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BUILDING MATERIAL

JASPAL SINGH
(EX IES)

BUILDING MATERIALS

- Cement
- Lime
- Mortar
- Aggregate
- Admixture
- Water
- Concrete
- Bricks
- Rock and stones.
- Timber.

CEMENT

→ It is an artificial building material which imparts binding property in construction, that is being developed around (1824 – 25) by "Joseph Aspedin".

→ Cement broadly consists of
(i) Calcareous compounds
Compounds having Ca, Mg.

(ii) Argillaceous compounds
Compounds having Silica, Alumina and oxides.

Examples;

Calcareous compound	Argillaceous compound
(i) Limes-ones	(i) Clay
(ii) Cemented rock	(ii) Shale
(iii) Chalk	(iii) Slate
(iv) Marine shell	(iv) Ash.
(v) Marl	
(vi) Alkali waste	

[Soundness : resistance again volume change]

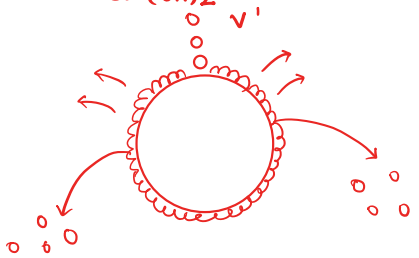
Different constituents of OPC

(i) Lime (CaO) [62-67%] : It imparts strength and soundness to the cement.

→ If it is in excess it makes the cement unsound, cause it to expand and finally disintegrate.

→ If it is in deficiency, it reduces strength and causes the cement set quickly.

$$\underset{V}{CaO} + H_2O \xrightarrow{\text{Slaking}} \underset{V'}{Ca(OH)_2}$$



$V' > V$

(ii) Silica (SiO_2) [17-25%] : It also imparts strength to cement.

→ If it is in excess, strength of cement is increased but it also increases the setting time of cement.

(iii) Alumina (Al_2O_3) [3-8%] :

→ It imparts quick setting property to the cement.

→ It act as a flux and helps in reducing clinkering temperature.

→ If it is in excess it weakens the cement.

(iv) Calcium Sulphate ($CaSO_4$) [3-4%]

→ It is generally added in the form of gypsum ($CaSO_4 \cdot 2H_2O$)

→ It helps in increasing the initial setting time of cement.

(v) Iron oxide (Fe_2O_3) [3-4%]

→ It imparts strength, hardness and colour to cement.

(vi) Magnesia (MgO) [1-3%]

→ It imparts strength, hardness and colour to cement but if it in excess it makes the cement unsound.

(vii) Sulphur (S) [1-3%]

→ Sulphur in cement is also responsible for volume changes in it there by leads to its unsoundness.

$\underbrace{Ca, Al}_{V} + Mg, S \longrightarrow \underbrace{CaSA}_{V'}$ $\quad V' > V$

(viii) Alkali (Na_2O, K_2O) [0.2-1%]

Alkalis in cement leads to efflorescense, thereby causes the development stains over the surface of structure in which it is used for construction.

→ Alkalis undergo expansive reactions with aggregate thereby leads to it disintegration.

→ Alkalies also accelerate the setting of cement paste.

When all the ingredients of cement as mentioned are intergrined and burnt, they fuse with each other and lead to the formation of complex chemical compound terms as "Bogues compound" which in actual are responsible for the properties of cement.

BOGUES COMPOUNDS

(i) Tricalcium Aluminate [$3CaO \cdot Al_2O_3$] [C_3A] (Celite) [9-14%]

→ It undergoes hydration within 24 hrs of addition of water into the cement, hence is responsible for flash setting of cement.

→ It produces max heat during it hydration process thereby results in loss of water added in cement for hydration, hence leads to development of cracks over the surface during setting process more over also

reduces the strength by inhibiting complete hydrati-on.

→ It also reduces the resistance of cement against the attack of sulphur.

→ It is referred as harmful ingredient of cement.

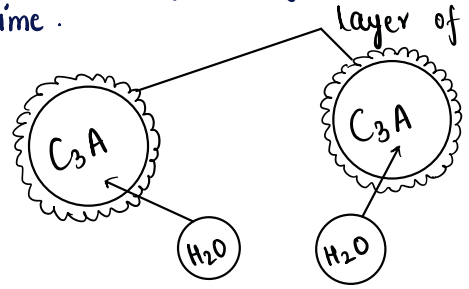
$C_3A + S \longrightarrow CS\ A$ (V') $\quad V' > V$

$C_3A + MgSO_4 \longrightarrow C_3S\ A$ (V') $\quad V' = 227\%\ V$

NOTE:

flash setting means immediate or instant setting of the cement which takes place due to the presence of Alumina in cement.

In order to neutralise the instant setting of cement gypsum is added in it which form a layer over C_3A particle and avoids its interaction with water, but this is temporary and get removed easily, thereby has no effect over final setting time.



→ Water of crystallisation of gypsum vaporises either completely or partially during the manufacturing of cement, hence when water is added in cement, it first reacts with gypsum to fulfill its water deficiency, during which it hardnes and gives the impression of "false setting" of the cement which can be identified by adding further more water into the cement.

(ii) Tetra Calcium Alumino ferrite $[C_4AF]$ $[4CaO.Al_2O_3.fe_2O_3]$
(felite) [10-18%]

→ It also undergoes hydration with 24 hr of addition of water into the cement, hence is responsible for flash setting of cement.

[Rate of hydration $C_4AF > C_3A$]

→ It is observed to have worst cementing property amongst all the Bogues compounds.

→ It also reduces the resistance of cement against the attack of sulphur.

→ It has no engineering use as it does not impart any property to the cement.

$C_4AF + MgSO_4 \longrightarrow C_4ASf$ (V') $\quad V' > V$

[Attack of sulphur on C_4AF is comparitively less than C_3A due to the presence of 'fe' in it]

(iii) Tri calcium silicate [$3CaO \cdot SiO_2$] [C_3S] [Alite] [45–65%]

→ It undergoes hydration within a week or two after the addition of water in cement hence is responsible for development of early strength.

NOTE:

If in any construction early strength is required proportion of C_3S is increased as in:

- Pavement construction
- Pre fabricated structures.
- Cold weather concreting
- where formwork is to be reused for speedy construction.

→ It is observed to have best cementous property amongst all bouges compound.

→ It also increases resistance of cement against frost action (freezing and thawing) (melting).

→ In real terms its effects on heat of hydration is more than C_3A.

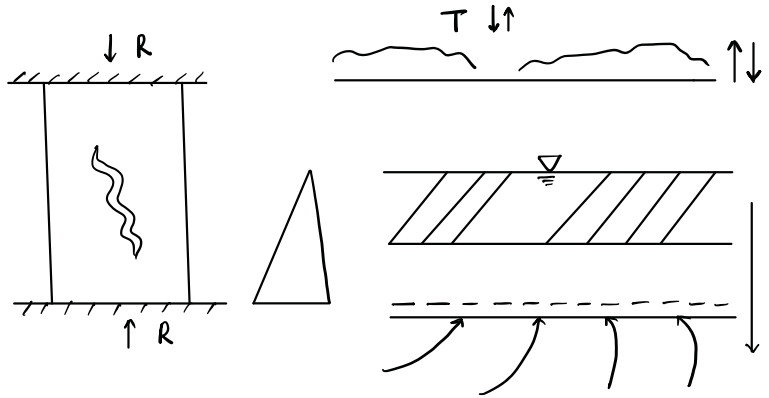
$C_3S + H_2O \longrightarrow C\text{-}S\text{-}H$ (Gel) (S-Silica).

$C_3S + H_2O \longrightarrow C\text{-}S\text{-}H + Ca(OH)_2$ (Gel)

C-S-H Gel: Cementous compound possessing binding property.

C-S-H Gel: CALCIUM SILICATE HYDRATE GEL also known as Thombohydrite gel.
(Also known as Tobermorite gel).

— $Ca(OH)_2$ released during hydration reduces the tendency of corrosion in reinforcement.



(iv) Di calcium silicate ($2CaO \cdot SiO_2$) (C_2S) (Belite) (15–35%)

→ It undergoes hydration within a year of so after the addition of water into the cement hence is responsible for development of ultimate or progressive strength in cement.

→ It also increase the resistance of cement against the attack of chemicals and acids.

→ If in any construction progressive strength is required proportion of C_2S is increased.

Ex: hydraulic structure : Dams, weirs, Barrage, Bridges etc.

$$C_3S + H_2O \longrightarrow C\text{-}S\text{-}H\,(Gel) + Ca(OH)_2$$
$$C_2S + H_2O \longrightarrow C\text{-}S\text{-}H\,(Gel) + Ca(OH)_2$$

Cementous compound.

NOTE:

It has been found that hydration of C_2S produces comparitively lower calcium hydroxide $Ca(OH)_2$ than C_3S.

→ Since $Ca(OH)_2$ is soluble in water and leaches out (to drain out) making the concrete porous particularly in hydraulic structures, thereby reduces the durability of concrete.

→ $Ca(OH)_2$ also reacts with sulphate present in water or soil and leads to the formation of $Ca(SO_4)$ which further reduces the durability of cement (By attacking C_3A and C_4AF).

→ The only advantage of $Ca(OH)_2$ is, it make the pH of concrete around 13. Hereby increases its resistance against corrosion.

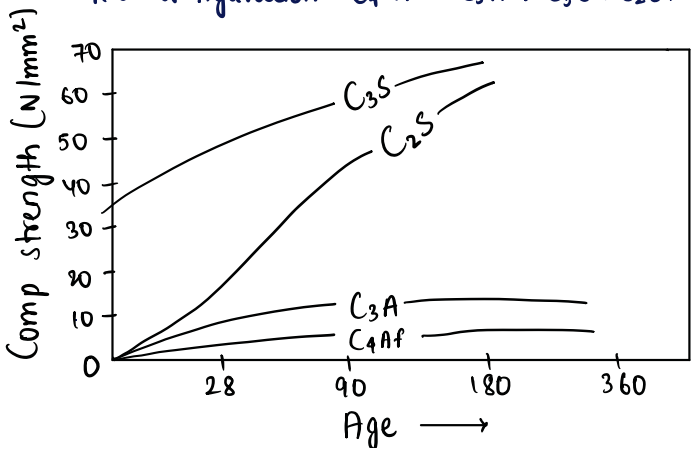
→ Leaching of $Ca(OH)_2$ is about 20-30% in OPC.

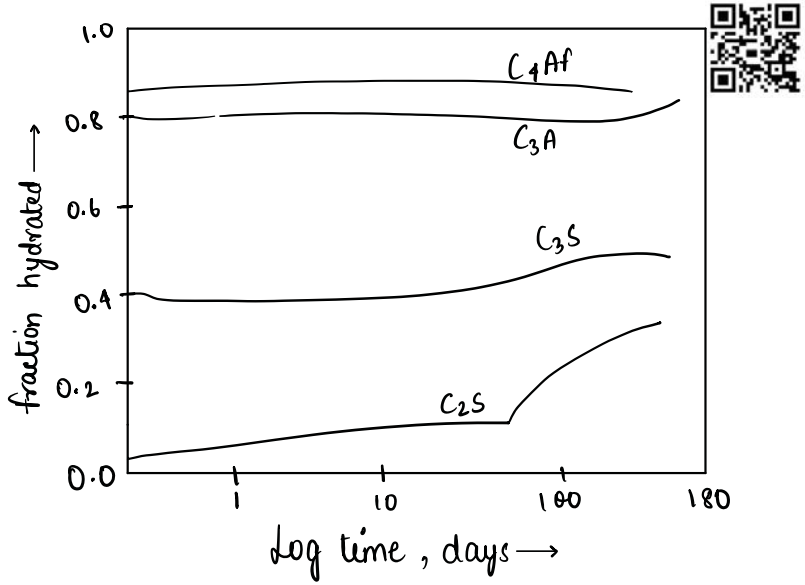
→ Hence % of C_3S is reduced and C_2S is increased for cement to be used in hydraulic structure.

→ Rate of setting in cement is regulated by adjusting the proportion of $\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$

→ Binding Property: $C_3S > C_2S > C_3A > C_4AF$

→ Rate of hydration: $C_4AF > C_3A > C_3S > C_2S$.





→ Heat of hydration and water required for hydration for different Bouges compounds are as follows.

	Heat of hydration		Water required for hydration
	3 days	90 days	
C_3A	210	310	≃ 20
C_4Af	70	100	≃ 20
C_3S	60	105	≃ 24
C_2S	10	40	≃ 21

→ Heat of hydration

$C_3A > C_3S > C_4Af > C_2S$

→ Water required for hydration

$C_3S > C_2S > C_3A \simeq C_4Af$.

→ Total heat of hydration of OPC

$H = aA + bB + cC + dD$

a, b, c, d = proportions of Bouges compound

A, B, C, D = Heat of hydration of respective Bogues compound.

100 gm (OPC) = $C_3A + C_4Af + C_3S + C_2S$

= (10%) (15%) (50%) (35%)

10 gm 15 gm 50 gm 35 gm.

$H_{(3\text{-days})} = (210 \times 10) + (70 \times 15) + (60 \times 40) + (10 \times 35)$.

$\Downarrow$ 2100 $\Downarrow$ 2400

→ Total water required for hydration.

$W = aP + bQ + cR + dS$

P, Q, R, S → water requirement.