

Concrete Technology.

Text book

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MODULE(1)

CEMENT:-

portland cement:-

In 1784, Joseph Aspdin, a brick layer and mason in Leeds, England, took out a patent on hydraulic cement that he called portland cement. Because its colour resembled the stone quarried on the Isle of portland, off the British coast.

* Cement is a key ingredient of concrete and the world's most widely used building material.

* The most common type of cement used is ordinary portland cement. It is manufactured by intimately mixing in definite proportions of argilicious and calcareous and other silica, alumina or iron-oxide bearing compounds to a partial fusion at a temperature of about 1400°C .

As a result, a product called "clinker" is formed which is cooled and then grinded to required fineness. No material is added after burning, other than gypsum [Natural / chemical] or water or both and not more than one percent of air-entraining agents or other agents. The fine ground material is called cement.

Types of Cements:-

* ordinary portland cement [33 grade, 43, 53 grades]

* Rapid hardening cement

* Extra Rapid hardening cement

* portland Slag cement

* portland pozzolana cement.

* high - alumina cement.

- * Hydrophobic cement
- * Super - Sulphated cement
- * Sulphate resisting portland cement

Ingridients of portland cement:-

Ingridients	percentage.
Lime (CaO)	60-65%.
Silica (SiO_2)	20-25%.
Alumina (Al_2O_3)	4-8%.
Iron Oxide (Fe_2O_3)	2-4%.
Magnesium Oxide (MgO)	1-3%.
Sulphur trioxide (SO_3)	1-2%.
Alkalies	0.3-1%.

Special Cements:-

- * White portland cement
- * Expansive cement
- * Masonry cement.

Different Tests for cements:-

- i) field Tests
- ii) Laboratory Tests

1. Determination of fineness:—
 - a) By dry sieving
 - b) By blain Air permeability Method.
2. Determination of consistency of Standard cement past.
3. Determination of Initial & Final setting times,
 - a) Initial setting time
 - b) Final setting time.

Setting time :-

The setting time is influenced by the percentage of water and its temperature and by the temperature & humidity of air.

a) Initial setting time :-

- * Take 300gm of cement & prepare a neat cement paste by gauging the cement with 0.85 times the water required to give a paste of std. consistency.
- * pour the paste in vicat mould completely. The mould resting on the Non-porous plate
- * level the surface of the paste
- * The needle [1mm^2] is lowered gently until it comes in contact with surface of the test block & released quickly to penetrate into the test block.
- * The penetration of the needle is read on the scale.

b) Final setting time :-

- * Replace the needle of the vicat apparatus used for setting time by the needle with an annular attachment
- * The cement should be considered finally set when upon applying needle gently to the surface of the test block, the needle makes an impression. the reason, while the attachment fails to do so.
- * The period elapsing b/w the time when the water added to the cement and the time at which the needle makes the an impression on the surface of the test block while the attachment fails to do so shall be the final setting time.

Chemical composition:-

The chief chemical constituents of portland cement are as follows:-

Lime $[CaO]$ \rightarrow 60-67%.

Silica $[SiO_2]$ \rightarrow 17-25%.

Alumina $[Al_2O_3]$ \rightarrow 3-8%.

Iron oxide $[Fe_2O_3]$ \rightarrow 0.5-6%.

Magnesia $[MgO]$ \rightarrow 0.1-4%.

Sulphurtrioxide $[SO_3]$ \rightarrow 1-3%.

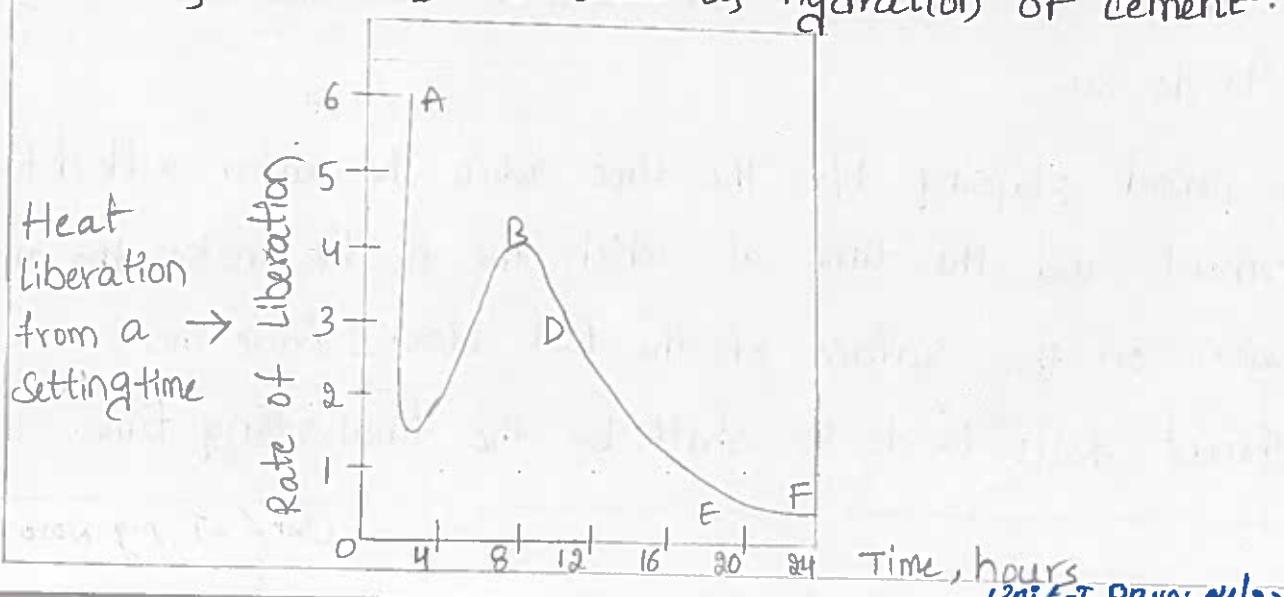
Soda/potash $[Na_2O + K_2O]$ \rightarrow 0.5-1.3%.

Hydration:-

Cement gets its strength from chemical reaction b/w cement and water. The process is called hydration.

Hydration of cement:-

Anhydrous cement does not bind fine and coarse aggregate. It acquires adhesive property only when mixed with water. The chemical reactions that takes place b/w cement & water is referred as hydration of cement.



Structure of Hydrated cement:-

- * To understand the behaviour of concrete, it is necessary to acquaint ourselves with the structure of hydrated hardened cement paste.
- * If concrete is considered as two phase material namely:-
 - i) paste phase
 - ii) aggregate phase
- * The understanding of paste phase becomes more important as it influences the behaviour of concrete to a much greater extent.
- * It will be discussed later that the strength, the permeability, the durability, the drying shrinkage, the elastic properties, the creep and volume change properties of concrete is greatly influenced by the paste structure.
- * The aggregate phase though important has less influence on the properties of concrete than the paste phase.
- * Therefore, in our study to understand concrete it is important that we have a deep understanding of the structure of the hydrated hardened paste at a phenomenological level.

Chemical composition of clinker:-

following are the typical composition for clinker

compound	formula	short hand form	% by weight
Tricalcium aluminate	$\text{Ca}_3\text{Al}_2\text{O}_6$	C_3A	10
Tetra calcium alumino ferrite	$\text{Ca}_4\text{Al}_2\text{Fe}_2\text{O}_{10}$	C_4AF	8
Belite or dicalcium Silicate	Ca_2SiO_5	C_2S	55-60

compound	formula	short hand form	% by weight.
Alite or tricalcium silicate	Ca_3SiO_4	C_3S	55
Sodium oxide	Na_2O	N	upto 2
Potassium oxide	K_2O	K	upto 2
Gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	CSH_2	5.

Different grades of cement:-

Cements are mainly classified on the basis of compressive strength of particular cement. mainly 3 grades of cement are used:-

- * 33 Grade OPC
- * 43 Grade OPC
- * 53 Grade OPC

* 33 grade ordinary portland cement:-

$$\text{fineness} = 300 \text{ m}^2/\text{kg}$$

$$\text{compressive strength after 3 days} = 16 \text{ N/mm}^2$$

$$\text{compressive strength after 7 days} = 22 \text{ N/mm}^2$$

$$\text{compressive strength after 28 days} = 33 \text{ N/mm}^2$$

Grade 33 cement has high workability and is mainly used for mortar in masonry work and for plastering.

* 43 grade ordinary portland cement:-

$$\text{fineness} = 225 \text{ m}^2/\text{kg}$$

$$\text{compressive strength after 3 days} = 23 \text{ N/mm}^2$$

$$\text{compressive strength after 7 days} = 33 \text{ N/mm}^2$$

Compressive Strength after 28 days = 43 N/mm²

Grade 43 cement is moderately sulphate resisting and has good workability. Grade 43 cement has chloride content and thus resists corrosion on R.C.C. Grade 43 cement has smooth and better finish.

Grade 43 cement is mainly used in:-

* Ready mix concrete [RMC]

* Reinforced cement concrete work [RCC]

* pre-cast concrete [example in Delhi metro pillars]

* Silos and chimneys.

* 53 Grade ordinary portland cement:-

Fineness = 225 m²/kg

Compressive Strength of cement after 3 days = 27 N/mm²

Compressive Strength of cement after 7 days = 37 N/mm²

Compressive Strength of cement after 28 days = 53 N/mm²

Grade 53 cement has low chloride content and is moderately sulphate resisting. Volume of cement required is less due to high strength and surface area which saves the cost of construction.

Grade of 53 cement is used in:-

* Industrial buildings, roads and subways

* pre-cast concrete.

* RCC Bridges

* concrete sleeper for railways.

* Test on physical properties:-

The various tests performed and confirm physical & chemical properties of cement as per standards are:-

* fineness

* setting time or consistency test

* Strength test

* Soundness test

* heat of hydration

* chemical composition test.

* fineness Test:-

So we need to determine the fineness of cement by dry sieving as per IS:4031(part-1)-1996. The principle of this that we determine the proportion of cement whose grain size is larger than specified mesh size.

* The apparatus used are 90μm IS sieve, Balance capable of weighing 10g to nearest 10mg, A nylon or pure bristle brush, preferably with 25-40mm bristle, for cleaning of sieve.

procedure to determine fineness of cement:-

* weigh approximately 10g of cement to the nearest 0.01g & place it on the sieve

* agitate the sieve by swirling, planetary and linear movements, until no more fine material passes through it.

* Gently brush all the fine material off the base of the sieve.

* Repeat the whole procedure using a fresh 10g sample to obtain R_2 . Then calculate R as the mean of R_1 & R_2 as a percentage, expressed to the nearest 0.1%. When the results differ by more than 1% absolute, carryout a third sieving and calculate the mean of the three values.

Result:-

The value of R , to the nearest 0.1%, as the residue on the 90um sieve.

Soundness Test:-

Soundness of cement is determined by le-chatelier method as per IS:4031 [part-3] - 1988.

Apparatus:-

The apparatus for conducting the le-chatelier test should conform to IS: 5514 - 1969. Balance, whose permissible variation at a load of 1000g should be $\pm 1.0\text{g}$ and water bath.

procedure to determine the soundness of cement:-

- * place the mould on a glass sheet and fill it with cement paste formed by gauging cement with 0.78 times the water required to give a paste of standard consistency.
- * cover the mould with another piece of glass sheet, place a small weight on this covering glass sheet and immediately submerge the whole assembly in water at a temperature of $27^\circ \pm 2^\circ\text{C}$ and keep it there for 24hrs.
- * Measure the distance separating the indicator points to the

nearest 0.5mm [d_1]

- * Submerge the mould again in water at a temperature prescribed above. Bring the water to boiling point in 25-30 min and keep it boiling for 3hrs.
- * Remove the mould from the water, allow it ^{to} cool and measure the distance b/w the indicator points [d_2]
- * [$d_1 - d_2$] represents the expansion of cement.

Consistency of cement :- consistency test.

The basic aim is to find out the water content required to produce a ~~water~~ cement paste of standard consistency as per IS:4031 [part-4] - 1988. The principle is that standard consistency of cement is that consistency at which the vicat plunger penetrates to a point 5-7mm from the bottom of the vicat mould.

Apparatus:-

Vicat apparatus conforming to IS 5513:1976, Balance, whose permissible variation at a load of 1000g should be $\pm 10g$, Gauging travel conforming to IS:10086 - 1982.
procedure to determine consistency of cement:-

- * weigh approximately 400g of cement and mix it with a weighed quantity of water. The time of gauging should be b/w 3-5 min.
- * Fill the vicat with paste and level it with a trowel.
- * Lower the plunger gently till it touches the cement surface.
- * Release the plunger gently it touches the cement surface

or

- * Release the plunger allowing it to sink into the paste.
- * Note the reading on gauge
- * Repeat the above procedure taking fresh samples of cement and different quantities of water until the reading on the gauge is 5-7mm.

Result:-

Express the amount of water as a percentage of the weight of dry cement to the first place of decimal.

Initial and Final Setting time:-

We need to calculate the initial and final setting time as per IS:4031 [part-5] - 1988. To do so we need Vicat apparatus conforming to 5513 - 1976, Balance, whose permissible variation at a load of 1000g should be $\pm 1.0\%$, Gauge trowel conforming to IS:10086 - 1982.

- * Procedure to determine initial and final setting time:-
 - * Prepare a cement paste by gauging the cement with 0.85 times the water required to give a paste of standard consistency.
 - * Start a stop-watch, the moment water is added to the cement.
 - * Fill the Vicat mould completely with the cement paste gauged as above, the mould resting on a non-porous plate and smooth off the surface of the paste making it level with the help top of the mould. The cement block thus prepared in the mould is the test block.

Initial setting time:

place the test under the rod bearing the needle. lower the needle gently in order to make contact with the surface of the cement paste and release quickly, allowing it to penetrate the ~~test~~ test block. Repeat the procedure till the needle fails to pierce the test block to a point 5.0 ± 0.5 mm measured from the bottom of the mould.

The time period elapsing b/w the time, water is added to the cement and the time needle fails to pierce the test block by 5.0 ± 0.5 mm measured from the bottom of the mould, is the initial setting time.

Final setting time:

Replace the above needle by the one with an annular attachment. The cement should be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression therein, while the attachment fails to do so.

The period elapsing b/w the time, water is added to the cement and the time, the needle makes an impression on the surface of the test block, while the attachment fails to do so, is the final setting time.

Admixtures

Admixtures:-

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

Types of Admixtures:- chemical admixtures

Accelerators, Retarders, water-reducing agents, super plasticizers, air entraining admixtures / air entraining agents etc.

Mineral admixtures:-

fly-ash, Blast furnace slag, silica fume and rice husk ash etc.

Chemical Admixtures

1. Accelerators:-

An admixture which, when added to concrete, mortar, grout, increase 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 24hrs by at least 120% at 20°C and at 5°C by at least 130% at 48hrs. 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 sulphate environment.

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 admixtures becomes more apparent.

In Summary, a hardening accelerator may be appropriate for strength gain upto 12hrs at ambient temperatures. Beyond these times, a high range water reducer alone will usually be more cost-effective.

2. Retarders:-

The function of the 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 hrs. The exact time depends mainly upon cement type & the temperature. This is called DORMANT PERIOD when the concrete is plastic and can be placed.

At the end of 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 concrete.

Retarding admixtures delay the end of the dormant period and the start of setting & 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 b/w layers of concrete placed

with a significant delay b/w them.

The mechanism of set retarder is based on absorption. The large admixtures anions molecules are absorbed on the surface of cement particles, which hinders further reactions b/w cement and water i.e., retards setting.

The commonly known retarders are calcium ligno-Sulphonates and carbohydrates derivatives used in fraction of percent by weight of cement.

3. Water reducing admixtures / plasticizers:-

These are the admixtures used for following purposes:-

- * To achieve a higher strength by decreasing the water cement ratio at the same workability as an admixture free mix.
- * To achieve the same workability by decreasing the cement content so as to reduce the heat of hydration in mass concrete.
- * To increase the workability so as to ease placing in accessible locations.
- * water reduction more than 5%, but less than 12%.
- * The commonly used admixtures are ligno-Sulphonates and hydrocarabolic acid salts.
- * plasticizers are usually based on lignosulphonate, which is a natural polymer, derived from wood processing in the paper industry.

4. 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 - levelling
- * self - compacting concrete
- * penetration and compaction round dense reinforcement.

Reduced w/c ratio:-

- * very high early strength, > 200% at 280 hours or earlier.
- * very high later age strength, > 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 most 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 90min. 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 possible undesirable side effects are reduced because they do not markedly lower the surface tension of the water.

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 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 & segregation in the plastic concrete.
- * stability of extruded concrete
- * cohesion and handling properties in bleed mortars.

Mineral admixtures in concrete

1. 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 (SiO_2) 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 ~~properties~~ in nature, contains less than 10% lime (CaO). The glassy silica and alumina of class F fly ash require a cementing agent, such as portland cement, quicklime, 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 ~~generally~~ does not require an activator. Alkali and sulphate [SO_4^{2-}] 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, & permeability, inhibits alkali-aggregate reaction and enhances sulphate 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 industry.

2. 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 & steel making] is rapidly chilled [quenched] by immersion in water. It is a granular product, high 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 melted, then in the melted state all the

impurities come at its surface which are removed called slag. It consists mainly of silicates and alluminosilicates 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 Blast furnace slag cement".

GGBFS is used to make durable concrete structures in combination with ordinary portland cement and other plasticizers or pozzolanic materials. Concrete made with GGBFS cement sets more slowly than concrete made with ordinary portland cement, depending on amount of GGBFS in the cementitious material, but also continues to gain strength over a longer period in production conditions.

Silica fume :-

The term condensed silica fume, microsilica, silica fume & volatilized silica are often used to describe the by-products extracted from the exhaust gases of silicon, ferrosilicon & other metal alloy furnaces. However, the terms microsilica & 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 1,50,000 ft²/lb or 13,000 to 30,000 m²/kg, with particles approximately 100 times smaller than the average cement particle. Silica fume is used in concrete to improve its properties. It has been found that silica fume improves compressive strength,

bond strength, 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.

Rice Husk Ash:-

This is a bio waste from the husk left from the grainy of rice. It is used as 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 filled with cellulose. When cellulose is burned, only silica is left, which is grinded to fine powder which is used as pozzolana.