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CONTENT

CHAPTER-1

CEMENT, CEMENT MORTAR AND CONCRETE

CHEMICAL COMPOSITION:

Ordinary Portland cement:

Table: Approximate Oxide Composition Limits of Ordinary Portland Cement

Oxide	Per cent, Content
CaO	60-67
SiO_2	17-25
Al_2O_3	3.0-8.0
Fe_2O_3	0.5-6.0
MgO	0.1-4.0
Alkalies (K_2O, Na_2O)	0.4-1.3
SO_3	1.3-3.0

Portland cement:

Table: The Oxide Composition of a typical Portland cement and the corresponding calculated compound composition.

Oxide composition Per cent		Calculated compound composition using Bogue's equation-per cent	
CaO	63	C_3S	54.1
SiO_2	20	C_2S	16.6
Al_2O_3	6	C_3A	10.8
Fe_2O_3	3	C_4AF	9.1
MgO	1.5		
SO_3	2		
K_2O, Na_2O	1.0		

- Oxides present in raw materials when subjected to high clinkering temperature forms complex compounds which are identified on the basis of R.H. Bogue's work hence these are known as "Bogue's compounds"
- Major Bogue's compounds are:

Table: Bogue's Compounds

Name of Compound	Formula	Abbreviated Formula
Tricalcium silicate	$3\ CaO.SiO_2$	C_3S
Dicalcium silicate	$2\ CaO.Sio_2$	C_2S
Tricalcium aluminate	$3\ Cao.Al_2O_3$	C_3A
Tetracalcium aluminoferrite	$4\ CaO.Al_2O_3.Fe_2O_3$	C_4AF

- C=cao ; S = Sio_2 ; A = Al_2O_3 ; F = Fe_2O_3 ; H = H_2O.
- C_2S and C_3S are responsible for strength.
- Average content of C_3S and C_2S are 45% and 25% respectively.
- Excess of lime (Cao) content causes unsoundness in cement.
- An increase in SiO_2 content at the expense of content of Al_2O_3 and Fe_2O_3 will make the cement difficult to fuse and form clinker.

Hydration of Cement:

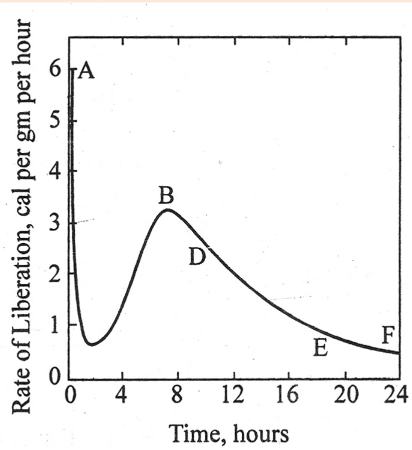

Figure: ***Heat Liberation from a Setting Cement.***

- Anhydrous cement compounds when mixed with water reacts to it to form hydrated compounds of very low solubility.
- The reaction is exothermic.
- Reaction of C_2S and C_3S with water:

$$2C_3S + 6H \rightarrow C_3S_2H_3 + 3Ca(OH)_2$$

Or, $2(3CaO.SiO_2) + 6H_2O \rightarrow 3CaO.2SiO_2.3H_2O + 3Ca(OH)_2$

And, $2C_2S + 4H \rightarrow C_3S_2H_3 + Ca(OH)_2$

$$2(2CaO.SiO_2) + 4H_2O \rightarrow 3CaO.2SiO_2.3H_2O + Ca(OH)_2$$

Calcium silicate hydrate

(C.S-H)

- C_3S produces less quantity of C-S-H and more quantity of Ca $(OH)_2$ than C_2S.
- C_3S produces more heat of hydration and gives early strength to concrete and hence cement with more C_3S content is better for cold weathering concreting.
- C_2S produces less heat of hydration and gives later strength of concrete.
- $Ca(OH)_2$ reacts with sulphates present in soil or water to form calcium sulphate which further reacts to C_3A and cause deterioration of concrete. This phenomena is known as **Sulphate Attack** . **Presence of** $(CaOH)_2$ makes pH of concrete approx. 13 which resist the corrosion of reinforcement.
- Reaction of pure C_3A with water is very fast and it leads to flash set. Hence to prevent flash set, **gypsum** is added at the time of grinding of cement clinker.
- Calcium Aluminate trisulphate Hydrate ($C_6AS_3H_{32}$) is known as **Ettringite.**

Type of Cement:

A. Ordinary Portland Cement (OPC):

- Classified into 33, 43 and 53 grade depending on 28 days strength as per IS: 4031-1988.
- Production of OPC is decreasing in comparison to PPC and other cements.

B. Rapid Hardening Cement:

- Similar to OPC and it develops strength rapidly.
- Strength developed by Rapid hardening cement in 3 days is equivalent to strength developed by OPC in 7 days.
- In this cement content of C_3S is higher than C_2S and fineness of cement particles is higher (Surface area > 3250 cm^2/gm)
- It is:

  Not used: In mass concrete construction

  Used in: Road repair work, pre-fabricated concrete construction, cold weather condition etc.

C. Extra Rapid Hardening Cement:

- Obtained by adding **calcium chloride ($Cacl_2$)** with rapid hardening Portland cement.
- Addition of $CaCl_2$ should not exceed 2% by weight of rapid hardening cement.
- It accelerates the settling and hardening process.
- Strength of extra rapid hardening cement is approximately 25% higher than rapid hardening cement in 1-2 days and 10-20% higher in 7 days.
- It is not covered by **Indian standard.**
- It is :

  Used in: Cold weather condition.

D. Sulphate Resisting Cement:

- It is used to prevent sulphate attack. Sulphate attack is accelerated due to alternate wetting and drying.
- In this cement, contents of C_3A and C_4AF are low and content of Silica is high.
- Maximum content of C_3A is upto 5%
- It is:

  Used in: Concreting in marine condition, Foundation and basement, sewage treatment works etc.

E. Portland Slag Cement (PSC):

- Obtained by mixing Portland cement clinker, gypsum and granulated blast furnace slag in suitable proportion.
- It is similar to OPC with respect to fineness, setting time, soundness and strength.
- Rate of hardening of this cement is slower than OPC during the first 28 days, after that it increases.
- Heat of hydration is slower than OPC.
- It is :

  Used in: Mass concrete structure

  Not used in: Cold weather condition

F. Quick Setting Cement:

- For this cement, gypsum content is reduced at the time of clinker grinding.
- It set very early.
- It is

  Used in: Under water construction, Typical grouting operations etc.

G. Super Sulphated Cement:

- This cement has high sulphate resistance.
- When this cement is used, the water/cement ratio should not be less than 0.5.
- It is more sensitive to deterioration during storage than Portland cement.
- It is

  Used in: Marine works, Fabrication of reinforced concrete pipe which is likely to be buried in sulphate bearing soil, foundation etc.

H. Low Heat Cement:

- In this cement, contents of C_3S and C_3A is reduced and contents of C_2S is increased.
- Rate of heat evolution is less and evolution of heat is extended over a long period.
- Rate of gain of strength is slow, but the ultimate strength of this cement is same as that of OPC.

I. Portland Pozzolana Cement:

- A Pozzolana material is a silicious or Aluminous material which doesn't possess any cementations properties but in the presence of water, it reacts with calcium Hydroxide ($Ca(OH)_2$) liberated in the hydration process at ordinary temperature to form compounds possessing cementations properties.
- PPC is manufactured by intergrading of OPC clinker with 15-35% of pozzolanic material.
- Pozzolana materials used in PPC are: Calcined clay, Fly ash etc.
- Some pozzolana materials are: Silica Fume, Rice Husk ash, Metakaoline, Blast furnace slag etc
- PPC produces less heat of hydration and offers greater resistance to the attack of aggressive water than OPC.
- It also reduces leaching of $Ca(OH)_2$ when used in hydraulic structures and it also reduces permeability.
- Rate of gain of strength of PPC is slower than OPC in initial stages.
- It is economical than OPC.
- As fly ash is finer and of lower density, the bulk volume of 50 Kg. bag is slightly more than OPC. Hence PPC gives more volume of mortar than OPC.
- It is

  Used in: Hydraulic Structures, Mass concrete structure e.g. dam, Bridge pier, marine structure, sewer and sewage disposal works etc.

J. Air Entraining Cement:

- It has not yet been covered by Indian standard.
- Obtained by mixing a small amount of an air-entraining agent with OPC clinker at the time of grinding.
- Types of air-entraining agents used are:
  (a) Alkali salts of wood resin
  (b) Synthetic detergents of alkyl-aryl sulphonate type
  (c) Calcium lignosulphate, calcium salts of glues and proteins.
- It modifies the property of hardened concrete towards its resistance to frost action.

K. Hydrophobic Cement:

- Obtained by grinding OPC clinker with water repellent film-forming substance such as **oleic acid, Stearic acid.**
- It is widely used in areas of heavy rainfall.
- Water repellant film formed around grains of cement, reduces the rate of deterioration of cement during long storage, transport or under unfavorable condition.

L. IRS-T 40 special Grade Cement.

- Used in manufacturing of concrete sleeper for Indian Railways.
- It contains high C_3S content to develop high early strength.

M. High Alumina Cement:

- Obtained by fusing or sintering a mixture of alumina and calcareous materials in suitable proportion and grinding the resultant product to a fine powder.
- Raw materials used for manufacturing of high Alumina cement are limestone and bauxite.
- It gives high early strength.
- It is used for making **refractory concrete** to withstand high temperature (up to 1600ºC)
- It is slow setting but rapid hardening cement.

Testing of Cement:

1. **Field Test:**

(a) The color of cement should normally be greenish grey and it should not have visible lumps.
(b) When hand is inserted into cement bag, it must give a cool feeling.
(c) When cement is thrown into a bucket full of water, it should float for some time before sinking.
(d) On rubbing the cement particles between fingers, it should given a smooth feeling.

2. **Laboratory Test:**

(a) Fineness Test:

Fineness of cement is tested in two ways:

(i) By Sieving:

- 100 gm. of cement is sieved through **90µ(micron)** sieve.
- After sieving the residue left on the sieve is weighted.
- The weight should not exceed 10% for ordinary cement.

(ii) By Air permeability method:

- The fineness of cement is represented by specific surface Total surface area (sq. cm) Wt. of cement (gm) (cm^2/gm. , m^2/kg).
- The principle is based on relation between the flow of air through the cement bed and the surface area of the particles comprising the cement and thus surface area is related to the permeability of a bed of given porosity.
- **Blaine Air permeability apparatus** is used for fineness testing.

(b) Standard Consistency Test:

- Standard consistency of a cement paste is defined as that consistency which will permit a vicat plunger having 10mm diameter and 50mm long to penetrate to a depth of 33-35 mm. from the top of the mould.
- The apparatus used for this test is vicat apparatus.
- Also, it is the percentage (%) of water required to produce a cement paste of standard consistency. It is denoted by **'P'**
- This test is conducted at a constant temperature (27º ± 2ºC) and constant humidity (90%)

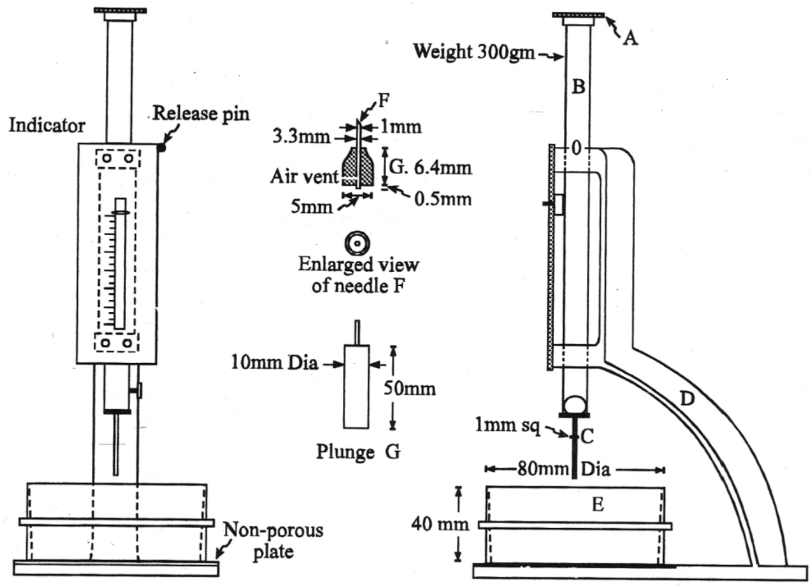

Figure: ***Vicat apparatus for determining the normal consistency and setting time for cement.***

(c) Setting Time Test:

- The vicat apparatus is used for this test and it is conducted with a standard consistency of **0.85P** at a temperature (27º ± 2ºC)

Initial Setting Time:

- It is the time elapsed between the time when water is added to the cement to the time when the paste starts losing its plasticity.
- Also, when vicat apparatus is used for this test, it is the time elapsed between the time when water is added to the cement and the time when the needle (c) penetrates the test block to a depth equal to 33-35 mm from the top
- Its value ranges between 30-60 min.

Final Setting Time:

- It is the time elapsed between the time when water is added to the cement and the time when the paste completely loses its plasticity and attains sufficient firmness to resist the certain applied pressure.
- Also it is the time when the centre needle does not pierce through the paste by more than **0.5 mm** but circular cutting edge fails to make an impression.

(d) Compressive Strength Test:

- The test specimen is in the form of cubes with side of 70.6 mm or 76 mm and the cement required for this is 185 gm. and 235 gm. respectively.
- Water/cement ratio is 0.4 & cement/sand ratio is 1 : 3

- 3 days strength $\nless$ 115 Kg/cm^2 and 7 days strength $\nless$ 175 kg/cm^2

(e) Tensile Strength Test:

- Cement/sand ratio is 1 : 3 and qty. of water is 8% by weight of cement and sand.
- The mortar is kept in Briquette mould and the cross-sectional area at its least section is **6.45 cm^2**.
- 3 days tensile stress $\nless$ 20 Kg/cm^2

  7 days tensile stress $\nless$25 Kg/cm^2
- Tensile strength is 10-15% of compressive strength

(f) Soundness Test:

(i) Le-Chatelier's Apparatus Method :

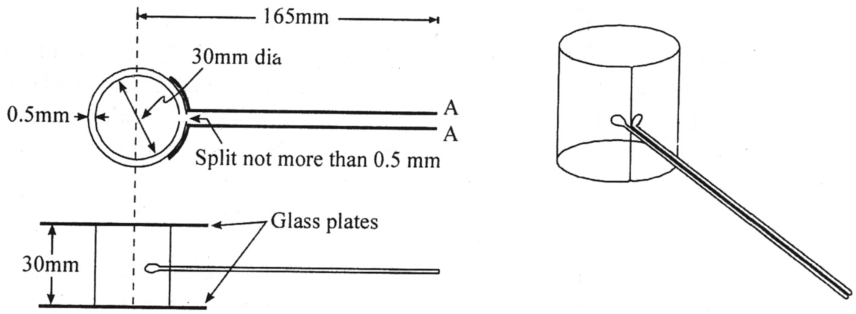

Figure: ***Le-Chatelier apparatus for finding soundness of cement.***

- Unsoundness in cement is due to presence of excess of line.
- It detects unsoundness due to free lime only
- Cement is gauged with a standard consistency of 0.78 P and filled into the mould
- The mould covered at its top is immersed in water at a temperature of 27-32ºC for 24 hours
- The distance between the points of indicator is noted and it should not exceed **10 mm.**
- If expansion is more than 10mm. the cement is said to be unsound.

(ii) Auto Clave Test:

- It detects unsoundness due to free magnesia and free lime both.
- A specimen of 25 × 25 mm is placed in a standard autoclave and the steam pressure in it is increased to a value of 21 Kg/cm^2 in 1-1¼ hour. and it is maintained for 3 hours.
- The autoclave is cooled and the length is measured.
- The high steam pressure accelerates the hydration of both magnesia and lime.

(g) Heat of Hydration (Δ):

- For a low heat Portland Cement :

  (Δ)$\nless$65 cal./gm. at 7 days.

and $(\Delta) \nless$ 75 cal./gm. at 28 days

MORTAR

- It is a mixture of cement, sand and water.

Sand

Based on the source type of sand are:

(i) Pit Sand

(ii) River Sand

(iii) Sea Sand

Bulking of Sand:

- Initially, when water is added to sand, the volume of sand increases. This happens because moisture causes formation of a film around sand particles which prevents the sand particle to come closer. This phenomenon is known as bulking of sand.
- At 5-8% water content, the increases in volume is 20-40% depending upon the grading of sand.
- As water is further added, the sand particles come much closer and thus bulking of sand decreases

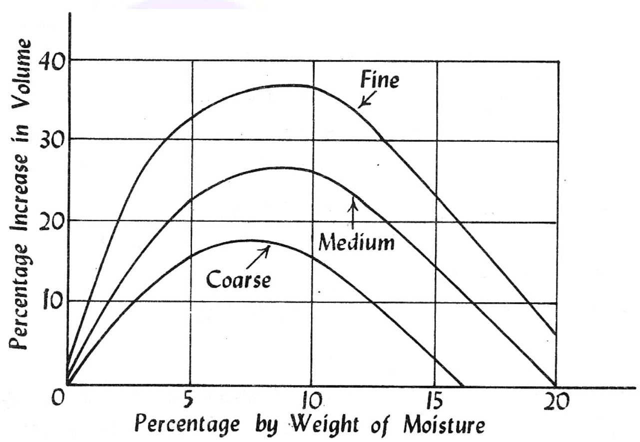

Figure: ***Chart Showing Bulking of Sand***

Function of Sand:

(i) Bulk

(ii) Setting

(iii) Shrinkage: It prevents excessive shrinkage of the mortar

(vi) Surface area

Substitutes of Sand:

- Stone screenings, surkhi, coke dust, cinders or ashes from coat etc. are also used in the place of sand.

Classification of Mortars:

1. **Based on bulk density:**
   (a) Heavy Mortar: Bulk density ≥ 15 KN/m^3.
   (b) Light weight mortar: Bulk density < 15 KN/m^3

2. **Based on binding materials used:**

(a) Lime Mortar:

- Lime is used as binding mortar
- Lime may be fat lime or hydraulic lime
- Fat lime shrinks to a great extent and this mortar is not used in water-logged areas or damp conditions.
- In Hydraulic lime, lime/sand ratio by volume is 1 : 2. It possesses more strength and used in damp conditions.
- Lime mortar is used for lightly loaded above-ground parts of buildings.

(b) Surkhi Mortar:

- Surkhi is used instead of sand.
- The surkhi mortar is used for ordinary masonary work in foundation and super structure.
- It is not used for plastering.

(c) Cement Mortar:

- Cement is used for binding material
- It is used where a mortar of high strength and water resisting properties is required e.g. underground construction water saturated soil etc.

(d) Gauged Mortar:

- By gauging process, cement is added to improve the quality of lime mortar and to achieve early strength.
- It makes lime mortar economical, strong and dense
- The cement/lime ratio is 1 : 6 to 1 : 8 by volume
- It is also known as **composite mortar or lime-cement mortar**
- It is used for bedding and for thick brick walls.

(e) Gypsum Mortar:

- Gypsum is used as binding material

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