Civil Engineering

Construction Materials

Comprehensive Theory

with Solved Examples and Practice Questions

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Construction Materials

Edition: 2020

Contents

Construction Materials

Chapter 3

Chapter 4

Chapter 5

Chapter 6

■■■■

CHAPTER 01

Cement

1.1 Introduction

- Cement is an extremely fine material having adhesive and cohesive properties which provide a binding medium for the discrete ingredients.
- The cement is a product obtained by pulverizing (to make into a powder form) clinker formed by calcinating the raw material preliminary consisting of Lime (CaO), Silicate (SiO_2), Alumina (Al_2O_3) and Iron oxide (Fe_2O_3).
- When cement is mixed with water it forms a paste which binds aggregates (fine and coarse) together to form a hard durable mass called concrete.
- The cement which is fine in nature is assume to have good setting property, finer the grains of the cement more is the strength of cement.
- The cement is having good heat of hydration due to which it sets early as compared to other binding material like lime.
- The cement experiences the exothermic chemical reaction when comes in a contact with water.
- The cement is assume to have a specific gravity of 3.15.
- Joseph Asp din manufactured cement and called it Portland cement because when it hardened, it produced a material resembling stone from the quarries near Portland in England.
- During grinding of clinker, "Gypsum or plaster of Paris" is added to prevent flash setting of the cement. The amount of gypsum is about 3 to 5 per cent by weight of clinker. It also improves the soundness of cement.
- The common calcareous materials are lime stone, chalk, marine shell and marl.
- The argillaceous materials are clay, shale, slate and selected blast furnace slag.
- The processes used for the manufacture of cement can be classified as dry and wet.
- The ideal net weight of cement bag is 50 kg and volume of 0.035 m^3.

1.2 Cement and Lime

Following points of differences may be noted between ordinary cement and lime:

1. The cement is used for the gain of early strength whereas lime gains the strength slowly.
2. The cement and lime color are different.

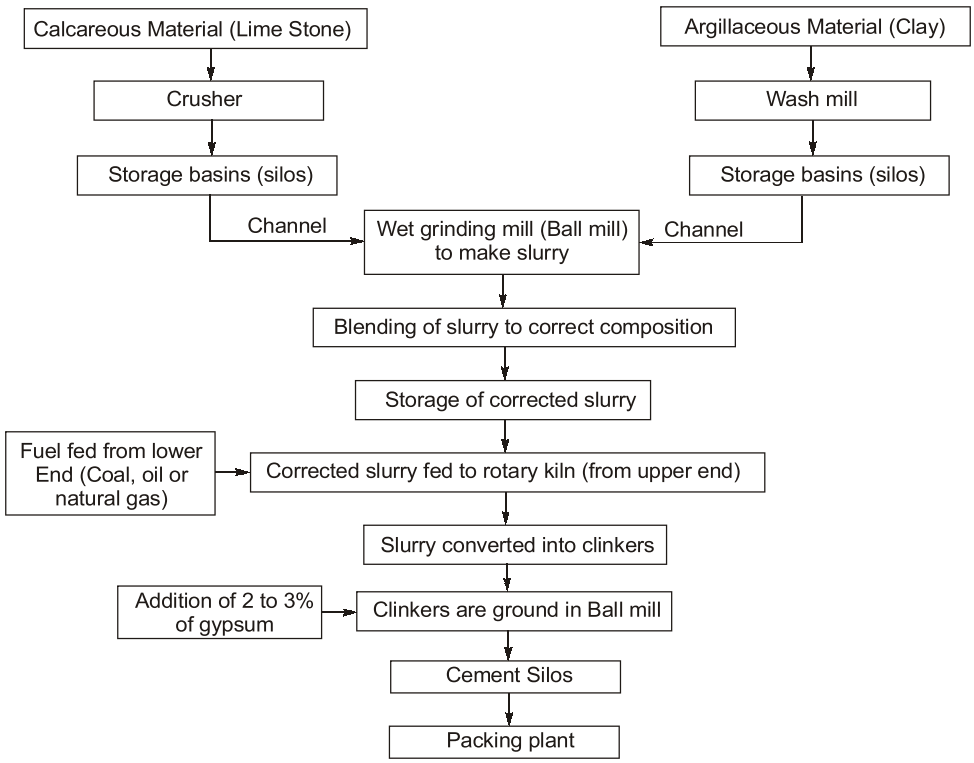
3. The cement and lime both is a binding material having good ultimate strength but lime experiences less early strength as compare to cement.

1.3 Manufacturing of Cement

- The cement is manufactured by integrating the calcareous component and argillaceous component in ratio of 3 : 1.
- The calcareous component can be **limestone, chalk, marine shells, marl** whereas argillaceous components can be **shale, clay, blast furnace slag, slate**.
- The calcareous component is used to derive the ingredient called lime whereas the argillaceous component composed of silica, alumina, iron oxide and other impurities.

(a) Wet process:

- It is the old method of manufacturing which is now a days obsoleted.
- It is a costly method of manufacturing because it requires higher degree of fuel consumption, power consumption.
- In this process the preheater is not used.

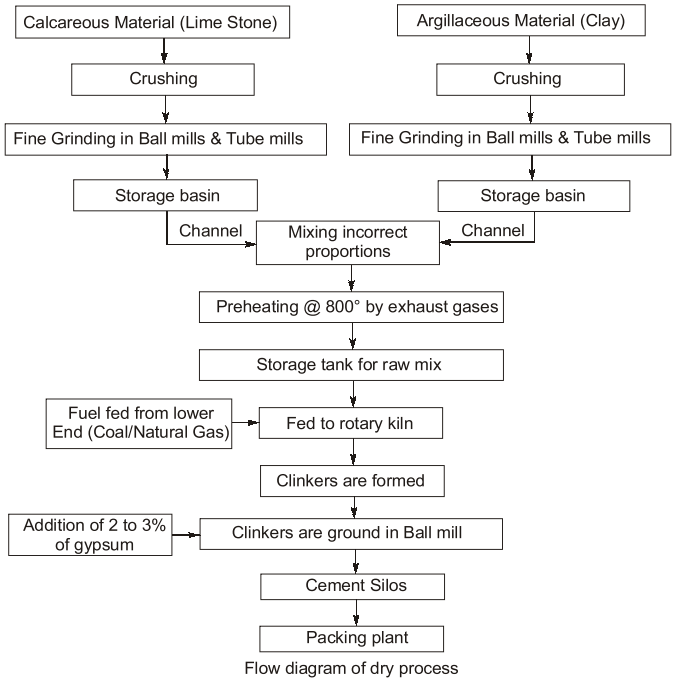


Flow diagram of wet process

(b) Dry process:

- It is a new method of manufacturing which is trending now-a-days.
- The fuel consumption, power consumption has been reduced to a greater extent by modifying the wet process.

Dry process:



Flow diagram of dry process

- In a dry process, first calcareous components (limestone) and argillaceous component (clay or shale) is reduced in size about 25 mm in a crushers separately in a ball mill or tube mill.

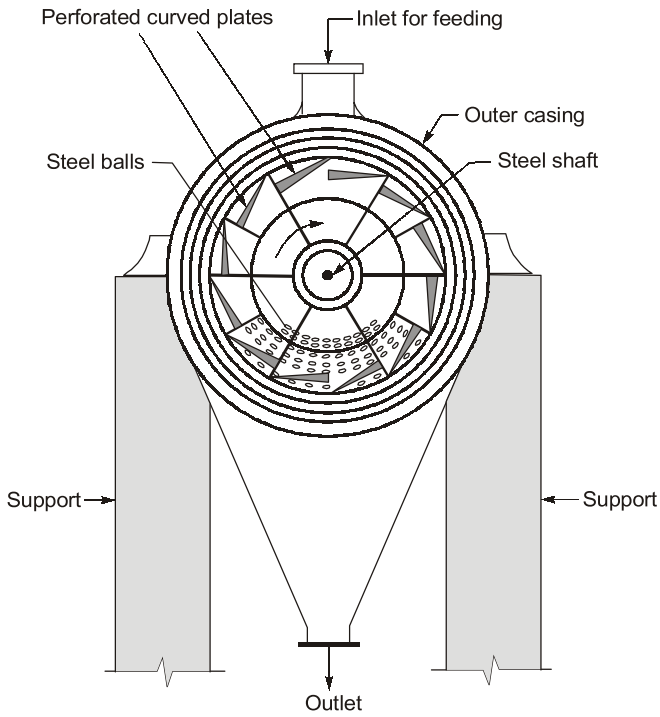


Fig. *Vertical Section of a Ball Mill*

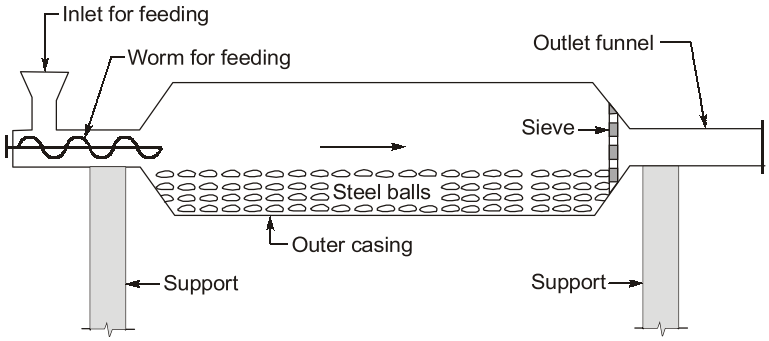


Fig. *Longitudinal Section of a Tube Mill*

- The calcareous component and argillaceous component after grinding are mixed with each other in a correct proportion and made it ready for next operation in rotary kiln.
- Before feeding into rotary kiln the raw mix is allowed in preheater at a temperature of 850°C which reduces the burning time of raw mix in rotary kiln.

NOTE

The crushed material are checked for content of $CaCO_3$, Lime, Alumina, Silica, Fe_2O_3. Any component found short in quarried material is added separately. **e.g.** Silica is less than crushed sandstone is separately added to raw mix and if lime is less then high grade limestone is crushed and added into raw mix.

- Now, the raw mix after heating for 2-3 hours in preheater, it is allowed to fed into "Rotary Kiln".

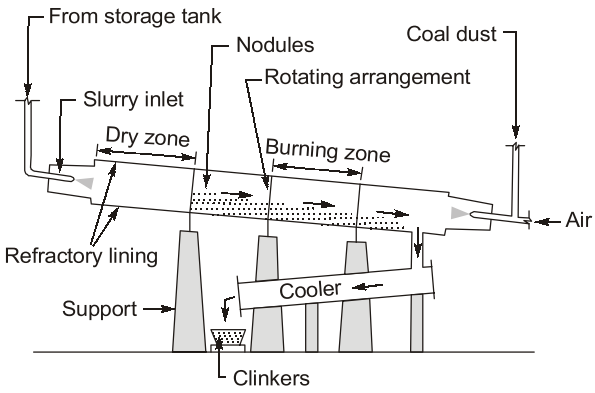


Fig. *Rotary Kiln*

Diameter = 2.50 to 3 metre
Length = 90 to 120 metre
Volume ≈ 706.3 m^3
Laid Gradient = 1 in 25 to 1 in 30
Revolution = 3 round/min about longer axis.

- **Nodule Zone:** In this zone calcination of limestone occurs and limestone get disintegrated into two parts i.e. lime and carbon dioxide.

$$CaCO_3 \xrightarrow[\text{Calcination}]{\text{Heat}} CaO + CO_2(\uparrow)$$

As the CO_2 is evaporated from the raw mix, the raw mix get converted into nodules.

Objective Brain Teasers

Q.1 The main ingredients of Portland cement are
(a) line and silica
(b) line and alumina
(c) silica and alumina
(d) line and iron

Q.2 The constituent of cement which is responsible for all the undesirable properties of cement is
(a) dicalcium silicate
(b) tricalcium silicate
(c) tricalcium aluminate
(d) tetra calcium alumino ferrite

Q.3 Le Chatelier's device is used for determining the
(a) setting time of cement
(b) soundness of cement
(c) tensile strength of cement
(d) compressive strength of cement

Q.4 Addition of pozzolana to ordinary Portland cement increase
(a) bleeding
(b) shrinkage
(c) permeability
(d) heat of hydration

Q.5 Proper amount of entrained air in concrete results in
1. better workability
2. better resistance of freezing and thawing
3. lesser workability
4. less resistance to freezing and thawing

The correct answer is
(a) 1 and 2 (b) 1 and 4
(c) 2 and 3 (d) 3 and 4

Q.6 The most commonly used retarder in cement is
(a) gypsum
(b) calcium chloride
(c) calcium carbonate
(d) none of the above

Q.7 The most common admixture which is used to accelerate the initial set of concrete is
(a) gypsum
(b) calcium chloride
(c) calcium carbonate
(d) none of these

Q.8 According to IS specifications, the compressive strength of ordinary Portland cement after three days should not be less than
(a) 7 MPa (b) 11.5 MPa
(c) 26 MPa (d) 21 MPa

Q.9 Increase in fineness of cement
(a) reduces the rate of strength development and leads to higher shrinkage
(b) increases the rate of strength development and reduces the rate of deterioration
(c) decreases the rate of strength development and increases the bleeding of cement
(d) increases the rate of strength development and leads to higher shrinkage

Q.10 The initial setting time for ordinary Portland cement as per IS specifications should not be less than
(a) 10 minutes (b) 30 minutes
(c) 60 minutes (d) 600 minutes

Answers

1. (a)	2. (c)	3. (b)	4. (b)	5. (a)
6. (a)	7. (b)	8. (c)	9. (d)	10. (b)

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CHAPTER 02

Mortar and Lime

The term mortar is used to indicate a paste prepared by addition of required quantity of water to a mixture of binding material like cement or lime and fine aggregate like sand.

- Building mortar is defined as a mixture of cement, sand and water.
- Mortar is similar to concrete but it does not contain coarse aggregate.
- Mortar is used for filling joints as a binder in stone and brick masonry.

2.1 Bulking of Sand

- The presence of moisture in sand increases the volume of sand. This is due to the fact that moisture creates a thin film of water around the sand particles which results in the increase of volume of sand. For a moisture content of about 5 to 8 percent, this increase of volume may be as much as 20 to 40 per cent, depending upon the grading of sand. The finer the material, the more will be the increase in volume for a given moisture content. This phenomena is known as the bulking of sand. The graph below shows the variation of percentage increase in volume of sand with moisture content.

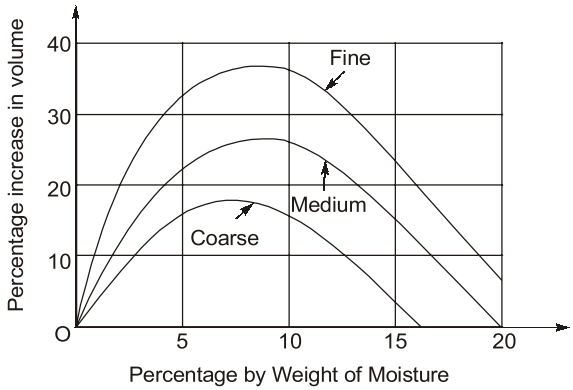


Fig. Chart showing bulking of sand

Do you know? The bulking of sand affects the volumetric proportioning of sand to a large extent. It is more with fine sand and less with coarse sand.

2.2 Mortars

Mortars are classified on the basis of the following :

(i) Bulk density
(ii) Type of binding materials
(iii) Nature of application
(iv) Special mortars

Bulk Density: According to the bulk density of mortar in dry state there are two types of mortars:

(i) **Heavy Mortars:** The mortars having bulk density of 15 kN/m^3 or more are known as heavy mortars and they are prepared from heavy quartz or other sands.

(ii) **Light weight mortars:** The mortars having bulk density less than 15 kN/m^3 are known as light weight mortars and they are prepared from light porous sands, pumice and other fine aggregates.

2.2.1 Type of Binding Material

The type of binding material for a mortar is selected by keeping in mind several factors such as expected working conditions, moisture conditions etc.

According to the type of binding materials, the mortars are classified into the following categories:

(i) **Lime Mortar :** In this type of mortar, lime is used as the binding material. The lime may either be fat lime or hydraulic lime.

- Fat lime shrinks to a great extent and hence it requires about 2-3 times its volume of sand.
- Lime should be slaked before use.
- Lime mortar is unsuitable for waterlogged areas or in damp situations.
- For hydraulic lime, the proportion of lime to sand by volume is about 1:2.
- Lime mortar has a high plasticity and it can be placed easily.
- It shrinks very little.
- It is sufficiently durable.
- It hardens slowly.

(ii) **Surkhi Mortar :** This type of mortar is prepared by using fully Surkhi instead of sand or by replacing half of sand in case of fat lime mortar.

- The Surkhi mortar is used for ordinary masonry work of all kinds in foundation and superstructure.
- It can not be used for plastering or pointing since surkhi is likely to disintegrate after some time.

(iii) **Cement Mortar :** In this type of mortar, the cement is used as the binding material.

- Depending upon the strength requirement and importance, the proportion of cement to sand by volume varies from 1 : 2 to 1 : 6 or more.
- The cement mortar is used where a mortar of high strength and water-resisting properties is required such as underground construction, water saturated soil.

(iv) **Gauged Mortar :** To improve the quality of lime mortar and to achieve early strength the cement is sometimes added to it. This process is known as gauging.

- It makes lime mortar economical, strong and dense.
- The usual proportion of cement to lime by volume is about 1 : 6 to 1 : 8.
- It is also known as the composite mortar or lime-cement mortar and it can also be formed by the combination of cement and clay.
- This mortar may be used for bedding and for thick brick walls.

2.2.2 Special Mortars

(i) **Fire resistant mortar :** This mortar is prepared by adding aluminous cement to the finely crushed powder of fire bricks.

- The usual proportion is 1 part of aluminous cement to 2 parts of powder of firebricks.

- This mortar is fire-resistant and it is therefore used with firebricks for lining furnaces, fire places, ovens etc.

(ii) **Light weight mortar :** This mortar is prepared by adding materials such as saw dust, wood powder to the lime mortar or cement mortar.

- Other materials which may be added are asbestos fibres, jute fibres, coir etc.
- This mortar is used in the soundproof and heatproof construction.

(iii) **Packing Mortar :** To pack oil wells, special mortar possessing the property of high homogeneity, water resistance, ability to form solid waterproof plugs in cracks and voids of rocks etc. is used for this purpose.

Do you know? The composition of packing mortar is decided by taking into consideration the hydrogeologic conditions, packing methods and type of timbering.

(iv) **Sound absorbing mortar :** To reduce the noise level, the sound-absorbing plaster is formed with the help of sound absorbing mortar.

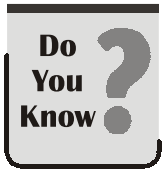
- The bulk density of such a mortar varies from 6-12 kN/m^3 and the binding materials employed in its composition may be Portland cement, lime, gypsum etc.

2.2.3 Properties of a Good Mortar

- It should be capable of developing good adhesion with the building units such as bricks, stones etc.
- It should be capable of developing the designed stresses.
- It should be cheap.
- It should be durable.
- It should be easily workable.
- It should set quickly so that speed in construction may be achieved.
- It should not affect the durability of materials with which it comes into contact.
- The joints formed by mortar should not develop cracks and they should be able to maintain their appearance for a sufficiently long period.

2.2.4 Uses of Mortar

- To bind the building units such as bricks, stones etc.
- To carry out pointing and plaster work on exposed surfaces of masonry.
- To form an even and soft bedding layer for building units.
- To form joints of pipes.
- To hide the open joints of brickwork and stonework.
- To improve the general appearance of structure.



The setting action of mortar is affected by the presence of frost. It is therefore advisable to stop the work in frosty weather or to execute it with cement mortar which will set before it commences to freeze.

Objective Brain Teasers

Q.1 Study the following statements:
1. Hydraulic lime is suitable for white washing.
2. Fat lime is suitable for whitewashing
3. Hydraulic lime is suitable for making mortar
4. Fat lime is suitable for making mortar.

The correct answer is
(a) 1 and 4 (b) 2 and 3
(c) 1 and 2 (d) 3 and 4

Q.2 The main constituent which imparts hydraulicity to hydraulic lime is
(a) calcium oxide (b) silica
(c) clay (d) water

Q.3 Hydraulic lime is obtained by
(a) burning of lime stone
(b) burning of kankar
(c) adding water to quick lime
(d) calcination of pure clay

Q.4 Quick lime is
(a) Calcium Carbonate
(b) Calcium Oxide
(c) Calcium Hydroxide
(d) None of these

Q.5 Quick lime is
1. slow in setting
2. rapid in slaking
3. good in strength

The correct answer is
(a) Only 1 (b) Only 2
(c) Both 1 and 2 (d) Both 2 and 3

Q.6 A gauged mortar is obtained by adding which of the following ingredients to cement?
(a) sand stone
(b) sand and surkhi
(c) sand and lime
(d) surkhi alone

Q.7 Surkhi is added to lime mortar to
(a) prevent shrinkage
(b) decrease setting time
(c) increase bulk
(d) impart hydraulicity

Answers

1. (b) 2. (c) 3. (b) 4. (b) 5. (c)
6. (c) 7. (d)