Cement

Cement is a dirty greenish heavy powder and finds its importance as a building material. It can be described as material possessing adhesive and cohesive properties and capable of bonding materials like stones, bricks, building blocks etc. Cement has the property of setting and hardening in the presence of water. So, it is called as hydraulic cement. The essential constituents of cement used for constructional purposes are compounds of calcium (calcareous) and Al +Si (argillaceous).

Classification:

Cement is classified into four types, based on the chemical composition.

1. Natural cement
2. Puzzolona cement
3. Slag cement
4. Portland cement

(1) Natural cement:

It is made by calcining a naturally occuring lime stone at high temperature and subsequently pulverizing the calcined mass. During calcination, silica and alumina combine with calcium oxide to form the corresponding calcium silicates and aluminates.

Properties:

1. It is of quick setting and relatively of low strength
2. Used for laying stones and setting stones.
3. Used for construction of dams and foundations.

Of these, Portland cement is the most widely used cement.

2) Puzzolona cement: These are materials which when mixed with lime, without the use of heat, form hydraulic cementing materials. These are made by simply mixing and grinding natural puzzolona consisting of glassy material, produced by rapid cooling of lava and slaked lime.

3) Slag cement: This is produced by mixing blast furnace slag and hydrated lime and grinding with small quantity of gypsum.

4) Portland cement: This is produced by the mixing of calcarious matter (lime containing matter) and argillacous matter (clay containing matter) and powdered with addition of 2-3% gypsum.

Properties: It most important and reliable cementing material, used for constructional work.

Chemical composition of Portland cement: It is finely powdered mixture of calcium silicates and calcium aluminates of varying compositions.

Ratio percentage of **lime to that of silica, alumina and iron oxide** when calculated by formula

$$\frac{CaO}{2.8SiO_2+1.2Al_2O_3+0.65Fe_2O_3}$$

1. Should be greater than 1.02 and not less than 0.66
2. Ratio percentage of alumina to that of iron oxide should not be less than 0.66
3. Weight of insoluble residue should not exceed 2%
4. Weight of magnesia should not be more than 6%
5. Total Sulphur contents, calculated as SO_3 should not be more than 2.75%
6. Total loss on ignition should not exceed 4%

Composition of Portland cement:

A good sample of Portland cement contains

1. Calcium Oxide or lime (CaO): 60-70%
2. Silica (SiO_2): 20-24%
3. Alumina (Al_2O_3): 5-7.5%
4. Magnesia (MgO): 2-3%
5. Ferric Oxide (Fe_2O_3): 1-2.5%
6. Sulphur trioxide (SO_3): 1-1.5%
7. Sodium Oxide (Na_2O): 1%
8. Potassium Oxide (K_2O): 1%

Manufacture of Portland cement:

Raw materials:

1. Calcarious matter, CaO (lime stone, chalk, marl etc)

2. Argillaceous matter, Al_2O_3 and SiO_2(clay, slate etc)

3. Powdered coal or fuel oil

4. Gypsum

Functions of the ingredients of cement:

1. lime: Its proportion must be properly regulated. Excess or lesser amount of lime reduces strength of cement and makes it quick setting.

2. Silica: Gives strength to cement

3. Alumina: Makes the cement quick setting

4. Gypsum: It enhances the initial setting time of cement.

5. Iron Oxide: Provides color, strength, hardness to the cement.

6. Alkalies: If present in excess, causes cement efflorescent.

Manufacture of portland cement involves the following steps:

1) Mixing of raw materials:

(a). Dry process: The raw materials and clay are crushed into small pieces, then these are ground to fine powder. Each separate powdered ingredients are stored in a separate hopper. Then, the powdered materials are mixed to get dry raw mix, which is stored in storage bins and kept ready to be fed in a rotary kiln.

b). Wet process:

The calcareous raw materials are crushed, powdered and stored in a big storage tank. The argilaceous material is thoroughly mixed with water in wash mills and made into slurry. The powdered lime and clay slurry are mixed in requisite proportions and then fed to a rotary kiln.

2). Burning:

It is done in rotary kiln, which is a steel tube lined inside with refractory bricks. The kiln is laid in slightly inclined position towards the lower end. The upper part of kiln temperature is 400 ºC but the temperature gradually increases upto 1750 ºC at the bottom. The raw slurry from the wet process and the dry process is passed into the rotary kiln through the lower end. The following reactions takes place in the rotary kiln.

a). Drying zone:

The upper part of the kiln where the temperature is only 400 ºC and the slurry gets dried.

b). Calcination zone:

It is the central part of kiln where the temperature is around 1000 ºC. Lime stone of dry mix or slurry undergoes decomposition to form quick lime and CO_2 + $CaCO_3 \rightarrow CaO + CO_2$

c). Clinkering zone:

In the lower part of the rotary kiln, the temperature is between 1500- 1700 ºC. Here the lime and clay combine to form calcium silicates and aluminates

$2CaO+SiO_2 \rightarrow 2CaO.SiO_2$(dicalcium silicates)

$3CaO+SiO_2 \rightarrow 3CaO.SiO_2$(tricalcium silicates)

$3CaO+Al_2O_3 \rightarrow 3CaO.Al_2O_3$ (tricalcium aluminates)

$4CaO+Al_2O_3+Fe_2O_3 \rightarrow 4CaO.Al_2O_3.Fe_2O_3$ (tetra calcium alumino ferrite)

The aluminates and silicates of calcium fuse together to form hard greyesh stones called clinkers. The cooled clinkers are collected in trolleys.

3). Grinding:

The cooled clinkers are ground to fine powder in ball mills together with 2-3% gypsum. The mixture of clinkers and gypsum powder is called cement. Here, gypsum acts as a retarding agent for easily setting cement.

4). Packing.

The ground cement is stored in silos, from which it is fed into automatic packing machine.

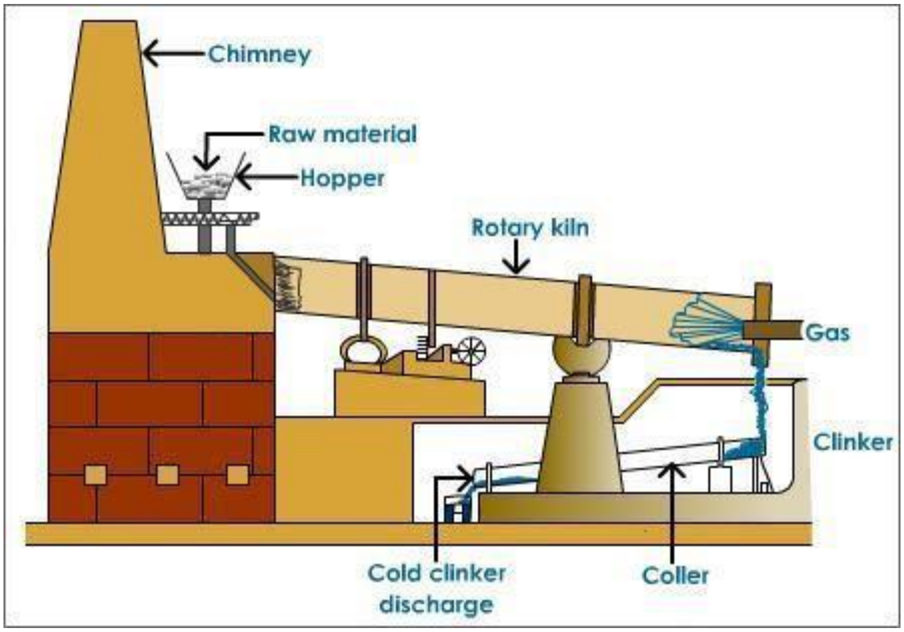

Fig. Manufacturing process of Cement

➢ Setting and Hardening of cement:

When mixed with water, cement sets to a hard mass. It first forms a plastic mass which hardens after some time due to 3-dimensional cross-links between the--Si-O-Si-- and --Si-O-Al-- chains. The first setting occurs within 24 hours whereas the subsequent hardening requires a fortnight, when it is covered by a layer of water. This transition from plastic to solid state is called setting.

The term 'Hardening' refers to the gain of strength of a set cement paste, although during setting the cement paste acquires some strength.

Reactions Involved in Setting of Cement:

On hydration silicates and aluminates of calcium get converted to their respective hydrated colloidal gels.

$$\underset{\text{tricalcium aluminate}}{3CaO.Al_2O_3} + 6H_2O \longrightarrow \underset{\text{hydrated colloidal gel of tricalcium aluminate}}{3CaO.Al_2O_3.6H_2O}$$

$$2CaO.SiO_2 + xH_2O \longrightarrow \underset{\text{hydrated colloidal gel of dicalcium silicate}}{2CaO.SiO_2.xH_2O}$$

At the same time, hydrolysis precipitates calcium hydroxide and aluminium hydroxide.

$$\underset{\text{tricalcium silicate}}{3CaO.SiO_2} + H_2O \longrightarrow Ca(OH)_2 + \underset{\text{dicalcium silicate}}{2CaO.SiO_2}$$

This calcium hydroxide binds calcium silicate particles together. On the other hand, aluminium hydroxide fills the interstices (an intervening space) rendering the mass impervious (not affording passage to a fluid).

$$\underset{\text{tricalcium aluminate}}{3CaO.Al_2O_3} + 6H_2O \longrightarrow 3Ca(OH)_2 + \underset{\text{aluminium hydroxide}}{2Al(OH)_3}$$

Role of gypsum - Gypsum reacts with tricalcium aluminate.

$$3CaO.Al_2O_3 + 3CaSO_4 + 2H_2O \longrightarrow \underset{\text{calcium sulpho aluminate}}{3CaO.Al_2O_3.3CaSO_4.2H_2O}$$

Quick Setting Cement:

Also known as fast setting cement, Quick setting cement is a special variant of Portland cement. It is prepared using **gypsum, aluminium sulphate, and Portland clinker in a pre-determined ratio.** The high setting speed of the cement is due to the presence of **aluminium sulphate** that accelerates the hydration process. The usual setting period for Quick-setting cement is **five minutes**. This genre of cement offers **high strength and durability** to the structure. Therefore, it is an ideal choice for constructions highly exposed to moisture. Additionally, the cement offers a dry shrinkage rate and fewer pores that make the construction highly resistant to cracks.

The unique composition of quick-setting cement typically includes:

Clinker: Quick-setting cement contains clinker, similar to Portland cement. Clinker is a key ingredient in most types of cement and is produced by heating a mixture of limestone, clay, and other minerals to high temperatures in a kiln.

Gypsum: Gypsum is often added to quick-setting cement to control the **setting time and prevent flash setting**, which is when the cement hardens too quickly. Gypsum helps regulate **the setting process,** allowing for a more controlled and predictable hardening time.

Accelerators: Quick-setting cement may include chemical accelerators, which are additives designed to speed up the hydration (chemical reaction with water) process. Common accelerators include **calcium chloride and calcium nitrate.** These chemicals promote the formation of hydrates in the cement paste, leading to rapid setting and hardening.

Fine Grinding: The clinker and other raw materials used in quick-setting cement are typically finely ground to increase surface area and promote faster hydration. Finer particles allow for quicker chemical reactions when water is added.

Reduced Amount of Tricalcium Aluminate (C3A): Quick-setting cement often contains a lower percentage of tricalcium aluminate (C3A) compared to ordinary Portland cement. C3A is responsible for early setting in cement, so reducing its content helps control the setting time.

Special Additives: Some quick-setting cement formulations may include additional additives to enhance specific properties, such as strength, durability, or workability, depending on the intended application.

Properties of Quick setting cement:

Following is some of the properties of Quick setting cement that make it an ideal choice for construction:

1. Unlike other cement variants, Quick setting cement has a little yellowish and brown appearance
2. If mixed and applied well, the cement can easily withstand harsh weather conditions
3. Quick setting cement works well with materials such as concrete, metals, wood, brick, and plastic
4. The hardening process of the Quick setting cement begins five minutes after it is put together. Hence, it has to be applied very quickly
5. Quick setting cement has waterproof properties, thus acting as a very good hardening material for underwater construction
6. The concrete made using Quick setting cement reaches final mechanical resistance after 28 days
7. Quick setting cement works best both in interior and exterior spaces

The End