Reinforced Cement Concrete

For

Civil Engineering

By

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Syllabus for Reinforced Cement Concrete

Concrete Technology-Properties of Concrete, Basics of Mix Design, Concrete Design-Basic Working Stress and Limit State Design Concepts, Analysis of Ultimate Load Capacity and Design of Members Subjected to Flexure, Shear, Compression and Torsion by Limit State Methods, Basic Elements of Pre-Stressed Concrete, Analysis of Beam Sections at Transfer and Service Loads

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"Success is never ending failure is never final."

.... **Dr. Robert Schuller**

CHAPTER 1 Concrete Technology

Learning Objectives

After reading this chapter, you will know:

1. Properties of Concrete
2. Classification of Cements
3. Specification of Portland Concrete
4. Specification of Aggregates
5. Measurement of Materials
6. Admixtures

Properties of Concrete

Cement Concrete: It is the construction material, which is obtained by hardening of mixture of cement, sand, gravel and water in a predetermined proportions, this mixture is used by pouring it into suitable moulds and allowed to harden and then cured.

Characteristics of Concrete

1. It has good compressive strength but it is weak for taking tensile loads.
2. It shows resistance to corrosion & fire.
3. The process of hardening of concrete is time varying and it gains strength with time.
4. Concrete structures are much more economical than steel.
5. Concrete can form hard surface and thus resist the abrasion.
6. Its strength depends upon quality of material and handling condition.
7. It shows the tendency of shrinking initially, because of loss of water. It also shrinks as the process of hardening goes on.
8. It can be placed with steel bars to form R.C.C.

Concrete & its Setting Time

(a) **Initial Setting Time of Concrete:** Usually (30 to 60 minutes). This is the time phase in which mixed proportion attains the pronounce resistance to flow and plasticity is decreased. As per the IS code it should be more than 30 minutes, so that during this phase concrete can be mixed, transported and used at required place.

(b) **Final Setting Time of Concrete:** Usually (5 to 6 Hours). This is the second time phase during which concrete remains relatively soft solid with no surface hardness. In this time concrete starts gaining the strength. As per IS codes, it should not be more than 10 hours.

(c) **Progressive Hardening and Increase in Strength:** This is the third time phase during which concrete almost attains most of its strength during initial stage, this process is quite rapid. It is generally one month after mixing.
A small quantity of Gypsum is added to the cement. The initial setting time is controlled by the quantity of Gypsum added. More is the quantity of Gypsum; more will be initial setting time.

Classification of Cements

1. **Portland Cement**

The main constituents of Portland cements are

Lime (CaO)	60 to 67%
Silica (SiO_2)	17 to 25%
Alumina (Al_2O_3)	3 to 8%
Calcium Sulphate ($CaSO_4$)	3 to 6%
Iron Oxide (Fe_2O_3)	0.5 to 6%
Magnesia (MgO)	0.1 to 4%
Sulphur trioxide (SO_3)	1 to 3%
Alkalies	0.5 to 1.3%

- Argillaceous material in the form of clays and shale and calcareous material in the form of lime, stone, chalk are used as raw materials in the ratio of 1:2.
- When raw material containing above constituents undergo burning & fusion, the chemical reaction takes place and following compounds are formed called Bogue's Compounds.
    1. Tricalcium Silicate ($3\,CaO.SiO_2$): C_3S
    2. Dicalcium Silicate ($2\,CaO.\,SiO_2$): C_2S
    3. Tricalcium Alluminate ($3\,CaO.SiO_2$): C_3A
    4. Tetracalcium Alumino Ferrite ($4\,CaO.Al_2O_3.Fe_2O_3$): C_4AF
- C_3S and C_2S contribute to most of eventual strength. However, initial setting is due to C_3S.
- C_3S quickly hydrates and contributes initial strength. Contribution of C_2S is after 7 days of mixing and extends up to 1 year. The strength in first 24 hours is imparted by C_3S. All the four compounds lose heat when mixed with water. C_2S generate minimum heat whereas C_3A generate maximum. Therefore C_3A is responsible for undesirable properties of concrete cement, having lower C_3A content will have higher ultimate strength, less generation of heat and less cracking.

Types of Portland Cement

(a) **Ordinary Portland cement (IS:269):[OPC]**
OPC-33(IS: 269-1989), OPC-43(IS: 8112-1989), and OPC-53 (IS: 12269-2013)
It is manufactured generally in larger quantities than others. It is generally suitable in concrete construction where there is no exposure to sulphates in soil or ground water.

(b) **Rapid Hardening Portland Cement (IS: 8041-1990)**
Also known as high early strength cement. It is ground finer, contains lesser C_2S and more C_3S compared to OPC. Strength developed in 3 days in rapid hardening. Portland cement is nearly equal to strength developed in 7 days in OPC but shuttering may be removed earlier, thus saving time and expanses. Similarly in concrete product industry, moulds can be released early. Also used in road construction when any delay has to be avoided.

(c) **Extra Rapid Hardening Cement**

Obtained by inter grinding $CaCl_2$ with rapid hardening cement. It imparts quick setting properties also.

(d) **Low Heat Portland Cement (IS: 12600-1989)**

It has low percentage of C_3A and C_3S and higher percentage of C_2S. It has low rate of gaining strength but practically equal ultimate strength. This is achieved by limiting the amount of calcium and increasing silicates in raw materials.

This is used where the rate at which heat can be lost at the surface is lower than the rate at which heat is being generated initially.

Examples: Abutments, Retaining walls, Dams etc.,

(e) **Portland Blast Furnace Cement (IS: 455)**

It is manufactured by inter grinding of Portland cement clinker with blast furnace slag. It has comparatively low heat of hydration and can be used in replacement of ordinary Portland cement. Proportions of slag vary from 25% to 65% by weight of cement. Gypsum is added to regulate the setting time of cement.

(f) **Portland Pozzolana Cement (IS: 1489-1991): [PPC]**

It is manufactured by inter grinding Portland cement clinker and pozzolana (burnt clay, shale or fly ash etc.) or by blending instead of inter grinding. 10% to 25% of pozzolana can be used. Pozzolana has no cementing value but combine with free lime. This cement has more resistance to chemical and sea water attack. It also has low heat evolution.

(g) **Sulphate Resisting Cement (IS: 12330-1988)**

In these cement the quantity of C_3A is strictly limited, and these are normally ground finer than OPC. Resistant skin formed through carbonation by action of atmospheric CO_2. This cement should be allowed to harden in air for as long as possible.

(h) **White and Coloured Portland Cement (IS: 138042 - 1989)**

Raw materials like chalk and lime stone having White Portland Cement 138042(1989) low percentage of iron are used. The percentage of iron oxide is limited to 1% sodium aluminum fluoride (Cryolite) is added to act as flux in absence of Fe_2O_3. Oil fuels are used instead of coal fuel to avoid contamination by coal ash. Colour is obtained by adding pigments in OPC or white cement. Pigment should be permanent & chemically inert.

2. **High Alumina Cement [IS: 6452 (B)-(1989)]**

Raw materials in manufacturing are of extremely high alumina content (chalk and Bauxite). It has dark colour, high early strength even than rapid hardening cement, high heat of hydration and more resistance to chemical attack. Rapid hardening is a proper arise from Monocalcium Aluminate ($Al_2O_3.CaO$). It has free hydrated lime as in case of OPC. Manufacture is more expensive than OPC.

3. **Super Sulphated Cement (IS: 6909-1990)**
It is manufactured from well granulated blast furnace slag (80 to 85%), Calcium sulphate (10 to 15%) and Portland cement (1 to 2%). It is ground finer than OPC. It has low heat of hydration totally and suited for construction of dams and mass concrete work. Concrete derived from this cement expands if cured in water and shrinks if cured in air. It has high resistance to chemical attack.

4. **Natural Cement**
These are manufactured from naturally occurring cement rocks with composition similar to mix of argillaceous and calcareous materials. Natural cement rocks are burned at comparatively lower temperature. The properties of these cement depends on the composition of cement rock.

5. **Masonry Cement (IS: 3466-1988)**
These are manufactured from grinding of Portland cement clinker, lime stone, gypsum & air-entraining agent. These are ground finer then the high early strength Portland cement. These are used as mortar for brick masonry. Lime stone & air-entraining agents impart plasticity and workability shrinkage is fairly low.

Specifications for Portland Cement

ISI has recommended following tests & specifications

1. **Chemical Compositions**: **(IS: 4032 – 1968)**
   (A) Ratio of percentage of lime to % age of silica, alumina and Fe_2O_3 calculated by following formula - Not greater than 1.02 but not less than 0.66
   $$\left(\frac{CaO - 0.7\ SO_3}{2.8\ SiO_2 + 1.2\ Al_2O_3 + 0.65\ Fe_2O_3}\right)$$
   (B) Ratio of % of alumina to that of Fe_2O_3 - Not less than 0.66
   (C) Weight of insoluble residue - Not more than 2%
   (D) Weight of Magnesia - Not more than 6%
   (E) Total Sulphuric Anhydride (SO_3) - Not more than 2.75%
   (F) Total loss on ignition - Not more than 4%

2. **Fineness:** By Blaine's air permeability method (IS: 4031 – 1968) this is done to check proper grinding.

Type of Cement	Specific Surface
Low heat	More than 3200
Rapid Hardening	More than 3250
Ordinary	More than 2250

3. **Soundness:** By 'Le Chatelier' method (IS: 4031 – 1968) Rapid hardening & low heat Portland cement should have expansion less than 10 mm.

4. **Setting Time: By Vicat Apparatus**
   (i) Initial setting time for Ordinary, Rapid hardening and low heat Portland cements should be around 30, 30 and 60 minutes respectively.
   (ii) The final setting time for Ordinary, Rapid hardening and low heat cements should be around 600, 60 and 600 minutes respectively.

5. **Compressive Strength:(IS: 4031 – 1968) – Cube Test:**
   Compressive strength at the end of 3 days should be more than 11.3 N/mm^2 and that at the end of 7 days should not be less than 17.2 N/mm^2.

6. **Heat of Hydration: (IS: 4031 – 1968)**
   Only for low heat cement heat of hydration after 7 days should not be more than 65 calories per gram and after 28 days should not be more than 75 cal/g.

7. **Tensile Strength:**
   $\frac{P}{5} + 2.5$ at 3 days should not be lesser than 2 N/mm^2
   $\frac{P}{5} + 2.5$ at 7 days should not be lesser than 2.5 N/mm^2
   Where, P is standard consistency of cement

Aggregates

(a) **Coarse Aggregates:** (Size > 4.75 mm)
The aggregates which are retained on 4.75 mm sieve. Maximum size of coarse aggregates is limited to one third of thickness of concrete section for thin slabs and walls.

(b) **Fine Aggregates:** (Size < 4.75 mm)
The aggregates which are passed through 4.75 mm sieve. Usually natural river sand is used. Angular grained sand produces good concrete because of interlocking.

Specification of Aggregates

(a) **Crushing Strength:** Normally 80 N/mm^2 minimum is acceptable. It is determined on a rock sample of specific size.

(b) **Aggregates Crushing Value:** It is given by,

$$\text{Aggregate crushing value} = 100\,\frac{W_2}{W_1}$$

W_1 = Weight of surface dry sample of aggregate passing through 12.5 mm IS sieve and retained on 10 mm IS sieve.

W_2 = Weight of material passing 2.36 mm IS sieve after a specified load is applied in a specified manner. A higher crushing value is indication of weak aggregates.

(c) **Aggregate Impact Value:** It lies between 30 to 45 for good quality concrete. Higher Aggregate impact value is indication of weak aggregates. It is given by,

$$\text{Aggregate impact value} = 100\,\frac{W_2}{W_1}$$

Where, W_1 = Weight of oven dried sample of aggregates passing 12.5 mm IS sieve and retained on 10 mm IS sieve.

W_2 = Weight of fractured aggregate finer than 2.36 mm, formed after IS impacts of a specified hammer falling from 300 mm.

(d) **Fineness Modulus (Grading of Aggregates): (IS: 383-1970)**

It is an index number which is roughly proportional to the average size of the particles in aggregate. Coarse aggregates, higher will be the fineness modulus. It is obtained by adding the percentage of weight of material retained on IS 80 mm, 40 mm, 20 mm, and 10 mm, 4.75 mm, 2.36 mm, 1.18 mm, 600 micron, 300 micron and 150 micron sieves (Total 10 sieves).

Water: It acts as lubricant for aggregates and chemically acts with cement, also used in curing. Potable water is satisfactory for mixing & curing purpose Tannic acid or iron should not be present in water. pH value should be more than 6.

Maximum Permissible Limits for Solids(IS 456:2000)	
(a) Organic solid	200 mg/l
(b) Inorganic solid	300 mg/l
(c) Sulphates (SO_3)	400 mg/l
(d) Chlorides (Cl)	200 mg/l for concrete not containing embedded steel and 500 mg/l for R.C.C work
(e) Suspended matter	2000 mg/l

When suitability of water is doubled regarding the development of strength, then compressive strength & initial setting time tests are done.

Measurement of Materials

(a) **Cement:** Preferably measured in terms of weight, but not in terms of volume. Each cement bag containing 50 kg under normal conditions; volume of cement bag is nearly equal to 34.5 liters.

(b) **Fine Aggregates:** Measured in weight for accurate works and by volume for ordinary works. The volume is increased due to water absorption by sand called as bulking of sand. Sand Particles are pulled apart because of surface tension caused by water. Increase in volume depends on gradation, but may be taken to be maximum at a moisture content of about 4% by weight of dry sands. Bulking increases with fineness and may be around 25% by volume.

$$\%\ \text{Bulking} = \frac{\text{Increase in Volume}}{\text{Original Volume}} = \frac{W_1 - W_2}{W_2} \times 100$$

Where, W_1 = Weight of one cubic meter of compacted dry sand

W_2 = Weight of dry sand contained in one cubic meter of wet loose sand

$$\text{Bulking factor} = \frac{W_1}{W_2}$$