Effendi was Necmeddin Okyay (1885–1976). He was the first to teach the art at the Fine Arts Academy in Istanbul. He is famous for the development of floral styles of marbling, in addition to *yazılı ebru* a method of writing traditional calligraphy using a gum-resist method in conjunction with ebru. Okyay's premier student was Mustafa Düzgünman (1920–1990), the teacher of many contemporary marblers in Turkey today. He is known for codifying the traditional repertoire of patterns, to which he only added a floral daisy design, in the manner of his teacher.[8]

5 - History in Europe :

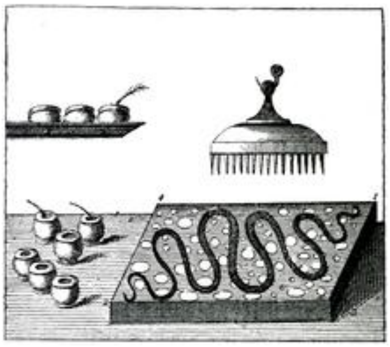
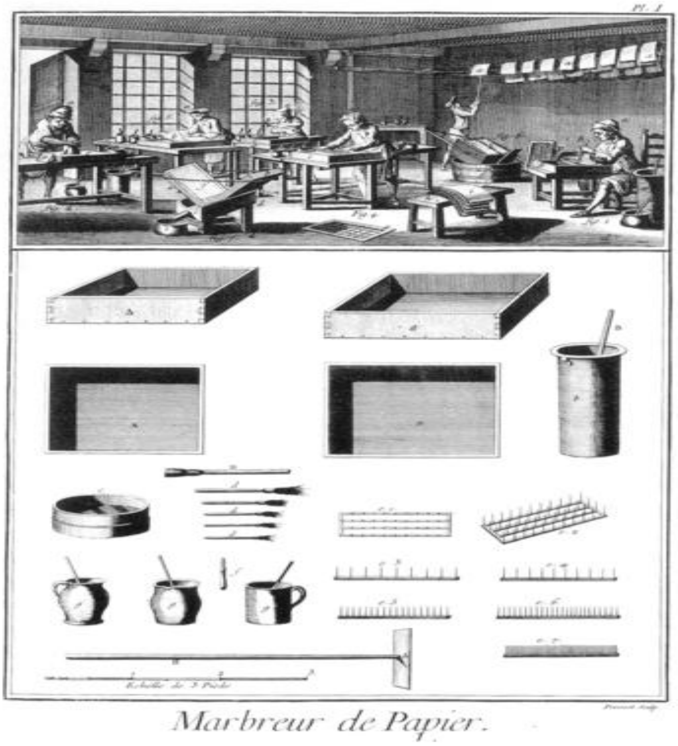


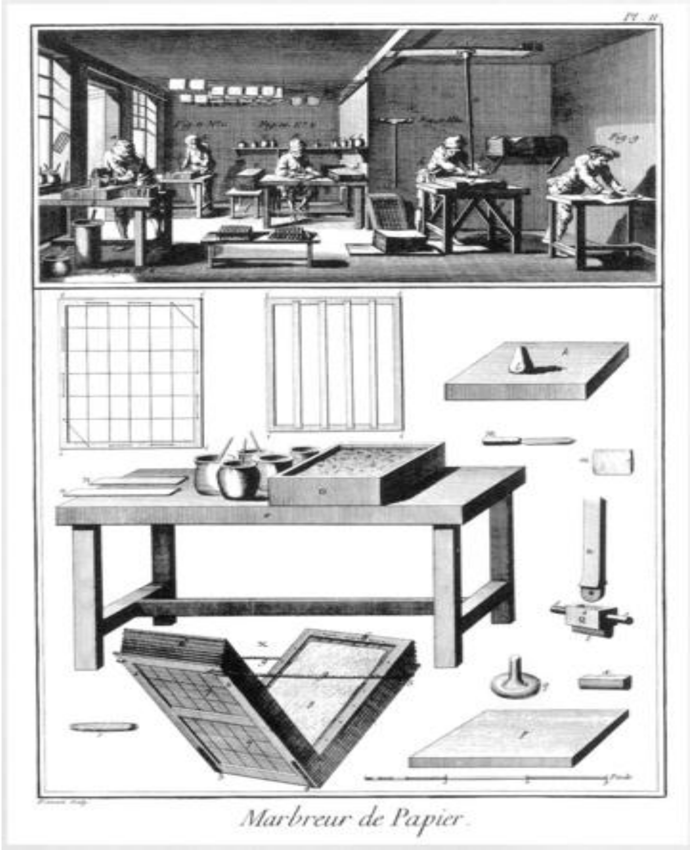
Illustration of the marbling tray and tools taken from the book School of Arts (1750) as reproduced in The Art of Bookbinding by Joseph Zaehnsdorf (1890).

In the 17th century European travelers to the Middle East collected examples of these papers and bound them into *alba amicorum*, which literally means "books of friendship" in Latin, and is a forerunner of the modern autograph album. Eventually the technique for making the papers reached Europe, where they became a popular covering material not only for book covers and end-papers, but also for lining chests, drawers, and bookshelves. The marbling of the edges of books was also a European adaptation of the art.

The unique methods of marbling attracted the curiosity of early scientists during the Renaissance. While the earliest published account was written in German by Daniel Schwenter, it wasn't published in his *Delicæ Physico-Mathematicæ* until 1671 A brief description of the art by Athanasius Kircher, published in *Ars Magna Lucis et Umbræ* in Rome in 1646, rapidly spread throughout Europe. (ibid) A thorough overview of the art with illustrations of marblers at work, and images of the tools of the trade was published in the *Encyclopédie* of Denis Diderot and Jean le Rond d'Alembert.



Marblers at work and illustrations of marbling equipment.



An edge marbler and paper finisher with related equipment.

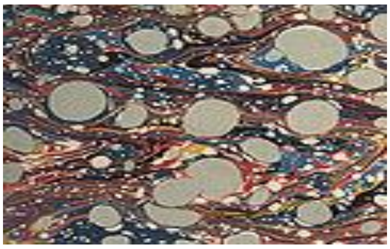
The art became a popular handicraft in the 19th century after the English maker Charles Woolnough published his *The Art of Marbling* (1853). In it, he describes how he adapted a method of marbling onto book-cloth, which he exhibited at the Crystal Palace Exhibition in 1851. (Wolfe, 79) Further developments in the art were made by Josef Halfer, a bookbinder of German origin, who lived in Budakeszi, in Hungary.[12] It was Halfer who discovered a method for preserving carrageenan, and his methods superseded earlier ones in Europe and the US.

Marbled paper is still made today, and the method is now applied to fabric and three-dimensional surfaces, as well as paper. Aside from continued traditional applications, artists now explore using the method as a kind of painting technique, and as an element in collage. In the last two decades, marbling has been the subject of international symposia and museum exhibitions. An active international group can be found on Yahoo! Groups, as well as the Society of Marbling, an organization of practicing marblers.

6 - Examples :

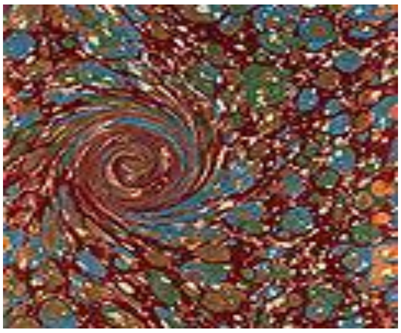
Marbled endpaper from a book bound in France around 1735

Marbled endpaper from a book bound in the Netherlands or Germany between 1720 and 1770



Paper marbling from a book bound in England around 1830 (detail)

Paper marbling from a book bound in England around 1830



Marbled endpaper from a book bound in France around 1880 (detail)

Marbled endpaper from a book bound in France around 1880

Combed marbled paper, from the front flyleaf of a binding of Oriental Fragments by Maria Hack, printed in London for Harvey and Dartman, 1828.

A combed marbled pattern from the front flyleaf of a binding of The Playmate: A Pleasant Companion for Spare Hours by Joseph Cundall, Printed by Barclay, 1847.

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Pulp (paper)

Contents

1 – Introduction :

Pulp is a ligno cellulosic fibrous material prepared by chemically or mechanically separating cellulose fibers from wood, fiber crops or waste paper. Wood pulp is the most common raw material in paper making.

2 - History :

Using wood to make paper is a fairly recent innovation. In the 1800s, fiber crops such as linen fibres were the primary material source, and paper was a relatively expensive commodity. The use of wood to make pulp for paper began with the development of mechanical pulping in Germany by F.G. Keller in the 1840s , and by the Canadian inventor Charles Fenerty in Nova Scotia . Chemical processes quickly followed, first with J. Roth's use of sulfurous acid to treat wood, followed by B. Tilghman's U.S. patent on the use of calcium bisulfite, $Ca(HSO_3)_2$, to pulp wood in 1867. Almost a decade later the first commercial sulfite pulp mill was built in Sweden. It used magnesium as the counter ion and was based on work by Carl Daniel Ekman. By 1900, sulfite pulping had become the dominant means of producing wood pulp, surpassing mechanical pulping methods. The competing chemical pulping process, the sulfate or kraft process was developed by Carl F. Dahl in 1879 and the first kraft mill started (in Sweden) in 1890. The invention of the recovery boiler by G. H. Tomlinson in the early 1930s allowed kraft mills to recycle almost all of their pulping chemicals. This, along with the ability of the kraft process to accept a wider variety of types of wood and produce stronger fibres made the kraft process the dominant pulping process starting in the 1940s.

Global production of wood pulp in 2006 was 160 million tonnes (175 million tons). In the previous year, 57 million tones (63 million tons) of market pulp (not made into paper in the same facility) was sold, with Canada being the largest source at 21% of the total, followed by the United States at 16%. Chemical pulp made up 93% of market pulp.

3 - Manufacture of wood pulp :

The timber resources used to make wood pulp are referred to as pulp wood. Wood pulp comes from soft wood trees such as spruce, pine, fir, larch and hemlock, and hard woods such as eucalyptus, aspen and birch.

A pulp mill is a manufacturing facility that converts wood chips or other plant fiber source into a thick fiber board which can be shipped to a paper mill for further processing. Pulp can be manufactured using mechanical, semi-chemical or fully chemical methods (kraft and sulfite processes). The finished product may be either bleached or non-bleached, depending on the customer requirements.

Wood and other plant materials used to make pulp contain three main components (apart from water): cellulose fibres (desired for paper making), lignin (a three - dimensional polymer that binds the cellulose fibers together) and hemi celluloses, (shorter branched carbohydrate polymers). The aim of pulping is to break down the bulk structure of the fiber source, be it chips, stems or other plant parts, into the constituent fibers.

Chemical pulping achieves this by degrading the lignin and hemi cellulose into small, water-soluble molecules which can be washed away from the cellulose fibers without depolymerizing the cellulose fibres (chemically depolymerizing the cellulose weakens the fibres). The various mechanical pulping methods, such as ground wood (GW) and refiner mechanical (RMP) pulping, physically tear the cellulose fibres one from another. Much of the lignin remains adhering to the fibers. Strength is impaired because the fibres may be cut. There are a number of related hybrid pulping methods that use a combination of chemical and thermal treatment to begin an abbreviated chemical pulping process, followed immediately by a mechanical treatment to separate the fibers. These hybrid methods include thermo mechanical pulping, also known as TMP, and chemi thermo mechanical pulping, also known as CTMP. The chemical and thermal treatments reduce the amount of energy subsequently required by the mechanical treatment, and also reduce the amount of strength loss suffered by the fibers.

Global pulp production by category (2000)

Pulp category	**Production [M ton]**
Chemical	131.2
-Kraft	*117.0*
-Sulfite	*7.0*
-Semi chemical	*7.2*
Mechanical	37.8
Non wood	18.0
Total virgin fibers	187.0
Recovered fibres	147.0
Total pulp	334.0

3 – 1 - Harvesting trees :

All kinds of paper are made out of 100 % wood with nothing else mixed into them (with some exceptions, like fancy resume paper, which may include cotton). This includes news paper, magazines and even toilet paper. Most pulp mills use good forest management practices in harvesting trees to ensure that they have a sustainable source of raw materials. One of the major complaints about harvesting wood for pulp mills is that it reduces the biodiversity of the harvested forest. Trees raised specifically for pulp production account for 42 percent of world pulp production , old growth forests account for 9 percent, and second- and third - and more generation forests account for the rest. Reforestation is practiced in most areas, so trees are a renewable resource. The FSC (Forest Stewardship Council), SFI (Sustainable Forestry Initiative), PEFC (Programmer for the Endorsement of Forest Certification), and other bodies certify paper made from trees harvested according to guidelines meant to ensure good forestry practices.

The number of trees consumed depends on whether mechanical processes or chemical processes are used. It has been estimated that based on a mixture of soft woods and hard woods 12 meters tall and 15-20 centimeters in diameter, it would take an average of 24 trees to produce 1 ton of printing and writing paper, using the kraft process (chemical pulping). Mechanical pulping is about twice as efficient in using trees since almost all of the wood is used to make fibre therefore it takes about 12 trees to make 1 ton of mechanical pulp or news print.

3 – 2 - Preparation for pulping :

Wood chipping is the act and industry of chipping wood for pulp, but also for other processed wood products and mulch. Only the heart wood and sap wood are useful for making pulp. Bark contains relatively few useful fibres and is removed and used as fuel to provide steam for use in the pulp mill. Most pulping processes require that the wood be chipped and screened to provide uniform sized chips.

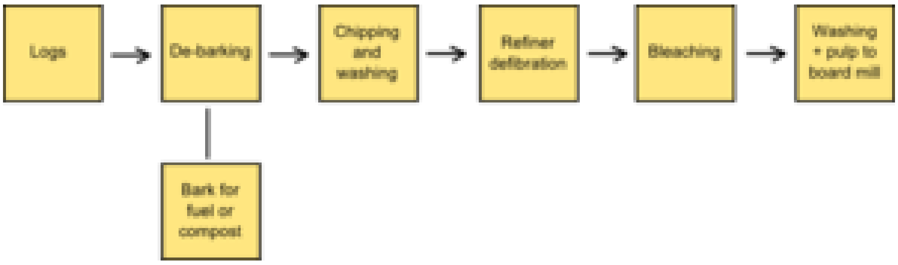
3 – 3 - Pulping :

There are a number of different processes which can be used to separate the wood fibres:

3 – 3 - 1 - Mechanical pulp :

Manufactured grind stones with embedded silicon carbide or aluminum oxide can be used to grind small wood logs called "bolts" to make stone ground wood pulp (SGW). If the wood is steamed prior to grinding it is known as pressure ground wood pulp (PGW). Most modern mills use chips rather than logs and ridged metal discs called refiner plates instead of grindstones. If the chips are just ground up with the plates, the pulp is called refiner mechanical pulp (RMP) and if the chips are steamed while being refined the pulp is called thermo mechanical pulp (TMP). Steam treatment significantly reduces the total energy needed to make the pulp and decreases the damage (cutting) to fibres. Mechanical pulps are used for products that require less strength, such as news print and paper boards.

3 – 3 - 2 - Thermo mechanical pulp :



Mechanical pulping process.

Thermo mechanical pulp is pulp produced by processing wood chips using heat (thus thermo) and a mechanical refining movement (thus mechanical). It is a two stage process where the logs are first stripped of their bark and converted into small chips. These chips have a moisture content of around 25 - 30 % and a mechanical force is applied to the wood chips in a crushing or grinding action which generates heat and water vapour and softens the lignin thus separating the individual fibres. The pulp is then screened and cleaned, any clumps of fibre are reprocessed. This process gives a high yield of fibre from the timber (around 95 %) and as the lignin has not been removed, the fibres are hard and rigid.

3 – 3 - 3 - Chemi thermo mechanical pulp :

Wood chips can be pretreated with sodium carbonate, sodium hydroxide, sodium sulfite and other chemicals prior to refining with equipment similar to a mechanical mill. The conditions of the chemical treatment are much less vigorous (lower temperature, shorter time, less extreme pH) than in a chemical pulping process since the goal is to make the fibres easier to refine, not to remove lignin as in a fully chemical process. Pulps made using these hybrid processes are known as chemi thermo mechanical pulps (CTMP).

3 – 3 - 4 - Chemical pulp :

Chemical pulp is produced by combining wood chips and chemicals in large vessels known as digesters where heat and the chemicals break down the lignin, which binds the cellulose fibres together, without seriously degrading the cellulose fibres. Chemical pulp is used for materials that need to be stronger or combined with mechanical pulps to give a product different characteristics. The kraft process is the dominant chemical pulping method, with sulfite process being second. Historically soda pulping was the first successful chemical pulping method.

3 – 3 - 5 - Recycled pulp :

Recycled pulp is also called **de inked pulp** (DIP). DIP is recycled paper which has been processed by chemicals, thus removing printing inks and other unwanted elements and freed the paper fibres. The process is called deinking.

DIP is used as raw material in paper making. Many news print, toilet paper and facial tissue grades commonly contain 100% deinked pulp and in many other grades, such as light weight coated for offset and printing and writing papers for office and home use, DIP makes up a substantial proportion of the furnish.

3 – 3 - 6 – Organo solvents pulping :

Organosolv pulping uses organic solvents at temperatures above 140 °C to break down lignin and hemi cellulose into soluble fragments. The pulping liquor is easily recovered by distillation.

3 – 3 - 7 - Alternative pulping methods :

Research is under way to develop biological pulping, similar to chemical pulping but using certain species of fungi that are able to break down the unwanted lignin, but not the cellulose fibres. This could have major environmental benefits in reducing the pollution associated with chemical pulping. The pulp is bleached using chlorine dioxide stage followed by neutralization and calcium hypochlorite. The oxidizing agent in either case oxidizes and destroys the dyes formed from the tannins of the wood and accentuated (reinforced) by sulfides present in it.

Steam exploded fiber is a pulping and extraction technique that has been applied to wood and other fibrous organic material.

3 – 4 - Bleaching :

The pulp produced up to this point in the process can be bleached to produce a white paper product. The chemicals used to bleach pulp have been a source of environmental concern, and recently the pulp industry has been using alternatives to chlorine, such as chlorine dioxide, oxygen, ozone and hydrogen peroxide.

4 - Alternatives to wood pulp :

Today, some people and groups advocate using field crop fiber or agricultural residues instead of wood fiber as being more sustainable . How ever, wood is also a renew able resource, with about 90 % of pulp coming from plantations or reforested areas. Non-wood fiber sources account for about 5 - 10 % of global pulp production, for a variety of reasons, including seasonal availability, problems with chemical recovery, brightness of the pulp etc. Non-wood pulp processing requires a high use of water and energy.

Nonwovens are in some applications alternatives to paper made from wood pulp, like filter paper or tea bags.

Comparison of typical feed stocks used in pulping

Component	**Wood**	**Non wood**
Carbohydrates	65-80 %	50-80 %
* Cellulose	40-45 %	30-45 %
* Hemi cellulose	23-35 %	20-35 %
Lignin	20-30 %	10-25 %
Extractives	2-5 %	5-15 %
Proteins	< 0.5 %	5-10 %
Inorganics	0.1-1 %	0.5-10 %
SiO_2	< 0.1 %	0.5-7 %

5 - Market pulp :

Market pulp is any variety of pulp that is produced in one location, dried and shipped to another location for further processing.

Important quality parameters for pulp not directly related to the fibres are brightness, dirt levels, viscosity and ash content. In 2004 about it accounted for about 55 million metric tons of market pulp.

5 - 1 - Air dry pulp :

Air dry pulp is the most common form to sell pulp. This is pulp dried to about 10 % moisture content. It is normally delivered as sheeted bales of 250 kg. The reason to leave 10 % moisture in the pulp is that this minimizes the fiber to fiber bonding and makes it easier to disperse the pulp in water for further processing to paper.

5 - 2 - Roll pulp :

Roll pulp or **reel pulp** is the most common delivery form of pulp to non traditional pulp markets. Fluff pulp is normally shipped on rolls (reels). This pulp is dried to 5 - 6 % moisture content. At the customer this is going to a comminution process to prepare for further processing .

5 - 3 - Flash dried pulp :

Some pulps are flash dried. This is done by pressing the pulp to about 50% moisture content and then let it fall trough silos that are 15–17 m high. Gas fired hot air is the normal heat source. The temperature is well above the char point of cellulose, but large amount of moisture in the fiber wall and lumen prevents the fibres from being incinerated. It is often not dried down to 10 % moisture (air dry). The bales are not as densely packed as air dry pulp .

6 - Environmental concerns :

The major environmental impacts of producing wood pulp come from its impact on forest sources and from its waste products.

6 - 1 - Forest resources :

The impact of logging to provide the raw material for wood pulp is an area of intense debate. Modern logging practices, using forest management seek to provide a reliable, renew able source of raw materials for pulp mills. The practice of clear cutting is a particularly sensitive issue since it is a very visible effect of logging. Reforestation, the planting of tree seedlings on logged areas, has also been criticized for decreasing biodiversity because reforested areas are mono cultures. Logging of old growth forests accounts for less than 10 % of wood pulp , but is one of the most controversial issues.

6 - 2 - Effluents from pulp mills :

The process effluents are treated in a biological effluent treatment plant, which guarantees that the effluents are not toxic in the recipient.

Mechanical pulp is not a major cause for environmental concern since most of the organic material is retained in the pulp, and the chemicals used (hydrogen peroxide and sodium dithionite) produce benign byproducts (water and sodium sulfate (finally), respectively).

Chemical pulp mills, especially kraft mills, are energy self-sufficient and very nearly closed cycle with respect to inorganic chemicals.

Bleaching with chlorine produces large amounts of organo chlorine compounds, including dioxins.

6 - 3 - Odor problems :

The kraft pulping reaction in particular releases foul-smelling compounds. The hydrogen sulfide reagent that degrades lignin structure also causes some demethylation to produce methanethiol, dimethyl sulfide and dimethyl disulfide. These same compounds are released during many forms of microbial decay, including the internal microbial action in Camembert cheese, although the kraft process is a chemical one and does not involve any microbial degradation. These compounds have extremely low odor thresholds and disagreeable smells; a common saying in communities economically dependent on nearby papermills is "Smells like a job" or "Smells like money."

7 - Applications :

The main applications for pulp are paper and board production. The furnish of pulps used depends on the quality on the finished paper. Important quality papra meters are wood furnish, brightness, viscosity, extractives, dirt count and strength.

Chemical pulps are used for making nano cellulose.

Speciality pulp grades have many other applications. Dissolving pulp is used in making regenerated cellulose that is used textile and cellophane production. It is also used to make cellulose derivatives. Fluff pulp is used in diapers, feminine hygiene products and nonwovens.

7 - 1 - Paper production :

The Fourdrinier Machine is the basis for most modern papermaking, and it has been used in some variation since its conception. It accomplishes all the steps needed to transform a source of wood pulp into a final paper product.

8 – Economics :

In 2009, NBSK pulp sold for $650 / ton in the United States. The market had experienced a drop in price due to falling demand when newspapers reduced their size, in part, as a result of the recession .

Paper Recycling

Waste paper collected for recycling in Italy

Contents

1 – Introduction :

Paper recycling is the process of turning waste paper into new paper products. There are three categories of paper that can be used as feed stocks for making recycled paper: mill broke, pre-consumer waste, and post-consumer waste. *Mill broke* is paper trimmings and other paper scrap from the manufacture of paper, and is recycled internally in a paper mill. *Pre-consumer waste* is material which left the paper mill but was discarded before it was ready for consumer use. *Post-consumer* waste is material discarded after consumer use, such as old corrugated containers (OCC), old magazines, old newspapers (ONP), office paper, old telephone directories, and residential mixed paper (RMP) . Paper suitable for recycling is called "scrap paper", often used to produce molded pulp packaging. The industrial process of removing printing ink from paper fibers of recycled paper to make deinked pulp is called deinking, an invention of the German jurist Justus Claproth.

2 - Paper recycling process :

The process of paper recycling involves mixing used paper with water and chemicals to break it down. It is then chopped up and heated, which breaks it down further into strands of cellulose, a type of organic plant material; the mixture is then called pulp, or slurry. It is strained through screens, which remove any glue or plastic that may still be in the mixture then cleaned, “de-inked,” bleached, and mixed with water. Then it can be made into new paper. The same fibers can be recycled about seven times, but they get shorter every time and eventually are strained out.

3 - Rationale for recycling :

Industrialized paper making has an effect on the environment both upstream (where raw materials are acquired and processed) and downstream (waste-disposal impacts).

Today, 90 % of paper pulp is created from wood. Paper production accounts for about 35 % of felled trees , and represents 1.2 % of the world's total economic output. Recycling one ton of newsprint saves about 1 ton of wood while recycling 1 ton of printing or copier paper saves slightly more than 2 tons of wood. This is because kraft pulping requires twice as much wood since it removes lignin to produce higher quality fibres than mechanical pulping processes. Relating tons of paper recycled to the number of trees not cut is meaningless, since tree size varies tremendously and is the major factor in how much paper can be made from how many trees.[9] Trees raised specifically for pulp production account for 16% of world pulp production, old growth forests 9% and second- and third- and more generation forests account for the balance.[6] Most pulp mill operators practice reforestation to ensure a continuing supply of trees . The Programme for the Endorsement of Forest Certification (PEFC) and the Forest Stewardship Council (FSC) certify paper made from trees harvested according to guidelines meant to ensure good forestry practices.[10] It has been estimated that recycling half the world's paper would avoid the harvesting of 20 million acres (81,000 km²) of forestland.

3 – 1 – Energy :

Energy consumption is reduced by recycling , although there is debate concerning the actual energy savings realized. The Energy Information Administration claims a 40 % reduction in energy when paper is recycled versus paper made with un recycled pulp , while the Bureau of International Recycling (BIR) claims a 64% reduction.[14] Some calculations show that recycling one ton of newspaper saves about 4,000 kWh (14 GJ) of electricity, although this may be too high (see comments below on un recycled pulp). This is enough electricity to power a 3-bedroom European house for an entire year, or enough energy to heat and air-condition the average North American home for almost six months . Recycling paper to make pulp actually consumes more fossil fuels than making new pulp via the kraft process; these mills generate all of their energy from burning waste wood (bark, roots) and byproduct lignin . Pulp mills producing new mechanical pulp use large amounts of energy; a very rough estimate of the electrical energy needed is 10 gigajoules per tone of pulp (2500 kW·h per short ton) . Recycling mills purchase most of their energy from local power companies, and since recycling mills tend to be in urban areas, it is likely that the electricity is generated by burning fossil fuels.

3 – 2 – Landfill use :

About 35 % of municipal solid waste (before recycling) by weight is paper and paper products.

3 – 3 – Water and air pollution :

The United States Environmental Protection Agency (EPA) has found that recycling causes 35 % less water pollution and 74 % less air pollution than making virgin paper . Pulp mills can be sources of both air and water pollution, especially if they are producing bleached pulp. Modern mills produce considerably less pollution than those of a few decades ago. Recycling paper decreases the demand for virgin pulp and thus reduces the overall amount of air and water pollution associated with paper manufacture. Recycled pulp can be bleached with the same chemicals used to bleach virgin pulp, but hydrogen peroxide and sodium hydrosulfite are the most common bleaching agents. Recycled pulp, or paper made from it, is known as PCF (process chlorine free) if no chlorine-containing compounds were used in the recycling process . How ever, recycling mills may have polluting by - products, such as sludge. De-inking at Cross Pointe's Miami, Ohio mill results in sludge weighing 22 % of the weight of wastepaper recycled .

4 - Recycling facts and figures :

In the mid-19th century, there was an increased demand for books and writing material. Up to that time, paper manufacturers had used discarded linen rags for paper, but supply could not keep up with the increased demand. Books were bought at auctions for the purpose of recycling fiber content into new paper, at least in the United Kingdom, by the beginning of the 19th century.

Internationally, about half of all recovered paper comes from converting losses (pre-consumer recycling), such as shavings and unsold periodicals; approximately one third comes from household or post-consumer waste.

Some statistics on paper consumption:

- The average per capita paper use worldwide was 110 pounds (50 kg) .
- It is estimated that 95 % of business information is still stored on paper.

- Recycling 1 short ton of paper saves 17 mature trees, 7 thousand US gallons (26 m^3) of water, 3 cubic yards (2.3 m^3) of landfill space, 2 barrels of oil (84 US gal or 320 l), and 4,100 kilowatt-hours (15 GJ) of electricity – enough energy to power the average American home for six months.
- Although paper is traditionally identified with reading and writing, communications has now been replaced by packaging as the single largest category of paper use at 41% of all paper used .
- 115 billion sheets of paper are used annually for personal computers The average web user prints 28 pages daily.
- Most corrugated fiberboard boxes have over 25% recycled fibe^rs · Some are 100 % recycled fiber.

5 - Paper recycling by region :

5 – 1 – European Union :

Paper recovery in Europe has a long history and has grown into a mature organization. The European papermakers and converters work together to meet the requirements of the European Commission and national governments. Their aim is the reduction of the environmental impact of waste during manufacturing, converting / printing, collecting, sorting and recycling processes to ensure the optimal and environmentally sound recycling of used paper and board products. In 2004 the paper recycling rate in Europe was 54.6% or 45.5 million short tons (41.3 Mt) . The recycling rate in Europe reached 64.5 % in 2007, which confirms that the industry is on the path to meeting its voluntary target of 66 % by 2010.

5 – 2 – Japan :

Municipal collections of paper for recycling are in place. However, according to the *Yomiuri Shimbun*, in 2008, eight paper manufacturers in Japan have admitted to intentionally mislabeling recycled paper products, exaggerating the amount of recycled paper used .

5 – 3 – United States :

Recycling has long been practiced in the United States. The history of paper recycling has several dates of importance:

- 1690: The first paper mill to use recycled linen was established by the Rittenhouse family .
- 1896: The first major recycling center was started by the Benedetto family in New York City, where they collected rags, newspaper, and trash with a pushcart.
- 1993: The first year when more paper was recycled than was buried in landfills .

Today, over half of the paper used in the United States is collected and recycled . Paper products are still the largest component of municipal solid waste, making up more than 40% of the composition of landfills . In 2006, a record 53.4 % of the paper used in the US (or 53.5 million tons) was recovered for recycling . This is up from a 1990 recovery rate of 33.5%.[36] The US paper industry has set a goal to recover 55 percent of all the paper used in the US by 2012. Paper packaging recovery, specific to paper products used by the packaging industry, was responsible for about 77 % of packaging materials recycled with more than 24 million pounds recovered in 2005 .

By 1998, some 9,000 curbside programs and 12,000 recyclable drop-off centers had sprouted up across the US for recycles collection. As of 1999, 480 materials recovery facilities had been established to process the collected materials .

5 – 4 – Mexico :

In Mexico, recycled paper, rather than wood pulp, is the principal feedstock in papermills accounting for about 75 % of raw materials .]

Parge Coat

Parge coat (concrete): A thin coat of a cementitious or polymeric mortar applied to concrete for refinement of the surface. The typical parge coat is 1/32"-1/16" in thickness; this may be less than the minimum thickness allowed by many mortars types. Usually applied with a parging bag.

The intent is to create a contiguous surface by filling surface air voids and bugholes (eliminating bughole-induced outgassing) and to level concrete with extreme rugosity to a level suitable for topcoating with a high-performance protective coating.

Parge coating can also be used to create air tightness for apartments.

Perlite

Expanded perlite

Contents

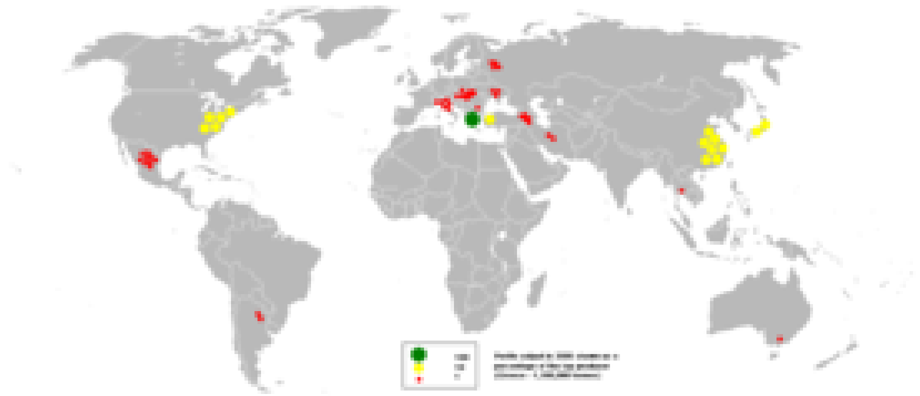
1 – Introduction :

Perlite is an amorphous volcanic glass that has a relatively high water content, typically formed by the hydration of obsidian. It occurs naturally and has the unusual property of greatly expanding when heated sufficiently. It is an industrial mineral and a commercial product useful for its light weight after processing.

2 – Properties :

When it reaches temperatures of 850 – 900 °C, perlite softens (because it is a glass). Water trapped in the structure of the material vapourizes and escapes, and this causes the expansion of the material to 7–16 times its original volume. The expanded material is a brilliant white, due to the reflectivity of the trapped bubbles. Unexpanded ("raw") perlite has a bulk density around 1100 kg/m^3 (1.1 g / cm^3), while typical expanded perlite has a bulk density of about 30 – 150 kg / m^3.

3 - Production and uses :



Perlite output in 2005

Perlite is a non - renewable resource. The world reserves of perlite are estimated at 700 million tones. In 2011, 1.7 million tones had been produced, mostly by Greece (500,000 t), United States (375,000 t) and Turkey (220,000 t); however, no information for China – a leading producer – was available.

Because of its low density and relatively low price (about US$50 per tone of unexpanded perlite), many commercial applications for perlite have developed. In the construction and manufacturing fields, it is used in lightweight plasters and mortars, insulation and ceiling tiles.

In horticulture, perlite can be used as a soil amendment or alone as a medium for hydroponics or for starting cuttings. When used as an amendment it has high permeability / low water retention and helps prevent soil compaction.

Perlite is an excellent filter aid. It is used extensively as an alternative to diatomaceous earth. The popularity of perlite usage in this application is growing considerably worldwide. Perlite filters are fairly commonplace in filtering beer before it is bottled.

Small quantities of perlite are also used in foundries, cryogenic insulation, as a light weight aggregate in mortar (fire stop) and in ceramics as a clay additive. It is also used by the explosive industry.[3]

In 2010, estimated perlite consumption in the US was as shown in the table :

Fraction	use
53 %	building construction products
14 %	horticultural aggregate
14 %	fillers
8 %	filter aid
11 %	other

The cost of unexpanded perlite has varied since 2001. :

end of year	Price in the US $ per t
2001	36.3
2002	36.5
2003	38.2
2004	41.8
2005	40.5
2006	42.9
2007	51.6
2008	60.0

4 - Typical analysis of perlite :

%	
70 – 75	Silicon dioxide: SiO_2
12 – 15	Aluminium oxide: Al_2O_3
3 – 4	Sodium oxide: Na_2O
3 – 5	Potassium oxide: K_2O
0.5 – 2	Iron oxide: Fe_2O_3
0.2 – 0.7	Magnesium oxide: MgO
0.5 – 1.5	Calcium oxide: CaO
3 – 5	loss on ignition (chemical / combined water)

Pervious Concrete

A pervious concrete street

Contents

1 – Introduction :

Pervious concrete is a special type of concrete with a high porosity used for concrete flat work applications that allows water from precipitation and other sources to pass directly through, thereby reducing the runoff from a site and allowing ground water recharge. The high porosity is attained by a highly interconnected void content. Typically pervious concrete has little or no fine aggregate and has just enough cementitious paste to coat the coarse aggregate particles while preserving the interconnectivity of the voids. Pervious concrete is traditionally used in parking areas, areas with light traffic, residential streets, pedestrian walk ways, and greenhouses.[1] It is an important application for sustainable construction and is one of many low impact development techniques used by builders to protect water quality.

2 – History :

Pervious concrete was first used in the 1800s in Europe as pavement surfacing and load bearing walls. Cost efficiency was the main motive due to a decreased amount of cement. It became popular again in the 1920's for two story homes in Scotland and England. It became increasingly viable in Europe after the Second World War due to the scarcity of cement. It did not become as popular in the US until the 1970s

3 - Storm water management :

The proper utilization of pervious concrete is a recognized Best Management Practice by the U.S. Environmental Protection Agency (EPA) for providing first flush pollution control and storm water management . As regulations further limit storm water runoff, it is becoming more expensive for property owners to develop real estate, due to the size and expense of the necessary drainage systems. Pervious concrete reduces the runoff from paved areas, which reduces the need for separate storm water retention ponds and allows the use of smaller capacity storm sewers. This allows property owners to develop a larger area of available property at a lower cost. Pervious concrete also naturally filters storm water and can reduce pollutant loads entering into streams, ponds and rivers.

Pervious concrete functions like a storm water infiltration basin and allows the storm water to infiltrate the soil over a large area, thus facilitating recharge of precious groundwater supplies locally. All of these benefits lead to more effective land use. Pervious concrete can also reduce the impact of development on trees. A pervious concrete pavement allows the transfer of both water and air to root systems allowing trees to flourish even in highly developed areas.

4 - Construction :

An experienced installer is vital to the success of pervious concrete pavements. The sub grade should be compacted to provide a uniform and stable surface. When placed directly on sandy or gravelly soils compact the sub grade to 92 to 96 % of maximum density.[3]

With silty or clayey soils, the level of compaction will [vary] and a layer of graded stone is placed over the soil. [Soil] fabrics are used to separate soils from the stone layer. Care must be taken not to over-compact soil with swelling potential. The sub grade should be moistened prior to concrete placement, and wheel ruts from the construction traffic should be raked and re - compacted.

The mixture is cement, coarse aggregate and water with little to no fine aggregates. The addition of a small amount of sand will increase the strength. water to cement ratio of 0.28 to 0.40 with a void content of 15 to 25 %.

The correct quantity of water in the concrete is critical. Too much water will cause paste drain down, and too little water can hinder curing and lead to premature surface failure. A proper water content gives the mixture a wet-metallic appearance. This material is sensitive to changes in water content, so field adjustment of the fresh mixture is usually necessary.

A common flatwork form has riser strips on top such that the screed is 3 / 8 – 1 / 2 in. (9 to 12 mm) above final pavement elevation. Mechanical screeds are preferable to manual. The riser are strips are removed to guide compaction. Immediately after screening , the concrete is compacted to improve the bond and smooth the surface. Excessive compaction may not be desirable.

Jointing varies little from other concrete slabs. Joints are tooled with a rolling jointing tool prior to curing or saw cut after curing. Curing should begin within 20 minutes of concrete discharge and continue through 7 days. Covering concrete with 6 mil. plastic sheeting is the standard method of curing, however, this contributes to a substantial amount of waste sent to landfills. Alternatively, preconditioned absorptive lightweight aggregate as well as internal curing admixture (ICA) have been used to effectively cure pervious concrete without waste generation.

5 - Testing and inspection :

Pervious concrete can attain a compressive strength ranging from 400 psi to 4000 psi (2.8 to 28 MPa) though strengths of 600 psi to 1500 psi (2.8 to 10 MPa) are more common. Pervious concrete, however, is not specified or accepted based on strength as there are not yet standardized test methods . More important to the success of a pervious pavement is the void content. Acceptance is typically based on the density (unit weight) of the in - place pavement. An acceptable tolerance is plus or minus 80 kg / m^3 of the design density. This should be verified through field testing. The fresh density (unit weight) of pervious concrete is measured using the test method described in ASTM C1688. Slump and air content tests are not applicable to pervious concrete. If the pervious concrete pavement is an element of the storm water management plan, the designer should ensure that it is functioning properly through visual observation of its drainage characteristics prior to opening of the facility. Questions have been raised about the freeze thaw durability of pervious concrete. Pervious concrete in freeze thaw environments must not become fully saturated. Saturation of installed pervious concrete pavement can be prevented by placing the pervious concrete on a thick layer of 200 to 600 mm of open graded stone base. Laboratory testing has shown that entrained air may improve the freeze thaw durability even when the pervious concrete is in a fully saturated condition. However, the entrained air content cannot be verified by any standard ASTM test procedure.

6 – Maintenance :

EPA recommends that pervious concrete pavement be cleaned regularly to prevent reduction in permeability. Cleaning can be accomplished through vacuum sweeping or pressure washing.

Phospho Gypsum

1 – Introduction :

Phospho gypsum refers to the gypsum formed as a by - product of processing phosphate ore into fertilizer with sulfuric acid.

Phospho gypsum is produced from the fabrication of phosphoric acid by reacting phosphate ore (apatite) with sulfuric acid according to the following reaction:

$$Ca_5 (P O_4)_3 X + 5 H_2 SO_4 + 10 H_2O \rightarrow$$

$$3 H_3 PO_4 + 5 Ca SO_4 \cdot 2 H_2O + H X$$

where X may include OH, F, Cl, or Br

Phospho gypsum is radioactive due to the presence of naturally occurring uranium and radium in the phosphate ore.

Marine-deposited phosphate typically has a higher level of radioactivity than igneous phosphate deposits, because uranium is present in seawater .

2 - In the United States :

The United States Environmental Protection Agency has banned most applications of phospho gypsum with a radium - 226 concentration of greater than 10 picocurie / gram (0.4 Bq / g). As a result, phospho gypsum which exceeds this limit is stored in large stacks.

Florida has a large quantity of phosphate deposits, particularly in Bone Valley region. However, the marine - deposited phosphate ore from central Florida is highly radioactive, and as such, the phospho gypsum by-product is too radioactive to be used for most applications. As a result, there are about 1 billion tons of phospho gypsum stacked in 25 stacks in Florida (22 are in central Florida) and about 30 million new tons are generated each year.

Various applications have been proposed for using phospho gypsum, including using it as material for :

- Road pavement
- Soil conditioner
- Cover for landfills
- Roof tiles
- Artificial reefs & oyster beds

Plaster

Gypsum - based plaster used in spray fire proofing in a low-rise industrial building in Vancouver , British Columbia.

Contents

1 – Introduction :

Plaster is a building material used for coating walls and ceilings. Plaster starts as a dry powder similar to mortar or cement and like those materials it is mixed with water to form a paste which liberates heat and then hardens. Unlike mortar and cement, plaster remains quite soft after setting, and can be easily manipulated with metal tools or even sandpaper. These characteristics make plaster suitable for a finishing, rather than a load-bearing material.

The term **plaster** can refer to gypsum plaster (also known as ***plaster of Paris***) , lime plaster , or cement plaster.

2 - Types :

2 – 1 - Gypsum plaster / Plaster of Paris

Gypsum plaster, or Plaster of Paris, is employed by mixing water with calcium sulfate hemi hydrate, nominally $CaSO_4 \cdot 1/2H_2O$. This is produced by heating gypsum to about 150 °C .

$2\ CaSO_4 \cdot 2H_2O \rightarrow 2\ CaSO_4 \cdot 0.5H_2O + 3\ H_2O$ (released as steam).

When the dry plaster powder is mixed with water, it re-forms into gypsum. If plaster or gypsum is heated above 200°C, anhydrite is formed, which will also re-form as gypsum if mixed with water.

A large gypsum deposit at Montmartre in Paris led gypsum plaster to be commonly known as "plaster of Paris".

One of the skills used in movie and theatrical sets is that of "plasterer", gypsum plaster often being used to simulate the appearance of surfaces of wood, stone, or metal. Nowadays, plasterers are just as likely to use expanded polystyrene, although the job title remains unchanged.

2 – 2 - Lime plaster :

Lime plaster is a mixture of calcium hydroxide and sand (or other inert fillers) . Carbon dioxide in the atmosphere causes the plaster to set by transforming the calcium hydroxide into calcium carbonate (lime stone) . White wash is based on the same chemistry.

To make lime plaster, lime stone (calcium carbonate) is heated to produce quick lime (calcium oxide) . Water is then added to produce slaked lime (calcium hydroxide) , which is sold as a wet putty or a white powder. Additional water is added to form a paste prior to use. The paste may be stored in air-tight containers. Once exposed to the atmosphere, the calcium hydroxide turns back into calcium carbonate, causing the plaster to set.

Lime plaster was a common building material for wall surfaces in a process known as lath and plaster, whereby a series of wooden strips on a stud work frame was covered with a semi-dry plaster that hardened into a surface. The plaster used in most lath and plaster construction was mainly lime plaster, with a cure time of about a month. To stabilize the lime plaster during curing, small amounts of plaster of Paris were incorporated into the mix. Because plaster of Paris sets quickly, "retardants" were used to slow setting time enough to allow workers to mix large working quantities of lime putty plaster. A modern form of this method uses expanded metal mesh over wood or metal structures, which allows a great freedom of design as it is adaptable to both simple and compound curves. Today this building method has been partly replaced with dry wall , also composed mostly of gypsum plaster. In both these methods a primary advantage of the material is that it is resistant to a fire within a room and so can assist in reducing or eliminating structural damage or destruction provided the fire is promptly extinguished.

Lime plaster is used for true frescoes. Pigments, diluted in water, are applied to the still wet plaster.

2 – 3 - Cement plaster :

Cement plaster is a mixture of suitable plaster , sand , portland cement and water which is normally applied to masonry interiors and exteriors to achieve a smooth surface. Interior surfaces sometimes receive a final layer of gypsum plaster. Walls constructed with stock bricks are normally plastered while face brick walls are not plastered. Various cement - based plasters are also used as proprietary spray fire proofing products. These usually use vermiculite as lightweight aggregate. Heavy versions of such plasters are also in use for exterior fireproofing, to protect LPG vessels, pipe bridges and vessel skirts.

3 - Uses :

3 – 1 - In architecture :

19th century plasterwork from House of Borujerdies in Kashan, Iran.

Plasterwork in Pompeii (79 AD)

Plaster may also be used to create complex detailing for use in room interiors. These may be geometric (simulating wood or stone) or naturalistic (simulating leaves , vines , and flowers) These are also often used to simulate wood or stone detailing found in more substantial buildings.

3 – 2 - In art :

Many of the greatest paintings in Europe, like Michelangelo's Sistine Chapel ceiling are executed in fresco , meaning they are painted on a thin layer of wet plaster, called intonaco (in fact the general term for plaster in Italian) ; the pigments sink into this layer so that the plaster itself becomes the medium holding them, which accounts for the excellent durability of fresco. Additional work may be added *a secco* on top of the dry plaster, though this is generally less durable .

Plaster may be cast directly into a damp clay mold. In creating this *piece molds* (molds designed for making multiple copies) or *waste molds* (for single use) would be made of plaster. This "negative" image, if properly designed, may be used to produce clay productions, which when fired in a kiln become terra cotta building decorations, or these may be used to create cast concrete sculptures. If a plaster positive was desired this would be constructed or cast to form a durable image artwork. As a model for stonecutters this would be sufficient. If intended for producing a bronze casting the plaster positive could be further worked to produce smooth surfaces. An advantage of this plaster image is that it is relatively cheap; should a patron approve of the durable image and be willing to bear further expense, subsequent molds could be made for the creation of a wax image to be used in lost wax casting, a far more expensive process. In lieu of producing a bronze image suitable for outdoor use the plaster image may be painted to resemble a metal image; such sculptures are suitable only for presentation in a weather-protected environment.

Plaster expands while hardening , then contracts slightly just before hardening completely. This makes plaster excellent for use in molds, and it is often used as an artistic material for casting. Plaster is also commonly spread over an armature (form) , usually made of wire, mesh or other materials, a process raised details. For these processes, limestone or acrylic based plaster may be employed .

3 – 3 - In medicine :

Plaster is widely used as a support for broken bones; a bandage impregnated with plaster is moistened and then wrapped around the damaged limb , setting into a close - fitting yet easily removed tube , known as an orthopedic cast ; how ever, this is slowly being replaced by a fibre glass variety.

Plaster is also used within radiotherapy when making immobilization casts for patients. Plaster bandages are used when constructing an impression of the patients head and neck, and liquid plaster is used to fill the impression and produce a plaster bust. Perspex is then vacuum formed over this bust creating an immobilization shell .

In dentistry, plaster is used for mounting casts or models of oral tissues. These diagnostic and working models are usually made from dental stone, a stronger, harder and denser derivative of plaster which is manufactured from gypsum under pressure. Plaster is also used to invest or flask wax dentures, the wax being subsequently removed and replaced with the final denture base material which is cured in the plaster mold .

3 – 4 - In fire protection :

Plasters have been in use in passive fire protection, as fire proofing products, for many decades.

The finished plaster releases water vapor when exposed to flame , acting to slow the spread of the fire, for as much as an hour or two depending on thickness . It also provides some insulation to retard heat flow into structural steel elements, that would other wise lose their strength and collapse in a fire. Early versions of these plasters have used asbestos fibres , which have by now been outlawed in industrialized nations and have caused significant removal and re - coating work . More modern plasters fall into the following categories:

- fibrous (including mineral wool and glass fiber)
- cement mixtures either with mineral wool or with vermiculite
- gypsum plasters, leavened with polystyrene beads, as well as chemical expansion agents to decrease the density of the finished product

One differentiates between interior and exterior fireproofing. Interior products are typically less substantial, with lower densities and lower cost. Exterior products have to withstand more extreme fire and other environmental conditions. Exterior products are also more likely to be attractively tooled, where as their interior cousins are usually merely sprayed in place. A rough surface is typically forgiven inside of buildings as dropped ceilings often hide them. Exterior fireproofing plasters are losing ground to more costly intumescent and endo thermic products, simply on technical merit. Trade jurisdiction on unionized construction sites in North America remains with the plasterers, regardless of whether the plaster is decorative in nature or is used in passive fire protection. Cementitious and gypsum based plasters tend to be endo thermic . Fireproofing plasters are closely related to fire stop mortars. Most firestop mortars can be sprayed and tooled very well, due to the fine detail work that is required of firestopping, which leads their mix designers to utilise concrete admixtures, that enable easier tooling than common mortars.

4 - Safety issues

The chemical reaction that occurs when plaster is mixed with water is exothermic in nature and can therefore cause severe burns.

The potential dangers were demonstrated in January 2007, when a sixteen - year - old girl suffered third - degree burns after encasing her hands in a bucket of plaster as part of a school art project in Lincolnshire , England . The burns were so severe that she subsequently had both thumbs and six of her fingers amputated . For this reason only thin layers of plaster should be used, with time to cool between layers, or strips of cloth in plaster laid-up in the method used by the medical field. In place of plaster, alginate can safely be used for casting body parts.

Some variations of plaster that contain powdered silica or asbestos may present health hazards if inhaled. Asbestos is a known irritant when inhaled in powder form can cause cancer, especially in people who smoke, and inhalation can also cause asbestosis. Inhaled silica can cause silicosis and (in very rare cases) can encourage the development of cancer. Persons working regularly with plaster containing these additives should take precautions to avoid inhaling powdered plaster, cured or uncured. (Note that asbestos is rarely used

Plaster Work

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1 – Introduction :

Plaster work refers to construction or ornamentation done with plaster, such as a layer of plaster on an interior wall or plaster decorative moldings on ceilings or walls. This is also sometimes called pargeting. The process of creating plasterwork, called **plastering**, has been used in building construction for centuries.

2 - History

The earliest plasters known to us were lime-based. Around 7500 BC, the people of 'Ain Ghazal in Jordan used lime mixed with unheated crushed limestone to make plaster which was used on a large scale for covering walls, floors, and hearths in their houses. Often, walls and floors were decorated with red, finger-painted patterns and designs. In ancient India and China, renders in clay and gypsum plasters were used to produce a smooth surface over rough stone or mud brick walls, while in early Egyptian tombs, walls were coated with lime and gypsum plaster and the finished surface was often painted or decorated.

Modeled stucco was employed throughout the Roman Empire. The Romans used mixtures of lime and sand to build up preparatory layers over which finer applications of gypsum, lime, sand and marble dust were made; pozzolanic materials were sometimes added to produce a more rapid set. Following the fall of the Roman Empire, the addition of marble dust to plaster to allow the production of fine detail and a hard, smooth finish in hand - modeled and moulded decoration was not used until the Renaissance. Around the 4th century BC, the Romans discovered the principles of the hydraulic set of lime, which by the addition of highly reactive forms of silica and alumina, such as volcanic earths, could solidify rapidly even under water. There was little use of hydraulic mortar after the Roman period until the 18th century.

Plaster decoration was widely used in Europe in the Middle Ages where, from the mid-13th century, gypsum plaster was used for internal and external plaster. Hair was employed as reinforcement, with additives to assist set or plasticity including malt, urine, beer, milk and eggs.

In the 14th century, decorative cool called pargeting was being used in South-East England to decorate the exterior of timber-framed buildings. This is a form of incised, moulded or modeled ornament, executed in lime putty or mixtures of lime and gypsum plaster.

During this same period, terracotta was reintroduced into Europe and was widely used for the production of ornament.

In the mid-15th century, Venetian skilled workers developed a new type of external facing, called marmorino made by applying lime directly onto masonry.

In the 16th century, a new highly decorative type of decorative internal plasterwork, called scagliola, was invented by stuccoists working in Bavaria. This was composed of gypsum plaster, animal glue and pigments, used to imitate coloured marbles and pietre dure ornament. Sand or marble dust, and lime, were sometimes added. In this same century, the sgraffito technique, also known as graffito or scratchwork was introduced into Germany by Italian artists, combining it with modeled stucco decoration. This technique was practised in antiquity and was described by Vasari as being a quick and durable method for decorating building facades. Here, layers of contrasting lime plaster were applied and a design scratched through the upper layer to reveal the colour beneath.

The 17th century saw the introduction of different types of internal plasterwork. Stucco marble was an artificial marble made using gypsum (sometimes with lime), pigments, water and glue. Stucco lustro was another a form of imitation marble (sometimes called stucco lucido) where a thin layer of lime or gypsum plaster was applied over a scored support of lime, with pigments scattered on surface of the wet plaster.

The 18th century gave rise to renewed interest in innovative external plasters. Oil mastics introduced in the UK in this period included a "Composition or stone paste" patented in 1765 by David Wark. This was a lime-based mix and included "oyls of tar, turpentine and linseed" besides many other ingredients. Another "Composition or cement", including drying oil, was patented in 1773 by Rev. John Liardet. A similar product was patented in 1777 by John Johnson. Widely used by the architect Robert Adam who in turn commissioned George Jackson to produce reverse-cut boxwood moulds (many of which to Adam designs). Jackson formed an independent company which still today produces composition pressings and retains a very large boxwood mould collection.

In 1774, in France, a mémoire was published on the composition of ancient mortars. This was translated into English as "A Practical Essay on a Cement, and Artificial Stone, justly supposed to be that of the Greeks and Romans" and was published in the same year. Following this, and as a backlash to the disappointment felt due to the repeated failure of oil mastics, in the second half of the 18th century water-based renders gained popularity once more.

- Mixes for renders were patented, including a "Water Cement, or Stucco" consisting of lime, sand, bone ash and lime-water (Dr Bryan Higgins, 1779).
- Various experiments mixing different limes with volcanic earths took place in the 18th century. John Smeaton (from 1756) experimented with hydraulic limes and concluded that the best limes were those fired from limestones containing a considerable quantity of clayey material.
- In 1796, Revd James Parker patented Parker's "Roman Cement". This was a hydraulic cement which, when mixed with sand, could be used for stucco. It could also be cast to form mouldings and other ornaments. It was however of an unattractive brown colour, which needed to be disguised by surface finishes.

Natural cements were frequently used in stucco mixes during the 1820s. The popularization of Portland cement changed the composition of stucco, as well as mortar, to a harder material. The development of artificial cements had started early in the 19th century. In 1811, James Frost took out a patent for an artificial cement obtained by lightly calcining ground chalk and clay together. The French Engineer Louis Vicat in 1812–1813 experimented with calcining synthetic mixtures of limestone and clay, a product he introduced in 1818. In 1822, in the UK, James Frost patented (another?) process, similar to Vicat's, producing what he called "British cement". Portland cement, patented in 1824 by Joseph Aspdin, was called so because it was supposed to resemble Portland stone. Aspdinís son William, and later Isaac Johnson, improved the production process. A product, very similar to modern Portland cement, was available from about 1845, with other improvements taking place in the following years.

Thus, after about 1860, most stucco was composed primarily of Portland cement, mixed with some lime. This made it even more versatile and durable. No longer used just as a coating for a substantial material like masonry or log, stucco could now be applied over wood or metal lath attached to a light wood frame. With this increased strength, it ceased to be just a veneer and became a more integral part of the building structure. Early 19th century rendered façades were colour-washed with distemper; oil paint for external walls was introduced around 1840.

The 19th century also saw the revival of the use of oil mastics. In the UK, patents were obtained for "compositions" in 1803 (Thomas Fulchner), 1815 (Christopher Dihl) and 1817 (Peter Hamelin). These oil mastics, as the ones before them, also proved to be short-lived.

Moulded or cast masonry substitutes, such as cast stone and poured concrete, became popular in place of quarried stone during the 19th century. However, this was not the first time "artificial stone" had been widely used. Coade Stone, a brand name for a cast stone made from fired clay, had been developed and manufactured in England from 1769 to 1843 and was used for decorative architectural elements. Following the closure of the factory in South London, Coade stone stopped being produced, and the formula was lost. By the mid 19th century manufacturing centers were preparing cast stones based on cement for use in buildings. These were made primarily with a cement mix often incorporating fine and coarse aggregates for texture, pigments or dyes to imitate colouring and veining of natural stones, as well as other additives.

Also in the 19th century, various mixtures of modified gypsum plasters, such as Keene's cement, appeared. These materials were developed for use as internal wall plasters, increasing the usefulness of simple plaster of Paris as they set more slowly and were thus easier to use.

A plasterer covering a wall, using a hawk (in his left hand) and trowel (in his right hand)

3 - Tools and materials :

Tools and materials include trowels, floats, hammers, screeds, a hawk, scratching tools, utility knives, laths, lath nails, lime, sand, hair, plaster of Paris, a variety of cements, and various ingredients to form color washes.

While most tools have remained unchanged over the centuries, developments in modern materials have led to some changes. Trowels, originally constructed from steel, are now available in a poly carbonate material that allows the application of certain new, acrylic-based materials without staining the finish. Floats, traditionally made of timber (ideally straight-grained, knot-free, yellow pine), are often finished with a layer of sponge or expanded polystyrene.

3 – 1 - Laths :

Lath seen from the back with brown coat oozing through
Main article: Lath

Traditionally, plaster was laid onto laths, rather than plaster board as is more commonplace nowadays.

Wooden laths are narrow strips of straight-grained wood depending on availability of species in lengths of from two to four or five feet to suit the distances at which the timbers of a floor or partition are set. Laths are about an inch wide, and are made in three thicknesses; single (⅛ to 3 ⁄ 16 inch thick), lath and a half (¼ inch thick), and double (⅜ – ½ inch thick).

The thicker laths should be used in ceilings, to stand the extra strain (sometimes they were doubled for extra strength), and the thinner variety in vertical work such as partitions, except where the latter will be subjected to rough usage, in which case thicker laths become necessary. Laths are usually nailed with a space of about ⅜ of an inch between them to form a key for the plaster.

Laths were formerly all made by hand. Most are now made by machinery and are known as sawn laths, those made by hand being called rent or riven laths. Rent laths give the best results, as they split in a line with the grain of the wood, and are stronger and not so liable to twist as machine-made laths, some of the fibers of which are usually cut in the process of sawing.

Laths must be nailed so as to break joint in bays three or four feet wide with ends butted one against the other. By breaking the joints of the lathing in this way, the tendency for the plaster to crack along the line of joints is diminished and a better key is obtained. Every lath should be nailed at each end and wherever it crosses a joist or stud. All timbers over three inches (76 mm) wide should be counter-lathed, that is, have a fillet or double lath nailed along the centre upon which the laths are then nailed. This is done to preserve a good key for the plaster.

Walls liable to damp are sometimes battened and lathed to form an air cavity between the damp wall and the plastering.

Lathing in metal, either in wire or in the form of perforated galvanised sheets, is now extensively used on account of its fireproof and lasting quality. There are many kinds of this material in different designs, the best known in England being the Jhilmil, the Bostwick, Lathing, and Expanded Metal lathing. The two last-named are also widely used in America.

Lathing nails are usually of iron, cut, wrought or cast, and in the better class of work they are galvanized to prevent rusting. Zinc nails are sometimes used, but are costly.

3 – 2 - Lime plastering :

Lime plastering is composed of lime, sand, hair and water in proportions varying according to the nature of the work to be done.

The lime mortar principally used for internal plastering is that calcined from chalk, oyster shells or other nearly pure limestone, and is known as fat, pure, chalk or rich lime. Hydraulic limes are also used by the plasterer, but chiefly for external work.

Perfect slaking of the calcined lime before being used is very important as, if used in a partially slaked condition, it will "blow" when in position and blister the work. Lime should therefore be run as soon as the building is begun, and at least three weeks should elapse between the operation of running the lime and its use.

3 – 2 – 1 – Hair :

Hair is used in plaster as a binding medium, and gives tenacity to the material. Traditionally horsehair was the most commonly-used binder, as it was easily available before the development of the motor-car. Hair functions in much the same way as the strands in fiberglass resin, by controlling and containing any small cracks within the mortar while it dries or when it is subject to flexing.

Ox-hair, which is sold in three qualities, is now the kind usually specified; but horsehair, which is shorter, is sometimes substituted or mixed with the ox-hair in the lower qualities. Good hair should be long (In the UK cow and horse hair of short and long lengths is used), and left greasy (lanolin grease) because this protects against some degradation when introduced in to the very high alkaline plaster.[1] Before use it must be well beaten, or teased, to separate the lumps. In America, goats' hair is frequently used, though it is not so strong as ox-hair. The quantity used in good work is one pound of hair to two or three cubic feet of coarse stuff (in the UK up to 7kg per metric cube). Hair reinforcement in lime plaster is common and many types of hair and other organic fibers can be found in historic plasters However, organic material in lime will degrade in damp environments particularly on damp external renders. This problem has given rise to the use of poly propylene fibers in new lime renders

Manila hemp fiber has been used as a substitute for hair. Plaster for hair slabs made with manila hemp fiber broke at b88 kg , plaster mixed with sisal hemp at 68 kg , jute at 66 kg , and goats' hair at 65 kg . Another test was made in the following manner. Two barrels of mortar were made up of equal proportions of lime and sand, one containing the usual quantity of goats' hair, and the other Manila fiber. After remaining in a dry cellar for nine months the barrels were opened. It was found that the hair had been almost entirely eaten away by the action of the lime, and the mortar consequently broke up and crumbled quite easily. The mortar containing the Manila hemp, on the other hand, showed great cohesion, and required some effort to pull it apart, the hemp fiber being undamaged .

3 – 2 – 2 – Sand / aggregate :

For fine plasterer's sand-work, special sands are used, such as silver sand, which is used when a light color and fine texture are required. In England this fine white sand is procured chiefly from Leighton Buzzard; also in England many traditional plasters had crushed chalk as the aggregate , this made a very flexible plaster suitable for timber frame buildings.

For external work Portland cement is undoubtedly the best material on account of its strength, durability, and weather resisting external properties, but not on historic structures that are required to flex and breathe , for this lime with out cement is used.

Sawdust has been used as a substitute for hair and also instead of sand as an aggregate. Sawdust will enable mortar to stand the effects of frost and rough weather. It is useful sometimes for heavy cornices and similar work, as it renders the material light and strong. The sawdust should be used dry. The sawdust is used to bind the mix sometimes to make it go further.

4 – Methods :

The first coat or rendering is from 1/2 to 3/4 inches thick, and is mixed in the proportions of from one part of cement to two of sand to one part to five of sand. The finishing or setting coat is about 3/16 inches thick, and is worked with a hand float on the surface of the rendering, which must first be well wetted.

4 – 1 - External plastering :

Stucco is a term loosely applied to nearly all kinds of external plastering, whether composed of lime or of cement. At the present time it has fallen into disfavor, but in the early part of the 19th century a great deal of this work was done. Cement has largely superseded lime for this work. The principal varieties of stucco are common, rough , trowel led and bastard. .

- Common stucco for external work is usually composed of one part hydraulic lime and three parts sand. The wall should be sufficiently rough to form a key and well wetted to prevent the moisture being absorbed from the plaster.
- Rough stucco is used to imitate stone work. It is worked with a hand float covered with rough felt (a stiff bristled brush can also be used), which forms a sand surface on the plaster. Lines are ruled before the stuff is set to represent the joints of stonework.
- Trowel led stucco, the finishing coat of this work, consists of three parts sand to two parts fine stuff. A very fine smooth surface is produced by means of the hand float.

- Bastard stucco is of similar composition, but less labor is expended on it. It is laid on in two coats with a skimming float, scoured off at once, and then trowel led.
- Colored stucco: lime stucco may be executed in colors, the desired tints being obtained by mixing with the lime various oxides. Black and grays are obtained by using forge ashes in varying proportions, greens by green enamel, reds by using litharge or red lead, and blues by mixing oxide or carbonate of copper with the other materials.

Roughcast or pebbledash plastering is a rough form of external plastering in much use for country houses. In Scotland it is termed "harling". It is one of the oldest forms of external plastering. In Tudor times it was employed to fill in between the woodwork of half-timbered framing. When well executed with good material this kind of plastering is very durable.

Roughcasting is performed by first rendering the wall or laths with a coat of well-haired coarse stuff composed either of good hydraulic lime or of Portland cement. This layer is well scratched to give a key for the next coat. The second coat is also composed of coarse stuff knocked up to a smooth and uniform consistency. Two finish two techniques can be used:

- dry dash: while the first coat is still soft, gravel, shingle or other small stones are evenly thrown on with a small scoop and then brushed over with thin lime mortar to give a uniform surface. The shingle is often dipped in hot lime paste, well stirred up, and used as required.
- wet dash: the traditional roughcast, harling the scratch or undercoat is left to cure and in the final coat the gravel / aggregate is mixed with the lime and sand and thrown on with the plaster spoon/scoop.

4 – 2 - Sgraffito (scratched ornament) :

Sgraffito is the name for scratched ornament in plaster. Scratched ornament is the oldest form of surface decoration, and is much used on the continent of Europe, especially in Germany and Italy, in both external and internal situations.

Properly treated, the work is durable, effective and inexpensive. A first coat or rendering of Portland cement and sand, in the proportion of one to three, is laid on about an inch thick; then follows the color coat, sometimes put on in patches of different tints as required for the finished design. When this coat is nearly dry, it is finished with a smooth-skimming, 1/12 to 1/8 inches thick, of Parian, selenitic or other fine cement or lime, only as much as can be finished in one day being laid on.

Then by pouncing through the pricked cartoon, the design is transferred to the plastered surface. Broad spaces of background are now exposed by removing the finishing coat, thus revealing the colored plaster beneath, and following this the outlines of the rest of the design are scratched with an iron knife through the outer skimming to the underlying tinted surface.

Sometimes the coats are in three different colors, such as brown for the first, red for the second, and white or grey for the final coat. The pigments used for this work include Indian red, Turkey red, Antwerp blue, German blue, umber, ochre, purple brown, bone black or oxide of manganese for black. Combinations of these colors are made to produce any desired tone.

4 – 3 – Coats :

Plasters are applied in successive coats or layers on walls or lathing and gains its name from the number of these coats.

- One coat work is the coarsest and cheapest class of plastering, and is limited to inferior buildings, such as outhouses, where merely a rough coating is required to keep out the weather and draughts. This is described as render on brick work , and lath and lay or lath and plaster one coat on studding.
- Two-coat work is often used for factories or warehouses and the less important rooms of residences. The first coat is of coarse stuff finished fair with the darby float and

scoured. A thin coat of setting stuff is then laid on, and trowelled and brushed smooth. Two-coat work is described as render and set on walls, and lath, plaster and set, or lath, lay and set on laths.

- Three - coat work is usually specified for all good work. It consists, as its name implies, of three layers of material, and is described as render, float and set on walls and lath, plaster, float and set, or lath, lay, float and set, on lathwork. This makes a strong, straight, sanitary coating for walls and ceilings.

The process for three coat work is as follows :

- For the first coat a layer of well-haired coarse stuff, about 1 inch thick, is put on with the laying trowel. This is termed "pricking up" in London, and in America "scratch coating". It should be laid on diagonally, each trowelful overlapping the previous one. When on laths the stuff should be plastic enough to be worked through the spaces between the laths to form a key, yet so firm as not to drop off. The surface while still soft is scratched with a lath to give a key for the next coat.In Scotland this part of the process is termed "straightening" and in America "browning", and is performed when the first coat is dry, so as to form a straight surface to receive the finishing coat.
- The second or "floating coat", and is 1/4 to 3/8 inches thick. Four operations are involved in laying the second coat, namely, forming the screeds; filling in the spaces between the screeds; scouring the surface; keying the face for finishing.
    - Wall screeds are plumbed and ceiling screeds leveled. Screeds are narrow strips of plastering, carefully plumbed and leveled, so as to form a guide upon which the floating rule is run, thus securing a perfectly horizontal or vertical surface, or, in the case of circular work, a uniform curve.
    - The filling in, or flanking, consists of laying the spaces between the screeds with coarse stuff, which is

brought flush with the level of the screeds with the floating rule.

  - The scouring of the floating coat is of great importance, for it consolidates the material, and, besides hardening it, prevents it from cracking. It is done by the plasterer with a hand float that he applies vigorously with a rapid circular motion, at the same time sprinkling the work with water from a stock brush in the other hand. Any small holes or inequalities are filled up as he proceeds. The whole surface should be uniformly scoured two or three times, with an interval between each operation of from six to twenty-four hours. This process leaves the plaster with a close-grained and fairly smooth surface, offering little or no key to the coat that is to follow.
  - To obtain proper cohesion, however, a roughened face is necessary, and this is obtained by keying the surface with a wire brush or nail float, that is, a hand float with the point of a nail sticking through and projecting about 1/8 inch; sometimes a point is put at each corner of the float.
- After the floating is finished to the walls and ceiling, the next part of internal plastering is the running of the cornice, followed by the finishing of the ceiling and walls.
- The third and final coat is the setting coat, which should be about 1/8 inch thick. In Scotland it is termed the "finishing coat", and in America the "hard finish coat" or "putty coat". Setting stuff should not be applied until the floating is quite firm and nearly dry, but it must not be too dry or the moisture will be drawn from the setting stuff.

The composition of an interior tree coat plaster :

- The coarse stuff applied as the first coat is composed of sand and lime, usually in proportions approximating to two to one, with hair mixed into it in quantities of about a pound to two or three cubic feet of mortar. It should be mixed with clean water to such a consistency that a quantity picked up on the point of a trowel holds well together and does not drop.

- Floating stuff is of finer texture than that used for pricking up, and is used in a softer state, enabling it to be worked well into the keying of the first coat. A smaller proportion of hair is also used.
- Fine stuff mixed with sand is used for the setting coat. Fine stuff, or lime putty, is pure lime that has been slaked and then mixed with water to a semi-fluid consistency, and allowed to stand until it has developed into a soft paste.
    - For use in setting it is mixed with fine washed sand in the ratio of one to three.
    - For cornices and for setting when the second coat is not allowed time to dry properly, a special compound must be used. This is often gauged stuff, composed of three or four parts of lime putty and one part of plaster of Paris, mixed up in small quantities immediately before use. The plaster in the material causes it to set rapidly, but if it is present in too large a proportion the work will crack in setting.

The hard cements used for plastering, such as Parian, Keene's, and Martin's, are laid generally in two coats, the first of cement and sand 1/2 to 3/4 inches thick, the second or setting coat of neat cement about 1/8 inch thick. These and similar cements have gypsum as a base, to which a certain proportion of another substance, such as alum, borax or carbonate of soda, is added, and the whole baked or calcined at a low temperature. The plaster they contain causes them to set quickly with a very hard smooth surface, which may be painted or papered within a few hours of its being finished.

Cement render :

In Western Australia plaster or cement render that is applied to external brickwork on dwellings or commercial buildings can be one or two coats.

- Materials used in the render are commonly sand of a light yellow colour with little clay content with fine to coarse grains or sand. Sand finish is the common term used for external render and may be one or two coats, the better being two coat as it gives a more consistent finish and less chance of becoming drummy or cracking.

- In two coat render a base coat is applied with a common mix of 4 parts sand to one part cement and one part dehydrated lime and water to make a consistent mortar. Render is applied using a hawk and trowel and pushed on about 12 mm thick to begin. Most plasterers use a tbar to screed the walls until it is plumb straight and square. The wall is scratched after screening is complete to give key to second coat.
- The second can be slightly weaker or the same 5/1/1 and maybe a water proofer in the mix added in the water to minimize efflorescence (rising of salts). Some plasterers used lime putty in second coat instead of dehydrated lime in the render. The mortar is applied to about 5 mm thick and when the render hardens is screened off straight. A wood float or plastic float is used to rub down the walls.
- Water is splashed on walls and immediately rubbing the float in a circular or figure 8 motion (figure of 8 can leave marks).After the work area is all floated, the finishing with a sponge using the same method as floating with wood float. Bringing sand to the surface.
- Most plasterers use a hose with a special nozzle with a fine mist spray to damped walls when rubbing up (using a wood float to bring a consistent finish). This method using a hose brings a superior finish and more consistent in colour as there is more chance in catching the render before it has a chance to harden too much.

4 – 4 – Moldings :

Plain, or unenriched, moldings are formed with a running mold of zinc cut to the required profile.

- For a cornice molding two running rules are usual, one on the wall, the other on the ceiling, upon which the mold is worked to and from by one workman, while another man roughly lays on the plaster to the shape of the molding. The miters at the angles are finished off with joint rules made of sheet steel of various lengths, three or four inches (102 mm) wide, and about one - eighth inch thick, with one end cut to an angle of about 30°. In some cases the steel plate is let into a stock or handle of hardwood.

Enrichments may be moldings added after the main outline molding is set, and are casted in molds made of gelatin or plaster of Paris.

4 – 5 – Cracks :

Cracks in plastering may be caused by settlement of the building, by the use of inferior materials or by bad work man ship.

However, due to none of these, cracks may yet ensue by the too fast drying of the work, caused through the laying of plaster on dry walls which suck from the composition the moisture required to enable it to set, by the application of external heat or the heat of the sun, by the laying of a coat upon one which has not properly set, the cracking in this case being caused by unequal contraction, or by the use of too small a proportion of sand.

Traditionally, crack propagation was arrested by stirring chopped horsehair thoroughly into the plaster mix.

4 – 1 – Slabs :

For partitions and ceilings, plaster slabs are used to finish quickly. For ceilings metal lathing require simply to be nailed to the joists, the joints being made with plaster, and the whole finished with a thin setting coat or slab. In some cases, with fireproof ceilings, for instance, the metal lathing are hung up with wire hangers so as to allow a space of several inches between the soffit of the concrete floor and the ceiling. For partitions metal laths are grouted in with semi - fluid plaster. Where very great strength is required the work may be reinforced by small iron rods through the slabs. This forms a very strong and rigid partition which is at the same time fire-resisting and of light weight, and when finished measures only from two to four inches (102 mm) thick . So strong is the result that partitions of this class only two or three inches (76 mm) thick were used for temporary cells for prisoners at Newgate Gaol during the rebuilding of the new sessions house in the Old Bailey in London.

The slabs may be obtained either with a keyed surface, which requires finishing with a setting coat when the partition or ceiling is in position, or a smooth finished face, which may be papered or painted immediately the joints have been carefully made.

4 – 7 - Fibrous plaster :

Fibrous plaster is given by plasterers the suggestive name "stick and rag", and this is a rough description of the material, for it is fibrous composed of plaster laid upon a backing of canvas stretched on wood. It is much used for moldings, circular and enriched casings to columns and girders and ornamental work, which is worked in the shop and fixed in position.

Desachy, a French modeler, took out in 1856 a patent for "producing architectural moldings, ornaments and other works of art, with surfaces of plaster," with the aid of plaster, glue, wood, wire, and canvas or other woven fabric.

The modern use of this material may be said to have started then, but the use of fibrous plaster was known and practiced by the Egyptians long before the Christian era; for ancient coffins and mummies still preserved prove that linen stiffened with plaster was used for decorating coffins and making masks. Cennino Cennini, writing in 1437, says that fine linen soaked in glue and plaster and laid on wood was used for forming grounds for painting.

Canvas and mortar were in general use in Great Britain up to the middle of the last century. This work is also much used for temporary work, such as exhibition buildings.

5 – Plastering :

5 – 1 - Modern interior plastering techniques :

There are two main methods in USA used in construction of the interior walls of modern homes, plasterboard, also called drywall, and veneer plastering.

Plaster board

In plaster board a specialized form of sheet rock known as "green board" (because on the outer paper coating is greenish) is screwed onto the wall-frames (studs) of the home to form the interior walls. At the place where the two edges of wallboards meet there is a seam. These seams are covered with mesh tape and then the seams and the screw heads are concealed with the drywall compound to make the wall seem as one uniform piece. The drywall plaster is a thick paste. Later this is painted or wallpapered over to hide the work. This process is typically called "taping" and those who use drywall are known as "tapers".

Plaster veneer

Veneer plastering covers the entire wall with thin liquid plaster, uses a great deal of water and is applied very wet. The walls intended to be plastered are hanged with "Blue board" (named as such for the industry standard of the outer paper being blue-grey in color). This type of sheet rock is designed to absorb some of the moisture of the plaster and thus allow it to cling the plaster better before it sets.

Veneer plastering is a one-shot one-coat application; taping usually requires sanding and then adding an additional coat; since the compound shrinks as it dries.

5 – 2 - Traditional Plastering :

The plasterer usually shows up after the hangers have finished building all the internal walls, by attaching blue board over the frames of the house with screws. The plasterer is usually a subcontractor working in crews that average about three veterans and one laborer. The job of the laborer is to set up ahead of and clean up behind the plasterers, so they can concentrate on spreading the "mud" on the walls.

5 – 2 - 1 - Laborer's tasks :

- Debris left on the floors from the "hanging" crew must be removed before floor paper can be set down and to remove any tripping hazards.
- Cover the floors with tar or brown paper since plaster can stain or be hard to remove from subflooring plywood.
- Run hoses and extension cords and set up job lights.
- Cover all seams with **mesh tape** as well as any large gaps around outlets caused by poor roto-zip work. Gouge out any bubble in the wallboard caused by broken sheetrock under the paper and cover the holes with mesh tape. Remove any loose screws (flies) left from the hanger missing the underlying frame.
- Cover all windows and doors with plastic sheets and masking tape to protect the wood of their frames and save on cleaning. If any plumbing fixtures or wall plugs have been installed they are also covered, as well as the bathtubs and showers.
- Set up for the next mix. As soon as the table is cleared the laborer is given instructions of how many bags will be needed as well as the next room to be worked in. The table typically consists of folding legs upon which is set a square board of wood and then covered in a plastic sheet upon which the plaster is placed in the center in a large pile.
- Mixing the product. The mixing barrel is usually pre-filled to a certain level with water; since it can take some time to fill. The amount of water is usually estimated (with a margin of error leaning towards too little). The amount of water required is obtained from the amount of bags planned to be mixed. The estimation is not difficult for an experienced plasterer; who knows how many sheets he can typically cover, and that one bag usually covers 2 & 1/2 to 3 sheets and 5 gallons of water is needed for one standard 50 pound bag. With a permanent crew

that normally does the same amount per mix one can simply fill up the barrel to a known cut - off point.

- Once the mix is set up and the plasterers are ready they instruct the laborer to start dumping the bags in the water barrel, while intermittently running the mixing drill. Once all bags are in the barrel more water is slowly added until the plaster is of proper consistency and is then thoroughly mixed. Before the mixing is completed, a margin trowel (or margin for short) is scraped along the inside wall of the barrel to knock off clinging unmixed clumps (known as cutting in) to be furthered mixed until all is homogeneous.
- While mixing the drill is slowly brought up and down and follows the edge of the barrel in a circular motion to drag the top of the mix down and ensure an even consistency throughout the mix. Care is taken not to allow the drill's paddle to hit the bottom or sides of the barrel; this can scrape off plastic bits that end up in the mix. At a certain point before the mixing is done a margin trowel is again used to scrape any clinging dry plaster into the rest of the mix. typically this is when the accelerator; if used is added. Mixing can be fatigueing in that the drill tends to not only be heavy but the mixer must also fight the torc of the paddle.
- Shovel the mix onto the table. The mixing barrel must be emptied as soon as possible, as the plaster will set faster in the barrel then on the table. but the table cannot be overfilled or it may tip or plaster will spill off the sides and splatter when it hits the floor. While shoveling care must also be taken not to splatter any plaster onto nearby walls.
- Clean up the mix barrel. This is done outside with a hose and nozzle. If any plaster remains they can contaminate the next mix with "rocks" that greatly vex the plasterers as they get dragged across the walls and the contamination causes the plaster to set much quicker.
- Final clean up. This includes rolling up all paper flooring in finished rooms. knocking the plaster out of plug outlet holes with a drywall hammer/hatchet, taking down any

masking tape and plastic, cleaning up any plaster that has splattered onto the floor etc.

5 – 2 - 2 - Plasterer's tasks :

Normally the contractor has already supplied all the bags of Gypsum plaster that will be needed, as well as any external supply of water if the house is not yet connected. Normally the type of plaster that is used is an industry standard called Uni-Kal. There is also another type not used as often called Kal-Kote; its finish is slightly different and not as bone white as Uncial. The two products are distinguished by a color stripe across the top of the bag. Uni-Kal is rusty red, and Kal-Kote is purplish/maroon. The plastering crew needs to bring their own tools and equipment and sometimes supply their own bead.

The Tasks that the plasterer is usually expected to accomplish.

- ***Hang corner bead***

The plasterer usually must first staple or tack Cornerbead onto every protruding (external) corner of the inside of the house. Care is taken to make sure this makes the wall look straight and is more of a skill of the eye than anything else.

  - "Bead" comes in many styles; Ranging from wire mesh attached by staples to heavier metal grades the need to be tacked on with nails. Plastic varieties also exist.
  - The bead must be measured and cut to size; care is taken not to bend or warp it. In places where more than one corner meets; the bead's ends are cut at an angle and the 2 or more tips are placed as close together as allowable; touching but not overlapping. The bead is completely covered with plaster as well as the rest of the wall and the plaster also helps to hold it firm. The finished product leaves only a small exposed metal strip at the protrusion of the corner which gets covered when the wall is painted. This leaves a clean, straight looking corner.

  - An alternative method seen in older houses of forming a rounded or bullnosed corner uses a quirked wooden staff bead. The staff bead, a 1 inch dowel with approx 1/3 shaved off the back, is set on the external corner by the joiner on site, fastened to wooden plugs set into the brick/block seams, or to the wood frame. Plaster is run up to the staff bead and then cut back locally to the bead or "quirked" to avoid a weak feather edge where the plaster meets the bead.
  - In architecture a quirk is a small 'V' shaped channel used to insulate and give relief to a convex rounded moulding. To create the plastered corner, backing coat (browning) is plastered up to the staff bead, then the quirk is cut into the backing coat a little larger than the finished size. When the top skimming coat is applied, again the bead is fully skimmed in and then, using a straight edge, the quirk is re-cut to the finished depth, usually on an approximate 45 degree angle into the bead. The quirk will hide the eventual small crack that will form between the staff bead and plaster.

- ***Sets up his tools***

The plasterer needs to fill a 5-gallon bucket partway with water. From this bucket he hangs his trowel or trowels and places into it various tools.

  - Normally a plasterer has one trowel for "laying on" (the process of placing mud onto the wall).
  - Some then keep an older trowel that has a decent bend in it (banana curve) to be used for the purpose of "texturing"; if called for by the homeowner. A lay-on trowel tends to be too flat for this and the vacuum caused by the water can stick it to the wall, forcing him to tear it off and thus he has to rework the area.
  - Finally, one may have a brand new trowel "not yet broken-in" which he will used for "grinding"; this is when the plaster is nearly hardened and he is smoothing

out any bumps or filling in any small dips (cat faces) to make the wall look like a uniform sheet of glossy white plaster.

Most plasterers have their own preference for the size of the trowel they use. some wield trowels as large as 20 inches long but the norm seems to be a 16"×5". *From my experience the preferred brand is a Marshalltown stainless steel. They have a brassy luster to them, a rubber handle and won't pit or rust if accidentally left in water overnight* while others prefer a regular steal trowel which requires more maintenance but lasts for quite a long time and the pitting can give it a "bite" that helps when "finishing" (the last pass when the plaster is setting).

Into the bucket also goes a large brush used to splash water onto the wall and to clean his tools, a paint brush for smoothing corners, and a corner bird for forming corners (*though many share one good bird to keep the room harmonious*).

These tool buckets are first kept near the mix table and then as the plaster starts to set are moved closer to the wall that is being worked on. *Time becomes a big factor here as once the plaster starts to harden (set) it will do so fairly rapidly and the plasterer has a small margin of error to get the wall smooth*.

Onto the mixing table the plasterer usually sets his "hawk" so it will be handy when he needs to grab it and to keep dirt off of it. Any debris in the plaster can become a major nuisance.

- ***Plaster tops or bottom?***

Plasterers will typically divide a room, (especially a large or high-ceilinged wall) into top and bottom. The one working on top will do from the ceiling's edge to about belly height and work off a milk crate for an 8-foot (2.4 m) ceiling, or work off stilts for 12-foot-high rooms. For cathedral ceilings or very high walls, staging is set up and one works topside, the others further below.

- ***Clean up before they finish a job***

Typically done with the laborer. No plaster globs left on the floors, walls or corner bead edges. (They will show up if painted and interfere with flooring and trim). Remove or neatly stack all trash.

- ***Inspection***

All rooms and walls are inspected for cracking and dents or scratches that may have been caused from others bumping into the walls. They are also inspected to make sure no bumps are left on the walls from splashed plaster or water. All rooms are checked to make sure all plaster is knocked out of the outlets so the electrician can install the sockets and to make sure no tools are left behind. This leaves the walls ready for the painters and finishers to come in and do their trade.

5 – 2 - 3 - Interior plastering techniques :

5 – 2 - 3 – 1 – Smooth :

The home owner and the plasterer's boss will usually decide beforehand what styles they will use in the house. Typically walls are smooth and sometimes ceilings. Usually a homeowner will opt to have the ceilings use a "texture" technique as it is much easier, faster, and thus cheaper than a smooth ceiling.

The plasterer quotes prices based on techniques to be used and board feet to be covered to the contractor or homeowner before work begins. The board feet is obtained by the hangers or estimated by the head subcontractor by counting the wallboards that come in an industry standard of 8' to 12' long. He then adds in extra expenses for soffits and cathedral ceilings.

- Ceiling second or first

Typically if the ceiling is to be smooth it is done first, before the walls. If it is to be textured, it is done after the walls.

The reason for this is that invariably when a ceiling is being worked on plaster will fall and splash onto the walls. However a texture mix doesn't need to be smoothed out when it starts to set:

- thus a retardant such as "Cream of tartar" or sugar can be used to prolong the setting time, and is easily scraped off the walls.
- and since time is not as restraining of a factor on textured ceilings a large mix, or back-to-back mixes can be done and all ceilings covered at the same time.
- another reason is that a bird is usually run along the top corner after doing a smooth ceiling, then it is easier to maintain this edge by doing the wall last. But a textured ceiling normally doesn't need to be birded, only blended in with a very wet paint brush. In this case the wall is done first and the corner formed with the bird.

- ***Scratching***

The first thing the plasterer tends to do is go over all the mesh-taped seams of the walls he is about to cover; in a very thin swatch. The wallboard draws moisture out of this strip so when the plasterer goes over it again when doing the rest of the wall it will not leave an indented seam that needs further reworking.

He then fills in the area near the ceiling so he will not have to stretch to reach it during the rest of the wall; And he forms the corner with his bird. This saves much needed time as this process is a race against the chemical reaction.

- ***Laying on***

From the mix table the plasterer scoops some "mud" onto the center of his hawk with his trowel. Holding the hawk in his off-hand and his trowel in his primary the plasterer then scoops a bulging roll of plaster onto his trowel. this takes a bit of practice to master, especially with soupy mixes.

Then holding the trowel parallel to the wall and at a slight angle of the wrist he tries to uniformly roll the plaster onto the wall. In a manner similar to a squeegee. He starts about an inch above the floor and works his way upwards to the ceiling. Care is taken to be uniform as possible as it helps in the finishing phase.

- ***Knocking down***

Depending on the setting time of the plaster. once the moisture of the plaster starts to be drawn by the board a second pass is made. this is called knocking down. it is much like applying paint with a roller in wrist action and purpose. to smooth out any lines and fill in any major voids that will make extra work once the plaster starts to truly set. very little pressure is applied and the trowel is kept relatively flat towards the wall.

- ***Setting***

Sometimes an accelerant will be added to a mix to hasten the time delay from the initial mixing phase to when the plaster starts to set. This is normally done on cold days when setting is delayed or for small jobs to minimize the wait.

Once the plaster is on the wall and starts to set (this can be determined by the table that sets first), the plasterer gingerly sprinkles water onto the wall; this helps to stall the setting and to create a slip. He then uses his trowel and often a wetted felt brush held in the opposite hand and lightly touching the wall ahead of the trowel to work this slip into any small gaps (known as "catfaces") in the plaster as well as smooth out the rough lay-on and flatten any air bubbles that formed during setting.

This is a crucial time because if the wall gets too hard it is nearly impossible to fill in any gaps as the slip will no longer set with the wall and will instead just dry and fall out. This leads to the need of what is called "grinding" as one must go over the hard wall again and again trying to smooth out the hardened wall and any major catfaces must be filled in with a contour putty, joint compound, or reworked by blending in a fresh, thin coat.

The finished wall will look glossy and uniformly flat and is smooth to the touch. After a few days it will become chalky white and can then be painted over.

- **Mix**

From the time the bags are dumped into the barrel to when the wall is completely set is called a mix. Varying on the technique used and whether accelerant or retardant is added, a mix typically lasts about two hours.

The final moments are the most frantic if it is smooth or if the mix sets quicker than anticipated. If this happens it is said the mix has "snapped" and is normally due to using old product or various types of weather (humidity or hot days can cause plaster to set quicker). Normally only three or four mixes are done in a day as plastering is very tiring and not as effective under unnatural lighting in the months with early dusk.

- **Seasons**

Plastering is done year round but unique problems may arise from season to season. In the summer, the heat tends to cause the plaster to set faster. The plaster also generates its own heat and houses can become quite hellish. Typically the plaster crew will try to arrive at the house well before dawn.

In winter months, short days cause the need of artificial lighting. At certain angles these lights can make even the smoothest wall look like the surface of the moon. Another dilemma in the winter months is needing to use propane jet heaters (which can stain the plaster yellowish but do not otherwise hurt it), not just to keep the plasterers warm but to also prevent the water in the mix from freezing and generating ice crystals before the plaster has time to set. Also if the water hose is not thoroughly drained before leaving it can freeze over night and be completely stopped up in the morning.

5 – 2 - 3 – 2 – Textured :

Texturing is usually reserved for closets, ceilings and garage walls.

Typically a retarding agent is added to the mix. this is normally Cream of Tartar (or "Dope" in the plasterer's jargon) and care must be taken with the amount added. Too much and the mix may never set at all. However the amount used is often estimated; much the way one adds a dash of salt to a recipe. you add a small scoop of retarder, dependent on the size of the mix. Retardant is added so that larger mixes can be made, since the texture technique doesn't require the person to wait until it starts to set before working it.

The lay-on phase is the same as smooth but it is added with a thicker coat. Once the coat is on uniformly the plasterer then goes back and birds his corners. Staying away from the corner he then gets a trowel with a nice banana curve in it and starts to run it over the wall in a figure eight or Ess pattern, making sure to cross all areas at least once. He adds a little extra plaster to his trowel if needed. The overall effect is layers of paint-like swaths over the whole of the ceiling or wall. He can then just walk away and let it set with care taken not too leave any globs and to make sure the corners look smooth and linear.

If a wall is to be smooth and the ceiling textured, typically the wall is done first, then the ceiling after the wall has set. Instead of rebinding the ceiling (which would have been done when the wall was laid on), a clean trowel is held against the wall and its corner is run along the ceiling to "cut it in" and clean the wall at the same time. This line is then smoothed with a paintbrush to make the transition seamless.

5 – 2 - 3 – 3 – Sponge :

The sponge (technically called a float), has a circle form and rough surface. it is fixed to a backing with a central handhold and is roughly the size of a standard trowel. Sponge is a variant texture technique and used normally on ceilings and sometimes in closets.

Typically when using a sponge ; sand is added to the mix and the technique is called sand - sponge.

Care must be taken not to stand directly under your trowel when doing this as it is very, very unpleasant, and dangerous to get a grain of sand in your eye; which is compounded by the irritation from the lime as well. This combination can easily scratch the eye.

The lay-on and mix is the same as with regular texturing. however after a uniform and smooth coat is placed on the ceiling and the edges are cut in; a special rectangular sponge with a handle is run across the ceiling in overlapping and circular motions. This takes some skill and practice to do well.

The overall look is a fish scale type pattern on the ceiling, closet wall, etc. Even though retarder is typically used; care must be taken to clean out the sponge thoroughly when finished as any plaster that hardens inside it will be impossible to remove.

5 – 2 - 3 – 4 – Ceilings :

Stilts are often required to plaster most ceilings and it is typically harder to lay- on and work than walls. For short ceilings one can also work with milk crates. The difficulty of working upside down often results in plaster bombs splattering on the floors, walls and people below.

This is why smooth ceilings, that use no retardant and sometimes even accelerant, are done before the walls. Retarded plaster can easily be scraped off a smooth plaster wall when wet. Any splatters from a smooth ceiling can easily be scraped off bare blueboard but not from an already plastered wall. Care must be taken when standing under your trowel or another plasterer.

The general difficulty of working a smooth ceiling fetches a higher cost. The technique is the same as a smooth wall but at an awkward angle for the plasterer.

5 – 2 - 4 –Tools of the trade :

- Broom
- Bucket trowel
- Corner bead
- corner bird
- **Display bird**-can be set for wider than 90 degree angles
- Drywall Hammer or Drywall Hatchet -- use to clear plaster globs out of plugholes.
- **extension cords**
- **5 gallon buckets**-for tools, washing, steps/stools, for small patch mixes, lugging plaster onto staging etc.
- Floor scraper -- *Optional*
- Gauging trowel
- **Halogen** work lights
- Hawk (plasterer's tool)
- **High RPM mixing drill** with appropriate paddle
- **ladders** and a few 6×4 planks-*supplemental*
- **masking tape** -- for window panes and door jambs
- mesh tape--multiple rolls
- Milk crate -- used to store tools and as stools
- **Multi cord outlet**
- Pipe Staging-*supplemental*
- **Plastic 30 to 50 gallon drum**-For mixing, often obtained from car washes
- putty knife --*supplemental*
- **Scoop** -*supplemental*-- to remove plaster from a bucket
- **Shovel** -- short handled, is used to load the table with plaster mud.
- soft bristle paintbrush -- for smoothing edges and corners
- Trowels--various sizes and levels of breaking-in (cost avg $ 60)
- Margin Trowel or margin for short—for edging the mix barrel
- **Spat or spatula trowel**

- sponge (tool)/Float
- **Staple gun** -- for corner bead
- **table stand** and a table board
- tar paper or brown paper rolls—tar paper offers more water protection and is a bit more resilient but is costlier to use.
- roll of **plastic sheeting**
- Uni-Kal -- a gypsum based plaster that comes in 50 pnd bags.
- Kal-Kote -- an alternate brand with a slightly less glossy finish
- DIAMOND Basecoat -- used in cases where cracking is suspected to occur, deep fill-ins
- Utility knife--to cut plastic sheeting for table boards and floor covering paper
- **Water hose and nozzle**
- **Water brush** – large, for cleaning tools and splashing walls

Plasticizer

PVC, as in these pipes, is the most important application of plasticizers.

Contents

1 – Introduction :

Plasticizers or **dispersants** are additives that increase the plasticity or fluidity of a material. The dominant applications are for plastics, especially polyvinyl chloride (PVC). The properties of other materials are also improved when blended with plasticizers including concrete, clays, and related products. The worldwide market for plasticizers in 2000 was estimated to be several million tons per year.

2 - For plastics :

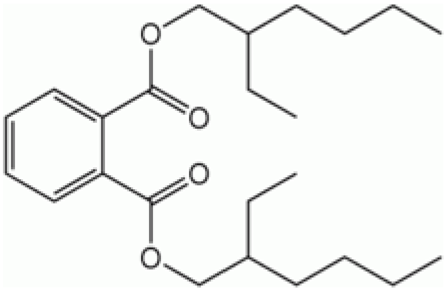
Plasticizers for plastics are additives, most commonly phthalate ester. Almost 90 % of the market for plasticizer is for PVC, giving this material improved flexibility and durability.[1] Plasticizers work by embedding themselves between the chains of polymers, spacing them apart (increasing the "free volume"), and thus significantly lowering the glass transition temperature for the plastic and making it softer. For plastics such as PVC, the more plasticizer added, the lower its cold flex temperature will be. This means that it will be more flexible and its durability will increase as a result of it. Plasticizers evaporate and tend to concentrate in an enclosed space; the "new car smell" is caused mostly by plasticizers evaporating from the car interior.

Plasticizers make it possible to achieve improved compound processing characteristics, while also providing flexibility in the end-use product. Ester plasticizers are selected based upon cost-performance evaluation. The rubber compounder must evaluate ester plasticizers for compatibility, process ability, permanence and other performance properties. The wide variety of ester chemistries that are in production include sebacates, adipates, gluterates, phthalates, azelates, and other specialty blends. This broad product line provides an array of performance benefits required for the many elastomer applications such as tubing and hose products, seals and gaskets, belts, wire and cable and print rolls. Low to high polarity esters provide utility in a wide range of elastomers including nitrile, poly chloroprene, EPDM, chlorinated polyethylene, and epichloro hydrin. Plasticizer-elastomer interaction is governed by many factors such as solubility parameter, molecular weight and chemical structure. Compatibility and performance attributes are key factors in developing a rubber formulation for a particular application .

Plasticizers also function as softeners, extenders, and lubricants, and play a significant role in rubber manufacturing.

2 - 1 - Ester plasticizers :

Plasticizers used in PVC and other plastics are often based on esters of poly carboxylic acids with linear or branched aliphatic alcohols of moderate chain length. These compounds are selected on the basis of many critieria including low toxicity, compatibility with the host material, nonvolatility, and expense. Phthalate esters of C8 alcohols meet these specifications and common plasticizers.



Bis(2-ethylhexyl) phthalate is a common plasticizer.

3 - For concrete :

Plasticizers or **water reducers**, and super plasticizer or **high range water reducers**, are chemical admixtures that can be added to concrete mixtures to improve work ability. Unless the mix is "starved" of water, the strength of concrete is inversely proportional to the amount of water added or water-cement (w/c) ratio. In order to produce stronger concrete, less water is added (without "starving" the mix), which makes the concrete mixture less workable and difficult to mix, necessitating the use of plasticizers, water reducers, superplasticizers or dispersants. b

Plasticizers are also often used when pozzolanic ash is added to concrete to improve strength. This method of mix proportioning is especially popular when producing high-strength concrete and fiber-reinforced concrete.

Adding 1- 2 % plasticizer per unit weight of cement is usually sufficient. Adding an excessive amount of plasticizer will result in excessive segregation of concrete and is not advisable. Depending on the particular chemical used, use of too much plasticizer may result in a retarding effect.

Plasticizers are commonly manufactured from pop ligno sulfonates, a by- product from the paper industry. Super plasticizers have generally been manufactured from sulfonated naphthalene condensate or sulfonated melamine formaldehyde, although newer products based on poly carboxylic ethers are now available. Traditional ligno sulfonate -based plasticisers, naphthalene and melamine sulfonate-based super plasticisers disperse the flocculated cement particles through a mechanism of electrostatic repulsion (see colloid). In normal plasticisers, the active substances are adsorbed on to the cement particles, giving them a negative charge, which leads to repulsion between particles. Lignin, naphthalene and melamine sulfonate super plasticisers are organic polymers. The long molecules wrap themselves around the cement particles, giving them a highly negative charge so that they repel each other.

Poly carboxylate ether super plasticizer (PCE) or just **poly carboxylate** (PC), work differently from sulfonate-based super plasticizers, giving cement dispersion by steric stabilization, instead of electrostatic repulsion. This form of dispersion is more powerful in its effect and gives improved workability retention to the cementitious mix.

In ancient times, the Romans used animal fat, milk and blood to improve work ability of concrete mixes.

4 - For gypsum wallboard production :

Plasticizers can be added to wall board stucco mixtures to improve workability. In order to reduce the energy in drying wallboard, less water is added, which makes the gypsum mixture very unworkable and difficult to mix, necessitating the use of plasticizers, water reducers or dispersants. Some studies also show that too much of lignosulfonate dispersant could result in a set-retarding effect. Data showed that amorphous crystal formations occurred that detracted from the mechanical needle-like crystal interaction in the core, preventing a stronger core. The sugars, chelating agents in ligno sulfonates such as aldonic acids and extractive compounds are mainly responsible for set retardation. These low range water reducing dispersants are commonly manufactured from ligno sulfonates, a by-product from the paper industry.

High range super plasticizers (dispersants) have generally been manufactured from sulfonated naphthalene condensate, although poly carboxylic ethers represent more modern alternatives. These high range water reducers are used at 1/2 to 1/3 of the ligno sulfonate types. c

Traditional ligno sulfonate and naphthalene sulfonate based plasticisers disperse the flocculated gypsum particles through a mechanism of electrostatic repulsion (see colloid). In normal plasticisers, the active substances are adsorbed on to the gypsum particles, giving them a negative charge, which leads to repulsion between particles. Lignin and naphthalene sulfonate plasticizers are organic polymers. The long molecules wrap themselves around the gypsum particles, giving them a highly negative charge so that they repel each other .

5 - Plasticizers for energetic materials :

Energetic material pyrotechnic compositions, especially solid rocket propellants and smokeless powders for guns, often employ plasticizers to improve physical properties of the propellant binder or of the overall propellant, to provide a secondary fuel, and ideally, to improve specific energy yield (e.g. specific impulse, energy yield per gram of propellant, or similar indices) of the propellant. An energetic plasticizer improves the physical properties of an energetic material while also increasing its specific energy yield. Energetic plasticizers are usually preferred to non-energetic plasticizers, especially for solid rocket propellants. Energetic plasticizers reduce the required mass of propellant, enabling a rocket vehicle to carry more payload or reach higher velocities than would otherwise be the case. However, safety or cost considerations may demand that non-energetic plasticizers be used, even in rocket propellants. The solid rocket propellant used to fuel the Space Shuttle solid rocket booster employs a non-energetic plasticizer / binder / secondary fuel : HTPB. HTPB is a synthetic rubber.

6 – Controversy :

Substantial concerns have been expressed over the safety of some plasticizers, especially because they have been classified as endocrine disruptors.

7 - Appendix : various specific plasticizers :

7 – 1 - Dicarboxylic / tricarboxylic ester - based plasticizers :

- Phthalate -based plasticizers are used in situations where good resistance to water and oils is required. Some common phthalate plasticizers are:
    - Bis (2-ethylhexyl) phthalate (DEHP), used in construction materials and medical devices
    - Di isononyl phthalate (DINP), found in garden hoses, shoes, toys, and building materials
    - Bis (n-butyl)phthalate (DnBP, DBP), used for cellulose plastics, food wraps, adhesives, perfumes, and cosmetics - about a third of nail polishes, glosses, enamels, and hardeners contain it, together with some shampoos, sunscreens, skin emollients, and insect repellents
    - Butyl benzyl phthalate (BBzP) is found in vinyl tiles, traffic cones, food conveyor belts, artificial leather, and plastic foams
    - Di isodecyl phthalate (DIDP), used for insulation of wires and cables, car undercoating, shoes, carpets, pool liners

  - Di-n-octyl phthalate (DOP or DnOP), used in flooring materials, carpets, notebook covers, and high explosives, such as Semtex. Together with DEHP it was the most common plasticizers, but now is suspected of causing cancer
  - Di isooctyl phthalate (DIOP), all-purpose plasticizer for polyvinyl chloride, polyvinyl acetate, rubbers, cellulose plastics, and polyurethane.
  - Di ethyl phthalate (DEP)
  - Di isobutyl phthalate (DIBP)
  - Di-n-hexyl phthalate, used in flooring materials, tool handles, and automobile parts

7 – 2 - Tri militates :

- Tri militates are used in automobile interiors and other applications where resistance to high temperature is required. They have extremely low volatility.
  - Tri methyl tri militate (TMTM)
  - Tri-(2-ethylhexyl) tri militate (TEHTM-MG)
  - Tri-(n-octyl , n-decyl) tri militate (ATM)
  - Tri-(heptyl , nonyl) tri militate (LTM)
  - n-octyl tri militate (OTM)

7 – 3 - Adipates , sebacates , maleates :

- Adipate-based plasticizers are used for low-temperature or resistance to ultraviolet light. Some examples are:
  - Bis (2-ethylhexyl) adipate (DEHA)
  - Di methyl adipate (DMAD)
  - Mono methyl adipate (MMAD)
  - Di octyl adipate (DOA)
  - Di butyl sebacate (DBS)
  - Di butyl maleate (DBM)
  - Di isobutyl maleate (DIBM)

7 – 4 - Other plasticizers :

- Benzoates
- Epoxidized vegetable oils
- Sulfonamides
    - N - ethyl toluene sulfonamide (o/p ETSA), ortho and para isomers
    - N-(2-hydroxypropyl) benzene sulfonamide (HP BSA)
    - N-(n-butyl) benzene sulfonamide (BBSA-NBBS)

- Organo phosphates
    - Tri cresyl phosphate (TCP)
    - Tri butyl phosphate (TBP)

- Glycols / poly ethers
    - Tri ethylene glycol di hexanoate (3G6, 3GH)
    - Tetra ethylene glycol di heptanoate (4G7)

- Polymeric plasticizers
- Poly butene

7 – 5 - Bio degradable plasticizers :

Safer plasticizers with better bio degradability and fewer biochemical effects are being developed. Some such plasticizers are:

- Acetylated mono glycerides ; these can be used as food additives

- Alkyl citrates, used in food packagings, medical products, cosmetics and children toys
    - Tri ethyl citrate (TEC)
    - Acetyl tri ethyl citrate (ATEC), higher boiling point and lower volatility than TEC
    - Tri butyl citrate (TBC)
    - Acetyl tri butyl citrate (ATBC), compatible with PVC and vinyl chloride copolymers

  - Tri octyl citrate (TOC), also used for gums and controlled release medicines
  - Acetyl tri octyl citrate (ATOC), also used for printing ink
  - Tri hexyl citrate (THC), compatible with PVC, also used for controlled release medicines
  - Acetyl tri hexyl citrate (ATHC), compatible with PVC
  - Butyryl tri hexyl citrate (BTHC, trihexyl *o*-butyryl citrate), compatible with PVC
  - Tri methyl citrate (TMC), compatible with PVC

- alkyl sulphonic acid phenyl ester (ASE), compatible with PVC, vinyl chloride copolymers, TPU, NBR etc.

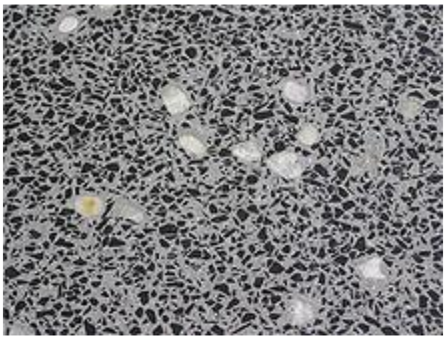
- 1,2- Cyclohexane dicarboxylic acid di isononyl ester (BASF trademark: DINCH) is used in food packaging, medical devices, toy and childcare articles. It is compatible with a wide range of polymers including PVC.

7 – 6 - Plasticizers for energetic materials :

Here are some energetic plasticizers used in rocket propellants and smokeless powders:

- Nitroglycerine (NG, aka "nitro", glyceryl trinitrate)
- Butane triol tri nitrate (BTTN)
- Di nitro toluene (DNT)
- Tri methyl olethane tri nitrate (TMETN, aka Metriol trinitrate, METN)
- Di ethylene glycol di nitrate (DEGDN, less commonly DEGN)
- Tri ethylene glycol di nitrate (TEGDN, less commonly TEGN)
- Bis (2,2- di nitro propyl) formal (BDNPF)
- Bis (2,2- di nitro propyl) acetal (BDNPA)
- 2,2,2-Tri nitroethyl 2- nitroxy ethyl ether (TNEN)

Polished Concrete



Black basalt polished concrete floor

Contents

1 – Introduction :

Polished concrete is concrete that has been treated with a chemical densifier and ground with progressively finer grinding tools. The grinding tools are usually progressive grits of diamond grinding cup wheels and diamond polishing pads . Typically, concrete is not considered polished before 400 grit , and it is normally finished to either the 800, 1500, or 3000 grit level. Stains and dyes are often applied to enhance polished concrete as well as other options such as scoring, creating radial lines, grids, bands, borders, and other designs.

2 - Benefits :

Polished concrete is considered a good sustainable design flooring option because it makes use of the materials already present. Most modern buildings are built on a concrete slab; polishing the exposed concrete eliminates the energy and material consumed by applying a floor covering. It is something to consider when building or modernizing towards a more green solution.

Polished concrete floors are low-maintenance, as they are more durable and easier to clean than many flooring options. Its relatively high coefficient of friction can make it non-slippery. Polished concrete reduces dust mite and allergen problems, and does not support mould growth. Anecdotal evidence suggests highly reflective polished concrete reduces lighting needs and improves natural lighting, but as of yet there has not been a study to confirm this. Polished concrete flooring is hard wearing and will not chip or dent like softer surfaces such as timber and mopping with warm soapy water once a week is the only maintenance required.

3 - New or retrofit :

In simple terms, the process of polishing concrete is similar to sanding wood. Heavy - duty polishing machines, for example concrete grinder, are used to gradually grind down surfaces to the desired degree of shine and smoothness. The closest equivalent example would be polished granite or marble.

Polished concrete floor installation is categorized into two types: new floors, and retrofit floors.

3 – 1 - New floors :

New polished concrete slab

New floors require less work resulting in lower costs, but there are a few things to be aware of before a new concrete floor can be polished. Firstly the slab can contain a decorative aggregate. The two most common aggregates are river stone, granite, and black basalt mix, however the aggregate can be almost anything. The finished surface of the concrete will need to be finished to a high standard to facilitate the polishing process. During the finishing phase any decorative aggregates such as seashells or car parts can be dropped into the surface of the concrete. Builder needs to be aware as early as possible if the concrete is to be polished so that the final finish is of the best quality.

3 – 2 - Retrofit floors :

Retrofit floors can be done in two ways. The existing floor slab can be cut or sanded and the natural aggregate will be the feature or a topping slab with a minimum thickness of 50 mm can be added on top of the existing slab.

4 - Process :

New polished concrete floor

Process involved in polishing concrete :

1. The concrete floor is cut with a variety of diamond abrasive grits, usually, 3- 8 depending on the gloss level desired. This can be done wet or dry depending on the site situation. However dry grinding can expose workers as well as the HVAC system with harmful amorphous silica dust. Wet grinding has become increasingly popular because of this.

2. A densifier is then applied once the concrete is opened up and in a condition to readily accept the chemical.
3. After the densifier is allowed to dry and cure for the manufacturers recommended time, followed by one or more resin abrasive cuts will hone and polish the floor to the desired gloss.
4. A clear liquid hardener referred to as an in densifier or concrete microfilm is then worked over the surface for about. The concrete in densifier or microfilm will provide a glossy look to the finished floor. It will also give the floor extra strength.
5. The floor is then burnished to give final gloss and clean the surface.
6. Timing of delivery depends on the type of equipment that a contractor uses. It can be expected that a 32" grinder will aver age 600 square feet per hour per grit, and a large Bobcat mounted 3 - headed grinder can grind 2,000 square feet per hour per grit. The Bobcat grinders have limited availability on the east and west coast.

Polymer Concrete

Contents

1 – Introduction :

Polymer concrete is part of group of concretes that use polymers to supplement or replace cement as a binder. The types include polymer - impregnated concrete, polymer concrete, and polymer – Portland - cement concrete. Polymers in concrete have been overseen by ACI Committee 548 since 1971 .

2 - Composition :

In polymer concrete, thermosetting resins are used as the principal polymer component due to their high thermal stability and resistance to a wide variety of chemicals. Polymer concrete is also composed of aggregates that include silica, quartz, granite, limestone, and other high quality material. The aggregate must be of good quality, free of dust and other debris, and dry. Failure of these criteria can reduce the bond strength between the polymer binder and the aggregate.

3 – Uses :

Polymer concrete may be used for new construction or repairing of old concrete. The adhesion properties of polymer concrete allow patching for both polymer and cementitious concretes. The low permeability of polymer concrete allows it to be used in swimming pools, sewer pipes, drainage channels, electrolytic cells for base metal recovery, and other structures that contain liquids. It can also be used as a replacement for asphalt pavement, for higher durability and higher strength.

4 - Advantages :

Advantages of polymer concrete include :

- Rapid curing at ambient temperatures
- High tensile, flexural, and compressive strengths
- Good adhesion to most surfaces
- Good long-term durability with respect to freeze and thaw cycles
- Low permeability to water and aggressive solutions
- Good chemical resistance
- Good resistance against corrosion
- Lightweight
- May be used in regular wood and steel formwork
- May be vibrated to fill voids in forms
- Allows use of regular form-release agents
- Dielectric

5 - Disadvantages :

Some safety issues arise out of the use of polymer concrete. The monomers can be volatile, combustible, and toxic. Initiators, which are used as catalysts, are combustible and harmful to human skin. The promoters and accelerators are also dangerous .

Portland Cement

A pallet with Portland cement

Blue Circle Southern Cement works near Berrima, New South Wales, Australia.

Contents

1 – Introduction :

Portland cement (often referred to as **OPC**, from *Ordinary Portland Cement*) is the most common type of cement in general use around the world because it is a basic ingredient of concrete, mortar, stucco and most non-specialty grout. It is a fine powder produced by grinding Portland cement clinker (more than 90 %) , a limited amount of calcium sulfate (which controls the set time) and up to 5% minor constituents as allowed by various standards such as the European Standard EN197-1 :

Portland cement clinker is a hydraulic material which shall consist of at least two-thirds by mass of calcium silicates ($3 CaO \cdot SiO_2$ and $2 CaO \cdot SiO_2$) , the remainder consisting of aluminium- and iron-containing clinker phases and other compounds. The ratio of CaO to SiO_2 shall not be less than 2.0. The magnesium oxide content (MgO) shall not exceed 5.0 % by mass.

(The last two requirements were already set out in the German Standard, issued in 1909).

ASTM C 150 defines portland cement as "hydraulic cement (cement that not only hardens by reacting with water but also forms a water-resistant product) produced by pulverizing clinkers consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an inter ground addition." Clinkers are nodules (diameters, 0.2-1.0 inch [5–25 mm]) of a sintered material that is produced when a raw mixture of predetermined composition is heated to high temperature. The low cost and widespread availability of the limestone, shales, and other naturally occurring materials make portland cement one of the lowest-cost materials widely used over the last century throughout the world. Concrete becomes one of the most versatile construction materials available in the world.

Portland cement clinker is made by heating, in a kiln, a homogeneous mixture of raw materials to a sintering temperature, which is about 1450 °C for modern cements. The aluminium oxide and iron oxide are present as a flux and contribute little to the strength. For special cements, such as Low Heat (LH) and Sulfate Resistant (SR) types, it is necessary to limit the amount of tricalcium aluminate ($3\,CaO \cdot Al_2O_3$) formed. The major raw material for the clinker-making is usually lime stone ($CaCO_3$) mixed with a second material containing clay as source of alumino-silicate. Normally, an impure limestone which contains clay or SiO_2 is used. The $CaCO_3$ content of these limestones can be as low as 80%. Second raw materials (materials in the rawmix other than limestone) depend on the purity of the limestone. Some of the second raw materials used are clay, shale, sand, iron ore, bauxite, fly ash and slag. When a cement kiln is fired by coal, the ash of the coal acts as a secondary raw material.

3 - History

Portland cement was developed from natural cements made in Britain in the early part of the nineteenth century, and its name is derived from its similarity to Portland stone, a type of building stone that was quarried on the Isle of Portland in Dorset, England .

The Portland cement is considered to originate from Joseph Aspdin, a British brick layer from Leeds. It was one of his employees (Isaac Johnson) , however, who developed the production technique, which resulted in a more fast-hardening cement with a higher compressive strength. This process was patented in 1824 . His cement was an artificial cement similar in properties to the material known as "Roman cement" (patented in 1796 by James Parker) and his process was similar to that patented in 1822 and used since 1811 by James Frost who called his cement "British Cement". The name "Portland cement" is also recorded in a directory published in 1823 being associated with a William Lockwood, Dave Stewart, and possibly others .

Aspdin's son William, in 1843, made an improved version of this cement and he initially called it "Patent Portland cement" although he had no patent. In 1848 William Aspdin further improved his cement and in 1853 he moved to Germany where he was involved in cement making . Many people have claimed to have made the first

Portland cement in the modern sense, but it is generally accepted that it was first manufactured by William Aspdin at North fleet, England in about 1842 . The German Government issued a standard on Portland cement in 1878 .

2 – 1 - Cement grinding (*Cement mill*) :

A 10 MW cement mill, producing cement at 270 tonnes per hour

In order to achieve the desired setting qualities in the finished product, a quantity (2 - 8 %, but typically 5 %) of calcium sulfate (usually gypsum or anhydrite) is added to the clinker and the mixture is finely ground to form the finished cement powder. This is achieved in a cement mill. The grinding process is controlled to obtain a powder with a broad particle size range, in which typically 15% by mass consists of particles below 5 µm diameter, and 5% of particles above 45 µm. The measure of fineness usually used is the "specific surface area", which is the total particle surface area of a unit mass of cement. The rate of initial reaction (up to 24 hours) of the cement on addition of water is directly proportional to the specific surface area. Typical values are 320–380 $m^2 \cdot kg^{-1}$ for general purpose cements, and 450–650 $m^2 \cdot kg^{-1}$ for "rapid hardening" cements. The cement is conveyed by belt or powder pump to a silo for storage. Cement plants normally have sufficient silo space for 1 – 20 weeks production, depending upon local demand cycles. The cement is delivered to end-users either in bags or as bulk powder blown from a pressure vehicle into the customer's silo. In industrial countries, 80% or more of cement is delivered in bulk.

Typical constituents of Portland clinker plus Gypsum

Cement chemists notation under CCN.

Clinker	CCN	Mass %
Tricalcium silicate $(CaO)_3 \cdot SiO_2$	C_3S	45-75%
Dicalcium silicate $(CaO)_2 \cdot SiO_2$	C_2S	7-32%
Tricalcium aluminate $(CaO)_3 \cdot Al_2O_3$	C_3A	0-13%
Tetracalcium aluminoferrite $(CaO)_4 \cdot Al_2O_3 \cdot Fe_2O_3$	C_4AF	0-18%
Gypsum $CaSO_4 \cdot 2\ H_2O$		2-10%

Typical constituents of Portland cement

Cement chemists notation under CCN.

Cement	CCN	Mass %
Calcium oxide, CaO	C	61 – 67 %
Silicon dioxide, SiO_2	S	19 – 23 %
Aluminum oxide, Al_2O_3	A	2.5 - 6 %
Ferric oxide, Fe_2O_3	F	0 - 6 %
Sulfate	$\bar{S}$	1.5 - 4.5 %

An alternative fabrication technique EMC (Energetically modified cement) uses very finely ground cements that are made from mixtures of cement with sand or with slag or other pozzolan type minerals which are extremely finely ground together. Such cements can have the same physical characteristics as normal cement but with 50 % less cement particularly due to their increased surface area for the chemical reaction. Even with intensive grinding they can use up to 50 % less energy to fabricate than ordinary Portland cements .

Chemical composition of EMC (50 / 50 OPC / FA - Fly Ash)

Compound	OPC %	FA %	EMC %
CaO	62.4	15.0	40.9
SiO_2	17.8	49.4	33.2
Al_2O_3	4.0	19.6	6.3

Fe_2O_3	3.9	5.2	4.1
SO_3	3.2	0.8	1.6
Na_2O	< 0.1	0.3	0.1
K_2O	0.3	1.2	1.2
Insolubles	0.5	51.3	21.6

3 - Setting and hardening :

Cement sets when mixed with water by way of a complex series of chemical reactions still only partly understood. The different constituents slowly crystallize and the interlocking of their crystals gives cement its strength. Carbon dioxide is slowly absorbed to convert the portlandite ($Ca(OH)_2$) into insoluble calcium carbonate. After the initial setting, immersion in warm water will speed up setting. In Portland cement, gypsum is added as a compound preventing cement flash setting.

4 - Use :

Decorative use of Portland cement panels on London's Grosvenor estate

The most common use for Portland cement is in the production of concrete . Concrete is a composite material consisting of aggregate (gravel and sand) , cement, and water . As a construction material, concrete can be cast in almost any shape desired, and once hardened, can become a structural (load bearing) element . Users may be involved in the factory production of pre - cast units, such as panels, beams , road furniture, or may make cast – *in* - *situ* concrete such as building superstructures, roads, dams. These may be supplied with concrete mixed on site, or may be provided with "ready-mixed" concrete made at permanent mixing sites. Portland cement is also used in mortars (with sand and water only) for plasters and screeds, and in grouts (cement / water mixes squeezed into gaps to consolidate foundations , road - beds , etc.).

When water is mixed with Portland Cement, the product sets in a few hours and hardens over a period of weeks. These processes can vary widely depending upon the mix used and the conditions of curing of the product, but a typical concrete sets in about 6 hours and develops a compressive strength of 8 MPa in 24 hours. The strength rises to 15 MPa at 3 days, 23 MPa at 1 week, 35 MPa at 4 weeks and 41 MPa at 3 months. In principle, the strength continues to rise slowly as long as water is available for continued hydration, but concrete is usually allowed to dry out after a few weeks and this causes strength growth to stop.

5 - Types :

5 – 1 – General :

There are different standards for classification of Portland cement. The two major standards are the ASTM C150 used primarily in the U.S. and European EN-197. EN 197 cement types CEM I, II, III, IV, and V do not correspond to the similarly named cement types in ASTM C 150.

5 – 2 – ASTM C150 :

There are five types of Portland cements with variations of the first three according to ASTM C150.

Type I Portland cement is known as common or general purpose cement. It is generally assumed unless another type is specified. It is commonly used for general construction especially when making precast and precast-prestressed concrete that is not to be in contact with soils or ground water. The typical compound compositions of this type are:

55 % (C_3S) , 19 % (C_2S), 10% (C_3A) , 7% (C_4AF) , 2.8% MgO, 2.9 % (SO_3), 1.0 % Ignition loss , and 1.0 % free CaO.

A limitation on the composition is that the (C_3A) shall not exceed fifteen percent.

Type II is intended to have moderate sulfate resistance with or without moderate heat of hydration. This type of cement costs about the same as Type I. Its typical compound composition is:

51 % (C_3S), 24% (C_2S) , 6% (C_3A) , 11% (C_4AF) , 2.9% MgO, 2.5 % (SO_3), 0.8 % Ignition loss, and 1.0 % free CaO.

A limitation on the composition is that the (C_3A) shall not exceed eight percent which reduces its vulnerability to sulfates. This type is for general construction that is exposed to moderate sulfate attack and is meant for use when concrete is in contact with soils and ground water especially in the western United States due to the high sulfur content of the soil. Because of similar price to that of Type I, Type II is much used as a general purpose cement, and the majority of Portland cement sold in North America meets this specification.

Note: Cement meeting (among others) the specifications for Type I and II has become commonly available on the world market.

Type III is has relatively high early strength. Its typical compound composition is:

57 % (C_3S), 19 % (C_2S) , 10 % (C_3A) , 7 % (C_4AF), 3.0 % MgO, 3.1 % (SO_3), 0.9 % Ignition loss, and 1.3 % free CaO.

This cement is similar to Type I, but ground finer. Some manufacturers make a separate clinker with higher C_3S and/or C_3A content, but this is increasingly rare, and the general purpose clinker is usually used, ground to a specific surface typically 50-80% higher. The gypsum level may also be increased a small amount. This gives the concrete using this type of cement a three day compressive strength equal to the seven day compressive strength of types I and II. Its seven day compressive strength is almost equal to types I and II 28 day compressive strengths. The only downside is that the six month strength of type III is the same or slightly less than that of types I and II. Therefore the long-term strength is sacrificed a little. It is usually used for precast concrete manufacture, where high 1-day strength allows fast turnover of molds. It may also be used in emergency construction and repairs and construction of machine bases and gate installations.

Type IV Portland cement is generally known for its low heat of hydration. Its typical compound composition is:

28 % (C_3S) , 49 % (C_2S), 4 % (C_3A) , 12 % (C_4AF) , 1.8 % MgO , 1.9 % (SO_3) , 0.9 % Ignition loss, and 0.8 % free CaO.

The percentages of (C_2S) and (C_4AF) are relatively high and (C_3S) and (C_3A) are relatively low. A limitation on this type is that the maximum percentage of (C_3A) is seven, and the maximum percentage of (C_3S) is thirty-five. This causes the heat given off by the hydration reaction to develop at a slower rate. However, as a consequence the strength of the concrete develops slowly. After one or two years the strength is higher than the other types after full curing. This cement is used for very large concrete structures, such as dams, which have a low surface to volume ratio. This type of cement is generally not stocked by manufacturers but some might consider a large special order. This type of cement has not been made for many years, because Portland-pozzolan cements and ground granulated blast furnace slag addition offer a cheaper and more reliable alternative.

Type V is used where sulfate resistance is important. Its typical compound composition is:

38 % (C_3S) , 43 % (C_2S) , 4 % (C_3A), 9 % (C_4AF), 1.9 % MgO, 1.8 % (SO_3), 0.9 % Ignition loss, and 0.8% free CaO.

This cement has a very low (C_3A) composition which accounts for its high sulfate resistance. The maximum content of (C_3A) allowed is five percent for Type V Portland cement. Another limitation is that the (C_4AF) + 2(C_3A) composition cannot exceed twenty percent. This type is used in concrete that is to be exposed to alkali soil and ground water sulfates which react with (C_3A) causing disruptive expansion. It is unavailable in many places although its use is common in the western United States and Canada. As with Type IV, Type V Portland cement has mainly been supplanted by the use of ordinary cement with added ground granulated blast furnace slag or tertiary blended cements containing slag and fly ash.

Types Ia , IIa , and IIIa have the same composition as types I, II, and III. The only difference is that in Ia, IIa, and IIIa an air-entraining agent is ground into the mix. The air-entrainment must meet the minimum and maximum optional specification found in the ASTM manual. These types are only available in the eastern United States and Canada but can only be found on a limited basis. They are a poor approach to air - entrainment which improves resistance to freezing under low temperatures.

Types II (MH) and II (MH) a have recently been added with a similar composition as types II and IIa but with a mild heat. The cements were added to ASTM C-150 in 2009 and will be in publication in 2010.

5 – 3 – EN 197 :

EN 197-1 defines 5 classes of common cement that comprise Portland cement as a main constituent. These classes differ from the ASTM classes.

I	Portland cement	Comprising Portland cement and up to 5% of minor additional constituents
II	Portland-composite cement	Portland cement and up to 35% of other single constituents
III	Blastfurnace cement	Portland cement and higher percentages of blast furnace slag
IV	Pozzolanic cement	Portland cement and up to 55% of pozzolanic constituents(volcaince ashs)
V	Composite cement	Portland cement, blastfurnace slag or fly ash and pozzolana

Constituents that are permitted in Portland - composite cements are artificial pozzolans (blast furnace slag, silica fume, and fly ashes) or natural pozzolans (siliceous or siliceous aluminous materials such as volcanic ash glasses, calcined clays and shale).

5 – 4 – White Portland cement :

White Portland cement or white ordinary Portland cement (WOPC) is similar to ordinary, gray Portland cement in all respects except for its high degree of whiteness. Obtaining this color requires substantial modification to the method of manufacture and, because of this, it is somewhat more expensive than the gray product.

Sampling fast set concrete made from Portland cement

6 - Safety issues :

Bags of cement routinely have health and safety warnings printed on them because not only is cement highly alkaline, but the setting process is exothermic. As a result, wet cement is strongly caustic and can easily cause severe skin burns if not promptly washed off with water. Similarly, dry cement powder in contact with mucous membranes can cause severe eye or respiratory irritation. Cement users should wear protective clothing .

When traditional Portland cement is mixed with water the dissolution of calcium, sodium and potassium hydroxides produces a highly alkaline solution (pH ~13) : gloves , goggles and a filter mask should be used for protection, and hands should be washed after contact as most cement can cause acute ulcerative damage 8–12 hours after contact if skin is not washed promptly . The reaction of cement dust with moisture in the sinuses and lungs can also cause a chemical burn as well as headaches, fatigue , and lung cancer . The development of formulations of cement that include fast - reacting pozzolans such as silica fume as well as some slow - reacting products such as fly ash have allowed for the production of comparatively low - alkalinity cements (pH < 11) that are much less toxic and which have become widely commercially available, largely replacing high - pH formulations in much of the United States. Once any cement sets, the hardened mass loses chemical reactivity and can be safely touched without gloves.

In Scandinavia, France and the UK, the level of chromium (VI), which is considered to be toxic and a major skin irritant, may not exceed 2 ppm (parts per million) .

7 - Environmental effects :

Portland cement manufacture can cause environmental impacts at all stages of the process. These include emissions of airborne pollution in the form of dust, gases, noise and vibration when operating machinery and during blasting in quarries, consumption of large quantities of fuel during manufacture, release of CO_2 from the raw materials during manufacture, and damage to countryside from quarrying. Equipment to reduce dust emissions during quarrying and manufacture of cement is widely used, and equipment to trap and separate exhaust gases are coming into increased use. Environmental protection also includes the re - integration of quarries into the countryside after they have been closed down by returning them to nature or re - cultivating them.

Epidemiologic Notes and Reports Sulfur Dioxide Exposure in Portland Cement Plants, from the Centers for Disease Control, states "Workers at Portland cement facilities, particularly those burning fuel containing sulfur , should be aware of the acute and chronic effects of exposure to SO_2 [sulfur dioxide] , and peak and full - shift concentrations of SO_2 should be periodically measured."

"The Arizona Department of Environmental Quality was informed this week that the Arizona Portland Cement Co. failed a second round of testing for emissions of hazardous air pollutants at the company's Rillito plant near Tucson. The latest round of testing, performed in January 2003 by the company, is designed to ensure that the facility complies with federal standards governing the emissions of dioxins and furans, which are byproducts of the manufacturing process " · Cement Reviews' "Environmental News" web page details case after case of environmental problems with cement manufacturing

An independent research effort of AEA Technology to identify critical issues for the cement industry today concluded the most important environment, health and safety performance issues facing the cement industry are atmospheric releases (including greenhouse gas emissions , dioxin , NO_x , SO_2 , and particulates) , accidents and worker exposure to dust .

The CO_2 associated with Portland cement manufacture falls into 3 categories:

Source 1. CO_2 derived from de carbonation of limestone,

Source 2. CO_2 from kiln fuel combustion,

Source 3. CO_2 produced by vehicles in cement plants and distribution.

Source 1 is fairly constant: minimum around 0.47 kg CO_2 per kg of cement, maximum 0.54, typical value around 0.50 worldwide.[citation needed] Source 2 varies with plant efficiency: efficient precalciner plant 0.24 kg CO_2 per kg cement, low-efficiency wet process as high as 0.65, typical modern practices (e.g. UK) averaging around 0.30.[citation needed] Source 3 is almost insignificant at 0.002-0.005. So typical total CO_2 is around 0.80 kg CO_2 per kg finished cement. This leaves aside the CO_2 associated with electric power consumption, since this varies according to the local generation type and efficiency. Typical electrical energy consumption is of the order of 90 - 150 kWh per tonne cement, equivalent to 0.09 - 0.15 kg CO_2 per kg finished cement if the electricity is coal - generated.

Overall, with nuclear- or hydroelectric power and efficient manufacturing, CO_2 generation can be reduced to 0.7 kg per kg cement, but can be as high as twice this amount. The thrust of innovation for the future is to reduce sources 1 and 2 by modification of the chemistry of cement, by the use of wastes, and by adopting more efficient processes. Although cement manufacturing is clearly a very large CO_2 emitter , concrete (of which cement makes up about 15 %) compares quite favorably with other building systems in this regard .

8 - Cement plants used for waste disposal or processing :

Used tires being fed to a pair of cement kilns

Due to the high temperatures inside cement kilns, combined with the oxidizing (oxygen - rich) atmosphere and long residence times, cement kilns are used as a processing option for various types of waste streams: indeed, they efficiently destroy many hazardous organic compounds. The waste streams also often contain combustible materials which allow the substitution of part of the fossil fuel normally used in the process.

Waste materials used in cement kilns as a fuel supplement :

- Car and truck tires – steel belts are easily tolerated in the kilns
- Paint sludge from automobile industries
- Waste solvents and lubricants
- Meat and bone meal - slaughterhouse waste due to bovine spongiform encephalopathy contamination concerns
- Waste plastics
- Sewage sludge
- Rice hulls
- Sugarcane waste
- Used wooden railroad ties (railway sleepers)
- Spent Cell Liner (SCL) from the aluminium smelting industry (also called Spent Pot Liner or SPL)

Portland cement manufacture also has the potential to benefit from using industrial by-products from the waste-stream.[19] These include in particular:

- Slag
- Fly ash (from power plants)
- Silica fume (from steel mills)
- Synthetic gypsum (from desulfurization)

Pottery

	
Traditional Pottery workshop reconstruction in the Museum of traditional crafts and applied arts, Troyan, Bulgaria	*Unfired "green ware" pottery on a traditional drying rack at Conner Prairie living history museum*

Contents

1 – Introduction :

Pottery is the material from which the pottery *ware* is made, of which major types include earthenware, stoneware and porcelain. The place where such wares are made is also called a *pottery* (plural "potteries"). Pottery also refers to the art or craft of the potter or the manufacture of pottery.

The definition of *pottery* used by ASTM is "all fired ceramic wares that contain clay when formed, except technical, structural, and refractory products " . Some archaeologists use a different understanding by excluding ceramic objects such as figurines which are made by similar processes, materials and the same people but are not vessels .

2 - Back ground :

Pottery is made by forming a clay body into objects of a required shape and heating them to high temperatures in a kiln which removes all water from the clay, which induces reactions that lead to permanent changes including increasing their strength and hardening and setting their shape. A clay body can be decorated before or after firing. Prior to some shaping processes, clay must be prepared. kneading helps to ensure an even moisture content throughout the body. Air trapped within the clay body needs to be removed. This is called de-airing and can be accomplished by a machine called a vacuum pug or manually by wedging. Wedging can also help produce an even moisture content. Once a clay body has been kneaded and de-aired or wedged, it is shaped by a variety of techniques. After shaping it is dried and then fired.

3 - Physical stages of clay :

Clay ware takes on varying physical characteristics during the making of pottery.

- **Green ware** refers to unfired objects. Clay bodies at this stage are in their most plastic form. They are soft and malleable. Hence they can be easily deformed by handling.
- **Leather-hard** refers to a clay body that has been dried partially. At this stage the clay object has approximately 15% moisture content. Clay bodies at this stage are very firm and only slightly pliable. Trimming and handle attachment often occurs at the leather-hard state.
- **Bone-dry** refers to clay bodies when they reach a moisture content at or near 0%. This will occur after glaze firing, when that is done, or after biscuit firing in the case of once-fired pottery.
- **Biscuit** refers to the clay after the object is shaped to the desired form and fired in the kiln for the first time, known as "biscuit fired". This firing changes the clay body in in several ways. Mineral components of the clay body will undergo chemical changes that will change the colour of the clay.
- **Glost fired** is the final stage of some pottery making. A glaze may be applied to the biscuit form and the object can be decorated in several ways. After this the object is "glost fired", which causes the glaze material to melt, then adhere to the object. The glaze firing may also harden the body still more as chemical processes can continue to occur in the body.

4 - Clays and mineral contents :

There are several materials that are referred to as clay. The properties of the clays differ in: Plasticity, the malleability of the body; porosity, the degree to which the fired pottery will absorb water; and shrinkage, the degree of reduction in size of a body as water is removed. The various clays also differ in the way in which they respond to different degrees of heat when fired in the kiln. Each of these different clays are composed of different types and amounts of minerals that determine the resulting pottery. There are wide regional variations in the properties of raw materials used for the production of pottery, and this can lead to wares that are unique in character to a locality. It is common for clays and other materials to be mixed to produce clay bodies suited to specific purposes. The two essential components of clay are Silica and Alumina which combine to form Aluminium silicate , also known as Kaolinite. Other mineral compounds in the clay may act as Fluxes to lower the melting point of the silica during firing. Following is a list of different types of clay used for pottery that are available in different regions of the world.

- Kaolin , is sometimes referred to as China clay because it was first identified in China.
- Ball clay An extremely plastic, fine grained sedimentary clay, which may contain some organic matter. It is usually added to porcelain to increase plasticity.
- Fire clay A clay having a slightly higher percentage of fluxes than Kaolin, but usually quite plastic. It is highly heat resistant form of clay which can be combined with other clays to increase the firing temperature and may be used as an ingredient to make stoneware type bodies.
- **Stone ware clay** Suitable for creating Stoneware. This clay has many of the characteristics between fire clay and ball clay, having finer grain, like ball clay but more heat resistant like fire clays.
- **Common red clay** and **Shale clay** have vegetable and Ferric oxide impurities which make them useful for bricks, but are generally unsatisfactory for pottery except under special conditions of a particular deposit.
- Bentonite An extremely plastic clay which can be added in small quantities to short clay to make it more plastic.

5 - Methods of shaping :

Hand building. This is the earliest forming method. Wares can be constructed by hand from coils of clay, combining flat slabs of clay, or pinching solid balls of clay or some combination of these. Parts of hand - built vessels are often joined together with the aid of slip, an aqueous suspension of clay body and water. Hand-building is slower than wheel - throwing, but it offers the potter a high degree of control over the size and shape of wares. The speed and repetitiveness of other techniques is more suitable for making precisely matched sets of wares such as table wares although some studio potters find hand-building more conducive to create one-of-a-kind works of art.

	
Handwork pottery in Kathmandu, Nepal	*man shapes pottery as it turns on a wheel. (Cappadocia, Turkey)*
	
Classic potter's kick wheel in Erfurt, Germany	*Pottery can be shaped by a range of methods that include: Hand made*

The potter's wheel . In a process called "throwing" (coming from the Old English word *thrawan* which means to twist or turn,[10] a ball of clay is placed in the centre of a turntable, called the wheel-head, which the potter rotates with a stick, with foot power or with a variable-speed electric motor.

During the process of throwing, the wheel rotates rapidly while the solid ball of soft clay is pressed, squeezed and pulled gently upwards and outwards into a hollow shape. The first step of pressing the rough ball of clay downward and inward into perfect rotational symmetry is called *centring* the clay-- a most important skill to master before the next steps: *opening* (making a centered hollow into the solid ball of clay) , *flooring* (making the flat or rounded bottom inside the pot), *throwing* or *pulling* (drawing up and shaping the walls to an even thickness), and *trimming* or *turning* (removing excess clay to refine the shape or to create a *foot*).

Considerable skill and experience are required to throw pots of an acceptable standard and, while the ware may have high artistic merit, the reproducibility of the method is poor.[11] Because of its inherent limitations, throwing can only be used to create wares with radial symmetry on a vertical axis. These can then be altered by impressing, bulging, carving, fluting, and incising. In addition to the potter's hands these techniques can use tools, including paddles, anvils & ribs, and those specifically for cutting or piercing such as knives, fluting tools and wires. Thrown pieces can be further modified by the attachment of handles, lids, feet and spouts.

Granulate pressing: As the name suggests, this is the operation of shaping pottery by pressing clay in a semi-dry and granulated condition in a mould. The clay is pressed into the mould by a porous die through which water is pumped at high pressure. The granulated clay is prepared by spray-drying to produce a fine and free-flowing material having a moisture content of between about 5 and 6 per cent. Granulate pressing, also known as *dust pressing*, is widely used in the manufacture of ceramic tiles and, increasingly, of plates.

Injection moulding: is a shape-forming process adapted for the tableware industry from the method long established for the forming of thermoplastic and some metal components . It has been called *Porcelain Injection Moulding*, or *PIM*. Suited to the mass production of complex-shaped articles, one significant advantage of the technique is that it allows the production of a cup, including the handle, in a single process, and thereby eliminates the handle-fixing operation and produces a stronger bond between cup and handle . The feed to the mould die is a mix of approximately 50 to 60 percent unfired body in powder form, together with 40 to 50 percent organic additives composed of binders , lubricants and plasticizers . The technique is not as widely used as other shaping methods.

Jiggering and jollying : These operations are carried out on the potter's wheel and allow the time taken to bring wares to a standardized form to be reduced. *Jiggering* is the operation of bringing a shaped tool into contact with the plastic clay of a piece under construction, the piece itself being set on a rotating plaster mould on the wheel. The jigger tool shapes one face while the mould shapes the other. Jiggering is used only in the production of flat wares, such as plates, but a similar operation, *jollying*, is used in the production of hollow-wares such as cups. Jiggering and jolleying have been used in the production of pottery since at least the 18th century. In large-scale factory production, jiggering and jolleying are usually automated, which allows the operations to be carried out by semi-skilled labour.

Shaping on a potter's kick wheel ; Gülşehir, Turkey

Roller-head machine: This machine is for shaping wares on a rotating mould, as in jiggering and jolleying, but with a rotary shaping tool replacing the fixed profile. The rotary shaping tool is a shallow cone having the same diameter as the ware being formed and shaped to the desired form of the back of the article being made. Wares may in this way be shaped, using relatively unskilled labour, in one operation at a rate of about twelve pieces per minute, though this varies with the size of the articles being produced. Developed in the U.K. just after World War II by the company *Service Engineers*, roller-heads were quickly adopted by manufacturers around the world; they remain the dominant method for producing flatware.

Pressure casting – specially developed polymeric materials allow a mould to be subject to application external pressures of up to 4.0 MPa–so much higher than slip casting in plaster moulds where the capillary forces correspond to a pressure of around 0.1 - 0.2 MPa. The high pressure leads to much faster casting rates and, hence, faster production cycles. Furthermore, the application of high pressure air through the polymeric moulds upon demoulding the cast means a new casting cycle can be started immediately in the same mould, unlike plaster moulds which require lengthy drying times. The polymeric materials have much greater durability than plaster and, therefore, it is possible to achieve shaped products with better dimensional tolerances and much longer mould life. Pressure casting was developed in the 1970s for the production of sanitary ware although, more recently, it has been applied to tableware.

RAM pressing : A factory process for shaping table wares and decorative ware by pressing a bat of prepared clay body into a required shape between two porous moulding plates. After pressing, compressed air is blown through the porous mould plates to release the shaped wares.

Slip casting: is often used in the mass production of ceramics and is ideally suited to the making of wares that cannot be formed by other methods of shaping. A slip, made by mixing clay body with water, is poured into a highly absorbent plaster mould. Water from the slip is absorbed into the mould leaving a layer of clay body covering its internal surfaces and taking its internal shape. Excess slip is poured out of the mould, which is then split open and the moulded object removed. Slip casting is widely used in the production of sanitary wares and is also used for making smaller articles, such as intricately detailed figurines.

6 - Decorating and glazing :

Pottery may be decorated in a number of ways including :

- In the clay body, for example, by incising patterns on its surface.

- Under glaze decoration (in the manner of many blue and white wares).

	
This is an Italian red earthenware vase covered with a mottled pale blue glaze. It has large blue and gold-coated flowers and a scalloped gold-coated rim.	*Contemporary pottery from Okinawa, Japan*

Under glaze may be applied by brush strokes, air brush, or by pouring the under glaze into the mold, covering the inside, creating a swirling effect, then the mold is filled with slip.

- In - glaze decoration
- On - glaze decoration
- Enamel

Pots in Punjab, Pakistan

Additives can be worked into the clay body prior to forming, to produce desired effects in the fired wares. Coarse additives such as sand and grog (fired clay which has been finely ground) are sometimes used to give the final product a required texture. Contrasting coloured clays and grogs are sometimes used to produce patterns in the finished wares. Colourants , usually metal oxides and carbonates, are added singly or in combination to achieve a desired colour. Combustible particles can be mixed with the body or pressed into the surface to produce texture.

Agateware: Named after its resemblance to the quartz mineral agate which has bands or layers of colour that are blended together, agate wares are made by blending clays of differing colours together but not mixing them to the extent that they lose their individual identities. The wares have a distinctive veined or mottled appearance. The term "agateware" is used to describe such wares in the United Kingdom; in Japan the term "*neriage*" is used and in China, where such things have been made since at least the Tang Dynasty, they are called "*marbled*" wares. Great care is required in the selection of clays to be used for making agatewares as the clays used must have matching thermal movement characteristics.

Banding: This is the application by hand or by machine of a band of colour to the edge of a plate or cup. Also known as "lining", this operation is often carried out on a potter's wheel.

Burnishing: The surface of pottery wares may be *burnished* prior to firing by rubbing with a suitable instrument of wood, steel or stone to produce a polished finish that survives firing. It is possible to produce very highly polished wares when fine clays are used or when the polishing is carried out on wares that have been partially dried and contain little water, though wares in this condition are extremely fragile and the risk of breakage is high.

Engobe : This is a clay slip, that is used to coat the surface of pottery, usually before firing. Its purpose is often decorative though it can also be used to mask undesirable features in the clay to which it is applied. Engobe slip may be applied by painting or by dipping to provide a uniform, smooth, coating. Engobe has been used by potters from pre-historic times until the present day and is sometimes combined with sgraffito decoration, where a layer of engobe is scratched through to reveal the colour of the underlying clay. With care it is possible to apply a second coat of engobe of a different colour to the first and to incise decoration through the second coat to expose the colour of the underlying coat. Engobes used in this way often contain substantial amounts of silica, sometimes approaching the composition of a glaze.

An ancient Armenian urn

Litho : This is a commonly used abbreviation for lithography, although the alternative names of transfer print or "*decal*" are also common. These are used to apply designs to articles. The litho comprises three layers: the colour, or image, layer which comprises the decorative design; the cover coat, a clear protective layer, which may incorporate a low-melting glass; and the backing paper on which the design is printed by screen printing or lithography. There are various methods of transferring the design while removing the backing-paper, some of which are suited to machine application.

Gold : Decoration with gold is used on some high quality ware. Different methods exist for its application, including:

- *Best gold* - a suspension of gold powder in essential oils mixed with a flux and a mercury salt extended. This can be applied by a painting technique. From the kiln, the decoration is dull and requires burnishing to reveal the full colour

- *Acid Gold* – a form of gold decoration developed in the early 1860s at the English factory of Mintons Ltd, Stoke-on-Trent. The glazed surface is etched with diluted hydrofluoric acid prior to application of the gold. The process demands great skill and is used for the decoration only of ware of the highest class.
- *Bright Gold* – consists of a solution of gold sulphoresinate together with other metal resonates and a flux. The name derives from the appearance of the decoration immediately after removal from the kiln as it requires no burnishing
- *Mussel Gold* – an old method of gold decoration. It was made by rubbing together gold leaf, sugar and salt, followed by washing to remove solubles

6 – 1 - Glazing :

Glaze is a glassy coating on pottery, the primary purposes of which are decoration and protection. One important use of glaze is to render porous pottery vessels impermeable to water and other liquids. Glaze may be applied by dusting the unfired composition over the ware or by spraying, dipping, trailing or brushing on a thin slurry composed of the unfired glaze and water. The colour of a glaze before it has been fired may be significantly different than afterwards. To prevent glazed wares sticking to kiln furniture during firing, either a small part of the object being fired (for example, the foot) is left unglazed or, alternatively, special refractory "*spurs*" are used as supports. These are removed and discarded after the firing.

Some specialized glazing techniques include :

- Salt-glazing, where common salt is introduced to the kiln during the firing process. The high temperatures cause the salt to volatize, depositing it on the surface of the ware to react with the body to form a sodium alumino silicate glaze. In the 17th and 18th centuries, salt-glazing was used in the manufacture of domestic pottery. Now, except for use by some studio potters, the process is obsolete. The last large-scale application before its demise in the face of environmental clean air restrictions was in the production of salt-glazed sewer-pipes.

- Ash glazing - ash from the combustion of plant matter has been used as the flux component of glazes. The source of the ash was generally the combustion waste from the fuelling of kilns although the potential of ash derived from arable crop wastes has been investigated . Ash glazes are of historical interest in the Far East although there are reports of small - scale use in other locations such as the Catawba Valley Pottery in the United States. They are now limited to small numbers of studio potters who value the unpredictability arising from the variable nature of the raw material.

7 – Firing :

Firing produces irreversible changes in the body. It is only after firing that the article or material is pottery. In lower - fired pottery, the changes include sintering, the fusing together of coarser particles in the body at their points of contact with each other. In the case of porcelain, where different materials and higher firing - temperatures are used, the physical, chemical and mineralogical properties of the constituents in the body are greatly altered. In all cases, the object of firing is to permanently harden the wares and the firing regime must be appropriate to the materials used to make them. As a rough guide, earthen wares are normally fired at temperatures in the range of about 1,000°C to 1,200 °C ; stone wares at between about 1,100 °C to 1,300 °C ; and porcelains at between about 1,200 °C to 1,400 °C . How ever, the way that ceramics mature in the kiln is influenced not only by the peak temperature achieved but also by the duration of the period of firing. Thus, the maximum temperature within a kiln is often held constant for a period of time to *soak* the wares to produce the maturity required in the body of the wares.

The atmosphere within a kiln during firing can affect the appearance of the finished wares. An oxidizing atmosphere, produced by allowing air to enter the kiln, can cause the oxidation of clays and glazes. A reducing atmosphere, produced by limiting the flow of air into the kiln, can strip oxygen from the surface of clays and glazes.

This can affect the appearance of the wares being fired and, for example, some glazes containing iron fire brown in an oxidising atmosphere, but green in a reducing atmosphere. The atmosphere within a kiln can be adjusted to produce complex effects in glaze.

Kilns may be heated by burning wood, coal and gas or by electricity. When used as fuels, coal and wood can introduce smoke, soot and ash into the kiln which can affect the appearance of unprotected wares. For this reason, wares fired in wood- or coal-fired kilns are often placed in the kiln in "sag gars", lidded ceramic boxes, to protect them. Modern kilns powered by gas or electricity are cleaner and more easily controlled than older wood- or coal-fired kilns and often allow shorter firing times to be used. In a Western adaptation of traditional Japanese Raku ware firing, wares are removed from the kiln while hot and smothered in ashes, paper or woodchips which produces a distinctive carbonized appearance. This technique is also used in Malaysia in creating traditional *labu sayung*.

8 – History :

A great part of the history of pottery is prehistoric, part of past pre-literate cultures. Therefore, much of this history can only be found among the artefacts of archaeology. Because pottery is so durable, pottery and sherds from pottery survive from millennia at archaeological sites.

Before pottery becomes part of a culture, several conditions must generally be met.

- First, there must be usable clay available. Archaeological sites where the earliest pottery was found were near deposits of readily available clay that could be properly shaped and fired. China has large deposits of a variety of clays, which gave them an advantage in early development of fine pottery. Many countries have large deposits of a variety of clays.
- Second, it must be possible to heat the pottery to temperatures that will achieve the transformation from raw clay to ceramic. Humans did not develop methods to control fire

until late in the development of cultures. Methods to reliably create fires hot enough to fire pottery came even later.

- Third, the potter must have time available to prepare, shape and fire the clay into pottery. Even after control of fire was achieved, humans did not seem to develop pottery until a sedentary life was achieved. It has been hypothesized that pottery was developed only after humans established agriculture, which led to permanent settlements.
- Fourth, there must be a sufficient need for pottery in order to justify the resources required for its production.[27]

8 – 1 - Early pottery :

Methods of forming: **Hand-shaping** was the earliest method used to form vessels. This included the combination of **pinching** and **coiling**.

Firing: The earliest method for firing pottery wares was the use of bonfires Pit fired pottery. Firing times were short but the peak-temperatures achieved in the fire could be high, perhaps in the region of 900 °C , and were reached very quickly.

Clay : Early potters used whatever clay was available to them in their geographic vicinity. However, the lowest quality common red clay was adequate for low-temperature fires used for the earliest pots. Clays tempered with sand, grit, crushed shell or crushed pottery were often used to make bonfire-fired ceramics because they provided an open-body texture that allowed water. The coarser particles in the clay also acted to restrain shrinkage during drying, and hence reduce the risk of cracking.

Form: In the main, early bonfire-fired wares were made with rounded bottoms to avoid sharp angles that might be susceptible to cracking.

Glazing : the earliest pots were not glazed.

The **potter's wheel** was invented in Mesopotamia sometime between 6,000 and 4,000 BCE (Ubaid period) and revolutionized pottery production.

Biscuit moulds were used to a limited extent as early as the 5th and 6th century BCE by the Etruscans and more extensively by the Romans .

Slip casting, a popular method for shaping irregular shaped articles. It was first practiced, to a limited extent, in China as early as the T'ang dynasty

Transition to kilns: The earliest intentionally constructed were pit-kilns or trench - kilns — holes dug in the ground and covered with fuel. Holes in the ground provided insulation and resulted in better control over firing.

kilns : Pit fire methods were adequate for creating earthenware, but higher - fired stoneware and porcelain required more sophisticated methods of firing using high - fire kilns .

8 – 2 - History of pottery types :

8 – 2 – 1 – Earthen ware :

The earliest forms of pottery were made from clays that were fired at low temperatures in pit-fires or in open bonfires. They were hand formed and undecorated. Because the biscuit form of earthenware is porous, it has limited utility for storage of liquids. However, earthenware has a continuous history from the Neolithic period to today. It can be made from a wide variety of clays. The development of ceramic glaze which makes it impermeable makes it a popular and practical form of pottery making. The addition of decoration has evolved throughout its history.

8 – 2 – 2 – Stone ware :

Glazed Stoneware was being created as early as the 15th century BCE in China. This achievement coincided with kilns that could be fired at higher temperatures.

8 – 2 – 3 – Porcelain :

Porcelain was first made in China during the Tang Dynasty (618-906 CE). Porcelain was also made in Korea and Japan around the 16th and 17th century AD after suitable kaolin was located in those countries. It was not created outside of the area until the 18th century.

8 – 3 – History by region :

The earliest-known pottery objects are Gravettian figurines such as those discovered at Dolní Věstonice in the modern-day Czech Republic. The Venus of Dolní Věstonice (Věstonická Venuše in Czech) is a Venus figurine, a statuette of a nude female figure dated to 29,000–25,000 BCE (Gravettian industry) . The earliest pottery vessels found include those excavated from the Yuchanyan Cave in southern China, dated from 16,000 BCE , and those found in the Amur River basin in the Russian Far East, dated from 14,000 BCE .

Other early pottery vessels include those made by the Incipient Jōmon people of Japan from around 10,500 BCE have also been found . The term "Jōmon" means "cord - marked" in Japanese. This refers to the markings made on the vessels and figures using sticks with cords during their production.

It appears that pottery was independently developed in Sub-Saharan Africa during the 11,000-10,000 BCE and in South America during the 10,000 BCE

8 – 3 – 1 – Far East Asia :

Sherds have been found in China and Japan from a period between 12,000 and perhaps as long as 16,000 years ago . In Japan, the Jōmon period has a long history of development of Jimson Pottery which was characterized by impressions of rope on the surface of the pottery created by pressing rope into the clay before firing. Glazed Stoneware was being created as early as the 15th century BCE in China. Porcelain became a renowned Chinese export during the Tang Dynasty (618-906 CE) and subsequent dynasties . Korean potters produced porcelain as early as the 14th century CE . Koreans brought the art of porcelain to Japan in the 17th century CE.

The secret of making such porcelain was sought in the Islamic world and later in Europe when examples were imported from the East. Many attempts were made to imitate it in Italy and France. However it was not produced outside of the Orient until 1709 in Germany.

8 – 3 – 2 – South Asia :

Pottery was in use in ancient India, including areas now forming Pakistan and northwest India, during the Mehrgarh Period II (5,500-4,800 BCE) and Mehrgarh Period III (4,800-3,500 BCE), known as the ceramic Neolithic and chalcolithic. Pottery, including items known as the ed-Dur vessels, originated in regions of the Indus Valley and have been found in a number of sites in the Indus Valley Civilization.

8 – 3 – 3 – Near East :

The earliest history of pottery production in the Near East can be divided into four periods, namely: the Hassuna period (7000-6500 BCE), the Halaf period (6500-5500 BCE), the Ubaid period (5500-4000 BCE), and the Uruk period (4000-3100 BCE).

The invention of the potter's wheel in Mesopotamia sometime between 6,000 and 4,000 BCE (Ubaid period) revolutionized pottery production. Specialized potters were then able to meet the expanding needs of the world's first cities.

Pottery making began in the Fertile Crescent from the 7th millennium BCE. The earliest forms, which were found at the

Hassuna site, were hand formed from slabs, undecorated, unglazed low-fired pots made from reddish-brown clays . Within the next millennium, wares were decorated with elaborate painted designs and natural forms, incising and burnished . By 4000 BCE , the potters wheel was developed. Newer kiln designs could fire wares to 1,050 °C to 1,200 °C which enabled new possibilities and new preparation of clays. Production was now carried out by small groups of potters for small cities, rather than individuals making wares for a family. The shapes and range of uses for ceramics and pottery expanded beyond simple vessels to store and carry to specialized cooking utensils, pot stands and rat traps. As the region developed new organizations and political forms, pottery became more elaborate and varied. Some wares were made using moulds, allowing for increased production for the needs of the growing populations. Glazing was commonly used and pottery was more decorated .

8 – 3 – 4 – Aegean region :

Civilization developed concurrently with the Fertile Crescent in the ancient Mediterranean islands around Greece from about 3200 to 1000 BCE and carried to Ancient Greece and Ancient Rome that is considered the Classical era in the Western world. The arts of these cultures eventually became a hallmark for Europe and the New World.

The Minoan pottery was characterized by elaborate painted decoration with natural themes.

The classical Greek culture began to emerge around 1000 BCE featuring a variety of well crafted pottery which now included the human form as a decorating motif. The pottery wheel was now in regular use. Although glazing was known to these potters, it was not widely used. Instead, a more porous clay slip was used for decoration. A wide range of shapes for different uses developed early and remained essentially unchanged during the Greek history.[54]

In the Mediterranean, during the Greek Dark Ages (1,100–800 BCE), amphoras and other pottery were decorated with geometric designs such as squares, circles and lines. In the Chalcolithic period in

Mesopotamia, Halafian pottery achieved a level of technical competence and sophistication, not seen until the later developments of Greek pottery with Corinthian and Attic ware .

The Etruscan pottery carried on the Greek pottery with its own variations.

The Ancient Roman pottery started by copying Greek and Etruscan styles but soon developed a style of its own .

The distinctive Red Samian ware of the Early Roman Empire was copied by regional potters throughout the Empire.

8 – 3 – 5 – Islamic pottery :

Early Islamic pottery followed the forms of the regions which the Muslims conquered. Eventually, however, there was cross-fertilization between the regions. This was most notable in the Chinese influences on Islamic pottery. Trade between China and Islam took place via the system of trading posts over the lengthy Silk Road. Islamic nations imported stoneware and later porcelain from China. China imported the minerals for Cobalt blue from the Islamic ruled Persia to decorate their blue and white porcelain, which they then exported to the Islamic world.

Likewise, Islamic art contributed to a lasting pottery form identified as Hispano-Moresque in Andalucia (Islamic Spain). Unique Islamic forms were also developed, including fritware, lusterware and specialized glazes like tin - glazing, which led to the development of the popular maiolica .

One major emphasis in ceramic development in the Muslim world was the use of tile and decorative tile work.

8 – 3 – 6 – Europe :

The early inhabitants of Europe developed pottery at about the same time as in the Near East, circa 5500 – 4500 BCE. These cultures and their pottery were eventually shaped by new cultural influences and technology with the invasions of Ancient Rome and later by Islam. The Renaissance art of Europe was a melding of the art of Classical era and Islamic art.

8 – 3 – 7 – Americas

Most evidence points to an independent development of pottery in the Amerindian cultures, starting with their Archaic Era (3500–2000 BCE), and into their Formative period (2000 BCE-200 CE). These cultures did not develop the stoneware, porcelain or glazes found in the old world.

8 – 3 – 8 – Africa :

Northern Africa includes Egypt, which had several distinct phases of development in pottery. During the early Mediterranean civilizations of the fertile crescent, Egypt developed a unique non-clay-based high-fired ceramic which has come to be called Egyptian faience.

The other major phase came during the Umayyad Caliphate of Islam, Egypt was a link between early center of Islam in the Near East and Iberia which led to the impressive style of pottery.

As for Sub - Saharan Africa, in 2007, Swiss archeologists discovered pieces of the oldest pottery in Africa in Central Mali, dating back to at least 9,500 BCE .

8 – 3 – 9 – Oceania :

Polynesia , Melanesia , and Micronesia :

Pottery has been found in archaeological sites across the islands of Oceania. It is attributed to an ancient archaeological culture called the Lapita. A form of pottery called **Plain ware** is found throughout sites of Oceania. The relationship between Lapita pottery and Plain ware is not altogether clear.

The Indigenous Australians were hunter-gatherer tribes and did not farm or cultivate crops, and in keeping with these cultural features, they also never developed pottery . After Europeans came to Australia and settled, they found deposits of clay which were analysed by English potters as excellent for making pottery. Less than 20 years later, Europeans came to Australia and began creating pottery. Since then, ceramic manufacturing, mass - produced pottery, and studio pottery have flourished in Australia .

9 - Archaeology :

For archaeologists, anthropologists and historians the study of pottery can help to provide an insight into past cultures. Pottery is durable, and fragments, at least, often survive long after artefacts made from less-durable materials have decayed past recognition. Combined with other evidence, the study of pottery arte facts is helpful in the development of theories on the organization, economic condition and the cultural development of the societies that produced or acquired pottery. The study of pottery may also allow inferences to be drawn about a culture's daily life, religion, social relationships, attitudes towards neighbours, attitudes to their own world and even the way the culture understood the universe.

Chronologies based on pottery are often essential for dating non-literate cultures and are often of help in the dating of historic cultures as well. Trace-element analysis, mostly by neutron activation, allows the sources of clay to be accurately identified and the thermo luminescence test can be used to provide an estimate of the date of last firing. Examining fired pottery shards from prehistory, scientists learned that during high-temperature firing, iron materials in clay record the exact state of Earth's magnetic field at that exact moment.

10 - Environmental issues in production :

Although many of the environmental effects of pottery production have existed for millennia, some of these have been amplified with modern technology and scales of production. The principal factors for consideration fall into two categories: (a) effects on workers, and (b) effects on the general environment. Within the effects on workers, chief impacts are indoor air quality, sound levels and possible over - illumination. Regarding the general environment, factors of interest are fuel consumption, off-site water pollution, air pollution and disposal of hazardous materials.

Historically, "plumbism" (lead poisoning) was a significant health concern to those glazing pottery. This was recognized at least as early as the nineteenth century, and the first legislation in the United Kingdom to limit pottery workers' exposure was introduced in 1899 . While the risk to those working in ceramics is now much reduced, it can still not be ignored. With respect to indoor air quality, workers can be exposed to fine particulate matter, carbon monoxide and certain heavy metals. The greatest health risk is the potential to develop silicosis from the long-term exposure to crystalline silica. Proper ventilation can reduce the risks, and the first legislation in the United Kingdom to govern ventilation was introduced in 1899.[60] Another, more recent, study at Laney College, Oakland, California suggests that all these factors can be controlled in a well-designed workshop environment .

The use of energy and pollutants in the production of ceramics is a growing concern. Electric firing is arguably more environmentally friendly than combustion firing although the source of the electricity varies in environmental impact .

11 - Other usages :

The English city of Stoke-on-Trent is widely known as **The Potteries** because of the large number of pottery factories or, colloquially, **Pot Banks**. It was one of the first industrial cities of the modern era where, as early as 1785, two hundred pottery manufacturers employed 20,000 workers . For the same reason , the largest foot ball club in the city is known as **The Potters** .

Power Concrete Screed

Power concrete screeds can be used in place of a man powered screed bar to strike off excess concrete. Concrete is poured from a wet mix of cement, sand, aggregate and water. Prior to the mix drying, the concrete should be smoothed out on the desired surface.

A power screed assists in the smoothing out process by leveling out and/or vibrating the wet mixture. There are friction screeds or "roller" screeds that level the concrete - such as the Lura enterprises Lightning Strike which is gas or electric, or the Bunyan striker which is a large heavy steel tube driven by hydraulics. Other power screeds rely on small gas powered engines or small electric motors such as a cordless drill for vibration which can in fact shake the heavier aggregate to the bottom of your pour.

Power Trowel

Walk Behind Power Trowel

a 13hp Boren Power Trowel

A **power trowel** (also known as a "power float", "helicopter" or "trowel machine") is a piece of light construction equipment used by construction companies and contractors, to apply a smooth finish to concrete slabs .

Power trowels differ in the way they are controlled :

- Ride-on power trowels are used by an operator sitting on a seat upon the machinery, controlling the power trowel with the necessary buttons.
- Walk-behind power trowels are used by an operator walking behind the machine.

Pozzolan

Contents

1 – Introduction :

A **pozzolan** is a material which, when combined with calcium hydroxide, exhibits cementitious properties. Pozzolans are commonly used as an addition (the technical term is "supplementary cementitious material", usually abbreviated "SCM") to Portland cement concrete mixtures to increase the long-term strength and other material properties of Portland cement concrete, and in some cases reduce the material cost of concrete. Pozzolans are primarily vitreous siliceous materials which react with calcium hydroxide to form calcium silicates; other cementitious materials may also be formed depending on the constituents of the pozzolan.

The pozzolanic reaction may be slower than the rest of the reactions that occur during cement hydration, and thus the short-term strength of concrete made with pozzolans may not be as high as concrete made with purely cementitious materials; conversely, highly reactive pozzolans, such as silica fume and high reactivity metakaolin can produce "high early strength" concrete that increase the rate at which concrete gains strength.

The first known pozzolan was pozzolana, a volcanic ash, for which the category of materials was named. The most commonly used pozzolan today is fly ash, though silica fume, high-reactivity metakaolin, ground granulated blast furnace slag, and other materials are also used as pozzolans.

A pozzolan is a siliceous or aluminosiliceous material, which is highly vitreous. This material independently has few/fewer cementitious properties, but in the presence of a lime-rich medium like calcium hydroxide, shows better cementitious properties towards the later day strength (> 28 days). The mechanism for this display of strength is the reaction of silicates with lime to form secondary cementitious phases (calcium silicate hydrates with a lower Ca/Si ratio) which display gradual strengthening properties usually after 7 days.

The extent of the strength development depends upon the chemical composition of the pozzolan: the greater the composition of alumina and silica along with the vitreous phase in the material, the better the pozzolanic reaction and strength display.

Many pozzolans available for use in construction today were previously seen as waste products, often ending up in landfills. Use of pozzolans can permit a decrease in the use of Portland cement when producing concrete; this is more environmentally friendly than limiting cementitious materials to Portland cement. Due to knowledge gained since the 1990s, current practice may permit up to a 40 percent reduction of Portland cement used in the concrete mix when replaced with a carefully designed combination of approved pozzolans. When the mix is designed properly, concrete can utilize pozzolans without significantly reducing the final compressive strength or other performance characteristics.

2 - Pozzolanic reaction :

At the basis of the Pozzolanic reaction stands a simple acid-base reaction between calcium hydroxide , also known as Portlandite , or ($Ca(OH)_2$) , and silicic acid (H_4SiO_4, or $Si(OH)_4$) . Simply, this reaction can be schematically represented as follows:

$$Ca(OH)_2 + H_4SiO_4 \rightarrow$$
$$Ca^{2+} + H_2SiO_4^{2-} + 2\ H_2O \rightarrow$$
$$CaH_2SiO_4 \cdot 2\ H_2O$$

or summarized in abbreviated notation of cement chemists:

$$CH + SH \rightarrow CSH$$

The product of general formula ($CaH_2SiO_4 \cdot 2\ H_2O$) formed is a calcium silicate hydrate, also abbreviated as CSH in cement chemist notation. The ratio Ca/Si, or C / S , and the number of water molecules can vary and the above mentioned stoichiometry may differ.

As the density of CSH is lower than that of portlandite and pure silica, a consequence of this reaction is a swelling of the reaction products. This reaction may also occur with time in concrete between alkaline cement porewater and poorly - crystalline silica aggregates. This delayed process is also known as alkali silica reaction, or alkali-aggregate reaction, and may seriously damage concrete structures because the resulting volumetric expansion is also responsible for spalling and decrease of the concrete strength.

Pozzolana

Pozzolana from Bacoli in the Bay of Naples

Contents

1 – Introduction :

Pozzolana, also known as pozzolanic ash (pulvis puteolanus in Latin), is a fine, sandy volcanic ash. Pozzolanic ash was first discovered and dug in Italy, at Pozzuoli. It was later discovered at a number of other sites as well. Vitruvius speaks of four types of pozzolana: black, white, grey, and red, all of which can be found in the volcanic areas of Italy, such as Naples.

2 – Chemistry :

Pozzolana is a siliceous and aluminous material which reacts with calcium hydroxide in the presence of water. This forms compounds possessing cementitious properties at room temperature which have the ability to set underwater. It transformed the possibilities for making concrete structures, although it took the Romans some time to discover its full potential. Typically it was mixed two-to-one with lime just prior to mixing with water. The Roman port at Cosa was built of Pozzolana that was poured underwater, apparently using a long tube to carefully lay it up without allowing sea water to mix with it. The three piers are still visible today, with the underwater portions in generally excellent condition even after more than 2100 years.

3 - Modern use :

Modern pozzolanic cements are a mix of natural or industrial pozzolans and Portland cement. In addition to underwater use, the high alkalinity of pozzolana makes it especially resistant to common forms of corrosion from sulfates. Once fully hardened, the Portland cement - Pozzolana blend may be stronger than Portland cement, due to its lower porosity, which also makes it more resistant to water absorption and spalling.

Some industrial sources of materials with pozzolanic properties are: class F (silicious) fly ash from coal-fired power plants, silica fume from silicon production, rice husk ash from rice paddy-fields (agriculture), and meta kaolin from oil sand operations. Metakaolin, a powerful pozzolan, can also be manufactured, and is valued for making white concrete.

Other industrial waste products used in Portland composite cements include class C (calcareous) fly ash and ground granulated blast furnace slag.

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Precast Concrete

A precast concrete walled house in construction

Contents

1 – Introduction :

Precast concrete is a construction product produced by casting concrete in a reusable mold or "form" which is then cured in a controlled environment, transported to the construction site and lifted into place. In contrast, standard concrete is poured into site-specific forms and cured on site. **Precast stone** is distinguished from precast concrete by using a fine aggregate in the mixture, so the final product approaches the appearance of naturally occurring rock or stone.

By producing precast concrete in a controlled environment (typically referred to as a precast plant), the precast concrete is afforded the opportunity to properly cure and be closely monitored by plant employees. Utilizing a Precast Concrete system offers many potential advantages over site casting of concrete. The production process for Precast Concrete is performed on ground level, which helps with safety throughout a project. There is a greater control of the quality of materials and workmanship in a precast plant rather than on a construction site. Financially, the forms used in a precast plant may be reused hundreds to thousands of times before they have to be replaced, which allows cost of formwork per unit to be lower than for site-cast production.

Many states across the United States require a precast plant to be certified by either the Architectural Precast Association (APA), National Precast Concrete Association (NPCA) or Precast Prestressed Concrete Institute (PCI) for a precast producer to supply their product to a construction site sponsored by State and Federal DOTs.

There are many different types of precast concrete, forming systems for architectural applications, differing in size, function, and cost. Precast architectural panels are also used to clad all or part of a building facade free-standing walls used for landscaping, soundproofing, and security walls, and some can be Prestressed concrete structural elements. Stormwater drainage, water and sewage pipes, and tunnels make use of precast concrete units. The New South Wales Government Railways made extensive use of precast concrete construction for its stations and similar buildings. Between 1917 and 1932, they erected 145 such buildings.

2 - Brief history :

Ancient Roman builders made use of concrete and soon poured the material into moulds to build their complex network of aqueducts, culverts, and tunnels. Modern uses for pre-cast technology include a variety of architectural and structural applications featuring parts of or an entire building system.

In the modern world, pre - cast paneled buildings were pioneered in Liver pool , England in 1905. A process was invented by city engineer John Alexander Brodie, whose inventive genius also had him inventing the football goal net. The tram stables at Walton in Liverpool followed in 1906. The idea was not taken up extensively in Britain. However, it was adopted all over the world, particularly in Eastern Europe and Scandinavia.

3 - Precast Concrete Products :

The following is a sampling of the numerous products that utilize precast / pre stressed concrete. While this is not a complete list, the majority of precast / pre stressed products can fall under one or more of the following categories :

3 – 1 - Agricultural Products :

Precast concrete products can withstand the most extreme weather conditions and will hold up for many decades of constant usage. Products include bunker silos, cattle feed bunks, cattle grid, agricultural fencing, H-bunks, J-bunks, livestock slats, livestock watering trough, feed troughs, concrete panels, slurry channels, and more. Pre stressed concrete panels are widely used in the UK for a variety of applications including agricultural buildings, grain stores, silage clamps, slurry stores, livestock walling, and general retaining walls. Panels can either be used horizontally and placed either inside the webbings of RSJs (I-beam) or in front of them. Alternatively panels can be cast into a concrete foundation and used as a cantilever retaining wall.

3 – 2 - Building and Site Amenities :

Precast concrete building components and site amenities are used architecturally as fireplace mantels, cladding, trim products, accessories, and curtain walls. Structural applications of precast concrete include foundations, beams, floors, walls, and other structural components. It is essential that each structural component be designed and tested to withstand both the tensile and compressive loads that the member will be subjected to over its lifespan .

	
An example of a precast concrete retaining wall.	*Precast concrete wall veneer formed to replicate brick*

3 – 3 - Retaining Walls :

Precast concrete provides the manufacturers with the ability to produce a wide range of engineered earth retaining systems. Products include: commercial retaining wall , residential retaining walls, sea walls, mechanically stabilized earth (MSE) panels, modular block systems, segmental retaining walls, etc. Retaining walls have 5 different types which include: gravity retaining wall, semigravity retaining wall, cantilever retaining wall, counterfort retaining wall, and buttress retaining wall .

3 – 4 - Sanitary and Storm water :

Sanitary and Storm water management products are structures designed for underground installation that have been specifically engineered for the treatment and removal of pollutants from sanitary and storm water run - off. These precast concrete products include storm water detention vaults, catch basins, and manholes .

3 – 5 - Transportation and Traffic Related Products :

Precast concrete transportation products are used in the construction, safety and site protection of road, airport and railroad transportation systems. Products include: box culverts, 3-sided culverts, bridge systems, railroad crossings, railroad ties, sound walls/barriers, Jersey barriers, tunnel segments, precast concrete barriers, TVCBs, central reservation barriers and other transportation products. These are used to make underpasses, surface - passes and pedestrian subways, so that traffic in cities is disturbed for less amount of time and for other purposes. Precast concrete is also used for the roll ways of some rubber tired metros.

3 – 6 - Utility Structures :

For communications, electrical, gas or steam systems, precast concrete utility structures protect the vital connections and controls for utility distribution. Precast concrete is nontoxic and environmentally safe. Products include: hand holes, hollow core products, light pole bases, meter boxes, panel vaults, pull boxes, telecommunications structures, transformer pads, transformer vaults, trenches, utility buildings, utility vaults, utility poles, controlled environment vaults (CEVs,) and other utility structures .

3 – 7 - Water and Waste water Products :

Precast water and wastewater products hold or contain water, oil or other liquids for the purpose of further processing into non-contaminating liquids and soil products. Products include : aeration systems, distribution boxes, dosing tanks, dry wells, grease inter ceptors, leaching pits, sand - oil /oil - water interceptors, septic tanks, water / sewage storage tanks, wet wells, fire cisterns and other water & wastewater products .

4 – Specialized Products

4 – 1 - Cemetery Products :

Under ground vaults or mausoleums - calls for quality watertight structures that withstand the tests of time and the forces of nature.

4 – 2 - Hazardous Materials Containment :

Storage of hazardous material, whether short-term or long-term, is an increasingly important environmental issue, calling for containers that not only seal in the materials, but are strong enough to stand up to natural disasters or terrorist attacks.[9]

4 – 3 - Marine Products :

Floating docks, underwater infrastructure, decking, railings and a host of amenities are among the uses of precast along the waterfront. When designed with heavy weight in mind, precast products counteract the buoyant forces of water significantly better than most materials.

4 – 4 - Modular Paving :

Modular paving is available in a rainbow of colors , shapes , sizes and textures, these versatile precast concrete pieces can be designed to mimic brick , stone or wood .

4 – 5 - Pre stressed / Structural Products :

Pre stressing is a technique of introducing stresses of a predetermined magnitude into a structural member to improve its behavior. This technique is usually found in concrete beams, spandrels, columns, single and double tees, wall panels, segmental bridge units, bulb-tee girders, I-beam girders, and others. "Prestressed member are crack-free under working loads and, as a result, look better and more watertight, providing better corrosion protection for the steel." Many projects find that pre stressed concrete provides the lowest overall cost, considering production and lifetime maintenance.

5 – Rein forced Concrete Box :

A **reinforced concrete box**, referred to as a box culvert in the UK and Hong Kong, is a square or rectangular "pipe" made of concrete with rebar or wire mesh fabric strewn throughout for the addition of extra strength. Multiple such boxes are arranged sideways to make a pipe or tunnel like structure.

RCC Magic Box, used to build an underpass at Madiwala at the junction of Hosur Road and Inner Ring Road, Bangalore City.

It is often used for sanitary sewer trunks, storm drain spillways, pedestrian subways, utility tunnels, catch basins, and other similar underground passage ways. Due to the enormous strength of reinforced concrete, it is often used in sewers or tunnels that have little cover above them which means they will be subjected to the stress of the road atop them. In India, pre-cast concrete boxes known as "Magic Boxes"" are used for the construction of flyovers and underpasses.

6 - Double Wall Precast — Concrete Sandwich Panels :

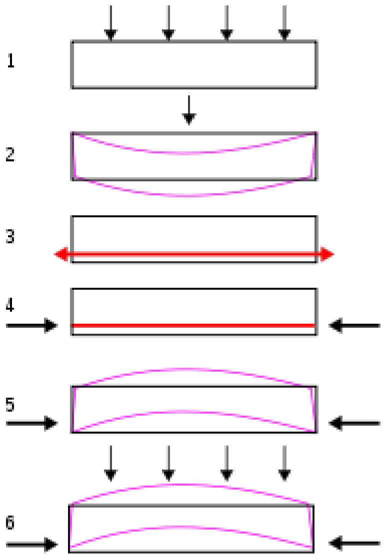
The double wall process has been in use in Europe for many years. The walls consist of two wythes of concrete separated by an insulated void. The most commonly specified thickness of the wall panels is 8 inches. The walls can also be built to 10 and 12 inches thick if desired. A typical 8-inch wall panel consists of two wythes (layers) of reinforced concrete (each wythe is 2-3/8 inches thick) sandwiched around 3-1/4 inches of high R-value insulating foam. The two wythes of the interior and exterior concrete layers are held together with steel trusses. Concrete sandwich panels held together with steel trusses are inferior to those held together with composite fibreglass connectors. This is because the steel creates a thermal bridge in the wall, significantly reducing the insulative performance and reducing the ability of the building to utilise its thermal mass for energy efficiency. There is also the risk that because steel does not have the same expansion coefficient as that of concrete, as the wall heats and cools, the steel will expand and contract at a different rate to the concrete, which can cause cracking and spalling (concrete "cancer"). Fiber glass connectors that are specially developed to be compatible with concrete significantly reduce this problem . The insulation is continuous throughout the wall section. The composite sandwich wall section has an R-value exceeding R-22. The wall panels can be made to any height desired, up to a limit of 12 feet. Many owners prefer a 9-foot clear height for the quality of look and feel it affords a building.

The walls can be produced with smooth surfaces on both sides because of the unique manufacturing process, which form finishes both sides. The walls are simply painted or stained on the exterior surface to achieve the desired color or textured surface. When desired, the exterior surface can be manufactured to have a wide variety of brick, stone, wood, or other formed and patterned appearances through the use of reusable, removable form liners. Interior surfaces of the double - wall panels are drywall quality in appearance right out of the plant, requiring only the same prime and paint procedure as is common when completing conventional interior walls made of drywall and studs.

Window and door openings are cast into the walls at the manufacturing plant as part of the fabrication process. Electrical and telecommunications conduit and boxes are flush - mounted and cast directly in the panels in the specified locations. The carpenters, electricians, and plumbers do need to make some slight adjustments when first becoming familiar with some of the unique aspects of the wall panels. However, they still perform most of their job duties in the manner to which they are accustomed.

Double-wall precast concrete sandwich panels can be used on most every type of building including but not limited to: multi-family, townhouses, condominiums, apartments, hotels and motels, dormitories and schools, and single - family homes. Depending upon building function and layout, the double-wall panels can be easily designed to handle both the structural requirements for strength and safety, as well as the aesthetic and sound attenuation qualities the owner desires. Speed of construction, durability of finished structure, and energy- efficiency are all hallmarks of a building that utilizes the double-wall system.

Pre Stressed Concrete



Pre stressed concrete diagram

Contents

1 – Introduction :

Pre stressed concrete is a method for overcoming concrete's natural weakness in tension. It can be used to produce beams, floors or bridges with a longer span than is practical with ordinary reinforced concrete. Pre stressing tendons (generally of high tensile steel cable or rods) are used to provide a clamping load which produces a compressive stress that balances the tensile stress that the concrete compression member would otherwise experience due to a bending load. Traditional reinforced concrete is based on the use of steel reinforcement bars, rebars , inside poured concrete.

Pre stressing can be accomplished in three ways: pre - tensioned concrete, and bonded or un bonded post - tensioned concrete.

2 – Pre - tensioned concrete :

Stressed ribbon pedestrian bridge, Grants Pass, Oregon, USA

Pre-tensioned concrete is cast around already tensioned tendons. This method produces a good bond between the tendon and concrete, which both protects the tendon from corrosion and allows for direct transfer of tension. The cured concrete adheres and bonds to the bars and when the tension is released it is transferred to the concrete as compression by static friction. However, it requires stout anchoring points between which the tendon is to be stretched and the tendons are usually in a straight line. Thus, most pretensioned concrete elements are prefabricated in a factory and must be transported to the construction site, which limits their size. Pre-tensioned elements may be balcony elements, lintels, floor slabs, beams or foundation piles. An innovative bridge construction method using pre-stressing is the stressed ribbon bridge design.

3 - Bonded post-tensioned concrete :

Bonded post - tensioned concrete is the descriptive term for a method of applying compression after pouring concrete and the curing process (*in situ*). The concrete is cast around a plastic, steel or aluminium curved duct, to follow the area where otherwise tension would occur in the concrete element. A set of tendons are fished through the duct and the concrete is poured. Once the concrete has hardened, the tendons are tensioned by hydraulic jacks that react (push) against the concrete member itself. When the tendons have stretched sufficiently, according to the design specifications (see Hooke's law), they are wedged in position and maintain tension after the jacks are removed, transferring pressure to the concrete. The duct is then grouted to protect the tendons from corrosion. This method is commonly used to create monolithic slabs for house construction in locations where expansive soils (such as adobe clay) create problems for the typical perimeter foundation. All stresses from seasonal expansion and contraction of the underlying soil are taken into the entire tensioned slab, which supports the building without significant flexure. Post-tensioning is also used in the construction of various bridges, both after concrete is cured after support by false work and by the assembly of prefabricated sections, as in the segmental bridge.

Among the advantages of this system over unbonded post-tensioning are :

- Large reduction in traditional reinforcement requirements as tendons cannot de stress in accidents.
- Tendons can be easily "woven" allowing a more efficient design approach.
- Higher ultimate strength due to bond generated between the strand and concrete.
- No long term issues with maintaining the integrity of the anchor/dead end.

3 – 1 - History of problems with bonded post-tensioned bridges :

The popularity of this form of pre stressing for bridge construction in Europe increased significantly around the 1950s and 60s. How ever, a history of problems have been encountered that has cast doubt over the long-term durability of such structures.

Due to poor work man ship of quality control during construction, some times the ducts containing the pre stressing tendons are not fully filled, leaving voids in the grout where the steel is not protected from corrosion. The situation is exacerbated if water and chloride (from de-icing salts) from the highway are able to penetrate into these voids.

Notable events are listed below :

- The Ynys-y-Gwas bridge in West Glamorgan, Wales – a segmental post-tensioned structure, particularly vulnerable to defects in the post - tensioning system – collapsed without warning in 1984.
- The Melle bridge, constructed in Belgium during the 1950s, collapsed in 1992 due to failure of post-tensioned tie down members following tendon corrosion.
- Following discovery of tendon corrosion in several bridges in England, the High ways Agency issued a moratorium on the construction of new internal grouted post-tensioned bridges and embarked on a 5-year programme of inspections on its existing post-tensioned bridge stock.
- In 2000, a large number of people were injured when a section of a foot bridge at the Charlotte Motor Speedway, USA, gave way and dropped to the ground. In this case, corrosion was exacerbated by calcium chloride that had been used as a concrete admixture, rather than sodium chloride from de-icing salts.
- In 2011, the Hammersmith Flyover in London, England, was subject to an emergency closure after defects in the post-tensioning system were discovered.

4 - Un bonded post-tensioned concrete :

Un bonded post - tensioned concrete differs from bonded post-tensioning by providing each individual cable permanent freedom of movement relative to the concrete. To achieve this, each individual tendon is coated with a grease (generally lithium based) and covered by a plastic sheathing formed in an extrusion process. The transfer of tension to the concrete is achieved by the steel cable acting against steel anchors embedded in the perimeter of the slab. The main disadvantage over bonded post-tensioning is the fact that a cable can de stress itself and burst out of the slab if damaged (such as during repair on the slab). The advantages of this system over bonded post-tensioning are:

1. The ability to individually adjust cables based on poor field conditions (For example: shifting a group of 4 cables around an opening by placing 2 to either side).
2. The procedure of post-stress grouting is eliminated.
3. The ability to de-stress the tendons before attempting repair work .

Picture number one (below) shows rolls of post- tensioning (PT) cables with the holding end anchors displayed. The holding end anchors are fastened to rebar placed above and below the cable and buried in the concrete locking that end. *Pictures numbered two, three and four* shows a series of black pulling end anchors from the rear along the floor edge form. Rebar is placed above and below the cable both in front and behind the face of the pulling end anchor. The above and below placement of the rebar can be seen in picture number three and the placement of the rebar in front and behind can be seen in picture number four. The blue cable seen in picture number four is electrical conduit. *Picture number five* shows the plastic sheathing stripped from the ends of the post-tensioning cables before placement through the pulling end anchors. *Picture number six* shows the post-tensioning cables in place for concrete pouring. The plastic sheathing has been removed from the end of the cable and the cable has been pushed through the black pulling end anchor attached to the inside of the concrete floor side form. The greased cable can be seen protruding from the concrete floor side form. *Pictures seven and eight* show the post-tensioning cables protruding from the poured concrete floor. After the concrete floor has been poured and has set for about a week, the cable ends will be pulled with a hydraulic jack.

5 - Applications :

Pre stressed concrete is the main material for floors in high-rise buildings and the entire containment vessels of nuclear reactors.

Un bonded post - tensioning tendons are commonly used in parking garages as barrier cable.[3] Also, due to its ability to be stressed and then de - stressed, it can be used to temporarily repair a damaged building by holding up a damaged wall or floor until permanent repairs can be made.

The advantages of prestressed concrete include crack control and lower construction costs; thinner slabs - especially important in high rise buildings in which floor thickness savings can translate into additional floors for the same (or lower) cost and fewer joints, since the distance that can be spanned by post-tensioned slabs exceeds that of reinforced constructions with the same thickness. Increasing span lengths increases the usable unencumbered floorspace in buildings; diminishing the number of joints leads to lower maintenance costs over the design life of a building, since joints are the major focus of weakness in concrete buildings.

The first pre stressed concrete bridge in North America was the Walnut Lane Memorial Bridge in Philadelphia, Pennsylvania. It was completed and opened to traffic in 1951. Pre stressing can also be accomplished on circular concrete pipes used for water transmission. High tensile strength steel wire is helically-wrapped around the outside of the pipe under controlled tension and spacing which induces a circumferential compressive stress in the core concrete. This enables the pipe to handle high internal pressures and the effects of external earth and traffic loads.

6 - Design agencies and regulations :

In the United States, pre-stressed concrete design and construction is aided by organizations such as Post-Tensioning Institute (PTI) and Precast / Pre stressed Concrete Institute (PCI). In Canada the Canadian Precast / Pre stressed Concrete Institute (CPCI) assumes this role for both post-tensioned and pre-tensioned concrete structures.

Europe also has its own associations and institutes. It is important to note that these organizations are not the authorities of building codes or standards, but rather exist to promote the understanding and development of pre-stressed design, codes and best practices. In the UK, the Post-Tensioning Association fulfills this role.

Rules for the detailing of reinforcement and pre stressing tendons are provided in Section 8 of the European standard EN 1992-2:2005 - Eurocode 2: Design of concrete structures - Concrete bridges: design and detailing rules.

In Australia the code of practice used to design reinforced and prestressed concrete is AS 3600-2009.

Properties of Concrete

Contents :

1 – Introduction :

Concrete has relatively high compressive strength, but significantly lower tensile strength, and as such is usually reinforced with materials that are strong in tension (often steel). The elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develops. Concrete has a very low coefficient of thermal expansion, and as it matures concrete shrinks. All concrete structures will crack to some extent, due to shrinkage and tension. Concrete which is subjected to long - duration forces is prone to creep.

Tests can be made to ensure the properties of concrete correspond to specifications for the application.

The density of concrete varies, but is around 2,400 kg / m³

As a result, without compensating, concrete would almost always fail from tensile stresses – even when loaded in compression. The practical implication of this is that concrete elements subjected to tensile stresses must be reinforced with materials that are strong in tension.

Reinforced concrete is the most common form of concrete. The reinforcement is often steel, rebar (mesh, spiral, bars and other forms). Structural fibers of various materials are available.

Concrete can also be prestressed (reducing tensile stress) using internal steel cables (tendons), allowing for beams or slabs with a longer span than is practical with reinforced concrete alone. Inspection of concrete structures can be non-destructive if carried out with equipment such as a Schmidt hammer, which is used to estimate concrete strength.

The ultimate strength of concrete is influenced by the water-cementitious ratio *(w/cm)*, the design constituents, and the mixing, placement and curing methods employed. All things being equal, concrete with a lower water-cement (cementitious) ratio makes a stronger concrete than that with a higher ratio. The total quantity of cementitious materials (portland cement, slag cement, pozzolans) can affect strength, water demand, shrinkage, abrasion resistance and density. All concrete will crack independent of whether or not it has sufficient compressive strength. In fact, high Portland cement content mixtures can actually crack more readily due to increased hydration rate. As concrete transforms from its plastic state, hydrating to a solid, the material undergoes shrinkage. Plastic shrinkage cracks can occur soon after placement but if the evaporation rate is high they often can actually occur during finishing operations, for example in hot weather or a breezy day. In very high-strength concrete mixtures (greater than 70 MPa) the crushing strength of the aggregate can be a limiting factor to the ultimate compressive strength. In lean concretes (with a high water-cement ratio) the crushing strength of the aggregates is not so significant.

The internal forces in common shapes of structure, such as arches, vaults, columns and walls are predominantly compressive forces, with floors and pavements subjected to tensile forces. Compressive strength is widely used for specification requirement and quality control of concrete. The engineer knows his target tensile (flexural) requirements and will express these in terms of compressive strength.

Wired.com reported on April 13, 2007 that a team from the University of Tehran, competing in a contest sponsored by the American Concrete Institute, demonstrated several blocks of concretes with abnormally high compressive strengths between 340 and 410 MPa (49,000 and 59,000 psi) at 28 days.[2] The blocks appeared to use an aggregate of steel fibres and quartz – a mineral with a compressive strength of 1100 MPa, much higher than typical high-strength aggregates such as granite (100–140 MPa or 15,000–20,000 psi).

Reactive Powder Concrete, also known as Ultra-High Performance Concrete, can be even stronger, with strengths of up to 800 MPa (116,000 PSI) . These are made by eliminating large aggregate completely, carefully controlling the size of the fine aggregates to ensure the best possible packing, and incorporating steel fibers (sometimes produced by grinding steel wool) into the matrix. Reactive Powder Concretes may also make use of silica fume as a fine aggregate. Commercial Reactive Powder Concretes are available in the 170–210 MPa (25,000–30,000 psi) strength range.

2 – Elasticity :

The modulus of elasticity of concrete is a function of the modulus of elasticity of the aggregates and the cement matrix and their relative proportions. The modulus of elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develops. The elastic modulus of the hardened paste may be in the order of 10-30 GPa and aggregates about 45 to 85 GPa. The concrete composite is then in the range of 30 to 50 GPa.

The American Concrete Institute allows the modulus of elasticity to be calculated using the following equation :

$$E_c = 33 w_c^{1.5} \sqrt{f'_c} \text{ (psi)}$$

where

w_c =weight of concrete (pounds per cubic foot) and where

$$90\frac{\text{lb}}{\text{ft}^3} \leq w_c \leq 160\frac{\text{lb}}{\text{ft}^3}$$

f'_c = compressive strength of concrete at 28 days (psi)

This equation is completely empirical and is not based on theory. Note that the value of E_c found is in units of psi. For normal weight concrete (defined as concrete with a w_c of 150 lb / ft^3 and subtracting 5 lb / ft^3 for steel) E_c is permitted to be taken as .

3 - Expansion and shrinkage :

Concrete has a very low coefficient of thermal expansion. However, if no provision is made for expansion, very large forces can be created, causing cracks in parts of the structure not capable of withstanding the force or the repeated cycles of expansion and contraction. The coefficient of thermal expansion of Portland cement concrete is 0.000008 to 0.000012 (per degree Celsius) (8 to 12 micro strains / °C) (8 - 12 1 / MK).

As concrete matures it continues to shrink, due to the ongoing reaction taking place in the material, although the rate of shrinkage falls relatively quickly and keeps reducing over time (for all practical purposes concrete is usually considered to not shrink due to hydration any further after 30 years). The relative shrinkage and expansion of concrete and brickwork require careful accommodation when the two forms of construction interface . Because concrete is continuously shrinking for years after it is initially placed, it is generally accepted that under thermal loading it will never expand to its originally placed volume . Due to its low thermal conductivity, a layer of concrete is frequently used for fireproofing of steel structures.

4 - Cracking :

Salginatobel Bridge, Switzerland.

All concrete structures will crack to some extent. One of the early designers of reinforced concrete, Robert Maillart, employed reinforced concrete in a number of arched bridges. His first bridge was simple, using a large volume of concrete. He then realized that much of the concrete was very cracked, and could not be a part of the structure under compressive loads, yet the structure clearly worked. His later designs simply removed the cracked areas, leaving slender, beautiful concrete arches. The Salginatobel Bridge is an example of this.

Concrete cracks due to tensile stress induced by shrinkage or stresses occurring during setting or use. Various means are used to overcome this. Fiber reinforced concrete uses fine fibers distributed throughout the mix or larger metal or other reinforcement elements to limit the size and extent of cracks. In many large structures joints or concealed saw-cuts are placed in the concrete as it sets to make the inevitable cracks occur where they can be managed and out of sight. Water tanks and highways are examples of structures requiring crack control.

4 – 1 - Shrinkage cracking :

Shrinkage cracks occur when concrete members undergo restrained volumetric changes (shrinkage) as a result of either drying, autogenous shrinkage or thermal effects. Restraint is provided either externally (i.e. supports, walls, and other boundary conditions) or internally (differential drying shrinkage, reinforcement). Once the tensile strength of the concrete is exceeded, a crack will develop. The number and width of shrinkage cracks that develop are influenced by the amount of shrinkage that occurs, the amount of restraint present and the amount and spacing of reinforcement provided.These are minor indications and have no real structural impact on the concrete member . Plastic-shrinkage cracks are immediately apparent, visible within 0 to 2 days of placement, while drying-shrinkage cracks develop over time. Autogenous shrinkage also occurs when the concrete is quite young and results from the volume reduction resulting from the chemical reaction of the Portland cement.

4 – 2 - Tension cracking :

Concrete members may be put into tension by applied loads. This is most common in concrete beams where a transversely applied load will put one surface into compression and the opposite surface into tension due to induced bending. The portion of the beam that is in tension may crack. The size and length of cracks is dependent on the magnitude of the bending moment and the design of the reinforcing in the beam at the point under consideration. Reinforced concrete beams are designed to crack in tension rather than in compression. This is achieved by providing reinforcing steel which yields before failure of the concrete in compression occurs and allowing remediation, repair, or if necessary, evacuation of an unsafe area.

5 - Creep :

Creep is the term used to describe the permanent movement or deformation of a material in order to relieve stresses within the material. Concrete which is subjected to long-duration forces is prone to creep. Short-duration forces (such as wind or earthquakes) do not cause creep. Creep can sometimes reduce the amount of cracking that occurs in a concrete structure or element, but it also must be controlled. The amount of primary and secondary reinforcing in concrete structures contributes to a reduction in the amount of shrinkage, creep and cracking.

6 - Concrete testing :

 *Same cylinder after failure*	 *Compression testing of a concrete cylinder*

Engineers usually specify the required compressive strength of concrete, which is normally given as the 28 day compressive strength in mega pascals (MPa) or pounds per square inch (psi). Twenty eight days is a long wait to determine if desired strengths are going to be obtained, so three-day and seven-day strengths can be useful to predict the ultimate 28-day compressive strength of the concrete. A 25% strength gain between 7 and 28 days is often observed with 100% OPC (ordinary Portland cement) mixtures, and up to 40% strength gain can be realized with the inclusion of pozzolans and supplementary cementitious materials (SCMs) such as fly ash and/or slag cement. Strength gain depends on the type of mixture, its constituents, the use of standard curing, proper testing and care of cylinders in transport, etc. It is imperative to accurately test the fundamental properties of concrete in its fresh, plastic state.

Concrete is typically sampled while being placed, with testing protocols requiring that test samples be cured under laboratory conditions (standard cured). Additional samples may be field cured (non-standard) for the purpose of early 'stripping' strengths, that is, form removal, evaluation of curing, etc. but the standard cured cylinders comprise acceptance criteria. Concrete tests can measure the "plastic" (un hydrated) properties of concrete prior to, and during placement. As these properties affect the hardened compressive strength and durability of concrete (resistance to freeze-thaw), the properties of workability (slump/flow), temperature, density and age are monitored to ensure the production and placement of 'quality' concrete. Tests are performed per ASTM International, European Committee for Standardization or Canadian Standards Association. As measurement of quality must represent the potential of concrete material delivered and placed, it is imperative that concrete technicians performing concrete tests are certified to do so according to these standards. Structural design, material design and properties are often specified in accordance with national/regional design codes such as American Concrete Institute.

Compressive strength tests are conducted using an instrumented hydraulic ram to compress a standard cylindrical or cubic sample to failure. Tensile strength tests are conducted either by three-point bending of a prismatic beam specimen or by compression along the sides of a standard cylindrical specimen. These are not to be equated with nondestructive testing using a rebound hammer or probe systems which are hand-held indicators, for relative strength of the top few millimeters, of comparative concretes in the field.

Pull Off Test

The **pull - off test** is a near-to-surface method in which a circular steel disc is glued to the surface of the concrete with an epoxy or polyester resin. The force required to pull this disc out from the surface, together with an attached layer of concrete, is measured. Simple mechanical hand - operated loading equipment has been developed for this purpose. Partial coring may be used, if necessary, to eliminate surface skin effects.

Pulverized Fuel Ash

Pulverized fuel ash (shortened to **PFA**), is a waste product of pulverized fuel (typically coal) fired power stations. The fuel is pulverized into a fine powder, mixed with heated air and burned. Approximately 18 % of the fuel forms fine glass spheres, the lighter of which (c. 75 %) are borne aloft by the combustion process. They are extracted from the flue gasses by cyclones and electrostatic precipitation . The resultant material is used as engineering fill and as a component for concrete. It has been widely used, particularly in the UK, for concrete block production. The blocks are lightweight and have excellent thermal insulation properties. PFA can undergo a pozzolanic reaction and become brittle over time. PFA has a fine dust texture and is grey in colour.

When newly produced the dust is strongly alkaline; a pH as high as 11 is known, and >9 is normal. It leaches a solution dominated by sodium and sulfate, with enough boron (>15mg l^{-1}) to kill most plants, though coastal species often tolerate the salinity and boron to grow on young ash lagoons. In dry conditions these solutes rise to the surface to form a hard salt crust, impeding all plant growth, though hardy grass species such as *Vulpia myuros* can later colonise it. A "waxy" layer has been known to form in some locations which inhibits root penetration, however, mixing crushed rock into the top layer has been found to inhibit the formation of the "waxy" layer.

As the ash weathers, its salinity, boron level and pH all fall; the former two are largely removed from surface layers after 5 years outdoors, while pH declines towards 7 in a generally linear fashion at a rate of about 1 pH unit per 20 years. The floral succession approximates to that of a coastal dune system, without the wind-blown deposition, so salt-tolerant plants are replaced by an attractive sward of legumes and perennials before turning to birch/willow scrub woodland. A notable feature are the *Dactylorhiza* orchids which often form spectacular colonies 10-20 years post dumping, only to fade away again as the woodland thickens. Hydro seeding is often used to establish vegetation onto PFA due to the inhospitable conditions of most sites.

Pumice

Specimen of highly porous pumice from Teide volcano on Tenerife, Canary Islands. Density of specimen approximately 0.25 g/cm^3

Contents

1 – Introduction :

Pumice is a textural term for a volcanic rock which is a solidified frothy lava. Pumice is typically created when super-heated, highly pressurized rock is violently ejected from a volcano. Alternatively it can be formed when lava and water are mixed. Most pumice is light enough that it floats on water.

The unusual foamy configuration of pumice happens because of simultaneous rapid cooling and rapid depressurization. The depressurization creates bubbles by lowering the solubility of gases (including water and CO_2) that are dissolved in the lava, causing the gases to rapidly exsolve (like the bubbles of CO_2 that appear when a carbonated drink is opened). The simultaneous cooling and depressurization freezes the bubbles in the matrix.

2 - Properties :

Pumice is composed of highly micro vesicular glass pyro clastic with very thin, translucent bubble walls of extrusive igneous rock. It is commonly, but not exclusively of silicic or felsic to intermediate in composition (e.g., rhyolitic , dacitic , andesite, pantellerite, phonolite, trachyte), but basaltic and other compositions are known. Pumice is commonly pale in color, ranging from white, cream, blue or grey, to green-brown or black. It forms when volcanic gases exsolving from viscous magma nucleate bubbles which cannot readily decouple from the viscous magma prior to chilling to glass. Pumice is a common product of explosive eruptions (plinian and ignimbrite-forming) and commonly forms zones in upper parts of silicic lavas. Pumice has an average porosity of 90%, and initially floats on water.

Scoria differs from pumice in being denser. With larger vesicles and thicker vesicle walls, it sinks rapidly. The difference is the result of the lower viscosity of the magma that forms scoria. When larger amounts of gas are present, the result is a finer-grained variety of pumice known as **pumicite**. Pumice is considered a glass because it has no crystal structure. Pumice varies in density according to the thickness of the solid material between the bubbles; many samples float in water. After the explosion of Krakatoa, rafts of pumice drifted through the Pacific Ocean for up to 20 years, with tree trunks floating among them. In fact, pumice rafts disperse and support several marine species . In 1979, 1984 and 2006, underwater volcanic eruptions near Tonga created large pumice rafts, some as large as 30 km that floated hundreds of kilometres to Fiji.

There are two main forms of vesicles. Most pumice contains tubular micro vesicles that can impart a silky or fibrous fabric. The elongation of the micro vesicles occurs due to ductile elongation in the volcanic conduit or, in the case of pumiceous lavas, during flow. The other form of vesicles are sub spherical to spherical and result from high vapor pressure during eruption.

3 – Uses :

Pumice is widely used to make lightweight concrete or insulative low- density breeze blocks. When used as an additive for cement, a fine-grained version of pumice called pozzolan is mixed with lime to form a light-weight, smooth, plaster-like concrete. This form of concrete was used as far back as Roman times. Roman engineers used it to build the huge dome of the Pantheon and as construction material for many aqueducts.

It is also used as an abrasive, especially in polishes, pencil erasers, cosmetic exfoliants, and the production of stone-washed jeans. "Pumice stones" are often used in beauty salons during the pedicure process to remove dry and excess skin from the bottom of the foot as well as calluses. It was also used in ancient Greek and Roman times to remove excess hair . Finely ground pumice is added to some toothpastes and heavy- duty hand cleaners (such as Lava soap) as a mild abrasive. Pumice is also used as a growing substrate for growing horticultural crops.

Pykrete

	
Pykrete is made of 14 percent sawdust and 86 percent water by weight.	*A slab of pykrete*

Contents

1 – Introduction :

Pykrete is a composite material made of approximately 14 percent sawdust or some other form of wood pulp (such as paper) and 86 percent ice by weight. Its use was proposed during World War II by Geoffrey Pyke to the British Royal Navy as a candidate material for making a huge , unsinkable aircraft carrier. Pykrete has some interesting properties, notably its relatively slow melting rate (because of low thermal conductivity), and its vastly improved strength and toughness over unmodified (crystalline) ice ; it is closer in form to concrete.

Pykrete is slightly more difficult to form than concrete, as it expands during the freezing process. However, it can be repaired and maintained using sea water. The mixture can be moulded into any shape and frozen, and it will be extremely tough and durable, as long as it is kept at or below freezing.

2 - History :

Geoffrey Pyke managed to convince Lord Mountbatten of the worth of his project (actually prior to the invention of pykrete) some time around 1942, and trials were made in two locations in Alberta in Canada. The idea for a ship made of ice impressed the United States and Canada enough that a 18 m long, 1,000 - ton ship was built in one month on Patricia Lake in the Canadian Rockies. It was, however, constructed using plain ice (from the lake), before pykrete was considered. It took slightly more than an entire summer to melt.

Plain ice proved to be insufficiently strong. Pyke learned from a report by Herman Mark and his assistant that ice made from water mixed with wood fibres formed a strong solid mass— much stronger than pure water ice. Max Perutz later recalled:

Then, one day, Pyke handed me a report that he said he found hard to understand. It was by Herman Mark, my former professor of physical chemistry in Vienna, who had lost his post there when the Nazis overran Austria, and found a haven at the Polytechnic Institute of Brooklyn. As an expert on plastics, he knew that many of them were brittle when pure, but could be toughened by embedding fibres such as cellulose in them, just as concrete can be reinforced with steel wires. Mark and his assistant, Walter P. Hohenstein, stirred a little cotton wool or wood pulp - the raw material of newsprint—into water before they froze it, and found that these additions strengthened the ice dramatically. When I had read their report, I advised my superiors to scrap our experiments with pure ice and set up a laboratory for the manufacture and testing of reinforced ice. Combined Operations requisitioned a large meat store five floors underground beneath Smithfield Market, which lies within sight of St. Paul's Cathedral, and ordered some electrically heated suits, of the type issued to airmen, to keep us warm at 0 °C (32 °F). They detailed some young commandos to work as my technicians, and I invited Kenneth Pascoe, who was then a physics student and later became a lecturer in engineering at Cambridge, to come and help me. We built a big wind tunnel to freeze the mush of wet wood pulp, and sawed the reinforced ice into blocks. Our tests soon confirmed Mark and Hohenstein's results. Blocks of ice containing as little as four percent wood pulp were weight for weight as strong as concrete; in honor of the originator of the project, we called this reinforced ice "pykrete". When we fired a rifle bullet into an upright block of pure ice two feet square and one foot thick, the block shattered; in pykrete the bullet made a little crater and was embedded without doing any damage. My stock rose, but no one would tell me what pykrete was needed for, except that it was for Project Habakkuk.

—*I Wish I'd Made You Angry Earlier*, *Perutz, Max*

Perutz would later learn that Project Habakkuk was the plan to build an enormous aircraft carrier, actually more of a floating island than a ship in the traditional sense. The experiments of Perutz and his collaborators in Smithfield Meat Market in the City of London took place in great secrecy behind a screen of animal carcasses.[2][3][4] The tests confirmed that pykrete is much stronger than pure ice and does not shatter, but also that it sags under its own weight at temperatures higher than -15 C.

Mountbatten’s reaction to the break through is recorded by Pyke's biographer David Lampe :

What happened next was explained several years after the war by Lord Mountbatten in a widely-quoted after-dinner speech. "I was sent to Chequers to see the Prime Minister and was told he was in his bath. I said, 'Good, that's exactly where I want him to be.' I nipped up the stairs and called out to him, 'I have a block of a new material which I would like to put in your bath.' After that he suggested that I should take it to the Quebec Conference." The demonstration in Churchill's steaming bath had been most dramatic. After the outer film of ice on the small pykrete cube had melted, the freshly exposed wood pulp kept the remainder of the block from thawing.

— *Pyke, the Unknown Genius*, *Lampe, David*

Another tale is that at the Quebec Conference of 1943 Mountbatten brought a block of pykrete along to demonstrate its potential to the entourage of admirals and generals who had come along with Winston Churchill and Franklin D. Roosevelt.

Mountbatten entered the project meeting with two blocks and placed them on the ground. One was a normal ice block and the other was pykrete. He then drew his service pistol and shot at the first block. It shattered and splintered. Next, he fired at the pykrete to give an idea of the resistance of that kind of ice to projectiles. The bullet ricocheted off the block, grazing the trouser leg of Admiral Ernest King and ending up in the wall. According to Perutz's own account , however, the incident of a ricochetting bullet hitting an Admiral actually happened much earlier in London and the gun was fired by someone on the project — not Mountbatten.

Despite these tests , the main Project Habakkuk was never put into action because of limitations in funds and the belief that the tides of the war were beginning to turn in favour of the Allies using more conventional methods . According to the memoirs of British General Ismay:

A good deal of consideration, much of it highly technical, was also given to the feasibility of building floating platforms which could either be used by fighters to support opposed landings until such time as airfields ashore were available, or act as staging points for ferrying aircraft over long distances. The idea as originally conceived by a member of Combined Operations staff, and vehemently supported by Mountbatten, was that these floating platforms should be constructed out of icebergs. They would be provided with engines which would enable them to steam at slow speed, and with refrigeration plants to prevent them melting. They would be unsinkable. The whole thing seemed completely fantastic, but the idea was not abandoned without a great deal of investigation. Various alternative methods of construction were then considered by the United States naval authorities, but in the end there was general agreement that carriers and auxiliary carriers would serve the same purpose more effectively."

—*The Memoirs of Lord Ismay*, *Ismay, General Lord*

Since WWII pykrete has remained a scientific curiosity, unexploited by research or construction of any significance. In 1985, pykrete was considered for a quay in Oslo harbour.

New concepts for pykrete however crop up occasionally among architects, engineers and futurists, usually regarding its potential for mammoth offshore construction or its improvement by applying super-strong materials such as synthetic composites or Kevlar.

3 - Durability :

The durability of pykrete is up for debate. Perutz has estimated a crushing strength value of around 1,100 psi (7.6 MPa).

A September 1943 proposal for making smaller pykrete vessels included the following table of characteristics :

Comparative properties of materials

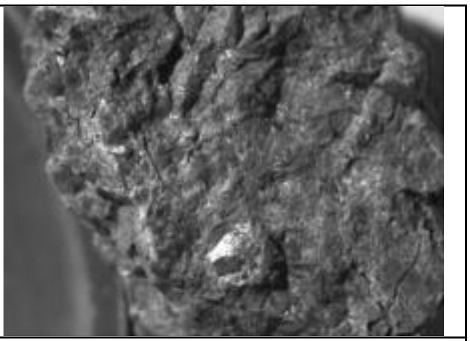
Mechanical properties	Ice	Concrete	Pykrete
Crushing strength [MPa]	3.447	17.240	7.584
Tensile strength [MPa]	1.103	1.724	4.826
Density [kg / m³]	910	2500	980

4 - In the media :

In 2009, the Discovery Channel program *MythBusters* episode 115 tested the properties of pykrete and the myths behind it. First, the program's hosts, Adam Savage and Jamie Hyneman compared the mechanical properties of common ice, pykrete and a new material specially created for the show, dubbed "super pykrete", using newspapers instead of woodpulp. Both versions of pykrete indeed proved to be much stronger than the chunk of ice, withstanding hundreds of pounds of weight. The super pykrete was much stronger than the original version.

The MythBusters then built a full-size boat out of the super pykrete, naming it *Yesterday's News*, and subjected it to real-world conditions. Though the boat managed to float and stay intact at speeds of up to 23 miles per hour (37 km / h) , it quickly began to spring leaks as the boat slowly melted. After twenty minutes the boat was deteriorating, and the experiment was ended. The boat lasted another ten minutes while being piloted back to shore. Though the boat worked, it was noted that it would be highly impractical for the original myth, which claimed that an entire aircraft carrier could be built out of pykrete.[12] Their conclusion was "Plausible, but ludicrous". However, the test was done at or slightly above freezing temperatures, and not with refrigeration units keeping the pykrete cold, as the original plans called for.

Pyroxene

	
Mantle-peridotite xenolith from San Carlos Indian Reservation, Gila Co., Arizona, USA. The xenolith is dominated by green peridot olivine, together with black orthopyroxene and spinel crystals, and rare grass-green diopside grains. The fine-grained gray rock in this image is the host basalt.(unknown scale)	*A sample of pyroxenite, a rock consisting mostly of pyroxene minerals.*

Contents

1 - Introductipn :

The **pyroxenes** are a group of important rock-forming inosilicate minerals found in many igneous and metamorphic rocks. They share a common structure consisting of single chains of silica tetrahedra and they crystallize in the monoclinic and orthorhombic systems. Pyroxenes have the general formula $XY(Si,Al)_2O_6$ (where X represents calcium, sodium, iron^{+2} and magnesium and more rarely zinc, manganese and lithium and Y represents ions of smaller size, such as chromium, aluminium, iron^{+3}, magnesium, manganese, scandium, titanium, vanadium and even iron^{+2}). Although aluminium substitutes extensively for silicon in silicates such as feldspars and amphiboles, the substitution occurs only to a limited extent in most pyroxenes.

The name pyroxene comes from the Greek words for *fire* and *stranger* . Pyroxenes were named this way because of their presence in volcanic lavas, where they are sometimes seen as crystals embedded in volcanic glass; it was assumed they were impurities in the glass, hence the name "fire strangers". However, they are simply early-forming minerals that crystallized before the lava erupted.

The upper mantle of Earth is composed mainly of olivine and pyroxene. A piece of the mantle is shown at right (orthopyroxene is black, diopside (containing chromium) is bright green, and olivine is yellow-green) and is dominated by olivine, typical for common peridotite. Pyroxene and feldspar are the major minerals in basalt and gabbro.

2 - Chemistry and nomenclature of the pyroxenes :

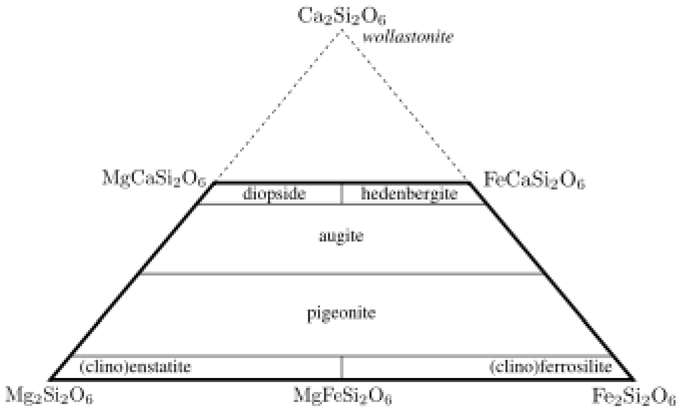


Figure 1 *: The nomenclature of the calcium, magnesium, iron pyroxenes.*

The chain silicate structure of the pyroxenes offers much flexibility in the incorporation of various cations and the names of the pyroxene minerals are primarily defined by their chemical composition. Pyroxene minerals are named according to the chemical species occupying the X (or M2) site, the Y (or M1) site, and the tetrahederal T site. Cations in Y (M1) site are closely bound to 6 oxygens in octahedral coordination. Cations in the X (M2) site can be coordinated with 6 to 8 oxygen atoms, depending on the cation size. Twenty mineral names are recognised by the International

Mineralogical Association's Commission on New Minerals and Mineral Names and 105 previously used names have been discarded

A typical pyroxene has mostly silicon in the tetrahedral site and predominately ions with a charge of +2 in both the X and Y sites, giving the approximate formula XYT_2O_6. The names of the common calcium – iron – magnesium pyroxenes are defined in the 'pyroxene quadrilateral' shown in Figure 1. The enstatite-ferrosilite series ($[Mg,Fe]SiO_3$) contain up to 5 mol. % calcium and exists in three polymorphs, orthorhombic orthoenstatite and protoenstatite and monoclinic clinoenstatite (and the ferrosilite equivalents). Increasing the calcium content prevents the formation of the orthorhombic phases and pigeonite ($[Mg,Fe,Ca][Mg,Fe]Si_2O_6$) only crystallises in the monoclinic system. There is not complete solid solution in calcium content and Mg-Fe-Ca pyroxenes with calcium contents between about 15 and 25 mol.% are not stable with respect to a pair of exolved crystals. This leads to a miscibility gap between pigeonite and augite compositions. There is an arbitrary separation between augite and the diopside-hedenbergite ($CaMgSi_2O_6$ – $CaFeSi_2O_6$) solid solution. The divide is taken at > 45 mol.% Ca. As the calcium ion cannot occupy the Y site, pyroxenes with more than 50 mol.% calcium are not possible. A related mineral wollastonite has the formula of the hypothetical calcium end member but important structural differences mean that it is not grouped with the pyroxenes.

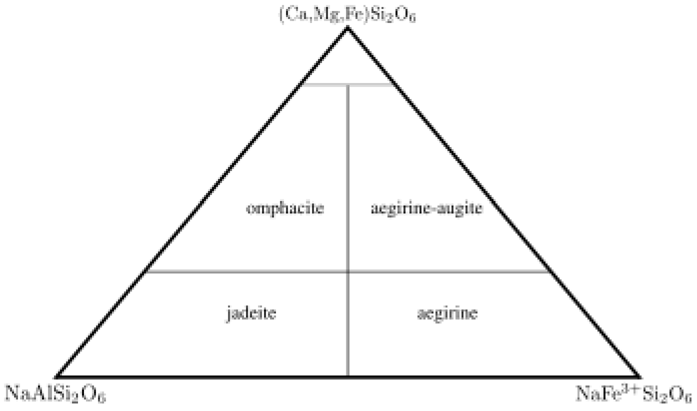


Figure 2 : *The nomenclature of the sodium pyroxenes.*

Magnesium, calcium and iron are by no means the only cations that can occupy the X and Y sites in the pyroxene structure. A second important series of pyroxene minerals are the sodium-rich pyroxenes, corresponding to nomenclature shown in Figure 2 . The inclusion of sodium, which has a charge of +1, into the pyroxene implies the need for a mechanism to make up the "missing" positive charge. In jadeite and aegirine this is added by the inclusion of a +3 cation (aluminium and iron (III) respectively) on the Y site. Sodium pyroxenes with more than 20 mol.% calcium, magnesium or iron(II) components are known as omphacite and aegirine-augite, with 80 % or more of these components the pyroxene falls in the quadrilateral shown in figure 1.

In assigning ions to sites the basic rule is to work from left to right in this table first assigning all silicon to the T site then filling the site with remaining aluminium and finally iron(III), extra aluminium or iron can be accommodated in the Y site and bulkier ions on the X site. Not all the resulting mechanisms to achieve charge neutrality follow the sodium example above and there are several alternative schemes:

1. Coupled substitutions of 1+ and 3+ ions on the X and Y sites respectively. For example Na and Al give the jadeite ($NaAlSi_2O_6$) composition.
2. Coupled substitution of a 1+ ion on the X site and a mixture of equal numbers of 2+ and 4+ ions on the Y site. This leads to *e.g.* $NaFe^{2+}_{0.5}Ti^{4+}_{0.5}Si_2O_6$.
3. The Tschermak substitution where a 3+ ion occupies the Y site and a T site leading to *e.g.* $CaAlAlSiO_6$.

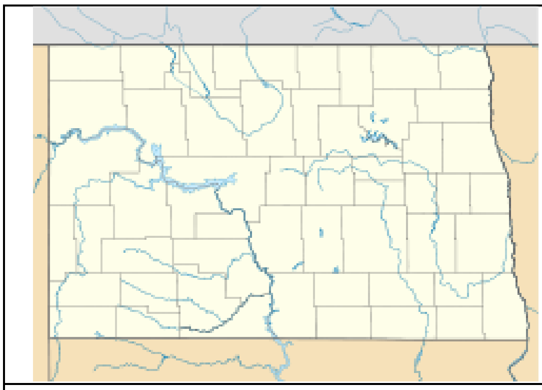
In nature, more than one substitution may be found in the same mineral.

3 - Pyroxene minerals :

- Clinopyroxenes (monoclinic)
    - Aegirine (Sodium Iron Silicate)
    - Augite (Calcium Sodium Magnesium Iron Aluminium Silicate)
    - Clinoenstatite (Magnesium Silicate)
    - Diopside (Calcium Magnesium Silicate, $CaMgSi_2O_6$)

  - Esseneite (Calcium Iron Aluminium Silicate)
  - Hedenbergite (Calcium Iron Silicate)
  - Jadeite (Sodium Aluminium Silicate)
  - Jervisite (Sodium Calcium Iron Scandium Magnesium Silicate)
  - Johannsenite (Calcium Manganese Silicate)
  - Kanoite (Manganese Magnesium Silicate)
  - Kosmochlor (Sodium Chromium Silicate)
  - Namansilite (Sodium Manganese Silicate)
  - Natalyite (Sodium Vanadium Chromium Silicate)
  - Omphacite (Calcium Sodium Magnesium Iron Aluminium Silicate)
  - Petedunnite (Calcium Zinc Manganese Iron Magnesium Silicate)
  - Pigeonite (Calcium Magnesium Iron Silicate)
  - Spodumene (Lithium Aluminium Silicate)
- Orthopyroxenes (orthorhombic)
  - Hypersthene (Magnesium Iron Silicate)
  - Donpeacorite, $(MgMn)MgSi_2O_6$
  - Enstatite, $Mg_2Si_2O_6$
  - Ferrosilite, $Fe_2Si_2O_6$
  - Nchwaningite (Hydrated Manganese Silicate)

R.S. Blome Granitoid Pavement in Grand Forks



Location:	Roughly, Lewis Blvd. S of Conklin Ave. and area around jcts. of Walnut St. and 3rd Ave. and Minnesota Ave. and 5th St., Grand Forks, North Dakota
Coordinates:	47°55′27″N 97°1′58″W 47.92417°N 97.03278°W
Area:	55 acres (22 ha) (original)
Built:	1910-1911
Architect:	Blome, R.S., Co. of Chicago
Governing body:	Local
NRHP Reference#:	91001583 and 10000605[1]
Added to NRHP:	November 5, 1991 (original) August 30, 2010 (decrease) Grand Forks, 10000605,

R.S. Blome Granitoid Pavement is a historic road surface, as well as the associated cut sandstone curbs in a few sections, found in three of the oldest residential sections of Grand Forks, North Dakota. It is a Portland cement–aggregate combination that was intended to bridge the gap between the needs of Horse-drawn vehicles, which required sure footing, and automobiles, which needed a hard, resilient surface, in the earliest part of the 20th century.

R.S. Blome Granitoid was made from a mixture of Portland cement and angular granite chips along with other stone and sand, laid down over an appropriately arched prepared road bed followed by a six-inch layer of loose gravel (macadam). It was laid in five-foot sections which were sealed at the joints with an asphalt and rubber mix to allow for expansion. Another intended benefit of laying the pavement in these sections was that it allowed for removal of only necessary portions for utility work. However it would appear that this intention was ignored as indicated by the presence of utility cuts and mismatched concrete and asphalt patching in the Grand Forks examples.

Over these sections was laid a two-inch finish layer of Portland cement and carefully screened angular granite chips measuring between 1/8 and 3/8 of an inch. Angular chips of granite were specified over rounded river gravel to ensure a firm bond and prohibit the dislodging of gravel common to concrete. As the surface dried it was brushed and scored to resemble cut stone, providing a good non-slip surface for horses. Though the Blome Company patent specified a gridded pattern of scoring, the Grand Forks pavement exhibits a running bond pattern.

Also surviving are a number of bronze name plates embedded into the paving surface which read "Established 1888. GRANITOID. R.S. Blome. Chicago. 1907."

This pavement type was selected after a lively discussion by city residents as a solution to the problem of ankle-deep mud which was an annual result of the spring thaw and rains. The residents determined to have a quality pavement that would last long "after it was paid for". Their choice has been validated as the Granitoid is still quite serviceable and well suited to modern automobile traffic after nearly a century of use.

Out of several extant locations where Blome Granitoid has been found, such as Duluth, Minnesota and Spokane and Seattle, Washington, there are several characteristics which make the Grand Forks sections particularly significant. There is more surviving

Granitoid and the associated brass name plates in Grand Forks, encompassing a number of streets in three distinct neighborhoods, than in any of the other locations. Another important difference is the aforementioned use of the running bond pattern in the scoring, which is unique among all of the remaining examples. It suggests a desire among the residents for an aesthetic, as well as functional, pavement.

A 55-acre (22 ha) area was listed on the National Register in 1991. However, the listing was modified in 2010 to decrease the listed area.

A section of R.S. Blome Granitoid pavement located on Chestnut St, Grand Forks, North Dakota.

U.S. National Register of Historic Places

Topics

- Architectural style categories
- Contributing property
- Historic district
- History of the National Register of Historic Places
- Keeper of the Register
- National Park Service
- Property types

Lists by states

- Alabama

- Alaska
- Arizona
- Arkansas
- California
- Colorado
- Connecticut
- Delaware
- Florida
- Georgia
- Hawaii
- Idaho
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- Montana
- Nebraska
- Nevada
- New Hampshire
- New Jersey
- New Mexico
- New York
- North Carolina
- North Dakota
- Ohio
- Oklahoma
- Oregon
- Pennsylvania

  - Rhode Island
  - South Carolina
  - South Dakota
  - Tennessee
  - Texas
  - Utah
  - Vermont
  - Virginia
  - Washington
  - West Virginia
  - Wisconsin
- Wyoming

Lists by insular areas

  - American Samoa
  - Guam
  - Minor Outlying Islands
  - Northern Mariana Islands
  - Puerto Rico
- Virgin Islands

Lists by associated states

- Federated States of Micronesia
- Marshall Islands
- Palau

Other areas

  - District of Columbia
- Morocco

Raw Mill

A medium sized dry process roller mill

Contents

1 – Introduction :

A **raw mill** is the equipment used to grind raw materials into "raw mix" during the manufacture of cement. Raw mix is then fed to a cement kiln, which transforms it into clinker, which is then ground to make cement in the cement mill. The raw milling stage of the process effectively defines the chemistry (and therefore physical properties) of the finished cement, and has a large effect upon the efficiency of the whole manufacturing process.

2 - History :

The history of the development of the technology of raw material grinding defines the early history of cement technology. Other stages of cement manufacture used existing technology in the early days. Early hydraulic materials such as hydraulic limes, natural cements and Parker's Roman cement were all based on "natural" raw materials, burned "as-dug". Because these natural blends of minerals occur only rarely, manufacturers were interested in making a fine-grained artificial mixture of readily available minerals such as limestone and clay that could be used in the same way. A typical problem would be to make an intimate mixture of 75% chalk and 25% clay, and burn this to produce an ”artificial cement". The development of the "wet" method of producing fine-grained clay in the ceramics industry afforded a means of doing this. For this reason, the early cement industry used the "wet process", in which the raw materials are ground together with water, to produce a slurry, containing 20–50% water. Both Louis Vicat and James Frost used this technique in the early 19th century, and it remained the only way of making rawmix for Portland cement until 1890. A modification of the technique used by the early industry was "double-burning", in which a hard limestone would be burned and slaked before combining with clay slurry. This technique avoided the grinding of hard stone, and was employed by, among others, Joseph Aspdin. Early grinding technology was poor, and early slurries were made thin, with a high water content. The slurry was then allowed to stand in large reservoirs ("slurry-backs") for several weeks. Large, un-ground particles would drop to the bottom, and excess water rose to the top. The water was periodically decanted until a stiff cake, of the consistency of pottery clay, was left. This was sliced up, discarding the coarse material at the bottom, and burned in the kiln. Wet grinding is comparatively energy-efficient, and so when good dry-grinding equipment became available, the wet process continued in use throughout the 20th century, often employing equipment that Josiah Wedgewood would have recognized.

3 - Materials ground :

Raw mixes are formulated to contain a correctly balanced chemistry for the production of calcium silicates (alite and belite) and fluxes (aluminate and ferrite) in the kiln. Chemical analysis data in cement manufacture are expressed in terms of oxides, and the most important of these in raw mix design are SiO_2, Al_2O_3, Fe_2O_3 and CaO. In principle, any material that can contribute any of these oxides can be used as a rawmix component. Because the major oxide required is CaO, the most prevalent raw mix component is limestone, while the others are mostly contributed by clay or shale. Minor adjustments to the chemistry are made by smaller additions of materials such as those shown below.

Typical raw mix component chemical analyses :

Oxide	Gray Limestone	White Limestone	Marl	Clay	Sand	Millscale	Kaolin	Bauxite	Fly ash
SiO_2	6.6	2.1	14.1	61.6	98.0	1.3	46.1	11.1	48.1
Al_2O_3	1.5	0.3	3.3	17.5	0.9	1.2	38.5	54.4	26.5
Fe_2O_3	0.7	0.13	1.3	7.5	0.13	96.8	0.35	9.7	6.3
CaO	48.4	53.7	43.8	1.1	0.1	0.3	0.3	0.6	4.7
MgO	2.0	0.8	0.7	1.1	0.0	0.6	0.1	0.1	1.2
Na_2O	0.07	0.02	0.07	0.5	0.02	0.11	0.01	0.05	0.3
K_2O	0.27	0.08	0.43	1.9	0.37	0.05	0.09	0.05	1.3
TiO_2	0.06	0.02	0.15	0.8	0.06	0.30	0.9	2.1	1.5
Mn_2O_3	0.03	0.01	0.02	0.12	0	0.63	0	0.09	0.07
LoI_{950}	40.0	42.7	35.8	6.8	0.3	0	13.7	20.8	9.1

Note : LoI_{950} is the Loss on ignition at 950 °C, and represents (approximately) the components lost during kiln processing. It consists mainly of CO_2 from carbonates, H_2O from clay hydrates, and organic carbon.

Using these materials , typical raw mixes could be composed :

- Mix 1 : General-purpose cement: 88.0% gray limestone, 8.9 % clay, 2.2 % sand and 0.9 % mill scale.
- Mix 2 : Sulfate-resisting cement: 87.6 % gray limestone, 5.2 % clay, 5.0 % sand and 2.2 % mill scale.
- Mix 3 : White cement: 82.3 % white lime stone, 6.8% kaolin and 10.9 % sand.

The chemical analyses of these raw mixes would be :

Oxide	Mix 1	Mix 2	Mix 3
SiO_2	13.46	13.91	15.55
Al_2O_3	2.91	2.30	2.96
Fe_2O_3	2.16	3.14	0.14
CaO	42.69	42.47	44.23
MgO	1.86	1.82	0.67
Na_2O	0.11	0.09	0.02
K_2O	0.41	0.35	0.11
TiO_2	0.13	0.10	0.09
Mn_2O_3	0.04	0.05	0.01
LoI_{950}	35.8	35.4	36.1

The raw materials and mixes shown are only "typical": considerable variations are possible depending on the raw materials available.

4 - Control of minor elements :

Apart from the major oxides (Ca O , SiO_2, Al_2O_3 and Fe_2O_3) the minor oxides are, at best, diluents of the clinker, and may be deleterious. However, cement raw materials are for the most part dug from the Earth's crust and contain most of the elements in the periodic table in some amount. The manufacturer therefore selects materials so that the deleterious effects of minor elements are minimized or kept under control.

Minor elements that are frequently encountered are as follows :

- **Fluorine** is beneficial to the kiln process in that it allows alite to form at lower temperature. However, at levels above 0.25 % in the clinker, delayed and erratic cement setting time results.

- **Alkali metals** (primarily sodium and potassium) cause processing problems because they form volatile salts in the kiln system. These evaporate in the kiln burning zone and re-condense in the cooler regions of the preheater, causing blockages. Alkalis are also deleterious to concrete, potentially causing alkali silica reaction. For this reason, many standards limit alkalis (typically expressed as "total equivalent soda" which is $Na_2O + 0.658\ K_2O$). Typical specification limits are in the range 0.5 – 0.8 %.

- **MgO** causes problems at levels over 2.5%. Small amounts are accommodated in solid solution in the clinker minerals, but above 2.5 %, "free" Mg O exists in the clinker as periclase. This can slowly hydrate to $Mg(OH)_2$ with expansion in the hardened concrete, causing cracking. Careful processing of the clinker to keep the periclase in a microcrystalline form allows levels up to 5% to be managed without serious effect. All standards limit MgO , typical limits being in the range 4-6%.

- **P_2O_5** at levels above 0.5 % starts to cause slow setting and low clinker reactivity.

- **Chlorine** produces very volatile salts and consequent pre heater blockages, and is usually limited to below 0.1 % in raw mix.

- **TiO_2** is ubiquitous, but is rarely present at levels (~1%) that might cause problems.

- **Chromium** can end up as chromates (Cr [VI]) in cement, particularly when the clinker is high in sulfate. Chromates cause allergic contact dermatitis in cement users, and for this reason cement Cr [VI] content is limited in many standards to 0.0002 %. Typical natural rawmixes contain around 0.01% Cr_2O_3 , and at this level, Cr [VI] formation can be controlled. Chromium present in the cement as Cr [III] is of no consequence.

- **Mn_2O_3** is not deleterious, acting as a substitute for iron. But it contributes more color to the cement than iron, and high-Mn_2O_3 cements (> 1 %) are almost black.

- **Zn O** is encountered in some rawmix additives (as well as tires used as kiln fuel). At levels above 0.2%, it causes slow setting and low clinker reactivity.

- **Strontium** and **barium** act as calcium replacements, and only start to reduce clinker reactivity at levels of 1.5% and 0.2 % respectively.

- **Toxic heavy metals**: among these, low levels of arsenic, selenium, cadmium, antimony and tungsten are not a problem, because they are absorbed in the basic clinker structure as anions. On the other hand, mercury, thallium and lead must be carefully controlled because they can be emitted as volatile halides in the kiln exhaust.

5 - Wet raw mills :

Wet grinding is more efficient than dry grinding because water coats the newly formed surfaces of broken particles and prevents re-agglomeration. The process of blending and homogenizing the rawmix is also much easier when it is in slurry form. The disadvantage is that the water in the resultant slurry has to be removed subsequently, and this usually requires a lot of energy. While energy was cheap, wet grinding was common, but since 1970 the situation has changed dramatically, and new wet process plant is now rarely installed. Wet grinding is performed by two distinct means: washmills and ball mills.

5 – 1 - Wash mill :

This represents the earliest raw milling technology, and was used to grind soft materials such as chalk and clay. It is rather similar to a food processor. It consists of a large bowl (up to 15 m in diameter) into which the crushed (to less than 250 mm) raw materials are tipped along with a stream of water. The material is stirred by rotating sets of harrows. The outside walls of the bowl consist of gratings or perforated plates through which fine product can pass. Grinding is largely autogenous (i.e. it takes place by collision between lumps of raw material), and is very efficient, producing little waste heat, provided that the materials are soft. Typically two or three wash mills are connected in series, these being provided with successively smaller outlet perforations. The entire system can produce slurry with the expenditure of as little as 5 kW·h of electricity per dry tonne. Relatively hard minerals (such as flint) in the mix, are more or less untouched by the grinding process, and settle out in the base of the mill, from where they are periodically dug out.

5 – 2 - Ball mills and wash drums :

The ball mill allows grinding of the harder lime stones that are more common than chalk. A ball mill consists of a horizontal cylinder that rotates on its axis. It holds spherical, cylindrical or rod-like grinding media of size 15–100 mm that may be steel or a variety of ceramic materials, and occupy 20–30% of the mill volume. The shell of the mill is lined with steel or rubber plates. Grinding is effected by impact and attrition between the grinding media. The various mineral components of the raw mix are fed to the mill at a constant rate along with water, and the slurry runs from the outlet end. The wash drum has a similar concept, but contains little or no grinding media, grinding being autogenous, by the cascading action of the larger raw material pieces. It is suitable for soft materials, and particularly for flinty chalk, where the un ground flint acts as grinding media.

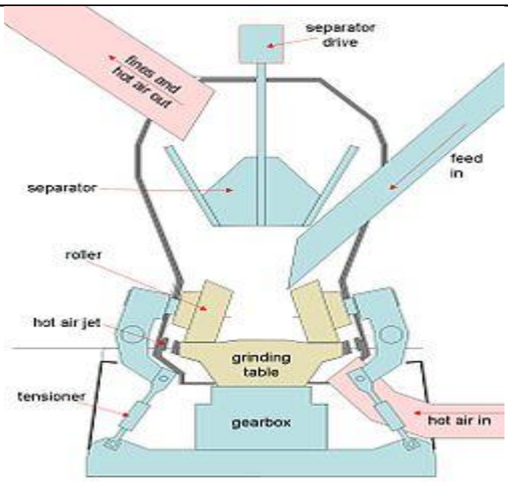
5 – 3 - Slurry fineness and moisture content :

A 1500 m³ storage tank of slurry, blended and prevented from settling out by a rotating arm injecting compressed air

It is essential that large particles (> 150 µm for calcium carbonate and > 45 µm for quartz) should be eliminated from the rawmix, to facilitate chemical combination in the kiln. In the case of slurries, larger particles can be removed by hydro cyclones or sieving devices. These require a certain amount of energy, supplied by high pressure pumping. This process, and the moving and blending of the slurry, require careful control of the slurry viscosity. Clearly, a thinner slurry is easily obtained by adding more water, but at the expense of high energy consumption for its subsequent removal. In practice, the slurry is therefore made as thick as the plant equipment can handle. Cement raw mix slurries are Bingham plastics which can also exhibit thixotropic or rheopectic behaviour. The energy needed to pump slurry at a desired rate is controlled mainly by the slurry's yield stress, and this in turn varies more or less exponentially with the slurry solids/liquid ratio. In practice, de flocculants are often added in order to maintain pump ability at low moisture contents. Common deflocculants used (at typical dose rates of 0.005–0.03%) are sodium carbonate, sodium silicate, sodium poly phosphates and ligno sulfonates. Under favourable circumstances, pump able slurries with less than 25% water can be obtained.

Raw mixes frequently contain minerals of contrasting hardness, such as calcite and quartz. Simultaneous grinding of these in a raw mill is inefficient, because the grinding energy is preferentially used in grinding the softer material. This results in a large amount of excessively fine soft material, which "cushions" the grinding of the harder mineral. For this reason, sand is sometimes ground separately, then fed to the main raw mill as a fine slurry.

6 - Dry raw mills :



Typical roller mill layout

A dry process air-swept ball mill

Dry raw mills are the normal technology installed today, allowing minimization of energy consumption and CO_2 emissions. In general, cement raw materials are mainly quarried, and so contain a certain amount of natural moisture. Attempting to grind a wet material is unsuccessful because an intractable "mud" forms. On the other hand, it is much easier to dry a fine material than a coarse one, because large particles hold moisture deep in their structure. It is therefore usual to simultaneously dry and grind the materials in the rawmill. A hot-air furnace may be used to supply this heat, but usually hot waste gases from the kiln are used. For this reason, the rawmill is usually placed close to the kiln pre heater. Types of dry rawmill include ball mills, roller mills and hammer mills.

6 – 1 - Ball mills :

These are similar to cement mills, but often with a larger gas flow. The gas temperature is controlled by cold-air bleeds to ensure a dry product without overheating the mill. The product passes into an air separator, which returns oversized particles to the mill inlet. Occasionally, the mill is preceded by a hot-air-swept hammer mill which does most of the drying and produces millimeter - sized feed for the mill. Ball mills are rather inefficient, and typically require 10–20 kW·h of electric power to make a tonne of rawmix. The Aerofall mill is sometimes used for pre-grinding large wet feeds. It is a short, large-diameter semi- autogenous mill, typically containing 15% by volume of very large (130 mm) grinding balls. Feed can be up to 250 mm, and the larger chunks produce much of the grinding action. The mill is air-swept, and the fines are carried away in the gas stream. Crushing and drying are efficient, but the product is coarse (around 100 µm), and is usually re-ground in a separate ball mill.

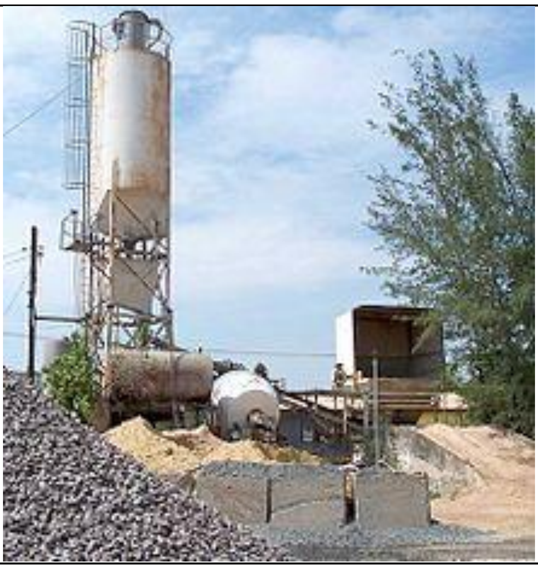
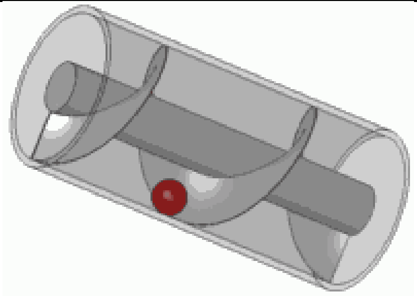
6 – 2 - Roller mills :

These are the standard form in modern installations, occasionally called vertical spindle mills. In a typical arrangement, the material is fed onto a rotating table, onto which steel rollers press down. A high velocity of hot gas flow is maintained close to the dish so that fine particles are swept away as soon as they are produced. The gas flow carries the fines into an integral air separator, which returns larger particles to the grinding path. The fine material is swept out in the exhaust gas and is captured by a cyclone before being pumped to storage. The remaining dusty gas is usually returned to the main kiln dust control equipment for cleaning. Feed size can be up to 100 mm. Roller mills are efficient, using about half the energy of a ball mill, and there seems to be no limit to the size available. Roller mills with output in excess of 800 tones per hour have been installed. Unlike ball mills, feed to the mill must be regular and uninterrupted; otherwise damaging resonant vibration sets in.

6 – 1 - Hammer mills

Hammer mills (or "crusher driers") swept with hot kiln exhaust gases have limited application where a soft, wet raw material is being ground. The simple design means that it can be operated at a higher temperature than other mills, giving it high drying capacity. However, the grinding action is poor, and the product is often re-ground in a ball mill.

Ready - Mix Concrete

	
small batching plant for local small deliveries	*1.6 cuM. transit mixer*
	
The inside of a transit mixer uses a simple Archimedes' screw to mix and to lift the concrete to the delivery chute.	*7 cuM. transit mixer*

Contents

1 – Introduction :

Ready-mix concrete is a type of concrete that is manufactured in a factory or batching plant, according to a set recipe, and then delivered to a work site, by truck mounted transit mixers . This results in a precise mixture, allowing specialty concrete mixtures to be developed and implemented on construction sites. The first ready-mix factory was built in the 1930s, but the industry did not begin to expand significantly until the 1960s, and it has continued to grow since then.

Ready-mix concrete is sometimes preferred over on-site concrete mixing because of the precision of the mixture and reduced work site confusion. However, using a pre-determined concrete mixture reduces flexibility, both in the supply chain and in the actual components of the concrete.

The leading ready-mix concrete supplier worldwide is the Mexican concrete company Cemex; its main competitor is France-based Lafarge and the leading ready-mix concrete supplier in Middle East is the Unibeton Ready Mix.

Ready Mixed Concrete is also referred as the customized concrete products for commercial purpose. the Ready-mix Concrete Company offer different concrete according to user's mix design or industrial standard.

The ready mixed concrete company is required to equip themselves with up-to-date equipments, such as transit mixer, concrete pump, and Concrete Batching Plant, which needs visualized production management software and also PLC controller.

Ready Mixed Concrete, or RMC as it is popularly called, refers to concrete that is specifically manufactured for delivery to the customer's construction site in a freshly mixed and plastic or unhardened state. Concrete itself is a mixture of Portland cement, water and aggregates comprising sand and gravel or crushed stone. In traditional work sites, each of these materials is procured separately and mixed in specified proportions at site to make concrete. Ready Mixed Concrete is bought and sold by volume - usually expressed in cubic meters. RMC can be custom-made to suit different applications.

Ready Mixed Concrete is manufactured under computer-controlled operations and transported and placed at site using sophisticated equipment and methods. RMC assures its customers numerous benefits.

2 - Standard ready-mix concrete -VS- site-mix concrete :

- A centralized concrete batching plant can serve a wide area. Site-mix trucks can serve a larger area including remote locations that standard trucks can not.
- The plants are located in areas zoned for industrial use, and yet the delivery trucks can service residential districts or inner cities. Site-mix trucks have the same capabilities.
- Better quality concrete is produced. Site mix can produce higher compression strength with less water then standard batching methods.
- Elimination of storage space for basic materials at site. Standard batch plant needs more room for its operation than site-mix trucks.
- Elimination of procurement / hiring of plant and machinery.
- Wastage of basic materials is avoided. With a site-mix truck, there is less waste and wash out. This is better for the environment.
- Labor associated with production of concrete is eliminated. It takes more people to operate a standard batch plant than a mobile-mix truck.
- Time required is greatly reduced. One mobile-mix truck can produce 8 yards of concrete in 8 minutes. It can also operate continuously without needing to be moved away from the pump truck. One mobile-mix truck can produce 460 yards of concrete in an 8-hour shift, whereas standard trucks must stop and move off the pump to bring in the next, thus taking nearly 3 hours longer to deliver the same amount of concrete. This increases the labor cost.

3 - Disadvantages of ready-mix concrete :

- The materials are batched at a central plant, and the mixing begins at that plant, so the traveling time from the plant to the site is critical over longer distances. Some sites are just too far away, though this is usually a commercial rather than a technical issue.

- Generation of additional road traffic. Furthermore, access roads and site access have to be able to carry the greater weight of the ready-mix truck plus load. ([Wet?] concrete is approx. 2.5 tone per m^3.) This problem can be overcome by utilizing so-called 'mini mix' companies which use smaller $4m^3$ capacity mixers able to access more-restricted sites.
- Concrete's limited time span between mixing and going - off means that ready-mix should be placed within 90 minutes of batching at the plant . Modern admixtures can modify that time span precisely, however, so the amount and type of admixture added to the mix is very important.
- It can also lead to unemployment of men on site i.e hand mixing method

Rebar

A tied rebar beam cage. This will be embedded inside cast concrete to increase the tensile strength of the concrete.

Contents

1 – Introduction :

A **rebar** (short for **reinforcing bar**), also known as **reinforcing steel**, **reinforcement steel**, **re rod** , a **deformed bar**, **reo**, or **reo bar**, is a common steel bar, and is commonly used as a tensioning device in reinforced concrete and reinforced masonry structures holding the concrete in compression. It is usually formed from carbon steel, and is given ridges for better mechanical anchoring into the concrete.

2 – History :

Rebars were known in construction well before the era of the modern reinforced concrete. Some 150 years before its invention rebars were used to form the carcass of the Leaning Tower of Nevyansk in Russia, built on the orders of the industrialist Akinfiy Demidov. The purpose of such construction is one of the many mysteries of the tower. The cast iron used for rebars was of very high quality, and there is no corrosion on them up to this day. The carcass of the tower was connected to its cast iron tented roof, crowned with the first lightning rod in the Western world. This lightning rod was grounded through the carcass, though it is not clear whether the effect was intentional.

3 - Use in concrete and masonry :

Concrete is a material that is very strong in compression, but relatively weak in tension. To compensate for this imbalance in concrete's behavior, rebar is cast into it to carry the tensile loads. For this purpose, the steel reinforcement of a concrete structure is, conceptually, divided in two types of reinforcement: primary reinforcement and secondary reinforcement. Primary reinforcement refers to the reinforcement steel which is employed specifically to guarantee the necessary resistance needed by the structure to support the design loads. Secondary reinforcement, also known as distribution reinforcement, is employed for durability and aesthetics reasons, by providing enough localized resistance to limit cracking and resist stresses caused by effects such as temperature changes and shrinkage. It is also employed to confer resistance to concentrated loads by providing enough localized resistance and stiffness for a load to spread through a wider area.

Masonry structures and the mortar holding them together have similar properties to concrete and also have a limited ability to carry tensile loads. Some standard masonry units like blocks and bricks are made with strategically placed voids to accommodate rebar, which is then secured in place with grout. This combination is known as reinforced masonry.

While any material with sufficient tensile strength could conceivably be used to reinforce concrete, steel and concrete have similar coefficients of thermal expansion: a concrete structural member reinforced with steel will experience minimal stress as a result of differential expansions of the two interconnected materials caused by temperature changes.

4 - Physical characteristics :

Steel has an expansion coefficient nearly equal to that of modern concrete. If this were not so, it would cause problems through additional longitudinal and perpendicular stresses at temperatures different than the temperature of the setting. Although rebar has ribs that bind it mechanically to the concrete, it can still be pulled out of the concrete under high stresses, an occurrence that often precedes a larger-scale collapse of the structure. To prevent such a failure, rebar is either deeply embedded into adjacent structural members (40-60 times the diameter), or bent and hooked at the ends to lock it around the concrete and other rebar. This first approach increases the friction locking the bar into place, while the second makes use of the high compressive strength of concrete.

Common rebar is made of unfinished tempered steel, making it susceptible to rusting. Normally the concrete cover is able to provide a pH value higher than 12 avoiding the corrosion reaction. Too little concrete cover can compromise this guard through carbonation from the surface. Too much concrete cover can cause bigger crack widths which also compromises the local guard. As rust takes up greater volume than the steel from which it was formed, it causes severe internal pressure on the surrounding concrete, leading to cracking, spalling , and ultimately, structural failure. This phenomenon is known as oxide jacking. This is a particular problem where the concrete is exposed to salt water, as in bridges built in areas where salt is applied to roadways in winter, or in marine applications.

Epoxy-coated, galvanized or stainless steel rebars may be employed in these situations at greater initial expense, but significantly lower expense over the service life of the project. Special care must be taken during the installation of epoxy- coated rebar, because even small cracks and failures in the coating can lead to intensified local chemical reactions not visible at the surface.

Fiber-reinforced polymer rebar is now also being used in high-corrosion environments. It is available in many forms, from spirals for reinforcing columns, to the common rod, to meshes and many other forms. Most commercially available rebars are made from unidirectional glass fiber reinforced thermo set resins.

5 - Sizes and grades:

5 – 1 - U.S. sizes :

Imperial bar designations represent the bar diameter in fractions of ⅛ inch, such that #8 = 8⁄8 inch = 1 inch diameter. Area = (bar size/9)^2 such that area of #8 = (8/9)^2 = 0.79 in ^{2} . This applies to #8 bars and smaller. Larger bars are sized to correspond to square bars that were formerly used. The diameter of the #9 bar is set so that the area is 1.000 inch^2, corresponding to a 1 inch square bar. The remaining bars, #10, #11, #14, and #18, correspond to 1⅛ inch, 1¼, 1½, and 2 inch square bars, respectively.[3] The tower and sign industry commonly use #14J and #18J (for "Jumbo") bars as anchor rods for large structures. The bars are fabricated from slightly oversized blanks such that standard 1.75" (#14J) and 2.25" (#18J) threads can be rolled at the ends to accept anchor nuts.

Imperial Bar Size	"Soft" Metric Size	Weight per unit length (lb⁄ft)	Mass per unit length (kg/m)	Nominal Diameter (in)	Nominal Diameter (mm)	Nominal Area (in^2)	Nominal Area (mm^2)
#3	#10	0.376	0.561	0.375 = ⅜	9.525	0.11	71
#4	#13	0.668	0.996	0.500 = ½	12.7	0.20	129
#5	#16	1.043	1.556	0.625 = ⅝	15.875	0.31	200
#6	#19	1.502	2.24	0.750 = ¾	19.05	0.44	284
#7	#22	2.044	3.049	0.875 = ⅞	22.225	0.60	387

#8	#25	2.670	3.982	1.000	25.4	0.79	509
#9	#29	3.400	5.071	1.128	28.65	1.00	645
#10	#32	4.303	6.418	1.270	32.26	1.27	819
#11	#36	5.313	7.924	1.410	35.81	1.56	1006
#14	#43	7.650	11.41	1.693	43	2.25	1452
#18	#57	13.60	20.284	2.257	57.3	4.00	2581
#18J		14.60	21.775	2.337	59.4	4.29	2678

5 – 2 - Canadian sizes :

Metric bar designations represent the nominal bar diameter in millimeters, rounded to the nearest 5 mm.

Metric Bar Size	**Mass per unit length (kg / m)**	**Nominal Diameter (mm)**	**Cross-Sectional Area (mm^2)**
10M	0.785	11.3	100
15M	1.570	16.0	200
20M	2.355	19.5	300
25M	3.925	25.2	500
30M	5.495	29.9	700
35M	7.850	35.7	1000
45M	11.775	43.7	1500
55M	19.625	56.4	2500

5 – 3 - European sizes :

Metric bar designations represent the nominal bar diameter in millimeters. Bars in Europe will be specified to comply with the standard EN 10080 (awaiting introduction as of early 2007), although various national standards still remain in force (e.g. BS 4449 in the United Kingdom).

Metric Bar Size	**Mass per unit length (kg/m)**	**Nominal Diameter (mm)**	**Cross-Sectional Area (mm^2)**
6,0	0.222	6	28.3
8,0	0.395	8	50.3

10,0	0.617	10	78.5
12,0	0.888	12	113
14,0	1.21	14	154
16,0	1.579	16	201
20,0	2.467	20	314
25,0	3.855	25	491
28,0	4.83	28	616
32,0	6.316	32	804
40,0	9.868	40	1257
50,0	15.413	50	1963

5 – 4 - Grades :

Rebar is available in different grades and specifications that vary in yield strength, ultimate tensile strength, chemical composition, and percentage of elongation.

The grade designation is equal to the minimum yield strength of the bar in ksi (1000 psi) for example grade 60 rebar has a minimum yield strength of 60 ksi. Rebar is typically manufactured in grades 40, 60, and 75.

Common ASTM specification are :

- ASTM A82: Specification for Plain Steel Wire for Concrete Reinforcement
- ASTM A184/A184M: Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement
- ASTM A185: Specification for Welded Plain Steel Wire Fabric for Concrete Reinforcement
- ASTM A496: Specification for Deformed Steel Wire for Concrete Reinforcement
- ASTM A497: Specification for Welded Deformed Steel Wire Fabric for Concrete Reinforcement
- ASTM A615/A615M: Deformed and plain carbon-steel bars for concrete reinforcement

- ASTM A616/A616M: Specification for Rail-Steel Deformed and Plain Bars for Concrete Reinforcement
- ASTM A617/A617M: Specification for Axle-Steel Deformed and Plain Bars for Concrete Reinforcement
- ASTM A706/A706M: Low-alloy steel deformed and plain bars for concrete reinforcement
- ASTM A767/A767M: Specification for Zinc-Coated(Galvanized) Steel Bars for Concrete Reinforcement
- ASTM A775/A775M: Specification for Epoxy-Coated Reinforcing Steel Bars
- ASTM A934/A934M: Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars
- ASTM A955: Deformed and plain stainless-steel bars for concrete reinforcement
- ASTM A996: Rail-steel and axle-steel deformed bars for concrete reinforcement
- ASTM A1035: Standard Specification for Deformed and Plain, Low-carbon, Chromium, Steel Bars for Concrete Reinforcement

ASTM marking designations are :

- 'S' billet A615
- 'I' rail A616 (superseded by A996)
- 'IR' Rail Meeting Supplementary Requirements S1 A616 (superseded by A996)
- 'A' Axle A617(superseded by A996)
- 'W' Low-alloy — A706

Historically in Europe, rebar is composed of mild steel material with a yield strength of approximately 250MPa (36ksi). Modern rebar is composed of high-yield steel, with a yield strength more typically 500MPa (72.5ksi). Rebar can be supplied with various grades of ductility. The more ductile steel is capable of absorbing considerably more energy when deformed - a behavior that resists earthquake forces and is used in design.

6 - Placing rebar :

Rebar cages are fabricated either on or off the project site commonly with the help of hydraulic benders and shears, however for small or custom work a tool known as a Hickey - or hand rebar bender, is sufficient. The rebars are placed by *rodbusters* or concrete reinforcing ironworkers with bar supports separating the rebar from the concrete forms to establish concrete cover and ensure that proper embedment is achieved. The rebars in the cages are connected either by welding, tying steel wire, or with mechanical connections. For epoxy coated or galvanized rebars only the latter is possible.

6 – 1 - Welding :

The American Welding Society (AWS) D 1.4 sets out the practices for welding rebar in the U.S. Without special consideration the only rebar that is ready to weld is *W grade* (Low-alloy — A706). Rebar that is not produced to the ASTM A706 specification is generally not suitable for welding without calculating the "carbon-equivalent". Material with a carbon-equivalent of less than 0.55 can be welded. (AWS D1.4)

ASTM A 616 & ASTM A 617 reinforcing are re-rolled rail steel & re-rolled rail axle steel with uncontrolled chemistry, phosphorus & carbon content. These materials are not common.

Rebar cages are normally tied together with wire, although welding of cages has been the norm in Europe for many years, and is becoming more common in the US. High strength steels for pre stressed concrete may absolutely not be welded.

6 – 2 - Mechanical Connections :

Also known as "mechanical couplers" or "mechanical splices", mechanical connections are used to connect reinforcing bars together. Mechanical couplers are an effective means to reduce rebar congestion in highly reinforced areas for cast-in-place concrete construction. These couplers are also used in precast concrete construction at the joints between members.

The structural performance criteria for mechanical connections varies considerably between different countries, codes, and industries. As a minimum requirement, codes typically specify that the rebar to splice connection meets or exceeds 125 % of the specified tensile strength of the rebar. More stringent criteria also requires the development of the specified ultimate strength of the rebar. As an example, ACI 318 specifies either Type 1 (125% F_y) or Type 2 (125% F_y and 100% F_u) performance criteria.

For concrete structures designed with ductility in mind, it is recommended that the mechanical connections are also capable of failing in a ductile manner, typically known in the reinforcing steel industry as achieving "bar-break". As an example, Caltrans specifies a required mode of failure (i.e., "necking of the bar").

6 – 3 - Safety :

To prevent workers and / or pedestrians from accidentally impaling themselves, the protruding ends of steel rebar are often bent over or covered with special steel - reinforced plastic "plate" caps. "Mushroom" caps may provide protection from scratches and other minor injuries, but provide little to no protection from impalement.

7 - Designations :

For clarity, reinforcement is usually tabulated in a "reinforcement schedule" on construction drawings. This eliminates ambiguity in the various notations used in different parts of the world. The following list provides examples of the different notations used in the architectural, engineering, and construction industry.

New Zealand

Designation	Explanation
HD-16-300, T&B, EW	High strength (500 MPa) 16 mm diameter rebars spaced at 300 mm centers (center-to-center distance) on both the top and bottom face and in each way as well (i.e., longitudinal and transverse).
3-D12	Three mild strength (300 MPa) 12 mm diameter rebars

R8 Stirrups @ 225 MAX	*D* grade (300 MPa) smooth bar stirrups, spaced at 225 mm centres. By default in New Zealand practice all stirrups are normally interpreted as being full, closed, loops. This is a detailing requirement for concrete ductility in seismic zones; If a single strand of stirrup with a hook at each end was required, this would typically be both specified and illustrated.

United States

Designation	Explanation
#4 @ 12 OC, T&B, EW	Number 4 rebars spaced 12 inches on center (center-to-center distance) on both the top and bottom faces and in each way as well, i.e. longitudinal and transverse.
(3) #4	Three number 4 rebars (usually used when the rebar perpendicular to the detail)
#3 ties @ 9 OC, (2) per set	Number 3 rebars used as stirrups, spaced at 9 inches on center. Each set consists of two ties, which is usually illustrated.
#7 @ 12" EW, EF	Number 7 rebar spaced 12 inches apart, placed in each direction (each way) and on each face.

8 - Recycling :

Workers extracting rebar from demolition rubble.

In China, and many other countries, after the demolition of a building, workers are called in to remove the rebar. They scour the site, extracting the metal using bolt cutters, welding equipment, sledgehammers, and other tools. The metal is partially straightened, bundled and sold. In April 2012, such rebar sold for 2.4 RMB per kilogram .

Rebar Spacer

	
Linear rebar spacer	*Point rebar spacer*

Contents

1 – Introduction :

A **rebar spacer** is a device that secures the reinforcing steel or "rebar" in reinforced concrete structures as the rebar is assembled in place prior to the final concrete pour. The spacers are left in place for the pour to keep the reinforcing in place, and become a permanent part of the structure.

The main categories of rebar spacers are :

- Linear Spacers (Π - section profiles, H-section profiles, or other 3 dimensional shapes) ,
- Point Spacers (wheel spacers, various tower or chair-like shapes) .

You can also divide the rebar spacers in two raw materials categories :

- Concrete spacers
- Plastic spacers

The concrete spacers have the advantage of the same raw material which will improve the water tightness and strength of the concrete. Plastic spacers have the advantage of the low cost production and fast processing. This was the inspiration for a Dutchman who started producing concrete spacers with plastic clips in about 1995. This invention made working with concrete spacers more profitable and easy.

2 - Function :

The engineering study of every concrete construction, whether it is a building, a bridge, a bearing wall or other structure, predicts the positioning of steel rebars at specific positions in the volume of concrete (predicted cover of steel reinforcement bars). This cover typically varies between 10mm and 100mm. The statics of every concrete construction are designed in such a way that steel and concrete properties are combined in order to achieve the maximum possible strength for the particular construction (e.g. anti-earthquake protection) as well as to prevent the long-term corrosion of steel that would weaken the construction. Rebar spacers secure the correct position of steel, thus assisting in the practical application of the theoretical specifications of concrete construction. The cover of the steel of a particular construction element (for example in a concrete slab or a beam) should be generally uniform within the element.

The use of spacers is particularly important in areas with high earthquake activity in combination with corrosive environment (like proximity to salt water of sea), as for example Japan, Iran, Greece, California etc.

Reinforced Concrete

Contents

1 – Introduction :

Reinforced concrete is concrete in which the material's undesirably low tensile strength and elasticity are counteracted by the inclusion of reinforcing structures that have high tensile strength. The structures usually, though not necessarily, are reinforcing bars of steel (rebar) and also usually, though also not necessarily, are embedded passively in the concrete before it sets. Such reinforcing structures are designed primarily to take up working stresses that otherwise would have placed regions within the concrete mass under unacceptable tension. Modern concrete reinforcing structures however, may instead or in addition contain non-steel materials with high tensile strength. They also may be permanently stressed before or after the mass sets, so as to improve the behaviour of the final structure under working loads. These two expedients are known as (pre-stressing) and (post-stressing) respectively.

For a strong, ductile and durable construction the reinforcement needs to have the following properties at least :

- High strength
- High toleration of tensile strain
- Good bond to the concrete, irrespective of pH, moisture, and similar factors
- Thermal compatibility, not causing unacceptable stresses in response to changing temperatures.
- Durability in the concrete environment, irrespective of corrosion or sustained stress for example.

2 - Use in construction :

Rebars of Sagrada Família's roof in construction (2009)

Concrete is reinforced to give it extra tensile strength; without reinforcement, many concrete buildings would not have been possible.

Reinforced concrete can encompass many types of structures and components, including slabs, walls, beams, columns, foundations, frames and more . Reinforced concrete can be classified as precast or cast in-situ concrete.

Designing and implementing the most efficient floor system is key to creating optimal building structures. Small changes in the design of a floor system can have significant impact on material costs, construction schedule, ultimate strength, operating costs, occupancy levels and end use of a building.

3 - Behavior of reinforced concrete :

3 – 1 - Materials :

Concrete is a mixture of coarse (stone or brick chips) and fine (generally sand or crushed stone) aggregates with a binder material (usually Portland cement). When mixed with a small amount of water, the cement hydrates to form microscopic opaque crystal lattices encapsulating and locking the aggregate into a rigid structure. Typical concrete mixes have high resistance to compressive stresses (about 4,000 psi (28 MPa)); however, any appreciable tension (*e.g.*, due to bending) will break the microscopic rigid lattice, resulting in cracking and separation of the concrete. For this reason, typical non-reinforced concrete must be well supported to prevent the development of tension.

If a material with high strength in tension, such as steel, is placed in concrete, then the composite material, **reinforced concrete**, resists not only compression but also bending and other direct tensile actions. A reinforced concrete section where the concrete resists the compression and steel resists the tension can be made into almost any shape and size for the construction industry.

3 – 2 - Key characteristics

Three physical characteristics give reinforced concrete its special properties :

1. the coefficient of thermal expansion of concrete is similar to that of steel, eliminating large internal stresses due to differences in thermal expansion or contraction.
2. when the cement paste within the concrete hardens, this conforms to the surface details of the steel, permitting any

stress to be transmitted efficiently between the different materials. Usually steel bars are roughened or corrugated to further improve the bond or cohesion between the concrete and steel.

3. the alkaline chemical environment provided by the alkali reserve (KOH, NaOH) and the portlandite (calcium hydroxide) contained in the hardened cement paste causes a passivating film to form on the surface of the steel, making it much more resistant to corrosion than it would be in neutral or acidic conditions. When the cement paste exposed to the air and meteoric water reacts with the atmospheric CO_2, portlandite and the Calcium Silicate Hydrate (CSH) of the hardened cement paste become progressively carbonated and the high pH gradually decreases from 13.5 – 12.5 to 8.5, the pH of water in equilibrium with calcite (calcium carbonate) and the steel is no longer passivated.

As a rule of thumb, only to give an idea on orders of magnitude, steel is protected at pH above ~11 but starts to corrode below ~10 depending on steel characteristics and local physico-chemical conditions when concrete becomes carbonated. Carbonation of concrete along with chloride ingress are amongst the chief reasons for the failure of reinforcement bars in concrete.[1]

The relative cross-sectional area of steel required for typical reinforced concrete is usually quite small and varies from 1% for most beams and slabs to 6 % for some columns. Reinforcing bars are normally round in cross-section and vary in diameter. Reinforced concrete structures sometimes have provisions such as ventilated hollow cores to control their moisture & humidity.

Distribution of concrete (in spite of reinforcement) strength characteristics along the cross-section of vertical reinforced concrete elements is inhomogeneous.

3 – 3 - Mechanism of composite action of reinforcement and concrete :

The reinforcement in a RC structure, such as a steel bar, has to undergo the same strain or deformation as the surrounding concrete in order to prevent discontinuity, slip or separation of the two materials under load. Maintaining composite action requires transfer of load between the concrete and steel. The direct stress is transferred from the concrete to the bar interface so as to change the tensile stress in the reinforcing bar along its length. This load transfer is achieved by means of bond (anchorage) and is idealized as a continuous stress field that develops in the vicinity of the steel-concrete interface.

3 – 4 - Anchorage (bond) in concrete : Codes of specifications :

Because the actual bond stress varies along the length of a bar anchored in a zone of tension, current international codes of specifications use the concept of development length rather than bond stress. The main requirement for safety against bond failure is to provide a sufficient extension of the length of the bar beyond the point where the steel is required to develop its yield stress and this length must be at least equal to its development length. However, if the actual available length is inadequate for full development, special anchorages must be provided, such as cogs or hooks or mechanical end plates. The same concept applies to lap splice length mentioned in the codes where splices (overlapping) provided between two adjacent bars in order to maintain the required continuity of stress in the splice zone.

3 – 5 - Anti - corrosion measures :

In wet and cold climates, reinforced concrete for roads, bridges, parking structures and other structures that may be exposed to deicing salt may benefit from use of epoxy-coated, hot dip galvanised or stainless steel rebar, although good design and a well-chosen cement mix may provide sufficient protection for many applications. Epoxy coated rebar can easily be identified by the light green colour of its epoxy coating. Hot dip galvanized rebar may be bright or dull grey depending on length of exposure, and stainless rebar exhibits a typical white metallic sheen that is readily distinguishable from carbon steel reinforcing bar. Reference ASTM standard specifications **A767** Standard Specification for Hot Dip Galvanized Reinforcing Bars, **A775** Standard Specification for Epoxy Coated Steel Reinforcing Bars and **A955** Standard Specification for Deformed and Plain Stainless Bars for Concrete Reinforcement.

Another, cheaper way of protecting rebars is coating them with zinc phosphate. Zinc phosphate slowly reacts with calcium cations and the hydroxyl anions present in the cement pore water and forms a stable hydroxy apatite layer.

Penetrating sealants typically must be applied some time after curing. Sealants include paint, plastic foams, films and aluminum foil, felts or fabric mats sealed with tar, and layers of bentonite clay, sometimes used to seal roadbeds.

Corrosion inhibitors, such as calcium nitrite [$Ca(NO_2)_2$], can also be added to the water mix before pouring concrete. Generally, 1–2 wt. % of [$Ca(NO_2)_2$] with respect to cement weight is needed to prevent corrosion of the rebars. The nitrite anion is a mild oxidizer that oxidizes the soluble and mobile ferrous ions (Fe^{2+}) present at the surface of the corroding steel and causes it to precipitate as an insoluble ferric hydroxide ($Fe(OH)_3$). This causes the passivation of steel at the anodic oxidation sites. Nitrite is a much more active corrosion inhibitor than nitrate, a less powerful oxidizer of the divalent iron.

4 - Reinforcement and terminology of Beams :

A beam bends under bending moment, resulting in a small curvature. At the outer face (**tensile face**) of the curvature the concrete experiences tensile stress, while at the inner face (**compressive face**) it experiences compressive stress.

A **singly reinforced** beam is one in which the concrete element is only reinforced near the tensile face and the reinforcement, called tension steel, is designed to resist the tension.

A **doubly reinforced** beam is one in which besides the tensile reinforcement the concrete element is also reinforced near the compressive face to help the concrete resist compression. The latter reinforcement is called compression steel. When the compression zone of a concrete is inadequate to resist the compressive Moment(positive moment), extra reinforcement has to be provided if the architect limits the dimensions of the section.

An **under-reinforced** beam is one in which the tension capacity of the tensile reinforcement is **smaller** than the combined compression capacity of the concrete and the compression steel (under-reinforced at tensile face). When the reinforced concrete element is subject to increasing bending moment, the tension steel yields while the concrete does not reach its ultimate failure condition. As the tension steel yields and stretches, an "under-reinforced" concrete also yields in a ductile manner, exhibiting a large deformation and warning before its ultimate failure. In this case the yield stress of the steel governs the design.

An **over-reinforced** beam is one in which the tension capacity of the tension steel is **greater** than the combined compression capacity of the concrete and the compression steel (over-reinforced at tensile face). So the "over-reinforced concrete" beam fails by crushing of the compressive-zone concrete and before the tension zone steel yields, which does not provide any warning before failure as the failure is instantaneous.

A **balanced-reinforced** beam is one in which both the compressive and tensile zones reach yielding at the same imposed load on the beam, and the concrete will crush and the tensile steel will yield at the same time. This design criterion is however as risky as over-reinforced concrete, because failure is sudden as the concrete crushes at the same time of the tensile steel yields, which gives a very little warning of distress in tension failure.

Steel - reinforced concrete moment - carrying elements should normally be designed to be under - reinforced so that users of the structure will receive warning of impending collapse.

The **characteristic strength** is the strength of a material where less than 5% of the specimen shows lower strength.

The **design strength** or **nominal strength** is the strength of a material, including a material - safety factor. The value of the safety factor generally ranges from 0.75 to 0.85 in Allowable Stress Design.

The **ultimate limit state** is the theoretical failure point with a certain probability. It is stated under factored loads and factored resistances.

5 - Pre stressed concrete :

Pre stressed concrete is a technique that greatly increases load bearing strength of concrete beams. The reinforcing steel in the bottom part of the beam, which will be subjected to tensile forces when in service, is placed in tension prior to the concrete being poured around it. Once the concrete has hardened, the tension on the reinforcing steel is released, placing a built-in compressive force on the concrete. When loads are applied, the reinforcing steel takes on more stress and the compressive force in the concrete is reduced, but does not become a tensile force. Since the concrete is always under compression, it is less subject to cracking and failure.

6 - Common failure modes of steel reinforced concrete :

Reinforced concrete can fail due to inadequate strength, leading to mechanical failure, or due to a reduction in its durability. Corrosion and freeze/thaw cycles may damage poorly designed or constructed reinforced concrete. When rebar corrodes, the oxidation products (rust) expand and tends to flake, cracking the concrete and un bonding the rebar from the concrete. Typical mechanisms leading to durability problems are discussed below.

6 – 1 - Mechanical failure :

Cracking of the concrete section can not be prevented; however, the size and location of the cracks can be limited and controlled by reinforcement, placement of control joints, the curing methodology and the mix design of the concrete. Cracking defects can allow moisture to penetrate and corrode the reinforcement. This is a serviceability failure in limit state design. Cracking is normally the result of an inadequate quantity of rebar, or rebar spaced at too great a distance. The concrete then cracks either under excess loading, or due to internal effects such as **early thermal shrinkage** when it cures.

Ultimate failure leading to collapse can be caused by crushing of the concrete, when compressive stresses exceed its strength; by yielding or failure of the rebar, when bending or shear stresses exceed the strength of the reinforcement; or by bond failure between the concrete and the rebar.

6 – 2 - Carbonation :

Carbonation, or neutralization, is a chemical reaction between carbon dioxide in the air with calcium hydroxide and hydrated calcium silicate in the concrete.

When designing a concrete structure, it is normal to state the concrete cover for the rebar (the depth within the object that the rebar will be). The minimum concrete cover is normally regulated by design or building codes. If the reinforcement is too close to the surface, early failure due to corrosion may occur. The concrete cover depth can be measured with a cover meter. However, carbonated concrete only becomes a durability problem when there is also sufficient moisture and oxygen to cause electro-potential corrosion of the reinforcing steel.

One method of testing a structure for carbonation is to drill a fresh hole in the surface and then treat the cut surface with phenolphthalein indicator solution. This solution will turn [pink] when in contact with alkaline concrete, making it possible to see the depth of carbonation. An existing hole is no good because the exposed surface will already be carbonated.

6 – 2 - Chlorides

Chlorides, including sodium chloride, can promote the corrosion of embedded steel rebar if present in sufficiently high concentration. Chloride anions induce both localized corrosion (pitting corrosion) and generalized corrosion of steel reinforcements. For this reason, one should only use fresh raw water or potable water for mixing concrete, ensure that the coarse and fine aggregates do not contain chlorides, and not use admixtures that contain chlorides.

Rebar for foundations and walls of sewage pump station.

It was once common for calcium chloride to be used as an admixture to promote rapid set-up of the concrete. It was also mistakenly believed that it would prevent freezing. However, this practice has fallen into disfavor once the deleterious effects of chlorides became known. It should be avoided when ever possible.

The use of de-icing salts on roadways, used to reduce the freezing point of water, is probably one of the primary causes of premature failure of reinforced or pre stressed concrete bridge decks, roadways, and parking garages. The use of epoxy-coated reinforcing bars and the application of cathodic protection has mitigated this problem to some extent. Also FRP rebars are known to be less susceptible to chlorides. Properly designed concrete mixtures that have been allowed to cure properly are effectively impervious to the effects of deicers.

Another important source of chloride ions is from sea water. Sea water contains by weight approximately 3.5 wt. % salts. These salts include sodium chloride, magnesium sulfate, calcium sulfate, and bicarbonates. In water these salts dissociate in free ions (Na^+, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-) and migrate with the water into the capillaries of the concrete. Chloride ions are particularly aggressive for the corrosion of the carbon steel reinforcement bars and make up about 50% of these ions.

In the 1960s and 1970s it was also relatively common for Magnesite, a chloride rich carbonate mineral, to be used as a floor-topping material. This was done principally as a levelling and sound attenuating layer. However it is now known that when these materials came into contact with moisture it produced a weak solution of hydrochloric acid due to the presence of chlorides in the magnesite. Over a period of time (typically decades) the solution caused corrosion of the embedded steel rebars. This was most commonly found in wet areas or areas repeatedly exposed to moisture.

6 – 4 - Alkali silica reaction :

This a reaction of amorphous silica (chalcedony, chert, siliceous limestone) sometimes present in the aggregates with the hydroxyl ions (OH^-) from the cement pore solution. Poorly crystallized silica (SiO_2) dissolves and dissociates at high pH (12.5 - 13.5) in alkaline water. The soluble dissociated silicic acid reacts in the porewater with the calcium hydroxide (portlandite) present in the cement paste to form an expansive calcium silicate hydrate (CSH). The *alkali silica reaction (ASR)*, causes localized swelling responsible of tensile stress and cracking.

The conditions required for alkali silica reaction are three fold :

(1) aggregate containing an alkali-reactive constituent (amorphous silica),
(2) sufficient availability of hydroxyl ions (OH^-), and
(3) sufficient moisture, above 75 % relative humidity (RH) within the concrete .

This phenomenon is sometimes popularly referred to as "concrete cancer". This reaction occurs independently of the presence of rebars: massive concrete structures such as dams can be affected.

6 – 5 - Conversion of high alumina cement :

Resistant to weak acids and especially sulfates, this cement cures quickly and reaches very high durability and strength. It was greatly used after World War II for making precast concrete objects. However, it can lose strength with heat or time (conversion), especially when not properly cured. With the collapse of three roofs made of pre stressed concrete beams using high alumina cement, this cement was banned in the UK in 1976. Subsequent inquiries into the matter showed that the beams were improperly manufactured, but the ban remained.

6 – 6 - Sulphates

Sulfates (SO_4) in the soil or in groundwater, in sufficient concentration, can react with the Portland cement in concrete causing the formation of expansive products, e.g. ettringite or thaumasite, which can lead to early failure of the structure. The most typical attack of this type is on concrete slabs and foundation walls at grade where the sulfate ion, via alternate wetting and drying, can increase in concentration. As the concentration increases, the attack on the Portland cement can begin. For buried structures such as pipe, this type of attack is much rarer especially in the Eastern half of the United States. The sulfate ion concentration increases much slower in the soil mass and is especially dependent upon the initial amount of sulfates in the native soil. The chemical analysis of soil borings should be done during the design phase of any project involving concrete in contact with the native soil to check for the presence of sulfates. If the concentrations are found to be aggressive, various protective coatings can be used. Also, in the US ASTM C150 Type 5 Portland cement can be used in the mix. This type of cement is designed to be particularly resistant to a sulfate attack.

7 - Steel plate construction :

In steel plate construction, stringers join parallel steel plates. The plate assemblies are fabricated off site, and welded together on-site to form steel walls connected by stringers. The walls become the form into which concrete is poured. Steel plate construction speeds reinforced concrete construction by cutting out the time consuming on-site manual steps of tying rebar and building forms. The method has excellent strength because the steel is on the outside, where tensile forces are often greatest.

8 – Fiber - reinforced concrete :

Fiber reinforcement is mainly used in shotcrete , but can also be used in normal concrete. Fiber-reinforced normal concrete is mostly used for on-ground floors and pavements, but can be considered for a wide range of construction parts (beams, pillars, foundations, etc.), either alone or with hand-tied rebars.

Concrete reinforced with fibers (which are usually steel, glass, or plastic fibers) is less expensive than hand-tied rebar, while still increasing the tensile strength many times. Shape, dimension, and length of fiber are important. A thin and short fiber, for example short, hair-shaped glass fiber, will only be effective the first hours after pouring the concrete (reduces cracking while the concrete is stiffening) but will not increase the concrete tensile strength. A normal-size fiber for European shotcrete (1 mm diameter, 45 mm length—steel or plastic) will increase the concrete's tensile strength.

Steel is the strongest commonly-available fiber, and comes in different lengths (30 to 80 mm in Europe) and shapes (end-hooks). Steel fibers can only be used on surfaces that can tolerate or avoid corrosion and rust stains. In some cases, a steel-fiber surface is faced with other materials.

Glass fiber is inexpensive and corrosion-proof, but not as ductile as steel. Recently, spun basalt fiber, long available in Eastern Europe, has become available in the U.S. and Western Europe. Basalt fibre is stronger and less expensive than glass, but historically has not resisted the alkaline environment of portland cement well enough to be used as direct reinforcement. New materials use plastic binders to isolate the basalt fiber from the cement.

The premium fibers are graphite-reinforced plastic fibers, which are nearly as strong as steel, lighter-weight, and corrosion-proof. Some experiments have had promising early results with carbon nano tubes, but the material is still far too expensive for any building.

9 - Non - steel reinforcement :

There is considerable overlap between the subjects of non-steel reinforcement and fiber-reinforcement of concrete. The introduction of non-steel reinforcement of concrete is relatively recent; it takes two major forms: non-metallic rebar rods, and non-steel (usually also non-metallic) fibres incorporated into the cement matrix. For example there is increasing interest in glass fiber reinforced concrete (**GFRC**) and in various applications of polymer fibers incorporated into concrete. Although currently there is not much suggestion that such materials will in general replace metal rebar, some of them have major advantages in specific applications, and there also are new applications in which metal rebar simply is not an option. However, the design and application of non-steel reinforcing is fraught with challenges; for one thing, concrete is a highly alkaline environment, in which many materials, including most kinds of glass, have a poor service life. Also, the behavior of such reinforcing materials differ from the behavior of metals, for instance in terms of shear strength, creep and elasticity.

Fibre-Reinforced Polymer (FRP) (Fiber - reinforced plastic or FRP) and Glass-reinforced plastic (GRP) consist of fibers of polymer, glass, carbon , aramid or other polymers or high-strength fibers set in a resin matrix to form a rebar rod or grid or fibers. These rebars are installed in much the same manner as steel. The cost is higher but, suitably applied, the structures have advantages, in particular a dramatic reduction in problems related to corrosion, either by intrinsic concrete alkalinity or by external corrosive fluids that might penetrate the concrete. These structures can be significantly lighter and usually have a longer service life. The cost of these materials has dropped dramatically since their widespread adoption in the aerospace industry and by the military.

In particular FRP rods are useful for structures where the presence of steel would not be acceptable. For example, MRI machines have huge magnets, and accordingly require non-magnetic buildings. Again, toll booths that read radio tags need reinforced concrete that is transparent to radio waves. Also, where the design life of the concrete structure is more important than its initial costs, non-steel reinforcing often has its advantages where corrosion of reinforcing steel is a major cause of failure. In such situations corrosion-proof reinforcing can extend a structure's life substantially, for example in the intertidal zone. FRP rods may also be useful in situations where it is likely that the concrete structure may be compromised in future years, for example the edges of balconies when balustrades are replaced and bathroom floors in multi-story construction where the service life of the floor structure is likely to be many times the service life of the waterproofing building membrane.

Plastic reinforcement often is stronger, or at least has a better strength to weight ratio than reinforcing steels. Also, because it resists corrosion, it does not need a protective concrete cover as thick as steel reinforcement does (typically 30 to 50 mm or more). FRP-reinforced structures therefore can be lighter and last longer. Accordingly, for some applications the whole-life cost will be price-competitive with steel-reinforced concrete.

The material properties of FRP or GRP bars differ markedly from steel, so there are differences in the design considerations. FRP or GRP bars have relatively higher tensile strength but lower stiffness, so that Deflections are likely to be higher than for equivalent steel-reinforced units. Structures with internal FRP reinforcement typically have an elastic deformability comparable to the plastic deformability (ductility) of steel reinforced structures. Failure in either case is more likely to occur by compression of the concrete than by rupture of the reinforcement. Deflection is always a major design consideration for reinforced concrete. Deflection limits are set to ensure that crack widths in steel-reinforced concrete are controlled to prevent water, air or other aggressive substances reaching the steel and causing corrosion. For FRP-reinforced concrete, aesthetics and possibly water-tightness will be the limiting criteria for crack width control. FRP rods also have relatively lower compressive strengths than steel rebar, and accordingly require different design approaches for reinforced concrete columns.

One drawback to the use of FRP reinforcement is the limited fire resistance. Where fire safety is a consideration, structures employing FRP have to maintain their strength and the anchoring of the forces at temperatures to be expected in the event of fire. For purposes of fireproofing an adequate thickness of cement concrete cover or protective cladding is necessary. The disadvantages are not on the side of the FRP however, addition of 1 kg/m^3 of polypropylene fibers to concrete has been shown to reduce spalling during a simulated fire . (The improvement is thought to be due to the formation of pathways out of the bulk of the concrete, allowing steam pressure to dissipate).

Another problem is the effectiveness of shear reinforcement. FRP rebar stirrups formed by bending before hardening generally perform relatively poorly in comparison to steel stirrups or to structures with straight fibers. When strained, the zone between the straight and curved regions are subject to strong bending, shear, and longitudinal stresses. Special design techniques are necessary to deal with such problems.

There is growing interest in application of external reinforcement of existing structures with advanced materials such as carbon fibre, that can impart exceptional strength.

Reinforced Solid

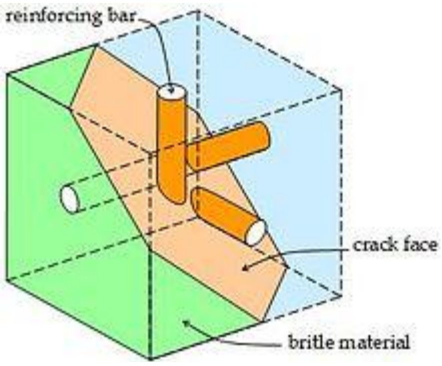


Figure 1: Small cube of a material with reinforcing bars. The cube is cracked and the material above the crack is removed to show the reinforcement that crosses the crack.

Contents

1 – Introduction :

In solid mechanics, a **reinforced solid** is a brittle material that is reinforced by ductile bars or fibres. A common application is reinforced concrete. When the concrete cracks the tensile force in a crack is not carried any more by the concrete but by the steel reinforcing bars only. The reinforced concrete will continue to carry the load provided that sufficient reinforcement is present. A typical design problem is to find the smallest amount of reinforcement that can carry the stresses on a small cube (Fig. 1). This can be formulated as an optimization problem.

2 - Optimization problem :

The reinforcement is directed in the x, y and z direction. The reinforcement ratio is defined in a cross - section of a reinforcing bar as the reinforcement area A_r over the total area A, which is the brittle material area plus the reinforcement area.

$$\rho_x = A_{rx} / A_x$$
$$\rho_y = A_{ry} / A_y$$
$$\rho_z = A_{rz} / A_z$$

In case of reinforced concrete the reinforcement ratios usually are between 0.1% and 2%. The yield stress of the reinforcement is denoted by f_y. The stress tensor of the brittle material is :

$$\begin{bmatrix} \sigma_{xx} - \rho_x f_y & \sigma_{xy} & \sigma_{xz} \\ \sigma_{xy} & \sigma_{yy} - \rho_y f_y & \sigma_{yz} \\ \sigma_{xz} & \sigma_{yz} & \sigma_{zz} - \rho_z f_y \end{bmatrix}.$$

This can be interpreted as the stress tensor of the composite material minus the stresses carried by the reinforcement at yielding. This formulation is accurate for reinforcement ratio's smaller than 5%. It is assumed that the brittle material has no tensile strength. (In case of reinforced concrete this assumption is necessary because the concrete has small shrinkage cracks.) Therefore, the principal stresses of the brittle material need to be compression. The principal stresses of a stress tensor are its Eigen values.

The optimization problem is formulated as follows. Minimize ρ_x + ρ_y+ ρ_z subject to all Eigen values of the brittle material stress tensor are less than or equal to zero (negative - semi definite).

3 - Solution :

The solution to this problem can be presented in a form most suitable for hand calculations . It can be presented in graphical form . It can also be presented in a form most suitable for computer implementation . In this article the latter method is shown.

There are 12 possible reinforcement solutions to this problem, which are shown in the table below. Every row contains a possible solution. The first column contains the number of a solution. The second column gives conditions for which a solution is valid.

Columns 3 , 4 and 5 give the formulas for calculating the reinforcement ratios.

	Condition	$\rho_x f_y$	$\rho_y f_y$	$\rho_z f_y$
1	$I_1 \leq 0$, $I_2 \geq 0$, $I_3 \leq 0$	0	0	0
2	$\sigma_{yy}\sigma_{zz} - \sigma_{yz}^2 > 0$ $I_1(\sigma_{yy}\sigma_{zz} - \sigma_{yz}^2) -$ ≤ 0 $I_2(\sigma_{yy}\sigma_{zz} - \sigma_{yz}^2) -$ ≥ 0	$\frac{I_3}{\sigma_{yy}\sigma_{zz} - \sigma_{yz}^2}$	0	0
3	$\sigma_{xx}\sigma_{zz} - \sigma_{xz}^2 > 0$ $I_1(\sigma_{xx}\sigma_{zz} - \sigma_{xz}^2) -$ ≤ 0 $I_2(\sigma_{xx}\sigma_{zz} - \sigma_{xz}^2) -$ ≥ 0	0	$\frac{I_3}{\sigma_{xx}\sigma_{zz} - \sigma_{xz}^2}$	0
4	$\sigma_{xx}\sigma_{yy} - \sigma_{xy}^2 > 0$ $I_1(\sigma_{xx}\sigma_{yy} - \sigma_{xy}^2) -$ ≤ 0 $I_2(\sigma_{xx}\sigma_{yy} - \sigma_{xy}^2) -$ ≥ 0	0	0	$\frac{I_3}{\sigma_{xx}\sigma_{yy} - \sigma_{xy}^2}$
5	$\sigma_{xx} < 0$	0	$\sigma_{yy} - \frac{\sigma_{xy}^2}{\sigma_{xx}} + \lvert\sigma_{yz}$	$\sigma_{zz} - \frac{\sigma_{xz}^2}{\sigma_{xx}} + \lvert\sigma_{yz}$
6	$\sigma_{yy} < 0$	$\sigma_{xx} - \frac{\sigma_{xy}^2}{\sigma_{yy}} + \lvert\sigma_{xz}$	0	$\sigma_{zz} - \frac{\sigma_{yz}^2}{\sigma_{yy}} + \lvert\sigma_{xz}$
7	$\sigma_{zz} < 0$	$\sigma_{xx} - \frac{\sigma_{xz}^2}{\sigma_{zz}} + \lvert\sigma_{x}$	$\sigma_{yy} - \frac{\sigma_{yz}^2}{\sigma_{zz}} + \lvert\sigma_{xy}$	0
8	$\sigma_{yz} + \sigma_{xz} + \sigma_{xy} \geq 0$ $\sigma_{xz}\sigma_{xy} + \sigma_{yz}\sigma_{xy} +$ ≥ 0	$\sigma_{xx} + \sigma_{xz} + \sigma_{xy}$	$\sigma_{yy} + \sigma_{yz} + \sigma_{xy}$	$\sigma_{zz} + \sigma_{yz} + \sigma_{xz}$
9	$-\sigma_{yz} - \sigma_{xz} + \sigma_{xy} \geq 0$ $-\sigma_{xz}\sigma_{xy} - \sigma_{yz}\sigma_{xy} +$ ≥ 0	$\sigma_{xx} - \sigma_{xz} + \sigma_{xy}$	$\sigma_{yy} - \sigma_{yz} + \sigma_{xy}$	$\sigma_{zz} - \sigma_{yz} - \sigma_{xz}$
10	$\sigma_{yz} - \sigma_{xz} - \sigma_{xy} \geq 0$ $\sigma_{xz}\sigma_{xy} - \sigma_{yz}\sigma_{xy} -$ ≥ 0	$\sigma_{xx} - \sigma_{xz} - \sigma_{xy}$	$\sigma_{yy} + \sigma_{yz} - \sigma_{xy}$	$\sigma_{zz} + \sigma_{yz} - \sigma_{xz}$
11	$-\sigma_{yz} + \sigma_{xz} - \sigma_{xy} \geq 0$	$\sigma_{xx} + \sigma_{xz} - \sigma_{xy}$	$\sigma_{yy} - \sigma_{yz} - \sigma_{xy}$	$\sigma_{zz} - \sigma_{yz} + \sigma_{xz}$

	$-\sigma_{xz}\sigma_{xy} + \sigma_{yz}\sigma_{xy} -$ ≥ 0			
12	$\sigma_{xy}\sigma_{xz}\sigma_{yz} < 0$	$\sigma_{xx} - \frac{\sigma_{xz}\sigma_{xy}}{\sigma_{yz}}$	$\sigma_{yy} - \frac{\sigma_{yz}\sigma_{xy}}{\sigma_{xz}}$	$\sigma_{zz} - \frac{\sigma_{yz}\sigma_{xz}}{\sigma_{xy}}$

I_1, $I_2$and $I_3$are the stress invariants of the composite material stress tensor. Additional constraints are $\rho_x \geq 0$, $\rho_y \geq 0$, $\rho_z \geq 0$.

The algorithm for obtaining the right solution is simple. Compute the reinforcement ratios of each possible solution that fulfills the conditions. Further ignore solutions with a reinforcement ratio less than zero. Compute the values of $\rho_x + \rho_y + \rho_z$and select the solution for which this value is smallest. The principal stresses in the brittle material can be computed as the Eigen values of the brittle material stress tensor, for example by Jacobi's method.

The formulas can be simply checked by substituting the reinforcement ratios in the brittle material stress tensor and calculating the invariants. The first invariant needs to be less than or equal to zero. The second invariant needs to be greater than or equal to zero. These provide the conditions in column 2. For solution 2 to 12, the third invariant needs to be zero.

4 – Examples :

The table below shows computed reinforcement ratios for 10 stress tensors. The applied reinforcement yield stress is f_y= 500 N/mm². In the table $\sigma_m$is the computed brittle material stress.

	σ_{xx}	σ_{yy}	σ_{zz}	σ_{yz}	σ_{xz}	σ_{xy}	ρ_x	ρ_y	ρ_z	σ_m
1	1 N/mm²	2 N/mm²	3 N/mm²	-4 N/mm²	3 N/mm²	-1 N/mm²	1.00%	1.40%	2.00%	-10.65 N/mm²
2	-5	2	3	4	3	1	0.00	1.36	1.88	-10.31
3	-5	-6	3	4	3	1	0.00	0.00	1.69	-10.15
4	-5	-6	-6	4	3	1	0.00	0.00	0.00	-10.44
5	1	2	3	-4	-3	-1	0.60	1.00	2.00	-10.58
6	1	-2	3	-4	3	2	0.50	0.13	1.80	-10.17
7	1	2	3	4	2	-1	0.40	1.00	1.80	-9.36
8	2	-2	5	2	-4	6	2.40	0.40	1.40	-15.21

9	-3	-7	0	2	-4	6	0.89	0.00	0.57	-14.76
10	3	0	10	0	5	0	1.60	0.00	3.00	-10.00

5 - Extension :

The above solution can be very useful to design reinforcement, however, it has some practical limitations. The following aspects can be included too if the problem is solved using convex optimization.

- Multiple stress tensors in one point due to multiple loads on the structure instead of only one stress tensor,
- A constraint imposed to crack widths at the surface of the structure,
- Shear stress in the crack (aggregate interlock),
- Reinforcement in other directions than x, y and z,
- The whole structure instead of one small material cube in turn.

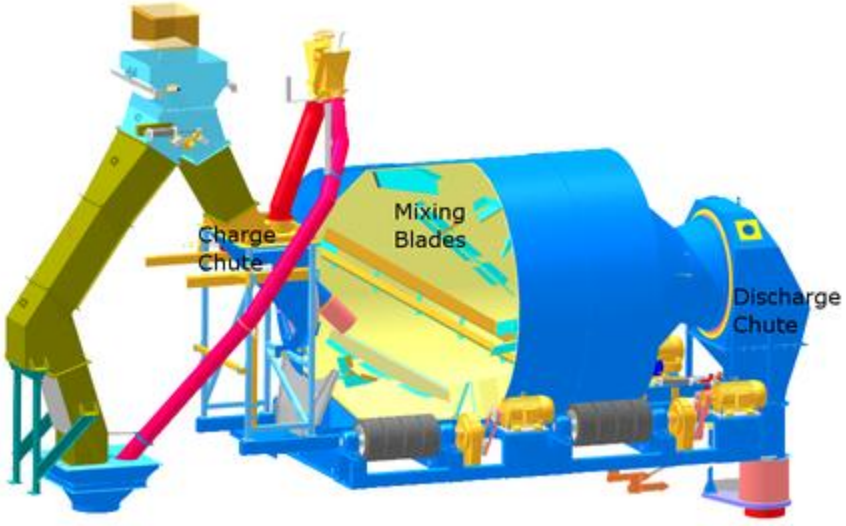
Reversing Drum Mixer

1 – Introduction :

A **reversing drum mixer** (also commonly called a **non-tilting mixer**) is a type of concrete mixer that produces concrete in single batches. The entire drum rotates around its axis as materials are loaded through a charge chute at one end of the drum and exit through a discharge chute at the opposite end of the drum.

2 - Mixing Action :

Mixing blades are mounted on the inside surface of the drum and as the drum rotates the blades mix by lifting and dropping the materials during each rotation . Once the materials are sufficiently mixed the rotation of the drum is reversed and the blade arrangement pushes the concrete through to the discharge end of the mixer.



A partial cross section of a reversing drum mixer.

Industrial sized reversing drum mixers can have a capacity of 9 m³ and can produce a mid quality concrete mix in as little as 40 seconds. Reversing drum mixers provide for efficient mixing and leave very little build up within the mixer . Wear is reduced as the drum rests on rubber or polyurethane wheels and there is no steel on steel contact. There is no direct contact between the stationary charge and discharge chutes and the rotating drum. The flexible tires, absorb vibration and make for low maintenance and a quiet operation. The efficient mixing within the concrete, results in a reduction in wear of the drum liners. The reversing drum mixers are known for the extremely low maintenance and operating costs, yet a good mixing effect relative to other drum mixers.

Rice Hulls

Rice hulls

Contents

1 – Introduction :

Rice hulls (or **rice husks**) are the hard protecting coverings of grains of rice. In addition to protecting rice during the growing season, rice hulls can be put to use as building material, fertilizer, insulation material, or fuel.

2 – Production :

Rice hulls are the coating for the seeds, or grains, of the rice plant. To protect the seed during the growing season, the hull forms from hard materials, including opaline silica and lignin. The hull is mostly indigestible to humans.

One practice, started in the seventeenth century, to separate the rice from hulls, it to put the whole rice into a pan and throw it into the air while the wind blows. The hulls are blown away while the rice fell back into the pan. This happens because the hull isn't nearly as dense as the rice. These steps are known as winnowing. Later pestles and a simple machine called a rice pounder were developed to remove hulls. In 1885 the modern rice hulling machine was invented in Brazil. During the milling processes, the hulls are removed from the raw grain to reveal whole brown rice, which may then sometimes be milled further to remove the bran layer, resulting in white rice.

3 – Use :

The temples of the Batujaya Archaeological Site in Indonesia (5th century AD) were built with bricks containing rice hulls.

A number of rice - producing countries, (e.g. Thailand), are currently conducting research on industrial uses of rice hulls. Some of the current and potential applications are listed below.

3 – 1 – Chemistry :

Rice hulls can be used to produce mesoporous molecular sieves (e.g., MCM), which are applied as catalysts for various chemical reactions, as a support for drug delivery system and as adsorbent in waste water treatment.

3 – 2 – Brewing :

Rice hulls can be used in brewing beer to increase the lautering ability of a mash.

3 – 3 – Building material :

Rice hulls are a class A insulating material because they are difficult to burn and less likely to allow moisture to propagate mold or fungi. It has been found out that when burned, rice hull produces significant amounts of silica. For these reasons it provides excellent thermal insulation.

3 – 4 – Fertilizer :

Rice hulls are organic material and can be composted. However, their high lignin content can make this a slow process. Sometimes earth worms are used to accelerate the process. Using vermicomposting techniques, the hulls can be converted to fertilizer in about four months.

3 – 5 – Fire works :

Rice hulls are coated with fine - grained gun powder and used as the main bursting charge in aerial fireworks shells.

3 – 6 – Fuel :

With proper techniques, rice hulls can be burned and used to power steam engines. Some rice mills originally disposed of hulls in this way . However the direct combustion of rice hulls tends to produce a lot of smoke. A far better alternative is to gasify rice hulls. Rice hulls are easily gasified in top - lit updraft gasifies. The combustion of this rice hull gas produces a beautiful blue flame, and rice hull bio char makes a wonderful soil amendment.

3 – 7 – Juice extraction

Rice hulls are used as a "press aid" to improve extraction efficiency of apple pressing.

3 – 8 – Pet food fiber :

Rice hulls are the outermost covering of the rice and come as organic rice hulls and natural rice hulls. Rice hulls are an inexpensive byproduct of human food processing, serving as a source of fiber that is considered a filler ingredient in cheap pet foods.

3 – 9 – Pillow stuffing :

Rice hulls are used as pillow stuffing. The pillows are loosely stuffed and considered therapeutic as they retain the shape of the head.

3 – 10 – Rice husk ash :

The ash produced after the husks have been burned, (abbreviated to RHA), is high in silica. A number of possible uses are being investigated for this .

These uses include :

- Aggregates and fillers for concrete and board production.
- Economical substitute for microsilica / silica fumes
- Absorbents for oils and chemicals
- Soil ameliorants
- As a source of silicon
- As insulation powder in steel mills
- As repellents in the form of "vinegar-tar"
- As a release agent in the ceramics industry
- As an insulation material for homes and refrigerants
- In Kerala, India - Rice husks (Umikari - in Malayalam) was universally used for over centuries in cleaning teeth - before toothpaste replaced it.

3 – 11 – Si C production :

Rice hulls are a low - cost material from which silicon carbide "whiskers" can be manufactured. The Si C whiskers are then used to reinforce ceramic cutting tools, increasing their strength tenfold.

Roller - Compacted Concrete

The rebuilt upper reservoir of the Taum Sauk plant, nearing completion in this photo, is the largest RCC dam in North America.

1 – Introduction :

Roller-compacted concrete (**RCC**) or **rolled concrete** is a special blend of concrete that has essentially the same ingredients as conventional concrete but in different ratios, and increasingly with partial substitution of fly ash for Portland cement . RCC is a mix of cement/fly ash, water, sand, aggregate and common additives, but contains much less water. The produced mix is drier and essentially has no slump. RCC is placed in a manner similar to paving; the material is delivered by dump trucks or conveyors, spread by small bulldozers or specially modified asphalt pavers, and then compacted by vibratory rollers.

In dam construction, roller-compacted concrete began its initial development with the construction of the Alpa Gera Dam near Sondrio in North Italy between 1961 and 1964. Concrete was laid in a similar form and method but not rolled . RCC had been touted in engineering journals during the 1970s as a revolutionary material suitable for, among other things, dam construction.[6] Initially and generally, RCC was used for backfill, sub-base and concrete pavement construction, but increasingly it has been used to build concrete gravity dams because the low cement content and use of fly ash cause less heat to be generated while curing than do conventional mass concrete placements. Roller-compacted concrete has many time and cost benefits over conventional mass concrete dams ; these include higher rates of concrete placement, lower material costs and lower costs associated with post-cooling and form work.

2 - Dam applications :

For dam applications, RCC sections are built lift-by-lift in successive horizontal layers resulting in a downstream slope that resembles a concrete staircase. Once a layer is placed, it can immediately support the earth-moving equipment to place the next layer. After RCC is deposited on the lift surface, small dozers typically spread it in one - foot- thick (300 mm) layers.

The first RCC dam built in the USA was the Willow Creek Dam on Willow Creek, a tributary in Oregon of the Columbia River. It was constructed by the Army Corps of Engineers between November 1981[8] and February 1983 . Construction proceeded well, within a fast schedule and under budget (estimated $50 million, actual $35 million). On initial filling though, it was found that the leakage between the compacted layers within the dam body was unusually high. This condition was treated by traditional remedial grouting at a further cost of $ 2 million, which initially reduced the leakage by nearly 75 %; over the years, seepage has since decreased to less than 10 % of its initial flow. Concern over the dam's long-term safety has continued however, although only indirectly related to its RCC construction. Within a few years of construction, problems were noted with stratification of the reservoir water, caused by upstream pollution and anoxic decomposition, which produced hydrogen sulfide gas. Concerns were expressed that this could in turn give rise to sulfuric acid, and thus accelerate damage to the concrete. The controversy itself, as well as its handling continued for some years. In 2004 an aeration plant was installed to address the root cause in the reservoir, as had been suggested 18 years earlier . In the quarter century since Willow Creek, considerable research and experimentation have yielded innumerable improvements in concrete mix designs, dam designs and construction methods for roller-compacted concrete dams; by 2008, about 350 RCC dams existed world - wide . Currently the highest dam of this type is Longtan Dam, at 216 m, with Diamer-Bhasha Dam planned at 272 m.

Roman Aqueduct - I

Aqueduct of Segovia

Contents

1 – Introduction :

The Romans constructed numerous aqueducts to serve any large city in their empire, as well as many small towns and industrial sites. The city of Rome had the largest concentration of aqueducts, with water being supplied by eleven aqueducts constructed over a period of about 500 years. They served drinking water and supplied the numerous baths and fountains in , as well as finally being emptied into the sewers, where the once-used gray water performed its last function in removing waste matter.

The first **Roman aqueduct** was the Aqua Appia, built in 312 BC during the Roman Republic. The methods of construction are described by Vitruvius in his work *De Architectura* written in the 1st century BC. His book would have been of great assistance to Frontinus, a general who was appointed in the late 1st century AD to administer the many aqueducts of Rome. He discovered a discrepancy between the intake and supply of water caused by illegal pipes inserted into the channels to divert the water, and reported on his efforts to improve and regulate the system to the emperor Trajan at the end of the 1st century AD. The report of his investigation is known as *De aquaeductu*. In addition to masonry aqueducts, the Romans built many more leats — channels excavated in the ground, usually with a clay lining. They could serve industrial sites such as gold mines, lead and tin mines, forges, water-mills and baths or thermae . Leats were much cheaper than the masonry design, but all aqueducts required good surveying to ensure a regular and smooth flow of water.

2 - Engineering :

The combined length of the aqueducts in the city of Rome is estimated between 490 to a little over 500 miles. However, only 29 miles (47 km) were above ground, as most Roman aqueducts ran beneath the surface of the ground. Building underground helped to keep the water free from disease (the carcasses of humans would not be able to get into the aqueduct) and helped protect the aqueducts from enemy attack. The longest Roman aqueduct was that of Constantinople (Mango 1995). "The known system is at least two and half times the length of the longest recorded Roman aqueducts at Carthage and Cologne, but perhaps more significantly it represents one of the most outstanding surveying achievements of any pre-industrial society". Perhaps the second longest, the Zaghouan Aqueduct, is 92.5 km in length. It was built in the 2nd century to supply Carthage (in modern Tunisia).

Arches are often used to depict an aqueduct but should not be confused with the aqueduct itself. These arches, some times on several tiers, together with tunnels, were constructed to maintain the pitch of the aqueduct, and the flow of water, over irregular terrain, for the long course to its destination.

Roman aqueducts were extremely sophisticated constructions, built to remarkably fine tolerances; for example, the gradient of the Pont du Gard is only 34 cm per km (3.4:10,000), descending only 17 m vertically in its entire length of 50 km (31 mi). Powered entirely by gravity, they could carry large amounts of water very efficiently.

A portion of the Eifel aqueduct, Germany, built in AD 80, showing the calcium carbonate that accretes on the sides of the channel without regular maintenance

The Pont du Gard could transport up to 20,000 cubic meters — nearly 6 million gallons — a day, and the combined aqueducts of the city of Rome supplied around 1 million cubic meters (300 million gallons) a day. The volume of water actually transported depended on the catchment hydrology – rainfall, absorption, and runoff – and the quality of maintenance. As a comparison, the maximum capacity of Rome's aqueducts is 126% of the current water supply of the city of Bangalore, which has a population of 6 million. Sometimes, where depressions deeper than 50m had to be crossed, gravity pressurized pipelines called inverted siphons were used to force water uphill (although they almost always used venter bridges as well); four inverted siphons crossed river valleys in the Aqueduct of the Gier, one of four supplying Lugdunum (Lyon). Modern hydraulic engineers use similar techniques to enable sewers and water pipes to cross depressions. In addition to the expertise needed to build them, Roman aqueducts required a comprehensive system of regular maintenance to repair accidental breaches, to clear the lines of debris, and to remove buildup of chemicals such as calcium carbonate that naturally occur in the water. Lead pipe inscriptions provided information on the owner to prevent water theft.

The methods of building aqueducts and the surveying needed to ensure a regular water supply is described by Vitruvius in Book 8 of his De Architectura. The work specifies the tests needed to ensure that the water is potable, and he warns against lead pipes for their toxicity, recommending either masonry channels or clay pipes. He suggests a low gradient of not less than 1 in 4800 for the channel, presumably to prevent damage to the structure. This value agrees well with the measured gradients of surviving masonry aqueducts, but many temporary aqueducts, such as those used for laundry, for example at Dolaucothi in Wales and Las Medulas in northern Spain, are much higher. At Dolaucothi, the gradient of the main 7 mile long structure is about 1:700, considerably higher than those of the permanent masonry aqueducts. Vitruvius also describes the construction of inverted siphons and the problems of blow - outs where the pressures were greatest. Aqueducts were built to supply water mills, the most famous excavated example being at Barbegal on the supply system for Arles. The engineering here is impressive, with a single aqueduct driving 15 overshot mills linked together in series. They were used to carry the water into the city.

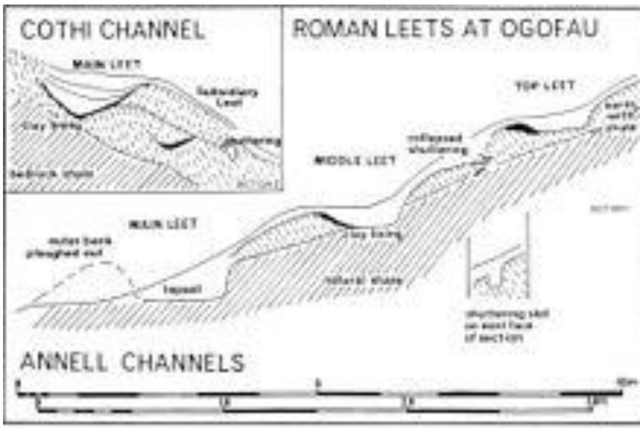
Catchment basin of the aqueduct of Metz, France

3 - Construction of Roman Aqueducts :

The aqueducts required very careful planning before building, especially to determine the water source to be used, the length of aqueduct needed and its size. Great skill and training were needed to ensure a regular grade so that the water would flow smoothly from its source without the flow damaging the walls of the channel. As the need for water grew, extra sources would be utilized, very often making use of existing structures as with the Aqua Claudia and Anio Novus in Rome. The problems of aqueduct building and use are described by Vitruvius and Frontinus, the latter producing a long report on the state of the aqueducts of Rome in the last years of the 1st century AD.

Several surveying tools were used to facilitate construction. Horizontal levels were checked using a *chorobates*, a flatbedded wooden frame fitted with a water level. Courses and angles could be plotted and checked using a *groma*; this relatively simple apparatus was probably displaced by the more sophisticated dioptra, precursor of the modern theodolite.

4 - Industrial Aqueducts :



The aqueducts at Dolaucothi

Rock-cut aqueduct feeding water to Las Medulas

Many aqueducts were built to supply water to industrial sites, such as gold mines, where the water was used to prospect for ore by hydraulic mining, and then crush and wash the ore to extract the gold. They usually consisted of an open channel dug into the ground, with a clay lining to prevent excessive loss of water and sometimes with wooden shuttering. They are often known as leats. However, they were built just as carefully as the masonry structures, but often at a higher gradient so as to deliver the greater volumes needed for mining operations . The large quantities of water supplied by the aqueducts were used for prospecting for ore-bodies by stripping away the overburden, and for working the ores in a method known as hushing. The technique was used in combination with fire - setting, which involved creating fires against the hard rock face to weaken the rock and so make removal much easier. These methods of mining survived into Medieval times until the widespread use of explosives. The water could also be used to wash ores, especially those of gold and tin, and probably to work simple machines such as ore-crushing hammers and water wheels.

The remains of such leats are visible today at sites like Dolaucothi in south-west Wales, and at Las Medulas in northwest Spain. These sites show multiple aqueducts, perhaps because they were relatively short-lived and deteriorated rapidly. There are, for example, at least seven major leats at Las Medulas, and at least five at Dolaucothi feeding water from local rivers direct to the mine head. At Dolaucothi, they used holding reservoirs as well as hushing tanks, and sluice gates to control flow, as well as drop chutes for diversion of supplies. The palimpsest of such channels allows the mining sequence to be inferred . Some aqueducts were used for mills, such as the dramatic site of Barbegal, where one aqueduct fed sixteen mills arranged in two columns down the side of the hill. There was a similar arrangement on the Janiculum at the terminus of Aqua Traiana, the highest aqueduct of the many feeding Rome . There are a number of other sites that were fed by several aqueducts but have not yet been thoroughly explored or excavated, such as those at Longovicium near Lanchester south of Hadrian's wall. It appears that the water supplies may have been used to power stamp mills for forging iron.

5 - Decline in use :

With the fall of the Roman Empire, although some of the aqueducts were deliberately cut by enemies, many more fell into disuse from the lack of an organized maintenance system. The decline of functioning aqueducts to deliver water had a large practical impact in reducing the population of the city of Rome from its high of over 1 million in ancient times to considerably less in the medieval era, reaching as low as 30,000. The massive masonry aqueducts and the many other visible remains, such as the Pantheon, Coliseum, and Baths of Diocletian, were to inspire architects and engineers of the Renaissance in order to build more amazing inventions. The first of the ancient aqueducts to be restored in renascent Rome was the Acqua Vergine: Pope Nicholas V renovated the main channels of the Roman *Aqua Virgo* in 1453. Previously Pedro Tafur, a Spanish visitor in

1436, unconsciously revealed that the very nature of the Roman aqueducts was popularly misunderstood :

> *Through the middle of the city runs a river, which the Romans brought there with great labour and set in their midst, and this is the Tiber. They made a new bed for the river, so it is said, of lead, and channels at one and the other end of the city for its entrances and exits, both for watering horses and for other services convenient to the people, and anyone entering it at any other spot would be drowned.*

On the other hand, many aqueducts elsewhere in the empire continued in use, such as the aqueduct at Segovia in Spain, a construction that shows advances on the Pont du Gard by using fewer arches of greater height, and so greater economy in its use of the raw materials. The skill in building aqueducts was not lost, especially of the smaller, more modest channels used to supply water wheels. Most such mills in Britain were developed in the medieval period for bread production, and used similar methods as that developed by the Romans with leats tapping local rivers and streams.

Roman Aqueduct - II

The multiple arches of the Pont du Gard, in Roman Gaul. Its lower tiers carry a road across the river, and the upper tiers support an aqueduct conduit that carried water to Nimes

Contents

1 – Introduction :

The Romans constructed aqueducts to bring a constant flow of water from distant sources into cities and towns, supplying public baths, latrines (public toilets), fountains and private households. Waste water was removed by the sewage systems and released into nearby bodies of water, keeping the towns clean and free from noxious waste. Some aqueducts also served water for mining, processing, manufacturing, and agriculture.

Aqueducts moved water through gravity alone, along a slight down ward gradient within conduits of stone, brick or concrete. Most were buried beneath the ground, and followed its contours; obstructing peaks were circumvented or less often, tunneled through. Where valleys or lowlands intervened, the conduit was carried on bridgework, or its contents fed into high-pressure lead, ceramic or stone pipes and siphoned across. Most aqueduct systems included sedimentation tanks, sluices and distribution tanks to regulate the supply at need.

Rome's first aqueduct supplied a water-fountain sited at the city's cattle - market. By the 3rd century AD, the city had eleven aqueducts, to sustain a population of over 1,000,000 in a water-extravagant economy; most of the water supplied the city's many public baths. Cities and municipalities through out the Roman Empire emulated this model, and funded aqueducts as objects of public interest and civic pride, "an expensive yet necessary luxury to which all could, and did, aspire ".

Most Roman aqueducts proved reliable, and durable; some were maintained into the early modern era, and a few are still partly in use. Methods of aqueduct surveying and construction are given by Vitruvius in his work *De Architectura* (1st century BC). The general Frontinus gives more detail, in his official report on the problems, uses and abuses of Imperial Rome's public water supply. Notable examples of aqueduct architecture include the supporting piers of the Aqueduct of Segovia, and the aqueduct-fed cisterns of Constantinople.

2 - Back ground :

> "The extraordinary greatness of the Roman Empire manifests itself above all in three things: the aqueducts, the paved roads, and the construction of the drains."
>
> Dionysius of Halicarnassus, *Roman Antiquities*

Before their development of aqueduct technology, Romans, like most of their contemporaries in the ancient world, relied on local water sources such as springs and streams, supplemented by groundwater from privately or publicly owned wells, and by seasonal rain-water drained from rooftops into storage jars and cisterns.[3] The reliance of ancient communities of such water resources restricted their potential growth. Rome's aqueducts were not strictly Roman inventions – their engineers would have been familiar with the ancient, tried and tested water-management technologies of Etruscan neighbours and Greek allies – but they proved conspicuously successful. By the early Imperial era, the city's aqueducts supported a population of over a million, and an extravagant water supply for public amenities such as baths, fountains and latrines had become a fundamental requirement for a civilized , Roman life.

2 – 1 - Aqueducts in the city of Rome :

Rome had several springs within its perimeter walls but its groundwater was notoriously unpalatable, and water from the Tiber was unsafe to drink. The city's demand for water had probably long exceeded its local supplies when the Aqua Appia, Rome's first aqueduct (312 BC) was commissioned by the censor Appius Claudius Caecus as one of two publicly funded, major projects; the other was a strategic road between Rome and Capua, the first leg of the so-called Appian Way. Both projects had probably high strategic value, as Rome's third Samnite War had been under way for some thirty years. The road allowed rapid troop movements; and by design or fortunate coincidence, most of the Aqua Appia ran within a buried conduit, relatively secure from attack. It was fed by a spring 16.4 km from Rome and dropped 10 meters over its length to discharge approximately 75,500 cubic meters of water *per diem* into a fountain at Rome's cattle market, the Forum Boarium, one of the city's lowest lying public spaces . A second aqueduct, the Old Anio, was commissioned some forty years later, funded by booty seized from Pyrrhus of Epirus. Its flow was more than twice that of the Aqua Appia, and it entered the city on raised arches, supplying water to higher elevations of the city .

Rome's Porta Maggiore, formed by a supporting arch of the Aqua Claudia and Rome's highest elevated aqueduct, the Aqua Anio Novus.

By 145 BC, the city had again outgrown its combined supplies; an official commission found the aqueduct conduits decayed, and depleted by leakage and illegal tapping. The praetor Quintus Marcius Rex restored them, and introduced a third, "more wholesome" supply, the Aqua Marcia, Rome's longest aqueduct and high enough to supply the Capitoline Hill. The works cost 180,000,000 sesterces, and took two years to complete . As demand grew still further, more aqueducts were built; the Aqua Tepula in 127 BC and the Aqua Julia in 33 BC. Aqueduct-building programmes reached a peak in the Imperial Era. Augustus' reign saw the building of the Aqua Virgo, and the short Aqua Alsietina that supplied Trastevere's artificial lake with "positively unwholesome" water for staged sea-fights to entertain the populace; its overspill was fit only for irrigation. Another short Augustan aqueduct supplemented the Aqua Marcia with water of "excellent quality". The emperor Caligula added or began two aqueducts completed by his successor Claudius; the 38 mile Aqua Claudia, which gave good quality water but failed on several occasions; and the Anio Novus, highest of all Rome's aqueducts and one of the most reliable but prone to muddy, discoloured waters, particularly after rain, despite its use of settling tanks. [9] Most of Rome's water supply now drew on various springs in the valley and highlands of the Annio, to the East. A complex system of aqueduct junctions, tributary feeds and distribution tanks supplied every part of the city east of the Tiber. West of the Tiber, no aqueduct supplied potable water until the emperor Trajan built the Aqua Traiana, which brought water from aquifers around Lake Bracciano . By the late 3rd century AD, the city was supplied by water from 11 aqueducts.

2 – 2 - Aqueducts in the Roman Empire :

Hundreds of similar aqueducts were built throughout the Roman Empire, although the systems were not as extensive as those supplying the city of Rome. Many of them have been destroyed, but a number of intact portions remain. Two of the most famous aqueducts are the Pont du Gard in France and the one located in Segovia, Spain.

3 - Planning, surveying and construction :

3 – 1 - Sources and surveying :

Springs were by far the most common sources for aqueduct water; most of Rome's supply came from various springs in the Anio valley and its uplands. Some systems drew water from purpose-built, dammed reservoirs, such as the two (still in use) that supplied the aqueduct at the provincial city of Emerita Augusta . In Book 8 of his De Architectura, Vitruvius describes the need to ensure a constant supply, methods of prospecting, and tests for potable water.

Various surveying tools were employed to plot the course of aqueducts across the landscape. Horizontal levels were checked using a *chorobates*, a flat bedded wooden frame fitted with a water level. Courses and angles could be plotted and checked using a *groma*, a relatively simple apparatus that was probably displaced by the more sophisticated dioptra, precursor of the modern theodolite.

3 - Conduits and gradients :

The water conduit of the Tarragona Aqueduct, Spain.

Most Roman aqueducts were flat-bottomed, arch-section conduits that ran 0.5 to 1 m beneath the ground surface, with inspection-and-access covers at regular intervals.[12] Conduits above ground level were usually slab-topped. Early conduits were ashlar-built but from around the late Republican era, brick-faced concrete was often used instead. The volume of water transported within depended on the catchment hydrology – rainfall, absorption, and runoff – the cross section of the conduit, and its gradient; most ran about two-thirds full. The conduit's cross section was also determined by maintenance requirements; workmen must be able to enter and access the whole, with minimal disruption to its fabric.

Vitruvius recommends a low gradient of not less than 1 in 4800 for the channel, presumably to prevent damage to the structure. This value agrees well with the measured gradients of surviving masonry aqueducts. The gradient of the Pont du Gard is only 34 cm per km (3.4:10,000), descending only 17 m vertically in its entire length of 50 km (31 mi): it could transport up to 20,000 cubic meters a day. The gradients of temporary aqueducts used for hydraulic mining could be considerably greater, as at Dolaucothi in Wales (with a maximum gradient of about 1:700) and Las Medulas in northern Spain. Where sharp gradients were unavoidable in permanent conduits, the channel could be stepped downwards, widened or discharged into a receiving tank to disperse the flow of water and reduce its abrasive force.

The combined conduit length of the aqueducts in the city of Rome is estimated between 490 to a little over 500 miles, of which approximately 29 miles (47 km) were carried above ground level, on masonry supports. They supplied around 1 million cubic meters (300 million gallons) a day: a capacity 126% of the current water supply of the city of Bangalore, which has a population of 6 million. The longest Roman aqueduct system was that of Constantinople (Mango 1995). "The known system is at least two and half times the length of the longest recorded Roman aqueducts at Carthage and Cologne, but perhaps more significantly it represents one of the most outstanding surveying achievements of any pre-industrial society". Perhaps the second longest, the Zaghouan Aqueduct is 57.5 miles (92.5 km) in length. It was built in the 2nd century to supply Carthage (in modern Tunisia).

3 – 3 - Bridge work and siphons :

The arches of an elevated section of the Roman provincial Aqueduct of Segovia, in modern Spain.

Conduits could be supported across valleys or hollows on arches of masonry, brick or concrete. The Pont du Gard, one of the most impressive surviving examples of a massive masonry multiple-piered conduit, also served as a road-bridge. Where particularly deep or lengthy depressions had to be crossed, inverted siphons could be used instead; here, the conduit terminated in a header tank which fed the water into pipes. These crossed the valley at lower level, supported by a low "venter" bridge, rose to a receiving tank at a slightly lower elevation and discharged into another conduit; the overall gradient was maintained. Siphon pipes were usually made of soldered lead, sometimes reinforced by concrete encasements or stone sleeves. Less often, the pipes themselves were stone or ceramic, jointed as male-female and sealed with lead . Vitruvius describes the construction of siphons and the problems of blockage, blow-outs and venting at their lowest levels, where the pressures were greatest. Nonetheless, siphons were versatile and effective if well-built and well-maintained. A horizonal section of high-pressure siphon tubing in the Aqueduct of the Gier was ramped up on bridgework to clear a navigable river, using nine lead pipes in parallel, cased in concrete.[16][17] Modern hydraulic engineers use similar techniques to enable sewers and water pipes to cross depressions.

3 – 4 – Inspection , maintenance and regulation :

Once constructed, Roman aqueducts required a comprehensive system of regular maintenance to repair accidental breaches, to clear the conduits of gravel and other loose debris, and to remove channel-narrowing accretions of calcium carbonate in systems fed by hard water sources. Inspection and access points were provided at regular intervals on the standard, buried conduits. Syphons that used hard-water supplies would have presented particular maintenance problems, due to the narrow diameter of their pipes; but lead, ceramic and stone pipes were made in fairly short lengths whose damaged sections could be replaced and some had sealed openings that might have been used as rodding eyes, possibly using a pull-through device. Little is known of the day to day business of aqueduct maintenance teams. Theirs was probably a demanding and never - ending routine, punctuated by occasional emergencies. Full closure of any aqueduct for servicing would have been a rare event, kept as brief as possible, with repairs preferably made when water demand was lowest, which was presumably at night.

Some form of registry was probably kept of licensed, fee-paying private users, and the bore of pipe that led water from the public supply to their private property – the wider the pipe, the greater the flow and the greater the fee. Tampering and fraud to avoid or reduce payment were commonplace; methods included the fitting of unlicensed outlets, additional outlets, and the illegal widening of lead pipes; any of which might involve the bribery or connivance of unscrupulous aqueduct officials or workers. Official lead pipes carried inscriptions with information on the pipe's manufacturer, its fitter, and probably on its subscriber and their entitlement.

4 - Uses :

Rome's first aqueduct discharged at a more-or-less constant rate in the city's main trading centre and cattle - market, probably into a low-level, cascaded series of troughs or basins; the upper for household use, the lower for watering livestock. Most Romans would have filled buckets and storage jars at the basins, and carried the water to their apartments; the better off would have sent slaves to perform the same task. Any surplus drained into Rome's main sewer, and from there into the Tiber. Its elevation was too low to offer any city household or building a direct supply. Rome had no public baths at the time; its first were probably built in the next century, based on precursors in neighbouring Campania .

4 – 1 – Industrial :

Rock-cut aqueduct feeding water to the mining site at Las Medulas

Some aqueducts supplied water to industrial sites, usually via an open channel cut into the ground, clay lined or wood-shuttered to reduce water loss. Most such leats were designed to operate at the steep gradients that could deliver the high water volumes needed in mining operations. Water was used in hydraulic mining to strip the overburden and expose the ore by hushing, to fracture and wash away metal-bearing rock already heated and weakened by fire-setting, and to power water-wheel driven stamps and trip-hammers that crushed ore for processing. Evidence of such leats and machines has been found at Dolaucothi in south-west Wales .

Mining sites such as Dolaucothi and Las Medulas in northwest Spain show multiple aqueducts that fed water from local rivers to the mine head. The channels may have deteriorated rapidly, or become redundant as the nearby ore was exhausted. Las Medulas shows at least seven such leats, and Dolaucothi at least five. At Dolaucothi, the miners used holding reservoirs as well as hushing tanks, and sluice gates to control flow, as well as drop chutes for diversion of water supplies. The palimpsest of such channels allows the mining sequence to be inferred.

A number of other sites fed by several aqueducts have not yet been thoroughly explored or excavated, such as those at Longovicium near Lanchester south of Hadrian's wall, in which the water supplies may have been used to power trip-hammers for forging iron.

At Barbegal in Roman Gaul, a reservoir fed an aqueduct that drove a cascaded series of 15 or 16 overshot water mills, grinding flour for the Arles region. Similar arrangements, though on a lesser scale, have been found in Caesarea, Venafrum and Roman-era Athens. Rome's Aqua Traiana drove a flour-mill at the Janiculum, west of the Tiber. A mill in the basement of the Baths of Caracalla was driven by aqueduct overspill; this was but one of many city mills driven by aqueduct water, with or without official permission. A law of the 5th century AD forbade the illicit use of aqueduct water for milling.

5 - Decline in use :

A portion of the Eifel aqueduct, Germany, built in AD 80. Its channel is narrowed by an accretion of calcium carbonate, accumulated through lack of maintenance.

With the fall of the Roman Empire, some aqueducts were deliberately cut by enemies but many more fell into disuse through lack of organized maintenance. Their failure had an impact on the population of cities; Rome's declined from its high of over 1 million in the Imperial era to as low as 30,000 in the medieval era. Observations made by Pedro Tafur, a Spanish visitor in 1436, reveal misunderstandings of the very nature of the Roman aqueducts:

Through the middle of the city runs a river, which the Romans brought there with great labour and set in their midst, and this is the Tiber. They made a new bed for the river, so it is said, of lead, and channels at one and the other end of the city for its entrances and exits, both for watering horses and for other services convenient to the people, and anyone entering it at any other spot would be drowned.[24]

During the Renaissance, the standing remains of the city's massive masonry aqueducts inspired architects, engineers and their patrons; Pope Nicholas V renovated the main channels of the Roman *Aqua Virgo* in 1453.[25] Many aqueducts Rome's former empire were kept in good repair. The 15th century rebuilding of aqueduct at Segovia in Spain shows advances on the Pont du Gard by using fewer arches of greater height, and so greater economy in its use of the raw materials. The skill in building aqueducts was not lost, especially of the smaller, more modest channels used to supply water wheels. Most such mills in Britain were developed in the medieval period for bread production, and used similar methods as that developed by the Romans with leats tapping local rivers and streams.

- 24 January 2010 – likely source of Trajan's Aqua Traiana found at Lake Bracciano

Roman Aqueducts

Croatia

- Diocletianus Aqueduct

France

  - Barbegal aqueduct
  - Pont du Gard
- Gier aqueduct

Germany

- Eifel Aqueduct

Italy

- Anio Novus
- Aqua Alexandrina
- Aqua Alsietina
- Aqua Appia
- Aqua Augusta (Naples)
- Aqua Augusta (Rome)
- Aqua Claudia
- Aqua Julia
- Aqua Martia
- Aqua Tepula
- Aqua Traiana
- Aqua Virgo
- Pont d'Aël

Jordan

- Gadara Aqueduct

Luxembourg

- Raschpëtzer Qanat

Spain

- Acueducto de los Milagros
- Aqueduct of Segovia
- Aqüeducte de les Ferreres
- Las Médulas

Turkey

- Valens Aqueduct

Wales

- Dolaucothi Gold Mines

Roman Architecture

The Pont du Gard, an aqueduct bridge in southern France

The Colosseum in Rome, Italy

Contents

1 – Introduction :

Ancient Roman architecture adopted certain aspects of Ancient Greek architecture, creating a new architectural style. The Romans were indebted to their Etruscan neighbors and forefathers who supplied them with a wealth of knowledge essential for future architectural solutions, such as hydraulics and in the construction of arches. Later they absorbed Greek and Phoenician influence, apparent in many aspects closely related to architecture; for example, this can be seen in the introduction and use of the Triclinium in Roman villas as a place and manner of dining.

Roman architecture flourished throughout the Empire during the Pax Romana.

2 – Context :

Factors such as wealth and high population densities in cities forced the ancient Romans to discover new (architectural) solutions of their own. The use of vaults and arches, together with a sound knowledge of building materials, enabled them to achieve un precedented successes in the construction of imposing structures for public use.

Examples include the aqueducts of Rome, the Baths of Diocletian and the Baths of Caracalla, the basilicas and Colosseum. They were reproduced at smaller scale in most important towns and cities in the Empire. Some surviving structures are almost complete, such as the town walls of Lugo in Hispania Tarraconensis, or northern Spain.

The Ancient Romans intended that public buildings should be made to impress, as well as perform a public function. The Romans did not feel restricted by Greek aesthetic axioms alone in order to achieve these objectives . The Pantheon is a example of this, particularly in the version rebuilt by Hadrian, which remains perfectly preserved, and which over the centuries has served, particularly in the Western Hemisphere, as the inspiration for countless public buildings. The same emperor left his mark on the landscape of northern Britain when he built a wall to mark the limits of the empire, and after further conquests in Scotland, the Antonine wall was built to replace Hadrian's Wall.

3 - Arch and the Dome :

Dome of the Pantheon, inner view

The Roman use of the arch and their improvements in the use of concrete and bricks facilitated the building of the many aqueducts throughout the empire, such as the Aqueduct of Segovia and the eleven aqueducts in Rome itself, such as Aqua Claudia and Anio Novus. The same idea produced numerous bridges, such as the still used bridge at Mérida.

The dome permitted construction of vaulted ceilings and provided large covered public space such as the public baths and basilicas. The Romans based much of their architecture on the dome, such as Hadrian's Pantheon in the city of Rome, the Baths of Diocletian and the Baths of Caracalla.

Art historians such as Gottfried Richter in the 1920s identified the Roman architectural innovation as being the Triumphal Arch. This symbol of power on earth was transformed and utilised within the Christian basilicas when the Roman Empire of the West was on its last legs: The arch was set before the altar to symbolize the triumph of Christ and the after life. The arch is seen in aqueducts, especially in the many surviving examples, such as the Pont du Gard, the aqueduct at Segovia and the remains of the Aqueducts of Rome itself. Their survival is testimony to the durability of their materials and design.

The Romans first adopted the arch from the Greeks, and implemented it in their own building. An arch is a very strong shape as no single spot holds all the weight and is still used in architecture today.

Interior of Pantheon

3 – 1 - Housing :

Insula in Ostia Antica

Although less visible level to the modern observer, ancient Romans developments in housing and public hygiene are impressive , especially given their day and age. Clear examples are public and private baths and latrines, and under-floor heating in the form of the hypocaust, double glazing (examples in Ostia Antica), and piped water (examples in Pompeii).

Multi story apartment blocks called insulae that catered to a wide range of residential situations. These buildings, solely intended for large scale accommodation, could reach several floors in height. Insulae were often dangerous, unhealthy, and prone to fires. There are examples in cities like the Roman port town of Ostia, that date back to the reign of Trajan and show how Roman architects met residential needs in a variety of situations.

An example is Via della Focette: a large-scale real estate development that catered to up-and-coming middle class entrepreneurs. Rather like modern semi-detached housing, these residences had repeated floor plans intended for easy, economical, and repetitive construction. Internal spaces were designed to be relatively low-cost, yet functional and with decorative elements reminiscent of the detached houses and villas to which the buyers might aspire later in their lives.

Each apartment had its own terrace and private entrance. External walls were in "Opus Reticulatum" and interiors in "Opus Incertum", which would then be plastered and sometimes painted.

Some existing examples show that a popular choice of interior decor was to paint panels in alternating red and rainbow.

4 - Common types of building :

Most Roman cities had at least one Thermae , which were centers of public bathing and socialization. Baths were extremely important for Romans. They stayed there for several hours and went daily. Wealthier Romans were accompanied by one or more slaves. After paying a fee, they would strip naked and wear sandals to protect their feet from heated floors. Slaves carried their masters' towels and got them drinks. Before bathing, patrons exercised. They did things such as running, mild weight-lifting, wrestling, and swimming. After exercising, servants covered their masters in oil and scraped it off with a strigil (a scraper made of wood or bone) which cleaned off the dirt . Roman bath-houses were also provided for private villas, town houses and forts; these were also called thermae. They were supplied with water from an adjacent river or stream, or more normally, by an aqueduct. The design of baths is discussed by Vitruvius in De Architectura.

The Baths of Caracalla, in 2009

Roman theatre of Aspendos,Turkey

Roman architecture was sometimes determined based upon the requirements of Roman religion. For example, the Pantheon was an amazing engineering feat created for religious purposes, and its design (the large dome and open spaces) was made to fit the requirements of the religious services. Some of the most impressive public buildings are the amphitheatres, over 220 being known and many of which are well preserved, such as that at Arles, as well as its progenitor, the Colosseum in Rome. They were used for gladiatorial contests, public displays, public meetings and bullfights, the last of which survives in Spain. They are among the most impressive remains of the Roman empire at its height, and many of them are still used for public displays and performances.

Every city of some size maintained a forum. In addition to its standard function as a marketplace, a forum was a gathering place of great social significance, and often the scene of diverse activities, including political discussions and debates, rendezvous, meetings, et cetera.

Panoramic view of the Forum Trajanum with the Trajan's Column on the far left.

Many lighthouses were built around the Mediterranean and around the shores of their expanding empire, including the Tower of Hercules at A Coruña in northern Spain, a structure which still survives to this day. A smaller lighthouse at Dover, England also still exists as a ruin about half the height of the original. The light would have been provided by a fire at the top of the structure.

At the center of a Roman city stood a forum. Forums were a common gathering place for the citizens. They were most often used as a marketplace but it was not uncommon to see religious, political, or social activities there. An example would be the Roman Forum in Rome, Italy.

Tower of Hercules

5 - Materials :

Frigidarium of Baths of Diocletian, today Santa Maria degli Angeli

Tile covered concrete quickly supplanted marble as the primary building material and more daring buildings soon followed, with great pillars supporting broad arches and domes rather than dense lines of columns suspending flat architraves. The freedom of concrete also inspired the colonnade screen, a row of purely decorative columns in front of a load-bearing wall. In smaller-scale architecture, concrete's strength freed the floor plan from rectangular cells to a more free-flowing environment. Most of these developments are described by Vitruvius writing in the first century AD in his work De Architectura.

Although concrete had been used on a minor scale in Mesopotamia, Roman architects perfected Roman concrete and used it in buildings where it could stand on its own and support a great deal of weight. The first use of concrete by the Romans was in the town of Cosa sometime after 273 BCE. Ancient Roman concrete was a mixture of lime mortar, sand with stone rubble, pozzolana, water, and stones, and stronger than previously-used concrete. The ancient builders placed these ingredients in wooden frames where it hardened and bonded to a facing of stones or (more frequently) bricks.

When the framework was removed, the new wall was very strong with a rough surface of bricks or stones. This surface could be smoothed and faced with an attractive stucco or thin panels of marble or other coloured stones called revetment. Concrete construction proved to be more flexible and less costly than building solid stone buildings. The materials were readily available and not difficult to transport. The wooden frames could be used more than once, allowing builders to work quickly and efficiently.

On return from campaigns in Greece, the general Sulla returned with what is probably the most well-known element of the early imperial period: the mosaic, a decoration of colourful chips of stone inset into cement. This tiling method took the empire by storm in the late first century and the second century and in the Roman home joined the well known mural in decorating floors, walls, and grottoes in geometric and pictorial designs.

Though most would consider concrete the Roman contribution most relevant to the modern world, the Empire's style of architecture can still be seen throughout Europe and North America in the arches and domes of many governmental and religious buildings.

6 - Modern influence :

Today, Roman influence can be seen among countless buildings such as banks, government buildings, houses, business buildings, etc. Roman culture resonates among modern building styles because of the structural mastering of the dome and the arch. When a building has substantial weight bearing down on lower levels, columns can easily support the weight when it is distributed through an arch, reducing the stress significantly. The arch, for this reason, is the most famous and most modernly used aspect of Roman architecture and can be seen nearly anywhere.

The Dome is not used as frequently among modern buildings, but it is widely used to show prominence and elegance. In Washington, D.C., domes are a common theme among the government buildings, originally meant to imitate the grandeur of ancient Rome. Modern use of Ancient Roman Architecture is most commonly used as an allusion to Ancient Rome itself, people recall the Roman Empire as a colossal, dominant, and extremely influential nation. To allude to Ancient Rome is to project the image of greatness and influence .

7 - List of buildings , features and types of buildings :

	
The Roman Forum	*Northern aisle of the Basilica of Maxentius in Rome*
	

Public architecture :

- Amphitheatre
- Basilica
- Circus (building)
- Forum (Roman)
- Insulae
- Temple (Roman)
- Roman theatre
- Thermae
- Triumphal arch

Public buildings :

- List of Roman amphitheatres
- Baths of Trajan
- Baths of Diocletian
- Baths of Caracalla
- Colosseum
- Trajan's Column, in Rome
- Circus Maximus, in Rome
- Curia Hostilia (Senate House), in Rome
- Domus Aurea (former building)
- Roman Forum
- Pantheon
- Tower of Hercules
- Tropaeum Traiani
- Hadrian's Villa

Private architecture :

- Roman gardens
- Alyscamps, a necropolis in Arles, France
- Domus
- Catacombs of Rome
- Roman villa

Civil engineering :

- Roman engineering
- Roman aqueduct
- Roman bridge
- Roman lighthouse
- Roman road
- Roman watermill

Military engineering :

- Antonine Wall, in Scotland
- Hadrian's Wall
- Limes Germanicus

Architectural elements :

- Hypocaust
- Mosaics
- Roman brick
- Roman roofs
- Roman spiral stairs

Roman Brick

	
An ancient tomb on the Appian Way in Rome featuring extensive Roman brickwork in opus latericium.	*Roman bricks in the Jewry Wall, Leicester. The 20th-century supporting arch in the background utilises modern bricks.*

Contents

1 – Introduction :

Roman brick can refer either to a type of brick originating in Ancient Rome and spread by the Romans to the lands they conquered; or to a modern type inspired by the ancient prototypes. In both cases, this brick characteristically has longer and flatter dimensions than those of standard modern ones.

2 - History :

2 – 1 - Ancient Rome :

The Romans made fired clay bricks, and the Roman legions, which operated mobile kilns, introduced bricks to many parts of the empire. Roman bricks are often stamped with the mark of the legion that supervised their production. The use of bricks in southern and western Germany, for example, can be traced back to traditions already described by the Roman architect Vitruvius.

The city walls of Constantinople,
showing several courses of brickwork.

Roman brick was almost invariably of a lesser height than modern brick, but was made in a variety of different shapes and sizes.[1] Shapes included square, rectangular, triangular and round, and the largest bricks found have measured over three feet in length.[2] Ancient Roman bricks had a general size of 1½ Roman feet by 1 Roman foot, but common variations up to 15 inches existed. Other brick sizes in Ancient Rome included 24" x 12" x 4", and 15" x 8" x 10". Ancient Roman bricks found in France measured 8" x 8" x 3". The Constantine Basilica in Trier is constructed from Roman bricks 15" square by 1½" thick . There is often little obvious difference (particularly when only fragments survive) between Roman bricks used for walls on the one hand, and tiles used for roofing or flooring on the other, and so archaeologists sometimes prefer to employ the generic term Ceramic Building Material (or **CBM**) . The Romans perfected brick-making during the first century of their empire and used it ubiquitously, in public and private construction alike. The Romans took their brick making skills everywhere they went, introducing the craft to the local populations . In the British Isles, the introduction of Roman brick by the Ancient Romans was followed by a 600–700 year gap in major brick production.

Detail of the wall of the Roman shore fort at Burgh Castle, Norfolk, showing alternating courses of flint and brick work.

When building in masonry, the Romans often interspersed the stonework at set intervals with thin courses of bricks, sometimes known as "bonding tiles". This practice gave the structure added stability. It also had a secondary aesthetic effect of creating a polychromatic appearance.

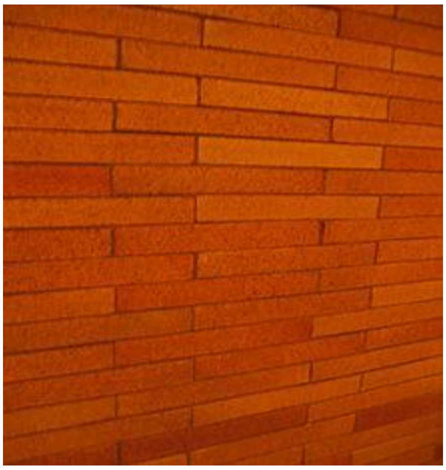
In the 1530s, the English antiquary John Leland successfully identified Roman bricks (albeit under the misleading designation of "Briton brykes") at several geographically dispersed sites, distinguishing them by size and shape from their medieval and modern counterparts. This has been described as one of the earliest exercises in archaeological typology .

2 – 2 - Medieval Europe :

After the Western Roman Empire fell in the 5th century many of the commercial stone quarries in Europe were abandoned . This led to a consistent pattern of reuse of Roman building materials throughout the next several hundred years . Like much of the Roman stone, Roman bricks were gathered for reuse throughout this period . For example in the 10th century the abbots of St. Albans gathered enough Roman brick during this time period to have their own stockpile of the building material .

When brick production resumed in earnest on the British Isles, the 1½" to 2" height of the Roman-style brick gradually increased during the early Medieval period . Brick from the Ancient Roman Empire was commonly reused in medieval Europe as well as in later periods . This reuse can be found across the former Roman Empire.[7] In Great Britain, where construction materials are less plentiful, Roman structures were quarried for their stone and brick and it was commonly reused . Examples of this type of reuse in Great Britain can be found in Anglo - Saxon churches at Brixworth, Corbridge, St. Martin's, Canterbury, and St Nicholas', Leicester, and also in St Albans Abbey church (now St Albans Cathedral) .

2 – 3 - Modern :



Roman brick in Frank Lloyd Wright's 1905 Frank L. Smith Bank.

Modern "Roman" bricks were introduced at the beginning of the 20th century. They are invariably longer and flatter than other modern brick types, but there are no fixed dimensions. Those used in the United States in the early 20th century had nominal dimensions of 4" x 2" x 12": this gave them a 6:2:1 ratio, compared with a roughly 4:2:1 ratio of most modern brick types. Others with nominal dimensions of 16" x 6" x 4" (38 cm x 15 cm x 10 cm) are also known. Demand has increased the availability of all types of bricks; there are more than a dozen commercially available brick types in modern construction . The Roman Brick Company of Glasgow currently offers "Roman" bricks in heights of 40, 52, 65 or 71mm; widths of 90 or 115mm; and lengths of 290, 365, 440, 490 and 600 mm .

Roman brick was introduced to the United States by the architectural firm McKim, Mead, and White. At one time, Roman brick was one of three available brick types in the United States; the other two were "Standard" and "Norman " . By 1920, there were at least five types of bricks commonly available to builders and architects , among them : Roman , Norman , Standard , English and Split .

Frank Lloyd Wright used Roman brick in his design for the Robie House in Chicago, and he favored it in many of his Prairie style homes . For the Robie House, Wright selected a brick later known as "Pennsylvania Iron Spot Roman brick", personally traveling to St. Louis to choose it . Wright's use of Roman brick in his masonry subtly emphasized the horizontal lines common to much of his Prairie style work . Further highlighting Wright's horizontal emphasis was the use of recessed horizontal mortar joints of contrasting color to the brick . The vertical joints were de - emphasized by ensuring the mortar was flush with, and of the same hue, as the brick . In modern times, as historic preservationists have worked to restore and preserve the work of Wright and his fellow Prairie School architects, Roman brick has proven difficult to obtain .

3 - Ancient Roman brick stamps

Around the middle of the 1st century BCE Roman brick makers began using unique identifying stamps on their bricks . The first of these brick stamps were simple and included minimal information such as, the name of a person and sometimes the name of the brickyard the brick was produced in . These earliest Roman brick stamps were emblazoned into the wet clay using a hard wood or metal mold prior to the firing of the brick . As the early Roman Empire progressed fired brick became the primary building material and the number of brick producers increased dramatically as more and more wealthy land owners began to exploit clay deposits on their land for brick - making . Brick stamps began to become more complex and include more and more information . In 110 the stamps included, for the first time, the name of the consuls for the year of production, which allows modern observers to pinpoint the year a brick was created .

Ancient Roman stamp on a hypocaust brick, used by the third cohort of Roman citizens from Thrace .

These brick stamps, once viewed more as a curiosity than archaeological artifacts, allow scholars to learn about the demand for bricks in Ancient Rome because through the dates on the stamps they provide a chronology . Today, brick stamp discoveries are carefully documented and that documentation, combined with the use of architectural context, has helped provide a reliable method of dating Ancient Roman construction . In addition, brick stamps have proved helpful in determining general Ancient Roman chronology.

Roman Bridges

Pons Cestius, Rome, during a flood

Pons Aelius in Rome, Italy

Roman stone pillar bridge in Trier, Germany. The arches were added in the 14th century.

Contents

1 – Introduction :

The Romans were the world's first major bridge builders . The following list constitutes an attempt to list all known Roman bridges, many of which still survive to this day.

A Roman bridge in the sense of this article includes any of these features:

- Roman arches
- Roman pillars
- Roman foundations
- Roman abutments
- Roman roadway
- Roman cutwaters

Also listed are bridges which feature substantially Roman material (Spolia), as long as the later bridge is erected on the site of a Roman precursor. Finally, incidences where only excavated bridge inscriptions lay testimony to the existence of a now perished Roman bridge are also included.

In the following, bridges are classified either according to their material or their function. Most data not otherwise marked comes from O'Connor's *Roman Bridges* which lists 330 stone bridges for traffic, 34 timber bridges and 54 aqueduct bridges.[2] An even larger compilation is offered by the Italian scholar Galliazzo who describes more than 900 Roman bridges (as of 2011, his list is used here only selectively) .

2 - Note on classification :

Bridges are particularly difficult to classify as they, more than other structures, are subject to wear, war and the impact of natural elements. The constant need for repairs through the ages has often turned bridges into hybrid structures, which make it often difficult or nearly impossible to determine the exact date and origin of individual parts of a bridge. Thus, the majority of the bridges listed below can be assumed to include medieval or (early) modern modifications, replacements or extensions, to a small or large extent.

3 - Masonry bridges :

Below bridges out of stone or brick. The vast majority features arches, although stone deck slabs were also known. Concerning the bridges' spans and height: S = small, M = middle and L = large.

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<tr><td colspan="2">Iran</td></tr>
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Italy, Central :

Italy, Insular :

Italy, Northern :

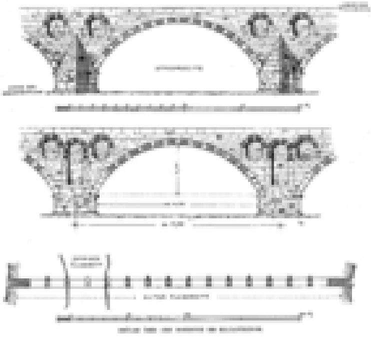
	
	

Italy, Rome & vicinity

	
	
	
Italy , Southern	
	
Luxembourg / Germany :	
	
Portugal :	
	

Spain :	
	
	
	
	
	
Spain / Portugal :	
	
Syria :	

	
Turkey	
 CENTRAL PIERS, S. FRONT.	
	
	
	

4 - Timber and stone pillar bridges :

A timber bridge is a structure composed wholly out of wood, while a stone pillar bridge features a wooden superstructure resting on stone pillars. Strictly speaking, many bridges of the second type should be rather called "concrete pillar bridges", as the Romans preferably used opus caementicium for constructing their bridge piers (stone was confined in these cases to covering). Both types, timber bridges and stone respectively concrete pillar bridges, are listed here in the same category as historically, with the consolidation of Roman power in the newly conquered provinces, wooden bridges often gave way to solid pillar bridges.

Germany

5 - Pontoon bridges :

As an alternative to ferry services, the Roman army often made use of pontoon bridges, along with timber structures, for river crossings. They usually consisted of boats lashed together, with the bows pointing towards the current. Permanent bridges of boats were also commonly set up for civilian traffic.

6 - Aqueduct bridges :

France

Germany :

Italy :

Italy, Northern

Palestine :

Spain :

Tunisia :

Turkey ;

Roman Cement

"Roman cement" is a substance developed by James Parker in the 1780s, and finally patented in 1796. It was, in fact, nothing like any material used by the Romans, but was a "Natural cement" made by burning septaria - nodules that are found in certain clay deposits, and that contain both clay minerals and calcium carbonate. The burnt nodules were ground to a fine powder. This product, made into a mortar with sand, set in 5 – 15 minutes. The success of "Roman Cement" led other manufacturers to develop rival products by burning artificial mixtures of clay and chalk.

There has been recent resurgence of interest in Natural Cements/ Roman Cements due mainly to the need for repair of facades done in this material in the 19th Century. The major confusion involved for many people in this subject is the terminology used. Roman Cement - was originally the name given, by Parker, to the cement he patented which is a Natural Cement (i.e. it is a marl (or limestone containing integral clay) dug out of the ground, burnt and ground to a fine powder .

Later, in the 1900s various sources of the correct type of marl - known also as Cement Stone, were discovered across Europe and so there were a range of natural cements (with varying properties) in use across Europe. It was in 1824 that Joseph Aspdin 'invented' Portland Cement. This was done by adding various materials together to make an artificial version of natural cement. There then followed a number of independently discovered or copied version of this 'Portland Cement' [Also referred to as Proto Portland cement]. Proto Portland cement does have a different chemical make up from other Natural Cements being produced at the same time: It was burnt at a higher temperature than other N.C.'s and thus crosses the barrier between traditional Vertical Kiln fired N.C. and the later Horizontal Kiln fired Artificial Cements. This Cement is NOT, however, the same as the modern Ordinary Portland Cement, which can be defined as Artificial Cement.

Artificial Cement: It is with the development in the 1860s of **rotating Horizontal Kiln** technology that the properties of cement changed quite dramatically and could be argued to result in modern Cement. Certainly it is now difficult to actually define whether an old render was a Natural Cement (Single Source Marl) or an artificial one, but there is no doubt if the cement was Vertically kiln fired or Horizontally. **The names Natural Cement or Roman Cement then defines a cement coming from a single source rock**. Early or Proto Portland Cement could be used for early cement that comes from a number of sourced and mixed materials. There is no widely used terminology for these 19th Century cements. There had been, in order to rediscover this technology, two projects carried out by the European Union ROCEM and subsequently ROCARE (an ongoing project). Both these only deal with Natural Cement - referred to as Roman Cement without reference to the early artificial cements.

Roman Concrete

The Pantheon in Rome , Italy,
is an example of Roman concrete construction.

Contents

1 – Introduction :

Roman concrete (also called *Opus caementicium*) was a material used in construction during the late Roman Republic through the whole history of the Roman Empire. Roman concrete was based on a hydraulic - setting cement with many material qualities similar to modern Portland cement. By the middle of the 1st century, the material was used frequently as brick-faced concrete, although variations in aggregate allowed different arrangements of materials. Further innovative developments in the material, coined the Concrete Revolution, contributed to structurally complicated forms, such as the Pantheon dome.

2 - Historic references :

Vitruvius, writing around 25 BC in his *Ten Books on Architecture*, distinguished types of aggregate appropriate for the preparation of lime mortars. For structural mortars, he recommended *pozzolana*, which were volcanic sands from the sandlike beds of Puteoli brownish-yellow-gray in color near Naples and reddish-brown at Rome. Vitruvius specifies a ratio of 1 part lime to 3 parts pozzolana for cements used in buildings and a 1:2 ratio of lime to pulvis Puteolanus for underwater work, essentially the same ratio mixed today for concrete used at sea.

Caesarea is the earliest known example to have used underwater Roman concrete technology on such a large scale.

By the middle of the 1st century, the principles of underwater construction in concrete were well known to Roman builders. The City of Caesarea was the earliest known example to have made use of underwater Roman concrete technology on such a large scale.

Rebuilding Rome after the fire in 64 AD, which destroyed large portions of the city, the new building code by Nero consisted of largely brick-faced concrete. This appears to have encouraged the development of the brick and concrete industries .

Example of opus caementicium on a tomb on the ancient Appian Way in Rome. The original covering has been removed.

In most usage, the raw concrete surface was considered unsightly and some sort of facing was applied. Different techniques were characteristic of different periods and included:

- *Opus incertum*: small irregular stones.
- *Opus reticulatum*: small squared tuff blocks laid in a diamond pattern.
- *Opus quadratum*: regularly laid courses of ashlars.
- *Opus latericium*: regularly laid courses of brick.
- *Opus spicatum*: brick laid in a herringbone pattern.
- *Opus vittatum*: square tuff blocks intersected by brick bands at regular and irregular distances.
- *Opus africanum*: vertical chains of upright blocks with alternating horizontal blocks.
- *Opus testaceum*: thick horizontal brick work.

3 - Material properties :

Roman concrete , like any concrete , consists of an aggregate and hydraulic mortar – a binder mixed with water that hardens over time. The aggregate varied, and included pieces of rock, ceramic tile, and brick rubble from the remains of previously demolished buildings. Reinforcing elements, such as steel rebar, were not used.

Gypsum and lime were used as binders. Volcanic dusts, called Pozzolana or "pit sand", were favored where they could be obtained. The pozzolanic mortar used had a high content of alumina and silica.

Concrete, and in particular, the hydraulic mortar responsible for its cohesion, was a type of structural ceramic whose utility derived largely from its rheological plasticity in the paste state. The setting and hardening of hydraulic cements derived from hydration of materials and the subsequent chemical and physical interaction of these hydration products. This differed from the setting of slaked lime mortars, the most common cements of the pre-Roman world. Once set, Roman concrete exhibited little plasticity, although it retained some resistance to tensile stresses.

The setting of pozzolanic cements has much in common with setting of their modern counterpart, Portland cement. The high silica composition of Roman pozzolana cements is very close to that of modern cement to which blast furnace slag , fly ash , or silica fume have been added .

Compressive strengths for modern Portland cements are typically at the 50 MPa level and have improved almost ten-fold since 1860.[4] There are no comparable mechanical data for ancient mortars, although some information about tensile strength may be inferred from the cracking of Roman concrete domes. These tensile strengths vary substantially from the water/cement ratio used in the initial mix. At present, there is no way of ascertaining what water/cement ratios the Romans used, nor are there extensive data for the effects of this ratio on the strengths of pozzolanic cements .

4 - Seismic technology

For an environment as prone to earthquakes as the Italian peninsula, interruptions and internal constructions within walls and domes created discontinuities in the concrete mass. Portions of the building could then shift slightly when there was movement of the earth to accommodate such stresses, enhancing the overall strength of the structure. It was in this sense that bricks and concrete were flexible. It may have been precisely for this reason that, although many buildings sustained serious cracking from a variety of causes, they continue to stand to this day .

Another technology used to improve the strength and stability of concrete was its gradation in domes. One example included the Pantheon, where the aggregate of the upper dome region consisted of alternating layers of light tuff and pumice, giving the concrete a density of 1350 kg/m^3. The foundation of the structure used travertine as an aggregate, having a much higher density of 2200 kg / m^3.

Rosendale Cement

Seal of the New York and Rosendale Cement Company.

Rosendale cement generally refers to a type of natural cement that may or may not have been produced in and around Rosendale, New York from argillaceous lime stone, but is a term that has had different definitions at different times. The fast-setting Rosendale natural cement mortars proved to be more efficient than the mortars based on lime and sand. Because of its reputation, "Rosendale Cement" has also been used as both a trade name and as a generic term referring to natural hydraulic cements produced elsewhere. It was used in the construction of many of the United States' most important landmarks, including the Brooklyn Bridge, the pedestal of the Statue of Liberty, Federal Hall, and one of the wings of the United States Capitol building.

Natural cement is produced in a simple process that begins with the calcination of crushed carbonate sedimentary rocks in kilns. The resulting clinker is ground into a fine powder before being shipped to market. Historically, this natural cement product was packaged in paper-lined wooden barrels or heavy canvas bags. Rosendale natural cement from the Rosendale area was produced from dolostone extracted from the Rosendale and Whiteport members of the Late Silurian Rondout Formation. The natural levels of magnesium and clay in the dolostone from the Rondout Formation are ideally suited for cement production and required none of the chemical additives characteristic of modern Portland cement production.

While Rosendale cement was extremely popular for the foundation of buildings (*e.g.* Statue of Liberty, Capitol Building, Brooklyn Bridge) and lining of water pipes, its long curing time of at least one month made it unpopular after World War I in the construction of highways and bridges, and many states and construction firms turned to the use of Portland cement. Because of the switch to Portland cement, by the end of the 1920s only one of the 15 Rosendale cement companies had survived. But in the early 1930s it was soon discovered that Portland cement, while it had a faster curing time, was not as durable, especially for highways, to the point that some states stopped building highways and roads with cement. An engineer, Bertrain H. Wait, whose company had worked on the construction of the New York Cities Catskill Aqueduct, and was impressed with the durability of Rosendale cement, came up with a blend of both Rosendale and synthetic cements which had the good attributes of both: i.e. was highly durable and had a much faster curing time. Mr. Wait convinced the New York Commissioner of Highways to construct an experimental section of highway near New Paltz, New York, of one sack of Rosendale to six sacks of synthetic cement. It proved a success, and for decades hence the Rosendale-synthetic cement blend became common use in highway and bridge construction .

Many of the original cement plants in the Rosendale area are preserved in the Snyder Estate Natural Cement Historic District.

Roman Engineering

Reconstruction of a 10.4 m high Roman Polyspastos at Bonn, Germany.

Contents :

1 – Introduction :

Romans are famous for their advanced engineering accomplishments, although some of their own inventions were improvements on older ideas, concepts and inventions. Technology for bringing running water into cities was developed in the east, but transformed by the Romans into a technology inconceivable in Greece. The architecture used in Rome was strongly influenced by Greek and Etruscan sources.

Roads were common at that time, but the Romans improved their design and perfected the construction to the extent that many of their roads are still in use today. Their accomplishments surpassed most other civilizations of their time, and after their time, and many of their structures have withstood the test of time to inspire others, especially during the Renaissance. Moreover, their contributions were described in some detail by authors such as Vitruvius, Frontinus and Pliny the Elder, so there is a printed record of their many inventions and achievements.

2 - Aqueducts :

Aqueduct of Segovia, Spain.

Three hundred million gallons of water were brought into Rome by 14 different aqueducts each day. Per capita water usage in ancient Rome matched that of modern-day cities like New York City or modern Rome. Most water was for public uses, such as baths and sewers.

The aqueducts could stretch from ten to sixty miles long, and typically descended from an elevation of one thousand feet above sea level at the source, to two hundred feet when they reached the reservoirs around the city. Roman engineers used inverted siphons to move water across a valley if they judged it impractical to build a raised aqueduct.

The Romans were among the first civilizations to harness the power of water. They built some of the first watermills outside of Greece for grinding flour and spread the technology for constructing watermills throughout the Mediterranean region. A famous example occurs at Barbegal in southern France, where no fewer than 16 overshot mills built into the side of a hill were worked by a single aqueduct, the outlet from one feeding the mill below in a cascade.

They were also skilled in mining, building aqueducts needed to supply equipment used in extracting metal ores, e.g. hydraulic mining, and the building of reservoirs to hold the water needed at the minehead. It is known that they were also capable of building and operating mining equipment such as crushing mills and dewatering machines. Large diameter vertical wheels of Roman vintage, for raising water, have been excavated from the Rio Tinto mines in Southwestern Spain. They were closely involved in exploiting gold resources such as those at Dolaucothi in south west Wales and in north-west Spain, a country where gold mining developed on a very large scale in the early part of the first century AD, such as at Las Medulas.

3 – Bridges :

Alcántara Bridge, Spain

Roman bridges were among the first large and lasting bridges ever built. They were built with stone, employing the arch as basic structure. Most utilized concrete as well. Built in 142 BC, the Pons Aemilius, later named *Ponte Rotto* (broken bridge) is the oldest Roman stone bridge in Rome, Italy.

The biggest Roman bridge was Trajan's bridge over the lower Danube, constructed by Apollodorus of Damascus, which remained for over a millennium; the longest bridge to have been built both in terms of overall and span length. They were normally at least 18 meters above the body of water.

An example of temporary military bridge construction are the two Caesar's Rhine bridges.

4 - Dams :

The Romans built many dams for water collection, such as the Subiaco dams, two of which fed Anio Novus, the largest aqueduct supplying Rome. One of the Subiaco dams was reputedly the highest ever found or inferred. They built 72 dams in Spain, such as those at Mérida, and many more are known across the empire. At one site, Montefurado in Galicia, they appear to have built a dam across the river Sil to expose alluvial gold deposits in the bed of the river. The site is near the spectacular Roman gold mine of Las Medulas.

Several earthen dams are known from Britain, including a well-preserved example from Roman Lanchester, Longovicium, where it may have been used in industrial-scale smithing or smelting, judging by the piles of slag found at this site in northern England. Tanks for holding water are also common along aqueduct systems, and numerous examples are known from just one site, the gold mines at Dolaucothi in west Wales. Masonry dams were common in North Africa for providing a reliable water supply from the wadis behind many settlements.

5 - Architecture :

The Colosseum in Rome.

The buildings and architecture of Ancient Rome were impressive even by modern standards. The Circus Maximus, for example, was large enough to be used as a stadium. The Colosseum also provides an example of Roman architecture at its finest. One of many stadiums built by the Romans, the Colosseum exhibits the arches and curves commonly associated with Roman buildings.

The Pantheon in Rome still stands a monument and tomb, and the Baths of Diocletian and the Baths of Caracalla are remarkable for their state of preservation, the former still possessing intact domes. Such massive public buildings were copied in numerous provincial capitals and towns across the empire, and the general principles behind their design and construction are described by Vitruvius writing at the turn of millennium in his monumental work *De architectura*.

The technology developed for the baths was especially impressive, especially the widespread use of the hypocaust for one of the first types of central heating developed anywhere. That invention was used not just in the large public buildings, but spread to domestic buildings such as the many villas which were built across the Empire.

6 - Materials :

The most common materials used were brick , stone or masonry, cement , concrete and marble . Brick came in many different shapes. Curved bricks were used to build columns, and triangular bricks were used to build walls.

Marble was mainly a decorative material. Caesar Augustus once boasted that he had turned Rome from a city of stone to a city of marble. The Romans had originally brought marble over from Greece, but later found their own quarries in northern Italy.

Cement was made of hydrated lime (calcium oxide) mixed with sand and water . The Romans discovered that substituting or supplementing the sand with a pozzolanic additive, such as volcanic ash, would produce a very hard cement , known as hydraulic mortar or hydraulic cement. They used it widely in structures such as buildings, public baths and aqueducts, ensuring their survival into the modern era.

7 – Roads :

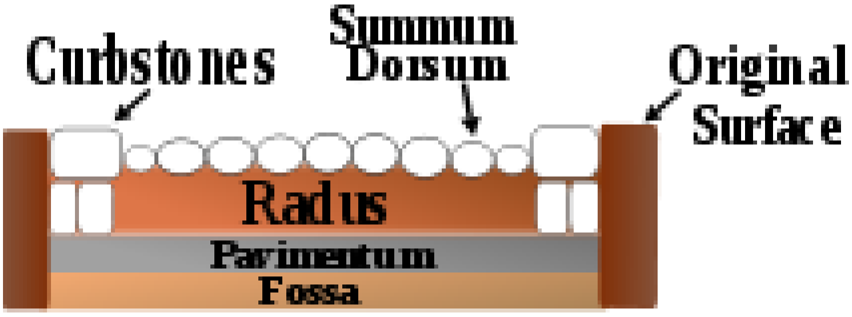


Diagram of Roman road construction

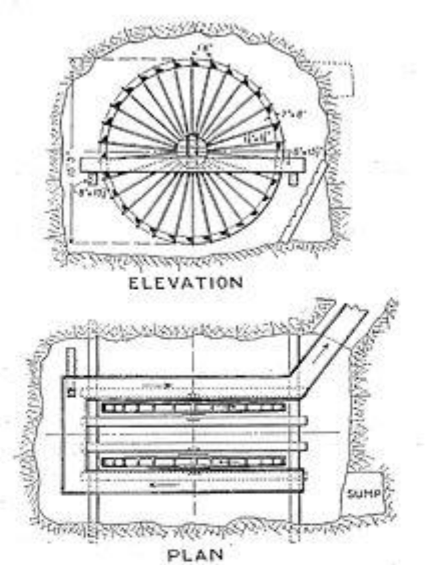
Roman roads were constructed to be immune to floods and other environmental hazards. Many roads built by the Romans are still in use today.

There were several variations on a standard Roman road. Most of the higher quality roads were composed of five layers. The bottom layer, called *pavimentum*, was one inch thick and made of mortar. Above this were four strata of masonry. The layer directly above the pavimentum was called the *statumen*. It was one foot thick, and was made of stones bound together by cement or clay.

Above that, there were the *rudens*, which were made of ten inches of rammed concrete. The next layer, the *nucleus*, was made of twelve to eighteen inches of successively laid and rolled layers of concrete. *Summa crusta* of silex or lava polygonal slabs, one to three feet in diameter and eight to twelve inches thick, were laid on top of the rudens. The final upper surface was made of concrete or well smoothed and fitted flint.

Generally, when a road encountered an obstacle, the Romans preferred to engineer a solution to the obstacle rather than redirecting the road around it. Bridges were constructed over all sizes of waterway, marshy ground called for the construction of raised causeways with firm foundations, and hills and outcroppings were frequently cut or tunneled through rather than avoided. The tunnels were made with square hard rock block.

8 – Mining :



Drainage wheel from Rio Tinto mines.

The Romans were the first to exploit mineral deposits using advanced technology, especially the use of aqueducts to bring water from great distances to help operations at the pithead. Their technology is most visible at sites in Britain such as Dolaucothi where they exploited gold deposits with at least 5 long aqueducts tapping adjacent rivers and streams. They used the water to prospect for ore by unleashing a wave of water from a tank to scour away the soil and so reveal the bedrock with any veins exposed to sight. They used the same method (known as hushing) to remove waste rock, and then to quench hot rocks weakened by fire-setting.

Such methods could be very effective in opencast mining, but fire-setting was very dangerous when used in underground workings. They were made redundant with the introduction of explosives, although hydraulic mining is still used on alluvial tin ores. They were also used to produce a controlled supply to wash the crushed ore. It is highly likely that they also developed water-powered stamp mills to crush hard ore, which could be washed to collect the heavy gold dust.

At alluvial mines, they applied their hydraulic mining methods on a vast scale, such as Las Medulas in north-west Spain. Traces of tanks and aqueducts can be found at many other early Roman mines.

The methods are described in great detail by Pliny the Elder in his Naturalis Historia.

He also described deep mining underground, and mentions the need to dewater the workings using reverse overshot water-wheels, and actual examples have been found in many Roman mines exposed during later mining attempts. The copper mines at Rio Tinto were one source of such artifacts, where a set of 16 was found in the 1920s. They also used Archimedean screws to remove water in a similar way.

9 - Military Engineering :

Engineering was also institutionally ingrained in the Roman military, who constructed forts, camps, bridges, roads, ramps, palisades, and siege equipment amongst others. One of the most notable examples of military bridge - building in the Roman Empire was Julius Caesar's bridge over the Rhine River. This bridge was completed in only ten days by a dedicated team of engineers. Their exploits in the Dacian wars under Trajan in the early 2nd century AD are recorded on Trajan's column in Rome.

The army was also closely involved in gold mining and probably built the extensive complex of leats and cisterns at the Roman gold mine of Dolaucothi in Wales shortly after conquest of the region in 75 AD.

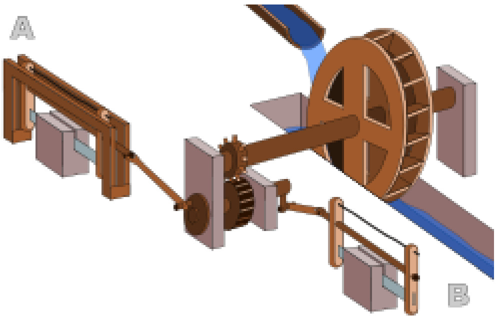
10 - Power Technology :

Mills below aqueduct

Arles Aqueduct

Water wheel technology was developed to a high level during the Roman period, a fact attested by Vitruvius and Pliny the Elder in De Architectura and Naturalis Historia respectively. The largest complex of water wheels existed at Barbegal near Arles, where the site was fed by a channel from the main aqueduct feeding the town. It is estimated that the site comprised 16 separate overshot water wheels arranged in two parallel lines down the hillside. The outflow from one wheel became the input to the next one down in the sequence.

Twelve kilometers north of Arles, at Barbegal, near Fontvieille, where the aqueduct arrived at a steep hill, the aqueduct fed a series of parallel water wheels to power a flour mill. There are two aqueducts which join just north of the mill complex, and a sluice which enabled the operators to control the water supply to the complex. There are substantial masonry remains of the water channels and foundations of the individual mills, together with a staircase rising up the hill upon which the mills are built. The mills apparently operated from the end of the 1st century until about the end of the 3rd century.[2] The capacity of the mills has been estimated at 4.5 tons of flour per day, sufficient to supply enough bread for the 12,500 inhabitants occupying the town of Arelate at that time.



Scheme of the water-driven Roman sawmill at Hierapolis,

The Hierapolis sawmill was a Roman water-powered stone saw mill at Hierapolis, Asia Minor (modern - day Turkey). Dating to the second half of the 3rd century AD , the sawmill is the earliest known machine to combine a crank with a connecting rod.

The watermill is shown on a raised relief on the sarcophagus of Marcus Aurelius Ammianos , a local miller. A waterwheel fed by a mill race is shown powering two frame saws via a gear train cutting rectangular blocks.

Further crank and connecting rod mechanisms, without gear train, are archaeologically attested for the 6th century AD water-powered stone sawmills at Gerasa, Jordan, and Ephesus, Turkey. Literary references to water-powered marble saws in Trier, now Germany, can be found in Ausonius' late 4th century AD poem *Mosella*. They attest a diversified use of water-power in many parts of the Roman Empire.

A complex of mills also existed on the Janiculum in Rome fed by the Aqua Traiana. The Aurelian Walls were carried up the hill apparently to include the water mills used to grind grain towards providing bread flour for the city. The mill was thus probably built at the same time as or before the walls were built by the emperor Aurelian (reigned 270-275 AD). The mills were supplied from an aqueduct, where it plunged down a steep hill.

The site thus resembles Barbegal , although excavations in the late 1990s suggest that they may have been undershot rather than overshot in design. The mills were in use in 537 AD when the Goths besieging the city cut off their water supply. However they were subsequently restored and may have remained in operation until at least the time of Pope Gregory IV (827- 44) .

Many other sites are reported from across the Roman Empire, although many remain unexcavated.

Roman Technology

The Pont du Gard in France is a Roman aqueduct built in ca. 19 BC.

Mercury gilded statue - *Marcus Aurelius*

Contents

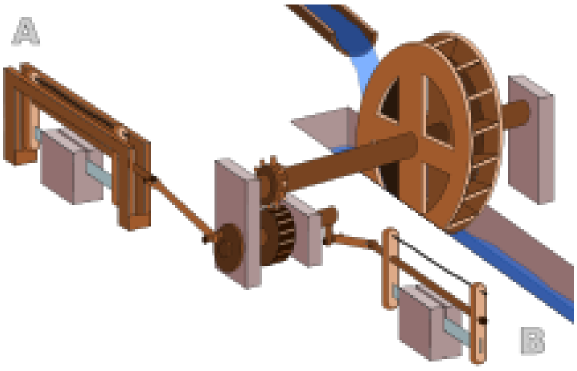
1 – Introduction :

Roman technology is the engineering practice which supported Roman civilization and made the expansion of Roman commerce and Roman military possible over nearly a thousand years.

The Roman Empire had the most advanced set of technologies of its time, some of which was lost during the turbulent eras of Late Antiquity and the early Middle Ages. Gradually, some of the technological feats of the Romans were rediscovered and/or improved upon, while others went ahead of what the Romans had done during the Middle Ages and the beginning of the Modern Era. Several Roman technological feats in different areas like civil engineering, construction materials, transport technology, and some inventions such as the mechanical reaper, were surprising achievements until the 19th century, and some, such as the arch, have remained untouched to this day.

2 - The energy constraint :

The sixteen overshot wheels at Barbegal are considered the biggest ancient mill complex. Their capacity was sufficient to feed the whole nearby city of Arles.



Scheme of the Roman Hierapolis sawmill, the earliest known machine to incorporate a crank and connecting rod mechanism.

All technology uses energy to transform the material into a desirable object or uses some form of mechanics combined with another form to make something better. The cheaper energy is, the wider the class of technologies that are considered economic. This is why technological history can be seen as a succession of ages defined by energy type i.e. human, animal, water, peat, coal, and oil.[3] The Romans used water power, and water mills were common throughout the Empire, especially to the end of the first century AD. They were used for corn milling, sawing timber and crushing ore. They exploited wood and coal for heating. There were huge reserves of wood, peat and coal in the Roman Empire, but they were all in the wrong place. Wood could be floated down rivers to the major urban centres but otherwise it was a very poor fuel, being heavy for its calorific value. If this was improved by being processed into charcoal, it was bulky. Nor was wood ever available in any concentration. Diocletian's Price Edict can give us a glimpse of the economics of transporting wood. The maximum price of a wagon load of 1,200 lbs of wood was 150 d.(denari). The maximum freight charge per mile for the same wagon load was 20 d. per mile. Room heating was normally better done by charcoal braziers than hypocausts. But hypocausts did allow them to exploit any poor-quality smoky fuels like straw, vine prunings and small wood locally available. Hypocausts also allowed them to generate a humid heat for their baths.

The Romans worked almost all the coalfields of England that outcropped on the surface, by the end of the 2nd century (Smith 1997; 323). But there is no evidence that this exploitation was on any scale.

After c.200 AD the commercial heart of the Empire was in Africa and the East where the climate severely limited timber growth. There was no large coalfield on the edge of the Mediterranean.

Nevertheless, the Romans were the first culture to assemble all essential components of the much later steam engine:

With the crank and connecting rod system, all elements for constructing a steam engine (invented in 1712) — Hero's aeolipile (generating steam power), the cylinder and piston (in metal force pumps), non-return valves (in water pumps) , gearing (in water mills and clocks) — were known in Roman times .

However, the aeolipile was a reaction engine, inefficient as a stationary engine. The first useful steam engine did not use steam pressure at all, but followed up a scientific advance in understanding air pressure.

3 - Craft basis :

Roman Cage Cup from the 4th century AD. Hypothesised as a floating wick oil lamp to give magical downwards lighting effects.

Roman technology was largely based on a system of crafts, although the term engineering is used today to describe the technical feats of the Romans. The Greek words used were mechanic or machine-maker or even mathematician which had a much wider meaning than now. There were a large number of engineers employed by the army. The most famous engineer of this period was Apollodorus of Damascus. Normally each trade, each group of artisans—stonemasons, glass blowers, surveyors, etc.—within a project had its own practice of masters and apprentices, and many tried to keep their trade secrets, passing them on solely by word of mouth, a system still in use today by those who do not want to patent their inventions. Writers such as Vitruvius, Pliny the Elder and Frontinus published widely on many different technologies, and there was a corpus of manuals on basic mathematics and science such as the many books by Archimedes, Ctesibius, Heron (a.k.a. Hero of Alexandria), Euclid and so on. Not all of the manuals which were available to the Romans have survived, as lost works illustrate.

Much of what is known of Roman technology comes indirectly from archaeology and from the third-hand accounts of Latin texts copied from Arabic texts, which were in turn copied from the Greek texts of scholars such as Hero of Alexandria or contemporary travelers who had observed Roman technologies in action. Writers like Pliny the Elder and Strabo had enough intellectual curiosity to make note of the inventions they saw during their travels, although their typically brief descriptions often arouse discussion as to their precise meaning. On the other hand, Pliny is perfectly clear when describing gold mining, his text in book XXXIII having been confirmed by archaeology and field-work at such sites as Las Medulas and Dolaucothi.

4 - Engineering and Construction :

The Colosseum in Rome, Italy

The Romans made great use of aqueducts, dams, bridges, and amphitheaters. They were also responsible for many innovations to roads, sanitation, and construction in general. Roman architecture in general was greatly influenced by the Etruscans. Most of the columns and arches seen in famous Roman architecture were adopted from the Etruscan civilization.

In the Roman Empire, cements made from pozzolanic ash/pozzolana and an aggregate made from pumice were used to make a concrete very similar to modern Portland cement concrete. In 20s BC the architect Vitruvius described a low-water-content method for mixing concrete. The Romans found out that insulated glazing (or "double glazing") improved greatly on keeping buildings warm, and this technique was used in the construction of public baths.

Another truly original process which was born in the empire was the practice of glassblowing, which started in Syria and spread in about one generation in the empire.

4 – 1 - Machines :

Reconstruction of a 10.4 - metre - high Roman construction crane at Bonn, Germany

There were many types of presses to press olives. In the 1st century, Pliny the Elder reported the invention and subsequent general use of the new and more compact screw presses. However, the screw press was almost certainly not a Roman invention. It was first described by Hero of Alexandria, but may have already been in use when he mentioned it in his Mechanica III.

Cranes were used for construction work and possibly to load and unload ships at their ports, although for the latter use there is according to the "present state of knowledge" still no evidence.[5] Most cranes were capable of lifting about 6-7 tons of cargo, and according to a relief shown on Trajan's column were worked by treadwheel.

4 – 2 - Roads :

Via Appia, a road connecting the city of Rome to the Southern parts of Italy remains usable even today.

The Romans primarily built roads for their military. Their economic importance was probably also significant, although wagon traffic was often banned from the roads to preserve their military value.At its largest extent the total length of the Roman road network was 85,000 kilometres (53,000 mi).

Way stations providing refreshments were maintained by the government at regular intervals along the roads. A separate system of changing stations for official and private couriers was also maintained. This allowed a dispatch to travel a maximum of 800 kilometres (500 mi) in 24 hours by using a relay of horses.

The roads were constructed by digging a pit along the length of the intended course, often to bed rock. The pit was first filled with rocks, gravel or sand and then a layer of concrete. Finally they were paved with polygonal rock slabs. Roman roads are considered the most advanced roads built until the early 19th century. Bridges were constructed over waterways. The roads were resistant to floods and other environmental hazards. After the fall of the Roman empire the roads were still usable and used for more than 1000 years.

4 – 3 - Aqueducts :

Aqueduct of Segovia

The Romans constructed numerous aqueducts to supply water. The city of Rome itself was supplied by eleven aqueducts made of limestone that provided the city with over 1 million cubic metres of water each day, sufficient for 3.5 million people even in modern day times , and with a combined length of 350 kilometers . Water inside the aqueducts depended entirely on gravity. The raised stone channels in which the water travelled were slightly slanted. The water was carried directly from mountain springs. After it had gone through the aqueduct, the water was collected in tanks and fed through pipes to fountains, toilets, etc . The main aqueducts in Ancient Rome were the Aqua Claudia and the Aqua Marcia . Most aqueducts were constructed below the surface with only small portions above ground supported by arches . The longest Roman aqueduct, 178 kilometres (111 mi) in length, was traditionally assumed to be that which supplied the city of Carthage. The complex system built to supply Constantinople had its most distant supply drawn from over 120 km away along a sinuous route of more than 336 km .

Roman aqueducts were built to remarkably fine tolerances, and to a technological standard that was not to be equaled until modern times. Powered entirely by gravity, they transported very large amounts of water very efficiently. Sometimes, where depressions deeper than 50 metres had to be crossed, inverted siphons were used to force water uphill . An aqueduct also supplied water for the overshot wheels at Barbegal in Roman Gaul, a complex of water mills hailed as "the greatest known concentration of mechanical power in the ancient world".

4 – 4 - Bridges :

1st century Roman bridge in Vaison la Romaine, France

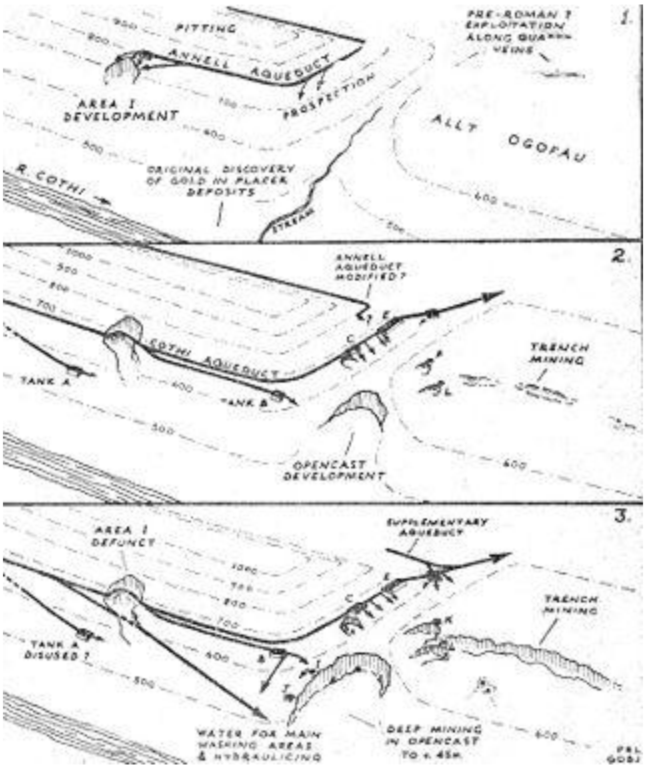
Roman bridges were among the first large and lasting bridges built. They were built with stone and had the arch as its basic structure. Most utilized concrete as well. Built in 142 BC, the Pons Aemilius, later named *Ponte Rotto* (broken bridge) is the oldest Roman stone bridge in Rome, Italy. The biggest Roman bridge was Trajan's bridge over the lower Danube, constructed by Apollodorus of Damascus, which remained for over a millennium the longest bridge to have been built both in terms of overall and span length. They were most of the time at least 60 feet above the body of water.

An example of temporary military bridge construction are the two Caesar's Rhine bridges.

4 – 5 - Dams :

They also built many dams for water collection, such as the Subiaco Dams, two of which fed Anio Novus, one of the largest aqueducts of Rome. They built 72 dams in just one country, Spain and many more are known across the Empire, some of which are still in use. At one site , Montefurado in Galicia, they appear to have built a dam across the river Sil to expose alluvial gold deposits in the bed of the river. The site is near the spectacular Roman gold mine of Las Medulas. Several earthen dams are known from Britain, including a well-preserved example from Roman Lanchester, Longovicium, where it may have been used in industrial - scale smithing or smelting, judging by the piles of slag found at this site in northern England. Tanks for holding water are also common along aqueduct systems, and numerous examples are known from just one site, the gold mines at Dolaucothi in west Wales. Masonry dams were common in North Africa for providing a reliable water supply from the wadis behind many settlements.

4 – 6 - Mining ;



Development of Dolaucothi mine

The Romans also made great use of aqueducts in their extensive mining operations across the empire, some sites such as Las Medulas in north-west Spain having at least 7 major channels entering the minehead. Other sites such as Dolaucothi in south Wales was fed by at least 5 leats, all leading to reservoirs and tanks or cisterns high above the present opencast. The water was used for hydraulic mining, where streams or waves of water are released onto the hillside, first to reveal any gold-bearing ore, and then to work the ore itself. Rock debris could be sluiced away by hushing, and the water also used to douse fires created to break down the hard rock and veins, a method known as fire-setting.

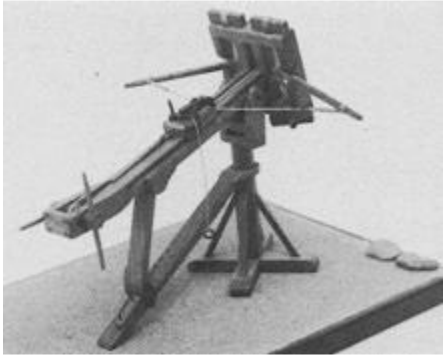
Alluvial gold deposits could be worked and the gold extracted without needing to crush the ore. Washing tables were fitted below the tanks to collect the gold-dust and any nuggets present. Vein gold needed crushing, and they probably used crushing or stamp mills worked by water-wheels to comminute the hard ore before washing. Large quantities of water were also needed in deep mining to remove waste debris and power primitive machines, as well as for washing the crushed ore. Pliny the Elder provides a detailed description of gold mining in book xxxiii of his Naturalis Historia, most of which has been confirmed by archaeology. That they used water mills on a large scale elsewhere is attested by the flour mills at Barbegal in southern France, and on the Janiculum in Rome.

4 – 7 - Sanitation :

Roman public baths in Bath, England. The loss of the original roof has encouraged green algae growth.

The Romans were one of the first known civilizations to invent indoor plumbing . The Roman public baths, or *thermae* served hygienic, social and cultural functions. The baths contained three main facilities for bathing. After undressing in the apodyterium or changing room, Romans would proceed to the tepidarium or warm room. In the moderate dry heat of the tepidarium, some performed warm-up exercises and stretched while others oiled themselves or had slaves oil them. The tepidarium 's main purpose was to promote sweating to prepare for the next room, the caldarium or hot room. The caldarium, unlike the tepidarium, was extremely humid and hot. Temperatures in the caldarium could reach 40 degrees Celsius (104 degrees Fahrenheit). Many contained steam baths and a cold-water fountain known as the labrum. The last room was the frigidarium or cold room, which offered a cold bath for cooling off after the caldarium. The Romans also had flush toilets.

5 - Roman military technology :



A Roman Ballista

The Roman military technology ranged from personal equipment and armament to deadly siege engines. They inherited almost all ancient weapons.

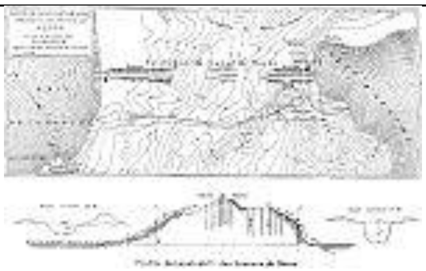
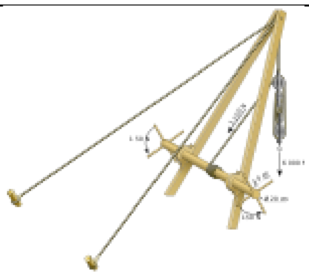
While heavy, intricate armour was not uncommon (cataphracts), the Romans perfected a relatively light, full torso armour made of segmented plates (lorica segmentata). This segmented armour provided good protection for vital areas, but did not cover as much of the body as lorica hamata or chainmail. The lorica segmentata provided better protection, but the plate bands were expensive and difficult to produce and difficult to repair in the field. Overall, chainmail was cheaper, easier to produce, cheaper and simpler to maintain, was one-size fits all, and was more comfortable to wear - thus, it remained the primary form of armor even when lorica segmentata was in use.

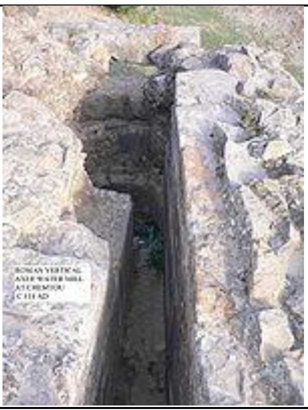
The Roman cavalry saddle had four horns and was believed to have been copied from Celtic peoples.

Roman siege engines such as ballistas, scorpions and onagers were not unique. But the Romans were probably the first people to put ballistas on carts for better mobility on campaigns. On the battlefield, it is thought that they were used to pick off enemy leaders. There is one account of the use of artillery in battle from Tacitus, Histories III,23:

> On engaging they drove back the enemy, only to be driven back themselves, for the Vitellians had concentrated their artillery on the raised road that they might have free and open ground from which to fire; their earlier shots had been scattered and had struck the trees without injuring the enemy. A ballista of enormous size belonging to the Fifteenth legion began to do great harm to the Flavians' line with the huge stones that it hurled; and it would have caused wide destruction if it had not been for the splendid bravery of two soldiers, who, taking some shields from the dead and so disguising themselves, cut the ropes and springs of the machine.

6 - Technologies invented or developed by the Romans :

	
The unfinished Roman Corinth Canal, 1st century AD	*Roman Pentaspastos ("Five-pulley-crane"), a medium-sized variant (ca. 450 kg load)*
	
Point able fire engine nozzle	*Ship with spritsail, the earliest fore-and-aft rig, 3rd century AD*

	
Late Roman paddle-wheel boat, 4th century AD (medieval copy)	*Donkey mills at Pompeii*
	
Modern oil screw press following Roman conceptual innovation	*Oil press of Early Roman type*
	
Roman turbine mill at Chemtou, Tunisia	*stern mounted rudder*
	
Roman harvesting machine: detail	*Roman harvesting machine: overview*

	
Glassware from Pompeii	*Roman surgery tools*

Salt - Concrete

Contents

1 – Introduction :

Salt-concrete (or *salzbeton*) is a construction material that is used to reduce the water inflow in mining shafts in salt mines. It is composed of 16 % cement, 39 % halite, 16 % lime stone powder, 14 % water and 15 % sand.

2 - History :

Salt-concrete was used for the first time in 1984 in the Kali mine in Rocanville in Canada.[v] A salt-concrete seal was also installed in the Asse II mine in Lower Saxony in 1995.

3 - Filling tunnels :

Since the end of the repository for radioactive waste Morsleben in 1998, the salt dome stability deteriorated to a state where it could collapse. Since 2003, a volume of 480.000 m^3 of salt concrete has been pumped into the pit to temporarily stabilize the upper levels. In addition another 4.000.000 m^3 of salt concrete will be used to temporarily stabilize the lower levels.

Sand

	
Sand dunes in Libya.	*Close-up of sand from the Gobi Desert, Mongolia, showing a surface area of 1 square centimetre.*

Contents

1 – Introduction :

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The composition of sand is highly variable, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz.

The second most common form of sand is calcium carbonate, for example aragonite, which has mostly been created, over the past half billion years, by various forms of life like coral and shell fish. It is, for example, the primary form of sand apparent in areas where reefs have dominated the ecosystem for millions of years, like the Caribbean.

2 - Composition :

	
Sand from Pismo Beach, California. Components are primarily quartz, chert, igneous rock and shell fragments. Scale bar is 1.0 mm.	*Sand from Kalalau Beach, Hawaii (Field width = 5.5 mm). We see a few grains of olivine, which is the green sand of some beaches of Hawaii.*
	
Sand from Coral Pink Sand Dunes State Park, Utah. These are grains of quartz with a hematite coating providing the orange color. Scale bar is 1.0 mm	*Heavy minerals (dark) in a quartz beach sand (Chennai, India).*

In terms of particle size as used by geologists, sand particles range in diameter from 0.0625 mm (or 1⁄16 mm) to 2 mm. An individual particle in this range size is termed a *sand grain*. Sand grains are between gravel (with particles ranging from 2 mm up to 64 mm) and silt (particles smaller than 0.0625 mm down to 0.004 mm). The size specification between sand and gravel has remained constant for more than a century, but particle diameters as small as 0.02 mm were considered sand under the Albert Atterberg standard in use during the early 20th century. A 1953 engineering standard published by the American Association of State Highway and Transportation Officials set the minimum sand size at 0.074 mm.

A 1938 specification of the United States Department of Agriculture was 0.05 mm.[1] Sand feels gritty when rubbed between the fingers (silt, by comparison, feels like flour).

ISO 14688 grades sands as fine, medium and coarse with ranges 0.063 mm to 0.2 mm to 0.63 mm to 2.0 mm. In the United States, sand is commonly divided into five sub-categories based on size: very fine sand (1⁄16 – ⅛ mm diameter), fine sand (⅛ mm – ¼ mm), medium sand (¼ mm – ½ mm), coarse sand (½ mm – 1 mm), and very coarse sand (1 mm – 2 mm). These sizes are based on the Krumbein phi scale, where size in Φ = -log base 2 of size in mm. On this scale, for sand the value of Φ varies from −1 to +4, with the divisions between sub-categories at whole numbers.

The most common constituent of sand, in inland continental settings and non-tropical coastal settings, is silica (silicon dioxide, or SiO_2), usually in the form of quartz, which, because of its chemical inertness and considerable hardness, is the most common mineral resistant to weathering.

The composition of sand is highly variable, depending on the local rock sources and conditions. The bright white sands found in tropical and subtropical coastal settings are eroded limestone and may contain coral and shell fragments in addition to other organic or organically derived fragmental material, suggesting sand formation depends on living organisms, too . The gypsum sand dunes of the White Sands National Monument in New Mexico are famous for their bright, white color. Arkose is a sand or sandstone with considerable feldspar content, derived from the weathering and erosion of a (usually nearby) granitic rock outcrop. Some sands contain magnetite, chlorite, glauconite or gypsum. Sands rich in magnetite are dark to black in color, as are sands derived from volcanic basalts and obsidian. Chlorite - glauconite bearing sands are typically green in color, as are sands derived from basaltic (lava) with a high olivine content. Many sands, especially those found extensively in Southern Europe, have iron impurities within the quartz crystals of the sand, giving a deep yellow color. Sand deposits in some areas contain garnets and other resistant minerals, including some small gemstones.

3 - Environments :

Sand is transported by wind and water and deposited in the form of beaches, dunes, sand spits, sand bars and related features. In environments such as gravel-bed rivers and glacial moraines it often occurs as one of the many grain sizes that are represented. Sand-bed rivers, such as the Platte River in Nebraska, USA, have sandy beds largely because there is no larger source material that they can transport. Dunes, a distinctive geographical feature of desert environments, are on the other hand sandy because larger material is generally immobile in wind. Sand is a component of soil.

4 – Study :

The study of individual grains can reveal much historical information as to the origin and kind of transport of the grain. Quartz sand that is recently weathered from granite or gneiss quartz crystals will be angular. It is called grus in geology or *sharp sand* in the building trade where it is preferred for concrete, and in gardening where it is used as a soil amendment to loosen clay soils. Sand that is transported long distances by water or wind will be rounded, with characteristic abrasion patterns on the grain surface. Desert sand is typically rounded. People who collect sand as a hobby are known as arenophiles. Organisms that thrive in sandy environments are psammophiles.

4 - Uses :

Sand sorting tower at a gravel extraction pit.

At 300 km / h , an ICE 3 (DB class 403) releases sand from several bogies to the rails.

- Agriculture : Sandy soils are ideal for crops such as watermelons, peaches, and peanuts, and their excellent drainage characteristics make them suitable for intensive dairy farming.
- Aquaria : Sand makes a low cost aquarium base material which some believe is better than gravel for home use. It is also an absolute necessity for saltwater reef tanks, which emulate environments composed largely of aragonite sand broken down from coral and shellfish.
- Artificial reefs : Geotextile bagged sand can serve as the foundation for new reefs.
- Beach nourishment : Governments move sand to beaches where tides, storms or deliberate changes to the shoreline erode the original sand .
- Brick : Manufacturing plants add sand to a mixture of clay and other materials for manufacturing bricks.
- Cob : Coarse sand makes up as much as 75% of cob.
- Mortar : Sand is mixed with cement and sometimes lime to be used in masonry construction.
- Concrete : Sand is often a principal component of this critical construction material.
- Hydraulic Fracturing: The drilling technique for natural gas also known as fracing use "frac sand". The rounded silica sand is used as a "proppant" a material that holds the cracks open that is caused by the hydraulic fracturing process.
- Glass : Sand is the principal component in common glass.
- Landscaping: Sand makes small hills and slopes (for example, in golf courses).
- Paint : Mixing sand with paint produces a textured finish for walls and ceilings or non-slip floor surfaces.
- Rail roads : Train operators use sand to improve the traction of wheels on the rails.
- Roads: Sand improves traction (and thus traffic safety) in icy or snowy conditions.
- Sand animation : Performance artists draw images in sand. Makers of animated films use the same term to describe their use of sand on front lit or backlit glass.

- Sand casting : Casters moisten or oil molding sand, also known as foundry sand and then shape it into molds into which they pour molten material. This type of sand must be able to withstand high temperatures and pressure, allow gases to escape, have a uniform, small grain size and be non-reactive with metals.
- Sand castles : Shaping sand into castles or other miniature buildings is a popular beach activity.
- Sand bags : These protect against floods and gunfire. The inexpensive bags are easy to transport when empty, and unskilled volunteers can quickly fill them with local sand in emergencies.
- Sand blasting : Graded sand serves as an abrasive in cleaning, preparing, and polishing.
- Water filtration: Media filters use sand for filtering water.
- Zoanthid "skeletons" : Animals in this order of marine benthic cnidarians related to corals and sea anemones, incorporate sand into their mesoglea for structural strength, which they need because they lack a true skeleton.

5 - Hazards :

While sand is generally non-toxic, sand-using activities such as sandblasting require precautions. Bags of silica sand used for sandblasting now carry labels warning the user to wear respiratory protection to avoid breathing the resulting fine silica dust. Material safety data sheets (MSDS) for silica sand state that "excessive inhalation of crystalline silica is a serious health concern".

In areas of high pore water pressure sand and salt water can form quicksand, which is a colloid hydrogel that behaves like a liquid. Quicksand produces a considerable barrier to escape for creatures caught within, who often die from exposure (not from submersion) as a result.

6 - Environmental Issues :

Sand's many uses require a significant dredging industry, raising environmental concerns over fish depletion, landslides, and flooding. Countries such as China, Indonesia, Malaysia and Cambodia ban sand exports, citing these issues as a major factor.

Sand Casting

Contents

1 – Introduction :

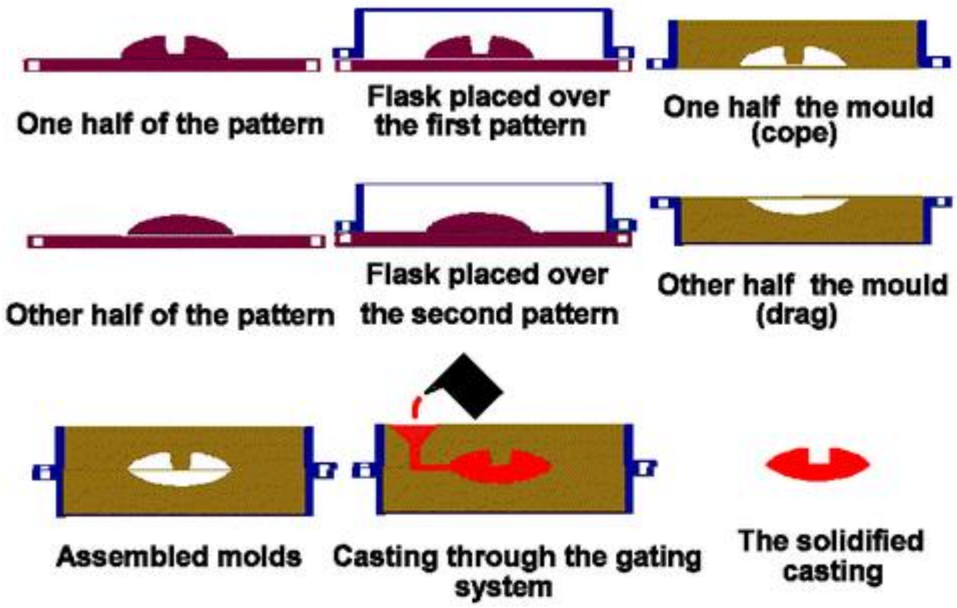
Sand casting, also known as **sand molded casting**, is a metal casting process characterized by using sand as the mold material. The term "sand casting" can also refer to an object produced via the sand casting process. Sand castings are produced in specialized factories called foundries. Over 70 % of all metal castings are produced via a sand casting process .

Sand casting is relatively cheap and sufficiently refractory even for steel foundry use. In addition to the sand, a suitable bonding agent (usually clay) is mixed or occurs with the sand. The mixture is moistened with water to develop strength and plasticity of the clay and to make the aggregate suitable for molding. The sand is typically contained in a system of frames or mold boxes known a flask. The mold cavities and gate system are created by compacting the sand around models, or patterns, and or carved directly into the sand.

3 - Basic process :

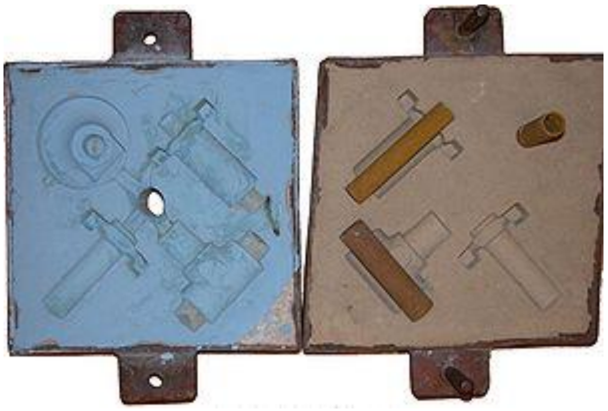
There are six steps in this process :

1. Place a pattern in sand to create a mold.
2. Incorporate the pattern and sand in a gating system.
3. Remove the pattern.
4. Fill the mold cavity with molten metal.
5. Allow the metal to cool.
6. Break away the sand mold and remove the casting.



2 – 1 - Components :

2 – 1 – 1 – Patterns :



Cope & drag (top and bottom halves of a sand mold), with cores in place on the drag

From the design, provided by an engineer or designer, a skilled *pattern maker* builds a *pattern* of the object to be produced, using wood, metal, or a plastic such as expanded polystyrene. Sand can be ground, swept or strickled into shape. The metal to be cast will contract during solidification, and this may be non-uniform due to uneven cooling. Therefore, the pattern must be slightly larger than the finished product, a difference known as *contraction allowance*. Pattern - makers are able to produce suitable patterns using 'Contraction rules' (these are sometimes called "shrink allowance rulers" where the ruled markings are deliberately made to a larger spacing according to the percentage of extra length needed). Different scaled rules are used for different metals because each metal and alloy contracts by an amount distinct from all others. Patterns also have core prints that create registers within the molds into which are placed sand cores. Such cores, sometimes reinforced by wires, are used to create under cut profiles and cavities which cannot be molded with the cope and drag, such as the interior passages of valves or cooling passages in engine blocks.

Paths for the entrance of metal into the mold cavity constitute the runner system and include the sprue, various feeders which maintain a good metal 'feed', and in-gates which attach the runner system to the casting cavity. Gas and steam generated during casting exit through the permeable sand or via risers, which are added either in the pattern itself, or as separate pieces.

2 – 1 – 2 – Molding box and materials :

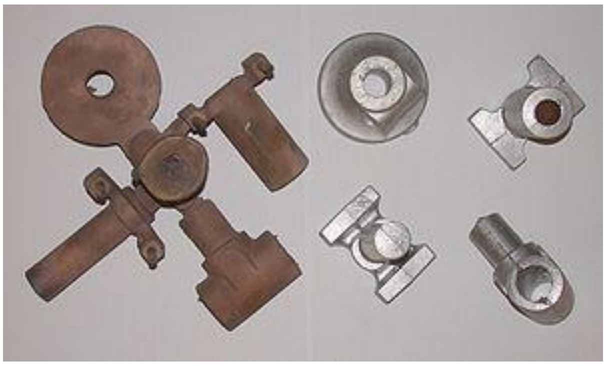
A multi-part molding box (known as a casting flask, the top and bottom halves of which are known respectively as the cope and drag) is prepared to receive the pattern. Molding boxes are made in segments that may be latched to each other and to end closures. For a simple object—flat on one side—the lower portion of the box, closed at the bottom, will be filled with a molding sand. The sand is packed in through a vibratory process called ramming and, in this case, periodically screeded level. The surface of the sand may then be stabilized with a sizing compound. The pattern is placed on the sand and another molding box segment is added. Additional sand is rammed over and around the pattern. Finally a cover is placed on the box and it is turned and unlatched, so that the halves of the mold may be parted and the pattern with its sprue and vent patterns removed. Additional sizing may be added and any defects introduced by the removal of the pattern are corrected. The box is closed again. This forms a "green" mold which must be dried to receive the hot metal. If the mold is not sufficiently dried a steam explosion can occur that can throw molten metal about. In some cases, the sand may be oiled instead of moistened, which makes possible casting without waiting for the sand to dry. Sand may also be bonded by chemical binders, such as furane resins or amine-hardened resins.

2 – 1 – 3 – Chills :

To control the solidification structure of the metal, it is possible to place metal plates, *chills*, in the mold. The associated rapid local cooling will form a finer-grained structure and may form a somewhat harder metal at these locations. In ferrous castings the effect is similar to quenching metals in forge work. The inner diameter of an engine cylinder is made hard by a chilling core. In other metals chills may be used to promote directional solidification of the casting. In controlling the way a casting freezes it is possible to prevent internal voids or porosity inside castings.

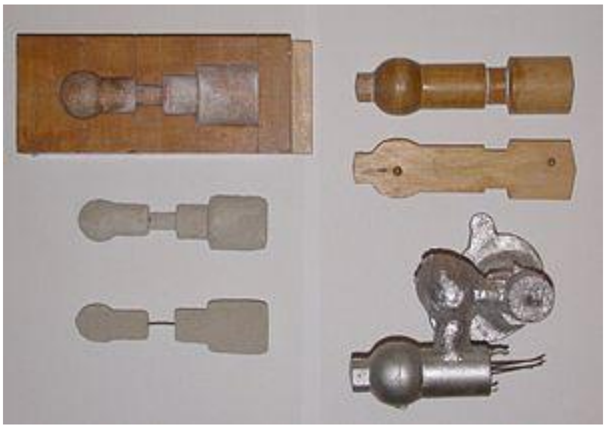
2 – 1 – 4 – Cores :

To produce cavities within the casting — such as for liquid cooling in engine blocks and cylinder heads — negative forms are used to produce *cores*. Usually sand - molded, cores are inserted into the casting box after removal of the pattern. Whenever possible, designs are made that avoid the use of cores, due to the additional set-up time and thus greater cost.



Two sets of castings (bronze and aluminium) from the above sand mold

With a completed mold at the appropriate moisture content, the box containing the sand mold is then positioned for filling with molten metal — typically iron, steel, bronze, brass, aluminium, magnesium alloys, or various pot metal alloys , which often include lead, tin, and zinc. After filling with liquid metal the box is set aside until the metal is sufficiently cool to be strong. The sand is then removed revealing a rough casting that, in the case of iron or steel, may still be glowing red. When casting with metals like iron or lead, which are significantly heavier than the casting sand, the casting flask is often covered with a heavy plate to prevent a problem known as *floating the mold*. Floating the mold occurs when the pressure of the metal pushes the sand above the mold cavity out of shape, causing the casting to fail.



Left : Core box, with resulting (wire reinforced) cores directly below. Right:- Pattern (used with the core) and the resulting casting below (the wires are from the remains of the core)

After casting, the cores are broken up by rods or shot and removed from the casting. The metal from the sprue and risers is cut from the rough casting. Various heat treatments may be applied to relieve stresses from the initial cooling and to add hardness—in the case of steel or iron, by quenching in water or oil. The casting may be further strengthened by surface compression treatment—like shot peening — that adds resistance to tensile cracking and smooths the rough surface.

2 – 1 – 5 – Design requirements :

The part to be made and its pattern must be designed to accommodate each stage of the process, as it must be possible to remove the pattern without disturbing the molding sand and to have proper locations to receive and position the cores. A slight taper, known as draft, must be used on surfaces perpendicular to the parting line, in order to be able to remove the pattern from the mold. This requirement also applies to cores, as they must be removed from the core box in which they are formed. The sprue and risers must be arranged to allow a proper flow of metal and gasses within the mold in order to avoid an incomplete casting. Should a piece of core or mold become dislodged it may be embedded in the final casting, forming a *sand pit*, which may render the casting unusable. Gas pockets can cause internal voids. These may be immediately visible or may only be revealed after extensive machining has been performed. For critical applications, or where the cost of wasted effort is a factor, non-destructive testing methods may be applied before further work is performed.

3 - Processes :

In general, we can distinguish between two methods of sand casting; the first one using *green sand* and the second being the *air set* method.

3 – 1 – Green sand :

These expendable molds are made of wet sands that are used to make the mold's shape. The name comes from the fact that wet sands are used in the molding process. Green sand is not green in color, but "green" in the sense that it is used in a wet state (akin to green wood). Unlike the name suggests, "green sand" is not a type of sand on its own, but is rather a mixture of:

- silica sand (SiO_2), or chromite sand ($Fe\ Cr_2\ O$) , or zircon sand ($Zr\ Si\ O_4$), 75 to 85 %, or olivine, or staurolite, or graphite.
- bentonite (clay) , 5 to 11 %
- water, 2 to 4 %
- inert sludge 3 to 5 %
- anthracite (0 to 1 %)

There are many recipes for the proportion of clay, but they all strike different balances between mold ability, surface finish, and ability of the hot molten metal to degas. The coal, typically referred to in foundries as sea - coal, which is present at a ratio of less than 5%, partially combusts in the presence of the molten metal leading to offgassing of organic vapors. Green Sand for non-ferrous metals do not use coal additives since the CO created is not effective to prevent oxidation. Green Sand for aluminum typically uses olivine sand (a mixture of the minerals forsterite and fayalite which are made by crushing dunite rock). The choice of sand has a lot to do with the temperature that the metal is poured. At the temperatures that copper and iron are poured, the clay gets inactivated by the heat in that the montmorillonite is converted to illite, which is a non-expanding clay. Most foundries do not have the very expensive equipment to remove the burned out clay and substitute new clay, so instead, those that pour iron typically work with silica sand that is inexpensive compared to the other sands. As the clay is burned out, newly mixed sand is added and some of the old sand is discarded or recycled into other uses. Silica is the least desirable of the sands since metamorphic grains of silica sand have a tendency to explode to form sub-micron sized particles when thermally shocked during pouring of the molds. These particles enter the air of the work area and can lead to silicosis in the workers. Iron foundries spend a considerable effort on aggressive dust collection to capture this fine silica. The sand also has the dimensional instability associated with the conversion of quartz from alpha quartz to beta quartz at 1250 degrees F. Often additives such as wood flour are added to create a space for the grains to expand without deforming the mold. Olivine, Chromite, etc. are used because they do not have a phase conversion that causes rapid expansion of the grains, as well as offering greater density, which cools the metal faster and produces finer grain structures in the metal. Since they are not metamorphic minerals, they do not have the polycrystals found in silica, and subsequently do not form hazardous sub-micron sized particles.

3 – 2 – The "air set" method :

The *air set* method uses dry sand bonded with materials other than clay, using a fast curing adhesive. The latter may also be referred to as no bake mold casting. When these are used, they are collectively called "air set" sand castings to distinguish them from "green sand" castings. Two types of molding sand are natural bonded (bank sand)

and synthetic (lake sand); the latter is generally preferred due to its more consistent composition.

With both methods, the sand mixture is packed around a *pattern*, forming a mold cavity. If necessary, a temporary plug is placed in the sand and touching the pattern in order to later form a channel into which the casting fluid can be poured. Air-set molds are often formed with the help of a two-part mold having a top and bottom part, termed the cope and drag. The sand mixture is tamped down as it is added around the pattern, and the final mold assembly is sometimes vibrated to compact the sand and fill any unwanted voids in the mold. Then the pattern is removed along with the channel plug, leaving the mold cavity. The casting liquid (typically molten metal) is then poured into the mold cavity. After the metal has solidified and cooled, the casting is separated from the sand mold. There is typically no mold release agent, and the mold is generally destroyed in the removal process.[2]

The accuracy of the casting is limited by the type of sand and the molding process. Sand castings made from coarse green sand impart a rough texture to the surface, and this makes them easy to identify. Castings made from fine green sand can shine as cast but are limited by the depth to width ratio of pockets in the pattern. Air-set molds can produce castings with smoother surfaces than coarse green sand but this method is primarily chosen when deep narrow pockets in the pattern are necessary, due to the expense of the plastic used in the process. Air-set castings can typically be easily identified by the burnt color on the surface. The castings are typically shot blasted to remove that burnt color. Surfaces can also be later ground and polished, for example when making a large bell. After molding, the casting is covered with a residue of oxides, silicates and other compounds. This residue can be removed by various means, such as grinding, or shot blasting.

During casting, some of the components of the sand mixture are lost in the thermal casting process. Green sand can be reused after adjusting its composition to replenish the lost moisture and additives. The pattern itself can be reused indefinitely to produce new sand molds. The sand molding process has been used for many centuries to produce castings manually. Since 1950, partially automated casting processes have been developed for production lines.

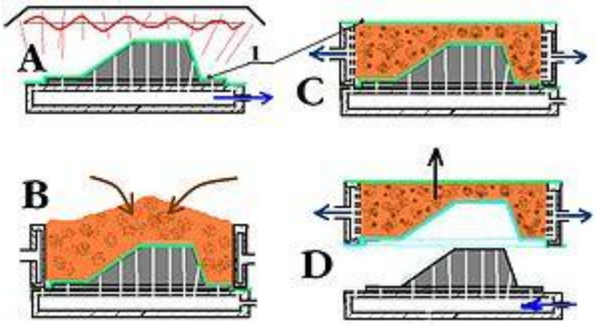
3 – 3 – Cold box :

Uses organic and inorganic binders that strengthen the mold by chemically adhering to the sand. This type of mold gets its name from not being baked in an oven like other sand mold types. This type of mold is more accurate dimensionally than green-sand molds but is more expensive. Thus it is used only in applications that necessitate it.

3 – 4 – No bake molds :

No bake molds are expendable sand molds, similar to typical sand molds, except they also contain a quick-setting liquid resin and catalyst. Rather than being rammed, the molding sand is poured into the flask and held until the resin solidifies, which occurs at room temperature. This type of molding also produces a better surface finish than other types of sand molds . Because no heat is involved it is called a cold-setting process. Common flask materials that are used are wood, metal, and plastic. Common metals cast into no bake molds are brass, iron ferrous, and aluminum alloys.

3 – 5 – Vacuum molding



A schematic of vacuum molding

Vacuum molding (*V - process*) is a variation of the sand casting process for most ferrous and non - ferrous metals , in which un bonded sand is held in the flask with a vacuum. The pattern is specially vented so that a vacuum can be pulled through it. A heat-softened thin sheet (0.003 to 0.008 in (0.076 to 0.20 mm)) of plastic film is draped over the pattern and a vacuum is drawn (200 to 400 mmHg (27 to 53 kPa)). A special vacuum forming flask is placed over the plastic pattern and is filled with a free-flowing sand. The sand is vibrated to compact the sand and a sprue and pouring cup are formed in the cope. Another sheet of plastic is placed over the top of the sand in the flask and a vacuum is drawn through the special flask; this hardens and strengthens the un bonded sand. The vacuum is then released on the pattern and the cope is removed. The drag is made in the same way (without the sprue and pouring cup). Any cores are set in place and the mold is closed. The molten metal is poured while the cope and drag are still under a vacuum, because the plastic vaporizes but the vacuum keeps the shape of the sand while the metal solidifies. When the metal has solidified, the vacuum is turned off and the sand runs out freely, releasing the casting .

The V - process is known for not requiring a draft because the plastic film has a certain degree of lubricity and it expands slightly when the vacuum is drawn in the flask. The process has high dimensional accuracy, with a tolerance of ±0.010 in for the first inch and ±0.002 in/in thereafter. Cross - sections as small as 0.090 in (2.3 mm) are possible. The surface finish is very good, usually between 150 to 125 rms. Other advantages include no moisture related defects, no cost for binders, excellent sand permeability, and no toxic fumes from burning the binders. Finally, the pattern does not wear out because the sand does not touch it. The main disadvantage is that the process is slower than traditional sand casting so it is only suitable for low to medium production volumes; approximately 10 to 15,000 pieces a year. However, this makes it perfect for prototype work, because the pattern can be easily modified as it is made from plastic .

3 – 6 – DISAMATIC :

3 – 7 – Fast mold making processes :

With the fast development of the car and machine building industry the casting consuming areas called for steady higher productivity. The basic process stages of the mechanical molding and casting process are similar to those described under the manual sand casting process. The technical and mental development however was so rapid and profound that the character of the sand casting process changed radically.

3 – 7 – 1 - Mechanized sand molding :

The first mechanized molding lines consisted of sand slingers and/or jolt-squeeze devices that compacted the sand in the flasks. Subsequent mold handling was mechanical using cranes, hoists and straps. After core setting the copes and drags were coupled using guide pins and clamped for closer accuracy. The molds were manually pushed off on a roller conveyor for casting and cooling.

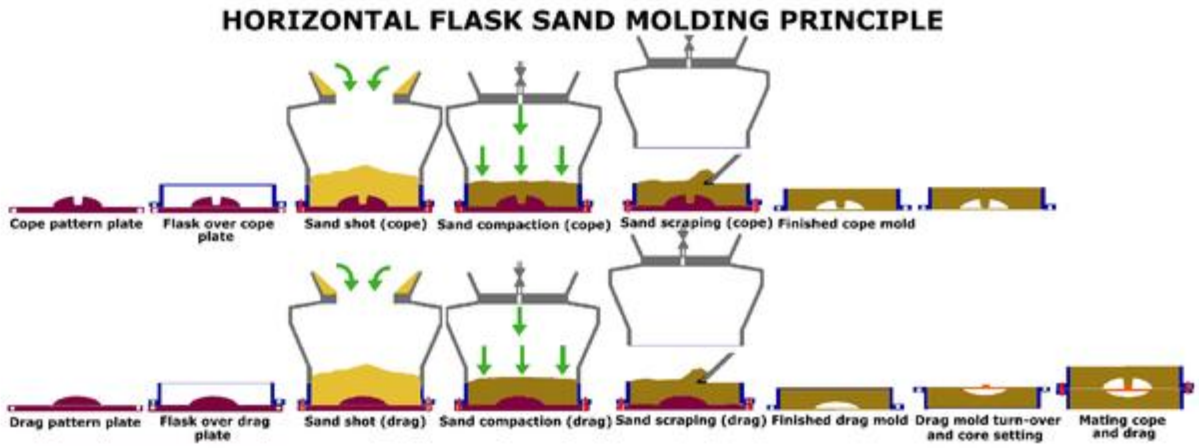
3 – 7 – 2 - Automatic high pressure sand molding lines :

Increasing quality requirements made it necessary to increase the mold stability by applying steadily higher squeeze pressure and modern compaction methods for the sand in the flasks. In early fifties the high pressure molding was developed and applied in mechanical and later automatic flask lines. The first lines were using jolting and vibrations to pre-compact the sand in the flasks and compressed air powered pistons to compact the molds.

3 – 7 – 2 – 1 - Horizontal sand flask molding :

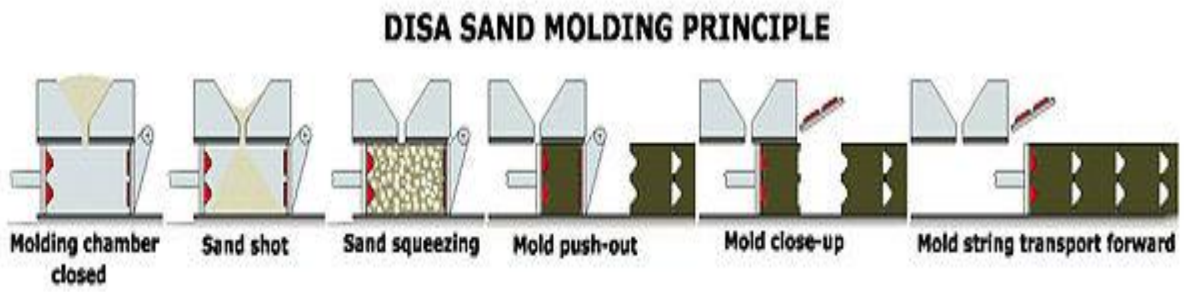
In the first automatic horizontal flask lines the sand was shot or slung down on the pattern in a flask and squeezed with hydraulic pressure of up to 140 bars. The subsequent mold handling including turn-over, assembling, pushing-out on a conveyor were accomplished either manually or automatically. In the late fifties hydraulically powered pistons or multi-piston systems were used for the sand compaction in the flasks. This method produced much more stable and accurate molds than it was possible manually or pneumatically. In the late sixties mold compaction by fast air pressure or gas pressure drop over the pre-compacted sand mold was developed (sand-impulse and gas-impact). The general working principle for most of the horizontal flask line systems is shown on the sketch below.

Today there are many manufacturers of the automatic horizontal flask molding lines. The major disadvantages of these systems is high spare parts consumption due to multitude of movable parts, need of storing, transporting and maintaining the flasks and productivity limited to approximately 90–120 molds per hour.



3 – 7 – 2 – 2 - Vertical sand flask less molding :

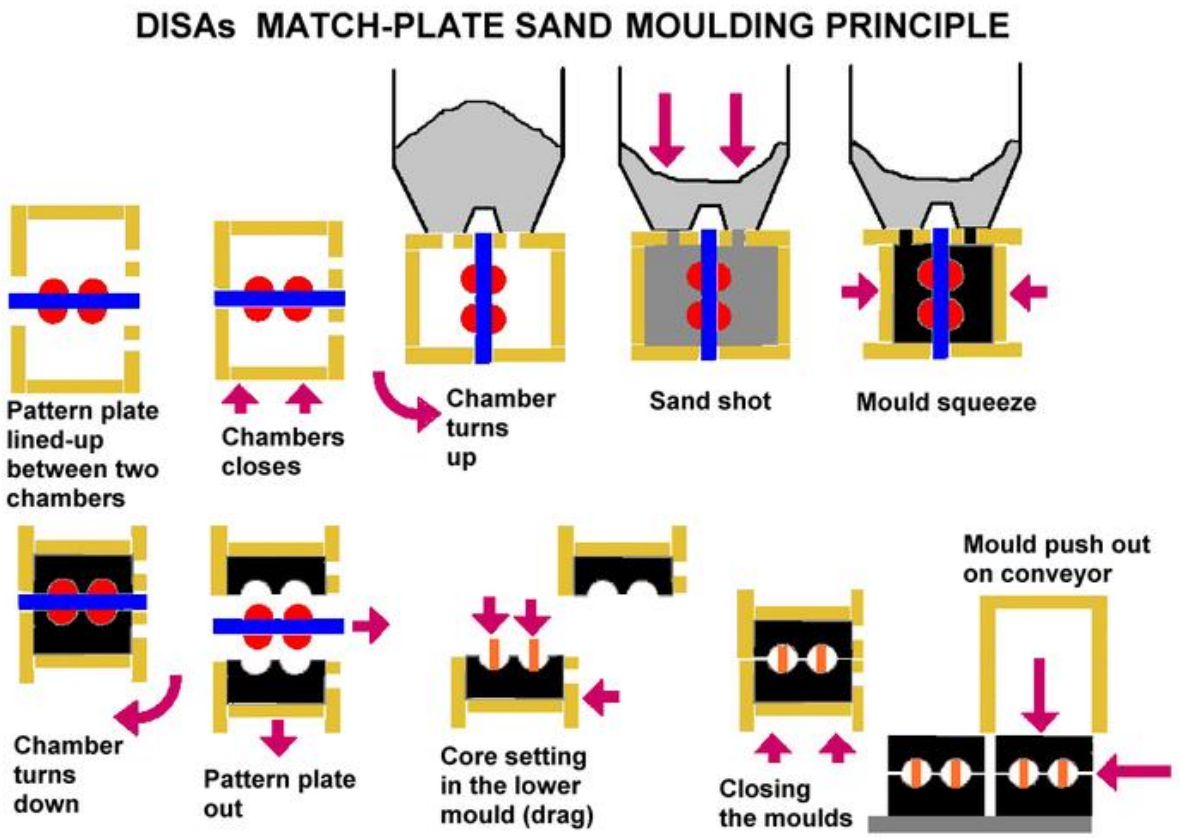
In 1962, Dansk Industry Syndicate A / S (DISA - DISAMATIC) invented a flask-less molding process by using vertically parted and poured molds. The first line could produce up to 240 complete sand molds per hour. Today molding lines can achieve a molding rate of 550 sand molds per hour and requires only one monitoring operator. Maximum mismatch of two mold halves is 0.1 mm (0.0039 in). Although very fast, vertically parted molds are not typically used by jobbing foundries due to the specialized tooling needed to run on these machines. Cores need to be set with a core mask as opposed to by hand and must hang in the mold as opposed to being set on parting surface.



3 – 7 – 2 – 3 - Match plate sand molding :

The principle of the match plate , meaning pattern plates with two patterns on each side of the same plate, was developed and patented in 1910, fostering the perspectives for future sand molding improvements. However, first in the early sixties the American company Hunter Automated Machinery Corporation launched its first automatic flaskless, horizontal molding line applying the matchplate technology.

The method alike to the DISA's (DISAMATIC) vertical moulding is flaskless, however horizontal. The match plate molding technology is today used widely. Its great advantage is inexpensive pattern tooling, easiness of changing the molding tooling, thus suitability for manufacturing castings in short series so typical for the jobbing foundries. Modern match plate molding machine is capable of high molding quality, less casting shift due to machine-mold mismatch (in some cases less than 0.15 mm (0.0059 in)), consistently stable molds for less grinding and improved parting line definition. In addition, the machines are enclosed for a cleaner, quieter working environment with reduced operator exposure to safety risks or service-related problems.



4 – Mold materials :

There are four main components for making a sand casting mold: *base sand*, a *binder*, *additives*, and a *parting compound*.

4 – 1 - Molding sands :

Molding sands, also known as *foundry sands*, are defined by eight characteristics: refractoriness, chemical inertness, permeability, surface finish, cohesiveness, flow ability, collapsibility , and avail ability / cost.

Refractoriness — This refers to the sand's ability to withstand the temperature of the liquid metal being cast without breaking down. For example some sands only need to withstand 650 °C if casting aluminum alloys, whereas steel needs a sand that will withstand 1,500 °C . Sand with too low a refractoriness will melt and fuse to the casting .

Chemical inertness — The sand must not react with the metal being cast. This is especially important with highly reactive metals, such as magnesium and titanium.

Permeability — This refers to the sand's ability to exhaust gases. This is important because during the pouring process many gases are produced, such as hydrogen, nitrogen, carbon dioxide, and steam, which must leave the mold otherwise casting defects, such as blow holes and gas holes, occur in the casting. Note that for each cubic centimeter (cc) of water added to the mold 16,000 cc of steam is produced.

Surface finish — The size and shape of the sand particles defines the best surface finish achievable, with finer particles producing a better finish. However, as the particles become finer (and surface finish improves) the permeability becomes worse.

Cohesiveness (or **bond**) — This is the ability of the sand to retain a given shape after the pattern is removed.

Flow ability – The ability for the sand to flow into intricate details and tight corners without special processes or equipment.

Collapsibility — This is the ability of the sand to be easily stripped off the casting after it has solidified. Sands with poor collapsibility will adhere strongly to the casting. When casting metals that contract a lot during cooling or with long freezing temperature ranges a sand with poor collapsibility will cause cracking and hot tears in the casting. Special additives can be used to improve collapsibility.

Availability / cost — The availability and cost of the sand is very important because for every ton of metal poured, three to six tons of sand is required . Although sand can be screened and reused, the particles eventually become too fine and require periodic replacement with fresh sand .

In large castings it is economical to use two different sands, because the majority of the sand will not be in contact with the casting, so it does not need any special properties. The sand that is in contact with the casting is called *facing sand*, and is designed for the casting on hand. This sand will be built up around the pattern to a thickness of 30 to 100 mm (1.2 to 3.9 in). The sand that fills in around the facing sand is called *backing sand*. This sand is simply silica sand with only a small amount of binder and no special additives.

4 – 1 – 1 – Types of base sands :

Base sand is the type used to make the mold or core without any binder. Because it does not have a binder it will not bond together and is not usable in this state.

4 – 1 – 1 – 1 - Silica sand :

Silica (SiO_2) sand is the sand found on a beach and is also the most commonly used sand. It is made by either crushing sandstone or taken from natural occurring locations, such as beaches and river beds. The fusion point of pure silica is 1,760 °C , however the sands used have a lower melting point due to impurities. For high melting point casting, such as steels, a minimum of 98 % pure silica sand must be used; however for lower melting point metals, such as cast iron and non-ferrous metals, a lower purity sand can be used (between 94 and 98 % pure) .

Silica sand is the most commonly used sand because of its great abundance, and, thus, low cost (therein being its greatest advantage). Its disadvantages are high thermal expansion, which can cause casting defects with high melting point metals, and low thermal conductivity, which can lead to unsound casting. It also cannot be used with certain basic metal because it will chemically interact with the metal forming surface defect. Finally, it causes silicosis in foundry workers.

4 – 1 – 1 – 2 - Olivine sand

Olivine is a mixture of ortho silicates of iron and magnesium from the mineral dunite. Its main advantage is that it is free from silica, therefore it can be used with basic metals, such as manganese steels. Other advantages include a low thermal expansion, high thermal conductivity, and high fusion point. Finally, it is safer to use than silica, therefore it is popular in Europe.

4 – 1 – 1 – 3 - Chromite sand :

Chromite sand is a solid solution of spinels. Its advantages are a low percentage of silica, a very high fusion point 1,850 °C . and a very high thermal conductivity. Its disadvantage is its costliness, therefore its only used with expensive alloy steel casting and to make cores.

4 – 1 – 1 – 4 - Zircon sand :

Zircon sand is a compound of approximately two-thirds zircon oxide (Zr_2O) and one-third silica. It has the highest fusion point of all the base sands at 2,600 °C , a very low thermal expansion, and a high thermal conductivity. Because of these good properties it is commonly used when casting alloy steels and other expensive alloys. It is also used as a mold wash (a coating applied to the molding cavity) to improve surface finish. However, it is expensive and not readily available.

4 – 1 – 1 – 5 - Chamotte sand :

Chamotte is made by calcining fire clay (Al_2O_3-SiO_2) above 1,100 °C . Its fusion point is 1,750 °C and has low thermal expansion. It is the second cheapest sand, however it is still twice as expensive as silica. Its disadvantages are very coarse grains, which result in a poor surface finish, and it is limited to dry sand molding. Mold washes are used to overcome the surface finish problem. This sand is usually used when casting large steel work pieces .

4 – 2 – 1 – Other materials :

Modern casting production methods can manufacture thin and accurate molds — of a material superficially resembling papier-mâché, such as is used in egg cartons, but that is refractory in nature — that are then supported by some means, such as dry sand surrounded by a box, during the casting process. Due to the higher accuracy it is possible to make thinner and hence lighter castings, because extra metal need not be present to allow for variations in the molds. These thin-mold casting methods have been used since the 1960s in the manufacture of cast-iron engine blocks and cylinder heads for automotive applications .

4 – 2 - Binders :

Binders are added to a base sand to bond the sand particles together (i.e. it is the glue that holds the mold together).

4 – 2 - 1 - Clay and water :

A mixture of clay and water is the most commonly used binder. There are two types of clay commonly used: bentonite and kaolinite, with the former being the most common.

4 – 2 - 2 – Oil :

Oils, such as linseed oil, other vegetable oils and marine oils, used to be used as a binder, however due to their increasing cost, they have been mostly phased out. The oil also required careful baking at 100 to 200 °C to cure (if overheated the oil becomes brittle, wasting the mold).

4 – 2 - 3 – Resin :

Resin binders are natural or synthetic high melting point gums. The two common types used are urea formaldehyde (UF) and phenol formaldehyde (PF) resins. PF resins have a higher heat resistance than UF resins and cost less. There are also cold-set resins, which use a catalyst instead of a heat to cure the binder. Resin binders are quite popular because different properties can be achieved by mixing with various additives. Other advantages include good collapsibility, low gassing, and they leave a good surface finish on the casting.

MDI (methylene di phenyl di iso cyanate) is also a commonly used binder resin in the foundry core process.

4 – 2 - 4 - Sodium silicate :

Sodium silicate [Na_2SiO_3 or $(Na_2O)(SiO_2)$] is a high strength binder used with silica molding sand. To cure the binder carbon dioxide gas is used, which creates the following reaction:

$$Na_2O(SiO_2) + CO_2 \rightleftharpoons Na_2CO_3 + 2SiO_2 + Heat$$

The advantage to this binder is that it occurs at room temperature and quickly. The disadvantage is that its high strength leads to shakeout difficulties and possibly hot tears in the casting.

4 – 3 – Additives :

Additives are added to the molding components to improve: surface finish, dry strength, refractoriness, and "cushioning properties".

Up to 5 % of *reducing agents*, such as coal powder, pitch, creosote, and fuel oil, may be added to the molding material to prevent wetting (prevention of liquid metal sticking to sand particles, thus leaving them on the casting surface), improve surface finish, decrease metal penetration, and burn-on defects. These additives achieve this by creating gases at the surface of the mold cavity, which prevent the liquid metal from adhering to the sand. Reducing agents are not used with steel casting, because they can carburize the metal during casting.

Up to 3 % of "cushioning material", such as wood flour, saw dust, powdered husks, peat, and straw, can be added to reduce scabbing, hot tear, and hot crack casting defects when casting high temperature metals. These materials are beneficial because burn-off when the metal is poured creating voids in the mold, which allow it to expand. They also increase collapsibility and reduce shakeout time.[17]

Up to 2% of *cereal binders*, such as dextrin, starch, sulphite lye, and molasses, can be used to increase dry strength (the strength of the mold after curing) and improve surface finish. Cereal binders also improve collapsibility and reduce shakeout time because they burn-off when the metal is poured. The disadvantage to cereal binders is that they are expensive.

Up to 2 % of iron oxide powder can be used to prevent mold cracking and metal penetration, essentially improving refractoriness. Silica flour (fine silica) and zircon flour also improve refractoriness, especially in ferrous castings. The disadvantages to these additives is that they greatly reduce permeability.

4 – 4 - Parting compounds :

To get the pattern out of the mold, prior to casting, a parting compound is applied to the pattern to ease removal. They can be a liquid or a fine powder (particle diameters between 75 and 150 micro meters (0.0030 and 0.0059 in)). Common powders include talc, graphite, and dry silica; common liquids include mineral oil and water-based silicon solutions. The latter are more commonly used with metal and large wooden patterns.

5 - History :

In 1924, the Ford automobile company set a record by producing 1 million cars, in the process consuming one-third of the total casting production in the U.S. As the automobile industry grew the need for increased casting efficiency grew. The increasing demand for castings in the growing car and machine building industry during and after World War I and World War II, stimulated new inventions in mechanization and later automation of the sand casting process technology.

There was not one bottle neck to faster casting production but rather several. Improvements were made in molding speed, molding sand preparation, sand mixing, core manufacturing processes, and the slow metal melting rate in cupola furnaces. In 1912, the sand slinger was invented by the American company Beardsley & Piper. In 1912, the first sand mixer with individually mounted revolving plows was marketed by the Simpson Company. In 1915, the first experiments started with bentonite clay instead of simple fire clay as the bonding additive to the molding sand. This increased tremendously the green and dry strength of the molds. In 1918, the first fully automated foundry for fabricating hand grenades for the U.S. Army went into production. In the 1930s the first high - frequency coreless electric furnace was installed in the U.S. In 1943, ductile iron was invented by adding magnesium to the widely used grey iron. In 1940, thermal sand reclamation was applied for molding and core sands. In 1952, the "D-process" was developed for making shell molds with fine, pre-coated sand. In 1953, the hotbox core sand process in which the cores are thermally cured was invented. In 1954, a new core binder - water glass (sodium silicate) hardened with CO_2 from

Sand Jacking

1 – Introduction :

Sand jacking is the process of lifting concrete and filling in the space underneath with sand, which allows for frugal repairs in concrete applications.[1] The basic premise is to lift concrete and to then fill the resultant void absolutely with compacted sand. Sand jacking includes the careful assessment of what is required to restore concrete to its original profile and the intelligent application of different materials to keep it that way. The filling provides the long term repair and protection of any flat concrete surface. Since the lifting and filling processes are distinctly separate events, each can be accomplished precisely.

2 - Overview :

The lifting process can utilize many different techniques, depending upon situational variables. The filling process uses compressed air to blow dry sand into any existing voids. The sand travels through hoses and nozzles to the void and deposits continuously. The sand travels wherever the air goes. It gradually loses momentum and deposits, nestling in with other grains of sand at 99 - 100 % density (Midwest Testing). The filling can be performed from the surface of the slab or from the side of the slab if available.

Separating the fill process from the lifting process is crucial in this system. After the void is filled with sand, the lift occurs. The concrete is lifted about ½ - ¾ inches and the filling process resumes. When the void is full the process starts again with the lift and repeating the iterations as many times as is necessary.

The benefit of sand jacking is the control of moisture. There are more voids under concrete than the average person would presume. Any void will acquire moisture, subjecting the slab to endless wet-dry cycles (freeze-thaw in colder climates). If the voids are full of sand, water can't accumulate in sufficient quantity to be destructive. Moisture in the lifting process is also undesirable; the only way to reduce it is to reduce the quantity of lifting material. It's important to fill first, then lift – creating a new void which is then filled with sand through the same hole. Since dry material will blow greater distances the holes required are few. Another benefit of the process is no point loading and the entire lift is gentle on the slab.

Sand Molding

1 – Introduction :

Molding sand, also known as **foundry sand**, is sand that when moistened or oiled tends to pack well and hold its shape. It is used in the process of sand casting.

2 - Green sand :

Green sand is an aggregate of sand, bentonite clay, pulverized coal and water. Its principal use is in making molds for metal casting. The largest portion of the aggregate is always sand, which can be either silica or olivine. There are many recipes for the proportion of clay, but they all strike different balances between moldability, surface finish, and ability of the hot molten metal to degas. The coal, typically referred to in foundries as sea-coal, which is present at a ratio of less than 5%, partially combusts in the presence of the molten metal leading to off gassing of organic vapors.

Sand casting is one of the earliest forms of casting practiced due to the simplicity of materials involved. It still remains one of the cheapest ways to cast metals because of that same simplicity. Other methods of casting, such as those using shell molds boast higher quality of surface finish, but higher cost.

Green sand (and other casting sands) is usually housed in what casters refer to as flasks which are nothing other than boxes without a bottom or lid. The box is split into two halves which are stacked together in use. The halves are referred to as the top (cope) and bottom (drag) flask respectively.

Green sand is not green in color, but "green" in the sense that it is used in a wet state (akin to green wood). According to the Cast Metals Federation website, an alternative casting method is to heat-dry the molded sand before pouring the molten metal. This dry sand casting process results in a more rigid mold better suited to heavier castings.

Saturated – Surface - Dry

Saturated surface dry (SSD) is defined as the condition of an aggregate in which the surfaces of the particles are "saturated" (*i.e.*, surface adsorption would no longer take place), but the inter-particle voids are otherwise dry. In this condition aggregates will not affect the free water content of a composite material.

If the mass of an oven dried test sample (M_{dry}) is compared to the mass of a saturated-surface-dry (M_{ssd}) sample, the water adsorption (A) can be calculated:

$$A = \frac{M_{ssd} - M_{dry}}{M_{dry}}$$

Self - Consolidating Concrete

1 – Introduction :

Self - consolidating concrete or **self - compacting concrete** (SCC) is characterized by a low yield, high deformability, and moderate viscosity necessary to ensure uniform suspension of solid particles during transportation, placement (without external compaction), and thereafter until the concrete sets.

Such concrete can be used for casting heavily reinforced sections, places where there can be no access to vibrators for compaction and in complex shapes of formwork which may otherwise be impossible to cast, giving a far superior surface than conventional concrete. SCC was conceptualized in 1986 by Prof. Okamura at Ouchi University, Japan.

The first generation of SCC used in North America was characterized by the use of relatively high content of binder as well as high dosages of chemicals admixtures, usually super plasticizer to enhance flowability and stability. Such high - performance concrete had been used mostly in repair applications and for casting concrete in restricted areas. The first generation of SCC was therefore characterized and specified for specialized applications.

The relatively high cost of material used in such concrete continues to hinder its widespread use in various segments of the construction industry, including commercial construction, however the productivity economics take over in achieving favorable performance benefits and works out to be economical in pre-cast industry. The incorporation of powder, including supplementary cementitious materials and filler, can increase the volume of the paste, hence enhancing deformability, and can also increase the cohesiveness of the paste and stability of the concrete. The reduction in cement content and increase in packing density of materials finer than 80 µm, like fly ash etc. can reduce the water - cement ratio, and the high-range water reducer (HRWR) demand. The reduction in free water can reduce the concentration of viscosity-enhancing admixture

(VEA) necessary to ensure proper stability during casting and thereafter until the onset of hardening. It has been demonstrated that a total sand content of about 50 % of total aggregate is favorable in designing for SCC.

The major breakthrough in SCC technology came with the advent of third generation poly - carboxylic ether based polymers, used as admixtures. The further developments were subsequent with introduction of VEA, to improve stability without undue increase in binder, which could cause plastic shrinkage of concrete.

Self - Drying Concrete Technology

1 – Introduction :

Self - drying concrete technology is found in certain cementitious patching and leveling materials and tile-setting mortars used in the flooring industry. Self-drying technology allows the cement mix to consume all of its mix water while curing, eliminating the need for excess water to evaporate prior to installing flooring. Traditional floor coverings, such as VCT, sheet vinyl, carpet and ceramic tile, can be installed before the material is completely dry and as soon as it hardens, which typically happens in the first two hours after placement.

Traditional concrete has a water : cement ratio of about 0.5, which refers to the weight of the water divided by the weight of the cement. A water : cement ratio of 0.5 provides good workability while keeping the amount of excess water in the mix fairly low. Without at least this much extra water, the concrete would be too dry to place.

The chemical reaction of Portland cement and water that is known as hydration, which is necessary for the strengthening of the concrete, requires a water : cement ratio of only about 0.25. With a water : cement ratio of 0.5, there is twice the amount of water in the concrete mix than what is needed for hydration. This excess water needs to evaporate before flooring can be installed, which typically takes 28 days. Conversely, a self-drying concrete blend consumes all of its mix water with a water : cement ratio of up to 0.6, maintaining good workability while allowing flooring to be installed before it is completely dry.

There are also cement products that are partially self-drying, meaning that they use a high percentage of their mix water for hydration as opposed to using 100% of it. This type of product might be used when the flooring does not need to be installed the same day but must still be installed more quickly than traditional concrete would allow. For instance, products that are 80 % self - drying allow flooring to be installed the next day, typically after a 16- hour cure.

Self - Leveling Concrete

1 – Introduction :

Self - leveling concrete is polymer-modified cement that has high flow characteristics and, in contrast to traditional concrete, does not require the addition of excessive amounts of water for placement. Self-leveling concrete is typically used to create a flat and smooth surface with a compressive strength similar to or higher than that of traditional concrete prior to installing interior floor coverings. Self-leveling concrete has increased in popularity as the degree of flatness and smoothness required for floor covering products has increased, with vinyl goods getting thinner and floor tiles getting larger, for example.

2 – History :

The term self - leveling was coined in the United States by ARDEX, Inc. in 1978 in reference to their first self - leveling product, ARDEX K 15 Premium Self-Leveling Concrete Underlayment. The term was used to differentiate it from traditional concrete, which is typically stiffer and requires more labor to get it into place and finish with a trowel.

3 – Application :

In the category of self - leveling concrete there are two main groups of materials: underlayment's and toppings . Underlayment's are installed over an existing subfloor to smooth it out and correct any surface irregularities prior to the installation of all types of floor coverings, including sheet vinyl, vinyl composition tile (VCT), wood, ceramic tile and carpet. Toppings perform a similar function but act as the actual finished floor without the need for a floor covering. Some typical applications for concrete toppings include warehouse floors, light industrial applications, retail stores and institutional facilities. Concrete toppings can also receive pigmented color dyes, stains, saw cuts or mechanical polishing to produce a decorative concrete finished wear surface.

When self-leveling concrete is poured, it has a viscosity similar to pancake batter. A gauge rake is used to move it into place without spreading it too thin. The finishing is then done by lightly breaking the surface tension of the product using a tool called a smoother. The polymers in the self-leveling mix keep the viscosity of the product such that it remains uniform in composition from top to bottom without the sand aggregates sinking to the bottom of the installed layer. The typical installation thickness of these products is about 0.25 inches to ensure there is enough mass present for the material to flow, although some self-leveling products now exist that can be installed at an average thickness of only 0.125 inches.

Serpentinite

	
Sample of serpentinite from the Golden Gate National Recreation Area, California, USA	*A sample of serpentinite rock, partially made up of chrysotile*

Contents

1 - Introduction :

Serpentinite is a rock composed of one or more serpentine group minerals. Minerals in this group are formed by **serpentinization**, a hydration and metamorphic transformation of ultramafic rock from the Earth's mantle. The alteration is particularly important at the sea floor at tectonic plate boundaries.

2 - Formation and petrology :

Serpentinization is a geological low-temperature metamorphic process involving heat and water in which low-silica mafic and ultramafic rocks are oxidized (anaerobic oxidation of Fe^{2+} by the protons of water leading to the formation of H_2) and hydrolyzed with water into serpentinite. Peridotite, including dunite, at and near the seafloor and in mountain belts is converted to serpentine, brucite, magnetite, and other minerals — some rare, such as awaruite (Ni_3Fe), and even native iron. In the process large amounts of water are absorbed into the rock increasing the volume and destroying the structure.[1]

The density changes from 3.3 to 2.7 g/cm^3 with a concurrent volume increase of about 40 %. The reaction is exothermic and large amounts of heat energy are produced in the process.[1]

Rock temperatures can be raised by about 260 °C,[1] providing an energy source for formation of non-volcanic hydrothermal vents. The magnetite-forming chemical reactions produce hydrogen gas under anaerobic conditions prevailing deep in the mantle, far from the Earth atmosphere. Carbonates and sulfates are subsequently reduced by hydrogen and form methane and hydrogen sulfide. The hydrogen, methane, and hydrogen sulfide provide energy sources for deep sea chemotroph micro organisms.

2 - 1 - Serpentinite reactions :

Serpentinite is formed from olivine via several reactions, some of which are complementary. Olivine is a solid solution between the magnesium- end member forsterite and the iron- end member fayalite. Serpentinite reactions 1a and 1b, below, exchange silica between forsterite and fayalite to form serpentine group minerals and magnetite. These are highly exothermic reactions.

Reaction 1a:

Fayalite + water → magnetite + aqueous silica + hydrogen

$$3Fe_2SiO_4 + 2H_2O \rightarrow 2Fe_3O_4 + 3SiO_2 + 2H_2$$

Reaction 1b:

Forsterite + aqueous silica → serpentine

$$3Mg_2SiO_4 + SiO_2 + 4H_2O \rightarrow 2Mg_3Si_2O_5(OH)_4$$

Reaction 1c:

Forsterite + water → serpentine + brucite

$$2Mg_2SiO_4 + 3H_2O \rightarrow Mg_3Si_2O_5(OH)_4 + Mg(OH)_2$$

Reaction 1c describes the hydration of olivine with water only to yield serpentine and $Mg(OH)_2$ (brucite). Serpentine is stable at high pH in the presence of brucite like calcium silicate hydrate, (C-S-H) phases formed along with portlandite ($Ca(OH)_2$) in hardened Portland cement paste after the hydration of belite (Ca_2SiO_4), the artificial calcium equivalent of forsterite.

Analogy of reaction 1c with belite hydration in ordinary Portland cement :

Belite + water → C-S-H phase + portlandite

$$2\ Ca_2SiO_4 + 4\ H_2O \rightarrow 3\ CaO \cdot 2\ SiO_2 \cdot 3\ H_2O + Ca(OH)_2$$

After reaction, the poorly soluble reaction products (aqueous silica or dissolved magnesium ions) can be transported in solution out of the serpentinized zone by diffusion or advection.

A similar suite of reactions involves pyroxene-group minerals, though less readily and with complication of the additional end-products due to the wider compositions of pyroxene and pyroxene-olivine mixes. Talc and magnesian chlorite are possible products, together with the serpentine minerals antigo rite, lizardite, and chrysotile. The final mineralogy depends both on rock and fluid compositions, temperature, and pressure. Antigo rite forms in reactions at temperatures that can exceed 600°C during metamorphism, and it is the serpentine group mineral stable at the highest temperatures. Lizardite and chrysotile can form at low temperatures very near the Earth's surface. Fluids involved in serpentinite formation commonly are highly reactive and may transport calcium and other elements into surrounding rocks; fluid reaction with these rocks may create meta somatic reaction zones enriched in calcium and called rodingites.

In the presence of carbon dioxide, however, serpentinitization may form either magnesite ($MgCO_3$) or generate methane (CH_4). It is thought that some hydrocarbon gases may be produced by serpentinite reactions within the oceanic crust.

Reaction 2a :

Olivine + water + carbonic acid → serpentine + magnetite + methane

$$\mathrm{(Fe, Mg)_2SiO_4 + nH_2O + CO_2 \rightarrow Mg_3Si_2O_5(OH)_4 + Fe_3O_4 + CH_4}$$

or, in balanced form:

$$\mathrm{18Mg_2SiO_4 + 6Fe_2SiO_4 + 26H_2O + CO_2 \rightarrow 12Mg_3Si_2O_5(OH)_4 + 4Fe_3O_4 + CH_4}$$

Reaction 2b:

Olivine + water + carbonic acid → serpentine + magnetite + magnesite + silica

$$\mathrm{(Fe, Mg)_2SiO_4 + nH_2O + CO_2 \rightarrow Mg_3Si_2O_5(OH)_4 + Fe_3O_4 + MgCO_3 + SiO_2}$$

Reaction 2a is favored if the serpentinite is Mg-poor or if there isn't enough carbon dioxide to promote talc formation. Reaction 2b is favored in highly magnesium compositions and low partial pressure of carbon dioxide.

The degree to which a mass of ultramafic rock undergoes serpentinisation depends on the starting rock composition and on whether or not fluids transport calcium, magnesium and other elements away during the process. If an olivine composition contains sufficient fayalite, then olivine plus water can completely metamorphose to serpentine and magnetite in a closed system. In most ultramafic rocks formed in the Earth's mantle, however, the olivine is about 90 % forsterite end member, and for that olivine to react completely to serpentine, magnesium must be transported out of the reacting volume.

Serpentinitization of a mass of peridotite usually destroys all previous textural evidence because the serpentine minerals are weak and behave in a very ductile fashion. However, some masses of serpentinite are less severely deformed, as evidenced by the apparent preservation of textures inherited from the peridotite, and the serpentinites may have behaved in a rigid fashion.

2 - 2 - Hydrogen production by anaerobic oxidation of fayalite ferrous ions :

In the absence of atmospheric oxygen (O_2), in deep geological conditions prevailing far away from Earth atmosphere, hydrogen (H_2) is produced by the anaerobic oxidation of ferrous ions (Fe^{2+}) present in the crystal lattice of the iron – end member fayalite by the protons (H^+) of water.

Considering three formula units of fayalite ($Fe_2(SiO_4)$) for the purpose of stoichiometry and reaction mass balance, four ferrous ions will undergo oxidation by water protons while the two remaining will stay un oxidized. Neglecting the ortho silicate anions not involved in the redox process, it is then possible to schematically write the two half-redox reactions as follows:

$4\ (Fe^{2+} \rightarrow Fe^{3+} + e^-)$ (oxidation of ferrous ions)
$2\ (H_2O + 2\ e^- \rightarrow O^{2-} + H_2)$ (reduction of protons into hydrogen)

This leads to the global redox reaction involving ferrous ions oxidation by water:

$$4\ Fe^{2+} + 2\ H_2O \rightarrow 4\ Fe^{3+} + 2\ O^{2-} + 2\ H_2$$

The two un oxidized ferrous (Fe^{2+}) ions still available in the three formula units of fayalite finally combine with the four ferric

(Fe^{3+}) cations and oxide anions (O^{2-}) to form two formula units of magnetite (Fe_3O_4).

Finally, considering the required rearrangement of the ortho silicate anions into free silica (SiO_2) and free oxide anions (O^{2-}), it is possible to write the complete reaction of anaerobic oxidation and hydrolysis of fayalite according to the following mass balance:

$$3\ Fe_2SiO_4 + 2\ H_2O \rightarrow 2\ Fe_3O_4 + 3\ SiO_2 + 3\ H_2$$

fayalite + water → magnetite + quartz + hydrogen

This reaction closely resembles the Schikorr reaction observed in the anaerobic oxidation of the ferrous hydroxide in contact with water:

$$3\ Fe(OH)_2 \rightarrow Fe_3O_4 + 2\ H_2O + H_2$$

ferrous hydroxide → magnetite + water + hydrogen

2 - 3 - Abiotic methane production on Mars by serpentinization :

The presence of traces of methane in the atmosphere of Mars has been hypothesized to be a possible evidence for life on Mars if methane was produced by bacterial activity. Serpentinization has been proposed as an alternative non-biological source for the observed methane traces.

3 - Impact on agriculture :

Soil cover over serpentinite bedrock tends to be thin or absent. Soil with serpentine is poor in calcium and other major plant nutrients, but rich in elements toxic to plants such as chromium and nickel.

4 - Uses for serpentinite :

4 - 1 - Decorative stone in architecture :

Grades of serpentinite higher in calcite, along with the breccia form of serpentinite, have historically been used as decorative stones for their marble-like qualities. Popular sources in Europe before contact with the New World were the mountainous Piedmont region of Italy and Larissa, Greece.

4 - 2 - Carving stone Tools, Oil lamp-known as the Qulliq and Inuit Sculpture :

Inuit and Aboriginal Peoples of the Arctic Areas and less so of southern areas used the carved bowl shaped serpentinite Qulliq or Kudlik lamp with wick, to burn oil or fat to heat, make light and cook with. Inuit made tools and more recently carvings of animals for commerce.

4 - 3 - Swiss oven stone :

A variety of chlorite talc schist associated with Alpine serpentinite is found in Val d' Anniviers , Switzerland and was used as *oven stone* in stove construction.

4 - 4 - Neutron shield in nuclear reactors :

Serpentinite has a significant amount of bound water, hence it contains abundant hydrogen atoms able to slow down neutrons by elastic collision (neutron thermalization process). Because of this serpentinite can be used as dry filler inside steel jackets in some designs of nuclear reactors. For example in RBMK series it was used for top radiation shielding to protect operators from escaping neutrons.[9] Serpentine can also be added as aggregate to special concrete used in nuclear reactor shielding to increase the concrete density (2.6 g cm^{-3}) and its neutron capture cross section.

Silica Aero gel

A 2.5 kg brick is supported by a piece of aero gel with a mass of only 2 grams.

Contents

1 – Introduction :

Aero gel is a synthetic porous material derived from a gel, in which the liquid component of the gel has been replaced with a gas. The result is a solid with extremely low density and thermal conductivity. It is nicknamed **frozen smoke**, **solid smoke**, **solid air** or **blue smoke** owing to its translucent nature and the way light scatters in the material; however, it feels like expanded poly styrene (styro foam) to the touch.

Aerogel was first created by Samuel Stephens Kistler in 1931, as a result of a bet with Charles Learned over who could replace the liquid in "jellies" with gas without causing shrinkage .

Aerogels are produced by extracting the liquid component of a gel through supercritical drying. This allows the liquid to be slowly drawn off without causing the solid matrix in the gel to collapse from capillary action, as would happen with conventional evaporation. The first aerogels were produced from silica gels. Kistler's later work involved aerogels based on alumina, chromia and tin dioxide. Carbon aerogels were first developed in the late 1980s .

2 – Properties :

A flower is on a piece of aero gel which is suspended over a Bunsen burner. Aerogel has excellent insulating properties, and the flower is protected from the flame.

Despite their name, aero gels are rigid, dry materials and do not resemble a gel in their physical properties; the name comes from the fact that they are derived from gels. Pressing softly on an aerogel typically does not leave a mark; pressing more firmly will leave a permanent depression. Pressing firmly enough will cause a catastrophic breakdown in the sparse structure, causing it to shatter like glass – a property known as *friability*; although more modern variations do not suffer from this. Despite the fact that it is prone to shattering, it is very strong structurally. Its impressive load bearing abilities are due to the dendritic microstructure, in which spherical particles of average size 2–5 nm are fused together into clusters. These clusters form a three-dimensional highly porous structure of almost fractal chains, with pores just under 100 nm. The average size and density of the pores can be controlled during the manufacturing process.

Aerogels are good thermal insulators because they almost nullify the three methods of heat transfer (convection, conduction, and radiation). They are good conductive insulators because they are composed almost entirely from a gas, and gases are very poor heat conductors. Silica aerogel is especially good because silica is also a poor conductor of heat (a metallic aero gel , on the other hand, would be less effective). They are good convective inhibitors because air cannot circulate through the lattice.

Owing to its hygroscopic nature, aero gel feels dry and acts as a strong desiccant. Persons handling aero gel for extended periods should wear gloves to prevent the appearance of dry brittle spots on their skin.

The slight color it does have is due to Rayleigh scattering of the shorter wavelengths of visible light by the nano sized dendritic structure. This causes it to appear smoky blue against dark backgrounds and yellowish against bright backgrounds.

Aerogels by themselves are hydrophilic, but chemical treatment can make them hydrophobic. If they absorb moisture they usually suffer a structural change, such as contraction, and deteriorate, but degradation can be prevented by making them hydrophobic. Aerogels with hydrophobic interiors are less susceptible to degradation than aerogels with only an outer hydrophobic layer, even if a crack penetrates the surface. Hydrophobic treatment facilitates processing because it allows the use of a water jet cutter.

3 – Types :

3 – 1 – Silica :

Peter Tsou with a sample of aero gel at Jet Propulsion Laboratory, California Institute of Technology

Silica aerogel is the most common type of aerogel and the most extensively studied and used. It is a silica-based substance, derived from silica gel. The lowest-density aerogel is a silica nano foam at 1 mg / cm^3, which is the evacuated version of the record-aerogel of 1.9 mg / cm^3. The density of air is 1.2 mg / cm^3 (at 20 °C and 1 atm). Only the recently manufactured metallic micro lattices have a lower density at 0.9 mg/cm^3. By convention, the mass of air is excluded when the micro lattice density is calculated. Allowing for the mass of the interstitial air, the true, un evacuated density of the micro lattice is approximately 2.1 mg/cm^3 (2.1 kg / m^3).

Silica aerogel strongly absorbs infrared radiation. It allows the construction of materials that let light into buildings but trap heat for solar heating.

It has remarkable thermal insulative properties, having an extremely low thermal conductivity : from 0.03 W/m·K down to 0.004 W / m·K , which correspond to R-values of 14 to 105 (US customary) or 3.0 to 22.2 (metric) for 3.5 in (89 mm) thickness. For comparison, typical wall insulation is 13 (US Customary) or 2.7 (Metric) for the same thickness. Its melting point is 1,200 °C .

By 2011, silica aero gel held 15 entries in *Guinness World Records* for material properties, including best insulator and lowest-density solid, though it was recently ousted from the latter title by the even lighter material, aero graphite.

3 – 2 – Carbon :

Carbon aerogels are composed of particles with sizes in the nano meter range, covalently bonded together. They have very high porosity (over 50 %, with pore diameter under 100 nm) and surface areas ranging between 400 –1,000 m^2 / g . They are often manufactured as composite paper: non - woven paper made of carbon fibers, impregnated with resorcinol – formaldehyde aerogel, and pyrolyzed. Depending on the density, carbon aerogels may be electrically conductive, making composite aerogel paper useful for electrodes in capacitors or deionization electrodes. Due to their extremely high surface area, carbon aerogels are used to create super capacitors, with values ranging up to thousands of farads based on a capacitance of 104 F / g and 77 F / cm^3. Carbon aerogels are also extremely "black" in the infrared spectrum, reflecting only 0.3% of radiation between 250 nm and 14.3 µm, making them efficient for solar energy collectors.

The term "aero gel" has been incorrectly used to describe airy masses of carbon nano tubes produced through certain chemical vapor deposition techniques – such materials can be spun into fibers with strength greater than Kevlar, and unique electrical properties. These materials are not aero gels, however, since they do not have a monolithic internal structure and do not have the regular pore structure characteristic of aero gels.

3 – 3 - Alumina :

Aero gels made with aluminium oxide are known as alumina aero gels. These aero gels are used as catalysts, especially when "doped" with a metal different from Al. Nickel–alumina aero gel is the most common combination. Alumina aero gels are also being considered by NASA for capturing of hypervelocity particles; a formulation doped with gadolinium and terbium could fluoresce at the particle impact site, with amount of fluorescence dependent on impact energy.

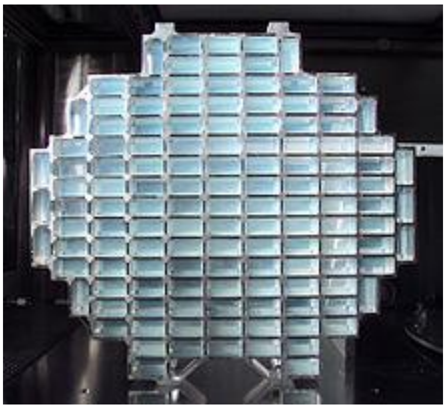
3 – 4 - Other :

Sea gel is a material similar to organic aero gel, made of agar.

Chalco gels are a type of aero gel made of chalcogens (the column of elements on the periodic table beginning with oxygen) such as sulfur, selenium, and other elements . Research is ongoing, and metals less expensive than platinum have also been used in its creation.

Aerogels made of cadmium selenide quantum dots in a porous 3 - D net work have recently been developed for use in the semiconductor industry.

4 - Applications :



The Stardust dust collector with aero gel blocks. (NASA)

There is a variety of applications for which aerogels are used :

- Commercially, aero gels have been used in granular form to add insulation to sky lights.
- Transparent silica aero gel would be very suitable as a thermal insulation material for windows, significantly limiting thermal losses of buildings. One research team has shown that producing aerogel in a weightless environment can produce particles with a more uniform size and reduce the Rayleigh scattering effect in silica aero gel, thus making the aero gel less blue and more transparent.

- Its high surface area leads to many applications, such as a chemical adsorber for cleaning up spills . This feature also gives it great potential as a catalyst or a catalyst carrier.
- Aero gel particles are used as thickening agents in some paints and cosmetics.
- Aero gels are being tested for use in targets for the National Ignition Facility.
- Aero gel performance may be augmented for a specific application by the addition of dopants, reinforcing structures, and hybridizing compounds. Using this approach, the breadth of applications for the material class may be greatly increased.
- Commercial manufacture of aero gel 'blankets' began around the year 2000. An aero gel blanket is a composite of silica aero gel and fibrous reinforcement that turns the brittle aerogel into a durable, flexible material. The mechanical and thermal properties of the product may be varied based upon the choice of reinforcing fibers, the aerogel matrix, and opacification additives included in the composite.

- NASA used aero gel to trap space dust particles aboard the Stardust spacecraft. The particles vaporize on impact with solids and pass through gases, but can be trapped in aero gels. NASA also used aero gel for thermal insulation of the Mars Rover and space suits.
- The US Navy is evaluating aero gel undergarments as passive thermal protection for divers.
- Aero gels are used in particle physics as radiators in Cherenkov effect detectors. ACC system of the Belle detector, used in the Belle Experiment at KEKB, is a recent example of such use. The suitability of aero gels is determined by their low index of refraction, filling the gap between gases and liquids, and their transparency and solid state, making them easier to use than cryogenic liquids or compressed gases. Their low mass is also advantageous for space missions.
- Resorcinol – formaldehyde aero gels (polymers chemically similar to phenol formaldehyde resins) are mostly used as precursors for manufacture of carbon aerogels, or when

an organic insulator with large surface is desired. They come as high-density material, with surface area about 600 m^2/g.

- The first residential use of aero gel as an insulator is in the Georgia Institute of Technology's Solar Decathlon House where it is used as an insulator in the semi-transparent roof.
- Metal–aero gel nano composites can be prepared by impregnating the hydro gel with solution containing ions of a transition metal. The impregnated hydro gel is then irradiated with gamma rays, leading to precipitation of nano particles of the metal. Such composites can be used as catalysts, sensors, electromagnetic shielding, and in waste disposal. A prospective use of platinum-on-carbon catalysts is in fuel cells.
- Aerogel can be used as a drug delivery system owing to its biocompatibility. Due to its high surface area and porous structure, drugs can be adsorbed from supercritical CO_2. The release rate of the drugs can be tailored based on the properties of aero gel.
- Carbon aero gels are used in the construction of small electrochemical double layer super capacitors. Due to the high surface area of the aero gel, these capacitors can be 1 / 2000th to 1/5000th the size of similarly rated electrolytic capacitors. Aerogel super capacitors can have a very low impedance compared to normal super capacitors and can absorb or produce very high peak currents. At present, such capacitors are polarity-sensitive and need to be wired in series if a working voltage of greater than about 2.75 V is needed.
- Dunlop has recently incorporated aerogel into the mold of its new series of tennis racquets, and has previously used it in squash racquets.
- Chalco gels have shown promise in absorbing the heavy metal pollutants mercury, lead, and cadmium from water.
- Aerogel can introduce disorder into super fluid helium-3.
- Arms control experts speculate it is used to transform radiation into pressure in multistage nuclear weapons.
- Grado Zero Espace, a company specialized in innovation products on demand, in 2001 in collaboration before

with NASA and then with European Space Agency Transfer Technology Programme , introduced to the market the first range of extreme sport equipments, with the brand "Aerogel Design System" an optimized system to integrate aerogel in sport clothing.

- Shiver Shield, a brand of cold weather garments that is insulated with encapsulated aero gel, was recently introduced to the market in 2011.

5 – Production :

Production of aerogels is done by the sol-gel process. First a gel is created in solution and then the liquid is carefully removed to leave the aerogel intact.

The first step is the creation of a colloidal suspension of solid particles known as a “sol”. Silica aero gel is made by the creation of colloidal silica. The process starts with a liquid alcohol such as ethanol which is mixed with a silicon alkoxide precursor, for example tetra methyl ortho silicate (TMOS) or tetra ethyl ortho silicate (TEOS). A hydrolysis reaction forms particles of silicon dioxide forming a sol solution . The oxide suspension begins to undergo condensation reactions which result in the creation of metal oxide bridges (either M – O – M, “oxo” bridges or M– OH – M, “ol” bridges) linking the dispersed colloidal particles.

When this inter linking has stopped the flow of liquid within the material, this is known as a gel. This process is known as gelation. These reactions generally have moderately slow reaction rates, and as a result either acidic or basic catalysts are used to improve the processing speed. Basic catalysts tend to produce more transparent aerogels with less shrinkage.

The removal of the liquid from a true aerogel involves special processing. Gels where the liquid is allowed to evaporate normally are known as xero gels. As the liquid evaporates, forces caused by surface tensions of the liquid-solid interfaces are enough to destroy the fragile gel network. As a result xero gels cannot achieve the high porosities and instead peak at lower porosities and exhibit large amounts of shrinkage after drying.

In 1931, to develop the first aero gels, Kistler used a process known as super critical drying. By increasing the temperature and pressure he forced the liquid into a supercritical fluid state where by dropping the pressure he could instantly gasify and remove the liquid inside the aero gel, avoiding damage to the delicate three-dimensional network. While this can be done with ethanol, the high temperatures and pressures lead to dangerous processing conditions. A safer, lower temperature and pressure method involves a solvent exchange. This is typically done by exchanging the ethanol for liquid acetone, allowing a better miscibility gradient, and then onto liquid carbon dioxide and then bringing the carbon dioxide above its critical point. A variant on this process involves the direct injection of supercritical carbon dioxide into the pressure vessel containing the aerogel. The end result of either process removes all liquid from the gel and replaces it with gas, without allowing the gel structure to collapse or lose volume.[27]

Aerogel composites have been made using a variety of continuous and discontinuous reinforcements. The high aspect ratio of fibers such as fiberglass have been used to reinforce aerogel composites with significantly improved mechanical properties.

Resorcinol – formaldehyde aero gel (RF aero gel) is made in a way similar to production of silica aero gel.

Carbon aero gel is made from a resorcinol–formaldehyde aerogel by its pyrolysis in inert gas atmosphere, leaving a matrix of carbon. It is commercially available as solid shapes, powders, or composite paper.

6 - Safety :

Aerogel safety depends on the material from which it's made, so an aerogel will have the same carcinogenic and toxic characteristics as the solid component it is derived from .

Silica-based aero gels are not known to be carcinogenic or toxic. However, they are a mechanical irritant to the eyes, skin, respiratory tract, and digestive system. They also can induce dryness of the skin, eyes, and mucous membranes. Therefore, it is recommended that protective gear including gloves and eye goggles be worn whenever handling aero gels.

Silica Fume

Contents

1 – Introduction :

Silica fume, also known as **micro silica**, (CAS number 69012-64-2, EINECS number 273-761-1) is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultra fine powder collected as a by- product of the silicon and ferro silicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete.

It is some times confused with fumed silica (also known as pyrogenic silica, CAS number 112945-52-2, EINECS number 231-545-4). The production process, particle characteristics and fields of application of fumed silica is however different as compared to silica fume.

2 - History :

The first testing of silica fume in Portland - cement - based concretes was carried out in 1952. The biggest draw back to exploring the properties of silica fume was a lack of material to experiment with. Early research used an expensive additive called fumed silica, an amorphous form of silica made by combustion of silicon tetrachloride in a hydrogen - oxygen flame. Silica fume on the other hand, is a very fine pozzolanic, amorphous material, a by-product of the production of elemental silicon or ferrosilicon alloys in electric arc furnaces. Before the late 1960s in Europe and the mid-1970s in the United States, silica fumes were simply vented into the atmosphere.

With the implementation of tougher environmental laws during the mid-1970s, silicon smelters began to collect the silica fume and search for its applications. The early work done in Norway received most of the attention, since it had shown that Portland cement-based-concretes containing silica fumes had very high strengths and low porosities. Since then the research and development of silica fume made it one of the world's most valuable and versatile admixtures for concrete and cementitious products.

3 - Properties :

Silica fume is an ultrafine airborne material with spherical particles less than 1 µm in diameter, the average being about 0.1 µm. This makes it approximately 100 times smaller than the average cement particle . The unit weight (bulk density) of silica fume depends on the metal from which it is produced and varies from 130 to 430 kg / m^3. The specific gravity of silica fume is generally in the range of 2.20 to 2.5. The specific surface area of silica fume can be measured with the BET method or nitrogen adsorption method. It typically ranges from 15,000 to 30,000 m^3 / kg.

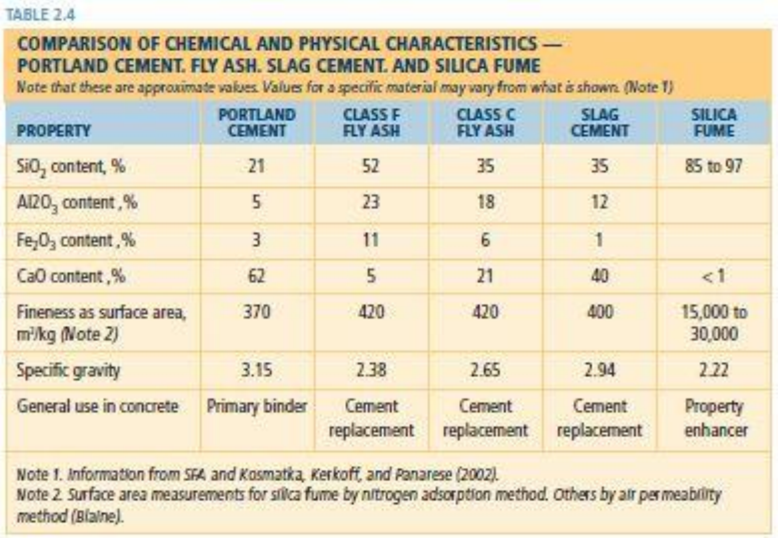


TABLE 2.4

COMPARISON OF CHEMICAL AND PHYSICAL CHARACTERISTICS — PORTLAND CEMENT. FLY ASH. SLAG CEMENT. AND SILICA FUME

Note that these are approximate values. Values for a specific material may vary from what is shown. (Note 1)

PROPERTY	PORTLAND CEMENT	CLASS F FLY ASH	CLASS C FLY ASH	SLAG CEMENT	SILICA FUME
SiO_2 content, %	21	52	35	35	85 to 97
$Al2O_3$ content ,%	5	23	18	12	
Fe_2O_3 content ,%	3	11	6	1	
CaO content ,%	62	5	21	40	< 1
Fineness as surface area, m^2/kg *(Note 2)*	370	420	420	400	15,000 to 30,000
Specific gravity	3.15	2.38	2.65	2.94	2.22
General use in concrete	Primary binder	Cement replacement	Cement replacement	Cement replacement	Property enhancer

Note 1. *Information from SFA and Kosmatka, Kerkoff, and Panarese (2002).*
Note 2. *Surface area measurements for silica fume by nitrogen adsorption method. Others by air permeability method (Blaine).*

4 - Production :

Silica fume is a by product in the carbothermic reduction of high-purity quartz with charcoal in electric arc furnaces in the production of silicon and ferrosilicon alloys.

5 – Applications :

5 – 1 – Concrete ;

Because of its extreme fineness and high silica content, silica fume is a very effective pozzolanic material . Standard specifications for silica fume used in cementitious mixtures are ASTM C1240 , EN 13263.

Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength, and abrasion resistance. These improvements stem from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste.[7]

Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions and those of humid continental roadways and runways (because of the use of deicing salts) and saltwater bridges.

Prior to the mid -1970s, nearly all silica fume was discharged into the atmosphere. After environmental concerns necessitated the collection and land filling of silica fume, it became economically viable to use silica fume in various applications, in particular high-performance concrete .

Effects of silica fume on different properties of fresh and hardened concrete include :

a) **Work ability :** With the addition of silica fume, the slump loss with time is directly proportional to increase in the silica fume content due to the introduction of large surface area in the concrete mix by its addition. Although the slump decreases, the mix remains highly cohesive.

b) **Segregation and bleeding :** Silica fume reduces bleeding significantly because the free water is consumed in wetting of the large surface area of the silica fume and hence the free water left in the mix for bleeding also decreases. Silica fume also blocks the pores in the fresh concrete so water within the concrete is not allowed to come to the surface.

Silicate Mineral Paint

Contents

1 – Introduction :

Silicate mineral paints or **silicate emulsion paints** are mineral based coatings formulated with potassium silicate or sodium silicate, other wise known as water glass as the binder, combined with inorganic, alkaline-resistant pigments. Traditionally, they have been fully inorganic (containing no organic solvents) and are non-off gassing. Modern silicate emulsion paints have small amounts of petroleum distillates, but far less than synthetic oil or latex paints. Mineral paints petrify, by binding to any silicates within the substrate, forming a micro - crystalline structure and a breathable finish. They are more of a stain, that becomes integral to the substrate, rather than a coating. They are alkaline and there fore inhibit microbial growth, and reduce carbonation of cementitious materials.

Various non-toxic concrete stains and limestone restoration products are water glass based. Mineral paints are also used as a non-toxic wood preservative.

The difference between the use of sodium silicate and potassium silicate as a binder is mainly geographic. The western hemisphere mainly produces sodium silicate, whereas Europe produces potassium silicate.

2 - Possible substrates :

- masonry
- stone
- concrete
- lime plasters
- earthen plasters

3 - Applications :

- environmentally friendly, non-toxic applications
- high durability, especially on masonry products, and lightfast
- mineral paints with high vapor permeability[1]
- acid rain resistance
- antifungal properties
- reduces carbonation of cement-based materials

Siliceous Lime stone (Kieselkalk)

1 – Introduction :

Kieselkalk is also known as the Helvetic Siliceous Lime stone. It has sedimented during the Lower Cretaceous epoch. It can contain up to 40 % of very fine (1-10 µm), evenly distributed authigenic quartz crystals. Early diagenetic dissolution of opal sponge spicules led to silica enrichment of interstitial waters, which reprecipitated silica in the overlying horizons, forming tiny quartz crystals in pore spaces.

Because of its high silica content, the Kieselkalk is much less susceptible to karstification than the overlying Schrattenkalk. In the Siebenhengste - Hohgant-Höhle cave system in Switzerland, large galleries, easily developing in the Schrattenkalk, become impenetrable fissures net works when water disappears in the Kieselkalk.

2 - Susceptibility to alkali silica reaction

Siliceous lime stones can be very prone to the Alkali Silica Reaction (ASR) and their use as aggregate is often the cause of premature concrete degradation and problems in civil engineering (concrete spalling, bridges failure, ...).

Sky Scraper

Sky scrapers in Chicago, United States. The Willis Tower (designed by Khan and Graham) in the middle has 108 storey's and is 442 meters tall. It utilizes the bundled tube design.

Contents

1 – Introduction :

A sky scraper is a building using a metal frame and then an outer materiel often brick, the first building in the world to use such type of building technique is the Dithering ton Flax Mill in Shrewsbury, shropshire England which was built in 1797 & is regarded as the forerunner to the sky scraper . A **sky scraper** is a tall, continuously habitable building of many storey's , usually designed for office and commercial use. There is no official definition or height above which a building may be classified as a sky scraper. One common feature of sky scrapers is having a steel framework from which curtain walls are suspended, rather than load-bearing walls of conventional construction. Most sky scrapers have a steel frame that enables the construction of load - bearing walls taller than of those made of reinforced concrete. Sky scrapers' walls are not load-bearing, and therefore most sky scrapers are characterized by large surface areas of windows made possible by the concept of steel frame and curtain walls. How ever, sky scrapers can have curtain walls that mimic conventional walls and a small surface area of windows.

Sky scrapers since 1960s utilize the tubular designs, innovated by a Bangladeshi - American structural engineer named Fazlur Rahman Khan. This engineering principle makes the buildings structurally more efficient and stronger. It reduces the usage of material (economically much more efficient), while simultaneously allows the buildings to reach greater heights. It allows fewer interior columns, and so creates more usable floor space. It further enables buildings to take on various shapes. There are several variations of the tubular design; these structural systems are fundamental to tall building design today . After the great depression, sky scraper construction was abandoned. Bangladeshi-American structural engineer Fazlur Khan, more than any others, ushered in a renaissance in sky scrapers construction from 1960s with structural innovations that transformed the industry. and made it possible for people to live and work in "cities in the sky". Other pioneers include Hal Iyengar, William Lemesserier, and etc. Cities have experienced a huge surge in sky scraper construction. Fazlur Rahman Khan is regarded as the "Einstein of Structural Engineering" for his revolutionary work which remain fundamental to modern sky scraper construction.[7] Khan created a legacy of innovations that is unparalleled and became an icon in both architecture and structural engineering.

Today, sky scrapers are an increasingly common sight where land is expensive, as in the centers of big cities, because they provide such a high ratio of rentable floor space per unit area of land. They are built not just for economy of space; like temples and palaces of the past, sky scrapers are considered symbols of a city's economic power. Not only do they define the skyline, they help to define the city's identity. In some cases exceptionally tall sky scrapers have been built, not out of necessity, but to help define the city's identity and presence or power as a city.

2 - Definition :

A relatively small building may be considered a sky scraper if it protrudes well above its built environment and changes the overall skyline. The maximum height of structures has progressed historically with building methods and technologies and thus what we today consider a sky scraper is taller than before. Also lacking an official definition, the term 'super tall' has arisen for the current generation of exceptionally tall buildings. High-rise buildings are considered shorter than sky scrapers. Home Insurance Building in Chicago, United States was considered a sky scraper when it was built in 1884, but it had only ten storeys . Today such a building would not be considered a sky scraper . There is no clear definition of any difference between a tower block and a sky scraper though a building lower than about thirty storeys is not likely to be a sky scraper and a building with fifty or more storeys is certainly a sky scraper .

The term "sky scraper " was first applied to buildings of steel framed construction of at least 10 storeys in the late 19th century, a result of public amazement at the tall buildings being built in major cities like Chicago, New York City, Detroit, and St. Louis. The first steel frame sky scraper was the Home Insurance Building (originally 10 storeys with a height of 42 m or 138 ft) in Chicago, Illinois in 1885. Some point to New York's seven-floor Equitable Life Assurance Building, built in 1870, as an early sky scraper for its innovative use of a kind of skeletal frame, but such designation depends largely on what factors are chosen. Even the scholars making the argument find it to be purely academic.

The structural definition of the word *sky scraper* was refined later by architectural historians, based on engineering developments of the 1880s that had enabled construction of tall multi-storey buildings. This definition was based on the steel skeleton—as opposed to constructions of load-bearing masonry, which passed their practical limit in 1891 with Chicago's Monadnock Building.

The steel frame developed in stages of increasing self-sufficiency, with several buildings in Chicago and New York advancing the technology that allowed the steel frame to carry a building on its own. Today, however, many of the tallest sky scrapers are built almost entirely with reinforced concrete.

The Emporis Standards Committee defines a high - rise building as "a multi-storey structure between 35– 100 meters tall, or a building of unknown height from 12–39 floors" and a sky scraper as "a multi-storey building whose architectural height is at least 100 m . Some structural engineers define a high rise as any vertical construction for which wind is a more significant load factor than earthquake or weight. Note that this criterion fits not only high-rises but some other tall structures, such as towers.

The word *sky scraper* often carries a connotation of pride and achievement. The sky scraper , in name and social function, is a modern expression of the age-old symbol of the world center or *axis* *mundi*: a pillar that connects earth to heaven and the four compass directions to one another .

A loose convention of some in the United States and Europe draws the lower limit of a sky scraper at 150 m .

The term 'super tall' has recently been coined.

The Council on Tall Buildings and Urban Habitat (CTBUH) defines “super tall” as a building over 300 m in height. Although great heights are now being achieved with built tall buildings — in excess of 800 m — at the mid-point of 2011 there only approximately 54 buildings in excess of 300 m completed and occupied globally.

3 – History :

The Two Towers of Bologna in the 12th century reached 97.2 m in height.

The 16th-century city of Shibam consisted entirely of over 500 high - rise tower houses.

3 – 1 - Pre - 19th century :

Modern sky scrapers are built with steel or reinforced concrete frameworks and curtain walls of glass or polished stone. They utilize mechanical equipment such as water pumps and elevators. Until the 19th century, buildings of over six storeys were rare, as having great numbers of stairs to climb was impractical for inhabitants, and water pressure was usually insufficient to supply running water above 50 m.

The tallest building in ancient times was the 146 m Great Pyramid of Giza in ancient Egypt, built in the 26th century BCE. It was not surpassed in height for thousands of years, the 14th century CE Lincoln Cathedral being conjectured by many to exceed it . The latter in turn was not surpassed until the 169 m Washington Monument in 1884. However, being uninhabited, none of these structures actually complies with the modern definition of a sky scraper . High - rise apartments flourished in classical antiquity. Ancient Roman insulae there and in other imperial cities reached 10 and more storeys . Beginning with Augustus (r. 30 BCE-14 CE), several emperors attempted to establish limits of 20–25 m for multi-storey buildings, but met with only limited success . Lower floors were typically occupied by shops or wealthy families, the upper rented to the lower classes . Surviving Oxyrhynchus Papyri indicate that seven-storey buildings existed in provincial towns such as in 3rd century CE Hermopolis in Roman Egypt .

The skylines of many important medieval cities had large numbers of high-rise urban towers, built by the wealthy for defense and status. The residential Towers of 12th century Bologna numbered between 80 to 100 at a time, capped by the 97.2 m "Two Towers". A Florentine law of 1251 decreed that all urban buildings be immediately reduced to less than 26 m. Even medium-sized towns of the era are known to have proliferations of towers, such as the 72 up to 51 m height in San Gimignano.

The medieval Egyptian city of Fustat housed many high-rise residential buildings, which Al-Muqaddasi in the 10th century described as resembling minarets. Nasir Khusraw in the early 11th century described some of them rising up to 14 storeys, with roof gardens on the top floor complete with ox- drawn water wheels for irrigating them . Cairo in the 16th century had high - rise apartment buildings where the two lower floors were for commercial and storage purposes and the multiple storeys above them were rented out to tenants. An early example of a city consisting entirely of high-rise housing is the 16th-century city of Shibam in Yemen. Shibam was made up of over 500 tower houses , each one rising 5 to 11 storeys high, with each floor being an apartment occupied by a single family. The city was built in this way in order to protect it from Bedouin attacks. Shibam still has the tallest mud brick buildings in the world, with many of them over 30 m high . An early modern example of high-rise housing was in 17th - century Edinburgh, Scotland, where a defensive city wall defined the boundaries of the city. Due to the restricted land area available for development, the houses increased in height instead. Buildings of 11 storeys were common, and there are records of buildings as high as 14 storeys. Many of the stone-built structures can still be seen today in the old town of Edinburgh. The oldest iron framed building in the world, although only partially iron framed, is The Flax mill (also locally known as the "Maltings"), in Shrews bury, England. Built in 1797, it is seen as the "grandfather of sky scrapers", since its fireproof combination of cast iron columns and cast iron beams developed into the modern steel frame that made modern sky scrapers possible. Unfortunately, it lies derelict and needs much investment to keep it standing.

	
The Wainwright Building, a 10-storey red brick office building in St. Louis, Missouri, built in 1891	*Oriel Chambers, Liverpool. The world's first glass curtain walled building. The stone mullions are decorative.*

3 – 2 - Early sky scrapers :

In 1852 Elisha Otis introduced the safety elevator, allowing convenient and safe passenger movement to upper floors. Another crucial development was the use of a steel frame instead of stone or brick, otherwise the walls on the lower floors on a tall building would be too thick to be practical. An early development in this area was Oriel Chambers in Liver pool. Designed by local architect Peter Ellis in 1864, the building was the world's first iron-framed, glass curtain-walled office building. It was only 5 floors high . Further developments led to the world's first sky scraper , the ten-storey Home Insurance Building in Chicago, built in 1884 –1885 . While its height is not considered very impressive today, it was at that time. The architect, Major William Le Baron Jenney, created a load-bearing structural frame. In this building, a steel frame supported the entire weight of the walls, instead of load - bearing walls carrying the weight of the building. This development led to the "Chicago skeleton" form of construction.

Burnham and Root's 1889 Rand McNally Building in Chicago, 1889, was the first all - steel framed sky scraper , while Louis Sullivan's Wainwright Building in St. Louis, Missouri, 1891, was the first steel-framed building with soaring vertical bands to emphasize the height of the building and is therefore considered by some to be the first true sky scraper .

Most early sky scrapers emerged in the land-strapped areas of Chicago, London, and New York toward the end of the 19th century. A land boom in Melbourne, Australia between 1888–1891 spurred the creation of a significant number of early sky scrapers, though none of these were steel reinforced and few remain today. Height limits and fire restrictions were later introduced. London builders soon found building heights limited due to a complaint from Queen Victoria, rules that continued to exist with few exceptions until the 1950s. Concerns about aesthetics and fire safety had likewise hampered the development of sky scrapers across continental Europe for the first half of the twentieth century (with the notable exceptions of the 1898 Witte Huis *(White House)* in Rotterdam; the Royal Liver Building in Liverpool, completed in 1911 and 90 m (300 ft) high;[35] and the 17-storey Kungstornen *(Kings' Towers)* in Stockholm, Sweden, which were built 1924–25,[36] the 15-storey Edificio Telefónica in Madrid, Spain, built in 1929; the 26-storey Boerentoren in Antwerp, Belgium, built in 1932; and the 31-storey Torre Piacentini in Genoa, Italy, built in 1940). After an early competition between Chicago and New York City for the world's tallest building, New York took the lead by 1895 with the completion of the American Surety Building, leaving New York with the title of tallest building for many years. New York City developers competed among themselves, with successively taller buildings claiming the title of "world's tallest" in the 1920s and early 1930s, culminating with the completion of the Chrysler Building in 1930 and the Empire State Building in 1931, the world's tallest building for forty years. The first completed World Trade Center tower became the world's tallest building in 1972. However, it was soon overtaken by the Sears Tower (now Willis Tower) in Chicago within two years. The Sears Tower stood as the world's tallest building for 24 years, from 1974 until 1998, until it was edged out by Petronas Twin Towers in Kuala Lumpur, which held the title for six years.

3 – 3 - Modern sky scrapers :

From the 1930s onwards, sky scrapers also began to appear in Latin America (São Paulo, Rio de Janeiro, Buenos Aires, Santiago, Caracas, Bogotá, Mexico City) and in Asia (Tokyo, Shanghai, Hong Kong, Manila, Singapore, Mumbai, Seoul, Kuala Lumpur, Taipei, Bangkok). Immediately after World War II, the Soviet Union planned eight massive sky scrapers dubbed "Stalin Towers" for Moscow; seven of these were eventually built. The rest of Europe also slowly began to permit sky scrapers, starting with Madrid, during the 1950s. Finally, sky scrapers also began to be constructed in cities of Africa, the Middle East and Oceania (mainly Australia) from the late 1950s. After the Great depression sky scrapers construction was abandoned for over thirty years . Fazlur Khan, more than any others, ushered in a renaissance in sky scrapers construction from 1960s with structural innovations that transformed the industry. Other pioneers include Hal Iyengar, William Lemesserier, and etc.

In the early 1960s structural engineer Fazlur Khan realized that the rigid steel frame structure that had dominated tall building design and construction so long was not the only system fitting for tall buildings, marking the beginning of a new era of sky scraper revolution in terms of multiple structural systems . His central innovation in sky scraper design and construction was the idea of the "tube" structural system, including the "framed tube", "trussed tube", and "bundled tube". These systems allowed far greater economic efficiency, and also allowed efficient sky scrapers to take on various shapes, no longer needing to be box- shaped. Over the next fifteen years, many towers were built by Khan and the "Second Chicago School",[42] including the massive 442 m (1,450 ft) Willis Tower. The tubular systems are fundamental to tall building design. Most buildings over 40 - storeys constructed since the 1960s now use a tube design derived from Khan’s structural engineering principles . Since 2000, Cities like Chicago, Shanghai, Dubai, New York, and Toronto have experienced a huge surge in sky scraper construction, thanks to Khan's innovations allowing economic sky scrapers. Chicago, Hong Kong, and New York City, otherwise known as "the big three," are recognized in architectural circles as having especially compelling skylines. A landmark sky scraper can inspire a boom of new high-rise projects in its city, as Taipei 101 has done in Taipei since its opening in 2004. In 2010, The Bank of America Tower at One Bryant Park became the world's first commercial LEED Platinum sky scraper .

4 - Design and construction :

The design and construction of sky scrapers involves creating safe, habitable spaces in very tall buildings. The buildings must support their weight, resist wind and earthquakes, and protect occupants from fire. Yet they must also be conveniently accessible, even on the upper floors, and provide utilities and a comfortable climate for the occupants. The problems posed in sky scraper design are considered among the most complex encountered given the balances required between economics, engineering, and construction management.

One common feature of sky scrapers is having a steel framework from which curtain walls are suspended, rather than load-bearing walls of conventional construction. Most sky scrapers have a steel frame that enables to build taller than load-bearing walls of reinforced concrete. Sky scrapers usually have particularly small surface area of what are conventionally thought of as walls, because the walls are not load - bearing and therefore most sky scrapers are characterized by large surface areas of windows made possible by the concept of steel frame and curtain walls. However, sky scrapers can have curtain walls that mimick conventional walls and a small surface area of windows.

The concept of a sky scraper is a product of the industrialized age, made possible by cheap fossil fuel derived energy and industrially refined raw materials such as steel and concrete. The construction of sky scrapers was enabled by steel frame construction that surpassed brick and mortar construction starting at the end of the 19th century and finally surpassing it in the 20th century together with reinforced concrete construction as the price of steel decreased and labour costs increased.

The steel frames become inefficient and uneconomic for super tall buildings as usable floor spaces are reduced for supporting column and due to more usage of steel . Since 1960 Tubular designs are used for high rises. This conception reduces the usage of material (more efficient in economic terms - Willis Tower uses 2/3 of the steel as Empire state building), yet allows greater height. It allows fewer interior columns, and so create more usable floor space. It further enables buildings to take on various shapes.

The amount of steel, concrete and glass needed to construct a single sky scraper is large, and these materials represent a great deal of embodied energy. Sky scrapers are thus energy intensive buildings, but sky scrapers have a long lifespan, for example the Empire State Building in New York City, United States completed in 1931 and is still in active use. Sky scrapers have considerable mass, which means that they must be built on a sturdier foundation than would be required for shorter, lighter buildings. Building materials must also be lifted to the top of a sky scraper during construction, requiring more energy than would be necessary at lower heights. Furthermore, a sky scraper consumes a lot of electricity because potable and non-potable water have to be pumped to the highest occupied floors, sky scrapers are usually designed to be mechanically ventilated, elevators are generally used instead of stairs, and natural lighting cannot be utilized in rooms far from the windows and the windowless spaces such as elevators, bathrooms and stairwells.

Elevators are characteristic to sky scrapers. In 1852 Elisha Otis introduced the safety elevator, allowing convenient and safe passenger movement to upper floors. Another crucial development was the use of a steel frame instead of stone or brick, otherwise the walls on the lower floors on a tall building would be too thick to be practical. Today major manufacturers of elevators include Otis, ThyssenKrupp, Schindler, and KONE. For supertall buildings sky lobbies with express elevators invented by F.R Khan are used.

Khan realized that the rigid steel frame structure that had "dominated tall building design and construction so long was not the only system fitting for tall buildings", marking "the beginning of a new era of sky scraper revolution in terms of multiple structural systems."[47] Khan's design innovations significantly improved the construction of high-rise buildings, enabling them to withstand enormous forces generated on these super structures. These new designs opened an economic door for contractors, engineers, architects, and investors, providing vast amounts of real estate space on minimal plots of land.

4 – 1 - Basic design considerations :

Good structural design is important in most building design, but particularly for sky scrapers since even a small chance of catastrophic failure is unacceptable given the high price. This presents a paradox to civil engineers: the only way to assure a lack of failure is to test for all modes of failure, in both the laboratory and the real world. But the only way to know of all modes of failure is to learn from previous failures. Thus, no engineer can be absolutely sure that a given structure will resist all loadings that could cause failure, but can only have large enough margins of safety such that a failure is acceptably unlikely. When buildings do fail, engineers question whether the failure was due to some lack of foresight or due to some unknowable factor.

4 – 2 - Loading and vibration :

Taipei 101 endures a typhoon (2005)

The load a sky scraper experiences is largely from the force of the building material itself. In most building designs, the weight of the structure is much larger than the weight of the material that it will support beyond its own weight. In technical terms, the dead load, the load of the structure, is larger than the live load, the weight of things in the structure (people, furniture, vehicles, etc.). As such, the amount of structural material required within the lower levels of a sky scraper will be much larger than the material required within higher levels. This is not always visually apparent. The Empire State Building's setbacks are actually a result of the building code at the time, and were not structurally required. On the other hand John Hancock Center's shape is uniquely the result of how it supports loads. Vertical supports can come in several types, among which the most common for sky scrapers can be categorized as steel frames, concrete cores, tube within tube design, and shear walls.

The wind loading on a sky scraper is also considerable. In fact, the lateral wind load imposed on super-tall structures is generally the governing factor in the structural design. Wind pressure increases with height, so for very tall buildings, the loads associated with wind are larger than dead or live loads.

Other vertical and horizontal loading factors come from varied, unpredictable sources, such as earthquakes.

4 – 3 - Shear walls :

A shear wall, in its simplest definition, is a wall where the entire material of the wall is employed in the resistance of both horizontal and vertical loads. A typical example is a brick or cinderblock wall. Since the wall material is used to hold the weight, as the wall expands in size, it must hold considerably more weight. Due to the features of a shear wall, it is acceptable for small constructions, such as suburban housing or an urban brownstone, to require low material costs and little maintenance. In this way, shear walls, typically in the form of ply wood and framing, brick, or cinderblock, are used for these structures. For sky scrapers, though, as the size of the structure increases, so does the size of the supporting wall. Large structures such as castles and cathedrals inherently addressed these issues due to a large wall being advantageous (castles), or ingeniously designed around (cathedrals). Since sky scrapers seek to maximize the floorspace by consolidating structural support, shear walls tend to be used only in conjunction with other support systems.

4 – 4 - Steel frame :

The classic concept of a sky scraper is a large steel box with many small boxes inside it. The genius of the steel frame is its simplicity. By eliminating the inefficient part of a shear wall, the central portion, and consolidating support members in a much stronger material, steel, a sky scraper could be built with both horizontal and vertical supports throughout. This method, though simple, has drawbacks. Chief among these is that as more material must be supported (as height increases), the distance between supporting members must decrease, which actually in turn, increases the amount of material that must be supported. This becomes inefficient and uneconomic for buildings above 40 stories tall as usable floor spaces are reduced for supporting column and due to more usage of steel.

4 – 5 - Tube structural systems :

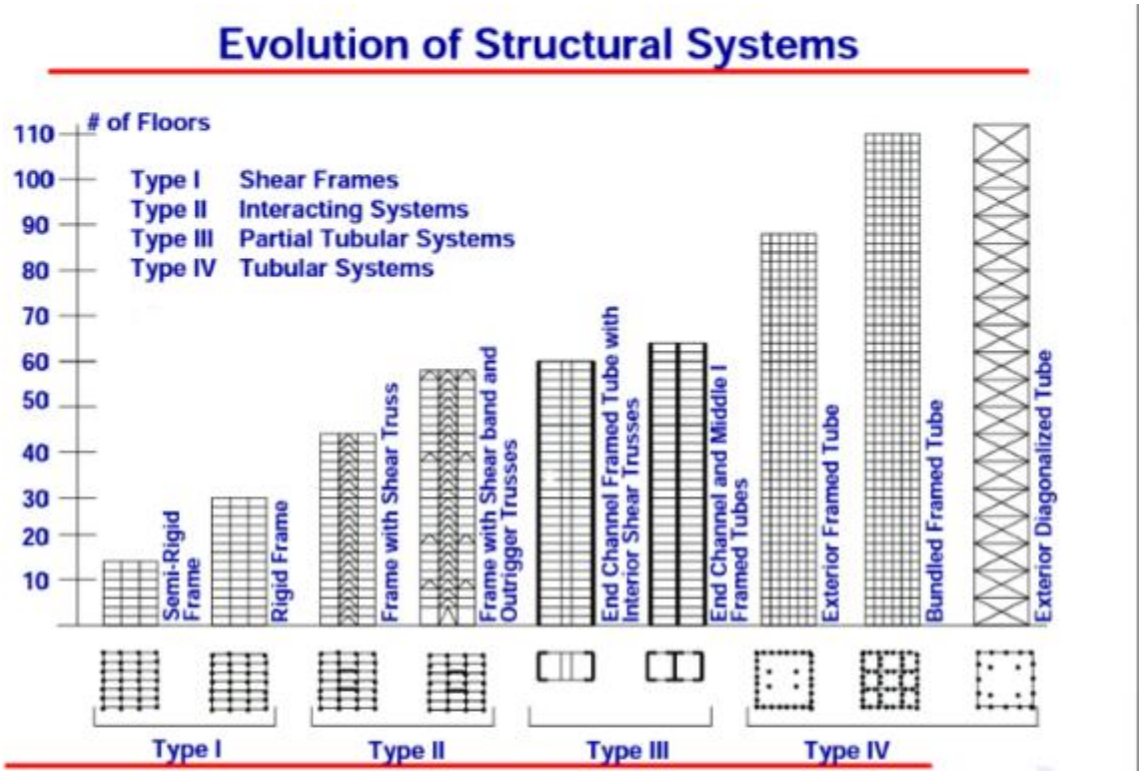
The Willis Tower showing the bundled tube frame design

Since 1963, a new structural system of framed tubes appeared. Fazlur Khan and J. Rankine defined the framed tube structure as "a three dimensional space structure composed of three, four, or possibly more frames, braced frames, or shear walls, joined at or near their edges to form a vertical tube - like structural system capable of resisting lateral forces in any direction by cantilevering from the foundation ". Closely spaced interconnected exterior columns form the tube. Horizontal loads (primarily wind) are supported by the structure as a whole. About half the exterior surface is available for windows. Framed tubes allow fewer interior columns, and so create more usable floor space. Where larger openings like garage doors are required, the tube frame must be interrupted, with transfer girders used to maintain structural integrity. Tube structures cut down costs, at the same time allow buildings to reach greater heights. Tube-frame construction was first used in the DeWitt - Chestnut Apartment Building , designed by Khan and completed in Chicago in 1963 . It was used soon after for the John Hancock Center and in the construction of the World Trade Center.

A variation on the tube frame is the bundled tube, which uses several interconnected tube frames. The Willis Tower in Chicago used this design, employing nine tubes of varying height to achieve its distinct appearance. The bundle tube design was not only highly efficient in economic terms, but it was also "innovative in its potential for versatile formulation of architectural space. Efficient towers no longer had to be box-like; the tube-units could take on various shapes and could be bundled together in different sorts of groupings " . The bundled tube structure meant that "buildings no longer need be boxlike in appearance: they could become sculpture " .

The tubular systems are fundamental to tall building design. Most buildings over 40 - storeys constructed since the 1960s now use a tube design derived from Khan’s structural engineering principles, examples including the construction of the World Trade Center, Aon Centre, Petronas Towers, Jin Mao Building, and most other supertall sky scrapers since the 1960s . The strong influence of tube structure design is also evident in the construction of the current tallest sky scraper , the Burj Khalifa.

Fazlur Rahman Khan, the father of tubular design, is the most influential structural engineer of the 20th century. He has been called the "Einstein of Structural Engineering" for his revolutionary work which remain fundamental to modern sky scraper construction.[7] His breakthroughs in structural engineering for tall and long-span buildings exerted an unprecedented and lasting influence on the profession, both nationally and internationally. With a career marked by a legacy of innovations that is unpeered, Khan has become an icon in both architecture and structural engineering.[51]



Changes of structure with height. The tubular systems by F.R Khan are fundamental for super tall buildings.

Khan's central innovation in sky scraper design and construction was the idea of the "tube" structural system for tall buildings, including the "framed tube", "trussed tube" and "bundled tube" variations. His "tube concept," using "all the exterior wall perimeter structure of a building to simulate a thin - walled tube, revolutionized tall building design " . The constructions of most super tall sky scrapers since the 1960s, including the construction of the World Trade Center, Petronas Towers and Jin Mao Building, employ a tube structural system.

4 – 5 - 1 - Framed tube :

Since 1963, the new structural system of framed tubes became highly influential in sky scraper design and construction. Khan defined the framed tube structure as "a three dimensional space structure composed of three, four, or possibly more frames, braced frames, or shear walls, joined at or near their edges to form a vertical tube-like structural system capable of resisting lateral forces in any direction by cantilevering from the foundation " . Closely spaced interconnected exterior columns form the tube. Horizontal loads, for example from wind and earthquakes, are supported by the structure as a whole. About half the exterior surface is available for windows. Framed tubes allow fewer interior columns, and so create more usable floor space. The bundled tube structure is more efficient for tall buildings, lessening the penalty for height. The structural system also allows the interior columns to be smaller and the core of the building to be free of braced frames or shear walls that use up valuable floor space. Where larger openings like garage doors are required, the tube frame must be interrupted, with transfer girders used to maintain structural integrity . The first building to apply the tube-frame construction was the DeWitt-Chestnut Apartments building that Khan designed and was completed in Chicago in 1963 . This laid the foundations for the framed tube structure used in the construction of the World Trade Center.

The John Hancock Center, designed by Skidmore, Owings and Merrill with chief designer Bruce Graham and structural engineer Fazlur Khan. The building was completed in 1969.

4 – 5 - 2 - Trussed tube and X – bracing :

Khan pioneered several other variations of the tube structure design. One of these was the concept of X-bracing, or the "trussed tube", first employed for the John Hancock Center. This concept reduced the lateral load on the building by transferring the load into the exterior columns. This allows for a reduced need for interior columns thus creating more floor space. This concept can be seen in the John Hancock Center, designed in 1965 and completed in 1969. One of the most famous buildings of the structural expressionist style, the sky scraper 's distinctive X - bracing exterior is actually a hint that the structure's skin is indeed part of its 'tubular system'. This idea is one of the architectural techniques the building used to climb to record heights (the tubular system is essentially the spine that helps the building stand upright during wind and earthquake loads). This X-bracing allows for both higher performance from tall structures and the ability to open up the inside floor plan (and usable floor space) if the architect desires. Original features such as the skin, pioneered by Fazlur Khan, have made the John Hancock Center an architectural icon . In contrast to earlier steel-frame structures, such as the Empire State Building (1931), which required about 206 kilograms of steel per square metre and Chase Manhattan Bank Building (1961), which required around 275 kilograms of steel per square metre, the John Hancock Center was far more efficient, requiring only 145 kilograms of steel per square meter . The trussed tube concept was applied to many later sky scrapers, including the Onterie Center, Citigroup Center and Bank of China Tower.

Sears Tower (now Willis Tower) , designed by Bruce Graham and Fazlur Khan and completed in 1974 , was the tallest building in the world at the time of its construction

4 – 5 - 3 - Bundle tube :

One of Khan's most important variations of the tube structure concept was the "bundled tube," which he used for the Sears Tower and One Magnificent Mile. The bundle tube design was not only the most efficient in economic terms, but it was also "innovative in its potential for versatile formulation of architectural space. Efficient towers no longer had to be box - like; the tube - units could take on various shapes and could be bundled together in different sorts of groupings " .

4 – 5 - 4 - Concrete tube structures :

The last major buildings engineered by Khan were the One Magnificent Mile and Onterie Center in Chicago, which employed his bundled tube and trussed tube system designs respectively. In contrast to his earlier buildings, which were mainly steel, his last two buildings were concrete. His earlier DeWitt-Chestnut Apartments building, built in 1963 in Chicago, was also a concrete building with a tube structure .

The influence of Khan's tube structure design can be seen in numerous buildings built since the 1960s. Tube structures have since been used in many sky scrapers, including the construction of the World Trade Center, Petronas Towers, Jin Mao Building, and most other super tall sky scrapers since the 1960s . The strong influence of tube structure design is also evident in the world's current tallest sky scraper , the Burj Khalifa in Dubai.

Khan invented a new way of building tall. [...] So Fazlur Khan created the unconventional sky scraper . Reversing the logic of the steel frame, he decided that the building's external envelope could – given enough trussing, framing and bracing – be the structure itself. This made buildings even lighter. The "bundled tube" meant buildings no longer need be boxlike in appearance: they could become sculpture. Khan's amazing insight – he was name-checked by Obama in his Cairo University speech last year – changed both the economics and the morphology of super tall buildings. And it made Burj Khalifa possible: proportionately, Burj employs perhaps half the steel that conservatively supports the Empire State Building. [...] Burj Khalifa is the ultimate expression of his audacious, lightweight design philosophy .

4 – 6 - The elevator conundrum

Elevators in the Empire State Building

The invention of the elevator was a precondition for the invention of sky scrapers, given that most people would not (or could not) climb more than a few flights of stairs at a time. The elevators in a sky scraper are not simply a necessary utility, like running water and electricity, but are in fact closely related to the design of the whole structure: a taller building requires more elevators to service the additional floors, but the elevator shafts consume valuable floor space. If the service core, which contains the elevator shafts, becomes too big, it can reduce the profitability of the building. Architects must therefore balance the value gained by adding height against the value lost to the expanding service core . Many tall buildings use elevators in a non - standard configuration to reduce their footprint. Buildings such as the former World Trade Center Towers and Chicago's John Hancock Center use sky lobbies, where express elevators take passengers to upper floors which serve as the base for local elevators. This allows architects and engineers to place elevator shafts on top of each other, saving space. Sky lobbies and express elevators take up a significant amount of space, however, and add to the amount of time spent commuting between floors. Other buildings, such as the

Petronas Towers , use double - deck elevators, allowing more people to fit in a single elevator, and reaching two floors at every stop. It is possible to use even more than two levels on an elevator, although this has never been done. The main problem with double-deck elevators is that they cause everyone in the elevator to stop when only people on one level need to get off at a given floor.

4 – 7 - Sky lobby :

The first sky lobby was also designed by Khan for the John Hancock Center. Later buildings with sky lobbies include the World Trade Center, Petronas Twin Towers and Taipei 101. The 44th-floor sky lobby of the John Hancock Center also features the first high-rise indoor swimming pool, which remains the highest in America.[60] This was the first time that people could have the opportunity to work and live "in the sky".

5 – Economic rationale :

Sky scrapers are usually situated in city centers where the price of land is high. Constructing a sky scraper becomes justified if the price of land is so high that it makes economic sense to build upwards as to minimize the cost of the land per the total floor area of a building. Thus the construction of sky scrapers is dictated by economics and results in sky scrapers in a certain part of a large city unless a building code restricts the height of buildings. Sky scrapers are rarely seen in small cities and they are characteristic of large cities, because of the critical importance of high land prices for the construction of sky scrapers. Usually only office, commercial and hotel users can afford the rents in the city center and thus most tenants of sky scrapers are of these classes. Some sky scrapers have been built in areas where the bedrock is near surface, because this makes constructing the foundation cheaper, for example this is the case in Midtown Manhattan and Lower Manhattan, in New York City, United States, but not in-between these two parts of the city.

Today, sky scrapers are an increasingly common sight where land is expensive, as in the centers of big cities, because they provide such a high ratio of rentable floor space per unit area of land.

$$\text{Simple price of floor area (currency/m}^2\text{)} = \frac{\text{price of land area (currency)}}{\text{total floor area (m}^2\text{)}}$$

6 - Environmental impact :

30 St Mary Axe in London is an example of a modern environmentally friendly sky scraper .

The environmental impact of sky scrapers and whether instead of sky scrapers multiple smaller, lighter buildings would be more environmentally friendly or sustainable is under debate. The concept of a sky scraper is a product of the industrialized age, made possible by cheap fossil fuel derived energy and industrially refined raw materials such as steel and concrete. The construction of sky scrapers was enabled by steel frame construction that surpassed brick and mortar construction starting at the end of the 19th century and finally surpassing it in the 20th century together with reinforced concrete construction as the price of steel decreased and labour costs increased.

The amount of steel, concrete and glass needed to construct a single sky scraper is large, and these materials represent a great deal of embodied energy. Sky scrapers are thus energy intensive buildings, but sky scrapers have a long lifespan, for example the Empire State Building in New York City, United States completed in 1931 and is still in active use. Sky scrapers have considerable mass, which means that they must be built on a sturdier foundation than would be required for shorter, lighter buildings. Building materials must also be lifted to the top of a sky scraper during construction, requiring more energy than would be necessary at lower heights. Furthermore, a sky scraper consumes a lot of electricity because potable and non-potable water have to be pumped to the highest occupied floors, sky scrapers are usually designed to be mechanically ventilated, elevators are generally used instead of stairs, and natural lighting cannot be utilized in rooms far from the windows and the windowless spaces such as elevators, bathrooms and stairwells.

Sky scrapers can be artificially lighted and the energy requirements can be covered by renewable energy or other electricity generation of low greenhouse gas emissions. Heating and cooling of sky scrapers can be efficient, because of centralized HVAC systems, heat radiation blocking windows and small surface area of the building. There is Leadership in Energy and Environmental Design (LEED) certification for sky scrapers. For example the Empire State Building received a gold Leadership in Energy and Environmental Design rating in September 2011 and the Empire State Building is the tallest LEED certified building in the United States, proving that sky scrapers can be environmentally friendly. Also the 30 St Mary Axe in London, the United Kingdom is an environmentally friendly sky scraper .

In the lower levels of a sky scraper a larger percentage of the building cross section must be devoted to the building structure and services than is required for lower buildings :

- More structure – because it must be stronger to support more floors above
- The elevator conundrum creates the need for more lift shafts — everyone comes in at the bottom and they all have to pass through the lower part of the building to get to the upper levels.
- Building services — power and water enter the building from below and have to pass through the lower levels to get to the upper levels.

In low - rise structures, the support rooms (chillers, transformers, boilers, pumps and air handling units) can be put in basements or roof space — areas which have low rental value. There is, however, a limit to how far this plant can be located from the area it serves. The farther away it is the larger the risers for ducts and pipes from this plant to the floors they serve and the more floor area these risers take. In practice this means that in high rise buildings this plant is located on 'plant levels' at intervals up the building.

7 - History of the tallest sky scrapers :

The Empire State Building in New York City is a well-known sky scraper and was the tallest in the world for nearly 40 years.
Main article: History of the tallest buildings in the world

At the beginning of the 20th century, New York City was a center for the Beaux-Arts architectural movement, attracting the talents of such great architects as Stanford White and Carrere and Hastings. As better construction and engineering technology became available as the century progressed, New York and Chicago became the focal point of the competition for the tallest building in the world. Each city's striking skyline has been composed of numerous and varied sky scrapers, many of which are icons of 20th century architecture:

- The **Flatiron Building**, designed by Daniel Hudson Burnham and standing 285 ft (87 m) high, was one of the tallest buildings in the city upon its completion in 1902, made possible by its steel skeleton. It was one of the first buildings designed with a steel framework, and to achieve this height with other construction methods of that time would have been very difficult. (The 1889 Tower Building, designed by Bradford Gilbert and considered by some to be New York's first sky scraper , may have been the first building to use a skeletal steel frame.)[61] Actually Home Insurance Building in Chicago, United States built in 1884 was the first building that had a skeletal frame. Subsequent buildings such as the **Singer Building**, the **Metropolitan Life Tower** were higher still.

- The **Woolworth Building**, a neo-Gothic "Cathedral of Commerce" overlooking City Hall, was designed by Cass Gilbert. At 792 feet (241 m), it became the world's tallest building upon its completion in 1913, an honor it retained until 1930, when it was overtaken by 40 Wall Street.
- That same year, the **Chrysler Building** took the lead as the tallest building in the world, scraping the sky at 319 m . Designed by William Van Alen, an Art Deco style masterpiece with an exterior crafted of brick,[63] the Chrysler Building continues to be a favorite of New Yorkers to this day.
- The **Empire State Building**, the first building to have more than 100 floors (it has 102), was completed the following year. It was designed by Shreve, Lamb and Harmon in the contemporary Art Deco style. The tower takes its name from the nickname of New York State. Upon its completion in 1931 at 1,250 feet (381 m), it took the top spot as tallest building, and towered above all other buildings until 1972. The antenna mast added in 1951 brought pinnacle height to 1,472 feet (449 m), lowered in 1984 to 443 m .
- The **World Trade Center** officially reached full height in 1972, was completed in 1973, and consisted of two tall towers and several smaller buildings. For a short time, the first of the two towers was the world's tallest building. Upon completion, the towers stood for 28 years, until the September 11 attacks destroyed the buildings in 2001. Various governmental entities, financial firms, and law firms called the towers home.

- The **Willis Tower** (formerly Sears Tower) was completed in 1974, one year after the World Trade Center, and surpassed it as the world's tallest building. It was the first building to employ the "bundled tube" structural system, designed by Fazlur Khan . The building was not surpassed in height until the Petronas Towers were constructed in 1998, but remained the tallest in some categories until Burj Khalifa surpassed it in all categories in 2010. It is currently the tallest building in the United States.

Momentum in setting records passed from the United States to other nations with the opening of the **Petronas Twin Towers** in Kuala Lumpur, Malaysia, in 1998. The record for world's tallest building remained in Asia with the opening of **Taipei 101** in Taipei, Taiwan, in 2004. A number of architectural records, including those of the world's tallest building and tallest free-standing structure, moved to the Middle East with the opening of the **Burj Khalifa** in Dubai, United Arab Emirates.

This geographical transition is accompanied by a change in approach to sky scraper design. For much of the twentieth century large buildings took the form of simple geometrical shapes. This reflected the "international style" or modernist philosophy shaped by Bauhaus architects early in the century. The last of these, the Willis Tower and World Trade Center towers in New York, erected in the 1970s, reflect the philosophy. Tastes shifted in the decade which followed, and new sky scrapers began to exhibit postmodernist influences. This approach to design avails itself of historical elements, often adapted and re-interpreted, in creating technologically modern structures. The Petronas Twin Towers recall Asian pagoda architecture and Islamic geometric principles. Taipei 101 likewise reflects the pagoda tradition as it incorporates ancient motifs such as the ruyi symbol. The Burj Khalifa draws inspiration from traditional Islamic art. Architects in recent years have sought to create structures that would not appear equally at home if set in any part of the world, but that reflect the culture thriving in the spot where they stand.For current rankings of sky scrapers by height, see List of tallest buildings in the world .The following list measures height of the **roof**. The more common gauge is the **highest architectural detail**; such ranking would have included Petronas Towers, built in 1998.

Built	Building	City	Country	Roof	Floors	Pinnacle	Current status	Built	Building
1870	Equitable Life Building[dubious – discuss]	New York City	United States	142 ft	43 m	8			Destroyed by fire in 1912
1889	Auditorium Building	Chicago	United States	269 ft	82 m	17	349 ft	106 m	Standing
1890	New York World Building	New York City	United States	309 ft	94 m	20	349 ft	106 m	Demolished in 1955
1894	Manhattan Life Insurance Building	New York City	United States	348 ft	106 m	18			Demolished in 1963
1895	Milwaukee City Hall	Milwaukee	United States	353 ft	108 m	15			Standing
1899	Park Row Building	New York City	United States	391 ft	119 m	30			Standing
1901	Philadelphia City Hall	Philadelphia	United States	511 ft	155.8 m	9	548 ft	167 m	Standing
1908	Singer Building	New York City	United States	612 ft	187 m	47			Demolished in 1968
1909	Met Life Tower	New York City	United States	700 ft	213 m	50			Standing
1913	Woolworth Building	New York City	United States	792 ft	241 m	57			Standing
1930	40 Wall Street	New York City	United States			70	927 ft	283 m	Standing
1930	Chrysler Building	New York City	United States	927 ft	282.9 m	77	1,046 ft	319 m	Standing
1931	Empire State Building	New York City	United States	1,250 ft	381 m	102	1,454 ft	443 m	Standing
1972	World Trade Center (North tower)	New York City	United States	1,368 ft	417 m	110	1,727 ft	526.3 m	Destroyed in 2001
1974	Willis Tower (formerly Sears Tower)	Chicago	United States	1,450 ft	442 m	108	1,729 ft	527 m	Standing
2004	Taipei 101	Taipei	Taiwan	1,474 ft	449 m	101	1,671 ft	509 m	Standing
2008	Shanghai World Financial Center	Shanghai	China	1,599 ft	487 m	101	1,614 ft	492 m	Standing
2010	Burj Khalifa	Dubai	United Arab Emirates	2,717 ft	828 m	160	2,717 ft	828 m	Standing

<table>
<tr><td></td><td></td></tr>
<tr><td>*The iconic World Trade Center twin towers were destroyed in 2001*</td><td>*Taipei 101, formerly the world's tallest sky scraper , was the first to exceed the half-kilometer mark.*</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">*The Petronas Twin Towers.*</td></tr>
<tr><td></td><td></td></tr>
<tr><td>*The Willis Tower in Chicago was the world's tallest building from 1974 to 1998, and remains the tallest in the Western Hemisphere*</td><td>*Tower 2 of the International Finance Centre in Hong Kong is one of the 20 tallest buildings in the world.*</td></tr>
</table>

8 - Future developments :

At the time Taipei 101 broke the half-km mark in height, it was already technically possible to build structures towering over a km above the ground . Proposals for such structures have been put forward, including the Kingdom Tower to be built in Jeddah, Saudi

Arabia and Burj Mubarak Al Kabir in Kuwait. Kilometer - plus structures present architectural challenges that may eventually place them in a new architectural category.

The following sky scrapers, all contenders for being among the tallest in their city or region, are under construction and due to be completed in the next few years:

- Construction of the 133-floor, 640 m tall **Digital Media City Landmark Building** in Digital Media City, Seoul, South Korea, started in 2009, which will be the second-tallest building in the world when it is completed in 2015, housing the world's tallest observatory and hotels. Being constructed at the fastest speed among major sky scraper projects by South Korea's Samsung C&T (who also built Burj Khalifa), the supertall is the first sky scraper to contain an entire city inside a building, including the world's largest aquarium, a luxury department store, shopping malls, clinic center, high-tech offices, first-class apartments, six to eight-star hotels, a concert restaurant, a broadcasting studio and an art center.
- Construction of the **Shanghai Tower** started on 29 November 2008 . The tower will be 632 m high and have 127 floors . The building will feature a glass curtain wall and nine indoor gardens when it is completed in 2014.
- Construction of the 151-floor, 610 m tall **151 Incheon Tower** in Songdo International City, Incheon, South Korea, started in 2008, which will be the tallest twin towers in the world when it is completed in 2014.
- The **Abraj Al-Bait Towers**, also known as the "Mecca Royal Clock Hotel Tower" is a complex under construction in Mecca, Saudi Arabia by the Saudi Binladin Group. The complex consists of seven towers, and the tallest tower (Hotel Tower) will have a height of 601 m . Upon completion in 2011, the structure will have the largest floor area of any structure in the world, at 1,500,000 m^2 .
- Construction of the 110-floor, 510 m tall **Busan Lotte World**, Busan, South Korea, started in 2009. It is due for completion in 2016.

- **One World Trade Center** is currently under construction in New York City and will be the tallest tower in the redevelopment of the site of the former World Trade Center. Its pinnacle will reach a height of 541.4 m , representing the year of the United States Declaration of Independence.
- **World One** is a 442 m tall residential sky scraper under construction in Mumbai, India. It is located in Upper Worli of Mumbai on a 17.5 acre site. The project will cost INR 2,000 crore (US $ 380 million) , be completed by 2014 and will have the world's second tallest residential tower once completed. It will be rated as Leed Gold Certified building by the Green Building Council. World One is designed by Pei Cobb Freed and Partners and Leslie E. Robertson Associates.
- Construction of **The Shard** in London, United Kingdom started in March 2009, and was completed in May 2012, in time for the London Olympics. At 310 m , it is set to be the tallest building in the European Union .
- **Gran Torre Santiago** will be the tallest building in Latin America with 300 m to the top. Construction started in 2006 and is planned to finish in 2013. It is located in Chile´s Capital Santiago and is being developed by Cencosud.

Slip Forming

Continuous slip formed gravity base structure supports under construction in a Norwegian fiord. The visible jib cranes would each be delivering buckets of concrete to the support cylinders during the continuous pour of concrete creating seamless walls.

Contents

1 – Introduction :

Slip forming, **continuous poured**, **continuously formed**, or **slip form construction** is a construction method in which concrete is poured into a continuously moving form.[1] Slip forming is used for tall structures (such as bridges, towers, buildings, and dams), as well as horizontal structures, such as roadways. Slip forming enables continuous, non-interrupted, cast-in-place "flawless" (i.e. no joints) concrete structures which have superior performance characteristics to piecewise construction using discrete form elements. Slip forming relies on the quick-setting properties of concrete, and requires a balance between quick-setting capacity and workability. Concrete needs to be workable enough to be placed into the form and packed, yet quick-setting enough to emerge from the form with strength. This strength is needed because the freshly set concrete must not only permit the form to "slip" upwards but also support the freshly poured concrete above it.

In **vertical slip forming** the concrete form may be surrounded by a platform on which workers stand, placing steel reinforcing rods into the concrete and ensuring a smooth pour. Together, the concrete form and working platform are raised by means of hydraulic jacks. Generally, the slip form rises at a rate which permits the concrete to harden by the time it emerges from the bottom of the form.

In **horizontal slip forming** for pavement and traffic separation walls concrete is laid down, vibrated, worked, and settled in place while the form itself slowly moves ahead. This method was initially devised and utilized in Interstate Highway construction initiated by the Eisenhower administration during the 1950s.

2 – History :

The slip forming technique was in use by the early 20th century for building silos and grain elevators. In the 1947-1950 period, AT&T Long Lines built 49 concrete towers up to 191 ft tall for microwave relay stations; most using the slip-form method.

AT&T Long Lines relay tower in Indiana constructed with the slip - form method.

The technique was introduced to residential and commercial buildings in the late 1960s . The first notable use of the method in a residential/retail business was the Skylon Tower in Niagara Falls, Ontario, which was completed in 1965. One of Its first uses in high-rise buildings the United States was on the shear wall supported apartment building at Turk & Eddy Streets in San Francisco, CA, in 1962. Another unusual structure was the tapered buttress structures for the Sheraton Waikiki Hotel in Honolulu, Hawaii, in 1969. Another shear wall supported structure was the Casa Del Mar Condominium on Key Biscayne, Miami, FL in 1970.

From the 1960s, the vertical technique was adapted to mining head frames, ventilation structures, below grade shaft lining, and coal train loading silos; theme and communication tower construction; high rise office building cores; shear wall supported apartment buildings; tapered stacks and hydro intake structures, etc. It is used for structures which would otherwise not be possible, such as the separate legs of the Troll A deep sea oil drilling platform which stands on the sea floor in water about 1000 feet (300 m) deep, has an overall height of 472 meters (1,549 ft), weighs 656,000 tons, and has the distinction of being the tallest structure ever moved (towed) by mankind.

In addition to the typical silos and shear walls and cores in buildings, the system is used for lining underground shafts and surge tanks in hydroelectric generating facilities. The technique was utilized to build the Inco Super stack in Sudbury, Ontario, and the CN Tower in Toronto. In 2010, the technique was used to build the core of the super tall Shard London Bridge tower in London, England. It is the most common method for construction of tall buildings in Australia.

Snyder Estate Natural Cement Historic District

Contents

1 – Introduction :

The **Snyder Estate Natural Cement Historic District** is located in the Town of Rosendale, New York, United States. It is a 275- acre (111 ha) tract roughly bounded by Rondout Creek, Binne water and Cotte kill roads and Sawdust Avenue. NY 213 runs through the lower portion of the district, paralleling the dry bed of the Delaware and Hudson Canal, where the product that gives the district its name was first discovered.

Within the district's bounds are 122 contributing properties representing what remains of five plants that turned out Rosendale cement, and the homes and dependencies of the Snyder family, who originally owned the land. They range in age from the bed of the canal, where the cement was first discovered in 1825 during construction, to some of the last factories built before production was ended in 1970. Included are not just homes, barns and factories but mines, reservoirs and a rail siding. After an aborted attempt to secure National Historic Landmark District status in 1978, the district was added to the National Register of Historic Places in 1992.

Snyder Estate Natural Cement Historic District

U.S. National Register of Historic Places

U.S. Historic district

Houses of Andrew (left) and Charles Snyder along Route 213, 2008

Location:	Rosendale, NY
Nearest city:	Kingston
Coordinates:	41°50′50″N 74°05′52″W41.84722°N 74.09778°W
Area:	275 acres (111 ha)
Built:	1825-1958
Architectural style:	Federal, other
Governing body:	Private residences, Century House Historical Society

2 - Geography

The district is shaped like a letter "r", solidly bounded by the roads and creek on three of its sides, but with its eastern boundary mostly following old roads between Route 213, Binne water and Sawdust. Physically, it is dominated by two large hills, foothills of the Shawangunk Ridge to the south, which rise to over 91 m in elevation, more than 61 m above the creek's waters to the south.

Between them in a narrow valley sit the remains of one the largest cement plants in it. An old Wallkill Valley Railroad siding runs from there to the northeast corner near where it once joined the main line at today's Binne water Historic District. Old mines and quarries are tunneled into the sides of both hills.

The property is mostly wooded save for the developed areas. Some of the areas along the road are old fields, today meadows.

3 – History :

Almost as soon as it was initially discovered, production of the cement within the bounds of the district grew rapidly. That changed with the development of Portland cement at the end of the century. Production dropped as demand fell, and only through the creativity of one of the Snyder descendants did the company remain in operation to 1970.

3 – 1 - 19 th century :

The property had been owned and farmed by the Snyder family since 1755. In 1809, Christopher and Deborah Snyder commissioned a house for their newlywed son Jacob Lowe Snyder, with an accompanying grist mill on the creek. Known today as the Century House, it is the oldest extant building in the district whose age is precisely known .

Sixteen years later, Jacob ceded a portion of his land to John B. Jervis of the Delaware and Hudson Canal Company, allowing it to be built across the property with the condition that the company build him a slip so he could use it to ship his produce to market, and a bridge to reach his mill. Crews excavating the area a short while later found large deposits of dolo stone, an argillaceous mineral that could be turned into natural cement, which needed no additives once pulverized and mixed.

Since similar cement had made construction of the Erie Canal possible, the company began setting up production facilities almost immediately. Not only would many of the finished canal locks use this new cement, it would guarantee the canal another customer besides the anthracite coal miners it was built to serve.[2] In 1830 Snyder leased the southeastern corner of his property to Watson Lawrence, who had already built a cement plant on adjacent land. Other mines and cement plants opened up in the 32-square-mile (83 km^2) area along the Rondout as well, creating a virbant local industry.

He reinvested a lot of the Lawrence Cement Company's profits in improving its technical quality, and courted procurers for large, high-profile government projects like New York City's Croton Aqueduct and the docks at the Brooklyn Navy Yard.[1] This helped create a reputation for quality, and soon "Rosendale cement" became a generic term for any such natural cement regardless of where it was produced . But it also strained the company's finances, and after several crises the company finally failed for good in 1858.

Lawrence retained control of the new Lawrenceville Cement Company, but after three years he was ousted and William Beach took over. He expanded the production facilities, in time for the rise in demand that occurred as the Gilded Age saw a rapid increase in demand after the lull caused by the Civil War. He died in 1881, and control passed to his son William N. Beach II shortly thereafter.

The younger Beach began taking advantage of the recently-constructed Wallkill Valley Railroad and its connections to the New York Central network as a way to get product to market, building a siding to the plant. In keeping with a general national trend, this began a shift away from the canal that had spawned the cement works, and within two decades the canal would carry its last loads.

3 – 2 - 20 th century :

As the century ended, the natural-cement industry dominated the market. The Snyder family was proud that their cement had been used in the Brooklyn Bridge, an icon of the era. Beach built another new plant in the northeast corner of the property to handle demand. But the development of the cheaper Portland cement during that time period eventually toppled the Rosendale variety, whose market share dropped 90 % in the first decade of the 20 th century. Local industrial magnate Samuel Coykendall eventually tried to salvage the Rosendale industry through mergers, combining all the local companies save the ones on the Snyder property into one. The Consolidated Rosendale Cement Company was no more successful than any of its component companies had been, and was in receivership by 1918.

In 1911 an Ulster County court had forced the sale of the Snyder company from William Snyder to 21-year-old Andrew J. Snyder II after a disagreement over the sharing of profits. The younger Snyder dismantled one of the larger plants and built a smaller one in its place. He was able to continue production on a reduced scale through the 1920s, and later in that decade attracted the interest of an investor from Cleveland named Kling, who leased a portion of the property from Snyder and started the Interstate Cement Company.[1]

The Great Depression soon put an end to that venture, and by 1935 it had become the Century Cement Manufacturing Co., wholly owned by Snyder. He was able to keep the company going through the later 1930s when he allowed mushroom growers to set up shop in the abandoned Beach Mine. Eventually that would produce five tons (4.5 tonnes) per day before it stopped in 1960.

At the same time he also took advantage of a discovery that Portland cement could be made even more quickly and last longer when combined with natural cement in an 80-20 ratio. This blend was particularly suited to high ways, then being built at a great pace everywhere due to the combination of New Deal public works projects and increasing automobile use. By the start of World War II production was again on the increase.

It fell during the war years, but rebounded afterwards to even higher levels as highway construction picked up again with the development of the Interstate Highway System. In 1954 Rosendale cement was used for the nearby sections of the New York State Thruway. However, it would be the last major public project in which it was used.

Snyder had been exploring the possibilities of making Portland cement as well. Geologists found that there were significant reserves in the Hudson Valley of the type of limestone needed, so in 1958 the copmpany bought a plant from the Swiss company Van Roll. Three years later it was built next to the existing facilities and began turning out cement. Around the same time, chemists developed an additive to Portland cement which eliminated the need for the Rosendale mix, and cut costs even further.

Snyder and the company's technical team tried to keep up with the changes, but they were as old as he was and had trouble getting the formula right. The market for the natural cement the property still produced was almost negligible, and in 1970 Snyder finally halted production almost a century and a half after Rosendale cement had first been discovered on the bed of the long-abandoned canal. He himself died five years later .

4 – Preservation :

Recognizing its historic importance not just to the region but the country as a whole, two staffers at the American Association for State and Local History prepared an application to have the district designated a National Historic Landmark in 1978 that was never completed . The Century House Historical Society (CHHS) acquired the 19 acres (7.7 ha) around the eponymous 1809 building where Jacob Lowe Snyder lived at the time of the canal's construction. It was chartered provisionally in 1992 and fully in 2000 . It runs the property as a museum devoted to both the house and the American natural cement industry .

In the plant's last years, one of the few markets it had left was the restoration of historic buildings that had originally used it or similar materials. The factory's closure left those builders without any source of authentic material. In 2004 Edison Coatings, Inc., of Plainville, Connecticut, trademarked the brand Rosendale Natural Cement Products and began offering an authentic, historically accurate replacement .

5 - Significant contributing properties :

Several of the many contributing resources to the district are notable in their own right. None have yet been separately listed on the Register, save the sections of canal bed, a National Historic Landmark.

The **Century House Historical Society** operates the site as a museum that is open to the public on Sunday afternoons in the summer season. The museum is also known as the "Century House Historical Society Museum" and the "Snyder Estate Museum".[6]

5 – 1 - Century House :

Jacob Lowe Snyder's 1809 frame house, renovated in the 1940s, is the core of the CHHS property and the oldest building in the district.

The house features the **Cement Industry Museum**, with artifacts and photographs from the Rosendale cement industry. Rosendale Natural Cement was used in the building of many historic buildings and structures, including the Brooklyn Bridge, the pedestal of the Statue of Liberty, the wings of the U.S. Capitol, the Washington Monument, Grand Central Terminal, the Croton Aqueduct and dams and many other public works projects. There is also a display of horse-drawn carriages and sleighs.

5 – 2 - Andrew J. Snyder I House :

Known also as the **Ceramic Brick House**. Originally built in 1887 as a Second Empire-style mansion complete with mansard roof, in 1950 the windows and roof were converted to a more standard gable with dormers. It was also refaced in polychrome glazed brick imported from Leeds. This drastic exterior redesign did not cost the house its historic status as its original framing and interior layout remain intact.

5 – 3 - Canal infrastructure :

In addition to the canal bed, other aspects of the canal remain within the district. There is a waste weir next to it, and just west of Binne water Road is a reservoir that was used to keep the canal full during dry stretches. The slip that the company built for Snyder is also intact, and is possibly the only remaining slip from the original construction along the entire length of the former canal.

5 – 4 - Widow Jane Mine :

The oldest cement mine, a drift into one of the hillsides. It was constructed using the room and pillar technique, where pillars of dolostone have been left to support the overlying rock. The largest of the mines, it has been likened to an underground pillared room. It is currently mostly flooded with ground water, but that has not stopped musicians from recording in it to take advantage of the acoustics.

Sodium Aluminate

Contents

1 – Introduction :

Sodium Aluminate is an important commercial inorganic chemical. It works as an effective source of aluminium hydroxide for many industrial and technical applications. Pure sodium aluminate (anhydrous) is a white crystalline solid having a formula variously given as Na Al O_2 , Na Al $(OH)_4$ (hydrated), $Na_2O·Al_2O_3$, or $Na_2Al_2O_4$. Commercial sodium aluminate is available as a solution or a solid.

Other related compounds, sometimes called sodium aluminate, prepared by reaction of Na_2O and Al_2O_3 are Na_5AlO_4 which contains discrete AlO_4^{5-} anions, $Na_7Al_3O_8$ and $Na_{17}Al_5O_{16}$ which contain complex polymeric anions, and $NaAl_{11}O_{17}$, once mistakenly believed to be β-alumina, a phase of aluminium oxide.

Other names :
Sodium aluminium oxide,
Sodium meta aluminate
Aluminate, (AlO_2^{1-}), sodium

Molecular Formula	Na Al O_2
Molar Mass	82 g / mol
Appearance	white powder
Density	1.5 g / cm^3
Melting point	1650 °C
Solubility in water	soluble

Solubility in Alcohol	soluble
Refractive index (n_D)	1.58

2 – Structure :

Anhydrous sodium aluminate, $NaAlO_2$, contains a three dimensional framework of corner linked AlO_4 tetra hedra. The hydrated form $NaAlO_2 \cdot 5/4H_2O$ has layers of AlO_4 tetra hedra joined into rings and the layers are held together by sodium ions and water molecules that hydrogen bond to O atoms in the AlO_4 tetra hedra.

3 – Manufacturing :

Sodium aluminate is manufactured by the dissolution of- aluminium hydroxide in a caustic soda (Na OH) solution. Aluminium hydroxide (gibbsite) can be dissolved in 20 –25 % aqueous NaOH solution at a temperature near the boiling point. The use of more concentrated Na OH solutions leads to a semi-solid product. The process must be carried out in steam-heated vessels of nickel or steel, and the aluminium hydroxide should be boiled with approximately 50% aqueous caustic soda until a pulp forms. The final mixture has to be poured into a tank and cooled; a solid mass containing about 70% $NaAlO_2$ then forms. After being crushed, this product is dehydrated in a rotary oven heated either directly or indirectly by burning hydrogen. The resulting product contains 90% $NaAlO_2$ and 1% water, together with 1% free Na OH.

4 - Reaction of aluminium metal and alkali :

Sodium aluminate is also formed by the action of sodium hydroxide on elemental aluminium which is an amphoteric metal. The reaction is highly exothermic once established and is accompanied by the rapid evolution of hydrogen gas. The reaction is sometimes written as:

$$2\ Al + 2\ Na\,OH + 2\ H_2O \rightarrow 2\ NaAlO_2 + 3\ H_2$$

however the species produced in solution is likely to contain the $[Al(OH)_4]^-$ ion or perhaps the $[Al(H_2O)_2(OH)_4]^-$.

This reaction has been proposed as a potential source of fuel for hydrogen powered cars.

5 - Uses :

In water treatment it is used as an adjunct to water softening systems, as a coagulant aid to improve flocculation, and for removing dissolved silica and phosphates.

In construction technology, sodium aluminate is employed to accelerate the solidification of concrete, mainly when working during frost.

Sodium aluminate is also used in the paper industry, for fire brick production, alumina production and so forth.

Sodium aluminate solutions are intermediates in the production of zeolites.

Sodium Carbonate

Contents

1 – Introduction :

Sodium Carbonate (also known as **washing soda** or **soda ash**), Na_2CO_3 is a sodium salt of carbonic acid. It most commonly occurs as a crystalline heptahydrate, which readily effloresces to form a white powder, the monohydrate. Sodium carbonate is domestically well known for its everyday use as a water softener. It can be extracted from the ashes of many plants. It is synthetically produced in large quantities from salt (sodium chloride) and limestone in a process known as the Solvay process.

Other Names : Soda ash - Washing soda - Soda crystals	
Molecular formula	$Na_2 CO_3$
Molar mass	105.9784 g/mol (anhydrous) 124.00 g/mol (mono hydrate) 286.14 g/mol (deca hydrate)
Appearance	White solid , hygroscopic
Odor	Odorless
Density	2.54 g/cm^3 (anhydrous)

	2.25 g/cm^3 (mono hydrate) 1.51 g/cm^3 (hepta hydrate) 1.46 g/cm^3 (deca hydrate)
Melting Point	851 °C (anhydrous) 100 °C (decomp, monohydrate) 33.5 °C (decomp, deca hydrate) 32 °C (hepta hydrate)
Boiling Point	1633 °C (anhydrous)
Solubility in water	71 g / L (0 °C) 215 g / L (20 °C) 455 g / L (100 °C)
Solubility	insoluble in ethanol , acetone
Basicity (pK_b)	4.67
Refractive index (n_D)	1.485 (anhydrous) 1.420 (monohydrate) 1.405 (decahydrate)
Coordination geometry	trigonal planar
EU classification	Irritant (Xi)
Flash Point	Non- flammable
LD_{50}	4090 mg / kg (rat , oral)

2 - Uses :

The manufacture of glass is one of the most important uses of sodium carbonate. When combined with silica and calcium carbonate and heated to high temperatures, then cooled rapidly, glass is produced. This type of glass is known as soda lime glass.

Sodium carbonate is also used as a relatively strong base in various settings. For example, sodium carbonate is used as a pH regulator to maintain stable alkaline conditions necessary for the action of the majority of photographic film developing agents.

It is a common additive in municipal pools used to neutralize the acidic effects of chlorine and raise pH.

In cooking, it is sometimes used in place of sodium hydroxide for lyeing, especially with German pretzels and lye rolls. These dishes are treated with a solution of an alkaline substance in order to change the pH of the surface of the food and thus improve browning.

In taxidermy, sodium carbonate added to boiling water will remove flesh from the skull or bones of trophies to create the "European skull mount" or for educational display in biological and historical studies.

In chemistry, it is often used as an electrolyte. This is because electrolytes are usually salt-based, and sodium carbonate acts as a very good conductor in the process of electrolysis. In addition, unlike chloride ions, which form chlorine gas, carbonate ions are not corrosive to the anodes. It is also used as a primary standard for acid-base titrations because it is solid and air-stable, making it easy to weigh accurately.

2 – 1 - Domestic use :

In domestic use, it is used as a water softener during laundry. It competes with the magnesium and calcium ions in hard water and prevents them from bonding with the detergent being used. Sodium carbonate can be used to remove grease, oil and wine stains. It is sold as washing soda, soda crystals, or sal soda. Sodium carbonate is also used as a descaling agent in boilers such as those found in coffee pots, espresso machines, etc.

In dyeing with fiber-reactive dyes, sodium carbonate (often under a name such as soda ash fixative or soda ash activator) is used to ensure proper chemical bonding of the dye with cellulose (plant) fibers, typically before dyeing (for tie dyes), mixed with the dye (for dye painting), or after dyeing (for immersion dyeing).

2 – 2 - Other applications :

Sodium carbonate is a food additive (E500) used as an acidity regulator, anti-caking agent, raising agent, and stabilizer. It is one of the components of *kansui*, a solution of alkaline salts used to give ramen noodles their characteristic flavor and texture. It is also used in the production of *snus* (Swedish-style snuff) to stabilize the pH of the final product. In Sweden, *snus* is regulated as a food product because it is put into the mouth, requires pasteurization, and contains only ingredients that are approved as food additives.

Sodium carbonate is also used in the production of sherbet powder. The cooling and fizzing sensation results from the endothermic reaction between sodium carbonate and a weak acid, commonly citric acid, releasing carbon dioxide gas, which occurs when the sherbet is moistened by saliva.

In China, it is used to replace lye-water in the crust of traditional Cantonese moon cakes, and in many other Chinese steamed buns and noodles.

Sodium carbonate is used by the brick industry as a wetting agent to reduce the amount of water needed to extrude the clay.

In casting, it is referred to as "bonding agent" and is used to allow wet alginate to adhere to gelled alginate.

Sodium carbonate is used in toothpastes, where it acts as a foaming agent and an abrasive, and to temporarily increase mouth pH.

Sodium carbonate is used to create the photo process known as reticulation.

Sodium carbonate, in a solution with common salt, may be used for cleaning silver. In a non-reactive container (glass, plastic or ceramic) aluminium foil and the silver object are immersed in the hot salt solution. The elevated pH dissolves the aluminium oxide layer on the foil and enables an electrolytic cell to be established . Hydrogen ions produced by this reaction reduce the sulphide ions on the silver restoring silver metal. The sulphide can be released as small amounts of hydrogen sulphide. Rinsing and gently polishing the silver restores a highly polished condition.

3 - Hazards :

According to the MSDS, Sodium Carbonate could cause the following hazards:

- Potential Acute Health Effects: Hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation (lung irritant).
- Potential Chronic Health Effects: Slightly hazardous in case of skin contact (sensitizer). The substance may be toxic to upper respiratory tract, skin, eyes. Repeated or prolonged exposure to the substance can produce target organ damage.

4 – Occurrence :

Sodium carbonate crystallizes from water to form three different hydrates:

1. sodium carbonate deca hydrate (natron)
2. sodium carbonate hepta hydrate (not known in mineral form)
3. sodium carbonate mono hydrate (mineral thermonatrite).

Sodium carbonate is soluble in water, and can occur naturally in arid regions, especially in mineral deposits (*evaporites*) formed when seasonal lakes evaporate. Deposits of the mineral natron have been mined from dry lake bottoms in Egypt since ancient times, when natron was used in the preparation of mummies and in the early manufacture of glass.

The anhydrous mineral form of sodium carbonate is quite rare and called natrite. Sodium carbonate also erupts from Ol Doinyo Lengai, Tanzania's unique volcano, and it is presumed erupted from other volcanoes in the past but, due to these minerals' instability at the earth's surface, are likely to be eroded. All three mineralogical forms of sodium carbonate, as well as trona, trisodium hydrogendicarbonate dihydrate, are also known from ultra-alkaline pegmatitic rocks, that occur for example in the Kola Peninsula in Russia.

5 – Production :

5 – 1 – Mining :

Trona , tri sodium hydrogen di carbonate di hydrate ($Na_3HCO_3CO_3 \cdot 2H_2O$), is mined in several areas of the United States and provides nearly all the domestic sodium carbonate. Large natural deposits found in 1938, such as the one near Green River, Wyoming, have made mining more economical than industrial production in North America. There are important reserves of Trona in Turkey. 2 million tons of soda ash produced from the reserves near Ankara. It is also mined from some alkaline lakes such as Lake Magadi in Kenya by dredging. Hot saline springs continuously replenish salt in the lake so that, provided the rate of dredging is no greater than the replenishment rate, the source is fully sustainable.

5 – 2 - Barilla and kelp :

Several "halophyte" (salt-tolerant) plant species and seaweed species can be processed to yield an impure form of sodium carbonate, and these sources predominated in Europe and elsewhere until the early 19th century. The land plants (typically glass worts or salt worts) or the seaweed (typically *Fucus* species) were harvested, dried, and burned. The ashes were then "lixiviated" (washed with water) to form an alkali solution. This solution was boiled dry to create the final product, which was termed "soda ash"; this very old name refers to the archetypal plant source for soda ash, which was the small annual shrub *Salsola soda* ("barilla plant").

The sodium carbonate concentration in soda ash varied very widely, from 2–3 percent for the seaweed-derived form ("kelp"), to 30 percent for the best barilla produced from saltwort plants in Spain. Plant and seaweed sources for soda ash, and also for the related alkali "potash", became increasingly inadequate by the end of the 18th century, and the search for commercially-viable routes to synthesizing soda ash from salt and other chemicals intensified.

5 – 3 - Leblanc process :

In 1791, the French chemist Nicolas Leblanc patented a process for producing sodium carbonate from salt, sulfuric acid, limestone, and coal. First, sea salt (sodium chloride) was boiled in sulfuric acid to yield sodium sulfate and hydrogen chloride gas, according to the chemical equation

$$2\ NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2\ HCl$$

Next, the sodium sulfate was blended with crushed lime stone (calcium carbonate) and coal, and the mixture was burnt, producing calcium sulfide.

$$Na_2SO_4 + CaCO_3 + 2\ C \rightarrow Na_2CO_3 + 2\ CO_2 + CaS$$

The sodium carbonate was extracted from the ashes with water, and then collected by allowing the water to evaporate.

The hydrochloric acid produced by the Leblanc process was a major source of air pollution, and the calcium sulfide byproduct also presented waste disposal issues. However, it remained the major production method for sodium carbonate until the late 1880s.[4][5]

5 – 4 - Solvay process :

In 1861, the Belgian industrial chemist Ernest Solvay developed a method to convert sodium chloride to sodium carbonate using ammonia. The Solvay process centered around a large hollow tower. At the bottom, calcium carbonate (lime stone) was heated to release carbon dioxide :

$$CaCO_3 \rightarrow CaO + CO_2$$

At the top, a concentrated solution of sodium chloride and ammonia entered the tower. As the carbon dioxide bubbled up through it, sodium bicarbonate precipitated:

$$NaCl + NH_3 + CO_2 + H_2O \rightarrow NaHCO_3 + NH_4Cl$$

The sodium bicarbonate was then converted to sodium carbonate by heating it, releasing water and carbon dioxide:

$$2\ NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$$

Meanwhile, the ammonia was regenerated from the ammonium chloride byproduct by treating it with the lime (calcium hydroxide) left over from carbon dioxide generation:

$$CaO + H_2O \rightarrow Ca(OH)_2$$
$$Ca(OH)_2 + 2\ NH_4Cl \rightarrow CaCl_2 + 2\ NH_3 + 2\ H_2O$$

Because the Solvay process recycles its ammonia, it consumes only brine and limestone, and has calcium chloride as its only waste product. This made it substantially more economical than the Leblanc process, and it soon came to dominate world sodium carbonate production. By 1900, 90 % of sodium carbonate was produced by the Solvay process, and the last Leblanc process plant closed in the early 1920s.

5 – 5 - Hou's process :

Developed by Chinese chemist Hou Debang in 1930s, the first few steps are the same as the Solvay process. However, instead of treating the remaining solution with lime, carbon dioxide and ammonia are pumped into the solution, then sodium chloride is added until the solution saturates at 40 °C. Next, the solution is cooled to 10 °C. Ammonium chloride precipitates and is removed by filtration, and the solution is recycled to produce more sodium carbonate. Hou's process eliminates the production of calcium chloride and the byproduct ammonium chloride can be refined or used as a fertilizer.

5 – 6 - Soda process :

(a subpart of the Solvay process) Sodium Bicarbonate is readily available as Baking Soda. Heating it releases water and carbon dioxide : $2NaHCO_3(s) \rightarrow Na_2CO_3 + H_2O + CO_2$

Sodium Hydroxide

Contents

1 – Introduction :

Sodium hydroxide, also known as **lye** or **caustic soda** , has the molecular formula **Na OH** and is a highly caustic metallic base. It is a white solid available in pellets , flakes , granules , and as a 50 % saturated solution .

Sodium hydroxide is soluble in water, ethanol and methanol. This alkali is deliquescent and readily absorbs moisture and carbon dioxide in air.

Sodium hydroxide is used in many industries, mostly as a strong chemical base in the manufacture of pulp and paper, textiles, drinking water, soaps and detergents and as a drain cleaner. Worldwide production in 2004 was approximately 60 million tones, while demand was 51 million tones . Although molten sodium hydroxide possesses properties similar to those of the other forms, its high temperature comparatively limits its applications.

Preferred IUPAC Name : Sodium hydroxide	
Systematic Name : Sodium oxidanide	
Other Names : Caustic soda – Lye – Ascarite - White caustic - Sodium hydrate	
Molecular Formula	Na OH
Molar Mass	40 g mol^{-1}
Appearance	White, waxy, opaque crystals
Odor	odorless
Density	2.13 g / cm^3
Melting point	318 °C
Boiling point	1388 °C
Solubility in water	111 g /100 mL (at 20 °C)
Solubility in methanol	23.8 g / 100 mL
Solubility in ethanol	<< 13.9 g / 100 mL
Vapor pressure	< 2.4 kPa (at 20 °C)
Acidity (pK_a)	13
Refractive index (n_D)	1.3576
EU classification	C

2 - Properties :

2 – 1 - Physical properties :

Pure sodium hydroxide is usually a white solid which may be pellets, flakes or granules, though some times it is in form of a 50%

saturated solution. It is very soluble in water with a lower solubility in ethanol and methanol but it is insoluble in ether and other non-polar solvents.

Similar to the hydration of sulfuric acid, dissolution of solid sodium hydroxide in water is a highly exothermic reaction in which a large amount of heat is liberated, posing a threat to safety through the possibility of splashing. The resulting solution is usually colourless and odorless with slippery feeling upon contact in common with other alkalis . $\Delta H°_{\text{dissolution}}$ for aqueous dilution is −44.45 kJ / mol; from aqueous solutions at 12.3 – 61.8 °C, it crystallizes in monohydrate, with a melting point 65.1 °C and density of 1.829 g/cm^3 . The standard enthalpy change of formation ($\Delta H°_{\text{form}}$) of anhydrous solid Na OH is − 425.61 kJ / mol.

2 – 2 - Chemical properties :

2 – 2 - 1 - Reaction with acids :

Sodium hydroxide reacts with protic acids to produce water and the corresponding salts. For example, when sodium hydroxide reacts with hydrochloric acid, sodium chloride is formed:

$$NaOH\,(aq) + HCl\,(aq) \rightarrow NaCl\,(aq) + H_2O\,(l)$$

In general such neutralization reactions are represented by one simple net ionic equation:

$$OH^-(aq) + H^+(aq) \rightarrow H_2O\,(l)$$

This type of reaction with a strong acid releases heat, and hence is exothermic. Such acid-base reactions can also be used for titrations. However, sodium hydroxide is not used as a primary standard because it is hygroscopic and absorbs carbon dioxide from air.

2 – 2 - 2 - Reaction with acidic oxides :

Sodium hydroxide also reacts with acidic oxides, such as sulfur dioxide. Such reactions are often used to "scrub" harmful acidic gases (like SO_2 and H_2S) produced in the burning of coal and thus prevent their release into the atmosphere. For example,

$$2\ Na\ OH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

2 – 2 - 3 - Reaction with amphoteric metals and oxides :

Sodium hydroxide slowly reacts with glass to form sodium silicate. Because of this, glass joints and stop cocks exposed to NaOH have a tendency to "freeze". Flasks and glass-lined chemical reactors are damaged by long exposure to hot sodium hydroxide, which also frosts the glass. Sodium hydroxide does not attack iron since iron does not have amphoteric properties (i.e., it only dissolves in acid, not base). A few transition metals, however, may react vigorously with sodium hydroxide.

In 1986, an aluminium road tanker in the UK was mistakenly used to transport 25% sodium hydroxide solution , causing pressurization of the contents and damage to the tanker. The pressurization was due to the hydrogen gas which is produced in the reaction between sodium hydroxide and aluminium:

$$2\ Al + 2\ Na\ OH + 2\ H_2O \rightarrow 2\ Na\ Al\ O_2 + 3\ H_2$$

2 – 2 - 4 – Precipitant :

Unlike Na OH, the hydroxides of most transition metals are insoluble, and there fore sodium hydroxide can be used to precipitate transition metal hydroxides . Aluminium hydroxide is used as a gelatinous flocculent to filter out particulate matter in water treatment. Aluminium hydroxide is prepared at the treatment plant from aluminium sulfate by reacting it with NaOH.

$$Al_2\ (SO_4)_3 + 6\ Na\ OH \rightarrow 2\ Al\ (OH)_3 + 3\ Na_2SO_4$$

2 – 2 - 5 - Saponification

NaOH can be used for the base-driven hydrolysis of esters (as in saponification), amides and alkyl halides. However, the limited solubility of Na OH in organic solvents means that the more soluble KOH is often preferred.

2 – 2 - 6 – Electrolysis :

In the laboratory, with carefully controlled conditions, sodium metal can be isolated from the electrolysis of the molten monohydrate in a low temperature version of the Castner process, according to the following reaction:

$$4 \text{ Na OH} \cdot H_2O_{\,(l)} \rightarrow 4 \text{ Na}_{\,(l)} + O_{2\,(g)} + 6\, H_2O_{\,(g)}$$

The monohydrate does not need to be heated in order to melt, as the process produces enough heat due to ohmic heating. However, it must be initiated with a small quantity of liquid water to create an electrically conductive electrolyte. As the system's temperature increases, the monohydrate will start to melt at about 65 °C as stated above. Only when the temperature reaches about 100 °C can sodium be isolated. Below this temperature, the water produced will react with the sodium: above this point, any water formed will be driven off in the vapour phase, creating an essentially anhydrous reaction. While this process has some advantages over other electrolytic processes, it is not preferred by most chemists because a marginal quantity of sodium produced boils at the electrode interface. The vapour thus given off consists primarily of fumed sodium oxide, which tends to settle on any surface in close proximity with corrosive consequences.

3 – Production :

Sodium hydroxide is industrially produced as a 50% solution by variations of the electrolytic chloralkali process. Chlorine gas is also produced in this process. Solid sodium hydroxide is obtained from this solution by the evaporation of water. Solid sodium hydroxide is most commonly sold as flakes, prills, and cast blocks .

In 2004, world production was estimated at 60 million dry metric tones of sodium hydroxide, and demand was estimated at 51 million tones . In 1998, total world production was around 45 million tonnes. North America and Asia collectively contributed around

14 million tonnes, while Europe produced around 10 million tonnes. In the United States, the major producer of sodium hydroxide is the Dow Chemical Company, which has annual production around 3.7 million tones from sites at Freeport, Texas, and Plaquemine, Louisiana. Other major US producers include Oxychem, PPG, Olin, Pioneer Companies, Inc. (PIONA, which was purchased by Olin), and Formosa. All of these companies use the chloralkali process.

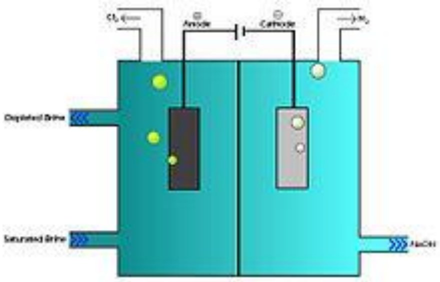
Of historic interest is the Leblanc process, which produced sodium carbonate, which was roasted to create carbon dioxide and sodium oxide, which readily absorbs water to create sodium hydroxide. This method is still occasionally used. It helped establish sodium hydroxide as an important commodity chemical. The Leblanc process was superseded by the Solvay process in the late 19th century.

$$Na_2\,CO_3 \rightarrow Na_2\,O + CO_2$$
$$Na_2O + H_2O \rightarrow 2\ Na\,OH$$

Sodium hydroxide may be formed by the metathesis reaction between calcium hydroxide (also known as lime) and sodium carbonate (also known as soda ash) :

$$Ca\,(OH)_2 + Na_2\,CO_3 \rightarrow CaCO_3 + 2\ Na\,OH$$

3 – 1 - Chloralkali electrolysis :



Basic membrane cell used in the electrolysis of brine.
Main article: Chloralkali process

Sodium hydroxide is produced (along with chlorine and hydrogen) via the chloralkali process. This involves the electrolysis of an aqueous solution of sodium chloride. The sodium hydroxide builds up at the cathode, where water is reduced to hydrogen gas and hydroxide ion :

$$2\ Na^{+} + 2\ H_2O + 2\ e^{-} \rightarrow H_2 + 2\ Na\ OH$$

More accurately :

$$2\ Na^{+}\ Cl^{-} + 2\ H_2O + 2\ e^{-} \rightarrow H_2 + 2\ Cl^{-} + 2\ Na\ OH$$

The Cl^{-} ions are oxidized to chlorine gas at the anode.

To produce Na OH it is necessary to prevent reaction of the NaOH with the chlorine. This is typically done in one of three ways, of which the membrane cell process is economically the most viable.

- **Mercury cell process** (also called the Castner-Kellner process): sodium ions are reduced to sodium metal, which forms an amalgam with a mercury cathode; this sodium is then reacted with water to produce Na OH. There have been concerns about mercury releases, although modern plants claim to be safe in this respect .
- **Diaphragm cell process**: a steel cathode is used, and the reaction of Na OH with Cl_2 is prevented by using a porous diaphragm, often made of asbestos fibers. In the diaphragm cell process the anode area is separated from the cathode area by a permeable diaphragm. The brine is introduced into the anode compartment and flows through the diaphragm into the cathode compartment. A diluted caustic brine leaves the cell. The sodium hydroxide must usually be concentrated to 50% and the salt then removed. This is done using an evaporative process with about three tones of steam per tone of sodium hydroxide. The salt separated from the caustic brine can be used to saturate diluted brine. The chlorine contains oxygen and is purified by liquefaction and evaporation .
- **Membrane cell process**; similar to the diaphragm cell process, with a Nafion membrane to separate the cathode and anode reactions. Only sodium ions and a little water pass through the membrane. This produces a higher quality of NaOH. Of the three processes, the membrane cell process requires the

lowest consumption of electric energy and the amount of steam needed for concentration of the caustic is relatively small (less than one tone per tone of sodium hydroxide) .

4 - Uses :

Sodium hydroxide is the principal strong base used in the chemical industry. In bulk it is most often handled as an aqueous solution, since solutions are cheaper and easier to handle. Sodium hydroxide, a strong base, is responsible for most of these applications. Another strong base such as potassium hydroxide is likely to yield positive results as well.

56 % of sodium hydroxide produced is used by the chemical industry, with 25 % of the same total used by the paper industry. Sodium hydroxide is also used for the manufacture of sodium salts and detergents, for pH regulation, and for organic synthesis. It is used in the Bayer process of aluminium production .

Sodium hydroxide is used in many scenarios where it is desirable to increase the alkalinity of a mixture, or to neutralize acids.

For example, sodium hydroxide is used as an additive in drilling mud to increase alkalinity in bentonite mud systems, to increase the mud viscosity, and to neutralize any acid gas (such as hydrogen sulfide and carbon dioxide) which may be encountered in the geological formation as drilling progresses.

In the same industry, poor quality crude oil can be treated with sodium hydroxide to remove sulfurous impurities in a process known as *caustic washing*. As above, sodium hydroxide reacts with weak acids such as hydrogen sulfide and mercaptans to give the non-volatile sodium salts which can be removed. The waste which is formed is toxic and difficult to deal with, and the process is banned in many countries because of this. In 2006, Trafigura used the process and then dumped the waste in Africa .

4 – 1 - Paper making :

Sodium hydroxide was also widely used in making paper. Along with sodium sulfide, Na OH is a key component of the white liquor solution used to separate lignin from cellulose fibers in the Kraft process. It also plays a key role in several later stages of the process of bleaching the brown pulp resulting from the pulping process. These stages include oxygen delignification, oxidative extraction, and simple extraction, all of which require a strong alkaline environment with a pH > 10.5 at the end of the stages.

4 – 2 - Tissue digestion :

In a similar fashion, sodium hydroxide is used to digest tissues, such as in a process that was used with farm animals at one time. This process involved placing a carcass into a sealed chamber, then adding a mixture of sodium hydroxide and water (which breaks the chemical bonds that keep the flesh intact). This eventually turns the body into a coffee - like liquid, and the only solid that remains are bone hulls, which could be crushed between one's fingertips . Sodium hydroxide is frequently used in the process of decomposing road kill dumped in landfills by animal disposal contractors .

4 – 3 - Dissolving amphoteric metals and compounds :

Strong bases attack aluminium. Sodium hydroxide reacts with aluminium and water to release hydrogen gas. The aluminium takes the oxygen atom from sodium hydroxide (Na OH), which in turn takes the oxygen atom from the water, and releases the two hydrogen atoms, The reaction thus produces hydrogen gas and sodium aluminate. In this reaction, sodium hydroxide acts as an agent to make the solution alkaline, which aluminium can dissolve in. This reaction can be useful in etching, removing anodizing, or converting a polished surface to a satin-like finish, but without further passivation such as anodizing or alodining the surface may become degraded, either under normal use or in severe atmospheric conditions.

In the Bayer process, sodium hydroxide is used in the refining of alumina containing ores (bauxite) to produce alumina (aluminium oxide) which is the raw material used to produce aluminium metal via the electrolytic Hall- Héroult process. Since the alumina is amphoteric it dissolves in the sodium hydroxide, leaving impurities less soluble at high pH such as iron oxides behind in the form of a highly alkaline red mud.

Other amphoteric metals are zinc and lead which dissolve in concentrated sodium hydroxide solutions to give sodium zincate and sodium plumbate respectively.

4 – 4 - Esterification and trans esterification reagent :

Sodium hydroxide is traditionally used in soap making (cold process soap, saponification) . It was made in the nineteenth century for a hard surface rather than liquid product because it was easier to store and transport.

For the manufacture of bio diesel, sodium hydroxide is used as a catalyst for the trans esterification of methanol and triglycerides. This only works with anhydrous sodium hydroxide, because combined with water the fat would turn into soap, which would be tainted with methanol. It is used more often than potassium hydroxide because it is cheaper and a smaller quantity is needed.

4 – 5 - Cleaning agent :

Sodium hydroxide is frequently used as an industrial cleaning agent where it is often called "caustic". It is added to water, heated, and then used to clean process equipment, storage tanks, etc. It can dissolve grease, oils, fats and protein based deposits. It is also used for cleaning waste discharge pipes under sinks and drains in domestic properties. Surfactants can be added to the sodium hydroxide solution in order to stabilize dissolved substances and thus prevent redeposit ion. A sodium hydroxide soak solution is used as a powerful degreaser on stainless steel and glass bake ware. It is also a common ingredient in oven cleaners.

A common use of sodium hydroxide is in the production of parts washer detergents. Parts washer detergents based on sodium hydroxide are some of the most aggressive parts washer cleaning chemicals. The sodium hydroxide based detergent include surfactants, rust inhibitors and defoamers. A parts washer heats water and the detergent in a closed cabinet and then sprays the heated sodium hydroxide and hot water at pressure against dirty parts for degreasing applications. Sodium hydroxide used in this manner replaced many solvent based systems in the early 1990s when tri chloro ethane was outlawed by the Montreal Protocol. Water and sodium hydroxide detergent based parts washers are considered to be an environmental improvement over the solvent based cleaning methods.

4 – 6 - Food preparation :

Food uses of sodium hydroxide include washing or chemical peeling of fruits and vegetables, chocolate and cocoa processing, caramel coloring production, poultry scalding, soft drink processing, and thickening ice cream. Olives are often soaked in sodium hydroxide for softening; or, if soaked longer, for transformation into black olives. Pretzels and German lye rolls are glazed with a sodium hydroxide solution before baking to make them crisp. Owing to the difficulty in obtaining food grade sodium hydroxide in small quantities for home use, sodium carbonate is often used in place of sodium hydroxide .

4 – 7 - Domestic uses :

Sodium hydroxide is used in the home as a drain cleaning agent for clearing clogged drains, usually in the form of a dry crystal or as a thick liquid gel. Sodium hydroxide saponifies the triglycerides found in fat into water soluble fatty acid salts and hydrolyzes the amide bonds in protein, such as those found in hair. These reactions are sped by the heat generated when sodium hydroxide and the other chemical components of the cleaner dissolve in water. Such drain cleaners and their acidic versions are highly caustic and should be handled with care.

Sodium hydroxide is used in some relaxers to straighten hair. However, because of the high incidence and intensity of chemical burns, manufacturers of chemical relaxers use other alkaline chemicals in preparations available to average consumers. Sodium hydroxide relaxers are still available, but they are used mostly by professionals.

A solution of sodium hydroxide in water was traditionally used as the most common paint stripper on wooden objects. Its use has become less common, because it can damage the wood surface, raising the grain and staining the colour.

4 – 8 - Historical uses :

Sodium hydroxide has been used for detection of carbon monoxide poisoning , with blood samples of such patients turning to a vermilion color upon the addition of a few drops of sodium hydroxide . Today, carbon monoxide poisoning can be detected by CO oximetry.

5 – Safety :

Chemical burn caused by sodium hydroxide solution photographed 44 hours after exposure.

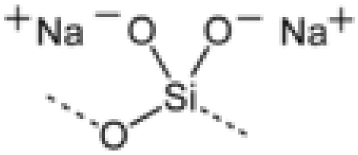
Like other corrosive acids and alkalis, drops of sodium hydroxide solution can decompose proteins and lipids in skin, eyes or other living tissues via amide hydrolysis and ester hydrolysis which consequently causes chemical burn and may induce permanent blindness if it contacts eyes. Solid alkali may also express its corrosive nature if there is water so protective equipment such as rubber gloves, safety clothing and eye protection should always be used when handling the material or its solutions. Solutions containing sodium hydroxide with percentage by mass of equal or more than 2% are said to be labeled as "corrosive" .

More over, dissolution of sodium hydroxide is highly exothermic, and the resulting heat may cause heat burns or ignite flammables. It also produces heat when reacted with acids.

The standard first aid measures for alkali spills on the skin is, as for other corrosives, irrigation with large quantities of water. Washing is continued for at least ten to fifteen minutes.

Sodium hydroxide is corrosive to some metals, e.g. aluminum, which produces flammable hydrogen gas on contact. Sodium hydroxide is also mildly corrosive to glass, which can cause damage to glazing or freezing of ground glass joints. Careful storage is needed.

Sodium Silicate



Contents

1 – Introduction :

Sodium Silicate is the common name for a compound sodium meta silicate, Na_2SiO_3, also known as **water glass** or **liquid glass**. It is available in aqueous solution and in solid form and is used in cements, passive fire protection, refractories, textile and lumber processing, and automobiles. Sodium carbonate and silicon dioxide react when molten to form sodium silicate and carbon dioxide :

$$Na_2CO_3 + SiO_2 \rightarrow Na_2SiO_3 + CO_2$$

Anhydrous sodium silicate contains a chain polymeric anion composed of corner shared $\{SiO_4\}$ tetrahedral, and not a discrete SiO_3^{2-} ion. In addition to the anhydrous form, there are hydrates with the formula $Na_2SiO_3 \cdot nH_2O$ (where n = 5, 6, 8, 9) which contain the discrete, approximately tetrahedral anion $SiO_2(OH)_2^{2-}$ with water of hydration. For example, the commercially available sodium silicate penta hydrate $Na_2SiO_3 \cdot 5H_2O$ is formulated as $Na_2SiO_2(OH)_2 \cdot 4H_2O$ and the nona hydrate $Na_2SiO_3 \cdot 9H_2O$ is formulated as $Na_2SiO_2(OH)_2 \cdot 8H_2O$.

In industry, the various grades of sodium silicate are characterized by their SiO_2:Na_2O ratio, which can vary between 2:1 and 3.75:1 . Grades with this ratio below 2.85:1 are termed 'alkaline'. Those with a higher SiO_2:Na_2O ratio are described as 'neutral'.

IUPAC name : Sodium meta silicate	
Other names : Liquid glass – Water glass	
Molecular Formula	$Na_2 O_3 Si$
Molar Mass	122 g mol^{-1}
Appearance	White to greenish opaque crystals
Density	2.4 g cm^{-3}
Melting Point	1088 °C
Solubility	insoluble in alcohol
Refractive index (n_D)	1.52
EU classification	C

2 - History

Water Glass was defined in Von Wagner's *Manual of Chemical Technology* (1892 translation) as any of the soluble alkaline silicates, first observed by Van Helmont in 1640 as a fluid substance made by melting sand with excess alkali. Glauber made what he termed "fluid silica" in 1648 from potash and silica. Von Fuchs, in 1825, obtained what is now known as water glass by treating silicic acid with an alkali, the result being soluble in water, "but not affected by atmospheric changes". Von Wagner distinguished *soda*, *potash*, *double*(soda and potash), and *fixin* as types of water glass. The *fixing* type was "a mixture of silica well saturated with potash water glass and a sodium silicate" used to stabilize inorganic water color pigments on cement work for outdoor signs and murals.

3 – Properties :

Sodium silicate is a white powder that is readily soluble in water, producing an alkaline solution. It is one of a number of related compounds which include sodium ortho silicate, Na_4SiO_4, sodium pyro silicate, $Na_6Si_2O_7$, and others. All are glassy, colourless and dissolve in water.

Sodium silicate is stable in neutral and alkaline solutions. In acidic solutions, the silicate ion reacts with hydrogen ions to form silicic acid, which when heated and roasted forms silica gel, a hard, glassy substance.

4 - CAS registry number and EINECS number :

Each and every substance has its own unique CAS registry number and EINECS number. The CAS No. and EINECS No. of sodium silicate and other related substances are :

Substance Name	CAS#	EC#(EINECS No.)
Silicic acid, sodium salt	1344-09-8	239-981-7
disodium meta silicate	6834-92-0	229-912-9
Sodium silicate	15859-24-2	215-687-4

5 – Uses :

5 – 1 - Metal repair :

Sodium silicate is used, along with magnesium silicate, in muffler repair and fitting paste. When dissolved in water, both sodium silicate, and magnesium silicate form a thick paste that is easy to apply. When the exhaust system of an internal combustion engine heats up to its operating temperature, the heat drives out all of the excess water from the paste. The silicate compounds that are left over have glass-like properties, making a temporary, brittle repair.

5 – 2 - Automotive repair :

Sodium silicate can be used to fill gaps within the head gasket. Commonly used on aluminum alloy cylinder head, which are sensitive to thermally induced surface deflection, and can be caused by many things including head-bolt stretching, deficient coolant delivery, high cylinder head pressure, over-heating, vapor-lock, etc.

"Liquid glass" (sodium silicate) is added to the system through the radiator, and allowed to circulate. Sodium silicate is suspended in the coolant until it reaches the cylinder head. At 100 – 105 °C sodium silicate loses water molecules to form a glass seal with a re-melt temperature above 810 °C.

A sodium silicate repair will last two years, some times longer. The repair occurs rapidly, and symptoms disappear instantly. This repair only works when the sodium silicate reaches its "conversion" temperature at 100 –105 °C. Contamination of engine oil is a serious possibility in situations in which a coolant-to-oil leak is present. Sodium silicate (glass particulate) contamination of lubricants is detrimental to their function.

5 – 3 - Home brewing

Sodium silicate flocculent properties are also used to clarify wine and beer by precipitating colloidal particles. But as a clearing agent sodium silicate (water glass) is sometimes confused with isinglass which is prepared from collagen extracted from the dried swim bladders of sturgeon and other fishes). Eggs preserved in a bucket of water glass gel, and their shells, are sometimes also used (baked and crushed) to clear wine.

5 – 4 - Car engine disablement :

Sodium silicate solution is used to inexpensively, quickly, and permanently disable automobile engines. Running an engine with about 2 liters of a sodium silicate solution instead of motor oil causes the solution to precipitate, catastrophically damaging the engine's bearings and pistons within a few minutes. In the United States, this procedure was used to comply with requirements of the Car Allowance Rebate System (CARS) program .

5 – 5 – Adhesive :

One common example of its use as a paper cement was for producing paper cartridges for black powder revolvers produced by Colt's Manufacturing Company during the period from 1851 until 1873, especially during the American Civil War. Sodium silicate was used to seal combustible nitrated paper together to form a conical paper cartridge to hold the black powder, as well as to cement the lead ball or conical bullet into the open end of the paper cartridge. Such sodium silicate cemented paper cartridges were inserted into the cylinders of revolvers, thereby speeding the reloading of cap and ball black powder revolvers. This use largely ended with the introduction of Colt revolvers employing brass-cased cartridges starting in 1873.

When used as a paper cement, the tendency is for the sodium silicate joint eventually to crack within a few years, at which point it no longer holds the paper surfaces cemented together.

5 – 6 – Aquaculture :

Sodium silicate gel is also used as a substrate for algal growth in aquaculture hatcheries.

5 – 7 - Food preservation :

Sodium silicate was also used as an egg preservation agent in the early 20th century with large success. When fresh eggs are immersed in it, bacteria which cause the eggs to spoil are kept out and water is kept in. Eggs can be kept fresh using this method for up to nine months. When boiling eggs preserved this way, it is well advised to pin - prick the egg to allow steam to escape because the shell is no longer porous.

5 – 8 - Drilling fluids :

Sodium silicate is frequently used in drilling fluids to stabilize borehole wells and to avoid the collapse of bore walls. It is particularly useful when drill holes pass through argillaceous formations containing swelling clay minerals such as smectite or montmorillonite.

5 – 9 - Concrete and general masonry treatment :

Concrete treated with a sodium silicate solution helps to significantly reduce porosity in most masonry products such as concrete, stucco, plasters. A chemical reaction occurs with the excess $Ca(OH)_2$ (portlandite) present in the concrete that permanently binds the silicates with the surface making them far more durable and water repellent. It is generally advised to apply this treatment only after the initial cure has taken place (7 days or so depending on conditions). These coatings are known as silicate mineral paint.

5 – 10 - Passive fire protection (PFP) :

Sodium silicates are inherently in tumescent. They come in prill (solid beads) form, as well as the liquid, water glass. The solid sheet form (Palusol) must be waterproofed to ensure long-term passive fire protection.

Standard, solid, bead form sodium silicates have been used as aggregate within silicone rubber to manufacture plastic pipe firestop devices. The silicone rubber was insufficient waterproofing to preserve the intumescing function and the products had to be recalled, which is problematic for fire stops that are concealed behind dry wall in buildings.

Pastes for caulking purposes are similarly unstable. This too has resulted in recalls and even litigation. Only 3M's "Expantrol" version, which has an external heat treatment that helps to seal the outer surface, as part of its process standard, has achieved sufficient longevity to qualify for DIBt approvals in the US for use in fire stopping

Not unlike other intumescents, sodium silicate, both in bead form and in liquid form are inherently endothermic, due to liquid water in the water glass and hydrates in the prill form. The absence in the US of mandatory aging tests, whereby PFP systems are made to undergo system performance tests *after* the aging and humidity exposures, are at the root of the continued availability, in North America, of PFP products that can become inoperable within weeks of installation. Indiscriminate use of sodium silicates without proper water proofing measures are contributors to the problems and risk. When sodium silicates are adequately protected, they function extremely well and reliably for long periods. Evidence of this can be seen in the many DIBt approvals for plastic pipe fire stop devices using Palusol, which use waterproofed sodium silicate sheets.

5 – 11 - Safe construction :

A mixture of sodium silicate and sawdust has been used in between the double skin of certain safes. This not only makes them more fire resistant, but also makes cutting them open with an oxyacetylene torch extremely difficult due to the smoke emitted.

5 – 12 - Refractory use :

Water glass is a useful binder of solids, such as vermiculite and perlite. When blended with the aforementioned lightweight aggregates, water glass can be used to make hard, high-temperature insulation boards used for refractories, passive fire protection and high temperature insulations, such as moulded pipe insulation applications. When mixed with finely divided mineral powders, such as vermiculite dust (which is common scrap from the exfoliation process), one can produce high temperature adhesives. The intumescence disappears in the presence of finely divided mineral dust, whereby the water glass becomes a mere matrix. Water glass is inexpensive and abundantly available , which makes its use popular in many refractory applications.

5 – 13 - Water treatment :

Water glass is used as coagulant / flocculent agent in waste water treatment plants. Water glass binds to colloidal molecules, creating larger aggregates that sink to the bottom of the water column. The microscopic negatively charged particles suspended in water interact with sodium silicate. Their electrical double layer collapses due to the increase of ionic strength caused by the addition of sodium silicate (doubly negatively charged anion accompanied by two sodium cations) and they subsequently aggregate. This process is called coagulation / flocculation .

5 – 14 - Detergent auxiliaries :

It also can be used in detergent auxiliaries like complex sodium disilicate and modified sodium disilicate .

5 – 15 - Magic crystals :

Water glass was used in the Magic rocks toys invented in 1940. When water glass was combined with a selection of various metals in solution, the water glass would cause the metals to precipitate. Each metal would precipitate separately causing a different color stalagmite . An early mention of crystals of metallic salts forming a "chemical garden" in sodium silicate is found in the 1946 Modern Mechanix magazine . This results in very colorful gardens—much more than shown in the illustrations.

In Europe the ingredients for such chemical gardens were available already around the early 1930s.

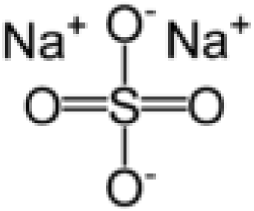
5 – 16 - Dye auxiliary :

Sodium silicate solution is used as a fixative for hand dyeing with reactive dyes that require a high pH in order to react with the textile fiber. After the dye is applied to a cellulose-based fabric, such as cotton or rayon, or onto silk, it is allowed to dry, after which the sodium silicate is painted on to the dyed fabric, covered with plastic to retain moisture, and left to react for an hour at room temperature.[13]

5 – 17 - Sealing of leaking water containing structures :

Sodium silicate with additives was injected into the ground in order to harden it and thereby to prevent further leakage of highly radioactive water from the Fukushima Daiichi nuclear power plant in Japan in April, 2011 . The residual heat carried by the water used for cooling the damaged reactors accelerated the setting of the injected mixture.

Sodium Sulfate



Contents

1 – Introduction :

Sodium sulfate is the sodium salt of sulfuric acid. When anhydrous, it is a white crystalline solid of formula Na_2SO_4 known as the mineral thenardite ; the deca hydrate $Na_2SO_4 \cdot 10H_2O$ has been known as **Glauber's salt** or, historically, **sal mirabilis** since the 17th century. Another solid is the hepta hydrate, which transforms to mirabilite when cooled. With an annual production of 6 million tonnes, it is a major commodity chemical product.

Sodium sulfate is mainly used for the manufacture of detergents and in the Kraft process of paper pulping. About two - thirds of the world's production is from mirabilite , the natural mineral form of the deca hydrate, and the remainder from by-products of chemical processes such as hydrochloric acid production.

Other Names : Thenardite (mineral) Glauber's salt (deca hydrate) Sal mirabilis (deca hydrate) Mirabilite (deca hydrate)	
Molecular Formula	$Na_2\ SO_4$
Molar Mass	142 g / mol (anhydrous) 322 g / mol (deca hydrate)
Appearance	white crystalline solid hygroscopic
Odor	odorless
Density	2.664 g / cm^3 (anhydrous) 1.464 g / cm^3 (deca hydrate)
Melting Point	884 °C (anhydrous) 32.38 °C (deca hydrate)
Boiling Point	1429 °C (anhydrous)
Solubility in water	*anhydrous:* 4.76 g/100 mL (0 °C) 42.7 g/100 mL (100 °C)
	Hepta hydrate : 19.5 g/100 mL (0 °C) 44 g/100 mL (20 °C)
Solubility	insoluble in ethanol soluble in glycerol and hydrogen iodide
Refractive index (n_D)	1.468 (anhydrous) 1.394 (deca hydrate)
Crystal structure	orthorhombic or hexagonal (anhydrous) monoclinic (deca hydrate)
EU Index	Not listed
Main hazards	Irritant

Flash Point	Non - flammable
Thermodynamic data	Phase behaviour : Solid , liquid , gas
Spectral data	UV, IR, NMR, MS

2 - History :

The hydrate of sodium sulfate is known as Glauber's Salt after the Dutch/German chemist and apothecary Johann Rudolf Glauber (1604–1670), who discovered it in 1625 in Austrian spring water. He named it *sal mirabilis* (miraculous salt), because of its medicinal properties: the crystals were used as a general purpose laxative, until more sophisticated alternatives came about in the 1900s .

In the 18th century, Glauber's salt began to be used as a raw material for the industrial production of soda ash (sodium carbonate), by reaction with potash (potassium carbonate). Demand for soda ash increased and supply of sodium sulfate had to increase in line. Therefore, in the nineteenth century, the large scale Leblanc process, producing synthetic sodium sulfate as a key intermediate, became the principal method of soda ash production.

3 - Physical and chemical properties:

Sodium sulfate is chemically very stable, being unreactive toward most oxidizing or reducing agents at normal temperatures. At high temperatures, it can be converted to sodium sulfide by carbo thermal reduction:

$$Na_2SO_4 + 2\,C \rightarrow Na_2S + 2\,CO_2$$

3 – 1 - Acid – base :

Sodium sulfate is a neutral salt, which forms aqueous solutions with pH of 7. The neutrality of such solutions reflects the fact that sulfate is derived, formally, from the strong acid sulfuric acid. Furthermore, the Na^+ ion, with only a single positive charge, only weakly polarizes its water ligands. Sodium sulfate reacts with sulfuric acid to give the acid salt sodium bisulfate :

$$Na_2SO_4 + H_2SO_4 \rightleftharpoons 2\ NaHSO_4$$

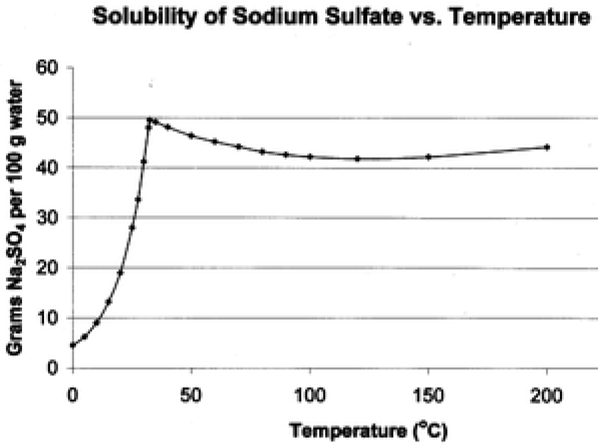
The equilibrium constant for this process depends on concentration and temperature.

3 – 2 - Solution and ion exchange :

Sodium sulfate has unusual solubility characteristics in water. Its solubility in water rises more than tenfold between 0 °C to 32.384 °C, where it reaches a maximum of 497 g / L. At this point the solubility curve changes slope, and the solubility becomes almost independent of temperature. This temperature at 32.384 °C, corresponding to the release of crystal water and melting of the hydrated salt, serves as an accurate temperature reference for thermometer calibration.

Sodium sulfate is a typical ionic sulfate, containing Na^+ ions and SO_4^{2-} ions. The existence of sulfate in solution is indicated by the easy formation of insoluble sulfates when these solutions are treated with Ba^{2+} or Pb^{2+} salts:

$$Na_2SO_4 + BaCl_2 \rightarrow 2\ NaCl + BaSO_4$$



Sodium sulfate displays a moderate tendency to form double salts . The only alums formed with common tri valent metals are Na Al $(SO_4)_2$ (unstable above 39 °C) and Na Cr $(SO_4)_2$, in contrast to potassium sulfate and ammonium sulfate which form many stable alums . Double salts with some other alkali metal sulfates are known, including $Na_2SO_4 \cdot 3K_2SO_4$ which occurs naturally as the mineral glaserite. Formation of glaserite by reaction of sodium sulfate with potassium chloride has been used as the basis of a method for producing potassium sulfate, a fertilizer . Other double salts include $3Na_2SO_4 \cdot CaSO_4$, $3Na_2SO_4 \cdot MgSO_4$ (vanthoffite) and $NaF \cdot Na_2SO_4$.

3 – 3 – Structure :

Crystals consist of $[Na(OH_2)_6]^+$ ions with octahedral molecular geometry, as seen for many metallic sulfate salts. These cations are linked to the sulfate anions via hydrogen bonds. The Na - O distances are 240 pm. Two molecules of water per formula unit are not coordinated to Na^+ . Crystalline sodium sulfate deca hydrate is also unusual among hydrated salts in having a measureable residual entropy (entropy at absolute zero) of 6.32 $J \cdot K^{-1} \cdot mol^{-1}$. This is ascribed to its ability to distribute water much more rapidly compared to most hydrates .

4 – Production :

The world production of sodium sulfate, mostly in the form of the deca hydrate amounts to approximately 5.5 to 6 million tones annually (Mt / a). In 1985, production was 4.5 Mt / a, half from natural sources, and half from chemical production. After 2000, at a stable level until 2006, natural production had increased to 4 Mt/a, and chemical production decreased to 1.5 to 2 Mt / a, with a total of 5.5 to 6 Mt/a . For all applications, naturally produced and chemically produced sodium sulfate are practically inter change able.

4 – 1 - Natural sources :

Two thirds of the world's production of the deca hydrate (Glauber's salt) is from the natural mineral form mirabilite, for example as found in lake beds in southern Saskatchewan. In 1990, Mexico and Spain were the world's main producers of natural sodium sulfate (each around 500,000 tones), with Russia, United States and Canada around 350,000 tones each. Natural resources are estimated as over 1 billion tones.

Major producers of 200,000 to 1,500,000 tones / a in 2006 include Searles Valley Minerals (California, US), Airborne Industrial Minerals (Saskatchewan, Canada), Química del Rey (Coahuila, Mexico), Criaderos Minerales Y Derivados and Minera de Santa Marta, also known as Grupo Crimidesa (Burgos, Spain), FMC Foret (Toledo, Spain), Sulquisa (Madrid, Spain), and in China Chengdu Sanlian Tianquan Chemical (Sichuan), Hongze Yinzhu Chemical Group (Jiangsu), Nafine Chemical Industry Group (Shanxi), and Sichuan Province Chuanmei Mirabilite (Sichuan), and Kuchuksulphat JSC (Altai Krai, Siberia, Russia) . In Saskatchewan, one of the major miners is Saskatchewan Minerals.

Anhydrous sodium sulfate occurs in arid environments as the mineral thenardite. It slowly turns to mirabilite in damp air. Sodium sulfate is also found as glauberite, a calcium sodium sulfate mineral. Both minerals are less common than mirabilite.

4 – 2 - Chemical industry :

About one third of the world's sodium sulfate is produced as by-product of other processes in chemical industry. Most of this production is chemically inherent to the primary process, and only marginally economical. By effort of the industry, therefore, sodium sulfate production as by-product is declining.

The most important chemical sodium sulfate production is during hydrochloric acid production, either from sodium chloride (salt) and sulfuric acid, in the Mannheim process, or from sulfur dioxide in the Hargreaves process . The resulting sodium sulfate from these processes are known as ***salt cake***.

Mannheim : $2\ NaCl + H_2SO_4 \rightarrow 2\ HCl + Na_2SO_4$

Hargreaves : $4\ NaCl + 2\ SO_2 + O_2 + 2\ H_2O \rightarrow 4\ HCl + 2\ Na_2SO_4$

The second major production of sodium sulfate are the processes where surplus sulfuric acid is neutralized by sodium hydroxide, as applied on a large scale in the production of rayon. This method is also a regularly applied and convenient laboratory preparation.

$$2\ \mathrm{Na\ OH}\ (aq) + H_2SO_4\ (aq) \rightarrow Na_2SO_4\ (aq) + 2\ H_2O\ (l)$$

In the laboratory it can also be synthesized from the reaction between sodium bicarbonate and magnesium sulfate.

$$2NaHCO_3 + MgSO_4 \rightarrow Na_2SO_4 + Mg(OH)_2 + 2CO_2$$

Formerly, sodium sulfate was also a by-product of the manufacture of sodium dichromate, where sulfuric acid is added to sodium chromate solution forming sodium dichromate, or subsequently chromic acid. Alternatively, sodium sulfate is or was formed in the production of lithium carbonate, chelating agents, resorcinol, ascorbic acid, silica pigments, nitric acid, and phenol.[13]

Bulk sodium sulfate is usually purified via the decahydrate form, since the anhydrous form tends to attract iron compounds and organic compounds. The anhydrous form is easily produced from the hydrated form by gentle warming.

Major sodium sulfate by-product producers of 50–80 Mt/a in 2006 include Elementis Chromium (chromium industry, Castle Hayne, NC, US), Lenzing AG (200 Mt/a, rayon industry, Lenzing, Austria), Addiseo (formerly Rhodia, methionine industry, Les Roches-Roussillon, France), Elementis (chromium industry, Stockton-on-Tees, UK), Shikoku Chemicals (Tokushima, Japan) and Visko-R (rayon industry, Russia).

5 – Applications :

5 – 1 - Commodity industries :

With US pricing at $ 30 per tone in 1970, in 2006 up to $ 90 per tone for salt cake quality and $ 130 for better grades, sodium sulfate is a very cheap material. The largest use is as filler in powdered home laundry detergents, consuming approx. 50% of world production. This use is waning as domestic consumers are increasingly switching to compact or liquid detergents that do not include sodium sulfate .

Another formerly major use for sodium sulfate, notably in the US and Canada, is in the Kraft process for the manufacture of wood pulp. Organics present in the "black liquor" from this process are burnt to produce heat, needed to drive the reduction of sodium sulfate to sodium sulfide. However, this process is being replaced by newer processes; use of sodium sulfate in the US and Canadian pulp industry declined from 1.4 Mt / a in 1970 to only approx. 150,000 tones in 2006.

The glass industry provides another significant application for sodium sulfate, as second largest application in Europe. Sodium sulfate is used as a fining agent, to help remove small air bubbles from molten glass. It fluxes the glass, and prevents scum formation of the glass melt during refining. The glass industry in Europe has been consuming from 1970 to 2006 a stable 110,000 tones annually.

Sodium sulfate is important in the manufacture of textiles, particularly in Japan, where it is the largest application. Sodium sulfate helps in "levelling", reducing negative charges on fibers so that dyes can penetrate evenly. Unlike the alternative sodium chloride, it does not corrode the stainless steel vessels used in dyeing. This application in Japan and US consumed in 2006 approximately 100,000 tones.

5 – 2 - Thermal storage :

The high heat storage capacity in the phase change from solid to liquid, and the advantageous phase change temperature of 32 °C makes this material especially appropriate for storing low grade solar heat for later release in space heating applications. In some applications the material is incorporated into thermal tiles that are placed in an attic space while in other applications the salt is incorporated into cells surrounded by solar – heated water. The phase change allows a substantial reduction in the mass of the material required for effective heat storage (the heat of fusion of sodium sulfate deca hydrate is 25.53 kJ / mol or about 19 cal / gm), with the further advantage of a consistency of temperature as long as sufficient material in the appropriate phase is available.

5 – 3 - Small - scale applications :

In the laboratory, anhydrous sodium sulfate is widely used as an inert drying agent, for removing traces of water from organic solutions . It is more efficient, but slower - acting, than the similar agent magnesium sulfate. It is only effective below about 30 °C, but it can be used with a variety of materials since it is chemically fairly inert. Sodium sulfate is added to the solution until the crystals no longer clump together .

Glauber's salt, the deca hydrate, was historically used as a laxative. It is effective for the removal of certain drugs such as acetaminophen from the body, for example, after an overdose .

In 1953, sodium sulfate was proposed for heat storage in passive solar heating systems. This takes advantage of its unusual solubility properties, and the high heat of crystallization (78.2 kJ / mol) .

Other uses for sodium sulfate include de - frosting windows, in carpet fresheners, starch manufacture, and as an additive to cattle feed.

Lately, sodium sulfate has been found effective in dissolving very finely electroplated micrometer gold that is found in gold electroplated hardware on electronic products such as pins, and other connectors and switches. It is safer and cheaper than other reagents used for gold recovery, with little concern for adverse reactions or health effects .

At least one company, Thermal Take , makes a laptop computer chill mat (iXoft Notebook Cooler) using sodium sulfate deca hydrate inside a quilted plastic pad. The material slowly turns to liquid and recirculates, equalizing laptop temperature and acting as an insulation.

5 – 4 - Fire Extinguishers :

In antique water extinguishers (Class A) of the soda-acid type, sodium sulfate was a resultant product of the reaction between the sulfuric acid and sodium bicarbonate used to propel (by means of the other by product carbon dioxide) the water out of the hose.

6 – Safety :

Although sodium sulfate is generally regarded as non-toxic,[23] it should be handled with care. The dust can cause temporary asthma or eye irritation; this risk can be prevented by using eye protection and a paper mask. Transport is not limited, and no Risk Phrase or Safety Phrase apply.

Soil Cement

Contents

1 – Introduction :

Soil cement is a construction material, a mix of pulverized natural soil with small amount of portland cement and water, usually processed in a tumble, compacted to high density. Hard, semi-rigid durable material is formed by hydration of the cement particles.

Soil cement is frequently used as a construction material for pipe bedding, slope protection, and road construction as a sub base layer reinforcing and protecting the sub grade. It has good compressive and shear strength, but is brittle and has low tensile strength, so it is prone to forming cracks.

Soil cement mixtures differs from Portland cement concrete in the amount of paste (cement-water mixture). While in Portland cement concretes the paste coats all aggregate particles and binds them together, in soil cements the amount of cement is lower and therefore there are voids left and the result is a cement matrix with nodules of uncemented material.

2 - Types of soil cement :

2 – 1 - Cement - modified soils (CMS) :

A **cement - modified soil** contains relatively small proportion of Portland cement. The result is caked or slightly hardened material, similar to a soil, but with improved mechanical properties - lower plasticity, increased bearing ratio and shearing strength, and decreased volume change.

2 – 2 – Soil - cement base (SCB) :

A **soil - cement base** contains higher proportion of cement than cement-modified soil. It is commonly used as a cheap pavement base for roads, streets, parking lots, airports, and material handling areas. Specialized equipment, such as a soil stabilizer and a mechanical cement spreader is usually required. A seal coat is required in order to keep moisture out. For uses as a road construction material, a suitable surface coating, usually a thin layer of asphalt concrete, is needed to reduce wear.

In comparison with granular bases, soil cement bases can be thinner for the same road load, owing to their slab-like behavior that distributes load over broader areas. In-place or nearby located materials can be used for construction - locally found soil, stone, or reclaimed granular base from a road being reconstructed. This conserves both material and energy.

The strength of soil-cement bases actually increases with age, providing good long-term performance.

2 – 3 - Cement - treated base (CTB) :

A **cement - treated base** is a mix of granular soil aggregates or aggregate material with Portland cement and water. It is similar in use and performance to soil - cement base.

Sorel Cement

Sorel cement (also known as **magnesia cement**) is a non-hydraulic cement first produced by Frenchman Stanislas Sorel in 1867.

The cement is a mixture of magnesium oxide (burnt magnesia) with magnesium chloride with the approximate chemical formula $Mg_4Cl_2(OH)_6(H_2O)_8$, corresponding to a weight ratio of 2.5–3.5 parts Mg O to one part $MgCl_2$. A variant uses zinc oxide with zinc chloride instead of the magnesium compounds.

In use it is usually combined with filler materials such as sand or crushed stone. It is used for grind stones, tiles, artificial stone, and even artificial ivory (e.g. for billiard balls). It can with stand 10,000 – 12,000 psi (69 - 83 MPa) of compressive force whereas standard Portland cement can only withstand 2,000 psi.

Its chief drawback is its poor water resistance, making it unsuitable for construction applications. In addition, it is relatively expensive compared to standard concrete and gypsum.

Spall

Contents

1 – Introduction :

Spall are flakes of a material that are broken off a larger solid body and can be produced by a variety of mechanisms, including as a result of projectile impact, corrosion, weathering, cavitation, or excessive rolling pressure (as in a ball bearing). **Spalling** and spallation both describe the process of surface failure in which spall is shed.

The terms **spall** and **spalling** have been adopted by particle physicists; in neutron scattering instruments, neutrons are generated by bombarding a uranium target with a stream of atoms. The neutrons that are ejected from the target are known as spall.

2 - Mechanical spalling :

Mechanical spalling occurs at high stress contact points, for example, in a ball bearing. Spalling occurs in preference to brinelling where the maximal shear stress occurs not at the surface, but just below, shearing the spall off.

One of the simplest forms of mechanical spalling is plate impact, in which two waves of compression are reflected on the free - surfaces of the plates and then interact to generate a region of high tension stress inside one of the plates.

Spalling can also occur as an effect of cavitation, where fluids are subjected to localized low pressures that cause vapor bubbles to form, typically in pumps, water turbines, vessel propellers, and even piping under some conditions. When such bubbles collapse, a localized high pressure can cause spalling on adjacent surfaces.

2 – 1 - Antitank warfare :

In anti - tank warfare , spalling through mechanical stress is an intended effect of high explosive squash head (HESH) anti-tank shells and many other munitions which may not be powerful enough to pierce the armor of a target. The relatively soft warhead, containing or made of plastic explosive, flattens against the armor plating on tanks and other armored fighting vehicles (AFVs) and explodes, creating a shock wave that travels through the armor as a compression wave and is reflected at the free surface as a tensile wave breaking (tensile stress/strain fracture) the metal on the inside. The resulting spall is dangerous to crew and equipment, and may result in a partial or complete disablement of a vehicle and/or its crew. Many AFVs are equipped with spall liners inside their armor for protection.

A kinetic energy penetrator, if it can defeat the armor, generally causes spalling within the target as well, which helps to destroy/disable the vehicle and/or its crew .

3 - Spalling in mechanical weathering :

Spalling is a common mechanism of rock weathering, and occurs at the surface of a rock when there are large shear stresses under the surface. This form of mechanical weathering can be caused by freezing and thawing, unloading, thermal expansion and contraction, or salt deposition.

Freeze thaw weathering is caused by moisture freezing inside cracks in rock. Upon freezing its volume expands, causing large forces which cracks spall off the outer surface. As this cycle repeats the outer surface repeatedly undergoes spalling, resulting in weathering.

Some stone and masonry surfaces used as building surfaces will absorb moisture at their surface. If exposed to severe freezing conditions the surface may flake off due to the expansion of the water. This effect can also be seen in terra - cotta surfaces (even if glazed) if there is an entrance for water at the edges.

Unloading is the release of pressure due to the removal of an overburden. When the pressure is reduced rapidly, the rapid expansion of the rock causes high surface stress and spalling.

3 – 1 – Exfoliation :

Granite dome exfoliation

Exfoliation (or onion skin weathering) is the gradual removing of spall due to the cyclic increase and decrease in the temperature of the surface layers of the rock. Rocks do not conduct heat well, so when they are exposed to extreme heat the outer most layer becomes much hotter than the rock underneath causing different thermal expansion. This differential expansion causes sub-surface shear stress, in turn causing spalling. Extreme temperature change, such as forest fires, can also cause spalling of rock. This mechanism of weathering causes the outer surface of the rock to fall off in thin fragments, sheets or flakes, hence the name exfoliation or onion skin weathering.

3 – 2 – Salt spalling :

Salt spalling is a specific type of weathering which occurs in porous building materials, such as brick, natural stone, tiles and concrete. Dissolved salt is carried through the material in water and crystallizes inside the material near the surface as the water evaporates. As the salt crystals expand this builds up shear stresses which break away spall from the surface.

Some believe that porous building materials can be protected against salt spalling by treatment with penetrating sealants which are hydrophobic (water repellent) and will penetrate deeply enough to keep water with dissolved salts well away from the surface. Great care and expert advice must be consulted, however, to ensure that any coating is compatible with the substrate in terms of breathability (ability to allow the release of vapors from inside while preventing water intrusion), or other serious problems can be created.

It must always be assumed that water — possibly even arriving in vapor from the interior — will collect behind the wall surface, and it must be allowed to both drain and evaporate . Many bricks and stones have been damaged beyond repair by the well-intentioned application of the wrong coating, once the coated masonry has passed through a few freeze-thaw cycles, pipe leaks, etc. Therefore it is important to find a qualified professional mason to assess damages and recommend the best method to correct the situation. Soft type bricks are more susceptible to moisture penetration than hard type bricks, but are often used by builders since they are less expensive.

Chimneys show spalling damage before other portions of buildings because they are more exposed to the elements.

4 - Corrosion :

In corrosion, spalling occurs when a substance (metal or concrete) sheds tiny particles of corrosion products as the corrosion reaction progresses. These corrosion products are not soluble or permeable, but, unlike passivation, they do not adhere to the parent material's surface to form a barrier to further corrosion. This happens as the result of a large volume change during the reaction.

In the case of actinide metals (most notably the depleted uranium used in some types of ammunition), the material expands so strongly upon exposure to air that a fine layer of oxide is forcibly expelled from the surface. A slowly oxidized plug of metallic uranium can sometimes resemble an onion subjected to desquamation. The main hazard however arises from the pyrophoric character of actinide metals which can spontaneously ignite when their specific area is high. This property, along with these elements inherent toxicity and (for some to a lesser extent) radioactivity, make them dangerous to handle in metallic form under air. There fore, they are often handled under an inert atmosphere (nitrogen or argon) inside an anaerobic glovebox.

Stadium (Software)

Contents

1 – Introduction :

STADIUM (Software for Transport and Degradation In Unsaturated Materials) is a concrete service life prediction method which uses finite element software in conjunction with certified lab testing to determine the service life of exposed reinforced concrete.

2 – Development :

2 – 1 - SUMMA :

STADIUM was originally developed in the late 1990s for in-house use by SIMCO Technologies, then an engineering firm specialized in the aging of concrete structures. STADIUM uses time - step finite element analysis to simulate the progress of harmful ions (including chloride, sulphate, and hydroxide) through concrete, by considering the chemical and physical properties of the concrete being analyzed.

As the US Navy needed a tool to accurately predict the degradation of waterfront concrete structures, SIMCO Technologies and its U.S. partner, the RJLee Group, were awarded Small Business Innovative Research (SBIR) funds from the US Navy for a Phase I feasibility study in 2002. In 2003, Phase II funds were awarded to the team to fully integrate chloride ingress and corrosion initiation prediction in STADIUM. Several industrial partners also joined this effort: Lafarge, Holcim, Euclid, BASF, Sika, MMFX, and Grace Chemicals. The consortium was called SUMMA.

The main outcomes of this research phase were :

- Integration of ionic exchange in the chemical module to model chloride binding.
- Determination of the chloride corrosion threshold based on the modified G109 test procedure (some of these tests are still ongoing).
- Integration of temperature effects in the model.
- Determination of transport properties for more than 20 concrete mixtures.
- Development of a Graphical User Interface for STADIUM.

2 – 2 - SUMMA 2 :

STADIUM development continued with the second phase of the SUMMA research program (SUMMA 2), leading to the commercialization of STADIUM 2.9 to coincide with the specification of STADIUM service life modeling for new water front constructions for the US Navy .

2 – 3 - STADIUM 2.99 :

STADIUM 2.99 is currently the most recent build of the STADIUM client. Being a web - based program, a user's files are accessible from any other computer with the STADIUM 2.99 client installed, and requires a secure username and password to access.

2 – 4 - STADIUM Lab :

As the STADIUM model relies on laboratory testing, STADIUM Lab is the software component required by concrete laboratories in order to characterize concrete for use in STADIUM, as well as service life quality control. Only labs accredited by SIMCO Technologies are qualified to perform STADIUM Lab testing .

3 - Applications :

STADIUM has been used as quality control for US Navy projects such as the Kilo Wharf extension project in Guam, the Modular Hybrid Pier, and evaluations of the Pearl Harbor Dry Docks.

State Departments of Transport have also begun using STADIUM, such as the NJDOT's use of STADIUM for analysis of the Route 21 Southbound Viaduct in Newark, New Jersey.

Stamped Concrete

Brick textured stamped concrete

Contents

1 – Introduction :

Stamped concrete is concrete that is patterned and/or textured or embossed to resemble brick , slate , flag stone, stone, tile, wood, and various other patterns and textures. Stamped concrete is commonly used for patios, side walks , drive ways, pool decks, and interior flooring. The ability of stamped concrete to resemble other building materials makes stamped concrete a less expensive alternative to using those other authentic materials such as stone, slate or brick.

There are three procedures used in stamped concrete which separate it from other concrete procedures; the addition of a base color, the addition of an accent color, and stamping a pattern into the concrete. These three procedures provide stamped concrete with a color and shape similar to the natural building material. It also is longer lasting than paved stone, and still resembles the look.

2 - Procedures :

2 – 1 - Adding base color :

The base color is the primary color used in stamped concrete. The base color is chosen to reflect the color of the natural building material. The base color is produced by adding a color hardener to the concrete. Color hardener is a powder pigment used to dye the concrete.

The color hardener can be applied using one of two procedures; integral color or cast-on color. Integral color is the procedure where the entire volume of concrete is dyed the base color. The entire volume of concrete is colored by adding the color hardener to the concrete truck, and allowing all the concrete in the truck to be dyed. Cast-on color is the procedure where the surface of the concrete is dyed the base color. The surface of the concrete is colored by spreading the color hardener onto the surface of the wet concrete and floating the powder into the top layer of the wet concrete.

Concrete can be colored in many ways; color hardener, integral liquid or powder, acid stains to name a few. The process of integrally coloring the concrete offers the advantage of the entire volume being colored; however, the surface strength is not increased as with the use of color hardener. Dry shake color hardener is another popular way to color concrete. You broadcast the hardener on the concrete as soon as it is floated for the first time. After letting the bleed water soak into the hardener you float and trowel it in. This method only covers the surface about 3/16 of an inch but it gives the concrete surface a longer wear life.

2 – 2 - Adding accent color :

The accent color is the secondary color used in stamped concrete. The secondary color is used to produce texture and show additional building materials (e.g. grout) in the stamped concrete. The accent color is produced by applying color release to the concrete. Color release has two purposes. Color release is a pigment used to color the concrete and color release is a non-adhesive used to prevent the concrete stamps from sticking to the concrete.

The color release can be applied in one of two procedures based on the two forms it is manufactured in: powdered (cast-on color release made up of calcium-releasing powders that repel water); or liquid - which is a light aromatic-based solvent, spray-on color release. Cast-on color release is a procedure where the powder color release is applied by spreading the color release on the surface of the concrete before the concrete is stamped. Spray-on color release is a procedure where liquid color release is sprayed on the bottom of the concrete stamps before the concrete is stamped.

2 – 3 - Stamping patterns :

Concrete being stamped with an Ashlar Slate pattern

The pattern is the shape of the surface of the stamped concrete. The pattern reflects the shape of the natural building material. The pattern is made by imprinting the concrete shortly after it has been poured with a "concrete stamp". Most modern concrete stamps are made of polyurethane, but older "cookie cutter" style stamps were made of various metals. The old style stamps lacked the capabilities of forming natural stone texture.

Concrete stamping is the procedure which uses the concrete stamps to make the pattern in the stamped concrete. Concrete stamps are placed on the concrete after the color release has been applied.

The concrete stamps are pushed into the concrete and then removed to leave the pattern in the stamped concrete.

In most cases concrete stamping is made to look like ordinary building products. Whether it be flagstone, brick, natural stone or any other common exterior looks, but there are many ways to personalize your own kind of stamp. It could be a homemade stamp or a recycled stamp, you can be as basic or as ornate as you wish. The Process is easy, first find a design that you, the homeowner, or contractor thinks will be a good fit. After making a mold of the desired stamp design, plan out the way it will look and fit in your designated area. The hardest part of stamping is the waiting, you must make sure the concrete is hard enough that the stamp won't sink but loose enough that it will make a clean stamp. Do not be afraid of trying new and creative stamps around your house. However, remember to be sure to test the stamp on a demo before stamping onto the permanent surface.

3 - History :

Stamping concrete increased in popularity in the 1970s when it was first introduced in the World of Concrete. Builders saw it as a new way to satisfy the customer and make their budget work simultaneously. This technique of stamping concrete has been done since at least the 1950s. When stamping concrete first began, there were very few choices of design and colors. However, as the industry grew more stamping patterns were being created along with many different types of stains to give us the vibrant colors we have today. Another advantage to using stamped concrete, is that it can be applied to many differents surfaces and textures. Such as driveways, highways, patios, decks, and even floors inside the home.

Sanitation in Ancient Rome

Contents

1 – Introduction :

Sanitation in ancient Rome was a complex system similar in many ways to modern sanitation systems. During the Dark Ages, the technical knowledge of the Roman system was lost and has subsequently been investigated by modern-era historians and archeologists.

2 - Sewer system :

The latrines are the best-preserved feature at Housesteads Roman Fort on Hadrian's Wall. The soldiers sat on wooden boards with holes, which covered the two big trenches. Water ran in the two small ditches at the soldiers' feet.

A system of thirteen aqueducts provided the inhabitants of Rome with water of varying quality, the best being reserved for potable supplies. Poorer-quality water was used in the public baths and in the latrines, which were an early form of toilet. Latrine systems have been found in many places, such as Housesteads, a Roman fort on Hadrian's Wall, in Pompeii, Herculaneum, and elsewhere that flushed waste away with a stream of water. Romans used sea sponges on sticks after defecation.

The Romans had a complex system of sewers covered by stones, much like modern sewers. Waste flushed from the latrines flowed through a central channel into the main sewage system and thence into a nearby river or stream. However, it was not uncommon for Romans to throw waste out of windows into the streets, at least according to Roman satirists. Despite this, Roman waste management is admired for its innovation.

HII estimate that the first sewers of ancient Rome were built between 800 and 735 BC. Drainage systems evolved slowly, and began primarily as a means to drain marshes and storm runoff. The sewers were mainly for the removal of surface drainage and underground water (Farnsworth, p. 942). The sewage system as a whole did not really take off until the arrival of the Cloaca Maxima, an open channel that was later covered, and one of the best-known sanitation artifacts of the ancient world. Most sources believe it was built during the reign of the three Etruscan kings in the sixth century BC. This "greatest sewer" of Rome was originally built to drain the low-lying land around the Forum. It is not known how effective the sewers were, especially in removing excrement .

From very early times the Romans, in imitation of the Etruscans, built underground channels to drain rainwater that might otherwise wash away precious top-soil, used ditches to drain swamps (such as the Pontine marshes), and dug subterranean channels to drain marshy areas. Over time, the Romans expanded the network of sewers that ran through the city and linked most of them, including some drains, to the Cloaca Maxima, which emptied into the Tiber River. In 33 BC, under the emperor Augustus, the Cloaca Maxima was enclosed, creating a large tunnel. The Cloaca Maxima, it is presumed, built in the fourth century BC and reconstructed under Augustus), still drains the Forum Romanum and surrounding hills. Strabo, a Greek author who lived from about 60 BC to AD 24, admired the ingenuity of the Romans in his *Geographica* , writing :

> *The sewers, covered with a vault of tightly fitted stones, have room in some places for hay wagons to drive through them. And the quantity of water brought into the city by aqueducts is so great that rivers, as it were, flow through the city and the sewers; almost every house has water tanks, and service pipes, and plentiful streams of water...In short, the ancient Romans gave little thought to the beauty of Rome because they were occupied with other, greater and more necessary matters.*

Stone pipes

A law was eventually passed to protect innocent bystanders from assault by wastes thrown into the street. The violator was forced to pay damages to whomever his waste hit, if that person sustained an injury. This law was enforced only in the daytime, it is presumed because one then lacked the excuse of darkness for injuring another by careless waste disposal.

Around AD 100, direct connections of homes to sewers began, and the Romans completed most of the sewer system infrastructure. Sewers were laid throughout the city, serving public and some private latrines, and also served as dumping grounds for homes not directly connected to a sewer. It was mostly the wealthy whose homes were connected to the sewers, through outlets that ran under an extension of the latrine.

3 - Public latrines :

In general, the poor used pots that they were supposed to empty into the sewer, or visited public latrines. Public latrines date back to the 2nd century BC. Whether intentionally or not, they became places to socialise. Long bench-like seats with keyhole - shaped openings cut in rows offered little privacy. Some latrines were free, for others small charges were made . According to Lord Amulree, the site where Julius Caesar was assassinated, the Hall of Curia in the Theatre of Pompey, was turned into a public latrine because of the dishonor it had witnessed. The sewer system, like a little stream or river, ran beneath it, carrying the wastes away to the Cloaca Maxima.

The Romans recycled public bath waste water by using it as part of the flow that flushed the latrines. Terra cotta piping was used in the plumbing that carried waste water from homes. The Romans were the first to seal pipes in concrete to resist the high water pressures developed in siphons and elsewhere. Beginning around the 5th century BC, city officials called aediles supervised the sanitary systems. They were responsible for the efficiency of the drainage and sewage systems, the cleansing and paving of the streets, prevention of foul smells, and general oversight of brothels, taverns, baths, and other water supplies . In the first century AD, the Roman sewage system was very efficient. In his Natural History, Pliny remarked that of all the things Romans had accomplished, the sewers were "the most noteworthy things of all".

4 - Aqueducts :

Remains of aqueducts Aqua Claudia and Anio Novus, integrated into the Aurelian Wall

The aqueducts provided the large volumes of water that—after serving drinking, bathing, and other needs—flushed through the sewers. A system of eleven aqueducts supplied the city with water from as far away as the river Anio. Anio Novus and Aqua Claudia were two of the biggest systems. The distribution system was carefully designed so that all waste water drained into the Cloaca Maxima.

The management and maintenance involved in keeping the aqueducts flowing is well described by Frontinus, a general appointed by the emperor Nerva as water commissioner toward the end of the first century AD. He described his work on the distribution system in De aquaeductu published at the end of the first century AD. When first appointed, he surveyed and mapped the entire system, and strove to investigate the many abuses of the water supply, such as the act of tapping into pipes illegally. He also systematized aqueduct maintenance with gangs of specially trained workmen. He also tried to separate the supply, so that the best-quality water went to drinking and cooking, while second-quality water flowed to the fountains, baths, and, finally, sewers.

Pont du Gard in *France*

The system in Rome was copied in all provincial towns and cities of the Roman Empire, and even down to villas that could afford the plumbing. Roman citizens came to expect high standards of hygiene, and the army was also well provided with latrines and bath houses, or thermae . Aqueducts were used everywhere in the empire not just to supply drinking water for private houses but to supply other needs such as irrigation, public fountains, and thermae. Indeed, many of the provincial aqueducts survive in working order to the present day, although modernized and updated. Of the eleven ancient aqueducts serving Rome, eight of them entered Rome close to each other on the Esquiline Hill . Also, the first aqueduct was the Aqua Appia built in 312 BC by the censor Appius . Other aqueducts of importance to Roman sanitation was the Aqua Marcia built between 144 -140 BC , which provided large amounts of quality water to Rome . One Aqueduct with some major importance to Rome was Traiana, which tapped from the clear springs of the northern and western slopes above lake Bracciano . It is said that the “Romans fully appreciated the importance of plentiful and wholesome supply of water, for domestic purposes to health of the Community (Amulree, p. 244). It was stated by Amulree that for 441 years after the building of Rome, it depended on water from the Tiber for drinking and other domestic purposes, but in 312 BC Appius Claudius Crassus provide Rome with water from the Springs of the Alban hills and brought to consumers by the mean of Aqueducts (Amulree, p. 244). The Amulree notes state that this practice is in line with the teachings of Hippocrates: that stagnant water should be refused, not the spring water from the hills or rain water .

5 – Rubbish :

Roman rubbish was often left to collect in alleys between buildings in the poorer districts of the city. It sometimes became so thick that stepping stones were needed. "Unfortunately its functions did not include house-to-house garbage collection, and this led to indiscriminate refuse dumping, even to the heedless tossing of trash from windows " . As a consequence, the street level in the city rose, as new buildings were constructed on top of rubble and rubbish.

Steel Plate Construction

Steel plate construction is a rapid method of constructing heavy reinforced concrete items. It was developed in Korea in 2004. At a steel fabricator, assemblies are constructed. Each assembly has two parallel plates joined with welded stringers. The assemblies are moved to the job site and placed with a crane. The plates are welded so that they form parallel walls joined by stringers. Finally, the space between the plate walls is filled with concrete.

Steel plate construction is roughly twice the speed of other reinforced concrete construction, because it avoids tying rebar and constructing forms on-site. The parallel plate assemblies can be constructed quickly in specialized off-site fabrication facilities. The method has excellent strength because the steel is on the outside, where tensile forces are often greatest.

Because the construction time is about half, sunk interest costs for heavy construction projects are about half when this method is used.

The method is of special interest for rapidly constructing nuclear power plants, which use large reinforced concrete structures, and typically have long construction times, with heavy interest costs.

Stone Engineered

Contents

1 – Introduction :

Engineered stone is a composite material made of crushed stone bound together by a polymer resin. It is used primarily for kitchen countertops. Related materials include geopolymers and cast stone. Unlike terrazzo, the material is factory made in slabs, cut and polished by fabricators, and assembled at the worksite.

Engineered stone products are gaining in popularity and are sometimes preferred over granite products because engineered stone requires less maintenance. Compared to unsealed granite, it has better resistance to stains . However, recent research reported in Consumer Reports magazine reveals virtually no difference in performance between quartz products and sealed granite.

Engineered stone kitchen countertops with under mount sink and cooktop installed. Tops are cut and polished at the fabricator's shop.

Engineered stone is also commonly referred to as agglomerate or 'quartz surface', though it is possible to create solid surface using fillers other than quartz .

2 - Manufacturing Equipment :

Breton S.P.A, a privately held company of Treviso Italy, is the dominant supplier of equipment for making engineered stone. A mixture of 93 % quartz and 7 % polyester resin is pressed into slabs (or larger blocks) using Breton's " vibro compression vacuum process".

Although Breton was the original manufacturer of slab moulding equipment, there are now several other companies producing similar machinery. The Chinese company Keda Stone Machinery being one of the largest.

China is currently the biggest market for new slab producing machines. There is estimated to be more than 100 engineered stone suppliers in China alone.

3 – Composition :

Quartz is the major filler, although other material like coloured glass, shells, metals, or mirrors might be added. A typical material will consist of 93 % quartz by weight and 7 % resin. Different types of resins are used by different manufacturers. Epoxy and polyester resin are the most common types. Chemicals such as UV absorbers and stabilizers are added. To aid curing, peroxide is added.

4 - Properties

Engineered stone is typically worked in the same way as natural stone using a water jet cutter or a diamond blade. This is in contrast with solid surface materials which can be cut with regular saws.[7]

The material can be produced in either 12 mm, 20 mm or 30 mm thicknesses. The most common slab format is 3040 mm x 1440 mm, but other sizes like 3040 mm x 1650 mm are produced according to market demand.

Engineered stone is typically stronger in flexibility and hardness, and less porous, than natural stone, but not in all cases. Less porous varieties are more resistant to mould and mildew then traditional stone . It is typically uniform in structure leading to inherent strength, whereas natural stone may by-nature contain fissures, cracks, or weaknesses in structure. Its polyester resin binding agents allow some flexibility, preventing cracking under flexural pressure. But, the binding agents often continue to harden, leading to a loss of flexural strength over time. The polyester resins are not completely UV stable and engineered stone should not be used in outdoor applications. Continuous exposure to UV can cause discoloration of the stone, and breakdown of the resin binder. The material is damaged by direct application of heat, and should not be used close to a direct source of ignition.

Stucco

Stucco from the House of Borujerdi-ha, 1850s, Kashan, Iran.

Contents

1 – Introduction :

Stucco or **render** is a material made of an aggregate, a binder, and water. Stucco is applied wet and hardens to a very dense solid. It is used as decorative coating for walls and ceilings and as a sculptural and artistic material in architecture. Stucco may be used to cover less visually appealing construction materials such as concrete, cinder block, or clay brick and adobe.

2 - Composition

The difference in nomenclature between stucco, plaster, and mortar is based more on use than composition. Until the later part of the nineteenth century, it was common that plaster, which was used inside a building, and stucco, which was used outside, would consist of the same primary materials: lime and sand (which are also used in mortar). Animal or plant fibers were often added for additional strength. In the later part of the nineteenth century, Portland cement was added with increasing frequency in an attempt to improve its durability. At the same time, traditional lime plasters were being replaced by gypsum plaster.

Traditional stucco is made of lime, sand, and water. Modern stucco is made of Portland cement, sand, and water. Lime is added to increase the permeability and workability of modern stucco. Sometimes additives such as acrylics and glass fibers are added to improve the structural properties of the plaster. This is usually done with what is considered a one-coat stucco system, as opposed to the traditional three-coat method.

Lime stucco is a relatively hard material that can be broken or chipped by hand without too much difficulty. The lime itself is usually white; color comes from the aggregate or any added pigments. Lime stucco has the property of being self-healing to a limited degree because of the slight water solubility of lime (which in solution can be deposited in cracks, where it solidifies). Portland cement stucco is very hard and brittle and can easily crack if the base on which it is applied is not stable. Typically its color was gray, from the innate color of most Portland cement, but white Portland cement is also used. Today's stucco manufacturers offer a very wide range of colors that can be mixed integrally in the finish coat.

3 - Traditional stucco :

As a building material, stucco is a durable, attractive, and weather-resistant wall covering. It was traditionally used as both an interior and exterior finish applied in one or two thin layers directly over a solid masonry, brick or stone surface. The finish coat usually contained an integral color and was typically textured for appearance.

Then with the introduction and development of heavy timber and light wood-framed construction methods, stucco was adapted for this new use by adding a reinforcement lattice, or lath, attached to and spanning between the structural supports and by increasing the thickness and number of layers of the total system. The lath added support for the wet plaster and tensile strength to the brittle, cured stucco; while the increased thickness and number of layers helped control cracking.

The traditional application of stucco and lath occurs in three coats — the scratch coat, the brown coat and the finish coat. The two base coats of plaster are either hand-applied or machine sprayed. The finish coat can be troweled smooth, hand-textured, floated to a sand finish or sprayed.

Originally the lath material was strips of wood installed horizontally on the wall, with spaces between, that would support the wet plaster until it cured. This lath and plaster technique became widely used.

In exterior wall applications, the lath is installed over a weather-resistant asphalt-impregnated felt or paper sheet that protects the framing from the moisture that can pass through the porous stucco.

Following World War II, the introduction of metal wire mesh, or netting, replaced the use of wood lath. Galvanizing the wire made it corrosion resistant and suitable for exterior wall applications. At the beginning of the 21st century, this "traditional" method of wire mesh lath and three coats of exterior plaster is still widely used. In some parts of the United States (California, Arizona, New Mexico and Florida), stucco is the predominant exterior for both residential and commercial construction.

4 - Sculptural and architectural use :

Stucco has also been used as a sculptural and artistic material. Stucco relief was used in the architectural decoration schemes of many ancient cultures. Examples of Egyptian, Minoan, and Etruscan stucco reliefs remain extant. In Roman art of the late Republic and early Empire, stucco was used extensively for the decoration of vaults. Though marble was the preferred sculptural medium in most regards, stucco was better for use in vaults because it was lighter and better suited to adapt to the curvature of the ceiling. The renaissance discovery of the stucco reliefs in the Domus Aurea led to the development of the grottesche style of decoration. Baroque and

Rococo architecture makes heavy use of stucco. Examples can be found in churches and palaces, where stucco is mostly used to provide a smooth, decorative transition from walls to ceiling, decorating and giving measure to ceiling surfaces. Stucco is an integral part of the art of belcomposto, the Baroque concept that integrates the three classic arts, architecture, sculpture, and painting.

Baroque stucco decorations of the main nave of the Jasna Góra Monastery basilica, 1693-1695.

Since stucco can be used for decoration as well as for figurative representation, it provides an ideal transitive link from architectural details to wall paintings such as the typically Baroque trompe l'oeil ceilings, as in the work of the Wessobrunner School. Here, the real architecture of the church is visually extended into a heavenly architecture with a depiction of Christ, the Virgin Mary or the Last Judgment at the center. Stucco is used to form a semi-plastic extension of the real architecture that merges into the painted architecture.

Islamic art makes use of stucco as a decorative means in mosques and palaces. Indian architecture knows stucco as a material for sculpture in an architectural context. It is rare in the countryside.

Because of its "aristocratic" appearance, Baroque-looking stucco decoration was used frequently in upper-class apartments of the 19th and early 20th century.

Beginning in the 1920s, stucco, especially in its Neo - Renaissance and Neo - Baroque materialization, became increasingly unpopular with modern architects in some countries, resulting not only in new buildings without stucco but also in a widespread movement to remove the stucco from existing tenements.

Stucco was still employed in the 1950s in molded forms for decorating the joints between walls and ceilings inside houses. It was generally painted the same color as the ceiling and used in designs where a picture rail or rat rail was in use.

5 - Modern stucco :

Modern stucco is used as an exterior cement plaster wall covering. It is usually a mix of sand, Portland cement, lime and water, but may also consist of a proprietary mix of additives including fibers and synthetic acrylics that add strength and flexibility.[2] Modern synthetic stucco can be applied as one base layer and a finish layer, which is thinner and faster to apply, compared to the traditional application of three-coat stucco.

As with any cement-based material, stucco must be reinforced to resist movement cracking. Plastic or wire mesh lath, attached with nails or screws to the structural framing, is embedded into the base coat to provided stiffening for the stucco. One method often used to help conceal the smaller surface cracks that may appear is the application of one of a variety of pre-mixed acrylic finishes. Flexible acrylic finishes have the ability to stretch and bridge over cracks, improving appearance and limiting the passage of moisture behind the stucco.

Where stucco is to be applied to a structure of wood-framing or light-gauge steel framing, the framing is protected from moisture damage by applying a vapor - permeable, water-resistant weather barrier; typically an asphalt - saturated paper or one of a variety of manufactured plastic-based sheets, known as "building wraps" or "stucco wraps". The properties of the weather barrier must not only protect the framing from rain and moisture, but at the same time allow the free passage of any water vapor generated inside the building to escape through the wall.

A wide variety of stucco accessories, such as weep screeds, control and expansion joints, corner-aids and architectural reveals are sometimes also incorporated into the lath. Wire lath is used to give the plaster something to attach to and to add strength. Types include expanded-metal lath, woven-wire lath, and welded-wire lath.

The first layer of plaster is called a "scratch coat," consisting of plastic cement and sand. A trowel is used to scratch the surface horizontally or in a crisscross pattern to provide a key for the second layer.Do not use a brush since this will cause delamination. The first coat is allowed to dry (cure) before the second layer is applied.

The next layer is called the "brown coat" or leveling coat. It also consists of sand, cement, and lime. It is leveled with tools called "darbies," "rods," and "featheredges," scraped smooth, and floated to provide a smooth, even surface onto which the finish coat is applied. It is then allowed to dry (cure) for 7–10 days minimum to allow "checking" (shrinkage) and cracking to take place.

If applied during very dry weather, the layers of stucco are sprayed with water for one or more days to keep a level of moisture within the stucco while it cures, a process known as "moist curing." If the stucco dries too soon, the chemical hardening ("hydration") will be incomplete, resulting in a weaker and brittler stucco.

The final, exterior layer is the "finish coat," of which there are two recommended types :

1. Color Coat is a colored sand, cement, and lime mixed finish and is typically 3 mm (0.12 in) thick. It is applied over the second coat (brown coat) and can be floated with water for a sandy finish or textured over with a trowel to create various styles of finishes. Premixed, bagged stucco is gaining in

use and is available in coarse graded sand and finer graded sand for creating a variety of toweled finishes; it is available in a variety of colors.

2. Acrylic Finish is an acrylic-based finish from 1 to 4 mm thick. It can be applied in many ways. It can be ordered in any color.

Hard Coating is another method of adding a finish to the stucco wall, although no longer recommended. In the 1960s and 1970s people added a variety of materials like glass chunks, stones or marble into the wet stucco wall. This kind of finish coat is very heavy and inflexible and is hard to repair.

6 - Stucco siding :

Stucco is valued as a siding material for its attractiveness and durability and is a relatively low-maintenance exterior finish. It is often used on (but is certainly not limited to) Spanish-style homes. Stucco can be directly applied to brick and concrete, or applied to a lath (paper or wire mesh) over a wood frame or other material.

While nothing prevents anyone from painting or whitewashing concrete to make it look like stucco, paint generally does not adhere to concrete longer than two or three years, requiring constant re-application. Removing these materials in order to re-stucco requires expensive sandblasting. Paint also prevents the concrete from breathing. A stucco home can be refinished with an integral color stucco which does not require painting. Color can also be added to concrete when it is originally placed before curing, and thus the concrete would

Stud Cast

Contents

1 – Introduction :

Stud cast concrete, also called "pre-framed concrete", combines relatively thin concrete layers with cold formed steel framing to create hybrid panels; the result is a panelized system usable for cladding, curtain walls, shaft walls, and load-bearing exterior and interior walls. Stud cast panels install in the same manner as prefabricated steel stud panels. The technology is applicable for both factory prefabrication and site-cast (tilt-up) wall construction on almost all types of buildings, including multifamily housing, schools, industrial, commercial and institutional structures.

2 – History :

Stud cast walls are prefabricated, ready-to-erect, high-performance concrete walls that weigh half as much as standard concrete walls. A hybrid between architectural precast concrete and panelized light-gage cold-formed steel framing, studcast walls combine the best features of each material in a way nullifies each material's weaknesses. They have been widely used as an exterior and interior wall system for over a decade.

Stud cast concrete was developed by combining the best aspects of two familiar technologies: the durability, fast erection, and architectural versatility of precast concrete and the light weight and high strength of panelized cold-formed steel stud framing. Both materials are widely available and relatively affordable; the benefit of studcast lies in joining them in a complementary and affordable manner that eliminates each of their disadvantages.

Studcast is a hybrid precast wall system that is lightweight, sustainable, fast - erecting, and compatible with a wide range of designs and architectural finishes. These composite walls can be made with as little as two inches of concrete thickness, as compared to six-to-ten inches for the typical precast panel. Utilizing lightweight aggregate, walls can weigh as little as 18 psf. For reference, a six-inch panel of ordinary precast concrete weighs about 70 psf.

The strength-to-weight ratio is high. The precast units can support their own weight and be lifted off the casting tables only 24 hours after casting, making cycle-time short and efficient. Large panel sizes are practical to cast and light enough to handle with lighter equipment, resulting in fewer panels to erect and fewer panel joints to seal.

Double-sided studcast walls were awarded the Hospitality Design and ASID Earth Minded Award for a product in 2009. They were cited for their role in sustainable hospitality design.

3 - Benefits & Sustainability :

Both the material and process fit within the principles of sustainable construction.

A studcast wall is both frame and skin. It can be dropped into place and bolted down, framing and enclosing the structure in a single step. This creates time and material savings that can potentially substantially reduce construction costs and time. This is also an environmental benefit, as reducing construction time reduces energy consumption of construction equipment and the impact of workers on the site.

It has a built-in cavity for insulating materials and utilities. It needs no additional furring to receive interior finishes.

Because stud cast is made of concrete and steel, it does not support mold growth or pest infestation. It is also highly resistant to moisture infiltration, freeze/thaw, and condensation. It releases no volatile organic compounds (VOCs).The automated roll forming system produces components to the exact length needed so there is minimal waste.Recycled material can be incorporated into studcast. Recycled steel can be used as raw material for the studs. The concrete can contain recycled aggregate and be made from locally extracted materials. Some manufacturers have 25 % or more recycled content.

Because each square foot of wall weighs so little, transportation-related energy consumption and pollution are kept to a minimum, as is shipping cost. At the job site, walls can be handled with light equipment. For a low-rise structure - for instance a school or commercial building - a fork lift is all that is needed to erect a wall.

The low mass of the wall requires smaller foundations. This is a two-fold environmental benefit: first for the reduction in consumption and transportation of raw materials in general; second for the reduced consumption specifically of portland cement, whose production emits large quantities of carbon dioxide (CO_2), a greenhouse gas.

Low mass walls have an additional benefit in high seismic activity zones, where they translate into less force shaking the structure during earthquake events.

4 – Applications :

Stud cast has both architectural and structural applications. It has been used in hospitality design, military construction, retail, commercial, industrial, and residential design.

Specific applications include :

- Free-standing temporary or permanent concrete walls
- Cladding
- Structural interior or exterior walls
- Curtain wall

5 – Appearance :

The versatility of architectural precast is well established and continually expanding due to the creativity of designers and innovation of pre casters. The heavy weight of concrete panels remains a limiting factor, however. That entire gamut of aesthetic possibilities applies to stud cast, in a package that can weigh only 20% of a typical precast panel.

The fine texture of the concrete makes it well suited to architectural finishes. It is also compatible with integral color. Form liners can be used to mold a variety of textures into the wall surface. These might include simulated masonry or stone textures, even carvings or decorative patterns. Architectural veneers such as thin brick or thin genuine stone are also options. Innovative materials such as crushed glass could also be cast into the surface.

The material is also suitable for decorative operations after casting. Carving, rasping, and gouging with hand-tools can create textures or contouring. Routed lines and grooves, reveals, digital cutting, and other power-tool working are also possible.

6 – Production :

Stud cast is typically prefabricated for improved efficiency and quality control. The designer’s CAD drawings are converted into computer instructions for a machine that transforms a coil of flat steel into precisely-cut and shaped studs and rails. Every bend and perforation needed to assemble the steel is also performed.

Workers assemble the cut pieces into panels using simple tools; no specialized clamps or jigs are required. The panels are accurate to within 1/32 inch over 60 feet (20 m).

Light weight concrete slurry is pumped into the panel until the steel frame is partially embedded. Various methods are used to create composite action between steel and concrete, and add sheer resistance and impact resistance.

Sulfur Concrete

Sulfur concrete is a composite construction material, composed of sulfur, aggregate (generally a coarse aggregate made of gravel or crushed rocks and a fine aggregate such as sand). Cement (commonly Portland cement) and water important compounds in normal concrete are not part of sulfur concrete. The concrete is heated above the melting point of sulfur ca. 140°C. After cooling the concrete reaches a high strength, not needing a prolonged curing like normal concrete. Sulfur concrete is resistant to some compounds like acids which attack normal concrete. Sulfur concrete was developed and promoted as building material to get rid of large amounts of stored sulfur produced by hydro desulfurization of gas and oil. Sulfur concrete is also a possible building material for a lunar base. Up to 2011 Sulfur concrete is only used in small quantities when fast curing or acid resistance is necessary.

Super Plasticizer

Contents

1 – Introduction :

Super plasticizers, also known as **high range water reducers**, are chemicals used as admixtures where well-dispersed particle suspension are required. These polymers are used as dispersants to avoid particle aggregation, and to improve the flow characteristics (rheology) of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture, and enables the production of self-consolidating concrete and high performance concrete. This effect drastically improves the performance of the hardening fresh paste. Indeed the strength of concrete increase whenever the amount of water used for the mix decreases. However, their working mechanisms lack of a full understanding, revealing in certain cases cement-super plasticizer incompatibilities.

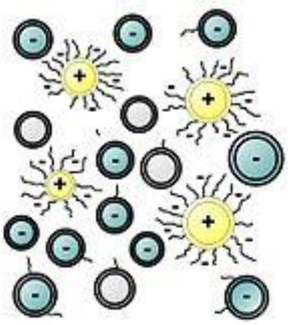
2 - Poly carboxylate ether super plasticizer :

The new generation of this kind of admixtures is represented by poly carboxylate ether based super plasticizers (PCEs). With a relatively low dosage (0.15 – 0.3 % by cement weight) they allow a water reduction up to 40 %, due to their chemical structure which enables good particle dispersion.

2 – 1 - Chemical structure

PCEs are composed by a methoxy - polyethylene glycol copolymer (side chain) grafted with methacrylic acid copolymer (main chain). The carboxylic acid COO Na dissociates in water, providing a negative charge along the PCE backbone. The polyethylene oxide (PEO or MPEG) group affords a not uniform distribution of electron cloud, which gives a chemical polarity to the side chains. The number and the length of side chains are flexible parameters easy to change. When the side chains have a huge amount of EO units, they lower with their high molar mass the charge density of the polymer, which enables poor performances on cement suspensions . To have both parameters on the same time, long side chain and high charge density, one can keep the number of main-chain-units much higher than the number of side-chain-units.[4]

2 - 2 - Working mechanisms :



Poly carboxylate displacement on a multi-phase suspension.

PCE's backbone, which is negatively charged, permits the adsorption on the positively charged colloidal particles. As a consequence of PCE adsorption, the zeta potential of the suspended particles changes, due to the adsorption of the COO- groups on the colloid surface. This displacement of the polymer on the particle surface ensures to the side chains the possibility to exert repulsion forces, which disperse the particles of the suspension and avoid friction. These forces can be directly detected by the use of the atomic force microscopy (AFM), working with model substances in liquid environment.

Syncrete

Syncrete or **Syn - crete** was an experimental synthetic concrete intended for road patching and repairs, created by blending an artificial polymer with concrete. According to its manufacturer, Hodson Chemical Construction Corp., Syncrete had been used successfully on small and large concrete repair projects throughout the West and Hawaii. How ever , most notoriously, in 1989 it was used by the Utah Department of Transportation (UDOT) in an unprecedented large-scale test, to pave a section of Interstate 15 between 5900 South and 3300 South in Salt Lake City, Utah.

Instead of a total reconstruction, which would have required closing sections of I-15 for up to a year, the "salt resistant" Syncrete was applied as 3/4"-thick overlay on top of the existing road surface.

Syncrete was promoted by Hodson consulting engineers as a quicker, cheaper, longer-lasting alternative to conventional concrete, and UDOT agreed to take on the risk for the experimental project. However, the freeway surface began crumbling shortly after the project's completion, and chunks of the resulting debris began causing vehicle damage. Less than a year later, UDOT tore out the syncrete. The original construction costs were $1.5 million, and tearing up the Syncrete cost approximately $ 795,000, bringing the total cost for the failed project to an estimated $ 2.7 million.

Tabby (Cement)

The remains of tabby buildings which served as slave quarters in colonial times at Kingsley Plantation in Jacksonville, Florida.

Tabby is a building material consisting of lime, sand, water, and crushed oyster shells. It was developed and used by English colonists in Beaufort County and on the Sea Islands of coastal South Carolina, in coastal Georgia, and in northern Florida in the Southern United States. The period of use extended from the Colonial Period into the early 19th century.

The labor-intensive process depended on slave labor to crush and burn the oyster shells to supply lime. They were combined with sand and water in wood forms to hold the shape until the material hardened. Tabby was used as a substitute for bricks, which were rare and expensive because of the absence of local clay. Some researchers believe that the name came from the Spanish word, *tapia*, which means "mud wall", but that English colonists developed their own process independently of the Spanish.

Thaumasite

Thaumasite is a silicate mineral with chemical formula $Ca_3Si(OH)_6(CO_3)(SO_4)\cdot 12H_2O$. It occurs as colorless to white prismatic hexagonal crystals, typically as acicular radiating groups. It also occurs as fibrous masses. Its Mohs hardness is 3.5 and it has a specific gravity of 1.88 to 1.90. Optically it is uniaxial negative with indices of refraction of nω = 1.507 and nε = 1.468.

It occurs as a hydrothermal alteration mineral in sulfide ore deposits and geothermal alteration of basalt and tuff. It occurs with zeolites, apophyllite, analcime, calcite, gypsum and pyrite.

Thaumasite can also be formed along with other calcium-silicate hydrates (CSH) during cement alteration, especially when sulfate attack develops.

It was first described in 1878 in Sweden and named from the Greek, "thaumazein", *to be surprised*, in reference to its unusual composition with carbonate, sulfate and hydroxysilicate anions.[3]

Another quite surprising feature of thaumasite is the presence of non-tetrahedral silicon in its crystal lattice . Indeed, an atypic octahedral configuration is observed for Si present in thaumasite in the form of hexahydroxysilicate: $[Si(OH)_6]^{2-}$, a species exhibiting a geometry similar to that of the hexafluorosilicate $[SiF_6]^{2-}$.

Category	Sulfate minerals
Chemical Formula	$Ca_3Si(OH)_6(CO_3)(SO_4)\cdot 12H_2O$
Unit cell	a = 11.030 Å , c = 10.396 Å ; Z = 2
Molar Mass	622.62 g / mol
Color	Colorless , white , pale yellow
Crystal habit	Prismatic , fibrous, massive, radial

Crystal system	Hexagonal dipyramidal
Cleavage	Indistinct
Mohs scale hardness	3.5
Luster	Vitreous to silky
Streak	White
Diaphaneity	Transparent to translucent
Specific gravity	1.877
Optical properties	Uniaxial (-)
Refractive index	nω = 1.498–1.507 nε = 1.458–1.470

Thick Bed Mortar

History

The thick bed mortar method has been around for hundreds, if not thousands of years. Historically, a sand / cement mixture was mixed with water to a fairly dry consistency and was spread on either a portland cement water paste (neat cement), or over cement powder spread on the surface which is then sprayed with water to create a slurry coat and spread over the surface. The thick bed mortar would then be compacted and screeded (made flat and/or level) prior to installation of tile or stone. As the slurry coat dried it would bond the mortar bed to the concrete surface on which it was installed. Mortar beds were used underneath almost every tile or stone installation until the late 1950s when a chemical engineer, Henry M. Rothberg, invented the technology which introduced latex to sand/cement mortar mixes, and created a new industry based on thin bed adhesive installations by founding Laticrete International, Inc.

Mortars used in this technique typically have a compressive strength ranging from at least 400 psi (2.8 MPa) to 1600 psi (11 MPa), when tested using ANSI testing procedures . However, with advancements in technology and materials, the potential strengths of the thick bed mortar system have increased.

Quality controlled manufacturing processes create thick bed mortar mixes which combine carefully graded, high quality aggregates (sand) in a precise ratio with portland cement. This means that a consistent mix can be achieved without the need for a laborer to blend sand/cement and possibly lime at the jobsite. These pre-packaged mortars also eliminate the problems caused by excessively damp sand, incorrect mixing ratios, quality of the raw materials, and piles of sand on a jobsite. Today's thick bed mortars can be fortified with the inclusion of a liquid latex or redispersible polymer per the manufacturer's directions to enhance the performance properties of the thick bed mortar.

Thin Set

Thin set is an adhesive mortar made of cement, fine sand and a water retaining agent such as an alkyl derivative of cellulose. It is usually used to attach tile or stone to surfaces such as cement or concrete.

Tilt up

A finished tilt-up building

Contents

1 – Introduction :

Tilt-up, tilt-slab or tilt-wall is a type of building and a construction technique using concrete. Though it is a cost - effective technique with a shorter completion time , poor performance in earthquakes has mandated significant seismic retrofit requirements in older buildings .

With the Tilt-up method concrete elements (i.e. walls, columns, structural supports, etc.) are formed horizontally on a concrete slab; usually the building floor, but sometimes a temporary concrete casting surface near the building footprint. After the concrete has cured, the elements are "tilted" to vertical position with a crane and braced into position until the remaining building structural components (roofs, intermediate floors and walls) are secured.

Tilt-up construction is a dominant method of construction throughout North America, several Caribbean nations, Australia, and New Zealand. It is not significantly used in Europe or the northern two thirds of Asia. It is gaining popularity in southern Asia, the Middle East, parts of Africa, Central and South America.

Concrete elements can also be formed at factories away from the building site.[5] Tilt-up differs from prefabrication, or plant cast construction, in that all elements are constructed on the job site. This eliminates the size limitation imposed by transporting elements from a factory to the project site.

2 – Construction :

A tilt-up building during construction. A cast wall section is being righted. Other sections are visible in their forms.

Tilt-up construction requires significant organization and collaboration on the building site. Following are the chronological steps that need to be taken for a tilt-up project: site evaluation, engineering, footings and floor slabs, forming tilt-up panels, steel placement, embeds and inserts, concrete placement, panel erection and panel finishing . Once the pad (casting surface or floor slab) has cured, forms are built on top. Dimensional lumber, a high quality plywood or fiber board that has at least one smooth face is typically used, although aluminum or steel forms can also be used. Carpenters work off engineered drawings designed for each panel or element to construct on site. They incorporate all door and window openings, as well as architectural features and other desired shapes that can be molded into the concrete. Studs, gussets and attachment plates are located within the form for embedding in the concrete. The forms are usually anchored to the casting surface with masonry nails or otherwise adhered to prevent damage to the floor slab .

Next, a chemically reactive bondbreaker is sprayed on the form's surfaces to prevent the cast concrete from bonding with the slab. This allows the cast element to separate from the casting surface once it has cured. This is a critical step, as improper chemical selection or application will prevent the lifting of the panels, and will entail costly demolition and rework.

A rebar grid is constructed inside the forms, after the form release is applied, spaced off the casting surface the desired distance with plastic "chairs". The rebar size and spacing is generally specified by the engineer of record .

Concrete is then placed, filling the desired thickness and surrounding all steel inserts, embedded features and rebar. The forms are removed when the concrete is cured, rigging is attached and a crane tilts the panel or lifts the element into place. In circumstances when space is at a premium, concrete elements can be cast one on top of the other, or stack cast. Quite often a separate casting pad is poured for this purpose and is removed when the panels are erected .

Cranes are used to tilt the concrete elements from the casting slab to a vertical position. The slabs are then most often set onto a foundation and secured with braces until the structural steel and the roof diaphragm is in place.

3 – Structure :

Concrete tilt-up walls can be very heavy, as much as 300,000 pounds (140 t) or more . Most tilt-up wall panels are engineered to work with the roof structure and/or floor structures to resist all forces; that is, to function as load - bearing walls. The connections to the roof and floors are usually steel plates with headed studs that were secured into the forms prior to concrete placement. These attachment points are bolted or welded. The upper attachment points are made to the roof trusses. Interior walls may be present for additional stiffness in the building structure as necessary, known as shear walls.

Insulation can be applied to either side of the panels or cast as an integral part of the panel between two layers of concrete to create sandwich panels. Concrete has the ability to absorb and store energy and is high mass, which regulates interior temperature (thermal mass) and provides sound proofing and durability.

Like all concrete construction, tilt-up buildings are fire-resistant. In addition, wall panels can be designed to sag inward when damaged, which minimizes collapse (this can also be done with prefabricated panels).

4 – Uses :

Schindler House is an early example of tilt-up house construction

Some authors believe that tilt-up was one of the concrete construction methods used in Ancient Rome or the ancient Middle East.[1][11] Modern tilt-up, made with reinforced concrete, was first used in America circa 1905. In 1908 Robert Akin patented the tilt-slab method of concrete construction used in the construction of Schindler home. [12] Early erection was done using tilt tables, but the development of the mobile crane and truck mixers allowed tilt-up construction to grow. Tilt-up gained widespread popularity in the post World War II construction boom . Tilt-up was not used successfully in Australia until 1969.

Most early tilt-up buildings were ware houses. Today the method is used in nearly every type of building from schools to office structures, houses to hotels. They range from single story to more than seven and can be more than 96 feet in height.

An early example of this method is found in the innovative Schindler House, built in 1922 in West Hollywood, California. Architect Rudolf Schindler claimed that with the assistance of a small hand-operated crane, just two workmen were needed to raise and attach the tilt - up walls .

5 – Appearance :

Early tilt-up architecture was very minimalist and boxy. Recent techniques have expanded the range of appearance and shape.

Many finish options are available to the tilt-up contractor, from paints and stains to pigmented concrete, cast-in features like brick and stone to aggressive erosion finishes like sandblasting and acid-etching. Shapes are also a feature that have become dominant in the tilt-up market, with many panels configured with circular or elliptical openings, panel tops that are pedimented or curved, facades that are curved or segmented and featured with significant areas of glazing or other materials.

6 – Association :

The Tilt-Up Concrete Association (TCA) is the international trade association for tilt-up concrete construction. TCA is a membership-based association, with nearly 500 members worldwide.[19] TCA members can be contractors (general contractors or tilt-up subcontractors), engineers, architects, developers, consultants, suppliers, specialty trade firms, educators and students.

TCA offers primarily educational, networking and exposure benefits to its members. TCA also offers an Achievement Awards program annually, recognizing the best examples of tilt-up construction over a variety of end uses .

7 – Risks :

In the wake of the 2011 Joplin tornado in which seven people were killed in a Home Depot when the 100,000 pounds (45 t) panel walls collapsed after the store was hit by an EF5 tornado, engineers in an article published in *The Kansas City Star* criticized the practice. They said that once one wall falls, it creates a domino effect. 28 people in an un-reinforced training room in the back of the building survived. According to a study of the collapse, the tornado hit the south corner of the store and lifted the roof up causing the west walls to collapse into the store. The walls on the east side (where the people survived) collapsed out. Only two walls remained standing. Engineers said that stronger roof-to-wall connections might have tempered the collapse. Two other big box stores at the corner that had concrete block construction (an Academy Sports and Walmart) lost their roofs but the walls remained intact. Three people died in the Walmart, but 200 survived. The engineers told the Star that when concrete blocks fail they usually break apart, and do not come down in the huge slabs. Home Depot, which has hundreds of stores built with tilt-up, said it disagreed with the finding and that it would use tilt-up when it rebuilt the Joplin store.

8 - Gallery :

	
Base detail of tilt-slab sat on strip footings. Finished floor level will be approx. 75mm higher than blue inserts. Inserts take threaded rebar into floor slab.	*Cast panel on temporary casting pad (foreground), with panels being erected in background. Small retail shop, Northern Australia.*
	
Stack-cast panels.	*Panel being hoisted into position.*

Tiocem

Contents

1 – Introduction :

Tiocem is a specialized cement with photocatalytic features, used on the surface of buildings to reduce air pollution caused by exposure of the cement to ultra violet light (UV).

2 – Technology :

Photocatalysis is initiated by titanium dioxide (TiO_2), which is added during the cement's production. Typical properties (i.e. strength) of cement applications (such as concrete) will be added to clean the air around the photocatalytic surface. Nitrogen dioxide (NO_2) will be particularly abated when daylight activates the photocatalytic surfaces.

The chemical process may be summarized as follows :

- Titanium dioxide (TiO_2) absorbs energy (UV radiation) and excites electrons (e-)

$$TiO_2 + h\nu \rightarrow TiO_2 + h^+ + e^-$$

- Oxygen existing in the air (O_2) reacts with electrons (e-), generating super-oxide ions (O_2^-)
- Super-oxide ions (O_2^-) react with hydrogen ions (H+), generating the reactive hydroxyl radicals (OH●)

$$H_2O + h^+ \rightarrow H^+ + OH^-$$

- Nitrogen dioxide (NO_2) reacts with the pollutant remover (OH●) and generates nitrate (NO_3^-), which reacts with the cement surface and is dissolved by water.

Using materials like Tiocem, the abatement of NO_2 could be measured by a test method using the Italian standard UNI 11247. which is being discussed as the basis of a European standard. This method involves test apparatus in which a mixture of air and pollutant flows in a chamber over a test object; the pollutant burden is measured with (and without) exposure to light. A defined level of NO_2 abatement is guaranteed by the label “TX Active” (plus an initial) and replication of the test results. Proof of the effective reduction of oxide-of-nitrogen exposure has been furnished under close-to-practical conditions by the PICADA (Photocatalytic Innovative Coverings Applications for Depollution Assessment) Project (supported by the European Union and other studies.

3 – Applications :

Since the photocatalytic effect is needed only on the surface of a building which is exposed to UV, Tiocem is used primarily in the top layer of a two-layer surface.

The most effective fields for application are :

- Pavement (stones and slabs)
- Roofing tiles
- Noise and screen barriers
- Facades (wall cladding)
- Rendering (dry mortar/exterior cement plaster)
- Road construction (e.g. whitetopping)

The abatement of NO_2 varyies with changing climatic conditions . Field tests were carried out with pavements in Bergamo, Italy, on the inside walls of a tunnel in Rome and stucco in Stockholm. In all cases, the requirements of TX Active for NO_2 abatement were met.

Tobermorite

Tobermorite is a calcium silicate hydrate mineral with chemical formula : $Ca_5Si_6O_{16}(OH)_2 \cdot 4H_2O$ or $Ca_5Si_6(O,OH)_{18} \cdot 5H_2O$

Two structural varieties are distinguished : tobermorite-11 Å and tobermorite-14 Å. Tobermorite occurs in hydrated cement paste and can be found in nature as alteration mineral in metamorphosed limestone (*e.g.* in the Maqarin Area (North Jordan), or in Crestmore (Riverside County, California, USA)) and in skarn.

Tobermorite was first described in 1880 for an occurrence in Scotland, on the Isle of Mull, around the locality of Tobermory.

Category	Silicate mineral , Calcium silicate hydrate
Chemical Formula	$Ca_5Si_6O_{16}(OH)_2 \cdot 4H_2O$, or ; $Ca_5Si_6(O,OH)_{18} \cdot 5H_2O$
Crystal symmetry	Ortho rhombic 2 2 2
Unit cell	a = 11.17 Å , b = 7.38 Å , c = 22.94 Å ; β = 90° ; Z = 4
Molar mass	702.36
Color	Pale pinkish white, white, brown
Crystal habit	As minute laths; fibrous bundles, rosettes or sheaves, radiating or plumose, fine granular, massive.
Crystal system	Orthorhombic - Disphenoidal
Mohs scale hardness	2.5
Luster	Vitreous, silky in fibrous aggregates
Streak	White

Diaphaneity	Translucent to translucent
Specific gravity	2.423 - 2.458
Optical properties	Biaxial (+)
Refractive index	nα = 1.570 nβ = 1.571 nγ = 1.575
Ultraviolet fluorescence	Fluorescent, Short UV:weak white to yellow, Long UV:weak white to yellow

Traffic Barrier

Contents

1 – Introduction :

Traffic barriers (some times called **crash barriers** or **armco barriers**) keep vehicles within their road way and prevent vehicles from colliding with dangerous obstacles such as boulders, buildings, walls or large storm drains. Traffic barriers are also installed at the road side to prevent errant vehicles from traversing steep (non-recoverable) slopes or entering deep water. Traffic barriers are installed within medians of divided highways to prevent errant vehicles from entering the opposing carriageway of traffic and help to reduce head-on collisions. Some of these barriers, designed to be struck from either side, are called median barriers. Crash barriers can also be used to protect vulnerable areas like school yards, pedestrian zones or fuel tanks from errant vehicles.

While barriers are normally designed to minimize injury to vehicle occupants, injuries do occur in collisions with traffic barriers. They should only be installed where a collision with the barrier is likely to be less severe than a collision with the hazard behind it. Where possible, it is preferable to remove, relocate or modify a hazard, rather than shield it with a barrier.

To make sure they are safe and effective, traffic barriers undergo extensive simulated and full scale crash testing before they are approved for general use. While crash testing cannot replicate every potential manner of impact, testing programs are designed to determine the performance limits of traffic barriers and provide an adequate level of protection to road users.

2 - Need and placement :

Roadside hazards must be assessed for the danger they pose to traveling motorists based on size, shape and rigidity and distance from the edge of travelway. For instance, small roadside signs and some large signs (ground-mounted breakaway post) often do not merit roadside protection as the barrier itself may pose a greater threat to general health and well-being of the public than the obstacle it intends to protect. In many regions of the world, the concept of clear zone is taken into account when examining the distance of an obstacle or hazard from the edge of travelway.

Clear zone, also known as clear recovery area or horizontal clearance[3] is defined (through study) as a lateral distance in which a motorist on a recoverable slope may travel outside of the travelway and return their vehicle safely to the roadway. This distance is commonly determined as the 85th percentile in a study comparable to the method of determining speed limits on roadways through speed studies and varies based on the classification of a roadway. In order to provide for adequate safety in roadside conditions, hazardous elements such as fixed obstacles or steep slopes can be placed outside of the clear zone in order to reduce or eliminate the need for roadside protection.

Common sites for installation of traffic barrier :

- Bridge ends
- Near steep slopes from roadway limits
- At drainage crossings or culverts where steep or vertical drops are present
- Near large signs/illumination poles or other roadside elements which may pose hazards

When barrier is needed, careful calculations are completed to determine length of need . The calculations take into account the speed and volume of traffic volume using the road, the distance from the edge of travelway to the hazard, and the distance or offset from the edge of travelway to the barrier.

3 - Barrier types and performance :

Traffic barriers are categorized in two ways: by the function they serve, and by how much they deflect when a vehicle crashes into them.

3 – 1 - Barrier functions :

Roadside barriers are used to protect traffic from roadside obstacles or hazards, such as slopes steep enough to cause rollover crashes, fixed objects like bridge piers, and bodies of water. Roadside barriers can also be used wide medians, to prevent vehicles from colliding with hazards within the median.

Median barriers are used to prevent vehicles from crossing over a median and striking an oncoming vehicle in a head-on crash. Unlike roadside barriers, they must be designed to be struck from either side.

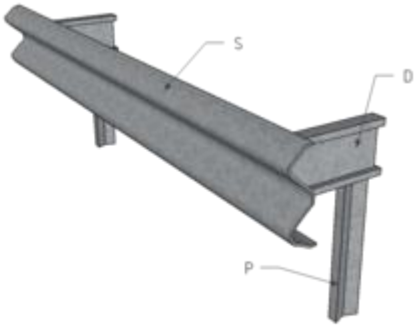
Bridge barrier is designed to restrain vehicles from crashing off the side of a bridge and falling onto the roadway, river or railroad below. It is usually higher than roadside barrier, to prevent trucks, buses, pedestrians and cyclists from vaulting or rolling over the barrier and falling over the side of the structure. Bridge rails are usually multi-rail tubular steel barriers or reinforced concrete parapets and barriers.

Work zone barriers are used to protect traffic from hazards in work zones. Their distinguishing feature is they can be relocated as conditions change in the road works. Two common types are used: temporary concrete barrier and water-filled barrier. The latter is composed of steel-reinforced plastic boxes that are put in place where needed, linked together to form a longitudinal barrier, then ballasted with water. These have an advantage in that they can be assembled without heavy lifting equipment, but they cannot be used in freezing weather.

3 – 2 - Barrier stiffness :

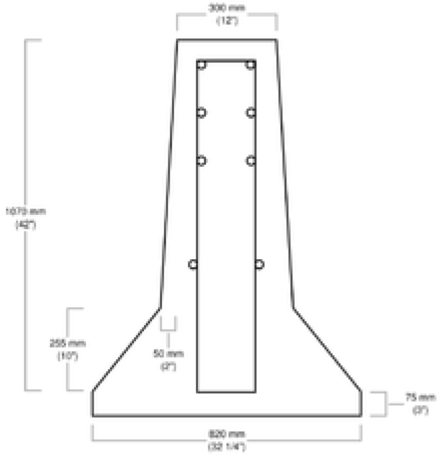
Barriers are divided into three groups, based on the amount they deflect when struck by a vehicle and the mechanism the barrier uses to resist the impact forces. In the United States, traffic barriers are tested and classified according to the AASHTO Manual for Assessing Safety Hardware (MASH) standards, which recently superseded Federal Highway Administration NCHRP Report 350. Barrier deflections listed below are results from crash tests with a 2000 kg pickup truck traveling 100 km/h, colliding with the rail at a 25 degree angle .

Flexible barriers include cable barriers and weak post corrugated guide rail systems. These are referred to as flexible barriers because they will deflect 1.6 meters to 2.6 meters (8.5 ft) when struck by a typical passenger car or light truck. Impact energy is dissipated through tension in the rail elements, deformation of the rail elements, posts, soil and vehicle bodywork, and friction between the rail and vehicle.



Components of a standard guiderail (A-profile): S – guardrail, D – distance piece/spacer, P – sigma post

Semi-rigid barriers include box beam guide rail, heavy post blocked out corrugated guide rail and thrie-beam guide rail. Thrie-beam is similar to corrugated rail, but it has three ridges instead of two. They deflect 3 feet (0.91 m) to 6 feet (1.8 m): more than rigid barriers, but less than flexible barriers. Impact energy is dissipated through deformation of the rail elements, posts, soil and vehicle bodywork, and friction between the rail and vehicle. Box beam systems also spread the impact force over a number of posts due to the stiffness of the steel tube.



42 inches (1.1 m)-high version of the Jersey barrier for deflecting automobiles and semi-trailer trucks.

Rigid barriers are usually constructed of reinforced concrete. A permanent concrete barrier will only deflect a negligible amount when struck by a vehicle. Instead, the shape of a concrete barrier is designed to redirect a vehicle into a path parallel to the barrier. This means they can be used to protect traffic from hazards very close behind the barrier, and generally require very little maintenance. Impact energy is dissipated through redirection and deformation of the vehicle itself. Jersey barriers and F-shape barriers also lift the vehicle as the tires ride up on the angled lower section. For low-speed or low-angle impacts on these barriers, that may be sufficient to redirect the vehicle without damaging the bodywork. The disadvantage is there is a higher likelihood of rollover with a small car than the single slope or step barriers. Impact forces are resisted by a combination of the rigidity and mass of the barrier. Deflection is usually negligible.

An early concrete barrier design was developed by the New Jersey State Highway Department. This led to the term Jersey barrier being used as a generic term, although technically it applies to a specific shape of concrete barrier. Other types include constant slope barriers, concrete step barriers and F-shape barriers.

Concrete barriers usually have smooth finishes. At some impact angles, coarse finishes allow the drive wheel of front wheel drive vehicles to climb the barrier, potentially causing the vehicle to roll over. However, along parkways and other areas where aesthetics are considered important, reinforced concrete walls with stone veneers or faux stone finishes are sometimes used. These barrier walls usually have vertical faces to prevent vehicles from climbing the barrier.

4 - Barrier end treatments :

Early traffic barrier designs often paid little attention to the ends of the barriers. Vehicles that struck blunt ends could stop abruptly or have steel rail sections penetrate into the passenger compartment, resulting in severe injuries or fatalities . As a result, barrier terminals were developed that brought the end of the terminal down to ground level. While this prevented the rail from penetrating the vehicle, it could also vault a vehicle into the air or cause it to roll over, since the barrier end formed a ramp. To address the vaulting and rollover crashes, energy absorbing terminals were developed. These have a large steel impact head that engages the frame or bumper of the vehicle. The impact head is driven back along the guide rail, dissipating the vehicle's kinetic energy by bending or tearing the steel in the guide rail sections. A guide rail may also be terminated by curving it back to the point that the terminal is unlikely to be hit end-on, or, if possible, by embedding the end in a hillside or cut slope.

An alternative to energy absorbing barrier terminals are impact attenuators. These are used for wider hazards that can't be effectively protected with a one - sided traffic barrier.

Tremie

Contents

1 – Introduction :

The **tremie** concrete placement method uses a pipe, through which concrete is placed below water level.

The lower end of the pipe is kept immersed in fresh concrete so that the rising concrete from the bottom displaces the water without washing out the cement content.

2 – Applications :

2 – 1 – Caissons :

Concrete is often poured through a tremie pipe in order to build caissons, which are the foundations of, among other things, bridges that span bodies of water.

2 – 2 – Monitoring wells :

Tremie methods are employed for materials other than concrete, and for industries other than construction. For example, bentonite slurries for monitoring wells are often emplaced via tremie pipe.

Tri Calcium Aluminate

Contents

1 – Introduction :

Tri calcium aluminate $Ca_3Al_2O_6$, often formulated as $3CaO·Al_2O_3$ to highlight the proportions of the oxides from which it is made, is the most basic of the calcium aluminates. It does not occur in nature, but is an important mineral phase in Portland cement.

Other Names : Aluminate , C_3A	
Molecular Formula	$Ca_3Al_2O_6$, or $3CaO·Al_2O_3$
Molar mass	270 g / mol
Density	3.064 gm / cc
Melting point	1542 °C (decomp)

2 – Properties :

Pure tri calcium aluminate is formed when the appropriate proportions of finely divided calcium oxide and aluminium oxide are heated together above 1300 °C. The pure form is cubic, with unit cell dimension 1.5263 nm and has density 3064 $kg·m^{-3}$. It melts with decomposition at 1542 °C. The unit cell contains 8 cyclic $Al_6O_{18}^{18-}$ anions, which can be considered to consist of 6 corner sharing AlO_4 tetrahedra.

In Portland cement clinker, tri calcium aluminate occurs as an "interstitial phase", crystallizing from the melt. Its presence in clinker is solely due to the need to obtain liquid at the peak kiln processing temperature (1400–1450 °C), facilitating the formation of the desired silicate phases. Apart from this benefit, its effects on cement properties are mostly undesirable. It forms an impure solid solution phase, with 15 - 20 % of the aluminium atoms replaced by silicon and iron, and with variable amounts of alkali metal atoms replacing calcium, depending upon the availability of alkali oxides in the melt.

The impure form has at least four polymorphs:

Alkali % m/m	Designation	Crystal
0 - 1.0	C_I	Cubic
1.0 - 2.4	C_{II}	Cubic
3.7 - 4.6	O	Orthorhombic
4.6 - 5.7	M	Monoclinic

Typical chemical compositions are :

Oxide	Mass % Cubic	Mass % Orthorhombic
SiO_2	3.7	4.3
Al_2O_3	31.3	28.9
Fe_2O_3	5.1	6.6
CaO	56.6	53.9
MgO	1.4	1.2
Na_2O	1.0	0.6
K_2O	0.7	4.0
TiO_2	0.2	0.5

3 - Effect on cement properties :

In keeping with its high basicity, tricalcium aluminate reacts most strongly with water of all the calcium aluminates, and it is also the most reactive of the Portland clinker phases. Its hydration to phases of the form $Ca_2AlO_3(OH)\cdot nH_2O$ leads to the phenomenon of "flash set" (instantaneous set), and a large amount of heat is generated. To avoid this, Portland-type cements include a small addition of calcium sulfate (typically 4-8%). Sulfate ions in solution lead to the formation of an insoluble layer of ettringite ($3CaO\cdot Al_2O_3\cdot 3CaSO_4\cdot 32H_2O$) over the surface of the aluminate crystals, passivating them. The aluminate then reacts slowly to form the AFm phase $3CaO \cdot Al_2O_3 \cdot CaSO_4 \cdot 12H_2O$. These hydrates contribute little to strength development.

Tricalcium aluminate is associated with three important effects that can reduce the durability of concrete :

- heat release, which can cause spontaneous overheating in large masses of concrete. Where necessary, tricalcium aluminate levels are reduced to control this effect.
- sulfate attack, in which sulfate solutions to which the concrete is exposed react with the AFm phase to form ettringite. This reaction is expansive, and can disrupt mature concrete. Where concrete is to be placed in contact with, for example, sulfate-laden ground waters, either a "sulfate-resisting" cement (with low levels of tricalcium aluminate) is used, or slag is added to the cement or to the concrete mix. The slag contributes sufficient aluminium to suppress formation of ettringite.
- delayed ettringite formation, where concrete is cured at temperatures above the decomposition temperature of ettringite (about 65 °C). On cooling, expansive ettringite formation takes place.

Because they are even more basic, the alkali-loaded polymorphs are correspondingly more reactive. Appreciable amounts (>1%) in cement make set control difficult, and the cement becomes excessively hygroscopic. The cement powder flowability is reduced, and air-set lumps tend to form. They withdraw water from gypsum on storage of the cement, leading to false set. For this reason, their formation is avoided wherever possible. It is more energetically favorable for sodium and potassium to form sulfates and chlorides in the kiln, but if insufficient sulfate ion is present, any surplus alkalis congregate in the aluminate phase. The feed and fuel in the kiln system are preferably controlled chemically to keep the sulfate and alkalis in balance. However, this stoichiometry is only maintained if there is substantial surplus oxygen in the kiln atmosphere: if "reducing conditions" set in, then sulfur is lost as SO_2, and reactive aluminates start to form. This is readily monitored by tracking the

Turner – Sclero Meter

The **sclerometer**, also known as the **Turner-sclerometer** (from Ancient Greek : meaning "hard"), is an instrument used by metallurgists, material scientists and mineralogists to measure the scratch hardness of materials. It was invented in 1896 by Thomas Turner (1861–1951), the first Professor of metallurgy in Britain, at the University of Birmingham.

The Turner-sclerometer test consists of microscopically measuring the width of a scratch made by a diamond under a fixed load, and drawn across the face of the specimen under fixed conditions.

Types of Concrete

	
Regular concrete paving blocks	*A highway paved with concrete.*

There are many **types of concrete**, designed to suit a variety or purposes coupled with a range of compositions, finishes and performance characteristics.

Contents

1 - Mix design :

Modern concrete mix designs can be complex. The choice of a concrete mix depends on the need of the project both in terms of strength and appearance and in relation to local legislation and building codes.

The design begins by determining the requirements of the concrete. These requirements take into consideration the weather conditions that the concrete will be exposed to in service, and the required design strength. The compressive strength of a concrete is determined by taking standard molded, standard-cured cylinder samples.

Many factors need to be taken into account, from the cost of the various additives and aggregates, to the trade offs between, the "slump" for easy mixing and placement and ultimate performance.

A mix is then designed using cement (Portland or other cementitious material), coarse and fine aggregates, water and chemical admixtures. The method of mixing will also be specified, as well as conditions that it may be used in.

This allows a user of the concrete to be confident that the structure will perform properly.

Various types of concrete have been developed for specialist application and have become known by these names..

Concrete mixes can also be designed using software programs. Such software provide the user an opportunity to select their preferred method of mix design and enter the material data to arrive at proper mix designs.

2 - Old concrete recipes :

Concrete has been used since ancient times. Regular Roman concrete for example was made from volcanic ash (pozzolana), and hydrated lime. Roman concrete was superior from other concrete recipes (for example those consisting of only sand and lime.[1] used used by other nations. Besides using volcanic ash for making regular Roman concrete, brick dust can also be used. Besides regular Roman concrete, the Romans also invented hydraulic concrete, which they made from volcanic ash and clay.

3 - Modern concrete :

Regular concrete is the lay term describing concrete that is produced by following the mixing instructions that are commonly published on packets of cement, typically using sand or other common material as the aggregate, and often mixed in improvised containers. The ingredients in any particular mix depends on the nature of the application. Regular concrete can typically withstand a pressure from about 10 MPa (1450 psi) to 40 MPa (5800 psi), with lighter duty uses such as blinding concrete having a much lower MPa rating than structural concrete. Many types of pre-mixed concrete are available which include powdered cement mixed with an aggregate, needing only water.

Typically, a batch of concrete can be made by using 1 part Portland cement, 2 parts dry sand, 3 parts dry stone, 1/2 part water. The parts are in terms of weight – not volume. For example, 1-cubic-foot (0.028 m^3) of concrete would be made using 22 lb (10.0 kg) cement, 10 lb (4.5 kg) water, 41 lb (19 kg) dry sand, 70 lb (32 kg) dry stone (1/2" to 3/4" stone). This would make 1-cubic-foot (0.028 m^3) of concrete and would weigh about 143 lb (65 kg). The sand should be mortar or brick sand (washed and filtered if possible) and the stone should be washed if possible. Organic materials (leaves, twigs, etc.)

should be removed from the sand and stone to ensure the highest strength.

4 – High - strength concrete :

High - strength concrete has a compressive strength greater than 40 MPa (5800 psi). High-strength concrete is made by lowering the water-cement (W/C) ratio to 0.35 or lower. Often silica fume is added to prevent the formation of free calcium hydroxide crystals in the cement matrix, which might reduce the strength at the cement-aggregate bond.

Low W / C ratios and the use of silica fume make concrete mixes significantly less workable, which is particularly likely to be a problem in high-strength concrete applications where dense rebar cages are likely to be used. To compensate for the reduced workability, super plasticizers are commonly added to high-strength mixtures. Aggregate must be selected carefully for high-strength mixes, as weaker aggregates may not be strong enough to resist the loads imposed on the concrete and cause failure to start in the aggregate rather than in the matrix or at a void, as normally occurs in regular concrete.

In some applications of high-strength concrete the design criterion is the elastic modulus rather than the ultimate compressive strength.

5 - Stamped concrete :

Stamped concrete is an architectural concrete which has a superior surface finish. After a concrete floor has been laid, floor hardeners (can be pigmented) are impregnated on the surface and a mold which may be textured to replicate a stone / brick or even wood is stamped on to give an attractive textured surface finish. After sufficient hardening the surface is cleaned and generally sealed to give a protection. The wear resistance of stamped concrete is generally excellent and hence found in applications like parking lots, pavements, walkways etc.

6 - High-performance concrete :

High-performance concrete (HPC) is a relatively new term used to describe concrete that conforms to a set of standards above those of the most common applications, but not limited to strength. While all high-strength concrete is also high-performance, not all high-performance concrete is high-strength. Some examples of such standards currently used in relation to HPC are:

- Ease of placement
- Compaction without segregation
- Early age strength
- Long-term mechanical properties
- Permeability
- Density
- Heat of hydration
- Toughness
- Volume stability
- Long life in severe environments
- Depending on its implementation, environmental [2]

7 - Ultra-high-performance concrete :

Ultra-high-performance concrete is a new type of concrete that is being developed by agencies concerned with infrastructure protection. UHPC is characterized by being a steel fibre-reinforced cement composite material with compressive strengths in excess of 150 MPa, up to and possibly exceeding 250 MPa.[3] UHPC is also characterized by its constituent material make-up: typically fine-grained sand, silica fume, small steel fibers, and special blends of high-strength Portland cement. Note that there is no large aggregate. The current types in production (Ductal, Taktl, etc.) differ from normal concrete in compression by their strain hardening, followed by sudden brittle failure. Ongoing research into UHPC failure via tensile and shear failure is being conducted by multiple government agencies and universities around the world.

8 - Self-consolidating concretes :

After identifying the defects in concrete in Japan were mainly due to a) high water cement ratio to increase workability, b) poor compaction mostly happened due to the need of speedy construction in 1960s–70s, Professor Hajime Okamura envisioned the need of a concrete that is highly workable and does not rely on the mechanical force for compaction. During the 1980s, Professor Okamura and his PhD student Kazamasa Ozawa (currently professor) at the University of Tokyo, Japan developed a concrete called Self Compacting Concrete (SCC) that was cohesive but flowable and took the shape of the formwork without use of any mechanical compaction. SCC is known as self-consolidating concrete in the United States. SCC is characterized by:

- extreme fluidity as measured by *flow*, typically between 650–750 mm on a flow table, rather than slump(height)
- no need for vibrators to compact the concrete
- placement being easier.
- no bleed water, or aggregate segregation
- Increased Liquid Head Pressure, Can be detrimental to Safety and work manship

SCC can save up to 50 % in labor costs due to 80% faster pouring and reduced wear and tear on formwork.

As of 2005, self-consolidating concretes account for 10–15% of concrete sales in some European countries. In the US precast concrete industry, SCC represents over 75 % of concrete production. 38 departments of transportation in the US accept the use of SCC for road and bridge projects.

This emerging technology is made possible by the use of polycarboxylates plasticizer instead of older naphthalene based polymers, and viscosity modifiers to address aggregate segregation.

9 - Vacuum concrete :

Vacuum concrete, made by using steam to produce a vacuum inside a concrete mixing truck to release air bubbles inside the concrete, is being researched. The idea is that the steam displaces the air normally over the concrete. When the steam condenses into water it will create a low pressure over the concrete that will pull air from the concrete. This will make the concrete stronger due to there being less air in the mixture. A drawback is that the mixing has to be done in a mostly airtight container.

10 – Shot crete :

Shotcrete (also known by the trade name *Gunite*) uses compressed air to shoot concrete onto (or into) a frame or structure. The greatest advantage of the process is that shotcrete can be applied overhead or on vertical surfaces without forming. It is often used for concrete repairs or placement on bridges, dams, pools, and on other applications where forming is costly or material handling and installation is difficult. Shotcrete is frequently used against vertical soil or rock surfaces, as it eliminates the need for formwork. It is sometimes used for rock support, especially in tunneling. Shotcrete is also used for applications where seepage is an issue to limit the amount of water entering a construction site due to a high water table or other subterranean sources. This type of concrete is often used as a quick fix for weathering for loose soil types in construction zones.

There are two application methods for shot crete :

- *Dry - mix* – the dry mixture of cement and aggregates is filled into the machine and conveyed with compressed air through the hoses. The water needed for the hydration is added at the nozzle.
- *Wet - mix* – the mixes are prepared with all necessary water for hydration. The mixes are pumped through the hoses. At the nozzle compressed air is added for spraying.

For both methods additives such as accelerators and fiber reinforcement may be used.

11 - Lime crete :

Lime crete or lime concrete is concrete where cement is replaced by lime . One successful formula was developed in the mid 1800s by Dr. John E. Park . We know that lime has been used since Roman Times either as mass foundation concretes or as lightweight concretes using a variety of aggregates combined with a wide range of pozzolans (fired materials) that help to achieve increased strength and speed of set. This meant that lime could be used in a much wider variety of applications than previously such as floors, vaults or domes. Over the last decade, there has been a renewed interest in using lime for these applications again. This is because of environmental benefits and potential health benefits, when used with other lime products.

Environmental Benefits :

- Lime is burnt at a lower temperature than cement and so has an immediate energy saving of 20 % (although kilns etc are improving so figures do change). A standard lime mortar has about 60 - 70 % of the embodied energy of a cement mortar. It is also considered to be more environmentally friendly because of its ability, through carbination, to re-absorb its own weight in Carbon Dioxide (compensating for that given given off during burning).
- Lime mortars allow other building components such as stone, wood and bricks to be reused and recycled because they can be easily cleaned of mortar/limewash.
- Lime enables other natural and sustainable products such as wood (including woodfibre, wood wool boards), hemp, straw etc to be used because of its ability to control moisture (if cement were used, these buildings would compost!).

Health Benefits :

- Lime plaster is hygroscopic (literally means 'water seeking') which draws the moisture from the internal to the external environment, this helps to regulate humidity creating a more comfortable living environment as well as helping to control condensation and mould growth which have been shown to have links to allergies and asthmas.

- Lime plasters and limewash are non-toxic, therefore they do not contribute to indoor air pollution unlike some modern paints.

12 - Pervious concrete :

Pervious concrete, used in permeable paving, contains a network of holes or voids, to allow air or water to move through the concrete.

This allows water to drain naturally through it, and can both remove the normal surface - water drainage infrastructure, and allow replenishment of groundwater when conventional concrete does not.

It is formed by leaving out some or all of the fine aggregate (fines). The remaining large aggregate then is bound by a relatively small amount of Portland cement. When set, typically between 15 % and 25 % of the concrete volume is voids, allowing water to drain at around 5 gal /ft² / min (70 L / m² / min) through the concrete.

12 – 1 – Installation :

Pervious concrete is installed by being poured into forms, then screeded off, to level (not smooth) the surface, then packed or tamped into place. Due to the low water content and air permeability, within 5–15 minutes of tamping, the concrete must be covered with a 6-mil poly plastic, or it will dry out prematurely and not properly hydrate and cure.

12 – 2 – Characteristics :

Pervious concrete can significantly reduce noise, by allowing air to be squeezed between vehicle tires and the roadway to escape. This product cannot be used on major U.S. state highways currently due to the high psi ratings required by most states. Pervious concrete has been tested up to 4500 psi so far.

12 – 3 - Cellular concrete :

Aerated concrete produced by the addition of an air-entraining agent to the concrete (or a lightweight aggregate such as expanded clay aggregate or cork granules and vermiculite) is sometimes called *cellular concrete*, *lightweight aerated concrete*, *variable density concrete*, *foamed concrete* and *lightweight or ultra-lightweight concrete* , not to be confused with aerated autoclaved concrete, which is manufactured off-site using an entirely different method.

12 – 4 – Cork - cement composites :

Waste Cork granules are obtained during production of bottle stoppers from the treated bark of Cork oak . These granules have a density of about 300 kg / m³, lower than most lightweight aggregates used for making lightweight concrete. Cork granules do not significantly influence cement hydration, but cork dust may.[13] Cork cement composites have several advantages over standard concrete, such as lower thermal conductivities, lower densities and good energy absorption characteristics. These composites can be made of density from 400 to 1500 kg/m³, compressive strength from 1 to 26 MPa, and flexural strength from 0.5 to 4.0 MPa.

12 – 5 – Roller - compacted concrete :

Roller-compacted concrete, sometimes called **rollcrete**, is a low-cement-content stiff concrete placed using techniques borrowed from earthmoving and paving work. The concrete is placed on the surface to be covered, and is compacted in place using large heavy rollers typically used in earthwork. The concrete mix achieves a high density and cures over time into a strong monolithic block.[14] Roller-compacted concrete is typically used for concrete pavement, but has also been used to build concrete dams, as the low cement content causes less heat to be generated while curing than typical for conventionally placed massive concrete pours.

12 – 6 - Glass concrete :

The use of recycled glass as aggregate in concrete has become popular in modern times, with large scale research being carried out at Columbia University in New York. This greatly enhances the aesthetic appeal of the concrete. Recent research findings have shown that concrete made with recycled glass aggregates have shown better long term strength and better thermal insulation due to its better thermal properties of the glass aggregates.

12 – 7 - Asphalt concrete :

Strictly speaking, *asphalt* is a form of concrete as well, with *bituminous* materials replacing cement as the binder.

12 – 8 - Rapid strength concrete :

This type of concrete is able to develop high resistance within few hours after being manufactured. This feature has advantages such as removing the formwork early and to move forward in the building process at record time, repair road surfaces that become fully operational in just a few hours.

12 – 9 - Rubberized concrete :

While "rubberized asphalt concrete" is common, rubberized Portland cement concrete ("rubberized PCC") is still under going experimental tests, as of 2009.

12 – 10 - Polymer concrete :

Polymer concrete is concrete which uses polymers to bind the aggregate. Polymer concrete can gain a lot of strength in a short amount of time. For example, a polymer mix may reach 5000 psi in only four hours. Polymer concrete is generally more expensive than conventional concretes.

12 – 11 – Geo polymer or *green* concrete :

Geo polymer concrete is a *greener* alternative to ordinary Portland cement made from inorganic aluminosilicate (Al-Si) polymer compounds that can utilise 100 % recycled industrial waste (e.g. fly ash and slag) as the manufacturing inputs resulting in up to 80% lower carbon dioxide emissions. Greater chemical and thermal resistance, and better mechanical properties, are said to be achieved by the manufacturer at both atmospheric and extreme conditions.[20]

Similar concretes have not only been used in Ancient Rome (see Roman concrete) as mentioned but also in the former Soviet Union in the 1950s and 1960s. Buildings in Ukraine are still standing after 45 years so that this kind of formulation has a sound track record .

12 – 12 - Refractory cement :

High-temperature applications, such as masonry ovens and the like, generally require the use of a refractory cement; concretes based on Portland cement can be damaged or destroyed by elevated temperatures, but refractory concretes are better able to withstand such conditions. Materials may include calcium aluminate cements, fire clay, ganister and minerals high in aluminum.

12 – 13 - Concrete canvas :

A recent innovation is a material called concrete canvas. It is a flexible concrete impregnated fabric that hardens on hydration to form a thin, durable, fire resistant and water proof concrete layer. It consists of a three - dimensional fibre matrix, containing a specially formulated dry concrete mix. A PVC backing on one surface of the Canvas ensures the material is waterproof, while hydrophilic fibers on the opposite surface aid hydration by drawing water into the concrete. Concrete Canvas can be used to create waterproof, fire resistant, fibre-reinforced thin concrete forms across a range of applications: water management, erosion control, ditch lining, slope stabilisation, bund lining, cable protective covering, pipeline protection, mining applications, ground re-surfacing, rapid trackway or landing surfaces and rapidly deployable emergency shelters . Concrete canvas is known as concrete cloth in the United States.

12 – 14 - Innovative mixtures :

On-going research into alternative mixtures and constituents has identified potential mixtures that promise radically different properties and characteristics.

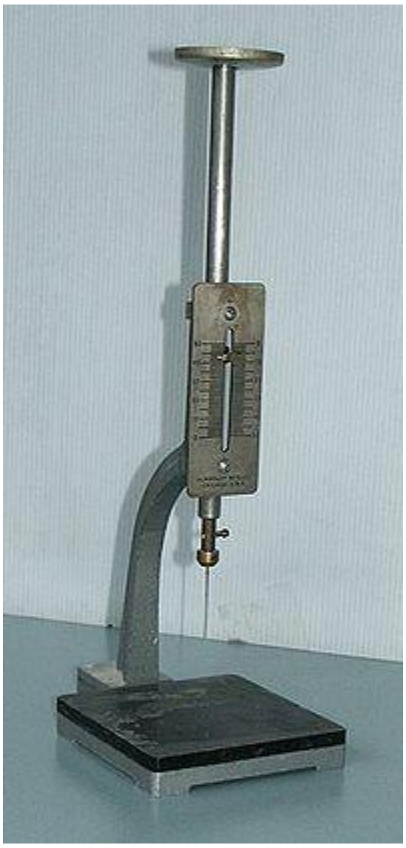
One university has identified a mixture with much smaller crack propagation that does not suffer the usual cracking and subsequent loss of strength at high levels of tensile . Researchers have been able to take mixtures beyond 3 percent strain, past the more typical 0.1% point at which failure occurs.

Other institutions have identified magnesium silicate (talc) as an alternative ingredient to replace Portland cement in the mix. This avoids the usual high-temperature production process that is very energy and greenhouse gas intensive and actually absorbs carbon dioxide while it cures.

14 - Gypsum concrete :

Gypsum concrete is a building material used as a floor underlayment used in wood-frame and concrete construction for fire ratings , sound reduction , radiant heating . and floor leveling. It is a mixture of gypsum, Portland cement, and sand .

Vicat Softening Point



Vicat needle for cement paste solidification time measurement

Vicat softening point or **Vicat hardness** is the determination of the softening point for materials that have no definite melting point, such as plastics. It is taken as the temperature at which the specimen is penetrated to a depth of 1 mm by a flat-ended needle with a 1 square mm circular or square cross-section. For the Vicat A test, a load of 10 N is used. For the Vicat B test, the load is 50 N.

Standards to determine Vicat softening point include ASTM D 1525 and ISO 306, which are largely equivalent . Property information for specific grades of resin are available in the Prospector Plastic Database. Property Search let's you search for plastics by more than 400 material properties. Vicat Softening Temperature - ISO 306

The temperature at which a 1mm2 flat-ended needle will penetrate 1mm into a material under a specified load and heating rate. The vicat softening temperature can be used to compare the heat-softening characteristics of different materials.

Four different methods may be used for testing :

Method	Load (N)	Heating rate (K/h)
A50	10	50
B50	50	50
A120	10	120
B120	50	120

ISO 10350 Note

ISO 10350 Vicat values are tested using the B50 method. Similar Standards

ASTM D1525

Property information for specific grades of resin are available in the UL IDES Prospector Plastic Database.

Volcanic Ash

	
Ash plume from Mt Cleveland, a strato volcano.	Ash cloud from the 2008 eruption of Chaitén volcano stretching across Patagonia from the Pacific to the Atlantic Ocean.

Contents

1 – Introduction :

Volcanic ash consists of fragments of pulverized rock, minerals and volcanic glass, created during volcanic eruptions, less than 2 mm (0.079 in) in diameter. The term volcanic ash is also often loosely used to refer to all explosive eruption products (correctly referred to as tephra), including particles larger than 2mm. Volcanic ash is formed during explosive volcanic eruptions when dissolved gases in magma expand and escape violently into the atmosphere. The force of the escaping gas shatters the magma and propels it into the atmosphere where it solidifies into fragments of volcanic rock and glass. Ash is also produced when magma comes into contact with water during phreatomagmatic eruptions, causing the water to explosively flash to steam leading to shattering of magma. Once in the air, ash is transported by wind up to thousands of kilometers away.

Due to the wide dispersal of ash it can impact society in a number of ways, including: human and animal health; disruption to aviation; disruption to critical infrastructure (e.g. electric power supply systems, telecommunications, water and wastewater networks, transportation); primary industries (e.g. agriculture); buildings and structures.

2 – Formation :

Volcanic ash is formed during explosive volcanic eruptions, phreatomagmatic eruptions and during transport in pyroclastic density currents.

Explosive eruptions occur when magma decompresses as it rises, allowing dissolved volatiles (dominantly water and carbon dioxide) to exsolve into gas bubbles. As more bubbles nucleate a foam is produced, which decreases the density of the magma, accelerating it up the conduit. Fragmentation occurs when bubbles occupy ~70-80 vol% of the erupting mixture. When fragmentation occurs, violently expanding bubbles tear the magma apart into fragments which are ejected into the atmosphere where they solidify into ash particles. Fragmentation is a very efficient process of ash formation and is capable of generating very fine ash even without the addition of water.

Volcanic ash is also produced during phreatomagmatic eruptions. During these eruptions fragmentation occurs when magma comes into contact with bodies of water (such as the sea, lakes and marshes) groundwater, snow or ice. As the magma, which is significantly hotter than the boiling point of water, comes into contact with water an insulating vapor film forms (Leidenfrost phenomenon). Eventually this vapor film will collapse leading to direct coupling of the cold water and hot magma. This increases the heat transfer which leads to the rapid expansion of water and fragmentation of the magma into small particles which are subsequently ejected from the volcanic vent. Fragmentation causes an increase in contact area between magma and water creating a feedback mechanism, leading to further fragmentation and production of fine ash particles.

Pyroclastic density currents can also produce ash particles. These are typically produced by lava dome collapse or collapse of the eruption column. Within pyroclastic density currents particle abrasion occurs as particles interact with each other resulting in a reduction in grain size and production of fine grained ash particles. In addition, ash can be produced during secondary fragmentation of pumice fragments, due to the conservation of heat within the flow. These processes produce large quantities of very fine grained ash which is removed from pyroclastic density currents in co-ignimbrite ash plumes.

Physical and chemical characteristics of volcanic ash are primarily controlled by the style of volcanic eruption . Volcanoes display a range of eruption styles which are controlled by magma chemistry, crystal content, temperature and dissolved gases of the erupting magma and can be classified using the Volcanic Explosivity Index (VEI). Effusive eruptions (VEI 1) of basaltic composition produce $< 10^5$ m^3 of ejecta, whereas extremely explosive eruptions (VEI 5+) of rhyolitic and dacitic composition can inject large quantities ($> 10^9$ m^3) of ejecta into the atmosphere. Another parameter controlling the amount of ash produced is the duration of the eruption: the longer the eruption is sustained, the more ash will be produced. For example, the second phase of the 2010 eruptions of Eyjafjallajökull was classified as VEI 4 despite a modest 8 km high eruption column, but the eruption continued for a month, which allowed a large volume of ash to be ejected into the atmosphere.

3 – Properties :

3 – 1 - Chemical :

The types of minerals present in volcanic ash are dependent on the chemistry of the magma from which it was erupted. Considering that the most abundant elements found in magma are silica (SiO_2) and oxygen, the various types of magma (and therefore ash) produced during volcanic eruptions are most commonly explained in terms of their silica content. Low energy eruptions of basalt produce a characteristically dark coloured ash containing ~ 45 – 55 % silica that is generally rich in iron (Fe) and magnesium (Mg) . The most explosive rhyolite eruptions produce a felsic ash that is high in silica (> 69 %) while other types of ash with an intermediate composition (e.g. andesite or dacite) have a silica content between 55 - 69 %.

The principal gases released during volcanic activity are water, carbon dioxide, sulfur dioxide, hydrogen, hydrogen sulfide, carbon monoxide and hydrogen chloride . These sulfur and halogen gases and metals are removed from the atmosphere by processes of chemical reaction, dry and wet deposition, and by adsorption onto the surface of volcanic ash.

It has long been recognised that a range of sulfate and halide (primarily chloride and fluoride) compounds are readily mobilised from fresh volcanic ash . It is considered most likely that these salts are formed as a consequence of rapid acid dissolution of ash particles within eruption plumes, which is thought to supply the cations involved in the deposition of sulphate and halide salts.

While some 55 ionic species have been reported in fresh ash leachates[9] the most abundant species usually found are the cations Na^+, K^+, Ca^{2+} and Mg^{2+} and the anions Cl^-, F^- and SO_4^{2-} . Molar ratios between ions present in leachates suggest that in many cases these elements are present as simple salts such as NaCl and $CaSO_4$. In a sequential leaching experiment on ash from the 1980 eruption of Mount St. Helens, chloride salts were found to be the most readily soluble, followed by sulphate salts Fluoride compounds are in general only sparingly soluble (e.g. CaF_2, MgF_2), with the exception of fluoride salts of alkali metals and compounds such as calcium hexafluorosilicate ($CaSiF_6$) . The pH of fresh ash leachates is highly variable, depending on the presence of an acidic gas condensate (primarily as a consequence of the gases SO_2, HCl and HF in the eruption plume) on the ash surface.

The crystalline-solid structure of the salts act more as an insulator than a conductor. However, once the salts are dissolved into a solution by a source of moisture (e.g. fog, mist, light rain, etc.), the ash may become corrosive and electrically conductive. A recent study has shown that the electrical conductivity of volcanic ash increases with (1) increasing moisture content, (2) increasing soluble salt content, and (3) increasing compaction (bulk density) . The ability of volcanic ash to conduct electric current has significant implications for electric power supply systems.

3 – 2 - Physical :

3 – 2 - 1 – Components :

Volcanic ash particles erupted during magmatic eruptions are made up of various fractions of vitric (glassy, non-crystalline), crystalline or lithic (non-magmatic) particles. Ash produced during low viscosity magmatic eruptions (e.g. Hawaiian and Strombolian basaltic eruptions) produce a range of different pyroclasts dependent on the eruptive process. For example, ash collected from Hawaiian lava fountains consists of sideromelane (light brown basaltic glass) pyroclasts which contain rare microlites (small quench crystals) and phenocrysts. Slightly more viscous eruptions of basalt (e.g. Strombolian) form a variety of pyroclasts from irregular sideromelane droplets to blocky tachylite (black to dark brown microcrystalline pyroclasts). In contrast, most high-silica ash (e.g. rhyolite) comprises pulverised products of pumice (vitric shards), individual phenocrysts (crystal fraction) and some lithic fragments (xenoliths).[21]

Ash generated during phreatic eruptio[e]ns consists primarily of hydrothermally altered lithic and mineral fragments, commonly in a clay matrix. Particle surfaces are often coated with aggregates of zeolite crystals or clay and only relict textures remain to identify pyroclast types.

3 – 2 - 2 – Morphology :

The morphology (shape) of volcanic ash is controlled by a plethora of different eruption and kinematic processes . Eruptions of low-viscosity magmas (e.g. basalt) typically form droplet shaped particles. This droplet shape is, in part, controlled by surface tension, acceleration of the droplets after they leave the vent, and air friction. Shapes range from perfect spheres to a variety of twisted, elongate droplets with smooth, fluidal surfaces .

The morphology of ash from eruptions of high - viscosity magmas (e.g. rhyolite, dacite, and some andesites) is mostly dependent on the shape of vesicles in the rising magma before disintegration. Vesicles are formed by the expansion of magmatic gas before the magma has solidified. Ash particles can have varying degrees of vesicularity and vesicular particles can have extremely high surface area to volume ratios . Concavities, troughs, and tubes observed on grain surfaces are the result of broken vesicle walls. Vitric ash particles from high-viscosity magma eruptions are typically angular, vesicular pumiceous fragments or thin vesicle-wall fragments while lithic fragments in volcanic ash are typically equant, or angular to subrounded. Lithic morphology in ash is generally controlled by the mechanical properties of the wall rock broken up by spalling or explosive expansion of gases in the magma as it reaches the surface.

The morphology of ash particles from phreatomagmatic eruptions is controlled by stresses within the chilled magma which result in fragmentation of the glass to form small blocky or pyramidal glass ash particles.[21] Vesicle shape and density play only a minor role in the determination of grain shape in phreatomagmatic eruptions. In this sort of eruption, the rising magma is quickly cooled on contact with ground or surface water. Stresses within the "quenched" magma cause fragmentation into five dominant pyroclast shape-types: (1) blocky and equant; (2) vesicular and irregular with smooth surfaces; (3) moss-like and convoluted; (4) spherical or drop-like; and (5) plate-like.

3 – 2 - 3 – Density :

The density of individual particles varies with different eruptions. The density of volcanic ash varties between 700–1200 kg/m^3 for pumice, 2350–2450 kg/m^3 for glass shards, 2700–3300 kg/m^3 for crystals, and 2600–3200 kg/m^3 for lithic particles. Since coarser and denser particles are deposited close to source, fine glass and pumice shards are relatively enriched in ash fall deposits at distal locations. The high density and hardness (~5 on the Mohs Hardness Scale) together with a high degree of angularity, make some types of volcanic ash (particularly those with a high silica content) very abrasive.

3 – 2 - 4 - Grain Size :

Volcanic ash consists of particles (pyroclasts) with diameters < 2 mm (particles > 2 mm are classified as lapilli) , and can be as fine as 1 µm . The overall grain size distribution of ash can vary greatly with different magma compositions. Few attempts have been made to correlate the grain size characteristics of a deposit with those of the event which produced it, though some predictions can be made. Rhyolitic magmas generally produce finer grained material compared to basaltic magmas, due to the higher viscosity and therefore explosivity. The proportions of fine ash are higher for silicic explosive eruptions, probably because vesicle size in the pre-eruptive magma is smaller than those in mafic magmas . There is good evidence that pyroclastic flows produce high proportions of fine ash by communition and it is likely that this process also occurs inside volcanic conduits and would be most efficient when the magma fragmentation surface is well below the summit crater.

4 – Dispersal :

	
Ash plume rising from Eyjafjallajökull on April 17, 2010.	*Ash plume rising from Mount Redoubt after an eruption on April 21, 1990.*

Ash particles are incorporated into eruption columns as they are ejected from the vent at high velocity. The initial momentum from the eruption propels the column upwards. As air is drawn into the column, the bulk density decreases and it starts to rise buoyantly into the atmosphere . At a point where the bulk density of the column is the same as the surrounding atmosphere, the column will cease rising and start moving laterally. Lateral dispersion is controlled by prevailing winds and the ash may be deposited hundreds to thousands of kilometres from the volcano, depending on eruption column height, particle size of the ash and climatic conditions (especially wind direction and strength and humidity).

Ash fallout occurs immediately after the eruption and is controlled by particle density. Initially, coarse particles fall out close to source. This is followed by fallout of accretionary lapilli, which is the result of particle agglomeration within the column. Ash fallout is less concentrated during the final stages as the column moves downwind. This results in a ash fall deposit which generally decreases in thickness and grain size exponentially with increasing distance from the volcano. Fine ash particles may remain in the atmosphere for days to weeks and be dispersed by high-altitude winds. These particles can impact on the aviation industry (refer to impacts section) and, combined with gas particles, can affect global climate.

Volcanic ash plumes can form above pyroclastic density currents, these are called co-ignimbrite plumes. As pyroclastic density currents travel away from the volcano, smaller particles are removed from the flow by elutriation and form a less dense zone overlying the main flow. This zone then entrains the surrounding air and a buoyant co-ignimbrite plume is formed. These plumes tend to have higher concentrations of fine ash particles compared to magmatic eruption plumes due to the abrasion within the pyroclastic density current.[1]

5 – Impacts :

5 – 1 – Introduction :

Population growth has caused the progressive encroachment of urban development into higher risk areas, closer to volcanic centres, increasing the human exposure to volcanic ash fall events.

Infrastructure is critical to supporting modern societies, particularly in urban areas, where high population densities create high demand for services. These infrastructure networks and systems support urban living, and provide lifeline services upon which we depend for our health, education, transport and social networking.

Infrastructure networks and services support a variety of facilities across a broad range of sectors.

Volcanic ash fall events can disrupt and or damage the infrastructure upon which society depends. Several recent eruptions have illustrated the vulnerability of urban areas that received only a few millimetres or centimetres of volcanic ash . This has been sufficient to cause disruption of transportation, electricity, water, sewage and storm water systems. Costs have been incurred from business disruption, replacement of damaged parts and insured losses. Ash fall impacts on critical infrastructure can also cause multiple knock-on effects, which may disrupt many different sectors and services.

Volcanic ash fall is physically, socially and economically disruptive. Volcanic ash can affect both proximal areas and areas many hundreds of kilometres from the source, and causes disruptions and losses in a wide variety of different infrastructure sectors. Impacts are dependent on: ash fall thickness; the duration of the ash fall; the grain size and chemistry of the ash; whether the ash is wet or dry; and any preparedness, management and prevention (mitigation) measures employed to reduce effects from the ash fall. Different sectors of infrastructure and society are affected in different ways and are vulnerable to a range of impacts or consequences. These are discussed in the following sections.

5 – 2 – Infrastructure sectors :

5 – 2 - 1 – Electricity :

Volcanic ash can cause disruption to electric power supply systems at all levels of power generation, transformation, transmission and distribution.

There are four main impacts arising from ash - contamination of apparatus used in the power delivery process :

- Wet deposits of ash on high voltage insulators can initiate a leakage current (small amount of current flow across the insulator surface) which, if sufficient current is achieved, can cause ‘flashover’ (the unintended electrical discharge around or over the surface of an insulating material).

If the resulting short-circuit current is high enough to trip the circuit breaker then disruption of service will occur. Ash-induced flashover across transformer insulation (bushings) can burn, etch or crack the insulation irreparably and will likely result in the disruption of power supply.

- Volcanic ash can erode, pit and scour metallic apparatus, particularly moving parts such as water and wind turbines and cooling fans on transformers or thermal power plants.

- The high bulk density of some ash deposits can cause line breakage and damage to steel towers and wooden poles due to ash loading. This is most hazardous when the ash and/or the lines and structures are wet (e.g. by rainfall) and there has been ≥10 mm of ash fall. Fine-grained ash (e.g. <0.5 mm diameter) adheres to lines and structures most readily. Volcanic ash may also load overhanging vegetation, causing it to fall onto lines. Snow and ice accumulation on lines and overhanging vegetation further increases the risk of breakage and or collapse of lines and other hardware.

- Controlled outages of vulnerable connection points (e.g. substations) or circuits until ash fall has subsided or for de-energised cleaning of equipment.

5 – 2 - 2 – Drinking water supplies :

Following an eruption, it is very common for the public to hold fears about chemical contamination of water supplies. However, in general, the physical impacts of an ashfall will tend to overwhelm problems caused by the release of chemical contaminants from fresh volcanic ash. Impacts vary according to the type of treatment system.

5 – 2 – 2 - 1 – Large water treatment plants (WTPs) :

Ground water-fed systems are resilient to impacts from ashfall, although airborne ash can interfere with the operation of well-head pumps. Electricity outages caused by ashfall can also disrupt electrically powered pumps if there is no backup generation.

For surface water sources such as lakes and reservoirs, the volume available for dilution of ionic species leached from ash is generally large. The most abundant components of ash leachates (Ca, Na, Mg, K, Cl, F and SO_4) occur naturally at significant concentrations in most surface waters and therefore are not affected greatly by inputs from volcanic ashfall, and are also of low concern in drinking water, with the possible exception of F. The elements Fe, Mn and Al are commonly enriched over background levels by volcanic ashfall. These elements may impart a metallic taste to water, and may produce red, brown or black staining of whiteware, but are not considered a health risk. Volcanic ashfalls are not known to have caused problems in water supplies for toxic trace elements such as mercury (Hg) and lead (Pb) which occur at very low levels in ash leachates.

A further point to note is that drinking-water treatment commonly involves the addition of treatment chemicals such as aluminium sulphate or ferric chloride as coagulants, lime for pH adjustment, chlorine for disinfection and fluoride compounds for dental health.

The physical impacts of ashfall can affect the operation of WTPs. Ash can block intake structures, cause severe abrasion damage to pump impellers and overload pump motors. Many WTPs have an initial coagulation/flocculation step that is automatically adjusted to turbidity (the level of suspended solids, measured in Nephelometric Turbidity Units) in the incoming water. In most cases, changes in turbidity caused by suspended ash particles will be within the normal operating range of the plant and can be managed satisfactorily by adjusting the addition of coagulant. Ashfalls will be more likely to cause problems for plants that are not designed for high levels of turbidity and which may omit coagulation/flocculation treatment. Ash can enter filtration systems such as open sand filters both by direct fallout and via intake waters. In most cases, increased maintenance will be required to manage the effects of an ashfall, but there will not be service interruptions.

The final step of drinking water treatment is disinfection to ensure that final drinking water is free from infectious microorganisms. As suspended particles (turbidity) can provide a growth substrate for microorganisms and can protect them from disinfection treatment, it is extremely important that the water treatment process achieves a good level of removal of suspended particles.

5 – 2 – 2 - 2 – Small treatment systems :

Many small communities obtain their drinking water from diverse sources (lakes, streams, springs and groundwater wells). Levels of treatment vary widely, from rudimentary systems with coarse screening or settling followed by disinfection (usually chlorination), to more sophisticated systems using a filtration step. It should be noted that unless a high quality source is used, such as secure groundwater, disinfection alone is unlikely to guarantee that drinking water is safe from protozoa such as Giardia and Cryptosporidium, which are relatively resistant to standard disinfectants and which require additional removal steps such as filtration.

Volcanic ashfall is likely to have major effects on these systems. Ash will clog intake structures, cause abrasion damage to pumps and block pipes, settling ponds and open filters. High levels of turbidity are very likely to interfere with disinfection treatment and doses may have to be adjusted to compensate. It is essential to monitor chlorine residuals in the distribution system.

5 – 2 – 2 - 3 – Rain water - fed supplies :

Many households, and some small communities, rely on rainwater for their drinking water supplies. Roof-fed systems are highly vulnerable to contamination by ashfall, as they have a large surface area relative to the storage tank volume. In these cases, leaching of chemical contaminants from the ashfall can become a health risk and drinking of water is not recommended. Prior to an ashfall, downpipes should be disconnected so that water in the tank is protected. A further problem is that the surface coating of fresh volcanic ash can be acidic. Unlike most surface waters, rainwater generally has a very low alkalinity (acid-neutralising capacity) and thus ashfall may acidify tank waters. This may lead to problems with plumbosolvency, whereby the water is more aggressive towards materials that it comes into contact with. This can be a particular problem if there are lead-head nails or lead flashing used on the roof, and for copper pipes and other metallic plumbing fittings.

5 – 2 – 2 - 4 – Water demand :

During ash fall events large demands are commonly placed on water resources for cleanup and shortages can result. Shortages compromise key services such as firefighting and can lead to a lack of water for hygiene, sanitation and drinking. Municipal authorities need to monitor and manage this water demand carefully, and may need to advise the public to utilise cleanup methods that do not use water (e.g. cleaning with brooms rather than hoses).

5 – 2 – 3 - Waste water treatment :

Wastewater networks may sustain damage similar to water supply networks. It is very difficult to exclude ash from the sewerage system. Systems with combined storm water/sewer lines are most at risk. Ash will enter sewer lines where there is inflow/infiltration by stormwater through illegal connections (e.g. from roof downpipes), cross connections, around manhole covers or through holes and cracks in sewer pipes.

Ash-laden sewage entering a treatment plant is likely to cause failure of mechanical prescreening equipment such as step screens or rotating screens. Ash that penetrates further into the system will settle and reduce the capacity of biological reactors as well as increasing the volume of sludge and changing its composition.

5 – 2 – 4 - Aircraft :

The principal damage sustained by aircraft flying into a volcanic ash cloud is abrasion to forward-facing surfaces, such as the windshield and leading edges of the wings, and accumulation of ash into surface openings, including engines. Abrasion of windshields and landing lights will reduce visibility forcing pilots to rely on their instruments. However, some instruments may provide incorrect readings as sensors (e.g. pitot tubes) can become blocked with ash. Ingestion of ash into engines causes abrasion damage to compressor fan blades.

The composition of most ash is such that its melting temperature is within the operating temperature (>1000°C) of modern large jet engines. The degree of impact depends upon the concentration of ash in the plume, the length of time the aircraft spends within the plume and the actions taken by the pilots. Critically, melting of ash, particularly volcanic glass, can result in accumulation of resolidified ash on turbine nozzle guide vanes, resulting in compressor stall and complete loss of engine thrust . The standard procedure of the engine control system when it detects a possible stall is to increase power which would exacerbate the problem. It is recommended that pilots reduce engine power and quickly exit the cloud by performing a descending 180° turn. Volcanic gases, which are present within ash clouds, can also cause damage to engines and acrylic windshields, although this damage may not surface for many years.

5 – 2 – 4 – 1 - Occurrence :

There are many instances of damage to jet aircraft as a result of an ash encounter. On 24 June 1982 a British Airways Boeing 747-236B (Flight 9) flew through the ash cloud from the eruption of Mount Galunggung, Indonesia resulting in the failure of all four engines. The plane descended 24,000 feet (7,300 m) in 16 minutes before the engines restarted, allowing the aircraft to make an emergency landing. On 15 December 1989 a KLM Boeing 747- 400 (Flight 867) also lost power to all four engines after flying into an ash cloud from Mount Redoubt, Alaska. After dropping 14,700 feet

(4,500 m) in four minutes, the engines were started just 1-2 minutes before impact. Total damage was US$80 million and it took 3 months work to repair the plane. In the 1990s a further US$100 million of damage was sustained by commercial aircraft (some in the air, others on the ground) as a consequence of the 1991 eruption of Mount Pinatubo in the Philippines.

In April 2010, airspace all over Europe was affected, with many flights cancelled - which was unprecedented-due to the presence of volcanic ash in the upper atmosphere from the eruption of the Icelandic volcano Eyjafjallajökull . On 15 April 2010 the Finnish Air Force halted training flights when damage was found from volcanic dust ingestion by the engines of one of its Boeing F-18 Hornet fighters.[40] On 22 April 2010 UK RAF Typhoon training flights were also temporarily suspended after deposits of volcanic ash were found in a jet's engines.[41] In June 2011 there were similar closures of airspace in Chile, Argentina, Brazil, Australia and New Zealand, following the eruption of Puyehue - Cordón Caulle, Chile.

5 – 2 – 4 – 2 - Detection

Coverage of the nine VAAC around the world

Volcanic ash clouds are very difficult to detect from aircraft as no onboard cockpit instruments exist to detect them. However, a new system called Airborne Volcanic Object Infrared Detector (AVOID) has recently been developed by Nicarnica Aviation, a daughter company of the Norwegian Institute for Air Research, which will allow pilots to detect ash plumes up to 100 km ahead and fly safely around them . The system uses two fast-sampling infrared cameras, mounted on a forward facing surface, that are tuned to detect volcanic ash. This system can detect ash concentrations of <1 mg/m^3 to > 50 mg/m^3, giving pilots approximately 7-10 minutes warning . The camera is currently being tested by easyJet airline company .

In addition, ground and satellite based imagery, radar and LIDAR can be used to detect ash clouds. This information is passed between meteorological agencies, volcanic observatories and airline companies through Volcanic Ash Advisory Centers (VAAC). There is one VAAC for each of the nine regions of the world. VAACs can issue advisories describing the current and future extent of the ash cloud.

5 – 2 – 4 – 3 - Airport systems :

Volcanic ash not only affects in-flight operations but can affect ground-based airport operations as well. Small accumulations of ash can reduce visibility, create slippery runways and taxiways, infiltrate communication and electrical systems, interrupt ground services, damage buildings and parked aircraft . Ash accumulation of more than a few millimeters requires removal before airports can resume full operations. Ash does not disappear (unlike snowfalls) and must be disposed of in a manner that prevents it from being remobilised by wind and aircraft.

5 – 2 – 5 – Land Transport :

Ash may disrupt transportation systems over large areas for hours to days, including roads and vehicles, rail ways and ports and shipping. Falling ash will reduce the visibility which can make driving difficult and dangerous . In addition, fast travelling cars will stir up ash, creating billowing clouds which perpetuate ongoing visibility hazards. Ash accumulations will decrease traction, especially when wet, and cover road markings . Fine - grained ash can infiltrate openings in cars and abrade most surfaces, especially between moving parts. Air and oil filters will become blocked requiring frequent replacement. Rail transport is less vulnerable, with disruptions mainly caused by reduction in visibility .

Marine transport can also be impacted by volcanic ash. Ash fall will block air and oil filters and abrade any moving parts if ingested into engines. Navigation will be impacted by a reduction in visibility during ash fall. Vesiculated ash (pumice and scoria) will float on the water surface in ‘pumice rafts’ which can clog water intakes quickly, leading to over heating of machinery.

5 – 2 – 6 – Communications :

Telecommunication and broadcast networks can be affected by volcanic ash in the following ways: attenuation and reduction of signal strength; damage to equipment; and overloading of network through user demand. Signal attenuation due to volcanic ash is not well documented; however, there have been reports of disrupted communications following the 1969 Surtsey eruption and 1991 Mount Pinatubo eruption. Research by the New Zealand-based Auckland Engineering Lifelines Group determined theoretically that impacts on telecommunications signals from ash would be limited to low frequency services such as satellite communication . Signal interference may also be caused by lightening, as this is frequently generated within volcanic eruption plumes .

Telecommunication equipment may become damaged due to direct ash fall. Most modern equipment requires constant cooling from air conditioning units. These are susceptible to blockage by ash which reduces their cooling efficiency . Heavy ash falls may cause telecommunication lines, masts, cables, aerials, antennae dishes and towers to collapse due to ash loading. Moist ash may also cause accelerated corrosion of metal components .

Reports from recent eruptions suggest that the largest disruption to communication networks is overloading due to high user demand . This is common of many natural disasters.

5 – 2 – 7 – Computers :

Computers may be impacted by volcanic ash, with their functionality and usability decreasing during ashfall, but it is unlikely they will completely fail . The most vulnerable components are the mechanical components, such as cooling fans, cd drives, keyboard, mice and touch pads. These components can become jammed with fine grained ash causing them to cease working; however, most can be restored to working order by cleaning with compressed air. Moist ash may cause electrical short circuits within desktop computers; however, will not affect laptop computers .

5 – 2 – 8 – Buildings and Structures :

Damage to buildings and structures can range from complete or partial roof collapse to less catastrophic damage of exterior and internal materials. Impacts depend on the thickness of ash, whether it is wet or dry, the roof and building design and how much ash gets inside a building. The specific weight of ash can vary significantly and rain can increase this by 50 - 100 %. Problems associated with ash loading are similar to that of snow; however, ash is more severe as 1) the load from ash is generally much greater, 2) ash does not melt and 3) ash can clog and damage gutters, especially after rain fall. Impacts for ash loading depend on building design and construction, including roof slope, construction materials, roof span and support system, and age and maintenance of the building.[48] Generally flat roofs are more susceptible to damage and collapse than steeply pitched roofs. Roofs made of smooth materials (sheet metal or glass) are more likely to shed ash than roofs made with rough materials (thatch, asphalt or wood shingles). Roof collapse can lead to widespread injuries and deaths and property damage. For example, the collapse of roofs from ash during the 15 June 1991 Mount Pinatubo eruption killed about 300 people .

5 – 3 – Human and Animal Health :

Ash particles of less than 10 µm diameter suspended in the air are known to be inhalable, and people exposed to ash falls have experienced respiratory discomfort, breathing difficulty, eye and skin irritation, and nose and throat symptoms . Most of these effects are short-term and are not considered to pose a significant health risk to those without pre-existing respiratory conditions . The health effects of volcanic ash depend on the grain size, mineralogical composition and chemical coatings on the surface of the ash particles . Additional factors related to potential respiratory symptoms are the frequency and duration of exposure, the concentration of ash in the air and the respirable ash fraction; the proportion of ash with less than 10 µm diameter, known as PM_{10}. The social context may also be important.

Chronic health effects from volcanic ash fall are possible, as exposure to free crystalline silica is known to cause silicosis. Minerals associated with this include quartz, cristobalite and tridymite, which may all be present in volcanic ash. These minerals are described as 'free' silica as the SiO_2 is not attached to another element to create a new mineral. However, magmas containing less than 58 % SiO_2 are thought to be unlikely to contain crystalline silica .

The exposure levels to free crystalline silica in the ash are commonly used to characterise the risk of silicosis in occupational studies (for people who work in mining, construction and other industries,) because it is classified as a human carcinogen by the International Agency for Research on Cancer. Guideline values have been created for exposure, but with unclear rationale; UK guidelines for particulates in air (PM10) are 50 µg/m^3 and USA guidelines for exposure to crystalline silica are 50 µg / m^3. It is thought that the guidelines on exposure levels could be exceeded for short periods of time without significant health effects on the general population .

There have been no documented cases of silicosis developed from exposure to volcanic ash. However, long-term studies necessary to evaluate these effects are lacking .

Ingesting ash may be harmful to livestock; causing abrasion of the teeth and in cases of high fluorine content, fluorine poisoning (toxic at levels of >100 µg/g for grazing animals . It is known from the 1783 eruption of Laki in Iceland that fluorine poisoning occurred in humans and livestock as a result of the chemistry of the ash and gas, which contained high levels of Hydrogen Fluoride. Following the 1995/96 Mount Ruapehu eruptions in New Zealand, two thousand ewes and lambs died after being affected by fluorosis while grazing on land with only 1-3 mm of ash fall . Ash ingestion may also cause gastrointestinal blockages . Sheep that ingested ash from the 1991 Mount Hudson volcanic eruption in Chile, suffered from diarrhoea and weakness. The added weight of ash in the wool led to fatigue and sheep could not stand up. The ash from Mount Hudson also caused irrigation channels to become blocked . Surface water ponds are also susceptible to contamination by ash .

5 – 4 – Environment and Agriculture :

Volcanic ash can have a detrimental impact on the environment which can be difficult to predict due to the large variety of environmental conditions that exist within the ash fall zone. Natural waterways can be impacted in the same way as urban water supply networks. Ash will increase water turbidity which can reduce the amount of light reaching lower depths, which can inhibit growth of submerged aquatic plants and consequently affect species which are dependent on them such as fish and shellfish. High turbidity can also affect the ability of fish gills to absorb dissolved oxygen. Acidification will also occur, which will reduce the pH of the water and impact the fauna and flora living in the environment. Fluoride contamination will occur if the ash contains high concentrations of fluoride.

Ash accumulation will also affect pasture, plants and trees which are part of the horticulture and agriculture industries. Thin ash falls (<20 mm) may put livestock off eating, and can inhibit transpiration and photosynthesis and alter growth. There may be an increase in pasture production due to a mulching effect and slight fertilizing effect, such as occurred following the 1980 Mount St. Helens and 1995 / 96 Mt Ruapehu eruptions . Heavier falls will completely bury pastures and soil leading to death of pasture and sterilization of the soil due to oxygen deprivation. Plant survival is dependant on ash thickness, ash chemistry, compaction of ash, amount of rainfall, duration of burial and the length of plant stalks at the time of ash fall . The acidic nature of ash will lead to elevated soil sulfur levels and lowered soil pH, which can reduce the availability of essential minerals and alter the soil's characteristics so that crops and plants will not survive. Ash will also impact upon arable crops, such as fruit, vegetables and grain. Ash can burn plant and crop tissue reducing quality, contaminate crops during harvest and damage plants from ash loading.

Young forests (trees < 2 years old) are most at risk from ash falls and are likely to be destroyed by ash deposits >100 mm. Ash fall is unlikely to kill mature trees, but ash loading may break large branches during heavy ash falls (> 500 mm) . Defoliation of trees may also occur, especially is there is a coarse ash component within the ash fall .

Land rehabilitation after ash fall may be possible depending on the ash deposit thickness. Rehabilitation treatment may include: direct seeding of deposit; mixing of deposit with buried soil; scraping of ash deposit from land surface; and application of new topsoil over the ash deposit.

5 – 5 – Inter dependence

Inter dependency of volcanic ash fall impacts from the Eyjafjallajökull 2010 eruptions.

Critical infrastructure and infrastructure services are vital to the functionality of modern society, to provide: medical care, policing, emergency services, and lifelines such as water, wastewater, and power and transportation links. Often critical facilities themselves are dependent on such lifelines for operability, which makes them vulnerable to both direct impacts from a hazard event and indirect effects from lifeline disruption.

The impacts on lifelines may also be inter - dependent. The vulnerability of each lifeline may depend on: the type of hazard, the spatial density of its critical linkages, the dependency on critical linkages, susceptibility to damage and speed of service restoration, state of repair or age, and institutional characteristics or ownership .

The 2010 eruption of Eyjafjallajokull in Iceland, highlighted the impacts of volcanic ash fall in modern society, and our dependence on the functionality of infrastructure services. During this event the airline industry suffered business interruption losses of €1.5-2.5 billion from the closure of European airspace for six days in April 2010, and subsequent closures into May 2010 . Ash fall from this event is also known to have caused local crop losses in agricultural industries, losses in the tourism industry, destruction of roads and bridges in Iceland (in combination with glacial melt water), and costs associated with emergency response and clean-up. However, across Europe there were further losses associated with travel disruption, the insurance industry, the postal service, and imports and exports across Europe and worldwide. These consequences demonstrate the inter dependency and diversity of impacts from a single event .

6 – Preparedness , mitigation and management :

Preparedness for ashfalls should involve sealing buildings, protecting infrastructure and homes, and storing sufficient supplies of food and water to last until the ash fall is over and clean - up can begin. Dust masks can be worn to reduce inhalation of ash and mitigate against any respiratory health affects . Goggles can be worn to protect against eye irritation.

At home, staying informed about volcanic activity, and having contingency plans in place for alternative shelter locations, constitutes good preparedness for an ash fall event. This can prevent some impacts associated with ash fall, reduce the effects, and increase the human capacity to cope with such events. A few items such as a flashlight, plastic sheeting to protect electronic equipment from ash ingress, and battery operated radios, are extremely useful during ash fall events.

The protection of infrastructure must also be considered within emergency preparedness. Critical facilities that need to remain operable should be identified, and all others should be shut down to reduce damage. It is also important to keep ash out of buildings, machinery and lifeline networks (in particular water and wastewater systems,) to prevent some of the damage caused by ash particles. Windows and doors should be closed and shuttered if possible, to prevent ingress of ash into buildings.

Communication plans should be made beforehand to inform of mitigation actions being undertaken. Spare parts and back-up systems should be in place prior to ash fall events to reduce service disruption and return functionality as quickly as possible. Good preparedness also includes the identification of ash disposal sites, before ash fall occurs, to avoid further movement of ash and to aid clean-up.[60] Protective equipment such as eye protection and dust masks should be deployed for clean-up teams in advance of ash fall events.

Some effective techniques for the management of ash have been developed including cleaning methods and cleaning apparatus, and actions to mitigate or limit damage. The latter include covering of openings such as: air and water intakes, aircraft engines and windows during ash fall events. Roads may be closed to allow clean-up of ash falls, or speed restrictions may be put in place, in order to prevent motorists from developing motor problems and becoming stranded following an ash fall. To prevent further effects on underground water systems or waste water networks, drains and culverts should be unblocked and ash prevented from entering the system.[60] Ash can be moistened (but not saturated) by sprinkling with water, to prevent remobilisation of ash and to aid clean-up. Prioritisation of clean-up operations for critical facilities and coordination of clean-up efforts also constitute good management practice.

Water – Cement Ratio

The **water – cement ratio** is the ratio of the weight of water to the weight of cement used in a concrete mix and has an important influence on the quality of concrete produced. A lower water-cement ratio leads to higher strength and durability, but may make the mix more difficult to place. Placement difficulties can be resolved by using plasticizers or super-plasticizers.

Often, the water–cement ratio is characterized as the water to cement plus pozzolan ratio, w/(c+p). The pozzolan is typically a fly ash, or blast furnace slag. It can include a number of other materials, such as silica fume, rice hull ash or natural pozzolans. The addition of pozzolans will influence the strength gain of the concrete.

The concept of water–cement ratio was developed by Duff A. Abrams and first published in 1918, see concrete slump test.

Concrete hardens as a result of the chemical reaction between cement and water (known as hydration, this produces heat and is called the heat of hydration). For every pound (or kilogram or any unit of weight) of cement, about 0.25 pounds (or 0.25 kg or corresponding unit) of water is needed to fully complete the hydration reactions. This requires a water-cement ratio of 1:4 often given as a proportion: 0.25. However, a mix with a w/c ratio of 0.25 may not mix thoroughly, and may not flow well enough to be placed, so more water is used than is technically necessary to react with the cement. More typical water-cement ratios of 0.4 to 0.6 are used. For higher-strength concrete, lower water:cement ratios are used, along with a plasticizer to increase flowability.

Too much water will result in segregation of the sand and aggregate components from the cement paste. Also, water that is not consumed by the hydration reaction may leave the concrete as it hardens, resulting in microscopic pores that will reduce the final strength of the concrete. A mix with too much water will experience more shrinkage as the excess water leaves, resulting in internal cracks and visible fractures (particularly around inside corners) which again will reduce the final strength.

The 1997 Uniform Building Code specifies a maximum 0.50 water-to-cement ratio (1:2) when concrete is exposed to freezing and thawing in a moist condition or to de-icing chemicals, and a maximum 0.45 water to cement ratio for concrete in severe or very severe sulfate conditions.

Water Reducer

Water reducers are special chemical products added to a concrete mixture before it is poured. They are from the same family of products as retarders. The first class of water reducers was the lignosulfonates which has been used since the 1930s. These inexpensive products were derived from wood and paper industry, but are now advantageously replaced by other synthetic sulfonate and polycarboxylate, also known as super plasticizers.

Water reducers offer several advantages in their use, listed below :

- reduces the water content by 5 - 10 %
- decreases the concrete porosity
- increases the concrete strength by up to 25% (as less water is required for the concrete mixture to remain workable)
- increases the workability (assuming the amount of free water remains constant)
- reduces the water permeability (due to less water being used)
- reduces the diffusivity of aggressive agents in the concrete and so improves the durability of concrete
- gives a better finish to surfaces (due to all of the above)

White Portland Cement

Contents

1 – Introduction :

White Taavo Portland cement or **white ordinary Portland cement** (WOPC) is similar to ordinary, gray Portland cement in all respects except for its high degree of whiteness. Obtaining this color requires substantial modification to the method of manufacture, and because of this, it is somewhat more expensive than the gray product.

2 – Uses :

White Portland cement is used in combination with white aggregates to produce white concrete for prestige construction projects and decorative work. White concrete usually takes the form of pre-cast cladding panels, since it is not economical to use white cement for structural purposes. White Portland cement is also used in combination with inorganic pigments to produce brightly colored concretes and mortars. Ordinary cement, when used with pigments, produces colors that may be attractive, but are somewhat dull. With white cement, bright reds, yellows and greens can be readily produced. Blue concrete can also be made, at some expense. The pigments may be added at the concrete mixer. Alternatively, to guarantee repeatable color, some manufacturers supply ready-blended colored cements, using white cement as a base. The *whiteness* of WOPC is measured as the powdered material having a reflectance value ("L value") in excess of 85 %. A particular success in the use of WOPC and added pigments is monocouche renders.

3 – Manufacture :

3 – 1 – Raw mix formulation :

The characteristic greenish-gray to brown color of ordinary Portland cement derives from a number of transitional elements in its chemical composition. These are, in descending order of coloring effect, chromium, manganese, iron, copper, vanadium, nickel and titanium. The amount of these in white cement is minimized as far as possible. Cr_2O_3 is kept below 0.003%, Mn_2O_3 is kept below 0.03%, and Fe_2O_3 is kept below 0.35% in the clinker. The other elements are usually not a significant problem. Portland cement is usually made from cheap, quarried raw materials, and these usually contain substantial amounts of Cr, Mn and Fe. For example, limestones used in cement manufacture usually contain 0.3-1% Fe_2O_3, whereas levels below 0.1% are sought in limestones for white manufacture. Typical clays used in gray cement rawmix may contain 5-15% Fe_2O_3. Levels below 0.5% are desirable, and conventional clays are usually replaced with kaolin. Kaolin is fairly low in SiO_2, and so a large amount of sand is usually also included in the mix. Iron and manganese usually occur together in nature, so that selection of low-iron materials usually ensures that manganese content is also low, but chromium can arise from other sources, notably from the wear of chrome steel grinding equipment during the production of rawmix. See rawmill. This wear is exacerbated by the high sand-content of the mix, which makes it extremely abrasive. Furthermore, to make a combinable rawmix, the sand must be ground to below 45 µm particle diameter. Often this is achieved by grinding the sand separately, using ceramic grinding media to reduce contamination.

3 – 2 – Kiln operation :

In general, the rotary kilns used to chemically combine the raw materials are operated at a higher peak temperature (1450-1500°C) than that required for gray clinker manufacture (1400-1450°C). This requires a higher fuel consumption (typically 20 - 50 % more), and results in lower kiln output (typically 20 - 50 % less) for a given sized kiln. The reason for this is the relatively small amount of liquid produced during sintering, because of the low iron-content of the mix. The final reaction in the kiln, conversion of belite to alite, requires the melt liquid as a solvent, and is slower if the amount of melt is low. This can be partially compensated by adding to the rawmix a combination of calcium sulfate and fluoride in the form of calcium fluoride or waste cryolite. This combination reduces the reaction temperature. In cases where the clinker Fe_2O_3 content is above 0.2% (which is almost always the case), the unique processes of "bleaching" and "quenching" are also employed. "Bleaching" involves directing a second flame (apart from that used to heat the kiln) onto the bed of clinker close to the kiln exit to reduce Fe (III) to Fe (II). This reduction is rigorously avoided in gray cement production, because of the deleterious effect it can have on clinker quality. But in white clinker production, where the iron content is low, this is not an issue. Subsequently, to prevent the re-oxidation of the iron, "quenching" is performed. This consists of rapidly lowering the clinker temperature from 1200°C to below 600°C in a few seconds, as it leaves the kiln. This usually involves dropping it into cold water. This contributes to the relatively poor energy efficiency of the process, since the sensible heat of the clinker is not recycled as in normal clinker manufacturer

3 – 3 – Clinker grinding and handling :

The clinker is next ground to cement (perhaps after a drying stage). Here calcium sulfate is added to control set, in the form of a high-purity grade of gypsum or anhydrite. In some specifications (not ASTM), a small amount of titanium dioxide may be added to improve reflectance. At all stages, great care is needed to avoid contamination with colored materials.

4 - Specifications :

White Portland cement differs physically from gray cement only in terms of its color. Its setting behavior and strength development are essentially the same as that expected in gray cement, and it meets standard specifications such as ASTM C 150 and EN 197. In practice, because much white cement is used in pre-cast concrete products, it is commonly made to a high-early strength specification such as ASTM C 150 Type III. This aids concrete manufacturers' production rate. Higher potential strength also helps to counteract the strength-diminishing effects of pigment addition. In addition to the usual specifications, manufacturers guarantee the whiteness of the product, typically in terms of a reflectance measurement, such as L*a*b L-value, or tristimulus. In the latter case, because off-color white cement tends to be greenish, the Tri-Y (green) value is used. Because the color so much depends upon the "bleaching" and "quenching" operations, merely specifying a low iron content does not guarantee good whiteness.

White Wash

3 different brands of Kalsomine; the directions for use are visible when viewing image at full size

Contents

1 – Introduction :

White wash, or **calcimine**, **kalsomine**, **calsomine**, or **lime paint** is a low - cost type of paint made from slaked lime (calcium hydroxide) and chalk (whiting). Various other additives are also used.

2 - White wash :

White wash cures through a reaction with carbon dioxide in the atmosphere to form calcium carbonate in the form of calcite, a reaction known as carbonatation.

When the paint initially dries it is uncured and has almost no strength. It takes up to a few days, depending on climate, to harden.

It is usually applied to exteriors; however, it is traditionally used internally in food preparation areas, particularly rural dairies, for its mildly antibacterial properties. Occasionally it is coloured and used on structures such as the hallways of apartment buildings, but it is not popular for this as it can rub off onto clothing to a small degree. In Britain and Ireland whitewash was used historically, both externally and internally, in workers' cottages, and still retains something of this association with rural poverty. In the United States, a similar attitude is expressed in the old saying: "Too proud to whitewash and too poor to paint", with the connotation that whitewash is a cheap imitation of "real" paint.

Whitewash is especially effective on adobe-like materials because it is absorbed easily and the resultant chemical reaction hardens the medium. Also, whitewash and adobe are both very low cost building materials.

2 – 1 - Farming applications :

White-painted trees in Turkey

Whitewash is applied to trees, especially fruit trees, to prevent sun scald . Some also claim that it helps prevent insect damage. Most often only the lower trunk is painted. In Poland painting the whole trunk is also said to help keep the body of the tree cool in late winter/ early spring months and hence help prevent fruit trees from blooming too soon i.e. when warm sunny days could promote rapid tree warming, rising sap and bloom and intermittent frosty nights could damage outer tree rings and destroy the young buds and blossoms.

In the middle of the 20th century, when family farms with dairy barns were common in the Upper Midwest of the USA, whitewash was a necessary part of routine barn maintenance. A traditional animal barn contains a variety of extremely rough surfaces that are difficult to wash and keep clean, such as stone and brick masonry, and also rough-cut lumber for the ceiling. Left alone these surfaces collect dust, dirt, insect debris and wastes, and can become very dirty. Whitewash aids in sanitation by coating and smoothing over the rough surfaces. Successive applications of whitewash build up layers of scale which flake off and in the process remove surface debris with it. The coating also has antimicrobial properties that provide hygienic and sanitary benefits for animal barns.

Typically the farm whitewash application is an annual process and has the following steps :

- Surfaces that are to be protected from whitewashing are enclosed in plastic sheeting or bags, such as windows, light fixtures, and the milk pipeline in a dairy barn.
- The interior is stripped of all removable equipment leaving walls, floors, and ceiling as bare as possible.
- A high volume compressed air wand is used to blast away loose whitewash scale from the walls and ceiling. This loose debris is swept into the barn gutter and goes into the manure handling system where it eventually contributes to soil fertility.
- A mobile whitewashing trailer is used to mix the quicklime into a thick liquid, which is then sprayed as a even coating over the interior walls, ceiling, and posts, into all accessible nooks and crevasses.
- The coating is allowed a few hours to dry and stop dripping from the ceiling, and the protective plastic coverings are removed. Eventually after the walls and ceilings have dried sufficiently, equipment is brought back into the barn.

Nonremovable electric equipment is often enclosed in protective outer shells that prevent whitewash intrusion. For example circuit breaker panels may be enclosed within wooden cabinetry which keeps the whitewash spray coating from entering the panel.

3 - Lime wash :

Lime wash is pure slaked lime in water. It produces a unique surface glow due to the refraction of calcite crystals. Limewash and whitewash both cure to become the same material.

When limewash is initially applied it has very low opacity, which can lead novices to overthicken the paint. Drying increases opacity, and subsequent curing increases opacity even further.

4 – Additives :

Additives that have been used include water glass, glue, egg white, Portland cement, salt, soap, milk, flour, soil.

White wash is some times colored with earths to achieve colours spanning the range of broken white, cream, yellow and a range of browns.

Pozzolanic materials are occasionally added to give a much harder wearing paint finish. This addition, however, creates a short open time, and therefore requires timely application of the altered paint.

Linseed oil is sometimes added (typically 0.5 - 2 %) to improve adhesion on difficult surfaces.

Cement addition makes a harder wearing paint in white or grey. Open time is short, so this is added at point of use. However, the use of cement restricts the breathable aspects of the limewash; Cement should not be applied to historic buildings in general.

Dilute glues improve paint toughness.

Wheat flour has been used as a strength enhancing binder. Salt is usually added to prevent the flour going mouldy later in damp conditions. The use of salt brings its own issues, such as deterioration of brick and stone.

4 – Cost :

Simple lime paints are very low cost. A 25 kg bag of lime makes around 100 kg of paint, and costs around £ 6 in the UK (2008).

Zeolite


Zeolite

Contents

1 – Introduction :

Zeolites are microporous, aluminosilicate minerals commonly used as commercial adsorbents. The term zeolite was originally coined in 1756 by Swedish mineralogist Axel Fredrik Cronstedt, who observed that upon rapidly heating the material stilbite, it produced large amounts of steam from water that had been adsorbed by the material. Based on this, he called the material *zeolite*, from the Greek meaning "to boil stone".

As of October 2011, 201 unique zeolite frameworks have been identified, and over 40 naturally occurring zeolite frame works are known.

Zeolites are widely used in industry for water purification, as catalysts, for the preparation of advanced materials and in nuclear reprocessing. They are used to extract nitrogen from air to increase oxygen content for both industrial and medical purposes. Their biggest use is in the production of laundry detergents. They are also used in medicine and in agriculture.

2 - Properties

Zeolites have a porous structure that can accommodate a wide variety of cations, such as Na^+, K^+, Ca^{2+}, Mg^{2+} and others. These positive ions are rather loosely held and can readily be exchanged for others in a contact solution. Some of the more common mineral zeolites are analcime, chabazite, clinoptilolite, heulandite, natrolite, phillipsite, and stilbite. An example mineral formula is: $Na_2Al_2Si_3O_{10}·2H_2O$, the formula for natrolite.

Natural zeolites form where volcanic rocks and ash layers react with alkaline groundwater. Zeolites also crystallize in post-depositional environments over periods ranging from thousands to millions of years in shallow marine basins. Naturally occurring zeolites are rarely pure and are contaminated to varying degrees by other minerals, metals, quartz, or other zeolites. For this reason, naturally occurring zeolites are excluded from many important commercial applications where uniformity and purity are essential.

Zeolites are the aluminosilicate members of the family of microporous solids known as "molecular sieves." The term molecular sieve refers to a particular property of these materials, i.e., the ability to selectively sort molecules based primarily on a size exclusion process. This is due to a very regular pore structure of molecular dimensions. The maximum size of the molecular or ionic species that can enter the pores of a zeolite is controlled by the dimensions of the channels. These are conventionally defined by the ring size of the aperture, where, for example, the term "8 - ring" refers to a closed loop that is built from 8 tetrahedrally coordinated silicon (or aluminum) atoms and 8 oxygen atoms. These rings are not always perfectly symmetrical due to a variety of effects, including strain induced by the bonding between units that are needed to produce the overall structure, or coordination of some of the oxygen atoms of the rings to cations within the structure. Therefore, the pores in many zeolites are not cylindrical.

3 – Sources :

Conventional open pit mining techniques are used to mine natural zeolites. The overburden is removed to allow access to the ore. The ore may be blasted or stripped for processing by using tractors equipped with ripper blades and front-end loaders. In processing, the ore is crushed, dried, and milled. The milled ore may be air-classified as to particle size and shipped in bags or bulk. The crushed product may be screened to remove fine material when a granular product is required, and some pelletized products are produced from fine material.

Currently, the world's annual production of natural zeolite is about 3 million tones. The major producers in 2010 were China (2 million tones), South Korea (210,000 t), Japan (150,000 t), Jordan (140,000 t), Turkey (100,000 t) Slovakia (85,000 t) and United States (59,000 t). The ready availability of zeolite-rich rock at low cost and the shortage of competing minerals and rocks are probably the most important factors for its large-scale use. According to the United States Geological Survey, it is likely that a significant percentage of the material sold as zeolites in some countries is ground or sawn volcanic tuff that contains only a small amount of zeolites. Some examples of such usage are dimension stone (as an altered volcanic tuff) , light weight aggregate , pozzolanic cement, and soil conditioners .

There are several types of synthetic zeolites that form by a process of slow crystallization of a silica-alumina gel in the presence of alkalis and organic templates. One of the important processes used to carry out zeolite synthesis is sol-gel processing. The product properties depend on reaction mixture composition, pH of the system, operating temperature, pre-reaction 'seeding' time, reaction time as well as the templates used. In sol-gel process, other elements (metals, metal oxides) can be easily incorporated. The silicalite sol formed by the hydrothermal method is very stable. Also the ease of scaling up this process makes it a favorite route for zeolite synthesis.

Synthetic zeolites hold some key advantages over their natural analogs. The synthetics can, of course, be manufactured in a uniform, phase-pure state. It is also possible to manufacture desirable zeolite structures which do not appear in nature. Zeolite A is a well-known example. Since the principal raw materials used to manufacture zeolites are silica and alumina, which are among the most abundant mineral components on earth, the potential to supply zeolites is virtually unlimited. Finally, zeolite manufacturing processes engineered by man require significantly less time than the 50 to 50,000 years prescribed by nature. Disadvantages include the inability to create crystals with dimensions of a comparable size to their natural counterparts.

4 – Uses :

4 – 1 - Commercial and domestic :

Zeolites are widely used as ion - exchange beds in domestic and commercial water purification, softening, and other applications. In chemistry, zeolites are used to separate molecules (only molecules of certain sizes and shapes can pass through), and as traps for molecules so they can be analyzed.

Zeolites have the potential of providing precise and specific separation of gases including the removal of H_2O, CO_2 and SO_2 from low-grade natural gas streams. Other separations include noble gases, N_2, O_2, freon and formaldehyde. However, at present, the true potential to improve the handling of such gases in this manner remains unknown.

On - Board Oxygen Generating Systems (OBOGS) use zeolites to remove nitrogen from compressed air in order to supply oxygen for aircrews at high altitudes.

4 – 2 – Petro chemical industry :

Synthetic zeolites are widely used as catalysts in the petrochemical industry, for instance in fluid catalytic cracking and hydro cracking. Zeolites confine molecules in small spaces, which causes changes in their structure and reactivity. The hydrogen form of zeolites (prepared by ion-exchange) are powerful solid-state acids, and can facilitate a host of acid-catalyzed reactions, such as isomerisation, alkylation, and cracking. The specific activation modality of most zeolitic catalysts used in petrochemical applications involves quantum-chemical Lewis acid site reactions.[*citation needed*]

Catalytic cracking uses reactor and a regenerator. Feed is injected onto hot, fluidized catalyst where large gasoil molecules are broken into smaller gasoline molecules and olefins. The vapor-phase products are separated from the catalyst and distilled into various products. The catalyst is circulated to a regenerator where air is used to burn coke off the surface of the catalyst that was formed as a byproduct in the cracking process. The hot regenerated catalyst is then circulated back to the reactor to complete its cycle.

4 – 3 - Nuclear industry :

Zeolites have uses in advanced reprocessing methods, where their micro - porous ability to capture some ions while allowing others to pass freely, allowing many fission products to be efficiently removed from nuclear waste and permanently trapped. Equally important are the mineral properties of zeolites. Their alumino-silicate construction is extremely durable and resistant to radiation even in porous form. Additionally, once they are loaded with trapped fission products, the zeolite-waste combination can be hot pressed into an extremely durable ceramic form, closing the pores and trapping the waste in a solid stone block. This is a waste form factor that greatly reduces its hazard compared to conventional reprocessing systems. Zeolites are also used in the management of leaks of radioactive materials. For example, in the aftermath of the Fukushima Daiichi nuclear disaster, sandbags of zeolite were dropped into the seawater near the power plant to adsorb radioactive caesium which was present in high levels .

4 – 4 - Biogas Industry :

The German group Fraunhofer e.V. announced that they had developed a zeolite substance for use in the biogas industry for long-term storage of energy at a density 4x more than water. Ultimately, the goal is to be able to store heat both in industrial installations and in small combined heat and power plants such as those used in larger residential buildings.

4 – 5 - Heating and refrigeration :

Zeolites can be used as solar thermal collectors and for adsorption refrigeration. In these applications, their high heat of adsorption and ability to hydrate and dehydrate while maintaining structural stability is exploited. This hygroscopic property coupled with an inherent exothermic (heat-producing) reaction when transitioning from a dehydrated to a hydrated form make natural zeolites useful in harvesting waste heat and solar heat energy. Zeolites are also used as a molecular sieve in cryosorption style vacuum pumps.

4 – 6 – Detergents :

The largest single use for zeolite is the global laundry detergent market. This amounted to 1.44 million metric tons per year of anhydrous zeolite A in 1992 .

4 – 7 – Construction :

Synthetic zeolite is also being used as an additive in the production process of warm mix asphalt concrete. The development of this application started in Germany in the 1990s. It helps by decreasing the temperature level during manufacture and laying of asphalt concrete, resulting in lower consumption of fossil fuels, thus releasing less carbon dioxide, aerosols, and vapours. Other than that, the use of synthetic zeolite in hot mixed asphalt leads to easier compaction and, to a certain degree, allows cold weather paving and longer hauls.

When added to Portland cement as a pozzolan, it can reduce chloride permeability and improve workability. It reduces weight and helps moderate water content while allowing for slower drying which improves break strength.

4 – 8 – Gemstones :

Thomsonites , one of the rarer zeolite minerals, have been collected as gemstones from a series of lava flows along Lake Superior in Minnesota and to a lesser degree in Michigan, U.S.A. Thomsonite nodules from these areas have eroded from basalt lava flows and are collected on beaches and by scuba divers in Lake Superior.

These thomsonite nodules have concentric rings in combinations of colors: black, white, orange, pink, red, and many shades of green. Some nodules have copper inclusions and rarely will be found with copper "eyes." When polished by a lapidary the thomsonites sometimes display chatoyancy.

4 – 9 – Medical :

Research into and development of the many bio chemical and biomedical applications of zeolites, particularly the naturally occurring species heulandite, clinoptilolite and chabazite has been ongoing.

Zeolite - based oxygen concentrator systems are widely used to produce medical - grade oxygen . The zeolite is used as a molecular sieve to create purified oxygen from air using its ability to trap impurities, in a process involving the adsorption of nitrogen, leaving highly purified oxygen and up to 5 % argon.

QuikClot brand hemostatic agent, which is used to stop severe bleeding , contains a calcium-loaded form of zeolite.

4 – 10 – Agriculture :

In agriculture, clinoptilolite (a naturally occurring zeolite) is used as a soil treatment. It provides a source of slowly released potassium. If previously loaded with ammonium, the zeolite can serve a similar function in the slow release of nitrogen. Zeolites can also act as water moderators, in which they will absorb up to 55% of their weight in water and slowly release it under the plant's demand. This property can prevent root rot and moderate drought cycles.

4 – 11 - Domestic pet care :

4 – 11 – 1 - Aquarium keeping :

Zeolites are marketed by pet stores for use as a filter additive in aquariums . In aquariums, zeolites can be used to adsorb ammonia and other nitrogenous compounds. However, due to the high affinity of some zeolites for calcium, they may be less effective in hard water and may deplete calcium. Zeolite filtration is used in some marine aquaria to keep nutrient concentrations low for the benefit of corals adapted to nutrient - depleted waters.

Where and how the zeolite was formed is an important consideration for aquariums. Most Northern hemisphere natural zeolites were formed when molten lava came in contact with sea water, thereby 'loading' the zeolite with Na (sodium) sacrificial ions. The mechanism is well known to chemists as ion exchange. These sodium ions will speciate with other ions in solution, thus the takeup of nitrogen in ammonia, with the release of the sodium. One deposit in southern Idaho near Bear River is a fresh water variety (Na < .05 %) In southern hemisphere zeolites, such as found in Australia, which were formed with fresh water, thus the calcium uptake on formation.

Zeolite is an effective ammonia filter, but must be used with some care, especially with delicate tropical corals that are sensitive to water chemistry and temperature.

5 - Zeolite mineral species :

The zeolite family includes :

- Amicite
- Analcime
- Barrerite
- Bellbergite
- Bikitaite
- Boggsite
- Brewsterite
- Chabazite
- Clinoptilolite
- Cowlesite
- Dachiardite
- Edingtonite
- Epistilbite
- Erionite
- Faujasite
- Ferrierite
- Garronite
- Gismondine
- Gmelinite
- Gobbinsite
- Gonnardite
- Goosecreekite
- Harmotome
- Herschelite
- Heulandite
- Laumontite
- Levyne
- Maricopaite
- Mazzite
- Merlinoite

- Mesolite
- Montesommaite
- Mordenite
- Natrolite
- Offretite
- Paranatrolite
- Paulingite
- Pentasil
- Perlialite
- Phillipsite
- Pollucite
- Scolecite
- Sodium Dachiardite
- Stellerite
- Stilbite
- Tetranatrolite
- Thomsonite
- Tschernichite
- Wairakite
- Wellsite
- Willhendersonite
- Yugawaralite