Building Materials

Natural Building Material

- All those building materials which are available naturally
- The properties can't be altered.

Artificial Building Material

- These materials are obtained from natural Building Material
- Depending upon requirement, the properties can be changed.

Cement

- Cement is an Artificial building material.
- It is used to import Binding property which is very important for construction.
- Cement was developed around 1825 by Joseph Aspedin.
- Prior to this lime was being used as a binding material.
- Broad Classification of Ingredients of cement:-

(i) Calcareous Compounds
(ii) Argillaceous Compounds.

(i) Calcareous Compounds:- Compounds having calcium & Magnesium

- Examples of calcareous compounds:-

(i) Chalk
(ii) Lime Stone
(iii) Marl Soil
(iv) Marine Shell
(v) Alkali Waste
(vi) Cemented Rocks.

(ii) Argillaceous Compounds:- Compounds which have Silica, Alumina, various oxides. Examples:-

(i) Clay
(ii) Shale
(iii) Slate
(iv) Fly Ash / Ash

- Mixture of Calcareous & Argillaceous compounds will

NOTE:- once the cement is ~~set~~ set, is Resembles a stone which is ~~formed~~ found in Portland.
∴ Cement is known as ordinary Portland Cement.

→ Various Constituents of ordinary Portland Cement (OPC):-

(i) Lime (CaO) [60-70%]

- It impart strength and soundness to cement
Strength:- Resistance against gradual load.
Soundness:- Resistance against Vol^m change.
- If lime is added in Excess, it will increase in the strength but may also lead to unsoundness of cement (Vol^m change) and vol^m change is not preferred in any hardened structure.
- In any of the Hardened structure vol^m change is not permitted.
- If lime is in deficiency, then strength of the material will be reduced & also it leads cement to set quickly.

(ii) Silica (SiO_2) (17-24%):-

- It also impacts strength to cement.
- If silica is present in excess, it will increase the setting time of cement.
- If silica is deficient, desirable strength will not be achived.

NOTE:- If nothing is specified regarding any property of cement, the by default, the property is assumed to be final property.

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

- It impacts Quick setting property to cement.
- It also helps to reduce Clinkering Temperature (Temperature at which cement clinkers are formed)
- This leads to reduction in cost of manufacturing as energy required to burn the ingredients will be less.

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

- calcium sulphate is added in the form of gypsum

Gypsum = $CaSO_4 \cdot 2H_2O$

- It is not present in calcareous & Argellaceous compound, it is added artificially by us.
- It helps to increase the **Initial Setting Time** of cemet.

(v) Iron Oxide (Fe_2O_3) (3-4%):-

- It imparts Strength, Hardnes & colour to the cement.
- If it is in excess it may cause overburning of cement,
- The characteristics colour of Fe_2O_3 is reddish brown, but the resultant colour of cement is grey.

NOTE:- Ability of a Material to resist Wear & Tear.

(vi) Magnesia (MgO) (1-3%):-

- It is also responsible for imparting strength, hardness & colour to cement.
- Colour = (Yellowish Tinge)
- If it is present in excess it will make the cement unsound.

(vii) Sulphur (1-3%):-

- It is also responsible for unsoundness of cement.

(viii) Alkali (Na_2O, K_2O) (0.1-1%):-

- It accelerate the setting time of cement.
- These alkalies, reacts with water and over a period of time, the water Evapourates & these salts/ Alkalies remain behind, Hence this leads to development of stains over the structure & reduce the Asthetic value. This reaction is known as **Efflorescence**.

- It undergoes reaction with Aggregates which increases the volume [Expansive Reaction]. This also leads disintegration of ingredients. The above reaction is termed as Alkali Aggregate Reaction.
- Since Alkali is leading to disintegration of ingredients it is also known as "Cancer of Cement."

NOTE!-

- When all the ingredients of cement are intergrind and mixed, they lead to formation of 4 chemical compounds & These compounds are complex in nature.
- As it was first identified by "BOGUES", Hence it is termed as Bogues Compounds.
- For properties of cement, these compounds are responsible.

(1) Tri Calcium Aluminate ($3CaO.Al_2O_3$)[C_3A] [Celite] (4-14%):

- It undergoes hydration just within 24 hours & this compound is responsible for Flash Setting (Instant Setting/ Quick setting ect).
- During hydration, because of C_3A Maximum heat will be evolved.

NOTE!- The Hydration Reaction = Chemical Reaction with water is Exothermic in Nature {Heat Evolution}

- Since reaction is Exothermic, It will lead to loss of water which is added to cement & this will lead to development of crack & ultimately reduces the strength.
- It reduce resistance of sulphur attack (or) it promotes the attack of Sulphur.
- Sulphur attack of Calcium & Aluminum.

(C_3A) + Sulphur $\longrightarrow$ C_3SuA

V $\qquad\qquad$ V'

V' > V by 227%

$C_3A + MgSO_4 \longrightarrow C_3SA$

(Tricalcium Alumino Sulphate)

- This C_3A is termed as <u>Harmful Ingredient of Cement</u>.
- C_3A also binds the chloride which has got high tendency to seep through cracks. Hence C_3A prevents corrosion of Reinforcing Bars.

② <u>Tetra Calcium Alumino Ferrate $[4CaO.Al_2O_3.Fe_2O_3]$ $[C_4AF]$</u>

<u>Felite (10-18%)</u>:-

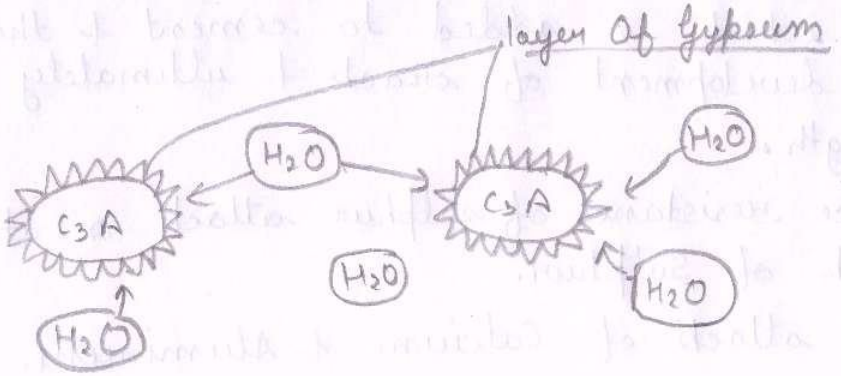
- It also undergoes hydration within 24 hours & it is also responsible for flash setting.
- C_3A and C_4AF both are responsible for flash setting but rate of hydration of C_4AF is more than C_3A.

Rate of Hydration:- $\boxed{C_4AF > C_3A}$

- It also reduces the resistance of cement against attack of sulphur, but due to presence of Iron in C_4AF, the tendency of Attack will be less as compared to C_3A.
- Out of all Bogues compounds, (C_4AF) is found to have least cementatious property & is of no engineering significance.

<u>NOTE</u>:-

- C_3A & C_4AF are responsible for <u>flash setting</u> where as Gypsum is responsible for <u>false setting</u>



- As gypsum is added over manufacturing process, it forms a layer over molecules of cement.
- Due to presence of this layer, the attack of water over the cement will not be possible and the process of setting will be slightly delayed.
- The layer formed by gypsum is temporary and over a period of time it breakes, Hence will not affect the final setting time.

NOTE:-

When gypsum is added during manufacturing of cement, Due to high clinkering temperature the water of crystalisation of Gypsum Evaporates.

- During Hydration process, the gypsum will first complete the deficiency of water of crystalisation ($2H_2O$) & the cement will appear to have get set.

This is known as False Setting.

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

- It undergoes hydration within (1-2) weeks after addition of water.
- This compound is responsible for early strength of cement. Hence those constructions which requires early strength should have higher proportion of C_3S.
- As per observation, the best binding property is imparted by C_3S.
- The presence of C_3S ~~promot~~ provides resistance against frost action i.e. It do not promote frost action (Freezing + Thawing).
- Iron & Magnesia (Mg) helps in fusing of Calcium (lime) and Silica & this leads to formation of C_3S.
  ∴ Fe + Mg imparts indirect strength to cement.
- Mechanism of Strength.

$$C_3S + H_2O \longrightarrow C\text{-}S\text{-}H\ (gel)$$
(Binding)

$$C_3S + H_2O \longrightarrow C\text{-}S\text{-}H + \boxed{Ca(OH)_2}$$
(Binding) (Hydrated lime / Slaked lime)

- The C-S-H gel also known as thomobydrite gel (or) Tobermoralinite gel
- It is actually responsible for binding property of cement.
- The slaked lime $Ca(OH)_2$ which is being formed is also responsible for prevention of corrosion of reinforcing bars as $Ca(OH)_2$ increases the basicity & PH also increases.
- Also $Ca(OH)_2$ leaches out from the structure hence reducing the overall volume of cement by making it Porous (voids more)
  ∴ Reduces durability of concrete structure.

$$Ca(OH)_2 + Su \longrightarrow \boxed{CaSO_4} \longrightarrow (C,A) \longrightarrow C\,Su\,A$$

- The $Ca(OH)_2$ as formed will also promote the attack of chemical & it reacts with sulphur which further reacts with lime & Alumina & leads to unsoundness.

(4) Dicalcium Silicate ($2CaO \cdot SiO_2$) (C_2S) (Belite) (15-30 to 35%):-

- It undergoes hydration within one year & so on
- This compound is responsible for later / ultimate / Progressive strength of ~~cement~~ Structure, Eg:- Hydraulic structure, Bridge.

$$C_2H + H_2O \longrightarrow C\text{-}S\text{-}H + Ca(OH)_2$$

- It increases the resistance of cement against attack of Sulphur / Chemical, as proportion of lime is less.
  As it reacts with water slowly the proportion of $Ca(OH)_2$ produced will be less.

- Compared to C_3S, proportion of lime in C_2S is less,
  ∴ It will liberate less calcium hydroxide.
⇒ It will impart better durability.
- ∵ calcium + silica reacts with water C-S-H gel will also be formed.

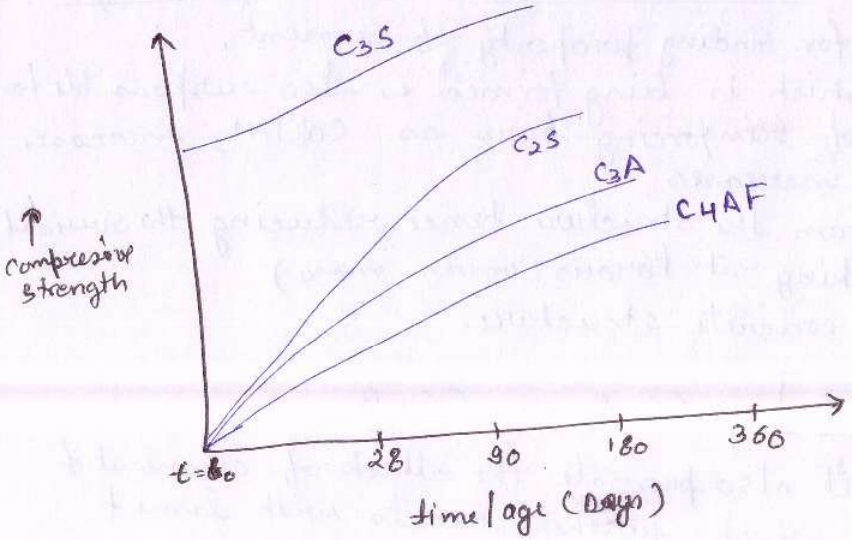
NOTE:- Frost action:- Freezing + Thawing (Melting).

- In order to carry out frost action the water should be present in the medium (Cement), + also water should be able to flow in the medium.
  ∴ Medium should be porous + permeable.
- As the size of C_3S is very small it leads to reduction in permeability. ∴ Frost action will not take place.

Imp Points:-

① Binding Property (Strength):- $C_3S > C_2S > C_3A > C_4AF$

② Rate of Hydration:- $C_4AF > C_3A > C_3S > C_2S$



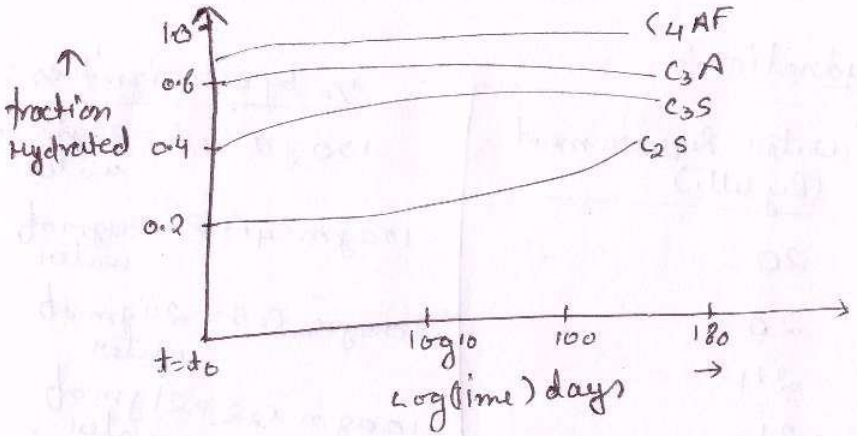
NOTE:- Strength increases with time is indicated by y-axis of the curve.
- Rate of gain of strength with time is indicated by slope of the curve.

- Conclusions Of the Curve:-

① In curve of C_3S initially slope is high, this shows that it imparts higher strength during early days + with time slope of the curve reduces ⇒ Rate of gain of strength decreases.

② from C_2S curve, It is clear that, strength increases with time & also rate of gain of strength increases with time, Hence C_2S is responsible for later stage / ultimate strength.

③ Rate of hydration :- $C_4AF > C_3A > C_3S > C_2S$



From the curve it can be seen that within 24 hrs,
Approximately :- 90% of C_4AF will be hydrated.
80% of C_3A " " "
40% of C_3S " " "
20% of C_2S " " "
} As per observation.

④ Heat of Hydration :- (HOH)

Bogues	(cal/gm) 3days HOH	(cal/gm) 90days HOH
C_3A	210	300 310
C_4AF	70	100
C_3S	60	105
C_2S	10	40

- Initially C_3A has evolved 210 cal/gm.
In later stages, it gave 310 cal/gm.
∴ Rate of heat evolution = $\left(\frac{310-210}{210}\right) \times 100 = 47\% \simeq 50\%$

- This shows rate of heat evolution decreases with time for C_3A.
- for C_2S, Initial heat evolved = 10 cal/gm & later stages = 40 cal/gm.
∴ % Rate of heat Evolution = $\frac{40-10}{10} \times 100 = 300\%$
This shows that higher heat is evolved during later stage of Hydration for C_2S.

Rate of Hydration ∝ Rate of heat of hydration

∴ Sequence of HOH $\boxed{C_3A > C_3S > C_4AF > C_2S}$

→ Water Requirement for Hydration:-

Bogues Compound	% Water Requirement (By wt.)
C_3A	20
C_4AF	20
C_3S	24
C_2S	21

% by wt. signifies:-

100gm C_3A = 20gm of water

100gm C_4AF = 20gm of water

100gm C_3S = 24gm of water

100gm C_2S = 21gm of water.

∴ Water required for hydration:-

$C_3S > C_2S > C_3A \simeq C_4AF$

- Total heat of hydration & total water requirement for OPC:-

(a) Total heat of Hydration of OPC:-

$$H = \sum^{\text{\% to Comp}} \left(\text{Proportion of Bogue compound} \times \text{Heat Evolved by respective Bogue compound.} \right)$$

$$\boxed{H = aA + bB + cC + dD}$$

a, b, c, d = Proportion of individual Bogue compound.

A, B, C, D. = HOH of respective Bogue compound.

NOTE:- The standard value of HOH for OPC for 7 days & for 28 days.

for 7 Days = (89-90) cal/gm.

28 Days = (90-100) cal/gm.

(b) Total Water Required for OPC:-

$$W = \sum \left(\text{Proportion of Individual Bogue compound} \times \text{Proportion of water required by individual Bogue compound} \right)$$