* **Introduction of materials, Construction materials, Physical properties, Mechanical properties, Chemical properties, Electrical & Thermal properties**

It is necessary for an engineer to be conversant with the properties of engineering materials. Right selection of materials can be made for a construction activity only when material properties are fully understood. Several materials are required for construction. **The materials used in the construction of Engineering Structures such as buildings, bridges and roads are called Engineering Materials or Building Materials**. They include Bricks, Timber, Cement, Steel and Plastics.

 **Classification of Engineering material**

The factors which form the basis of various systems of classifications of materials in material science and engineering are: *(i)* the chemical composition of the material, *(ii)* the mode of the occurrence of the material in the nature, *(iii)* the refining and the manufacturing process to which the material is subjected prior it acquires the required properties, *(iv)* the atomic and crystalline structure of material and *(v)* the industrial and technical use of the material.

Common engineering materials that falls within the scope of material science and engineering may be classified into one of the following groups:

*(i)* Metals (ferrous and non-ferrous) and alloys

*(ii)* Ceramics

*(iii)* Polymers

*(iv)* Composites

*(v)* Advanced Materials

Some of the most important properties of building materials are grouped as follow

|  |  |
| --- | --- |
| **Group** | **Properties** |
| Physical | Shape, Size, Density, Specific Gravity etc., |
| Mechanical | Strength, Elasticity, Plasticity, Hardness, Toughness, Ductility, Brittleness, Creep, Stiffness, Fatigue, Impact Strength etc., |
| Thermal | Thermal conductivity, Thermal resistivity, Thermal capacity etc., |
| Chemical | Corrosion resistance, Chemical composition, Acidity, Alkalinity etc., |
| Optical | Colour, Light reflection, Light transmission etc., |
| Acoustical | Sound absorption, Transmission and Reflection. |
| Physiochemical | Hygroscopicity, Shrinkage and Swell due to moisture changes |

**Definitions**

**Density**: It is defined as mass per unit volume. It is expressed as kg/m3.

**Specific gravity**: It is the ratio of density of a material to density of water.

**Porosity**: The term porosity is used to indicate the degree by which the volume of a material is occupied by pores. It is expressed as a ratio of volume of pores to that of the specimen.

**Strength**: Strength of a material has been defined as its ability to resist the action of an external force without breaking.

**Elasticity**: It is the property of a material which enables it to regain its original shape and size after the removal of external load.

**Plasticity**: It is the property of the material which enables the formation of permanent deformation.

**Hardness**: It is the property of the material which enables it to resist abrasion, indentation, machining and scratching.

**Ductility**: It is the property of a material which enables it to be drawn out or elongated to an appreciable extent before rupture occurs.

**Brittleness**: It is the property of a material, which is opposite to ductility. Material, having very little property of deformation, either elastic or plastic is called Brittle.

**Creep**: It is the property of the material which enables it under constant load to deform slowly but progressively over a certain period.

**Stiffness**: It is the property of a material which enables it to resist deformation.

**Fatigue**: The term fatigue is generally referred to the effect of cyclically repeated stress. A material has a tendency to fail at lesser stress level when subjected to repeated loading.

**Impact strength**: The impact strength of a material is the quantity of work required to cause its failure per its unit volume. It thus indicates the toughness of a material.

**Toughness**: It is the property of a material which enables it to be twisted, bent or stretched under a high stress before rupture.

**Thermal Conductivity**: It is the property of a material which allows conduction of heat through its body. It is defined as the amount of heat in kilocalories that will flow through unit area of the material with unit thickness in unit time when difference of temperature on its faces is also unity.

**Corrosion Resistance**: It is the property of a material to withstand the action of acids, alkalis gases etc., which tend to corrode (or oxidize).

**STONE:**

* **Introduction, Types, Applications, Characteristics of good building stones, artificial stones.**

**DEFINITION**- The process of taking out stones from natural rock beds is known as the quarrying. The term quarry is used to indicate the exposed surface of natural rocks. The stones, thus obtained, are used for various engineering purposes. The difference a mine and quarry should be noted. In case of a mine, the operations are carried out under the ground at great depth. In case of quarry, the operations are carried out at ground level in an exposed condition.

**SITE FOR QUARRY**-The selection of site for a quarry of stones should be done after studying carefully the following aspects:

1. Availability of tools, power, materials and labors for the efficient working of quarry.

2. Easy availability of clean water in sufficient quantity all the year round.

3. Economy in quarrying.

4. Drainage of quarrying pit.

5. Facility of carrying and conveying stones from quarry.

6. Quality of stone available from quarry.

**METHODS OF QUARRYING-**

Following are the three methods of quarrying:

I. Quarrying with hand tools

II. Quarrying with channeling machine

III. Quarrying with blasting.

**QUARRYING WITH HAND TOOLS-**There three methods of doing this type of quarrying:

a) Digging or Excavating

b) Heating

c) Wedging

(a) Digging or Excavating- In this method, the stones are merely excavating with the help of suitable instruments such as pick-axes, hammers, showels, chisels, etc. This method is useful when a soft stone occurs in form of large and small blocks.

(b) Heating- In this method, the top surface of rock is heated. This method is useful when small blocks of more or less regular shape are to be taken out from quarry. It is suitable when the rock formation consists of horizontal layers of shallow depth. This type of rocks are used in coursed rubble masonry.

(c) Wedging-In this method, if rock surface contains cracks or fissures, the steel wedges or points are driven through such cracks by means of hammers. The blocks of stones are then shifted and they are removed with the help of suitable instruments.

The wedging is adopted for costly stratified rocks which are comparatively soft such as laterite, marble, limestone, sandstone, etc. The wedging is preferred to the blasting, wherever possible.

**QUARRYING WITH CHANNELLING MACHINE**: In this method, the channeling machine driven by steam, compressed air or electricity are used to make vertical or oblique grooves or channels on the rock mass. These machines make rapidly the grooves having length of about 24m, width of about 50mm to 75mm and depth of about 2.40m to 3.70m. The process consists of the following steps:

(a) The channels are cut around the stone block which is to be removed from the rock mass.

(b) The horizontal holes are drilled beneath the rock.

(c) The wedges are driven into the holes and the block is then broken loose from its bed.

**QUARRYING WITH BLASTING**:In this method, the explosives are used to convert into small pieces of stones. The main purpose of quarrying stones by is to loosen large masses of rocks and not to violently blow up the whole mass so as to convert it into very small pieces of practically no use.

This method is adopted for quarrying hard stones, having no fissures or cracks. The stones obtained by blasting are usually of small size and they are used as ballast in railways, aggregate for concrete, road metal, etc. The process of blasting is important with respect to the stone quarrying.

**Commonly used Stones in Asia**

**Marble:**

**Origin and composition**: - it is a most common variety of metamorphic rock. It is formed from crystallized limestone by metamorphism\, chemically, it is calcareous and is chiefly composed of calcium carbonate.

**Properties** :- following are the properties of marble:

* the usual color of marble is white, but it is also available in different shades of colors such as grey, black, red, brown, yellow and combination of these
* it is compact and crystalline in structure due to which it can take a fine polish
* it is les durable
* It can be carved easily and thus is most suited for sculpture work.

**Chief uses:-** used as building stone and in decorative panels

**Sandstone:**

**Origin and composition:-**This stone is a common variety of sedimentary rocks mechanical origin. It is physically siliceous in nature, it is chiefly composed of quartz (grains of sand) bound together by a cementing material, but other minerals such as felspar, mica, magnetite etc. are also present.

**Properties:-** following are the properties of sand stone:-

• It is white, grey, yellow, light brown, and red in color.

• Its specific gravity is 2.3 to 2.4.

• **Chief uses**: - general walls building flagstone.

**Slate:**

• its crushing strength varies from 700 to 2100 kg/cm2

• it is hard, tough and least absorptive

• It also offers good abrasive resistance.

• It is a good heat and electrical insulator.

Following are the uses of slate.

• It is a valuable material for roofing and black boards.

• Thick slabs of harder variety of slates are used for flooring steps shelves mental pieces sills of doors and window etc.

**Basalt:-**

**Origin and Composition**: these stones are the common varieties of igneous rocks they are formed by solidification of lava on the earth’s surface due to volcanic eruption. Some basalts develop step like appearance and are known as traps. They are chiefly composed of silica, alumina and felspar.

**Properties**:- Following are the properties of basalt and trap

* Their crushing strength is 700 to 850 kg/sq.cm.
* They are hard and tough
* They are greenish grey to dark grey in color.

**Limestone :-**

* Color :- White light grey to light buff.
* Texture :- fine to crystalline, may have fossils
* Parting :-parallel to beds: also may have irregular fractures.
* Hardness:- fairly soft steel easily catches
* May show fossils.
* All lime stone are of sedimentary origin and have for their principal ingredient carbonate of lime.
* When clay is present, the stone is called argillaceous limestone; when silica predominates, siliceous limestone; when iron is prevalent, ferruginous limestone.

**Granite:-**

• Granite is one of the most valuable stones for construction purposes. Although the quality of granite varies according to the proportions of the constituents and their method of aggregation, this kind of stone is generally durable, strong, and hard.

• The hardest and most durable granites contain a greater proportion of quartz and a smaller proportion of feldspar and mica.

 Because of its uniform structure, granite can be quarried in large blocks. The uses for which granite is suitable depend on the texture of the stone. Medium-grained stone is best fitted for building construction. Fine-grained stone can be carved and polished.

**Schist:-**

• Schist has a more crystalline structure than slate, and the crystals are easily seen. It is composed chiefly of minerals that cleave readily, such as hornblende, mica, etc., mixed with a variable amount of granular quartz and feldspar.

Schist is sometimes used in building construction but it disintegrates very rapidly and is not durable.

**Gneiss -**

• it is laminated rock formed by metamorphism of either sedimentary or igneous rock.

• It is often used as structural material and as concrete aggregate.

**Shale -**

• Shale is a typical clay rock that splits readily in lines parallel to the bedding.

• Sand and lime carbonate are always present in this stone and, with increase of either, the rock grades into shaly sandstone or shaly limestone.

• Shale is used for light traffic roads and in the manufacture of brick ,tile, and other burned clay products, but it is not suitable for concrete aggregate.

**Conglomerate -**

• Stratified rock composed of rounded pebbles of any material, such as limestone, quartz, shale, granite grains, feldspar, etc., cemented together is known as conglomerate.

• When the pebbles are quartz with siliceous binding the rock is strong and hard to quarry or dress.

• When the intersection between the pebbles are not filled by the binder, the rock is very porous, and may hold great amounts of ground water.

• This stone is seldom used in building construction.

**CEMENT AND LIME**

* **Introduction and manufacture of Ordinary Portland cement, Constituents of cement, Types of cement, Cement hydration, Properties and field tests of cement, Special cements, Introduction and manufacture of lime, Setting and hardening of lime, Applications of lime, Comparison of lime and cement,.**

Cement is a binder, a substance that sets and hardens and can bind other materials together. Cements used in construction can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to be used in the presence of water. Non-hydraulic cement will not set in wet conditions or underwater, rather it sets as it dries and reacts with carbon dioxide in the air. Hydraulic cement is made by replacing some of the cement in a mix with activated aluminium silicates, pozzolanas, such as fly ash. Example is Ordinary Portland cement.

**Use**

• Cement mortar for Masonry work, plaster and pointing etc.

• Concrete for laying floors, roofs and constructing lintels,beams,weather-shed,stairs,pillars etc.

• Construction for important engineering structures such as bridge,culverts,dams,tunnels,light house,clocks,etc.

• Construction of water,wells, tennis courts,septic tanks, lamp posts, telephone cabins etc.

• Making joint for joints,pipes,etc.

• Manufacturing of precast pipes,garden seats, artistically designed wens, flower posts, etc.

• Preparation of foundation, water tight floors, footpaths, etc.

**Portland cement**: Hydraulic cementitous material composed of calcium silicates and aluminates, and a small amount of added gypsum. The cement is made by burning mixtures of limestone and argilaceous rocks (slates).

**Cement clinker:** is a dark grey nodular material made by heating ground limestone and clay at a temperature of about 1400 °C - 1500 °C. The nodules are ground up to a fine powder to produce cement, with a small amount of gypsum added to control the setting properties. Nodules range in size from 1mm to 25mm or more and are composed mainly of calcium silicates, typically 70%-80%. Portland cement clinker contains four principal minerals: (i) Alite (tricalcium silicate), (ii) Belite (dicalcium silicate), (iii) Aluminate(tricalcium aluminate) and (iv) Ferrite (tetracalcium aluminoferrite)

**Setting time**: The transition from fresh cement paste to hardened cement paste. The terms “initial set” and “final set” refer to specific times when the paste becomes no longer workable and completely rigid, respectively. “Setting” is the process by which transition occurs.

**Hydration:** The chemical reactions between cement and water. Hydration is what causes cement paste to first set and then harden.

**Hydration products:** The new solid phases that are formed by hydration.

**Heat of hydration**: Like most spontaneous chemical reactions, the hydration reactions between cement and water are exothermic, meaning that they release heat. Large volumes of concrete can warm up considerably during the first few days after mixing when hydration is rapid.

**Cement paste:** Mixture of Portland cement and water alone (used for filling cracks and sealing small spaces)

**Mortar:** Mixture of Portland cement, fine sand and water (used for example for the construction of brick walls)

**Concrete:** Mixture of Portland cement, coarse and fine aggregates (rock pebbles, sand), water and chemical additives. The mechanical strength can be reinforced by the insertion of steel bars.

**Types of Cements**

Many types of cements are available in markets with different compositions and for use in different environmental conditions and specialized applications. A list of some commonly used cement is described in this section:

***Ordinary Portland cement***

Ordinary Portland cement is the most common type of cement in general use around the world. This cement is made by heating limestone (calcium carbonate) with small quantities of other materials (such as clay) to 1450°C in a kiln, in a process known as calcination. The resulting hard substance, called 'clinker', is then ground with a small amount of gypsum into a powder to make 'Ordinary Portland 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.

***Rapid hardening Portland cement***

• It is firmer than Ordinary Portland Cement

It gets rapid early than opc.

Used inside flow of water.

• It contains more C3S are less C2S than the ordinary Portland cement.

• Its 3 days strength is same as 7 days strength of ordinary Portland cement.

***Low heat Portland cement***

• Heat generated in ordinary Portland cement at the end of 3days 80 cal/gm. While in low heat cement it is about 50cal/gm of cement.

Whose heat of hydration is less.

I harden slow than opc.

Used for decorative purposes.

Low strength.

• It has low percentage of C3A and relatively more C2S and less C3S than O.P. Cement.

• Reduce and delay the heat of hydration.

***Sulphate resisting Portland cement***

type of cement that is used in area where sulphate attack more.

Or used water table is near.

 • Maximum C3A content.

• Firmer than ordinary pot land cement.

• Sulphate forms the sulpha-aluminates which have expensive properties and so causes disintegration of concrete.

***Pozzolanic cement***

• This Cement has higher resistance to chemical agencies and to sea water because of absence of lime.

• It evolves less heat and initial strength is less but final strength is 28 days onward equal to ordinary Portland cement.

• It possesses less resistance to the erosion and weathering action.

• It imparts higher degree of water tightness and it is cheap.

***White Portland cement***

• Grey colour of O.P. cement is due to presence of Iron Oxide. Hence in White Cement Fe2O3 is limited to 1 %. Sodium Alumina Ferrite (Crinoline) Na3AlF6 is added in the absence of Iron-Oxide.

• It is quick drying possesses ,high strength and has superior aesthetic values and it also cost less than ordinary Cement because of specific requirements imposed upon the raw materials and the manufacturing process.

• White Cement are used in Swimming pools, for painting garden furniture, moulding sculptures and statues etc.

***Coloured Portland***

• The Cement of desired colour may be obtained by mixing mineral pigments with ordinary Cement.

• The amount of colouring material may vary from 5 to 10 percent. If this percentage exceeds 10percent, the strength of cements is affected.

• The iron Oxide in different proportions gives brown, red or yellow colour. The coloured Cement are widely used for finishing of floors, window sill slabs, stair treads etc.

***Expansive cement***

***This type of cement is used where we need expansion after hardening for example in pouring of cracks in order to occupy properly.***

• This type of cement is produced by adding an expanding medium like sulpho aluminate and a stabilising agent to the ordinary cement.

• The expanding cement is used for the construction of water retaining structures and for repairing the damaged concrete surfaces.

***High alumina cement***

• This cement is produced by grilling clinkers formed by calcining bauxite and lime. It can stand high temper lures.

• If evolves great heat during setting. It is therefore not affected by frost.

**Composition of Cement clinker**

The various constituents combine in burning and form cement clinker. The compounds formed in the burning process have the properties of setting and hardening in the presence of water. They are known as Bogue compounds after the name of Bogue who identified them. These compounds are as follows: Alite (Tri calcium silicate or C3S), Belite (Di calcium silicate or C2S), Celite (Tri calciumalluminate or C3A) and Felite (Tetra calciumalumino ferrite or C4AF).

***Tricalcium silicate***

It is supposed to be the best cementing material and is well burnt cement. It is about 25-50% (normally about 40 per cent) of cement. It renders the clinker easier to grind, increases resistance to freezing and thawing, hydrates rapidly generating high heat and develops an early hardness and strength. However, raising of C3S content beyond the specified limits increases the heat of hydration and solubility of cement in water.

***Dicalcium silicate***

It constitutes about 25-40% (normally about 32 per cent) of cement. It hydrates and hardens slowly and takes long time to add to the strength (after a year or more). It imparts resistance to chemical attack. Rising of C2S content renders clinker harder to grind, reduces early strength, decreases resistance to freezing and thawing at early ages and decreases heat of hydration

***Tri calcium alluminate***

It is about 5-11% (normally about 10.5 per cent) of cement. It rapidly reacts with water and is responsible for flash set of finely grounded clinker. The rapidity of action is regulated by the addition of 2-3% of gypsum at the time of grinding cement. Tri calcium-aluminate is responsible for the initial set, high heat of hydration and has greater tendency to volume changes causing cracking. Raising the C3A content reduces the setting time, resistance to sulphate attack and lowers the ultimate strength, heat of hydration and contraction during air hardening.

***Tetra calcium alumino ferrite***

It constitutes about 8–14% (normally about 9 per cent) of cement. It is responsible for flash set but generates less heat. It has poorest cementing value. Raising the C4AF content reduces the strength slightly.

**Hydration of Cement**

In the anhydrous state, four main types of minerals are normally present: alite, belite, celite and felite. Also present are small amounts of clinker sulfate (sulfates of sodium, potassium and calcium) and gypsum, which was added when the clinker was ground up to produce the familiar grey powder.

When water is added, the reactions which occur are mostly exothermic, that is, the reactions generate heat. We can get an indication of the rate at which the minerals are reacting by monitoring the rate at which heat is evolved using a technique called conduction calorimetry. Almost immediately on adding water some of the clinker sulphates and gypsum dissolve producing an alkaline, sulfate-rich, solution. Soon after mixing, the (C3A) phase (the most reactive of the four main clinker minerals) reacts with the water to form an aluminate-rich gel The gel reacts with sulfate in solution to form small rod-like crystals of ettringite. (C3A) reaction is with water is strongly exothermic but does not last long, typically only a few minutes, and is followed by a period of a few hours of relatively low heat evolution. This is called the dormant, or induction period .The first part of the dormant period, up to perhaps half-way through, corresponds to when concrete can be placed. As the dormant period progresses, the paste becomes too stiff to be workable. At the end of the dormant period, the alite and belite in the cement start to react, with the formation of calcium silicate hydrate and calcium hydroxide. This corresponds to the main period of hydration , during which time concrete strengths increase. The individual grains react from the surface inwards, and the anhydrous particles become smaller. (C3A) hydration also continues, as fresh crystals become accessible to water. The period of maximum heat evolution occurs typically between about 10 and 20 hours after mixing and then gradually tails off. In a mix containing OPC only, most of the strength gain has occurred within about a month. Where OPC has been partly-replaced by other materials, such as fly ash, strength growth may occur more slowly and continue for several months or even a year.Ferrite reaction also starts quickly as water is added, but then slows down, probably because a layer of iron hydroxide gel forms, coating the ferrite and acting as a barrier, preventing further reaction.

**Products of Hydration**

During Hydration process several hydrated compounds are formed most important of which are, Calcium silicate hydrate, calcium hydroxide and calcium aluminium hydrates which is important for strength gain.

***Calcium silicate hydrate:***

This is not only the most abundant reaction product, occupying about 50% of the paste volume, but it is also responsible for most of the engineering properties of cement paste. It is often abbreviated, using cement chemists' notation, to "C-S-H," the dashes indicating that no strict ratio of SiO2 to CaO is inferred. C-S-H forms a continuous layer that binds together the original cement particles into a cohesive whole which results in its strong bonding capacity..

***Calcium hydroxide:***

The other products of hydration of C3S and C2S are calcium hydroxide. In contrast to the C-S-H, the calcium hydroxide is a compound with distinctive hexagonal prism morphology. It constitutes 20 to 25 per cent of the volume of solids in the hydrated paste. The lack of durability of concrete is on account of the presence of calcium hydroxide. The calcium hydroxide also reacts with sulphates present in soils or water to form calcium sulphate which further reacts with C3A and cause deterioration of concrete. This is known as sulphate attack. To reduce the quantity of Ca (OH)2 in concrete and to overcome its bad effects by converting it into cementitious product is an advancement in concrete technology. The use of blending materials such as fly ash, silica fume and such other pozzolanic materials are the steps to overcome bad effect of Ca(OH)2 in concrete. However, Ca(OH)2 is alkaline in nature due to which it resists corrosion in steel.

***Calcium aluminium hydrates:***

These are formed due to hydration of C3A compounds. The hydrated aluminates do not contribute anything to the strength of concrete. On the other hand, their presence is harmful to the durability of concrete particularly where the concrete is likely to be attacked by sulphates. As it hydrates very fast it may contribute a little to the early strength.

**Various tests on cement:**

Basically two types of tests are under taken for assessing the quality of cement. These are either field test or lab tests. The current section describes these tests in details.

***Field test:***

There are four field tests may be carried out to as certain roughly the quality of cement. There are four types of field tests to access the colour, physical property, and strength of the cement as described below.

*Colour*

• The colour of cement should be uniform.

• It should be typical cement colour i.e. grey colour with a light greenish shade.

*Physical properties*

• Cement should feel smooth when touched between fingers.

• If hand is inserted in a bag or heap of cement,it should feel cool.

*Presence of lumps*

• Cement should be free from lumps.

*Strength*

• A thick paste of cement with water is made on a piece of thick glass and it is kept under water for 24 hours. It should set and not crack.

***Laboratory tests:***

Six laboratory tests are conducted mainly for assessing the quality of cement. These are: fineness, compressive strength, consistency, setting time, soundness and tensile strength.

*Fineness*

• This test is carried out to check proper grinding of cement.

• The fineness of cement particles may be determined either by sieve test or permeability apparatus test.

• In sieve test ,the cement weighing 100 gm is taken and it is continuously passed for 15 minutes through standard sieve number 200.The residue is then weighed and this weight should not be more than 10% of original weight.

• In permeability apparatus test, specific area of cement particles is calculated. This test is better than sieve test. The specific surface acts as a measure of the frequency of particles of average size.

*Compressive strength*

• This test is carried out to determine the compressive strength of cement.

• The mortar of cement and sand is prepared in ratio 1:3.

• Water is added to mortar in water cement ratio 0.4.

• The mortar is placed in moulds. The test specimens are in the form of cubes and the moulds are of metals.

• Then the mortar is compacted in vibrating machine for 2 minutes and the moulds are placed in a damp cabin for 24 hours.

• The specimens are removed from the moulds and they are submerged in clean water for curing.

• The cubes are then tested in compression testing machine at the end of 3days and 7 days. Thus compressive strength is found out.

*Consistency*

• The purpose of this test is to determine the percentage of water required for preparing cement pastes for other tests.

• Take 300 gm of cement and add 30 percent by weight or 90 gm of water to it.

• Mix water and cement thoroughly.

• Fill the mould of Vicat apparatus and the gauging time should be 3.75 to 4.25 minutes.

• Vicat apparatus consists of a needle is attached a movable rod with an indicator attached to it.

• There are three attachments: square needle, plunger and needle with annular collar.

• The plunger is attached to the movable rod. The plunger is gently lowered on the paste in the mould.

• The settlement of plunger is noted. If the penetration is between 10+1 or 10\_1mm from the bottom of mould, the water added is correct. If not process is repeated with different percentages of water till the desired penetration is obtained.

*Setting time*

• This test is used to detect the deterioration of cement due to storage. The test is performed to find out initial setting time and final setting time.

• Cement mixed with water and cement paste is filled in the Vicat mould.

• Square needle is attached to moving rod of vicat apparatus.

• The needle is quickly released and it is allowed to penetrate the cement paste. In the beginning the needle penetrates completely. The procedure is repeated at regular intervals till the needle does not penetrate completely.(upto 5mm from bottom)

• Initial setting time =<30min for ordinary Portland cement and 60 min for low heat cement.

• The cement paste is prepared as above and it is filled in the Vicat mould.

• The needle with annular collar is attached to the moving rod of the Vicat apparatus.

• The needle is gently released. The time at which the needle makes an impression on test block and the collar fails to do so is noted.

• Final setting time is the difference between the time at which water was added to cement and time as recorded in previous step,and it is =<10hours.

*Soundness*

• The purpose of this test is to detect the presence of uncombined lime in the cement.

• The cement paste is prepared.

• The mould is placed and it is filled by cement paste.

• It is covered at top by another glass plate. A small weight is placed at top and the whole assembly is submerged in water for 24 hours.

• The distance between the points of indicator is noted. The mould is again placed in water and heat is applied in such a way that boiling point of water is reached in about 30 minutes. The boiling of water is continued for one hour.

• The mould is removed from water and it is allowed to cool down.

• The distance between the points of indicator is again measured. The difference between the two readings indicates the expansion of cement and it should not exceed 10 mm.

*Tensile strength*

• This test was formerly used to have an indirect indication of compressive strength of cement.

• The mortar of sand and cement is prepared.

• The water is added to the mortar.

• The mortar is placed in briquette moulds. The mould is filled with mortar and then a small heap of mortar is formed at its top. It is beaten down by a standard spatula till water appears on the surface. Same procedure is repeated for the other face of briquette.

• The briquettes are kept in a damp for 24 hours and carefully removed from the moulds.

• The briquettes are tested in a testing machine at the end of 3 and 7 days and average is found out.

**LIME**

There are two main forms of lime; quick-lime and hydrated lime. Quicklime is produced by heating any material containing calcium carbonate to a temperature of around 1000°C for several hours. In this process, known as 'calcining' or simply 'burning', the carbon dioxide in the calcium carbonate is driven off leaving calcium oxide plus any impurities.

Quicklime is a chemically unstable and hazardous material and is therefore normally hydrated, becoming not only more stable but also easier and safer to handle. Hydrated lime is produced by adding water to quicklime in a process called 'hydration' or 'slaking', where the calcium oxide and water combine chemically to form calcium hydroxide.

**Raw materials**

Limestone is the most common raw material used to produce lime, although other calcareous materials such as marble, coral and shells are also used. With large-scale excavation of any raw material, care must be taken to minimize environmental damage, particularly in the case of coral and, to a lesser extent, sea shells.

**Hydration**

Hydration, in small quantities, can be undertaken manually by sprinkling water onto a pile of quicklime which is then turned and mixed with a rake as more water is added. In large quantities, hydration is normally automated and done in large hydrators where measured quantities of water and quicklime are fed in and mechanically agitated.

During hydration, the quicklime lumps will disintegrate to a fine powder. For high quality limes some form of screening and/ or classification, during which the lime is sorted by particle size and density, will be required to grade the lime. Hydrated lime is normally supplied and sold bagged, as a dry powder.

If quicklime is hydrated with an excess of water and well agitated, it forms a milky suspension known as milk of lime. Allowing the solids to settle and drawing off the excess water forms a paste-like residue known as lime putty. Lime in this form is considered, by many, to be preferable for use in building as it ensures complete hydration, produces excellent mortars and, if kept in a saturated condition, will not deteriorate over time.

**Applications of lime**

Lime is much better than cement in plasterwork. The setting is slow, but the result will look better and the softer surface will be less likely to crack. Lime mortars have a high degree of workability which is highly desirable in mortars and plasters. Lime products also set more slowly which allows mixing in large quantities without fear of going off before use

Lime also has considerable economic advantages over Portland cement. The latter is relatively expensive to produce and critically for developing countries, often requires expensive imported technologies and fuels. Lime has none of these disadvantages and is normally considerably cheaper to produce

**MORTARS AND CONCRETE**

**Introduction about mortars**

The term mortar is used to indicate a paste prepared by adding required quantity of water to a mixture of binding material like cement or lime and fine aggregate like sand.

The above two components of mortar, namely, the binding material and fine aggregate are sometimes referred to as the matrix and adulterant respectively. The matrix binds the particles of the adulterant and as such, the durability, quality and strength of mortar will mainly depend on the quantity and quality of the matrix. The combined effect of the two components of mortar is that the mass is able to bind the bricks or stones firmly.

**Methods of preparation of mortars,**

For preparing mortar, the water is added to an intimate mixture of binding material and sand. The water to be used for this purpose should be free from clay, earth and other impurities. The water which is fit for drinking should only be used for preparing mortar.

**The different mortars are prepared in the following ways:**

**(1) Lime Mortar:**

The lime mortar is prepared either by pounding or grinding. The pounding is adopted for preparing small quantities of mortar. The grinding is adopted for preparing large quantities of mortar and to ensure a steady and continuous supply of mortar.

**Following are the two objects of pounding or grinding lime mortar:**

(i) To crush the particles of un-slaked lime, if any, so as to ensure slaking; and

(ii) To make an intimate mixture of the whole mass so that no two grains of sand are without an intervening film of the binding material.

**Pounding:**

In this method, the pits are formed in hard ground and they are provided with lining of bricks or stones at their sides and bottom. The lime and sand are mixed in dry state and the mixture is then placed in pits. A small quantity of water is added and four to five persons with heavy wooden pounders or beaters work on mortar. They turn mortar up and down frequently. The required quantity of water is added at intervals. When desired consistency is achieved, the mortar from pits is taken out.

**Grinding:**

In this method, the grinding mills are used to prepare mortar.

**(2) Cement Mortar:**

This mortar does not require pounding or grinding. The cement and sand are mixed in required proportions in dry state on a watertight platform or steel trough. The mixing in dry state is done twice or thrice. The water is then added and the ingredients are again thoroughly mixed.

Ratio 1:2.75

**(3) Surkhi Mortar:**

This type of mortar is prepared by using fully surkhi instead of sand or by replacing half of sand in case of fat lime mortar.

The surkhi mortar is used for ordinary masonry work of all kinds in foundation and superstructure. But it cannot be used for plastering or pointing since surkhi is likely to disintegrate after some time.

**(4) Gauged Mortar:**

To improve the quality of lime mortar and to achieve early strength, the cement is sometimes added to it. This process is known as the ganging. It makes lime mortar economical, strong and dense.

The usual proportion of cement to lime by volume is about 1:6 to 1:8. It is also known as the composite mortar or lime-cement mortar and it can also be formed by the combination of cement and clay. This mortar may be used for bedding and for thick brick walls.

**Properties and application of mortars**

The important properties of a good mortar mix are mobility, place-ability and water retention.

The term mobility is used to indicate the consistency of mortar mix which may range from stiff to fluid. The mobility of mortar mix depends on the composition of mortar and the mortar mixes to be used for masonry work, finishing work, etc. are made sufficiently mobile.

The place-ability or the ease with which the mortar mix can be placed with minimum cost in a thin and uniform layer over the surface depends on the mobility of the mortar. The place-ability of mortar mix should be such that a strong bond is developed with the surface of the bed.

A good mortar mix should possess the ability of retaining adequate humidity during transportation and laying over the porous bed. If water retention power of mortar mix is low, it separates into layers during transportation and when it comes into contact with porous bed such as brick, wood, etc., it gives away its water to that surface.

Thus the mortar becomes poor in amount of water and the remaining water proves to be insufficient for its hardening. Hence the required strength of mortar will not be achieved with such a mortar mix.

**Following are the properties of a good mortar:**

(i) Mortar should have good adhesion with the building units such as bricks, stones, etc.

(ii) It should be capable of developing the designed stresses.

(iii) It should be capable of resisting penetration of rain water.

(iv) It should be cheap.

(v) It should be durable.

(vi) It should be easily workable.

(vii) It should not affect the durability of materials with which it comes into contact.

(viii) It should set quickly so that speed in construction may be achieved.

(ix) The joints formed by mortar should not develop cracks and they should be able to maintain their appearance for a sufficiently long period.

**Following are the Applications of mortar:**

(i) To bind the building units such as bricks, stones, etc. into a solid mass,

(ii) To carry out pointing and plaster work on exposed surfaces of masonry,

(iii) To form an even and soft bedding layer for building units,

(iv) To form joints of pipes,

(v) To improve the general appearance of structure,

(vi) To prepare moulds for coping, corbels, cornice, etc.,

(vii) To serve as a matrix or cavity to hold coarse aggregates, etc.,

(viii) To distribute uniformly the super incumbent weight from upper layer to lower layer of bricks or stones,

(ix) To hide the open joints of brickwork and stonework,

(x) To fill up the cracks detected in the structure during maintenance process, etc

**TYPES OF CONCRETE**

## HIGH-STRENGTH CONCRETE

High-strength concrete is different from normal-strength concrete in the amount of force it can resist without breaking. The American Concrete Institute differentiates high-strength from normal-strength at a compressive strength of over 6,000 psi (pounds square inch). In addition to varying the proportions of the materials used in normal-strength concrete, silica fume is added to the mixture in order to strengthen the bond between the cement and the aggregate. However, this admixture causes the cement to hydrate much faster, meaning that it dries quicker than usual. In order to keep consistent the balance between workability and strength, a superplasticizer is added to high-strength concrete. This slows down the chemical reaction between the cement and water, allowing for workers to place the concrete at a more effective pace.

## HIGH-PERFORMANCE CONCRETE (HPC)

High-performance concrete, in contrast to high-strength concrete, is not necessarily known for its compressive resistance. While high-performance concrete can include a high compressive strength, other characteristics used to define “high performance” are the ease of placement without affecting strength, long-term mechanical properties, toughness, and longevity in various weather conditions among others.

## ULTRA HIGH-PERFORMANCE CONCRETE

This type of concrete is more often than not pre-mixed in bags because of the numerous ingredients needed to make it. It includes Portland cement, silica fume, quartz flour, and fine silica sand. However, high-range water reducers, water, and other steel or organic fibers are used to increase the strength of the mixture. Ultra-high performance concrete is particularly durable because of the combination of fine powders. Other types of concrete normally need a steel rebar or reinforcing to retain the intended structure, but UHPC is generally self-placing in addition to its incredible compressive strength of up to 29,000 psi. Its post-cracking longevity is one of UHPC’s strong points because even after this concrete cracks, it still is able to maintain structural integrity with an impressive tensile strength of 725 psi.

## STAMPED CONCRETE

Stamped concrete is another type of concrete that is very commonly used. Often seen in parking lots, pavements, or other like high-traffic areas, stamped concrete has more of an architectural application. Once concrete has been laid, a kind of mold can be placed on top of, or stamped, onto the hardening concrete to create the appearance of natural stone. Once the floor has been hardened, it will likely be sealed to increase the longevity of the dried mixture.

## SELF-CONSOLIDATING CONCRETE

Normally, concrete requires a mechanical vibration while being set in order to release excess air that may be in the mixture. Self-consolidating concrete eliminates the need for mechanical consolidation (the vibrations) mainly through its malleable viscosity. Being able to control the flowability and stability, as achieved by using high-range-water-reducing admixtures, allows concrete to be placed quicker. Not only does this save time, but because there is no need for the mechanical consolidation, self-consolidating concrete saves labor, saves money, and makes it easier for workers to fill restricted or hard-to-reach areas.

## SHOTCRETE

Invented by taxidermist, Carl Akeley in 1907, the initial dry method for placing shotcrete was by using a compressed air nozzle to shoot dry mix and injecting water through a separate hose at the head of the nozzle while the dry material is hurled toward the wall. The wet-mix shotcrete was developed later in the 1950’s and is only slightly different than the dry-mix shotcrete wherein dry-mix shotcrete involves the continuous feeding of a hopper through which dry mix would shoot through a nozzle and mix at the point of exit. Wet-mix shotcrete, however, involves the use of pre-mixed concrete. The concrete has already been prepared and therefore only involves one pump. The upside to using wet-mix shotcrete is that dry-mix shotcrete creates more waste (excess powder that falls to the floor), more rebound off the wall, and wet-mix shotcrete can place a larger quantity in a smaller amount of time.

## LIMECRETE

Also known as lime concrete, limecrete is a type of concrete where instead of using cement in the mix, lime is replaced. Doing so has certain benefits environmentally and health-wise. Environmentally, lime absorbs carbon dioxide as it sets and allows natural products like wood, straw, and hemp to be used as fibers without fear of composting or deterioration since limecrete controls moisture. In terms of health, lime plaster draws moisture out from inside which means that humidity control is more regulated, resulting in mold growth prevention. Furthermore, limewash and lime plasters are non-toxic so they do not contribute to air pollution inside like other paints would.

**EFFECTS OF VARIOUS CHEMICALS ON CONCRETE**

Following are the different chemical actions on concrete structures

* Sulphate attack
* Chloride attack
* Alkali aggregate reaction
* Carbonation
* Acid attack

## Sulphate attack on concrete

Most of the soil types contains sulphates in the form of calcium, magnesium, sodium, ammonium and potassium. They occur in soil or ground water. When a concrete structure is built on these types of soils, they may attack the concrete.

Generally sulphates in solid form do not attack the concrete severely but when they are in liquid form they pass into the voids of concrete and react with hydrated cement products. Calcium sulphate causes minimum damage because of its low solubility while magnesium sulphate causes maximum damage.

Most of the sulphates attacks calcium hydroxide and hydrated calcium aluminates present in the concrete and results in changing the volume of cement paste in concrete. Hence deterioration of concrete structure takes place. Along with calcium hydroxide, Magnesium sulphate also reacts with hydrated calcium silicate and makes concrete into powdered mass.



**Precautions**

* Concrete with low water cement ratio is less affected by magnesium sulphate while high water cement ratio concrete is highly affected.
* Sulphate-resisting Portland cement should be used where sulphates are present in the soil, water or atmosphere and come into contact with the concrete.
* Super-sulphated cement, made from blast furnace slag, can also be used although it is not widely available. This cement can resist the highest concentrations of sulphates.

## Chloride attack on concrete

Chloride attack on concrete is one of the important aspects of durability of concrete. It primarily affects the reinforcement of concrete and cause corrosion. Chlorides can be introduced into the concrete either during or after construction as follows.

* Before construction Chlorides can be admitted in admixtures containing calcium chloride, through using mixing water contaminated with salt water or improperly washed marine aggregates.
* After construction Chlorides in salt or sea water, in airborne sea spray and from de-icing salts can attack permeable concrete causing corrosion of reinforcement.

The chloride in the presence of water and oxygen reacts with alkaline protected layer around the reinforcement and removes it.



## Alkali-Aggregate reaction on concrete

Alkali aggregate reaction is the chemical reaction between alkali in cement and silica content of aggregates. Hence it can also be called as Alkali Silica reaction. When this reaction takes place, a gel like substance is formed which absorbs water and volume of concrete will increase. This increasing volume develops cracking and disintegration of concrete.

Alkali Silica reaction only occurs when the following are present together:

* Concrete with high moisture level.
* When cement contains high alkali content in it.
* Aggregate with Alkali reactive constituents.



### Precautions

The standard recommends that the following precautions be taken if uncertainty exists:

* Reduce the Saturation of concrete.
* Usage of Low alkali Portland cement.
* Use replacement cementitious materials such as blast furnace slag or pulverized fuel ash. Most normal aggregates behave satisfactorily.

## Carbonation in concrete

When the carbon dioxide from the atmosphere penetrates into concrete and reacted with calcium hydroxide to form calcium carbonate then this process is called carbonation.

In general concrete with high alkali content form a protective layer around the reinforcement. But when the carbon dioxide changes into dilute carbonic acid it reduces the alkalinity as a result the corrosion of reinforcement takes place.



## Acid attack on concrete

Acids can attack concrete easily since concrete is not fully resistant against acids. Some acids like oxalic acid, phosphoric acids are not harmful to the concrete. Calcareous aggregates are more affected by acids while siliceous aggregates are good resistant.

The damage level is purely depends upon the pH of the acid solution. Damage is very severe if the pH value is very low. If they reach reinforcement through crack or pores, they will cause corrosion of bars and cracking of concrete will occur.



### Prevention of acid attack

To prevent acid attack good dense concrete with adequate cover is required and sulphate-resistant cements should be used.

**CERAMICS AND BRICKS**

**History and evolution of ceramics,**

The word ceramic is derived from the greek term keramos, which means “potter’s clay” and keramikos means “clay products”. Till 1950s, the most important types of ceramics were the traditional clays, made into pottery, bricks, tiles etc. **A ceramic material is an inorganic, non-metallic material and is often crystalline**. Traditional ceramics are basically clays. The earliest application was in pottery. Most recently, different types of ceramics used are alumina, silicon carbide etc. Latest advancements are in the bio-ceramics with examples being dental implants and synthetic bones

**Manufacture of ceramics,**

Ceramics generally start with a clay-based material dug from the ground that's mixed with water (to make it soft and flexible) and other materials, squashed into shape, then fired at high-temperature in a large industrial oven called a kiln. Firing is what most ceramics have in common. These four basic processes—digging the raw material from the ground, adding water, shaping, and firing—have been used to make ceramics for thousands of years.

**Properties**

* High melting points (so they're heat resistant).
* Great hardness and strength and more durable.
* Low electrical and thermal conductivity (they're good insulators).
* Chemical inert (they're unreactive with other chemicals).

**Applications of ceramics in buildings,**

* Pottery, floor and roof tiles, bricks, cookware, sanitary ware
* Used for decorative purposes.
* As low conductance so used as temperature control material.
* Fire clay is used in refractory (high-temperature) bricks and cement.
* Used in Inner lining of furnance.
* High temperature applications such as lining material in furnaces
* Common clay is mostly used for bricks, cement, and aggregate
* Bentonite has a variety of industrial uses, including drilling mud and foundry sand
* Ball clay is a high quality clay prized for its use in ceramics, sanitaryware, and wall and floor tiles

**BRICKS**

A small hard block of backed clay used to build structures**.**

**History and evolution of bricks**

Bricks are one of the oldest known construction materials dating back to 7000BC. The first bricks were sun dried mud bricks, But because of more weather resistance of fired bricks, they were used in majority of constructions afterwords.

Modern machinery has made brick construction much more productive and efficient. Modern bricks can be made from clay, calcium silicate and concrete.

**Properties and applications of bricks**

Following are the desired properties of good quality bricks

* High compressive strength
* When prepared properly, brick can resist heavy fire up to 6 hours.
* Bricks should have a uniform rectangular size, with sharp and straight edges. Standard size is 9”\*4.5”\*3”.
* Standard brick should be well burnt with uniform color.
* Bricks must be hard enough. Check is to scratch it with finger.
* The brick should have pre-compacted and uniform texture and a broken surface must not show any cracks or holes.
* The brick must have a proper frog (depression in middle) so that mortar can be properly filled and result in good bonding. The standard frog size is 100mm length, 40mm width, 100 depth
* Bricks must be durable against any harsh weathers.

The Applications of bricks in buildings are,

* Structural use such as foundations, walls and floors.
* Construction of arches
* Construction of retaining walls
* Broken bricks are used as aggregates in concrete
* Decorative material
* Pavement construction
* Shock absorbing material
* For heat insulation in slabs

**Manufacture of bricks**

**The traditional way**

Bricks are made from clay where bricks are first molded and then dried until they get hardened. It consists of following stages

1. Clay get mix with water.
2. Moulding of bricks
3. Drying of bricks
4. Burning of bricks

**Classification of bricks**

1. **Concrete bricks**

Pale green or grey color, prepared from small sized aggregate concrete. Formed in steel moulds by vibration and compaction.

1. **High alumina bricks**

They contain 50 to 90 % alumina and high quality aggregates to be used in harsh temperature conditions.

Hard and glossary.

More resistance to temperature and weather.

Not need surface treatment.

1. **Fire bricks**

These are blocks of ceramic materials used in masonry construction. They have extreme weather, chemical and mechanical resistance.

1. **Light weight hollow blocks/bricks**

They are mostly used for construction in earthquake prone areas. They contain fly ash, cement and gypsum etc.

* Have high tensile strength because addition of steel bars.
* High temperature resistant.

Classification according to construction

**Un-burnt brick:**

They are sun dried bricks used for cheap construction and for filling works.

**Burnt bricks:**

1. First class bricks

They have deep red or copper color and have crushing strength equal to 2000 psi.

1. Second class bricks

They are slightly over burnt and must give clear ringing sound when struck together. The minimum crushing strength is 1500 psi. They might have slight irregularities in shape and sizes.

1. 3rd class bricks

They might be slightly under burnt or over burnt. They are not uniform in shape and size. Strength equal to 1000psi. If immersed in cold water, they shall not absorb water more than 25% or their dry weight after 24 hours.

1. 4th class bricks

They are over burnt bricks with irregular shape and size. They are used as aggregates in concrete and flooring. They are not used for building construction.

Used for filling purposes and in surkhi mortar.