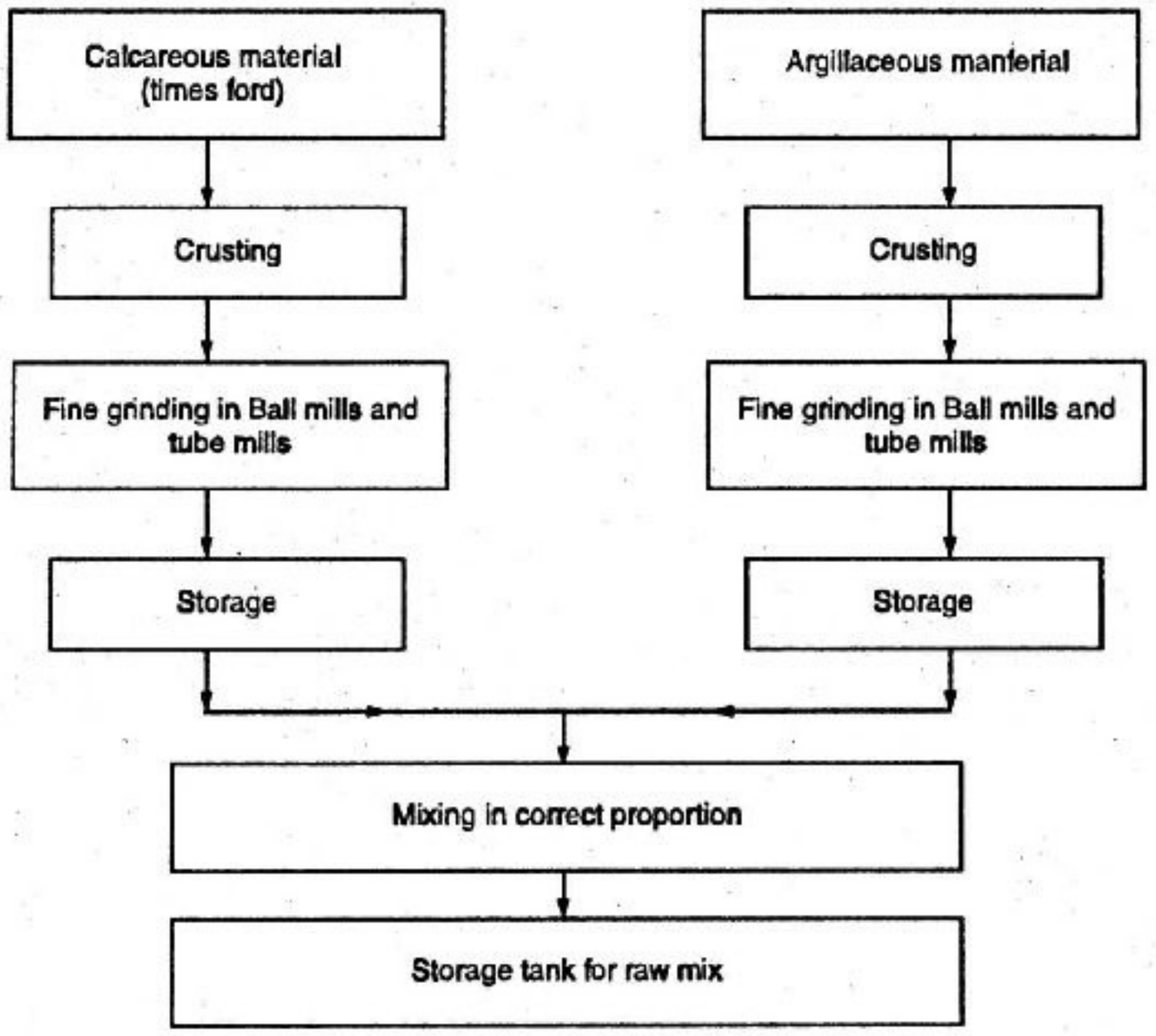
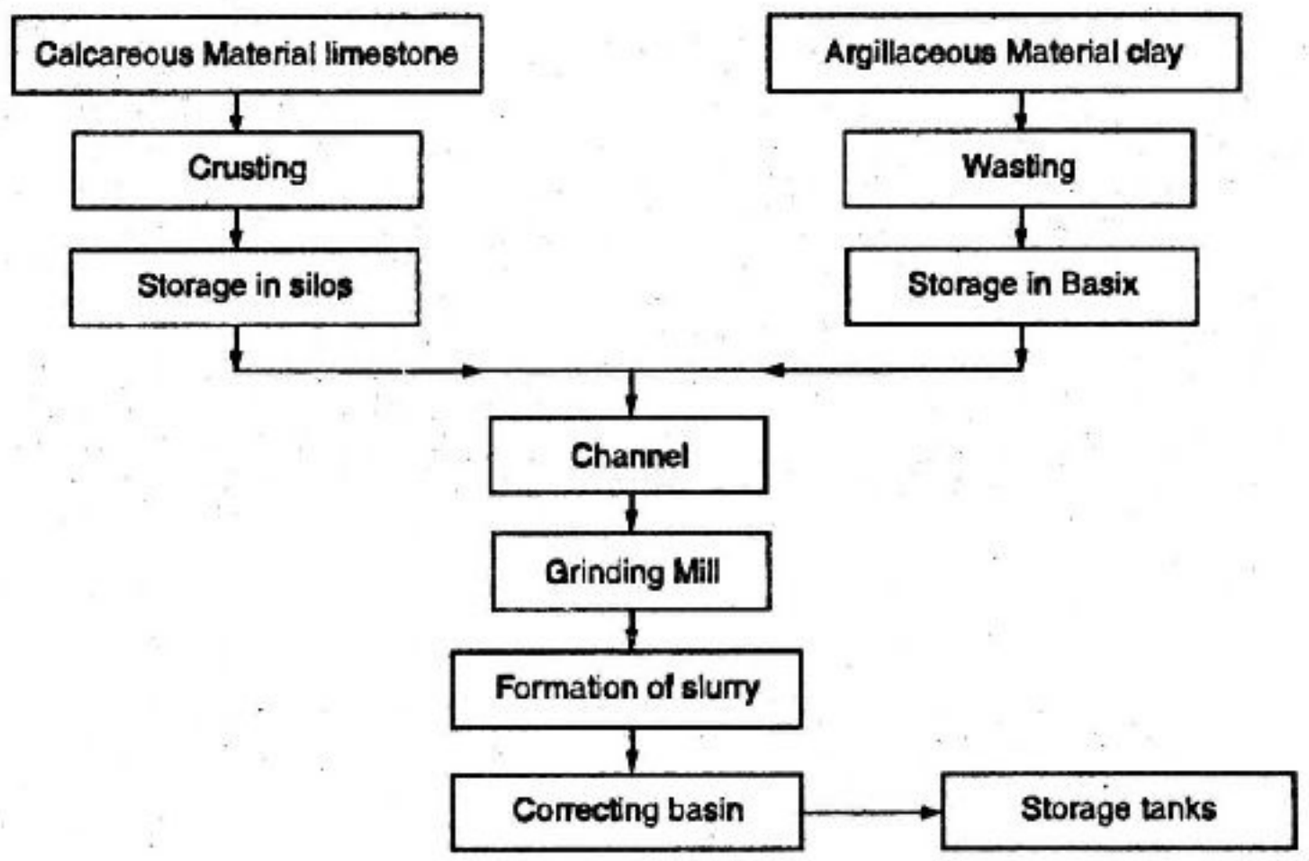
(*i*) Flow diagram of Dry Process



(*ii*) Flow diagram of net processs



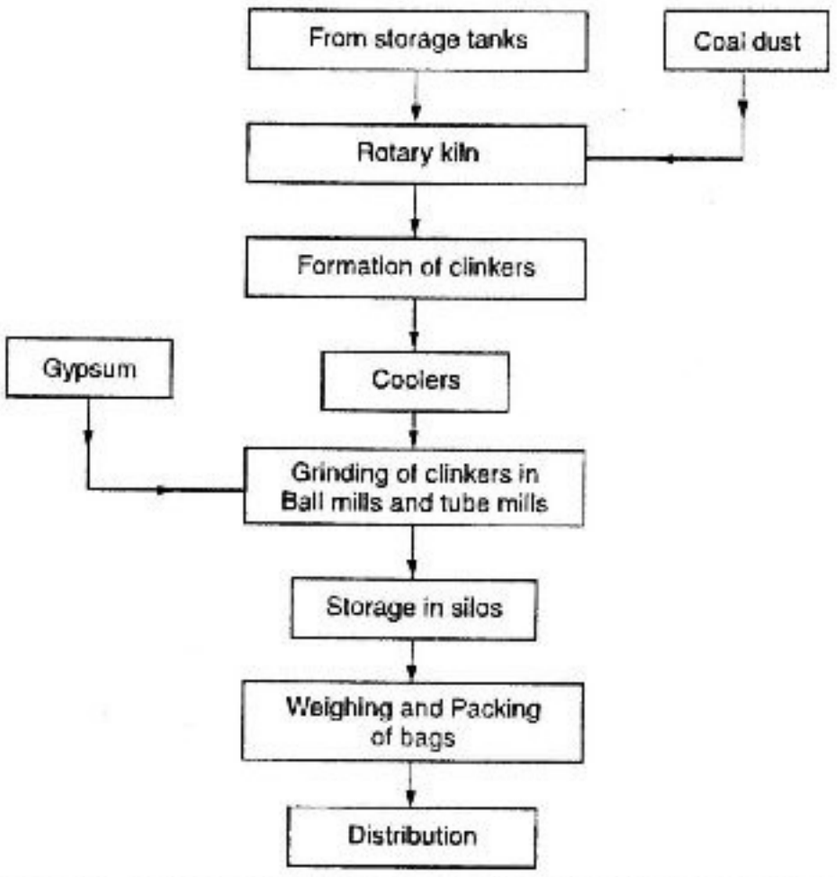
The remaining two operations namely, burning and grinding, are the same for both the processes.

2. **Burning :** Burning in a rotary kiln at a temperature of 1400 to 1500°C clinkers is formed of size 5 mm to 20 mm.
3. **Grinding :** The clinkers as obtained from the rotary kiln are finely ground in ball mills and tube mills. During grinding, a small quantity, about 3 to 4 per cent of gypsum is added. The gypsum controls the initial setting time of cement. If gypsum is not added, the cement would set as soon as water is added. The gypsum acts as a retarder and it delays the setting action of cement.

   Each bag of cement contains 50 kg or about 0.035 m^3 of cement.

   Floor area = 0.30m^2 and volume occupied = 0.054m^3.

Flow Diagram of Burning and Grinding operations of cement



The ball mills are used to have preliminary grinding and the tube mills are used to carry out final grinding.

Field Tests for Cement (To determine good quality)

1. **Colour:** The colour of cement should be uniform, i.e. grey colour.
2. **Physical Property:** Feel smooth when touched, feel cool. If small quantity of cement is thrown in a bucket of water, it should sink and not float on the surface.
3. Presence of Lumps
4. Strength

Laboratory Tests for Cement:

Sample of cement is taken in such as

1. **When cement is loose:** It should be taken from at least 12 points from heap or heaps of cement.
2. **When cement is in bags :** It should be taken from at least 12 different bags or packages.

Following are the purposes of testing cement (BIS : 4031/1968)

1. To determine the physical and chemical properties of cement.
2. To regulate the various stages in the manufacturing process as a slight difference in the process of manufacture of cement may cause a great difference in the quality of cement; and
3. To understand the behaviour of cement after its use on the works.

Following are the Standard Tests for Cement

1. Chemical composition
2. Fineness
3. Compressive strength
4. Tensile strength
5. Consistency
6. Setting times
7. Soundness

1. **Chemical Composition:** Following are the chemical requirements of ordinary cement as per BIS : 269 - 1975 :

   (*i*) *Ratio of percentage of alumina to that of iron oxide*: This ratio should not be less than 0.66.

   (*ii*) *Ratio or % of lime to those of alumina, iron oxide and silica* : This ratio should not be less than 0.66 and it should not be greater than 1.02, when calculated by the following formula.

$$\frac{CaO - 0.7SO_3}{2.8SiO_2 + 1.2Al_2O_3 + 0.65Fe_2O_3}$$

   (*iii*) *Total loss on ignition* : This should not be greater than 5%

   (*iv*) *Total sulphur content* : The sulphur content is calculated as SO_3 and it should not be greater than 2.75 per cent.

   (*v*) *Weight of insoluble residue* : This should not be greater than 2%.

   (*vi*) Weight of magnesia : This should not exceed 6%.

2. **Fineness :** This test is carried out to check proper grinding (BIS or IS sieue No - 9) (British standard - 170) of cement.

   The fineness of cement particles may be determined either by **sieve test** or by **permeability apparatus test**.

   In permeability apparatus test, the specific surface of cement should not be less than 2250 cm^2/gm. specific surface of rapid hardening cement shall not be less than 3250 cm^2/gm.

3. **Compressive Strength :** This test is carried out to determine the compressive strength of cement. Specimen size 70.6 mm or 76 mm.

   Percentage of water by weight of dry material,

$$P = \frac{P_n}{4} + 3.5, \quad \frac{w}{e} = 0.4 \quad \square \quad x : 3x$$

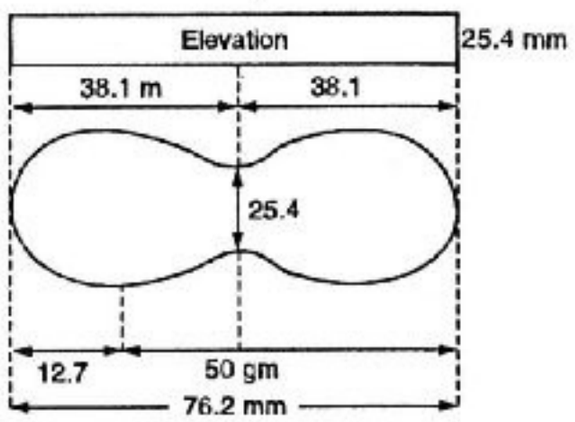
   where P_n = percentage of water required for cement paste of normal consistency.

   The compressive strength at the end of 3 days should not be less than 115 kg/cm^2 and that at the end of 7 days should not be less than 175 kg/cm^2.

4. **Tensile Strength :** The water is added to the mortar. The quantity of water is 8% by weight of cement and sand.

The briquettes is kept in a damp cabin for 24 hours. The briquettes are carefully removed from the moulds and they are submerged in clean water for curing.

$$P = 0.2\,P_n + 2.5$$



The tensile stress at the end of 3 days should not be less than 20 kg/cm^2 and that at the end of 7 days should not be less than 25 kg/cm^2.

5. **Consistency:** The purpose of this test is to determine the percentage of water required for preparing cement pastes for other tests. The interval between the addition of water to the commencement of filling the mould is known as time of gauging and it should be $3\frac{1}{4}$ to $4\frac{1}{4}$ minutes.

Vicat apparatus : Weight of movable rod 300 gm, diameter 10 mm and length 50 mm (40 mm to 50mm^3)

An indicator attached to the movable rod.

There are three attachments:

square needle, plunger and needle with annular collar.

The square needle is used for initial setting time test, the plunger is used for consistency test and the needle with annual collar is used for final setting time test.

The settlement of plunger is noted. If the penetration is between 5 mm to 7 mm from the bottom of mould, the water added is correct.

6. **Setting Times :** This test is used to detect the deterioration of cement due to storage. Initial setting time : Square needle of cross-section 1 mm × 1 mm.

   The initial setting time is the interval between the addition of water to cement and the stage when needle ceases to penetrate completely. This time should be about 30 minutes for ordinary cement.

   Final Setting Time : The needle with annular collar is attached to the movable rod of the Vicat apparatus.

   The needle is gently released. The time at which the needle makes an impression on test block and the collar fails to do so is noted. This time should be about 10 hours for ordinary cement.

7. **Soundness :** The purpose of this test is to detect the presence of uncombined lime in cement. This test is performed with the help of Le Chatelier apparatus.

   Following procedure is adopted :

   (*i*) Cement paste is prepated.

   (*ii*) The mould is placed on a glass plate and it is filled by cement paste.

   (*iii*) It is covered at top by another glass plate. A small weight is placed at top and the whole assembly is submerged on water for 24 hours. The temperature of water should be between 29°C to 35°C.

   (*iv*) The distance between the points of indicator is noted. The mould is again placed in water and heat is applied in such a way that boiling point of water is reached in about 30 minutes. The boiling of water is continued for one hour.

   (*v*) The mould is removed from water and it is allowed to cool down.

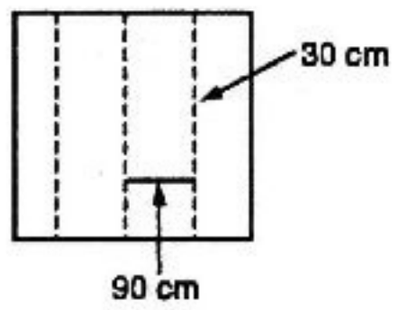
   (*vi*) The distance between the points of indicator is again measured. The difference between the two readings indicates the expansion of cement and it should not exceed 10 mm.

STORAGE OF CEMENT

It is economically to form a pile of 10 bags of cement.

Varieties of Cement:

In addition to ordinary cement, the following are other important varieties of cement.



1. Acid resistant cement
2. Blast furnace cement
3. Coloured cement
4. Expanding cement
5. High alumina cement
6. Hydrophobic cement
7. Low heat cement
8. Pozzalanic cement
9. Quick setting cement
10. Rapid hardening cement
11. Sulphate resisting cement
12. White cement

1. **Acid Resistant Cement :** It composed of

   (*i*) Acid resistant agg. such as quartz, quartrites etc.

   (*ii*) Sodium fluosilicate

   (*iii*) Soluble glass

2. **Blast Furnace Cement :** The clinkers of cement are ground with about 60 to 65% of slag. The

properties of this cement are more or less the same as those of ordinary cement. Its strength in early days is less and hence, it requires longer earning period. This cement is durable, but not suitable for use in dry arid zones.

3. **Coloured Cement :** Chromium oxide give green colour

   Cobalt – blue colour

   MgO – black or brown coloured cement

4. **Expanding Cement :** This cement expands whereas, other cements shrink. It is used for the construction of water retaining structures and also for repairing the damaged concrete surfaces.

5. **High Alumina Cement or Cement Fondu (England) or Lumnite (America) :** This cement is produced by grinding clinkers formed by calcining bauxite and lime.

   Advantages of this cement are :

   (i) The initial setting time of this cement is more than $3\frac{1}{2}$ hours. The final selting time is about 5 hours.

   (*ii*) It can stand high temperatures.

   (*iii*) It evolves great heat during setting. It is therefore not effected by frost.

   (*iv*) It resists the action of acids in a better way.

   (*v*) It sets quickly and attains higher ultimate strength in a short period.

   (*vi*) Its setting action mainly depends on the chemical reactions and hence, it is not necessary to grind it to fine powder.

6. **Hydrophobia Cement:**

7. **Low Heat Cement :** It contains lower percentage of C_3A of about 5% and higher percentage or C_2S of about 46%.

8. **Pozzuolana Cement :** The pozzuolana is a volcanic powder.

   Following are the advantages of this cement:

   (*i*) It attains compressive strength with age.

   (*ii*) It can resist action of sulphates.

   (*iii*) It evolves less heat during selting.

   (*iv*) It imparts higher degree of watertightness.

   (*v*) It is cheap.

   (*vi*) It offers great resistance to the expansion.

   (*vii*) It possesses higher tensile strength.

   This cement is used for marine structure. It is also used in sewage works and for laying concrete under water.

9. **Quick Setting Cement :** This cement is produced by adding a small percentage of aluminium sulphate and by finely grinding the cement. The percentage of gypsum is also reduced.

   This cement is used to lay concrete under static water or running water.

10. **Rapid Hardening Cement :** It contains high percentage of C_3S to the extent of about 56%. Rapid hardening cement attains early strength due to larger proportion of time grounded finer than normal cement.

11. **Sulphate Resisting Cement :** In this cement, the percentage of C_3A is kept below 5% and it results in the increase in resisting power against sulphates.

12. **White Cement :** This is just a variety of ordinary cement and it is prepared from such raw materials which are practically free from the oil fuel is used instead of coal. It is while in colour and is used for floor finish, plaster work, ornamental work etc.

MORTAR

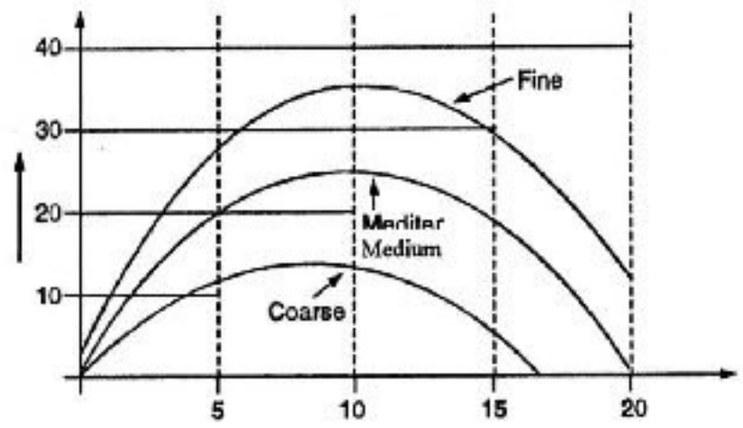
Classification of Sand

Fine sand – diameter -1.5875 mm used for plastering

Coarse sand - diameter - 3.175 mm used for masonry work

Grarelly sand - diameter - 7.62 mm used for concrete work

Bulking of Sand :



Properties of Good Sand:

The fineness modulus of sand should be between 2 and 3.

Substitutes for Sands:

Surkhi plays the same functions as those of sand. But in addition, it gives strength and improves hydraulic property of the mortar. As it disintegrates under the action of air and humidity, the mortar with surkhi should not be used for external plaster or pointing work.

Classification of Mortars:

The mortars are classified on the basis of the following :

1. **Bulk Density**

   (*i*) Heavy mortar

   (*ii*) Light mortar

2. **Types of Binding Material**

   According to the type of binding material, the mortar are classified into the following five categories:

   (*i*) Lime mortar

   (*ii*) Surkhi mortar

   (*iii*) Cement mortar

   (*iv*) Gauged mortar

   (*v*) Gypsum mortar

3. **Nature of Application**

   (*i*) Bricklaying mortar

   (*ii*) Finishing mortar

4. **Special Mortar**

   (*i*) Fire-resisting mortar : It is prepared by aluminous cement

   (*ii*) Light weight mortar

   (*iii*) Packing mortar

   (*iv*) Sound-absorbing mortar

   (*v*) X-ray shielding mortar

Asbestos Products

Asbestos fibers are strong, durable, and resist heat, acids, and friction. They are virtually indestructible. Because of these useful physical properties, asbestos fibers were often combined with other materials for use in thousands of industrial, maritime, automotive, scientific and building products. The following list shows the wide range of materials that could contain asbestos:

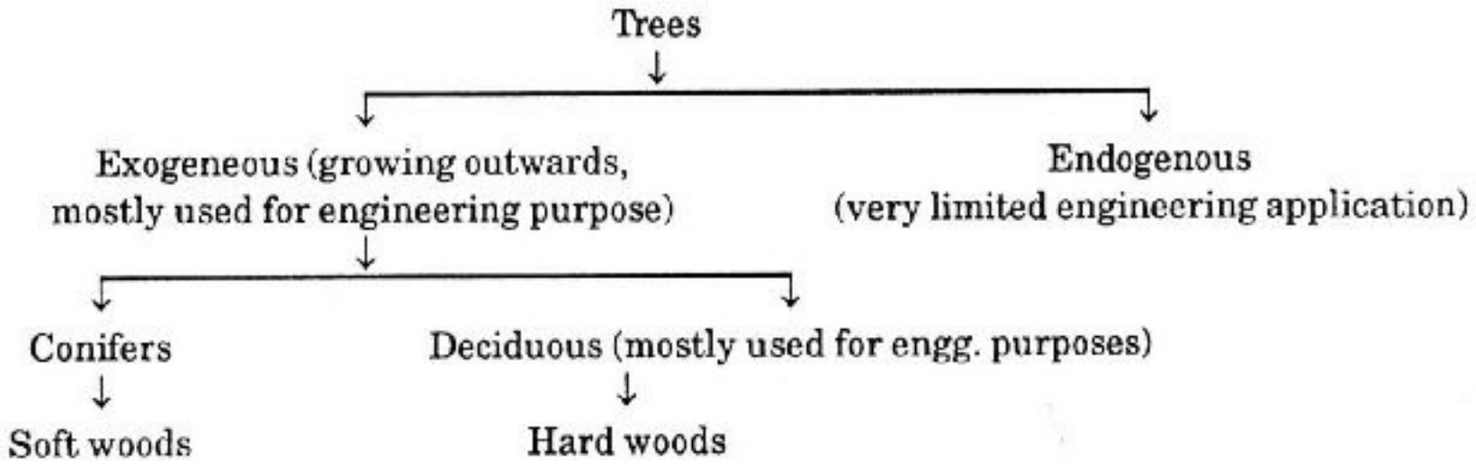
1. **Insulation** (Pipe, boiler, corrugated air-cell, breaching, and block insulation; HVAC duct insulation; sprayed-in insulation; blown-in insulation; thermal paper products; electrical wiring insulation)
2. **Fireproofing/Acoustical Texture Products** (includes acoustical plaster, decorative plaster, textured paint or coatings, fire blankets, fire curtains, fire doors)
3. **Textile and Cloth Products** (includes blankets, protective cloth coverings, garments, asbestos gloves, threads, cords, yarns, braids)
4. **Spackling, Patching & Taping Compounds** (includes caulking, putties, joint compounds, adhesives, tapes, thermal taping compounds)
5. **Gaskets and Packings** (includes high temperature gaskets, packings for industrial products, high pressure packing, asbestos packing reinforced with steel or copper wire)
6. **Asbestos-cement Pipe and Sheet Material**
7. **Tiles, Wallboard, Siding and Roofing** (includes roofing shingles, roofing felt, base flashing, cement wallboard, cement siding, ceiling tiles and lay-in panels, asphalt floor tile, vinyl floor tile, vinyl sheet flooring, flooring backing, vinyl wall coverings)
8. **Friction Materials** (automotive and railroad brakes and clutches)
9. **Vermiculite** (used in some horticultural potting mixes, brake pads, acoustic tiles, insulation)
10. **Laboratory hoods and table tops**

Asbestos may also be found in elevator brake shoes, elevator equipment panels, ductwork, electrical panel partitions, electrical cloth, cooling towers, and chalkboard.

TIMBER

1. **Converted Timber :** This indicates timber which is saw and cut into suitable commercial sizes.
2. **Rough Timber :** This indicates timber which is obtained after felling a tree.
3. **Standing Timber :** This indicates timber contained in a living tree.

Classification of Trees:



Comparison of Soft Woods and Hard Woods

S.No.	Item	Soft Woods	Hard Woods
1.	Annual ring	Distinct	Indistinct
2.	Colour	Light	Dark
3.	Fire resistance	Poor	More
4.	Medullary ray	Indistinct	Distinct
5.	Strength	Strong for direct pull and weak for resisting thrust or shear	Equally strong for resisting tension compression and shear
6.	Structure	Resinous and split easily	Non-resinous and close-grained
7.	Weight	Light	Heavy
		e.g. Chir, deodar, fir, kail, pine sprue, walnut etc.	e.g. Babul, mahogany, oak, sal, teak etc.

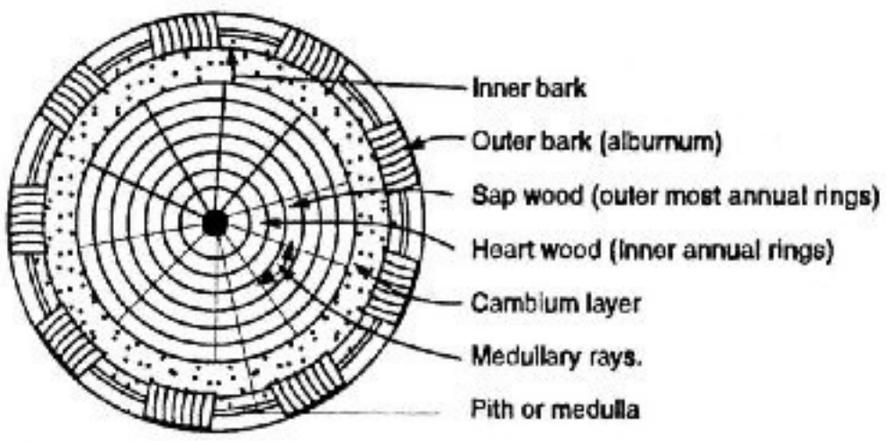
Endogenous Trees: These trees grow inwards and fibrous mass is seen in their longitudinal sections e.g. bamboo, cane, palm, etc.

Structure of a Tree

Trunk : Supports the crown and to supply water and nutrients from the roots to the leaves through branches and from the leaves back to the roots.

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

1. Macrostructure (visible to the naked eyes)
2. Microstructure



Defects of Timber:

1. Defects due to conversion
2. Defects due to fungi
3. Defects due to insects
4. Defects due to natural forces
5. Defects due to seasoning

1. **Defects due to Conversion :**
   - (*i*) Chip mark
   - (*ii*) Diagonal grain (due to improper sawing of timber)
   - (*iii*) Torn grain: Small depression is formed on the finished surface of timber by falling of a tools or so.
   - (*iv*) Wane

2. **Defects due to Fungi:** Fungi attack timber only when the following two conditions are satisfied simultaneously:
   - (*i*) The moisture content of timber is above 20%.
   - (*ii*) There is a presence of air and warmth for the growth of fungi.

   Following defects are caused in the timber by the fungi :
   - (*i*) Blue stain
   - (*ii*) **Brown rot:** The term rot is used to indicate decay or disease of timber.
   - (*iii*) **Dry rot:** caused due to insufficient circulation of air. It is caused due to attack of fungies.
   - (*iv*) Heart rot
   - (*v*) Sap strain
   - (*vi*) **Wet rot:** Wet rot is decay of timber due to alternate wetting and drying.
   - (*vii*) White rot

3. **Defects due to Insects :**

   Type of insects are
   - (*i*) Beetles
   - (*ii*) Marine borers
   - (*iii*) Termites

4. **Defects due to Natural Forces:**
   - (*i*) Abnormal growth and
   - (*ii*) Rupture of tissues

   Following defects are caused by these forces :
   - (*i*) **Burls:** Irregular projections appears on the body of timber due to injury in young age.
   - (*ii*) **Callus:** It indicates soft tissue or skin which covers the wound of a tree.
   - (*iii*) Chemical stain
   - (*iv*) Coarse grain
   - (*v*) Dead wood

(*vi*) **Druxiness :** The defect indicated by white decayed spots in timber is known as druxiness. They are probably formed for the access of fungi.

(*vii*) **Foxiness :** It is caused either due to poor ventilation during storage or by commencement of decay due to over maturity or due to growth of tree.

(*viii*) **Knots:** The formation of dark, hard rings due to broken or cut-off the branches from the trees.

(*ix*) **Rind galls:** Peculiar curved swellings found on the body of a tree are known as the rind galls.

(*x*) **Shakes :** These are cracks which partly or completely separate the fibres of wood.

Following are the different varieties of shakes.

(*a*) Cup shakes

(*b*) **Heart shakes:** These cracks occur in the centre of c/s of tree and they extend from pith to sap wood in the direction of medulary ralp. These cracks occurs due to shrinkiage of inferior part of tree.

(*c*) Ring Shakes

(*d*) **Star shakes:** These are cracks which extend from bark towards the sap wood. They are usually formed due to extreme heat or severe frost during the growth of the tree

(*e*) Radial shakes

(*xi*) Twisted fibres

(*xii*) Upsets

(*xiii*) Water stain

(*xiv*) Wind cracks

5. **Defects due to Seasoning**

(*i*) **Bow :** Curvature formed in the direction of length.

(*ii*) **Case-hardening :** Due to improper dries of exterior and inferioe portion.

(*iii*) **Check :** A check is a crack which separates fibres of wood.

(*iv*) **Collapse :** Due to uneven shrinkage.

(*v*) **Cup :** Curvature formed in the transverse direction of timber.

(*vi*) Honey-combing

(*vii*) Radial shake

(*viii*) **Split :** When a check extends from one end to the other, it is known as a split.

(*ix*) **Twist :** When a piece of timber has spirally distroyed along its length.

(*x*) **Warp :** When a piece of timber has twisted out of shape, it is said to have warped.

Decay of Timber:

Following are the various causes or situations which favour the early decay of timber :

1. Alternate dry and wet conditions
2. Bad storage or stacking of timber,
3. Fungi which are responsible for developing diseases,
4. Improper seasoning,
5. Insects such as beetles, marine borers, termites, etc.,
6. Keeping timber in contact with damp wall, damp earth, etc.,
7. Shocks or imparts received during young age from natural forces such as fast blowing wind etc.,
8. Use of timber without taking out sap wood from its structure,
9. Using seasoned timber without applying suitable preservative on its surface, and
10. Using unseasoned wood with the application of protective coat of paints or tar.

PRESERVATION OF TIMBER

Objects:

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

Types of Preservatives:

1. Ascu treatment
2. Chemical salts
3. **Coal Tar:** It makes timber unsuitable for painting.
4. **Creosote oil:** Process of coated with creosote oil is known as creosoting or *Bethel's method of preservation of timber*. The creosote oil is obtained by the distillation of tar.
5. Solignum paints.

Methods:

1. Brushing
2. Charring
3. Dipping and steeping
4. Hot and cold open tank treatment
5. Injecting under pressure
6. Spraying

Seasoning of Timber:

- The process of removing water from the timber before any engineering purposes are known as seasoning of timber.

- The wood is a hygroscopic material. The capacity of wood to absorb water vapours from air is called the *hygroscopicity of wood*.
- A process of drying timber or removing moisture or sap from a freshly felled tree, is called seasoning of timber.

A well seasoned timber may contain about 10 to 12 % moisture which is necessary for proper retention of the shape and size of the articles manufactured from the timber.

Fibre Board:

These are rigid boards and they are also known as the pressure wood and reconstructed wood. The thickness varies from 3 mm to 12 mm. They are available in lengths varying from 3 m to 4.5 m and in width varying from 1.2 m to 1.8 m.

Trades names are : Euraka, Indianite, Insulite, Masonite etc.

Impreg Timbers : The timber which is fully or partly covered with resin is known as the impreg timber. It's trade name is Formier, Sunglass, Sunmica etc.

Compreg Timber : The process of preparing compreg timbers is same as that of impreg timbers except that curing is carried out under pressure.

- **Teak :** It ia the most valuable timber trees of the world.
- **Sal :** It is durable under ground and water.
- **Shisham :** It is strong and tough. It is used for high class furniture plywoods, bridge piles, sport goods, railway carriages, etc.
- **Chair**
- According to IS 399-1965, the weight of the timber is specified at 12% moisture content.

Marked Forms of Timber

1. **Batten :** This is the timebr piece whose breadth and thickness do not exceed 50 mm.
2. **Baulk :** A piece of sawn timber whose cross-sectional dimensions exceed 5 cm, in one direction and 20 cm in the other direction is call a baulk.
3. **Board :** It is a plank i.e. a timber piece with parallel sides. Its thickness is less than 50 mm and width exceeds 150 mm.
4. **Deal:** It is a piece of soft wood with parallel sides.

   Thickness = 50 mm to 100 mm, width does not exceed 230 mm.
5. **Log :** It is a trunk of tree obtained after removal of branches.
6. **Plank :** It is a timber piece with parallel sides, its thickness is less than 50 mm and its width exceeds 50 mm.

- Hard woods shrink more than soft woods.
- For the same variety heavy weight timber is stronger and more sound as compared to light weight timber.
- Wood impregnated with borad, resists fire.

FERROUS METALS

The metals will be grouped into the following two categories :

1. Ferrous metals
2. Non-ferrous metals

The ferrous metals contain iron as their main constituent. There are three important ferrous metals, namely

(*i*) Cast iron
(*ii*) Wrought iron and
(*iii*) Steel

The non-ferrous metals do not contain iron as their main constituent. Some of the non-ferrous metals such as aluminium, copper etc. have limited use for the engineering purposes.

An ore may be defined as a solid naturally occurring mineral aggregate of economic interest, from which one or more valuable constituents may be recovered by certain treatment. The term gangue is used to indicate substances occurring along with ores.

Important Varieties of Iron Ores :

1. **Haematite (Fe_2O_3) :** It is red oxide of iron. It is a rich iron ore and it contains about 65 to 70% of iron. Specific gravity –4.5 to 5.3
2. **Limenite ($2Fe_2O_3.3H_2O$):** It is broven haematite. It contains 60% of iron. Sp. gr. 3.6 to 4.0 and hardness 5 to 5.5.
3. **Magnetite (Fe_3O_4):** It is a black oxide of iron. It is the richest iron ore and it contains about 70 to 73% of iron.
4. Pyrite(FcS_2)
5. Siderite ($FeCO_3$)

Pig-iron:

The crude impure iron which is extracted from iron ores is known as the pig-iron and it forms the basis material for the manufacture of cast-iron, wrought-iron and steel.

Manufacture of Pig-Iron : Following three distinct operations are involved in the manufacturing process of Pig-iron:

1. **Dressing :** The iron are obtained from mines are crushed into pieces of size of 25 mm dia. for removal of impurities or clay adhering to iron ores is known as dressing.

2. **Calcination and roasting :** The calcination consists of heating ores in presence of air so that they are oxidized. The water and carbon dioxide are removed from ores by calcination. The roasting consists of making the ores hot and very dry. Roasting is not ncessary if iron ore is an oxide.
3. **Smelting :** The smelting so as to separate metal from ore is known as the smelting. It is carried out in a special type of furnace, known as the blast furnace.

Properties of Pig-Iron:

1. It can be hardened but not tempered.
2. It cannot be magnetised.
3. It cannot be welded or riveted.
4. It does not rust.
5. It is difficult to bend.
6. it is hard and brittle.
7. It is neither ductile nor malleable.
8. It melts easily and its fusion temperature is 1200°C.
9. It possess high compression strength. But it is weak in tension and shear.

Types of Pig-Iron:

1. **Bessemer Pig :** Obtained from haemalite ores. This pig is used in the manufacture of steel by Bessemer or acid open-hearth process.
2. **Grey Pig or Foundry Pig :** This is a soft variety of pig and it is mainly used for the cast iron castings.
3. **White Pig or Forge Pig :** It is used in the manufacture of wrought-iron.
4. **Mottled Pig :** It is unfit for light and ornamental castings. It is used for heavy foundry castings.

Other Methods for Pig-Iron Manufacture:

1. Electric reduction furnace
2. Low shaft blast furnace
3. Sponge iron process

Some Terms:

1. **Brittle Material :** A material which easily breaks into pieces or which can be easily reduced to powder form is known as brittle material e.g. glass
2. **Ductile Material :** A material which can be drawn into fine wires is known as a ductile material, e.g. silver and copper.
3. **Hard Material :** A material which cannot be cut by a sharp tool is known as a hard material, e.g. diamond.
4. **Malleable Material :** A material which can be beaten into thin sheets or leaves is known as a malleable material e.g. gold.
5. **Soft Material :** A material which can be easily cut by a sharp weapon is known as a soft material, e.g. lead.
6. **Tough Material:** A material which does not easily break under a hammer is known as a tough material e.g. basalt.

CAST IRON

The cast iron is manufactured by remelting pig-iron with coke and limestone. This remelting is done in a furnace known as the **Cupola Furnace**.

Composition of Cast-Iron

- Carbon — 2 to 4% in addition, it contains the various impurities such as manganese, phosph rus, silicon and sulphur.
- Manganese — below 0.75%. It makes cast-iron brittle and hard when it excess.
- Phosphorus — The phosphorus increases fluidity of cast-iron. It also makes cast-iron brittle.

Properties of Cast-iron : (sp. gr. 7.5)

1. It placed in salt water, it becomes soft.
2. It can be hardened by heating and sudden cooling, but it cannot be tempered.
3. It cannot be magnetised.
4. It does not rust easily.
5. It is fusible.
6. It is hard, but it is brittle also.
7. It is not ductile and hence, it cannot be adopted to absorb shocks and impacts.
8. Its melting temperature is about 1250°C.
9. It is weak in tension and strong in comp. Its average value is 150 N/mm^2 and 500 N/mm^2 respectively.
10. The two pieces of cast-iron cannot be connected by the process of riveting or welding. They are connected to nuts and bolts.

Use of Cast-iron :

The use of cast-iron is not recommended in horizontal direction either for heavy or variable loads. Its uses are :

1. For making cisterns, water pipes, gas pipes and sewers, manhole covers and sanitary fittings.
2. For making ornamental castings such as brackets, gates, lamp posts, spiral staircases etc.
3. For making parts of machinery which are not subjected to heavy shocks.
4. For manufacturing compression members like columns in building, bases of columns etc.
5. For preparing agricultural implementations.
6. For preparing rail chairs, carriage wheels etc.

Types of Casting

1. **Centrifugal Casting :** This method is generally used to prepare pipes.
2. Chilled casting
3. Die casting
4. Hollow casting
5. Sand casting
6. **Vertical Sand Casting :** This method of casting is used to prepare cast-iron pipes for carrying water under pressure.

Wrought-Iron:

Manufacture of Wrought-Iron: The wrought-iron is almost pure iron and it hardly contains carbon more than 0.15% or so. But the process of its manufacture is laborious and tedious. Following four distinct operations are involved in its manufacture :

1. Refining
2. Pudding: Forge pig may be converted to wrought iron by pudding
3. Shingling
4. Rolling

- The variety of pig iron used for manufacture of wrought iron is white forge pig.
- The slag which floats on the surface of the molten iron generally contains:
  - Lime (Cao) 45%
  - Silica (SiO_2) 35%
  - Alumina (Al_2O_3) 12%
  - MgO, $CaSO_4$, $KMnO_4$ and FeO 8%
- Impurities float on the molten iron as slag.
- If the ore impurities is clay, lime stone is used as flux.
- If the ore impurities is limestone, clay is used as flux. If the ore impurities is quartz, lime stone and argallaceous iron ores are used as flux.
- Pig iron made from Heamatite ores free from sulphur, phosphorus and copper, is known as Bessemer pig.
- Pig iron obtained from the furnace which is properly provided with fuel at a very high temperature is called grey or foundry pig.
- If the furnace is provided with insufficient fuel at low temperature, the type of pig-iron produced, is called white forge pig.
- The variety of pig iron used for the manufacture of steel by Bessemer process is Bessemer Pig-
- The variety of pig iron used for manufacture of wrought iron is white forge pig.
- **For melting one tonne of cast iron, requirements are**
  - 700 m^3 air
  - 20 kg limestone
  - one quintal coke

STEEL

The cast iron contains carbon from 2 to 4%. In wrought-iron, carbon content does not exceed 0.15%. In steel, the carbon content varies from anything below 0.25% to 1.50% maximum. The steel becomes harder and tougher as its carbon contents goes on increasing.

The cast-iron can take up only compressive stresses and its use is limited to the compression members only. The wrought-iron is of a fibrous nature and it is suitable to resist tensile stresses. The steel is suitable for all constructional purposes in general and hence, it has practically replaced cast-iron and wrought-iron in the present day practice of building construction. It is equally strong in compression as well as in tension.

If a drop of nitric acid is placed on steel, it will produce a dark grey stain due to the presence of higher percentage of carbon content.

Manufacture of Steel:

The steel is manufactured by the following processes :

1. Bessemer process
2. **Cementation process :** It consists in converting pig-iron to almost pure wrough-iron and then preparing steel by adjusting carbon content.
3. Crucible steel process
4. Duplex process
5. Electric process
6. **L-D process :** The process is economical in initial cost as well as in maintenance cost. This is the only process where sulphur can be effectively reduced. This process of steel making is specifically suitable for the Indian pig-irons and it has been adopted on a large scale at the SAIL projects.
7. Open-hearth process

Use of Steel:

Depending upon the carbon content, the steel is designated as the mild steel (carbon content is about 0.10 to 0.25 %) or Medium carbon steel (carbon content is about 0.25 to 0.60%) or high carbon steel or hard steel (carbon content is about 0.60 to 1.10%).

Factors Affecting Physical Properties of Steel (ductility, elacticity, strength etc.)

1. Carbon content

2. Presence of impurities (silicon 0.2%, sulphur 0.02 to 0.1%, phosphorus 0.12% and manganese 0.3 to 1.0%)
3. Heat treatment process

- The mild steel having carbon content of about 0.10 to 0.25% is widely used for structural work.
- If silicon content is raised to about 0.3 to 0.4% the elasticity and strength of steel are considerably increased without serious reduction in its ductility.
- The excess of sulphur decreases strength and ductility of steel.
- The phosphorous produces detrimental effect and steel. It is desirable to keep its content below 0.12%. It reduces shock resistance, ductilicity and strength of steel.
- The manganese helps to improve the strength of mild steel. Its desirable content is between 0.30 to 1.00%. When its content exceeds about 1.5% or so, the steel becomes very brittle and hence, it loses its structural value.

Heat Treatment Processes:

It is possible to alter the properties of steel by heating and cooling steel under controlled conditions. The term heat treatment is used to indicate the process in which the heating and cooling of solid steel is involved to change the structural or physical properties of steel. The principal processes involved in heat treatment of steel are as follows :

1. Annealing
2. Case hardening
3. Cementing
4. Cyaniding
5. Hardening
6. Nitriding
7. Normalizing
8. Tempering

1. **Annealing (cool slowly) :** The main object of this process is to make the steel soft so that it can be easily worked upon with a machine.
2. **Case-hardening :** In this treatment, the core of specimen remains tough and ductile and at the same time, the surface becomes hard. Such a result is achieved by increasing the carbon content at the surface. It is also known as a process of chemical heat treatment.
3. **Cementing :** In this process, the skin of the steel is saturated with carbon.
4. **Cyaniding :** This process is used to produce hard cases on the surfaces of low or medium carbon steels. It consists in adding carbon and nitrongen to the surface layer of the steel so as to increase its hardness, wear resistance and fatigue limit.
5. **Hardening:** The object of this process is just the reverse of that of the annealing process. The steel is to be made hard by this process whereas it is made soft by the annealing process.

   The process of hardening is just similar to that of annealing except that there is difference in rate of cooling. In hardening process, the cooling is to be carried out at controlled rate. Such a controlled rate of cooling is known as the quenching.
6. **Nitriding :** The process of saturating the surface layer of steel with nitrogen by heating is known as the nitriding.
7. **Normalizing :** The object of this process is to restore steel structure to normal condition and it is adopted when structure of steel is seriously disturbed for any reason.
8. **Tempering :** The process is applied to the steels which are treated with the hardening process. The hardened steel is in a stressed condition and very brittle and cannot be used for practical purposes. The steels after hardening must be tempered to achieve objects.

Properties of Mild Steel:

1. It can be magnetised permanently.
2. It can be readly forged and tempered.
3. It cannot be easily hardened and tempered.
4. It has fibrous structure.
5. It is malleable and ductile.
6. It is not easily attacked by salt water.
7. It is tougher and more elastic than wrought-iron.
8. It is used for all types of structural work.
9. It rusts easily and rapidly.
10. Its melting point is about 1400°C.
11. Its sp. gravity is 7.8
12. Its ultimate comp. strength is about 80 to 120 KN/cm^2.
13. Its ultimate tensile strength and shear strength are about 60 to 80 KN/cm^2.

BITUMINOUS MATERIALS

Bitumen is an essential component of any pavement and is used widely throughout the world. It can be termed as the building block of the pavements without which all the pavement materials would behave independently and thus will be deemed useless. Almost ninety percent of bitumen is used in road construction. It is usually available in dark colors ranging from brown