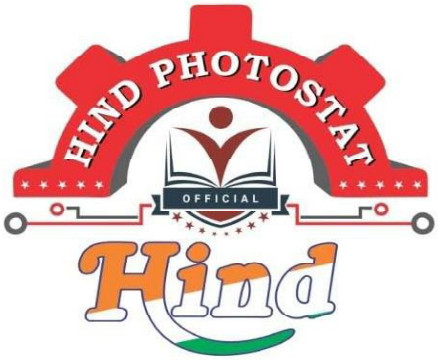

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(DTDC & INDIA POST)

Name – Mohammad Rashid

B.Tech (CE)

B.M.C

Date
3-Mar-2022

- There are following types of building material which are used for construction work:

**(1) Cement
(2) Lime
(3) Mortar
(4) Aggregates
(5) Admixtures → water
**(6) Concrete
(7) Bricks/Rocks
(8) Steel
**(9) Timber
(10) Misc^{n} [paint, plastic --]

- Natural Building material → like lime, aggregate, timber, rocks
- Before the artificial building material (like, cement, admixtures, steel --), we used to used natural building material as construction work.
- We cannot alter the property of natural BM hence we adopt artificial BM for desirable properties.
- For every natural building material, we have corresponding artificial building material de developed by us. [timber → steel
  Brick → stone & Rock
  Cement → lime

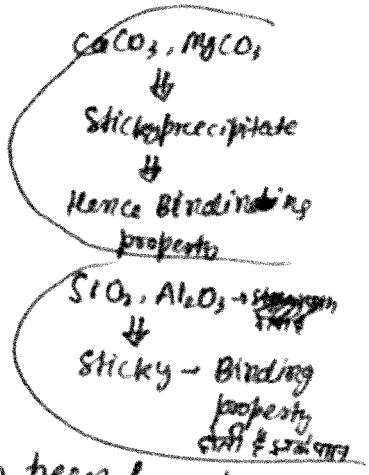
(1) Cement

- It is an artificial building material used for imparting binding property in the construction work that was being developed by Joseph Aspedin in 1824-25.
- Cement Broadly consist of following ~~of following~~ :

(i) Calcareous compound [having Ca & Mg in it]

(ii) Argillaceous compound [having silica, alumina, oxide it]

Calcareous compound	Argillaceous compound
• Chalk	• Clay
• Limestone	• Shale
• Cemented rock	• Slate
• Marl	• Ash
• Alkali waste	
• Marine shell	



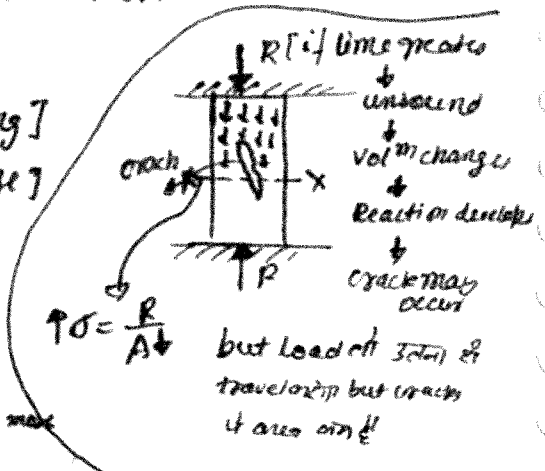
- [The cement after the setting resembles a stone which is been found in Portland (found in England) hence the name of that cement is OPC ordinary Portland cement made by Joseph Aspedin.] Lime → binding property material

Different Constituents of OPC :⇒ (1) lime CaO [62-67%] :⇒

- It imparts *strength to the cement & is responsible for its *soundness.
- If it is an excess it makes the cement unsound, causes it to expand & finally disintegrate. (vol^m on change ↑↑)
- If it is in *deficiency it *reduces the strength of the cement & causes it to *set quickly.

✓ [strength → resistance against gradual loading]

✓ [Soundness → resistance against volume change]



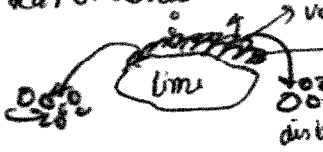
CaO (quick lime) $+ H_2O \xrightarrow{\text{Slaking reaction}} Ca(OH)_2$ (Hydrated lime)

V → V'

V' > V → means expansive reaction → means vol^m will be more

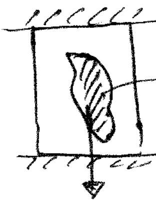
[Toughness → resistance against toughness]

[Hardness → resistance against wear & tear or abrasion].

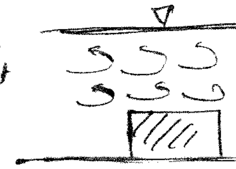


(2) Silica (SiO_2) [17–25%] :⇒ • It also* imparts strength to the cement.
(has binding property)
• If it is an excess it increases the strength of the cement along with its setting time.

[In general the requirement of setting time will depends upon type of construction].



→ grouting [filling of cement in cracks]
↓
in grouting we require quick setting property.



under water construction
↳ we require quick setting property → hence reduce the silica.

(3) Alumina [Al_2O_3] [3–8%] :⇒ • It impart quick setting (means Final) property to the cement.
↳ has binding property
• It acts as a flux & helps in reducing clinkering temperature.

• If it is an excess, it* weakens the cement.

flux → aid या help
clinker temp at temp होता है जहाँ cement (particle) manufacture होता है

जब भी किसी भी BM (→ building material) की बात कर रहे हो उसकी property की बात हो इसका मतलब हम उसकी final property या ultimate property की बात कर रहे हैं not talking about initial property. या initial property लिखा होगा

(4) Calsium Sulphate [$CaSO_4$] [3–4%] :⇒ • It is generally added in the form of gypsum [$CaSO_4 \cdot 2H_2O$]. (इसे seperately add करना पड़ता है।)

• It helps in increasing the initial setting time of cement. (यहाँ साफ-2 लिखा है initial time मतलब यहाँ initial property की बात हो रही है)

(5) Iron Oxide [Fe_2O_3] [3–4%] :⇒ • It imparts strength, hardness & colour to the cement.

[Hardness → resistance against wear & tear or abrasion].

• Iron imparts red brown colour (Reddish Brown)

(6) Magnesia [MgO] [1–3%] :⇒ • It also imparts strength, hardness & colour to the cement. (Yellowish)

• It also responsible for unsoundness of cement^ if it is an excess. (इसमें MgO या S या Alumina... add alkali नहीं किया है already calcareous और argillaceous में present होता है)

(7) Sulphur (1–3%) :⇒ • It is also responsible for* unsoundness of cement. (means not required)

(8) Alkalis [Na_2O, K_2O] [0.2–1%] :⇒ • Presence of alkali in cement leads to efflorescence & expansive reaction with aggregates (↑ the volume) (It is termed as cancer of cement).

[Reaction of alkali with aggregates is termed as cancer of cement].

[efflorescence mean reaⁿ with water due to which stains (…) are developed].

When the ingredients of cement are intergrinded & burnt they fuse (react) with each other leading to the formation of complex chemical compound termed as Bogues compounds which is actual are responsible for properties of the cement.

· Bogues compounds :⇒ (1) Tri-calcium Aluminate ($3CaO \cdot Al_2O_3$) (C_3A) (Celite) (→ 3 mole of lime)
(4-14% in OPC)

- It undergoes hydration within 24 hrs of addition of water into the cement hence is responsible for "flash setting" of the cement. (flash setting → immediate setting, → Quick setting → Alumi…)
- It produces maximum heat during its hydration, hence leads to vapourization of water added for hydration during setting process only thereby leads to the development of cracks over the surface [reduces the strength] during setting process moreover also reduces the strength by inhibiting complete hydration.
- It also reduces the resistance of the cement against the attack of sulphate.
- It is the considered as the Harmful ingredients of the cement.

[reaⁿ with water → hydration, cemical reaⁿ with water → hydration]

[at heat which is evolved during the hydration process is known as heat of hydration
at heat of cement at hydration of lime & release है उसे हम heat of hydration कहते]

$\bar{S}$ → sulphur   sulphur → lime और alumina को attack करता है

S → silica

C → lime

A → alumina

- $C_3A + \bar{S} \longrightarrow C\bar{S}A$ (V' > V)
  V   V'
- $C_3A + MgSO_4 \longrightarrow C_3\bar{S}A$ → tricalcium sulpho aluminate (C_3S_uA)
  V'   (V' ≃ 227% V)

(2) Tetra-Calcium Alumino Ferrate [$4CaO \cdot Al_2O_3 \cdot Fe_2O_3$] [$C_4AF$] [10-18%] [Felite]

- It also undergoes hydration within 24 hrs of addition of water into the cement hence is responsible for flash setting of the cement.
- It also reduces the resistance of the cement against the attack of sulphur [But is more inert than C_3A due to the presence of Fe in it].
- Of all the Bogues compounds it posses least ~~binding pro~~ cementous property.
- It has no engineering significance as it does not import any property ~~to the cement~~

$C_4AF + MgSO_4 \longrightarrow C_4AS_uF$ (V' > V)
V   V'

Note:⇒ • Rate of hydration of $C_4AF > C_3A$ alumia → quick setting

• Rate Reactivity with sulphur ($\bar{S}$) $C_3A > C_4AF$ (due to presence of Fe it is inert)

Note:⇒ "Flash setting" of the cement is due to Alumina but "False setting" of the cement is due to gypsum.

crack hydration की वजह से develop नहीं होता है & crack heat of hydration की वजह से होता है।

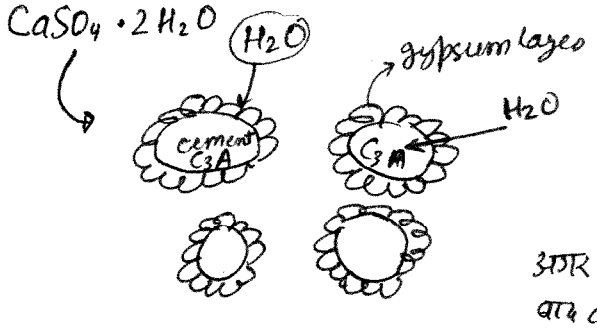
Flash setting → quick setting / immediate / instantaneous ⇒ due to Alumina

False setting → slow setting

$CaSO_4 \cdot 2H_2O$ → water of crystallisation is lost due to high heat during the manufacturing of cement (partially / completely)

Clinker → particle of cement

↳ gypsum form of layer around the cement particle (temporary)



gypsum के लिये temporary होती है कुछ time बाद ये break हो जाती है इसलिये पानी react कर जाता है cement के साथ और final setting time पे कोई फर्क नहीं पड़ता।

अगर Ip के वक्त पानी मिलाने के बाद तो इसका मतलब false setting हुयी थी gypsum की

पहले पहले पानी C_4AF से react करता है इसलिये इसका Rate of Hydration ज्यादा होता है

Rate of Hydration ↓ chemical reaction b/w water + cement

gypsum से जो पानी lost कर दिया था manufacturing के time पे इस at पहले पहले पानी को absorb करता है और जब at gypsum पानी को दोबारा regain करता है तो ये Hard हो जाता है जिससे ये impression आता है कि at set हो गया है इसलिये इसे false setting कहते हैं जिसके लिये gypsum react करता है पानी के साथ cement नहीं।

(3) Tri-Calcium Silicate $[C_3S]$ $[3CaO \cdot SiO_2]$ [Alite] :⇒ [45-65%]

- It undergoes hygration within a week or two after the addition of water into the cement, hence is responsible for early strength.
- "It is observed to have "Best cementous property" amongst all the bouges compounds".
- It also increases the resistance of the cement against "frostaction".

How lime & silica imparts strength

$C_3S + H_2O \longrightarrow$ C-S-H (Gel) → provides strength (actual)
(lime, silica) [To-bermorilite gel]

* $C_3S + H_2O \longrightarrow$ C-S-H (Gel) + $Ca(OH)_2$ → If it present, it reduces the corrosion of RF bcz it provide lime alkalinity
Binding property, leaching

* $Ca(OH)_2 + \bar{S} \longrightarrow CaSO_4 \xrightarrow{\text{attack}} C_3A \longrightarrow C\bar{S}A$ (V) (V) ↳ means it causes unsoundness

C-S-H gel → calcium silicate hydrated gel → cementous compound possessing Binding property. [Thombohydride Gel]

(cold whether (ct से early strength चाहिए होता है) → $CaSO_4$ → $CaSO_4 \cdot 2H_2O$

(setting का strength से कोई लेना देना नहीं होता है) (setting का मतलब होता है Loss of plasticity)

(4) ~~Di-calcium silicate~~: **Frost action:** → it means Freezing & thawing (melting) of water, termed as frost action.

- For frost action, (cement) medium should be porous enough.
- For frost action, medium ~~to~~ should be permeable.
- ✓ C_3S particles are small ~~comp~~ as compared to C_4AF & C_3A, hence if C_3S particles are greater then permeability would be disappear hence water cannot flow hence frost action would (X) not be done ~~hence~~ so if the proportion of C_3S is greater, resistance against frost action ~~against~~ increases.

(4) Di-Calcium Silicate [$2CaO \cdot SiO_2$] [C_2S] [15-35%] [Belite]: ⇒

- It have both lime and silica hence provide strength (binding property) also.
- It undergoes hydration within a year ~~also~~ of so after the addition of water into the cement hence is responsible for progressive/ultimate strength of the cement.
- It also increases the resistance of the cement against the attack of chemicals and acids as it librates lesser $Ca(OH)_2$ during its hydration, thereby is suitable to be in higher proportion in hydraulic construction where leaching of $Ca(OH)_2$ can cause great damage.

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

C-S-H: Tobermorilite Gel (cementous compound)

(Hardening का मतलब है होता है development of strength)

Note: (i) Leaching of $Ca(OH)_2$ in cement is approximately 20-30%.

Note: (ii) The rate of setting in cement is regulated by adjusting the proportion of ratio of $\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$

Note:

(i) Setting | strength rate = ✓

(ii) Setting | strength = ✓

(Strength, होती ही rate setting के depend नहीं करता है)

(Rate of gain of strength of setting के बाद होगा)

(Hardening, setting से पहले भी हो सकती है ये 100% sure है।)

	Final setting time	Strength (N/mm^2) OPC 33		
		3 days	7 days	28 days
Reference	10 hrs	17	22	33
(i)	0 hrs	17	22	33
(ii)	13 hrs	17	22	33
(iii)	10 hrs	15	10	31
(iv)	10 hrs	20	25	36

Rate of gain of strength का setting time से कोई लेना देना नहीं है

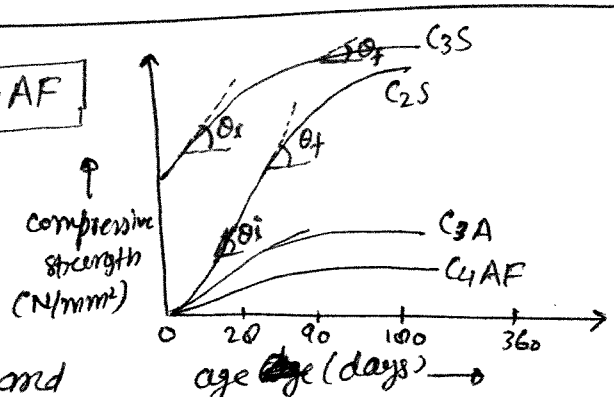
Setting का मतलब होता है, plasticity को loose करना, firmness को achieve करना पर इसका मतलब ये नहीं कि strength gain कर लिया है

conclusion पर strength develop होना तभी start होगी जब setting पूरी हो जायेगी but rate of gain of strength does not depends upon rate of setting.

obj Notes:→

(i) Binding property (or Strength) : $C_3S > C_2S > C_3A > C_4AF$

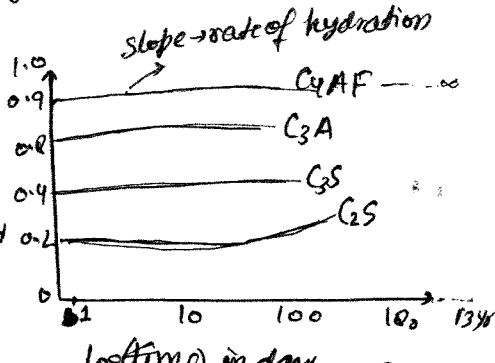
Binding property → मतलब strength



- The above curve give the value of strength and slope will give the Rate of gain of strength.

obj * (ii) Rate of Hydration: $C_4AF > C_3A > C_3S > C_2S$

- C_4A & C_4AF is reacted with the water almost by 90% in 1 days.



obj (iii) Heat of Hydration: $C_3A > C_3S > C_4AF > C_2S$ (Based on ultimate heat of hydration means at 90 days)

	Heat of Hydration (cal/gm)		water required for Hydration
	3 days	90 days	
① C_3A	210	(310)	≃20%
③ C_4AF	70	100	≃20%
② C_3S	60	(105)	≃24%
④ C_2S	10	40	≃21%

$\Delta d = 87$ days

$\Delta H = \frac{100}{210} \times 100 \simeq 50\%$

$\Delta H = \frac{30^{(40-10)}}{10} \times 100 = 300\%$

C_4AF जल्दी heat evolve करेगा लेकिन heat कम करेगा क्योंकि C_4AF का Rate of hydration ज्यादा है पर heat of hydration कम है

% By weight होता है

C_3A → Rate of evolution of heat

$\frac{210}{3} = 70$ cal/gm/d

C_3A → 1 gm C_3A जब 0.2 gm पानी को react करेगा तो 3 दिन में 210 cal/gm heat निकालेगा।

* Water required for hydration → $C_3S > C_2S > C_3A \simeq C_4AF$

[20 - 25%]

* Alkalies → Alkalies in cement leads to efflorescence thereby causes the development of stains over the surface of structure in which it is used for construction.

- Alkalies undergo expansive reaction with aggregates, thereby leads to it disintegration.
- Alkalies also accelerate the setting of cement paste.

- The compound of calcareous and argillaceous compounds fuses at a particular temperature is called Clinker temp.

Note:- Flash setting means immediate or instant setting of the cement which takes place due to presence of alumina in cement.

- In order to neutralize the instant setting of cement gypsum is added in which form a layer over C_3A particles and avoids its interaction with water but this layer is temporary and gets 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 react with gypsum to fulfill its water deficiency during which it hardens and gives the impression of "False setting" of cement, which can be identified by adding further more water into the cement.

Note:- If in any const^{n} early strength is required proportion of C_3S is increased as in -

→ Pavement construction
→ Prefabricated structures (like railway sleepers)
→ cold weather concreting
→ where formwork is to be reused for speedy construction.

✓ For C_3S, in real terms its effect on heat of hydration is more than C_3A.

If temp (↑) → Rate chemical reaⁿ rate with water (↑) & vice versa.