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CEMENT

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PORTLAND CEMENT

> Mix of lime, clay & crushed slag from iron-making hardened under water.

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CEMENT:

Inorganic Cements → Hydraulic cementing material (harden under water)

Inorganic Cements → Non-hydraulic cementing material (harden in air)

* Constituents:

→ Calcareous Materials: Compound of Ca like limestone chalk, cement rock, marine shells, waste $CaCO_3$.

→ Argillaceous Materials: Supply of silica, Al, Fe oxides like clay, shale, furnace slag, ashes

→ Gypsum: $CaSO_4 \cdot 2H_2O$

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Functions of Constituents:

> Lime :→ Principal constituent,
→ Makes cement expand / disintegrate
→ Lack of lime makes it quick setting

> Silica :→ Imparts strength

> Alumina :→ Same as lime

> $CaSO_4$:→ Retards setting action of cement

> Fe oxide :→ Provides color, strength, hardness

> SO_3 :→ Imparts soundness (stability of volume change in ~~hardening~~ hardening & setting)

> Alkalis :→ Excess causes efflorescent (white chalky substance)

Manufacture of Portland Cement:

Quarrying

> Raw Material → 80% limestone
→ 20% clay/shale (silica, alumina, Fe_2O_3 source)

> Quarried & Stored separately.

I Raw Material Preparation

> Material initially has 1-50% moisture

> Process: Dry process, semi-dry process, wet process.

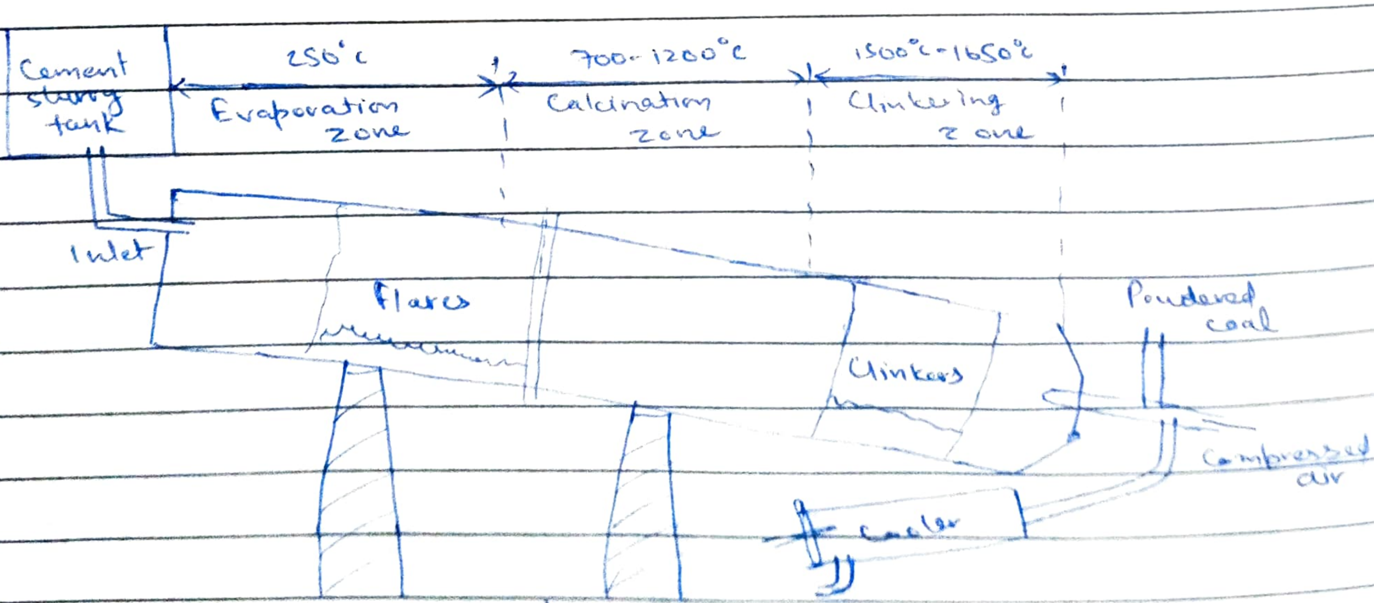
(i) Dry Process :> Separate crushing of clay & limestone till a tennis ball size remains > Mineral analysis done. > Minerals are added as per requirement (Al, Fe etc) > Clay and limestone are fed into a mill > The dry mix stored in silos (bins)

(ii) Wet process :> Clay is mixed with water & pulverized > Crushed lime is then added > Mineral test done > Moisture content (38-40%).

(iii) Semi-Dry process : Raw materials mixed with 10-14 % water.

DRY PROCESS	VS	WET PROCESS
1. Costly grinding	1.	Cheap Grinding
2. Short kiln sufficient	2.	Long kiln required
3. Less fuel consumtion	3.	More fuel consumption (water remov
4. In dry climate	4.	In humid climate
5. Slow	5.	Faster
6. Inferior quality	6.	Superior quality

III Clinkering
(Using Rotary kiln).
> Shell made of steel



* Events: (Chronological)
1. Evaporation of free water
2. Evolution of combined water in clay
3. Calcination of $CaCO_3$ & CaO.

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4. Reaction of CaO with silica (dicalcium silicate)
5. Reaction of CaO with Al & Fe
6. Evaporation of volatilities Clinker formation
7. Evaporation of volatilities
8. Excess CaO reaction with dicalcium silicate (tricalcium silicate)

* Events: (with increasing temp.)
1. Uncombined raw material water ~~raw~~ evaporation @ 100°C
2. Dehydration from 100-430°C for oxides of Si, Al, Fe.
3. CO_2 evolution / Calcination @ 900-982°C to form CaO.
4. Clinker formation of oxides @ 1510°C.

* Reaction Process:

Zone 1: Drying Zone (400°C)

Zone 2: Pre-heating Zone (400-700°C)

Zone 3: Calcining Zone (700-1000°C)

$CaCO_3 \rightarrow CaO + CO_2$ (small lumps / nodules)

Zone 4: Clinkering Zone (1500-1700°C)

$2CaO + SiO_2 \rightarrow 2CaO \cdot SiO_2$ (dicalcium silicate)

$2CaO \cdot SiO_2 + CaO \rightarrow 3CaO \cdot SiO_2$ (tricalcium silicate)

$3CaO + Al_2O_3 \rightarrow 3CaO \cdot Al_2O_3$ (tricalcium aluminate)

$3CaO \cdot Al_2O_3 + CaO + Fe_2O_3 \rightarrow 4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ (tetracalcium aluminoferrite)

* Cooler: Drops clinker temp. from 1000°C to 150°C

Cement Milling > Clinker mixed with gypsum (2-3%) as Set Retarder for 30 min.

> Cement then packed in 50kg bags.

GYPSUM ($CaSO_4 \cdot 2H_2O$)

→ 79.1% $CaSO_4$, 20.9% H_2O

→ Heated @ 120-160°c to form $CaSO_4 \cdot \frac{1}{2} H_2O$ (PoP)

→ Expands slightly while setting.

Setting & Hardening of Cement

> Setting: Stiffening of original mass due to gel format^n.

> Hardening: Crystalisation leading to strength development.

> They are due to hydration / hydrolysis.

⇒ Stepwise Setting & Hardening

$$3CaO \cdot Al_2O_3 + 6H_2O \rightarrow 3CaO \cdot Al_2O_3 \cdot 6H_2O + \Delta$$

$$4CaO \cdot Al_2O_3 \cdot Fe_2O_3 + 7H_2O \rightarrow 3CaO \cdot Al_2O_3 \cdot 6H_2O + CaO \cdot Fe_2O_3 \cdot H_2O + \Delta$$

$$2[2CaO \cdot SiO_2] + 4H_2O \rightarrow 3CaO \cdot SiO_2 \cdot 3H_2O + Ca(OH)_2 + \Delta$$

$$2[3CaO \cdot SiO_2] + 6H_2O \rightarrow 3CaO \cdot 2SiO_2 \cdot 3H_2O + 3Ca(OH)_2 + \Delta$$

Characteristics of Constituents:

1) Tricalcium Silicate ($C_3S \rightarrow 3CaO \cdot SiO_2$):
   > Medium hydration rate
   > Quick high strength development (begins in 24hrs till 7days)
   > Heat of hydration = 500 kJ/kg

2) Dicalcium Silicate ($C_2S \rightarrow 2CaO \cdot SiO_2$):
   > Low early strength
   > Slow ultimate strength development (begins 7 days till 28days)
   > Heat of hydration = 250 kJ/kg

3) Tri calcium Aluminate ($C_3A \rightarrow 3CaO \cdot Al_2O_3$)
   > Fast Hydration

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> Quick setting of gypsum due to C_3A called initial set / flash set
> Negligible strength Contribution
> Heat of hydration = 88 kJ/kg

4) Tetra calcium aluminoferrite ($C_4AF \rightarrow 4CaO \cdot Al_2O_3 \cdot Fe_2O_3$)
> Fast hydration
> Low strength centri.
> Heat of hydration - 420 kJ/kg.

Role of Gypsum: (in Cement)
→ Gypsum retards C_3A dissolution
→ Gypsum prevents flash setting during manufacturing
→ Retards setting time
→ Allows longer transportation / working time
→ Brings down heat of hydration (coolant)
→ Imparts strength
→ Less water requirements

High - Alumina Cement (HAC)
→ Made by limestone (Ca) & bauxite (Al) fusion @ 1500-1600°C
→ Composes Monocalcium Aluminate (CA), & C_3A_S.
→ Fast hardening ; setting same as Portland cement.
→ Attains full strength in 1 day.

AdV.
> Retains strength @ high temp.
> Chemical resistance to sea water
> Resistance to dilute acid & H_2S solⁿ.
> Rapid heat evolution good in cold conditions.
(could be disadv.

High Early-Strength (HES) Cement.
→ High lime to silica (5:2)
→ High C_3S, thus quick hardening (5min initial to 30min co
→ No gypsum
→ Finely grinded
→

White Portland Cement
→ Same as Portland + extra white
→ ~~Added~~ Cr, Mn, Fe reduced to remove color.
→ Used in prestige construction / decoration.

Water Proof Cement
→ Added calcium stearate, aluminum stearate, gypsum with tannic acid.
→ Chemically inactive substances like Ca/Al soaps, resins, veg. oils, waxes, block pores.

Barium & Strontium Cement
→ Ba & Sr replace Ca
→ Radioactive penetration resistant. Thus used in concrete shields for atomic piles in power plants

Concrete
→ Comprises cement, sand, coarse grains, water
→ Cure rate is modified by fly ash, furnace slag etc
→ Accelerators, air-entraining agents etc (uses)
✱ Curing of concrete
Process of ideal moisture / temperature maintainence

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to continue cement hydration is curing.
> Creates gels & crystals
> Develops strength
> Takes away heat of hydration
> Prevents cracking.

Reinforced Cement Concrete (RCC)
→ Contains steel bars (reinforcement bars)
→ Steel bars are tied to make a formwork called reinforcement cage, Liquid concrete is poured in & allowed to harden.

Adv.
> Easier to cast in desired shape
> Highly rigid
> Low maintainence cost
> Distributes small cracks.