**UNIT - II**

**BUILDING MATERIALS-II**

**ORDINARY & SPECIAL CEMENTS**

**CEMENT:**

Cement in its broadest term means, any substance which acts as a binding agent for materials. Natural cement (Roman Cement) is obtained by burning and crushing the stones containing clay, carbonates of lime and some amount of carbonate of magnesia. The clay content in such stones is about 20 to 40 percent. Natural cement resembles very closely eminent hydraulic lime. It is not strong as artificial cement, so it has limited use in practice.

 Artificial cement is obtained by burning at very high temperature a mixture of calcareous and argillaceous materials in correct proportion. Calcined product is known as clinker. A small quantity of gypsum is added to clinker and it is then pulverized into very fine powder is known as cement. Cement was invented by a mason Joseph Aspdin of Leeds in England in 1824. The common variety of artificial cement is known as normal setting cement or ordinary cement or Portland cement.

**USES:**

* 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.

**INGREDIENTS- FUNCTIONS:**

Ordinary Portland cement contains two basic ingredients, namely argillaceous and calcareous. In argillaceous materials, clay predominates and in calcareous materials, calcium carbonate predominates. Good ordinary cement contains following ingredients.

1. Lime (Cao) – 62%
2. Silica (Sio2) – 22%
3. Alumina (Al2o3) – 5%
4. Calcium Sulphate (CaSo4) – 4%
5. Iron oxide (Fe2O3) – 3%
6. Magnesia (Mgo) – 2%
7. Sulphur – 1%
8. Alkalies – 1%

Functions of ingredients are,

* **Lime**: Lime is an important ingredient of cement and its proportion isto be maintained carefully. Lime in excess makes the cement unsound and causes the cement to expand and disintegrate. On the other hand, if lime is in deficiency the strength of the cement is decreased and it causes cement to set quickly.
* **Silica**: This also an important ingredient of cement and it gives orimparts quick setting property, which imparts strength to cement.
* **Alumina**: This ingredient imparts quick setting property to cement. Excess alumina weakens the cement.
* **Calcium Sulphate**: This ingredient will be in the form of gypsum and itsfunction is to increase the initial setting time of cement.
* **Magnesia**: Small amount of this ingredient imparts hardness andcolor to cement.
* **Sulphur**: A very small amount of sulphur is useful in making soundcement. If it is in excess, it causes the cement to become unsound.
* **Alkalies**: Most of the alkalies present in raw material are carried awayby the flue gases during heating and only small quantity will be left. If they are in excess in cement, efflorescence is caused.

**TYPES OF CEMENTS:**

In addition to ordinary cement, the following are the other varieties of cement.

* **Acid Resistance Cement**: This is consists of acid resistance aggregates such as quartz, quartzite, etc., additives such as sodium fluro silicate (Na2SiO6) and aqueous solution of sodium silicate. This is used for acid-resistant and heat resistant coating for installations of chemical Industry. By adding 0.5 percent of unseed oil or 2 percent of ceresin, its resistance to water is increased and known as acid water resistant cement.
* **Blast Furnace Cement:** For this cement slag as obtainedfrom blast furnace in the manufacture of pig iron is used. Slag contains basic elements of cement, namely alumina, lime and silica. The properties of this cement are more or less the same as those of ordinary cement and prove to be economical as the slag, which is waste product, is used in its manufacture.
* **Coloured Cement:** Cement of desired colour may beobtained by intimately mixing mineral pigments with ordinary cement. The amount of colouring may vary from 5 to 10 percent. It effects the strength of cement if it exceeds 10 percent. Chromium oxide gives brown, red or yellow for different proportions. Coloured cements are used for finishing of floors, external surfaces, artificial marble, windows
* **Expanding Cement :** This type of cement is produced byadding an expanding medium like sulpho – aluminate and a stabilizing agent to ordinary cement. Hence this cement expands where as other cement shrinks. Expanding cement is used for the construction of water retaining structures and also for repairing the damaged concrete surfaces.
* **High alumina Cement:** This cement is produced bygrinding clinkers formed by calcining bauxite and lime. The total content should not be less than 32 percent and the ratio by weight of alumina to lime should be between 0.85 and 1.30. Advantages of this cement are,
* Initial setting time is about 31/2 hours therefore, allows more time for mixing and placing operations
* It can withstand high temperatures.
* It evolves great heat during setting therefore not affected by frost.
* It resists the action of acids in a better way.
* It lets quickly and attains higher ultimate strength.

 Disadvantages are,

* It is costly
* It cannot be used in mass construction as it evolves great heat and as it sets soon.
* Extreme care is to taken to see that it does not come in contact with even traces of lime or ordinary cement.
* **Hydrophobic Cement:** This type of cement contains admixtures,which decreases the wetting ability of cement grains. The usual hydrophobic admixtures are acidol napthene soap, oxidized petrolatum etc., when hydrophobic cement is used, the fine pores in concrete are uniformly distributed and thus the frost resistance and the water resistance of such concrete are considerably increased.
* **Low Heat Cement:** Considerable heat is produced during thesetting action of cement. In order to reduce the amount of heat, this type of cement is used. It contains lower percentage of tri calcium aluminates C3A and higher percentage of dicalcium silicate C2s. This type of cement is used for mass concrete works.
* **Pozzolona Cement:** Pozzolona is a volcanic powder and thepercentage should be between 10 to 30.

**Advantages are,**

* It attains compressive strength with age.
* It can resist action of sulphates.
* It evolves less heat during setting.
* It imparts higher degree of water tightness.
* It imparts plasticity and workability to mortar and concrete prepared from it.
* It offers great resistance to expansion
* It possesses higher tensile strength

**Disadvantages are,**

* Compressive strength in early days is less.
* It possesses less resistance to erosion and weathering action.
* **Quick Setting Cement:** This cement is prepared by adding a small percentage of aluminum sulphate which reduce the percentage of gypsum which retards setting action and thus accelerates the setting action of cement.. This cement is used to lay concrete under static water or running water.
* **Rapid Hardening cement:** This cement has same initial andfinal setting times as that of ordinary cement. But it attains high strength in early days due to burning at high temperature, increased lime content in cement composition, very fine grinding.

**Advantages:**

* Construction work may be carried out speedily.
* Formwork of concrete can be removed earlier.
* It is light in weight.
* It is not damaged easily.
* This cement requires short period of curing.
* Use of this cement also higher permissible stresses in the design.
* Structural member constructed with this cement may be loaded earlier.
* **Sulphate Resisting Cement:** In this cement percentage oftricalcium aluminate is kept below 5 to 6 percent and it results in the increase in resisting power against sulphate. This cement is used for structure which are likely to be damaged by sever alkaline condition such as canal linings, culverts, siphons etc.
* **White Cement:** This is a variety of ordinary cement and it isprepared form such raw materials which are practically free from colouring oxides of Iron, manganese or chromium. For burning of this cement, oil fuel is used instead of coal. It is used for floor finish; plaster work, ornamental works etc.

**Manufacture of Cement**

Manufacturing of cement involves various raw materials and processes. Each process is explained chemical reactions for manufacture of Portland cement.Cement is a greenish grey colored powder, made of calcined mixtures of clay and limestone. When mixed with water becomes a hard and strong building material.



**Manufacturing of cement**

The history of cement goes back into Roman Empire. The modern day cement. That is Portland cement was first produced by a British stone mason, Joseph Aspdin in 1824, who cooked cement in his kitchen. He heated a mixture of limestone and clay powder in his kitchen, and grind the mixture into powder creating cement, that hardens when mixed with water. The name Portland was given by the inventor as it resembles a stone quarried on the Isle of Portland.The first use of modern day Portland cement was in the tunnel construction in the Thames River in 1828.

**Manufacture Process of Cement**

The manufacture procedures of Portland cement is described below.

1. Mixing of raw material
2. Burning
3. Grinding
4. Storage and packaging

**1. Mixing of raw material**

The major raw materials used in the manufacture of cement are Calcium, Silicon, Iron and Aluminum. These minerals are used in different form as per the availability of the minerals.

Table shows the raw materials for Portland cement manufacture



The mixing procedure of the manufacture of cement is done in 2 methods,

* Dry process
* Wet process

#### a) Dry Process

The both calcareous and argillaceous raw materials are firstly crushed in the gyratory crushers to get 2-5cm size pieces separately. The crushed materials are again grinded to get fine particles into ball or tube mill.

Each finely grinded material is stored in hopper after screening. Now these powdered minerals are mixed in required proportion to get dry raw mix which is then stored in silos and kept ready to be sent into rotary kiln. Now the raw materials are mixed in specific proportions so that the average composition of the final product is maintained properly.



 **Fig: Manufacture of Cement by Dry Process**

#### b) Wet Process

The raw materials are firstly crushed and made into powdered form and stored in silos. The clay is then washed in washing mills to remove adhering organic matters found in clay.

The powdered limestone and water washed clay are sent to flow in the channels and transfer to grinding mills where they are completely mixed and the paste is formed, i.e., known as slurry.

The grinding process can be done in ball or tube mill or even both. Then the slurry is led into collecting basin where composition can be adjusted. The slurry contains around 38-40% water that is stored in storage tanks and kept ready for the rotary kiln.



 **Fig: Manufacture of Cement by wet Process**

### Comparison of dry process and wet process of Cement Manufacture

|  |  |  |
| --- | --- | --- |
| **Criteria** | **Dry process** | **Wet process** |
| **Hardness of raw material** | Quite hard | Any type of raw material |
| **Fuel consumption** | Low | High |
| **Time of process** | Lesser | Higher |
| **Quality** | Inferior quality | Superior quality |
| **Cost of production** | High | Low |
| **Overall cost** | Costly | Cheaper |
| **Physical state** | Raw mix (solid) | Slurry (liquid) |

### 2. Burning of Raw Materials

The burning process is carried out in the rotary kiln while the raw materials are rotated at 1-2rpm at its longitudinal axis. The rotary kiln is made up of steel tubes having the diameter of 2.5-3.0 meter and the length differs from 90-120meter. The inner side of the kiln is lined with refractory bricks.

The kiln is supported on the columns of masonry or concrete and rested on roller bearing in slightly inclined position at the gradient of 1 in 25 to 1 in 30. The raw mix of dry process of corrected slurry of wet process is injected into the kiln from the upper end. The kiln is heated with the help of powdered coal or oil or hot gases from the lower end of the kiln so that the long hot flames is produced.

As the kiln position is inclined and it rotates slowly, the material charged from upper end moves towards lower end at the speed of 15m/hr. In the upper part, water or moisture in the material is evaporated at 400oC temp, so this process is known as Drying Zone.

The central part i.e. calcination zone, the temperature is around 10000C, where decomposition of lime stone takes place. The remaining material is in the form of small lumps known as nodules after the CO2 is released.

CaCO3 = CaO + CO2

The lower part (clinkering zone) have temperature in between 1500-17000C where lime and clay are reacts to yielding calcium aluminates and calcium silicates. This aluminates and silicates of calcium fuse to gather to form small and hard stones are known as clinkers. The size of the clinker is varies from 5-10mm.

The lower part i.e. clinkering zone has the temperature around 1500-1700C. In the region lime and clay reacts to yield calcium aluminates and calcium silicates. This products of aluminates and silicates of calcium fuses together to form hard and small stones known as clinkers. The size of the small and hard clinkers varies from 5 to 10mm.

2CaO + SiO2 = Ca2SiO4(declaim silicate (C2S))

3CaO + SiO2 = Ca3SiO5 (tricalcium silicate (C3S))

3CaO + Al2O3= Ca3Al2O6 (dicalcium aluminate (C2A))

4CaO + Al2O3 + Fe2O3 = Ca4Al2Fe2O10 (tetracalcium aluminoferrite(C4AF))

The clinker coming from the burning zone are very hot. To bring down the temperature of clinkers, air is admitted in counter current direction at the base of the rotary kiln. The cooled clinkers are collected in small trolleys.

### 3. Grinding of Clinkers

The cooled clinkers are received from the cooling pans and sent into mills. The clinkers are grinded finely into powder in ball mill or tube mill. Powdered gypsum is added around 2-3% as retarding agent during final grinding. The final obtained product is cement that does not settle quickly when comes in contact with water.

After the initial setting time of the cement, the cement becomes stiff and the gypsum retards the dissolution of tri-calcium aluminates by forming tricalcium sulfoaluminate which is insoluble and prevents too early further reactions of setting and hardening.

3CaO.Al2O3 + xCaSO4.7H2O = 3CaO.Al2O3.xCaSO4.7H2O

### 4. Storage and packaging

The grinded cement is stored in silos, from which it is marketed either in container load or 50kg bags.

**PLAIN CEMENT CONCRETE (PCC)**

**Plain Cement Concrete (PCC)** is a construction material generally used as a binding materials and is composed of cement, (commonly Portland Cement) and other cementitious materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of gravels or crushed rocks such as limestone or granite, plus a fine aggregate such as sand), water, and chemical admixtures.

**Specifications for Plain Cement Concrete (PCC)**

**Materials Specifications**

**Aggregate** shall be of invert materials and should be clean, dense, hard, sound, durable, non-absorbent and capable of developing good bond with mortar.

**Coarse aggregate** shall be of hard broken stone of granite or similar stone, free from dust, dirt and other foreign matters. The stone ballast shall be of 20mm size and smaller. All the coarse material should be retained in a 5mm square mesh and should be well graded such that the voids do not exceed 42%.

**Fine aggregate** shall be of coarse sand consisting of hard, sharp and angular grains and shall pass through a screen of 5mm square mesh. Sand shall be of standard specifications, clean and free from dust, dirt and organic matter. Sea sand shall not be used.

**Cement shall be fresh Portland cement of standard ISI specifications** and shall have the required tensile and compressive stresses and fineness.

**Water** shall be clean and free from alkaline and acid matters and suitable for drinking purposes.

**Thickness of PCC:**
The thickness of PCC is normally 50mm over Brick Flat Soling (BFS). If we don’t use BFS below PCC then the thickness should be 75­mm. when the PCC is used in car park area then the thickness should be 75mm over BFS.

**Proportion Specifications**

1:2:4 (cement : sand : stone ballast) by volume when specified. Minimum compressive strength of concrete of 1:2:4 proportion shall be 140 kg/cm2 in 7 days.

**Hand mixing**

Mixing shall be done on masonry platform or sheet iron tray.

**Machine mixing**

Stone ballast, sand and cement shall be put into cement concrete mixer to have the required proportions.

**Slump**

Regular slump test should be carried out to control the addition of water and to maintain the required consistency. A slump of 7.5cm to 10cm may be allowed for building work.

**Formwork**

Formwork centering and shuttering shall be provided as required as per the standard specification before laying concrete to confine to support or to keep the concrete in position. The inner surface of shuttering shall be oiled to prevent concrete sticking to it.

**Laying Technique**

Concrete shall be laid gently (not thrown) in layers not exceeding 15cm and compacted by pinning with rods and tamping with wooden tampers or with mechanical vibrating machine until a dense concrete is obtained.

**Placing and Compaction of PCC:**

* Make sure brick soling/sand bed level for PCC is ok.
* Make form work for PCC with wooden plank as per specified dimentions.
* Clean dust or foreign or loose earth from concreting area.
* Spread polythene over the bed of PCC.
* Make level pillars of fresh concrete in the area at suitable intervals but not more than 2m c/c both ways.
* Place the concrete gently (don’t through) from one side. Use the mixed concrete within 45 minutes after the water is added.
* Use wooden rammer for compaction and finishing of PCC.
* Make the surface of PCC roughen for joining future work before the concrete become harden.

**Curing Method**

After about two hours of laying of concrete, when the concrete has begun to harden, it shall be kept damp by covering with wet gunny bags or wet sand for 24 hours.

Plain cement concrete (PCC) is used to provide rigid impervious bed to RCC in foundation where the earth is soft and yielding. PCC can be used over brick flat soling or without brick flat soling.

Plain cement concrete can also called only "cement concrete (CC)" or "binding concrete".

**Checking and Inspection:**

* Check the dimensions of form work of PCC before mixing concrete.
* Check polythene sheet is laid over PCC bed.
* Check the concrete slump (maximum slump should be 75mm)
* Check the thickness level of PCC before casting by putting steel pegs in concreting area or putting level pillar of fresh concrete at suitable distance.
* Check the finish level of PCC by thread fixing with nails in form work.
* Inspect if the concrete is placing gently.

**REINFORCED CEMENT CONCRETE (R.C.C.)**

Reinforced cement concrete (R.C.C.)  is the above said mixture of cement concrete with addition of reinforced to it. As started above, the plain concrete is weak in tension, so steel reinforcement is added to make it strong both in compression and tension. The resulting product of cement, aggregate, water and steel reinforcement is called Reinforced cement concrete. The cementing materials i.e., cement used for the R.C.C. is generally the port-land cement.

**2. Materials used for Reinforced Cement Concrete (R.C.C.)**

As discussed above, the materials used for R.C.C. are cement, fine aggregate, coarse aggregate, water and steel reinforcement in shape of bars.

* **Cement:** Cement is used as building material. Generally, port-land cement conforming to I.S.I. specification is used.
* **Fine Aggregate:**Aggregates are obtained from sedimentary igneous and metamorphic rocks. The aggregate which passes through IS Sieve No.480 is called fine aggregate. The particle size of this 8%. Fine aggregate is generally known as sand. It is obtained from the river beds, lake beds, pits etc. It should be free from silt, clay, salts and other organic matter.
* **Coarse Aggregate:** The aggregates which is retained over IS sieve No. 480 is called coarse aggregate. The size of this aggregate depends upon the type and nature of work. The maximum size used in the construction of building work should be between  20 mm to 25 mm. In the case of heavy mass concrete work for dams, weirs, syphons regulators etc., The size of aggregate may be more than 25 mm. It should be soft, porous, or flaky. It should not absorb more than 5% of water by weight when immersed for 24 hours.
* **Water:** The water used for making concrete should be free from dirt, organic impurities, sulphur contamination and chlorides which cause eflorescence. The clear water used for drinking purposes should be used. Sea water contains chlorides which may corrode reinforcement hence it should be avoided.
* **Reinforcement:** Steel is used as reinforcement which should be free from loose mill scales, dust, loose rust and coats of paints, oil or other coatings which may destroy or reduce bond. Round bars of mild steel between 5 mm to 50 mm diameters having high tensile strength should be used. Steel is used as reinforcement because its co-efficient of expansion is nearly same as that of concrete and can develop good bond with concrete and can be freely available.

**3. Advantages of Reinforced Cement Concrete (R.C.C.)**

Reinforced cement concrete (R.C.C.) has following advantages:

* It is easy to make.
* It can be molded to any desired shape.
* The materials for its preparation are easily available.
* It is durable.
* It is fire resisting.
* It can be made water-tight by using proper proportions of mix.
* It is more rigid.
* It has low maintenance cost.
* It can be used under water.

**Uses of R.C.C.**

1. R.C.C. is used as a structural member wherever bending of the member is expected. Thecommon structural elements in a building where R.C.C. is used are:

(a) Footing

(b) Columns

(c)  Beams, lintels

(d)  Chejjas, roof slabs

(e)  Stairs.

2. R.C.C. is used for the construction of storage structures like:

(a)  Water tanks

(b)  Dams

(c)  Silos, bunkers

3. They are used for the construction of

(a)  Bridges

(b)  Retaining walls

(c)  Docks and harbours

(d)  Under water structures

4. R.C.C. is used for building tall structures like

(a)  Multistorey buildings

(b)  Chimneys

(c)  Towers.

5. R.C.C. is used for paving

(a)  High ways

(b)  City roads

(c)  Airports.

6.R.C.C. is used in atomic plants to prevent radiation. For this purpose R.C.C. walls built

are as thick as 1.5 m to 2.0 m.

**CONCRETE**

Concrete is a composite material composed mainly of water, aggregate, and cement. Often, additives and reinforcements are included in the mixture to achieve the desired physical properties of the finished material. When these ingredients are mixed together, they form a fluid mass that is easily molded into shape. Over time, the cement forms a hard matrix which binds the rest of the ingredients together into a durable stone-like material with many uses.

The aim is to mix these materials in measured amounts to make concrete that is easy to: Transport, place, compact, finish and which will set, and harden, to give a strong and durable product. The amount of each material (ie cement, water and aggregates) affects the properties of hardened concrete.

**Production of concrete**

A good quality concrete is essentially a homogeneous mixture of cement, coarse and fineaggregates and water which consolidates into a hard mass due to chemical action between the cement and water. Each of the four constituents has a specific function. The coarser aggregate acts as a filler. The fine aggregate fills up the voids between the paste and the coarse aggregate. The cement in conjunction with water acts as a binder. The mobility of the mixture is aided by the cement paste, fines and nowadays, increasingly by the use of admixtures.The stages of concrete productionare:Batching or measurement of materials, Mixing, Transporting, Placing, Compacting, Curing andFinishing.

***Batching***

It i s the process of measuring concrete mix ingredients either by volume or by mass and introducing them into the mixture. Traditionally batching is done by volume but most specifications require that batching be done by mass rather than volume.The proportions of various ingredients are determined by proper mix design.

A concrete mix is designed to produce concrete that can be easily placed at the lowest cost. The concrete must be workable and cohesive when plastic, then set and harden to give strong and durable concrete. The mix design must consider the environment that the concrete will be in; ie exposure to sea water, trucks, cars, forklifts, foot traffic or extremes of hot and cold. Proportioning concrete is a mixture of cement, water, coarse and fine aggregates and admixtures. The proportions of each material in the mixture affects the properties of the final

hardened concrete. These proportions are best measured by weight. Measurement by volume is not as accurate, but is suitable for minor projects.

Cement content as the cement content increases, so does strength and durability. Therefore to increase the strength, increase the cement content of a mix. WaterContent adding more water to a mix gives a weaker hardened concrete. Always use as little water as possible, only enough to make the mix workable.Water to cement ratio as the water to cement ratio increases, the strength and durability of hardened concrete decreases. To increase the strength and durability of concrete, decrease the water-cement ratio.Aggregates too much fine aggregate gives a sticky mix. Too much coarse aggregate gives a harsh or boney mix.Mixing concrete must be mixed so the cement, water, aggregates and admixtures blend into an even mix. Concrete is normally mixed by machine. Machine mixing can be done on-site or be a pre-mixed concrete company. Pre-mixed concrete is batched (proportioned) at the plant to the job requirements. Truck mixing the materials are normally added to the trucks at batching plants and mixed for required time and speed at the plant. The trucks drum continues to rotate to agitate the concrete as it is delivered to the site. Site mixing when site mixing begin by loading a measured amount of coarse aggregate into the mixer drum. Add the sand before the cement, both in measured amounts.

***Mixing***

The mixing operation consists of rotation or stirring, the objective being to coat the surface the all aggregate particles with cement paste, and to blind all the ingredients of the concrete into a uniform mass; this uniformity must not be disturbed by the process of discharging from the mixer. The mixing may done by manually or by mechanical means like, Batch mixer, Tilting drum mixer, Non tilting drum mixer, Pan type mixer, Dual drum mixer or Continuous mixers.

There are no general rules on the order of feeding the ingredients into the mixer as this depend on the properties of the mixer and mix. Usually a small quantity of water is fed first, followed by all the solids materials. If possible greater part of the water should also be fed during the same time, the remainder being added after the solids. However, when using very dry mixes in drum mixers it is necessary to feed the coarse aggregate just after the small initial water feed in order to ensure that the aggregate surface is sufficiently wetted.

***Compaction***

The operation of placing and compaction are interdependent and are carried out simultaneously. They are most important for the purpose of ensuring the requirements of strength, impermeability and durability of hardened concrete in the actual structure. As for as placing is concerned, the main objective is to deposit the concrete as close as possible to its final position so that segregation is avoided and the concrete can be fully compacted. The aim of good concrete placing can be stated quite simply.

It is to get the concrete into position at a speed, and in a condition, that allow it to be compacted properly. To achieve proper placing following rules should be kept in mind:The concrete should be placed in uniform layers, not in large heaps or sloping layers.The thickness of the layer should be compatible with the method of vibration so that entrapped air can be removed from the bottom of each layer.The rate of placing and of compaction should be equal. If you proceed too slowly, the mix could stiffen so that it is no longer sufficiently workable. On no account should water ever be added to concrete that is setting. On the other hand, if you go too quickly, you might race ahead of the compacting gang, making it impossible for them to do their job properly. Each layer should be fully compacted before placing the next one, and each subsequent layer should be placed whilst the underlying layer is still plastic so that monolithic construction is achieved. Collision between concrete and formwork or reinforcement should be avoided.For deep sections, a long down pipe ensures accuracy of location of concrete and minimum segregation.You must be able to see that the placing is proceeding correctly, so lighting should be available for large, deep sections, and thin walls and columns.Once the concrete has been placed, it is ready to be compacted. The purpose of compaction is to get rid of the air voids that are trapped in loose concrete.

It is important to compact the concrete fully because:Air voids reduce the strength of the concrete. For every 1% of entrapped air, the strength falls by somewhere between 5 and 7%. This means that concrete containing a mere 5% air voids due to incomplete compaction can lose as much as one third of its strength.Air voids increase concrete's permeability. That in turn reduces its durability. If the concrete is not dense and impermeable, it will not be watertight. It will be less able to withstand aggressive iquids and its exposed surfaces will weather badly.Moisture and air are more likely to penetrate to the reinforcement causing it to rust. Air voids impair contact between the mix and reinforcement (and, indeed, any other embedded metals). The required bond will not be achieved and the reinforced member will

not be as strong as it should be.Air voids produce blemishes on struck surfaces. For instance, blowholes and honeycombing might occur. There are two methods for compaction which includes: vibration by vibrators or by tamping using tamping rods.

***Curing***

Curing is the process of making the concrete surfaces wet for a certain time period after placing the concrete so as to promote the hardening of cement. This process consists of controlling the temperature and the movement of moisture from and into the concrete.

Curing of concrete is done for the following purposes. Curing is the process of controlling the rate of moisture loss from concrete to ensure an uninterrupted hydration of Portland cement after concrete has been placed and finished in its final position.Curing also helps maintain an adequate temperature of concrete in its early stages, as this directly affects the rate of hydration of cement and eventually the strength gain of concrete or mortars.

Curing of concrete must be done as soon as possible after placement and finishing and must continue for a reasonable period of time, for the concrete to achieve its desired strength and durability.Uniform temperature should be maintained throughout the concrete depth to avoid thermal shrinkage cracks.

Material properties are directly related to micro-structure. Curing assists the cement hydration reaction to progress steadily and develops calcium silicate hydrate gel, which binds aggregates leading to a rock solid mass,makes concrete denser, decreases the porosity and enhances the physical and mechanical properties of concrete.

Some other purposes of curing can be summed up as: curing protects the concrete surfaces from sun and wind, the process of curing increase the strength of the structure, the presence of water is essential to cause the chemical action which accompanies the setting of concrete. Generally there is adequate quantity of water at the time of mixing to cause the hardening of concrete,but it is necessary to retain water until the concrete is fully hardened.

If curing is efficient, the strength of concrete gradually increases with age. This increase in strength is sudden and rapid in early stages and it continues slowly for an indefinite period.By proper curing, the durability and impermeability of concrete are increased and shrinkage is reduced.The resistance of concrete to abrasion is considerably increased by proper curing.

***Curing period:***

For ordinary Portland cement, the curing period is about 7 days to 14 days.If rapid hardening cement is used the curing period can be considerably reduced.

***Disadvantages of improper curing:***

Following are the disadvantages of improper curing of concrete:

The chances of ingress of chlorides and atmospheric chemicals are very high.The compressive and flexural strengths are lowered.The cracks are developed due to plastic shrinkage, drying shrinkage and thermal effects.The durability decreases due to higher permeability.The frost and weathering resistances are decreased.The rate of carbonation increases.The surfaces are coated with sand and dust and it leads to lower the abrasion resistance.The disadvantages are more prominent in those parts of surfaces which are directly exposed or which have large surfaces compared to depth such as roads, canal, bridges, cooling towers, chimneys etc.

***Factors affecting evaporation of water from concrete:***

The evaporation of water depends upon the following 4 factors: Air temperature, Fresh concrete temperature, Relative humidity and Wind velocity.

From the above mentioned factors it can be concluded environment directly influences the process of evaporation, hence only the fresh concrete temperature can be monitored or supervised by the concrete technologists.The evaporation of water in the first few hours can leave very low amount of water in the concrete hydration, this leads to various shrinkage cracks.Under normal condition the average loss of water varies from 2.5 to 10 N per m2 per hour.The major loss occurs in the top 50 mm layer over a period of 3 hours, the loss could be about 5% of the total volume of that layer.

***Methods of curing:***

While selecting any mode of curing the following two factors are considered:

* The loss of water should be prevented.
* The temperature should be kept minimum for dissipation of heat of hydration.

Methods of curing can be categorised into the following categories:

Water curing-preventing the moisture loss from the concrete surface by continuously wetting the exposed surface of concrete.

Membrane curing-minimizing moisture loss from concrete surface by covering it with an impermeable membrane.

Steam curing-keeping the surface moist and raising the temperature of concrete to accelerate the rate of strength gain.

Water curing is of the following types:

***Ponding:*** most inexpensive and common method of curing flat slabs, roofs, pavements etc. Adike around the edge of the slab, is erected and water is filled to create a shallow pond. Care must be taken to ensure that the water in the pond does not dry up, as it may lead to an alternate drying and wetting condition.

***Sprinkling:*** fogging and mist curing- using a fine spray or fog or moist of water to theconcrete can be efficient method of supplying water to concrete during hot weather, which helps to reduce the temperature of concrete.

***Wet coverings***: water absorbent fabrics may be used to maintain water on concrete surfaces.They must be continuously kept moist so as to prevent the fabrics from absorbing water from the body of concrete,due to capillary action.

Impermeable membrane curing is of following types:-

***Formwork:*** leaving the form work in place during the early age of concrete is an efficientmethod of curing.

***Plastic sheeting:*** plastic sheets form an effective barrier to control the moisture losses fromthe surface of concrete, provided they are secured properly and protected from damage. The efficiency of this system can be enhanced by flooding the concrete surface with water, under the plastic sheet.

***Membrane curing compounds:*** Curing compounds are wax, acrylic and water based liquidsare spread over the freshly finished concrete to form an impermeable membrane that minimises the loss of moisture from the concrete surfaces.These are cost effective methods of curing where standard curing procedures are difficult to adopt.When applied to cure concrete the time of the application is critical for maximum effectiveness.Too early application dilutes the membrane, whereas too late application results in being absorbed into the concrete.They

must be applied when the free water on the surface has evaporated.For concrete with low w/c ratio, this is not a suitable process.

***Steam curing***: Steam curing is the process of accelerating the early hardening of concrete andmortars by exposing it to steam and humidity. These types of curing systems are adopted for railway sleepers, concrete blocks, pipes, manhole covers, poles etc.Precast iron is cured by this method under pressure.Curing in hot and cold weather requires additional attention.

***Hot weather:*** During hot weather, concrete must be protected from excessive drying andfrom direct wind and sun. Curing materials which reflect sunlight to reduce concrete temperature must be used.

***Cold weather:*** Some problems associated with temperature below 400C are:

* Freezing of concrete before strength is developed.
* Slow development of concrete strength.
* Thermal stresses induced by the cooling of warm concrete to cooler ambient temperatures

***Chemical curing***: In this method water is sprinkled over the surface, after adding certainamount of some hygroscopic material (e.g. sodium chloride or calcium chloride). The hygroscopic materials absorb moisture from the atmosphere and thus keep the surface damp.

***Alternating current curing:*** Concrete can be cured by passing alternating current throughfreshly laid concrete.

**Water cement ratio and compressive strength**

A cement of average composition requires about 25% of water by mass for chemical reaction. In addition, an amount of water is needed to fill the gel pores. Nearly 100 years ago, Duff Abrams discovered the direct relationship between water-to-cement ratio and strength, i.e.,lesser the water used higher the strength of the concrete,since too much water leaves lots of poresin the cement past. According toAbram’s law, *the strength of fully compacted* *concrete at a given age and normal temperature is inversely proportional to the water – cement ratio.* Here the water-cement ratio is the relative weight of water to the cement in themixture. For most applications, water-to-cement ratio should be between 0.4 and 0.5 lower for lower permeability and higher strength. In concrete, the trade off, of course,is with workability, since very low water content result in very stiff mixtures that are difficult to place. The water-to-cement ratio is a factor selected by the civil engineer.

**Workability**

Workability is one of the physical parameters of concrete which affects the strength and durability as well as the cost of labor and appearance of the finished product. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e without bleeding or Segregation. Unworkable concrete needs more work or effort to be compacted in place, also honeycombs &/or pockets may also be visible in finished concrete.Definition of Workability “The property of fresh concrete which is indicated by the amount of useful internal work required to fully compact the concrete without bleeding or segregation in the finished product.”

***Factors affecting workability:***

* Water content in the concrete mix
* Amount of cement & its Properties
* Aggregate Grading (Size Distribution)
* Nature of Aggregate Particles (Shape, Surface Texture, Porosity etc.)
* Temperature of the concrete mix
* Humidity of the environment
* Mode of compaction
* Method of placement of concrete
* Method of transmission of concrete

***How to improve the workability of concrete***

* Increase water/cement ratio
* Increase size of aggregate
* Use well-rounded and smooth aggregate instead of irregular shape
* Increase the mixing time
* Increase the mixing temperature
* Use non-porous and saturated aggregate
* With addition of air-entraining mixtures

**Workability tests:**

There are 4 types of tests for workability.They are slump test, compacting factor test, flow test, and vee bee test

**Slump test**

The slump test result is a slump of the behavior of a compacted inverted cone of concrete under the action of gravity. It measures the consistency or the wetness of concrete.Metal mould, in the shape of the frustum of a cone, open at both ends, and provided with the handle, top internal diameter 4 in (102 mm), and bottom internal diameter 8 in (203 mm) with a height of 1 ft (305 mm). A 2 ft (610 mm) long bullet nosed metal rod, (16 mm) in diameter.Apparatus Required: Compacting Factor apparatus, Trowels, Graduated cylinder, Balance and Tamping rod and iron bucket

The test is carried out using a mould known as a slump cone or [Abrams](http://en.wikipedia.org/wiki/Duff_Abrams) **cone**. The cone is placed on a hard non-absorbent surface. This cone is filled with fresh concrete in three stages, each time it is tamped using a rod of standard dimensions. At the end of the third stage, concrete is struck off flush to the top of the mould. The mouldis carefully lifted vertically upwards, so as not to disturb the concrete cone. Concrete subsides. This subsidence is termed as slump, and is measured in to the nearest 5 mm if the slump is <100 mm and measured to the nearest 10 mm if the slump is >100 mm.

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.



This test is usually used in laboratory and determines the workability of fresh concrete when size is about 40 mm maximum. The test is carried out as per specification of IS: 1199-1959.

**Compacting factor test:**

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Steps for performing the experiment:

* keep the apparatus on the ground and apply grease on the inner surface of the cylinders.
* Measure the mass as w1 kg by weighing the cylinder accurately and fix the cylinder on the base in such a way that the central points of hoppers and cylinder lie on one vertical line and cover the cylinder with a plate.
* For each 5 kg of aggregate mixes are to be prepared with water-cement ratio by weight with 2.5 kg sand and 1.25 kg of cement and then add required amount of water thoroughly until and unless concrete appears to be homogeneous.
* With the help of hand scoop without compacting fill the freshly mixed concrete in upper hopper part gently and carefully and within two minutes release the trap door so that the concrete may fall into the lower hopper such that it bring the concrete into standard compaction.
* Fall the concrete to into the cylinder by bringing the concrete into standard Compaction immediately after the concrete has come to rest and open the trap door of lower hopper and then remove the excess concrete above the top of the cylinder by a pair of trowels, one in each hand will blades horizontal slide them from the opposite edges of the mould inward to the center with a sawing motion.
* Clean the cylinder from all sides properly. Find the mass of partially compacted concrete thus filled in the cylinder and say it W2 kg. After this refill the cylinder with the same sample of concrete in approximately 50 mm layers, by vibrating each layer heavily so as to expel all the air and obtain full compaction of the Concrete.
* Struck off level the concrete and weigh and cylinder filled with fully compacted concrete. Let the mass be W3 kg.
* Calculate compaction factor by using the formula: C.F = W2 – W1 / W3 – W1

**Flow Table Test:**

The flow table test or flow test is a method to determine the consistence of fresh [concrete.](http://en.wikipedia.org/wiki/Concrete)

Flow table with a grip and a hinge, 70 centimetres (28 in) square.Abrams cone, open at the top and at the bottom - 30 centimetres (12 in) high, 17 centimetres (6.7 in) top diameter, 25 centimetres (9.8 in) base diameter.Water bucket and broom for wetting the flow table.Tamping rod, 60 centimetres (24 in) longConducting the testTheflowtable is wetted.The cone is placed in the center of the flowtable and filled with fresh concrete in two equal layers layers. Each layer is tamped 10 times with tamping rod.Wait 30 seconds before lifting the coneThe cone is lifted, allowing the concrete to flow.The flowtable is then lifted up 40mm and then dropped 15 times, causing the concrete to flowAfter this the diameter of the concrete is measured.

**Vee-Bee Test:**

This test is useful for concrete having low and very low workability. In this test the concrete is moulded into a cone in a cylinder container and the entire set up is mounted on a vibrating table. When vibrator starts, concrete placed on the cone starts to occupy the cylindrical

container by the way of getting remoulded. Remoulding is complete when the concrete surface becomes horizontal. The time required for completion of remoulding since start of vibrator is measured and denoted as vee-bee seconds. This provides a measure for workability. Lesser is the vee-bee seconds more is the workability.

**MORTAR**

**Introduction:**

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 aggregates like sand. The two components of mortar namely the binding material and fine aggregates are sometimes referred to as matrix. The durability, quality and strength of mortar will mainly depend on 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.

**Properties & Uses:**

* The important properties of a good mortar mix are mobility, place ability and water retention.
* The mobility is used to indicate the consistency of mortar mix, which may range from stiff to fluid and it depends upon composition of mortar and mortar mixes to be used for masonry work, finishing works, etc.,
* The placeability 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 mortar. The placeablity 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 if retaining adequate humidity during the 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 in contact with the porous bed like brick, wood, etc., it gives away its water to that surface. Thus the mortar becomes poor and remaining water proves to be insufficient for its hardening. Hence required strength of mortar will not be achieved with such a mortar mix.

Properties of a good mortar are,

* It should be capable of developing good adhesion with the building units such as bricks, stones etc.
* It should be capable of developing the designed stresses.
* It should be capable of resisting penetration of rainwater.
* It should be cheap.
* It should be durable.
* It should be easily workable.
* It should not affect the durability of materials with which it comes into contact.

Uses are,

* To bind the building units such as bricks, stones etc.
* To carry out painting and plaster works on exposed surfaces of masonry
* To form an even bedding layer for building units
* To form joints of pipes
* To improve the appearance of structure.

**Types of Mortar:**

The mortar are classified on the basis of the following,

1. Bulk density
2. Kinds of binding material
3. Nature of application
4. Special mortar

**Bulk density:** According to bulk density of mortar in dry state, the mortars are two types

**a. Heavy mortars -** bulk density is more than 1500kg/m3 andprepared from heavy quartz

**b. Lightweight mortars** – bulk density is less than 1500/mg3and prepared from light porous sands.

**Kinds of binding Material:** According to the kinds of binding material, several factors such as expected working conditions, hardening, temperature, moisture conditions, etc., should be considered. The mortars are classified into four categories.

1. **Lime Mortar -** in this motor, lime is used as binding material.Lime may be fate lime or Hydraulic lime. Fat lime mortar 1:2 to 1:3 and hydraulic lime mortarmay be1:2 by volume
2. **Cement mortar:** In this mortar, cement is used as bindingmaterial. Depending upon the strength required and importance of work, the proportion of cement to sand varies from 1:2 to 1:6 or more.
3. **Gauged Mortar or composite mortar:** The process of adding cement to lime mortar to improve the quality of lime mortar is known as gauging. It makes lime mortar economical, strong and dense. The usual proportion of cement to lime by volume is about 1:6 to 1:8
4. **Gypsum mortar:** These mortars are prepared from gypsum binding material such as building gypsum and anhydrite binding materials.

**Nature of application:** According to the nature of application, the mortars are classified into two categories.

1. **Brick laying mortars:** Mortars for brick laying are intended tobe used for brick works and walls. Depending up on the working conditions and type of construction, the composition of masonry mortars with respect to the kind of binding materials is decided.
2. **Finishing Mortars:** these mortars include common plasteringwork and mortars for developing architectural or ornamental effects. Generally cement or lime is used as binding material.

**Special Mortars:**

1. **Fire resistant mortar-** This mortar is prepared by adding 1:2ratio of aluminous cement with crushed powder of fire bricks used for fire brick lining furnaces, fire places, ovens etc.
2. **Light weight mortar –** This mortar is prepared by addingsawdust, wood powder to lime or cement mortar for sound proof and heat proof construction
3. **Packing Mortar –** To pack of oil wells, special mortarspossessing the properties of high homogeneity, water resistance, predetermined setting time, ability to form solid water proof plugs in cracks and voids of rocks, resistance to subsoil water pressure etc. have to be formed with cement sand, cement loam and cement sand loam mortars.
4. **Sound absorbing mortars:** To reduce the noise level, soundabsorbing mortars with Portland cement, lime, gypsum, slag Portland cement etc as the binding materials employed in its composition. The aggregates re selected from lightweight porous material such as pumice, cinders etc.
5. **X-ray shielding mortar:** This type of mortar is used forproviding the plastering coat to walls and ceiling of x-ray cabinets. This is heavy mortar with bulk density over 2200kg/m3 is used. The aggregates are obtained from heavy rock and suitable admixture are added to enhance protective property of such a mortar.

**Preparation of Cement Mortar:**

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

 Cement mortar may be prepared by manual mixing or by mechanical mixing. Mechanical mixing is preferred when mortar is required in large quantities to be used in continuous order.

**Mixing in mechanical mixer:** In this case, cement andsand in desired proportion are fed in the mixer and mixed dry. Water is then added gradually and the wet mixing a continued for at least one minute to obtain the mortar of desired consistency. It is necessary to ensure that only the quantity of mortar which can be used within half an hour of its mixing should be prepared at a time. This is essential as after 30 minutes the mortar begins to set.

**Manual mixing:** In this case, specified quantity of sand isspread and leveled on clean dry masonry platform. Required quantity of cement bags are emptied over the sand layer. The ingredients are then mixed thoroughly by turning them over the sand layer. The ingredients are then mixed thoroughly by turning them over and over. Backward and forward several times with the help of spade. Dry mixing is continued till the mix have attains a uniform colour. A batch of dry mix is then put in the shallow masonry tank and just sufficient quantity of water is added to bring the mortar to the consistency of a paste. The quantity of dry mix taken in each batch should be such the mortar formed each time is consumed within half an hour.

**Precautions in using Mortar:**

**Consumption of Mortar:** The consumption of mortar should be as early as possible.

Lime mortar consumption within 36 hours after preparation, for Cement Mortar within 30 minutes, gauged mortar within 2 hours.

**Frost action** - Setting action of mortar is affected by the presenceof frost and not advisable in frosty weather.

**Soaking of building units:** Building units should not be soakedbefore application of mortar. If this precaution is not taken, water of mortar will be absorbed by the building units and mortar will become weak.

**Sprinkling of water:** The construction work carried out bymortar should be kept dam or wet by sprinkling water for about 7 to 10 days to avoid rapid drying of mortar.

**Workability:** Mortar should not contain excess water and itshould be stiff as can be conveniently used. Joints should be well formed and excess mortar from joints should be neatly taken off by a trowel. Surface formed by mortar for building units to rest should be even.

**ADMIXTURES OF CONCRETE**

A material other than water, aggregates, or cement that is used as an ingredient of concrete or mortar to control setting and early hardening, workability, or to provide additional cementing properties.

**Why is admixture used?**

Over decades, attempts have been made to obtain concrete with certain desired characteristics such as high compressive strength, high workability, and high performance and durability parameters to meet the requirement of complexity of modern structures.

The properties commonly modified are the heat of hydration, accelerate or retard setting time, workability, water reduction, dispersion and air-entrainment, impermeability and durability factors.

**Types of Admixtures**

1. Chemical admixtures - Accelerators, Retarders, Water-reducing agents, Super plasticizers, Air entraining agents etc.
2. Mineral admixtures - Fly-ash Blast-furnace slag, Silica fume and Rice husk Ash etc

1. **Water-reducing admixture / Plasticizers:**

These admixtures are used for following purposes:

1.To achieve a higher strength by decreasing the water cement ratio at the same workability as an admixture free mix.

2.To achieve the same workability by decreasing the cement content so as to reduce the heat of hydration in mass concrete.

3.To increase the workability so as to ease placing in accessible locations

4.Water reduction more than 5% but less than 12%

5.The commonly used admixtures are Ligno-sulphonates and hydrocarbolic acid salts.

6.Plasticizers are usually based on lignosulphonate, which is a natural polymer, derived from wood processing in the paper industry.

**Actions involved:**

1.Dispersion:

Surface active agents alter the physic chemical forces at the interface. They are adsorbed on the cement particles, giving them a negative charge which leads to repulsion between the particles. Electrostatic forces are developed causing disintegration and the free water become available for workability.

2.Lubrication:

As these agents are organic by nature, thus they lubricate the mix reducing the friction and increasing the workability.

3.Retardation:

A thin layer is formed over the cement particles protecting them from hydration and increasing the setting time. Most normal plasticizers give some retardation, 30–90 minutes.

**2. Super Plasticizers:**

These are more recent and more effective type of water reducing admixtures also known as high range water reducer.

The main benefits of super plasticizers can be summarized as follows:

**Increased fluidity:**

■Flowing

■Self-leveling

■Self-compacting concrete

■Penetration and compaction round dense reinforcement

**Reduced W/C ratio:**

■Very high early strength, >200% at 24 hours or earlier

■Very high later age strengths, >100 MPa or 15000 psi.

■Reduced shrinkage, especially if combined with reduced cement content.

■Improved durability by removing water to reduce permeability and diffusion.

The commonly used Super Plasticizers are as follows:

■Sulphonated melamine formaldehyde condensates (SMF)

Give 16–25%+ water reduction. SMF gives little or no retardation, which makes them very effective at low temperatures or where early strength is most critical. However, at higher temperatures, they lose workability relatively quickly. SMF generally give a good finish and are colorless, giving no staining in white concrete. They are therefore often used where appearance is important.

■Sulphonated naphthalene formaldehyde condensates (SNF)

Typically give 16–25%+ water reduction. They tend to increase the entrapment of larger, unstable air bubbles. This can improve cohesion but may lead to more surface defects. Retardation is more than with SMF but will still not normally exceed 90 minutes. SNF is a very cost-effective.

■Polycarboxylate ether superplasticizers (PCE)

Typically give 20–35%+ water reduction. They are relatively expensive per liter but are very powerful so a lower dose (or more dilute solution) is normally used.

In general the dosage levels are usually higher than with conventional water reducers, and the possible undesirable side effects are reduced because they do not markedly lower the surface tension of the water.

**3. Accelerators:**

An admixture which, when added to concrete, mortar, or grout, increases the rate of hydration of hydraulic cement, shortens the time of set in concrete, or increases the rate of hardening or strength development.

Accelerating admixtures can be divided into groups based on their performance and application:

**1.Set Accelerating Admixtures,**

Reduce the time for the mix to change from the plastic to the hardened state. Set accelerators have relatively limited use, mainly to produce an early set.

**2.Hardening Accelerators,**

Which increase the strength at 24 hours by at least 120% at 20ºC and at 5ºC by at least 130% at 48 hours. Hardening accelerators find use where early stripping of shuttering or very early access to pavements is required. They are often used in combination with a high range water reducer, especially in cold conditions.

Calcium chloride is the most effective accelerator and gives both set and hardening characteristics. However, is limited due to acceleration of corrosion of steel reinforcement and decrease resistance of cement paste in a sulfate environment. For this reason, it should not be used in concrete where any steel will be embedded but may be used in plain unreinforced concrete. Chloride-free accelerators are typically based on salts of nitrate, nitrite, formate and thiocyanate. Hardening accelerators are often based on high range water reducers, sometimes blended with one of these salts. Accelerating admixtures have a relatively limited effect and are usually only cost effective in specific cases where very early strength is needed for, say, access reasons. They find most use at low temperatures where concrete strength gain may be very slow so that the relative benefit of the admixture becomes more apparent.

In summary, a hardening accelerator may be appropriate for strength gain up to 24 hours at low temperature and up to 12 hours at ambient temperatures. Beyond these times, a high range water reducer alone will usually be more cost-effective.

**4. Set Retarders:**

The function of retarder is to delay or extend the setting time of cement paste in concrete. These are helpful for concrete that has to be transported to long distance, and helpful in placing the concrete at high temperatures.

When water is first added to cement there is a rapid initial hydration reaction, after which there is little formation of further hydrates for typically 2–3 hours. The exact time depends mainly on the cement type and the temperature. This is called the dormant period when the concrete is plastic and can be placed. At the end of the dormant period, the hydration rate increases and a lot of calcium silicate hydrate and calcium hydroxide is formed relatively quickly. This corresponds to the setting time of the concrete. Retarding admixtures delay the end of the dormant period and the start of setting and hardening. This is useful when used with plasticizers to give workability retention. Used on their own, retarders allow later vibration of the concrete to prevent the formation of cold joints between layers of concrete placed with a significant delay between them.

The mechanism of set retards is based on absorption. The large admixture anions and molecules are absorbed on the surface of cement particles, which hinders further reactions between cement and water i.e. retards setting. The commonly known retards are Calcium Ligno-sulphonates and Carbohydrates derivatives used in fraction of percent by weight of cement.

**5. Air Entrained Admixtures:**

An addition for hydraulic cement or an admixture for concrete or mortar which causes air, usually in small quantity, to be incorporated in the form of minute bubbles in the concrete or mortar during mixing, usually to increase its workability and frost resistance. Air-entraining admixtures are surfactants that change the surface tension of the water. Traditionally, they were based on fatty acid salts or vinsol resin but these have largely been replaced by synthetic surfactants or blends of surfactants to give improved stability and void characteristics to the entrained air. Air entrainment is used to produce a number of effects in both the plastic and the hardened concrete. These include:

■Resistance to freeze – thaw action in the hardened concrete.

■Increased cohesion, reducing the tendency to bleed and segregation in the plastic concrete.

■Compaction of low workability mixes including semi - dry concrete.

■Stability of extruded concrete.

■Cohesion and handling properties in bedding mortars.

**Types of Mineral Admixtures**

**1.Cementitious**

These have cementing properties themselves. For example:

■Ground granulated blast furnace slag (GGBFS)

**2.Pozzolanic**

A pozzolan is a material which, when combined with calcium hydroxide (lime), exhibits cementitious properties. Pozzolans are commonly used as an addition (the technical term is "cement extender") 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. Examples are:

■Fly ash

■Silica Fume

■Rice Husk Ash

■Metakaolin

**Pozzolanic Action:**

The additive act in three ways

1.Filler

2.Nucleating

3.Pozzolanic

**1. Filler:**

These additives/admixtures are finer than cement, so when added to concrete they occupy the small pores previously left vacant.

**2. Nucleating:**

These fine particles accelerate the rate of hydration and precipitation starts.

**3. Pozzolanic:**

When cementing material reacts with water the following reaction take place:

C2S + H CSH + CH

C3S + H CSH + CH

CSH is responsible for strength while CH is a soluble material reacts and dissolves in water leaving behind pores. So when admixture is added

SiO3 or Al2O3+ CH CSH

Thus, it reduces the amount of CH & increase CSH

**Conditions to Declare a Material Pozzolan:**

■Having silica + Alumina oxide+ ferrous oxide more than 70%.

■Surface area on normal admixture is more than 300m²/kg.

■Surface area should be more than cement used

**3. Ground Granulated Blast Furnace Slag (GGBFS)**

Ground granulated blast-furnace slag is the granular material formed when molten iron blast furnace slag (a by-product of iron and steel making) is rapidly chilled (quenched) by immersion in water. It is a granular product, highly cementitious in nature and, ground to cement fineness, hydrates like Portland cement.

(Blast-Furnace Slag: A by-product of steel manufacture which is sometimes used as a substitute for Portland cement. In steel industry when iron ore is molted, then in the molted state all the impurities come at its surface which are removed called slag. It consists mainly of the silicates and aluminosilicates of calcium, which are formed in the blast furnace in molten form simultaneously with the metallic iron. Blast furnace slag is blended with Portland cement clinker to form PORTLAND BLASTFURNACE SLAG CEMENT). GGBFS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. GGBFS 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.

Concrete made with GGBFS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBFS 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 GGBFS 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.

**Benefits:**

**1.Durability**

1.GGBFS cement is routinely specified in concrete to provide protection against both sulphate attack and chloride attack

2.GGBFS is also routinely used to limit the temperature rise in large concrete pours. The more gradual hydration of GGBFS cement generates both lower peak and less total overall heat than Portland cement.

**2.Appearance**

1.In contrast to the stony grey of concrete made with Portland cement, the near-white color of GGBFS cement permits architects to achieve a lighter colour for exposed fair-faced concrete finishes, at no extra cost.

**3.Strength**

1.Concrete containing GGBFS 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 GGBFS continues to gain strength over time, and has been shown to double its 28 day strength over periods of 10 to 12 years.

**4. Fly Ash:**

The finely divided residue resulting from the combustion of ground or powdered coal. Fly ash is generally captured from the chimneys of coal-fired power plants; it has POZZOLANIC properties, and is sometimes blended with cement for this reason.

Fly ash includes substantial amounts of silicon dioxide (SiO2) (both amorphous and crystalline) and calcium oxide (CaO). Toxic constituents include arsenic, beryllium, boron, cadmium, chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium.

**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 10% lime (CaO). 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.

**Class C Fly Ash:**

Fly ash produced from the burning of younger lignite or subbituminous 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 (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO4) contents are generally higher in Class C fly ashes.

In addition to economic and ecological benefits, the use of fly ash in concrete improves its workability, reduces segregation, bleeding, heat evolution and permeability, inhibits alkali-aggregate reaction, and enhances sulfate resistance. Even though the use of fly ash in concrete has increased in the last 20 years, less than 20% of the fly ash collected was used in the cement and concrete industries.

One of the most important fields of application for fly ash is PCC pavement, where a large quantity of concrete is used and economy is an important factor in concrete pavement construction.

**5. Silica Fume**

■By-product of semiconductor industry

The terms condensed silica fume, microsilica, silica fume and volatilized silica are often used to describe the by-products extracted from the exhaust gases of silicon, ferrosilicon and other metal alloy furnaces. However, the terms microsilica and silica fume are used to describe those condensed silica fumes that are of high quality, for use in the cement and concrete industry.

Silica fume was first ‘obtained’ in Norway, in 1947, when environmental restraints made the filtering of the exhaust gases from the furnaces compulsory.

Silica Fume consists of very fine particles with a surface area ranging from 60,000 to 150,000 ft²/lb or 13,000 to 30,000 m²/kg, with particles approximately 100 times smaller than the average cement particle. Because of its extreme fineness and high silica content, Silica Fume is a highly effective pozzolanic material. Silica Fume is used in concrete to improve its properties. It has been found that Silica Fume improves compressive strength, bond strength, and abrasion resistance; reduces permeability of concrete to chloride ions; and therefore helps in protecting reinforcing steel from corrosion, especially in chloride-rich environments such as coastal regions.

**6. Rice Husk Ash:**

This is a bio waste from the husk left from the grains of rice. It is used as a pozzolanic material in cement to increase durability and strength.

The silica is absorbed from the ground and gathered in the husk where it makes a structure and is filled with cellulose. When cellulose is burned, only silica is left which is grinded to fine powder which is used as pozzolana.

**TESTING OF CEMENT:**

Basically two types of tests are under taken for assessing the quality of cement. These are either field test or lab tests.

**Field Tests:**

There are four field tests carried out to ascertain 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. For a moisture content of about 5 to 8%,this increase of volume may be much as 20 to 40 %,depending upon the grading of sand.
* **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 BIS sieve no. 9. 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. For 70.6 mm and 76 mm cubes ,the cement required is 185gm and 235 gm respectively.
* 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 was 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, plungerand 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 5 mm to 7 mm 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.(up to 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.