Civinnovate

Discover, Learn, and Innovate in Civil Engineering

TABLE OF CONTENTS

1. INTRODUCTION TO CIVIL ENGINEERING MATERIAL

1.1) Introduction:

The subject deals with the study of materials in respect of:

- Sources, composition and properties.
- Manufacturing methods and techniques and testing.
- Modern techniques being developed for handling and using materials to materialize economic and safer design of structures.

The main objective of this subject is to present information on the structure and properties of materials that are used in engineering design and to present guidelines to assist the designer in selecting right materials for a given job.

Civil Engineering Materials: It deals with the study of materials that are extensively used in the civil engineering design and construction processes.

Civil Engineering materials are bricks, building stones, cement, lime, mortar, timber, metal etc.

1.2) Selection Criteria of Civil Engineering Materials:

Selection of the civil engineering material is very important aspects in the design process of any civil engineering structures. Depending upon the various properties of the materials suitable selection should be done considering technical, social and economical aspects. Selection of the material may not remain constant. At the instant material may seem best but after sometime they may not be the best one. Thus, the best material today would be light, strong and durable. Such a selection of material is possible if the designer has an understanding of various material systems and their advantages and disadvantages and can call upon this knowledge to make a material selection.

The Selection Process:

The material selection process involves the following major steps:

i. Analysis of the material application problems.
ii. Translation of the materials application requirements to material property values.
iii. Selection of the candidate materials
iv. Evaluation of the candidate materials.

Factors affecting the selection of the materials :

i. **Properties of the material:** Properties of material defines special characteristics of the materials and form a basis for predicting behaviour of the materials under different condition.

The important properties of materials are :

- Physical Properties
- Mechanical Properties
- Thermal Properties

https://civinnovate.com/civil-engineering-notes/

- Chemical Properties
- Electrical Properties
- Magnetic Properties etc.

ii. **Performance Requirements:** The material of which a part is composed must be capable of performing the part's function without failure. For eg. A component part to be used in the furnace must be of the material which can withstand high temperature.

iii. **Material Reliability:** The material must be reliable. It should remain stable enough to function in service for the intended life of the product without failure

iv. **Safety:** A material must safely perform its function.

v. **Physical Attributes:** Physical attributes such as configuration, size, weight and appearance sometime also serve as a functional requirement.

vi. **Environmental Condition:** The material needs to be selected as per the environment condition.

vii. **Availability:** Materials must be readily available and available in large amount for the intended application.

viii. **Disposability and Recyclability:** Most of the materials need to be disposable and recyclable.

ix. **Economic Factors:** Cost, is perhaps one of the important factor in controlling the given material application. The material selected should be within the limit.

1.3) Classification of Civil Engineering Materials:

Civil Engineering materials are classified in the various ways:

1. **Based on the existence:** It is classified into two types:
   i. Natural existing engineering materials: for e.g. stone, iron, timber, aluminium etc.
   ii. Artificially made engineering materials: for e.g. plastic, fibreglass, cement etc.

2. **Based on Metallurgy:** It is classified into two types:
   i. Metal:
      a. Ferrous: e.g. steel
      b. Non Ferrous: e.g. aluminium
   ii. Non Metal: for e.g. timber, stone, plastic etc.

3. **Based on Use:** It is classified into two types:
   i. Structural Engineering Materials: for e.g. stone, brick, cement, steel etc,
   ii. Aesthetic Engineering Materials: use to get beauty to the structure for e.g. marble, chips, paints etc.

4. **Based on Physical and Chemical Characteristics:** This is the most common way to classify engineering materials. These are:

   i. **Metal and Alloys:** Metals are basically made of elements or group of elements. It possesses metallic properties such as lustre (shine), transmission of heat, malleability, ductility and electrical conductivity. For eg. Iron, copper, aluminium etc.

   Alloys are produced by melting two or more metals or metals and a non metal together. Properties of alloys are modified than their parents metal. For eg. Steels, bronze, invar etc.

   ii. **Ceramics:** These are non metallic solids made of inorganic compounds such as oxides, nitrides, silicides and carbides etc. The term 'Ceramics' means hard, brittle objects made of porcelain, china clay, glass etc. The basic properties of ceramics materials are brittleness, hardness, insulation, opaqueness, non corrosive etc. Ceramics materials in civil engineering fields are bricks, tiles, glazed ceramics, glass etc.

   Types of Ceramics:

   a) *Traditional Ceramics:* They were made from crude naturally occurring mixtures having inconsistent purity. They have been used essentially in the manufacture of porcelain, tiles, bnele, silicate glasses etc.

   b) *New Generation Ceramics:* They possess exceptional electrical, magnetic, chemical, structural and thermal properties of material. Such ceramics are now extensively used in the electronic control device like computers, Nuclear Engineering, Geo space field.

   iii. **Polymers:** Polymers are organic substances and derivatives of carbon and hydrogen. They possess high corrosion resistance and can be moulded into various shapes applying heat, light weight, insulation etc. For eg. Polyethylene, polystyrene, bitumen, tar, PVC, glue and various types of rubber.

   iv. **Composites:** Composites are the composition of metals with ceramics or organic polymers. Although much dissimilarity may exist between different materials, they frequently can be utilized in conjunction to produce a material with unique properties and behaviour. Composites possess the diverse characteristics such as high strength with non corrosiveness, strength with brittleness, compressive strength, tensile strength etc. For eg. RCC, fibreglass, plastic etc.

1.4) Properties of Civil Engineering Materials:

In order to specify the material for the particular use, classify them and testing them for acceptance, we need to know their properties. The properties can be as highlighted groups:

- Physical Properties
- Mechanical Properties
- Thermal Properties
- Magnetic Properties
- Electrical Properties
- Chemical Properties

1. **Physical Properties:** It exhibit physical status of the materials.

i. *Specific Gravity:* It is the ratio of weight /mass of a given volume of solids to the weight/mass of an equal volume of water at 4^0C.

$$G_s = \frac{\gamma_s}{\gamma_w} = \frac{\rho_s}{\rho_w} \quad \text{At } 4^0\text{C } \gamma_s = 1\text{g/cc or } 9.8 \text{ KN/m}^3$$

ii. *Density:* Mass of a material per unit volume (homogeneous materials)

$$\rho = \frac{M}{V} \text{ g/cm}^3$$

iii. *Bulk Density:* It is defined as a unit volume of a material in its natural state. (with pores and voids). For most material bulk density is less than density but for liquid and materials like glass and dense stone materials, these properties are practically same.

iv. *Porosity:* It is the ratio of volume of voids in a material to the volume of granular materials.

$$n = \frac{V_v}{V}$$

v. *Water Absorption:* It denotes the ability of the material to absorb and retain water.

vi. *Permeability:* It is the capacity of the material to allow water to penetrate under pressure. Materials like glass, steel and bitumen are impervious.

vii. *Fire Resistance:* It is the ability of the material to resist the action of high temperature without any appreciable deformation and substantial loss of strength.

viii. *Frost Resistance:* It is the ability of the material to resist the action of repeated thawing and freezing of water in porous material. Dense, close pores are best in resisting the action of frost.

ix. *Corrosion:* It is the gradual destruction of metal or alloy due to chemical process as oxidation.

x. *Durability:* It is the resistance of the material to destruction by natural agencies.

xi. *Hygroscopicity:* The property of material to absorb water vapour from air and is governed by the air temperature, number of pores and nature of substance involved.

Selection of the civil engineering material is very important aspects in the design process of any civil engineering structures. Depending upon the various properties of the materials suitable selection should be done considering technical, social and economical aspects. Selection of the material may not remain constant. At the instant material may seem best but after sometime they may not be the best one. Thus, the best material today would be light, strong and durable. Such a selection of material is possible if the designer has an understanding of various material systems and their advantages and disadvantages and can call upon this knowledge to make a material selection.

2. **Mechanical Properties:** It refers to the properties of material resisting various straining action or forces.

i. *Strength:* It is the ability to withstand various forces to which it is subjected during a test or service.

ii. *Elasticity:* It is the ability of the material to restore its initial form and dimensions after the load is removed.

Hooke's Law: stress α strain

$$\frac{\sigma}{\epsilon} = E$$, Small E –Flexible and vice versa

iii. *Plasticity:* It is the property that enables the formation of permanent deformation in a material due to applied forces. It is reverse of elasticity.

iv. *Ductility:* It is the ability of material to withstand elongation and bending without breaking. For eg. making a wire by elongation. Large deformation without failure is ductility.

v. *Malleability:* This is the property by virtue of which a material may be hammered, rolled into thin sheets without rupture. This property increases with increase in temperature.

vi. *Toughness or (Tenacity):* Capacity to resist tearing. The area under stress-strain curve gives toughness. $T = \frac{\sigma_y + \sigma_u}{2} * \epsilon_f$, where ϵ_f = rupture strain

σ_y and σ_u = yield and ultimate stress

vii. *Brittleness:* When a body breaks without significant deformation known as brittleness. Lack of ductility is brittleness.

viii. *Hardness:* It is the ability of material to resist penetration by a harder body. Hard material resists scratches or being worned out by friction with another body.

ix. *Fatigue:* It is the phenomenon that leads to fracture under fluctuation and repeating loads. Fatigue failure starts at a point of highest stress (weak point). Weak points are the point of stress concentration grooves, scratches or marks, internal voids, cracks and other defects in the materials.

x. *Creep:* It is the property of material by which it undergoes deformation with respect to time under a constant load.

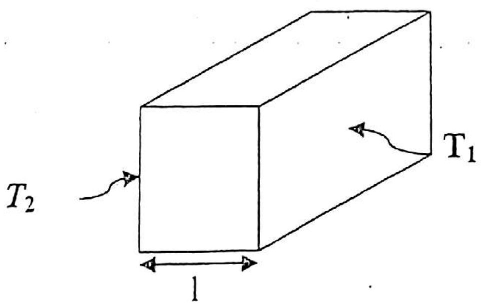
xi. *Resilience:* It is the property of material to store the energy (when deformed elastically and to retain when loaded) to resist the impact or stock. It resists the springing effect of material. It is also describe as the property of material or ability of material to resist the maximum external force without fracture within the elastic deformation.

xii. *Impact Strength:* Strength to resist sudden shock or impact over the material is known as impact strength. Impact strength of the material indicates the toughness of material. Impact strength machine is used to determine the impact strength of material.

3. **Thermal Properties:** It indicates the flow of heat across the material. These are.

i. *Heat Capacity:* It is amount of heat required to raise the temperature of unit mass of material by one degree.

ii. *Thermal Conductivity:* It is the rate at which heat can flow through a material under the influence of temperature gradient.



$$K = \frac{dQ/dt}{(T_2 - T_1)A/l}$$ where dQ/dt = rate of heat flow

A= area through which heat flow

l= distance separating the surfaces of temperature T_2 and T_1

iii. *Thermal Stability:* It is the ability of material to resist the deformation due to thermal change. For eg. Asbestos, fire clay etc.

iv. *Thermal Resistivity:* It is opposite of thermal conductivity.

4. **Electrical Properties:** Related to transfer of electric current.
   i. *Resistivity(ρ):* It is the electric property of a material due to which it resists the flow of electricity through it.
   ii. *Conductivity (σ):* It is reciprocal of electrical resistivity. It is electrical property of material due to which electric current flows easily through the material.
   iii. *Dielectric Strength:* It is the insulating capacity of a material against high voltage. A material having high dielectric strength can withstand high voltage field across it before it will breakdown and conduct.

5. **Magnetic Properties:**
   i. *Absolute Permeability:* It is the ratio of flux density to the magnetising force producing that flux density.
   ii. *Magnetic Hysteresis:* At rising temperature material becomes less magnetic and at low temperature it becomes magnetic. This phenomenon is called magnetic hysteresis.

6. **Chemical Properties:**
   Acidity, Alkalinity, corrosion etc.

2. BUILDING STONE

2.1) Introduction:

The stone are derived from rocks which form the earth's crust and have no definite shape or chemical composition. They are mixture of two or more minerals. Stones that are used for construction of structures are known as Building Stones. Stones are natural materials of construction and are obtained from quarries.

Following are some of the uses of building stones:

- Construction of building
- Construction of dam, weirs, abutment of bridge etc.
- Used as aggregate for concrete
- Used in decorating purpose eg. cladding in front and interior of the building
- As lime stone, it is used in the manufacture of lime cement etc.
- Thin slab of impervious stones are used for laying (DPC) Damped Proof Course in the building.

2.2) Characteristics of Good Building Stone:

Stones are used for construction of various civil engineering structures. To find the suitability of stones under different conditions, the following characteristics should be considered:

i. *Appearance and Colour:* Should have uniform and appealing colours and should be free from flaws and clay holes.

ii. *Strength:* A stone should be strong and durable to withstand the disintegrating action of weather. Compressive strength of building stones in practice range between 60 to 200 N/mm^2

iii. *Weight:* It is the indication of porosity and density. For stability of structures such as dams, retaining walls etc, heavier stones are required whereas for arches domes, vaults (arches roof) etc light stone may be the choice.

iv. *Hardness and Toughness:* Stones must be adequately hard and tough so that they may resist wear and tear. Hardness may be tested by scratching with a pen knife which should not be able to produce any impression on hard rock. Toughness of stone can be tested by subjecting it to a hammer action.

v. *Porosity and absorption:* A porous stone disintegrates as the absorbed rain water freezes, expands and causes cracking. The stones which are less porous are considered good stones. For a good stone, percentage absorption by weight after 24 hrs should not exceed 0.60.

vi. *Seasoning:* Good stone must be free from quarry sap. Proper seasoning should be done before it is used.

vii. *Weathering:* The capability of stone to withstand the adverse affect of various atmospheric and external agencies, such as rain, frost, wind etc. is termed as weathering. Good weathering stone should be used for the face work.

viii. *Resistance to fire:* Stone should be free from calcium carbonate, oxides of iron having different coefficient of thermal expansion, to withstand the effect of ordinary fires without suffering any serious damage.

ix. *Specific Gravity:* The specific gravity of most of the stone should lie between 2.3 to 2.5.

x. *Durability:* A good building stone should be durable. The power of resistance against wear and tear, atmospheric and other agencies is called durability. It depends on the chemical composition, physical structure, homogeneity etc.

xi. *Fineness of Grains:* For carving and moulding works fine grained stones are considered most suitable. A good building stone should have crystalline structure because such stones are generally durable and strong.

2.3) Selection and Uses of Stone:

S.No.	Use	Name of Stone	Reason for Selection
1.	Building exposed to high wind blowing particles	Granite and Sandstone	Hardness due to presence silica
2.	General building works	Sandstone	Hard and durable
3.	For heavy engineering work	Granite and gneiss	Strong, durable and capable of resisting thrust.
4.	Building exposed to fire	Compact Sandstone	Fire resisting property
5.	For building in industrial town	Granite and compact sandstone	Acids and smoke proof.
6.	For road metal and railway ballast	Granite and basalt	Hard, tough and possess abrasion resistance
7.	Electrical switch board	Slab of marble and slate	Possess electrical resistance
8	Manufacture of lime	Lime stone	Decomposed into quick lime heating
9.	As flux in the manufacture of iron	Limestone	Special characteristics.

2.4) Deterioration and Preservation of Stone:

Deterioration:

The various agencies can cause deterioration of stones:

i. *Rain:* Alternate drying and wetting for long time causes disintegration of stones.

ii. *Temperature:* Stones are composed of several minerals with different coefficient of thermal expansion. Rise or fall of temperature causes differential expansion or contraction of the minerals which causes deterioration of stones.

iii. *Frost Action:* In cold climatic condition, water present in the pores of stone may freezes and expands causes splitting of the stone.

iv. *Wind:* Strong wind causes fine particles strikes against stone and cause its decay.

v. *Atmospheric Impurities:* In the industrial areas, presence of acids and fumes in the atmosphere adversely affect the stone containing carbonate of lime.

vi. *Vegetative growth:* Vegetative growth keeps the stone in wet condition causing decay of rock stone.

vii. *Living Organisms:* Holes are bored by certain insects due to which they become weak.

Preservation:

It is always good if policy of using good stone is adopted rather than preserving the inferior stone. However, inferior stones may have to be used if good stones are not locally available. Secondly even good stones require preservation, when atmospheric condition is heavily polluted with sulphurous or carbonic acids. Hence preservation of stones is required.

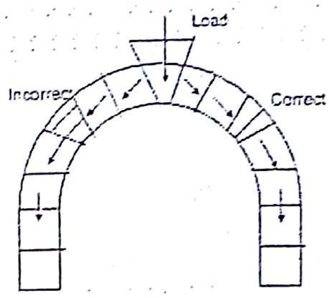
The stones can be preserved in the following ways:

- Filling up the stone pores.
- Providing the stone with a coat of preservative to prevent the entrance of moisture into the pores.
- The use of stone containing carbonate of lime in industrial town should be discouraged.
- Growth of plants and trees on the stone should be checked.
- Binding material which doesn't have any adverse effect on the particular stone should be selected.

Some of the Preservatives:

- Coal Tar: applied on the surface of stone, objectionable colour, absorb heat from sun.
- Paint: change the original colour of stone, deep penetration paint act as preservative.
- Linseed Oil:
- Bartya Solution (Barium hydroxide): used as preservative for the stones to be preserved in the atmosphere charged with carbonic and sulphurous acid. Barium hydroxide when applied to the surface of stones fills the pores and causes the hardening of the surface. This surface resists s atmospheric absorption.

2.5) Natural Bed of Stone:



It is the plane of bed on which the sedimentary rock was originally deposited. In the case of metamorphic rock, the plane of foliation or the plane of cleavage is assumed to be its natural bed. It is very difficult to trace the natural bed in the case igneous rocks and the natural bed is not given due attention. Natural bed has an important effect on the durability of stones. The stone should be so placed that the load line is at the right angle to the natural bed. In doing so, stones offer maximum resistance to crushing and disintegration by frost and rain.

Quarrying: It is an art of extracting stone from the rock beds. Open part of the natural rock from which useful material obtained is known as quarry.

2.6) Dressing of Stones:

The art of cutting the stones to shape required for the use in the structure is called dressing. Stones are dressed to give them a definite and regular shape with smooth faces.

The degree to which these objects are achieved depends upon the quality of masonry work in which the stone is to be used.

Dressing should be done as quickly after quarrying as possible and the stone should be allowed to be seasoned thereafter.

Methods of Dressing:

i. *Pitched Faced Dressing:*

In this method, edges shall be made level to a minimum width of 2.5cm and shall be absolutely square with the end of the stone. Superfluous stone on the face shall be allowed to remain left raised.

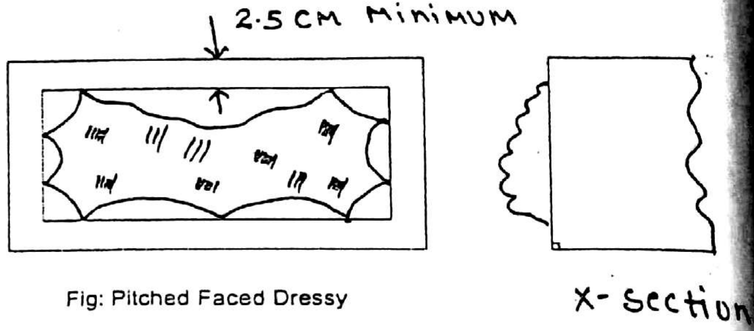


Fig: Pitched Faced Dressy

ii. *Hammer Dressed, Hammer Faced, Quarry Faced or Rustic Faced:*

It has no sharp or irregular corners and has comparatively even surface so as to fit well in masonry. Hammer dressed stone also has rough tooling for a minimum width of 2.5cm along the four edges of the face of the stone.

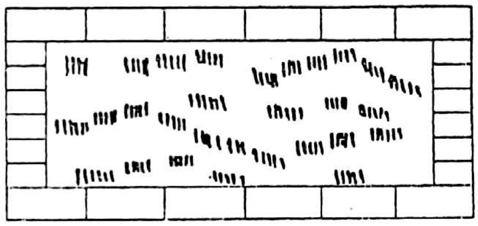


Fig: Hammer Faced

iii. *Rock Faced and Chisel Drafted:*

It has minimum 2.5cm wide chisel draft (outline of something to be done) at four edges. Superfluous stone at the centre shall be removed by pitching too; or scrapping hammer.

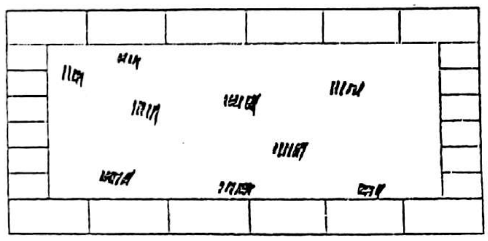


Fig: Rock Faced or Chisel Drafted

iv. *Rough Tooled:*

Edges and corner of it are made perfectly square and true. Rest of it has series of bands 4 to 5 cm wide, more or less parallel to tool marks all over the surface. Band may be vertical, horizontal or inclined at 45^0. A depression not more than 3mm is permissible. Rough tooled stones are used when a fairly smooth surface finish is desired.

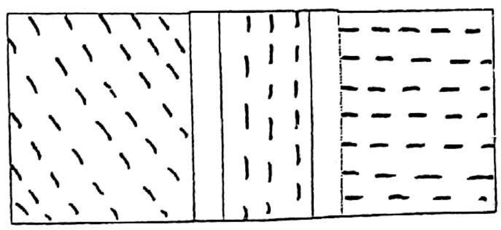


Fig: Rough Tooled

v. *Punched Dressed:*

A rough tooled surface is further dressed by making parallel cuts with chisel. A depression not more than 2mm is permissible. This finish is also called Brouched or Two Lined Dressed finish. These stones are used when an even surface is required.

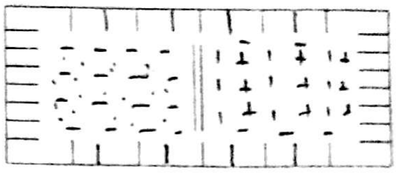


Fig: Punched Dressed

vi. *Closed Picked Dressed:*

A punched dressed stone is given a further smooth finish with chisel cut. Only very small chisel marks are left. Not more than 1mm gap should be left between the surface and the straight edge held against it. This finish is also known as sparrow finish or three line dressed.

Fig: Closed Picked Dressed

vii. *Fined Tooled:*

Close picked stones are further dressed for finer works. All projections are removed and a fairly smooth surface is obtained. There are not more than 3.4 lines per cm width of the surface.

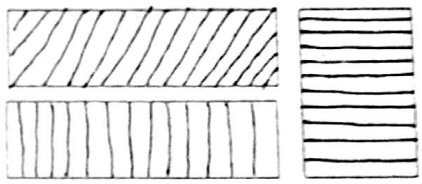
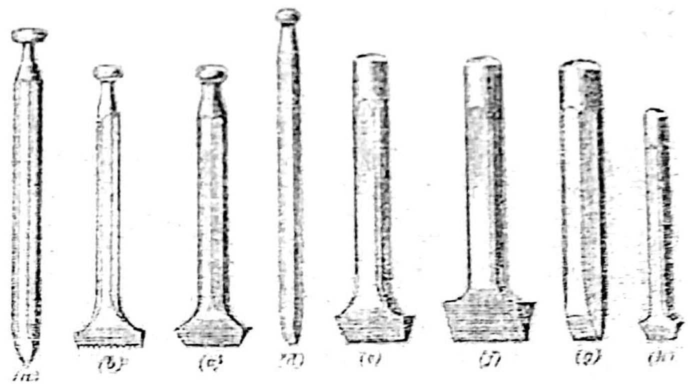


Fig: Fine Dressed



Types of Chisels

Artificial or Cast Stone:

It is the term used to represent a building material made with cement and natural aggregate cast to various shapes with a good surface finish for used in place of natural stone. For good appearance and durability white cement with aggregates of the crushed stone and stand selected to have matching colour are used. For thermal insulation the stone is made hollow.

3. CLAY PRODUCTS

3.1) Introduction:

All the materials that are made from clay are known as clay products for eg. bricks, tiles, earthenware, stoneware, refractory bricks etc. are some of construction clay materials. Brick is the most commonly used building materials. It may be defined as "Structural unit of rectangular shape and convenience size that are made from suitable types of clay by different processes involving moulding, drying and burning". Brick do not require dressing and have uniform colour, shape and size.

3.2) Constituents of Brick Earth:

Brick earth is derived from disintegration of igneous rock. Potash, felspar, orthoclase or microcline is mainly responsible for yielding clay minerals in the earth. This mineral decomposes Kaolinite a silicate of alumina which on hydration gives a clay deposit $Al_2O_3.2H_2O$ known as Kaolin (China Clay).

$$2KAlSi_3O_8 + 2H_2O + CO_2 = Al_2Si_2O_5(OH)_4 + K_2CO_3 + 4SiO_2$$

Felspar + Carbonic acid = Kaolinite + Potassium Carbonate + Silica Colloids

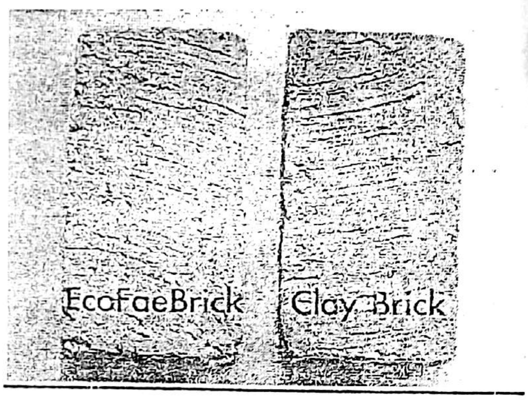
A good brick earth should be such that it can be easily moulded and dried without cracking and warping.

Chemical Composition of Brick Earth:

A good brick earth should have the following composition.

i. Alumina or Clay (Al_2O_3): 20-30% by weight.
ii. Silica (SiO_2): 35-50% by weight.
iii. Silt: 20-25% by weight. (Small part of sand, mud)
iv. Iron Oxide (Fe2O3)
v. Magnesia (MgO)
vi. Lime (CaO)
vii. Sodium Potash etc.

(iv–vii) → 1 to 2% by wt.



Function of Ingredient:

i. *Alumina or Clay (Al_2O_3):* It is principal constituent of brick. It is plastic, when wet and is capable of being moulded to any shape. On drying, it loses its plasticity and becomes hard, shrinks, warps and cracks. Burning causes the fusion of its constituents thereby making it homogeneous, harder and stronger.

ii. *Silica (SiO_2):* It exists in brick earth either in chemical composition with alumina as silicate of alumina or mechanically mixed with clay as sand. If silica in suitable proportion is added to clay, it imparts hardness to the brick and checks shrinkage, cracking and warping on drying. But if added in greater amount makes brick brittle. It also increases hardness, durability and resistance to heat.

iii. *Lime:* It helps silica to melt at lower temperature and binds the particles of the brick together. It also reduces shrinkage on drying. Excess of lime causes the brick to melt and loses its shape. If lime is present in lumps, on burning it will change to quick lime and disintegrate the brick on absorbing water.

Quick lime: expands on absorption of moisture.

iv. *Iron Oxide:* It gives pleasing red colour to the bricks. Excess amount (8 to 11%) of it causes the brick dark blue. It improves impermeability and durability and also helps the fusion of brick particles. It gives strength and hardness.

v. *Magnesia:* It affects the colour and makes the brick yellow. It reduces shrinkage. But excess of it leads decay of bricks.

Harmful Ingredient:

i. *Lime stone or Kankar nodules:*
   - Round shaped lumps.
   - Lime stone gets converted to lime on heating which in contact with water swells and causes the brick to split.
   - Certain quantity of lime is required to bind the particles of brick and reduces shrinkage on drying.

ii. *Alkalies:*
   - They lower fusion point of clay causes to brick to fuse, twist and warp during burning.

iii. *Pebbles of stone and gravel:*
   - No harmful effect chemically.
   - Make non uniform.

iv. *Iron Pyrites (FeS_2) (Iron disulphide):*
   - Present in earth, decomposes and oxidise in the brick causes splitting of brick.

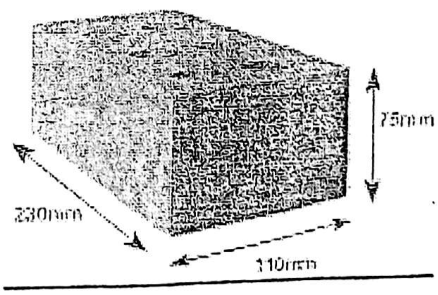
v. *Kallar or reh:*
   - Sulphate of soda mixed with common salt and carbonate of soda. Effect same as alkalies.

vi. *Vegetation and organic matters:*
   - Makes the brick porous.

Requirements of good brick earth:

i. Brick earth must have proportion of sand, silt and clay.
ii. It must be homogeneous.
iii. It must be free from lumps of lime and kankar nodules.
iv. It must be free from alkali salt, kallar or reh, pebbles etc.
v. It must not contain vegetative and organic matters.
vi. It should not be mixed with salty water.

Standard Brick Dimensions



3.3) Manufacture of Brick:

Following are the steps used in the manufacture of bricks:

i. **Preparation of Clay:** It involves: a) Selection of site and unsoiling
b) Digging and cleaning
c) Weathering and blending
d) Tempering

a. *Selection of site and Unsoiling:* The site selected for the manufacturing of bricks must have suitable soil available in sufficient amount. The fuel like coal and wood must be easily available. The site should be selected after giving due consideration to suitability of soil and location of the water table. Water table should be at least 1m below the floor of kiln. About 20 cm of the top layer of the earth normally contains stones, pebbles, gravels, roots etc. is removed and known as unsoiling.

b. *Digging and Cleaning:* After removing the top layer, the soil below 200mm is dug before rain and then cleaned off. All the lumps of soil are broken into powder form.

c. *Weathering and Blending: After* cleaning, the dug earth is heaped on level ground in layers of 60 to 120 cm. The soil is left in heap and exposed to weather at least for at least one month for atmospheric action; this process is known as weathering. It is done to develop homogeneity and imparts plasticity and strength to clay. The earth is then mixed with sandy-earth and calcareous earth in suitable proportion to modify the composition of soil. Moderate amount of water is mixed so as to obtain the right consistency for moulding. The earth is covered with cloths or mats. The process of mixing ingredients is called blending.

d. *Tempering:* Tempering consists of kneading the earth with feet so as to make the mass stiff and plastic. It should preferably be carried out by storing the soil in a cool place in layer of about 30cm thickness for not less than 36 hrs. This will ensure homogeneity in the mass of clay for subsequent processing. For manufacturing good bricks, tempering is done in pug mills and operation is called pugging.

ii. **Moulding of Bricks:** It is the process of giving a required shape to the brick from the prepared brick earth. Moulding may be carried out by hand or by machine.

a. *Hand Moulding:* It is further classified as ground moulding and table moulding.

- The process of moulding bricks on the ground by manual labour is ground moulding. In this process, the ground is levelled and sand is sprinkled on it. The moulded bricks are left for drying. During moulding, the lump of well pugged earth is kept in mould and shaping is done. The surplus clay on the top surface is removed with a sharp edge metal plate called strike.
- The process of moulding bricks on specially designed tables called table moulding. The bricks are moulded in a small wooden board with a raised central projection carrying frog, is known as stock boards. The process of filling clay is same as ground moulding. After this, a thin board called pallet is placed over the mould. The mould containing the brick is then smartly lifted off the stock board and inverted so that the moulded clay along with the mould rests on the pallet and then is carried to drying site.

Frog: It is impression left on the face of a brick moulding process. It serves for the following two purposes:

- It provides a key for holding the mortar and therefore develop structural grip.
- It provides the place to write the name of manufacturer.

b. *Machine Moulding:* It can be done in two ways. Plastic method and Dry press method. In plastic method, the pugged, stiffer clay is forced through a rectangular opening of brick size by means of an auger. Clay comes out of the opening in form of a bar. The bricks are cut from the bar by a frame consisting of several wires at a distance of brick size. It is a quick and economical method.

The moist, powered clay is fed into the mould on a mechanically operated press, where it is subjected to high pressure and the clay in the mould takes the shape of bricks. Such press bricks are more dense, smooth and uniform than ordinary bricks. These are burnt are fully as they are likely to crack.

iii. **Drying of Bricks:** Green bricks contain 7-30% moisture depending upon the method of manufacture. The object of drying is to remove the moisture to control the shrinkage and save fuel and time during burning. It is done in two ways.

a) Natural drying
b) Artificial drying

In natural drying process, the bricks are normally dried in natural open air driers. They are stacked on raised ground and are protected from bad weather and direct sunlight. A gap of about one meter is left in the adjacent layer of stacks so as to allow free movement of the workers.

In artificial Drying process, the bricks are dried by using driers such as hot floor drier and tunnel driers. In this heat is received from special furnish built for the purpose and in tunnel driers bricks are heated by fuels underneath, by steam pipes, or by hot air from cooling kilns.

iv. **Burning of Bricks:** The bricks after moulded and dried are burnt in kilns in order to impart hardness and hardness to bricks and to increase the density of water so that they will absorb less quantity of water. The bricks may be burnt in any one kiln.

Clamp or open kiln or Pazawah:

- Suitable for burning inferior brick (ground moulded)
- The bricks and fuels are placed in alternate layer. Fuel is generally composed of grass, cow dung, litter, rice husk etc.
- When clamp is loaded for about one third height, it is fired from bottom. The clamp takes about one or two months for burning and equal time for cooling.
- The burnt bricks are taken out.

Kilns:

- The kiln is a system, designed more scientifically to burn the bricks in very large numbers.
- The kilns used for burning the bricks are:

Intermittent Kiln:	Continuous Kiln
- In such kilns, where operation of burning of bricks is not continuous. The kiln is loaded then fired, then allowed to cool and lastly unloaded. -Supply of bricks is intermittent. -Quality of bricks is not uniform.	-These Kilns are continuous in operation and thus ensure continuous supply of burnt bricks. -All operation like loading firing, cooling and unloading is carried out simultaneously.

3.4 Good Qualities of Bricks:

i. *Shape and size:* A good brick should be uniform in size and plane, rectangular surface with parallel sides and sharp straight edges. Standard size of brick is (190*90*90) mm with weight of 30N. But in Nepal there is variation of sizes. Commonly the size is (230*110*55) mm.

ii. *Colour:* The brick should have a uniform deep red or cherry colour as indicative of uniformity in chemical composition and thoroughness in the burning of bricks.

iii. *Texture and Compactness:* The surfaces should not be too smooth to cause slipping of mortar. The brick should have pre-compact and uniform texture.

iv. *Hardness and Soundness:* The brick should be so hard that when scratched by a finger nail no impression is made. When two bricks are struck together, a metallic sound should be produced.

v. *Water Absorption:* A good brick should not exceed 20% of its dry weight when kept immersed in water for 24 hours.

vi. *Strength:* Minimum crushing strength is 10 N\mm^2 of a good brick. Ordinarily it should not break when dropped flat on hard ground for a height of about 1m.

vii. *Resistance to fire:* A good brick should have adequate resistance to fire. Ordinary bricks can resist temperature up to 1200 degree

viii. *Efflorescence:* A good brick shouldn't contain much alkaline salt, which may causes Efflorescence on its surface and decay the brick.

ix. *Durability:* a good brick should be able to resist the effects of weathering agencies like temperature, variation, rain, frost action etc.

3.5 Classification of Bricks:

Commonly the bricks are classified into two groups.

1) Sun dried bricks
2) Burnt bricks

1. **Sun dried bricks:** They are dried with the help of sun after moulding. These are used only in construction of temporary and cheap structures. Are avoided in expose of heavy rain.
2. **Burnt bricks:** These are burnt is clamp or Kiln and are hard, strong and durable. So, they are generally used in permanent works. Further divided into four types:
   a) First class brick :
   b) Second class brick
   c) Third class brick
   d) Over burnt or Jhama bricks

a. *First class brick:* These are table moulded and are burnt in kiln.

Characteristics:

- Thoroughly burnt and are of deep red, cherry copper colour.
- Smooth, rectangular with parallel, sharp and straight edges.
- It should have uniform texture and free from cracks and stones.
- Water absorption shall not be more than 1/6 (12-15%) of its dry weight when kept immersed for 16 hrs.
- A metallic or ringing should come when two bricks are struck against each other.
- It has specific gravity of 1.8
- No marks can be produced on it with finger nails.
- It has minimum crushing strength of 10.5 N\mm^2.

Uses:

First class bricks are recommended for pointing, exposed face work in masonry structures, flooring, cladding and reinforced brick work.

b. *Second class brick:* They are ground moulded and are burnt in kilns.

Characteristics:

- Well burnt but may be irregular in shape and size.
- Rough surface with edges neither being straight nor well defined.
- Minimum crushing strength of 7N\mm^2.
- A little higher water absorption of about (16-20) % it's dry with is allowed.

Uses:

They are recommended for brick work with the plastered face, brick ballast in Rcc and in lime concrete and for unimportant conditions and for internal walls.

c. *Third class brick:* They are under burnt, ground moulded and burnt in clamps (open Kiln).

Characteristics:

- It has light yellowish colour
- Produce dull sound when struck against each other.
- Water absorption is about 25% of dry weight
- Edges are irregular and surface quite rough.

Uses:

It is used for building temporary structure not subjected to heavy loads.Used in inferior quality of works.

d. *Over burnt bricks:* They are over burnt and badly distorted in shape and size.

Characteristics:

- They are darker in colour
- Irregular shape and size, hard and strong
- Are nitrified (charged into a glass like substance)

Uses:

It is used as aggregate for concreting. Used in foundation, floors. Is used in filling materials.

3.6) Standard Test for Bricks:

Certain tests are necessary to be conducted before any brick is accepted or rejected. Followings are some of the tests which reveal the suitability of bricks. The tests are:

i) Water Absorption Test
ii) Crushing Strength (Compressive Strength) Test
iii) Efflorescence Test
iv) Structure Test
v) Shape and Size Test
vi) Soundness Test
vii) Hardness Test

i) **Water Absorption Test:** In this test any brick is chosen from the heap and weight dry. For dry weight the dry brick is kept in an oven at 105 to 115^{0}C for some time. The brick is then kept immersed in water maintained at temperature of 27±2 ^{0}C for 24 hrs, and weighed after brick is whipped with damp cloth. The increase in weight of brick after immersion in water indicates the amount of water absorbed by brick.

ii) **Crushing Strength (Compressive Strength) Test:** In this test, well burnt bricks are selected. Specimen is immersed in water for 24 hrs. The frog of the brick is filled with 1:3 mortar and the brick is stored under damp jute bags for 24 hrs followed by immersion in clean water for 3 days. The sample is then placed between the plates of Compression Testing Machine. Load is applied axially at a uniform rate of 14 N/mm^2 and maximum load at which the specimen fails is noted.

$$Compressive\ Strength = \frac{Maximum\ Load\ at\ Failure}{Loaded\ area\ of\ brick}$$

Compressive Strength ≥ 3.5 N/mm^2 for common bricks
≥14 N/mm^2 for high quality bricks

If no testing machine is available at the field, strength can be roughly judged from the force required to break the brick with hammer. The brick should not break when fallen flat on the ground from a height of 2 m.

iii) **Efflorescence Test:** The soluble salts if present in the brick, cause efflorescence on the surface of the brick. To find soluble salts in brick, it is immersed in water for 24 hrs. It is then taken out and allowed to dry in shade. The absence of grey or white deposits on the surface indicates absence of soluble salts. If white deposits cover about 10% surface, the efflorescence is said to be slight, and it is considered as moderate when the white deposits cover about 50% on surface. For more than 50%, it becomes heavy and is considered as serious.

iv) **Structure Test:** A specimen brick is broken and its structure is examined. It should be homogeneous, compact and free from any defects e.g. Holes, lumps etc.

v) **Shape and Size Test:** All the face of the brick should be truly rectangular and sharp edges. It should be of standard sizes. 20 bricks of standard size (190*90*90) mm are randomly selected and staked lengthwise, breadth wise and height wise then,
Total Length = 3680 to 3920 mm
Total Breadth= 1740 to 1860 mm
Total Height= 1740 to 1860 mm

vi) **Soundness Test:** Soundness of a brick is estimated by stricking two specimen bricks with each other. The bricks should not break and emit clear ringing sound.

vii) **Hardness Test:** This test is carried out by making a scratch on brick surface with the help of finger nail. If no impression, then the brick is sufficiently hard.

Some Terminologies:

- **Efflorescence:** Alkaline salts if present in finished bricks absorb moisture from atmosphere and create damp conditions. On drying the moisture evaporates leaving behind grey and white powder deposits on the brick which spoil the appearance. The phenomenon is called efflorescence. It should always be dry brushed away before plastering a wall, wetting it will carry the salts back into the wall to reappear later.

- **Vitrification:** to convert the mass into glass like substance.

3.7) Tiles and their Types:

- They are thin slabs of brick earth burnt in kiln.
- Are thinner than bricks and have greater tendency to crack and warp in drying.
- Are mainly used for roof covering and paving.
- Are more liable to break.

Type s:

According to their uses:

1. **Roofing Tiles:**
   - Used in roofs
   - They should be strong durable and perfectly leak proof
   - Expensive in initial cost but less maintenance cost

   Common roofing tiles are:

   a. Flat Tiles: These are ordinary rectangular tiles and are of various dimensions. They are laid in cement or lime mortar.

      Types of flat tiles:

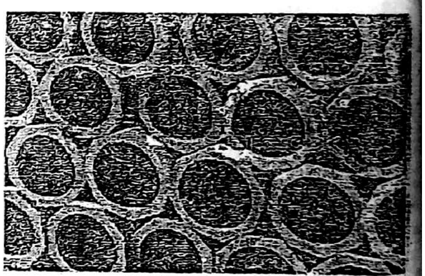
i. Slate Tiles: Size found are 60cm*30cm*15mm and 50cm*25cm*10mm. They should be reasonable straight, of uniform colour, texture etc. Water absorption ≤ 21% by weight after soaking for 24 hrs.

ii. Burnt Clay Flat Terracing Tile: They should be uniform in shape, size and be free from irregularities (e.g. bends, twists, cracks etc). Water absorption ≤ 20% by weight. Compressive strength should not be less than 7.5 N/mm^2

b. Pot Tiles or Country Tiles: These are also known as pan tiles. They are hand moulded, first into flat tiles then to the required shape on wooden pattern and burnt into a kiln after drying. They are of semicircular in section and used alone or with flat tiles generally in rural areas.

c. Corrugated Tiles: They have corrugation. While placing, a side lap of one or two corrugation is formed. Give good appearance.

2. **Flooring Tiles:**
   - Are usually square or rectangular in shape
   - Flat tiles
   - These are used for covering surface of the floor of buildings or may be any type of finishing the surface of floor of bathrooms, kitchens, hospitals, terrace, footpaths etc.
   - They may be glazed or unglazed and show maximum resistance to impact.
3. **Wall Tiles:**
   - Are thin tiles generally pressed after moulding
   - Are used for face work, cladding purpose, to some extent on arches and for architectural ceilings etc.
4. **Drain Tiles:**
   - Are long curved or semicircular sectioned tiles.
   - Used to drain out the waste water and sometime rain water from roof.
   - They may be glazed or unglazed.



3.8) Earthenware and Glazing:

Earthenware:

The clay products which is manufactured from clay mixed with sand,, crushed pottery etc by burning at low temperature called earthenware. They are generally soft and porous and are liable to damage by atmospheric action.

Uses: They are use for making ordinary drain pipes, partition blocks, electric cable conduits etc. Glazed earthenware tiles are used for finishing floors and walls of kitchens, bathrooms etc.

Types:

1. **Terra Cotta:**
   - It is high quality earthenware which is used as a substitute for stone for ornamentation of buildings.
   - Light in weight and can be easily cleaned.
   - Available in several colors and desired shapes.
   - Not affected by acid and atmospheric agencies.

2. **Porcelain:**
    - This is fine earthenware which is white, thin and semi transparent having zero water absorption
    - It is also called whiteware.
    - It is prepared from clay, felspar, quartz and minerals.
    - The constituents are finely ground and then are thoroughly mixed in liquid state. The mixture is given desired shape and is burnt at high temperature.
    - These are used for sanitary wares, electric insulation, crucibles, reactor chamber etc.

Glazing:

Bricks, tiles, earthenware, stoneware etc consists some transparent or opaque film over their surface to protect them from chemical attack and other weathering agencies. Such process is known as glazing. The glaze is glassy coat of thickness about 0.1 to 0.2 mm on the surface of items and then is fused into place by burning at high temperature. It should not form fine cracks on the surface of clay.

Types:

1. **Transparent Glazing:**
    - Transparent film is formed.
    - Salt glazing is most commonly used, since this make the items impermeable.
    - It consists of sodium chloride in the kiln when burning is at peak (1200^{0}C -1300 ^{0}C). The heat of the kiln volatises the salt, which enters into the pores of the burning items and combines with the silica in clay to make soda silicate. This soda silicate so formed combines with alumina, lime and iron in the clay to form a permanent thin, transparent surface coating.

2. **Lead Glazing:**
    - Clay items are burned thoroughly and then dipped in a solution of lead oxide and tin oxide. The particles of lead and tin adhere to the surface of clay items.
    - After this, the items are return in kiln where the particles melt forming a film of glass over the outer layer.
    - This method is used for items of inferior clay which cannot withstand high temperature required for salt glazing.

3. **Opaque Glazing:**
    - This is known as enamelling.
    - Borax, kaolin, chalk, colouring matter, felspar, oxides of tin, zinc, lead etc are mixed and ground to fin paste (known as slip) in the presence of water.
    - The items to be glazed is dried first and then dipped into the slip and then burned in the furnace at the temperature of about 120^{0}C. During this process the composition gets completely vitrified and forms uniform glaze of desired colour.
    - In this process burning and glazing are done simultaneously.

4. LIME

4.1) Introduction:

Until the invention of Portland cement, lime was used as a chief cementing material in the building construction both for mortar and plaster. In Nepal, upto today, lime has been extensively used for many types of structures. Palaces, forts, monuments, etc. that were constructed many years ago are still existing in good condition. In Kathmandu, the use of lime in construction is in increasing rate.

Lime is an important material in building construction. When it is mixed with sand and water, the mixture is called lime mortar and used for brickwork and plasterwork. When it is mixed with sand, coarse aggregate and water, the mixture is called lime concrete.

Composition:

Lime does not occur in nature in Free State. It is obtained from substance having lots of calcareous content in it. The calcareous substance has calcium carbonate ($CaCO_3$) as a chief constituent. By heating calcareous substance we obtain calcium oxide (CaO).

Lime is mainly composed of higher percentage of calcium oxide and some percentage of silica and alumina (in the form of clay). The percentage of constituent varies depending upon the type of lime.

Manufacture:

The principal stages of manufacture of lime are:

a. *Calcination or burning*
b. *Hydration or slaking*

a. Calcination or burning: This is the process of heating the limestone to redness in the presence of atmospheric air. During calcination carbon dioxide is driven out and calcium oxide is left as the final product.

$$\underset{\text{(Limestone)}}{CaCO_3} + \text{Heat} \longrightarrow \underset{\text{(Lime)}}{CaO} + \underset{\text{(Carbon- dioxide)}}{CO_2}$$

b. Hydration or slaking: The lime obtained from calcination is known as quick lime. Quick lime has greater affinity for moisture. The quick lime as it comes out from kilns is known as lump lime. Adding water in sufficient quantity to quick lime is known as *slaking*. When water is added to quick lime, it swells and cracks. Lot of heat is generated during slaking and quick lime gets converted into hydrated lime or calcium hydrate[$Ca(OH)_2$]

$$\underset{\text{(Quick Lime)}}{CaO} + \underset{\text{(Water)}}{H_2O} \longrightarrow \underset{\text{(Hydrated lime)}}{Ca(OH)_2}$$

The hydrated lime is also called slaked lime. Hydrated lime thus obtained is in the form of dry power, which is sold in market in packed bags.

4.2) Types, Properties and Uses of Lime:

Limes are usually divided into three classes as:

Types:

i) Fat, rich, pure, high calcium or white lime
ii) Poor or lean lime
iii) Hydraulic lime
- Feebly Hydraulic Lime
- Moderately Hydraulic Lime
- Eminently Hydraulic Lime

i) **Fat Lime:** Lime having high (about 95%) calcium oxide content and is dependent for setting and hardening solely on the absorption of CO_2 from atmosphere. It contains < 5% impurities of silica and alumina. It swells about 2 to 3 times of its original volume when water is added. It is slow setting and takes much time for hardening. It is used for plastering and white washing.

ii) **Poor Lime:** When the clay content is more than 30%, the lime is known as poor lime. It sets and hardens slowly. It does not dissolve in water and forms a thin paste with water. It has poor binding property therefore it is used in inferior types of works. It is also known as impure or lean lime.

iii) **Hydraulic Lime:** It sets not only absorbing CO_2 from atmosphere but also sets under water, hence called hydraulic lime. It is used in building material where strength is required.
- **Feebly Hydraulic Lime:** It contains less than 15% silica and alumina. Little increase in volume during slaking and used in inferior masonry works.
- **Moderately Hydraulic Lime:** It contains 15% to 25% silica and alumina. Small increase in volume on slaking. Rate of slaking is very slow. Gives stronger mortar than feebly hydraulic lime.
- **Eminently Hydraulic Lime:** It is of better quality than above two, contains 25% to 30% silica and alumina. It possesses same property of moderate hydraulic lime but gives stronger lime. It is used for structural purposes and works carried under water or in damped condition.

Properties of lime:

i) Easily workable and provides strength to the masonry.
ii) Possess good plasticity and offers good resistance to moisture.
iii) It stiffens quite easily and in short time.
iv) It has good adhering properties with stone and brick both.
v) Lime masonry proves durable due to low shrinkage in drying.

Uses of lime:

i) It can be used in mortar, concrete, plastering and white washing.
ii) It is used for knotting of timber works before painting.
iii) It is used for production of artificial stone, lime-sand bricks etc.
iv) It is used as flux in manufacture of steel.

v) It is used in soil stabilization.
vi) It is used for creating good sanitary condition in foul, damp and fitting places.
vii) It is used for manufacturing paints.

Comparison between Fat lime and hydraulic lime:

S.N	Properties	Fat Lime	Hydraulic Lime
1.	Raw Material	Lime Stone	Kankar
2.	Impurities	Less than 5%	In the form of clay &iron oxide 5% to 30%
3.	Color	White	Greyish white
4.	Slaking Action	Creates hissing noise & lot of heat emitted. 2 to 3 times volume increases. The rate of slaking is fast for initial 2 to 4 hrs.	No sound and heat evolution & slight increase in volume. Slaking action is very slow.
5.	Setting Process	Sets only in the presence of air.	It sets under water.
6.	Hydraulicity	It does not exhibit hydraulic property.	It exhibit hydraulic property.
7.	Plasticity	It has better plasticity hence better workability.	It is comparatively less plastic and less workable.
8.	Shrinkage	It has higher shrinkage tendency.	It has comparatively less tendency to shrinkage.
9.	Strength	It does not have much strength	It is stronger.
10.	Uses	White washing, lime plastering, lime mortar for the walls, manufacture of artificial hydraulic lime, lime cement mortar, lime surkhi mortar.	Mortar for heavy masonry works, lime concrete, works under water and foundations.

4.3) Properties and Uses of Pozzolanic Materials:

Introduction:

- Pozzolona is derived from Pozzouli, a town in Italy near Mount Vesuvious.
- The sand (volcanic dust) around this town when mixed with hydrated lime was found to possess hydraulic properties.
- Pozzolona may be defined as siliceous and aluminous material which do not have cementitious properties themselves but reacts in the presence of water with lime at normal temperature to form compounds of low solubility having cementitious properties.
- Volcanic ash containing 80% clay.
- Before the advent of cement these were used with lime to make concrete.
- Currently, its principal use is to replace a proportion in cement when making concrete.

Properties:

- Improvement in workability of concrete mix with reduction of bleeding and segregation.
- Economical to use.
- Greater imperviousness, to freezing and thawing and to attack by sulphates and natural waters.
- Assists the early setting and hardening of the mortar.
- Low heat of hydration
- Do not possess cementitious properties themselves.

Uses:

The main justification for using pozzolana is the possibility of reducing costs. If they are to reduce cost, they must be obtained locally and it is for this reason that they have not so far been much in used.

- They are used for producing lean mixes of concrete to improve their workability.
- Useful in mortars and concretes to be used for hydraulic structures weir, dams etc.

Types:

Self study: Not in syllabus

- Natural:
    - Clays and Shales
    - Opaline materials
    - Volcanic Tuffs and pumicities
- Artificial
    - Fly ash
    - Burnt Clay or Ground Bricks
    - Slag

Some Terminologies:

Hydraulicity: It is the property due to which lime (or cement) will set in damp places or underwater or in thick masonry walls where there is no free access of air. Pure limestone (such as white chalk and marble) and also mechanical mixture of limestone and sand do not possess hydraulic properties. Surkhi is considered as artificial pozzolana and used in lime to maintain hydraulicity.

5. CEMENT

5.1) Introduction:

Cement in general sense are adhesive and cohesive materials which are capable of binding together particles of solid matter into compact durable mass. For civil engineering, it is one of the important materials. Today Cement finds extensively used in all types of construction works such as road, building, bridge, water tanks, dams, tunnels etc.

Cement commonly used for normal construction work is known as Ordinary Portland Cement (OPC) (Cementing materials resembling a natural stone quarried from Portland, in UK). However, for use under specific condition a variety of cements are available these days. Its quick setting property, high plasticity, workability, moisture resisting property, strength and ease with which it can be used under variety of conditions has made it the most popular cementing materials.

Cement may be natural or artificial. Natural cement is available by crushing the natural cements stones which contain 20% to 40% of argillaceous matter (clay) and remaining content mainly calcareous matter (calcium carbonate). Artificial cements are made artificially in factory. Some examples of natural cement are Roman Cement, Pozzolana Cement and Medina Cement.

5.2) Properties and Uses of Cement:

Properties of cement:

Good cement possesses the following properties (which depend upon its chemical composition, thoroughness of burning and fineness of grinding).

i) Possess good plasticity and workability.
ii) It is stronger and hardens easily.
iii) It is good moisture resistant. So, known as an excellent building material.

Uses of cement:

i) It is used in cement mortar for masonry work, plastering, making joints for pipes, drains etc.
ii) It is used for laying floors, roofs and constructing important engineering structures such as bridge, culverts, dams, tunnels etc, .
iii) It is used for preparation of foundation, water tight floors, footpaths etc.

Types of cement: *Discussed later*

5.3) Ingredients of Cement (OPC):

The main constituents of cement are calcareous and argillaceous materials. The ordinary cement consists of three ingredients predominantly, which are clay or alumina, silica and lime. Approximate composition of raw materials used for manufacturing ordinary Portland cement is:

S.N	Raw Materials	Function of Ingredients	Composition (%)
1.	Lime(CaO)	Controls strength and soundness. Its deficiency strength and setting time	60% to 65%
2.	Silica (SiO_2)	Imparts strength to the cement due to the formation of dicalcium and tricalcium silicate. In excess it provides greater strength but at same time prolongs setting time.	20% to 25%
3.	Alumina(Al_2O_3)	It imparts quick setting quality to cement. It acts as a flux and lowers the clinkering temperature. Excess amount of it reduces the strength of cement	4% to 8%
4.	Iron Oxide (Fe_2O_3)	It provides colour, hardness and strength to the cement. It also helps the fusion of raw materials during manufacturing of cement.	2% to 4%
5.	Magnesium Oxide (MgO)	If present in small amount, imparts hardness and colour to the cement. In excess makes the cement unsound.	1% to 3%
6.	Sulphur trioxide (SO_3)	If present in small amount makes the cement unsound (weak strength)	1% to 3%
7.	Alkalies	In excess causes efflorescence.	0.2% to 1%
8.	Gypsum ($CaSO_4$)	Imparts setting time of cement	3% to 5%

Harmful Ingredients of cement:

The presence of the following two oxides affects the quality of the cement adversely:

i) Alkali Oxide (K_2O and Na_2O): If the amount of alkali oxide exceeds 1%, it leads to the failure of concrete made from that cement.

ii) Magnesium Oxide (MgO): If the content of MgO exceeds 5%, it causes cracks after mortar or concrete hardness.

5.4) Manufacture of Cement (Flow Diagram):

Calcareous and argillaceous raw materials are used in the manufacture of Portland cement. The calcareous materials used are cement rock, limestone, marl, chalk, and marine shell. The argillaceous materials consist of silicates of alumina in the form of clay, shale, slate and blast furnace slag. From the above materials, other like lime, silica, alumina, iron oxide and small quantities of other chemicals are obtained. Cement can be manufactured by the following two methods:

1. *Dry Process (Modern Technology):*
   The dry process is adopted when the raw materials are quite hard. The process is slow and the product is so costly. In this process lime stone and clay are ground separately to fine powders and then mixed together in the desired proportions. Dry mixing and blending is done and the resulting product is dried and burnt in kilns. To the clinker obtained after

burning is added three to five percent of gypsum and ground to very fine powder. This final product is cement and ready for use.

It is difficult to have the correct proportion of constituents so the quality of cement is not as good as that of the one manufactured by the wet process.

2. *Wet Process (Old Technology)*

The operation in the wet process of cement manufacture are mixing, burning and grinding. The crushed raw materials are fed into ball mill and little water is added. On operating the ball mill, the steel ball in it pulverise the raw material which form slurry with water. The slurry is passed to silos (storage tanks), where the proportioning of the compounds is adjusted to ensure desired chemical composition. The corrected slurry having 40% moisture content is the fed into rotary kiln where it loses moisture and forms into lumps or nodules. These are finally burned at 1500-1600^{0}C. The nodules changes to clinker (0.3 to 2.5 cm diameter) at this temperature. Clinker is cooled and then ground in tube mills. While grinding the clinker, about 3% gypsum is added. After grinding, fine powder is formed and made ready for packing in the bags.

5.5 Composition and function of Cement clinker:

The various constituents combine in burning and form cement clinker. The compounds formed in the burning process have the properties of setting and hardening in the presence of water. The following compounds are formed during clinkering process:

Principal Compounds	Formula	Name	Symbol
1.Tricalcium Silicate	$3CaOSiO_2$	Alite	C_3S
2.Dicalcium Silicate	$2CaOSiO_2$	Belite	C_2S
3.Tricalcium Aluminate	$3CaOAl_2O_3$	Celite	C_3A
4.Tetra calcium alumino ferrite	$4CaOAl_2O_3Fe_2O_3$	Felite	C_4AF

Function

i) Tri calcium Silicate (C_3S):

- It is about 25-50% (normally about 40%) of cement.
- It renders the clinker easy to grind.
- Hydrates rapidly and generate high heat
- Develops early hardness (responsible for 7 days hardness) and strength.

ii) Dicalcium Silicate (C_2S):

- It is about 25-40% (normally about 32%) of cement.
- It imparts resistance to chemical attack.
- Hardens and hydrates slowly.
- Imparts ultimate strength to the cement.

iii) **Tricalcium Aluminate (C_3A):**

- It is about 5-11% (normally about 10.5%) of cement
- Weak against sulphate attack.
- Reacts fast with water and is responsible for flash set off finely grounded clinker.
- Causes initial setting of cement.
- High heat of hydration.

iv) **Tetra calcium Alumino ferrite (C_4AF):**

- It is about 8-14% (normally about 9%) of cement.
- It has poor cementing value.
- Reacts slowly and generate small amount of heat.

It has been observed that most of the strength developing properties of cement are controlled by C_3S and C_2S. Thus by changing the relative proportions of these compounds, various types of cements are manufactured.

- High % of C_3S and low C_2S:
  - Rapid hardening
  - Early strength with high heat of hydration
  - Less resistance to chemical attack.
- Low % of C_3S and high C_2S:
  - Slow hardening
  - Much more ultimate strength
  - Greater resistance to chemical attack

Grades of OPC:

Generally three grades of cement are available, 33 grades, 43 grades and 53 grades. Tested as per IS 4031-1983, 28 days strength should not be less than 33 MPa, 43 MPa and 53 MPa.

IS- 10262 has classified OPC grade wise from A to F based on 28 days compressive strength.

Category	Strength (MPa)		Market Available Fall in
A	32.5-37.5	33 grade	
B	37.5-42.5		
C	42.5-47.5	43 grade	
D	47.5-52.5		43 grade
E	52.5-57.5	53 grade	
F	57.5-62.5		53 grade

5.6) Standard Test of Cement:

i. **Chemical Composition Test:**

Heat 1 gm of the sample for 15 mins in a platinum crucible or for 1 hr in porcelain crucible at a temperature of 900^0C to 1000^0C. Cool and Weigh:

- Loss of ignition ≯ 4%
- Wt of insoluble residue ≯ 2%

- Wt of magnesia ≯ 5%
- Lime saturation factor ≯ 1.02%
- Ratio of percentage of alumina to Fe_2O_3 ≮ 0.66

ii. **Fineness Test:**

The degree of fineness of cement is the measure of the mean size of the grains in it. Finer cement has quicker action with water and gain early strength. Finer test is carried out by:

- *Sieve Test:* The maximum residue after sieving through 90μ I.S sieve should be limited to 10% by wt. of OPC and 5% for rapid hardening and Portland Pozolana cement.
- *Surface Area Test:* It is also called specific surface test. Better than sieve test. Specific surface is the total surface of all the particles of cement per unit test. It can be determined by Air Permeability Method. Properly ground for OPC specific surface ≮ 2250cm^2/gm.

iii. **Consistency Test:**

This is the test to estimate the quantity of mixing water to form a paste of normal consistency. This test precedes the test of cement for soundness, setting time, tensile strength or compressive strength. It is done with the help of Vicat's Apparatus.

- A trail paste of cement (300 gm) and water 25% by weight of cement is mixed and placed in the Vicat's mould.
- The plunger is then brought into the contact with the paste surface and then released. Under the action of it, plunger will penetrate the paste.
- The depth of penetration depends on the consistency of cement paste.
- Standard consistency is obtained when the plunger will penetrate the paste to a point 5 to 7 mm from the bottom of the mould. Usual range is 26 to 35%.
- Consistency is expressed in % by weight of cement.

iv. **Setting Time Test:**

The term setting implies solidification of the plastic cement paste. Initial and Final setting time may be regarded as the two stiffening states of cement. The beginning of solidification is called initial set.

Initial setting time is determined to give sufficient time for mixing, transportation, placing and compaction of cement mortar and concrete.

- Cement paste of normal consistency is prepared and filled in Vicat's mould.
- A round or square needle of cross-sectional area of 1 mm^2 is attached to the moving rod. The needle is then brought to contact and released quickly and allowed to penetrate. The needle is then taken out and dropped at fresh place.
- The procedure is repeated at regular interval of time.
- The initial set is said to have taken place when the needle fails to penetrate beyond a point 5mm above the glass plate. The time taken from the instant water was added to the cement to the moment when the needle fails to penetrate beyond 5mm above the glass plate is called initial setting time. It should not be less than 30 min for OPC.

For final setting time, the 1 mm square needle is replaced by the annular collar and needle arrangement. The needle has 1mmϕ and 0.5 mm projection with annular collar and dia 5mm. The collar and needle is brought into contact with cement paste of normal consistency and released. The final set shall be considered when the needle makes and impression but circular cutting edge fails to do so. The time taken from mixing water to that time is known as final setting time. For OPC = 10 hrs. Final setting time defines the beginning of development of mechanical strength.

v. **Soundness Test:**

Once the concrete in a structure has hardened, it is necessary to ensure that no volumetric changes take place. The test is performed to find the presence of uncombined lime and magnesia in cement. It is tested with Le- Chatelier Apparatus.

- Cement paste of normal consistency is prepared.
- The brass cylinder (30mm dia, 30 mm high and 0.5 mm thick) is placed on a glass plate and filled by cement paste. It is covered by another glass plate at the top. A small weight is placed at the top.
- The whole assembly is immersed in water for 24 hrs. (24^0C to 35^0C)
- At the end of the period the distance between the indicators is measured.
- The mould is immersed in water again and brought to boil in 30 mins. After boiling for one hour, the mould is removed and after cooling the distance between the indicators is again measured. The increase in this distance represents the expansion of the cement according to I.S it should not exceed 10mm of any type of OPC.
- Fine grinding of raw materials and clinker help to produce sound cement.

If expansion exceeds 10mm, the cement is not rejected but a further test is made after the cement has been spread and aerated for 7 days (allows the lime to hydrate) after that again Le- Chatelier test is performed. The expansion should not exceed 5mm.

vi. **Tensile Strength Test:**

The tensile strength may be determined by Briquette test.

- 1:3 mortars is prepared with 8% of water (total weight of solid) and mould into a briquette.
- Briquettes are then cured for 24 hrs at temperature 27 ± 2^0C and relative humidity of 90% and tested in direct tension.
- The average strength of 6 briquette samples after 3 and 7 days should not be less than 2 and 2.5 N/mm^2 respectively.

vii. **Compressive Strength Test:**

Compressive strength is the basic data required for mix design. By this test, the quality and quantity of concrete can be controlled and the degree of adulteration can be checked.

- The test specimens are cubes of (1:3) cement mortars are made by gauging 185 gm of cement, 555 gm of sand and 74 gm of water.
- Moulded cube is then placed at damp for 24 hrs. Then kept immersed in water for 3 to 7 days till the test is performed.
- After 3 days, compressive strength should not be less than 16N/mm^2 for OPC.

.2) Types of Cement (Contd.):

roadly divided into two parts:

A. Portland Cement

i. Ordinary Portland Cement
ii. Modified Portland Cement
iii. Rapid Hardening Portland Cement
iv. Low Heat Portland Cement
v. Sulphate resisting Portland Cement
vi. Water repelling Portland Cement
vii. Water Proof Portland Cement

B. Other varieties of Cement

i. High Alumina Cement
ii. Quick Setting Cement
iii. Blast furnace Slag Cement
iv. White Cement
v. Coloured Cement
vi. Acid resisting Cement
vii. Expanding Resisting Cement
viii. Hydrophobic Cement
ix. Portland Pozzolana Cement
x. Super sulphate Cement etc.

A. Ordinary Portland Cement

i. ***Portland Cement:*** Ordinary Portland cement is the common type of cement available in the market. This has medium rate of strength development and medium rate of heat generation. Initial and final setting times of OPC are 30 minutes and 10 hours respectively. It possesses sufficient resistance against dry shrinkage and cracking but less resistance to chemical attack. It is used in almost all types of general construction.

ii. ***Modified Portland Cement:*** This cement on setting develops less heat of hydration than OPC. Due to low heat of hydration it can be employed in hot climate. Generally used for mass construction works such as heavy abutments, large piers, retaining walls etc.

iii. ***Rapid Hardening Portland Cement:*** Rapid hardening Portland Cement gives strength faster than OPC, though its initial and final setting time is same as that of OPC. This cement contains more Tri-calcium silicate, which is responsible for the rapid hardening of the cement. It is also made finer than OPC. This cement is used in the construction field where strength should be achieved more quickly and formwork should be removed earlier. It is lighter than OPC and curing period is also short.

iv. ***Low Heat Cement:*** Low heat cement is due to the lesser rate of heat production. It has low percentage (5%) of C_3S which is responsible of high heat of hydration) and high percentage (46%) of C_2S which hydrate slowly. It contains less lime and possesses less compressive strength. Initial setting time 1 hour and final setting time is 10 hours. It is used in mass concrete works such as dams, large raft foundation etc.

v. ***Sulphate Resisting Portland Cement:*** In hardened cement there exist two compounds which are sensitive to sulphate attack e.g calcium and Aluminates hydrate which reacts with $MgSo_4$ and Na_2So_4 to form sodium Magnesium sulpho aluminate. This reaction involves on increase of volume of solid about 2 to 4 times and disintegrates the mass. In this case, the % of C_3A is kept about 5% and it results in the increase in resisting power against sulphates. It is used at place where sulphur action is source (Seawater, underground water construction)

vi. ***Water Repellent Portland Cement:*** It contains as small percentage of water proofing material uniformly mixed with the cement and is manufactured under the name Aquacrete. The cement is prepared with ordinary or rapid hardening cement and white cement. It is used in the water tight concrete works to check moisture penetration in basement etc.

vii. ***Water Proofing Portland Cement:*** These cements are prepared by mixing with OPC or rapid hardening cements, a small percentage of some metal stearate (Calcium, aluminium etc) during grinding. The concrete is more resistant to penetration by water and some oils than OPC and also corrosive resistance against acid and alkalies. It is used for tanks reservoirs retaining walls, swimming Pools etc.

B. Other varieties of Cement

i. ***High Alumina Cement:*** It is prepared by fusion of lime stone and bauxite in correct proportion at high temperature (1600 degree Celsius). It contains meanly 35% of alumina and the ratio of alumina to lime is between 0.55 and 1.3. It develops strength rapidly and resists chemical attacks especially sulphate attack and carbon dioxide attack dissolved in water. So use in the manufacture of RCC pipes. It should not be used in place where temperature exceeds 18 degree Celsius.

ii. ***Quick Setting Cement:*** The quantity of gypsum is reduced and small percentage of aluminium sulphate is added, which accelerate the setting action. It is ground much finer than OPC. Its initial and final setting time is 5 minutes and 30 minutes respectively. It is used when concrete is to laid under water or in running water.

iii. ***Blast furnace Slag Cement:*** It is made by intergrading Portland cement clinker and blast furnace slag. Less heat of hydration, cheaper than OPC and more resistive against weathering agencies and chemical attacks. It is used in mass concreting and sea water construction. (Sulphate resisting)

iv. ***White and coloured Cement:*** White cement possesses same strength properties as that of OPC but it has greater aesthetic value than OPC. It is clear white in colour. This white colour is due to the absence of Iron Oxide and MgO in the cement. Also, cement is heated in the kiln where oil is used as fuel instead of coal to avoid the contamination by coal ash. Special consideration is also taken while grinding the clinker. White cement is costlier and is only used for interior decoration and architectural finish.

For giving colour to the cement pigments of suitable colours are added during grinding. These are mostly used in floor finishing, external surface finish; stair treads windows sill's slabs etc

v. ***Acid resisting Cement:*** It consists of an aqueous solution of sodium silicate (soluble glass), an acid resistant aggregate and an additive (hardening accelerant). The micro aggregates are quartz, quartzite, diabase and other acid resistant materials; hardening accelerant is sodium fluosilicate. The acid resistant cements are used for lining chemical apparatus and building towers, tanks and other installation for chemical industry.

vi. ***Expanding Resisting Cement:*** It is made by adding an extra expanding medium sulpho – aluminate and a stabilising agent to the ordinary cement. It is used for the construction of water retaining structure, repairing the damage concrete surface.

vii. ***Hydrophobic Cement:*** It contains admixture (acidol, naphthene soap, oxidize petroleum etc) which form a thin film around cement grains and decrease the melting ability of cement grains. It is used to make water resistance structure (frost resistance)

viii. ***Portland Pozzolana Cement:*** It is mixture of cement and Pozzolana. About 25% of Pozzolanic materials is added to ordinary cement Clinker and ground finely. It gives less heat of hydration, cheaper, possesses plasticity and higher tensile strength etc. It is used in the construction of hydraulic structures.

ix. ***Super sulphate Cement:*** It is made by inter-grinding a mixture of 80-85% of granulated slag with 10-15% of calcium sulphate and about 5% Portland cement clinker and ground to a fineness of 4000 to 5000 cm^2/gm. It is highly resistive against sulphate attack. It is used in places where sulphate attack is aggressive (in sea water, soil water, marine works, pipes carrying industrial wastages etc.)

5.7) Cement Water Proofers:

Cement mortar or concrete, rich in cement, becomes fairly water tight when set. However, addition of certain water proofers to cement mortar or concrete, during mixing, makes them absolutely water tight on setting. These water proofers render mortar or concrete water tight either by filling the pores physically or reacting chemically. The water proofers may be in power, paste or liquid forms. The amount to be added must be in accordance with the instruction of manufacture.

Uses:

a. Swimming Pool
b. Basement
c. Cold Storage
d. Water Supply and Sewage work.
e. Bathroom and Kitchen

f. Hospitals
g. Reservoirs

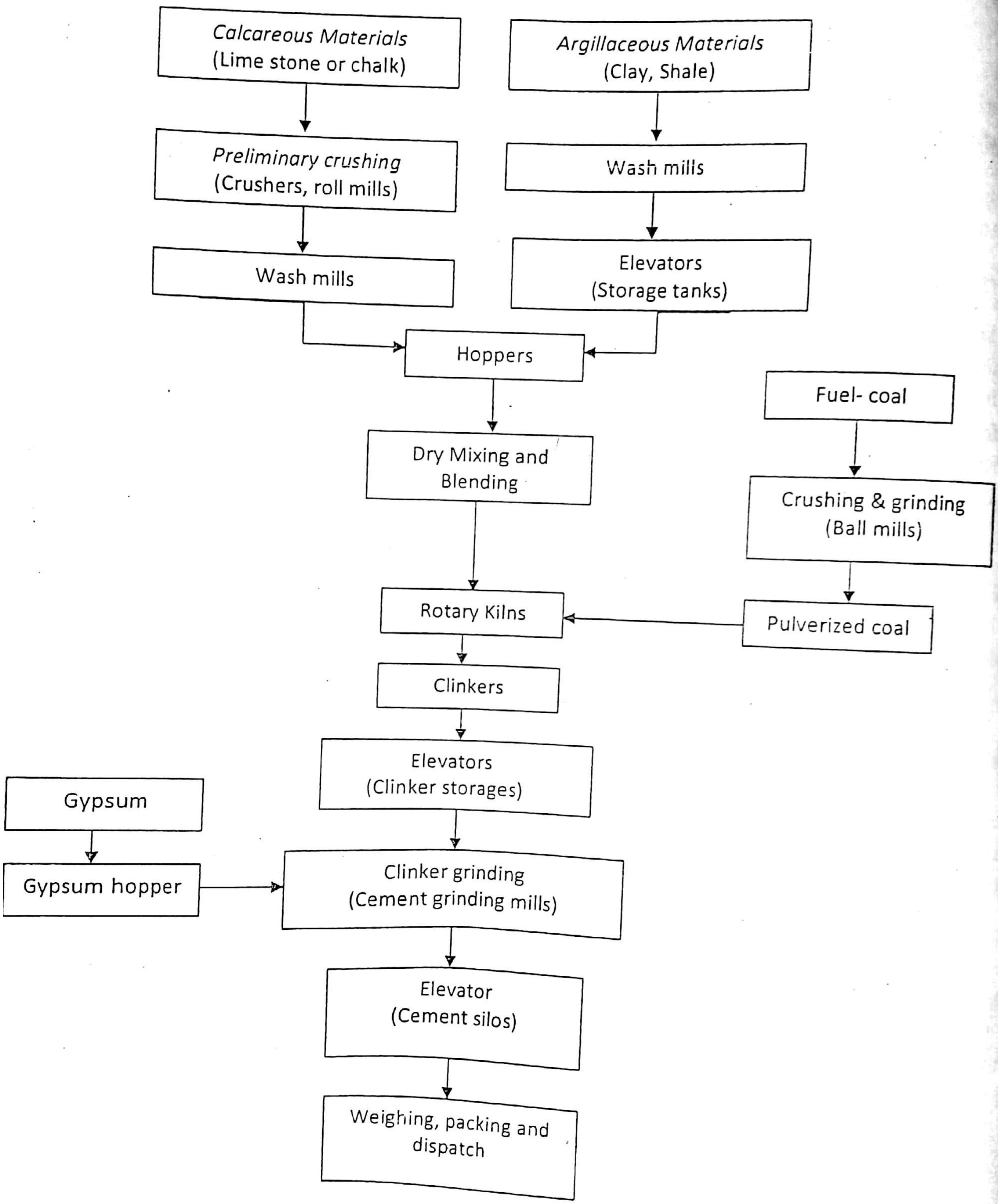
5.8 Admixtures:

Admixtures are the materials which are added in cement mortar or concrete to improve their quality. Various admixtures with differ trade names are available in the market.

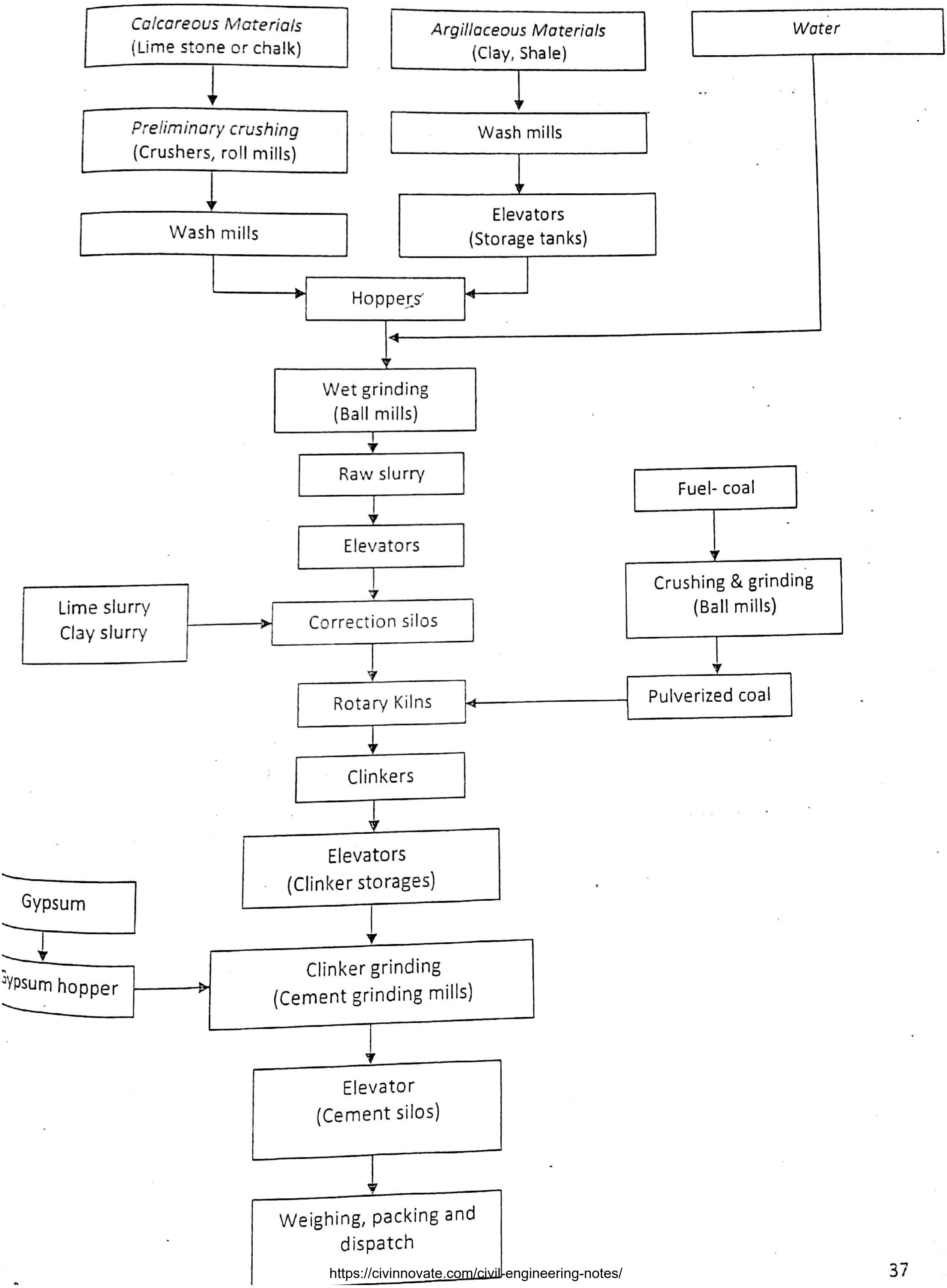
Purposes of Admixtures:

a. Improve the workability.
b. Retard setting action of mortar or concrete.
c. Increase the bond strength between reinforcement and concrete.
d. Improve the water proofing properties of the cement mortar or concrete.
e. Reduce shrinkage during setting of mortar or concrete.
f. Reduce bleeding and segregation effect of concrete.

Flow diagram for Dry process



Flow diagram for wet process



6. BUILDING MORTAR

6.1) Introduction:

Mortar is a paste formed by mixing water, binding materials (Cement and Lime) and inert material as fine aggregate in varying proportions. Mortar is usually named according to the binding material for eg cement mortar, lime mortar, mud mortar wood etc. It is used as a binding material in brick or stone masonry and for plastering purpose.

6.2) Types of Mortar:

The various types of mortar are:

i) **Cement Mortar:**

Cement mortar consists of a mixture of cement, sand and water in suitable proportion. The proportion of cement to sand by volume varies 1:3 to 1:6 or even more. This mortar is stronger than all other mortars and as such is commonly used in the construction of load bearing walls, pillars, columns etc. Being impervious, it is advantageously used for external walls, exposed situations and below ground level.

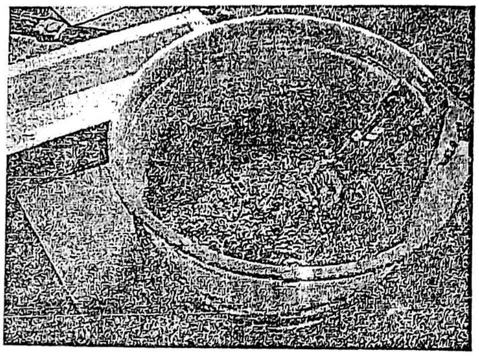


Fig: Cement Mortar

ii) **Lime Mortar:**

In this type of mortar, lime which may be fat lime or hydraulic lime is used as a binding material. During setting, lime shrinks considerably and hence, 2 to 3 times its volume of sand is added to limit the shrinkage. If fat lime were to be used in the mortar it should be slaked before use. Fat lime mortar is suitable for water logged and damped situation.

Fig: Lime Mortar

In case hydraulic lime, proportion of lime to sand by volume is about 1:2 or so on. This mortar should be used within one hour after mixing. This mortar can withstand damp condition and is stronger than fat lime mortar.

iii) **Lime-Cement Mortar (Composite mortar or Gauged mortar):** This mortar is nothing, but lime mortar prepared as before, but in it some cement is also added at the time of using it. Addition of small amount of cement in lime mortar increases the strength, hydraulicity and rate of setting of the mortar. Such mortars are more plastic and workable. It is used bedding, for thick brick walls, as masonry in foundation, plinth and super structures etc.

Special Mortars:

i) **Mud Mortar:** In this clay is pugged with water until acquires the required consistency. Sometime certain a fibrous material (or gobber) is also added to prevent shrinkage crack. It is also called Gara and can be used for plastering Kuchha huts etc.

ii) **Cement Clay Mortar:** Finely ground clay and cement are mixed with 1:1 proportion. Addition of clay improves the grain composition, workability and make impervious. It is used masonry joints and plastering.

iii) **Light Weight and Heavy Weight Mortar:** Light weight mortar is obtained by adding materials such as asbestos fibres, wood powder, saw dust etc. to ordinary cement or lime mortars. They are used in heat proof and sound proof structures, where load acting is also very low.

In heavy weight mortars, heavy quartz or other sands are added. Have higher density and used in load bearing structures.

iv) **Decorative Mortars:** Such mortars are made by using coloured cements, pigments and fine aggregates in suitable proportion. They are used where aesthetic works are needed.

v) **Air Entrained (Plasticized) Mortar:** Plasticizers are used to make mortar workable and to improve their flow capacity without using water. The air entrained makes the mortar light and better heat and sound insulation.

vi) **Sound Absorbing Mortar:** Mixing of lime/cement/gypsum slag etc. and aggregate of light weight (porous). Its main purpose is to reduce noise level.

vii) **X-ray Shielding Mortar:** Aggregates are from heavy rock mixed with binding materials and suitable admixtures are added to enhance this property. These are used for plastering of walls or ceiling of X-ray cabinets.

viii) **Fire Resistant Mortar:** This mortar is obtained by mixing powder of fire bricks or firer clays with aluminous cement. This mortar can withstand the effect of very high temperature and as such is used for lining of furnace, fire places and ovens.

ix) **Packing Mortars:** In order to pack oil wells, packing mortars are used. These are special mortars having the properties of high homogeneity, water resistance, predetermined setting etc.

6.3) Function and Uses of mortar:

1. Function:

a. It provides a binding force between the structural units i.e. bricks or stones.
b. It acts as a medium for distributing the forces throughout the structure uniformly.
c. It imports to the structure additional strength and resistance against rain penetration and other such weathering agencies.
d. To fill up the dry or empty joints a thin liquid mortar is used and is called grout.

2. Uses:

a. It is used to bind the masonry.
b. It is used in pointing and plastering

c. Used in concrete as matrix (cementing material)
d. Used to improve general appearance of structure.

Selection of Mortar for Different Engineering Works :

Thick joints in stone masonry	Hydraulic lime sand mortar(1:2 to 3)
Stone masonry in foundation and superstructure of ordinary bldg.	1:2 fat lime surkhi mortar or 1:1:1 surkhi lime sand mortar
Brickwork in arches, plastering inside of walls	1:5 to 1:6 cement sand mortar or lime surkhi mortar (1:2)or lime, surkhi and sand (1:1:1) mortar
Reinforced brickwork	1:3 cement sand mortar
Mass concrete in foundation, paving tiles, cavity walls, plastering of ceiling and external plastering work etc. where good finish is required.	1:4 cement sand mortar or 1:2 or 3 hydraulic lime mortars.
Massive works, dams, retaining walls, damp proofing, cement concrete flooring etc.	1:3 cement sand mortar
Massive work below GL specially in water logged areas	1:3 cement sand mortar or 1:3 lime (eminently hydraulic) sand
Pointing works	1:1 to 1:2 cement sand mortar
General RCC works such as slabs, beams and columns etc.	1:2 cement sand mortar
DPC and cement concrete roads	1:2 cement sand mortar
RCC tanks and other retaining structures etc.	1:1.5 cement sand mortar
Highly stressed structures	1:1 cement sand mortar
Laying firebricks	Fire resisting, mortar consisting of 1 part of aluminous cement to 2 part of finely crushed powder of fire bricks.

7. TIMBER

7.1) Introduction:

Wood is obtained from trees. It includes all types of woods which may be burning wood, structural wood, furniture wood etc. But wood suitable for use as a structural material is called *timber*.

When it forms part of a living tree is called standing timber. When the tree has been felled it is called rough timber. When it has been shown to various market forms such as beams, batten and planks etc it is called converted tree.

Timber is one of the oldest materials of construction.

- Green Timber: The tree felled freshly which has not lost much of its moisture or the timber with free water in its cells after freshly felled.
- Dressed Timber: It is the timber which has been sawn, placed and worked to the exact required condition.
- Structural Timber: The timber used in framing and load bearing structures.
- Clear Timber: The timber free from defects and stains .

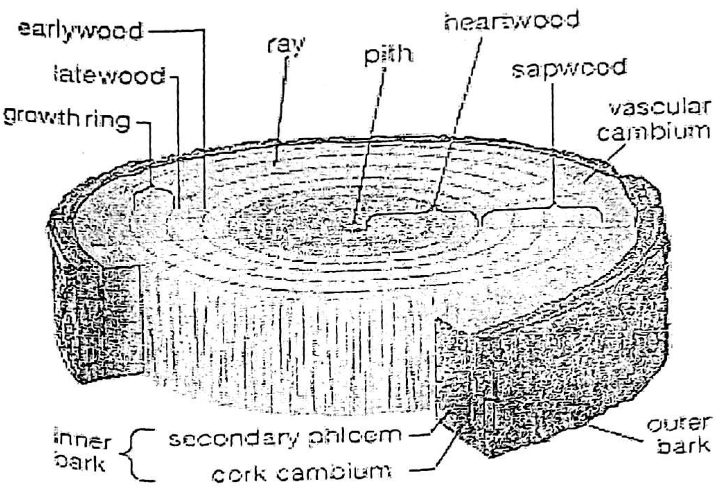
7.2) Growth and Structure of Tree:

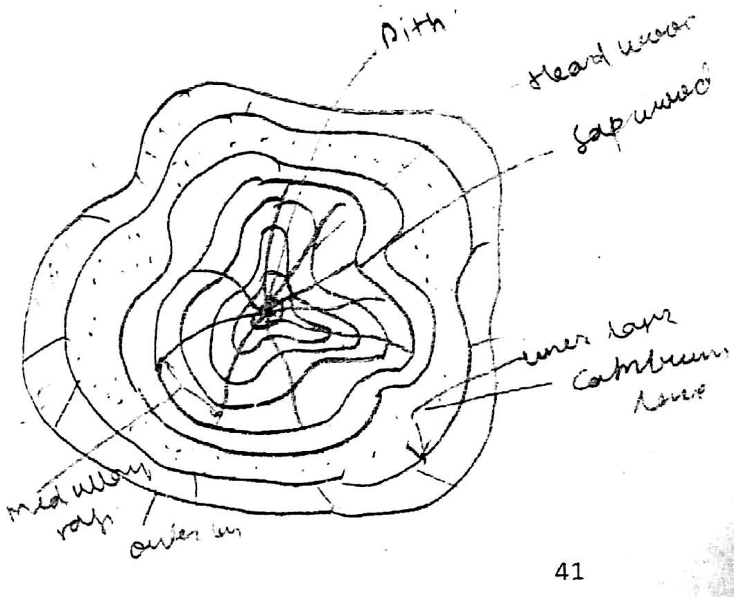
Growth:

In Spring, the roots of the tree suck soil salt as food from soil which reaches the branches and the leaves. It contains moisture which gets evaporated. It observes CO_2 form air in presence of sun light and becomes denser. This transformed viscous solution is called *Sap*. In Autumn, the sap descends and deposits in the form of a layer below the bark. This layer, referred to as the *cambium layer*, hardens and adds a layer of wood to the outside of trees every year in form of concentric rings called *annual rings*. The new ring represents a year's growth of tree.

Structure of tree:

On examining the X- Section of trunk of an exogenous tree, we see the different parts as shown in the figure.





xi) **Pith or Medulla:** It is first formed portion of the stem of tree. It consists entirely of cellular tissues. The pith, in the young plants contains large amount of fluid and nourishes the plant. It dies up and decays when plants become a old.

xii) **Annual Ring:** These consist of cellular tissue and woody fibres arranged in distinct concentric circles round the pith. Annual rings are generally formed in every year, due to the sap deposition below bark. So, number of annual rings represents the age of the tree.

xiii) **Heart Wood:** Innermost rings surrounding the pith constitute the heart wood. It is almost the dead part of the wood. It is darker in colour, stronger, more compact and durable.

xiv) **Sap Wood:** The wood is saturated with sap which becomes the source for fungal attack, insect attack, shrinkage and crack. Sap wood is light in colour, has high moisture content and transmits the sap from roots to the branches.

xv) **Cambium Layer:** It is the layer in between the bark and the outermost annual ring. It is not yet converted into sap wood.

xvi) **Medullary Rays:** These are thin horizontal veins radiating from pith towards the bark. They carry sap from outside to the inner part of the tree and nourish it.

xvii) **Inner Bark or Bast:** Inner thin layer covering the cambium layer is the inner bark. It protects the cambium layer from injury.

xviii) **Outer Bark or Cortex:** It is the outermost protective layer of tree. It prevents the tree from external injuries and weathering action.

7.3) Classification of Trees:

Based on the mode of growth, trees are classified into two categories:

iv) **Exogenous Tree:** Those trees, which grow outwardly with the addition of a ring every year known as annual rings are the exogenous tree. Thus number of annual rings shows the age of the tree at the timber of its felling. Due to the solid nature of the tree, structural timber or timber mostly used for engineering purpose is obtained from this category of trees for eg. Sal, Deodar, Chir, Teak etc.

v) **Endogenous Tree:** Those trees grows chiefly longitudinally by mingling new fibres with old ones, with minimum growth in the outwardly direction. Due to the hollowness of the core and predominant longitudinal growth, the stem are light and tough but are too flexible and slender to furnish material suitable for engineering purpose for eg: bamboos, palm, cane etc.

7.4) Characteristics of Good Timber:

Following are the qualities of good timber:

- It should be hard and durable.
- It should be from the heart of a sound tree and be free from sap.
- It should have straight and close fibre.
- It should be of uniform colour.
- Freshly cut surface should give sweet smell.
- It should be free from dead knots, from too many knots, shakes and other defects.
- It should have regular and narrow annual rings.

- It should be capable of resisting shocks.
- Teeth of saw should not clog while sawing.
- It should be strong enough to withstand bending and shear effects efficiently.

7.5) Defects of Timber:

Basically two types of defects:

i) Defects that develop during the growth of tree.
ii) Defects that develop after felling the tree.

Defects that develop during growth of trees:

i) **Shake:** This is the most serious type of defect in timber. These are sort of cracks which partly or completely separate the fibres of wood along the grains. These may be of different types.

a. **Star Shake:**

These are radial cracks or split that extends from bark and usually remain confined up to the plane of sap wood. This defect usually develops due to fierce (extreme) heat and frost.

Fig: Star Shake

b. **Heart Shake:**

These are wide splits running right through the heart wood of the tree. These splits radiate from the pith running towards the sap wood. These are caused over matured trees.

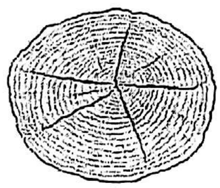


Fig: Heart Shake

c. **Cup Shake & Ring Shake:**

These are curved splits separating one annual ring from the adjacent one either wholly and partly. These are caused by strong by strong winds swaying the tree and by excessive frost action on the moisture present in the tree, especially while it is still young.

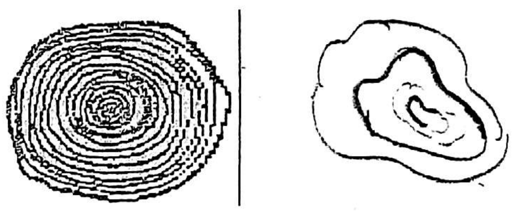
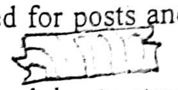


Fig: Cup Shake

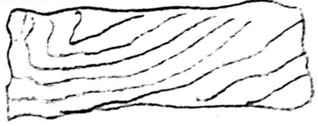
d. **Radial Shake:** similar to star shake but are numerous, fine and irregular. They usually occur when felled tree is exposed to sun for seasoning. The crack run for a short distance from bark to the centre and follow the path along medullary rays.

ii) **Rind Gall:** Rind means bark and gall means abnormal growth. These are peculiar curved swelling found on the body of the tree which are usually caused by the growth of the layer over. The wound left after the branches have been cut off in an irregular and improper manner.

iii) **Twisted Fibres:** Fibres are twisted by strong winds turning the tree constantly in one direction. The timber having this defect is mostly used for posts and poles in an unsawn condition.



iv) **Upset:** It is due to crushing of fibres which are deformed due to stresses during growth of trees and also due to unskilful felling of trees.



v) **Knots:**

A knot is either the root of a branch that is embedded in the stem with the formation of annual rings at right angle to those of the stem. These knots are of two classes.

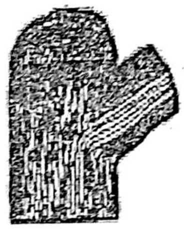


Fig: Knots

a. **Dead or Loose Knot:** can be separated from the body of the wood.
b. **Live or Sound Knot:** These are firmly attached to timber and cannot be separated.

vi) **Course Grain:** Timber having very wide annual rings because of rapid growth of tree is said to have coarse grains. This type of wood is not durable and is deficient of strength.

vii) **Foxiness:** Presence of reddish and yellowish stains shows the beginning of decay in timber because of bad ventilation during strong or due to over maturity of the tree.

viii) **Druxiness:** This is the defect in which decayed spots of timber remain concealed under healthy wood. This defect is probably caused due to access of fungi.

Defects after felling timber or Diseases of Timber:

i) **Dry Rot:**

It is disintegration of converted timber by harmful effects of certain fungi. This fungus feeds on wood and converts it into dry fine powder. This defect occurs, when timber is imperfectly seasoned and also when it is subjected to warm moist conditions.

Fig: Dry Rot

ii) **Wet Rot:**

It is decomposition of the timber due to alternate wetting and drying. In this defect the affected timber decays and gets converted into greyish brown powder. To overcome this defect, the timber to be used should be seasoned and painted to protect from moisture.

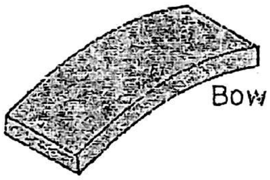
Fig: Wet Rot

iii) **Check:** A crack separating wood fibres is known as check. It does not extend from one end to another end.

iv) **Case hardening:** The defect in which timber is subjected to stresses and strains due to unequal shrinkage of internal and external surfaces is known as case hardening.

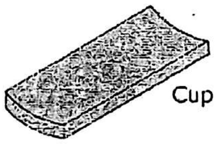
v) **Bow:**

When planks of converted timber shrink and bend in covered form, in the direction of length, the defect so indicated is called bow.



vi) **Cup:**

This defect is indicated when wooden planks bend in covered form, in transverse direction is called cup.



vii) **Honey Combing Defect:** Various radial as well as circular cracks develop in the internal portion of the timber due to stress develop during drying. The timber thus assumes honey comb defect.

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

Physical and Mechanical Properties of Timber:

Physical Properties:

i. **Colour and Odour:** Most trees are characterised with a typical colour and odour. So colour and odour of trees varies from one another.
ii. **Specific Gravity:** Wood is very light material, its specific gravity being always less than one. Hence wood floats in water. Wood shows good deal of variation in the specific gravity. The heart wood is heavier than sap wood in the same tree.
iii. **Moisture content:** All wood are porous to some extent. It absorbs moisture more than 2 to 2.5 times its own weight depending upon atmospheric condition. The permissible water content of air seasoned dry wood is 12 to 15% of dry weight.
iv. **Grain:** The arrangement and direction of growth of tree is known by grain. The fibres that grow parallel to the length of the tree trunk are called straight grains. The grain must be tightly and closely packed.
v. **Shrinkage and Swelling:** The newly cut wood lose moisture when subject to drying naturally and artificially. On drying, the wood under goes shrinkage and getting rain soaked or wetted may undergo considerably swelling. Shrinkage in longitudinal direction is least (0.1 to 0.5%) where as it is highest (7 to 15%) in direction tangential to cell wall

Mechanical Properties:

The most important fact about the strength of timber is that it is not the same in all the direction because wood is an isotropic material (having different structure in different direction). Hence, the strength of wood is determined with reference to the direction of grain of the wood under load.

i. **Compressive Strength :** Timber from most of the tree is amazingly strong under compression load 500 to 700 kg/cm^2.It is however to be noted that other things being same, the compressive strength parallel to grain is always less than that determined at right angles to the grain in the same type of wood.
ii. **Tensile Strength:** Wood is very strong to the tensile force acting parallel to the grain but very weak when these forces are made to act perpendicular to the grain. Thus the tensile strength of some wood ranges from 500 to 2000 kg/cm^{2}parallell to the grain whereas same value lies between 10 to 100kg/cm^2 for the same varieties when tested perpendicular to the grain.
iii. **Bending Strength:** The most important use of timber as beams is based on the fact that wood has very high bending strength. It may be vary from 300 to 500 kg/cm^2 or more.

7.6) Seasoning of Timber:

The process of drying timber or removing moisture or sap present in a freshly felled timber under more or less controlled condition is called seasoning of timber. Freshly filled timber contains about 100% to 200% sap based on dry weight of wood. A well seasoned wood contains about 10% to 12% moisture. If the sap is not removed the timber is likely to warp, crack and shrink. It may even decay.

Following are the advantages of seasoning the timber:

- It decreases the weight of timber and makes it lighter.
- It checks the tendency of timber to warp, crack and shrinkage.
- It increases the strength and makes it stable
- It reduces the possibility of attack by fungi and insects.
- It provides dimensional stability of timber.
- It enables timber to be easily planed, polished and preserved.

Methods of Seasoning:

Seasoning of timber may be carried out two ways:

1. Natural Seasoning:
   i) Air Seasoning: Timbers are stacked in a dry place at about one foot above the floor level with some centimetre space apart to allow free air circulation. The stacked is protected from direct rainwater and direct sunlight. It is economical but takes more time from 2 to 4 yrs and covers more space.

ii) Water Seasoning: The log of wood is kept completely immersed in running water so that sap, sugar etc. are leached out of wood and replaced by water. Then the log is kept out of water and placed in air. It is quick process but reduces elasticity and durability of timber.

2. **Artificial Seasoning:**

i) Kiln Seasoning: In this process timber is seasoned under controlled temperature and humidity condition with proper air circulation and ventilation system. Circulated air causes uniform drying of timber and the wrapping and cracks of timber and ventilation reduces the excessive heat. Due to uniform drying in controlled way, any moisture content can be obtained in this method. But timber obtained is of inferior quality than that from natural seasoning.

ii) Chemical and Electrical Seasoning: Chemical seasoning is also known as salt seasoning is the process at which the timber is immersed in soluble salt and seasoned in ordinary way. In electrical seasoning, the timber to be seasoned is passed through an induction coil due which moisture is reduced constantly. It is highly costly process.

7.6) Deterioration and Preservation of Timber:

Deterioration of timber depends on the various factors:

- Moisture
- Imperfect seasoning
- Alternation of dry and wet states
- Vegetation growth
- Attack of fungi ,insects etc
- Bad storage or stacking of timber
- Decay can be due to dry rot or wet rot

Preservation of timber indicates the art of treating the timber with some chemicals so as to increase its life. Following are the methods of preservation:

i) **Tarring:** Applying a coat of tar or tar mixed with pitch (coal tar). It is used for rough types of works such as timber fence, ends of doors and windows frame, battens and beams built in wall are usually tarred.

ii) **Charring:** Lower ends of the posts that are to be embedded in ground are generally charred with a view to prevent dry rot and attack of worms. It is done by quenching the ends of posts in water after they are charred on wood fire to a depth of 1.5cm.

iii) **Painting:** It works as a preservative as well as it improves appearance of timber. Only well seasoned timber should be painted otherwise timber will decay by entrapping moisture into it. They bear effectively white ants (termite) attack.

iv) **Creosoting:** It is most widely used method. Creosote (oil from coal tar) oil is dark brown thick oil. It is used as a water repellent substance to wood. Wood is placed in an air tight chamber first. Then the air is exhausted and creosote oil is pumped in pressure of 9 kg /cm^2 at 50^{0}C to saturate the timber with oil. This oil preserves the timber from rot and attack of insect, creosoting in timber produces undesirable colour and smell.

v) **Ascue Treatment:** Ascue is the preservative found in the form of powder. This powder is soluble in water. 6% solution of ascue is prepared in water and is sprayed on the timber. Wood treated by this method can be painted, varnished and polished. Fire resisting powder is increased.

vi) **Abel's Process:** In this process, the surface of the timber is first painted with dilute solution of Sodium Silicate and with a cream like a paste of slaked fat lime and finally with a concentrated solution of soda. It improves the fire resistance of timber.

vii) **Fire Proofing of Timber:** Wood can not be made fire proof, but some chemical treatment may reduce the fire attack towards the timber. Soaking timber in ammonium sulphate, ammonium chloride, zinc chloride etc. improves the fire resisting capacity of the timber.

7.7) Commercial Product of Timber:

1. **Veneers:**

These are thin sheets of wood are peeled off, sliced or sawn from a log of wood having attractive or artistic arrangement of grains. Thickness varies from 0.4mm to 6mm. These veneers are than glued to inferior timber surfaces. They are used to make plywood, lamin board, and batten boards.

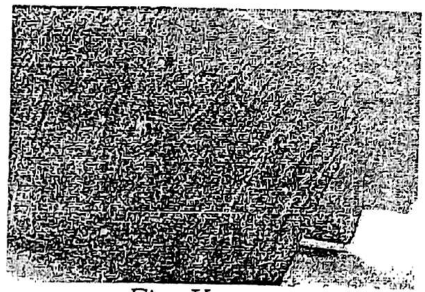


Fig: Veneers

2. **Plywood:**

These are made by cementing together several layers of wood which may be thin Veneers or thicker boards. Gluing is done under pressure. These are usually 3 ply, 5 ply or 7 ply depending upon the number of plies used. Plies are arranged so that grains of each layer should be perpendicular to each other.

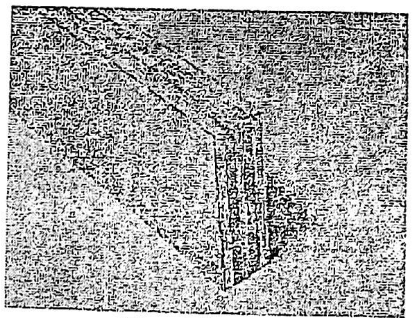


Fig: Plywood

3. **Lamin Board:**

These consist of a core built up of laminae not more than 7mm wide and glued between two or more plies. Grains of core laminae should be perpendicular to those to outer plies. These are pressed into sheets 1cm – 5cm thick. These are available up to 1.5m in width and 2.5 to 3m in length. These are used for the construction of partition walls, ceilings, doors, packing cases etc.

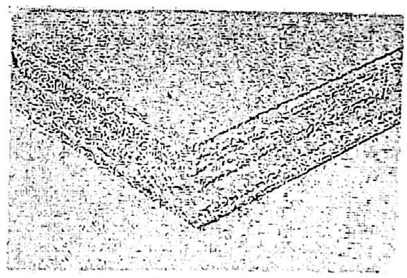


Fig: Lamin Board

4. **Block Board:**

These are similar to Lamin Boards. The core is built up of blocks not exceeding 2.5cm wide and glued between two or more outer plies. The wooden strip of the core shall be cut from specified timber and seasons to moisture content not exceeding 12%. These boards are extensively used for construction of railways carriage, bus bodies, marine, and river crafts and for furniture making, partitions, panelling etc.

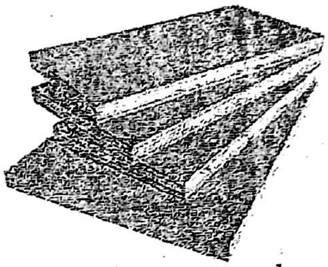


Fig: Block Board

5. **Batten Board:**

These are similar to block board. The core consists of close grained battens not more than 8cm in width, 2- 3cm thick and is edge glued between two or more outer plies. These are light and strong. These boards are used for door panel, table tops etc.

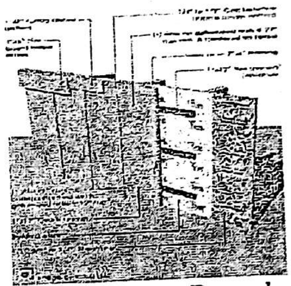


Fig: Batten Board

6. **Hard Board:**

Woods wastes obtain from saw mils, inferior timber or short logs etc with machine the raw material is converted into chips which are than softened with steam and converted into fibres. Water repellents and synthetic resins are added to increases strength. These are than pressed to boards of uniform thickness in hydraulic presses.

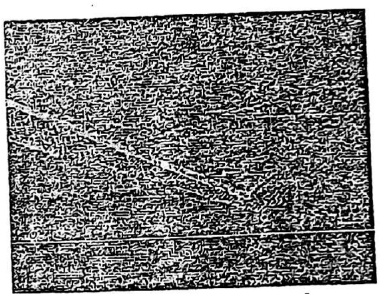


Fig: Hard Board

8. METAL AND ALLOYS

8.1) Introduction:

Metals are the elements represented in the left bottom of the periodic table. Some metals like copper, gold, silver, etc. are found in the free state in the nature while other metals e.g. iron, manganese, aluminium, magnesium, etc. are found in the combined form as their oxide carbonate, sulphate etc. the metal in their combined form or in the natural state is known as the ore. After chemical treatment to remove the impurities, metals are found in pure state.

Metals have special property that they can dissolve other metal or materials in the solid state also. Because of this property, metals can form different alloys are the backbone of the civil engineering construction and production activities.

Metals with the engineering importance are classified as ferrous metals and non-ferrous metals. Ferrous metals are those, whose contains iron as the main constituent. Cast iron, wrought iron, steel, etc. are the examples of the non-ferrous metals.

8.2) Types Properties and Uses of Iron:

Ferrous Metals (Iron):

Metal which contains iron as main constituent is known as ferrous metals. Iron can't be found the pure state in nature. It is first extracted as pig iron from different ores of iron. All other forms of iron such as wrought iron, cast iron or different types of steel are obtained by suitably purifying the pig iron. Important ores of the iron are:

i. Magnetite (Fe_3O_4): contains 70 – 75% of iron
ii. Hematite (Fe_2O_3): contains 70% of iron
iii. Iron Pyrite (FeS_3):contains 47% of iron
iv. Sidrite ($FeCO_3$): contains 40% of iron

Types:

i. *Pig iron:* Pig iron is the crudest form of iron, which is obtained from the iron ores. Pig iron is obtained from the iron ore after smelting the ore in a blast furnace. Pig iron contains 92-95 % of pure iron and 3-4 % of carbon. Other impurities present in the pig iron are sulphur, Phosphorous, manganese etc. Iron thus obtained is casted as rough bars known as the pig. Pig iron is weak and brittle. It also can't be welded or riveted. So it is not used for the structural purpose. It is used to prepare other forms of iron such as wrought iron, cast iron, steels etc.
ii. *Cast iron:* Cast iron is more purified form of iron, which contains fewer amounts of impurities than in the pig iron. This is obtained by re-melting the pig iron in the blast furnace like structure known as the cupola.

Formation of cast iron:

Cast iron is formed by re-melting the pig iron in a furnace known as the cupola furnace. This furnace consists of a cylindrical iron vessel lined inside with refractory fire bricks. It is open at the top. There is a charging door at the upper part of the furnace while at the lower part there are two semicircular gates at different level. One for skimming the slag and other for trapping molten iron. In between slag skimming gate and charging gate, there is an arrangement to blow air inside the furnace. These are known as tuyers.

Coke is used as fuel in the furnace. First of all the coke at the bottom of the furnace is fired and coke is added to make the strong heat. When sufficient heat is produced, then the alternate layers of pig iron and coke is charged to the furnace. At the same time, the air at the high pressure is blown inside the furnace. This air when gets high temperature inside goes up and escapes out, while doing so, it melts the pig iron charged inside. Limestone is used as flux to combine with the impurities and fuel ash. Slag thus formed is skimmed out from the slag-skimming door. When sufficient amount of molten iron is formed inside the furnace, trapping door is opened and metal is collected at about 1200-1400°Cat the ladle. In this way cast iron is classified as:-

- Grey cast iron
- White cast iron
- Molted cast iron
- Malleable cast iron
- Alloy cast iron etc.

Composition of cast iron:

Cast iron is also an impure iron which contains 2-5% carbon. Other impurities present in the cast iron are sulphide and phosphide. As they are found in fewer amounts, they do not affect the property of cast iron.

Propertied of cast iron:

i. Cast iron is neither malleable nor ductile.
ii. It is brittle metal and cannot resist impact of shock.
iii. Cast iron is less corrosive but becomes soft in saline water.
iv. It structure is fibrous crystalline and corrosion.
v. It is strong in compression but weak in tension.
vi. It can be hardened but cannot be tempered.
vii. Its melting point is 1200°C and specific gravity is 7.5
viii. It cannot be welded generally.

Use of cast iron:

- It is used in the sewer pipe, gutters, rain water pipes etc.
- They are also used to make manhole cover, balustrades, railings etc.
- It may also be used as the raw material to make the wrought iron.

iii. *Wrought iron:* Wrought iron is known as the purest form of commercial iron generally found from the pig iron. Wrought iron is formed from the pig iron after removing the impurities in the pig iron. There are different methods to prepare wrought iron. Popular two methods are puddling process and Aston process.

Before the invention of steel, wrought iron was popular as an important structural material. But its importance is replaced now by stronger and easily manufactured steels. Wrought iron consists of more than 99.5% of pure iron and less than 0.5% of other impurities.

Wrought iron is fibrous with silky lustre. It is malleable and ductile. It is equally strong in tension compression and shear also. It can also withstand shocks and impacts. It melts at $1500^{0}C$ and the specific gravity is 7.25. Wrought iron is replaced by mild steel ad basically used to make roofing sheets, water pipes etc.

8.3) Composition and Properties of Steel:

Steel is the alloy of iron and carbon. Steel nowadays has become backbone of civil engineering construction. Steel may be plain carbon steel or alloy steel. Plain carbon steel is the steel at which carbon only forms alloy with iron. About 92% of steel are produced as the plain carbon steel. Alloy steel is that at which iron is alloyed with other metals and carbon. About 85% steel is found as alloy steel.

Increase in the carbon content increases the tensile and compressive strength of the steel. But the brittleness of the steel increases and thus the malleability and ductility decreases.

There are different methods developed to make various grades of steel. These methods are listed as:

i. Cementation process
ii. Bessemer process
iii. Open hearth process
iv. Electrical process
v. Duplex process
vi. Kaldo process etc.

Composition of steel:

Steel is composed of iron, carbon and other alloying metals. Steel containing only iron and carbon is known as plain carbon steel. Depending upon the carbon content, steel is classified as low carbon steel, medium carbon steel and high carbon steel. Steel containing less than 0.25% of carbon is known as low carbon steel. If the carbon content lies between 0.25% to 0.7%then the steel is known as medium carbon steel and if the carbon content is greater than 0.7% it is referred as high carbon steel.

If the steel contains other metal also in the form of alloy with iron, steel is known as alloy steel. Stainless steel, nickel steel, vanadium steel, tungsten steel etc. are the examples of alloy steel.

Properties of steel:

Mechanical properties of the steel are determined by the carbon content in the steel. In general following are the properties of steel:

i. Steel possesses high strength than other forms of iron such as cast iron or wrought iron.
ii. It can absorb shock and is elastic.
iii. Heat treatment can be done in the steel to improve the grain distribution and the quality of steel.
iv. Some alloy steel has corrosion resistance, but plain carbon steel is affected by corrosion.
v. It can be welded to lain carbon steel easily.

Classification of steels:

Depending upon various modes classification of steels can be of various types. However, the classification on the basis of their chemical composition is very commonly adopted. Two major groups of steels recognized on this basis are-

- The plain carbon steels
- The Alloy steels

i. ***The plain carbon steels:***

This is the first major group of steels. In them carbon is the only controlling component besides iron. They are further sub- divided into three sub-types.

- Low carbon steels(C=0.05 to 0.35%): These are also termed as soft steels or very commonly as mild steel (MS). The mild steels are tough and ductile. These can be easily welded. These steels are used for making nuts, bolts, rivets, sheets and other parts of common utility.
- Medium carbon steels (C=0.35 to 0.55%): These are also termed as medium steels. These are hard and strong comparatively. They are resistant to wear. They are used commonly for construction purpose as structural members and reinforcement.
- High carbon steels(C=0.55to 1.5%): These are also termed as hard steels. They posses very great hardness and high compressive strength values. They are resistant to wear. They are used commonly for manufacturing of ball bearing roller, saw, crushers and locomotive tyres.

Functions of carbon in steels:

i. Carbon in steel plays very vital role in controlling their properties, Thus the tensile strength of steel increase with an increase in the carbon content till its proportion reaches 0.83% Any increase in carbon content beyond this limit will affect the tensile strength of steel adversely.
ii. The ductility of steels decreases with an increase in carbon content
iii. The hardness of steels increases with the increase in carbon content.
iv. The compressive strength is also found increased with the increase in carbon content.

Usual impurities in steel and their effects:

- Manganese (0.2 to 1%-has positive influence like increases tensile strength and hardness of steel. But beyond this limit it increases the brittleness of steel)
- Silicon (Kept below 0.4%, since this acts as a deoxidizer. Beyond this limit this increases the brittleness.)
- Phosphorus (Kept below 0.05% this shows cold short effect if exceeds this limit.)
- Sulphur (Kept below 0.05% this shows red short effect if exceeds this limit.)

Differences between cast iron, wrought iron, mild steel and hard steel.

Cast iron (C.I)	Wrought iron (W.I)	Mild steel (M.S)	Hard steel (H.S)
2.5% of C	Purest form of iron 0 to 0.25% of C	0.08 to 0.35 of C	0.55 to 1.3 % of C
Crystalline coarse Granular structure	Fibrous structure of bluish colour	Bright fibrous structure	Fine granular structure
Hard and brittle	Tough and more elastic than C.I	Tough and more elastic than W.I	Tough and more elastic than M.S
Cannot be magnetized	Can be temporarily magnetized	Can be permanently magnetized	Can be permanently magnetized
Melting point 1200^0C	Melting point -1530^0C	Melting point 1400^0C	Melting point- 1300^0C
Neither malleable nor ductile	Very malleable and ductile	Malleable and ductile	Brittle and less ductile than M.S
Does not rust easily	Rust more easily than C.I	Rust readily	Rust rapidly
Cannot absorb shock.	Can stand certain and excessive shock	Can absorbs shocks	Can absorbs shocks
Tensile strength is fair and compressive strength is good	Tensile strength is better and compressive strength is not so good	Tensile strength better than C.I. and W.I. but compressive strength is better than W.I. but less than C.I.	Both Tensile strength and compressive strength is better than rest of the three
Becomes soft in salty water	Resist salty water than C.I.	Not much effected by salty water	Not much effected by salty water
Used for water pipes, electric pole, etc.	Corrugated sheets, Crain hooks, core of electromagnet, etc.	Used in all kinds of structural member and bridges and building works, channel section.	Used in cutting tools, pre-stressed concrete.
Sp. Gravity = 7.5	Sp. Gravity = 7.25	Sp. Gravity = 7.8	Sp. Gravity = 7.9

Defects of steels:

i. ***Segregation:*** During the process of solidification of metal in mould the entire metal does not cool at once. The liquid metal in contact with the wall of the mould solidified first and then the process goes inward. But experience shows that pure solidified first than the impurities. So these impurities accumulate towards the centre of mould so solid section of steel may not be found homogeneous. This defect is called segregation.

ii. ***Pipe:*** It is defined as a central continuous cavity developed within an ingot (Casting vessel). When the steel is powered into the mould it starts cooling and solidification starts from the wall and bottom of the mould due to decrease in temperature and the steel contracts and forms a cavity at the plane where the solidification completes. This defect is known as pipe defects.

iii. ***Slag inclusions or sonims:*** Slag may be included on steel collected at ladle (collecting vessel). These slags are the impurities like oxides, silicates, phosphorous of metal. These slags are found scattered throughout the mass of metal in the mould. When steel is rolled they are crushed and forms crack. This defect is called slag inclusion or sonims.

iv. ***Blow Holes:*** These are small holes like opening continuous or discontinuous that may be developed within ingot. They are produced when the gases escape from the metal at the time of cooling into the mould.

v. ***Ingotism:*** It signified the development of coarse crystalline structure due to the slow rate of cooling.

vi. ***Scabs:*** When metal is poured into the mould, the liquid steel splashes up after heating the bottom of mould. These splashed particles being hot get oxidised. When the liquid steel rises up and comes in contact with splashed drops, they can remain as scabs in the surface of steel.

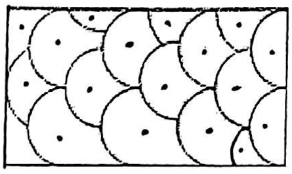
v. Extrusion: Squeezing or forcing out metal through a specified hole under high pressure similar from its pack is known as extrusion.

Microstructure Study of steel:

It is the microscopic study of steel or metal to observe or examine the textures, grain size micro cracks, faults, fracture etc.

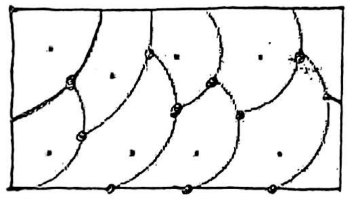
i. ***Ferrite (α – iron):***

Iron which contents little or no carbon is called ferrite. It is very soft and ductile it forms smaller crystal when cooled from bright red heat at rapid rate.



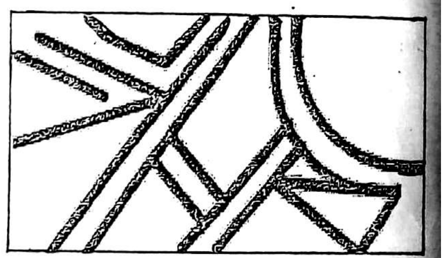
ii. ***Cementite (Carbide of iron- Fe_2C):*** (6.6% C +93.4% Fe)

It is extremely hard and herder than the glass its presence in steel decreases the tensile strength but increases hardness and cutting quality.



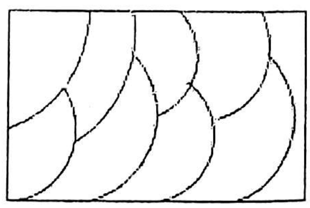
iii. ***Pearlite (C=0.9 nearly equal to 100% pearlite) :*** (87.5% Ferite+12.5% Cementite)

It comprises of alternate layers of ferrite and cementite in steel. Under high magnification the ferrite and cementite can be seen to be arranged in alternate lamination. It is characteristics of soft steel that they contains ferrite and pearlite and hardness increases with increase increases with increase in proportion of pearlite hence hard steel is the mixture of pearlite and cementite.



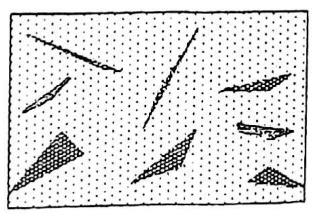
iv. ***Austenite:***

It is the solid solution of iron and carbon which is stable only within a specific range of temperature and composition. Mild— 730^0C – 885^0C below 730^0C ppt. of ferrite and pearlite form above 730^0C solid solution starts above 885^0C ferrite and cementite dissolved and tends to melt.



v. ***Martensite:***

It is a hard brittle mass of fibrous or needle like structure and is the chief constituent of hardened steel. It is strong extremely hard and brittle. It is formed by decomposition of austenite during cooling from 325^0C to 200^0C.



vi. ***Troostite:*** This product is obtained by further decomposition of austenite by slow cooling it occurs in irregular grains, softer, weaker and little bit ductile.

vii. ***Sporbite:*** It is a structure which consist of evenly distributed carbide particles in a mass of ferrite it is strong and tough.

8.4 Heat Treatment Process:

Heat treatment is defined as an operation or combination of operations, involving heating and cooling of a metal or alloy of metal in its solid state to obtain the change in mechanical properties of the metal.

Principle of heat treatment:

The principle of heat treatment is based on the fact a change takes place in the internal structure of steel at specific temperatures. Hard and brittle iron carbide does not become fully combined with the iron, however, until a temperature of approximately 800 is reached. If the steel is heated progressively, there will be no change in temperature for a while. This is due to the fact that the heat applied is consumed to bring the structural and chemical change in steel. The carbon and iron forms solid solution, although the steel is well below the melting point. This point of temperature is known as decalescence point. After this the rise in temperature begins again.

If the steel is removed from heat and allowed to cool, a point will again be found at which cooling appears to be arrested, and temperature may even be raised slightly. This point is known as recalescene point. This point indicates that steel is converted to pearlite and ferrite or cementite from austenite.

Objective of heat treatment:

Following are the objectives of the heat treatment of steel

i. To bring the change in the grain or texture property of steel.
ii. To make the steel workable in mechanical treatment.
iii. To relieve the internal stresses produced during the mechanical treatment of steel.
iv. To improve the mechanical properties of steel such as hardness, toughness, ductility etc.
v. To improve or carryout the variation in mechanical properties of steel in the same section e.g. surface hardening of ductile steel.
vi. Casting

Heat treatment process:

There are numbers of heat treatment process that are used to obtain desired mechanical properties of steel. These are:

i. Annealing
ii. Normalizing
iii. Quenching\hardening
iv. Tempering
v. Surface hardening etc.

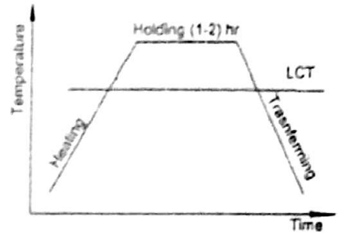
i. ***Annealing:*** Annealing is the process of heating steel to the temperature generally above the critical temperature, holding it for definite period of time and cooling it in slow rate. While cooling steel is embedded inside the ash, lime or sand like non conducting materials. Annealing is done to achieve the following:

a) To improve machine ability.
b) To soften the steel by re-crystallization and refine the grain size.
c) To improve ductility and malleability.
d) To relieve the internal stresses produced during forging , pressing etc.
e) To improve the electrical and magnetic properties of steel.
f) To remove the entrapped air, blow holes, pipes etc. formed during casting.
g) To overcome other imperfection produced during plastic deformation.

Annealing may of following type:

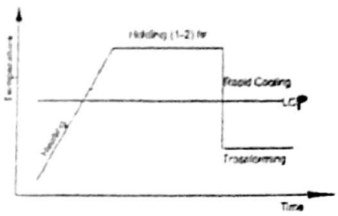
1. *Full annealing:*

In this process the metal is heated up to 50^0C above the critical temperature and holds it for 1 to 2 hrs and then cooling at a pre determine rate to obtain desired micro structure. The rate at which any steel is cooled determines its final microstructure.



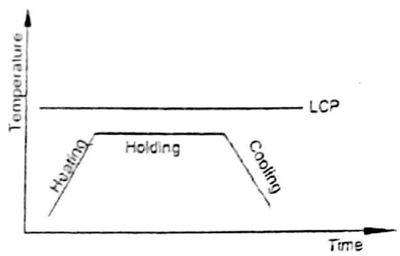
2. *Isothermal annealing:*

In isothermal annealing process steel is heated as in full annealing and allowed to rapid cool up to the temperature at which the transformation is desired. Then the steel is held at the temperature necessary to complete the transformation.



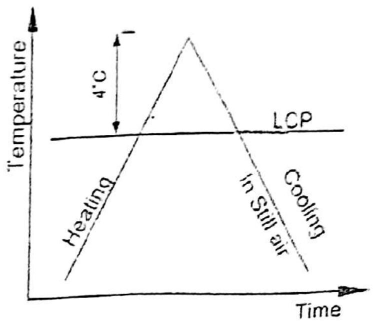
3. *Sub critical annealing:*

This type of annealing is done by heating the steel below the critical temperature and hold for sufficient period of time to form small spheroids, then cooling very slowly



ii. *Normalizing:*

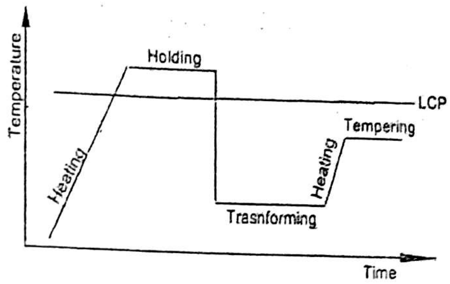
Normalizing is the process of heat treatment in which steel is heated up to 5°C above the critical temperature and allowed to cool in still air. This process is used to improve the quality of casted, welded or forged steel. It is also used to improve the quality of over heated or non-uniformity heated steel. Normalizing is done to obtain the following objectives:



a) To eliminate the coarse grained structure obtained during forging, rolling, extrusion etc.
b) To improve the strength of medium carbon steel.
c) To improve the machinability of steel.
d) To reduce the internal stresses etc.

iii. ***Quenching\ hardening:***

Quenching is the process of heat treatment at which the steel is heated above its critical temperature and allowed to cool rapidly by plunging it into the liquid bath. This form the extremely hard needle like structure known as martensite. Clear water, salty water or oil is used as quenching media to obtain desired hardness. It not only increases the hardness and resistance against wearing but also decreases the toughness and increases and increase brittleness.



iv. ***Tempering:*** Tempering is the process of heating quenched steel to some predetermined temperature between room temperature and critical temperature, holding it for the time sufficient to transformation and then cooling it at slow rate in air.

Steel when allowed for quenching produces extremely hard structure known as martensite. Martensite is not only hard but also brittle and thus decreases toughness and machinability. So tempering is done to improved the quality of quenched steel or martensitic steel in following manner.

a) To increase the toughness and ductility.
b) To decrease the hardness.
c) To relieve the stress produced during quenching.

v. ***Surface hardening:*** Surface hardening is the process at which outer surface of the steel is hardened and core of the steel is only refined. There are different methods of surface hardening. These are:

i. *Case hardening*:

Case hardening is the process which steel is heated in presence of solid, liquid or gas which is rich in carbon content in order to enable the surface to be hardened, while retaining a tough ductile core. Case hardening may be done by following methods.

a) *Pack hardening:* In this process steel is kept inside a box and surrounded by carbon rich compound and heated to a temperature of 9000^0C to 920^0C, depending upon the composition of steel. Then the steel is allowed to cool and removed from the box. Now, it is quenched in water or other suitable media.

b) *Liquid carburizing:* In this process, the steel is plunged to molten salt containing carbon such as sodium cyanide. This produces the thin layer of hardened steel. Then the steel is quenched as in the case of pack hardening.

c) *Gas carburizing:* This process is carried out by heating the steel in furnace into which the gas is rich in carbon such as methane, propane etc. are introduced. There should be the continuous flow of carburizing gas.

ii. *Nitriding:*

This process of surface hardening is used for only special alloy steel and not for plain carbon steel. In this process no carbon is used for hardening, but nitrogen gas is used. Nitrogen is introduced to the steel by passing ammonia gas through the furnace containing steel and heated to temperature between 4800C to 5400C.

iii. *Cyaniding:*

In this process steel is heated in molten cyanide salt at about 8500C followed by quenching. Both carbon and nitrogen are absorbed in this process.

iv. *Flame hardening:*

In this process the part of the surface to be hardened is heated above the critical temperature buy flame and quenched rapidly. It is used to harden the more wearing parts of the machine such as gear teeth.

8.5) Alloy of Steel:

Besides carbon other elements that impart distinctive characteristics to steel are add in iron to produce alloy steel formation of alloy steel is made to increase strength hardness toughness resistances again corrosion etc. Important steel alloys and function of alloying elements are discussed below.

1. ***Stainless steel:*** Stainless Steel is the alloy steel containing more than 12 of Chromium alloyed with the iron Chromium forms a dense and tough layer of oxide around the metal surface and is highly resistive to corrosion. Stainless steel is basically subcategorized in to three groups.

   First group of stainless steel consist of less than 14% of Chromium and is known as plan Chromium stainless steel. It contains sass than 0.4% of carbon with traces of copper, tungsten, Nickel etc. this Group of stainless steel can be hardened, Welded, machined and are satisfactory corrosion resistant, they are used to prepare steam valves turbine besides surgical instrument scissors knifes gears shafts ball bearing spring etc.

   Second group of stainless steel consists of 14-20% of chromium and 0.45 of carbon they are more brittle and difficult to heat treatment. They can be forged welded machined and rolled. They are used to prepare wire pipes. They are also used in chemical and food plants.

   When the steel contains at least 24 of combined Chromium and Nickel, then it goes under the third category of steel Generally 188 stainless steel – 18chromium and nickel alloyed with Iron_ is very common in use. This steel has excellent resistance against corrosion and improved tensile strength. This steel is very tough. It can be welded; forged and rolled Machining of this steel is difficult. These steels are used in chemical plants, tanks, cooking utensils, preparing pump shaft, screw, nut bolt etc.

2. ***Nickel steel:*** Nickel steel contains about 3.5% f nickel alloyed with iron. It contains 0.5% to 1% of carbon. Presence of nickel imparts hardness; toughness improves strength and corrosion resistance. This type of alloy steel is used in automatic arts, airplane, cables and shafts. Inver, widely used to prepare measuring tape is the alloy of nickel and steel. It consists of 30-40% of nickel and has very coefficient of thermal expansion.

3. ***Tungsten steel:*** Tungsten steel is known as high speed steel as it is used in the high speed cutting tools and drilling machines. It contains 14-20 % of tungsten and 3-8 % of chromium. It also contains carbon, vanadium and molybdenum.

4. ***Vanadium steel:*** Vanadium steel possesses high value of elasticity and is capable of resisting shocks. It is very strong and more ductile. It also improves fatigue resistance. It is used for making tools. It contains 0.1 to 2% of vanadium.

5. ***Manganese steel:*** Manganese steel contains different amount of manganese ranging from 1-14% depending up nth purpose of resulting product. It is very hard, tough and strong. It improves the plasticity of metal. It is used in preparing machine parts; rails etc. manganese steel is non-magnetic.

Corrosion in Steel:

It is the gradual chemical or electro chemical attack on a metal by its surroundings such that the metal is converted into oxide, salt or some other compounds factor influencing corrosion:

- *Chemical nature*
- *Environment*
- *Internal structure*
- *Nature of Engineering Application for which is used*
- *Ability of metal to form surface*

Types of Corrosion:

i. Chemical or Dry Corrosion: It occurs mainly through the chemical reaction of the gaseous such as sulphur vapour, halogens and nitrogen with metal or alloy.
   Types:
   a) *Oxidation Corrosion:* This type of corrosion involves reaction of metal with oxygen at high temperature in the absence of moisture.
   b) *Corrosion by other gases:* The corrosion effect of other gases such as CO_2, SO_2, chlorine, fluorine etc. on a metal depends on their chemical affinity.
   c) *Liquid Metal Corrosion:* It is caused due to chemical attack of a flowing liquid metal at high temperature on a solid metal.

ii. Electrochemical or Wet Corrosion: It is the type of corrosion occurring due to the electro chemical action between the metal and corrodent acting as the electrolyte. Electro chemical corrosion occurs due to the existence of anodic and cathodic areas separated by some distances and flowing current due to some potential difference between them. There are various types of electrochemical corrosion. These are:
   a) *Galvanic Corrosion:* Galvanic corrosion occurs when two dissimilar metal are in electrical contact with each other and are exposed to an electrolyte. Depending upon the position of metal in Electro-chemical series metal acting as anode is corroded.

b) *Micro-biological corrosion:* Corrosion caused by the various metabolic activities of micro-organism is called the micro biological corrosion.

c) *Stress Corrosion:* Stress corrosion is the combined effect of tensile stress and corrosive environment. Stress corrosion causes cracking in the ductile metal. Such crack or fracture due to the deposition of brittle material by Electro-chemical action.

d) *Erosion Corrosion:* Erosion corrosion is caused by the combined effect of corrosion and wear produced by the turbulent flow of gases, vapours and liquids and rubbing action of solids over the metal surface.

Control and Preservation of Corrosion:

As the corrosion is an unwanted phenomenon, it is controlled or prevented as per the requirement and ability.

Following methods are adopted for this:

i. ***Protection by design and fabrication procedure.***
ii. ***Modifying the corrosive environment.***
iii. ***Application of inhibitors.***
iv. ***Cathodic Protection.***
v. ***Alloying.***
vi. ***By embedding in concrete.***

i. ***Protection by design and fabrication procedure:*** Corrosion may be reduced by proper fabrication and design of the metal structure to maintain the uniformity. For this following should be taken in consideration
   - Avoid the dissimilar metal to prevent galvanic corrosion.
   - Avoid the sharp corners as far as possible.
   - Reduce the stress concentration.

ii. ***Modifying the corrosive environment:*** Modification of corrosion environment can be done to reduce the corrosion. Such modification can be done either by changing the environmental variation such as temperature, pressure, salt concentration, velocity etc. or eliminating the corrosive ingredients such as humidity, oxidizing agents etc.

iii. ***Application of inhibitors:*** An inhibitor may be defined as any material or substance which when added to the corrosive environment decreases the rate of corrosion. Such materials are added to the corrosive environment to reduce corrosion.

iv. ***Cathodic Protection:*** in electrochemical process, there is the corrosion of anode and the cathode is protected. If whole of the metal surface is made to work as cathode and some extra surface is used as anode, we can protect the cathode.

v. ***Alloying:*** Alloying of metal increases the corrosion resistance of the metal as in the case of stainless steel where the chromium forms a thin corrosion resistance oxide layer.

vi. ***Application of protective coating:*** Corrosion may also be reduced by the application of some protective coating over the surface of metals. There are different methods of applying such coatings:
   - Electroplating
   - Galvanizing
   - Sheradizing
   - Tin Plating
   - Painting by enamel or other paints
   - Tarring etc.

vii. ***By embedding in concrete:*** If steel is kept embedded in concrete, it is not affected by corrosion eg. RCC

8.6) Non Ferrous Metals:

a) Aluminium :

Aluminium is a non- ferrous metal widely used in the civil engineering construction as an important aesthetic material. This is used in false ceiling, door, window fixtures, frames and shutters.

Formation:

Aluminium is a never found in Free State in nature. It is found as the hydrated oxide of aluminium known as the bauxite. Bauxite is the mixture of mono-hydrated and tri-hydrated Aluminium oxide. Bauxite is first crushed and treated with caustic soda to be precipitated out. It is then calcinated to obtain alumina (Al_2O3). Alumina thus obtained is deoxidized by the process of electrolysis and the aluminium is obtained. Aluminium thus obtained contains 99 to 99.5% purity.

Properties of Aluminium:

i) Aluminium is highly malleable and ductile.
ii) Pure aluminium has high resistance against corrosion than that of the steel.
iii) Aluminium shows the silvery bright lustre.
iv) It is light metal with specific gravity of 2.7.
v) It has low melting point of 658^0C.
vi) It is a good conductor of heat and electricity.

Some of the other non ferrous metals are:

- Copper
- Lead
- Tin
- Zinc
- Magnesium
- Nickel

8.7) Commercial Products of Metals:

a) Steel:- plain carbon steel, medium carbon steel, high carbon steel
   i) Bars:-Round, Flat, Square
   ii) Plates:- 5mm to 50mm Size
   iii) Angles section
   iv) T-Section
   v) Channel Section
   vi) T Section
   vii) Corrugated Sheets.

b) Cast Iron
c) Copper
d) Copper Alloys
e) Aluminium
f) Aluminium Alloys etc.

9. PAINT AND VARNISH

9.1) Function, Ingredient, Type and Uses of Paint and Varnish:

Paint: It is a fluid material that will spread over a solid surface and dry or harden to an adherent (supporter), coherent (sticking together), obscuring (dark, hidden) skin or film.

Paint is a fluid prepared by dissolving a base into a vehicle (carrier) along with a colouring pigment.

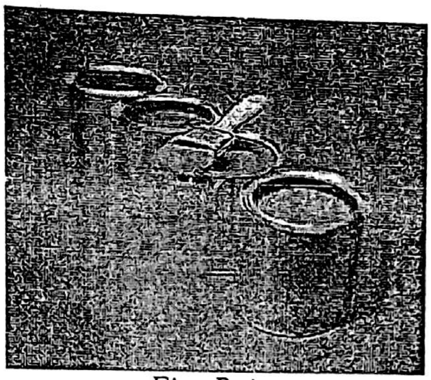


Fig: Paint

Function of Paint:

- To protect the surface from weathering action of atmosphere and action of other liquids, fumes and gases.
- To prevent decay of wooden members and corrosion of metallic surface.
- To make surface smooth for easy cleaning.
- To provide pleasing, colourful and decorative appearance.

Constituents of Paint:

1. **Base:** The base, usually a metallic oxide, is the principal constituent of the paint. It makes the paint film opaque and possesses binding properties which reduces the shrinkage cracks in the film on drying. Some of the examples are white lead, zinc white, red lead, aluminium powder etc.
2. **Vehicle:** Also known as binder, vehicle is an oil to which the base is mixed. It holds the constituents of paint in suspension and helps spread it over the surface to be painted, imparts durability, toughness and water proofness to the paint film and resistance to weathering and gloss to the painted surface and forms the body of the paint. Various vehicles are linseed oil, dehydrated castor oil, soya bean oil, fish oil etc.
3. **Pigments:** It is real colouring substance. They are finely divided solid material, which provides required shade and colour to the paint.
4. **Thinner:** A thinner, solvent or diluents is a volatile substance that is added to the paint to make its application easy and smooth. The common thinning agents used are petroleum, spirit, naptha, turpentine oil etc. Turpentine oil is used extensively due to high solvent power, flattening properties and ideal rate of evaporation.
5. **Drier:** It is a substance which acts as catalyst and quickens the drying of the vehicle. Driers used are heavy metallic soaps such as napthenates, resinates etc of CO, Mn, Pb and Zn.

6. **Inner Filler:** Adulterant are usually mixed to bring down the overall cost, reduce the weight and increase the durability. It also helps to reduce cracking of dry paint and sometimes helps to keep the pigments in suspension eg. Barium sulphate, Silica, Calcium carbonate etc.
7. **Anti skinning Agent:** They are used to prevent gelling and skinning of the paint. Generally polyhydroxyl phenols.
8. **Plasticizers:** These are used to give elasticity to the film and minimize or prevent cracking. Some oils are used as plasticizers.

Types of Paint:

1. **Oil Paint:**
   - Ordinary cheap paint, easy to apply.
   - Generally applied in three coats, prime, undercoats and finishing coats
   - Possesses good opacity and low gloss.
   - Should not be applied during humid and damp weather.
2. **Aluminium Paint:**
   - Consists aluminium powder (as base) held in suspension by varnish.
   - Highly heat reflective and resistant to acid fumes.
   - Used for painting metal roofs, hot water pipes, oil storage tank, etc.
3. **Asbestos Paint:**
   - Main constituent is fibrous asbestos.
   - Used for leakage in metal roofs and sometime on the outer surface of basement wall to prevent dampness.
   - Also called fire proof paint.
4. **Bituminous Paint:**
   - Made of asphalt bitumen dissolved in mineral spirit or naptha.
   - Black in colour
   - Employed for painting iron works under water
   - They deteriorate very fast, when exposed to sunlight.
5. **Cellulose Paint:**
   - Made by cellulose sheets, nitro cotton dissolved in petroleum.
   - Also known as lacquers and hardens by evaporation of thinning agents.
   - It resists extreme degree of hot and cold.
   - The trade names are spray paint, Ducco etc.
   - It presents flexible, hard and smooth surface.
6. **Cement Paint:**
   - White or Coloured Portland cement (60 to 65%) mixed with pigments forms base.
   - Thinned with water during application
   - Proper curing is necessary for strength and durability.
   - Used commonly as a last finish on the outer surface of wall and ceiling in residential buildings etc.
7. **Colloidal Paint:**
   - Paint with no inert material.
   - Requires more time to settle and during settlement it penetrates the surface.

- Can be used in interior or exterior wall

8. **Emulsion Paint:**
   - Consists of polyvinyl acetate and synthetic resin as binding material.
   - Easy to apply and dry quickly.
   - Possesses excellent alkali resistance.
   - Colour of paint is retained for long time.
   - Can be cleaned by washing with water.
   - Used for painting in steel and woodworks.
9. **Enamel Paint:**
   - Available as ready made paint.
   - Consists of zinc white or white lead ground in small quantity of oil and mixed with petroleum spirit and resinous matter.
   - Dries slowly and forms a hard and durable surface.
   - Not affected by cold and hot water.
   - Acid resistant, not affected by alkalies.
   - Used for painting doors, windows frames, protecting timbers and used for both external and internal works.
10. **Graphite Paint:**
    - It is black paint.
    - Used on iron parts in mines, underground railways etc.
    - The graphite particles spread easily over metal surface and make it resistant to corrosion by variety of chemicals such as chlorine, ammonia and compounds.
11. **Silicate Paint:**
    - Prepared by mixing calcined to finely ground silica with resinous substance.
    - It is resistant to chemical attack and also against heat.
    - Surface should not be painted with it in hot weather.
    - Can be applied brick, plaster or concrete surface after making them wet.
12. **Luminous Paint:**
    - It contain calcium sulphide with varnish.
    - The surface with this paint shines like radium dial of watches after the light surface has been cut off.
    - It proves quite helpful in nights.
    - Applied on surface free from corrosion.
13. **Anti corrosive Paint:**
    - It consists oil and a strong drier.
    - Cheap, durable and black in appearance.
    - Prevents corrosion.
14. **Plastic Paint:**
    - Have plastic as base with water as thinner.
    - Have high covering capacity and give a neat, decorative and pleasing appearance to the surface.
    - Due to high cost they are mainly used in interiors of auditoriums, showrooms, modern houses and office.

15. **Synthetic Rubber Paint:**

- It is prepared from resins.
- Dries quickly and offers good resistance to water.
- Easy to apply and also can be applied on surface which may not be completely dried (eg. Fresh concrete)
- Light affect by sunlight and water.
- Moderate in cost.

Characteristics of an Ideal Paint:

i. Uniform spread as a thin film, high coverage.
ii. Good workability.
iii. Sufficient elasticity to remain unaffected by expansion or contraction of the surface to be painted.
iv. Unaffected by weathering action.
v. It should be impervious, cheap and economical forming hard surface.
vi. It shouldn't crack on drying.
vii. The film should be glossy and washable.

Varnish: A varnish may be defined as a homogeneous liquid containing essentially a resinous substance dissolved in suitable oil or a volatile liquid. The oil dries with time and the solvent evaporates leaving behind a solid transparent resin film on surface. It doesn't contain pigment. Always used as finishing work.

Function of Paint:

- Decorative and protective covering of paint.
- To brighten an appearance of grains in wood.

Constituents of Varnish:

i. Resin or resinous substance:
   - It is natural or synthetic organic substance which is soluble in some organic solvents.
   - Acts as base and provides body to varnish.
   - For eg. Rosin, copal, gum, amber etc.

ii. Solvent:
   - Acts as vehicle of the varnish
   - Helps to spread resins over the surface to be varnished.
   - For eg. Linseed oil, Turpentine oil and methylated spirit etc.

iii. Drier:
   - It accelerates process of drying.
   - It should be added in small proportion.
   - For eg. White copper, lead acetate etc.

Types of Varnish:

i. Oil Varnish:
- Linseed oil has been added as solvent.
- Base material may be amber or copal.
- Dry slowly and form hard and durable film.
- Use in external finish because they are quite resistant to weather change.

ii. Turpentine Varnish:
- Made by dissolving gum, mastic or rosin in turpentine.
- They dry quickly but not durable and easily affected by moisture.
- Used for interior works only and varnish on painted surface.

iii. Spirit Varnish:
- Commonly used varnish for furnitures.
- Consists shellac dissolved in methylated spirit.
- French Polish is one of its type.
- Not durable and easily affected by weathering action.

iv. Water Varnish:
- Lac dissolved in water nixed with ammonia, borax, potash or soda.
- Used for pictures, varnishing maps etc.

Characteristics of a Good Varnish:

i. It should appear uniform and pleasing.
ii. It should not fade.
iii. It shouldn't show crack on drying.
iv. It should dry rapidly and give permanent glossy film.
v. It should be tough, hard and durable.

9.2) Distemper:

Distemper is made with base as white chalk and thinner as water. Some colouring pigments and glue are added. They are available in powder and paste forms and are substantially cheaper than paints. They are most suitable for plastered surface as well as white washed surfaces of interior walls. 'Dry Distemper' are distemper in powder form and 'Oil bound Distemper' are in paste form.

Characteristics/ Properties of Distemper:

i. The coatings are thick and more brittle than paints.
ii. They are workable, easy in application but less durable.
iii. The film being porous can be applied on even newly plastered surface.
iv. They provide reflecting coating.

Types of Distemper:

Broadly classified in two types:

i. *Non Washable Distemper:*

- Consists of whiting with glue and pigments in suitable proportion.
- Marketed in powdered form.
- Glue is water soluble and hence this type of distemper has no water resistance.
- When glue used is of poor quality, it gives off bad odour.

ii. *Washable Distemper:*

- It consists a water resistant binder, usually an emulsion of a drying oil or varnish.
- Also known as oil bound distemper.
- Marketed in paste form to be thinned with water just prior to the application.
- After some days of application, it can be cleaned by sponging.
- They are quick drying, easy to apply and odourless.

9.3) Anti- Termite Treatment:

The building gets damaged due to the following types of termites:

i. Dry Wood Termites:

- They reside in wood and can survive without soil connection.
- Causes less damage to the building than subterrarean termites.

ii. Subterrarean termites:

- They survive on the amount of moisture supplied by the soil. So, cannot survive without soil connection.
- They are mainly responsible for causing damage to the building.
- They enter in building through foundation and move upward through floor destroying everything that comes within their reach.

Types of Anti Termite Treatment:

Since the termites breed and spread so fast they can damage a building in 4 to 5 yrs. So, it is desirable to take suitable measures to prevent the ingress of termite.

i. *Pre- Construction Treatment::*

- Site should be cleared by removal of dead woods, old trees stump, roots etc within seven meters of the foundation of the building.
- Damp Proof Course of rich and dense concrete is made protect against white ants.
- Lean lime mortar shouldn't be in contact with soils and no crack and dry joints should be present in sub- structures.
- Cracks/ gaps, if any, should be filled with tar or cement mortar.
- All sub- floors should be of dense cement concrete (1:3:6) as should be continuous through walls.

ii. *Post- Construction Treatment:]*

It is done for the buildings which have already been attacked by the termites. Following operation are involved.

- Inspection:

- The portion of the building in contact with earth such as basements, ground floor, steps leading from ground, areas having damp or humid condition etc. need to be inspected.
- Remove the termite runways where detected.
- Inject oil, kerosene oil in the wood works.
- Structural addition may be made to eliminate direct contact between soil and affected part.

- Soil Treatment for foundation:
  - Dig the trenches along the external peripheral wall and fill the holes with chemical emulsion in water.

- Soil Treatment under Floor:
  - The termites from soil enter the floor through the cracks, which usually occurs at junction of the floor and walls.
  - Drill holes (12mm dia, 300 mm centre to centre) along the cracks in the floor in different areas.
  - Inject chemical emulsion into the holes (shouldn't be greater than 1 lit. Per hole) till the soil below gets fully saturated.
  - Sealing of the holes after treatment.
- Treatment of voids in masonry:
  - Drill holes of 12mm dia, 300 mm centre to centre at downward angle about 45^0 from both side of the walls at plinth level.
  - Pump chemical emulsion into holes until masonry gets fully saturated.
  - Seal the holes after treatment.
- Treatment of Wood works:
  - Badly damaged woodworks are replaced by new timber which is adequately brushed with chemical emulsion.
  - Drills holes (6 mm dia 150 mm centre to centre) and pump chemical emulsion.

10. ASPHALT, BITUMEN, TAR AND MISCELLANEOUS PRODUCTS

10.1) Types, Properties and Uses of Asphalt, Bitumen and Tar:

Asphalt:

Asphalt is a natural or artificial mixture in which bitumen is associated with inert mineral matter. It is black or brownish in colour. It is semi-solid sticky product formed by partial evaporation or distillation of certain petroleum oils. At temperature between 50-100^{0}C, it is in liquid state whereas temperature less than this it remain in solid state. It is soluble in varying degrees in carbon disulphide. It is basic paving material in use today.

Properties of asphalt:

- Sticky and binds strongly as cement.
- It is water proof.
- It becomes plastic and workable when heated.
- Good conductor of heat, sound and electricity.
- Ductile and can be stretched without breaking.
- Not seriously affected by adverse weather.

Uses of asphalt:

- Used in D.P.C for preventing dampness in walls, floor and roof of building.
- Lining walls of tanks, swimming pools etc.
- Used for preparing paints and flooring purpose.
- Used for surface dressing, paving roads etc.

Types of asphalt:

i. *Natural Asphalt:* It is also known as nature asphalt. When obtained from lakes it is termed as lake asphalt. It is used for making pavements, for water proofing of structures, stopping vibration in machine foundation, tunnels and subways, in manufacture of marine glue and in lining trenches.
ii. *Rock Asphalt:* It is naturally occurring rock formation, usually limestone or sandstone intimately impregnated throughout its mass with 6-14% bitumen.
iii. *Refined Asphalt:* It is obtained by heating pitch (crude tar) to drive off the water and to drive off the water and to draw off the mineral matter by segregating the impurities.(52% bitumen, 38% inorganic matter, 10% organic matter).
iv. *Mastic Asphalt:* It is obtained by heating natural asphalt with sand and mineral filters; the resulting product is a void less impermeable mass.Used for damp proofing and water proofing.
v. *Cutback Asphalt:* It is dried by distillation of asphalt in volatile solvents. It contains about 80% asphalt and remaining the solvents.Used for preparing bituminous paints, for repairing roofs etc.

vi. *Asphaltic Cement:* It is prepared by oxidizing asphalt at a high temperature. Highly resistant to varying climatic condition. Used roofing, flooring, water proofing and as filler for expansion joints in concrete.

Bitumen:

Bitumen is a non crystalline solid or viscous material derived from petroleum, by natural or refinery process and substantially soluble in carbon disulphide. It is asphalt in solid sate, mineral tar in (semi fluid state and petroleum in fluid state. Bitumen is brown or black in colour.

Properties of bitumen:

- It is in solid or semi solid, black and sticky.
- It melts or softens on application of heat.
- It is binder in all types of asphalt.
- It is completely soluble in carbon disulphide.
- Posses great chemical stability, but is affected by oil.
- Specific gravity 1.09

Uses of bitumen:

- Used in damp proof course in walls.
- Extensively used as a road making materials.
- It is used in lining tanks, swimming pools etc.
- Used for making bituminous paints.

Types of bitumen:

The various types of bitumen or asphalt cement is as follows:

i. *Straight Run Bitumen:* The bitumen which has been distilled to a definite viscosity without further treatment is known as Straight run bitumen. During processing, by regulating rate of flow and temperature, bitumen from very soft to very hard consistency grade can be produced. This bitumen is most used for road construction.

ii. *Air Blown Bitumen:* Special properties can be developed in semi solid bitumen by blowing air through the residue, still in hot condition. This bitumen is sometime called oxidised bitumen also. This bitumen is not used in paving mixes, but is a useful material for roofing, battery boxes, waterproofing etc. It is widely used as crack and joint filler materials for concrete pavements.

iii. *Cut Back Bitumen:* Cut back is defined as bitumen whose viscosity has been reduced by the addition of a volatile diluent. Volatile diluents are gasoline, kerosene and light oils. The important features of a cut back are its viscosity at the temperature of its use and also the rate at which it sets. The rate of setting is the rate at which solvent evaporates from cut back.

iv. *Plastic Bitumen:* It comprises thinner bitumen and suitable inert filler (40 to 45%). It is used for stopping leakages and for filling cracks in masonry structures.

v. *Bitumen Emulsion:* It is a combination of water, bitumen and emulsifying agent. The bitumen is suspended in the aqueous medium with the help of some suitable stabilising agent. Emulsion makes it possible to carry out construction work practically in any weather above zero temperatures. Emulsion can be used for soil stabilisation, patch repair works of bituminous road. Its main feature is that it can be used in wet conditions and also it does not require heating.

Tar:

It is dark black viscous liquid produced by distillation of organic material such as coal, oil, lignite and wool. Depending upon the source of origin

Properties of tar:

- It is black to brown in colour.
- It contains 75 to 95% bituminous content.
- It has higher percentage of carbon.
- It hardens quicker and is more adhesive than asphalt.
- It possesses toxicity to a high degree.

Uses of tar:

- It is used for roofing and road construction.
- It is used for making paints and water proofing compounds.
- Coal tar is used as preservative for timber.
- It is used for painting of bathroom walls.

Types of tar:

i. *Coal Tar:* It is obtain as a by product in the destructive distillation of coal, or in the manufacture of coal gas. It is heavy, strong smelling and black. These generally have high specific gravities and viscosities, and good adhesive properties. It is used for coating of wooden poles, sleepers, iron poles, latrine walls etc.

ii. *Mineral Tar:* It is obtained by the destructive distillation of resinous wood (pine etc). It contains creosote and as such is a very strong preservative

iii. *Wood Tar:* It is obtained by distillation of bituminous shale. Some examples are tarmac, tar paving and tar macadam.

10.2) Types, Properties and Uses of Glass:

Glass:

Glass is an amorphous solid substance that has been formed by super cooling a liquid solution containing chiefly silica and some other selected components.

Glass may also defined as a hard, brittle, transparent or translucent material chiefly compound of silica, combined with varying proportions of oxides of sodium, potassium, calcium, magnesia, iron and other minerals.

Properties of glass:

- Glass has quite high tensile strength. In very fine wires drawn from melts glass may show tensile strength as high $7*10^5$ Kg/cm^2. The ordinary glass threads posses' tensile of 700 to 1400 Kg/cm^2. The modulus of elasticity of glass is also very high. Both these properties, shows great variations depending upon the composition of the composition of the glass and method of manufacture.
- Glass has low ductility, low conductivity and low coefficient of thermal expansion.
- Glass is resistant to acids and many other chemicals. Hence they are ideal material for storage of chemical.
- Glasses are very good electrical insulators.
- They have very high softening point and can be used at very high temperature.

Uses of glass:

- Used in windows and doors of buildings, vehicles etc.
- Used for making laboratory apparatus, electric lamps, thermometers etc.
- Can be used in place where light is required without transparency such as windows panes, bathroom ventilators.
- Used for heat and sound insulation
- Hollow glass blocks can be used for the construction of the walls and ceilings of modern homes.
- Used for construction of partition walls.
- Used for preparing acid resistant cement.

Types of glass:

According to chemical composition:

i. *Silica Glass:* It is pure silica sio_2, without any additives. Its use is restricted to high temperature applications. It has a high softening temperature.

ii. *Soda Lime Glass:* This is the most common type of glass used extensively for domestic purpose window panel, plate glass, light bulbs. A typical composition of soda lime glass is as follows. SiO_2-71 to 74%, Na_2O -13 to 17%, CaO-5 to 14%

iii. *Leaded Glass:* This glass has high refractive index so use in the manufacturing of optical instruments. This property is included into the glass by adding lead oxide with silica during the manufacturing stage. A typical composition of leaded glass is as follows
SiO_2-67 to 73%, PbO -15 to 30%, Na_2O-9 to 12%, K_2O – 4to 7%

iv. *Borosilicate Glass (Pyrex):* It is a special type glass made by adding boron oxide as a chief additive with silica at a time of manufacture. This addition of boron on oxide gives the special property of increasing its melting point and resistance against thermal shock .So,it is used extensively in high temperature conditions. Pyrex is a thread name for a borosilicate glass. Atypical composition of Borosilicate glass is as follows.
SiO_2- 81%, Na_2O - 4%, Al_2O_3 – 2%, B_2O_3 –12%

According to commercial forms:

i. *Sheet glass:* it is made by blowing glass into hollow cylinder, splitting the cylinder and finally flattening it over a plane surface. It is manufactured in thickness varying from 1.5 to 5mm. It is generally used for door and windows.

ii. *Plate glass:* It is made by pouring white hot glass over an iron table and rolling it to a uniform thickness under heavy roller. It is thicker, stronger and more transparent to sheet glass. It is used for wind screen of motors and glass house.

iii. *Wired glass:* It is glass with wire netting embedded in it during manufacture .It resists fire better than ordinary plate glass, so in case the glass in fractured does not fall into pieces. So, it is used for sky light and roofing.

iv. *Laminated glass:* This glass is made of several layers of plate glass and alternate layers consist of vinyl resin plastic. The thickness of this type of glass may vary from 15mm to 75mm or more. This is an also bullet proof glass.

v. *Insulating glass:* This is transparent glass unit composed of two or more plates of glass, separated by 6 to 13mm of dehydrated air and sealed to provide heat insulation ensuring transmission of light in insulating glass.

vi. *Glass Block:* These are manufactured from pressed glass by fusing two or more sheets in such away that a partial vacuum is caused in the interior of the block. They provide insulation against heat, cold, noise etc. and for construction of transparent wall.

10.3) Plastic Materials:

Plastics are made from resin with or without fillers, plasticizers and pigments. These are organic materials of high molecular weight which can be moulded to any desired form when subjected to heat and pressure in the presence of a catalyst. The plastic are natural (shellac and resin) or synthetic in origin.

Plastics are replacing glass, ceramics and outer building materials due to the low temperature range in which they can be brought to the plastic state and the consequent is of forming and fabrication and also for their low cost and easy availability. Plastic are classified as Thermoplastic and Thermosetting.

i. ***Thermoplastic:*** The thermoplastic variety softens on heating and hardens on cooling i.e. their hardness is a temporary property subjected to change with rise or fall of temperature and can be brought again to plastic stage on heating. These are formed by addition polymerization and have long chain molecular structure. They can be remoulded, for use, as many times as required. Examples are polythene, polyvinyl chloride (PVC), polystyrene, polytetrafluroethylene (PTEE) etc.

ii. ***Thermosetting:*** Thermosetting plastic cannot be reused. They require great pressure and momentary heat during moulding and finally get hardened on cooling. The chemical reaction in this process cannot be reversed. Once solidified they cannot be softened. The thermosetting plastics acquire 3- dimensional cross-linked structure with predominantly strong covalent bonds during polymerization retaining strength even on heating; under prolonged heating they fail by charring. Compared to thermoplastics, they are hard, strong and more brittle. Examples are phenolics, polyesters, expoxies, silicones etc.

Properties of Plastics

- Can be moulded to any desired shape or size and have tensile or compressive strengths.
- Easy to work upon.
- Light in weight and a few varieties are glossy like glass.
- Not attack by insects and fungi.
- Available in desired colour and texture.
- Require a little maintenance.
- Good electrical insulators and have low thermal conductivity.
- Shock absorbing material.
- Can be sawn, drilled, punched and welded easily.
- High strength to weight ratio.
- High resistance to weathering conditions.
- Corrosion resistance.
- Decorative surface effect- paining or polishing of the surface is not required.
- High refractive index.
- Some varieties are hard as steel.
- Withstands moisture, oil and grease well.
- Inflammable.
- High coefficient of thermal expansion (about times of steel)
- Deterioration under prolonged exposure to sun's ultra violet rays.
- Low manufacturing cost, hence cheap.

Constituents of Plastics

i. *Binder:* Binder may be resin or cellulose derivatives and are responsible for holding different constituents together.

ii. *Filler:* It is added up to 50% of the moulding mixture to increase the hardness, tensile strength and bond, opacity, finish , workability besides reducing the cost, shrinkage on setting, and brittleness of the final product. These are powder (quartz powder, chalk, talcum etc.), fibrous (asbestos, wood wool, saw dust, glass fibre etc.) and laminated (paper, cotton etc.) fillers.

iii. *Plasticizers:* They are added to plastics to make them soft, to improve their toughness at finished stage and to make them flexible. For examples vegetable oils, aluminium stearates etc.

iv. *Pigments:* It is added to achieve desired colour of the plastic and should be resistant to the action of sunlight.

v. *Lubricant:* It is used to make moulding of plastic easier to prevent sticking of materials to the mould for a flawless finish. For examples stearates, oleates and soaps.

vi. *Catalyst:* It is added only in case of thermosetting plastics to accelerate the polymerization of fusible resin during moulding operation in cross- linked infusible form.

10.4) Insulating Materials:

The materials which control the transmission of heat and cold and offer resistance to reflection and transmission of sound and electricity are known as insulating materials.

- Sound Insulation:
- Electrical Insulation:

1. **Heat Insulation:** Heat insulation is the reduction of the effects of the various processes of heat transfer between objects so as to provide a proper temperature inside the rooms of the building.

The purpose of heat or thermal insulation is to restrict the heat transfer from warmer to cooler areas. The commonly used insulating materials work on the principle of either air space formed between structural components, surface insulation or internal insulation. Well known products are aerated concrete, gypsum boards, fibre boards, asbestos cement boards, chip boards, cork boards, glass wool, thermocol etc.

Requirements:

- It should be impermeable to water, fire proof, and resist insect attacks.
- Resistance to vibration and shock
- Non inflammability.
- Economical in its initial cost.
- Odourless.
- Resistance to moisture.

Heat Insulating Materials:

i. *Asbestos:* It is available in nature as a mineral. It is a silicate of calcium and magnesium found in the form of very thin fibres in vein of metamorphic rocks.

- It has low water permeability.
- It is brown, grey and white in colour.
- It is resistant to acid and alkalies.
- It acts as reinforcing material when mixed with OPC.

Uses: They are extensively used for heat insulation. It is also used for making fire proof padding, packing sheets and clothes for firemen and electrician. In the form of paper and mill boards asbestos is used for low voltage insulation.

ii. *Cork:* It is made from the bark of a tree. It is ground, sized and barked in moulds.

- It is highly elastic and compressible.
- It is light and is unaffected by moisture.
- It can be easily moulded.

Uses: Cork sheets and boards are used for insulating walls and ceilings, both for heat and sound insulation. They are used as non conducting material for scientific apparatuses. It is also used in refrigeration and cold storage insulation.

iii. *Thermocol:* It is light and cellular plastic material. Initially it is obtained in liquid form and then moulded into desired forms.

- It is very light, strong and durable.
- It resists dampness.
- Very good shock protecting properties.
- Low value of thermal conductivity.

Uses: It is used for heat and sound insulation in refrigerators and conditioning buildings. It is also used in acoustic treatment and lining of ceilings and walls.

iv. *Glass Wool:* Thin fibre of glass is spun out of molten glass. These fibres are fairly flexible and have high tensile strength as such they can be woven into mats.

- Fibrous in structure.
- Light in weight.
- Low thermal conductivity.
- Quite durable.

Uses: Mostly used for insulation of pipes, bends, valves etc. Used in boilers, ovens, cylinder or pipe insulation. It can be also used for the construction of partition walls for thermal insulation purpose.

2. **Sound Insulation:** Sound insulation is the process of soundproofing an enclosed space, such as a room. This type of insulating activity is usually employed when there is a need to keep sound from filtering into or out of the space. Sound insulation techniques are often used in business settings, as well as in multi-family dwellings like duplexes and apartment buildings.

The commonly used sound insulating materials are cellular concrete, gypsum plaster, glass silk, asbestos, mineral wool boards etc.

Requirements:

- It should have low density, porous texture.
- Resistance to moisture.
- It should be incombustible, light in weight and easy to handle and fix.
- Resistant to attack of vermins, insects, termites and dry hot
- It should be fire resistant.
- It should be economical in initial cost.

Sound Insulating Materials:

i. *Soft Materials:* These materials have sufficient porosity and are good sound absorber. For examples asbestos, rock wool, glass, silk etc.

ii. *Semi- Hard Materials:* They are stiff enough to stand rough handling and can also serve as building panels. For examples mineral wool boards, cane fibres etc.

iii. *Hard Materials:* These are hard materials which have been made porous during manufacture. They also serve as protective surface. For examples Porous tiles of masonry.

3. **Electrical Insulation:** It is provided to separate the electrical conductors from other bodies to prevent escape of electricity.

The commonly used electrical insulating materials are ebonite, mica, quits and mats etc.

Requirements:

- It should have high dielectric strength
- Least thermal expansion.
- High mechanical and thermal strength.
- Should be resistant to thermal and chemical deterioration.
- High thermal conductivity.
- Low permittivity.

Electrical Insulating Materials:

i. *Ebonite:* It is obtained by vulcanising rubber with large amount of sulphur. It becomes soft on heating and can be moulded to any shape,
- It takes good polish
- It is unaffected by moisture or light acid is durable.
- Its colour varies from grey to dark

Uses: They are extensively used for electric insulation.

ii. *Mica:* It is natural mineral found in thin sheets whose colour and composition varies.
- It is an excellent insulator of electricity.
- Fairly good insulator of heat.

Uses: They are extensively used for electric and heat insulation

10.5) Gypsum Products:

Gypsum:

Gypsum is non hydraulic binder occurring naturally as a soft crystalline rock or sand. Pure gypsum is a white translucent crystalline mineral and is soft that it can be scratched by a finger nail. Its chemical formula is $CaSO_4.2H_2O$ (hydrated sulphate of calcium).

Properties of gypsum:

- Good sound absorber.
- It has small bulk density.
- They are incombustible.
- They are rapid drying and hardening with negligible shrinkage.
- They develop high creep under load, especially in moist surroundings.
- Superior surface finish.

Uses of gypsum:

- It is used as filler in paints, paper and rubber industries.
- Used in manufacture of cement to increase its setting time.
- Used for preparing Plaster of Paris and gypsum boards.

Types of gypsum Products:

i. *Plaster of Paris:* Gypsum found as hydrous sulphate of calcium in amorphous mineral or crystalline form when heated turns into a fine white powder called *Plaster of Paris.*
- It sets quickly on mixing with water.
- While setting it gives out heat. Because of its property of slight expansion on setting, it is excellent for filling of cracks, holes in plastered surface.
- It is also used for filling cracks and knots in wooden surfaces before painting or polishing.

ii. *Gypsum Plaster Board:* On heating further, after the formation of Plaster of Paris, the remaining water is expelled and calcium sulphate anyhydrite is formed, which is known as second settle plaster. This plaster is mixed with a small amount of accelerator to make Gypsum Plaster Board.

- They are used for lining walls and ceilings of buildings.
- Decoration may be applied direct to the face of gypsum wall boards.
- They are comparatively light and have high fire resisting properties.

10.6) Composite Materials:

Two types of materials while combines with each other may constitute third materials with some different properties as that of the parent materials are known as composites. These combinations may be metal and ceramics or ceramics with polymers. Improvements in quality with respect to strength, flexibility etc. are the attraction of the composites.

Metal, Alloy + ceramics = Reinforced Concrete

Ceramics + Organic Polymers = Fibre glass

Metal, Alloy + Organic Polymers = Vinyl coated

They have following characteristics:

- Stiffness.
- High corrosion resistance.
- High strength (Compressive)

Civinnovate

Discover, Learn, and Innovate in Civil Engineering