PORTLAND CEMENT

General

Portland cement is one of the most widely used construction material and is the most important hydraulic cement.

History of Portland Cement

In 1824, Joseph Aspdin, a British stonemason, obtained a patent for a cement he produced in his kitchen.

The inventor heated a mixture of finely ground limestone and clay in his kitchen stove and ground the mixture into a powder create a hydraulic cement-one that hardens with the addition of water.

Aspdin named the product “Portland cement” because it resembled a stone quarried on the Isle of Portland off the British Coast.

Oxide Composition of Portland cement

The Main minerals required for the production of cement

Oxide Ingredient	***Range,%***
Lime, CaO	60-66
Silica ,SiO_2	19-25
Alumina, Al_2O_3	3-8
Iron, Fe_2O_3	1-5
Magnesia, MgO	0-5
Sulfur trioxide, SO_3	1-3

Raw Materials

Portland cement is made from materials which must contain the proper proportions of:

- lime (CaO),
- silica (SiO_2),
- alumina (Al_2O_3),
- iron (Fe_2O_3)

with miner amounts of magnesia and sulfur trioxide.

Sources of Raw Materials

Components			
Lime	**Silica**	**Alumina**	**Iron**
Lime stone	Sand	Clay	Iron ore
Chalk	Trap rock	Shale	Iron dust
Marble	Calcium silicate	Slag	
Cement rock			

Methods used in Portland cement production

There are two basic methods used in Portland cement production:

- Dry process

  Dry materials are proportioned, ground to a powder, blended and fed into the kiln.

- Wet process

  Involves adding water to the proportioned raw materials and completing the grinding and blending operations in slurry form.

The manufacture of Portland cement occurs through a series of steps:

- Quarrying
- Crushing
- Grinding
- Mixing

Treatment of Raw Materials

- Calcining
- Addition of retarder
- Packing

Dry Process

The four main steps in this process are:

- Treatment of raw materials
- Burning of the dry mix
- Grinding of the clinker
- Packaging and storage

Treatment of Raw Materials

The raw materials are subjected to such processes as: crushing, drying, grinding, proportioning and blending or mixing before they are fed into the kiln for burning.

Burning or Calcinations

The well-proportioned finely powdered mixture (raw meal) is charged into long steel cylinder, called rotary kiln.

Three reactions are take place during the burning stage:

a) *Complete dehydration*

Water is completely driven off at a very initial stage of burning at temperatures as low as 400°C.

b) *Dissociation of carbonate*

Carbonates of calcium are completely dissociated at temperature between 800-900°C as per the following reaction:

$$CaCO_3 \longrightarrow CaO + CO_2$$

C) Compound formation

- *3 Ca O. SiO2 (Tricalcium silicate), abbreviated as **C3S***
- *2CaO. SiO2 (Dicalcium silicate), abbreviated as **C2S***
- *3CaO. Al2 O3 (Tricalcium Aluminate), abbreviated as **C3A***
- *4CaO. Al2O3. Fe2O3 (Tetracalcium Aluminoferrite) abbreviated as **C4 AF***

Grinding of the Clinker

The completely burnt or calcined raw materials of cement are converted to lump-shaped product called ***clinker***, which is drawn out from the lower end of the rotary kiln.

Packing and storage of cement

Cement is most commonly stored after its manufacture in specially designed concrete storage tanks called **silos** where from it is drawn off mechanically for the market. For convenience, the cement comes to the customer in **bags.**

Wet process

Wet process is considered a better and convenient process for the manufacture of cement, specifically where limestone of soft variety is available in abundance.

Steps in wet process are:

1. Preparation of slurry
2. Burning or calcinations and
3. Grinding of Clinker

1. Preparation of Slurry

Raw materials are supplied to the kiln in the form of an intimate mixture with a lot of water in it. This is called **slurry**

1. The raw materials are first crushed separately.

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2. The crushed materials are stored in separate tanks or silos
3. The crushed materials are drawn from the silos in prefixed proportions in to the wet grinding mills
4. In the presence of a lot of water, thus ground to a fine thin paste

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5. The slurry is stored in a silo
6. The composition of the slurry is tested once again and corrected by adding limestone slurry in required proportions
7. Such corrected slurry is then fed into the rotary kiln

2. Burning

In burning of slurry:

- Rotary kiln of almost similar type is used as described under dry process.
- All the moisture is driven off the slurry as it passes through the drying zone.
- In the subsequent zones, it undergoes some transformation as mentioned under dry process.

3. Grinding of Clinker

As the lump-shaped clinker comes out from the kiln, it is extremely hot. It is, therefore, passed through cooling rotary cylinders.

There after it is mixed with 3-5 percent of gypsum and ground to a very fine powder as in dry process. The fine cement obtained is stored and packed in paper bags.

Compounds of cement clinker

The temperature in the kiln reaches about 1200-1500°c.

This drives off water and gases and produces new chemical compositions in particles called clinker.

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The four major compounds of cement clinker are:

- 3 $CaO.SiO_2$ (Tri-calcium silicate), **C_3S**
- $2CaO.SiO_2$ (Di-calcium silicate), **C_2S**
- $3CaO.Al_2O_3$ (Tri-calcium Aluminate), **C_3A**
- $4CaO.Al_2O_3.\ Fe_2O_3$ (Tetra-calcium Aluminoferrite) **$C_4\ AF$**

Cont’d

The relative amounts of these four chemicals in the final product depend on the desired properties such as:

- Rate of hydration(hardening)
- Strength - early and ultimate
- Rate and amount of heat given off
- Resistance to chemical attack

1.C_3S (Tri-calcium Silicate)

- The most desirable constituent
- It hardens rapidly and accounts for the high early strength (the first 7 days) of the cement
- The proportion of C_3S ranges from 25-60%
- When water is added to tri-calcium silicate, a rapid reaction occurs as follows:

Tobermorite- gives cement its strength

$$2C_3S + 6H_2O \rightarrow 3CaO.\ 2SiO_2.\ 3H_2O + 3Ca(OH)_2$$

2.C_2S (Di-calcium Silicate)

- Hardens slowly
- Contributes to strength increase at ages beyond one week
- The proportion of C_2S ranges from 13-50%.

3.C_3A (Tri-calcium Aluminate)

- A large amount of heat, (heat of hydration), during the first few days of hardening
- It also contributes to early strength development
- Tri-calcium aluminate hydrates with water to form a ‘hydrated tri-calcium aluminate’ $3CaO.\ Al_2O_3.6H_2O$

Cont’d

- If gypsum is added it acts as a retarder, and the heat of evolution is less and the setting occurs more slowly.

This is due to the fact that gypsum when present, results in the formation of calcium sulfoaluminate ($3CaO.\ Al_2O_3.\ 3CaSO_4$) rather than hydrated tricalcium aluminate.

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- The proportion of C_3A ranges from 5-15%
- Prone to chemical (sulfate attack)

4. C_4AF (Tetra-calcium Aluminoferrite)

- Reduces the clinkering temperature, thereby assisting in the manufacture of Portland cement
- Contributes very little to strength
- The proportion of C_4AF ranges from 8-15%
- Good in resisting chemical attack

Summary of characteristics of the four compounds of clinker

Characteristics	C_3S	C_2S	C_3A	C_4AF
Rate of hydration	Medium	Slow	Fast	Slow
Strength - early - Ultimate	High High	Low High	Medium Low	Low Low
Amount of heat liberated	Medium	Low	High	Low
Resistance to chemical attack	Good	Good	Poor	Good

End of Presentation