→ Cement → Aggregates
→ lime → Admixture
→ Mortar → Concrete
→ Bricks → Timber

: Cement :

→ It basically constitute of two different type of compounds.

Agilacious Compounds & Calcareous Compound.

{Clay} } Calcium Carbonate}

→ It consist of → lime(1), → silica(2), → Alumina(3), → Calcium Sulphate(4)
→ Iron Oxide(5) → Magnesia(6) → Sulphur(7)
→ Alkalies(8).

For Ordinary Portland Cement

(1) Lime →	62-65%	(CaO)
(2) Silica →	17-25%	(SiO_2)
(3) Alumina →	3-8%	(Al_2O_3)
(4) Cal. Sulphate →	3-4%	($CaSO_4$)
(5) Iron Oxide →	3-4	(Fe_2O_3)
(6) Magnesia →	1-3	(MgO)
(7) Sulphur →	1-3	(S)
(8) Alkalies. →	0.2-1	(Na_2O, K_2O)

Max^m are in their Oxide form.

Functions of different ingredients of Cement :-

(1) Lime (62-65%) :- Lime imparts strength and soundness to the cement, if it is in excess it makes the cement unsound, causes it to expand and disintegrate.

→ If it is in defficiency it reduces the strength of the cement and causes it to set quickly.

→ (2) Silica (17-25%) :- Silica also imparts strength to the cement.

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

Silica ↑↑ → Strength ↑↑ → Setting time ↑↑.

(3) Alumina (3-8%) :- It imparts quick setting property to the cement. It acts as a flux and It helps in reducing the clinkering temperature during the burning of the cement & manufacturing

→ If it is in excess it weakens the cement.

(4) Calcium Sulphate (3-4%) :- It is generally added in cement in form of gypsum it helps in increasing the initial setting time of cement.

Initial setting time → Water Added to cement starts loses it's Plasticity

Final setting time → Water Added to cement Ends loses Plasticity. Completely.

(5) Iron Oxide (3-4%) :- It imparts colour, Strength and hardness to cement.

- Strength → Gradual loading
- Toughness → Impact loading
- Hardness → Wear & Tear.

Resistance

It imparts Reddish brown tint in cement.

(6.) Magnesia (1-3%) :- It also imparts colour and hardness to the cement.

→ It gives yellowish tint to cement.

→ If it is in excess it makes the cement unsound

(7.) Sulphur (1-3%) :- It is also responsible for inducing the soundness in cement.

Soundness due to Sulphur can't be measured

Lime, Magnesia } Can be measured.

Sulphur → Nuissance causing Bacteria.

(8.) Alkalies → Na_2O, K_2O (0.2 to 1%) :- Presence of alkalies in cement leads to efflorescence and staining of structure in which the cement is used for construction. .....
As these alkalies absorbes the moisture and reacts with it and leads to development of white-grey spots over the surface of structure (Staining)

* Bogues Compound :- When water is added in cement, it reacts with the ingredients of the cement chemically and results in format" of complex chemical compound termed as B. compound. which are not formed simultaneously.

(A) Tricalcium Aluminate ($3CaO.Al_2O_3$) (C_3A)
(4 to 14%)
It's formed in within 24 hours of the addition of water in cement.

→ This compound is responsible for max" evolution of heat of hydration.

(B) Tetra Calcium Alumino Ferrate ($4CaO \cdot Al_2O_3 \cdot Fe_2O_3$)
(10-18 %) (C_4AF)

It is also formed within 24 hours of addition of water in cement.

→ This compound is also responsible for high heat of hydration in it's initial period which ~~later~~ gradually reduces in later stages.

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

Example: (i) Pre fabricated Conc. Constn
(ii) Cold weather Concreting
(iii) Formwork is to be raised for speedy Construct^n.

This compound is formed within a week ~~of~~ ~~Soo~~ or so of the addition of water in cement. and is responsible for strength (Early strength) development in it's initial stages. ∴ Used in Cold weathe

→ If in any structure early development of strength is req^d proportion of C_3S is increased Constctn

(D.) Di-Calcium Silicate ($2CaO \cdot SiO_2$) (C_2S)
(15-35 %)

It is the last compound which is formed during the hydration process which may take a year or so for it's formation.

→ It is rep responsible for progressive strength of cement in it's later stage.

→ If in any structue strength is Req^d in later stages the proportion of C_2S is increased

Ex :- Hydraulic Struct.
Bridges etc.

Heat of hydration of diff Bogues Compounds at different Age :-

Unit of Heat of Hydration = Cal/gm

	3 days	90 days
C_3A (4-14%)	212	310
C_4AF (10-18%)	69	98
C_3S (45-65%)	58	105
C_2S (15-35%)	12	42

Heat of Hyd^{n} of Cement :-

$$H = aA + bB + cC + dD$$

a, b, c and d are %age of Bogues Comp. in Cement conc simultaneously.

→ Heat of Hyd^{n} of O.P.C. in 7 days is Approx^{ly} 89 to 90 Cal/gms and during 28 day → 90 to 100 cal/gms

→ On an Avg. 23% of water by weight of cement is Req^{d} to carryout the hydration completely.

→ Approx^{ly} 15% of water is intrapped within the void of the cement particles, and is not available for hydration hence effectively 38% of the water is Req^{d}. to carry out the complete hydration.

Imp. 10 Mark.

★ Manufacturing of Cement :- (i) It is carried out in 3- distinct operations

(1) Mixing of Raw Ingridients.
(2) Burning
(3) Grinding.

(ii) Generally two methods are available for manufact^{n} of cement :-

(a) Dry Process :- Calcaries Comp (CaO4) | Argillaceous Comp

↓ Crushing (25mm) | ↓ Crushing (25mm)

↓ Fine Grinding in Ball/Tube Mill | ↓ Fine Grinding in tube/Ball Mill

↓ Storage | ↓ Storage

↓ Channels → Mixing of Ingredients in Corrected Proportion ← Channels.

↓ → On next page.

↓

Preheating of Ingredients @ 800°C by Exhaust Gases

↓

Fed to Rotary Kiln for Burning

↓

Clinkers are formed.

↓

Fine Grinding in Tube Mills

↓

Cement Silos

↓

Packaging Plants.

(b) Wet Process (OLD Method)

Calcareous Compound → Crushing (25 mill) → Storage → Channel

Argillaceous Compound → H_2O → Wash mill → Storage → Channel

Channel → Wet Grinding in tube mill To form slurry ← Channel (Gypsum)

↓

Blending of Slurry To corrected proportions

↓

Fed to Rotary Kiln for Burning

↓

Clinkers are formed

↓

Gypsum → Fine grinding in Tube mills

↓

↓

Cement in Silos

↓

Packaging Plant.

Testing of Cement :- (i) It is carried out to find the presence of desirable properties in it.

(ii) Generally 3- Class of test are ~~avail~~ available for this purpose

(A) Field Test :- (a) Colour test :- (i) The cement should have uniform grey colour.

(b) Physical Property test :- (i) The cement should feel smooth when rubbed in b/w fingers.

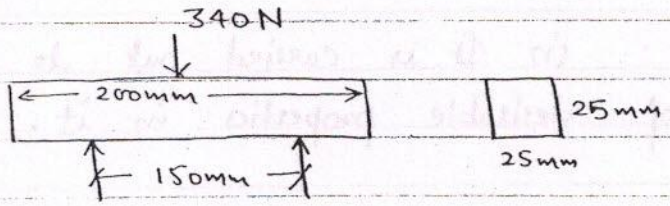
(ii) Throw a small quantity of cement ~~over~~ a in a bucket of water it should sink and float over the surface of water.

Sp. Gty → Cement (Inorganic) → 2 - 2.6 > ρ_w

(iii) The sample of cement should be free from lumps which are formed due to absorption of moisture from atmosphere by cement.

(C) Strength Test :- (i) Prepare a block of 25 mm x 25 mm x 200 mm from given sample of cement. and immerse it in water for a curing for 7 days.

Remove the block and place it over the supports that are 150mm apart, subject the block to a Point load of 340 N. It should show no sign of failure under the application of load.



(B) Laboratory test :- (b_1) Fineness test :- Fineness of cement is tested in order to check it's extent of grinding that directly affects the rate of hydratn, rate of gain of strength, and rate of evolution of heat.

Fine Grinding ↑↑ → Rate of hydratn ↑↑
↓
Rate of evolutn of heat ↕↑

(i) Fineness of cement can be tested by any of the following Methods :-

(I) Sieve test :- Take 100 gms of cement to be tested and place it over std. I.S. sieve no. 9 (90 micron).

→ Sieve the sample of cement for approximately 15 minutes along with the breaking of air set lumps formed during sieving. Note the weight of Residue left over sieve after the test.

- For OPC it shouldn't exceed 10% of the original weight. (10gms)

•• Siere test is rarely used now days to find the fineness of the cement.

(II) Air permeability Test :- This mthd of test covers the procedure for determining the finering of cement that is represented as specific surface area and expressed as total surface area per unit weight. (cm^2/gm)

Blains

- Generally blaines air pespeability apparatus is used to perform this test.

•• Principle of this test is based upon the relat'sp b/w flow of air through the cement bed. and surface area of the cement particles forming the cement bed.

Finer the cement ↑↑ → Greater the Surface Area

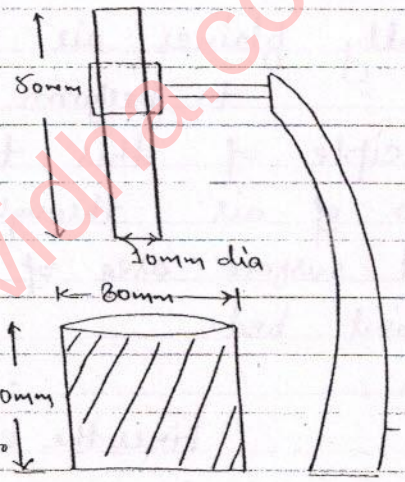
Greater the surface area → More pressure on air to pass through.

- For OPC Sp. Surface Area should not be less than 2250 cm^2/gm

(b_2) Standard consistency test :- (i) In order to find the initial setting time, final setting time and soundness of the cement, a parameter termed as std. consistancy must be known.

(ii) Std. Consistancy is the consistency of cement paste which permits Vicats plunger of size 10mm and height 50mm, to penetrate upto a depth of 33-35 mm into the mould prepared from the given sample of the cement paste from the top.

(iii) The test is concerned with finding the water content at which cement paste with std. consistancy can be prepared.



-: Vicat's Apparatus. :-

(iv) In order to perform this test take 500gms of cement and add 23 to 24% of water by weight of cement in 1st trial. Lower the needle gently upto the top surface of the mould and release it quickly. Repeat the test uptill the penetration of 33 to 35 mm from the top is being observed.

(v) The water content at which this penetration is observed is denoted by "P", the temp. at which the test should be perform vary b/w 27 ± 2°c and Relative humidity of 90% should be maintained during the test.

(b_{21}) Setting time test :- It is tested for finding it's deterioration due to storage.

(i) Generally two setting time are being associated with cement
→ Initial
→ Final
Setting Time

- Initial Setting time :- (i) Initial setting time is regarded as a time that is being measured from the instant water is added to the cement upto the time it (cement) starts loosing it's plasticity."

(ii) In order to perform this test take 500 gms of cement and gauge it with "0.85 P" (Add 85 % of water i.e. req^{d} to produce the cement paste of std. consist^{cy})

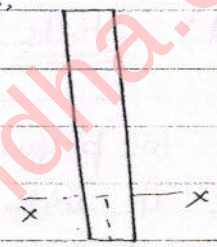
(iii) Lower the square needle gently upto the top surface of the mould and release it quickly. Note the time Req^{d} by this needle to penetrate upto the depth of 33-35 mm from the top. this time is regarded as initial setting time of the cement.

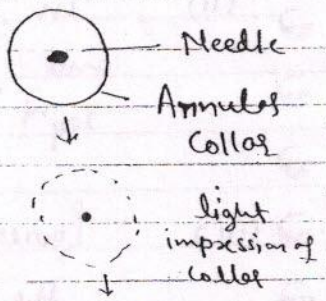
(iv) For OPC initial setting time is Approx^{y} 30 minutes.

- Final Setting Time test :- (i) Final setting time is regarded as the time which is been measured from the instant water is added to the cement upto the time it completely loses it's plasticity.

(ii) In order to find the final setting time of the cement, mould ~~be~~ is prepared same as above, and it is taken as the time at which needle makes an impression over the mould and annular collar failed to do so.

(iii) For OPC Final set. time ⇒ 10 hrs.



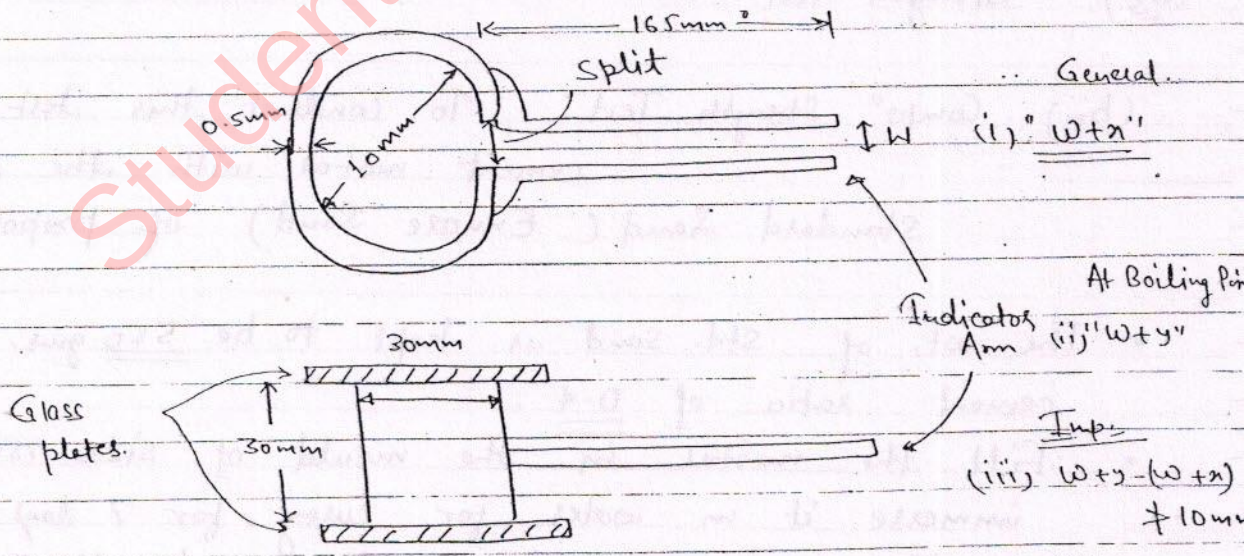


(b_{12}) Soundness Test :- (i) It is important the cement after setting do not shows any appriciable change in Volm.
As it seriously affects the durability of structure prepared from this cement.

(ii) Soundness of cement is due to presence of lime, Magnisia and Sulphur

(1) Soundness due to lime :- Soundness due to lime is measured using Le - Chatleiss apparatus that consist of small splitt cylinders of spring brass having dia and hight of 30 mm.

- It also includes two indicator arms of length 165mm placed on either side of split which is used to measure it's displacement.
- In order to perform this test take 500gms of cement and gauge it with "0.78 P"
- Fill the mould with cement paste and cover it from top and bottom with help of glass plates. Immerse the entire assembly into water having temp^re in the range of 27° to 32°C for 24 hrs. Remove the mould and note the displacement of the splits with help of indicator arms.
- Again immerse the entire assembly in water and raise the water temperature upto it's boiling point in 25 to 30 minute and maintain it for next 3 hrs Note the displacement of splits with help of indicator arms in this case also.
- The diff^nce of the reading in both the part of the test should not exceed 10mm for OPC.



"Le- Chatleirs Apparatus"

(2) Soundness due to Magnesia :- It is tested using "Autoclave" test which is best sensitive to both lime and Magnesia.

(i) In order to perform this test prepare a mould of 25 mm from lean cement and place it in Autoclave.

(ii) Increase the pressure of steam in Autoclave upto 21 kg/cm² and maintain it for next 3 hrs. Remove the mould and note the %age expansion in each direct^{n}.
For OPC it should not be greater than 0.8 %.
(± 0.8 %.)

(b_3) Strength Test :-

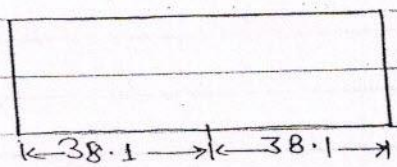
(b_{31}) Comps^{v} Strength Test :- To conduct this test prepare cement motar with the help of Standard Sand (Ennore Sand) of proportion 1:3

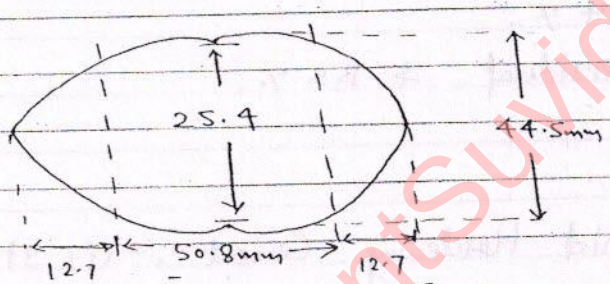
- The wt. of std. Sand is kept to be 550 gms. and water cement ratio of 0.4.
- Fill the mortar in the mould of size 75mm and immesse it in water for curing for 7 days.
- Comp^{sv} Strength can further be tested with "Universal Testing Machine".

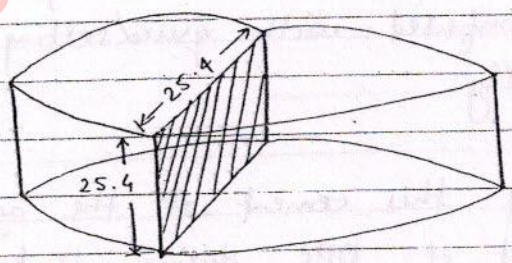
(b32) Tensile Strength Test :- (i) Tensile strength of cement can't be ~~measu~~ tested directly as there is no shape of mould and any apparatus available due to which uniform tensile stresses are developed throughout the section of the mould.

(ii) In order to find the tensile strength of cement, Mortar is prepared as above and is placed in Std. ~~fig~~ briquette

Concrete { Comp - f_{ck}
Tensile - $0.7\sqrt{f_{ck}}$
Related to Comp^{sv} Strength.







Tensile strength = $\frac{\text{Failure load}}{25.4 \times 25.4}$ = $\frac{\text{failure load}}{6.45\ cm^2}$

(C) Chemical Composition Test :- • The Ratio of Alumina to Iron Oxide should ≯ 0.66.

• The Ratio of lime to silica, Alumina and Iron oxide ≯ 1.02 and ≮ 0.66.

This ratio is termed as lime Saturation factor.

$$1.02 \not< \frac{CaO - 0.7\,SO_3}{2.8\,SiO_2 + 1.2\,Al_2O_3 + 0.65\,Fe_2O_3} \not< 0.66$$

- Total sulphur content ≯ 2.75 %.
- Total weight of Magnesia ≯ 5 %.
- Total loss on Ignition ≯ 4 %.
- Total wt. of insoluble red residual ≯ 1.5 %.

Types of Cement :- (1) Rapid Hardening Cement :- (i) It is the type of cement that shows the higher rate of developement of strength and must not be confused with quick setting cement that only sets quickly.

(ii) The strength of this cement at the age of 3 days is same as that of OPC during 7 days.

(iii) This cement is produced by fine grinding the cement clinkers and increasing the proportion of C_3S and reducing the proportion of C_2S.

{ "Specific Surface area of this cement should not be less than 3250 cm^2/gm." } { OPC - 2250 cm^2/gm }

C_3S ↑↑ to 50 %.
C_2S ↓↓ to 9 to 10 %.

- This cement finds it's application in =

(i) Cold weather concreting
(ii) & Emergency Road Repair
(iii) Prefabricated Concrete Construct^n
(iv) Where formwork is to be removed early for speedy construc

(2.) Extra Rapid hardening Cement :- (i) This cement is manufacture-ed by intergrinding the Rapid hardening cement clinkers with Calcium Chloride "proportion of which should not be greater than the 2% by wt. of cement."

(ii) If the cement should be mixed, transported, placed, compact and finished within 20 minutes of it's formation.

(iii) This cement is found to have 20 to 25 % higher strength than Rapid Hardening cement during 1 to 2 days and 10 to 15 % higher strength during 7 days. This Rate of gain of strength of this cement decreases with age and at the age of 90 days, the strength of the cement is same as that of OPC.

Rate of gain of Strength.

1 to 2 day → 20 to 25 % ↑
7 days → 10 to 15 % ↑

(iv) This cement also finds it's applicat^{n} where "Rapid H. Cement" is used.

(3.) Sulphate Resisting Cement :- (i) OPC is highly succeptable against the attack of Sulphate specially to that of Magnesium Sulphate that reacts with both Calcium hydroxide to form Calcium Sulphate and Calcium Aluminate to form Calcium Sulpho Aluminate. Vol^{m} of which is Approx^{y} 227 % age more than that of original constituent.

(ii) This cement is produced by Reducing the proportion of C_3A and C_4AF.

$C_3A \rightarrow 5\%$

$C_3A + C_4AF \rightarrow 25\%$

(iii) This cement find it's applicat^{n}

- In sewage treatment works
- Marine structures
- Foundat^{n} works.
- Construct^{n} of Pipe to be laid in Marshy Area.

(4.) Super Sulphated Cement :- (i) This cement is manufacto-red by intergrinding 80 - 85 % grainulated blast furnace slag, 15 % hard burnt gypsum and 5 % Clinkers.

(ii) This cement finds it's applicat^{n} where Sulphate Resis. Cement is used.

(5) Portland Slag Cement :- (i) This cement is manufactored by Intergrinding granulated blast furnace slag with gypsum and cement clinkers in definite proportion.

(ii) This cement offers higher resistance against the attack of Chlorides and Sulphates.

(iii) It posses higher degree of water tightness due to it's low permeability that is attained due to refinement of pore structure.

(iv) It is a low heat cement (Compaired to OPC)

(6.) Quick Setting Cement :- (i) This cement is produced by adding small quantity of aluminium sulphate, fine grinding the cement clinkers and reducing the proportion of Gypsum.

(ii) This cement is generally used in grouting operating and underwater concreting.

(7.) Low Heat Cement :- (i) This type of cement is produced by reducing the proportion of C_3A, C_3S and increasing the proportion of C_2S.

(ii) This cement offers slow rate of developement of strength.

(iii) Heat of hydration of this cement during 7 days is less than 65 Cal/gm and during 28 days is less than 75

		OPC
7 days	65	89-90
28 days	75	90-100

(iv) This cement is generally used where Mass Concreting is to be Done. { Hydraulic Struc. / Bridges }

(8) Portland Pozolana Cement :- This cement is manufactured by intergrinding cement clinkers with 10-25 % ~~Oza~~ potato pazzolonic materials.

(i) Pazolonic material are generally & essentially } Silicious or Aluminous compounds which in them selves donot possesses any cementeous property but wher finely grinded in presence of water reacts with Calcium hydroxide formed during hydration of cement results in the formatn of a compound that possess cementi-ous property.

Pozolonic Material + Water + $Ca(OH)_2$ → C-S-H (Gel)

{ Non-cementous Compnd } { Cementing Compound }

Pazolona :- Fly Ash, Rice husk Ash, Silica fumes
Granulated Blast Furnace Slag.

(ii) This cement is found to have

(a) High tensile Strength
(b) High Water tightness
(c) Higher Resistance Against the attack of Clorides and Sulphat
(d) It attains Comp^{sv} str. with age.
(e) It's a low heat cement.
(f) Offers higher resistance against Expansion.

(9) Hydrophobic Cement :- (i) This cement is manufactored by Intergrinding the cement clinkers with water repelling film forming substances like "Oelic Acid and Steric Acid".

☆☆☆☆☆☆ Storage of Cement → At max^{m} 90 days.

(ii) This water Repellent film reduces the rate of deterioration of cement during the storage, hence it generally find it's application in Remote site Condit^{n}s. where long transportat^{n} period is req^{d}.

(10) IRS-T-40 :- (i) It is a especial type of cement that is produced by fine grinding the cement clinkers and increasing the proportion of C_3S in Order to attain high early strength.

(ii) It's generally used to manufactor the Concrete Sleepers by Indian Railways.

(11.) High Aluming Cement :- (i) This cement is produced by intergrinding clinkers obtained by the calcination of boxite and Calcium Carbonate.
↳ Aluminium ← Oxes → ↳ lime

(iii) In this cement proportion of Al^m should not be less than 32% and the ratio of Al^m to lime should be in range of 0.85 to 1.35.

(iii) This cement provides initial setting time of more than 3.5 hrs and final setting time of Approx 5 hrs. hence it offers max time for placing.

{Greater initial setting, less final setting time}

(iv) This cement can withstand high temperature and resists the action of acids → {Chemical factories}

(v) It also shows high rate of development of strength as it gains 20% of the Ultimate Str. in a day and substancial strength of within 6-8 hrs.