Building Materials

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Bricks and stones

Brick

Composition of Good Brick Earth

Following are the constituents of brick earth:

1. Alumina

It is the chief constituent of every kind of clay. A good brick earth should contain about 20 to 30 per cent of alumina. This constituent imparts plastici y to earth so that it can be moulded.

2. Silica

- A good brick earth should contain about 50 to 60 per cent of silica. Presence of this constituent prevents cracking, shrinking and warping of raw bricks. It thus imparts uniform shape to the bricks.
- Excess of silica destroys the cohesion between particles and bricks become brittle.

3. Lime

- It should be present in a finely powdered state and not in lump.
- Lime prevents shrinkage of raw bricks. Sand alone is infusible. But it slightly fuses at kiln temperature in presence of lime.
- Excess of lime causes the brick to melt and hence, its shape is lost. Lumps of lime are converted into quick lime after burning and this quicklime slakes and expands in presence of moisture.

4. Oxide of Iron

- About 5 to 5 per cent is desirable in good brick earth. It helps lime to fuse sand. It also imparts red color to bricks.
Excess of oxide of iron makes the bricks dark blue or blackish

5. Magnesia

A small quantity of magnesia in brick earth imparts yellow tint color to bricks and decreases shrinkage. But excess of magnesia leads to the decay of bricks.

Harmful Ingredients in Brick Earth

1. Lime

- It causes unsoundness in brick if present in excess amounts.

2. Iron pyrites

- If iron pyrites are present in brick earth, bricks are crystallized and disintegrated during burning.

3. Alkalies

These are mainly in the form of soda and potash

4. Pebbles

The presence of pebbles or grits of any kind is undesirable in brick earth because it will not allow the clay to be mixed uniformly and thoroughly which will result in weak and porous bricks.

5. Organic Matter

Presence of organic matter in brick earth assists in burning. But if such matter is not completely burnt, bricks become porous.

Manufacture of bricks

1. Preparation of clay

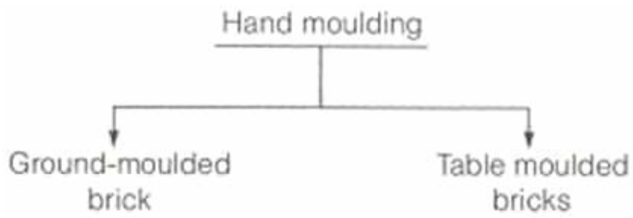
Clay of bricks is p epared in the following order:

i. Unsoiling
ii. Digging
iii. Cleaning
iv. Weathering
v. Blending
vi. Tempering

2. Moulding

Hand Moulding

- Machine Moulding



- Plastic Clay Machine
- Dry Clay Machine

3. Drying

4. Burning: Burning of bricks is done either in clamps or in kilns.

(a) Clamps: Its shape in plan is generally trapezoidal. Floor of clamp is prepared in such a way that short end is slightly in the excavation and wider end is raised at an angle of about 15° from ground level.

(b) Kilns: A kiln is a large over which is used to burn bricks. The kilns which are used in the manufacture of bricks are of the following two types.

(i) Intermittent kilns (ii) Continuous kilns

(i) Intermittent Kiln: This may be over ground or underground they are classified in two ways: (a) intermittent up-drought kilns, (b) Intermittent down-drought kilns

Comparison between bull's trench kiln and Hoffman's kiln

No. item	Bull's trench kiln	Hoffman's kiln
1. Burning capacity	About 3 lakhs in 12 days	About 40 lakhs in one season
2. Continuity of working	It stops functioning during monsoon as it is not provided with a permanent roof	It functions all the year with a permanent roof
3. Cost of fuel	High as consumption of fuel is more	Low
4. Drying space	It requires more space	It requires less space
5. Initial cost	Low	High
6. Nature	It is semi-continuous in loose sense	It is continuous is nature
7. Popularity	More popular because of less initial cost	Less popular because of high initial cost
8. Quality of bricks	Percentage of good quality brick is small	Percentage of good quality bricks is more.

Comparison between clamp Burning and kiln Burning

No. item	Clamp-burning	Kiln burning
1. Capacity	About 2000-100000	Avg. 25000
2. Cost of fuel	Low as grass, cow dung, litter may be used	High because of coal dust is to be used
3. Initial cost	Very low as no structures are to be built	More as permanent structures are to be constructed
4. Quality of bricks	The percentage of good quality bricks is small about 60%	Percentage of good quality bricks is high 90%
5. Regulation of fire	It is not possible to control or regulate fire during the process of burning	The fire is under control throughout the process of burning
6. Skilled supervision	Not necessary throughout the process of burning	The continuous skilled supervision is necessary
7. Structure	Temporary structure	Permanent structure
8. Suitability	For small scale	For large scale
9. Time of burning and cooling	It requires about 2-6 months	Actual burning times is 24 hr. and 12 days are required for cooling of bricks

Tests For Bricks

1. Absorption

- A brick is taken and it is weighted dry. It is then immersed in water for a period of 16 hours.
- Then weight again and the difference in weight should not, in any case, exceed
  (a) 20 per cent of weight of dry brick for first class bricks.
  (b) 22.5 per cent for second class bricks.
  (c) 25 per cent for third class bricks.

2. Crushing strength

- Minimum crushing strength for first class bricks $\not< 10N/mm^2$ and for second class bricks $\not< 7.5N/mm^2$

3. Hardness

In this test, a scratch is made on brick surface with the help of a finger nail. If no impression is left on the surface, brick is treated to be sufficiently hard.

4. Presence of soluble salts

- Soluble salts, if present in bricks, will cause efflorescence on the surface of bricks.

- It is immersed in water for 24 hours. It is then taken out and allowed to dry in shade. Absence of grey or white deposits on its surface indicates absence of soluble salts.
- If the white deposits cover about 10% surface, the efflorescence is said to be slight.
- When white deposits cover about 50% of surface thin it is said to be moderate.
- If grey or white deposits are found on more than 50% of surface, the efflorescence becomes heavy and it is treated as serious.

5. Shape and Size

- Its shape should be truly rectangular with sharp edges.
- 20 bricks are randomly selected of standard (19 × 9 × 9 cm) for good quality bricks, the results should be within the following permissible limits:
  Length – 368 cm to 392 cm
  Width – 174 cm to 186 cm
  Height – 174 to 186 cm

6. Soundness

- In this test, two bricks are taken and they are struck with each other.
- Bricks should not break and clear ringing sound should be produced.

7. Structure

- It should be homogenous compact and free from any defects such as holes, lumps, etc.
- High duty fire clays can resist temperature range of 1482°C to 1648°C; medium du y fi e-clays can resist temperature range of 1315°C to 1482°C and low duty fire-clays can resist temperature up to 870°C only.

Quality of Good Bricks

- The bricks should be table-moulded, well burnt in kilns, copper-coloured free from cracks and with sharp and square edges.
- The bricks should be uniform in shape and should be of standard size.
- The bricks should give a clear metallic ringing sound when struck with each other.
- The bricks when broken or fractured should show a bright homogeneous and uniform compact structure free from voids.

- The brick should be sufficiently hard. No impression should be left on brick surface, when it is scratched with finger hail.
- The bricks should not break into pieces when dropped flat on hard ground from a height of about one meter.
- The bricks, when soaked in water for 24 hour should not show deposits of white salts when allowed to dry in shade.
- No brick should have the crushing strength below 5.50 N/MM^2.

Classification of Bricks

The bricks can broadly be divided into two categories:

1. Unburnt Bricks: The unburnt or sun dried bricks are dried with the help of heat received from the sun after the process of moulding. These bricks can only be used in the construction of temporary and cheap structures. Such bricks should not be used at places exposed to heavy rains.

2. Burnt Bricks: These are classified in four categories:

i. **First Class Bricks**
   - These bricks are table-moulded and of standard shape and they are burnt in kilns.
   - The surfaces and edges of the bricks are sharp square smooth and straight.
   - First class bricks have all qualities of good bricks.
   - These bricks are used for superior work of permanent nature.

ii. **Second Class Bricks**
   - These bricks are ground moulded and they are burnt in kilns.
   - The surface of these bricks is somewhat rough and shape is also slightly irregular.
   - These bricks are commonly used at places where bricks work is to be provided with a coat of plaster.

iii. **Third Class Bricks**
   - These are ground moulded and they are burnt in clamps.
   - These bricks are not hard and they have rough surface with irregular and distorted edges.
   - These bricks gives dull sound when struck together.
   - They are used for unimportant and temporary structures.

Size and Weight Of Bricks(For India)

- Standard size of bricks is 19 cm × 9 cm × 9 cm

- Normal size (with mortar) is 20 cm × 10 × 10 cm.
- The commonly adopted nominal size of traditional bricks is 23 cm × 11.4 cm × 7.6 cm.
- It is found that the weight of 1 m^3 of bricks earth is about 1800 kg. Hence the average weight of a brick will be about 3 to 3.50 kg.

Shape of Bricks

1. Bulinose Brick

- A brick moulded with a rounded angle is termed as a bulinose. It is used for a rounded quoin.
- A connection which is formed when a wall takes a turn is known as quoin.

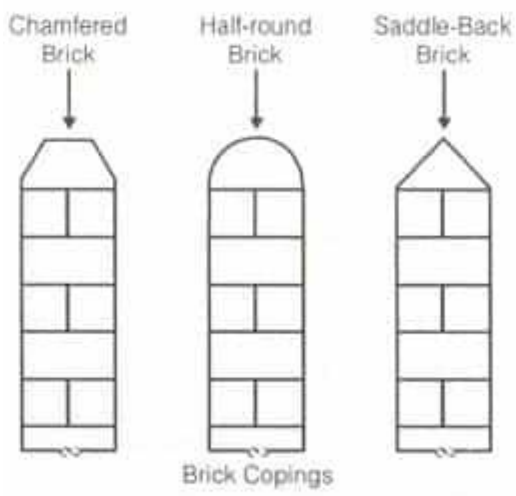
Bullnose Brick

2. Channel Bricks

- These bricks are moulded to the shape of a gutter or a channel and they are very often glazed.
- These bricks are used to function as drain.

3. Coping bricks

- These bricks are made to suit the thickness of walls on which coping is to be provided.
- Such bricks take various forms such as chamfered half-round or saddle-back.



4. Cownose Bricks

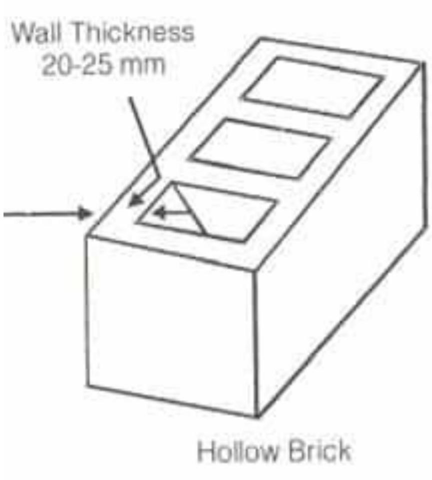
- A brick moulded with a double bulinose on end is known as cownose.

5. Curved Sector Bricks

- These bricks are in the form of curved sec or and they are used in the construction of circular brick masonry pillars, brick chimneys.
- The perforation may be circular, square, rectangular or any other regular shape in cross-section.
- The water absorption after immersion for 24 hour in water should not exceed 15% by water
- Compressive strength of perforated bricks should not be less than 7 N/mm^2 on gross area.

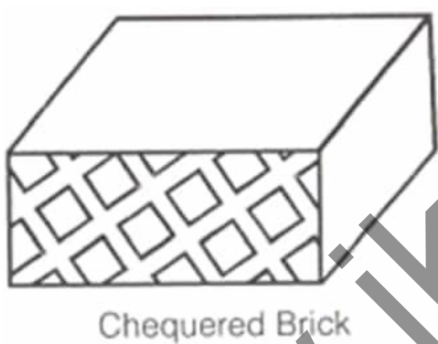
6. Hollow Bricks

- These are al o known as cellular or cavity bricks. Such bricks have wall thickness of about 20 mm to 25 mm. They are prepared from special homogeneous clay. They are light in weight about one third the weight of the ordinary bricks of the same size. The use of such bricks leads to speedy construction. They also reduce the transmission of heat, sound and damp. They are used in the construction of brick partitioning.



7. Paving bricks

- These bricks are prepared from clay containing a higher percentage of iron. Excess iron vitrifies the bricks at a low temperature. Such bricks resist better the abrasive action of traffic. Paving bricks may be plain or checkered.



8. Perforated Bricks

- Perforated bricks are used in the construction of brick panels for lightweight structures and multi-storeyed framed structures.

STONES

1.GENERAL CLASSIFICATION OF STONES

The building stones are obtained form rocks which as classified in following three ways.

1. Geological classification
2. Physical classification
3. Chemical classification

1.1. Geological classification

(i) Igneous rocks is formed by the cooling of molten magma

Example :- Plutonic rocks – Granite

Hypabyssal rocks – dolerite

Volcanic rocks – Basalt

(ii) Sedimentary rocks are formed by the deposition of products of weathering on pre-existing rocks. residual deposits, sedimentary deposits, chemical deposits and organic deposits are the type of sedimentary deposits.

Example :- Gravel, sandstone, limestone, gypsum etc

(iii) Metamorphic rocks are formed by the change in character in pre-existing rocks.

Example :- quartzite anthracite.

1.2. Physical classification

Based on general structure of rock.

(i) Stratified rocks :- It possesses plane of stratification. The sedimentary rocks are distinctly stratified rocks.

(ii) Unstratified rocks :- The structure may be crystalline granular or compact granular.

(iii) Foliated Rocks :– It is a very common case of metamorphic rocks.

1.3. Chemical classification

(i) Siliceous Rocks- Silica Predominates.

Example :- Granite, Quartzites

(ii) Argillaceous Rocks- Argil or clay predominates

Example :- Slates, laterites

(iii) Calcareous Rocks- Carbon Predominates.

Example :- Limestone, Marble.

2.TESTS FOR STONE

2.1. Acid Test

In the test, a sample of stone weighing about 0.5N to 1N is tak n and placed in a solution of hypo chloric acid having strength of one percent for seven days. The solution is agitated at intervals. A good building stone maintains its sharp edges.

2.2. Attrition test

Test is conducted to find out the wear of stones which are used in road construction. The results of the test indicate the resisting power of stones against grinding action under traffic.

2.3. Crushing Test

The compressive strength of stone is found out with test. The sample of stone cut into cubes of size 40mm × 40mm × 40mm are used.

2.4. Crystallization Test

In this test, four cubes of sid 40mm are taken and dried for 72 hours and weighed. They are then 14% solution of Na_2SO_4 for 2 hrs and dried at 100°C. The difference in weigh is noted and each time difference is noted in on at least 5 samples.

2.5. Freezing and thawing test

The specimen of stone is kept immersed in water for 24 hours and the placed at a freezing temperature of —12ºC for 24 hours. It is then thawed or warmed at atmospheric temperature.

2.6. Hardness Test

A cylinder of diameter 25 mm and height 25 mm is taken and weighed. It is placed in Dorry's testing machine and pressed at a pressure of 12.5 N. The disc of machine is rotated at a speed of 28 rpm. During the rotation of disc the coarse and sand of standard specification it sprinkled on top of disc. After 1000 revolutions, specimen is taken and weighed.

2.7. Microscopic Test

In this test, a sample of stone is subjected to microscopic examination for various properties such as average grain size, existence of pores, fissures mineral constituents and texture of stone.

3.QUALITIES OF GOOD BUILDING STONE

(i) For a good structural stone, the crushing strength should be greater than 100 N/mm^2.

(ii) The stones to be used for work should be decen in appearance and be capable of preserving their color for a long time.

(iii) A good building stone should be dur ble

(iv) The stones should be such that they can be easily conserved, moulded cut and dressed.

(v) For a good building ston , its fracture should be sharp even bright and clear with grains.

(vi) The coefficient of hardness worked out in hardness test should be greater than π to be used in road work.

(vii) If the wear in the attrition test is more than 3 percent, the stone is not satisfactory.

(viii) For a good building stone, its specific gravity should be greater than 2.7 or so

(ix) All stones more or less porous, percentage absorption by weight after 24 hours should not exceed 0.6

(x) A good building stone should have compact fine cry stalling structure free from patches.

Cement

Introduction

- Cement is an extreme ground material having adhesive and cohesive properties which provide a binding medium for the discrete ingredients.
- The processes used for the manufacture of cement can be classified as dry and wet.
- In the wet process, the limestone brought from the quarries is first crushed to smaller fragments. Then, it is taken to a ball or tube mill where it is mixed with clay or shale as the case may be and ground to a fine consistency of slurry with the addition of water. The slurry is stored in tanks under constant agitation and fed into huge firebrick lined rotary kilns.
- In the dry process, the raw materials are ground, mixed and fed to the rotary kiln in the dry state.

Chemical Composition

- The identification of the major complex compounds is largely based on R.H. Bougue's work and hence these are called Bougue's compounds.

Constituents	Percentage	Average
Lime (CaO)	60 to 67%	63
Silica (SiO_2)	17 to 25%	20
Alumina (Al_2O_3)	3 to 8 %	6
Iron oxide (Fe_2O_3)	0.5 to 6%	3
Magnesia (MgO)	0.1 to 4%	2
Sulphur Trioxide (SO_3)	1 to 3%	1.5
Soda and Potash ($Na_2O + K_2O$)	0.5 to 1.3%	1

Bogue's Compounds

- **Bogues Compounds when** water is added to cement it react with the ingredients of the cement chemically & results in the formation of complex chemical compounds terms as BOGUES compounds. which are not for simultaneously.

- **Tri-Calcium Aluminate ($3CaO.Al_2O_3$ or C_3A) ------------------------8-12%**
- **Tetra Calcium Alumino Ferrate ($4CaO.Al_2O_3.Fe_2O_3$ or C_4AF)----6-10%**
- **Tri-Calcium Silicate ($3CaO.SiO_2$ or C_3S)---------------------------------30-50%**
- **Di-Calcium Silicate ($2CaO.SiO_2$ or C_2S)--------------------------------- 20-45%**

1. Tri-Calcium Aluminate ($3CaO.Al_2O_3$ or C_3A)

- Formed in 24 hrs of addition of water
- Max. evolution of heat of hydration
- check setting time of cement

2. Tetra Calcium Alumino Ferrate ($4CaO.Al_2O_3.Fe_2O_3$ o C4AF)

- Formed within 24 hrs of addition of water
- High heat of hydration in initial periods

3. Tri-Calcium Silicate ($3CaO.SiO_2$ or C_3S)

- Formed within week
- Responsible for initial strength of cement
- Contribute about 50-60% of strength
- Content increase for the pre fabricated concrete construction, Cold weathering construct on.

4. Di-Calcium Silicate (2CaO SiO2 or C2S)

- Last compound formed during hydration of cement
- responsible for progressive later stage strength
- Structure requires later stages strength proportion of this component increa e
- e g hydraulic structures, bridges.

Type of Cements

i. Ordinary Portland Cement
ii. Rapid Hardening Cement – **IS: 8041-1990**
iii. Extra Rapid Hardening Cement
iv. Low Heat Portland Cement - **IS: 12600-1989**

v. Portland Slag Cement – **IS: 455-1989**
vi. Portland Pozzolana Cement – **IS: 1489-1991 (Part 1 and 2)**
vii. Sulphate Resisting Portland Cement – **IS: 12330-1988**
viii. White Portland Cement – **IS: 8042-1989**
ix. Coloured Portland Cement - **IS: 8042-1989**
x. Hydrophobic Cement - **IS: 8043-1991**
xi. High Alumina Cement - **IS: 6452-1989**
xii. Super Sulphated Cement - **IS: 6909-1990**
xiii. Special Cements
   a. Masonry Cement
   b. Air Entraining Cement
   c. Expansive Cement
   d. Oil Well Cement

In addition to ordinary portland cement there are many varieties of cement. Important varieties are briefly explained below:

(***i***) **White Cement:** The cement when made free from colouring oxides of iron, maganese and chlorium results into white cement. In the manufacture of this cement, the oil fuel is used instead of coal for burning. White cement is used for the floor finishes, plastering, ornamental works etc. In swimming pools white cement is used to replace glazed tiles. It is used for fixing marbles and glazed tiles.

(***ii***) **Coloured Cement:** The cements of desired colours are produced by intimately mixing pigments with ordinary cement. The chlorium oxide gives green colour. Cobalt produce blue colour. Iron oxide with different proportion produce brown, red or yellow colour. Addition of manganese dioxide gives black or brown coloured cement. These cements are used for giving finishing touches to floors, walls, window sills, roofs etc.

(***iii***) **Quick Setting Cement**: Quick setting cement is produced by reducing the percentage of gypsum and adding a small amount of aluminium sulphate during the manufacture of cement. Finer grinding also adds to quick setting property. This cement starts setting within 5 minutes after adding water and becomes hard mass within 30 minutes. This cement is used to lay concrete under static or slowly running water.

(***iv***) **Rapid Hardening Cement:** This cement can be produced by increasing lime content and burning at high temperature while manufacturing cement. Grinding to very fine is also necessary. Though the initial and final setting time of this cement is the same as that of portland cement, it gains strength in early days. This property helps in earlier removal of form works and speed in construction activity.

(***v***) **Low Heat Cemen**t: In mass concrete works like construction of dams, heat produced due to hydration of cement will not get dispersed easily. This may give rise to cracks. Hence in such constructions, it is preferable to use low heat cement. This cement contains low percentage (5%) of tricalcium aluminate (C_3A) and higher percentage (46%) of dicalcium silicate (C_2S).

(***vi***) **Pozzolana Cement**: Pozzolana is a volcanic power found in Italy. It can be processed from shales and certain types of clay also. In this cement pozzolana material is 10 to 30 per cent. It can resist action of sulphate. It releases less heat during setting. It imparts higher degree of water tightness. Its tensile strength is high but compressive strength is low. It is used for mass concrete works. It is also used in sewage line works.

(***vii***) **Expanding Cement:** This cement expands as it sets. This property is achieved by adding expanding medium like sulpho aluminate and a stabilizing agent to ordinary cement. This is used for filling the cracks in concrete structures.

(***viii***) **High Alumina Cement:** It is manufactured by calcining a mixture of lime and bauxite. It is more resistant to sulphate and acid attack. It develops almost full strength within 24 hours of adding water. It is used for under water works.

(***ix***) **Blast Furnace Cement:** In the manufacture of pig iron, slag comes out as a waste product. By grinding clinkers of cement with about 60 to 65 per cent of slag, this cement is produced. The properties of this cement are more or less same as ordinary cement, but it is cheap, since it utilise waste product. This cement is durable but it gains the strength slowly and hence needs longer period of curing.

(***x***) **Acid Resistant Cement:** This cement is produced by adding acid resistant aggregated such as quartz, quartzite, sodium silicate or soluble glass. This cement has good resistance to action of acid and water. It is commonly used in the construction of chemical factories.

(***xi***) **Sulphate Resistant Cement:** By keeping the percentage of tricalcium aluminate C_3A below five per cent in ordinary cement this cement is produced. It is used in the construction of structures which are likely to be damaged by alkaline conditions. Examples of such structures are canals, culverts etc.

(***xii***) **Fly Ash Blended Cement:** Fly ash is a byproduct in thermal stations. The particles of fly ash are very minute and they fly in the air, creating air pollution problems. Thermal power stations have to spend lot of money to arrest fly ash and dispose of safely.

It is found that one of the best way to dispose fly ash is to mix it with cement in controlled condition and derive some of the beneficiary effects on cement. Now-a-days cement factories produce the fly ash in their own thermal stations or borrow it from other thermal stations and further process it to make it suitable to blend with cement. 20 to 30% fly ash is used for blending.

Field Tests For Cement

- **Colour:** Grey colour with a light greenish shade.
- **Physical Properties:** Cement should feel smooth when touched between fingers.
- If hand is inserted in a bag or heap of cement, it should feel cool.
- If a small quantity of cement is thrown in a bucket of water, it should sink and should not float on the surface.
- **Presence of lumps:** Cement should be free from lumps.
- **Permissible Limits for Impurities in Water**

Impurity	Permissible Limits
Organic	200 mg/L
Inorganic	3000 mg/L
Sulphates (SO_3)	400 mg/L
Chlorides (CI)	2000 mg/L for plain concrete work, 500 mg/L for reinforced concrete work
Suspended matter	2000 mg/L

Laboratory Tests For Cement

1. Chemical Composition Test

- Ratio of percentage of lime to percentage of silica, alumina and iron oxide known as Lime Saturation Factor (LSF), when calculated by the formula shall not be greater than 1.02 and not less than 0.66.

$$\frac{CaO - 07SO_3}{(28SiO_2 + 12Al_2O_3 + 0.65Fe_2O_3)}$$

- Ratio of percentage of alumina (al_2O_3) to that of iron oxide (Fe_2O_3) shall not be less than 0.66
- Weight of insoluble residue shall not be more than 4 per cent.
- Weight of Magnesia Shall not be more than 6 per cent
- Total loss on ignition shall not be more than 5 per cent.
- Total sulphur content calculated as sulphuric anhydride shall not be more than 2.5% when C_3A is 5% or less and shall not be more than 3% when C_3A is more than 5%

2. Normal Consistency Test

- The normal (standard) consistency of a cement paste is defined as that consistency which will permit a Vicat plunger having 10 mm diameter and 50 mm length to penetrate a depth of 33 to 35 mm from the top (or 5 to 7 mm from the bottom) of the mould.
- **Vicat Apparatus:** Vicat apparatus assembly consists of a plunger 300 gm in weight with a length of 50 mm and diameter of 10 mm and a mould which is 40 mm deep and 80 mm in diameter.

3. Initial Setting Time Test

When water is added to cement, the resulting paste starts to stiffen and gain strength and lose the consistency simultaneously. The term setting implies solidification of the plastic cement paste. Initial and final setting times may be regarded as the two stiffening states of the cement. The beginning of solidification, called the initial set, marks the point in time when the paste has become unworkable

- Initial setting time should not be less than 30 minutes for OPC and 60 minutes for low heat cement.

4. Final Setting Time Test

The final setting time is the time after which the paste becomes so hard that the angular attachment to the needle, under standard weight, fails to leave any mark on the hardened concrete. Initial and final setting times are the rheological properties of cement.

- The final setting time should not be more than 10 hours.

5. Soundness Test

- The soundness of cement is determined either by 'Le Chatelier's method' or by means of a 'Autoclave' test.
- No satisfactory test is available for deduction of soundness due to excess of calcium sulphate. But its content can be easily determined by chemical analysis.
- Le Chatelier's Method
- Autoclave Test

6. Strength Test

(a) Compressive Strength Test

- Three cubes are tested for compressive strength at 1 day, 3 day, 7 days and 28 day where the period of testing being reckoned from the completion of vibration.
- The compressive strength shall be the average of the strengths of the three cubes for each period respectively.
- The compressive strength of 33 grade OPC at 3 day and 28 day is 16 MPa, 22 MPa and 33 MPa respectively.

(b) Tensile Strength Test

- Six briquettes are tested and average tensile strength is calculated.
- A load is applied steadily and uniformly, starting from zero and increasing at the rate of 0.7 N/mm^2 in 12 seconds.
- OPC should have a tensile strength of not less than 2 MPa and 2.5 MPa after 3 and 7 days respectively.
- Generally, tensile strength is 10-15% of compressive strength.

7. Fineness Test: There are three methods for testing fineness viz.

(a) Sieve Method

- 100 gm of cement sample is taken and air set lumps, if any, in the sample are broken with fingers.
- The sample is placed on a 90 micron sieve and continuously sieved for 15 minutes.
- The residue should not exceed the limits specified below:

	Type of cement	% Residue by weight
(i)	Ordinary Portland cement	10
(ii)	Rapid hardening cement	5
(iii)	Portland Pozzolana cement	5

(b) Air Permeability Method

- Fineness of cement is represented by specific surface i.e. total surface area in cm^2 per gram of cement.

(c) Wagner Turbidimeter Test

- The cement is dispersed uniformly in a rectangular glass tank filled with kerosene.
- Parallel light rays are passed through the solution which strike the sensitivity plate of a photoelectric cell.

8. Heat of hydration Test

- The apparatus used to determine the heat of hydration of cement is known as **calorimeter**.
- The heat of hydration for low heat Portland cement should not be more than 66 and 75 cal/gm for 7 and 28 days respectively.

9. Specific Gravity Test

- The specific gravity of cement is obtained by using **Le Chatelier's flask**.

Uses of Cement

Cement is used widely for the construction of various structures. Some of them are listed below:

(i) A cement slurry is used for filling cracks in concrete structures.

(ii) Cement mortar is used for masonry work, plastering and pointing.

(iii) Cement concrete is used for the construction of various structures like buildings, bridges. water tanks, tunnels, docks, harbours etc.

(iv) Cement is used to manufacture lamp posts, telephone posts, railway sleepers, piles etc.

(v) For manufacturing cement pipes, garden seats, dust bins, flower pots etc. cement is commonly used.

(vi) It is useful for the construction of roads, footpaths, courts for various sports etc.

Concrete

Corrosion steel in concrete

The term corrosion is used to indicate the conversion of metals by natural agencies into various compounds. The term rusting is used to refer corrosion of ferrous metals.

Theories of Corrosion

1. Chemical Action Theory

$$Fe + O + 2CO_2 + H_2O = Fe(HCO_3)_2 \quad ...(i)$$
$$2Fe(HCO_3)_2 + O = 2Fe(OH)CO_3 + 2CO_2 + H_2O \quad ...(ii)$$
$$Fe(OH)CO_3 + H_2O = Fe(OH)_3 + CO_2 \quad ...(iii)$$

- The combined action of oxygen, carbon dioxide and moisture on steel results in soluble ferrous bicarbonate $Fe(HCO_3)_2$. This ferrous bicarbonate is then oxidized to basic ferric carbonate $2Fe(OH)CO_3$. This basic ferric carbonate is converted into hydrated ferric oxide $Fe(OH)_3$ (final product) and carbon dioxide is liberated.

Electrolytic Theory According to this theory, metal contains anodic and cathodic areas and these areas, when connected by electrolytes such as water, moisture; aqueous solutions, etc. cause corrosion.

Causes of Corrosion

i. Congested reinforcement in small concrete sections.
ii. Excessive water-cement ratio.
iii. Improper construction methods.
iv. Inadequate design procedure.
v. Insufficient cover to steel from exposed concrete surface.

vi. Presence of moisture in concrete.
vii. Presence of salts.

Effect of Corrosion

Important effect of corrosion is the formation of cracks and these cracks usually progress or advance most rapidly where shearing stresses are the greatest and where slipping occurs due to loss of bond.

Water-cement Ratio

Important properties of water to be used for cement concrete are

- Content of organic solids not more than 0.02%
- Content of inorganic solids not more that 0.30%
- Content of sulphates not less than 0.05%
- Content of sulphate alkali chlorides not more than 10%
- Turbidity not more than 2000 ppm.
- Acid not more than 10,000 ppm.
- pH should be between 4.5 to 8.5.

Bleeding of Concrete

If excess water in the mix comes up at the surface causing small pores through the mass of concrete, it is called bleeding. **Bleeding** is one form of segregation, where water comes out to the surface of the **concrete**, being lowest specific gravity among all the ingredients of **concrete**. **Bleeding** can be easily identified in the field by the appearance of a thin layer of water in the top surface of freshly mixed concrete

Segregation

Segregation in **concrete** is a case of particle **segregation** in **concrete** applications, in which particulate solids tend to **segregate** by virtue of differences in the size, density, shape and other properties of particles of which they are composed.

It is caused when coarse aggregate is separated out from the finer materials resulting in large voids, less durability and less strength.

Some rules-of-thumb are developed for deciding the quantity of water in concrete.

- Weight of water = 28% of the weight of the cement + 4% of the weight of total aggregate.
- Weight of water = 30 % of the weight of the cement + 5% of the weight of total aggregate.

Workability of Concrete

- Workability is the amount of work to produce full compaction.
- The important facts in connection with workability are:

(i) If more water is added to attain the required degree of workman hip, t results into concrete of low strength and poor durability.

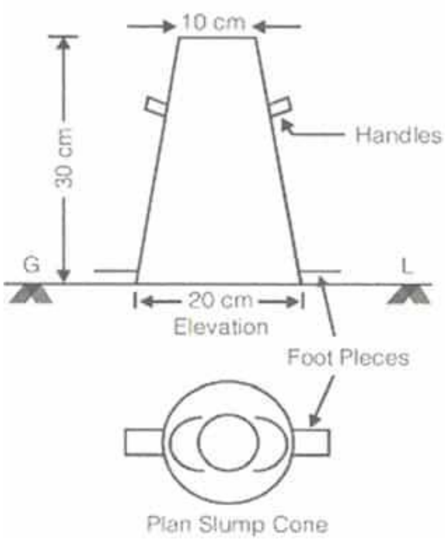
(ii) If the strength of concrete is not to be affected, the degree of workability can be obtained:

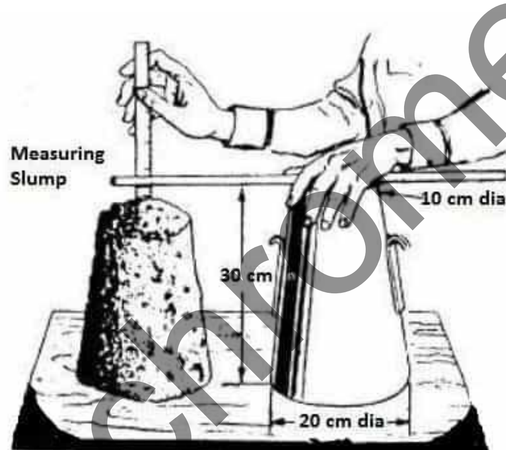
- by slightly changing the proportions of fine and oarse aggregates, in case the concrete mixture is too we; and
- by adding a small quantity of water cement paste in the proportion of original mix, in case the concrete mixture s too dry.

(iii) The workability of concrete is also affected by the maximum size of the coarse aggregates to be used in the mixture.

Slump Test

- Slump test is the most commonly used method of measuring consistency of concrete which an be employed either in laboratory or at site of work.
- It is not a suitable method for very wet or very dry concrete and stiff mix.
- It does not measure all factors contributing to workability.
- The diameter of the rod is 16 mm and its length is 60 cm. The strokes to be given for ramming vary from 20 to 30.





Recommended Slumps of Concrete

No.	Type of Concrete	Slump
1.	Concrete for road construction	20 to 40 mm
2.	Beams and slabs	50 to 100 mm
3.	Normal RCC work	80 to 150 mm
4.	Mass concrete	25 to 50 mm
5.	Concrete to be vibrated	10 to 25 mm
6.	Impermeable work	75 to 120 mm

Compaction Factor Test

- In the compaction factor test the degree of workability is measured in terms of internal energy required to compact the concrete thoroughly.
- A compaction factor of 0.95 represents flowing concrete having high workability; 0.92 plastic concrete having medium workability; 0.85 stiff

plastic concrete having low workability and a compaction factor of 0.75 represents stiff concrete having very low workability.

- The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field.
- The degree of compaction called the compacting factor is measured by the density ratio i.e., the ratio of the density actually achieved in the test to density of same concrete fully compacted.

Workability, Slump and Compacting Factor of Concrete with 20 mm or 40 mm Maximum Size of Aggregate

Degree of workability	Slump (mm)	Compacting factor		Use for which concrete is suitable
		Small apparatus	Large apparatus	
Very low	–	0.78	0.80	Roads vibrated by power-operated machines. At the more workable end of this group, concrete may be compacted in certain cases with hand-operated machines.
Low	25 – 75	0.85	0.87	Roads vibrated by hand-operated machines. At the more workable end of this group, concrete may be manually compacted in roads using aggregate of rounded or irregular shape. Mass concrete foundations without vibration or lightly reinforced sections with vibration.
Medium	50-100	0.92	0.935	At the less workable end of this group, manually compacted flat slabs using crushed aggregates. Normal reinforced concrete manually compacted and heavily reinforced sections with vibration.
High	100-150	0.95	0.96	For sections with congested reinforcement. Not normally suitable for vibration, for pumping and tremie placing.
Very high	–	–	–	Flow table test is more suitable.

Vee-Bee Test

- This is carried out in such a manner that the specimen concrete in the test receives more or less same treatment in respect of the method of placing as it would in actual execution of the work. This test is preferred for finding workability of stiff concrete mix having very low workability.
- In this test a Vee-Bee time of 5 to 3 seconds represent stiff plastic concrete having medium workability, 10 to 15 seconds represents stiff

concrete of low workability and Vee-Bee time to 18 to 10 seconds represent very stiff concrete having very low workability.

Vee Bee Consistometer

- This is a good laboratory test to measure indirectly the workability of concrete.
- This test consists of a vibrating table, metal pot, a sheet metal concrete a standard iron rod.
- The time required for the shape of concrete to change from slump concrete shape to cylindrical shape in second is known as Vee Bee Degree.
- This method is very suitable for very dry concrete whose slump value cannot be measured by slump test but the vibration is too vigorous for concrete with a slump greater than about 50 mm

Flow Test

- This is a laboratory test which gives an indication of the quality of concrete with respect to consistency cohesiveness and the proneness to segregation.
- The spread or the flow of the concrete is measured and this flow is related to workability.

$$Flow\ percent = \frac{\text{Spread diams in cm-25}}{25} \times 100$$

The value could range anything from 0-150%.

It can be realized that the compacting factor test measures the inherent characteristics of the concrete which relates very close to the workability requirements of concrete and as such it is one of the good test to depict the workability of concrete.

Estimating Yield of Concrete

- A rule-of-thumb as given below, may be used to find out the approximate yield of concrete from a given concrete mix.
- If the proportion of concrete is a: b: c, i.e., if a parts of cement, b parts of sand and c parts of coarse aggregates are mixed by volume, the resulting concrete will have a volume of 2/3 (a + b + c).

- Let w, a, b and c be absolute volumes of water, cement, fine aggregate and coarse aggregate respectively. Then, w + a + b + c = 1.

$$Absolute\ volume = \frac{\text{Weight of the materials}}{\text{Apparent sp. gr.} \times \text{Unit wt. of water}}$$

Methods for Proportioning Concrete Mixes

1. Minimum voids method

The quantity of sand used should be such that it completely fills the voids of the coarse aggregate and similarly the quantity of cement used should be such that it fills the voids of sand. However in actual practices the quant ty of sand used in the mix is kept 10% more than the voids in the coarse aggregate and the quantity of cement is taken 15% more than the voids in the sand.

2. Maximum density method

Method of minimum voids was later improved by Fuller. For maximum density of mix.

He gave following expression.

$$P = 100\left(\frac{d}{D}\right)^{1/2}$$

D = Maximum size of aggregate.

P = % by weight of matter finer than diameter d.

3. Abram's water-cement ratio law

- This law tates that for any given conditions of test the strength of workable concrete mix is dependent only on the water cement ratio. It means that if the concrete is fully compacted, the strength is not affected by aggregate shape, type or surface texture or the aggregate grading. According to this law, the strength of mix increases with decrease in water content.

- In terms of crushing strength after 7 days curing $P_7 = \frac{984}{7^x} kg / cm^2$ where P_7 is cylinder crushing strength in kg/cm^2 and x is water cement ratio by volume.
- In terms of crushing strength after 28 days curing $P_{28} = \frac{984}{7^x} kg / cm^2$ where P_{25} is cylinder crush strength after 28 days curing.
- Strength of concrete increases with age.

Months	Age factor
1	1.00
3	1.10
6	1.15
12	1.20

Mix Design

- When the task of deciding the proportion of the constituents of concrete is accomplished by use of certain established relationships (which are based on inferences drawn rom large number of experiments) the concrete thus produced is termed as Design mix concrete.
- When the proportions of cement, aggregate and water are adopted based on arbitrary standard the concrete produced is termed as Nominal mix concrete.
- Nominal mix concrete is used in works where the quality control requirement for design mixes are difficult to be implemented. Nominal mix concrete can be produced by taking cement, fine and coarse aggregate in the ratio of 1: n: 2n for normal work. However, the ratio of the coarse aggregate to fine aggregate can vary from 1.5: 2.5: 1 in situations where denser or more workable concrete is to be produced.

Aggregates Size

- For RCC work the maximum size of aggregates is limited to 20-25 mm.

- For a concrete of given workability rounded aggregates require least water cement ratio. Particle shape is very important since the water cement ratio governs greatly the strength of concrete.
  Coarse aggregates > 4.75 mm size.
  Fine aggregates < 4.75 mm size.

Fineness modulus

- The fineness modulus of an aggregate is an index number which is roughly proportional to the average size of the particles in the aggregate
  The coarser the aggregate, the higher the fineness modulus.
- Fineness modulus is obtained by adding the % of the weight of the material retained on the total 10 number of IS sieves (between 80 mm to 150 μm) and dividing it by 100.

Aggregate	Fineness modulus
Coarse aggregate	6 to 8.5 (in general 6.93)
Fine aggregate	2 to 3.5 (in general 3.05)
Mixed aggregate	4.7 to 7.0
Fine sand	2.2 to 2.6
Medium sand	2.6 to 2.9
Coarse sand	2.9 to 3.2

Vibrators: Following are the four types of vibrators:

1. **Internal Vibrators:** These vibrators consist of a metal rod which is inserted in fresh concrete. Skilled and experience men should handle internal vibrators. These vibrators are more efficient than other types of vibrators.
2. **Surface Vibrators:** These vibrators are mounted on platform or screeds. They are used to finish concrete surfaces such as bridge floors, road slabs, station platform, etc.
3. **Form Vibrators:** These vibrators are attached to the formwork and external centering of walls, columns, etc. The vibrating actions is conveyed to concrete through the formwork during transmission of vibrations. Hence they are not generally used. But they are very much helpful for concrete sections which are too thin for the use of internal vibrations.
4. **Vibrating Tables:** These vibrators are widely used for making precast products.
5. **Period of Curing:** The curing period is about 7 to 14 days.

Water-proofing Cement Concrete

- Cement concrete to a certain extent may be made impermeable to water by using hydrophobic cement.

Following are the three methods adopted for water-proofing of RCC flat roofs:

1. **Finishing:** For ordinary building of cheap construction, finishing of roof surface is done at the time of laying cement concrete. The finishing of flat roof is carried out in cement mortar of proportion 1: 4, i.e., one part of cement to four parts of sand by volume.
2. **Bedding Concrete and Flooring:** In this method, the surface of RCC slab is kept rough and on this surface, a layer of concrete is laid. The concrete may be brickbats lime concrete (1:2:4) or brickbats cement concrete (1:8:14). The thickness of the concrete layer is about 10 cm.
3. **Mastic Asphalt and Jute Cloth:** In this method, a layer of hot mastic asphalt is laid on the roof surface. Jute cloth is spread over this year.

Lightweight Concrete

The bulk density of ordinary concrete is about 2300 kg/m^3. Concrete having bulk density between 500 to 1800 kg/m^3 is known as lightweight concrete and it is prepared from the following materials:

1. **Binding material:** Ordinary Portland cement and its varieties can be used as binding material
2. **Aggregates:** For lightweight concrete, loose porous materials are used as aggregates.
3. **Steel:** Lightweight concrete is highly porous and hence, it leads to corrosion of reinforcement.

IS 456 Guidelines

For **Min. Cement Content**, **Min./Max.** Grade **of Concrete** & **Max. W/C Ratio** for **Plain** and **Reinforced** Cement Concrete **for Different Exposures** with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(Clauses 6.1.2, 8.2.4.1 and 9.1.2)

Sl No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	–	300	0.55	M 20
ii)	Moderate	240	0.60	M 15	300	0.50	M 25
iii)	Severe	250	0.50	M 20	320	0.45	M 30
iv)	Very severe	260	0.45	M 20	340	0.45	M 35
v)	Extreme	280	0.40	M 25	360	0.40	M 40

NOTES

1 Cement content prescribed in this table is irrespective of the grades of cement and it is inclusive of additions mentioned in 5.2. The additions such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and water-cement ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit of pozzolona and slag specified in IS 1489 (Part 1) and IS 455 respectively.

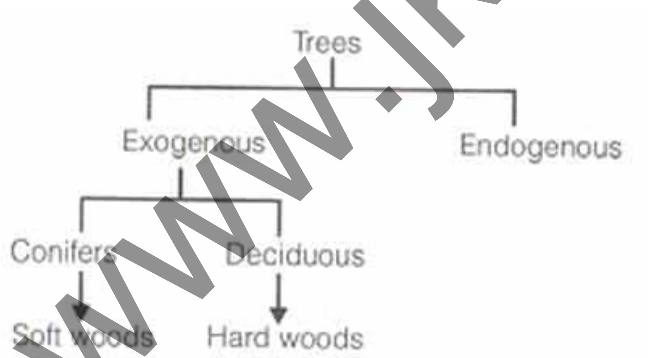
2 Minimum grade for plain concrete under mild exposure condition is not specified.

Timber, Lime and other materials

Timber

Classification of trees

- Trees are classified acc rding to their mode of growth. Following is the classification of t ees



1. Exogenous Trees

- Conifers are also known as evergreen trees and leaves of these do not fall till new ones are grown. As these bear cone-shaped fruits, they are given the name conifers. These trees yield soft woods.

- Deciduous trees are also known as broadleaf trees and leaves of these trees fall in autumn and new ones appear in spring season. Timber for engineering purposes is mostly derived from deciduous trees. These trees yield hard woods.

Comparison of Soft Wood and Hard Wood

No.	Item	Soft woods	Hard woods
1	Annual rings	Distinct	Indistinct
2	Colour	Light	Dark
3	Fire resistance	Poor	More
4	Medullary rays	Indistinct	Distinct
5	Strength	Strong for direct pull and weak for resisting thrust of shear	Equally strong for resisting tension, compression and shear
6	Structure	Resinous and split easily	Non-resinous and close-grained
7	Weight	Light	Heavy

2. Endogenous Trees

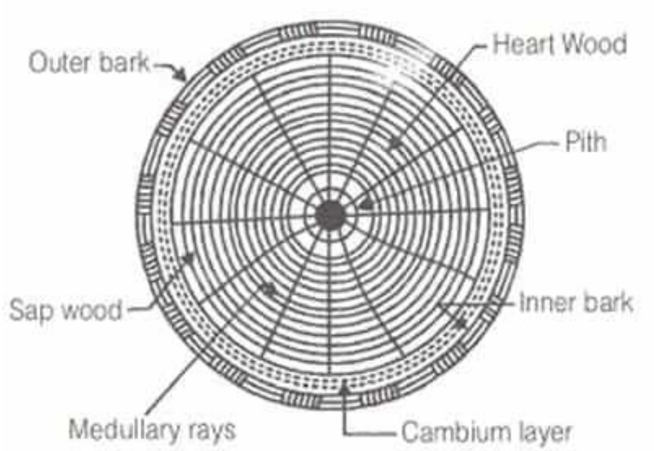
These trees grow inwards and fibrous mass is seen in their longitudinal sections. Timber from these trees has very limited engineering applications. Examples of endogenous trees are bamboo, cane palm etc.

STRUCTURE OF A TREE

From the visibility aspect the structure of a tree can be divided into two categories:

1. Macrostructure

- Pith: The innermost central portion or core of the tree is called the pith of medulla
- Hear Wood: The inner annual rings surrounding the pith is known as heart wood. t is usually dark in colour.



Cross-section of an exogenous tree

- Sap Wood: The outer annual rings between heart wood and cambium layer is known as sap wood.
- Cambium Layer: The thin layer of sap between ap wood and inner bark is known as cambium layer.
- Inner Bark: It gives protection of cambium layer from any injury.
- Outer Bark: It consists of cells of wood fibre and is also known as cortex.
- Medullary Rays: The thin radial fibres extending from pith to cambium layer are known as medullary rays.

2. Microstructure

- Wood consists of living and dead cells of various sizes and shapes.
- A living cell consist f four parts, namely (i) membrane, (ii) protoplasm (iii) sap (iv) core. Cell membrane consists mainly of cellular tissue and cellulose. Protoplasm is a granular, transparent viscous vegetable protein composed of carbon, hydrogen, oxygen nitrogen and sulphur. Core of cell differs from protoplasm merely by the presence of phosphorus and it is general y oval.
- **Age of trees for felling:** The age of good trees for felling varies from 50 to 100 years.
- **Season for felling:** In autumn and spring, sap is in vigorous motion and hence, felling of trees in these seasons should be avoided. For hilly areas, mid-summer would be the proper season for felling as there is heavy rainfall in winter. For plain areas, mid-winter would be the proper season for felling as in summer, water contained in sap would be easily evaporated and it will lead to the formation of cracks.

DEFECTS IN TIMBER

Defects occurring in timber are grouped into the following five divisions.

1. **Defect Due to Conversion**
   i. Chip mark
   ii. Diagonal grain
   iii. Torn grain
   iv. Wane
2. **Defects Due to Fungi**
   i. Blue Stain
   ii. Brown Rot
   iii. Dry Rot
   iv. Heart rot
   v. Sap Stain
   vi. Wet Rot
   vii. White Rot
3. **Defects Due to Insects**
   i. Beetles
   ii. Marine Borers
   iii. Termites
4. **Defects Due to Natural Forces**
   i. Burls
   ii. Callus
   iii. Chemical stain
   iv. Coarse grain
   v. Dead wood
   vi. Druxiness
   vii. Foxines
   viii. knots
   ix. Rind galls
   x. Shakes
   xi. Twisted fibres
   xi Upsets
   xiii. Water stain
   xiv. Wind cracks
5. **Defects Due to Seasoning**
   Follow defects occur in seasoning process of wood.
   i. Bow
   ii. Case-hardening
   iii. Check

iv. Collapse
v. Cup
vi. Honey-combing
vii. Radial shakes
viii. Split
ix. Twist
x. Warp

PRESERVATION OF TIMBER

Preservation of timber is carried out to achieve the following three objects:

- To increase the life of timber structures
- To make the timber structures durable, and
- To protect the timber structures from the attack of destroying agencies such as fungi, insects, etc.

Requirements of a Good Preservative

- It should allow decorative treatment on timber after being applied over timber surface.
- It should be capable of covering a large area with small quantity.
- It should be cheap and easily available.
- It should be free from unpleasant smell.
- Its penetrating power into wood fibres should be high. It is necessary for the preservative to be effective to penetrate at least for a depth of 6 mm to 25 mm.

Types of Preservatives

1. **Ascu Treatment**
    - Ascu is special preservative which is developed at the Forest Research Institute, Dehradun. Its composition is as follows.
    - X-Part by weight of hydrated arsenic pentoxide, ($As_2O_5.2H_2O$).
    - Y-Part by weight of blue vitriol or copper sulphate, ($CuSO_4.5H_2O$).
    - Z-Part by weight of potassium dichromate ($K_2Cr_2O_7$) or sodium dichromate ($Na_2Cr_2O_7.2H_2O$)
    - This preservative gives timber protection against the attack of white ants. The surface treated with this preservative can be painted, polished, varnished or waxed.
2. **Chemical Salts**

- These are water-borne preservatives and they are mostly salts dissolved in water. The usual salts used are copper sulphate, mercury chloride, sodium fluoride and zinc chloride.
- These preservatives are odourless and non-inflammable.

3. **Coal Tar**
   Its cheapness and effective resistance. Coal tar increases protection against the penetration of water and fire. But asthetic value of timber decreases.
4. **Creosote oil**
   In this case, timber surface is coated with creosote oil.
   - Creosote oil is one of the best antiseptic. It is a black or brown liquid, weakly affected by water, neither volatile nor hygroscopic, harmless to wood or metal, inflammable, with an unpleasant odour and having low wood-penetrating ability to the extent of 1 mm to 2 mm only.
   - Creosote oil should not be used for interior su faces of dwelling houses, foodstuff-storage premises, in underground installations and near inflammable surfaces.
5. **Oil Paints**
   - The timber surface is coated with 2 or 3 coats of oil paint.
   - The wood should be seasoned othe wise sap will be confined and if will lead to the decay of timber.
   - The oil paints preserve timber from moisture and make it durable.
6. **Solignum Paints**
   - These paints preserve timber from white ants as they are highly toxic in nature.
   - They can be mixed with colour pigment and applied in hot state with the help of brush
   - The timber surface may therefore be given the desired colour or appearance.

Method for Preservation

There are six Methods Adopted for Preservation of Timber:

1. **Brushing**
   - The solution prepared from preservative is applied on timber surface by good quality of brushes.
   - This is the simplest method and it is generally adopted for seasoned timber.
   - The crocks should be filled up before the application of preservative.
2. **Charring**

- The surface to be charred is kept wet for about half an hour and it is then burnt up to a depth of about 15 mm over a wood fire.
- The charred portion is then cooled with water.
- Due to burning, a layer of coal is formed on the surface.
- This layer is not affected by moisture and it is not attacked by white ants, fungi.
- The disadvantage of this method are:
  (i) The charred surface becomes black in appearance and hence it cannot be used for exterior work.
  (ii) There is some loss of strength of timber as the cross section is reduced due to charring.

3. **Dipping and Steeping**
   - In this method, the timber to be given preservative treatment is dipped or soaked for a short period in the solution of preservative.
   - This method gives slightly better penetration of preservative than in case of brushing or spraying.
4. **Hot and Cold Open Tank Treatment**
   - In this method, the timber is submerged in a tank containing solution of preservative which is heated for a few hours at temperature of $85^\circ C$ - $95^\circ C$.
   - Tank is then allowed to cool down gradually while the timber is still submerged in the tank.
   - This method is effective in giving protection to the sap wood.
5. **Injecting Under Pressure**
   This method proves to be essential for treating non-durable timbers which are to be used as places where there is danger of attack by fungi and insects.
6. **Spraying**
   - In this method the solution of preservative is filled in a spraying pistol and it is then applied on timber surface under pressure.
   - This method is also quite effective and it is superior than brushing.

FIRE RESISTANCE OF TIMBER

1. **Application of Special Chemicals**
   - It is found that two coats of solution of borax or sodium arsenate with strength of 2 per cent are quite effective in rendering the timber fire-resistant.
   - When the temperature rises, they either melt or give off gases which hinder or forbid combustion.

2. **Sir Abel's Process**
   In this process, timber surface is cleaned and it is coated with a dilute solution of sodium silicate. A cream-like paste of slaked fat lime is then applied and finally, a concentrated solution of silicate of soda is applied of the timber surface.

SEASONING OF TIMBER

1. **Object of Seasoning**
   - To allow timber to burn readily, if used as fuel.
   - To decrease the weight of timber and thereby to lower the cost of transport and handling.
   - To make timber safe from the attack of fungi and insects.
   - To reduce the tendency of timber to crack, shrink and warp.
   - To make timber fit for receiving treatment of paints, preservatives, varnishes.
   - To import hardness, stiffness, strength and better electrical resistance to timber.
2. **Methods of Seasoning**

(a) Natural Seasoning

In this method, the seasoning of timber is carried out by natural air and hence it is also sometimes referred to as air seasoning.

Advantage

- Depending upon the climatic conditions, the moisture content of ward can be brought down to about 10-20%
- It does not require skilled supervision
- This method of seasoning timber is cheap and simple.
- It is uneconomical to provide artificial seasoning to timber sections thicker than 100 mm, as such sections dry very slowly.

Disadvantage

- As the process depends on the natural air, it sometimes becomes difficult to control it
- The drying of different surface may not be even and uniform.
- If ends of thick sections of timber are not projected by suitable moisture proof coating, there are chances for end splitting.

(b) Artificial Seasoning

- Following are the reasons for adopting the artificial seasoning to the natural seasoning.

A. The defects such as shrinkage, cracking and warping are minimized.

B. The drying is controlled and there are practically no chances for the attack of fungi and insects.

C. The drying of different surface is even and uniform.

D. It considerably reduces the period of seasoning.

E. There is better control of circulation of air, humidity and temperature.

i. **Boiling**
   In this method of artificial seasoning, timber is immersed in water and water is then boiled. But it affects the elasticity and strength of wood.
ii. **Chemical seasoning**
   This is also known as salt seasoning. In this method, timber is immersed in a solution of suitable salt. It is then taken out and seasoned in the ordinary way.
iii. **Electrical seasoning**
   - In this method, use is made of high frequency alternating currents.
   - This is the most rapid method of seasoning.
   - Due to high cost this method is unecomonical.
iv. **Klin Seasoning**
   - In this method, drying of timber is carried out inside an airtight chamber or oven.
v. **Water Seasoning**
   - Timber pieces are immersed wholly in water, preferably in running water of a stream. Care should be taken to see that timber is not partly immersed.
   - Timber is taken out after a period of about 2 to 4 weeks. During this period, sap contained in timber is washed away by water.

Lime

Some Basic Definitions

1. **Calcination:** The heating of limestone to redness in contact with air is known as the calcinations.
2. **Hydraulicity:** It is the property of lime by which it sets or hardens in damp places, water or thick masonry walls where there is no free circulation of air.
3. **Quick Lime:** The lime which is obtained by the calcination of comparatively pure limestone is known as the quick lime or caustic lime. It is capable of slaking with water and has no affinity for carbonic acid.
   - Its chemical composition is (CaO) oxide of calcium an it has great affinity for moisture.
   - The quick lime as it comes out from kilns is known as the lump lime.
4. **Setting:** The process of hardening of lime after it has been converted into paste form is known as the setting. It is quite different from mere drying.

1. **Slaked Lime** The product obtained by slaking of quick lime is known as the slaked lime or hydrate of lime. It is in the form of white powder and its chemical composition is $Ca(OH)_2$ or hydrated oxide of calcium.

CaO	+	H_2O	→	$Ca(OH)_2$ + Heat
Quick Lime		water		(Hydrated Lime)

1. **Slaking:** When water is added to the quick lime in sufficient quantity a chemical reaction takes place.
   - Due to this chemical reaction the quick lime cracks, swell and falls into a powder form which is the calcium hydrate Ca $(OH)_2$ and it is known as the hydrated lime.
   - This process is known as the slaking.

Classification of Limes

1. **Fat Lime:** This lime is also known as the high calcium lime. Pure Lime, rich lime or white lime. It is popularly known as the fat lime as it slakes vigorously and its volume is increased to about 2-2-5 times the volume that of quick lime. The percentage of impurities in such limestone is less than 5%.
2. **Hydraulic Lime:** This lime is also known as the water lime as it sets under water. It contains clay and some amount of ferrous oxide. Depending upon the percentage of clay present the hydraulic lime is divided into following three types.

1. Feebly hydraulic lime
2. Moderately hydraulic lime
3. Eminently hydraulic lime

The hydraulic lime can set under water and in thick walls where there is no free circulation of air.

1. **Poor Lime:** This lime is also known as the impure or lean lime. It contains more than 30% of clay. It slakes very slowly.

Impurities in Limestones

1. **Magnesium carbonate**
    - The magnesium limestones are hard, heavy and compact in texture.
    - The magnesium limestones display irregular properties of calcination, slaking and hardening.
    - Upto 5% of magnesium oxide imparts excellent hydraulic properties to the lime.
2. **Clay**
    - It is mainly responsible for the hydraulic properties of lime.
    - The percentage of clay to produce hydraulicity in time stone usually varies from 10 to 30
    - Limes containing 3-5 per cent of clay do not display any hydraulic property and do not set and harden under water.
3. **Silica:** In its free form it has a detrimental effect of the properties of lime.
4. **Iron Compounds**
    - Iron occurs in small proportions as oxides, carbonates and sulphides.
    - Pyrite or iron sulphide is regarded to be highly undesirable.
    - For hydraulic limes 2-5 per cent of iron oxide is necessary.
5. **Sulphates:** Sulphates if present slow down the slaking action and increase the setting rate of limes.
6. **Alkalis:** When pure lime is required the alkalis are undesirable. However, up to 5 per cent of alkalis in hydraulic lime do not have any ill effect.

Mortar

Some Basic Definition

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

Bulking of Sand

- In the case of aggregates there is another effect of the presence of moisture viz. bulking which is an increase in the volume of a given mass of sand (fine aggregate) caused by the films of water pushing the sand particle apart. For a moisture content of about 5-8% this increase of volume may be as much as 20-40% depending upon grading of sand.
- Finer the materials more will be the increase in volume for a given moisture content.

Classification of Mortars

- Mortars are classified on the basis of the following:
- Bulk density
- Kind of binding materials
- Nature of application
- Special mortars

Properties of Good Mortar Mix and Mortar

The important properties of a good mortar mix are mobility, place ability and water retention.

- **Mobility**
- It is used to indicate the cons stency of mortar mix which may range from stiff to fluid.
- The mobility of mortar mix depends on the compositions of mortar and the mortar mixes to be used for masonry work are made sufficiently mobile.
- **Placeability**
- The placeability of mortar mix should be such that a strong bond is developed w th the surface of the bed.

Properties of a Good Mortar

- It should be capable of developing good adhesion with the building units such as bricks, stones etc.
- It should be capable of developing the designed stresses.
- It should be cheap
- It should be durable.
- It should be easily workable.
- It should set quickly so that speed in construction may be achieved.

Uses of Mortar

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

Functions of Sand in Mortar

1. Bulk
2. Setting
3. Shrinkage
4. Strength

Tests for Mortars

1. **Adhesiveness to Building Units:** Mortar is placed to join them so as to from a horizontal joint. If size of bricks is 9 cm x 9 cm x 9, a horizontal join of 9 cm x 9 cm = 81 cm^2 will be formed. Ultimate adhesive strength of mortar per cm^2 area is obtained by dividing maximum load with = 81 cm^2 area.
2. **Crushing Strength:** Brick masonry or stone masonry laid in mortar to be tested are crushed in compre sion machine. The load at which the masonry crushes gives the crushing strength
3. **Tensile Strength:** The briquettes are tested in a tension testing machine. Cross-sectional area of central portion is 38 mm x 38 mm or 1444 mm^2 or 14.44 cm^2

GUNITING

- The guniting is the most effective process of repairing concrete work which has been damaged due to inferior work or other reasons. It is also us d for providing an impervious layer.
- Gunite is a mixture of cement and sand, the usual proportion being 1:3. A cement gun is used to deposit this mixture on the concrete surface under a pressure of about 2 to 3 kg/cm^2.
- The surface to be treated is cleaned and washed. The nozzle of gun is generally kept at a distance of about 75 cm to 85 cm from the surface to be treated and velocity of nozzle varies from 120 to 160 m/sec.