MADE EASY

India's Best Institute for IES, GATE & PSUs

CIVIL ENGINEERING

Building Materials

Handwritten Notes

MADE EASY

2.0

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(Faculty MADE EASY)

1. CEMENT

→ Cement is an artificial binding material which impart cohesion, adhesion both.

→ Cement also impart hydraulicity that means ability to set in water on damped Locations

→ Joseph Aspdin (1825-25)

↓

Cement

Calcareous Compounds (Ca, Mg)

↓

Limestone, Chalk, Marine shell, cement Rock, Alkali waste, Ash etc.

Argillicious Compounds (Si, Al)

↓

clay, shale, Slate etc.

mix → heat → Cement + water ⇒ Paste was looking like a stone present at Portland ⇒ Portland Cement

Manufacturing of Cement

→ Cement can be manufactured by any of two process i.e., Dry process and wet process.

→ Any process contains three steps of manufacturing

i) mixing in required proportion

ii) Burning in Rotary kiln

iii) Grinding in Ball mill ($\leq 90\mu$)

→ Timber & stone is not natural nor artifical. It is a process building material.

→ Powder Form की कोई भी चीज cohesive, plastic & mouldable होगा।

→ Cement Cohesive है bcz it is made by clay. And it is adhesive bcz it binds with bricks, stone etc.

→ Calcareous compound such as limestone contain 'Ca' as well as 'Mg'.

→ Lime is more durable than cement

→ Lime को कितना भी refine कर दे फिर भी उसमें कुछ न कुछ impurities होती ही है, उस impurities में ही Mg present होता है।

→ In the wet process, initial cost of mixing is less and also results in Homogenous mix due to addition of water.

→ In wet process, Burning time required more and Fuel consumption is also more.

→ Wet process may require Longer kilns.

→ Wet process is not able to satisfy variable clinker demand.

→ In Wet Process, provision of pre heating was not there.

→ Dry Process is update over wet process

→ Dry Process results into Formation of economic cement without compromising in Quality.

→ Approx 2.5mm size used For Grinding

→ Temperature is taken of Lower value if given in Question.
For eg: 1400°, 1500°, 1600°, 1700°c
So take 1400°C Answer

→ Burning में high Fuel consumption होता है।

→ Pre-heating economy के लिए करते हैं।

→ Pre-heating में Gas कहाँ से आता है?
↳ Burning Process में जो exhausted gas निकलता है वही pre-heating में use करते हैं।

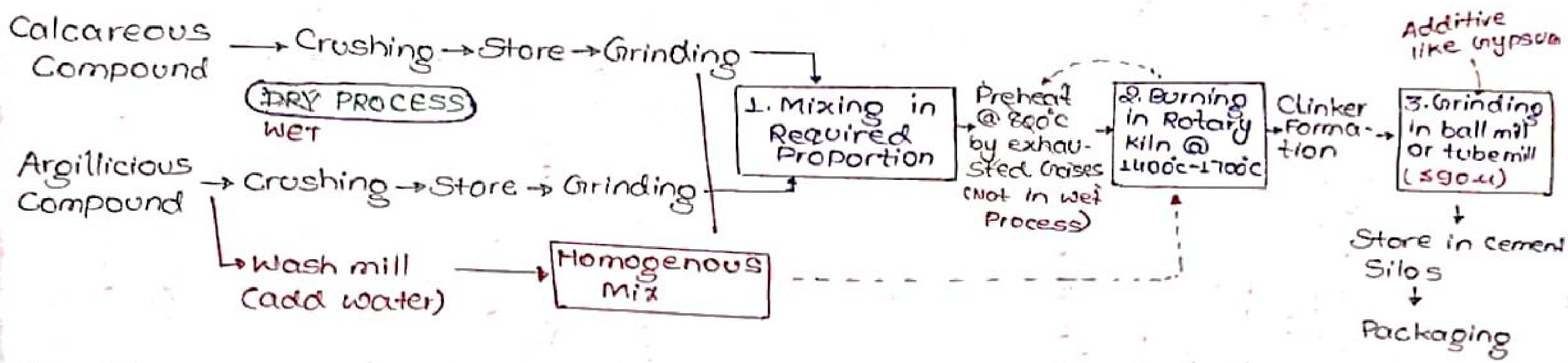
→ Wet process में pre-heating नहीं होता है।

→ Wet Process में Burning time ज्यादा होता है।

→ Quality of cement is same in both wet process and dry process.

→ Burning time, raw ingredients & temperature are responsible For Quality of cement

DRY PROCESS & WET PROCESS



Constituents of Cement

Lime, [CaO]	Silica, [SiO_2]	Alumina, [Al_2O_3]	Gypsum, [$CaSO_4$]	Iron Oxide, [Fe_2O_3]	MgO,	Sulphur,	Alkali (Na_2O+K_2O)
62-67%	17-25%	3-8%	3-4%	0.5-6%	$\not>$ 5-6%	$\not>$ 3.5%	$\not>$ 0.8-1%

→ Dry process में water use नहीं होता है।

→ Burning के पहले Pre-heating कर देते हैं जिससे की Burning में time कम लगे bcz सबसे ज्यादा Fuel consumption Burning में ही होता है।

→ Dry Process & wet Process दोनों में ही Cement का Quality same आता है।

→ Wet Process में Burning का time बहुत ज्यादा होता है जिससे कि Fuel Consumption ज्यादा होता है जो कि Uneconomical हो जाता है इसलिए उसको update कर के Dry process लाया गया।

→ Dry process is used now-a-days.

→ Wet Process में wash mill में compound को water के साथ मिलाते हैं जिससे कि Homogenous mix बनता है जो कि good for cement But जब Burning process होता है तो water evaporate हो जाता है और वह Dry process की तरह बन जाता है।

→ जो Fuel Consumption Homogenous mix की वजह से कम हो गया था वही Burning के time उससे कहीं ज्यादा Fuel consumption हो जाता है। that makes uneconomy.

* Lime (CaO) 62-67%.

• Impart Binding/Strength.

Excess:

$CaO + H_2O \rightarrow Ca(OH)_2$
(Free lime)

Volume of $[Ca(OH)_2]$ > Volume of CaO
↓
Expansion
↓
Unsoundness
↳ Crack
↓
Strength ↓

जितना lime cement को चाहिए होता है वो use कर लेता और excess amount वाला lime Free lime के Form में present होता है तो वो water के साथ react कर के volume को increase कर देता है,

Deficiency:

→ Reduce strength

* Silica (SiO_2) 17-25%.

• Impart Binding/Strength

Excess: increases setting time

Deficiency: Reduce strength

Note: Setting → Stiffness w/o Strength or Loose the Plasticity

Strength → Resistance against Gradual Loading

Hardening → Process of Gaining strength

* Alumina (Al_2O_3) 3-8%.

• Impart initial/quick/Flash setting

• Rate of Hydration ↑↑
↓
Heat of Hydration ↑↑
↓
• water evaporated → Plastic Shrinkage cracks
↳ disturbs strength development

• It works like Flux i.e., it reduces requirement of Temp. for same degree of Fusion. hence makes manufacturing economical.

→ Gypsum is not a raw ingredient But it is an additive which is very important for making paste of cement.

→ Lime provides Adhesive property.
clay provides cohesive property.

→ Crack होता है तो Grain to Grain contact break हो जाता है & Stress concⁿ ↑

→ Lime is like a salt. if more (ie. >62-67%) then Free lime water में add होने के बाद expand होने लगता है फिर unsound हो जाएगा then crack develop हो जाएगा then strength ↓

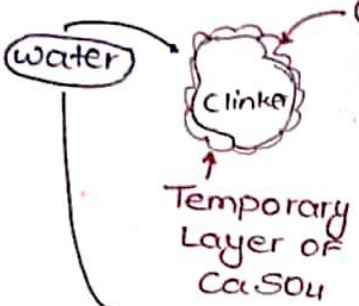
Setting → hardening → Strength

→ Silica clay से आया, clay में plasticity होता है।
if Silica ↑ → plasticity ↑ → setting time ↑
time ↑ → Retard (not favourable)
time ↓ → Accelerate

→ Alumina पानी को देखते ही react करने लगता है तो rate of hydration ज्यादा होता है उसकी वजह से heat of hydration भी ज्यादा ही होगा।
जितना जल्दी alumina पानी के साथ react करता है उतना

* Gypsum ($CaSO_4 \cdot 2H_2O$) 3-4%

- Delay / Retard initial setting time.



Gypsum ($CaSO_4 \cdot 2H_2O$) added in HOT Clinker during grinding
↓
Crystallized water of gypsum evaporated.

→ Gypsum recollect it's lost water & gains it's original Form i.e., Hard gypsum which cause FALSE SET.

→ Gypsum Clinker के ऊपर एक layer बना देता है जिसकी वजह से Alumina water के contact में नहीं आता है इसलिए initial setting time increase हो जाता है।

→ Grinding के time जब Gypsum add किया जाता है तो उस time clinker Hot होता है जिसके कारण Gypsum का crystalline water evaporate हो जाता है।
उसके बाद जब cement water के contact में आता है तो Gypsum अपने lost water को recollect करता है और अपने original Form में आ जाता है (Hard Gypsum) जिससे False set होते हैं।

* Iron Oxide (Fe_2O_3) 0.5-6%

→ It imarts strength, hardness and colour to the cement.

→ Excess of Iron Oxide makes the clinker hard hence difficult to grind.

→ जहाँ Lime max होता है तो Burn करने पर राख के colour (i.e. Grey) हो जाता है और Iron Oxide का redish brown colour कम होता है इसलिए cement का colour Grey होता है।

→ Fe_2O_3 helps in Fusion of Lime & Silica and that's why strength come in cement.

→ if Fe_2O_3 present नहीं होता then cement में कोई Strength नहीं होता। For eg: white cement

→ excess of Fe_2O_3 makes the cement uneconomical due to hardness in Grinding.

* MgO $\ngtr$ 5-6%

→ It impart strength, hardness and tinge of yellow colour.

→ Excess of MgO cause unsoundness

* Sulphur $\ngtr$ 3.5% →Comes From Gypsum → external Sulphur attack is harmful.

→ It cause only unsoundness

Ca, Al + S → Calcium Sulpho Aluminate

$MgO + S \rightarrow MgSO_4$

* Alkali ($Na_2O + K_2O$) $\ngtr$ 0.8-1%

→ It cause efflorescense (white patches)

→ Excess of Alkali may cause acceleration in setting.

→ Alkali salts when in the dissolved Form enters into aggregate through its pores under the effect of Osmosis Process.

→ ($Na_2O + K_2O$) → जब तक salt dissolved Form में रहता है तो कोई भी Problem नहीं होता है But evaporate होने के बाद white patches आ जाते हैं।

→ we can only reduce Alkali - agg. rkn but cannot remove it.

→ इस rkn में expansion होने लगता है

→ if we use inert aggregate then Alkali aggregate rkn can be reduced. or we can use agg. having less pores.

- It react with Silica present in Aggregate and Forms stable compound which results into expansion cause unsoundness, known as Alkali aggregate reaction or alkali Silica reaction or cancer of Concrete.
- The above reaction occurs in presence of moisture only.

Note 1 → Alkali cause unsoundness in aggregates not in cement.

Note 2 → All the above ingredients fuse together during burning and results into Formation of complex compounds known as Bouge's Compound.

Note 3 → Iron oxide helps lime and Silica to Fuse with each other during burning hence impart strength indirectly.

★ Bouge's Compounds

① C_3A (Tricalcium Aluminate) $3CaO \cdot Al_2O_3$ (6–10%)

- Responsible For initial/quick/Flash set.
- Rate of Hydration ↑↑ {≃ 80–90% hydrates within 24 hrs}
- It reacts rapidly with water.
- Heat of Hydration ↑↑↑ {≃ 310 cal/g (90 days); ≃ 212 cal/g (3 days)}
  ↓
  water evaporate {• Plastic Shrinkage Crack; • Disturbs strength development.}
- Resistance against Sulphur attack ↓↓
- Harmful Compound.

- Alkali do not cause soundness in cement. It causes soundness in aggregate.
- In mortar, soundness is caused by lime, MgO, Silica & Alkali.
- If only 'set' is given that means Final setting.
- जहाँ Alumina होगा वहाँ सबसे पहले setting होगा।
- C_3A में Lime & Alumina तो Alumina के कारण quick setting होती है।
- C_3A पहले rk^n में आता है और 24 hr rk^n में part लेता है But C_4AF बाद में आता है और 1 hr में ही अपना rk^n complete कर लेता है।
- C_3A starting days में Fast rate से rk^n करता है। (Rate of hydration starting days में ज्यादा होता है और फिर Later days में Rate of hydration slow हो जाता है)
- Initial setting & early strength – C_3A
- C_3S is only For strength.
- C_3A & C_4AF cause Plastic shrinkage. Other than these cause drying shrinkage cracks.

2) C_4AF (Tetracalcium alumino Ferrite) $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ (10-18%)

→ Responsible For initial/Quick/Flash set

→ Rate OF hydration ↑↑↑↑ {≃90% hydrates within 1h r}

→ Heat OF hydration ↑ {≃ 100 cal/g (90 days), ≃ 69 cal/g (3 days)}

→ All properties are similar to C_3A but with less intensity like resistance against Sulphur attack is less but better than C_3A.

→ WORST COMPOUND, as it doesn't impart cementing properties Further.

③ C_3S (Tricalcium Silicate) $3CaO \cdot SiO_2$ (45-65%)

→ Responsible For EARLY STRENGTH

→ Rate OF Hydration {≃60-70% hydrates within 7 days}

→ Heat OF Hydration {≃105 cal/g (90 days), ≃ 50 cal/g (3 days)}

→ Causes drying shrinkage cracks.

→ Resistance against Frost Action.

(Size of C_3S ≃ 2μ-10μ, K↓↓)

Use:

- Cold weather construction
- Road repair/construction
- Precast construction
- wherever Formwork is limited

$$2C_3S + 6H_2O \longrightarrow \text{C-S-H gel} + \underbrace{3Ca(OH)_2}_{\text{20-25\% OF vol. OF solid hydrated}}$$

C-S-H gel ↓

Responsible For Strength {
hydrated Calcium Silicate gel
(or)
Tobermite gel
(or)
Thumbohydrated gel
}

→ C_4AF में rate of hydration C_3A से भी ज्यादा होता है।

→ But as compare to C_3A, C_4AF has less heat of hydration that is good.

C_4AF → worst है क्योंकि वो सिर्फ 1hr के लिए exist करता है, इसका सारा property सही है but existance is of very less time.

→ C_4AF is 10-18% जो only कुछ देर के लिए काम करता है बाकि वो तो सिर्फ waste के जैसे cement में present होता है।

→ C_3A में Lime & Alumina दोनों present है इसलिए Lime strength देगा & Alumina → Initial setting. Hence C_3A will provide initial setting as well as early strength.

But C_3S has only lime & silica that is only responsible For strength.

Frost action eg: Soil में

ऊपर की Layer ठंड के कारण जम जाएगी तो उसमें -ve pressure develop होगा और नीचे की Layer में पानी है तो +ve pres. है तो ज्यादा pores होंगे तो water ज्यादा जल्दी ऊपर आएगा & जम जाएगा इसी process को Frost Action बोलते हैं।

Since C_3S का size बहुत छोटा होता है तो उसमें permeability कम होती है जिसके कारण Frost के against resistance मिलती है।

$3Ca(OH)_2$

- Portlandite Leaches out by malching pores at the surface which impact durability drastically.
- if used in Foundation Laid in clay it increases chances of Sulphur attack (brickwall in Foundation can resist it)
- because of OH^- ion, pH ↑↑↑
  ↓
  Resistance against acceleration of Corrosion increases.

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

→ Responsible For Later/Ultimate/Progressive strength.

→ Rate of Hydration (≃ Yearly)

→ Heat of Hydration $\left\{ \begin{array}{l} \simeq 40 \text{ Cal/g (90 days)} \\ \simeq 12 \text{ Cal/g (3 days)} \end{array} \right\}$

→ Least drying shrinkage cracks.

→ Resistance against chemical attack ↑

Use:

- Mass concreting like Dams/hydraulic Structures, Bridges)

$$2C_2S + 4H_2O \longrightarrow C\text{-}S\text{-}H \text{ gel} + 1 \cdot Ca(OH)_2$$

↓

- Portlandite leaches out is very less hence doesn't impact durability infact increases.
- because of release of OH^- ion is very less. Hence resistance against acceleration of Corrosion decreases.

mass concreting
↳ volume of concrete is much more than steel

→ Attringite is Product of C_3A responsible For Flash set

→ C_3S Strength तो देता है C-S-H gel के through But इसका disadvantage ये है कि ये Portlandite $Ca(OH)_2$ बना देता है।

Portlandite concrete से टपक-टपक कर बाहर निकल जाता है जिसके कारण str. में pores बना देते हैं। जिससे str. की durability कम हो जाती है।

→ OH^- → Basic in nature होता है जिसके कारण corrosion होने की possibility कम कर देता है।

→ Since C_2S में 4 mole of water ही है इसलिए इसमें drying shrinkage crack least होती है।

★ Some Important Points

① Rate of Hydration $C_4AF > C_3A > C_3S > C_2S$

② Rate of Binding $\underset{\text{Aelite}}{C_3S} > \underset{\text{Belite}}{C_2S} > \underset{\text{Celite}}{C_3A} > \underset{\text{Felite}}{C_4AF}$

③ Amount of Bouge's Compound $\underset{(45-65\%)}{C_3S} > \underset{(15-35\%)}{C_2S} > \underset{(10-18\%)}{C_4AF} > \underset{(6-10\%)}{C_3A}$

④ Water Requirement $\underset{(\simeq 24\%)}{C_3S} > \underset{(\simeq 21\%)}{C_2S} > C_3A \simeq C_4AF$ $(\simeq 20\%)$

⑤ Heat of Hydration $\underset{(\simeq 310\,cal/g)}{C_3A} > \underset{(\simeq 105\,cal/g)}{C_3S} > \underset{(\simeq 100\,cal/g)}{C_4AF} > \underset{(\simeq 40\,cal/g)}{C_2S}$

Note → ⑥. In Absolute term, C_3S is actually responsible for release of highest heat of hydration because it is present in highest amount in cement. Hence, drying shrinkage is more significant.

⑦. Approximately 23% water is required by weight of cement for its complete hydration, known as Bound water or chemically combined water.

- Out of this 15% water stuck in voids known as gel water or capillary water. Hence in order to do the complete hydration 38% water by wt. of cement should be added.
- Deficiency of water ($w/c < 0.38$) reduces ~~be~~ strength because of incomplete hydration.
- Excess water ($w/c > 0.38$) also reduces the strength because excess water remain free in nature and can be found in capillary pores, in adsorbed layer, in inter layers. This free water cause evaporation which leads to result in shrinkage.

→ Mass concreting means high amount of concrete as compare to steel.

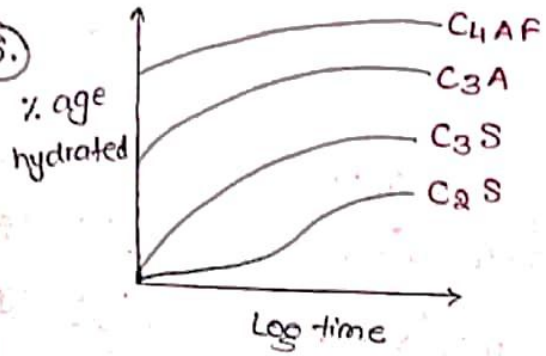
RCC में concrete और steel → designed amount में present होते हैं।

PCC में only concreting होता है steel नहीं होता है।

Attringite gel is responsible for setting in C_3A.

C_2S require less water.

8.



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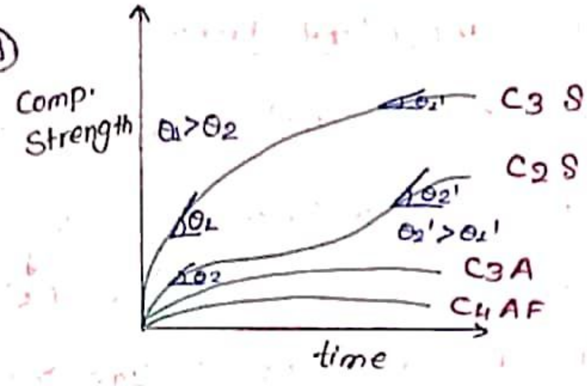


10. At any time of Hydration in cement, hydrated nucleas, Unhydrated nucleus, C-S-H gel, portlandite, water can be Found.

11. Cement achieves terminal value of its creep strain in 5 years.

12. <u>Alumina Ratio (Alumina Modulus) ≮ 0.66</u>

$$AR = \frac{Al_2O_3}{Fe_2O_3}$$

$AR\uparrow \rightarrow Al_2O_3\uparrow$
- IST↓, Plastic Shrinkage↑
- Resistance against Sulphur attack↓
- Fuel Consumption↓ {No Hard Burning}
- Requirement of Gypsum↑

$AR\downarrow \rightarrow Fe_2O_3\uparrow$
- Hard Clinker
- Quality of Cement↓
  $\because C_4AF\uparrow$

$AR < 0.66 \rightarrow 100\%\ C_4AF$

13. Silica Ratio (Silica Modulus) 2.1 - 2.4

$$SR = \frac{SiO_2}{Al_2O_3 + Fe_2O_3}$$

SR↑ → SiO_2↑
- Strength ↑
- Setting time ↑
- C_2S↑ → Slow hardening
- Durability ↑, Drying Shrinkage ↓↓

SR↑ → Al_2O_3↓,
- IST ↑, Plastic Shrinkage ↓
- Fuel Consumption ↑ (Hard burning)

SR↑ ↓

Slow Setting
&
Slow Hardening
OR
Long term Stable

14. Lime Saturation Factor (LSF) 0.66-1.02

$$LSF = \frac{CaO}{(CaO)_{max}} = \frac{CaO - 0.7SO_3}{2.8\,SiO_2 + 1.2Al_2O_3 + 0.65Fe_2O_3}$$

LSF↑ CaO↑ → C_3S↑ → High early strength Cement

LSF↓ CaO↓ → C_3S↓
C_2S Proportion
⇓
Slow Hardening Cement

eg: $\boxed{\frac{65}{65}}$ A $\boxed{\frac{30}{65}}$ B

A: $C_3S \Rightarrow 60\%$, $C_2S = 30\%$ } 90%

B: $C_3S = 40\%$, $C_2S = 30\%$ } 75%

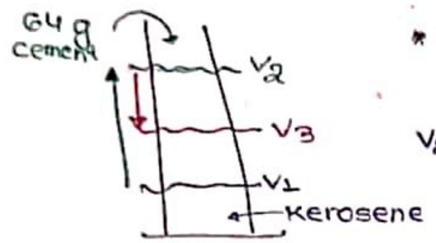
LSF < 0.66 → 100% C_2S

LSF > 1.02 → Unsoundness due to Free lime

Lab Test

① Specific Gravity Test

→ Le-Chatelier Flask



* $G_{cs} = \dfrac{\rho_{cs}}{\rho_w} = \dfrac{M_{cs}}{V_{cs}\,\rho_w}$ * $G_K = \dfrac{\rho_K}{\rho_w}$

$V_2 - V_1$ = equivalent to volm of $\underbrace{64\text{ g cement}}_{\text{Solid + air voids}}$

$V_3 - V_1$ = equivalent to volm of Cement Solid

$$G' = \frac{\rho_{cs}}{\rho_K} = \frac{M_{cs}}{V_{cs}\,\rho_K} = \frac{M_{cs}}{V_{cs}\,\rho_w \cdot G_K} = \frac{G_{cs}}{G_K}$$

$$\boxed{G_{cs} = G' \cdot G_K}$$

→ Sp. Gravity of Kerosene

True sp. Gravity of cement solid w.r.to water

Sp. Gravity of Cement Solid w.r.to Kerosene

we use kerosene bcz cement will not react with kerosene. if we use water then cement will react easily with water.

→ Le-Chatelier Flask में kerosene लेंगे तो vol 'V₁' होगा इसमें फिर 64 g cement add करेंगे तो vol 'V₂' होगा।
$V_2 - V_1$ → cement में solid + air दोनों होगा तो air को remove करने के लिए Flask को shake करेंगे तो air निकलने के कारण vol. reduce होकर V_3 पर पहुँच जाएगा। इसके बाद True sp. Gravity of cement solid w.r.to water find कर लेंगे।

② Fineness Test

Fineness ↑

Rate of Hydration ↑

- → Rate of Gain of Strength ↑
- → Rate of Setting ↑
- → Rate of Prehydration ↑
- → Rate of Alkali-agg reacn ↑

Fineness Test
This is lab test but gives result like Field test.
इसमें Fineness की value नहीं मिलती बस पता चलता है कि या standard है या undergrinding है या overgrinding है।

Sieve Test → 15 min Sieving

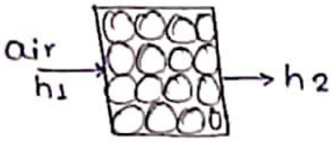
$\dfrac{10\%\text{ Retain}}{90\%\text{ Pass}}$ 90µ → Standard

$\dfrac{20\%\text{ Retain}}{80\%\text{ Pass}}$ 90µ → Undergrinding → ज्यादातर particles 90µ से बड़े रह गए हैं means properly grinding नहीं हुआ है। → इस case में directly reject कर देते हैं।

$\dfrac{3\%\text{ Retain}}{97\%\text{ Pass}}$ 90µ → Overgrinding → इसमें जरूरत से ज्यादा Grind हो गया है। → इसमें 7% जो extra है वो पता नहीं चलता कि कितना होता है अगर सारे particles बहुत छोटे हुए तो Fineness बहुत ज्यादा increase हो जाएगी → जो कि disadvantage बन जाएगा।

{ Extent of over-grinding can't be explained by Sieve test }

③ Air Permeability Test (Nurse - Blaine Test)



$h_1 > h_2$
$\downarrow$
head loss

Fineness ↑
↓
Specific Surface Area ↑
↓
Frictional Resistance ↑
↓
Head Loss ↑

* Fineness of OPC = 2250 cm^2/g

Note → Wanger Turbid-meter is also used to determine fineness of cement.

★ Special Type of Cement

① Rapid Hardening Cement

→ $C_3S \uparrow \simeq 56\%$, Fineness $\simeq 3250\ cm^2/g$

{ 3rd day strength OF RHC ≃ 7th day strength OF OPC
1st day strength OF RHC ≃ 3rd day strength OF OPC }

→ Resistance against Frost action & Corrosion ↑
→ Durability ↓
→ Water Requirement ↑
→ Drying Shrinkage ↑

{ IST, FST ≃ OPC
Use: Refer C_3S }

→ RHC requires more quantity of Gypsum in order to control rate of setting which could have increased due to Fineness.

② Extra Rapid Hardening Cement

→ RHC + 2% $CaCl_2$ by wt. of Cement

- Accelerator → 1st day strength of ERHC is 25% more than RHC.
- Deliquescent

→ IST of ERHC < OPC ≃ 20 min

(Note) → Accelerator are more effective in Slow Hardening Cement.

③ IRS-T40 Cement

→ It is a RHC of grade OPC-43s, OPC-53s used by Indian Railways For concrete sleepers manufacturing.

Early strength → C_3S ↑ Strength को Fast करने के लिए Fineness ↑ कर देते हैं।

→ C_3S ↑ → Portlandite ↑ → Resistance to Corrosion ↓

→ Fineness ↑ → Water Req ↑
Durability ↓

→ Lime ↑ → costly

→ Fineness ↑ → SA ↑ → Rate of Hydration ↑ → req. Gypsum ↑

Deliquescent → पानी से rxn Fast करती है किसी भी चीज का।

→ Underwater means Flowing water.

→ Pipe से mortar Fill करना → Grouting

→ Pipe से concrete मारना → Shortcrete

→ Gun से mortar Fill करना → Guniting.

→ Quick setting है तो only set Fast होगा. strength OPC की तरह ही होगा।

→ RHC only strength Fast करेगा, set OPC की तरह ही होगा।

④ Quick Setting Cement

$C_3A \uparrow$ Gypsum $\downarrow$

IST $\simeq$ 5min FST $\simeq$ 30min

Use: Underwater construction, Grouting, Guniting, shortcrete etc.

→ Resistance against Sulphur attack $\downarrow$, Durability $\downarrow$

→ पहले Fineness check करेंगे then Bogue's Compound then admixture use करेंगे।

⑤ White Cement

→ Iron Oxide < 1%

→ Strength $\downarrow$

Use: Flooring, white wash/decorative purpose

→ IS Scale & Hunter Scale used to check intensity of white colour.

⑥ Expansive Cement

→ It is prepared by adding 8-20% of Sulpho-Alumino clinker due to which this cement expand during hardening.

→ It is also known as Shrinkage compensating and Self Stress releasing cement used at Grouting.

⑦ Low Heat Cement

$C_3A \downarrow$	$C_3S \downarrow$	$C_2S \uparrow$
• IST $\uparrow$ • Plastic Shrinkage $\downarrow$ • Heat of Hydration $\downarrow$ • Resistance against Sulphur attack $\uparrow$	• No early strength • Drying shrinkage $\downarrow$ • Heat of Hydration $\downarrow$ • Resistance against Frost action & Corrosion $\downarrow$	• In order to compensate Loss in strength which could occur due to decrement in C_3S. • Slow Hardening • Durability $\uparrow$ • Resistance against Chemical attack $\uparrow$

$\because C_2S \uparrow \rightarrow$ Silica $\uparrow \rightarrow$ FST $\uparrow$

* Fineness $\simeq$ 3250 cm²/g

IST $\simeq$ 60min & 30min

3rd day strength & 10 N/mm²

7-28 day heat collection = 65-75 cal/g {whereas for OPC it is 90-100 cal/g}

Use: Mass Concreting

→ C_2S को increase करने का Purpose है strength increase करना।

→ $C_3A \downarrow$ → Sulphur attack कम हो जाएगा।

→ $C_3S \downarrow$ → Resistance against Frost action & corrosion $\downarrow$ bcz Portlandite कम बनेगा & OH^- कम निकलेगा।

Low heat cement → slow hardening & slow setting

→ Low heat cement is also known as Low C_3S Cement.

(8) Sulphate Resisting Cement

→ $C_3A \downarrow < 5\%$

(or)

$2C_3A \downarrow + C_4AF \uparrow < 25\%$

→ Fineness $\simeq$ OPC, IST, FST $\simeq$ OPC

→ Resistance against sulphur attack ↑

Use:

- marine structure
- Foundation work
- Sewer
- Canal Lining
- Marshy Land

optional

→ In above cement a few amount of Silica can be increased so that it can form more C_2S which will not allow entry of sulphur by making impermeable surface. but 3rd day strength will be less in that case.

SRC:

→ C_3A की कमी से भी setting time बढ़ जाता है उसकी पूर्ति के लिए C_4AF को incr. कर देते जिससे IST maintain हो जाता।

→ यह provide only benefit to increase Resistance against sulphur attack.

→ strength & setting will be same as OPC.

(9) Portland Pozzolanic Cement (Binary cement)

→ It is prepared by adding pozzolanic material in original cement clinkers.

→ Pozzolanic materials are obtained from industrial waste.

→ These are silicious material which does not impart binding by itself but when react with soluble hydrated Calcium Hydroxide, it impart binding.

→ Pozzolonic materials are artificial mineral additive.

$$\underset{\text{eg.}(60\%)}{\text{Cement Clinker}} + \underset{(15-35\%)}{\overset{(30\%)}{\text{Pozzolonic material}}} + \overset{(10\%)}{\text{Gypsum}}$$

PPC:

→ उपरोक्त से C-S-H gel बनता रहता है, एक C_3S & C_2S & दूसरा Pozzolonic material से।

So, it makes strength ↑

→ Pozzolonic material suck Portlandite $[Ca(OH)_2]$ so, it makes impermeable surface. So, durability ↑↑

→ Pozzolonic material is more finer.

→ $C_3S \downarrow$ → water req. ↓

bcz original cement is less then C_3S is 50% of cement थी कि, बहुत कम हो जाता।

→ $\rho_{Fly\ ash} < \rho_{cement}$

$G_{Fly\ ash} = 2.2$

$\left\{ \rho_f = \frac{M}{V \uparrow} \right\}$

10 ~~Portland Pozzo~~

Pozzolonic Material

Fly Ash → Obtained by burning Pulvarized Coal

GBFS → Grounded Blast Furnace Slag
→ Obtained From ore of iron industry (Smelting iron)

Surkhi → Grounded Brick
→ Calcinated clay

Silica Fume → Obtained From Ferrosilicon industry

Rice Husk → Obtained by burning agricultural waste.

$$2C_3S + 6H_2O \rightarrow C\text{-}S\text{-}H + 3Ca(OH)_2$$

$$\text{Pozzolonic material} + Ca(OH)_2 \rightarrow C\text{-}S\text{-}H \text{ gel}$$

- Improved Strength
- Impermeable Surface
- Durability ↑↑
- Resistance against Sulphur attack ↑ (∵ C_3A ↓)
- Resistance against chemical attack ↑ (Electrolyte Resistance)
- Fineness ≃ 3000 cm^2/g (more than OPC)

∴ IST, FST ≃ OPC

- Fineness ↑ Cohesion ↑ Segregation ↓
- water Requirement ↓ (∵ C_3S ↓) → Bleeding ↓
→ Alkali-agg rkn ↓
- ∵ ρ_{ppc} ↓ ∴ by using PM in mortar it results into Formation of more volume.

{For a particular volm, no. of PPC bags req. lesser}

- due to impermeable surface, corrosion activity will not initiate but once initiated can not be resisted. (hence high replacement decreases corrosion Resistance)
- No Early strength
- ≯ 40% ≯ 15%
  10μ 45μ
  Rapidly react Gradually React

→ Economical

→ Environment Friendly (Green cement)

→ Heat of Hydration ↓

PPC: → other than quick setting purpose all other qualities are good.

(10) Patland Slag Cement

→ It is a combination of cement clinker, slag and Gypsum.

→ Remaining properties are same as PPC.

(11) Super Sulphate Resisting Cement

→ It is prepared by replacing more than 70% cement clinker with slag.

→ Sulphur attack resistance is very high.

→ It results into typically impermeable surface. Hence can be used for DPC and water proofing.

→ Fineness > 4000 cm^2/g which control IST & FST

SSRC: • water proofing, & DPC में use कर सकते हैं।

(12) Oil well Cement

→ In order to prevent leakage from oil wells cement slurry is prepared by adding Pozzolonic material which ~~pre~~ makes surface impermeable after hydration and by adding retarder like starch in order to prevent shrinkage crack.

Note → For oil well cement, loss on ignition should not be more than 3% &

Insoluble residue ≯ 0.75%.