# PART - A

# UNIT I

# STONES – BRICKS – CONCRETE BLOCKS

**1. What are the uses of stone in construction?**

- ✓ Masonry
- ✓ Pavements
- ✓ Flooring
- ✓ Facing work in buildings
- ✓ Concrete aggregates

**2. List the characteristics to be considered in selection of stones.**

- ✓ Crushing strength
- ✓ Appearance
- ✓ Density
- ✓ Durability
- ✓ Easiness of dressing
- ✓ Fire resistance
- ✓ Fracture
- ✓ Impact resistance
- ✓ Hardness
- ✓ Resistance to wear

**3. List some causes for deterioration of stones.**

- ✓ Alternate wetting and drying.
- ✓ Alternate freezing and thawing.
- ✓ Deleterious substances present in the atmosphere near the seashores and industrial areas.
- ✓ Movement of chemicals between materials.
- ✓ Nature of mortar..
- ✓ Wind.

**4. List some methods of conservation of granite.**

- ✓ Consolidation using consolidates
- ✓ Injection using injection materials and
- ✓ Filling using filling materials.

**5. What are the field tests to be conducted on stones?**

- ✓ Absorption test
- ✓ Smith's test
- ✓ Toughness test
- ✓ Moh's scale of hardness test
- ✓ Acid test
- ✓ Crystallization test

**6. Name the laboratory tests to be conducted on stones.**

- ✓ Attrition test
- ✓ Crushing test
- ✓ Freezing and thawing test
- ✓ Hardness test

- ✓ Impact test
- ✓ Microscopic test

**7. Classify minerals based on abrasion.**

- ✓ Talc
- ✓ Gypsum
- ✓ Calcite
- ✓ Fluorspar
- ✓ Apatite
- ✓ Orthoclase feldspar
- ✓ Quartz
- ✓ Topaz
- ✓ Corundum (Saphire)
- ✓ Diamond

**8. Write notes on Acid test on stone.**

This is to test the presence of poorly weathering calcium carbonates in sandstones. The test consists of placing a cube of the stone weighing about 50 to 100 gm in one per cent hydrochloric acid for 7 days. A good building stone should be free from powder formation on the surface of the cube and the sharp edges should not be broken up after the above immersion.

**9. Write notes on Crystallization test.**

This test consists of immersing a sample of stone (cubes of say 40 mm) in 14 % sodium sulphate solution for two hours and then drying it in an oven at 100°C. This procedure is repeated for at least five times. The loss of weight and the presence of cracking are noted. There should not be any visible defect formed, and the loss in weight should be minimal.

**10. Classify bricks according to their use.**

- ✓ Common bricks
- ✓ Engineering bricks (special bricks for carrying heavy loads)
- ✓ Facing bricks
- ✓ Fire bricks
- ✓ Specials (special shapes)

**11. List the tests made on bricks.**

- ✓ Compressive strength
- ✓ Water absorption
- ✓ Efflorescence
- ✓ Dimensional tolerance
- ✓ Hardness
- ✓ Soundness.
- ✓ Structure

# PART -B



**1. Write the Criteria for Selection of Stones**

**Criteria for selection of stones:**

Stone should be selected according to their use. In any case, it should be durable and free from defects.

**1. Stone for masonry**. Any type of stone can be used for rough work like random rubble. However, for ornamental works and dressing the stones to different finishes (as for ashlar work ) we have to use stones suitable for these purposes. Soft stones like limestones and sandstones can be dressed more easily than granite. For ornamental works in temples or heavy engineering works like facing work in docks and harbours or bridge piers, we will prefer well- dressed granite.

**2. Stone for pavements.** Generally, hardstones of any type can be used for paving walkways, driveways, etc.

**3. Stone for flooring**. Stones are used for heavy duty flooring in many situations. Nowadays, with the help of machines, we can produce large slabs for flooring even from hard rocks like granite. In some locations like bathrooms, marble floorings are preferred. Materials like marble, kotastones can take polish and are prefered in many places. They can also be obtained in pleasing colours. Cuddapa slabs are popular for using in kitchen platforms, shelves, etc.

4. **Stones for facing work in buildings**. The facing stones should have attractive colours. It should be durable. Both impervious stones like granites, marbles and pervious stones like limestones are used. The impervious varieties are preferred as they do not get change in colour with time, especially in an industrial atmosphere.

5. **Stones for concrete aggregates**. Hard igneous rocks like granite are always preferred for high strength concrete as needed in prestressed concrete. Aggregates of moderate strength like limestones are also useful for making concrete of moderate strength.

**2. Enumerate the characteristics to be considered in selection of stones.**
**Characteristics to be considered in selection of stones:**

The desirable qualities depend on the use of the stone. Hard stones are used for heavy engineering works like building quay walls. Many types of stones are used as aggregates for concrete. Stones like marbles are used for appearance. Now, we will deal with the important general properties to took for.

**1. Crushing strength.** The following are the ultimate strengths of some of the common types of stones as compared to 15 to 20 N/mm 2 for ordinary concrete.

(a) Igneous rocks

Granite 80 to 150 N/mm 2
Basalt 150 to 200 N/mm 2
Trap 300 to 350 N/mm 2

(b) Metamorphic rocks

Gneiss 200 to 350 N/mm 2
Slate 75 to 200 N/mm 2

(c) Sedimentary rocks

Limestone 50 to 60 N/mm 2
Sandstone 50 to 70 N/mm 2
Shale 1 to 10 N/mm 2

(d) Other types

Laterite 2 to 3 N/mm 2

Most of the stones have more than the required compressive strength for masonry, compared to hand -made bricks available in India with a strength of only 2 to 10 N/mm2. clip

**2. Appearance**. Appearance is very important for stones used for decorative Works and the facing work of buildings.

**3. Density**. It should be dense. Its specific gravity should he greater than 2.7

**4. Durability.** This property is very important, especially when used in exposed conditions,

**5. Easiness of dressing**. This property depends on its usage. Stones used for tacitly, work should have easiness to get dressed to the required texture.

**6. Fire resistance.** Argillaceous stones like limestones resist fire better than the stones containing quartz which explodes on heating. Thus, limestone resists fire up to 800°C.whereas granites with quartz minerals can stand only up to 600°C.

**7. Fracture.** The grains should be well cemented and sharp if we examine a fractured surface.

**8. Impact resistance**. It is a measure of toughness of the stone. An impact test value of 19 is good and a value below 13 shows bad quality of stone

**9. Hardness**. This test gives resistance against wear as in road works. Hardness greater than 17 is good and less than 14 is considered as poor

**10. Resistance to wear**. Resistance to wear is indicated by attrition test. It is also an important quality for use as coarse aggregate in concrete. For a good facing stone, its value can be as low as 3. However, for use as coarse aggregate a much higher value is needed.

**11. Seasoning**. Many type of stones fresh from the quarry contain moisture (quarry sap). They can be dressed easily at freshly quarried stage. Such stones should be dressed and kept apart for some time for the moisture to evaporate before they are used. (For example, laterite is a special stone which require good seasoning. When quarried, it is soft, and it hardens only when exposed to the atmosphere. The iron compounds get oxidized and gives it the necessary strength. Hence, laterite should always be dressed as soon as it is quarried and stored away from rain for some time before it is used on the works.)

**12. Texture**. It should have a pleasing texture and should be free from cracks and cavities.

**13. Water absorption**. For durability the percentage of absorption should be less than 0.6 per cent. Otherwise, in exposed situations, water can seep into the stone and leach out the salts.

**14. Weathering**. It should weather well as shown by its use in similar types of old buildings in which they have weathered well.

**3. Write short notes on deterioration of stones work and preservation of stones**

**Deterioration of stones**

The following are the main causes for deterioration of stones:

1. Alternate wetting and drying.
2. Alternate freezing and thawing.
3. Deleterious substances present in the air such as in the atmosphere near the seashores and industrial areas.
4. Living organisms, growth of vegetation (like seedlings of banyan trees that grow from droppings of birds) and living worms or bacteria that live in the stone can cause decay.
5. Movement of chemicals between materials. This occurs when limestones and sandstones are used together. The granular limestone can absorb magnisium sulphate present in other rocks if they are used adjacent to the other.
6. Nature of mortar. If the mortar has chemicals, they can affect the stonework.
7. Temperature variation. Large variations of temperature and alternate heating and cooling can cause expansion and contraction which cause cracking of stone.
8. Waterfalls and rainfalls. Falling of water from great heights or falling of water containing chemicals (like rainwater absorbing gases from the atmosphere) can cause deterioration of stones.
9. Wind. Winds blowing for a long time can over deserts contain sand and dust, which passing over the stones for a long lime can cause their deterioration.

**Preservation of stones**

There are two aspects to be considered under this heading. Firstly, the precautions to be taken before and during the construction of stonework and secondly, the steps to be taken after the stonework has been completed.

1. **Precautions during Construction**

The precautions to be taken during the construction are the following:

The type and size of stones selected should be good. Only compact and durable stones should be selected for construction. The size of these stones should be as large as possible to minimize the number of joints. The stones should be well seasoned and washed clean before they are used. The construction should be up to the required specifications. The stones should be placed on their natural beds and the joints completely filled with mortar so that there is no cavity. External renderings like pointing is preferred for exposed stones. Otherwise, it should be plastered with high -quality plaster.

2. **Methods of Preservation of Completed Stonework**

Stonework after construction also needs careful attention if they are to be preserved in their natural condition. The art of preserving ancient stone statues in museums consists of special techniques and is a specialised subject. For preserving stonework in buildings which tend to deteriorate with time, we usually resort to coating the stone with one of the following preservatives.

a) Linseed oil. Raw linseed oil is light in colour while boiled linseed oil is dark and hence discolour the stone.

b) Solution of alum and soap. Alum and soap in 40 to 60 proportions respectively dissolved in water can be applied on the stone to act as a protective coating.

c) Solution of barium hydroxide (Baryta). If the decay is due to $CaSO_4$, then this treatment is effective. The reaction is as follows

d) $Ba(OH)_2 + CaSO_4 = BaSO_4 + Ca(OH)_2$

a. The barium sulphate is insoluble and the $Ca(OH)_2$ absorbs carbon dioxide and gives strength to the stonework.

e) Paraffin. It is used alone or dissolved in naphtha as a paint medium. However it may changes the colour of the stone.

f) Paint. Painting preserves the stone but changes the colour of the stone. If applied under pressure, it can till the pores in the stone. The paint should be neutral and should not react with the stone. Modern colourless paints are also available.

g) coal tar. Even though it is listed as a preservative, it is a highly objectionable material to be used as it completely changes the colour of the stone. The chemicals in coal tar may not also suit some types of stones.

3. **Conservation of Granite**

As there are a large number of art works and monuments made of granite in this world, a large amount of research has gone into methods of conservation of granite. In general the following three methods are commonly used depending on the state of existence of the granite work to be made good:

- Consolidation using consolidates
- Injection using injection materials and

- Filling using filling materials.

  The binding medium used are ethylsilicate, acrylic resin, epoxy resins and others.

Filler materials like suitably coloured sands from 0.1 mm to 2 mm are also added if needed. This art of conservation of stones and especially granite is extensiverly practiced in the laborations attached to museums.

**4. Explain physical tests on stones**

Physical tests on stones:

Building stones are to be tested for the following tests:

1. Absorption test
2. Smith's test
3. Toughness test
4. Moh's scale of hardness test
5. Acid test
6. Crystallization test
7. Attrition test (see also Chapter 8 on coarse aggregates)
8. Crushing test
9. Freezing and thawing test (for cold countries)
10. Hardness test (see Chapter 8 on coarse aggregates)
11. Impact test (see Chapter 8 on coarse aggregates)
12. Microscopic test

Tests 1 to 6 are simple tests that can be carried out in the field and are usually made on building stones. Tests 7 to 12 are carried out in a laboratory and are often performed to find suitability of coarse aggregate for concrete. These tests are briefly described below:

**SIMPLE FIELD TESTS:**

i. **Absorption test** This is a simple test that should be done on all stones. It consists of keeping a sample of rock of about 50 gm in distilled water and finding the water absorbed in 24 hours. It should not exceed 0.6 per cent.

ii. **Smith's test** This test is to determine the deterioration of stones when immersed in water. A sample of the stone is placed in distilled water in a glass vessel and vigorously stirred. It is kept in water for at least 24 hours. If the water turns muddy, then the stone contains earthy substances. Some very consolidated sands which look like sandstones simply slump under water in this test. We should ensure that all stones we use pass this test.

iii. Toughness test. Hit the stone with a hammer and find how tough it is to break it with the hammer.

iv. Moh's scale of hardness test. One simple way of describing strength of stones is in terms of hardness of the surface. We scratch the stone with a penknife and classify hardness by Moh's scale of hardness. It is based on the relative abrasiveness of minerals (the softest being talc and the hardest diamond), the scale being divided into 10 scales as shown below:

    1. Talc
    2. Gypsum
    3. Calcite

4. Fluorspar
5. Apatite
6. Orthoclase feldspar
7. Quartz
8. Topaz
9. Corundum (Saphire)
10. Diamond

(Note: Schmidt rebound hammer tests are increasingly being used for finding the strength of in situ rocks than Mohr's hardness test.)

v. Acid test This is to test the presence of poorly weathering calcium carbonates in sandstones. The test consists of placing a cube of the stone weighing about 50 to 100 gm in one per cent hydrochloric acid for 7 days. A good building stone should be free from powder formation on the surface of the cube and the sharp edges should not be broken up after the above immersion.

vi. Crystallization test This test consists in immersing a sample of stone (cubes of say 40 mm) in 14 per cent sodium sulphate solution for two hours and then drying it in an oven at 100°C. This procedure is repeated for at least five times. The loss of weight and the presence of cracking are noted. There should not be any visible defect formed, and the loss in weight should be minimal.

**LABORATORY TESTS:**

i. Attrition test (as described under coarse aggregates). This is carried out in a Deval testing machine (see Chapter 8, Section 8.5.8).

ii. Crushing test This test consists of finding the compressive strength of a stone cube 40 mm in size in a compression -testing machine. The rate of loading used is 140 kg per cm- per minute.

iii. Freezing and thawing test. This test is applicable to the regions where the temperature can go below the freezing point. It consists of keeping a specimen of the stone in water for 24 hours and then freezing it at —12°C for 24 hours. It is then thawed. This is repeated at least seven times after which the specimens are carefully examined for any damage.

iv. Hardness test This test is different from the attrition test. Here, we use the Dorry's testing machine. A cylinder of 25 mm of the rock is rubbed against a steel disc sprinkled with coarse sand. The specimen is given a pressure of 1.25 kg. After 1000 revolutions, the loss in weight is determined.

$$\text{Coefficient of hardness} = \frac{20 \text{ loss of weight in gm}}{3}$$

v. **Impact test** (as described under coarse aggregates in Section 8.5.7).

vi. Microscopic test In this test, thin sections of the stone are taken and placed under the microscope to study its grain size, mineral constituents and presence of harmful materials.

**5. What are the 3types of classification of bricks?**

CLASSIFICATION OF BRICKS

Bricks can be classified in three ways namely according to their use, or its general physical requirements and strength or as in IS classification. The classification of bricks on the basis of these criteria is as follows:

a) **According to use**. Bricks are, sometimes, broadly classified according to their uses as:
   i. Common bricks
   ii. Engineering bricks (special bricks for carrying heavy loads)
   iii. Facing bricks
   iv. Fire bricks
   v. Specials (special shapes)

b) **According to general physical requirements**. In some specifications, clay bricks are classified as Class I, Class II and Class III according to their general physical properties indicated in Table 2.2. As can be seen, the bricks of different classes differ in their water absorption property. No good brick should disintegrate when immersed in water even for a long period. Such disintegration shows lack of good burning.

c) **I.S. Classification of bricks.** Indian Standards I.S. 3102-1971 "Classification of burnt clay solid bricks" classifies bricks according to their strengths as given in Table 2.3.

**Table 2.2 Requirements of Different Classes of Burnt Clay Bricks**

| | *Class I Bricks* | *Class II Bricks* | *Class III Bricks* |
|---|---|---|---|
| 1. General requirements | Shall have a uniform colour, shall be thoroughly burnt but not overburnt, shall have plane rectangular faces with parallel sides and sharp straight right angled edges. They shall have a compact and uniform texture. | Shall have a uniform colour and may be slightly overburnt. The bricks may be slightly distorted and have round edges. They shall have a fine compact and uniform texture. | May be slightly underburnt or overburnt. They may be distorted and have round edges. The defects in uniformity or shape shall not be such as to cause difficulty in obtaining uniform courses with their use. |
| 2. Water absorption after 24-hour immersion in cold water. | Not more than 20 per cent by weight. | Not more than 22 per cent by weight. | Not more than 25 per cent by weight. |
| 3. Efflorescence | Slight | Slight | Moderate |

(*Note*: Coverburnt bricks are classified as fourth class bricks.)

**Table 2.3 I.S. Classification of Bricks According to Strength**

| *Class designation* | *Compressive strength requirement (not less than)* | *Additional requirements* |
|---|---|---|
| 10 | 10 N/mm$^2$ | Dimensional tolerance ±3%, surface must be smooth, corners should be sharp, should give a ringing sound when struck. |
| 7.5 | 7.5 N/mm$^2$ | Dimensional tolerance ±8%, permitted to have slight distortion but it should not cause difficulty in laying. |
| 5.0 | 5.0 N/mm$^2$ | Dimensional tolerance ±8%, permitted to have slight distortion but it should not cause difficulty in laying. |
| 3.5 | 3.5 N/mm$^2$ | Dimensional tolerance ±8%, permitted to have slight distortion but it should not cause difficulty in laying. |

Note: Generally, factory -made (wire -cut) bricks in India give a strength of the order of 17 N/mrn2 when dry and 12 N/mm2 when wet. Common hand -made bricks, generally, give the strength of the order of only 3 to 5 N/mm 2 when dry.

**6. Describe the Testing of Bricks**

**SAMPLING FOR TESTING OF BRICKS**

Indian Standards I.S. 3495-1992 "Method of test for burnt claybricks parts I to 4" gives details of the tests. The sampling and testing of bricks is carried out as shown in Table 2.4.

**Table 2.4 Sampling and Testing of Bricks (I.S.)**

| *Class designation* | *Sampling size* | *Lot size* | *Tests to be made* |
|---|---|---|---|
| 10 | 20 bricks | 50,000 or more | 1. Comp. strength<br>2. Water absorption<br>3. Efflorescence<br>4. Dimensional test<br>5. Hardness<br>6. Soundness |
| 7.5 to 3.5 | 20 bricks | 100,00 or more | Tests at the discretion of the Engineer in-charge |

**TESTS FOR BRICKS**

The tests to be made on bricks, as already given in Table 2.4 are as follows:

1. Compressive strength
2. Water absorption
3. Efflorescence
4. Dimensional tolerance
5. Hardness
6. Soundness.
7. Structure

We will now deal with the above -mentioned tests.

**1. Compressive strength**. Five bricks are taken at random and their dimensions are measured to 1 mm accuracy. They are, then, immersed in water of 25°C to 29°C for 24 hours. The surplus moisture is allowed to drain and the frog. if any. is filled with mortar 1:3 (1 cement, 3 clean coarse sand 3 mm and down). It is kept under a jute bag for another 24 hours after which it is immersed in clean water for three days. At the time of testing, these bricks are removed from water, wiped dry of any trace of moisture and placed with the flat surface horizontal and mortar-filled face up between three plywood sheets each of 3 mm thickness (plaster of Paris may also be used to ensure uniform surface).

The load is applied at the rate of 140 kg/cm 2 per minute till the failure of the specimen takes place as indicated by the needle of the testing machine turning back. Average of the five test values is reported. While finding the average, any single value obtained as compressive strength which is higher than the upper value of the class of the bricks tested, should be taken only as the upper limit of the class. Values less than 20% below the average value should be discarded. The average value should not be less than the specified value.

**2. Water absorption.** Five bricks are taken for test. They are allowed to dry in an oven at 110' to 115° C till they attain a constant weight which usually takes place in 48 hours. They are then allowed to cool at room temperature, which generally takes 4 to 6 hours without a fan and 2 to 3 hours with a fan blowing on it and weight $W_1$ is measured.

They are then kept in clear water at 27 + 2°C for 24 hours and then wiped dry with a damp cloth and weight W) is measured. The average percentage of water absorbed as percentage of dry weight is reported. Average of the five tests is reported. This value should not be more than the values specified in Table 2.2.

Percentage absorption = $W2 - W1$ x 100

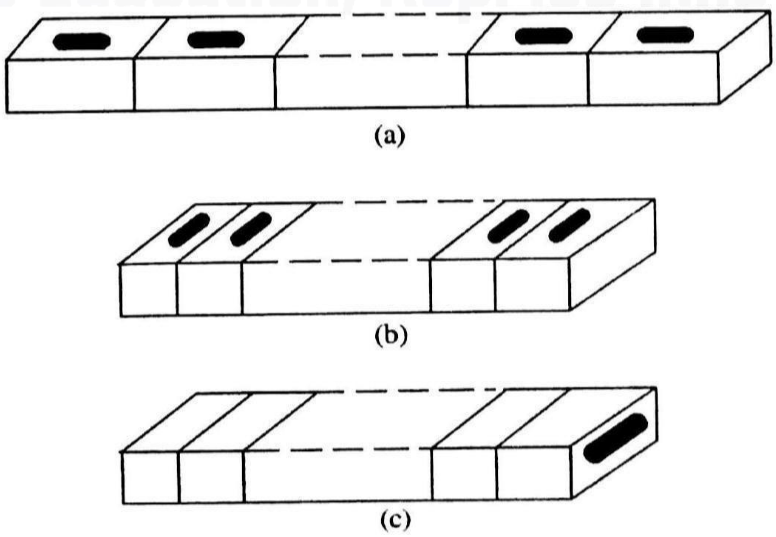
**3. Efflorescence.** This test should he conducted in a well -ventilated room at 18-30°C. Average value on five samples taken at random is to he reported. The brick is placed vertically in a dish 30 cm x 20 cm approximately in size with 2.5 cm immersed in distilled water. The whole water is allowed to be absorbed by the brick and evaporated through it. After the bricks appear dry, a similar quantity of water is placed in the dish, and the water is allowed to evaporate as before. The brick is to be examined after the second evaporation and reported as follows:

a) Nil. When there is no perceptible deposit of salt.
b) Slight. When not more than 10 per cent of the area of brick is covered with salt.
c) Moderate. When there is heavy deposit covering up to 50% of the area of the brick but unaccompanied by powdering or flaking of the surface.
d) Heavy. When there is heavy deposit covering more than 50% of the area of the brick accompanied by powdering or flaking of the surface.
e) Serious. When there is a heavy deposit of salts accompanied by powdering and/or flaking of the surface and this deposition tends to increase in the repeated wetting of the specimen.

Bricks for general construction should not have more than slight -to –moderate efflorescence.

**4. Dimensional tolerance.** Twenty whole bricks are selected at random to check measurement of length, width, height, etc. These dimensions are to be measured in one or two lots of ten each as shown in Fig. 2.2. Variations in dimensions are allowed only within narrow limits, ±3 % for class one and ±8% for other classes.

**5. Hardness.** A scratch is made on the surface of the brick with the finger nail. In a good brick, no impression will be left on the surface.



## UNIT - II

## LIME – CEMENT – AGGREGATES – MORTAR

**1. What is curing? State its importance.**

It is absolutely essential that moisture should be present in the initial stages for the development of strength of cement. This process of supplying moisture environment is known as curing. Thus, curing of the products of cement is very important in all the works connected with cement like construction of masonry. Plastering, concreting. etc.

**2. What is White cement and where is it used?**

White cement is made from chalk or limestone or shelllime free from impurities and white clays like china clay free from oxides of iron, manganese, etc. White cement is very much used for making of mosaic tiles, coloured cements, etc.

**3. What are the types of cement produced in India?**

- ✓ Ordinary portland cement (OPC)
- ✓ Portland pozzolana cement (PPC)

**4. What are the IS specifications of Cement?**

- ✓ Ordinary portland cement (OPC) in 3 grades
  - ➢ Grade 33 IS 269-1989 designated as C-33
  - ➢ Grade 43 — IS 8112-1989 designated as C-43
  - ➢ Grade 53 — IS 12269-1987 designated as C-53
- ✓ Portland pozzolana cement (PPC) (a mixture of OPC and Pozzolanas)
  - ➢ IS 1489 (Pan 0-1991 (flyash-based)
  - ➢ IS 1489 (Part II) -1991 (calcined clay -based)
- ✓ Sulphate -resisting cement—IS 12330-1988
- ✓ Portland slag cement—IS 455-1989 (PSC)
- ✓ Low -heat cement—IS 12600-1989
- ✓ Rapid -hardening cement—IS 8041-1990

**5. List the physical tests on Cement.**

- ✓ Fineness test
- ✓ Consistency test
- ✓ Soundness test
- ✓ Setting time test

**6. What is hydration of cement?**

Hydration of cement is a chemical reaction that happens when cement is introduced to water and it produces heat. In very massive construction, this effect can raise the temperature of concrete as much as 50°C. In such cases, we should use low—heat cements or adopt cooling methods.

**7. List the tests conducted on aggregates.**

- ✓ Particle Size,(grading) shape and flakiness (3tests)
- ✓ Organic impurities
- ✓ Moisture content
- ✓ percent fines value
- ✓ Water absorption and specific gravity
- ✓ Aggregate crushing value
- ✓ Aggregate impact value

- ✓ Aggregate abrasion value
- ✓ Bulk density and void ratio

**8. Classify aggregates based on their shape.**

- ✓ Rounded
- ✓ Irregular or partly -rounded
- ✓ Angular
- ✓ Flaky

**9. Define flakiness index.**

The flakiness or elongation index of an a aggregate is defined as the percentage weight of particles in the given aggregate which has its length greater than 1.8 times and its least dimension (thickness) is less than 3/5 (or 0.6) times its mean dimension.

**10. What is Impact test?**

This test is for aggregates in concrete that undergoes impact as in runways in airports. Materials passing through 12.5 mm and retained as 10 mm are tilled in the standard cylinder in three layers, each layer tamped with 25 strokes of an iron rod. A hammer weighing 14 kg is dropped from a height of 380 mm 15 times and the resulting material is sieved through a 2.36 mm I.S. sieve. The percentage fine is the aggregate impact test value.

**11. Write notes on Abrasion test.**

This test is for the stones used in road construction. We use the Deval's abrasion testing machine or the Los Angeles abrasion machine for this purpose. It should not be more than 16 per cent for a good aggregate.

**12. Write the procedure of Los Angles Abrasion test.**

A sample of specified grading which varies with the maximum size of aggregate to be tested is placed in the machine with steel or cast iron spheres of 48 mm diameter and 390 to 445 gm weight. The machine is rotated for specified revolutions depending on the grading (500 to 1000 revolutions). The resulting material is sieved through 1.7 mm sieve. The percentage of wear is called the Los Angeles aggregate abrasion value.

**13. Why gypsum is used in cement?**

Gypsum is used for retarding the setting time of cement.

**14. What are the two methods of manufacture of cement?**

- ✓ Wet process
- ✓ Dry process

## UNIT II

## LIME – CEMENT – AGGREGATES – MORTAR

**1. List the composition of Portland cement.**

**COMPOSITION OF PORTLAND CEMENT**

The cementing properties of cement develop due to chemical reaction of the above—mentioned compounds. Depending on the raw materials, type of firing, etc., the proportion of these various constituents can be made to differ and the resulting product will also give differing properties. Of all the main constituents of cement, C 3 S and CA control the setting and early strengths and heat of hydration. The compound GIS is responsible for strength at longer ages. C3A also generates higher heat than other compounds. Increase in C 3 S results in higher long-term strength and high heat of hydration. If C3 A and C 4 AF are kept low, then the resistance to chemicals such as sulphates is increased. Portland cement itself is produced in different types by varying the proportions of the constituents of cement as shown in Table .1

| *Description* | *Approximate percentage of constituents* | | | |
|---|---|---|---|---|
| | $C_2S$ | $C_3S$ | $C_3A$ | $C_4AF$ |
| 1. Normal or ordinary | 25 | 45 | 12 | 8 |
| 2. Rapid hardening | 26 | 45 | 5 | 15 |
| 3. Low heat | 31 | 21 | 6 | 14 |

Notes:

1. We should note the difference between setting of lime (given in Chapter 4) and setting of cement. Cement after its final set can set strong under water. Whereas the cementing property of lime depends on its exposure to air, the cementing property of Portland cement is due to the chemical reaction between its various constituents in the presence of moisture It is absolutely essential that moisture should be present in the initial stages for the development of strength of cement. This process of supplying this kind of environment is known as curing. Thus, curing of the products of cement is very important in all the works connected with cement. like construction of masonry. Plastering, concreting. Etc

**2.** The total percentage of C 2 S and C A S in all types of Portland cements is around 70 percent, so that even though the strength development of two cements at early stages may be different, the final strength obtained after long periods of time may not be different. However, removal of formwork, prestressing of concrete depends to a large extent on the early strength of concrete.

**3.** When producing low -heat Portland cement the percentage of C 2 S is increased and that of C A S and C 3 A is decreased. This type of cement is of particular use in construction of dams, massive foundation, etc. to reduce the production of heat.

**4.** Reducing C 3 A increases. Sulphate resistance but the 7 day and 28 day strengths also get lowered as compared to the ordinary Portland cement. Sulphate -resisting Portland cement has less than 5% C 3 A. This type of cement is recommended for sewer works.

**5.** Rapid hardening cements compared to ordinary cements have more or less the same composition except that the latter is more finely ground and may sometimes contain higher percentage of C 3 S. The increased fineness increases the 7 day strength.

## WHITE CEMENT

White cement is very much used for making of mosaic tiles, coloured cements, etc. White cement is made from chalk or limestone or shelllime free from impurities and white clays like china clay (kaoline clay) free from oxides of iron, manganese, etc. Shelllime is on ideal raw material. In some factories, oil is used instead of coal as fuel. Grinding is also done in a special mill to avoid iron oxide. White cement is the base for all coloured cements. However, all concretes made from coloured cement tend to fade with time due to deposition of lime salts on the surface. Hence. the best coloured concretes are those in which naturally coloured aggregates are relied upon for the colour effect and the colour of the cement should play only a secondary role.

**2. Explain types of cement produced in India.**

## TYPES OF CEMENT PRODUCED IN INDIA

Ordinary portland cement (OPC) and Portland pozzolana cement (PPC), (the latter being a mixture of Portland cement and 15 to 35% pozzolanas,) are the types of cements prescribed in India. Even though formerly it was mandatory in India to indicate on the cement bags the nature of its contents (OPC or PPC) nowadays this is not legally necessary. Only the grade of the cement is marked on the bag. Most cements sold in India is portland cement mixed with various proportions of pozzolanes like flyash. Cement is specified by its grade, i.e. the mortar cube strength in 1N/mm2 in 28 days. (We use compression strength of 1:3 cement mortar as cubes of 50 cm 2 area (7.06 cm) in 28 days for defining strength.) Thus. Grade -33 cement (C-33) means cement with standard mortar cube strength of 33 Islimm 2 in 28 days. In India, cement is available in the market in bags of 50 kg. The tolerance allowed is
-±2.5% in weight per hag and an in overall tolerance of ±0.5% per wagon load of 20 to 25 tonnes. In case of massive works like dams, it is to be supplied in bulk and is stored in large bins at the site. The following ale the IS specifications.

I. Ordinary portland cement (OPC) in 3 grades
   - (a) Grade 33 IS 269-1989 designated as C-33
   - (b) Grade 43 — IS 8112-1989 designated as C-43
   - (c) Grade 53 — IS 12269-1987 designated as C-53

2. Portland pozzolana cement (PPC) (a mixture of OPC and Pozzolanas)
   - (a) IS 1489 (Pan 0-1991 (flyash-based)
   - (b) IS 1489 (Part II) -1991 (calcined clay -based)
3. Sulphate -resisting cement—IS 12330-1988
4. Portland slag cement—IS 455-1989 (PSC)
5. Low -heat cement—IS 12600-1989
6. Rapid -hardening cement—IS 8041-1990
7. Concrete sleeper -grade cement—IS T40-1985
8. Coloured cement—White Cement—IS 8042-1989
9. Oil well cement—IS 8229-1986
10. Hydrophobic cement -1S 8043-1991
11. Masonry cement—IS 3466-1988
12. High -alumina cement—IS 6452-1989
13. Supersulphated cement—IS 6909-1990

14. Expansive cement
15. Quick -setting cement.

The more important types of cement are the following:

**1. Ordinary Portland cement (OPC)**. About 70% of cement produced in India was of this category and in 3 grades, viz. Grade 33, 43 and 53 as already stated above. However pure portland cement is generally not marketed nowadays in bags.

**2. Portland pozzolana cement (PPC).** This type of cement is the most common type available now in the market and is made by blending 10 to 25% reactive pozzolana like flyash or calcined clay with OPC. Addition of pozzolana makes cement sensitive to curing and PPC requires longer curing than OPC. This type (PPC) is also available in three grades.

**3. Sulphate -resisting Portland cement (SRPC or SRC).** This kind of cement is produced in small quantities in India. It is special OPC with less than 5% C3A and are superior in resistance against sulphates. Cements called Birla Coastal comes in this category. They should not be confused with supersulphated cements (SSC) made from blast furnace slag, calcium sulphate and small quantities of OPC. (SSC is not recommended for use in places with temperatures above 40°C as in India.) IS 456-2000 recommends that where chlorides is encountered along with sulphate in foundation soil or ground water, OPC with C 3A content

5 to 8 per cent is desirable to be used instead of supersulphate-resisting cement. Alternately, Portland slag cement having more than 50% slag or a blend of OPC and slag cement (which has been found to be of good performance) is recommended.

**4. Portland blact furnace slag cement or Portland slag cement (BFSC or PSC).** This type of cement constitutes about 10% of cement produced in India. The slag forms 25 to 60`1 of

the cement. Every ton of cast iron produces about 0.3 tons of blast furnace slag which can be

used in the cement industry. During its setting, the $Ca(OH)_2$ liberated by OPC hydration acts as an activator for the slag. They are also less costly than OPC. Even though it is equated with OPC, it behaves more like PPC and has lower heat of hydration and better sulphate resistance At present, the BFSC cement produced in India is only Grade -33 and there arc proposals to make Grade -43 cements with 45 -70% slag content. Blast furnace slag cement with more than 50% slag has good sulphate resistance too.

**5. Hydrophobic cement**. In places of high rainfall and humidity, normal cement tends to set when stored due to moisture present in the atmosphere By grinding the cement clinker with a water-repellent film forming substance like oleic acid, a water-repellent film is formed around cement particles during the manufacturing itself. This prevents setting of cement during storage. During mixing with aggregates, this film is broken and cement behaves as ordinary cement.

**6. Blended cement** For economy, a mixture of Portland cement, blast furnace slag and flyash is allowed to be used in some countries. It is known as blended cement. This type of cement is not marketed in India.

**3. Explain grades of cements available in India and Tests on Cement. GRADES OF CEMENTS AVAILABLE IN INDIA**

In the U.S.A. and U.K., cement is covered by one specification, whereas in Germany, it is available in 3 grades. The German practice has also been accepted in India and it came about as follows: Till around 1973, only Grade -33 cement was available in India. However,

between 1973-75 the Indian Railways adopted the use of prestressed concrete sleepers in a big way for running the high speed trains. It was soon apparent that the common Grade -33 cement available in the market was inadequate to develop the needed minimum characteristic concrete strength of about 50 N/mm - required for the purpose. Hence, the railways developed their own specification for "sleeper cements" with a minimum cement strength of
52.5 N/mm2 in 28 days. Some of the factories in India came forward to make these type of cements for the railways, which made them available only to the sleeper manufacturers. Very soon, with the advancement of cement technology, more and more factories found it easy to manufacture higher grade cements with their modernized cement plants. Thus, we have the following types of cement in India:

1. Grade -33 as per IS 269 (1989)—C 33
2. Grade -43 as per IS 8112 (1989)—C 43
3. Grade -53 as per IS 12269 (1987)—C 53

**4.** Sleeper cements as per IRS -T40-85 (this will be between C 43 and C 53) supplied only to the railways.

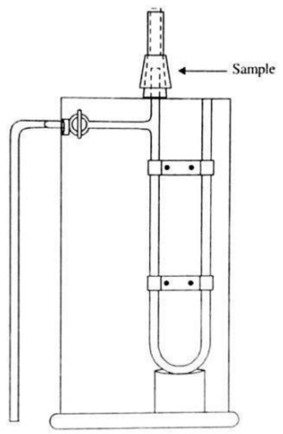
The easily available cement today is of Grade -43. It should be noted that the testing procedures used in India are different from those in U.S.A., where cylinders are used so that the 53 -Grade cement produced in India would give approximately 25 to 30% less strength as per ASTM standards. The compressive strength developed by the cements with time is shown in Table 2.

Table 2 Compressive Strengths of Mortar Cubes of Different Grades of Cement in N/mm$^2$

| Age (in days) | Grade | | | Sleeper cement | |
|---|---|---|---|---|---|
| | Grade 33 | Grade 43 | Grade 53 | Code | Actual |
| | | Recommended values | | | |
| 3 | 16 | 23 | 27 | – | 40.3 |
| 7 | 22 | 33 | 37 | 37.5 | 55.3 |
| 28 | 33 | 43 | 53 | – | 70.3 |
| | Observed laboratory values as percentage of 28-day strength | | | | |
| 3 | 30–40 | 50–60 | 70–80 | | |
| 7 | 50–65 | 65–80 | 80–90 | | |
| 28 | 100 | 100 | 100 | | |
| 90 | 100–125 | 105–115 | 100–105 | | |
| 180 | 115–130 | 110–120 | 105–110 | | |

**4. Description of physical tests on Cement.**

**DESCRIPTION OF PHYSICAL TESTS (IS 4031: PARTS 1 TO 11)**




The physical tests are specified in Parts Ito 11 of IS 4031. We shall briefly deal with some of the main laboratory physical tests in the following sections. The concerned Indian Standards should be consulted for details of these tests. In engineering college laboratories, only physical tests are carried out. Chemical tests are carried out in cement factory laboratories and they are shown in the test certificates for each batch manufactured and supplied by the manufacturer to their field agents.

**Test for Fineness**

The first requirement is that 90% of cement should pass IS 90 microns. Indian Standards also specifies fineness test by Blaine's Air -permeability method as described in IS 4031-1968. The principle is based on the relation between the rate of flow of air through a cement bed and the surface area of the particles comprising the cement bed of a given porosity. The finer the cement the more the surface area and less the porosity in the permeability test. The Blane's apparatus is shown in Fig. As shown in Table .3 it should be at least 225 m2/kg.

**Test for Normal or Standard Consistency**

Many tests for cements like soundness, setting time are to be carried out with cement to which water required to produce what is called the "normal consistency". Normal consistency is determined by the apparatus called Vicars needle. It is the consistency at which the Vicat plunger G of 10 mm diameter and 50 mm length will penetrate 33-35 mm within 3 to 5 minutes of mixing. The test procedure is to carry out at least three trial experiments by mixing the cement with distilled water varying from about 24 to 27 per cent of the weight of cement.

**Test for Soundness**

The soundness test is an indication of excess of lime caused by inadequate burning of cement or excess of magnesia or sulphates. Excess of these substances is harmful and thus. not allowed in cements. The following two types of tests are used for testing for soundness

(a) Le Chatelier's test (using Le Chatelier's apparatus)

(b) Autoclave test

**Le Catelier's test:** Le Chatelier's test shows unsoundness due to lime only. Unaerated cement paste at normal consistency is first tested for expansion. If the test results does not satisfy

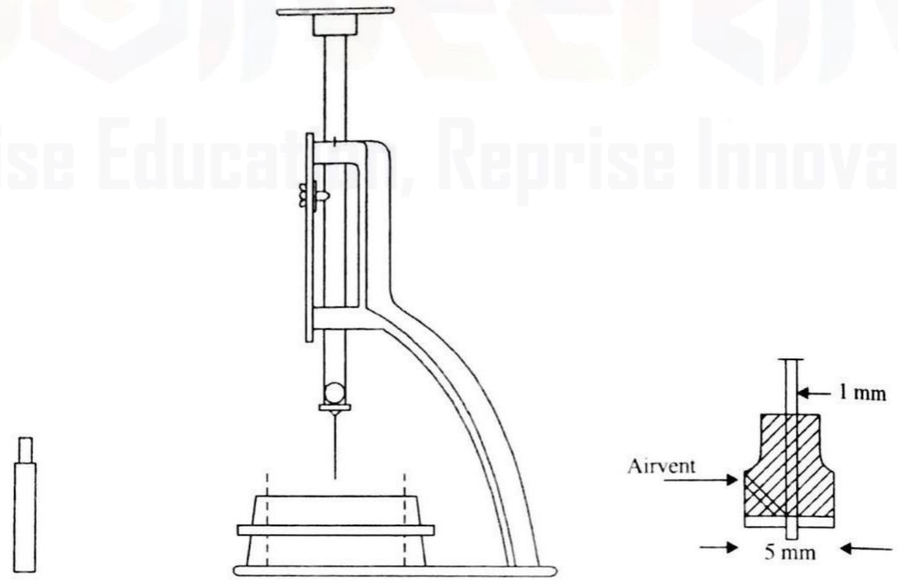



Fig.2 Vicat apparatus with various plungers (a) 10 mm dia needle for normal consistency (b) q mm square needle for initial set (c) 5 mm dia needle for final set. requirement of 10 mm expansion, another test shall be made after aeration of the cement by spreading of the sample

to a depth of 75 mm at a relative humidity of 50 to 80% for 7 days. The expansion in this aerated cement test should not be more than 5 mm.

The apparatus used is shown in Fig. 5.3. Cement pastes with normal consistency is filled into the mould. After covering both sides with glass, it is first placed in water of temperature 24 to 35°C for 24 hours. It is taken out and the distance between pointers is measured. The mould is then placed in water and the water is heated to the boiling point in 30 minutes. The boiling of water is continued for one hour. The mould is then removed and after cooling, the distance between the points is again measured.

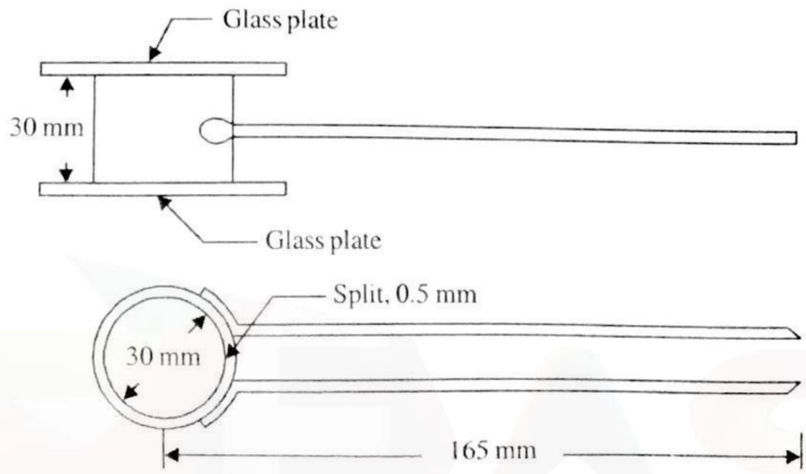



Fig.3 Le Chatelier's apparatus

**Autoclave test**. Autoclave test is another test used sensitive for soundness ot cement. It is to both lime and magnesia. All the cement having magnesia content more than 3 per cent is to be tested for soundness by this test with unaerated cement. The test consists of heating bars made of cement paste with water of normal consistency and measuring its expansion. Effect of unsoundness of cement does not appear in the field for a considerable period of time. hence, these accelerated tests are needed to determine them. In autoclave test, we use higher pressure and temperature to accelerate the reactions. The autoclave expansion of unaerated cement should not be more than 0.8 per cent and that of aerated cement not more than 0.6 percent.

**Test for Setting Time**

The setting time is also determined by the Vicat's needle on cement paste of normal consistency. For this test, we use a 1 mm square needle (needle C). For this needle, the time to penetrate 33-35 mm is taken as initial setting time.

For final setting time, we use special needle F (which has a diameter of 5 mm) and the time at which this needle will not penetrate more than 0.5 mm is taken as the final set.

False set happens when the ratio of the penetration of the Vicat's C needle after 300 seconds to the penetration in 20 seconds is less than 1/2. In such cases the test has to be repeated. The temperature of water and test room should be 27 ± 2°C.

**Compressive Strength**

Compressive strength of cement is a very important test. Compressive strength of cement is determined from cubes of face 50 cm 2 in area (7.06 cm cubes) made of cement mortar with one part of cement and three parts of standard sand (conforming to IS 650-1966) by weight and water corresponding to 25% normal consistency plus three per cent of the combined weight of the cement and sand (P/4 + 3.0 per cent weight of cement and sand). The average cube strength of three samples is taken as the test value. Strengths in 3, 7 and 28 days are to be reported. Usually 555 gm of sand and 185 gm of cement are used for the test. The procedure can be described as follows:

1. 555 gm of standard sand and 185 gm of the given cement enough to make three standard cubes are mixed with water equal to 0.25 normal consistency plus three per cent of the combined weight of the cement and sand to a uniform mix (1:3 mortar with a water cement ratio of 0.4 is also specified for this test).
2. The mortar is placed in the standard 7.05 cm size cubes and compacted in a vibrating machine for 2 minutes (The former method of ramming has now been standardized by the vibrating machine).
3. The moulds, with the mortar, is placed under a damp gunny bag or cabin for 24 hours for the cement mortar to set.
4. The cubes are removed after 24 hours and submerged in clean water for curing for 3. 7 or 28 days.
5. The cubes are tested in sets of three after 3 days and 7 days and 28 days afterzdrying the specimen with a cloth. The strengths should conform to the specified. strength of Table .2.

**Heat of Hydration (IS 4031-1968)**

Hydration of cement is a chemical reaction and it produces heat. In very massive construction this effect can raise the temperature of concrete as much as 50°C. In such cases, we should u se low—heat cements or adopt cooling methods. This test is, hence, required only as a check fo r low_ heat cements. It is made by the principle of determining heat gain as in physics experiments; the test is carried out by a Calorimeter. Low heat cements should satisfy the following criteria.

a) In 7 days, heat generated should not be more than 65 calories per gram of cem ent.
b) In 28 days, heat generated should not be more than 75 calories per gram of cement,

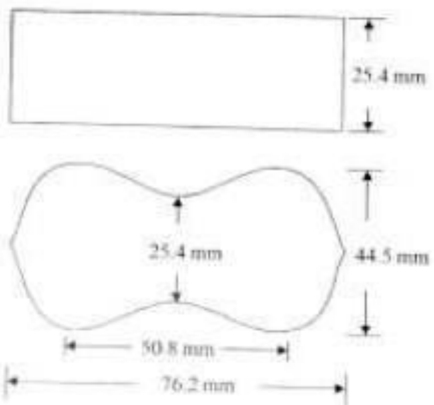
**Chemical Composition Tests (Test for LSF)**

The Lime Saturation Factor or LSF is the most important factor. It is determined by applying the following formula to the various constituents of the given cement.

$$\frac{CaO - 0.7SO_3}{2.8SiO_2 + 1.2Al_2O_3 + 0.65Fe_2O_3} \ngtr 1.02 \text{ and } \nless 0.66$$ for Grades C-33 and Grade C-43 cements and $\ngtr 1.02$ and $\nless 0.8$ for Grade C-53 cement. As shown in Table 5.3 the $C_3A$ content is also determined when the cement's sulphate resistance is also required.

**Tests for Tensile Strength**

This test was once used as a routine test for cement but has been discontinued as test for cement, but is used for testing mortars (see Chapter 10). For this test, briquettes as shown in Fig. 5.4 are made from 1:3 cement mortar using standard sand and water of 8 per cent the weight of cement and sand. They are cured and the 3 -day and 7 -day tensile strengths are reported. It is generally specified that the 3 -day tensile strength should not be less than 2 N/mm- and the 7 -day strength not less than 2.5 N/mm 2 . The



briquettes are tested in a special briquette –testing machine. (The shape of briquettes for cement mortar test is shown in Fig. It has an area of 25.4 x 25 mm or 1 x 1 inch, compared to 38 x 38 mm for test on lime mortar).

**5. Explain sampling and testing of aggregates.**

**SAMPLING AND TESTING OF AGGEGATES**

The routine and other tests usually prescribed on coarse aggregates are as follows:

1. Routine tests
    a) Particle Size,(grading) shape and flakiness (3tests)
    b) Organic impurities
    c) Moisture content
    d) percent fines value
    e) Water absorption and specific gravity
2. Other special tests
    a) Aggregate crushing value
    b) Aggregate impact value
    c) Aggregate abrasion value
    d) Bulk density and void ratio

**DESCRIPTION OF ROUTINE TESTS**

Of the above tests, only the first five tests are specified as mandatory and important in many specifications like CPWD specification 77. These are briefly described below:

**Particle Size, Shape and Flakiness (IS 2386-1963: Part I)**

1. Test for particle size. This is carried out in the field by sieve analysis. The results are plotted as a grading curve as already shown for sand in Fig. 7.1.
2. Tests for shape. Aggregates are classified according to their shape as follows:
    (a) Rounded
    (b) Irregular or partly -rounded
    (c) Angular
    (d) Flaky

The shape of aggregates becomes important in case of high strength (high performance) concrete where very low water -cement ratios are to be used. In such cases, cubical –shaped aggregates are preferred for better workability. Improved makes of crushers such as Hydrocone crushers, Barma rock or Rock VSI crushers, give better products than ordinary jaw crushers. The laboratory test for shape is known as test for flakiness or elongation index. The apparating used is shown in Fig. 8.1.

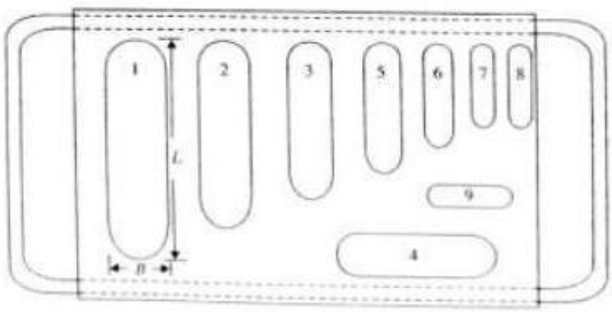


Fig. 8.1 Apparatus to test flakiness of coarse aggregates.

**3.** Test for elongation index (flakiness). The flakiness or elongation index of an a ggregate is defined as the percentage weight of particles in the given aggregate which has its length greater than 1.8 times and its least dimension (thickness) is less than 3/5 (or 0.6) times its mean dimension. A length gauge with holes of various sizes as specified is available as a standard piece of laboratory equipment as shown in Fig.
8.1. This test is not used for aggregate sizes smaller than 6.3 mm.

For the test, sufficient quantity of sample should be taken so that the minimum number of 200 pieces of any standard size fraction is to be tested. The following is the procedure of the test.

1) Take sufficient quantity of the aggregate and sieve it through the different standard sizes of sieve shown in Table 8.3 into fractions. Each fraction should be tested for flakiness.
2) Each fraction is gauged in turns through the hole of dimension of thickness 0.6 times and of length 1.8 times the mean size of the aggregate as shown in Table 8.3.
3) The total amount passing through the various gauges is weighed to an accuracy of 0.1% of the weight of the sample.
4) Flakiness index is the total weight of the material passing through the gauges of various thickness expressed as a percentage of the total weight of the sample taken.

British specifications limit this index to 50 for natural aggregate and 40 for crushed coarse aggregate. For wearing surfaces like roadwork, we may adopt a lower value.

**Table 8.3 Mean Sieve Sizes and Size of Gauges**
**(I.S. 2386, Part 1-1963)**

| *Sieve sizes* (mm) | | *Mean size* (mm) | (B × L) *Dimensions of gauge* (mm) | Fig. 8.1 |
|---|---|---|---|---|
| Passing | Retained | | | |
| 63 | 50 | 56.5 | 33.9 × 100 | 1 |
| 50 | 40 | 45* | 27.0 × 81.0 | 2 |
| 40 | 25 | 32.5 | 19.5 × 58.5 | 3 |
| 31.5 | 25 | 28.25 | 16.95 × 50.85 | 4 |
| 25 | 20 | 22.5 | 13.5 × 40.5 | 5 |
| 20 | 16 | 18.0 | 10.8 × 32.4 | 6 |
| 16 | 12.5 | 14.25 | 8.55 × 25.6 | 7 |
| 12.5 | 10.0 | 11.25 | 6.75 × 20.2 | 8 |
| 10.0 | 6.3 | 8.15 | 4.89 × 14.7 | 9 |

**Example:* For mean size 45 mm, the gauge size is (0.6 × 45) and (1.8 × 45) = 27 × 81 mm

**Test for Organic Impurities, Clay Content and Percentage Fines**

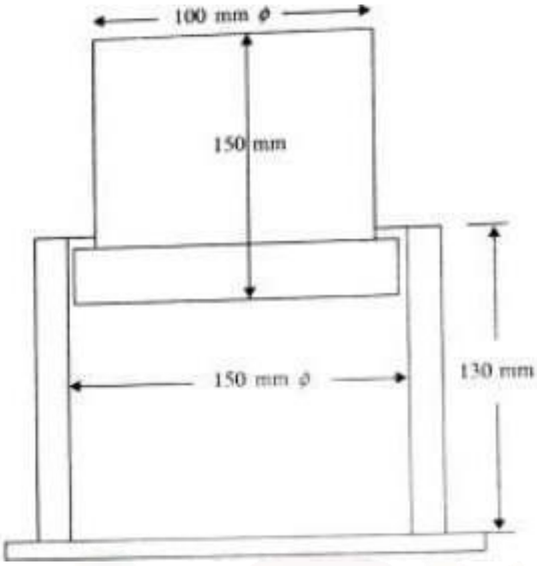
The same test as described for fine aggregate (sand) can be used for coarse aggregate also. The clay content and percentage fines can be found by immersing the aggregate in water and examining the suspended particles in the water.

### Test for Moisture Content

The easy test is the drying method in an oven or heating in an open pan in the field. It can also be carried out by pouring an inflammable liquid like methylated spirit and igniting it to evaporate the water.

### Test for Load for 10% Fineness Value or Crushing Value

(Sample preparations for this test and also for the test called aggregate crushing test described later are similar). About 6.5 kg material consisting of material passing 12.5 mm and retained on 10 mm sieve is taken and compacted in the standard cylinder used for this test in th ree layers—each layer being compacted 25 times with a tamping rod. The top layer is levelled off . The weight of the sample is recorded. The same weight should be taken for subsequent te sts also. The apparatus used is shown in Fig.




On the cylinder with the base plate, the plunger is placed and the unit is set up in a compression testing machine. The load is applied gradually at a uniform rate so that the plunger penetration is as given below in 10 minutes: About 15 mm for rounded or partially - rounded aggregate like natural gravel samples: 20 mm for normal crushed stones and 24.0 mm for honeycombed aggregates like shale and slag_ After reaching the necessary penetration the load is released and the material is sieved through 2.36 mm I.S. sieve. The percentage of the fines passing the above sieve is expressed as a percentage of the weight of the test sample. This should be on the range of 7.5 to 12.6% (i.e. about 10%). Repeat the test till we find the load for the above result. Then load for 10% fines is calculated as follows.

$$\text{Load for 10\% fines} = \left(\frac{14}{y+4}\right)x$$

where

x = load in tonnes for causing 7.5 to 12.6% fines

y = mean of the percentage of tines from two tests at x tonnes load

The value is reported in the nearest 0.5 tonnes and the recommended values are as follows:

(a) For normal concrete, not less than 5 tonnes

(b) For wearing surface for road pavements, not less than 10 tonnes

(c) For ganolithic concrete in buildings, not less than 15 tonnes

### Aggregate Crushing Value

In this test, we find the percentage of fines at a specified load of 40 tonnes. The preparation for this test is the same as that for 10 per cent fines. In this test, after the specimen is set in the compression machine, the plunger is loaded to 40 tonnes in 10 minutes. The load is released and the material is sieved through 2.36 mm sieve (same sieve as used in 10% fine test) to obtain the aggregate crushing value or the percentage fines. It is usually recommended as 45 per cent for aggregates used for concrete other than that used for wearing surfaces. For concrete for wearing purposes, it should not exceed 30 per cent. Generally, it ranges from 18 to 27% for Indian aggregates.

**Test for Water Absorption and Specific Gravity (IS 2386-1963: Part III)**

A sample of aggregates not less than 2 kg is washed and immersed in water for 24 hours and its immersed weight in water is found (A). It is taken out of the water and the saturated surface dry sample is weighed in air (B). It is then over -dried and weighed (C).

Specific gravity = $\frac{B-C}{B-A}$ and Percent water absorption = $\frac{B-C}{C} \times 100$

**Aggregate Impact Test**

This test is for aggregates in concrete that undergoes impact as in runways in airports. Materials passing through 12.5 mm and retained as 10 mm are tilled in the standard cylinder in three layers, each layer tamped with 25 strokes of an iron rod. A hammer weighing 14 kg is dropped from a height of 380 mm 15 times and the resulting material is sieved through a 2.36 mm I.S. sieve. The percentage tine is the aggregate impact test value. It should not be more than 45% for aggregates for concrete for ordinary use and not more than 30% for aggregates for concrete for runways and pavements. For Indian aggregates, it ranges from 15 to 30%.

**Aggregate Abrasion Value (Attrition Test)**

This test is for the stones used in road construction. We use the Deval's abrasion testing machine or preferably the Los Angeles abrasion machine for this purpose. hi the latter test, a sample of specified grading which varies with the maximum size of aggregate to be tested is placed in the machine with steel or cast iron spheres of 48 mm diameter and 390 to 445 gm weight. The machine is rotated for specified revolutions depending on the grading (500 to 1000 revolutions). The resulting material is sieved through 1.7 mm sieve The percentage of wear is called the Los Angeles aggregate abrasion value. It should not be more than 16 per cent for a good aggregate.

**Bulk Density and Void Ratio**

Bulk density is determined by packing the aggregate into a specified container of known volume and determining the weight of the aggregates packed.

$$\frac{\text{Weight}}{\text{Volume}} = \gamma = \text{bulk density}$$

$$\text{Void ratio} = \frac{G_s - \gamma}{\gamma}$$

where $G_s$ = Specific gravity of aggregate

**Aggregate Crushing Strength**

This test is performed on a core or cube obtained from the original rock. It gives a measure of the strength of the parent rock (see Section 1.5.1).

**MEASURE OF STRENGTH OF AGGREGATES**

As discussed earlier, the three tests that deal with the strength of aggregates are

(a) Ten percent fineness value

(b) Aggregate crushing value

(c) Aggregate crushing strength

Of these, the ten per cent fineness value is considered a good test for weak aggregates while the crushing value is considered good for general aggregates. As already stated, crushing strength gives only the strength of the parent rock.

**ALKALI AGGREGATE REACTION**

It was as late as in 1940 that it was discovered by the American Bureau of Reclamation that some of the natural aggregates that contain reactive silica (like traps, andesites, rhyolite, some types of limestones, sandstones and natural gravels) react with the alkali of the cement and produce compounds that cause expansion and deterioration of concrete. Such concrete can become unserviceable even in one year's time. Aggregates from such sources should be tested for reactive silica by special tests for its suitability for making concrete.

**6. List the raw materials for cement production and Explain**

**RAW MATERIALS FOR CEMENT PRODUCTION**

The raw materials used in the cement production are listed as follows;

**A. Calcareous Materials**

The calcareous material is the first major principal material for the cement production. The cal-careous portion of the raw materials is mainly limestone. Other lime bearing materials like chalk, sea -shells, calcareous sea sand, coral and by-product calcium carbonate from other industries are also sometimes used. Since the chemical quality of limestone varies widely, there can be varieties of limestone. However, limestone of specified chemical composition alone can give the rigid stan- dards in the quality of cement.

Basically, limestone suitable for making cement should have the following chemical composition;

- a minimum content of 80 percent calcium carbonate ($CaCO_3$)
- maximum contents of 12 percent each of magnesium carbonate ($MgCO_3$) and Silicon dioxide ($Si0_2$)
- a minimum percentage of aluminium oxide ($A1_2O3$) and iron -oxide ($Fe_2O_3$ ) such that ratio of $SiO_2$ $A1_2O_3$ plus $Fe\ _2O_3$ is around 2:5. And
- a total alkali content (potassium oxide, sodium oxide etc.) of preferably less than 0.5 percent.

**B. Argillaceous Materials**

The second principal raw material is argillaceous materials which are clay, laterite, sandstone bauxite and iron ore. These corrective materials are used in appropriate quantities to bring the chemical composition of raw mix to the desired limits.

**C. Gypsum**

Gypsum used for retarding the setting time is also a raw material. Natural gypsum and marine gypsum (a by—product from the salt industry) are both used.

**D. Coal/Furnace Oil/Natural Gas for Burning**

For burning the raw material, coal, furnace oil or natural gas can be used. Natural gas is scarce in India and is not used for the manufacture of cement. Furnace oil also is very costly and it is not generally used except for the manufacture of white cement. Coal is, therefore, the fuel used for manufacture of cement. The Government does not allow the use of selected grade coals for the manufacture of cement; only grade I coal having 22 to 25 percent ash is allotted for the purpose.

**7. Explain manufacture of Portland cement.**
**MANUFACTURE OF PORTLAND CEMENT**

The specifications laid down by Bureau of Indian Standard (BIS)— IS : 269-4989 the manufacture of Portland cement are as follows;

*"Portland cement shall be manufactured by intimately mixing together calcare- ous and argillaceous and/or other silica, alumina or iron oxide bearing materials, burning them at a clinkering temperature (1450 to 1500°C) and grinding the resultant clinker so as to produce a cement capable of complying with this specification. No material shall be added after burning other than gypsum and not more than one percent of air -entraining agents or detergents such as vinsol resin and derex which have proved not to be harmful."*

The above mentioned specification of the process of Portland cement manufacture passes through several distinct stages which are enumerated as follows,

i. Selection of site where raw materials are available. Nearly 1.5 tonnes of limestone are required to produce one tonne of cement. Naturally, it is cheaper to transport cement to consuming centres than to build factories at consuming centres and transport the raw materials there. Usually, therefore, cement factories are located closest to the limestone deposits with the clay or shale deposits located nearby. Cement is consumed more in urban and industrial areas and facilities to transport cement from factories to these areas become an important factor in the location of cement plants. Equally important are facilities to transport the heavy machinery needed for the plant. Generally, however, the occurrance of limestone deposits is the main factor, the hest site of cement plant will be at the source of good limestone deposites close to the existing railway lines.

ii. Preparation of raw materials. The rocky terrain of calcareous materials and argillaceous materials are cleared of overburden. In order to remove the rock mass from its existing position, it is loosened first. For this, the area under consideration is drilled of suitable dimensions in appropriate pattern with suitable drilling equipments. The holes are filled –up with explosives and explosives are discharged. A tremendous energy is produced and the resultant gases try to escape into the air by path of least resistance causing fragmentation of the rock mass. Using power shovel, dragline or other suitable excavating equipments, fragmented rocks are easily removed and carried to the crushing mill at cement plant where the rocks are crushed to the extent to be ready for mixing operation.

iii. Grinding & Mixing of Raw Materials. The grinding and mixing of the raw material (Calcareous materials in the form of limestone or chalk and argillaceous materials in the form of clay or shale) can be done either in water or in a dry condition, hence the names WET or DRY process, respectively. The choice of method depends also upon hardness of the raw materials used and on their moisture content.

**WET PROCESS**

- In the wet process limestone brought from the querries is crushed to smaller fragments passing through various crushers. Finally the broken rock particles of required size dispersed in water in a wash mill. The wash mill is a circular pit with revolving radial arms carrying rakes which break up the lumps of solid matter.

- The clay is also broken up and mixed with water, usually in a similar wash mill.
- These two mixtures from the respective storage basin are now pumped into wet grinding mills to make SLURRY. The slurry is a liquid of creamy consistency with the water content between 35 to 50 percent.
- The slurry is pumped into slurry tanks or basins where it is kept in an agitated conditions by means of rotating arms or blowing compressed air from the bottom to prevent settling of limestone and clay particles.
- The slurry is tested by the experienced cement chemists to achieve the required chemical composition and final adjustments can be made by blending slurries from different storage tanks, sometimes using an elaborate system of blending tanks.
- Finally the corrected slurry is stored in the final storage tank and kept in homogeneous conditions by the agitation of slurry.

**DRY PROCESS**

In the dry process, the raw materials are crushed dry and fed in the correct proportions into a grinding mill, where they are dried and reduced in size to a fine powder. The dry powder, called RAW MEAL, is then pumped to a blending silo and corrected for its right chemical composition and mixed by means of compressed air. The aerated materials (powder) tends to behave almost like liquid and in about one hour of aeration, a uniform mixture is obtained.

**SEMI -DRY PROCESS**

In the semi -dry process, the blended meal of dry process is further sieved and fed into a rotating disc called GRANULATOR. A quantity of water weighing about 12% of the meal is added to make the blended meal into PELLETS. This is done to permit air flow for exchange of heat for further chemical reactions of formation of cement clinkers.

**WET PROCESS VS DRY PROCESS**

| WET PROCESS | DRY PROCESS |
|---|---|
| There has been better control over chemical composition of raw materials and their mixing, better quality of clinkers are obtained and the cement quality is quite satisfactory, but it uses more fuel consumption, more kiln length and more expensive than dry process | It uses less fuel consumption, less kiln length and more economical than wet process but, initially there has been less quality control and the cement obtained was not up to the mark. Now a days, due to advancement in computer technology and quality control at various stages it has been possible to obtain cement of the very good quality by the dry process also. As per the published report during March 1998, in India, there was 173 large plants operating, out of which 49 plants used wet process, 115 plants used dry process and 9 plants used sami-dry process. |
| Typically, The consumption of coal in the dry process in 100 kg as against 350 kg in wet process for producing one tonne of cement. | |

## BURNING

Raw mix, in the form of either slurry with 36% moisture or in the form of dry raw mix or in the terms of nodules with 10 to 12% moisture, is now ready to be fed to the burning equipment called KILN. Kiln used in India is mostly of rotary type not in shaft type.

- A Rotary kiln is a long slender horizontal steel cylinder lined with fire bricks and rotating at a speed of about 1 rpm (revolution per minute).
- The thickness of iron plate of rotary kiln as about 18 to 20 mm.
- The kiln is aligned with a slope of about 4 percent, so that due to the rotation of the kiln, the material fed at the upper end of the kiln is transported to the lower end because of gravity.
- The diameter and length of the kiln depend upon the quantity of production and the process. (one typical rotary kiln may be 3 to 3.5 m in diameter and 90 to 120 m in length). The long rotary kiln is supported at 15 m aparts.
- In the wet process, the long rotary kiln is equipped with integral or external heat recuperating systems at the feed end, while in the dry process, it may be either a long rotary kiln fitted with integral heat recuperating system at the feed end or short rotary kiln with external suspension pre -heaters (cyclone type) at the feed end. In the semi - dry process. however, it is a short rotary kiln with a travelling grate heat exchanger at the feed end.
- The rotary kiln for the wet process is shown in the Fig. 1.1

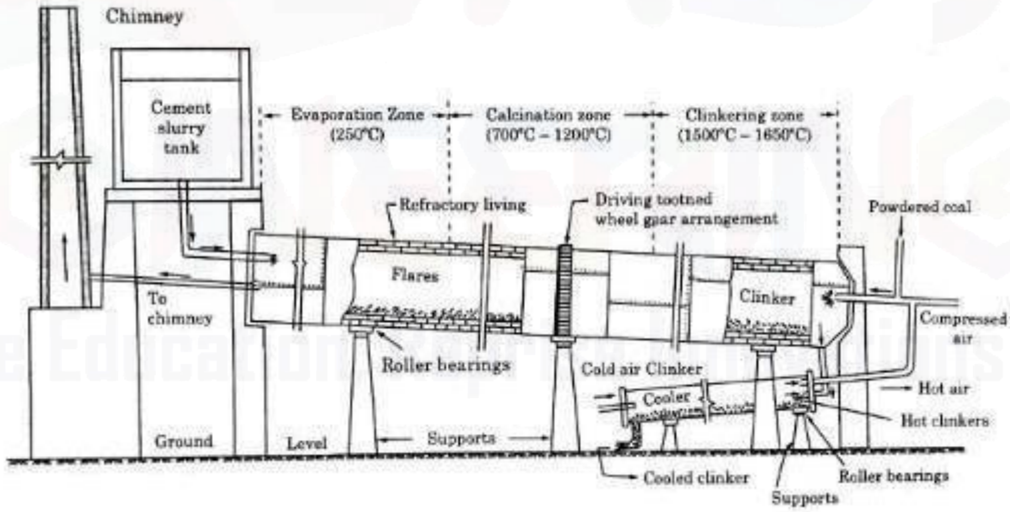



Fig. 1.1 Wet Process rotary kiln.

- The slurry in fed in at the upper end of the kiln while the pulverised coal is blown at the lower end of the kiln, where the temperature reaches about 1500 to 1650°C. The coal selected for the purpose must not have too high ash content. In India only glade I coal (22 to 25 percent ash content) is used. Better grade coal has to be used for better quality reasons. In addition to coal, natural gas or furnace oil can also be used for burning purpose. But, natural gas is scarce in India and is not used for the manufacture of the cement. Furnace oil also is very costly and it is not generally used except if the manufacture of white cement.
- The slurry, in its movement down the kiln because of the gravity, encounters a progr higher temperature. In the evaporating zone (up to 250°) water from the slurry is

driven off. Next it reaches the calcination zone (700 — 1200°C), G0 2 is liberated, further on, the dry material undergoes a series of chemical reactions until finally, in the clinkering zone (up to1500 to 1650°C) some 20 to 30 percent of the material becomes liquid and the lime, silica and alumina recombine. The mass then fuses into balls of 3 to 25 mm in diameter called CLINKERS.

**COOLING**

The clinkers are dropped into another rotary kiln where they are cooled under controlled conditions. It is important to note that the rate of cooling the clinkers greatly influences the properties of the cement. The experimental results reported by Enkegaard are shown in the table 1.1.

Table 1.1 Influence of Rate of Cooling On compressive Strength

| Type of cement | Cooling Pattern | Compressive strength ($N/mm^2$) | | |
|---|---|---|---|---|
| | | 3 days | 7 days | 28 days |
| Normal Cement | Quick | 9.9 | 15.3 | 26 |
| | Moderate | 9.7 | 21.0 | 27 |
| | Slow | 9.7 | 19.3 | 24 |
| | Very Slow | 8.7 | 18.7 | 23 |
| High Early Strength Cement | Quick | 10.2 | 18.8 | 29 |
| | Moderate | 14.2 | 26.7 | 33 |
| | Slow | 10.2 | 21.0 | 29 |
| | Very Slow | 9.1 | 18.1 | 28 |

The experimental results indicate that the MODERATE RATE OF COOLING OF CLINKERS is the best option to get the quality cement. By moderate rate of cooling it is implied that from

about clinkering temperature is brought to about 500°C in about 15 minutes and from 500°C to the normal atmospheric temperature in about 10 mts.

The rate of cooling influences the degree of crystallisation, the size of the crystals and the amount of amorphous materials present in the clinkers which determine the quality of the cement.

**GRINDING**

The final step in the production of cement is to grind the clinkers to a very fine powder in BALL MILLS and TUBE MILLS. Measured quantity of GYPSUM ($CaSO_4$) nearly 3 percent is also added during grinding of clinkers in order to prevent flash - setting of the cement. Clinker are ground in Ball mill as shown in the Fig. 1.2 first which consists of a steel cylinder, containing from halls 5 to 10 cm in diameter. Cylinder is kept in horizontal position and is rotated at the rate of 60 to 80 revolutions per minute. Outer casing Curved steel

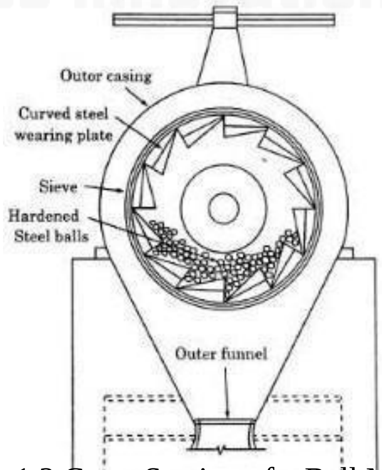



Fig. 1.2 Cross Section of a Ball Mill

Grounded material obtained from Ball mill is further grounded in Tube mill as shown in the fig. 1.3 to a very fine powder. Tube mill consists of a horizontal rotating cylinder 2 to 2.5 m in diameter and 8 to 10m in length, containing smaller steel balls 2 to 3 cm in diameter.

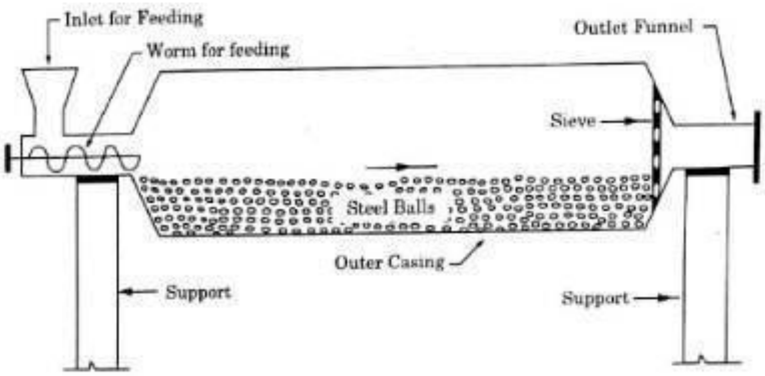



Fig. 1.3 Longitudinal section of a tube mill

The particles crushed to the required fineness are separated by currents of air and taken to storage silos. This finished product is known as PORTLAND CEMENT and is taken to the storage silos. The manufacturing process of Portland cement by wet process and dry process are self explanatory by their respective flow Diagrams (Fig. 1.4A and 1.4B).

## CEMENT PACKAGING

Traditionally cement used to be packed exclusively in jute bags, resulting in a lot of seepage and wastage from the bag, apart from creating a dust nuisance. However, now -a - days, jute packaging is being replaced by woven HDPE (High Density Polyethylene) or multi wall paper bags. In these type of packing, seepage is almost eliminated, particularly in the case of multi wall paper bags and as a result, dust nuisance is greatly reduced.

## CEMENT BAG SPECIFICATION

- Each bag of cement weighs 50 kg.
- Each bag can be assumed to contain 0.035 cubic meter or 35 liters or 1.25 eft of cement in volume.
- One cubic meter cement constitutes 30 bags in numbers or 1440 kg in weight.
- One tonne of cement shall comprise of 20 bags.
- Volume/space occupied by one cement bag = 0.054 $n^3$
- Floor area occupied by one cement bag = 0.3 m 2
- Height covered by one cement bag = 180 mm.
- The gauging of cement in works shall be in terms of number of bags on the assumption that one bag cement weighs 50 kg.

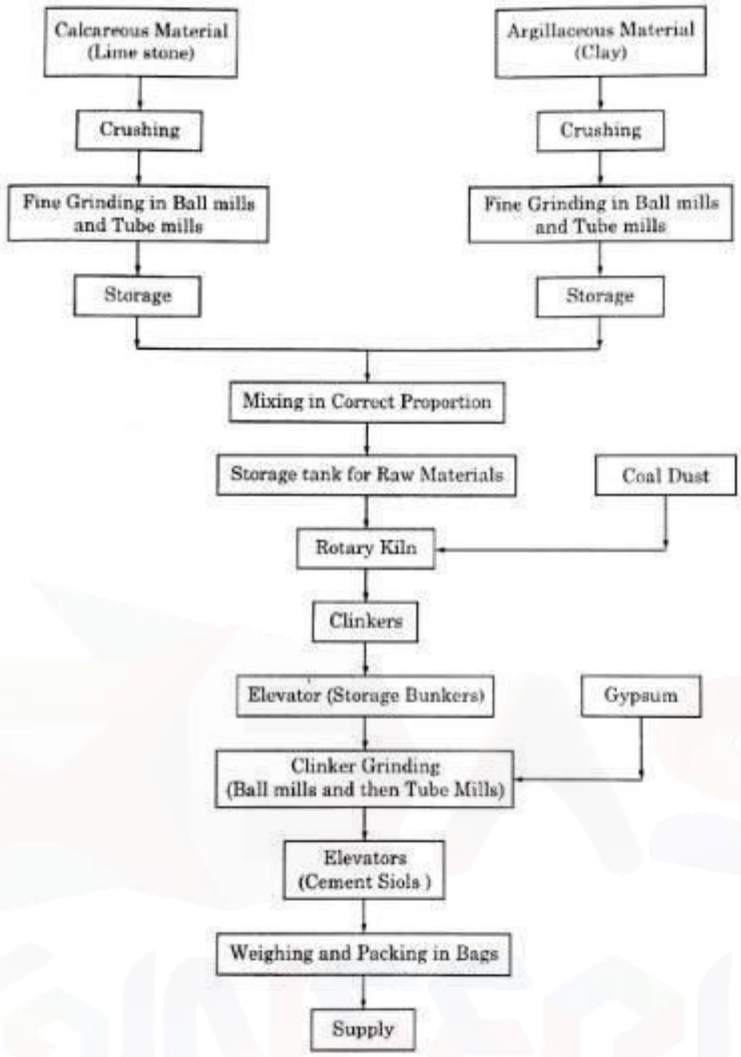
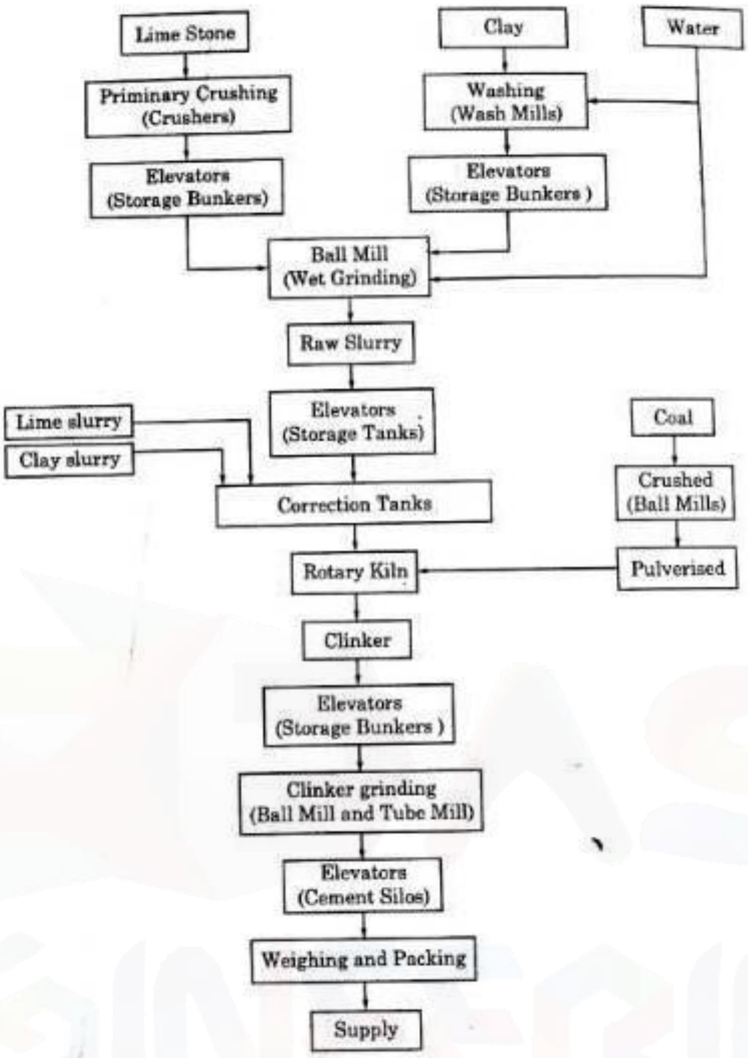


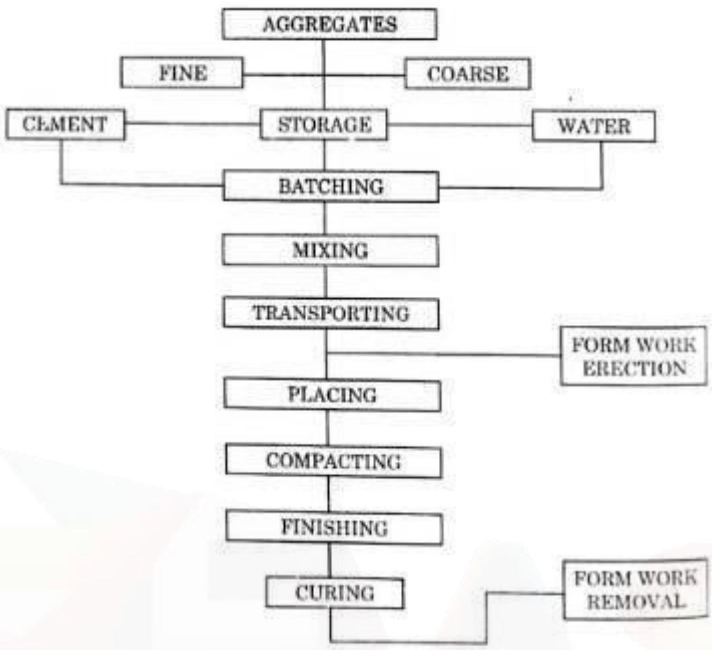

**Fig. 1.4-A** Flow Diagram of Cement Manufacture (Dry Process)




Fig, 1.4-B Flow Program of Cement Manufacture (Wet Process)

# UNIT III
# CONCRETE

**1. List the various operations requires in the production of concrete.**




**2. What are the stages of concrete?**

- Fresh concrete
- Hardened concrete

**3. What is Fresh concrete?**

The fresh concrete or plastic concrete is the initial stage of concrete period and it is counted from the mixing stage till it is transported, placed, compacted and finished in the position.

**4. Define workability.**

It is defined as the property of freshly mixed concrete or mortar which determines the case and homogeneity with which it can be mixed, placed, compacted and finished. The degree of ease in working with concrete is called workability.

**5. List some tests to measure workability.**

- ✓ Slump test
- ✓ Compacting Factor test
- ✓ Flow test
- ✓ Vee-Bee test
- ✓ Kelly Ball test

**6. What are the limitations of slump test?**

- ✓ It is not suitable for concrete made with aggregate size more than 40 mm
- ✓ Not suitable for harsh mixes

**7. Write the formula for flow percent.**

The average diameter of the spread concrete is measured and flow of concrete is obtained in percentage.

$$\text{Flow percent} = \frac{-25}{25} \times 100$$

The value may be between 0 to 150.

**8. List the factors affecting workability**

- ✓ Water content
- ✓ Mix proportion
- ✓ Size of aggregate
- ✓ Shape of aggregate
- ✓ Surface texture of aggregate
- ✓ Grading of aggregate
- ✓ Use of admixtures

**9. What is a good concrete?**

A good concrete is one in which the ingredients are properly distributed to make a homogenous mixture and it should not show any sign of segregation or bleeding.

**10. Define segregation.**

Segregation can be defined as the separation of coarse aggregate from the main mass of concrete in the plastic stage and it occurs in case of dry mix of insufficient and non - uniform mixing.

**11. Define bleeding.**

Bleeding is a form of segregation in which some of water in the mix tends to rise the surface of freshly placed concrete. This is because of the inability of the solid constituents of the mix to hold all the mixing water in the place when they settle downwards.

**12. List the factors affecting compressive strength of concrete.**

- ✓ The characteristics of cement.
- ✓ The characteristics and properties of aggregates.
- ✓ The degree of compaction
- ✓ The efficiency of curing
- ✓ Age at the time of testing.
- ✓ Conditions of testing.

**13. What is Water-Cement ratio?**

The water -cement ratio, defined as the ratio of the mass of free water (i.e. excluding that absorbed by the aggregate) to that of cement in a mix, is the most important factor that controls the strength and many other properties of concrete. In practice, this ratio lies generally in the range of 0.35 to 0.65, although the purely chemical requirement (for the purpose of complete hydration of cement) is only about 0.25.

# PART-B



**1. Write the short note on Production of Concrete/Concrete Operations**
**PRODUCTION OF CONCRETE/CONCRETE OPERATIONS**

The concrete operations i.e. the various operations required in production of concrete for a concrete construction project are listed down as follows;

(i) Storing
- (a) Storing of cement
- (b) Storing of aggregates
- (c) Storing of water

(ii) Batching
- (a) Batching of cement
- (b) Hatching of aggregates
- (c) Batching of water

(iii) Mixing

(a) Hand mixing
(b) Machine -mixing

(iv) Handling and Transporting
(v) Placing
(vi) Compacting
(vii) Finishing
(viii) Curing.

The operations listed above have been illustrated in the flow -diagram of Fig. 5.1.

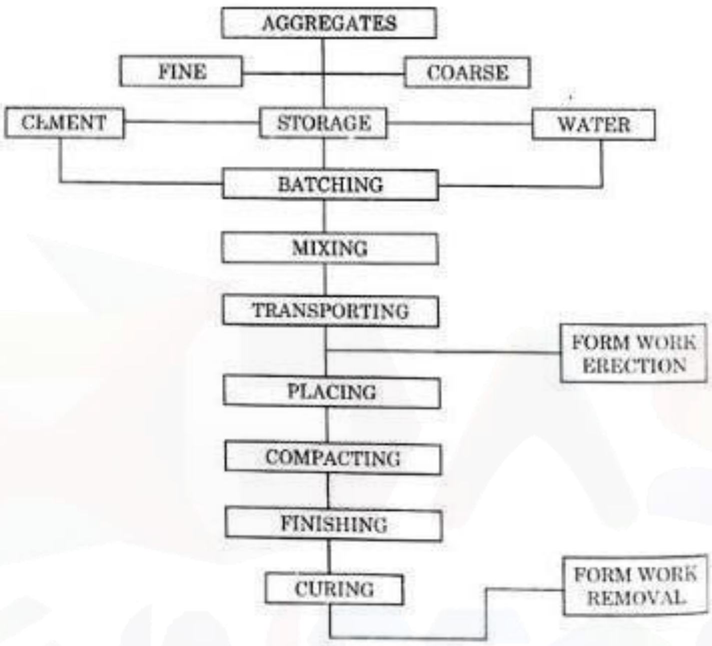



Fig. 5.1

1

**2. What are the stages of Concrete Period? And Explain Properties of Fresh Concrete.**

**STAGES OF CONCRETE PERIOD**

There are two distinct stages of the concrete period. Each stage has its qwn requirements for its ideal properties. These stages are:

(A) Fresh concrete
(B) Hardened concrete

**PROPERTIES OF FRESH CONCRETE**

The fresh concrete or plastic concrete is the initial stage of concrete period and it is counted from the mixing stage till it is transported, placed, compacted and finished in the position. The fresh concrete must satisfy the following requirements.

**Ideal Requirements of Fresh Concrete**

**i.** Mixability

The mix should be able to produce a homogeneous and uniform fresh concrete from the constituent materials of each batch under the action of mixing forces.

**ii.** Stability

The mix should be stable meaning thereby it should not segregate during transporting and placing and also the tendency of the bleeding should be minimum.

**iii.** Mobility/Flowability

The mix should be mobile enough to surround all reinforcement without leaving any voids behind as well as to completely fill the formwork.

**iv.** Compactability

The mix should be amenable to proper and thorough minpaction into a dense compact concrete under the existing facilities of compaction at site.

**v.** Finishability

It should be able to obtain a uniform and satisfying surface finish.

**Workability**

All the diverse and various requirements of fresh concrete viz mixability, stability mobility, compactability and finishability are unified in a single term WORKABILITY. It is difficult to define workability precisely in a single definition.

*IS: 6461 (part VII) -1973 defines 'workability that property of freshly mixed concrete or mortar which determines the case and homogeneity with which it can be mixed, placed, corn- pacted and finished.*

Here, it should bear in mind that the optimum workability of concrete varies from situation to situation. Concrete which is workable for pouring into large sections with minimum reinforcement may not be equally workable for pouring the same in thin sections with heavy conjestion of reinforcement. A concrete may not be workable when compacting by hand but may be satisfactory when mechanical vibrator is used.

**Measurement of Workability**

There are a number of different empirical tests available for measuring the workability of fresh concrete but there is no acceptable test which can measure directly the workability as defined by IS: 6461 (part VID-1973. Each test measures only a particular aspect of it and there is really no unique method which can measure the workability in its totality. The widely used empirical tests are as follows,

i. Slump test
ii. Compacting Factor test
iii. Flow test
iv. Vee-Bee test
v. Kelly Ball test

**Slump Test**

- The slump test is used extensively in the site work all over the world because of the simplicity of the apparatus required and test procedure.
- The slump tea indicates the behaviour of a compacted concrete cone under the action of gravitational forces
- The slump test is very useful on the site as a check on batch -to -batch or hour -to – hour variation in the materials being fed into the mixer.
- Too high or too low slump gives immediate warning and enables the mixer operator to remedy the situations.
- The slump test is suitable only for concrete of medium to high workabilities (slump 25 mm to 125 mm)
- The mould for slump test is essentially a frustum of cone with no top and bottom as shown in fig. 5.11.

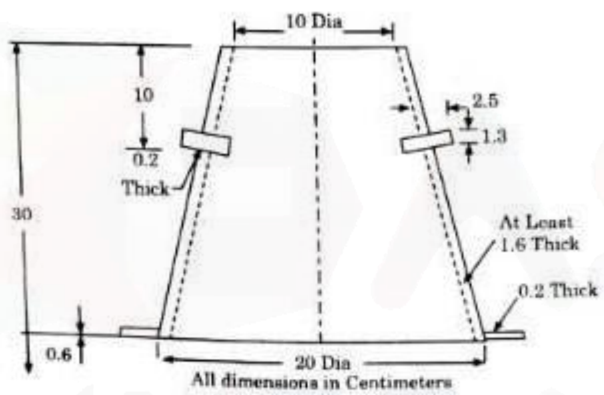



Fig. 5.11 Typical mould for Slumr test.

- Specifications of slump -test -mould as per IS: 1169-1959.

  Bottom diameter =20 cm

  Top diameter = 10 cm

  Height = 30 cm.

  Thickness of metallic sheet of mould = 1.6 cm.

  Two handles from top = 10 cm.

  Tamping rod = 16 mm in dia, 60 cm long rounded at one end.

- The slump cone is placed on horizontal and non-absorbent surface and filled in three equal layers of fresh concrete, each layer being tamped 25 times with a standard tamping rod. The top layer is struck off level and the mould is lifted vertically without disturbing the concrete cone and the unsupported concrete will now slump -hence the name of t he test.
- Three types of slump may pattern as shown in Fig. 5.12.

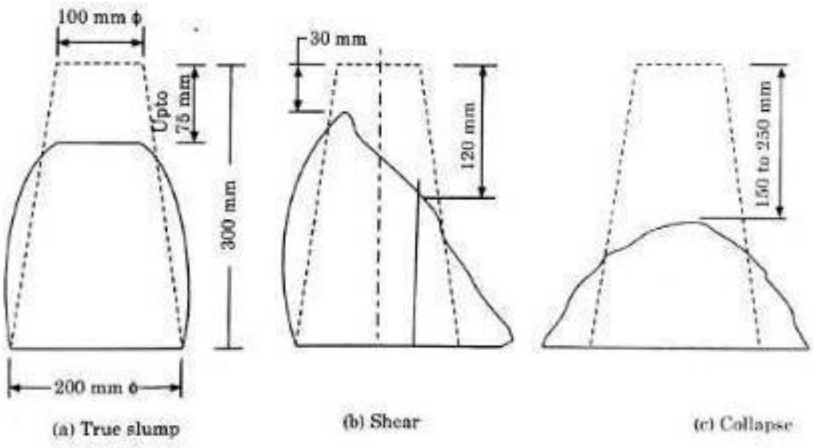



Fig. 5.12 Types of Slump.

(i) True slump— Slumping evenly all round measuring up to 150 mm from top

(ii) Shear slump— One half of the cone sliding down

(iii) Collapse slump— When slump measuring more than 150 mm from top.

- True slump is desirable but shear slump indicates the concrete is non -cohesive and showing the sign of segregation. Collapse slump indicates the excess of water content. Shear slump and collapse slump are undesirable and remedial measures must be applied to the concrete mix.
- Limitations of slump test
  - Not suitable for concrete made with aggregate size more than 40 mm
  - Not suitable for harsh mixes.
- The only advantage of the slump test is that the water content of successive batches of concrete of the same identical mix can be easily detected.

**Compacting Factor Test**

- The compacting factor test indicates [redacted] behaviour of fresh concrete under the action of external forces. It measures the COMPACTABILITY of concrete which is an important aspect of workability, by measuring the amount of compaction achieved for a given amount of work.
- This test is more sensitive and precise when compared to slump test and is generally recommended for concrete mixes of low to medium workability, that is, when concrete is to be compacted by vibration.
- For concrete of very low workability of the order of 0.70 or below, this test is not suitable. Because compaction of such concrete is obtained under heavy pressure such as pavement concrete.
- The compacting factor apparatus consists essentially of two hoppers, each in the shape of frustum of a cone, and one cylinder, the three

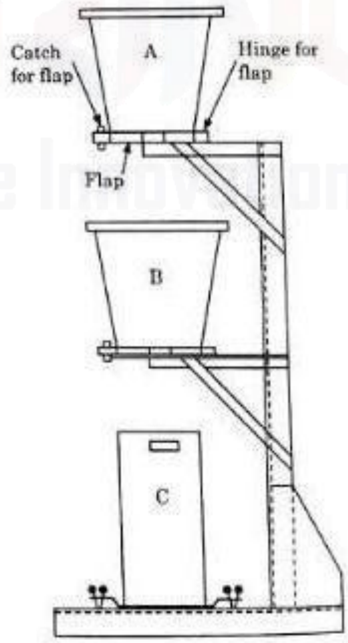



**Fig. 5.13** The compaction factor apparatus.

being above one another The hoppers have hinged doors at the bottom, as shown in Fig. 5.13. All surfaces are polished to reduce friction.

- The dimensions of the apparatus as factor apparatus. per IS: 1119-1950 are tabulated as shown in the table 5.3

Table 5.3 Dimensions of Compacting Factor Apparatus

**Table 5.3** Dimensions of Compacting Factor Apparatus

| *Details* | *Dimensions in cm.* |
|---|---|
| **Upper Hopper-A** | |
| (i) Top internal diameter... | 25.4 |
| (ii) Bottom internal diameter... | 12.7 |
| (iii) Internal height... | 27.9 |
| **Lower Hopper-B** | |
| (i) Top internal diameter | 22.9 |
| (ii) Bottom internal diameter | 12.7 |
| (iii) Internal height | 22.9 |
| **Cylinder-C** | |
| (i) Internal diameter | 15.2 |
| (ii) Internal height | 30.5 |
| Distance between bottom of upper hopper and top of the lower hopper | 20.3 |
| Distance between bottom of bottom hopper and top of cylinder | 20.3 |

- The upper hopper is filled with concrete so gently that no work is done on concrete to produce compaction. The bottom door of the upper hopper is opened and the concrete falls into the lower hopper. Then the trap door of the lower hopper is opened and the concrete falls into the cylinder. The weight of the concrete in the cylinder is found out and this weight is known as "weight of partially compacted concrete", The ratio of the weights of concrete filling the cylinder by this fall (i.e. weight of partially compressed concrete) to the weight of concrete that can be filled in the cylinder by vibration is known as compacting factor;

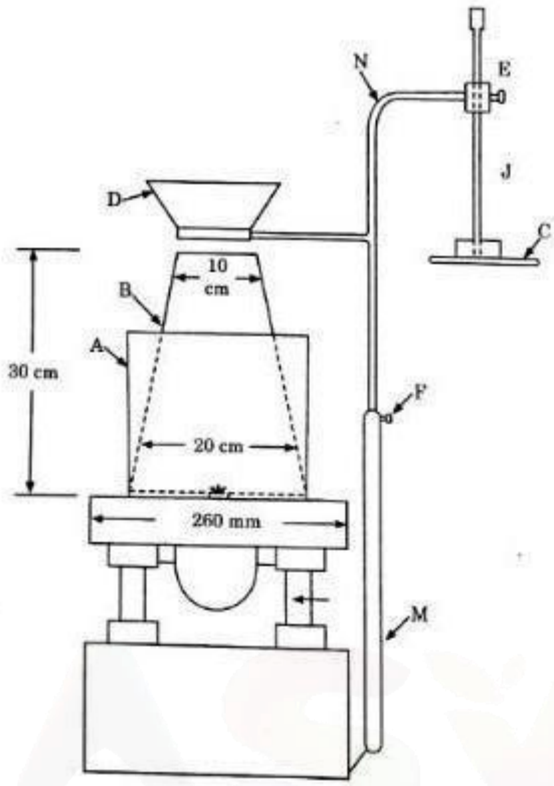
**The compacting factor =** ____________________

- It can be realised that the compacting factor test measures the inherent characteristics of the concrete which relates very close to the workability requirements of concrete in the field.
- The test has been more popular in laboratory conditions and more accurate than slump test specially concrete for low and medium workability.

**Vee-Bee Consistency Test**

- The name Vee-Bee (Vebe) is derived from the initials of V. Bahrner of Sweden who invented this test.
- This test is recommended for stiff concrete mixes having low and very low workability.
- The veebee test also has the additional advantage that the treatment of concrete during the test is comparatively closely related to the method of placing in practice.

- Veebee is a good laboratory test and this is in contrast to the compacting factor test where error may be introduced by tendency of some dry mixes getting stuck in the hopper
- This test consists in moulding a fresh concrete cone in a cylindrical container mounted on a vibrating table as shown in Fig. 5.14. The concrete cone when subjected to vibration start; to occupy the cylindrical container by way of getting remoulded. By visual inspection. When the concrete surface becomes horizontal, the remoulded is considered complete and it expressed in vee-bee seconds.
- This test is not suitable for high workable (slump excess of 125 mm) concrete because tin remoulding is so quick, it is difficult to measure vee bee time.




**Flow Test**

- The flow test developed in Germany in 1933 is a good indication of quality of concrete with regards to consistency. Cohesiveness and proneness to segregation.

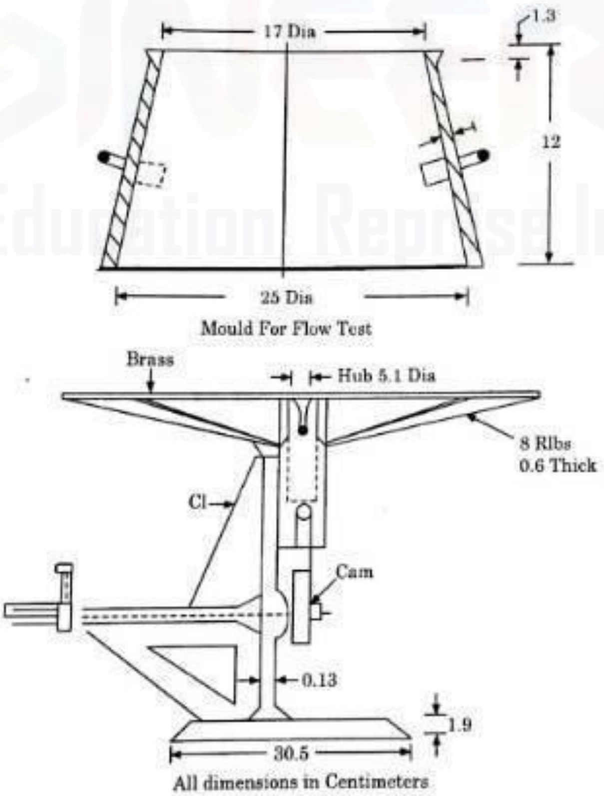



Fig. 5.15 Flow Table Apparatus

- Fig. 5.15 shows the details of the Flow table consisting a mould made from metal casting in the shape of a frustum of cone with internal dimensions 25 cm in bottom, 17 cm in top and 12 cm in height. The mould is filled with concrete in two layers and is lifted vertically upward. The table is raised and dropped 12.5 mm, 15 times in about 15 seconds. The average diameter of the spread concrete is measured and flow of concrete is obtained in percentage.

$$\text{Flow, percent} = \frac{-25}{25} \times 100$$

The value may be between 0 to 150.

**Kelly Ball Test**

- This is a simple field test similar to slump test and it is recommended for routine checking of consistency for control purposes.
- The apparatus as shown in Fig 5.16 consists of 15 cm diameter metal hemisphere weighing 13.6 kg which is placed on fresh concrete. The ball is lowered gradually and depth of penetration is measured on the stem. It is performed in about 15 seconds.

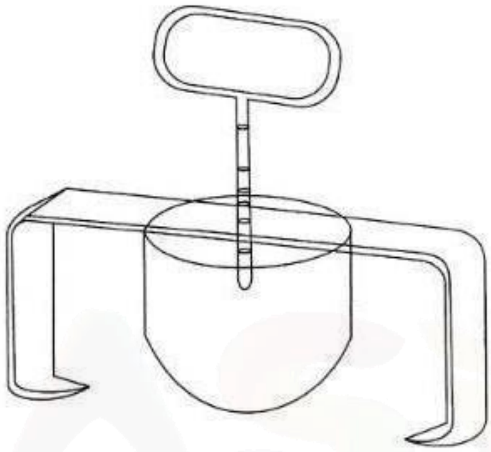


Fig. 5.16 Kelly Ball

- It was devised by J.W. Kelly and hence known as Kelly Ball Test. This test has been covered by Indian Standard specification also.

**Comparison of Tests**

It is difficult to compare the various tests because each test measures the behaviour of concrete under different conditions. However the test method for different workability, is listed in the table 5.4.

**Table 5.4 Test Method for Different Workabilities**

| *Workability* | *Method* |
|---|---|
| Very low | Vee-Bee time |
| Low | Vee-Bee time, Compacting Factor |
| Medium | Compacting factor, slump |
| High | Compacting factor, slump, Flow |
| Very high | Flow |

Table 5.5 gives the range of expected value of workabilities measured by different test methods for comparable concrete.

**Table 5.5 Suggested Values of Workability for Different Placing Condition**

| Placing Condition | Degree workability | compacting factor | Slump | Vee-Bee time |
|---|---|---|---|---|
| (i) Prolonged vibration accompanying pressure (Pavement concrete) | Extremely low | 0.65–0.68 | — | 20–30 seconds |
| (ii) Shallow section with vibration and no reinforcement | Very low | 0.75–0.78 | 0–25 | 10–20 seconds |
| (iii) Light reinforced section with vibration | Low | 0.83–0.85 | 25–50 | 5–10 seconds |
| (iv) Lightly reinforced without vibration & heavily reinforced with vibration | Medium | 0.50–0.92 | 50–75 | 2–5 seconds |
| (v) Concreting of heavily reinforced without vibration | High | 0.95 | 100–150 | — |

**Factors Affecting Workability**

The factors helping concrete to have lubricating effect (workability) to reduce internal friction, for helping easy compaction are listed below;

(a) Water content
(b) Mix proportion
(c) Size of aggregate
(d) Shape of aggregate
(e) Surface texture of aggregate
(f) Grading of aggregate
(g) Use of admixtures.

**(a) Water Content**

The basic factor affecting the workability is water content which is expressed in litres of water per cubic meter of concrete. The higher the water content, higher will be the fluidity of concrete but subject to limitation of water -cement ratio. More water can be added, provided a correspondingly higher quantity of cement is also added to keep the w/c ratio same so that the strength of concrete remains unchanged.

**(b) Mix Proportion**

Aggregate/cement ratio is the inversely proportion to the workability. With lower aggregate/cement ratio (rich concrete), more paste is available to make the mix cohesive and fatty to give better workability. On the other hand, the higher aggregate/cement ratio (leaner concrete), less quantity of paste is available to provide lubrication and thereby lowers workability.

**(c) Size of Aggregate**

For the given quantity of water and paste, bigger size of aggregate will give higher workability because of reduction of total specific surface area and inter -particle frictional resistance.

**(d) Shape of Aggregate**

The shape of aggregates influences the workability greatly. Angular/elongated/flaky aggregate makes the concrete very harsh whereas rounded aggregate enhances the workability in good measure because of reduction in total specific surface area and inter - particle frictional resistance for a given volume or weight. This explains the reason why river sand and gravel provide greater workability to concrete than crushed sand (crushed aggregate).

**(e) Surface Texture of Aggregate**

Rough textured aggregate will exhibit poor workability whereas smooth or glossy textured aggregate will impart better workability because of reduction of inter -particle frictional resistance offered by smooth surface thereby contributing higher workability.

**(f) Grading of Aggregate**

A well graded aggregate has lesser amount of voids in a given volume. Other factors being constant, if the total voids are less, excess paste is available to give better lubricating effect. The mixture becomes cohesive and fatty preventing segregation of particles. Therefore, better is grading, less is the void content and higher is the workability.

**(g) Properties of Cement**

The workability is also affected by the physical and chemical properties of cement, but to a much lesser extent. Rapid -hardening cement will have reduced workability as compared to ordinary portland cement because of higher specific surfaces.

**(h) Use of Admixtures**

The presence and nature of admixtures affect the workability considerably. The use of the plasticizers and super plasticizers improve the workability manifolds. Use of air - entraining agents which are normally surface-active, reduces the internal friction between the particles. The air –entraining agents like resin, soap or chemicals introduce a large number of very minute air bubbles which act as rollers and increase workability. They decrease bleeding and segregation also.

**Sign of a Good Concrete**

A good concrete is one in which all the ingredients are properly distributed to make a homogeneous mixture and it should not shown any sign of

(a) Segregation

(b) Bleeding

**(a) Segregation**

Segregation can be defined as the separation of coarse aggregate from the main mass of concrete in the plastic stage and it occurs in case of dry mix of insufficient and non - uniform mixing.

**Basic reasons for segregation can be stated as follows, if**

- There are considerable difference in the sizes and specific gravities of mix constituents used.
- The aggregates used are not well graded.
- In the concrete, sufficient matrix is not available to bind the aggregates.
- The mix is too dry or too wet.
- The mix handling is very improper like dropping concrete from a considerable height, transporting and travelling concrete over a longer length, passing concrete along a chute, particularly with changes of direction and discharging against a obstacle.
- The vibrator is used to spread a heap of concrete over a larger area.
- The vibration is allowed to continue too long.

The remedial measures to eliminate segregation can be summarised as follows;

- Reducing the height of drop of concrete.
- Not using vibration as a means of spreading a heap of concrete over a large area.
- Reducing the continued vibration over a longer time.
- By correctly proportioning the mix.
- By proper handling, transporting, placing, compacting and finishing.
- By taking into consideration of various parameters such as grading, size, shape and surface texture of aggregate with optimum quantity of water to make a cohesive mix.

**(b) Bleeding**

Bleeding, known as WATER GAIN, is a form of segregation in which some of water in the Mix tends to rise the surface of freshly placed concrete. This is because of the inability of the solid contitutents of the mix to hold all the mixing water in the place when they settle downwards. water having the lowest specific gravity of all mix constituents.

- Bleeding is predominant in a highly wet mix, badly proportioned and insufficiently mixed concrete.
- Bleeding causes the formation of a porous, weak and non -durable concrete layer at the top of placed concrete.
- In case of lean mixes, bleeding may create capillary channels increasing the permeability of concrete.
- The formation of cement paste at the surface is known as LAITAN C E. The laitance formed in pavement concrete does not have good wearing quality, produces dust in summer and mud in rainy season. It also develops higher shrinkage crack.

**Remedial measures to minimise bleeding**

- It can be reduced by proper proportioning and uniform and complete mixing.
- Reduction in bleeding is obtained by addition of pozzolanas viz flyash or silica fume.
- Air entrainment effectively reduces bleeding so that finishing can follow casting without delay.
- The presence of an adequate proportion of very fine aggregate particles (finer than 150 micron) significantly reduces bleeding.
- The use of crushed fine aggregate than rounded natural sand can reduce bleeding effectively.
- Bleeding is decreased by increasing the fineness of cement possibly because finer particles hydrate earlier and also because their rate of sedimentation is lower.
- The cement containing high alkali content and a high $C_3A$ content produces very le&, bleeding.

**3. Explain Properties of Fresh Concrete.**

**PROPERTIES OF HARDENED CONCRETE**

The concrete is a basic prime building material because of various properties being possessed during its hardened state which starts from the day it attains the full designed strength to the end of its life. For hardened concrete, the various properties which need consideration are as follows.

(A) STRENGTH

(a) Compressive strength

(b) Tensile strength
(c) Flexural strength
(d) Shear strength
(e) Bond strength

(B) Durability
(C) Impermeability
(D) Dimensional Changes

(a) Elasticity
(b) Shrinkage
(c) Creep
(d) Thermal expansion
(e) Fatigue

(E) Fire Resistance

**Strength of Concrete**

The strength of concrete is the most important property as far as structural designs are concerned. Indirectly, it gives the idea of other properties (Impermeability, durability, wear resistance etc) also. A strong concrete is more dense, compact, impermeable and resistant to weathering and chemical attacks. Meaning thereby, the strength of concrete gives an overall idea of its quality. Strength of concrete is defined as the ability to resist force and for structural purposes, it is taken as the unit force required to cause rupture which may be caused by compressive stress, tensile stress, flexural stress, shear stress, bond stress etc.

**Compressive Strength of Concrete**

The compressive strength of concrete is considered the basic character of the concrete. Consequently, it is known as the CHARACTERISTIC COMPRESSIVE STRENGTH OF CONCRETE (fck) which is defined as that value below which not more than five percent of test results are expected to fall based on IS: 456-2000. In this definition the test results are based on 150 mm cube cured in water under temp. of 27 ± 2°C for 28 days and tested in the most saturated condition under direct compression. Other strength viz, direct tensile stress, flexural stress, shear stress and bond stress also are directly proportional to the compressive stress. Higher is the compressive stress, higher is other stresses also. Not only stresses, other properties for example modulus of elasticity, abrasion and impact resistances, durability are also taken to be related to the compressive strength, hence, the compressive strength is an index of overall quality of concrete.

**Factors Affecting Compressive Strength**

Among the materials and mix variables, WATER -CEMENT RATIO is the most important parameter governing the compressive strength. Besides W/C ratio, following factors also affect the compressive strength.

- The characteristics of cement.
- The characteristics and properties of aggregates.
- The degree of compaction
- The efficiency of curing
- Age at the time of testing.
- Conditions of testing.

## Water -Cement Ratio

The water -cement ratio, defined as the ratio of the mass of free water (i.e. excluding that absorbed by the aggregate) to that of cement in a mix, is the most important factor that controls the strength and many other properties of concrete. In practice, this ratio lies generally in the range of 0.35 to 0.65, although the purely chemical requirement (for the purpose of complete hydration of cement) is only about 0.25.

The compressive strength of concrete at a given age and under normal temperature, depends primarily on w/c ratio; lower the w/c ratio, greater is the compressive strength and vice versa. This was first enunciated by Abrams as S = ______ where S is the compressive

strength, w/c is water -cement ratio of a fully compacted concrete mix, $K_1$ and $K_2$ are empirical constants. In day- to-day practice, the constants K 1 and K2 are not evaluated, instead the relationship between cornpressive strength and w/c ratio are adopted which are supposed to be valid for a wide range of conditions. This relationship is expressed in the following figure 5.17.

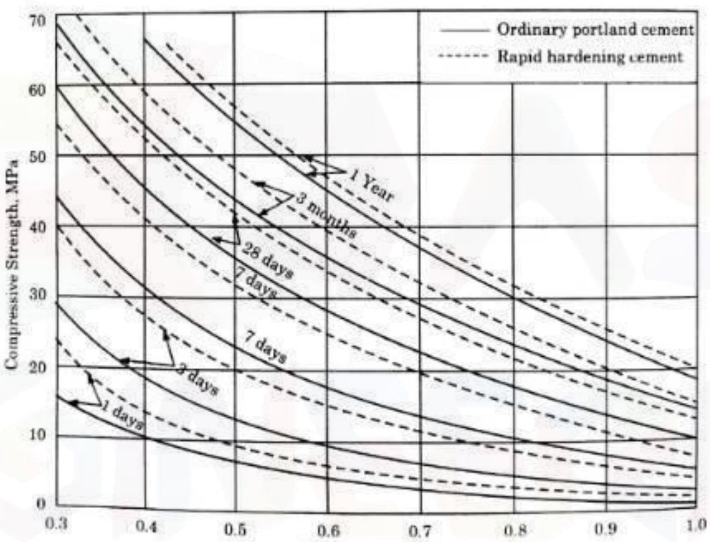



Fig. 5.17 Effect of water -cement ratio on compressive strength at different ages.

A simple chart, in which strength is non-dimensionalised, developed for the desig - n purposes is shown in Fig. 5.18.

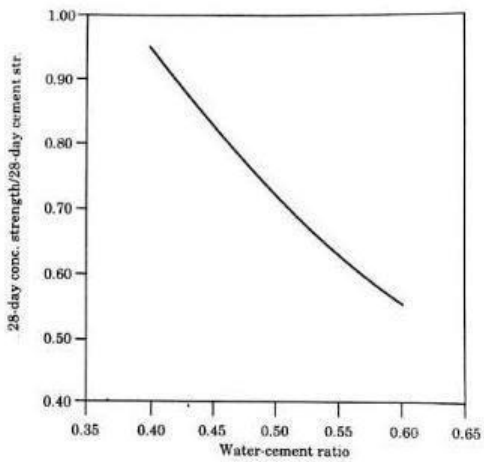



Fig. 5.18 Relation between water -cement ratio and compressive strength

A reduction in the water cement ratio generally results in an increased quality of concrete in terms of strength, density, impermeability, reduced shrinkage and creep etc.

*The probable reason, why lower w/c ratio gives higher strength of concrete may be found by considering the cement forms a paste with water and it is this paste that binds the different particles of aggregates. So thicker is the consistency of the paste, greater is its binding property. Another reason is that the quantity of water required for chemical combi- nation is very small (about 25% of the weight of cement) compared with that required for workability and the excess water ultimately on evaporation leaves pores. The greater is the excess of water, greater is loss of strength and water -tightness.*

The tensile strength and bond strength with steel do not decrease with increase in w/c ratio to the same extent as compressive strength does. Say with increase in w/c ratio from 0.5 to 0.6, the decrease in tensile strength and bond strength is 10% but decrease in compressive strength is about 25%.

**Characteristics and Properties of Cement**

The type of cement and fineness of cement affect the strength of concrete. With respect to Ordinary Portlord cement (OPC), Rapid Hardening Portland Cement (RHPC) and Low Heal Portland Cement (141-1PC) give higher and lower strength respectively. The rate of gain of strength depends entirely upon fineness of the cement. Finer cement increases the rate of hydration And hydrolysis which results in early development of strength though the ultimate strength is not affected.

**Characteristics and Properties of Aggregates**

The strength of concrete is governed by

- strength of aggregate
- strength of mortar
- bond strength between mortar and aggregate

The strength of aggregate is normally greater than the strength of mortar and bond between mortar and aggregate. The strength of mortar depends upon w/c ratio whereas bond between mortar and aggregate depends upon the strength of mortar and the size, shape, texture and grading of aggregate.

Larger maximum size of coarse aggregate gives lower compressive strength of concrete. The reasons behind may be stated as follows.

• The larger maximum size aggregate gives lower surface area for development of gel bond which is responsible for lower strength. Aggregates of smaller size, angular aggregate and aggregate of rough surface texture provides more surface area and more consumption of cement and hence more bond strength.

• Bigger aggregate size causes a more heterogeneity in the concrete and this prevents uniform distribution of load when stressed.

• For larger size aggregate the transition zone becomes much weaker due to development of micro cracks which result in lower compressive strength.

**The Degree of Compaction**

Higher is the compaction of freshly mixed concrete, more is the reduction of the voids and consequently greater is the compressive strength of concrete.

## The Efficiency of Curing

Curing is the name given to procedures used for promoting the hydration of cement, and consist of a control of temperature and of the moisture movement from and into the concrete. Hydration of cement takes place in capillaries filled with water. By keeping concrete saturated, loss of water by evaporation from the capillaries is prevented and loss of water by self desiccation (due to the chemical reactions of hydration of cement) from outside. Cuing should be continued until the originally water filled space in the fresh cement paste has been filled by product of hydration to the desired extent. Curing temperature should be from 23° to 30°C (27°C average).

The curing must be adequate at favourable temperature for sufficient period which helps in attaining the maximum strength and other desirable properties.

## Age of Concrete

The strength of concrete increases with age as the hydration of cement prolongs for a considerable time. Relative strength of concrete w.r.t 28 days at different age are given in the table 5.6.

**Table 5.6** Strength Factor at Different Ages

| *Age of concrete after casting* | *Strength Factor* |
|---|---|
| 1 day | 0.16 |
| 3 days | 0.40 |
| 7 days | 0.65 |
| 14 days | 0.90 |
| 28 days | 1.00 |
| 2 month | 1.10 |
| 3 months | 1.15 |
| 6 months | 1.20 |
| 12 months | 1.25 |

## Conditions of Testing

After adequate curing, the concrete mould is tested in the moist saturated condition with surface wiped out under direct compression. The strength of concrete is influenced by moisture content at the time of testing, because moisture content in concrete provides lubrication effect and reduces the strength when compared with dry sample.

Strength in dry sample = 1.10 to 1.20 times the strength of the saturated sample.

## Strength of Prism Vs 150 mm Strength

The characteristic strength of concrete (fck) is based on 150 mm cube but if it is tested on the prism mould, the strength of prism specimen decreases with increase in height to the side ratio and stabilizes when this ratio is 5 and above as shown in Table 5.7.

**Table 5.7** Strength of Prism Vs 150 mm Cube Strength

| *Hight/Side* | 0.5 | 1.0 | 2.0 | 3.0 | 4.0 | 5 and above |
|---|---|---|---|---|---|---|
| *Relative Strength* | 1.5 | 1.0 | 0.8 | 0.72 | 0.68 | 0.66 |

## Variation in Strength with Size of Cubes

The characteristic strength of concrete is based on 150 mm cube but the strength of concrete determined through the cube specimen varies with the size of cubes. The strength of specimen increases with decrease in size and vise -versa as indicated in the table 5.8.

**Table 5.8** Approx. Strength of Concrete w.r.t. that of 150 mm Cube

| Cube size (mm) | 100 | 150 | 200 | 300 |
|---|---|---|---|---|
| Relative Strength w.r.t. 150 mm cube | 1.05 | 1.00 | 0.95 | 0.87 |

**Cube (150 mm) Strength Vs Cylinder (150 mm dia, 300 mm ht) Strength**

If the concrete is tested on cylinder having 150 mm diameter and height 300 mm instead of 150 mm cube, the cube strength can be estimated as

Cylinder strength (fcu) = 0.80 * cube strength (fck)

**Tensile Strength**

• Tensile strength of concrete under direct tension is very small and generally neglected in normal design practice. Although the value ranges from 8 to 12% of its compressive strength. An average value 10% is the proper choice.

• The direct tension method suffers the problem like holding the specimen properly in the testing machine and the application of uniaxial tensile load not being free of eccentricity.

• The tensile strength can be calculated indirectly by loading a concrete cylinder to the compressive force along the two opposite ends (with its axis horizontal) as shown in the Fig. 5.19.

• Due to uniform tensile stress acting horizontally along the length of cylinder, the cylinder splits into two halves. The magnitude of this tensile stress (acting in a direction perpendicular to the line of action of applied compression) is given by

S = 2 where; S = Tensile stress in $kg/cm^2$ P = load causing rupture in kg

D = Dia in cm (15 cm)

L = Length in cm (30 cm)

• The indirect tensile stress is known as SPLITTING TENSILE STRENGTH.

**Flexural Strength**

The maximum tensile stress resisted by the plain concrete in flexure (bending) is called FLEXURAL STRENGTH (or MODULUS OF RUPTURE) expressed in $N/mm^2$ or $kg/m^2$.

• The most common plain concrete subjected to flexure is a highway/runway pavement. The strength of pavement concrete is evaluated by means of bending test on beam specimen.

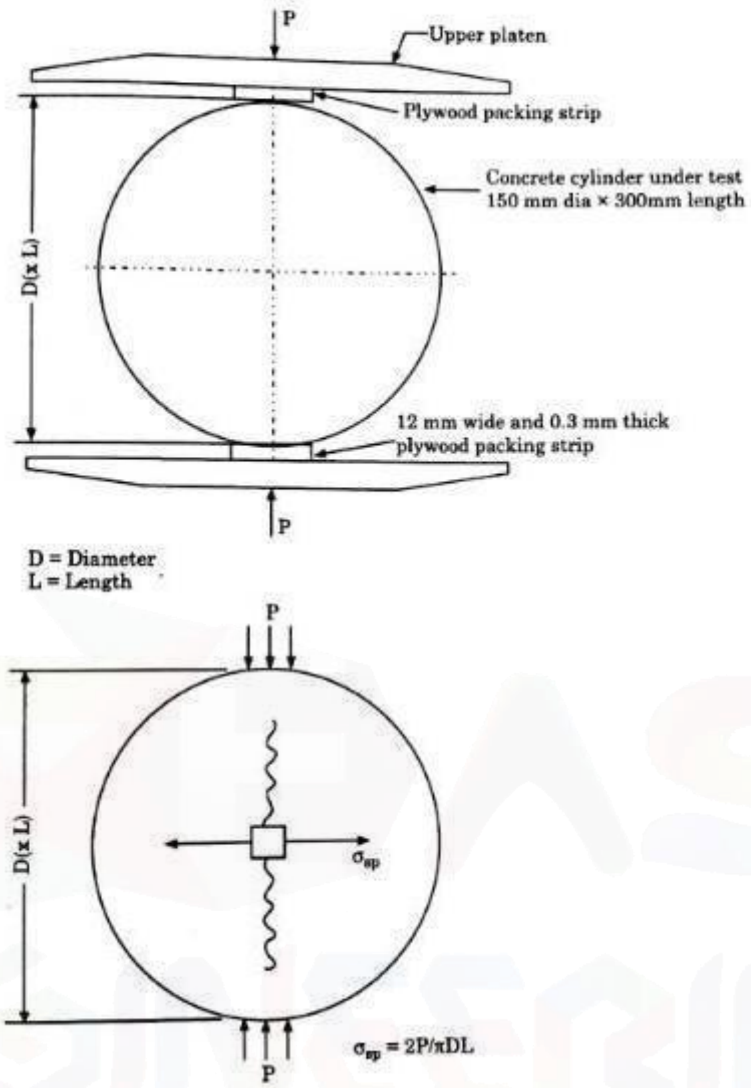



Fig. Loading arrangement for split strength determination

• The flexural strength (modulus of rupture) is determined by testing standard test specimens of 150 mm x 150 mm x 700 mm over a span of 600 mm or 100 mm x 100 mm x 500 mm over a span of 400 min. under symmentrical two point loading as shown in Fig. 5.20A.

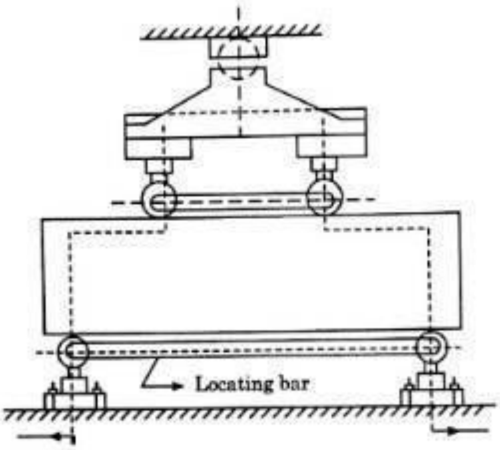



Fig. 5.20-A

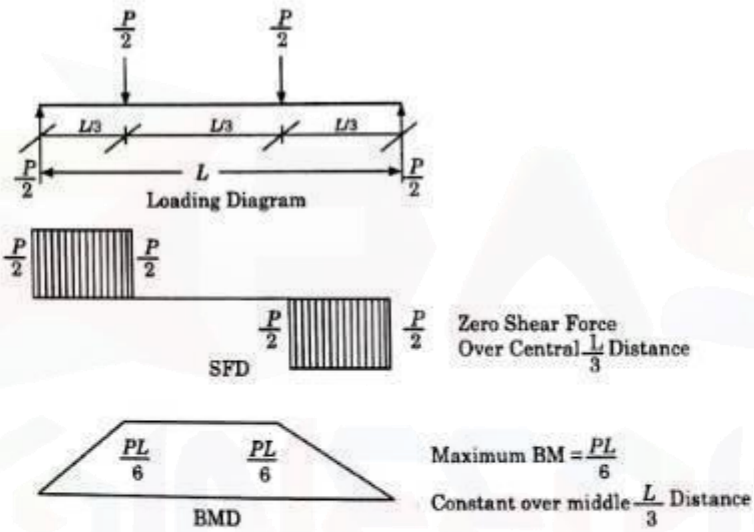



Fig. 5.20-B

• using = = _

where fcr = modulus of rapture
P = load applied

a = distance between crack and nearest support
d = depth of specimen

b = width of specimen

**For 15 cm x 15 cm specimen**

(a) a > zu cm, icr =

(b) a between 17 and 20 cm, fcr ³ ^2 =

(c) a < 17 cm, discard the result

**For 10 cm x 10 cm specimen**

(a) a> 13.3 cm, fcr =

(b) a between 11 and 13.3 cm, fcr =

(c) a < 11 cm, discard the result

**Reasons for testing specimen under Symmetrical two point loading**

• Two point loading system, the maximum bending moment extends over central L/3 distance accompanied by zero shear force (a case of pure bending as shown in Fig 5.20B. Over the central length L/3 wherever will be the weakest section, the concrete will fail at that section. Variability of the result is very less.

• In all the cases, central loading (i.e. single point loading) gives higher value than the two point loading, irrespective of the size of the sample. As per relationship established by central Road Research laboration,

$$X_1 = X_2 + 0.72$$

where $x_1$ = flexural strength $(N/mm^2)$ of concrete under central point loading

$x_2$ = flexural strength $(N/mm^2)$ of concrete under two point loading.

The higher strength obtained in the case of central loading may be attributed to the fact that the beam is being subjected to the maximum stress at a pre -determined location not necessarily the weakest.

**Relationship between compressive strength and flexural strength**

The Indian Standard IS: 456-2000 gives the following relationship between the compressive strength and flextural strength as

$fcr = 0.7$

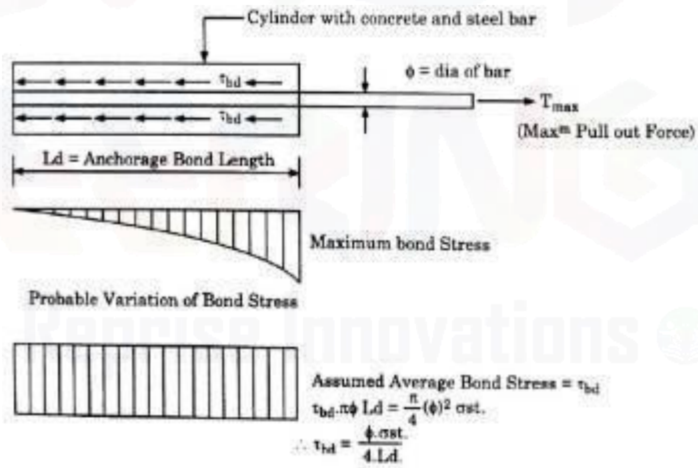
where fcr = flexural strength in $N/rnm^2$

fck = characteristic compressive strength in $N/m\,m^2$

**Shear Strength**

• Shear strength is the capacity of concrete to resist the sliding of the section over the adjacent section. A good amount of shear strength capacity is possessed by concrete depending upon the grade of concrete and percentage of tensile reinforcement in the section.

• It is difficult to obtain shear strength of concrete but I.S. code suggests the value for different grade of concrete.




**Bond Strength**

• Bond strength is the shear stress at the interface of reinforcement bar and surrounding concrete developed to resist any force that tries slippage of the reinforcement to its surrounding concrete. It is determined by PULL OUT TEST as shown in the Fig. 5.21.

The av. bond strength is 10% of compressive strength of concrete The bond strength depends upon grade of concrete, higher the grade, higher is the value of bond strength.

# UNIT IV
# TIMBER AND OTHER MATERIALS

**1. Define Plywood.**

Plywood is a laminate made of thin layers of wood.

**2. Write about Veneer.**

In woodworking, veneer refers to thin slices of wood, usually thinner than 3 mm, that typically are glued onto core panels (typically, wood, particle board or medium-density fiberboard) to produce flat panels such as doors, tops and panels for cabinets, parquet floors and parts of furniture.

**3. What are the types of Veneer?**

- ✓ Raw veneer
- ✓ Paper backed veneer
- ✓ Phenolic backed veneer
- ✓ Laid up veneer
- ✓ Reconstituted veneer
- ✓ Wood on Wood or 2-ply veneer

**4. What are the Advantages of using veneer?**

Furniture made with wood veneer uses less wood than the same piece of furniture made with solid wood. Some projects built using wood veneer would not be possible to construct using solid lumber, owing to expansion and contraction caused by fluctuation of temperature and humidity.

**5. List the applications of Thermocole.**

- ✓ Its high thermal insulation makes it an excellent material to use in the construction of walls and ceilings and its high sound absorption makes it the ideal choice for sound-proofing.
- ✓ Another recent application of Thermocol (EPS) is as ―Geofoam‖ in landfills. This application is made possible because of Thermocol's (EPS's) light weight, water resistance, dimensional stability and inert nature.

**6. List the application of Aluminium composites.**

A popular application for aluminium composite is folded structures. From sign trays to fascia panels and column cladding aluminium composite is easy to form and light enough to install easily. Using the correct type of tooling aluminium composite can be scored and then folded.

**7. Write notes on Paint.**

Paint is any liquid, liquefiable, or mastic composition that, after application to a substrate in a thin layer, converts to a solid film. It is most commonly used to protect, color, or provide texture to objects.

**8. What is a binder?**

The binder is the film-forming component of paint. It is the only component that must be present. The binder imparts adhesion and strongly influences properties such as gloss, durability, flexibility, and toughness.

**9. What is the purpose of a diluent?**

The main purposes of the diluents are to dissolve the polymer and adjust the viscosity of the paint. It is volatile and does not become part of the paint film. It also controls flow and application properties, and in some cases can affect the stability of the paint while in liquid state. Its main function is as the carrier for the non volatile components.

**10. What are pigments? How are they classified?**

Pigments are granular solids incorporated in the paint to contribute color.

Pigments can be classified as either natural or synthetic. Natural pigments include various clays, calcium carbonate, mica, silicas, and talcs. Synthetics would include engineered molecules, calcined clays, blanc fixe, precipitated calcium carbonate, and synthetic pyrogenic silicas.

**11. Write notes on Varnishes.**

Varnish is a transparent, hard, protective finish or film primarily used in wood finishing but also for other materials. Varnish is traditionally a combination of a drying oil, a resin, and a thinner or solvent. Varnish finishes are usually glossy but may be designed to produce satin or semi-gloss sheens by the addition of "flatting" agents.

**12. What is bitumen?**

Bitumen is a sticky, black and highly viscous liquid or semi-solid form of petroleum. It may be found in natural deposits or may be a refined product; it is a substance classed as a pitch. Bitumen is an oil based substance.

# UNIT IV
# TIMBER AND OTHER MATERIALS

**1. Explain in detail the application of timber in construction.**

In comparison with other construction materials, using timber is energy saving. The manifold material values can also be expanded with the material selection. The selection between different materials like round wood, squared wood, sawn wood or glued laminated timber which has been improved through industrial methods, or different sorts of plywood, provides different resistance qualities with economical and competitive construction possibilities. Wood sections are a further quality to take into account beside resistance criteria when using round- or sawn wood. The treatment preceding the drying and the considering of the extension of the year rings in different forms of sections, as well as the profiles of the wood sections are most important for an economical formation of detail in the constructive use of timber.

**Techniques and Means of Assembling**

New highly efficient means of assembling, i.e. connections with lower section weakening and needs of steal, have to be developed for a highest possible degree of pre-fabrication in the workshop and in order to reduce the working time on the site as much as possible.

The use of new connecting systems like nailed tinplates, screws, lag bolts as well as connectors with wood contact allow a much higher quality of more filigree supporting systems when linked with deterministic non-destructive testing methods in order to avoid sporadic problems, which arise in highly stressed construction elements. Connectors combining fiberglass and mechanical fasteners allow also a noticeable increase in the load capacity, as shown in a recent study on fiberglass reinforced timber joints.

In order to give timber a new chance as a construction material, the different research development and marketing programs should not aim at the quantity of material used, but at the manifold quality of material steadiness, section variability, material diversity as well as facilitated construction control and quick usage of the new techniques in timber engineering construction.

Timber as load-bearing material has only a chance if the conception of the construction can show a quality which is not only functional, technical or architectural, but which can also justify its economy. This presupposes, how-ever, a more important planning and a better cooperation between architect and engineer, in order to make the most of the diversity of forms, structures and techniques applicable to timber.

It is essential to define clearly the quality criteria of a timber construction and to aim at reading easily the force and load fluctuations, and reducing the material through load- and detail planning with an optimally functional adaptation to technique and construction.

**New Techniques in Timber Construction**

The increasing use of timber in the construction depends on engineering developments of timber as a load-bearing material, in order to raise the modest portion of the total construction volume from about 1 per cent to perhaps 2 or 3 per cent.

The criteria of development are: better evaluation of the timber quality, increase of the diversity and better treatment of material varieties, development of new time-sparing assembling techniques which allow the highest possible degree of pre-fabrication.

Quantity related techniques for floors, walls and roofs of the dense housing and public buildings linked with other massive construction materials, as well as quality related high- tech systems, which play a significant role in the modern architecture of roof, hall and bridge construction, should correct the image of timber and offer a competitive alternative to other materials used in construction.

The material selection is no proof for "good architecture". It is, however, an important contribution to the environmental conservation, even if it needs more concentration on the planning phase.

**2. Write short notes on Plywood, Veneer and Thermacole.**

**Plywood**

Plywood is a laminate made of thin layers of wood.

**Veneer**

In woodworking, veneer refers to thin slices of wood, usually thinner than 3 mm (1/8 inch), that typically are glued onto core panels (typically, wood, particle board or medium-density fiberboard) to produce flat panels such as doors, tops and panels for cabinets, parquet floors and parts of furniture. Plywood consists of three or more layers of veneer, each glued with its grain at right angles to adjacent layers for strength. Veneer beading is a thin layer of decorative edging placed around objects, such as jewelry boxes. Veneer is also used to replace decorative papers in Wood Veneer HPL. Veneer is also a type of manufactured board.

Veneer is obtained either by "peeling" the trunk of a tree or by slicing large rectangular blocks of wood known as flitches. The appearance of the grain and figure in wood comes from slicing through the growth rings of a tree and depends upon the angle at which the wood is sliced. There are three main types of veneer-making equipment used commercially:

- A rotary lathe in which the wood is turned against a very sharp blade and peeled off in one continuous or semi-continuous roll. Rotary-cut veneer is mainly used for plywood, as the appearance is not desirable because the veneer is cut concentric to the growth rings.
- A slicing machine in which the flitch or piece of log is raised and lowered against the blade and slices of the log are made. This yields veneer that looks like sawn pieces of wood, cut across the growth rings; such veneer is referred to as "crown cut".
- A half-round lathe in which the log or piece of log can be turned and moved in such a way as to expose the most interesting parts of the grain.

Each slicing processes gives a very distinctive type of grain, depending upon the tree species. In any of the veneer-slicing methods, when the veneer is sliced, a distortion of the grain occurs. As it hits the wood, the knife blade creates a "loose" side where the cells have been opened up by the blade, and a "tight" side.

**Types:**

✓ **Raw** veneer has no backing on it and can be used with either side facing up. It is important to note that the two sides will appear different when a finish has been applied, due to the cell structure of the wood.

✓ **Paper backed** veneer is, as the name suggests, veneers that are backed with paper. The advantage to this is it is available in large sizes, or sheets, as smaller pieces are joined together prior to adding the backing. This is helpful for users that do not wish to join smaller pieces of raw veneers together. This is also helpful when veneering curves and columns as the veneer is less likely to crack.

✓

**Phenolic backed** veneer is less common and is used for composite, or manmade wood veneers. Due to concern for the natural resource, this is becoming more popular. It too has the advantage of being available in sheets, and is also less likely to crack when being used on curves.

✓

**Laid up** veneer is raw veneer that has been joined together to make larger pieces. The process is time-consuming and requires great care, but is not difficult and requires no expensive tools or machinery. Veneers can be ordered through some companies already laid up to any size, shape or design.

✓

**Reconstituted veneer** is made from fast-growing tropical species. Raw veneer is cut from a log, and dyed if necessary. Once dyed, the sheets are laminated together to form a block. The block is then sliced so that the edges of the laminated veneer become the

―grain‖ of the reconstituted veneer.

✓

**Wood on Wood** Also called 2-ply is a decorative wood veneer face with a utility grade wood backer applied at an opposing direction to the face veneer

**Advantages:**

Furniture made with wood veneer uses less wood than the same piece of furniture made with solid wood. Some projects built using wood veneer would not be possible to construct using solid lumber, owing to expansion and contraction caused by fluctuation of temperature and humidity.

**Thermacole:**

Its high thermal insulation makes it an excellent material to use in the construction of walls and ceilings and its high sound absorption makes it the ideal choice for sound-proofing.

Another recent application of Thermocol (EPS) is as ―Geofoam‖ in landfills. This application is made possible because of Thermocol's (EPS's) light weight, water resistance, dimensional stability and inert nature.

**Construction with EPS**

By using EPS rigid foam, architects and construction engineers today are also at the same time making use of the opportunity presented by system solutions and incorporate them in their plans appropriately for the functions concerned. The trend is clearly toward specific insulation systems, such as external wall and roof insulation systems, under floor heating systems etc. Such systems give the owner of a building under construction not only considerable cost/benefit advantages but also reduce the risk of technical errors in the planning and execution of work. Even today, 4 decades after its invention, EPS has lost nothing of its attractiveness and is more a part of today's construction industry than ever.

**Roof constructions with EPS:** From the viewpoint of construction physics, the roof, no matter of what design, is the most highly stressed party of a building. Heat and Cold, dryness and wetness, storms and snow act from the outside, internal relative humidity acts from inside, either alternately or both at the same time. Roof designs and materials have to be adapted to these conditions if the roof is to fulfill its protective function. Plastics play a significant part in this connection as insulation layers, waterproofing membranes, vapor barriers, underlays, gutters, downpipes and many other functional elements. Whether a flat roof or a pitched roof, whither someone's home or an office building, or factories, workshops or warehouses, whether a roof garden or an underground garage; EPS sheets are always involved because they have outstanding insulation and offer economical answers as insulation systems.

**Flat roofs:** Flat roof insulation is an important field of application for EPS (Thermocol)sheets. Depending on the roof design, the insulation material is laid loosely, fixed by hot or cold adhesive or mechanically fastened to the underlying surface. The insulation of a non ventilated flat roof is performed simply and economically by means of insulation units of EPS which have been precoated with roofing felt. The lamination with roofing felt protects the insulating layers when the hot bitumen is applied to fix the roof seal. In the case of rollable insulating sheets, the lamination already counts as the first roof sealing layer. Unlaminated rigid foam boards are used on what are known as tarpaulin roofs. In this case, the insulating boards and the plastic tarpaulin sealing are loosely laid and provided with a ballast (e.g. gravel) or are fixed with special dowels.

**Pitched roofs:** In many countries, use of the roof space for living purposes is already a consideration during the planning of a building. Even on existing buildings, roof space is increasingly being developed as additional living areas for guest rooms, play rooms or hobby rooms. Adequate thermal insulation of the roof surface – as the area bounding indoors from outdoors – must be provided. Making the insulating layer adequately thick is also worthwhile with regard to the effect of sunlight in the summer. Suitable for use as insulation in pitched roofs are EPS sheets in the form of filler insulating boards between the rafters, laid on the rafters or in the form of thermally insulating structural composite units. Such insulation systems make economical construction work possible and offer lasting thermal protection. One example of this offers advantages in particular in the case of subsequently installed roof insulation: foam moulded boards with underlying vapour barrier are laid on the existing roof battens. The tiles are then re-laid on the profiled insulating units.

**Wall constructions with EPS:** A wall is both a load-bearing and a protective building unit. It protects the surrounded space against the effects of temperature and weather and against noise. Nowadays, the thermal insulation function is assumed by modern insulating materials, such as EPS sheets. In what is the optimum type of external insulation from a construction physics viewpoint, the EPS insulating layer is applied on the outside of the load-bearing masonry and weather-protected either by a reinforced special plaster or by a ventilated facing layer. Another effective type of external insulation is an insulating plaster with foamed EPS particles as lightweight aggregate, applied as a continuous layer. But composite

EPS/plasterboard units are also used to achieve thermal insulation to today's requirements by insulation external walls from the inside, for examples by subsequent interior insulation on existing buildings. A method widely used in Europe is that of external insulation with EPS boards and fabric-reinforced plaster coating. In this method, the insulating boards are fixed to the masonry by bonding mortar and subsequently covered with a fabric-reinforced dispersion plaster. The reinforcement of the plaster layer with alkali resistant glass fiber sheets is necessary to absorb the material and temperature – dependent stresses in the plaster layer occurring on the insulated façade as the result of temperature fluctuations. The production of lightweight large panel wall units with a plaster coated external insulation is particularly widespread in the USA. The supporting board is mounted on the sectional steel frame and provided with the insulation and fabric-reinforced plaster coating. The easy-to assemble compound units give the impression of a solid external wall. Another system of thermal insulation which is likewise widespread – is the use of mouldings from EPS for the external walls of buildings. The mouldings are placed dry and then filled with concrete. Walls and floors are produced ―in one‖ when EPS formwork elements are used for the production of reinforced concrete ribbed floors. The formwork elements are easy to lay and produce an even, thermally insulated ceiling which can subsequently be plastered or lined. There is an extremely wide variety of variations of wall moulding systems: large wall units, produced on continuous moulding machines and, for example, mouldings of EPS with stainless steel connecting elements already provided with a pre-coating for plaster bonding. In the case of a cavity wall, the insulating layer is provided between load-bearing wall and weather-resistant facing masonry. The closed-cell boards, rebated all around, make it possible to dispense with the otherwise customary air gap between insulation and facing masonry. The cavity between the two wall skins can be fully utilized for insulation. For the insulation of an already existing cavity wall, there is likewise an economical method; foamed particles are blown into the cavity between the two masonry skins. For this purpose holes are drilled into the skin a closed again after the filling operation. Foamed beads are delivered in special silo vehicles. A method of construction which is as simple as it is economical is the use of special masonry blocks in which the EPS insulation has already been introduced into the cross-section of the block. This may be performed by the insulating boards being pushed manually into corresponding block cavities or already molded-in during block production. Another method is to fill the block cavities with pre expanded beads and then foam them with steam. This economical production method makes possible an integrated insulation and thus a substantially improved thermal insulation capacity of the hollow blocks. To reduce heat loss through the mortared joints, a light masonary mortar is generally used.

**Insulating plaster** A further possibility of improving the thermal insulation of external walls is to coat them with a thermally insulating lightweight plaster. In this case, small, foamed EPS particles are added to the plastering mortar mix, substantially reducing the apparent density of the plaster and thus increasing its thermal insulation. The dry mix is delivered to the construction site in sacks or containers and is prepared ready-for-use just by adding water. Such lightweight EPS plasters can be mechanically processed and sprayed on up to a thickness of 6 cm in a single operation.3 to 5 days after applying the layer of insulating plaster, a mineral plaster is added for surface protection. Depending on the plaster thickness, profiling and surface coating, unconventional façade designs are also possible.

**Lightweight concrete** Foamed EPS beads are not only suitable for lightweight plasters, but also for the production of lightweight concrete and porous bricks. The possible applications of EPS concrete as a thermally insulating, light-weight construction material have already been investigated and formulations for various apparent density ranges with different concrete properties developed. From the point of view of structural thermal insulation and economical processing, EPS concretes of particular interest in the low, very light apparent density range; for example as a special prefabricated system in which the tabular cavities in the light-weight EPS concrete wall units are later filled with normal concrete, which undertakes load bearing and reinforcing functions. Recesses or opening can be cut out simply by using a saw. Or for the production of domed houses, using a blown-up shell on which the EPS concrete is mechanically sprayed.

**Prefabricated Systems** The use of EPS sheets as thermal insulation in large format façade units of normal concrete (sandwich construction) has long since proven successful. The high mechanical load-bearing capacity and dimensional stability of EPS sheets also make possible a trouble-free production of large panel lightweight units which can be covered with various materials depending on the intended application. Such as sheeting with wood or chipboards as load-bearing wall or roof unit in prefabricated home construction; an economical dry insulation technique which is used particularly in North America, where it has been recognized that houses made from prefabricated EPS units make possible far more cost- effective construction and energy-saving living than conventional building methods. Such as sandwich units covered with fibrated concrete slabs, as infill thermal-insulating façade units. Such as large-format wall and roof units with metal coating as systems for industrial constructions and cold stores. Such structural systems are preferred in particular in states where there is a high demand for cold rooms or cold storage houses, such as Uttar Pradesh, Uttaranchal and Maharashtra. In this application, as in the insulation of refrigeration lines, the good thermal insulation and dimensional stability of EPS foamed plastics prove effective even at low temperatures. The lightweight, prefabricated composite units can be transported cost effectively over large distances. They are therefore also used as a structural system in the construction of houses and housing estates, in particular in locations where living quarters have to be created under difficult climatic and constructional conditions. Whether in the cold of the Antarctic or in the heat of dry desert regions: EPS composite units make economical construction possible and offer pleasant living conditions.

**Floor constructions with EPS** Footfall sound insulation In some countries, structural sound insulation is even today only of secondary importance, nevertheless, in the meantime noise pollution has become so great everywhere, especially in large conurbations, that adequate sound insulation is becoming ever more important. As well as limiting sound transmission through external compound units, impact sound insulation is of great importance. To achieve effective impact sound insulation, the sound which is made by walking on a floor must be prevented from being transmitted to other compounds units. For instance, a thick carpet may be laid on a concrete floor. However, this is only a temporary solution, as the carpet wears out or may be taken up. Another possibility is to increase the weight of the floor and thus reduce the sound transmission. However, this is only possible to a limited extent for financial and technical reasons. All of these considerations finally led to the development of what is known as the ―floating floor system‖, a flooring structure common in particular in Germany and a number of other European countries. A floating floor is flooring (for example cement screed) which is laid on a flexible insulating layer and can freely oscillate, thus acting as a spring-mass system. This substantially prevents the penetration of structure-borne sound into the floor structure. Special EPS sheets, which are elasticized by special subsequent treatment, have proven their value for impact sound insulation. Such boards have a low dynamic rigidity (comparable with an air cushion) and are nevertheless sufficiently compression-resistant to bear the load of the floor permanently.

**3. Write notes on Aluminium Composite.**

**Aluminium Composite material:**

In the recent technological innovations there is a growing awareness to synthesize Al – alloy composites with an aim to achieve a combination of properties which are not normally available in any one of the constituent phases. Composite materials can be selected to give combination of properties such as stiffness, strength, high temperature performance, corrosion resistance, hardness, conductivity etc. Aluminum matrix composites are finding wide range of applications in automobile, aerospace, defense and general engineering sectors, because of their higher specific strength and stiffness, good wear and seizure resistance and improved high temperature properties as compared to the base alloy. The strength and wear resistance of AMCs were found to be comparable to cast irons. AMCs are lighter than cast iron or steels and the former one have better specific strength and wear resistance as compared to the later one. Thus, considerable efforts are being made to replace these components with AMCs. It will not only improve the life of components but also reduce the weight and improve the fuel efficiency Aluminium composite is a lightweight panel material which is designed for interior and exterior applications. Aluminium Composite sheet has a polyethylene core. This make up 90% of the structure of each sheet. Depending on which brand of Aluminium Composite you use this core will be either a Clear/ Grey or Black colour. The polyethylene core of your Aluminium Composite sheet is faced with two thin sheets of aluminium. This aluminium is bonded onto the core during the manufacturing process and it is virtually impossible to separate the layers of material once they have been bonded. The applications for aluminium composite are wide and varied. Versatile lightweight and durable material aluminium composite performs well for internal and external applications.

Addition of second phase particles to aluminium based alloys has emerged as a potential technique for the development of (aluminium - alloy) composite materials especially suitable for structural and elevated temperature applications. In this case, usually one set of properties is improved at the cost of the other and hence a compromise has to be made in the case of composite materials in this regard. Much lighter than other metal and plastic sheet aluminium composite allows the creation of lightweight yet strong structures. Manufactured from plastic and aluminium this material is easy to handle and simple to machine.

A popular application for aluminium composite is folded structures. From sign trays to fascia panels and column cladding aluminium composite is easy to form and light enough to install easily. Using the correct type of tooling aluminium composite can be scored and then folded.

**4. Write notes on Paints, Varnishes and Distempers.**

**Paint** is any liquid, liquefiable, or mastic composition that, after application to a substrate in a thin layer, converts to a solid film. It is most commonly used to protect, color, or provide texture to objects. Paint can be made or purchased in many colors—and in many different types, such as watercolour, artificial, etc. Paint is typically stored, sold, and applied as a liquid, but dries into a solid.

The **binder**, commonly called the vehicle, is the film-forming component of paint. It is the only component that must be present. Components listed below are included optionally, depending on the desired properties of the cured film. The binder imparts adhesion and strongly influences properties such as gloss, durability, flexibility, and toughness.

Binders include synthetic or natural resins such as alkyds, acrylics, vinyl-acrylics, vinyl acetate/ethylene (VAE), polyurethanes, polyesters, melamine resins, epoxy, or oils. Binders can be categorized according to the mechanisms for drying or curing. Although drying may refer to evaporation of the solvent or thinner, it usually refers to oxidative cross- linking of the binders and is indistinguishable from curing. Some paints form by solvent evaporation only, but most rely on cross-linking processes.

The main purposes of the **diluents** are to dissolve the polymer and adjust the viscosity of the paint. It is volatile and does not become part of the paint film. It also controls flow and application properties, and in some cases can affect the stability of the paint while in liquid state. Its main function is as the carrier for the non volatile components. To spread heavier oils (for example, linseed) as in oil-based interior house paint, a thinner oil is required. These volatile substances impart their properties temporarily—once the solvent has evaporated, the remaining paint is fixed to the surface. This component is optional: some paints have no diluent. Water is the main diluent for water-borne paints, even the co-solvent types. Solvent- borne, also called oil-based, paints can have various combinations of organic solvents as the diluent, including aliphatics, aromatics, alcohols, ketones and white spirit. Specific examples are organic solvents such as petroleum distillate, esters, glycol ethers, and the like. Sometimes volatile low-molecular weight synthetic resins also serve as diluents.

**Pigments** are granular solids incorporated in the paint to contribute color. Fillers are granular solids incorporate to impart toughness, texture, give the paint special properties, or to reduce the cost of the paint. Alternatively, some paints contain dyes instead of or in combination with pigments.

Pigments can be classified as either natural or synthetic. Natural pigments include various clays, calcium carbonate, mica, silicas, and talcs. Synthetics would include engineered molecules, calcined clays, blanc fixe, precipitated calcium carbonate, and synthetic pyrogenic silicas.

Hiding pigments, in making paint opaque, also protect the substrate from the harmful effects of ultraviolet light. Hiding pigments include titanium dioxide, phthalo blue, red iron oxide, and many others.

Fillers are a special type of pigment that serve to thicken the film, support its structure and increase the volume of the paint. Fillers are usually cheap and inert materials, such as diatomaceous earth, talc, lime, barytes, clay, etc. Floor paints that must resist abrasion may contain fine quartz sand as filler. Not all paints include fillers. On the other hand, some paints contain large proportions of pigment/filler and binder.

Some pigments are toxic, such as the lead pigments that are used in lead paint. Paint manufacturers began replacing white lead pigments with titanium white (titanium dioxide), before lead was banned in paint for residential use in 1978 by the US Consumer Product Safety Commission. The titanium dioxide used in most paints today is often coated with silica/alumina/zirconium for various reasons, such as better exterior durability, or better hiding performance (opacity) promoted by more optimal spacing within the paint film.

**Applications:**

Paint can be applied as a solid, a gaseous suspension (aerosol) or a liquid. Techniques vary depending on the practical or artistic results desired. As a solid (usually used in industrial and automotive applications), the paint is applied as a very fine powder, and then baked at high temperature. This melts the powder and causes it to adhere to the surface. The reasons for doing this involve the chemistries of the paint, the surface itself, and perhaps even the chemistry of the substrate (the object being painted). This is called "powder coating" an object. As a gas or as a gaseous suspension, the paint is suspended in solid or liquid form in a gas that is sprayed on an object. The paint sticks to the object. This is called "spray painting" an object. The reasons for doing this include:

- ✓ The application mechanism is air and thus no solid object touches the object being painted
- ✓ The distribution of the paint is uniform, so there are no sharp lines
- ✓ It is possible to deliver very small amounts of paint
- ✓ A chemical (typically a solvent) can be sprayed along with the paint to dissolve together both the delivered paint and the chemicals on the surface of the object being painted
- ✓ Some chemical reactions in paint involve the orientation of the paint molecules.

In the liquid application, paint can be applied by direct application using brushes, paint rollers, blades, other instruments, or body parts such as fingers and thumbs.

Rollers generally have a handle that allows for different lengths of poles to be attached, allowing painting at different heights. Generally, roller application requires two coats for even color. A roller with a thicker nap is used to apply paint on uneven surfaces. Edges are often finished with an angled brush.

**Varnishes:**

Varnish is a transparent, hard, protective finish or film primarily used in wood finishing but also for other materials. Varnish is traditionally a combination of a drying oil, a resin, and a thinner or solvent. Varnish finishes are usually glossy but may be designed to produce satin or semi-gloss sheens by the addition of "flatting" agents. Varnish has little or no color, is transparent, and has no added pigment, as opposed to paints or wood stains, which contain pigment and generally range from opaque to translucent. Varnishes are also applied over wood stains as a final step to achieve a film for gloss and protection. Some products are marketed as a combined stain and varnish.

After being applied, the film-forming substances in varnishes either harden directly, as soon as the solvent has fully evaporated, or harden after evaporation of the solvent through certain curing processes, primarily chemical reaction between oils and oxygen from the air (autoxidation) and chemical reactions between components of the varnish. Resin varnishes "dry" by evaporation of the solvent and harden almost immediately upon drying. Acrylic and waterborne varnishes "dry" upon evaporation of the water but experience an extended curing period. Oil, polyurethane, and epoxy varnishes remain liquid even after evaporation of the solvent but quickly begin to cure, undergoing successive stages from liquid or syrupy, to tacky or sticky, to dry gummy, to "dry to the touch", to hard. Environmental factors such as heat and humidity play a very large role in the drying and curing times of varnishes. In classic varnish the cure rate depends on the type of oil used and, to some extent, on the ratio of oil to resin. The drying and curing time of all varnishes may be sped up by exposure to an energy source such as sunlight, ultraviolet light, or heat. Varnishes and drying oils may cause fires. Many varnishes contain plant-derived oils (e.g. linseed oil), synthetic oils (e.g. polyurethanes) or resins as their binder in combination with organic solvents. These are highly flammable in their liquid state.

**Distemper:**

Distemper is an early form of whitewash, also used as a medium for artistic painting, usually made from powdered chalk or lime and size (a gelatinous substance). Alternatives to chalk include the toxic substance white lead. Distempered surfaces can be easily marked and discoloured, and cannot be washed down, so distemper is best suited to temporary and interior decoration. The technique of painting on distempered surfaces blends watercolors with whiting and glue. The colours are mixed with whitening, or finely-ground chalk, and tempered with size.

**5. Explain applications of Bitumens.**

Bitumen is a sticky, black and highly viscous liquid or semi-solid form of petroleum. It may be found in natural deposits or may be a refined product; it is a substance classed as a pitch. Bitumen is an oil based substance. It is a semi-solid hydrocarbon product produced by removing the lighter fractions (such as liquid petroleum gas, petrol and diesel) from heavy crude oil during the refining process. As such, it is correctly known as refined bitumen.

The primary use of asphalt/bitumen is in road construction, where it is used as the glue or binder mixed with aggregate particles to create asphalt concrete. Its other main uses are for bituminous waterproofing products, including production of roofing felt and for sealing flat roofs. The vast majority of refined bitumen is used in construction: primarily as a constituent of products used in paving and roofing applications. According to the requirements of the end use bitumen is produced to specification. This is achieved either by refining process or blending. The production of asphalt involves mixing sand, gravel and crushed rock with bitumen, which acts as the binding agent. Other materials, such as polymers, may be added to the bitumen to alter its properties according to the application for which the asphalt is ultimately intended.

85% of all the bitumen produced is used as the binder in asphalt for roads. It is also used in other paved areas such as airport runways, car parks and footways. A further 10% of global bitumen production is used in roofing applications, where its waterproofing qualities are invaluable. The remaining 5% of bitumen is used mainly for sealing and insulating purposes in a variety of building materials, such as pipe coatings, carpet tile backing and paint.

Naturally occurring asphalt/bitumen is sometimes specified by the term "crude bitumen". Its viscosity is similar to that of cold molasses while the material obtained from the fractional distillation of crude oil boiling at 525 °C (977 °F) is sometimes referred to as "refined bitumen".

# UNIT V
# MODERN MATERIALS

**1. What is a geofabric?**

These are synthetic fabrics which are sufficiently durable to last a good length of time in soil environment used in geotechnical engineering. Some geofabrics are polyester, nylon, polyethylene and geotechnical engineering.

**2. List the functions of geofabric.**

- ✓ Drainage paths for water for soil consolidation
- ✓ Separation of different types of soil materials
- ✓ Soil reinforcement in reinforced earth construction
- ✓ Filtration of water from soil.

**3. What are the classifications of geofabrics?**

- ✓ Geotextiles
- ✓ Geogrids
- ✓ Geomembranes
- ✓ Linear strips for soil reinforcement

**4. List some properties of Glass.**

- ✓ It absorbs, refracts or transmits light. It can be made transparent or translucent.
- ✓ It can take excellent polish.
- ✓ It is an excellent electrical insulator.
- ✓ It is strong and brittle.
- ✓ It is not affected by atmosphere.
- ✓ It has excellent resistance to chemicals.

**5. List the types of Glass**

- ✓ Soda Lime Glass
- ✓ Potash Lime Glass
- ✓ Potash Lead Glass
- ✓ Common Glass
- ✓ Special Glasses

**6. What is a Fibre-Reinforced Plastic?**

Fibre-reinforced plastic (FRP) (also fibre-reinforced polymer) is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon, basalt or aramid, although other fibres such as paper or wood or asbestos have been sometimes used.

**7. Name some structural clay products.**

- Building brick
- Paving brick
- Terra-cotta facing tile
- Roofing tile
- Drainage pipe.

**8. What is a laminar composite?**

A laminar composite is a composite material that consists of two or more layers of different materials that are bonded together. They are also called laminated composites or laminates. A laminate usually consists of two or more layers of planar composites in which each layer (also called lamina or ply) may be of the same or different materials.

**9. Define Refractories.**

Refractories are defined as non-metallic materials having those chemical and physical properties that make them applicable for structures, or as components of systems, that are exposed to environments above 1,000 °F. A refractory material is one that retains its strength at high temperatures.

**10. What is a sealant?**

Sealants are typically lower strength, yet flexible, bonding agents used between substrates of differing physical properties to form a seal between the materials. A sealant may be viscous material that has little or no flow characteristics and which stay where they are applied.

**11. What is a ceramic?**

A ceramic is an inorganic, nonmetallic solid prepared by the action of heat and subsequent cooling. Ceramic materials may have a crystalline or partly crystalline structure, or may be amorphous (e.g., a glass).

## MODERN MATERIALS

### 1. Explain in detail about Geofabrics.

Geofabrics are also called geosynthesis or geotextiles. These are synthetic fabrics which are sufficiently durable to last a good length of time in soil environment used in geotechnical engineering. Some geofabrics are polyester, nylon, polyethylene and geotechnical engineering. The fabric may be woven, knitted or punched. They are used for the following functions:

1. Drainage paths for water for soil consolidation
2. Separation of different types of soil materials
3. Soil reinforcement in reinforced earth construction
4. Filtration of water from soil.

**Uses**

1. As drainage paths to assist consolidation. Geotextiles are used as drainage wicks to assist f=drainage and consolidation of clayey deposits. The modern readymade ―plastic geotextile drain‖ consists of a plastic drain core and a geotextile jacket covering the plastic core pipe. They are efficient for soil drainage to assist in preloading of foundations.
2. As a separation medium. It is used as under railway track, to separate the ballast from sub grade, thus decreasing penetration of ballast into the weak sub grade.
3. As soil reinforcement. These reinforcements are used in the reinforced earth techniques for the following purposes
   i) For retaining walls and stability of slopes
   ii) For improving the bearing capacity of foundations.
4. As a filtration medium for drainage. In many situations, when used for drainage and separation, it also acts as a filter.

**Classification**

1. **Geotextiles**: These materials consist of either woven or non-woven fabrics and are generally used for separation, drainage, filtration and reinforcement. From strength considerations, the strongest of these are woven fabrics, then the resin bonded, melt bonded and finally the needle punched fabrics.
2. **Geogrids**: They have large openings and are made of materials with high tensile strength, low elongation and dimensional stability. They are made from plain polymer sheets by punching holes in it followed by 2 stretching operations so that a grid is formed. They can be designed to have different strength or same strength in two directions. They are mainly used for soil reinforcement or for separation of materials or for improving bearing capacity of soil.
3. **Geomembranes**: These materials are available in wide range of permeability. Continuous geomembrane barriers of sufficiently low permeability can be used to control fluid migration in geotechnical engineering while those of high permeability are used for drainage.
4. **Linear strips for soil reinforcement**: Polymer fibres are made into strips which can be used for reinforced earth in retaining walls. Glass- reinforced plastics are also considered as suitable for soil reinforcement.

**Use in Embankments**

As the embankments for flyovers in cities should occupy as little width as possible, the use of geotextiles as soil reinforcement for these embankments comes in very handy. Much steeper slopes than normally admissible with earth only can be provided by using soil reinforcement in the embankment. Similarly, consolidation of foundations of many new railway embankments for Indian Railways has been carried out by using plastic geotextile drains instead of old fashioned sand or wick drains.

**2. Write notes on types of Glass and its properties.**

Silica is the main constituent of glass. But it is to be added with sodium potassium carbonate to bring down melting point. To make it durable lime or lead oxide is also added. Manganese oxide is added to nullify the adverse effects of unwanted iron present in the impure silica. The raw materials are ground and sieved. They are mixed in specific proportion and melted in furnace. Then glass items are manufactured by blowing, flat drawing, rolling and pressing.

**Important Properties of Glass:**

1. It absorbs, refracts or transmits light. It can be made transparent or translucent.
2. It can take excellent polish.
3. It is an excellent electrical insulator.
4. It is strong and brittle.
5. It can be blown, drawn or pressed.
6. It is not affected by atmosphere.
7. It has excellent resistance to chemicals.
8. It is available in various beautiful colours.
9. With the advancement in technology, it is possible to make glass lighter than cork or stronger than steel.
10. Glass panes can be cleaned easily.

**Types of Glass**

The glass may be broadly classified as:

1. **Soda Lime Glass:** It is mainly a mixture of sodium silicate and calcium silicate. It is fusible at low temperature. In the fusion condition it can be blown or welded easily. It is colourless. It is used as window panes and for the laboratory tubes and apparatus.
2. **Potash Lime Glass:** It is mainly a mixture of potassium silicate and calcium silicate. It is also known as hard glass. It fuses at high temperature. It is used in the manufacture of glass articles which have to with stand high temperatures.
3. **Potash Lead Glass:** It is mainly a mixture of potassium silicate and lead silicate. It possesses bright lustre and great refractive power. It is used in the manufacture of artificial gems, electric bulbs, lenses, prisms etc.
4. **Common Glass:** It is mainly a mixture of sodium silicate, calcium silicate and iron silicate. It is brown, green or yellow in colour. It is mainly used in the manufacture of medicine bottles.
5. **Special Glasses:** Properties of glasses can be suitably altered by changing basic ingradients and adding few more ingradients. It has now emerged as versatile material to

meet many special requirement in engineering. The following is the list of some of the special glasses:

(a) Fibre glass
(b) Foam glass
(c) Bullet proof glass
(d) Structural glass
(e) Glass black
(f) Wired glass
(g) Ultraviolet ray glass
(h) Perforated glass.

**3. Explain the methods of forming Fibre-reinforced plastic (FRP). Also state its merits and demerits.**

Fibre-reinforced plastic (FRP) (also fibre-reinforced polymer) is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon, basalt or aramid, although other fibres such as paper or wood or asbestos have been sometimes used. The polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic, and phenol formaldehyde resins are still in use. FRPs are commonly used in the aerospace, automotive, marine, construction industries and ballistic armor.

The moulding processes of FRP plastic begins by placing the fibre preform on or in the mold. The fibre preform can be dry fibre, or fibre that already contains a measured amount of resin called "prepreg". Dry fibres are "wetted" with resin either by hand or the resin is injected into a closed mold. The part is then cured, leaving the matrix and fibres in the shape created by the mold. Heat and/or pressure are sometimes used to cure the resin and improve the quality of the final part. The different methods of forming are listed below.

**Bladder moulding**

Individual sheets of prepreg material are laid up and placed in a female-style mould along with a balloon-like bladder. The mould is closed and placed in a heated press. Finally, the bladder is pressurized forcing the layers of material against the mould walls.

**Compression moulding**

When the raw material (plastic block,rubber block, plastic sheet, or granules) contains reinforcing fibres, a compression molded part qualifies as a fibre-reinforced plastic. More typically the plastic preform used in compression molding does not contain reinforcing fibres. In compression molding, A "preform" or "charge", of SMC, BMC is placed into mould cavity. The mould is closed and the material is formed & cured inside by pressure and heat. Compression moulding offers excellent detailing for geometric shapes ranging from pattern and relief detailing to complex curves and creative forms, to precision engineering all within a maximum curing time of 20 minutes.

**Autoclave / vacuum bag**

Individual sheets of prepreg material are laid-up and placed in an open mold. The material is covered with release film, bleeder/breather material and a vacuum bag. A vacuum is pulled on part and the entire mould is placed into an autoclave (heated pressure vessel). The part is cured with a continuous vacuum to extract entrapped gasses from laminate. This is a very common process in the aerospace industry because it affords precise control over moulding due to a long, slow cure cycle that is anywhere from one to several hours. This precise control creates the exact laminate geometric forms needed to ensure strength and safety in the aerospace industry, but it is also slow and labour-intensive, meaning costs often confine it to the aerospace industry.

**Mandrel wrapping**

Sheets of prepreg material are wrapped around a steel or aluminium mandrel. The prepreg material is compacted by nylon or polypropylene cello tape. Parts are typically batch cured by vacuum bagging and hanging in an oven. After cure the cello and mandrel are removed leaving a hollow carbon tube. This process creates strong and robust hollow carbon tubes.

**Wet layup**

Wet layup forming combines fibre reinforcement and the matrix as they are placed on the forming tool. Reinforcing Fibre layers are placed in an open mould and then saturated with a wet [resin] by pouring it over the fabric and working it into the fabric. The mould is then left so that the resin will cure, usually at room temperature, though heat is sometimes used to ensure a proper cure. Sometimes a vacuum bag is used to compress a wet layup. Glass fibres are most commonly used for this process, the results are widely known as fibreglass, and are used to make common products like skis, canoes, kayaks and surf boards.

**Chopper gun**

Continuous strands of fibreglass are pushed through a hand-held gun that both chops the strands and combines them with a catalysed resin such as polyester. The impregnated chopped glass is shot onto the mould surface in whatever thickness the design and human operator think is appropriate. This process is good for large production runs at economical cost, but produces geometric shapes with less strength than other moulding processes and has poor dimensional tolerance.

**Filament winding**

Machines pull fibre bundles through a wet bath of resin and wound over a rotating steel mandrel in specific orientations Parts are cured either room temperature or elevated temperatures. Mandrel is extracted, leaving a final geometric shape but can be left in some cases.

**Pultrusion**

Fibre bundles and slit fabrics are pulled through a wet bath of resin and formed into the rough part shape. Saturated material is extruded from a heated closed die curing while being continuously pulled through die. Some of the end products of pultrusion are structural shapes, i.e. I beam, angle, channel and flat sheet. These materials can be used to create all sorts of fibreglass structures such as ladders, platforms, handrail systems tank, pipe and pump supports.

**RTM & VARTM**

Also called resin infusion. Fabrics are placed into a mould which wet resin is then injected into. Resin is typically pressurized and forced into a cavity which is under vacuum in RTM (Resin Transfer Molding). Resin is entirely pulled into cavity under vacuum in VARTM (Vacuum-Assisted Resin Transfer Molding). This moulding process allows precise tolerances and detailed shaping but can sometimes fail to fully saturate the fabric leading to weak spots in the final shape.

**Advantages and limitations**

FRP allows the alignment of the glass fibres of thermoplastics to suit specific design programs. Specifying the orientation of reinforcing fibres can increase the strength and resistance to deformation of the polymer.

Glass reinforced polymers are strongest and most resistive to deforming forces when the polymers fibres are parallel to the force being exerted, and are weakest when the fibres are perpendicular. Thus this ability is at once either an advantage or a limitation depending on the context of use.

Weak spots of perpendicular fibres can be used for natural hinges and connections, but can also lead to material failure when production processes fail to properly orient the fibres parallel to expected forces.

When forces are exerted perpendicular to the orientation of fibres the strength and elasticity of the polymer is less than the matrix alone.

In cast resin components made of glass reinforced polymers, the orientation of fibres can be oriented in two-dimensional and three-dimensional weaves. This means that when forces are possibly perpendicular to one orientation, they are parallel to another orientation; this eliminates the potential for weak spots in the polymer.

**Failure modes**

Structural failure can occur in FRP materials when:

Tensile forces stretch the matrix more than the fibres, causing the material to shear at the interface between matrix and fibres.

Tensile forces near the end of the fibres exceed the tolerances of the matrix, separating the fibres from the matrix.

Tensile forces can also exceed the tolerances of the fibres causing the fibres themselves to fracture leading to material failure.

**4. Discuss about the manufacture and properties of Clay Products.**

Structural clay products, ceramic products intended for use in building construction. Typical structural clay products are building brick, paving brick, terra-cotta facing tile, roofing tile, and drainage pipe. These objects are made from commonly occurring natural materials, which are mixed with water, formed into the desired shape, and fired in a kiln in order to give the clay mixture a permanent bond. Finished structural clay products display such essential properties as load-bearing strength, resistance to wear, resistance to chemical attack, attractive appearance, and an ability to take a decorative finish.

**Manufacture**

Structural clay products are made from 35 to 55 percent clays or argillaceous (clayey) shales, 25 to 45 percent quartz, and 25 to 55 percent feldspar. As with all traditional ceramic products, the clay portion acts as a former, providing shaping ability; the quartz (silica) serves as filler, providing strength to the formed object; and the feldspar serves as a fluxing agent, lowering the melting temperatures of the clay and quartz during firing. The proportions cited above are often found directly in shale deposits, so that blending is often not necessary. In addition, little or no beneficiation, or crushing and grinding of the mined material, is employed. Local clays or shales of highly variable composition are used in order to keep transportation costs as low as possible. The colour of the finished product derives from impurities, most notably iron oxides, present in the raw materials. Colours can range from buff and other light shades of brown through red to black, depending upon whether an oxidizing or reducing atmosphere exists in the kiln.

In the processing of structural clay products, stiff-mud plastic-forming operations predominate—for example, pressing operations for brick and extrusion for brick or pipe. Formed objects are usually fired in continuous conveyor belt or railcar operations, with the ware, as it traverses the tunnel kiln, proceeding from room temperature into a hot zone and finally to a cooler zone at the other end.

**Properties**

The properties exhibited by structural clay products are determined by particle size, firing temperature, and ultimate microstructure. Compared with finer ceramic products such as whitewares, much coarser filler particles are used, and lower firing temperatures are employed—typically in the range of 1,050° to 1,100° C (approximately 1,925° to 2,000° F). At such low temperatures the filler particles (usually crushed quartz) are normally not affected. Instead, the clay or shale ingredients contain sufficient impurities to melt and form a glass, thus bonding the particles together. As is the case with whitewares, crystalline mullite needles grow into this glassy phase. The resulting microstructure consists of large secondary particles embedded in a matrix of fine-grained mullite and glass—all containing a substantial volume of large pores.

Because of the presence of large and small particles in their microstructures, fired clay products have relatively high compressive strengths. This ability to bear relatively heavy loads without fracture is the prime property qualifying these products for structural applications. The size and number of pores is also important. If underfired, structural clay products have low strength and poor resistance to frost and freezing, owing to the presence of many small pores in the clay regions. Overfired ware, on the other hand, has too much glass. It is strong but brittle and is susceptible to failure under mechanical and thermal stress. Furthermore, it is impossible to obtain a good bond when glassy products are used with mortars. Small pores and high glass content are desirable, however, when chemical resistance and imperviousness to water penetration are required.

**Products**

By some estimates structural clay products make up as much as 50 percent of the entire ceramics market. The industry is highly conservative, with development aimed primarily at automation and labour minimization rather than the introduction of new products.

There is a wide variety of structural clay products, broadly classified as facing materials, load-bearing materials, paving materials, roofing tile, and chemically resistant materials. Examples of facing materials are face brick, terra-cotta, brick veneer, sculptured brick, glazed brick and tile, and decorative brick. Building brick, hollow brick, and structural tile for floors and walls are examples of load-bearing materials. Paving materials include light traffic pavers, quarry tile, and paving brick—this last product once in more common use than at present. Roofing tiles are quite common in many parts of the world, red and black colours being of particular note. Chemically resistant materials include sewer pipe, industrial floor brick, drain tile, flue liners, chimney brick, and chemical stoneware.

**5. Laminar composites**

A laminar composite is a composite material that consists of two or more layers of different materials that are bonded together. They are also called laminated composites or laminates. A laminate usually consists of two or more layers of planar composites in which each layer (also called lamina or ply) may be of the same or different materials. Similarly, a sandwich laminate is a composite construction in which a metallic or composite core layer is sandwiched between two metallic or composite face layers. The composite face layers may also be in the form of laminates. Laminated and sandwich composite structures are very strong and stiff, and are commonly recommended for lightweight structural applications. In materials science, Composite laminates are assemblies of layers of fibrous composite materials which can be joined to provide required engineering properties, including in-plane stiffness, bending stiffness, strength, and coefficient of thermal expansion.

The individual layers consist of high-modulus, high-strength fibers in a polymeric, metallic, or ceramic matrix material. Typical fibers used include graphite, glass, boron, and silicon carbide, and some matrix materials are epoxies, polyimides, aluminium, titanium, and alumina.

Layers of different materials may be used, resulting in a hybrid laminate. The individual layers generally are orthotropic (that is, with principal properties in orthogonal directions) or transversely isotropic (with isotropic properties in the transverse plane) with the laminate then exhibiting anisotropic (with variable direction of principal properties), orthotropic, or quasi-isotropic properties. Quasi-isotropic laminates exhibit isotropic (that is, independent of direction) inplane response but are not restricted to isotropic out-of-plane (bending) response. Depending upon the stacking sequence of the individual layers, the laminate may exhibit coupling between inplane and out-of-plane response. An example of bending-stretching coupling is the presence of curvature developing as a result of in-plane loading.