UNIT 1

Introduction

Learning Objectives

After completing this unit, the student will be able to understand

- About the scope of the construction technology
- About the purpose of the construction technology

1.1 General

Engineering structures are built with both natural and processed materials. Materials used in construction, in one form or the other are known as Construction Materials or Engineering Materials or Building Materials. Stones, bricks, timber, steel, lime, cement, metals, paints, etc. are some commonly used materials by civil engineers.

Selection of the right material is the first and most important step to achieve economy in construction. Selection of building material, to be used in a particular construction, is done on the basis of their important properties like strength, durability, appearance, etc.

The construction professionals should have the knowledge of properties of various engineering materials for the selection of right material to be used in the engineering applications.

The subject construction materials deal with sources, composition, properties, manufacturing, testing of various materials as per I.S.I standards and their utility.

1.2 Scope and Purpose of the Subject

Scope

The scope of this book include wide coverage of building materials such as stone, bricks, lime, mortars, concrete, asbestos, gray iron, cast iron, steel castings, aluminium, wood, architectural paints and so many others with their applications in building construction. It includes the common defects of materials and ways to overcome them. It also encompasses the Do's and Don'ts to be followed for better durability while using certain materials.

The book is resourceful for all professionals related to construction field, technocrats and students.

Purpose

Study of Construction Materials provides essential information that will help improve efficiency, productivity and economy in construction.

The purpose of study of Construction Materials is to

- Know the sources of construction materials.
- Identify and know the properties of various construction materials.
- Know how the materials are tested as per I.S.I standards.
- Know how to choose proper material from the commercially available varieties for a particular purpose of construction.
- Know common defects in the materials.
- Know various precautions to be taken while construction for better durability.

It is therefore vital reading for all professionals.

UNIT 2

Stones

Learning Objectives

After completing this unit, the student will be able to understand

- Know what are building stone and rocks;
- Describe how rocks are classified;
- Explain the common varieties of building stones;
- Know the availability of important building stones;
- Explain the dressing of Stones;
- Explain different surface finishes;
- Know what are aggregates & grading of aggregates.

2.1 Introduction

Stone is a natural construction material. It is obtained from rocks by quarrying.

A Building Stone is a piece of rock quarried and worked into a specific size and shape for a particular purpose.

The properties of stones depend upon the mother rock from which they are extracted. Stones, quarried fresh from the rock are irregular in shape and

size and are soft. They are cut into to desired shape & size and seasoned before put to use in construction. Stones are long lasting and naturally available in large quantities.

Rock is a solid mass consisting of a mixture of common minerals. Rocks make up the majority of the Earth's crust. Rocks can be hard or soft, as small as a grain or as large as a building.

There are many kinds of rock, and they are classified in a number of ways.

2.2 Classification of Rocks

Building stones are obtained from rocks. Rocks are classified into the following three types:

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

2.2.1 Geological Classification

This classification is based on the mode of natural formation. According to this classification, the rocks are of the following three types.

- Igneous Rocks (formed directly from liquid rock),
- Sedimentary Rocks (formed by eroded materials from other rocks),
- Metamorphic Rocks (formed by direct alteration of existing rocks).

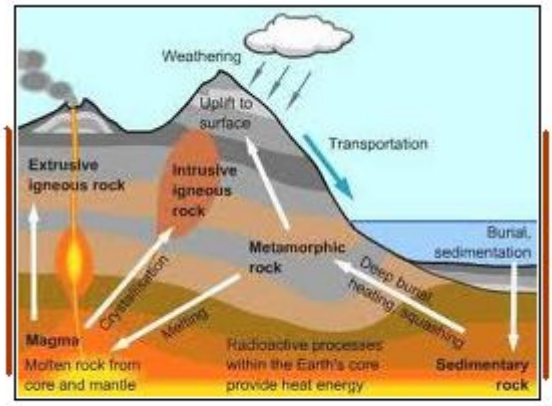


Fig. 2.1 Different types of Rocks

Igneous rocks

Rocks that have crystallized from magma are called igneous rocks.

The oldest type of all rocks is the igneous rock. The word "igneous" comes from a Greek word for **fire**. Deep inside the earth, the temperature is very high and the minerals there are in liquid form called **magma**. As the magma pushes towards the earth's surface, it starts to cool and turns into solid igneous rock. These are also known as **primary rocks**.

All igneous rocks do not cool the same way. That is why they do not look all the same. Some cool slowly, deep under the earth's surface. These are called **intrusive igneous rocks**. The slow cooling form rocks with large crystals. **Granite** is an example of a rock that cooled slowly and has large crystals.

Other rocks formed when the magma erupted from a volcano or reached the earth's surface through long cracks. Magma is called **lava** when it reaches the earth's surface. Lava cools quickly and forms rocks with small crystals. They are called **extrusive igneous rocks**. **Basalt** is an example of this type of rock. **Obsidian** is an example of another extrusive igneous rock that cooled so fast that it has no crystals and looks like **shiny, black glass**.

Types of Igneous Rocks:

- **Plutonic rocks -** large mass of intrusive igneous rock believed to have solidified **deep within the earth**.
- **Hypabyssal Rocks -** intrusive igneous rocks which form **near the surface** are known as hypabyssal rocks.
- **Volcanic Rocks -** Finely crystalline or glassy igneous rock resulting from volcanic activity **at or near the surface** of the earth. Also known as extrusive rock.

Fig. 2.2 Obsidian

Major characteristics of Igneous rocks

- Classified by texture and composition
- Normally contains no fossils
- Rarely reacts with acid
- Usually has no layering
- Usually made of two or more minerals
- May be light or dark colored
- Usually made of mineral crystals of different sizes
- Sometimes have openings or glass fibers
- May be fine-grained or glassy (extrusive)

Sedimentary rocks

The rocks formed by the **deposition** of material carried by the **weathering agencies** at the Earth's surface and within bodies of water are known as Sedimentary rocks.

Rain, water, wind or glaciers are known as weathering agencies.

Particles that form a sedimentary rock are called **sediment**. Sediment is formed by the erosion of pre-existing rocks, transportation and accumulating of particles by weathering agencies.

Sedimentation is the collective name for processes that cause mineral and/or organic particles to settle and accumulate from a solution.

Sedimentary rocks are deposited in layers as strata, forming a structure called **bedding**. Sedimentary rocks are important because they possess natural resources including important fossil fuels, drinking water or ores.

Some Common Sedimentary Rocks

Name	Color	Composition
Sandstone	Red or Gray	Sand grains cemented together
Limestone	White to Gray	Calcite and sometimes fossils
Shale	Dark Gray	Compacted mud
Conglomerate	Different Colors	Rounded pebbles cemented together

Metamorphic rocks

Metamorphic rocks form deep within the Earth when heat and pressure are applied to either igneous rocks or sedimentary rocks. This heat and pressure in essence cooks the rocks, changing their structure substantially which are known as **metamorphism**.

Metamorphism means **"change in form"**. It is a process in which the original rock undergoes profound physical and/or chemical change under increased pressure, temperature (greater than 150 to 200 °C) & chemically active fluids. The original rock may be **sedimentary rock, igneous rock or another older metamorphic rock.**

They may be formed simply by being deep beneath the Earth's surface (about 12 to 16km beneath the Earth's surface), subjected to high temperatures and the great pressure of the rock layers above it. The temperature is supplied by the heat of Magma.

Metamorphic rocks make up a large part of the Earth's crust.

One very common metamorphic rock is **marble**. Marble is formed when heat and pressure are applied to **limestone** for many thousands of years.

Major characteristics of metamorphic rocks:

- Classified by texture and composition
- May have alternate bands of light and dark minerals
- May be composed of only one mineral, ex. marble & quartzite
- May have layers of visible crystals
- Rarely have pores or openings.

Some common Metamorphic Transformations:

Original Rock	Metamorphic Rock
Lime Stone (Sedimentary Rock)	Marble
Sand Stone (Sedimentary Rock)	Quartzite
Shale (Sedimentary Rock)	Slate
Granite (Igneous Rock)	Gneiss

2.2.2 Physical Classification

This classification is based on general structure (arrangement of particles) of rocks. According to this classification, rocks are of the following three types

1. Stratified Rocks : These rocks are having layered structure. They possess planes of stratification or cleavage. They can be easily split along these planes. Sand stones, lime stones, slate etc. are the examples of this class of stones.

2. Unstratified Rocks: These rocks are not stratified. They possess crystalline and compact grains. They cannot be split in to thin slab. Granite, trap, marble etc. are the examples of this type of rocks.

3. Foliated Rocks: These rocks have a tendency to split along a definite direction only. The direction need not be parallel to each other as in case of stratified rocks. This type of structure is very common in case of metamorphic rocks.

Chemical Classification

This classification is based on chemical composition of rocks. According to this classification rocks are classified into three types.

· **Siliceous rocks**: silica (SiO_2) is the major constituent of these rocks. These rocks are hard, durable and not easily effected by weathering agencies.

Ex: Granite, Quartzite, etc.

· **Argillaceous Rocks:** clay or alumina ($Al_2 O_3$) is the major constituent of these rocks. These rocks may be dense and compact or may be soft.

Ex: slates, Laterites etc.

· **Calcareous rocks:** calcium Carbonate ($CaCO_3$) or Lime is the major constituent of these rocks. Durability of these rocks will depend upon the constituents present in the surrounding atmosphere.

Ex: Lime Stone, marble etc.

The Rock Cycle

We know that all three rock types can be turned into metamorphic rocks but all three types can also be changed through the rock cycle. All rocks can be weathered and eroded into sediments, which can then form sedimentary rock. Rocks can also be completely melted into magma and reborn as igneous rock.

Fig. 2.2 Rock Cycle

Qualities of Good Building Stones

A good building stone should have the following characteristics:

Appearance: Good building stone should be of uniform colour, and free from clay holes, spots of other colour bands etc capable of preserving the colour for longtime.

Crushing Strength: A good building stone should have sufficient crushing strength to withstand the load of superstructure .In general; it should not be less than 1000 kg /cm^2

Hardness, Toughness and resistance to Abrasion: The stone to be used in stairs, pavements, as railway ballast or road metal must be sufficiently hard, tough and resistant to abrasion, it must be able to resist wear and tear. (Coefficient of hardness >14. Toughness index > 13).

Durability: A good building stone must be durable enough to resist the effect of weathering agencies like rain, wind, temperature etc. It should have fine grained, compact and crystalline structure.

Texture: A good building stone should have a close grained and compact texture.

Seasoning: Stones should be well seasoned before putting into use. A period of about 6 to 12 months is considered to be sufficient for proper seasoning.

Seasoning is best done by keeping the stones in open sheds for about 6 to 12months.

Workability: The stone to be used for ornamental carving and architectural appearance should be easily and economically dressed.

Porosity: A good building stone should be less porous. It should not absorb more than 5% water by weight after 24 hours. Any stone absorbing 10% of water should be rejected.

Resistance to fire: A good building stone be fire proof. Sandstone, Argillaceous stone resists fire quite well.

Specific gravity: it is a measure of weight of the stone. The stone to be used on heavy engineering works, docks, harbours, gravity dams etc. must have high specific gravity. It varies from 2.4 to 2.8.

Generally stones from igneous and metamorphic rocks are heavier and more durable than stones from sedimentary rocks.

(Specific gravity refers to the ratio of the density of a solid or liquid to the density of water at 4 degrees Celsius. Specific gravity is a dimensionless quantity; that is, it is not expressed in units.)

Availability: It should be easily available and cheap.

Uses of stones

1. Structure

Stones are used for foundations, walls, columns, lintels, arches, roofs, floors, damp proof course etc.

2. Face works

Stones are adopted to give massive appearance to the structure. Facing of Walls of bricks is done in stones of desired shades. This is known as composite masonry.

3. Paving stones

These are used to cover floor of buildings of all types. They are also adopted to form paving of roads, foot paths etc.

4. Basic material

Stones are disintegrated and converted to form a basic material for cement concrete, moorum of roads, calcareous cements, artificial stones, hallow blocks etc.

5. Miscellaneous

Stones are also used for (i) ballast for railways (ii) flux in blast furnace (iii) Blocks in the construction of bridges, piers, abutments, retaining walls, light houses, dams etc.

2.3 Common Varieties of Stones and Their Uses

In order to ensure suitable selection of stones for a particular work, one must be conversant with its composition, characteristics, uses and place of availability.

Granite: The term "Granite" means "grain" in Latin word "Granum" because of its granular nature. It is a common and widely occurring type of intrusive igneous rock.

Composition : Feldspar, quartz, and small amounts of mica are the primary minerals of the average granite with minor accessory minerals (usually hornblende).

Properties

- It is the hardest building stone. It provides excellent wearing surface.
- It is available in wide ranging colours, usually in grey, green, brown and pink and red. It shows consistency in colour and texture.
- It is a good material for load bearing applications because of its Flexural strength (the ability to resist bending force).
- Granite usually has a medium- to coarse-grained and homogeneous in texture.
- The Specific Gravity of granite is between 2.65 and 2.75. Its compressive strength usually lies between 1000 – 1400 kg/cm^2. Melting temperature is 1215 - 1260 °C.
- It has negligible porosity. Its Water Absorption is 0.1-0.6%
- The principal characteristics of granite also include high load bearing capacity, crushing strength, abrasive strength, amenability to cutting and shaping without secondary flaws, ability to yield thin and large slabs and - above all - durability.
- Due to highly dense grain, it is almost impervious to stain.
- Granite is also resistant to many acids and other caustic chemicals. So it is often used as a liner in commercial vats.

Uses of Granite

- Used as building blocks, but has poor resistance to fire as it crumbles when exposed to intense heat.

· Used as road metal, railway ballast, aggregate for concrete; for construction of bridges, piers and marine works; for luxury flooring, for ornamental and monumental items, etc.

Fig. 2.4 Granite

Availability

Good varieties of granite are available in the states of Andhra Pradesh, Madhya Pradesh, Rajasthan, Karnataka, Kashmir and Gujarat.

India is one of the largest producers of granite blocks, granite tiles and processed granite slabs.

Basalt

1. Igneous rock

2. It is compact, hard and heavy

3. Available in red, yellow grey, blue and greenish black colour

4. Specific gravity is 3 and compressive strength varies from 1530 to 1890 kg/cm^2.

5. Used for ornamental, rail road ballast, aggregates for concrete etc.

Fig. 5.5 Basalt

Sand Stone

Fig. 2.6 Sand Stone

1. Sedimentary rock

2. It is available in variety of formations: fine grained, coarse grained compact or porous

3. Available in white, green, blue, black, red and yellow colours.

4. Specific gravity 2.65 to 2.95

5. Compressive strength is 650kgs / cm2

6. Used for ashlar works.

Lime Stone

Limestone is calcareous sedimentary rock formed at the bottom of lakes and seas with the accumulation of shells, bones and other calcium rich goods. It is composed of calcite (CaCO3).

It is available in a variety of forms which differ from one another in colour Compaction, texture, hardness and durability.

Hardness	3 to 4 on Moh's Scale
Density	2.5 to 2.7 Kg/cm3
Compressive Strength	60-170 N/mm2
Water Absorption	Less than 1%
Porosity	Quite low
Weather Impact	Resistant

Uses of Limestone

- Flooring and roofing
- Wall cladding
- Vanity tops
- Furniture
- Cement Production
- Refining Metals
- Blackboard chalk.

Note: Limestone, like marble and other calcareous stones are referred to as acid sensitive. Calcareous stones are readily dissolved in acid; therefore acidic products should not be used on limestone and marbles.

Availability of Limestone:

India: Khasi, Jayantia and Garo Hills of Meghalaya,Satna limstone belt, Madhya Pradesh.

Limestone deposits in Andhra Pradesh:

Andhra Pradesh has the privilege of possessing about 32% of the country's total reserves of limestone. Commercial grade limestone deposits are being exploited from Bethamcherla, Macherla, Neereducherla, Tandur, Mudimanikyam of Kurnool, Guntur, Anantapur, Rangareddy, and Nalgonda districts are widely used in our country for panelling, and flooring purposes. Andhra Pradesh's limestone reserves are estimated about 30,424 million tones.

\Marble

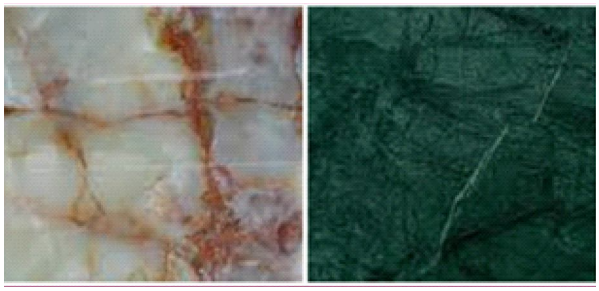


Fig. 2.7 Marble

1. Metamorphic rock

2. Available in white, blue, green, yellow black and red colours

3. High compactness,

4. Suitable for decorative works, wall lining columns, pile, table slabs, hearths, tiled floors, steps of stair case etc.

Slate

Fig. 2.8 Slate

1. Metamorphic rock

1. Non absorbent, compact fine grained and produce metallic ringing sound when struck.

2. Available in black, dark blue, grey, reddish brown etc.

3. Used for providing damp proof course, paving dados etc.

Common Uses of Stones

Stones are used in the following civil engineering constructions:

1. Stone masonry is used for the construction of foundations, walls, columns and arches.

2. Stones are used for **flooring**.

3. Stone slabs are used as **damp proof courses, lintels** and even as **roofing** materials.

4. Stones with good appearance are used for the **face works** of buildings. Polished marbles and granite are commonly used for face works.

5. Stones are used for **paving** of roads, **footpaths** and open spaces round the buildings.

6. Stones are also used in the constructions of **piers** and **abutments of bridges**, **dams** and **retaining walls**.

7. Crushed stones with gravel are used to provide **base course for roads**. When mixed with tar they form finishing coat.

8. Crushed stones are used in the following works also:

(a) As **coarse aggregate** in concrete

(b) For making **artificial stones** and building blocks

(c) As **railway ballast**.

Suitability of different types of Stones for various Works

Suitability of various types of stones for different purposes:

a. For **face work**, in general marble, granite and close-grained sand stone are used in the form of thin slabs (veneers) where the structure is subjected to adverse weather effects.

b. For **pillars, balustrade, pedestals, columns statues and door and window sill and paving stone**, granite marble and compact lime stone can be recommend because they can take good polish.

c. For **ornamental works** such as moulding and carvings, fine grained sand stone, fine grained marble and fine grained granite are used.

d. For bridges, piers, docks, break-waters and other marine structures the stone should be very hard, heavy, strong and durable granite and gneiss are recommended for this purpose

e. For **road metal**, stones should be hard, tough, resistant to abrasion and durable. Basalt and course-grained granite are generally recommended for this purpose.

f. For **railway ballast**, the stone should be hard, dense, durable, tough and easily workable sandstone, compact lime stone, trap and quartzite are commonly used.

g. In situation like **steps, doors sills, paving** etc where there is a regular flow of traffic, stone should be hard, dense, easily workable and durable. Marble, slates and sand stones are commonly used in such places.

h. In **fire proof construction**, compact sand stone should always be preferred.

\Artificial stones

These are also known as cast stones or reconstructed stones. Artificial stones may take up various forms such as

a. **Cement concrete:** This is the mixture of cement, fine aggregates, coarse aggregates and water. It may be cast in site or pre-cast if steel is used with cement concrete, it is known as reinforced cement concrete.

b. **Mosaic tiles:** Pre-Cast concrete tiles with marble chips at top surface are known as tiles. They are available in different shades and widely adopted at present.

c. **Terrazo:** This is a mixture of marble chips and cement. It is used for bathrooms residential buildings, temples etc.

Fig. 2.9 Terrazo

New Technologies

d. Light Weight Cellular Concrete (LCC)

Concrete of substantially lower density than that made from gravel or crushed stone in known as LCC. It is usually made with lightweight aggregate or by injecting air or gas into the mortar.

Light weight cellular concrete refers the general name for a large group of concretes with a density of less than 1,800 kg/m3. Such concretes include aerated and cellular concretes. In modern construction, aerated concrete is widely used for modular and reinforced-concrete structural members and items to lessen the weight of the construction elements and improve the heat-engineering properties of enclosing structures. Cellular concretes are used in making enclosing elements of buildings and thermal insulation.

It is widely used for roof insulation & sound insulation in the developed countries.

Properties of LCC:

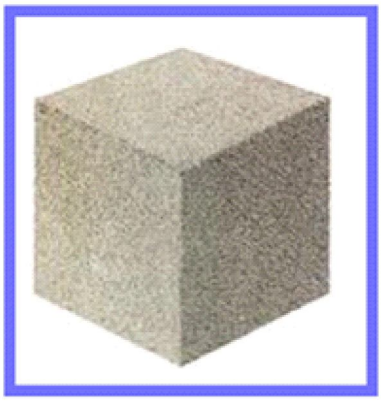


Fig. 2.10 Light weight Cellular Concrete

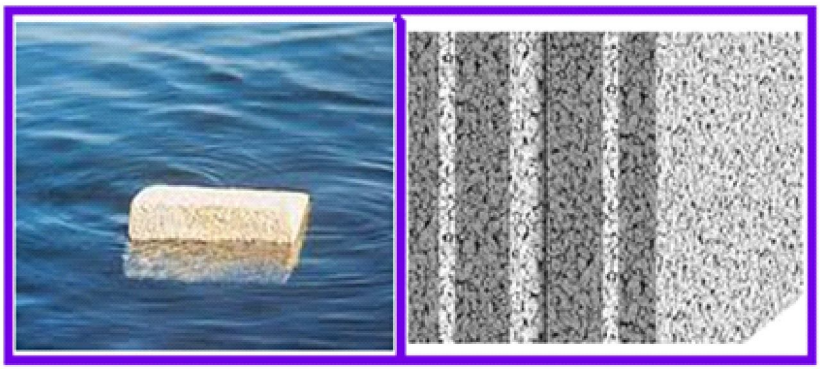


Fig. 2.11 Light weight cellular concrete

- It is very light in weight.
- It has extra-ordinary thermal insulation properties. If used for partition walls of a residential building, the Air Conditioning bills will go down by almost three fourths.
- It has moderate to high sound insulation properties.
- It is easily workable. It can be cut like a cake. It is probable the best material for partition walls.
- It floats in the water.

- It gains strength with the age. The composition can be modified with desired strength.
- Lightweight concrete is extremely fire resistant and thus well suited to fire related applications. Furthermore, the application of intense heat, such as an oxy torch held close to the surface, does not cause the concrete to explode as is the case with normal dense weight concrete.
- It can be used for pouring mono-cast walls.
- Its usage reduces the structural weight of concrete and helps in economic construction.
- It is environmental friendly. All ingredients are natural substances.

Advantages of artificial stones

- **Cavities may be kept** in artificial stones to convey pipes, electric wires etc.
- **Grooves can be kept** in artificial stone.
- It can be cast in **desired shape**
- It can be made in a **single piece** and hence trouble of getting large blocks of stone for lintels, beams etc is avoided.
- It can be made **stronger** than natural stone
- It is cheap and **economical**
- It is more **durable** than natural stone
- **Natural bed is absent** in artificial stones and hence, the question of taking precautions with respect to the natural bed of stones does not arise.

2.4 Availability of Important Stones

Stone : Basalt & Trap

Classification : Igneous

Qualities : Hard &Tough, difficult to work. Sp. gr is 3. comp. strength: 18 to 29KN/mm2

Uses : Foundation work, road metal, rubble masonry,etc

Availability : Maharashtra, Bihar, Gujarat, Bengal &MP

Stone : Granite

Classification : Igneous

Qualities : Hard&durable, can take nice polish, available in dif fferent colours. Sp. gr 2.6 to 2.7. comp. strength: 26 to 27KN/mm2

Uses : Steps, wall, brick piers, columns, road metal, facing work, etc. not suitable for carving

Availability : Kashmir, U.P,Madras, Punjab, M.P, Rajasthan, Assam, Bengal, Bihar, Orissa, kerala, Gujarat.

Stone : Limestone

Classification : Sedimentary

Qualities : Consists of carbonate of lime, easy to work. Sp. gr 2 to 2.75. comp. strength: 54N/mm2

Uses : Manufacture of Lime, floors, steps, walls, road metal,etc.

Availability : A.P, M.P, Gujarat Maharashtra, , Punjab, Bengal, Bihar, UP Himachal Pradesh & Andaman Islands

Stone : Marble

Classification : Metamorphic

Qualities : Available in diff colours, can take good polish. Sp. gr 2.65. comp. strength: 71N/mm2

Uses : Flooring, Facing, Ornamental work, columns,etc

Availability : Rajasthan, Gujarat, A.P, Maharashtra, Mysore, M.P and U.P

Stone : Sand stone

Classification : Sedimentary

Qualities : Easy to work, available in diff colors, Sp. gr 2.65 to 2.95. comp. strength: 64N/mm2.

Uses : Weight 20to22kN/m3 Columns, facing, flooring, road metal, ornamental work,etc

Availability : A..P, M.P, Punjab, Rajasthan, Maharashtra, Gujarat, U.P, Bengal, Bihar, Himachal Pradesh, Kashmir, Tamilanadu & Andaman Islands.

Stone : Quartzite

Classification : Metamorphic

Qualities : Hard, crystalline, brittle, difficult to dress.

Uses : Road metal, concrete aggregate, rubble masonry, retaining walls, facing,etc.

Availability : A.P, H.P, U.P, Bengal, Mysore, Gujarat, Tamilnadu, Punjab and Rajasthan.

2.5 Dressing of Stones

The freshly quarried stones are irregular in size and shape. The process of **shaping**, **cutting** and **finishing** the blocks of stone as per the requirement is known as dressing of stones.

Purpose of Dressing

Dressing of stones is carried out to

- Make the transport from the quarry economical,
- Get desired appearance from the stones,
- Suit the requirements of stone masonry.

Based on location of work, dressing may be classified as Quarry dressing & site dressing. Stones are roughly dressed at the quarry because of the following advantages:

- Freshly quarried stones contain moisture (known as quarry sap) and are soft. Hence, they are easy to dress.
- Cheap labor is available at the quarry.
- Natural bed of stones can be made prominent.
- Heavy machinery at the quarry site can be used.
- Irregular edges of stones can be removed and thereby transportation cost can be reduced.

2.6 Surface Finishes

Following are some important varieties of surface finishes obtained by dressing of stones:

1. Rough tooled surface Finish

In this type of finish, the projections of stone block are removed by means of chisels. The corners and edges are made accurate and the sides are roughly finished to ensure proper bedding.

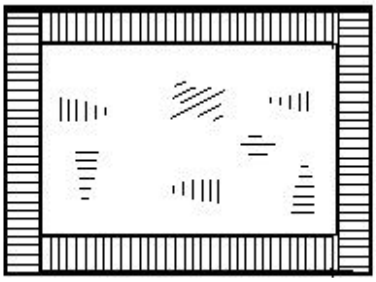


Fig. 2.12 Rough Tooled Finish

2. Tooled Surface Finish

The stone surface is finished by means of a chisel and parallel continuous marks, either inclined or horizontal are formed.

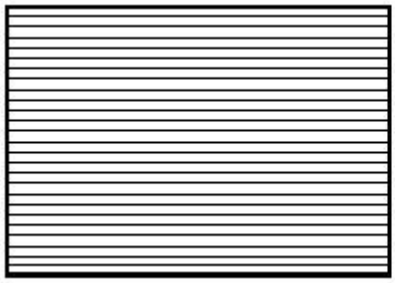


Fig. 2.13 Machine Tooled Finish

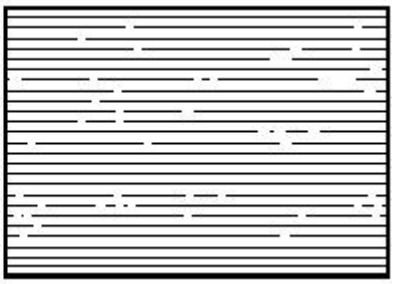


Fig. 2.14 Hand Tooled Finish

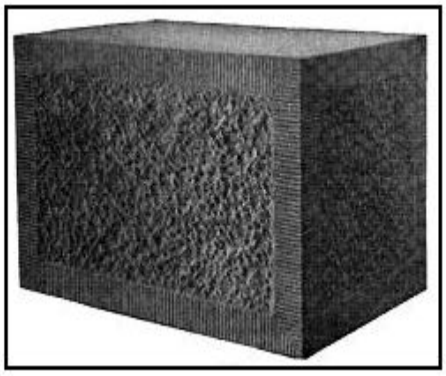


Fig. 2.15 Tooled Pointed Finish

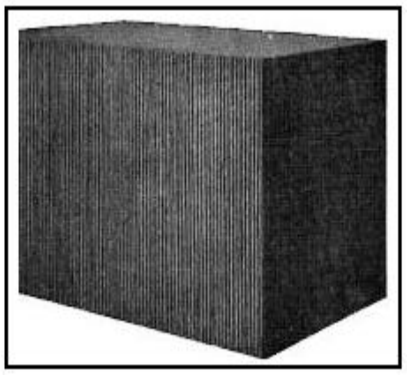


Fig. 2.16 Machine Tooled Finish

3. Hammer-dressed Finish

Unwanted projection on the stone are removed with a quarry hammer and finally stones are made roughly square or rectangular blocks. In this type of finish, stones will not have sharp edges and they will be even in shape to fit well In the masonry.

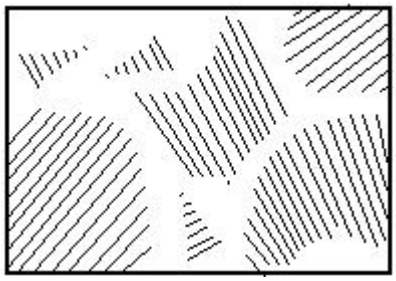


Fig. 2.17 Hammer Dressed Finish

4. Plain Finish

The surface of the stone is roughly made smooth using a chisel or a saw in this type of finish.

5. Polished Finish

The surface of stones like Marble, Granite, etc, is polished either by means of hand or suitable machine.

6. Circular Finish

In this type of finish, the surface of stone is made circular or round as in the case of a column.

7. Dragged Finish

In this type of finish, a steel drag or wire brush is used to rub the surface in all directions. This finish is suitable for soft stones only.

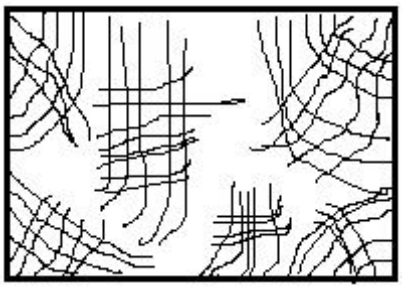


Fig. 2.18 Dragged Finish

8. Boasted or Droved Finish

Boaster is used to make marks of non-continuous lines in this type of finish. Boaster is a chisel having an edge of width about 60 mm. The marks may be horizontal, vertical or inclined.

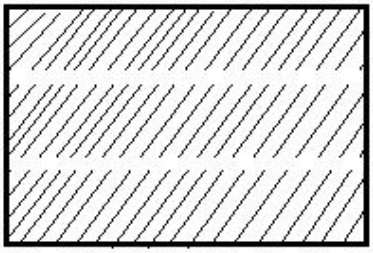


Fig. 2.19 Boased or Droved Finish

9. Vermiculated Finish

The worm-eaten appearance obtained usually by the use of machines is known as vermiculated finish. Stones cut in this manner are used principally as quoins, or corner stones, and in base courses. Owing to the cost, this style of dressing is not often used.

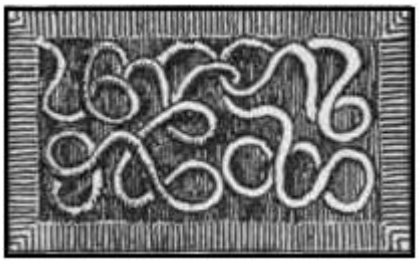


Fig. 2.20 Vermiculated Finish

10. Reticulated Finish

This type of finish presents a net-like appearance. A margin of about 20mm is marked on the edges of stone and irregular sinking is made on the enclosed surface.

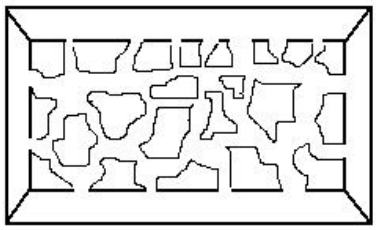


Fig. 2.21 Reticulated Finish

2.7 Aggregates - Grading

"Aggregate" in general designates both fine and coarse inert materials used in the manufacture of concrete. Aggregates are also used as base material under foundations, roads, and railroads.

Aggregate is the component of a composite material used to resist compressive stress. Aggregates are derived from igneous, sedimentary and metamorphic rocks, etc. The properties of concrete are directly related to those of its constituents. Aggregates should be hard, strong, durable, and free from clay, loam, vegetables and other such foreign matters. The presence of clay or dirt coating prevents the adhesion of cement on the surface of aggregates and ultimately retards the setting and hardening of cement and reduces the strength, durability and soundness of concrete. Sometimes, artificial aggregates, such as blast-furnace slag or specially burned clay, are also used.

Depending upon their size, the aggregates are classified as

(i) Fine Aggregates and (ii) coarse aggregates.

(i) Fine Aggregates: The material, most of which passes through 4.75mm I.S. sieve size, is termed as fine aggregates. It should not contain more than 1 to 8% of fine particles, which may be obtained from sea, river, lake or pit may be used as fine aggregates but care should be taken and all its impurities must be removed.

(ii) Coarse Aggregates: The material whose particles are of such size as are retained on 4.75mm, I.S sieve are called coarse aggregates. The size of the coarse aggregates used depends upon the nature of work. The maximum size may be 23mm for mass concrete such as dams etc. and 63mm for plain concrete. Crushed hard stone and gravel is the common materials used as coarse aggregates for structural concretes. Coarse aggregates usually obtained by crashing granite, gneiss, crystalline lime stone and good variety of sandstone etc.

Grading of Aggregates

Grading of aggregates consists of proportioning the fine and coarse aggregates in such a ratio, so as to get strongest and densest mix with the least amount of cement.

It also refers to the amount of each size of particle used in the mix. Too large a particle size of coarse aggregate requires more cement paste to fill the voids. Aggregates that have "good grading" or are "well graded" have the same % of each size stone. It is the aggregates that give concrete its high compressive strength.

Grading the aggregates is so graded as to have **minimum voids** when mixed with all ingredients, and water should render a concrete mass of easy workability.

Points to be kept in mind:

- The intermediate aggregate should ideally have the same shape and texture as the larger coarse aggregate.
- The mixture must not be over or under-sanded.

The grading of aggregates is done by the following methods:

(i) By Trail – In this method, proportioning of aggregates is so done as to give heaviest weight for same volume to get the densest concrete.

(ii) By Finesse modulus method (sieve analysis method): in this method, the samples of both coarse and fine aggregates are passed through a set of nine standard sieve and the percentage of sample retained on each of the said sieves is determined. The total of these percentages divided by 100 gives the finesses modulus of sample.

(iii) By Minimum voids method: This method is based on the fact that to obtain dense concrete the quantity of cement should also be slightly in excess of voids more than that of the fine aggregates. In this method the voids in the fine and coarse aggregates are separately found out with the help of graduated cylinder and water. The percentage of voids in aggregate, "X" given by the equation.

$$X = (V1 - V2)/V2 \times 100$$

Where v1, volume of water filled

v2, volume of aggregates.

(iv) By Arbitrary standards: It is a commonly adopted method of propitiating the aggregates in a concrete mix for small works of moderate importance. This method is not recommended for large works or important works. In this method, the volume of cement, sand and coarse aggregates are taken in the proportion of **1n:2n** respectively. The quantity of water to be used a varied suit the workability descried.

Ex: 1:1:2 – M250 rich mix for columns, beams

1:1:3 – M200 Water retaining structures etc

1:3:6 – M150 slab's columns roads etc

1:3:6 – M100 – foundations,

1:4:8 – For mass concrete.

Summary

Rocks formed by the solidification of molten magma or lava are known as igneous rocks.

1. Building stones obtained from rocks occurring in nature is classified into
   - Geological classification
   - Physical classification
   - Chemical classification
2. According or geological classification rocks are classified as
   - Igneous rocks
   - Sedimentary rocks
   - Metamorphic rocks
3. According to physical classification the rocks are classified into
   - Stratified rocks
   - Unstratified rocks
   - Foliated rocks
4. According to chemical classification the rocks are
   - Silicious rocks
   - Argillaceous rocks
   - Calcareous rocks
5. A good building stone should have the following qualities
   - Crushing strength
   - Appearance
   - Durability
   - Fracture
   - Hardness
   - Percentage wear

- Resistance to fire
- Specific gravity
- Texture
- Water absorption
- Seasoning
- Toughness index

6. The stones are used for

- Structural work
- Face work
- Paving work
- Basic materials
- Other purposes like ballast for railways; flux in blast furnace etc

7. The artificial stones are cast stones or reconstructed stones

Ex. 1. Cement concrete

2. Mosaic tiles

3. Terrazo

8. The artificial stones are used for to convey pipes, electric wires, fixing various fittings, cast to any shape, stones for lintels or beams etc.

9. Depending upon their size, the aggregates are classified as

- Fine aggregates
- Coarse aggregates

10. The grading of aggregates is done by

- By trail
- By fineness modulus method
- By minimum voids method
- By arbitrary method

Objective Type Questions

1. Molten material beneath or within the earth's crust, from which igneous rock is formed is called:

a) Lava b) Magma c) Both a & b d) None.

2. Molten rock that reaches the earth's surface through a volcano or fissure is called

a) Lava b) Magma c) Both a & b d) None.

3. Granite is an example of

a) Igneous Rock b) Metamorphic Rock c) Sedimentary Rock d) None.

4. Marble is an example of

a) Igneous Rock b) Metamorphic Rock c) Sedimentary Rock d) None.

5. Sand Stone is an example of

a) Igneous Rock b) Metamorphic Rock c) Sedimentary Rock d) None.

6. Igneous rocks solidified deep within the earth are known as

a) Plutonic Rocks b) Hypabyssal Rocks c) Volcanic Rocks d) None.

7. Rocks having layered structure are called:

a) Stratified Rocks b) Unstratified Rocks c) Foliated Rocks d) None.

8. Clay or alumina ($Al_2 O_3$) is the major constituent of these rocks

a) Siliceous Rocks b) Argillaceous Rocks c) Calcareous Rocks d) None.

9. The aggregate, most of which passes through 4.75mm I.S. sieve size, is termed as

a) Coarse Aggregate b) Fine Aggregate c) Both a&b d) None.

10. Concrete is an example of

a) Igneous Rock b) Metamorphic Rock c) Sedimentary Rock d) Artificial Stone.

Short Answer Type Questions

1. Name the classification of stones.
2. Name the types of rocks according to geological classification.
3. Name the types of rocks according to physical classification.
4. Name the types of rocks according to chemical classification.
5. Define igneous rocks.
6. Define sedimentary rocks.
7. Define metamorphic rocks.
8. List any four properties of Granite.
9. List any four properties of Marble.
10. List the uses of Granite.
11. List the uses of Marble.
12. Name any four building stones.
13. Name any four good qualities of stones.
14. Name any two uses of stones.
15. Define Dressing of Stones.
16. Mention any four varieties of Surface finishes of Stones.
17. What are artificial stones?

Long Answer Type Questions

1. Explain the classification of stones.
2. Explain in detail about the geological classification of stones.
3. Explain the qualities of good building stone.
4. Explain the uses of stones as building materials.
5. Explain physical and chemical classification of stones.
6. Explain the uses of the following building materials.

   a) Marble b) Granite c) Basalt d) Sandstone
7. Explain the grading of aggregates.

8. Explain the advantages of artificial Stones.

OJT / Practical Assignments

Collect and Identify different varieties of building stone samples and their current prices in the market.

UNIT 3

Bricks

Learning Objectives

After completing this unit, the student will be able to understand

- Know the composition of good brick earth
- Know the requirements of good brick earth
- Describe the manufacturing process of Bricks
- Explain the Field tests of good bricks
- Explain the Characteristics of good bricks
- Explain Classification of Bricks as per I.S
- Describe Special forms of Bricks
- Know about Special Purpose Bricks.

Introduction

Bricks are obtained by **moulding** clay in rectangular blocks of uniform size and then by **drying** and **burning** these blocks. As bricks are of uniform size, they can be properly arranged, light in weight and hence bricks replace stones.

Bricks are widely used in building construction because of their adequate strength, durability, availability and low cost. They can be made in desired shape and size.

3.1 Composition of good Brick Earth

Following are the constituents of good brick earth:

According to IS: 2117 – 1975, the clay for bricks should preferably conform to the following composition for good results:

1. Alumina or clay : 20 to 30% by weight
2. Silt : 20 to 35% by weight
3. Silica or Sand : 35 to 50% by weight
4. Other ingredients(Lime (CaO),

Iron oxide(FeO),

Magnesia Oxide(MgO),

Manganese(Mn),

Sodium, Potash, etc) : 1 to 2 % by weight

NOTE:

- The total content of clay and silt shall not be less than 50% by weight.
- The total soluble minerals should not be more than 1% by weight.

Function of various ingredients of Brick Earth

Following are the constituents of good brick earth and their functions:

1. Alumina: It is the chief constituent of every kind of clay. A good brick earth should contain about 20% to 30% of alumina. This constituent **imparts plasticity** to the earth so that it can be moulded. If alumina is present in excess, with inadequate quantity of sand, the raw bricks shrink and warp on drying and become too hard when burnt

2. Silica: It exists in clay either as free or combined. As free sand, it is mechanically mixed with clay and in combined form it exists in chemical composition with alumina. A good brick earth should contain about 50% to 60% of silica. The presence of this constituent **prevents cracking**, **shrinking** and **warping** of raw bricks. It thus imparts uniform shape to the bricks. The durability of bricks depends on the proper proportion of silica in brick earth. The excess of silica destroys the cohesion between particles and the bricks become brittle.

3. Lime: A small quantity of lime not exceeding 5 % is desirable in good brick earth. It should be present in a very finely powered state, otherwise it causes flaking on the bricks. The lime **prevents shrinkage** of raw bricks. The excess of lime causes the brick to melt and hence its shape is lost.

The lumps of lime if present are converted into quick lime after burning and this quick lime slakes and expands in presence of moisture. Such an action results in splitting of bricks into pieces.

4. Oxide of iron: A small quantity of oxide of iron to the extent of about 5 to 6 percent is desirable in good brick earth. It helps as lime to **fuse sand**. It also **imparts red color** to the bricks. The excess of oxide of iron makes the bricks dark blue or blackish. If, on the other hand, the quantity of iron oxide is comparatively less, the bricks will be yellowish in color.

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

Harmful Ingredients

The ingredients like, lime, iron pyrites, alkalies, pebbles, organic matter should not present in good brick earth.

3.2 Requirements of good brick earth

A good brick earth should satisfy the following requirements:

a) It should have required proportion of clay, sand and other ingredients.

b) It should be free from harmful ingredients like alkalies and Iron Pyrities, etc.

c) It must be free from pebbles, lumps and other organic matter.

d) It should not shrink, warp or crack excessively.

e) It should become homogenous on thorough mixing.

3.3 Manufacture of Bricks

The manufacturing of brick involved the following operations:

1. Preparation of clay

2. Moulding

3. Drying &

4. Burning

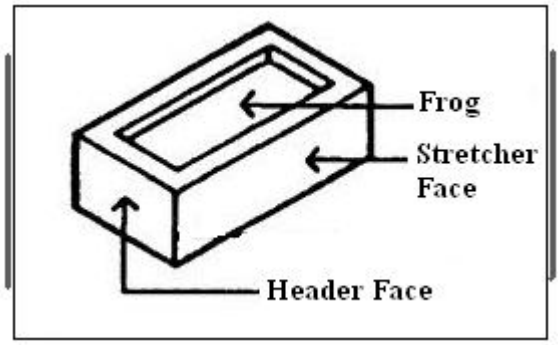


Fig. 3.1 Brick Faces

3.3.1 Preparation of Clay

The preparation of clay involves following operations:

a) Unsoiling : Top layer of 20cm depth is removed as it contain impurities.

b) Digging : Clay dug out from ground is spread on level ground about 60cm to 120cm heaps.

c) Cleaning: Stones, pebbles, vegetable matter etc removed and converted into powder form.

d) Weathering: Clay is exposed to atmosphere from few weeks to full season.

e) Blending: Clay is made loose and any ingredient to be added is spread over the top by turning it up and down in vertical direction.

f) Tempering: Clay is brought to a proper degree of hardness, then water is added to clay and whole mass is kneaded or pressed under the feet of men or cattle. For large scale, tempering is usually done in a pug mill.

Process: - Clay with water is placed in pug mill from the top. When the vertical staff is rotated by electric power, steam or diesel or turned by pair of bullocks, Clay is thoroughly mixed up by the actions of horizontal arms and knives. When clay is sufficiently pugged, hole at the bottom of tub, is opened out and the pugged earth is taken out from ramp for the next operation of moulding.

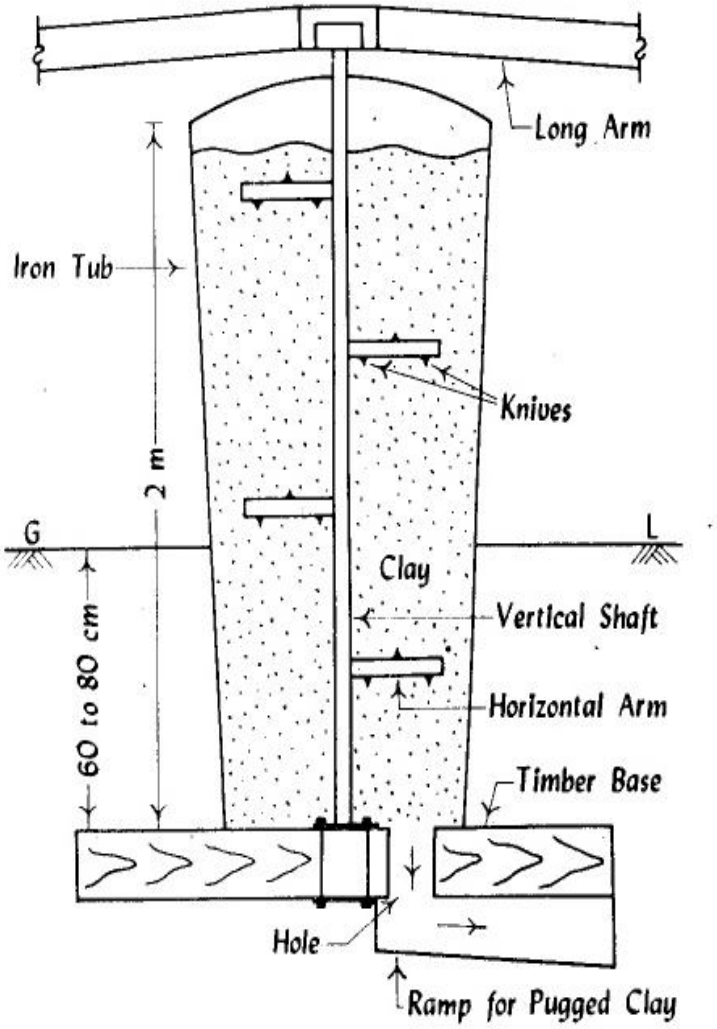


Fig. 3.2 Pug Mill

3.3.2 Moulding

Clay, which is prepared form pug mill, is sent for the next operation of moulding.

Following are the two ways of moulding

d Moulding: Moulds are rectangular boxes of wood or steel, which are open at top and bottom. Steel moulds are more durable and used for manufacturing bricks on large scale as shown in figure.3.2.3

Bricks prepared by hand moulding are of two types:

a) Ground moulded bricks

b) Table moulded bricks

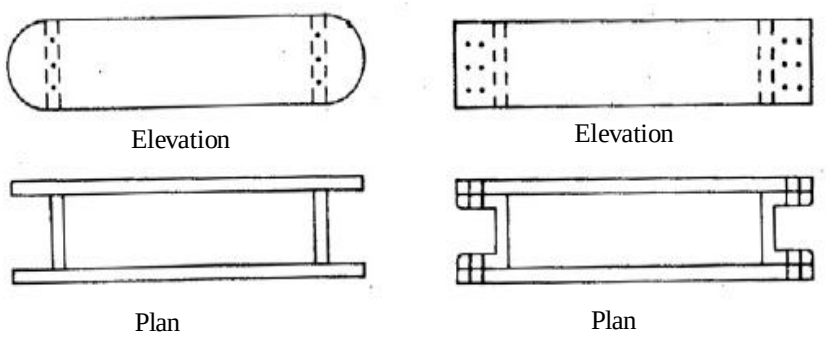


Fig. 3.3 Wooden Mould & Steel Mould

(a) Ground moulded bricks: ground is first made level and fine sand is sprinkled over it. Mould is dipped in water and placed over the ground to fill the clay. Extra clay is removed by wooden or metal Strike after the mould is filled forced mould is then lifted up and raw brick is left on the ground. Mould is then dipped in water every time lower faces of ground moulded bricks are rough and it is not possible to place frog on such bricks.

Ground moulded bricks of better quality and with frogs on their surface are made by using a pair of pallet boards and a wooden block.

(b) Table-moulded bricks: Process of moulding these bricks is just similar to ground bricks on a table of size about 2m x 1m.

(**1) Machine moulding:** This method proves to be economical when bricks in huge quantity are to be manufactured at the same spot. It is also helpful for moulding hard and string clay. These machines are broadly classified in two categories

(a) Plastic clay machines

(b) Dry clay machines

a) **Plastic clay machines:** This machine containing rectangular opening of size equal to length and width of a brick. Pugged clay is placed in the machine and as it comes out through the opening, it is cut into strips by wires fixed in frames, so there bricks are called wire cut bricks.

b) **Dry clay machines**: In these machines, strong clay is first converted into powder form and then water is added to form a stiff plastic paste. Such paste is placed in mould and pressed by machine to form hard and well shaped bricks. These bricks are behavior than ordinary hand moulded bricks. They carry distinct frogs and exhibit uniform texture.

3.3.3 Drying

The damp bricks, if burnt, are likely to be cracked and distored. Hence moulded bricks are dried before thay are taken for the next operation of burning. Bricks are laid along and across the stock in alternate layers. The drying of brick is by the following means

(i) Artificial drying: drying by tunnels usually 1200C about 1 to 3 days

(ii) Circulation of air: Stacks are arranged in such a way that sufficient air space is left between them free circulation of air.

(iii) Drying yard: special yards should be prepared slightly higher level prevent the accumulation of rain water

(**iv) Period for drying**: usually about 3 to 10 days to bricks to become dry

(v) Screens: screens are necessary, may be provided to avoid direct exposure to wind or sun.

3.3.4 Burning

This is very important operation in the manufacturing of bricks to impart hardness, strength and makes them dense and durable. Burning of bricks is done either in clamps or in kilns. Clamps are temporary structures and they are adopted to manufacture bricks on small scale. Kilns are permanent structures and they are adopted to manufacture bricks on a large scale. A typical clamp is as shown in figure below.

(1) A trapezoidal shape in plan with shorter is slightly in excavation and wider end raised at an angle of 150 from ground level.

(2) A brick wall with mud is constructed on the short end and a layer of 70cm to 80cm thick fuel (grass, cow dung, ground nuts, wood or coal) laid on the floor.

(3) A layer consists of 4 or 5 courses of raw bricks laid on edges with small spaces between them for circulation of air.

(4) A second layer of fuel is then placed, and over it another layer of raw bricks is putap. The total height of clamp in alternate layers of brick is about 3 to 4 m.

(5) When clamp is completely constructed, it is plastered with mud on sides andtop and filled with earth to prevent the escape of heat.

(6) The period of burning is about one to two months and allow the same time for cooling.

(7) Burnt bricks are taken out from the clamp.

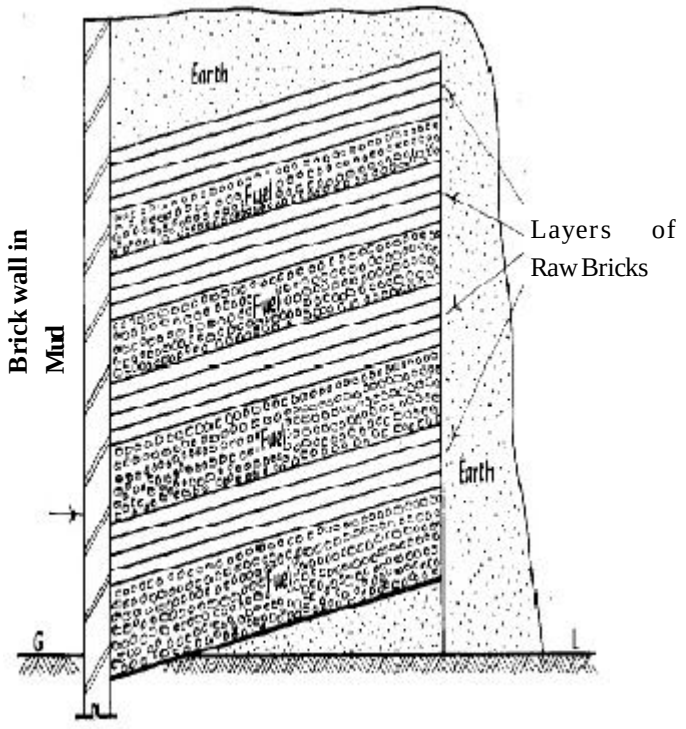


Fig. 3.4 Clamp

Advantages

(i) The bricks produced are tough and strong because burning and cooling are gradual

(ii) Burning in clamps proves to be cheap and economical.

(iii) No skilled labour and supervision are required for the construction of clamps.

(iv) There is considerable saving of clamps fuel.

Disadvantages

(i) Bricks are not of required shape

(ii) It is very slow process

(iii) It is not possible to regulate fire in a clamp

(iv) Quality of brick is not uniform

Kilns

A kiln is a large oven, which is used to burnt bricks by

1) Intermittent kilns

2) Continuous kilns

1) Intermittent kilns: These intermittent in operation, which means that they are loaded, fired, cooled and unloaded.

a) Intermittent up-draught kilns

b) Intermittent down-draught kilns

a) Intermittent up-draught kiln: This is in the form of rectangular with thick outside walls as shown in the figure below; wide doors are provided at each end for loading and unloading of kilns. A temporary roof may be installed to protect from rain and it is removed after kiln is fired. Flues are provided to carry flames or hot gases through the body of kiln.

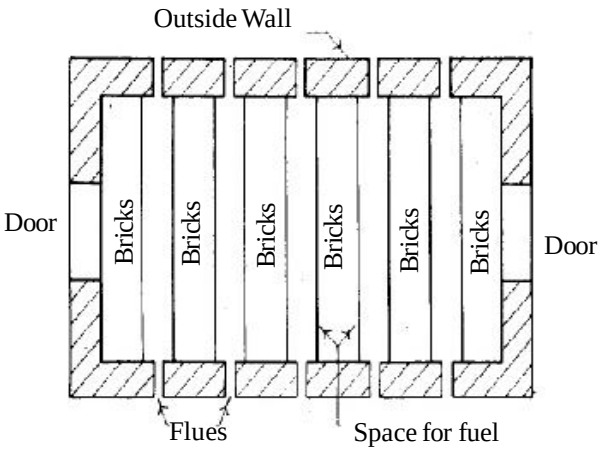


Fig. 3.5 Intermittent Kiln

(i) Raw bricks are laid in row of thickness equal to 2 to 3 bricks and height 6 to 8 bricks with 2 bricks spacing between rows.

(ii) Fuels are filled with brush wood which takes up a free easily.

(iii) Loading of kiln with raw bricks with top course is finished with flat bricks and other courses are formed by placing bricks on edges.

(iv) Each door is built up with dry bricks and is covered with mud or clay.

(v) The kiln is then fired for a period of 48 to 60 hours draught rises in the upward direction from bottom of kiln and brings about the burning of bricks.

(vi) Kiln is allowed to cool down and bricks are then token out.

(vi) Same procedure is repeated for the next burning

Bricks manufactured by intermittent up drought kilns are better than those prepared by clamps but bricks burnt by this process is not uniform, supply of bricks is not continuous and wastage of fuel heat.

(b) Intermittent down-draught kilns

These kilns are rectangular or circular in shape. They are provided with permanent walls and closed tight roof. Floor of the kiln has opening which are connected to a common chimney stack through flues. Working is same as up-draught kiln. But it is so arranged in this kiln that hot gases are carried through vertical flues upto the level of roof and they are then released. These hot gases move down ward by the chimney draught and in doing so, they burn the bricks.

Advantages

(i) Bricks are evenly burnt

(ii) Performance of this kiln is better than that of up-draught kiln

(iii) This kiln is suitable for burning of structural clay tiles, terra cota because of close control of heat.

2. Continuous kilns

These kilns are continuous in operations. This means that loading, firing, cooling and unloading are carried out simultaneously in these kilns. There are three types of continuous kilns.

a) Bull's trench kiln

b) Hoffman's kiln

c) Tunnel kiln

a) Bull's trench kiln: This kiln may be of rectangular, circular or oval shape in the plan as shown in fig 2.5. It is constructed in a trench excavated in ground either fully underground partially projecting above ground openings is provided in the outer walls to act as flue holes. Dampers are in the form of iron plates and they are used to divide thekilns in suitable sections and most widely used kiln in India.

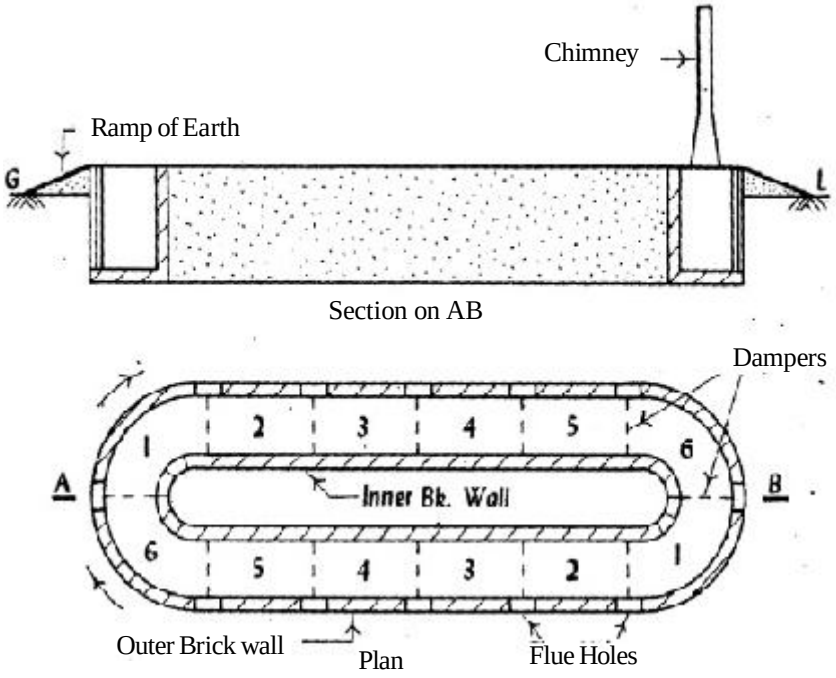


Fig. 3.6 Bull's Trench Kiln

The bricks are arranged in such a way that flues are formed. Fuel is placed in flues and it is ignited through flue holes after covering top surface with earth and ashes to prevent the escape of heat usually two movable iron chimneys are employed to form draught. These chimneys are placed in advance of section being fired. Hence, hot gases leaving the chimney warm up the bricks in next section. Each section requires about one day to burn.

The tentative arrangement for different sections may be as follows:

Section 1 – Loading

Section 2 – Empty

Section 3 – Unloading

Section 4 – Cooling

Section 5 – Burning

Section 6 – Heating

b) Haffman's kiln:

This kiln is constructed over ground and hence, it is sometimes known as flame kiln. Its shape is circular to plan and it is divided into a number of compartments or chambers. A permanent roof is provided; the kiln can even function during rainy season. The following fugure shows plan and section of Hoffman's kiln with 12 chambers

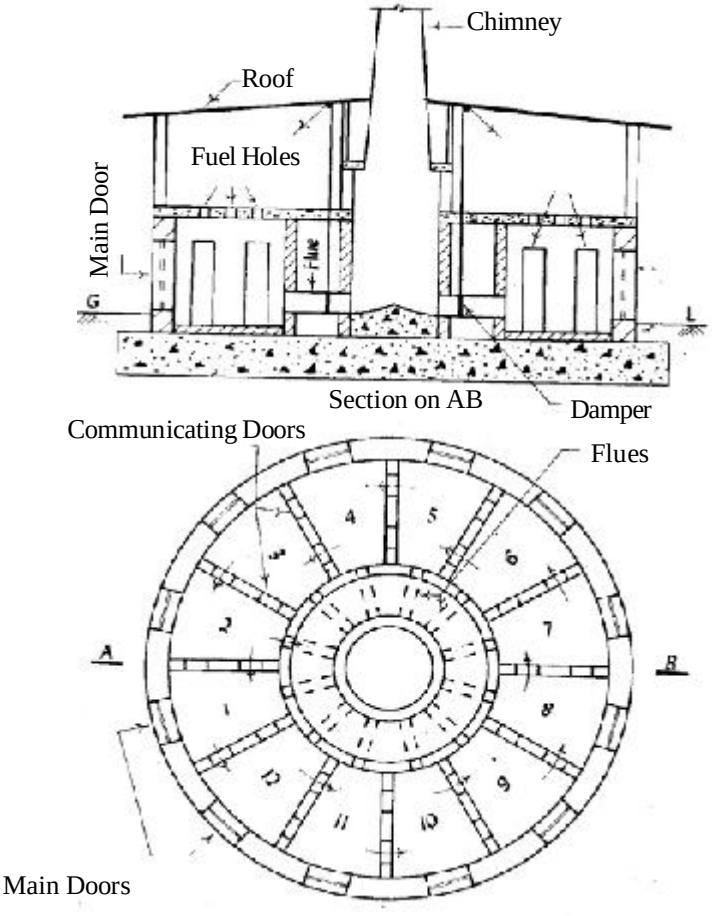


Fig. 3.7 Hoffman's Kiln

Chamber 1 - loading

Chamber 2 to 5 – drying and pre-heating

Chambers 6 and 7 - burning

Chambers 8 to 11 - cooling

Chamber 12 – unloading

The initial cost of installing this kiln is high. Following are its **advantages**:

(i) Good quality of bricks are produced

(ii) It is possible to regulate heat inside the chambers through fuel holes.

(iii) Supply of bricks is continuous and regular

(iv) There is considerable saving in fuel due to pre heating of raw bricks by flue gases.

c) Tunnel kiln

This type of kiln is in the form of tunnel, which may be straight, circular or oval in the plan. Raw bricks are placed in trolleys which are then moved from one end to the other end of tunnel. Raw bricks get dried and pre-heated as they approach zone of fire. In zone of fire, bricks are burnt and then pushed forward for cooling. When bricks are sufficiently cooled, they are unloaded. The kiln proves to be economical when the bricks are manufactured on a large scale. As temperature is under control, uniform bricks of better quality are produced.

Comparision between Clamp-Burning and Kiln Burning

No.	Item	Clamp - Burning	Kiln - Burning
1.	Capacity	About 20000 to 100000 bricks can be preparedat a time.	Average 25000 brickscan be prepared per day.
2.	Cost of Fuel	Low as grass, cow dung,litter, etc. may be used.	Generally high as coaldust is to be used.
3.	Initial Cost	Very low as no structuresare to be built.	More as permanentstructures are to beconstructed.

4. Quality of Bricks	Percentage of good quality bricks is small about 60% or so.	Percentage of good quality bricks is more , about 90% or so.
5. Regulation of fire	It is not possible to control or regulate fire during burning.	Fire can be controlled throughout the process of burning.
6. Skilled supervision	Not necessary	Continuous skilled supervision is necessary
7. Structure	Temporary Structure	Permanent
8. Suitability	Suitable for small scale brick manufacturing and when the demand is not continuous.	Suitable for large scale manufacturing and when there is continuous demand for bricks.
9. Time of burning & cooling	2 to 6 months	For burning:24hours For cooling:12days.
10. Wastage of heat	Considerable wastage from top & sides and hot flue gas is not properly utilized.	Hot flue gas is used to dry and pre-heat raw bricks. Wastage is least.

3.4 Field Tests of Good Bricks

1. Size and Shape

The brick should be of standard size and shape with sharp corners. Corners should not be rounded.

2. Colour and appearance:

A well burnt brick should have uniform copper red colour and free from cracks and lumps. It should not be over-burnt or under-burnt.

3. Hardness

Bricks should be sufficiently hard. No impression should be left on brick surface when scratched with a finger nail.

4. Soundness

Brick should give a clear metallic ringing sound when struck with another brick.

5. Strength

The brick should not break when dropped on a hard flat ground from a height of about of 1 metre.

6. Efflorescence

The grayish white deposit on the exposed surface of brick is known as efflorescence. It should slight to moderate only.

3.5 Characteristics of good bricks

1. Bricks should be table moulded, well burnt in kilns, copper coloured, free from cracks and with sharp and square edges.
2. Bricks should be of uniform shape and should be of standard size.
3. Bricks should give clear ringing sound when struck with each other.
4. Bricks when broken should show a bright homogeneous and compact structure free from voids.
5. Bricks should not absorb water more than 20 percent by weight for first class bricks and 22 percent by weight for second class bricks when soaked in coldwater for a period of 24 hours.
6. Bricks should be sufficiently hard. No impression should be left on brick surface when scratched with finger nail.
7. Bricks should have low thermal conductivity and they should be sound proof.
8. Bricks should not break when dropped flat on hard ground from a height of about one meter.
9. Bricks, when soaked in water for 24hours, should not show deposits of white salts when allowed to dry in shade.
10. No brick should have crushing strength below 55kg/cm^2.

3.6 I.S.I Specification for Bricks

According to IS 1077 – 1971, the standard properties of burnt clay bricks should be as following:

1. The common brick used in construction are classified on the basis of their minimum compressive strength. For all bricks minimum compressive strength should not be less than 50 kg/cm2. For example a brick of compressive strength 50 kg/cm2 shall be classified as 50. The compressive strength of any brick of each class shall not vary by 20%.

Each class of above brick is further divided into two sub-classes namely "Class A" and "Class B" based on its shape and tolerance. For example, the bricks of classification 100 shall have sub-class as 100A and 100B.

Class A Bricks: Bricks belonging to this class will possess smooth rectangular faces with sharp corners. These bricks will emit ringing sound when struck with each other and tolerance limit shall be plus or minus 3%.

Class B Bricks: these bricks are allowed to have slight distortion and unsharp edges provided no difficulty shall arise in laying of uniform course. Their tolerance limit shall be plus or minus 8%.

2. General Quality: Bricks shall be hand or machine moulded. They shall be free from cracks, flaws and nodules of free lime. Bricks of 9cm height shall be moulded with a frog 1 to 2cm deep on one of its flat sides. Bricks of 4cm height may not be provided with frogs.

3. Dimensions : The standard sizes of common building bricks shall be as following:

Length in cm	Width in cm	Height in cm
19	9	9
19	9	4

Tolerance: Twenty bricks shall be collected at random from a selectd sample.. all small projections, loose particles of clay, all blister shall be removed. They shall be arranged on a level surface successively as shown in the figure below in a straight line successively.the overall length of all bricks shall be measured with a steel tape. The dimensions of bricks shall be within the following limits as shown in the Table below:

Sub-Class A	a) Length b) Width c) Height	368 to 392 cm 174 to 186 cm 174 to 186 cm (in case of 9cm high bricks) 77 to 83cm (In case of 4cm high bricks)
Sub-Class B	a) Length b) Width c) Height	350 to 410 cm 165 to 195 cm 165 to 195 cm (in case of 9cm high bricks) 74 to 86cm (In case of 4cm high bricks)

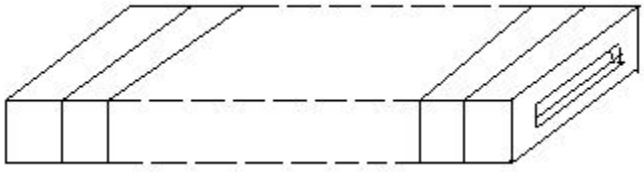


Fig. 3.8 Measurement of Height

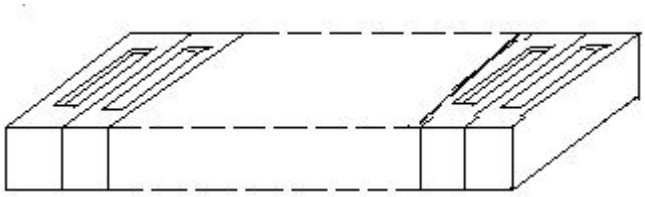


Fig. 3.9 Measurement of Width

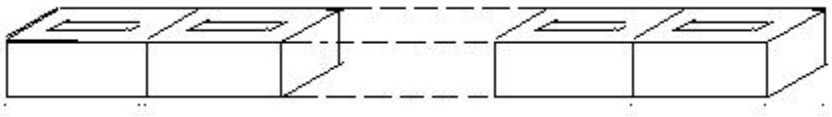


Fig. 3.10 Measurement of Length

Physical Properties

When tested in accordance with the procedure given in **IS 3495 – 1966**, the common building bricks shall have the following properties:

a) Compressive strength: Common building bricks shall have minimum compressive strength of 30 kg/cm2. It should not fall below 20% for all classes of bricks.

b) Water Absorption: it should not be more than 20% for up to class 125 bricks and 15% for higher class of bricks by weight after immersion in cold water for 24 hours.

c) Efflorescence: The rating of efflorescence shall not be more than 'moderate' up to class 125 and 'slight' for higher classes.

Classification of Bricks

According to **conventional classification**, Bricks are broadly divided into two categories:

(i) Unburnt or sundried bricks

(ii) Burnt bricks

(i) Unburnt or Sun dried bricks- These bricks are dried with the help of heat of the sun after moulding. These are used in the construction of temporary and cheap structures. Such bricks should not be used at places exposed to heavy rains.

(ii)Burnt Bricks: The bricks used in construction works are burnt bricks and they are classified into the following four categories.

· **First Class bricks:** These bricks are table moulded and of standard shape. The surface and edges of the bricks are sharp, square, smooth and straight. They comply with all qualities of good bricks and used for superior work of permanent nature.

· **Second class bricks:** These bricks are ground moulded and burnt in kilns. The surface of bricks is slightly rough and shape is also slightly irregular. These bricks are commonly used at places where brick work is to be provided with a coat of plaster. Also used as coarse aggregate in concrete.

· **Third class bricks:** These bricks are ground moulded and they burnt in clamps. These bricks are not hard and they have rough surfaces with irregular and distorted edges. These bricks give dull sound when struck together. They are used for unimportant and temporary structures and at places where rainfall is not heavy.

· **Fourth class bricks:** These are over burnt bricks with irregular shape and dark colour. These bricks are used as aggregate for concrete in foundation,

floors, roads, etc because of the fact that the over burnt bricks have compacted structure and hence, they are sometimes found stronger than even first class bricks.

The above classification is not rigid. The quality specified under one class often overlap with other class. To overcome this non-uniformity, I.S.I has classified the bricks.

3.7 Classification of Burnt Clay Bricks as per I.S 3102-1965

Type of Brick	Class Designation	Compressive Strength kg/cm^2 (minimum)	Water absorption 24hrs immersion percentage (maximum)	Efflorescence
Heavy duty Bricks	450	450	10	Nil
	400	400	10	Nil
	350	350	15	Slight
	300	300	15	Slight
	250	250	15	Slight
	200	200	15	Slight
Common Burnt clay Building Bricks	175	175	15	Slight
	150	150	15	Slight
	125	125	20	Moderate
	100	100	20	Moderate
	75	75	20	Moderate
	50	50	20	Moderate

3.8 Special Forms of Bricks

Bricks are made in a wide range of shapes and to suit the requirements of construction where they are to be used. Special form of bricks may be needed due to structural consideration or for ornamental decoration.

Specially moulded bricks avoid the cumbersome process of cutting and rounding the rectangular bricks to the desired shape. Some of the special types of bricks commonly used are given below.

(a) Squint Bricks.

(b) Bull Nosed Bricks.

(c) Perforated Bricks.

(d) Hollow Bricks.

(e) Circular Bricks.

(f) Plinth cornice and String Course Brick

a. Squint Bricks: These bricks are made in a variety of shapes and are used to the construction of a cute and obtuse squint quoins as shown in the above figure.

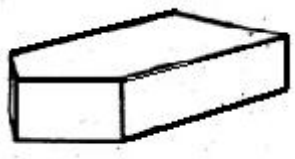
b. Bull Nosed Bricks: These bricks are used to form rounded quoins.

c. Perforated Bricks: These bricks may be standard size bricks produced with perforations running through their thickness. Perforated bricks are easy to burn and their light weight makes it possible to cut down the weight of the structure and effect in foundations. The aperture of the perforations is such that it gives maximum amount of ventilation. But does not permit the entry of rats or mice. These bricks are used for constructing load bearing walls of low buildings, panel walls for multistoried buildings and for providing partition walls.

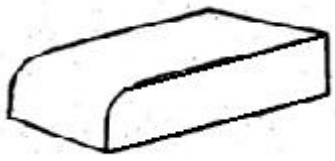
d. Hallow Bricks: These bricks are made of clay and are provided with one or more cavities. Hallow bricks are light in weight and are used to increase insulation against heat and dampness. They are used for the construction of load bearing walls, partition walls or panel walls to multistoried buildings.

e. Circular Bricks: These bricks have internal and external faces curved to meet the requirement of the particular curve and radius of the wall. These bricks are used for wells, towers etc

f. Plinth cornice and String Course Brick: These bricks are moulded in several patterns with the object of adding architectural beauty to the structure and at the same time to helping to throw the rack water off the face of the walls.



(a) Squint Brick



(b) Bull Nose Brick

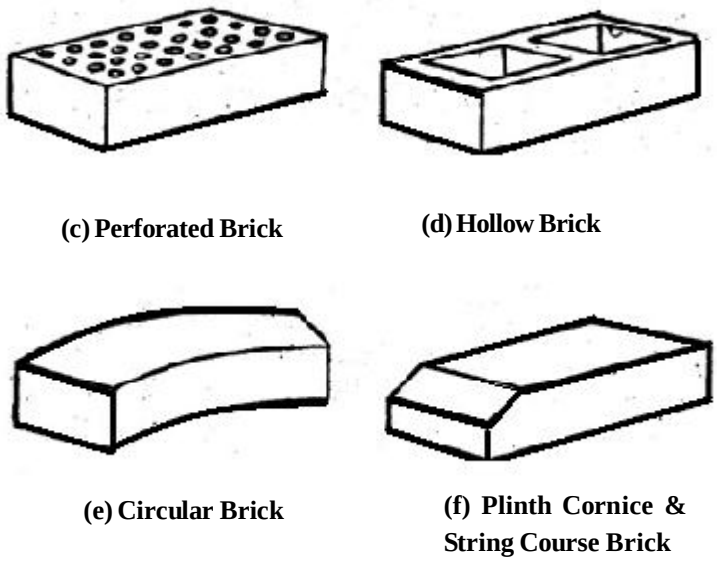


Fig. 3.11 Special Forms of Bricks

g. Coping Bricks: These bricks are manufactured in a variety of shapes to set the thickness of the wall and are throated on the underside to throw off rain water as shown in the above figue.

h. Paving Bricks: These bricks are specially made for paving the surface of streets and highways. These bricks are usually made from shale, fire clay on a mixture of the two. They are unaffected by weather and ordinary traffic wear. They are loaded on the bed of sand which in term rests on foundation of stone or concrete. The bricks are laid by grouting with cement mortar or asphalt. They are machine moulded and are burnt in a continuous kiln to ensure high degree of vitrification.

3.9 Special Purpose Bricks

3.9.1 Fly Ash Bricks

Fly ash is a residue or waste generated from thermal power plants in which coal is used as fuel to generate electricity. Fly ash is a very fine which contains oxides of calcium, aluminium and silicon. They are lighter in weight than ordinary clay bricks and less porous too.

Owing to the high concentration of calcium oxide in class C fly ash, the brick can be described as "self-cementing". The manufacturing method is said to save energy, reduce mercury pollution, and costs 20% less than traditional clay brick manufacturing.

The raw materials

The raw material that is used for fly ash brick are: Fly ash, Sand/Stone dust, Lime, Gypsum and Cement. Flyash bricks are lighter than clay bricks.

The blocks are removed from the blocks after 24 hours and immersed in water for curing for about 28days. The bricks are then ready for use. The strength is high compared to conventional clay bricks and give good appearance. The colour of fly ash bricks can be altered with the addition of admixtures during the process of brick making.

Advantages

1. Due to high strength, practically no breakage during **transport** & use.

2. Due to uniform size of bricks **mortar** required for joints & plaster reduces almost by 50%.

3. Due to lower water penetration **seepage** of water through bricks is considerably reduced.

4**. Plaster of Paris**/Gypsum Plaster can be directly applied on these bricks without a backing coat of plaster

5. These bricks do not require soaking in water for 24 hours. Only sprinkling of water before use is enough.

6. Compressive strength of fly ash sand lime bricks is **9.00 N/mm^2** on an average **(**as against 3.50 N/mm2 for handmade clay bricks**).**

Dis-advantages

1. Poor quality and outlook in colour without plastering

2. Mechanical bonding strength is weak. But this can be rectified by adding marble waste.

3. Limitation of size. Only modular size can be produces. Large size will have more breakages

3.9.2 Precast Concrete Blocks

Due to various advantages over traditional building materials like bricks and stones, concrete blocks are extensively used now a days. They can be made solid or hollow. Solid blocks are used for load bearing walls and hollow blocks are used for non-load bearing walls.

The materials required for the production of concrete blocks are cement, aggregates and water.

The recommended sizes of common concrete blocks are:

39cm x 19cm x 30cm,

39cm x 19cm x 20cm, and

39cm x 19cm x 10cm.

Advantages of Concrete Blocks

- Width of wall can be reduced compared to brick walls.
- It provides better heat & sound insulation and fire resistance properties.
- Construction will be much faster.
- No of joints in the masonry are reduced and the mortar can be saved.

Tests for Bricks

A brick is generally subjected to following tests to find out its suitability of the construction work.

i. Absorption

ii. Crushing strength or compression strength

iii. Hardness

iv. Presence soluble salts

v. Shape and size

vi. Soundness

vii. Structure

(1) Absorption: A good should not absorb not more than **20 percent** of weight of dry brick.

(2) Compressive strength: crushing or compressive strength of brick is found out by placing it in compression testing machine. It is pressed till it breaks. Minimum crushing strength of brick is **35kg/cm^2** and for superior bricks, it may vary from **70 to 140 kg/cm^2**

(3) Hardness: No impression is left on the surface the brick is treated to be sufficiently hard.

(4) Presence of soluble salts: The bricks should not show any grey or white deposits after immersed in water for **24 hours**.

(**5) Shape and size:** It should be standard size and shape with sharp edges.

(6) Soundness: The brick should give clear ringing sound struck each other.

(**7) Structure:** The structure should be homogeneous, compact and free from any defects.

Grading of Bricks

As per IS10719557 and 1970 code specifications,

a. Bricks with compressive strength not less than 140kg/cm2 – **Grade A- A class.**

b. Bricks with compressive strength not less than 105kg/cm2 – First class bricks - **Grade A.**

c. Bricks with compressive strength not less than 70kg/cm2 – Second class bricks – **Grade B.**

d. Bricks with compressive strength not less than the average value 35kg/ cm^2 – class III bricks – **Grade C**.

Summary

1.Brick is a building material composed of following materials

- Alumina
- Silica
- Lime
- Oxide of iron
- Magnesia

2. The manufacture of bricks is carried out by the following operations

- Preparation of clay
- Moulding
- Drying
- Burning

3. Bricks are classified conventionally as

- Un-burnt or sun dried bricks
- Burnt bricks
- First class bricks
- Second class bricks
- Third class bricks
- Fourth class bricks

4. A good brick should Table moulded, well burnt, uniform shape size, should give clear ringing sound, should be hard, water absorption not more than 20% for 24 hours.

5. The special types of bricks commonly used are

- Squint bricks
- Bull nosed bricks
- Perforated bricks
- Hallow bricks
- Circular bricks
- Coping bricks
- Paving bricks.

6. Different grades of bricks as per IS1077-1957 & 1970

1. Grade A – A class < 140kg/cm2
2. Second class bricks – grade B < 70kg/cm2.
3. First class bricks – grade A <105kg/cm2.
4. Class III bricks – grade C average 35kg/cm2.

Short Answer Type Questions

1. What is the composition of good brick earth?
2. What are the harmful ingredients in brick earth?
3. Name the steps involved in the manufacture of brick.
4. What are the types special purpose bricks?
5. Name the types of special forms bricks.
6. What are the important qualities of brick?
7. What are the uses of hallow bricks?
8. What is the size and weight of standard brick?
9. What is meant by blending?
10. What is tempering of clay?

Long Answer Type Questions

1. Explain the manufacturing process of bricks in detail.
2. Explain the classification of bricks.
3. Explain the qualities of bricks.
4. Explain the special types of bricks.
5. Explain the composition of good brick in detail (function of each constituent).
6. Explain the tests to be conducted to a brick.
7. Explain IS Specifications of Bricks.
8. Explain the field tests of Bricks.
9. What are Fly ash bricks? Explain their advantages and disadvantages.
10. What are Concrete Blocks? Explain their advantages.
11. Briefly explain different special forms of Bricks.

On Job Training / Assignment

· Brick manufacturing units are to be visited to understand the process of manufacturing.

· Collection of different samples of bricks and ascertaining the current rates of different varieties of bricks.

UNIT 4

Clay Products

Learning Objectives

After completing this unit, the student will be able to understand

- Know what are tiles and different types of tiles
- Explain about Roofing Tile
- Explain about Flooring Tiles
- Know about Stone ware pipes
- Write about Glazing
- Know about Porcelain
- Write about Terra-cotta

4.1 Tiles

Tiles are simply thin slabs of **burnt clay**. These are prepared in various shapes, sizes and textures to suit the construction requirements. Tiles are generally used for covering roofs, floors, walls, showers and other objects such as tabletops.

Special care has to be taken while drying and burning, as the thickness of tiles is very thin. Technologies such as pressure drying and burning are adopted. Tiles are dried under the shade, burnt in specially made kilns and cooled gradually.

They are either hand moulded or machine moulded. For hand moulding, thickness of tile is taken between 12mm and 15mm and for machine moulding, thickness of tile is taken as 10mm.

Based on the use, tiles are classified as:

- Roof Tiles
- Floor Tiles and
- Wall Tiles

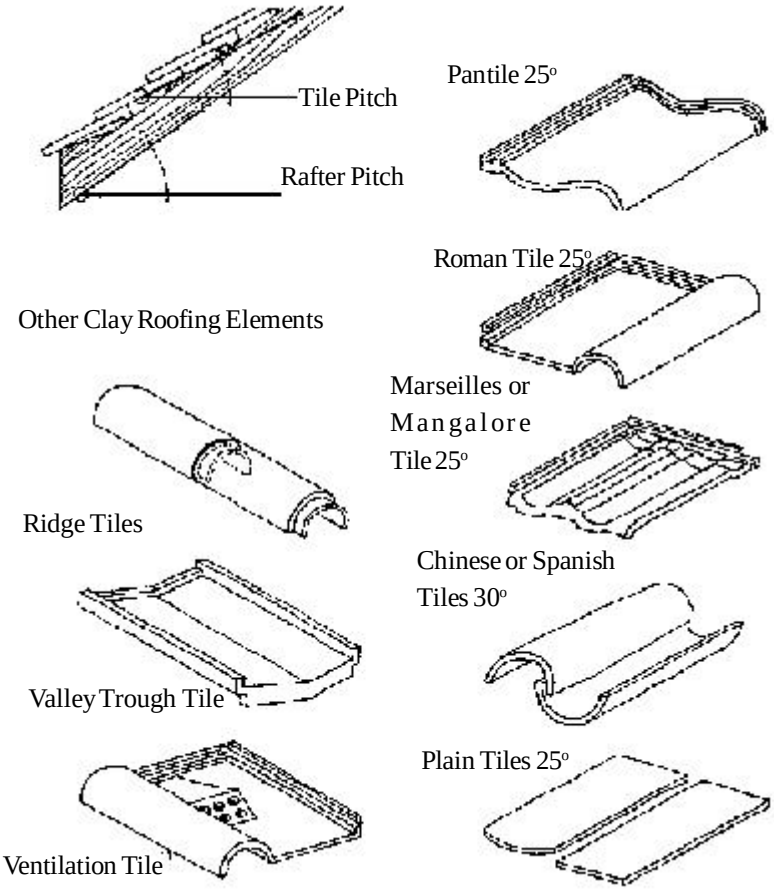


Fig. 4.1 Types of Tiles

4.2 Roof Tiles

Tiles used for covering the roof of a building or house are called roof tiles.

Roof tiles are designed mainly to keep out rain, and Sun. They are traditionally made from clay. Some clay tiles have a waterproof glaze. For a better Roof tiles, high resistance to moisture, heat and other weathering agencies is desirable.

A large number of shapes of roof tiles have evolved as per the construction requirements. These include: Flat Tile, Interlocking Tiles and Curved Tile (Pot Tiles and Pan Tiles).

Flat Tiles

These are available in rectangular shape in various sizes.These are the simplest type of roof tiles, which are laid in regular overlapping rows. They can be used for flat or sloped roofs. The tiles are nailed on to the horizontal reapers or battens. These tiles are laid in one or two layers in Cement or Lime mortar.

Interlocking Tiles

These tiles are flat and rectangular in shape with corrugations in the middle. The corrugations help interlocking the tiles when placed in layers. The corrugations also help in improving the architectural appearance and in draining off the rain water. These are usually Machine made.

Some of the leading inter-locking tiles are

(a) Mangalore Tiles & (b) Allahabad Tiles

Mangalore Tiles

These tiles are originated in Mangalore city of Karnataka State, India where they were first manufactured.

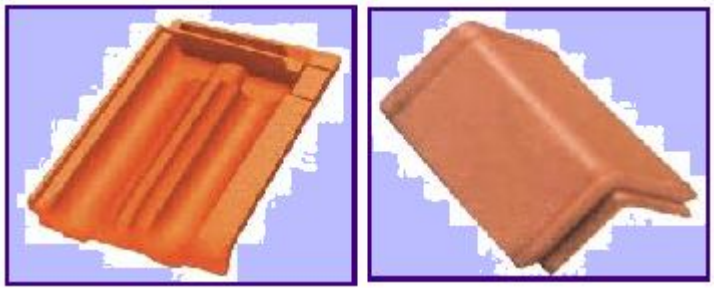


Fig. 4.2 Mangalore Tiles

These are typical rectangular flat tiles with corrugations to provide interlocking and to drain off the rain water. These are basically red in colour. Now a days, these are produced in various colours to suit the construction demands. For ventilation purposes, special type Mangalore Tiles are also available.

According to IS: 654-1972, these tiles are categorised as Class A and Class AA tiles based on their water absorption and breaking load.

Class	Length	Width	Thickness
A & AA	410 mm 420 mm 425 mm	235 mm 250 mm 260 mm	Varies between 30mm & 50mm

Water Absorption

After 24hrs of soaking, maximum percentage of water absorption should not be greater than 24% for Class A tiles and 19% for Class AA tiles.

Breaking Load

Average Minimum Breaking load should not fall below 820N for Class A tiles and 1020N for Class AA tiles.

Weight

Average weight of 6 tiles should not be less than 2kg and should not be greater than 3kg.

Curved Tiles

These are half round ordinary country roof tiles, with 100mm to 133mm diameter at one end and 75 to 105mm at the other end. The length varies between 200mm to 250mm and thickness varies between 12mm to 20mm. These are prepared by hand on potter's wheel. Surface polishing is done by smooth wet cloth or leather strip. They are moulded as frustum of cone and cut into two equal halves and then dried and burnt. These tiles are placed on the reepers in rows with their concavity upwards and then they are interlocked by another row of tiles with their concavity downwards.

Fig. 4.3 Curved Roof Tiles

Types of Curved Tiles

Pan Tiles

These roof tiles are similar to pot tiles with less curvature. These are thicker, stronger and durable than pot tiles.

These are first prepared flat and then moulded to required curvature. Length varies between 330mm and 380mm, and width varies between 230mm to 280mm.

Pot Tiles

These roof tiles are ordinary curved tiles. These are semi-circular in cross-section with varying diameter from the larger end (about 230mm) to the smaller end (about 200mm) along the length of 300mm.

These are prepared on potter's wheel as frustum of cone and cut into two equal halves. Polishing is done by wet cloth.

Roof tiles are 'hung' from the framework of a roof by fixing them with nails. The tiles are usually hung in parallel rows, with each row overlapping the row below it to exclude rainwater and to cover the nails that hold the row below.

There are also roof tiles for special positions, particularly where the planes of the several pitches meet. They include ridge, hip and valley tiles.

4.3 Floor Tiles

Floor tiles are used similar to the Marble or Granite flooring slabs. Because of the added advantages like ease of construction & repair, light in weight, equally strong &durable, stain resistant and their availability in wide ranging colours and textures, artificial tiles are fast replacing the natural stones tiles.

Floor tiles are made of strong & fine clay. The top surface is glazed and vitrified to prevent water absorption. These are made in different colours, sizes and finishes.

Flooring tiles are laid on a finished wet mortar and the joints are finished with white cement.

Following are different forms of tiles available:

a) Vitrified Tiles & b) Marbonite Tiles

Both vitrified and Marbonite tiles are vitrified tiles with varying percentage of water absorption and surface finish.

Vitrification: It is the process of obtaining glossy finish on the tile surface by the application of heat.

Vitrified tile

Vitrified tile is a tile which has been processed in such a way that it has very very low porosity (and water absorption) which make it stain resistant and very strong.

Marbonite tiles are fully vitrified with very less water absorption and look similar to natural marble.Vitrified tiles possess better strain resistant, hygienic, scratch resistance, impact resistance and acid resistance than Marble, Granite or other ceramic tiles.

Fig. 4.4 Vitrified Tiles

Is vitrified tile better than marble or granite?

Vitrified Tiles have far superior properties compared to marble or natural granite because being a manufactured product their quality is controlled whereas in naturally occurring marble and granite good quality is just a coincidence. Vitrified tiles posses much better mechanical strength, scratch resistance, resistance to acids, alkalis and chemicals, resistance to staining etc compared to marble or natural granite.

Ceramic tiles may be painted and glazed. Floor tiles are typically set into mortar consisting of sand, cement and often a latex additive for extra strength. The spaces between the tiles are nowadays filled with sanded or unsanded floor grout, but traditionally mortar was used.

Some stone tiles such as polished granite and marble are inherently very slippery when wet. On the other hand, Ceramic tiles for use in wet areas can be made more slip resistant either by using very small tiles so that the grout lines act as grooves or by imprinting a contour pattern onto the face of the tile.

Wall Tiles

These are similar to floor tiles but light in weight, less in thickness and strength. These are available in different sizes and colours. These are easy to clean and are mostly used for bathrooms, kitchen and hospital walls.

Fig. 4.5 Wall Tiles

Characteristics of Good Tiles

- They should be of uniform size and shape
- They should be free from cracks and bends.
- They should possess compact granular structure. Compactness imparts mechanical strength, based on which the right tile is selected to suit a purpose.
- They should be free from foreign materials visible to the naked eye.
- They should be sound hard and durable.
- They should be well burnt.
- They should be tough or impact resistant.
- They should produce ringing sound when struck with each other.
- They should possess better stain resistance and very low water absorption. Tiles with low water absorption usually have higher mechanical strength. Firing a tile at high temperatures makes it less porous and less water absorbent.
- They should be non-slippery and easy to clean.
- They should be slip resistant.
- They should have resistance against surface abrasion. Porcelain tiles are more surface abrasion resistant and have higher durability.

Earthenware

Ceramic with a water absorption rate of more than 10% after firing it at temperatures between 950° and 1150°C is known as earthenware. Earthenware is easy to work and easy to decorate. Because it is so porous though, it should only be used indoors to prevent weathering caused by frost. Earthenware is mainly used as glazed wall tiles.

Two different procedures for manufacturing earthenware can be distinguished: In the single firing technology (monoporasa), the liquid glaze is applied onto the tile immediately after shaping. Then the desired decoration can be applied onto the tile. In the double firing technology (biporosa) the body is fired first. Afterwards it is glazed, decorated and then fired again.

Fig. 4.5 Gazed Ceramic Tiles

4.4 Stoneware

Articles prepared from refractory clay mixed with stone and crushed pottery are known as Stoneware. The mixture is burnt at high temperature and cooled slowly.

Glazing of Stoneware pipes makes them impervious, acid resistant and weathering resistant.

Fig. 4.6 Stoneware Pipes and Fittings

Stoneware has a water absorption rate of less than 3%. Compared to earthenware, stoneware has a higher density and better mechanical strength. Unlike earthenware, stoneware is fired at temperatures between 1150 and 1300°C. Porosity can be reduced by adding fluorite and other fluxes.

Stoneware pipes are used to drain the waste water from Toilets to the main sewage pipes. These pipes are available in length about 900mm and in varying diameters up to 500mm. one end of these pipes is provided with a collar for interlocking with the smaller end of other pipe and the joints are cemented. Other stoneware articles such as wash basins, glazed tiles, water closets, etc. are very popular. Almost all tiles for floor coverings exposed to high traffic such as for industry, commerce or public areas are made of unglazed stoneware. Stoneware tiles with glaze are classical ceramics for floors. Abrasion and slip resistance are determined by the technical properties of the glaze.

4.5 Porcelain

Porcelain is a hard, white, translucent ceramic made by firing pure clay and then glazing it with variously colored fusible materials.

It is non-porous, hard and brittle. It is prepared by subjecting the high quality clay to very high temperatures ranging from 1200 to 1400 degrees centigrade. The ingredients, viz., fine clay, feldspar, quartz, and minerals are finely ground and mixed thoroughly in liquid state. The mixture is then given desired shape and then burnt at high temperature.

Fig. 4.7 Porcelain Articles

Porcelain is of two types, Soft Porcelain and Hard Porcelain. They are available in different grades.

Porcelain is used as sanitary wares, electric insulators, crockery, storage vessels, etc.

4.6 Glazing

Glazing is a process of obtaining shiny or dull surface finish (of very thin film of about 0.1mm to 0.2mm) on the surface of clay products.

Glazing improves appearance and protects the clay products against corrosion, weathering and makes them impervious and durable.

Glazing may be either transparent or opaque. Transparent glazing is obtained by Salt(Sodium Chloride) or Lead

Glazing Methods:

Opaque glazing is obtained by dipping the burnt clay products in slurry of fine clay (known as slip) & reburning them.

Salt glazing is used for Sanitary PIPES and Chemical Stoneware.

Lead glazing is used for terra-cotta and fire-clay wares and earthen wares.

Opaque glazing is used for Sanitary ARTICLES.

4.7 Terracotta

Terracotta is a soft ceramic of natural clay. It has been used for building construction and decorative arts since ancient times in cultures around the world.

Fig. 4.8 Terracotta Tiles & Pipes

Terracotta, which literally means “baked earth,” is made from natural clay, which gives it a characteristic reddish-brown color. The color varies slightly depending on the clay used. Sometimes a small quantity of sand, powdered

glass, old terra-cotta or pottery is added to clay to obtain strength, rigidity and to reduce shrinkage cracks on drying.

Terracotta may be glazed for extra durability or to provide color. It is a waterproof and very sturdy material, and many ancient terracotta sculptures are still in excellent shape.

Terracotta was widely used in the decorative arts of ancient China. Terracotta pipe was also one of the oldest materials used in plumbing.

Characteristics of Terra cotta:

· Fired clay

· Light in weight.

· Typically hollow, formed by pressing clay into a mould, by hollowing out portions of a solid, or by extruding it.

· Usually low-fired

· Typically a reddish, unglazed ceramic material. It may also be a hard-fire glazed or unglazed ceramic material. Glazed variety is impervious.

· Durable (dependent upon the degree of firing)

· Fireproof

· Porous variety is Soundproof

· Strong

· It can resist weathering action effectively than many varieties of stones.

· Can be moulded into virtually any shape

· Available in a variety of designs, colors and finishes.

Typical Uses

- Historically used for Sculptures
- Unglazed units are used for structural purposes
- Glazed units are used for building exteriors

Typical **current uses** for terra cotta include:

- Cladding
- Used in both commercial and residential applications

- It can be used for ornamental work in buildings such as arches, cornices, etc.
- Sound insulation
- Fire protection of Steel or RCC members
- Hollow blocks are used for masonry work.

Summary

• Tiles are simply thin slabs of **burnt clay**. Tiles are generally used for covering roofs, floors, walls, showers and other objects such as tabletops.

• Based on the **use**, tiles are classified as:

• Roof Tiles

• Floor Tiles and

• Wall Tiles

• **Roof Tiles:** Tiles used for covering the roof of a building or house are called roof tiles. According to their shape roof tiles can be categorized as:

• Flat Tile, Interlocking Tiles and Curved Tile (Pot Tiles and Pan Tiles).

• **Floor tiles** are made of strong & fine clay. The top surface is glazed and vitrified to prevent water absorption. These are made in different colours, sizes and finishes.

• Different forms of floor tiles available are: Vitrified Tiles & Marbonite Tiles.

• **Wall Tiles**: These are similar to floor tiles but light in weight, less in thickness and strength.

• **Earthenware**: Ceramic with a water absorption rate of more than 10% after firing it at temperatures between 950° and 1150°C is known as earthenware.

• **Stoneware** : Articles prepared from refractory clay mixed with stone and crushed pottery are known as Stoneware. The mixture is burnt at high temperature and cooled slowly.

• **Porcelain** : Porcelain is a hard, white, translucent ceramic made by firing pure clay and then glazing it with variously colored fusible materials. It is non-porous, hard and brittle.

• **Glazing** : Glazing is a process of obtaining shiny or dull surface finish (of very thin film of about 0.1mm to 0.2mm) on the surface of clay products.

• **Terracotta:** Terracotta, literally means **"baked earth"** is a soft ceramic of natural clay. Terracotta may be glazed for extra durability or to provide color. It is a waterproof and very sturdy material.

Short Answer Type Questions

1. Mention different types of tiles.
2. Define Terracotta.
3. Define Stoneware.
4. Define Glazing.
5. Define Porcelain.
6. State any four characteristics of good tiles.
7. State any four uses of Terracotta.
8. State any four characteristics of Terracotta.
9. Define Pot tiles.
10. Define Pan tiles.

Long Answer Type Questions

1. Explain the characteristics of good tiles.
2. Explain Pan tiles and Pot tiles.
3. Explain briefly about
   a. Ceramic tiles and
   b. Vitrified tiles.
4. List the uses of Terracotta.
5. Write short notes on:
   a. Stone ware
   b. Porcelain &
   c. Glazing.

OJT Assignments

Collection of sample of different varieties of tiles, stoneware, porcelain, and terracotta products from the market and recoding the current prices & properties of new products.

UNIT 5

Lime

Learning Objectives

After completing this unit, the student will be able to understand

- Know what is Lime, its properties and uses;
- State different sources of Lime;
- Understand what is calcinations of Lime;
- Know what is slaking of Lime;
- Explain the classification of Lime.

5.1 Introduction

Lime is one of the most important and largely used building materials. In fact, it is used as the main cementing material till the advent of Port land cement. Some of the unique properties which can be attributed to lime are better **workability**, **early hardening, good strength and hydraulicity** (property by which it set in damp conditions and thick masonry walls) and excellent adhesion to masonry units. Although it has been largely replaced by cement in India, lime still stands comparable to cement in most important properties. Lime industries and the use of many of the resulting products date from prehistoric periods in both the Old World and the New World.

The rocks and minerals from which these materials are derived are composed primarily of calcium carbonate. Depending upon percentage of calcium carbonate

($caco_3$) presence in limestone, it is classified into Class A, B, and C, and they are used for masonry, plastering, mortar, etc. The lime that is obtained from the **calcination**s of the pure lime stone is called **quick lime**. By burning kankar, shells of sea animals and boulders of limestone from the bank of Old River, lime stone is obtained. The subsequent **addition of water** to the highly caustic quick lime, makes it into the less caustic **slaked lime** or hydrated lime (calcium hydroxide, $Ca(OH)_2$), the process of which is called slaking of lime.

5.2 Uses of Lime

Lime is an important engineering material and its uses are:

- It is used in **purification** of **water** and **sewage treatment**.
- It is used as an ingredient in **concrete** and **mortar**.
- It is used as a **refractory lining** in furnaces.
- It is used as a **flux** (a chemical cleaning agent) in metallurgy.
- It is used in the **production of glass**.
- It is used for **plastering** of walls and ceilings.
- It is used in the production of **artificial stone, lime-sand bricks**, etc.
- It is used for **white washing** and for serving as a base coat for distempering.
- It is used in the preparation of **Cement-Lime Mortar**, which can be used in place of costly cement mortar.

5.3 Sources of lime

Generally lime is not found in nature in the free state but it is obtained by burning one of the following materials.

- Lime stone found in lime stone hills
- Lime stone boulders found in the beds of old rivers.
- Kankar found below ground
- Shells of sea animals

Note: White chalk is pure lime stone; kankar is an impure lime stone.

Fig. 5.1 Line Stone Boulder along Hill sdie and River Bed

Fig. 5.2 Sea Shells

5.4 Calcination of Lime

Calcination

Calcination is a process in which the decomposition of **calcium carbonate (limestone)** to calcium oxide (lime) and carbon dioxide takes place by the **application of heat**. Calcination is carried out in furnaces or reactors or kilns of various designs.

$CaCO_3$ + heat '! CaO + CO_2 (g)

Common lime

Calcium Oxide is known as common lime. It is the product obtained by **burning** (CLACINATION) of limestone. Its chemical composition is **CaO** (**Calcium Oxide**).

Firing is carried out in shaft or rotary kilns at a temperature of 1000-1200 degrees Celsius. The result is a lump lime, **quicklime,** which is ground in ball mills. Other ingredients (the slag, limestone, fly ash) are added to improve properties and reduce the cost.

5.5 Quick Lime

Quicklime (**calcium oxide**) is a white solid having a crystalline structure. Quicklime is produced by calcinating comparatively pure limestone, according to the reaction:

$CaCO_3$ + heat '! CaO + CO_2

The chemical composition of quick lime is (CaO). Quicklime is highly reactive with water, generating considerable heat in the hydration process. It can be bought at masonry supply stores.

CAUTION : HIGHLY CAUSTIC (CORROSIVE)

5.6 Slaking of Lime

Slaking is adding water to Quick lime. The product **Calcium hydroxide** with the chemical formula **$Ca(OH)_2$** is traditionally called **slaked lime**. It is a colorless crystal or white powder and is obtained when calcium oxide (called lime or **quicklime**) is mixed, or "slaked" with sufficient quantity of **water**. It has many names including hydrated lime, builders lime, slaked lime, or pickling lime. It is of low toxicity. Calcium hydroxide is used in many applications, including food preparation.

Calcium hydroxide is produced commercially by treating lime with water:

CaO + H_2O '! $Ca(OH)_2$

Uses:

It is an ingredient in whitewash, mortar, and plaster.

It is an additive to sea water to reduce atmospheric CO_2 and mitigate the greenhouse effect.

5.7 Classification of Lime

Limes obtained from the calcination of limestone are classified into the following three categories:

- Fat lime,
- Hydraulic lime, and
- Poor lime.

Fat lime: Fat lime is named as high calcium lime, **pure lime**, rich lime, or white lime. It is obtained from the pure limestone, shell and coral. When compared

with quick lime, the **volume of fat lime gets increased** to about 2 - 2 1/2 times **during slaking**. That is why it is popularly known as fat lime.

Fig. 5.3 Fat Line Motor

1. Composition

Fat lime is produced from sea shell, coral deposits etc or from lime stone containing impurities like free sand and soluble silica combined with alumina, magnesium, carbonate etc. If the proportion of free sand is large, the resulting lime becomes progressively poor and is called poor or lean lime.

2. Behavior in Slaking

Fat lime slakes rapidly when water is added giving out considerable heat and making **cracking noise** and increases 2 to 3 times its original volume. Fat lime if exposed to air, absorbs moisture and CO_2 from the atmosphere and becomes inert $CaCO_3$ or chalk again and loses its cementing power. For developing the cementing power, quick lime must be slaked with water as early as possible, after it is obtained from the kiln.

3. Shrinking

Fat lime has a greater tendency to shrink and crack as it dries. To prevent this, a large quantity of sand (2 to 3 times) must be mixed with it to prepare mortar.

4. Hardening or Setting

Fat lime is hydrated calcium oxide and sets by the absorption of CO_2 from the air.

$$\mathbf{Ca(OH)_2 + CO_2 \text{ '! } CaCO_3 + H_2O}$$

Crystals of $CaCO_3$ are formed and the water goes by evaporation. Thus fat lime hardens only where it comes in contact with air (CO_2), as in plaster work.

In the interior of thick walls, it does not acquire strength as air cannot reach there. Mixing of sand (2 to 3 times) forms pores for access of air and helps hardening.

Instead, Lime mortar with **surki** (powdered burnt bricks) can be used for thick masonry walls and foundations, etc, as it contains good hydraulic and setting properties.

5. Strength

Crystals of $CaCO_3$ formed by fat lime are not very strong. Fat lime, therefore, does not possess much strength. It is used for plastering walls, white washing etc.

Properties of Fat lime

- It hardens very slowly.
- It is having the high degree of plasticity.
- The color is pure white.
- In the presence of air, it tends to set very slowly.
- It slakes vigorously.

Use of Fat lime

It is used in

- **White washing**
- **Plastering** of walls.
- It forms **lime mortar** with sand, which sets in thin joints. This type of mortar can be used to apply in thin joints of brickwork and stone work.

Hydraulic lime

Hydraulic lime has the capacity to set and **harden even under water**, where the quick lime cannot able to do it. The composition of the hydraulic lime is different from quick lime. It contains a definite quantity of **clay** which gives its hydraulic property. Hydraulic lime is obtained by burning the limestone rich in clay, or adding clay materials to the lime stone while burning.

Composition:

Hydraulic lime consists of

- Calcium Oxide(CaO) : 70-80% and
- Clay about : 15 – 30%.

Depending upon the hydraulicity, it is divided into feebly hydraulic, moderately hydraulic, and eminently hydraulic.

Hydraulicity is the property of lime by which it hardens or sets in water, damp places or thick masonry walls where there is no air circulation.

Properties of Hydraulic Lime:

- Lime with about 30% clay, the eminently hydraulic lime resembles natural cement. It can be used for damp places.
- Hydraulicity of lime increase with clay percentage but makes slaking difficult.
- It slakes slowly and is not accompanied by sound or heat. Its volume is increased slightly.
- Hydraulic lime mortar can be used for damp or underwater conditions and for thick walls where air cannot enter.
- Its colour is not perfect white. It varies with percentage of clay.
- With water, it forms a thin paste.
- For using in plaster work, finely powdered hydraulic lime is mixed with sand and kept as a heap for about a week and, ground again and then used.
- It is strong and can be used where strength is required.

Poor lime

Lime with clay content more than 30% is known as poor lime. This lime is called impure lime or lean lime.

The properties of poor lime:

- This poor lime consists of more than 30% clay.
- It slakes very slowly.
- The thin paste is formed along with water.
- It never gets dissolved with water and gets frequently changed.

- It hardens very slowly.
- The binding property is very poor.

Precautions to be taken in Handling Lime

- Quick lime should be stored away from water before slaking.
- Workers should be provided with goggles and respirators as the lime dust causes irritation, skin burns particularly in the presence of moisture.
- Worker should be instructed to wash their skin properly after work. Application of oil avoids skin burns.
- Slaking of lime generates immense heat. Hence, proper precautions should be taken to avoid amy fire hazards.

Summary

- Lime is a dry white powdery substance obtained by calcination of Lime stone.
- Sources of lime: Generally lime is not found in nature in the free state. It is obtained by burning one of the following materials:
  - Lime stone found in lime stone hills
  - Lime stone boulders in the beds of old rivers.
  - Kankar found below ground
  - Shells of sea animals
- Calcination is the process of burning Lime stone (Calcium Carbonate) and producing Calcium oxide(CaO), which is known as Quick lime.
- Slaking is the process of adding sufficient quantity of water to Quick Lime and preparing Hydrated Lime $Ca(OH)_2$. During this process immense amount of heat is generated.
- Limes obtained from the calcination of limestone are classified into the following three categories:

  a) Fat lime,

  b) Hydraulic lime, and

  c) Poor lime.

- Fat lime is high calcium lime, **pure lime** or white lime obtained from the pure limestone, shell and coral. Fat lime is hydrated calcium oxide and sets by the absorption of CO_2 from the air.

- Hydraulic lime: Lime with property to set and **harden even under water** is known as Hydraulic lime. It is due to the presence of Clay up to 30%.

- Lime with clay content more than 30% is known as poor lime.

Objective Type Questions

1. Which one of the following is not the chief source of lime:

   a) Sea Shells b) Lime stone hills c) kankar found below ground d) bauxite.

2. Quick Lime is

   a) Calcium Carbonate b) Calcium Oxide c) Calcium Hydrauxide d) all of these.

3. Quick Lime is produced from Lime Stone through a process of

   a) Calcination b) Slaking c) Grinding d) None of these.

4. Chemical equation of Quick Lime is

   a) $CaCo_3$ b) CaO c) $Ca(OH)_2$ d) CO_2

5. Addition of sufficient quantity of water to Quick Lime is known as

   a) Calcination b) Slaking c) Mixing d) Curing

6. Chemical equation of Builders Lime or hydrated Lime is

   a) $CaCo_3$ b) CaO c) $Ca(OH)_2$ d) CO_2

7. Which one of the following is the ingredient of White Wash

   a) $CaCo_3$ b) CaO c) $Ca(OH)_2$ d) CO_2

8. Which one of the following makes crackling noise while slaking

   a) Fat Lime b) Hydraulic Lime c) Poor Lime d) all of these

9. Which of the following lime sets even under water

   a) Fat Lime b) Hydraulic Lime c) Poor Lime d) all of these

10. Which of the follow contains more than 30% clay

    a) Fat Lime b) Hydraulic Lime c) Poor Lime d) none of these

Short Answer Type Questions

1. What is lime?
2. What are the sources of lime?
3. Define Calcination.
4. What is Slaking?
5. What is Fat Lime?
6. What is Hydraulic Lime?
7. What is Poor Lime?
8. Write any two uses of Lime.
9. What is Quick Lime?

Long Answer Type Questions

1. Explain the classification of Lime;
2. Write the uses of Lime.
3. Explain Calcination and Slaking of Lime.
4. Explain classifications of lime?
5. What are the properties and uses of Fat Lime?
6. What are the properties and uses of Hydraulic Lime?

OJT Assignments

Collection of field information regarding availability of different varieties and their rates of Lime in the market.

UNIT 6

Cement

Learning Objectives

After completing this unit, the student will be able to understand

- Know what is Cement and its Chemical Composition;
- Describe the manufacturing process of Ordinary Portland Cement;
- Know how the field tests of Cement are done;
- Know how various tests on Cement according to I.S.I are done;
- Explain different types of Cement.

6.1 Introduction

Cement is a binding material. It is made by grinding calcined limestone and clay to a fine powder.

Cement can be described as a material with adhesive and cohesive properties which make it capable of bonding materials into a compact whole. For construction purposes, cement is restricted to bonding with materials like stones, bricks, building blocks, aggregate etc.

Natural cement is obtained by burning and crushing the stones containing clay, carbonate of lime and some amount of carbonate of magnesia. Natural cement is brown in color. It sets very quickly after addition of water. It is not as strong as artificial cement.

Artificial cement is obtained by burning at a very high temperature, a mixture of calcareous and argillaceous materials. Common variety of artificial cement is ordinary Portland cement. This cement was invented by a mason Joseph Aspdin of Leeds in England. After setting, this cement resembles a type of sandstone in Portland in England. It is therefore popular as Portland cement.

6.2 Chemical Composition of Portland Cement

Ordinary cement consists of two basic ingredients, namely, argillaceous and calcareous. In argillaceous materials, clay predominates and in calcareous materials, calcium carbonate predominates. A typical chemical analysis of good ordinary cement is as follows:

Ingredient	Percent
Lime(CaO)	62
Silica(Sio_2)	22
Allumina(Al_2o_3)	5
Calcium sulphate ($CaSo_4$)	4
Iron oxide(Fe_2O_3)	3
Magnesia(MgO)	2
Sulphur(S)	1
Alkalies(OH)	1
	100

Functions of cement Ingredients

The functions of various ingredients of cement are as follows

- **Lime (Cao):** This is the important ingredient of cement. Its proportion is to be carefully maintained .Lime in excess causes the cement to expand and disintegrate .If the proportion of lime is less, the strength of cement decreases and cement sets quickly.

- **Silica (Sio_2):** Silica gives **strength** to the cement. This is an important ingredient of cement.

- **Alumina (Al_2o_3):** Alumina imparts **quick setting** property of cement. Alumina in excess weakens the cement.

- **Calcium sulphate ($CaSo_4$):** This ingredient is in the form of **gypsum**. Its function is to **increase the initial setting time of cement.**

- **Iron oxide (Fe_2o_3):** Iron oxide imparts **color**, **hardness** and **strength** to cement.

- **Magnesia (Mgo):** If magnesia is present in small amount, it imparts **hardness** and **color** to cement.

- **Sulphur (S):** A very small amount of sulphur is useful in making **sound** cement. If it is in excess it causes the cement to become unsound.

- **Alkalies:** As most of the alkalies present in raw materials are carried away by the flue gases during heating cement contains only a small amount of alkalies. If they are in excess in cement, **effloresence** is caused.

6.3 Manufacture of Ordinary Portland Cement

The process of manufacture of cement consists essentially of **grinding** the raw materials, **mixing** them intimately in certain proportions, **burning** in a large rotator kiln at a temperature of about 1450 0C. Due to this temperature the material melts and partially fuses into balls known as clinkers. The clinker is cooled and ground to a fine powder and a small percentage of gypsum is added. The product formed is commercial Portland cement.

Cement is manufactured in either (A) dry process or (B) wet process.

6.3.1 Dry Process

In this process, the raw materials are first reduced in size of about 25 mm in crushers. A current of dry air is then passed over these dried materials. These dried materials are pulverized into fine powder in ball mills and tube mills. All these operations are done separately for each raw material and they are stored in containers called hoppers. They are then mixed in correct proportions and made ready for the feed of rotary kiln. Dry process is adopted when the raw materials are hard.

Advantages of Dry process:

- It increases the productivity of labour.
- The capital required for manufacture of ton of cement is less.
- The fuel consumption is reduced.

Disadvantages of Dry process:

- The process is **slow**.

- The cement produced is of **inferior quality**.

6.3.2 Wet Process

Mixing

In this process, calcareous materials such as limestone are crushed and stored in storage tanks. Argillaceous materials such as clay are thoroughly mixed with water in a container known as wash mill. The washed clay is stored in basins. Now, crushed limestone from silos and wet clay from wash mill are allowed to fall in a channel in correct proportions. This channel leads the materials to grinding mills where they are brought into intimate contact to form slurry. Grinding is carried out in ball mills or tube mills or both. The slurry is led to correcting basin where it is constantly stirred. At this stage, the chemical composition is adjusted as necessary. The corrected slurry is stored in storage tanks and kept ready for burning in a rotator kiln.

Burning:

A rotator kiln is formed of steel tubes. Its diameter varies from 250 cm to 300 cm. Its length varies from 90 m to 120 m. It is laid at a gradient of about 1 in 25 to 1 in 30. The kiln rotates once in every minute about its longitudinal axis. The corrected slurry or raw mix is injected at the upper end of the kiln. Hot gases or flames are forced through the lower end of the kiln .Portion of the kiln near the upper zone is known as dry zone. Here water of slurry is evaporated. As the slurry gradually descends, there is rise in temperature and in the next section of kiln, carbon dioxide from the slurry is evaporated. Small lumps known as nodules are formed at this stage.

These nodules then reach the burning zone where the temperature is about 1500^0C to 1700^0C. In burning zone, calcined product is formed. Nodules are converted into small hard stones known as clinkers.

The size of the clinkers varies from 5 mm to 10 mm and they are very hot when they come out of the burning zone. A smaller size rotary kiln is provided for cooling the clinkers.

Grinding:

Clinkers as obtained from the rotary kiln are finely ground in ball mills and tube mills. During grinding 3 to 4 per cent, of gypsum is added. Gypsum controls the initial setting time of cement. If gypsum is not added, cement would set as soon as water is added.

6.4 Field tests for cement

Following field tests are carried out to ascertain roughly the quality of cement.

Color: The color of cement should be uniform. It should be typical cement color, grey color with greenish shade.

Physical properties: If cement is touched or rubbed in between fingers, we should feel smooth. If it is felt rough it indicates adulteration with sand. If hand is inserted in a bag of cement it should feel cool. If small quantity of cement is thrown in a bucket of water, it should sink and should not float on the surface.

Presence of lumps: Cement should be free from any hard lumps. Such lumps are formed by the absorption of moisture from the atmosphere. Any bag of cement containing such lumps should be rejected.

Strength: Cement briquettes of size 75 mmx25 mm x12 mm are prepared with a proportion of cement to sand as 1:6. The briquettes are immersed in water for 3 days. If the briquettes are not easily broken and it is difficult to convert them into powder, it indicates cement of sound quality.

6.5 Tests on cement as per I.S.I

The following tests are conducted on cement as per I.S.I:

6.5.1 Fineness Test of Cement :

This test is carried out to check proper grinding of cement. Fineness of cement particles may be determined by sieve test or by permeability apparatus test.

In **sieve test**, cement weighing 100 gm is taken. It is continuously passed for 15 minutes through I.S. sieve No. 9. The residue is then weighed and this weight should not be more than 10 percent of original weight.

Weight of cement sample taken = w1

Weight of sample passing through IS sieve No.9 = w2

Weight of cement sample retained = w1-w2

Fineness = 100 x (w1-w2)/w1

In permeability apparatus test, the specific area of cement particles is calculated. Specific surface of the cement should not be less than **2250** cm2/ gm.

Vicat Apparatus: Consistency, initial setting time and final setting time are determined using vicat apparatus. Vicat apparatus consists of a frame which is added to the movable rod. An indicator is attached to the movable rod. This indicator moves on a vertical scale and it gives the penetration .Vicat mould is in the form of a cylinder. It is placed on a non porous plate. For consistency, a plunger is attached to the movable rod of the vicat apparatus, while square needle and annular needle are used respectively for initial setting time and final setting time.

Fig. 6.1 Vicat Apparatus

6.5.2 Consistency Test

The performance of this test is to determine the **percentage of water** required for preparing cement paste of required workability. For consistency test **plunger** is attached to the movable rod of the vicat apparatus. The following procedure is adopted.

Take **300 gm** of cement and add certain percentage of water to it.

Mix water and cement on a non-porous surface. Mixing should be done thoroughly

Fill the mould of vicat apparatus and keep the mould on a non-porous plate.

Plunger is attached to the movable rod of the vicat apparatus and it is gently lowered on the plate in the mould.

The settlement of the plunger is noted. A penetration of **5 mm to 7 mm** indicates consistency.

If this penetration is not attained, the process is repeated with different percentages of water till the desired penetration is reached.

6.5.3 Initial and Final Setting times of Cement

Initial setting times and final setting times are determined by fixing **square needle** and **annular needles** to the moving arm of the vicat apparatus. For good O.P.C. the initial setting time should be around **30 minutes** and final setting time about **10 hours**.

Procedure for initial setting time:

Cement weighing 300 gm is taken and it is mixed with percentage of water as per consistency.

Cement paste is placed in vicat mould, placed over a non-porous plate.

Square needle of cross section **1 mm x 1 mm** is attached to the moving rod of vicat apparatus.

The needle is allowed to penetrate cement the paste. Initially it penetrates completely. It is then taken out and dropped at a fresh place.

This process is repeated at regular intervals till the needle does not penetrate completely.

Initial setting time is the time interval between the addition of water to cement and the stage when the needle does not penetrate completely. This should be about 30 minutes for ordinary cement.

Procedure for final setting time test

Cement weighing 300 gm is taken and water as per consistency is added to the cement.

This cement paste is placed on the vicat mould.

Needle with annular collar is attached to the moving rod of the vicat apparatus. This needle makes an impression on the cement paste.

The time at which the needle and collar fails to make impression on test block is noted.

This time corresponds to the final setting time. This time should be around 10 hours for ordinary cement.

6.5.4 Compressive strength

To determine the compressive strength of cement, the following procedure is adopted.

A cement mortar of proportion **1:3** is prepared.

Water is added to the mortar. Water cement ratio of 0.4 is taken and mixed thoroughly.

The mortar is placed in the moulds. Moulds are test specimen in the form of cubes of size 70.6 mm or 76 mm. Cement required is 185 gm and 235 gm respectively for 70.6 mm and 76 mm size.

The mortar in the mould is compacted in vibrating machine for 2 minutes.

The moulds are placed in damp cabin for 24 hours.

The specimen is then removed from the moulds and they are submerged in clean water for curing.

The cubes are then tested in **compressive testing machine** at the end of 3 days and 7 days. During testing load is applied uniformly at the rate of 350 kg/ cm2.

Compressive strength at the end of 3 days should not be less than 115 kg/ cm2 and at the end of 7 days it should not be less than 175 kg/cm2.

6.6 Types of Cement

As per the composition and its properties cement is classified as Ordinary Portland cement, low heat cement, quick setting cement, rapid hardening cement, blast furnace slag cement, Pozzuolana cement etc.

6.6.1 Grades of cement

The various grades of cement are **33 grade 43 grade and 53 grade**. The initial and final setting times are same as that of ordinary Portland cement .Various properties of these cement are same as that of ordinary Portland cement. Ordinary Portland cement is of 33 grade. The compressive strength of this cement is 33 N/mm^2. Similarly the compressive strength of 43 grade is 43 N/mm^2 and for 53 grade it is 53 N/mm^2. Higher grades of 43 and 53 generate greater heat of hydration and need proper curing. They should be used only for higher strengths.

6.6.2 Ordinary Portland Cement (OPC)

It is obtained by burning calcareous and argillaceous materials at high temperatures. The color of this cement is grey with greenish shade. Its initial

setting time is 30 minutes and final setting time is 10 hours .The expansion in soundness test is less than 10 mm .This cement contains not less than two thirds of its mass made up of C3s and C2s taken together. A small quantity of gypsum is added. Most of the cement used for construction is ordinary Portland cement.

6.6.3 Quick Setting Cement

This cement is produced by adding a small percentage of **aluminum sulphate** and by **finely grinding** the cement. The percentage of gypsum is reduced considerably to reduce the setting time. The setting action of cement starts within **5 minutes** of adding water to cement and it becomes hard like a stone in **30 minutes**. Thus the initial setting time of this cement is 5 minutes and the final setting time is 30 minutes. Sufficient care should be taken to complete mixing and placing of concrete in a short time.

6.6.4 Rapid hardening cement

Initial and final setting times are same as that of ordinary cement. But it attains high strength in early days. This cement is **burnt at high temperatures**, its **lime content is increased** and it is subjected to **very fine grinding**. This cement is costlier than ordinary cement but it has the following advantages.

Advantages

- As it sets rapidly, construction may be carried out fast.
- Formwork of concrete can be removed quickly.
- It obtains strength in a short period.
- It is light in weight.
- It is not damaged easily.
- Structural members constructed with this cement may be loaded earlier.
- This cement requires short period of curing.
- This cement allows higher permissible stresses in the design.

6.6.5 White Cement

This cement is prepared from raw materials which are practically **free from colouring oxides of iron, manganese or chromium**. It is white in color. It is used for floor finish, plaster work, ornamental work etc. It should not set earlier than 30 minutes. It is more costlier than ordinary cement. It is specially used for preparing different colors with oxides for flooring with tiles.

6.6.6 Portland Pozzuolana Cement (PPC)

In preparing this cement a **volcanic powder pozzuolana** is added to the Portland cement. It is specially used **to resist the action of sulphates**. The percentage of this pozzuolana is **10 to 30 percent**.

Following are the **advantages** of this cement:

- It attains compressive strength with age.
- It can resist action of sulphates.
- It evolves less heat during setting.
- It imparts higher degree of water tightness.
- It imparts plasticity and workability to mortar and concrete prepared from it.
- It is cheap.
- It offers great resistance to expansion.
- It posses higher tensile strength.

The following are the **disadvantages** of this cement:

- Its compressive strength in early days is less.
- It posses less resistance to erosion and weathering action.

This cement is used to prepare **mass concrete of lean mix** and for **marine structures**. It is also used in **sewerage works** and for laying **concrete in water**.

How to Store Cement:

Precautions that must be taken in the storage of Portland cement are given below in a series of DON'Ts.

1. Do not store bags in a building or a godown in which the walls, roof and floor are not completely weatherproof.

2. Do not store bags in a new warehouse until the interior has thoroughly dried out.

3. Do not be content with badly fitting windows and doors, make sure they fit properly and ensure that they are kept shut.

4. Do not stack bags against the wall. Similarly, don't pile them on the floor unless it is a dry concrete floor. If not, bags should be stacked on wooden planks or sleepers.

5. Do not forget to pile the bags close together.

6. Do not pile more than 15 bags high and arrange the bags in a header-and-stretcher fashion.

7. Do not disturb the stored cement until it is to be taken out for use.

8. Do not take out bags from one tier only. Step back two or three tiers.

9. Do not keep dead storage. The principle of first-in first-out should be followed in removing bags.

10. Do not stack bags on the ground for temporary storage at work site. Pile them on a raised, dry platform and cover with tarpaulin or polythene sheet.

Summary

· Cement is a binding material. It is made by grinding calcined limestone and clay to a fine powder.

· Chemical composition of Cement:

Ingredient	Percent
Lime(CaO)	62
Silica(Sio_2)	22
Allumina(Al_2o_3)	5
Calcium sulphate ($CaSo_4$)	4
Iron oxide(Fe_2O_3)	3
Magnesia(MgO)	2
Sulphur(S)	1
Alkalies(OH)	1
	100

· Field tests for Cement: Cement is tested in the field in the following aspects

Colour, Physical properties, Presence of lumps and Strength.

· Tests of Cement as per ISI: Fineness Test, Consistency test, Initial and Final setting times test & Compressive Strength Test.

· Grades of Cement: different grades of cement are 33, 43 and 53 grades.

· Types of Cement:

i. Ordinary Portland Cement (OPC)

ii. Quick Setting Cement

iii. Rapid Hardening Cement

iv. White Cement

v. Portland Puzzuolana Cement (PPC).

Short Answer Type Questions

1. What is the chemical composition of cement?
2. What are the functions of various ingredients of cement?
3. What are the steps involved in the manufacture of Cement?
4. What are the advantages of Dry process of manufacturing OPC?
5. What is the initial and final setting time of OPC?
6. What are different grades of Cement?

Long Answer Type Questions

1. Explain the manufacturing process of ordinary Portland cement by dry process.
2. Explain the manufacturing process of ordinary Portland cement by wet process.
3. What are the field tests of cement?
4. What are various laboratory tests to be conducted on cement?
5. What are various types of cement? Explain.
6. What are the advantages and disadvantages of PPC?
7. What are the advantages of rapid hardening cement?

UNIT 7

Sand

Learning Objectives

After completing this unit, the student will be able to understand

- Know different Sources of Sand;
- Differentiate between Natural and Artificial Sand;
- Understand Characteristics of good Sand;
- Know grading of Sand;
- Explain Bulking of Sand & its importance.

Introduction

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The composition of sand is highly variable, depending on the local rock sources and conditions, but the most common constituent of sand is silica.

Sand forms the important ingredient of mortar and concrete apart from other uses. It consists of **fine grains of silica (SiO_2).** It is used in mortar and concrete as fine aggregate.

Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 5 mm. For increased workability and for economy as reflected by use of less cement, the fine aggregate should have a **rounded**

shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

Fine aggregate quality is affected by a number of factors:

- The mean particle size
- The grading
- The presence of impurities
- Shape
- Texture

7.1 Sources of Sand

Depending upon the **source**, sand can be broadly classified as

A) Natural Sand and B) Artificial Sand

7.2 Natural Sand

According to the source from which it is obtained, sand is of the following three different kinds:

- Pit sand
- River sand
- Sea sand

Pit sand

It is found as deposits in soil. It is obtained by making pits into soil. This Sand is usually composed of grains that are relatively angular; it often contains clay and organic matter which imparts colour to it. When washed and screened it is good sand for general purposes, i.e, for lime and cement mortars.

River sand

This sand is obtained from banks or river beds. River sand consists of fine rounded grains free from impurities. The colour of river sand is almost white and its particle size is smaller than pit sand. It is widely used for all purposes.

Sea sand

This sand is obtained from sea shores. Like river sand, sea sand contains small rounded grains. It is light brown in colour. Sea sand contains salts. These salts attract moisture from the atmosphere causes dampness and efflorescence

and retards setting time of cement. Sea sand is generally avoided to be used for construction purposes. However, it should be thoroughly washed to remove the salts if it has to be used.

7.3 Artificial Sand or ROBO SAND

Natural sand is weathered and worn out particles of rocks and are of various grades or size depending on weathering. The main natural and cheapest resource of sand is river sand. Dams are constructed on every river hence these resources are erasing very fast. Now a days, good sand is not readily available. It should be transported from long distance. Those resources are also exhausting very rapidly due to rapid increase in the construction activity. So it is need of the time to find some substitute to natural river sand.

The artificial sand produced by **crushing stones** can be a better substitute to river sand. The process of manufacturing robo sand is totally different from ordinary stone crushers from which we get 40 mm, 20 mm, 10mm size coarse aggregate.The byproduct obtained from stone crushing process is not called robo sand. It is a stone dust. The sand should be sharp, clean and course. The grains should be of durable material. The grain sizes must be such that it should give minimum voids. The presence of clay and silt retards the setting of the cement and makes the mortar weaker and the walls or the slab leaks and holds dampness. The sand in the mortar does not add any strength but it is used as an adulterant for economy. It prevents the shrinkage and cracking of mortar on setting. The sand must be of proper gradation (it should have particles from 150 microns to 4.75 mm in proper proportion). When fine particles are in proper proportion, the sand will have fewer voids. The cement required will be less when there are fewer voids in sand. Such sand will be more economical.

7.4 Characteristics of good sand

1. It should contain coarse, angular, sharp and durable particles of silica.
2. It should not contain harmful chemicals.
3. It should be chemically inert.
4. It should be clean and well graded. Grains should pass through 4.75 mm I.S. sieve and should retain entirely on 75 microns I.S sieve.
5. It should not contain salts which attract moisture from atmosphere.
6. Fineness modulus of sand should be between 2 and 3.
7. Sand should be free from any organic or vegetable matter.

8. Colour of sand should be uniform.

Functions of Sand

1. Sand adds to the **bulk** of the mortar and makes it economical.
2. It helps **prevention of cracks** of mortar on drying.
3. Sand **prevents excessive shrinkage** of binding materials like cement, lime, etc.
4. By varying the proportion of sand, strength of mortar or concrete can be modified.
5. It **helps in setting of fat lime** effectively.

7.5 Grading of Sand

According to **grain size**, sand is classified as (a) Fine Sand, (b) Coarse Sand and (c) Gravelly Sand.

(a) Fine Sand: sand particles passing through sieve with clear openings of 1.587 mm size is known as fine sand. It is suitable for **plastering work.**

(b) Coarse sand: sand passing through sieve with clear openings of 3.175 mm size is known as coarse sand. This sand is suitable for **masonry work.**

(c) Gravelly Sand: sand passing through sieve with clear openings of 7.62 mm size is known as gravelly sand. This sand is suitable for **concrete work.**

7.6 Bulking of Sand

Sand has a phenomenal property of bulking. Bulking of sand means increase in its volume due to presence of surface moisture. The volume increases with increase in moisture content. **The volume may increase up to 20 to 40% when moisture content is 5 to 10 %.** It is actually a thin film of water around the sand grains and interlocking of air in between the sand grains and film of water that makes the sand bulkier.

When moisture content is increased by adding more water, sand particles pack near each other and the amount of bulking of sand is decreased. This phenomenon starts when the moisture content is about **11 to 12%** and then onwards this reversal continues. **Near about 28 to 30%, bulking of sand is almost zero.** Thus the dry sand and the sand completely flooded with water have practically the same volume.

Demonstration: Take some sand in a container and measure the height of it. Then add 1% of water by weight of sand. Then again pour the sand in the

container and measure the height. You will observe an increase in its height. Keep repeating the same process. At certain point you will observe that the sand has regained its original height.

It means that fully dry sand and fully saturated sand occupy the same volume.

Allowance for bulkage of sand has to be made while **proportioning by volume** for mortar or concrete. Otherwise, amount of sand taken will be less. This makes the concrete insufficiently workable.

TEST:

For finding the bulking of sand, a test is carried out with following procedure as shown in the fig.

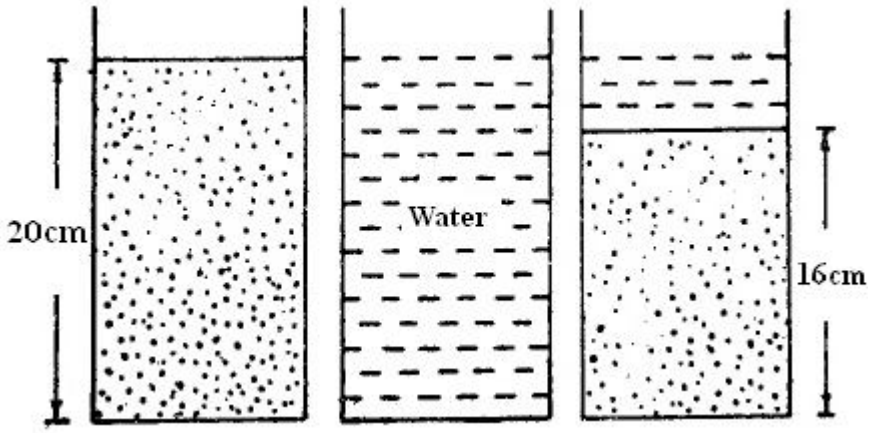


Fig. 6.1 Bulking of Sand

i. A container is taken and it is filled two third with the sample of sand to be tested.

ii. The height is measured, say 20cm.

iii. Sand is taken out of container

iv. The container is filled with water

v. Sand is then slowly dropped in the container and it is thoroughly stirred by means of a rod.

vi. The height of sand is measured say 16cm, then bulking of sand =

$$= \frac{20-16}{16} = \frac{4}{16} \text{ or } 25\%$$

Compensation for Bulkage:

Ex) Calculate how much actual quantity of sand has to be added for 50cum of sand, if the bulkage is **25%** ?

Quantity of sand to be added

= actual quantity + compensation for bulkage

= 50 + (25/100) 50

= 50 + 12.5

= **62.5 cu m.**

Summary

1. Sand forms the important ingredient of mortar and concrete apart from other uses. It consists of fine grains of silica (SiO_2). It is used in mortar and concrete as fine aggregate.
2. The sources of sand are
   - Pit sand
   - River sand
   - Sea sand
3. The sand should be
   - Chemically inert
   - Clean and coarse
   - Sharp, angular and durable
   - Not contain salts
   - Well graded
4. According to the size of grains, sand is classified as fin, coarse and gravelly sand.
5. Sand prepared by crushing stones is known as Artificial sand
6. The presence of moisture in sand increases the volume of sand known as bulking of sand.

Objective Type Questions

1. Which one of the following is fine aggregate

a) Cement b) Sand c) Crushed Stone Pebbles d) both a & b

2. Which one of the following is not natural sand

a) Pit Sand b) River Sand c) Sea Sand d) Crushed Stone Powder.

3. Which one of the following is suitable for Plastering Work?

a) Fine Sand b) Medium Sand c) Coarse Sand d) all of these.

4. Due to the presence of moisture content in the Sand, bulking means

a) Increase in Volume b) Decrease in Volume Sand c) both a & b d) all of these.

Short Answer Type Questions

1. What are sources of natural sand?
2. Write any four characteristics of good sand?
3. What is artificial sand?
4. What are different grades of sand?
5. What is bulking of Sand?
6. Write any four functions of Sand.

Long Answer Type Questions

1. Explain the sources of sand.
2. Explain the characteristics of good sand.
3. Explain how sand is classified according to grain size.
4. Explain the importance of bulking of sand.

OJT / Assignments

1. Ascertain the current rates of different varieties of sand.
2. Make a visit to the stone crushing unit and find out the rates of artificial sand.

UNIT 8

Mortars

Learning Objectives

After completing this unit, the student will be able to understand

- Explain what is a mortar,
- Know how mortars are classified,
- Know different proportions of mortars for various construction works
- Explain different precautions in the use of mortars.

8.1 Introduction

Mortar is a workable paste prepared by mixing water to the mixture of binding material like Cement or Lime and fine aggregate like Sand or Surkhi.

Mortar is used to bind construction blocks together and fill the gaps between them. The blocks may be stone, brick, fly ash blocks, etc. Mortar becomes hard when it sets, resulting in a rigid aggregate structure.

Traditionally mud is used to prepare mortar. Modern mortars are typically made from a mixture of sand, a binder such as cement or lime, and water. Mortar can also be used to fix, or point, masonry when the original mortar has washed away.

The durability and strength of mortar will depend on the quality of ingredients of the mortar. The proper selection of mortar for masonry is very important.

Choosing the right mortar type can lead to a durable masonry wall. Improper selection of mortar types for a particular masonry job can result in a leaky wall or deteriorating mortar. Mortar is the bonding agent that transforms the masonry unit and the mortar into a lasting masonry wall. It has to be durable, capable of keeping the masonry intact, and resist moisture penetration.

Properties of good mortar:

- It should develop **good bond** between the layers of bricks and stones.
- It should be **durable**.
- It should develop **impervious layer** for heat and rain water.
- It should be easily **workable**.
- It should be **cheap**.
- It should not adversely affect the durability of the other building materials.
- It should be capable of **develop**ing **desired stresses**.
- It should **harden** in reasonably **short** period of **time**.
- It should accept and maintain the colour of the paint or wash for a longer period of time.

Uses of Mortar

- It should **bind** bricks or stones in the masonry together into a solid mass.
- It is used to **join pipes**.
- It is used for **plastering** and **pointing** works.
- It is used to prepare all types of **concrete mixes**.
- It is used to **cover defects** of the building materials or unevenness due to improper workmanship in construction.
- It is used to provide **smooth and hard surface** to masonry walls and floors.
- It is used to form **even bedding** layer for placing the building units.

8.2 Classification of Mortars

Following are various types of mortar used in construction:

1. Lime Mortar

2. Cement Mortar
3. Surki Mortar
4. Blended Mortar.

1. Lime Mortar

The uniform paste prepared by mixing water to sand and lime in suitable proportion is known as lime mortar.

Lime mortar is of two types. They are Hydraulic Lime Mortar and Fat Lime Mortar.

- **Hydraulic Lime Mortar**

Hydraulic lime is used as binding material in this mortar. The usual proportion of **Lime:Sand** of this mortar is **1:2 or 1:3**. It possesses good strength and used in various works. It can be used in damp or wet conditions. It should be used within **one hour** after mixing.

- **Fat Lime Mortar**

Fat lime is used as binding material in this mortar. The usual proportion of **Lime:Sand** of this mortar is **1:1 or 1:2**. The strength of this mortar is less than that of hydraulic lime mortar. It is used for inferior works. It cannot be used in damp or wet conditions.

2. Cement Mortar

In this type of mortar, cement is used as binding material. It is widely used for all important works due to its strength and other superior qualities.

A workable paste prepared by mixing water with cement and sand in suitable proportion is known as cement mortar.

General proportion of **Cement : Sand** of this mortar varies from **1:2 to 1:6** depending upon the strength requirements.

It should be consumed in the first **30minutes** after adding water to the mix, which is the initial setting time of cement.

This mortar is used in the construction of pipes, foundations, dams, bridges, canal lining, flooring, plastering, pointing,etc.

The following are the properties of cement mortar:

1. When water is added to intimate dry mixtures of cement and sand, hydration of cement starts and it binds sand particles and the surrounding surfaces of masonry and concrete.

2. The strength of mortar depends upon the proportion of cement and sand. Strengths obtained with various proportions of cement and sand are shown in table.

3. A mix richer than 1:3 proportion is prone to shrinkage.

4. Well proportioned mortar provides impervious surface.

5. A leaner mix is not capable of closing the voids in sand, and hence the plastered surface is pervious.

Table: Compressive strengths for various mix proportions:

Sr.no.	Mix proportion (Cement: Sand)	Compressive strength
1.	1:3	10 N/mm2
2.	1:4	7.5 N/mm2
3.	1:5	5.0 N/mm2
4.	1:6	3.0 N/mm2
5.	1:8	0.7 N/mm

Preparation of Cement Mortar

Cement mortar may be prepared by manual mixing or by mechanical mixing. Mechanical mixing is preferred when mortar is required in large quantities to be used in continuous order.

a) Mixing in Mechanical Mixer

In this case, cement and sand in desired proportion are fed in the mixer and mixed dry. Water is then added gradually and the wet mixing a continued for at least one minute to obtain the mortar of desired consistency. It is necessary to ensure that only the quantity of mortar which can be used within half an hour of

its mixing should be prepared at a time. This is essential as after 30 minutes the mortar begins to set.

b) Manual Mixing

In this case, specified quantity of sand is spread and leveled on clean dry masonry platform. Required quantity of cement bags are emptied over the sand layer. The ingredients are then mixed thoroughly by turning them over the sand layer. The ingredients are then mixed thoroughly by turning them over and over. Backward and forward several times with the help of spade. Dry mixing is continued till the mix have attains a uniform colour. A batch of dry mix is then put in the shallow masonry tank and just sufficient quantity of water is added to bring the mortar to the consistency of a paste. The quantity of dry mix taken in each batch should be such the mortar formed each time is consumed within half an hour.

3. Surki Mortar

Surki is the powder obtained by crushing the over burnt bricks or brick bats. It is finely ground and sieved. Lime or Cement is used as binding material and surki is used instead of sand. The usual proportion is 1:1 or 1:2. The mortar attains less strength and it is used for inferior works.

When used with Lime, surki imparts hydraulic properties to the mortar and it should be used within 24hrs from the time of grinding the mix.

4. Blended Mortar

It is prepared by **mixing cement** to the **lime mortar** in a desirable proportion. This process is known as blending or ganging. Cement improves the quality of lime mortar. It makes the mortar strong, dense and economical. The usual proportion of Cement:Lime is 1:3. It should be consumed within 24 hours.

It is used for rubble masonry work and brick masonry of less important quality.

8 .3 Proportions of Mortars for various construction works:

S.No.	Name of the Work	Type of Mortar Proportion by Volume
1.	Brick Masonry: for partition walls and parapet walls	Cement mortar 1:3
2.	Brick Masonry below GL & external walls above GL	Cement mortar 1:4
3.	Masonry work below GL especially in water logged areas	Cement Mortar 1:3
4.	Stone Masonry in foundations & superstructure of ordinary buildings (thick joints)	Cement Mortar 1:6 or Lime Mortar 1:2. (Hydraulic Lime)
5.	Plastering work of ceiling, external walls where good finish is required, Mass concrete in foundations	Cement Mortar 1:3 to 1:4 or lime mortar 1:2
6.	Pointing work, plastering swimming pools, etc, R.C.C members such as columns, beams and slabs	Cement Mortar 1:2
7.	Damp proof course and cement concrete roads	Cement Mortar 1:2
8.	Heavy stressed members of structures	Cement Mortar 1:1
9.	R.C.C tanks and water retaining structures	Cement Mortar 1:1.5
10.	Massive concrete works: Dams, Retaining walls, Reinforced brick work, Lining of reservoirs & water channels	Cement Mortar 1:3
11.	Brick work in arches, plastering of inside walls	Cement Mortar 1:5 to 1:6

8.4 Precautions in the use of Mortars

Following are the precautions to be taken while using mortar:

1. The cement mortar should be used within **30 minutes** after it is prepared since the cement starts setting. The lime mortar should be used within

36 hours after its preparation and it should be kept wet. The ganged mortar should be used within 2 hours after the addition of cement.

2. The Bricks or Cement blocks should be **soaked** well in water just before the erection of walls or any other structure. Otherwise, water in the mortar will be absorbed by the bricks and the mortar will become weak.
3. Use of **seawater** should be totally **avoided** with cement or pure lime mortar. The use of sea water will lead to efflorescence. In the absence of pure water, sea water may be used with hydraulic lime.
4. The water used should be clean and free from alkalies, oils, dust or any other dirt.
5. The size of the **sand** should be less than **3 mm**.
6. The mortar should be mixed well with adequate quantities of ingredients as specified.
7. The mortar **should not contain excess water**; else its workability is affected.
8. The setting action of cement is affected in cold weather due to **frost action**. Hence during frosty weather, the work should be stopped.
9. The construction work carried out by mortar should be kept damp or **wet** by sprinkling water for about **7 to 10 days** to avoid rapid drying of mortar.

Summary

1. The mortar is a paste prepared by adding required quantity of water to a mixture of cement or lime and fine aggregates.
2. The mortar is used for
   - Binding bricks, stones
   - Plastering
   - Forming joints
   - Improving the appearance
3. The types of mortars are
   a. Lime mortar
   b. Cement mortar

c. Composed mortar

d. Gypsum mortar

4. According to nature of application mortars are classified'

a. Brick laying mortars

b. Finishing mortars

5. The special mortars used generally are

a. Fire resistant mortars

b. Light weight mortars

c. Packing mortars

d. Sound absorbing mortars

e. X-ray shielding mortars

6. The preparation of cement mortar by

a. Manual mixing – for smaller works

b. Mechanical mixing – in larger quantities to be used in continuous order

7. Precautions using mortar are

a. Consumed within the specified time

b. Frosty weather affect the setting time

c. Building units should not be soaked before application of mortar

d. Apply sprinkling of water for a period of 7 to 10 days

e. Mortar should not contain excess water and should be stiff as can be conveniently used.

Short Answer Type Questions

1. Define mortar.

2. What are the important properties of mortar?

3. Write any four important uses of mortar.

4. Name the types of mortar.

5. What are the precautions to be taken while preparing a cement mortar?

Long Answer Type Questions

1. Explain the properties of mortar.
2. Explain the procedure for preparation of mortar.
3. Write the uses of mortar.
4. Explain the precautions to be taken in the use of mortars.

UNIT 9

Concrete

Learning Objectives

After completing this unit, the student will be able to understand

- Know what is concrete and the purpose of using it.
- Know different types of concrete.
- Know the ingredients of plain concrete.
- Understand the proportions and uses of different grades of concrete.
- State what is reinforced concrete.
- State what is Pre-cast Concrete.
- Explain Water-Cement Ratio.
- Understand concrete mixing methods.
- Describe Batching of Concrete.
- Know various methods of transportation of concrete.
- Understand placing of concrete.
- Know about compaction of concrete & various types of vibrators.
- Explain methods of curing.

- Understand workability of concrete-Slump test.

9.1 Definition and Purpose of Concrete

Concrete is a composite construction material made from a mixture of broken stone or gravel, sand, cement, and water. When placed in forms and allowed to cure, it becomes hard like stone. The hardening is caused by chemical action called hydration between water and cement which continues for a long time.

Concrete has relatively high compressive strength, but much lower tensile strength. For this reason it is usually reinforced with materials that are strong in tension (often steel).

Purpose of concrete : Concrete has attained the status of a major building material in all branches of modern construction. It is used for the following reasons.

· To mould it into a durable structural items of various sizes and shapes without considerable labour expenditure.

· To control the properties of cement concrete within a wide range by using appropriate ingredients and by special processing techniques- mechanical, chemical and physical.

· To mechanise completely its preparation and placing process.

· To provide adequate plasticity for mechanical working.

9.2 Types of Concrete

As per the **method of preparation** of concrete, the concrete is classified as Precast concrete Insitu concrete and prestressed concrete. Depending on the provision of steel reinforcement concrete is classified as Plain cement concrete and Reinforced cement concrete. Based on the ingredients used, concrete is further classified as Light weight concrete, No fines concrete, High density concrete, High strength concrete, Ferro cement concrete, Fibre reinforced concrete, Cellular concrete and Polymer concrete. As per the proportions of cement, sand and coarse aggregate, concrete is further classified as M5,M7.5,M10,M15,M20,M25,M30M35,,M40.

9.3 Ingredients of Plain cement concrete P.C.C)

The ingredients of plain cement concrete are cement, fine aggregate such as sand, coarse aggregate such as hard broken granite (hbg) and other than granite (otg) and water.

9.4 Ingredients of reinforced cement concrete (R.C.C.)

In reinforced cement concrete, steel is provided in addition to cement, fine aggregate, coarse aggregate and water. Plain Cement Concrete is weak in tension and strong in compression. Hence, steel reinforcement is used in Plain Cement Concrete to improve the tensile strength of concrete.

Advantages of Reinforce Cement Concrete

1. R.C.C members can be moulded in any shape and size.
2. It is quiet durable. Its life span is about 75years.
3. It is fire resistant and sound resistant.
4. Materials for concrete making are easily available.
5. Its maintenance cost is almost nil.
6. It is almost water tight and impermeable to moisture.

9.5 Proportions and uses of concretes of different grades

Concrete is designated in seven grades namely M10, M15, M20, M25, M30,M35 and M40. The letter 'M' refers to the mix and the number indicates the compressive strength of that mix after 28 days curing in N/mm2. **For lean concrete** bases and simple foundations for masonry walls, **M5 and M7.5** grades of concrete may be used. **Grades of concretes lower than M15 are not used for R.C.C. work.**

Grade Designation	Characteristic Strength at 28 days	Proportion
M5	5 N/mm2	1:5:10
M7.5	7.5 N/mm2	1:4:8
M10	10 N/mm2	1:3:6
M15	15 N/mm2	1:2:4
M20	20 n/mm2	1:11/2:3
M25	25 N/mm2	1:1:2

Concrete grades from M10 to M20 are used in ordinary concrete works. M25 to M55 are used in Standard concrete works. M60 to M80 are used in High strength concrete.

9.6 Pre-cast concrete

In pre–cast concrete, concrete is manufactured at the factory. It is possible to prepare well-made pre-cast products by keeping a high standard of finishing. Pre-cast products vary from simple structures such as fencing posts, pipes, paving slabs etc to elaborate and complicated artificial concrete blocks.

Procedure for preparing pre-cast products is as follows:

- Moulds, which may be of timber, steel or sand are prepared to the shape of the product.
- Reinforcement if any is put up in the mould as per design.
- Concrete is mixed in the desired proportion and placed in the moulds.
- Finishing of the products is then carried out.
- The products are then sufficiently cured in specially constructed tanks.
- The products are then dispatched for use at site of work.

Advantages of Pre-cast concrete:

- Concrete of superior quality is prepared.
- It is not necessary to provide joints in pre-cast concrete.
- The moulds used are more durable and they can be used several times.
- The pre-cast articles may be given the desired shape and finish with accuracy.
- The pre-cast articles can be dismantled, when required and they can be suitably used elsewhere.
- The work can be completed in a short time, when pre-cast units are adopted.
- Scaffolding and form-work can be reduced considerably when pre-cast structures are used.

Disadvantages of Pre-cast Concrete:

- If not handled properly, the pre-cast units may be damaged during transport.
- It is difficult to produce satisfactory connections between the pre-cast members.
- It is necessary to arrange for special equipment for lifting and moving of pre-cast units.
- The economy achieved in pre-cast construction is balanced by the amount spent in transport and handling of pre-cast members.

9.7 Water-Cement Ratio

The ratio of volume of water in litres to that of the weight of cement in a concrete mix is known as water- cement ratio.

Water has to perform two functions:

- Water enters into chemical action with cement and causes setting and hardening of cement.
- Water lubricates the aggregate making the concrete workable.

Minimum quantity of water should be used to have reasonable degree of workability. If excess water is added the strength of the concrete is considerably reduced. Water cement ratio is 0.45 to 0.55 for structures subjected to regular wetting and drying. Water cement ratio is 0.55 to 0.65 for thin sections and mass concrete continuously under water.

Workability: Workability may be defined as the ease or difficulty with which the concrete is mixed, transported and placed in position, with minimum loss of homogeneity.

If the concrete mixture is too wet, coarse aggregates settle at the bottom of concrete mass and the resulting concrete becomes of non-uniform composition. On the other hand, if the concrete mixture is too dry, it will be difficult to handle and place in position.

If more water is added to attain the required degree of workmanship, it results into concrete of low strength and poor durability.

If the strength of concrete is not to be affected, the degree of workability can be obtained by slightly changing the proportions of fine and coarse aggregates, in case the concrete mixture is too wet. By adding a small quantity of water

cement paste in the proportion of original mix, in case the concrete mixture is too dry.

A concrete mixture for one work may prove to be too stiff or too wet for another work. The workability of concrete is also affected by the maximum size of the coarse aggregates to be used in the mixture.

The following **tests** are conducted to determine the workability of concrete. Slump cone test, compacting factor test and Vebe test and Astm flow test. Out of these, **Slump cone** test is popularly used.

Slump test:

The standard slump cone consists of a slump cone having its **top diameter of 10 cm, bottom diameter of 20 cm, and a height of 30 cm**. Cement concrete of required proportions is prepared and placed in the mould consisting of the slump cone. The slump cone is firmly placed on the ground. The cone is filled with about one fourth portion and rammed with a tamping rod. This rod is of **16 mm diameter** and **its length is 60 cm**. The ramming is done with **25 strokes**. The remaining portion of the cone is filled in two layers. It is rammed similarly. The top portion of the concrete is struck of so that the cone is completely full of concrete. The cone is gradually raised vertically and removed.

Initial height of concrete in the slump cone = h1 = 30 cm.

Height of the concrete after removing slump cone = h2

Slump = h1-h2 cm.

Recommended Slumps of Concrete

No.	Type of Concrete	Slump
1.	Concrete for road construction	20 mm to 40 mm
2.	Concrete for tops of curbs, parapets, piers, slabs and walls those are horizontal	40 mm to 50 mm
3.	Concrete for canal linings	70 mm to 80 mm
4.	Concrete for arch and side walls of tunnels	90 mm to 100 mm
5.	Normal R.C.C. Work	80 mm to 150 mm
6.	Mass Concrete	25 to 50 mm
7.	Concrete to be vibrated	10 mm to 25 mm

Classification of Concrete Mixes

Slump	Nature of concrete mix
No slump	Stiff and extra stiff mix
From 10 mm to 30 mm	Poorly mobile mix
From 40 mm to 150 mm	Mobile mix
Over 150 mm	Cast mix

9.8 Mixing of Concrete

The process of mixing various constituents of concrete in specified proportions is known as mixing. The mixing of the constituents should be continued till the concrete attains uniform color and consistency. The various materials are mixed carefully to obtain good quality of concrete.

Methods of Mixing: The following two methods are generally used for mixing purposes. Hand mixing and machine mixing.

Hand Mixing: The process of mixing the ingredients of concrete by manual labour is called hand mixing. The concrete prepared by this method is known as hand mixed concrete. It is generally used for small works and in special cases where noise is to be avoided.

The following operations are adopted in hand mixing.

· A platform is constructed with bricks or lean cement concrete.

· The required quantity of cement is spread uniformly over sand and both are mixed together in dry state with the help of kassies or shovel.

· After this the above mixture is spread uniformly over a stack of coarse aggregates and whole mass is mixed in dry state in order to have uniform color.

· After obtaining a uniform coloured mix by mixing the ingredients in dry state, a hollow is made in the centre of the mixed material. After this 75% of the required quantity of water based on the water cement ratio is added and the material is turned towards the middle with the help of shovels. The mixture is mixed thoroughly to obtain uniform color and consistency. The remaining amount of water is added with continuation of mixing process.

Machine Mixing

Fig. 9.1 Concrete Mixture

The process of mixing the ingredients of concrete by a machine is called machine mixing. It is adopted by big projects where large quantity of concrete is required continuously. Machine mixing requires **less quantity of cement** than hand mixing. The concrete is produced at a much faster rate. The concrete produced by this process is known as machine mixed concrete.

The machine used for this purpose is known as a concrete mixer. The concrete mixers are classified as Batch mixers and Continuous mixers. In the batch mixers, materials are charged in batches whereas the materials are fed continuously in continuous mixers. Batch mixers are further classified as Non-tilting type and tilting type. Continuous mixes are further classified as **Gravity type** and **forced type**.

Operation of Mixers: Concrete should be mixed for at least 1 minute and preferably for **3 minutes**. Under normal conditions, 10% of the mixing water should be placed in the drum before adding dry materials. Water should be then added uniformly with dry materials leaving 10% to be added after all the other materials are placed in the drum. The mixers should not be loaded above their rated capacity. The speed of the mixer is generally **15 revolutions per minute**.

General principles in the use of concrete mixers:

- Water should be added to the mixer at the same time and over the same period as other constituents.
- Mixing should be continued until the concrete is of uniform color and consistency.

- The mixer should not be loaded beyond its designed capacity.
- The mixer should be set accurately.
- Adherence of cement should be reduced by rubbing grease or oil over the mixer after cleaning.
- Extra 10% of cement should be added for the first batch.
- Badly worn and bent blades should be replaced.
- The speed of the mixer should be uniform and it should be checked up at regular intervals.

9.9 Batching of Concrete

The process of proportioning various ingredients in concrete is known as batching. In each batch of mixing the proportions are fixed by weight or by volume. In concrete mixers the ingredients are loaded into the mix for each rotation of the mixer. This is known as concrete mixing by batch. When cement is supplied in bulk, we chose the batch quantities so that their sum is equal to the capacity of the mixer. When cement is supplied in bags, batch quantities are chosen as the multiples of the bag of cement. In a concrete mixer, fine aggregate and coarse aggregate are proportioned as multiples of a bag of cement in volume. In hand mixing, sand and coarse aggregates are stacked to the required volume and cement in bags as per the proportion in volume is mixed to the aggregate mixture.

9.10 Transporting Concrete

Concrete as it comes out of the mixer is to be taken to the formwork to be placed in position. This process is known as transportation of concrete. For ordinary building works, human ladder is formed and concrete is conveyed in pans from hand to hand. For important works, various mechanical devices such as dumpers, truck mixers, buckets, chutes, belt conveyors, pumps, hoist, etc., may be used.

The precautions necessary in the transport of concrete are as follows:

- The concrete should be transported in such a way that there is no segregation of the aggregates.
- Water should not be added to the concrete during its passage from the mixer to the formwork.

9.11 Placing of Concrete

The concrete coming out of the mixer is transported and it is placed in the formwork. This process is known as placing of concrete.

The **precautions** to be taken during the placing of concrete are as follows:

- The formwork or the surface to receive fresh concrete should be properly cleaned, prepared and well watered.
- The concrete should be deposited as nearly as practicable to its final position.
- Large quantities of concrete should not be deposited at a time.
- Concrete should be dropped vertically from a reasonable height.
- Concrete should be deposited in horizontal layers of about 15 cm height.
- As far as possible, concrete should be placed in single thickness. In case of deep sections, proper care should be taken in developing enough bond between successive layers.
- Concrete should be placed in the formwork as son as possible. But in no case, it should be placed after 30 minutes of its preparation.

9.12 Compaction of Concrete

The process of eliminating the air voids in the concrete to increase the density of concrete is known as compaction. About 5% of air voids reduce the strength of the concrete by 30% compaction is to be done to increase the strength of the concrete.

Methods of Compaction

Compaction can be done by hand ramming or by mechanical compaction by vibrators.

Hand ramming: For unimportant works compaction can be carried out by hand methods like ramming, tamping, spading and slicing with suitable tools. Hand methods require use of a fairly wet concrete.

Vibrators: The mechanical devices which are used for compaction of concrete in the formwork are known as vibrators.

9.12.1 Types of vibrators

Depending on the depth of the concrete, and the importance of the work different types of vibrators are used.

· **Internal vibrators:** These types of vibrators are used for structures such as beams having sufficient depth. These vibrators consist of a metal rod which is inserted in fresh concrete. The rod vibrates while it is being inserted, vibrates the concrete and removes the air. Internal vibrators should be inserted and withdrawn slowly and they should be operated continuously while they are being withdrawn. These vibrators are more efficient than other types of vibrators. These are also known as needle vibrators.

· **Surface vibrators:** These vibrators are mounted on platforms or screeds. They are used for finishing concrete surfaces such as bridge floors, road slabs, station platform and where the thickness of the structure is less.

· **Form vibrators:** These vibrators are attached to the formwork and the vibrating action is conveyed to concrete through the formwork during vibrations. These are used for structures which are too thin for the use of needle vibratos.

· **Vibrating Tables:** These are in the form of a table and concrete is placed on the table. The vibration of the table increases the compaction of the concrete. These vibrators are widely used for making pre-cast products.

9.13 Curing of Concrete

Concrete structures are kept wet for a certain period after placing of concrete. This process is known as curing of concrete. In curing, water enters into chemical action with cement causing the setting of cement concrete. As the strength of concrete gradually increases with age, curing is necessary to produce durable and impermeable concrete.

Methods of Curing

As per the conditions at the site and depending upon the size, shape and position of the member, different methods of curing are adopted.

Ponding of water over the concrete surface after it has set: This is the most common method of curing the concrete slab or pavements. It consists of storing the water to a depth of 50 mm on the surface by constructing small puddle clay bunds all around. Ponding may lead to efflorescence by leaching.

Covering the concrete with wet straw or damp earth: In this method the damp earth or sand in layers of 50 mm are placed over the surface of concrete pavements. The material is kept moist by sprinkling water periodically.

Covering the concrete with wet burlap: The concrete is covered with burlap (coarse jute or hemp) as soon as possible after placing. The material

kept moist continuously for the curing period. The covering material can be reused considerably.

Sprinkling of water: This is a useful method for curing vertical and inclined surfaces of concrete. This method is not effective as it is difficult to ensure that all the parts of concrete are wet all time. Water can be sprinkled by spraying or flogging. Spraying produces fine sprays whereas flogging produces mist like effect.

Covering the surface with waterproof paper: Waterproof paper prevents loss of water from concrete and protects the surface from damage. This method is used for concrete slabs and pavements. A good quality paper can be often reused.

Membrane curing of concrete: The process of employing a membrane forming compound on concrete surface is termed membrane curing. The curing membrane serves as a physical barrier to prevent loss of moisture from the concrete to be cured. The different sealing compounds used as membranes are bituminous and asphaltic, rubber latex emulsions, emulsions of resins and emulsions of paraffin.

9.14 Ready – Mixed Concrete

Ready-mix concrete is a type of concrete that is manufactured in a factory or batching plant, according to a set proportion, and then delivered to a work site, by truck mounted transit mixers. This results in a precise mixture, allowing specialty concrete mixtures to be developed and implemented on construction sites.

Fig. 9.2 Ready Mix Concrete

Ready – mixed concrete is particularly useful on congested sites or in road construction where little space for a mixing plant and for extensive aggregate stockpiles is available. The greatest advantage of this ready-mixed concrete is that it is made under better conditions of control than are normally possible. Since the central mixing plant operates under near factory conditions, a close control of all operations of fresh concrete is possible. Proper care during transportation of concrete is also ensured by the use of agitator trucks. The responsibility of placing and compacting of concrete lies with the personnel at the site. The use of ready-mixed concrete is useful when only small quantities of concrete is required or when concrete is to be placed at intervals.

There are two types of ready mixed concrete. In the first case, mixing is done at a central plant and the mixed concrete is transported, usually in an agitator truck which revolves slowly so as to prevent segregation and undue stiffening of the mix. Such a concrete is known as **centrally mixed concrete**. The second category is the **transit mixed** or truck mixed concrete. Here the materials are batched at a central plant but are mixed in a mixer truck either in transit to site or immediately prior to the concrete being discharged.

Proportion of Ingredients of cement concrete for different items of work

Nature of Work	Mix Proportion	Maximum size of coarse aggregate
Very heavily stressed members of structures.	1:1:2	12.7mm
R.C.C tanks, pipes other water retaining structures & thin engineering structures.	1:11/2:3	12.7mm
Flooring, DPC & general RCC works such as slabs, beams, columns, lintels etc., for ordinary buildings.	1:2:4	20mm
Massive works, dams retaning walls for each fill.	1:3:6	Specified combination of 20 & 40mm
Mass concrete foundation (depends on the type of structure) under flooring etc.	1:4:8 or 1:5:10	40mm

Summary

1. Concrete is a mixture of cement, sand, pebbles or crushed rock and water

2. Concrete is uses for

   (i) Heavy loaded RCC columns, arches etc

   (ii) Pre-cast members

   (iii) Water tanks, bridges, sewers etc

   (iv) Foot path, concrete roads etc

   (v) Foundation footings

3. The mixing of concrete may be

   i) By hand mixing

   ii) Machine mixing

4. Machine mixing may be carried out commonly by

   i) Continuous mixers

   ii) Batch mixers

5. The function of consolidation or compaction is to expel the air bubbles in the mass and make it impermeable in addition to its securing desired depth

6. Compaction may be done by

   Hand ramming & Vibrators.

7. Mechanical compaction may be done by

   i) Internal vibrators

   ii) External vibrations

   iii) Surface vibrations

8. Curing of concrete is the process of keep the set concrete damp for some days in order to enable the concrete gain more strength.

9. By curing the concrete should get

   i) Strength

   ii) Durability and impermeability

iii) Resistance to abrasion

Short Answer Type Questions

1. Define Cement Concrete.
2. Sate the uses of Cement Concrete.
3. What are the ingredients of plain cement concrete?
4. What are the ingredients of Reinforced cement concrete?
5. Define Water-Cement ratio.
6. What is meant by curing of concrete?
7. Mention different methods of curing concrete.
8. What is Pre-Cast Concrete?
9. What is meant by Ready Mix Concrete?
10. What are the advantages of RCC?

Long Answer Type Questions

1. What are the advantages of Pre-cast Concrete?
2. Explain the importance of Water-Cement Ratio in a concrete mix.
3. What is Workability of Concrete? How is it tested?
4. Explain Hand mixing & Machine Mixing.
5. Explain methods of curing briefly.

OJT Assignments

1. Make a visit to Ready Mix Concrete plant : Ascertain the mix proportions and unit rates of ready mix concrete.
2. Make a site visit and observe hand mixing and machine mixing of concrete.

UNIT 10

Timber

Learning Objectives

After completing this unit, the student will be able to understand

- Explain definition, properties and drawbacks of timber,
- Know the defects in timber along with causes for the defects,
- Know common varieties of timber in A.P, and their uses,
- Know commercial wood products, and
- State the characteristics of good timber.

10.1 Introduction

Wood can be considered the best natural building material. Wood is a hard, fibrous tissue found in many trees. It has been used for hundreds of thousands of years for both fuel and as a construction material. It is probably the first construction material used by man.

Timber is that sort of wood which is proper for buildings or for tools, utensils, furniture, etc. Technically the wood of growing trees which can support loads and suitable for construction purposes is known as timber.

Timber is used for making doors, windows, ventilators, shelves, rafters, reapers, floors, etc. During construction, it is also used for formwork, centering, etc.

Timber is also widely used to manufacture products like plywood, eco-board, hard board, particle board, veneers, etc. Wood and wood products which are free from defects are widely used in the construction industry due to their versatility.

Structure of Timber

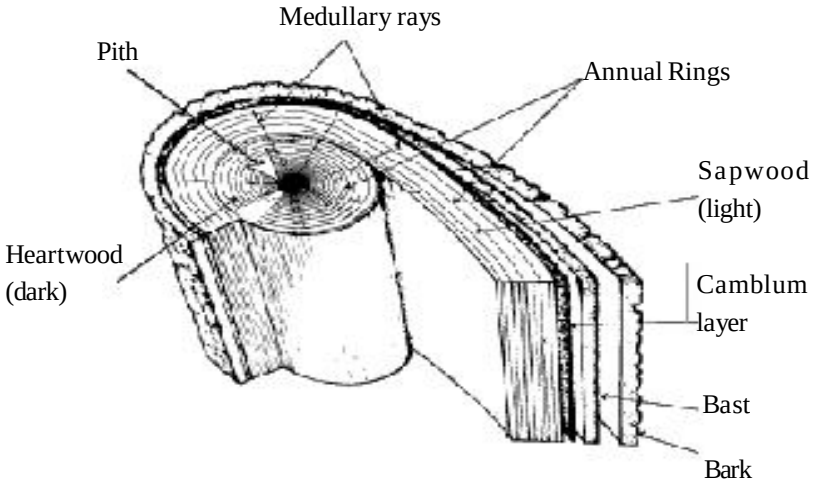


Fig. 10.1 Inside a Trunk

10.2 Defects in Timber

Defects are structural faults within the timber which may impair its strength, resilience or durability and should not be confused with surface blemishes. Features of some timbers such as knots may be termed NATURAL DEFECTS while others such as short grain are termed ARTIFICIAL DEFECTS, because they could have been reduced with more careful conversion (sawing of the log into useful sizes) or seasoning (the reduction of the moisture content in the timber.)

The main defects caused in timber are:

- Defects due to NATURAL FORCES
- Defects due to CONVERSION
- Defects due to FUNGI
- Defects due to INSECTS
- Defects due to SEASONING

Defects due to NATURAL FORCES:

These are caused basically due to abnormal growth and rapture of tissues. Following are the defects caused by these forces:

- Burls
- Callus
- Chemical stain
- Coarse grain
- Dead wood
- Druxiness
- Foxiness (Having reddish brown color)
- Knots
- Rind galls
- SHAKES: These are SPLITS along the length of the plank where the cells or fibres have separated.
- Cup shakes
- Heart shakes
- Ring shakes
- Star shakes
- Radial shakes
- Fibers
- Upsets
- Water strains
- Wind cracks
- **Burls**

These are formed when a tree has received injury or shock in its young age. Due to such injury, the growth of tree gets completely upset and irregular projections appear on the body of the timber.

- **Chemical Stain**

Due to chemical action by some external agency, wood is sometimes discoloured. This is known as chemical stain.

- **Coarse Grain**

If a tree grows rapidly, annual rings are widened. It is known as coarse grained timber and such timber possesses less strength.

- **Dead Wood**

Timber which is obtained from dead standing trees contains dead wood. It is indicated by light weight and reddish colour.

- **Knots**

Knots are the remains of outgrowing branches of a tree. Their grain runs at an angle to that of the main timber and where the knots are large and numerous the fibres are distorted and the strength of the timber much reduced.

Defects due to Conversion

During the process of converting timber to commercial form, the following defects may occur:

- **Chip mark:** this defect is indicated by the marks or signs placed by chips on the finished surface of timber
- **Diagonal grain:** improper sawing of timber
- **Torn grain:** when a small depression is made on the finished surface due to falling of some tool
- **Wane:** presence of original rounded surface on the finished surface

Defects due to Fungi

Fungi attacks timber when these conditions are all present:

1. The timber moisture content is above 25%
2. The environment is warm enough
3. There is lots of air

Wood with less than 25% moisture remains free of fungi for centuries. Similarly, wood submerged in water will not be attacked by fungi because of absence of air.

- Blue strained
- Brown rot
- Dry rot
- Heart rot
- Wet rot
- White rot
- Sap strained

Defects due to Insects :

Timber may be attacked in certain circumstances by various wood-boring insects, which differ in their choice of species and condition of the wood- from standing trees to woodwork which has been in service for many years.

Insects responsible for the decay of timber:

- **Beetles**

These are small insects. They form pin holes and form tunnels in all directions. They convert timber into fine powder.

- **Marine borers**

These are found in marine water. They do not feed on wood. They dig holes or form tunnels for shelter and the wood looses colour and strength.

- **Termites**

Popularly known as white ants, these insects are found in tropical and sub-tropical countries. They feed on wood inside out, form tunnels and live in colonies. They usually do not disturb out shell. Good timbers like teak, sal, etc are not attacked by termites.

Defects due to Seasoning :

- **Bow:** Bending of timber along its length.
- **Case hardening:** Due to quick drying of exposed surface, internal tension develop irregular cracks known as case hardening.
- **Check:** Check A check is a crack along the length of a board which may be very small and therefore not a serious weakness.
- **Collapse:** Flattening of wood on drying due to uneven shrinkage.

- **Cup:** Bending of wood or formation of curvature in the transverse direction.
- **Honey combining:** Development of internal cracks due to drying
- **Radial shakes:** These are radial cracks.
- **Split:** These are checks over the entire length of timber.
- **Twist:** It is a spiral distortion along its length.
- **Warp:** Twisting of timber in a small portion.

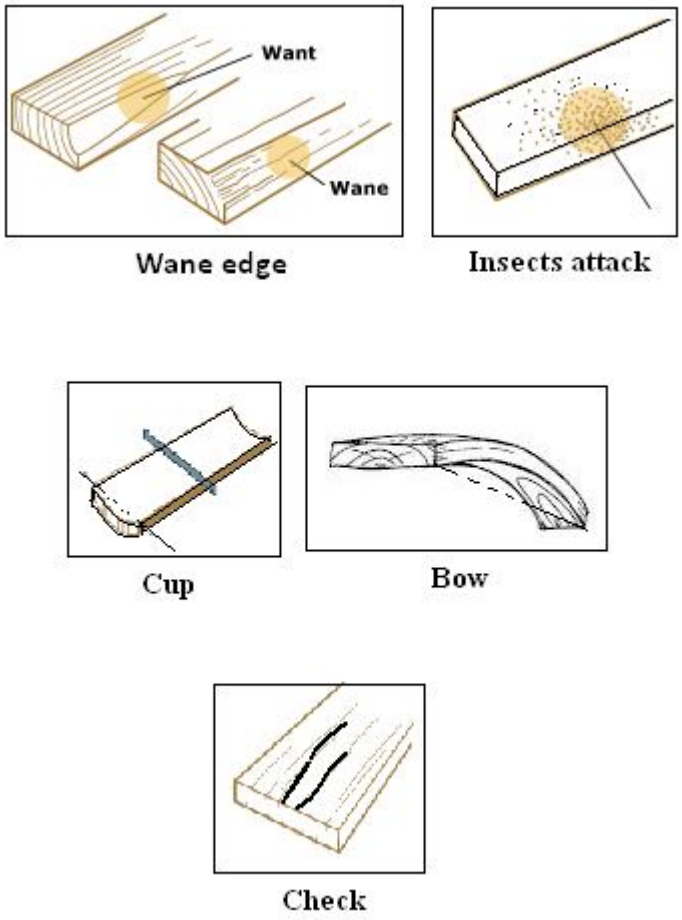
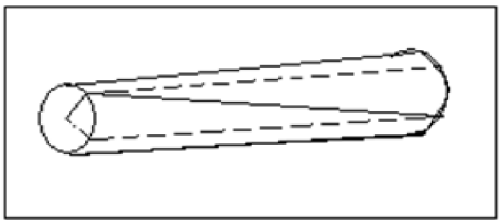
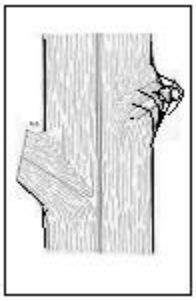


Fig. 10.2 Defects due to Seasoning and Insects.

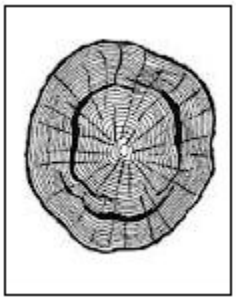


Cross-Crack or Split

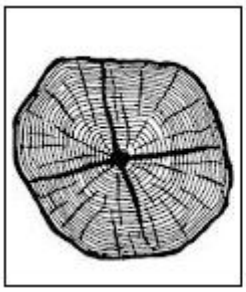
Cup & Star Shakes



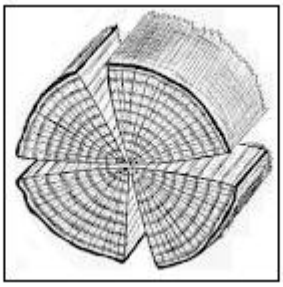
Rind Gall and Knot



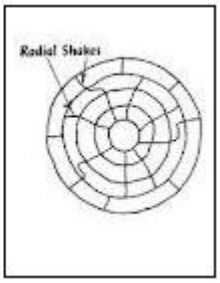
Ring Shakes



Hear Shakes



Wind Crakes



Radial Shakes

Twisted Fibres

Fig. 10.3 Defects of Timber due to natural forces

-

10.3 Common Varieties of Timber found in Andhra Pradesh

Sl.No.	Timber Name	Colour	Brief Description	Uses
1.	Babul	Whitish red,	Close grained, heavy & and it takes up a good polish. Density: 835 kg/m³	Bodies and wheels of bullock cart, agricultural instruments, tool handles, scaffolding, roofing, etc.
2.	Bamboo		Flexible, very strong and durable	Scaffoldings, thatched roofs, rafters, temporary bridges, etc.
3.	Black Palm	Reddish Grey	Durable specially under water	Well curbs, rafters for thatched roofs.
4.	Guava		Fine grained. Hard, tough, light, flexible and strong.	Handles of instruments, toys, engraving works.
5.	Yack	Yellow, darkens with age	Even grained, compact, hard and smooth.	Houses, boats, oars, well curbs, door panels.
6.	Gumar	Pale Yellow	Strong and durable especially under water; easily worked. Density: 580 kg/m³	Planks for door panels, furniture, carriages, well curbs & yokes.
7.	Mango	Deep gray	It is easy to work, moderately strong, maintains its shape well. Density: 560-720 kg/m³	Cheap furniture, toys, packing boxes, cabinet work, panels for doors and for windows

8. Sal	Brown	It is hard, fibrous and close-grained. It does not take up a good polish. It requires slow and careful seasoning. It is durable under ground and water. Density: 880-1050 kg/m³	It is used for house building, railway sleepers, shipbuilding, and bridges.
9. Stain Wood	Yellow	It is close grained, very hard and durable. Density : 960 kg/m³	It is used for furniture and other ornamental works.
10. Tamarind	Dark Brown	It is knotty and durable. Density: 1280 kg/m³	It is used for agricultural instruments, well curbs, sugar mills, carts and brick burning.

Decay of Timber

Following are the causes for the early decay of timber:

(i) Alternate dry and wet conditions.

(ii) Bad storage or stacking of timber.

(iii) Fungi which are responsible for developing diseases in timber such as blue stain, brown rot, dry rot, heart rot, sap stain, wet and white rot.

(iv) Improper seasoning.

(v) Insects such as beetles, marine borers, termites, etc.

(vi) Keeping timber in contact with damp wall, damp earth, etc.

(vii) Shocks or impacts received during young age from natural forces such as fast blowing wind, etc.

(viii) Use of timber without taking out sap wood from its structure.

(ix) Using seasoned timber without applying suitably preservative on its surface.

(x) Using unseasoned wood with the application of protective coat of paint or tar.

10.4 Wood Products

Following are the few products of wood which are widely used for furniture, partitions, etc.:

1. Veneer
2. Plywood
3. Particle board
4. Laminated wood
5. Straw board
6. Ecoboard

1. Veneer

Veneer refers to thin slices of wood, usually thinner than 3 mm (1/8 inch), that typically are glued onto core panels (typically, wood, particle board or medium-density fiberboard) to produce flat panels such as doors, tops and panels for cabinets, parquet floors(the inside lower horizontal surface) and parts of furniture.

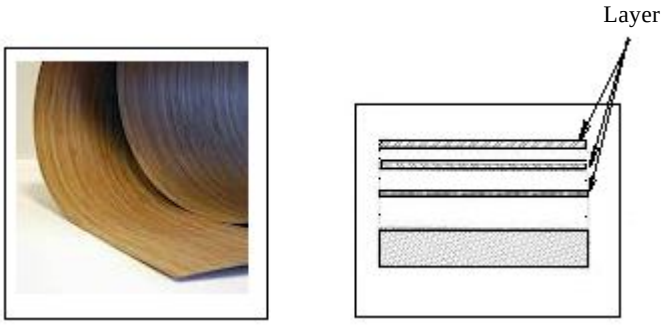


Fig. 10.5 Veneers

Plywood consists of three or more layers of veneer, each glued with its grain at right angles to adjacent layers for strength. Veneer beading is a thin layer of decorative edging placed around objects, such as jewelry boxes. Veneer is also a type of manufactured board.

Veneer is obtained either by "peeling" the trunk of a tree or by slicing large rectangular blocks of wood. The appearance of the grain and figure in wood comes from slicing through the growth rings of a tree and depends upon the angle at which the wood is sliced.

Walnut is a very suitable wood for veneering. Other species like teak, sisoo, elm padwick, oak, rosewood, etc, are commonly used.

Depending on the process of cutting, veneers may be classified as:

1. Rotary Veneers and 2. Sliced Veneers.

2. Plywood

Plywood is a manufactured wood panel made from thin sheets of wood veneer. It is one of the most widely used wood products. It is flexible, inexpensive, workable, re-usable, and can be locally manufactured. Plywood is used instead of plain wood because of its resistance to cracking, shrinkage, splitting, and twisting/warping, and its general high degree of strength.

Plywood layers (called veneers) are glued together with adjacent plies having their grain at right angles to each other.

Cross-graining has several important benefits: it reduces the tendency of wood to split when nailed at the edges, it reduces expansion and shrinkage equating to improved dimensional stability, and makes the strength of the panel consistent across both directions. There are usually an odd number of plies so that the sheet is balanced—this reduces warping. Because of the way plywood is bonded (with grains running against one another and with an odd number of composite parts) it is very hard to bend it perpendicular to the grain direction.

Plywood is commercially available in thickness ranging from 4mm 25mm.

Advantages of Plywood

- It is light in weight, and has good strength depending upon thickness.
- It is available in bigger dimensions than natural wood. Hence joints can be avoided.
- No seasoning is required.
- It can be cut, nailed and glued easily in making furniture.
- It has high resistance to cracking, splitting and warping.
- It has less tendency to shrink and swell as it is cross-grained.

3. Particle Board

Particleboard is a composite product of wood manufactured from wood particles, such as wood chips, sawmill shavings, or even saw dust, and a synthetic resin or other suitable binder. The moisture content of wooden chips is first reduced to about 15% and then pressed in the presence of heat and moisture to form long sheets of particleboard.

The wood pieces used to make particleboard may be hardwoods or softwoods.

Particleboard is cheaper and denser than solid wood, and is often used for indoor products in which appearance and durability are not key requirements. Surfaces that will be visible are often painted or covered with wood veneers for better appearance.

A major disadvantage of particleboard is that it is very much prone to expansion and discoloration due to moisture, particularly when it is not covered with paint or another sealer. Therefore, it is rarely used outdoors or places that have high levels of moisture.

Fig. 10.6 Particle Board

4. Laminated Board

Laminated wood is an engineered wood product composed of thin layers of wood, or veneers, that are glued together to make a stronger wood product. The inner core consists of wooden strips of thickness not exceeding 7mm. The layers are laid and glued with all wood grains parallel. They are strong and durable and do not split easily.

It is also made similar to the plywood. Plywood is a stronger form of laminated wood, where the wood grains of each layer are laid perpendicular to each other.

Laminated woods are used in building applications, such as partitions, packing cases, floor coverings, furniture and wall panels.

Fig. 10.7 Laminated Board

5. Straw Board

Fig. 10.8 Straw Board

The environmental friendly, economical, and recyclable solid panels are made of all natural fibrous raw materials.

These rigid building panels are designed to replace labor intensive drywall construction for interior partition walls. The durable panels feature thermal and acoustic insulation as well as fire and termite resistance and are available for a variety of applications to speed up the construction processes. Other applications for strawboard panels include load and non-bearing ceilings, roofing, doors, flooring, and prefabricated buildings.

Strawboard panels are made of solid core, compressed wheat or rice straw. High pressure and temperatures (240°C) forces the straw to release a natural resin that binds the fibers together. The compressed panels are then covered with paper liners and adhered to both sides with water based non-toxic glue. The panel's high density and low oxygen content does not support combustion. These straw boards are made in various thicknesses ranging from 25mm to 75mm.

The product's workability is similar to wood as it can be sawn, drilled, routed, nailed, screwed, and glued. Lightweight wall attachments such as shelf brackets, picture frames, mirrors, and towel bars can be attached directly to the panel.

6. Ecoboard

Fig. 10.9 Ecoboard

Ecoboards are 100% environment friendly. However, these are not made from wood. It is manufactured from sugarcane waste (known as 'bagasse') obtained from sugar factories. Bagasse is broken into small size particles and fed into hammer mills to obtain good quality fibre, which is then dried to reduce the moisture content to below 2%.

The dried and sized material is mixed with glue binders. The glued bagasse is formed in 3 layers, coarse in the middle, fines in top and bottom side and then subjected to high pressure with high temperature. These bagasse boards are made at different thicknesses. The boards are allowed to cure for a day or two and then subjected to sanding to obtain smooth surface and to relieve loose material in the surface and to have uniform thickness of the board.

Some are pressed with base paper to make the bagasse boards water resistant and to ensure durability.

Properties of plain Ecoboard

100% wood free smooth surface and excellent bonding strength, High durability, Easy maintenance, Excellent machinability, Dimensional stability, More economical, saves time and labor, No deformation, Moisture resistance, Fire retardant, High resistance to abrasion, Termite resistance, Excellent screw holding capacity. It is relatively cheaper.

Uses of Ecoboard:

It is used for partitions, vanity flooring, decorative railings, doors, windows, false ceiling, wall paneling, all types of furniture, etc.

10.5 Characteristics of a Good Timber

Following are the characteristics or qualities of a good timber:

1) It should be free from sap and be from heart of a sound tree.
2) It should have straight and close fibres.
3) It should give a clear ringing sound when struck. Dull heavy sound is a sign of internal decay.
4) It should be of uniform dark colour. Light colour usually indicates timber with low strength.
5) It should have regular annual rings.
6) Timbers with narrow annual rings are generally the strongest.
7) Freshly cut surface should give sweet smell.
8) It should have bright and smooth surface when planed. Dull appearance is a sign of defective timber.
9) Teeth of saw should not get clogged while sawing.
10) Out of same variety of timber, darker and heavier pieces are stronger.
11) It should be free from dead knots, from too many knots, shakes or other defects.
12) It should have firm adhesion of fibers and compact medullary rays.
13) A good timber should be durable. It should be capable of resisting the actions of fungi, insects, chemicals etc.
14) A good timber should be capable of retaining its shape during conversion or seasoning. It should not bow or warp or split.

15) A good timber should be capable of offering resistance to shocks due to vibrations.

Summary

In this unit, you have gained adequate knowledge of Timber as one of the important construction materials. Wood is used as structural elements in buildings for various purposes. The timber used for engineering purposes should be free from defects as far as possible. Defects free timber is possible only when tree has been felled at proper time and with adequate precautions. It is also necessary that timber should be properly seasoned and necessary preservatives are used before it is used for engineering purposes.

Synopysis

- Timber is building material used for the construction of doors, windows, roofs, partitions, beams, cupboards etc.
- The defects occurring in a timber are classified into
- Defects due to conversion chip mark, diagonal grain, torn gain, wane
- Defects due to fungi, blue shain, brown rot, dry rot, heart rot, sap stain, wet rot, white rot etc
- Defects due to insects beetles, marine borers, termites etc
- Defects due to natural forces burls, callus, chemical stain, coarse grain, dead wood, druxiness, knots, shakes etc
- The wood based products are
  - · Veneers
  - · Plywood
  - · Fibre boards
  - · Impreg timbers
  - · Compreg timbers
- A good timber should have

  i) Shinning appearance

  ii) Dark colour

  iii) Free from defects

iv) Durable to action of fungi, insects, chemicals etc

v) Fire resistance

vi) Should hard

vii) Mechanical wear

viii) Sweet smell

ix) Should give char ringing sound

x) Structure should be uniform

xi) Should have low water permeability

Short Answer Type Questions

1. Name any four defects in timber
2. What are the important qualities of timber?
3. Name any four wood based products
4. What is plywood?
5. What is meant by seasoning?

Long Answer Type Questions

1. Explain different defects in timber briefly.
2. Explain the important qualities of timber.
3. Explain any two wood based products briefly.
4. What are the advantages of plywood?

UNIT 11

Metals

Learning Objectives

After studying this unit, the student will be able to

- Know different types of metals.
- Know the properties, chemical composition and uses of cast iron;
- Know the properties, chemical composition and uses of wrought iron;
- Know the properties and uses of steel;
- Know the commonly used structural steel sections;
- Know about reinforcing steel, its types & chemical compostion;
- Know the tests on Metals.

Introduction

Metals and their alloys are integral part of construction industry. They are employed for various purposes such as structural members, roofing materials, doors, windows, tanks, pipes, etc.

11.1. Types of Metals

Metals can be grouped under the following two categories:

- Ferrous metals &

- Non-Ferrous metals

Ferrous Metals

In a more general sense, ferrous metals are metals or metal alloys that mainly contain iron. Carbon steel and Stainless steel are examples of ferrous metals. They are both alloys (mixture of different metals) that contain a fair amount of iron and therefore known as Ferrous metals.

Three important ferrous metals are Cast-Iron, wrought-Iron and Steel.

Non-Ferrous metals

These are metals that contain no iron but also include some alloys that contain appreciably very small amounts of iron.

These are generally more expensive than ferrous metals, non-ferrous metals are used because of desirable properties such as low weight (e.g., aluminum), higher conductivity (e.g., copper), non-magnetic property or resistance to corrosion (e.g., zinc). Some non-ferrous materials are also used in the iron and steel industries.

11.2 Cast Iron

Chemical Composition

Cast iron is formed by remelting Pig Iron, and is useful for a variety of engineering purposes. (Pig Iron is a crude impure iron extracted from iron ores.)

Cast iron is an alloy, a blend of the elements iron, carbon and silicon. The carbon content in cast iron is 3% to 4.5% by weight. It contains 95% iron with other impurities. Silicon and small amounts of Manganese, Sulfur, and Phosphorus are also present in it. It is popular because of its low cost and ability to make complex structures.

The products of cast iron exhibit reasonable resistance against corrosion. The cast iron is neither malleable nor ductile, and it cannot be hardened like steel. It melts at about 1200^0C, and has either a crystalline or a granular fracture. The mechanical properties of cast iron are very much dependent on the carbon content.

Following are some of the properties of cast iron

1. It has granular crystalline structure.
2. It is hard but brittle also.
3. It has a low melting point. It melts at 1200^0C.

4. Its specific gravity is 7.5.
5. It cannot absorb impact loads as it is not ductile.
6. It has weak tensile strength (150 N/mm^2). Addition of vanadium can increase the strength of cast iron.
7. It has high compressive strength (600 N/mm^2)
8. It has good resistance to oxidation. It does not rust easily.
9. Cast iron structures show resistance to deformation and provide a rigid frame.
10. It cannot be magnetized.
11. It cannot be welded.
12. It becomes soft in salt water.

Uses of cast iron

Cast irons have a wide range of applications, including machine and car parts like cylinder heads, blocks, and gearbox cases; cookware; water, gas and sewer pipes; ornamental castings like lamp posts, gates; compression members like columns, column bases; agriculture implements; rail chairs etc. It is used in the manufacture of wrought iron and steel.

11.3 Wrought Iron

Wrought iron is the purest form of commercial iron, containing only 0.10% to 0.15% of carbon and less than 0.25% of impurities like sulfur, phosphorus, silicon and manganese. Due to the presence of siliceous slag, its structure is fibrous and it gets anti-corrosive properties.

Properties

Wrought iron is made of iron with less than 1 percent carbon and a glass-like slag. It is the only ferrous metal that contains siliceous slag.

Properties of Wrought Iron

1. The chief properties of wrought iron are as follows, viz.:
2. It is very malleable and ductile, and can be readily forged, particularly when heated.

3. It cannot be cast, as it fuses with difficulty at very high temperature (about 2800° F.), and merely becomes pasty at the usual furnace temperatures, though because of this quality it is readily united by welding.

4. It cannot be hardened, due to lack of carbon.
5. If pulled apart, the fracture shows a fibrous break.
6. Wrought iron is tough
7. It is unaffected by saline water.
8. It is moderately elastic
9. Its melting point is about 1500^0C
10. Its specific gravity is 7.8
11. Its compressive strength is about 200 N/mm^2
12. Its tensile strength is about 400 N/mm^2
13. Wrought iron is durable.

Similarities with Mild Steel

While wrought iron and mild steel resemble each other, there are certain distinct advantages of wrought iron which cause it to be retained for some uses. Among its advantages are (1) it welds better than does steel, (2) lasts longer when exposed to weather or to water, (3) is better to resist shock and vibration (fatigue), and (4) its fibrous structure arrests fracture, as its breaking is in the nature of a gradual tearing, which often gives warning of a dangerous stress, while steel breaks suddenly.

Among the disadvantages of wrought iron are, (1) its elastic and tensile strength are lower than those of steel, (2) and its production is more costly.

The Uses of Wrought Iron occurring inside the iron crystals and prevent the layers from sliding past each other. This is what makes steel harder than iron. Varying the amounts of these hardening agents creates different grades of steel.

The ductility, hardness and mild steel tensile strength are a function of the amount of carbon and other hardening agents, present in the alloy. The amount of carbon is a deciding factor, which decides hardness of the steel alloy.

A steel alloy with a high carbon content is mild steel, which is in fact, more harder and stronger than iron. Though, increased carbon content increases the hardness of the steel alloy, it causes a decrease in its ductility. Steel with increased carbon content can be made harder and stronger than iron, but is also more brittle.

The maximum solubility of carbon in iron is 1.7% by weight, occurring at 1130° Celsius; higher concentrations of carbon or lower temperatures will

produce cementite which will reduce the material's strength. Alloys with higher carbon content than this are known as cast iron because of their lower melting point. Steel is also to be distinguished from wrought iron with little or no carbon, usually less than 0.035%.

Mild steel can also be described as steel which is not stainless steel. Mild steel differs from stainless steel in its chromium content. Stainless steel contains a lot more chromium than ordinary carbon or mild steel.

To a great extent, mild steel has replaced wrought iron. Its usage is limited to places where tough material is required.

At present wrought iron is used for chains, ornamental works, rivets, water and steam pipes, electro-magnets, bolts and nuts, roofing sheets, etc.

It is used in the manufacture of steel.

11.4 Steel

Steel is an alloy of iron, consisting of carbon (usually 0.1-1.7%), as a hardening agent. Besides carbon, there are many metal elements that are part of steel alloys.

The elements other than iron and carbon, used in steel are chromium, manganese, tungsten and vanadium. All these elements along with carbon, act as hardening agents. They prevent dislocations from

Types and Uses

Steel is often classified by its carbon content:

- **Mild (low carbon) steel**

Carbon content : 0.05% to 0.26%

They are the most common form of steel as they come at a relatively low cost and provide material properties that are acceptable for many applications. They are neither brittle nor ductile, but are malleable. The surface hardness can be increased through carburizing.

- **Medium Carbon Steel**

Carbon content : 0.29% to 0.54%

They balance ductility and strength and have good wear resistance. They are used in forging and for large industrial and automotive components

- **High carbon Steel**

Carbon content: 0.55% to 0.95%

They are very strong and are used for springs and high-strength wires.

- **Very high carbon steel:**

Carbon content: 0.96% to 2.1%

These steels can be tempered to great hardness and are used for specialized products such as knives, axles, or punches. Steels above a carbon content of 1.2% are generally formed through powder metallurgy. Steels with carbon content above 2% are considered to be cast iron.

High-carbon steel is serviceable for dies and cutting tools because of its great hardness and brittleness.

Low- or medium-carbon steel is used for sheeting and structural forms because of its amenability to welding and tooling.

Alloy steels, now most widely used, contain one or more other elements to give them specific qualities.

Alloy steels contain varying amounts of different metals and materials to specialize their properties.

· Aluminum steel is smooth and has a high tensile strength.

· Chromium steel finds wide use in automobile and airplane parts on account of its hardness, strength, and elasticity, as does the chromium-vanadium variety. Stainless steel, which was developed in England, has a high tensile strength and resists abrasion and corrosion because of its high chromium content.

· Nickel steel is the most widely used of the alloys; it is nonmagnetic and has the tensile properties of high-carbon steel without the brittleness.

· Nickel-chromium steel possesses a shock resistant quality that makes it suitable for armor plate.

· Wolfram (tungsten), molybdenum, and high-manganese steel are other alloys.

Mild Steel

Composition:

· **Iron** **99%**

- **Carbon** **0.1 to 0.25%**
- **Sulphur** **0.06%**
- **Phosphorous** **0.06%**

Properties of Mild Steel

Mild Steel is one of the most common of all metals and one of the least expensive steels used. It is to be found in almost every product created from metal.

1. It has fibrous structure.
2. Being a softer metal it is easily welded.
3. It is very durable (although it rusts).
4. It is relatively hard and is easily annealed.
5. It has poor resistance to corrosion. It must be protected by painting as it rusts readily.
6. It is malleable and ductile.
7. It can be permanently magnetized.
8. Its Modulus of Elasticity is 210 KN / mm^2
9. Ultimate compressive strength is 475 N/mm^2
10. Ultimate tensile strength is 600 N/mm^2
11. Its specific gravity is 7.85
12. Its melts at about 1400^0 C

Uses of Mild Steel

· Having less than 2 % carbon it will magnetize well and being relatively inexpensive can be used in most projects requiring a lot of steel.

· Most everyday items made of steel have some milder steel content. Anything from cookware, motorcycle frames through to motor car chassis, use this metal in their construction.

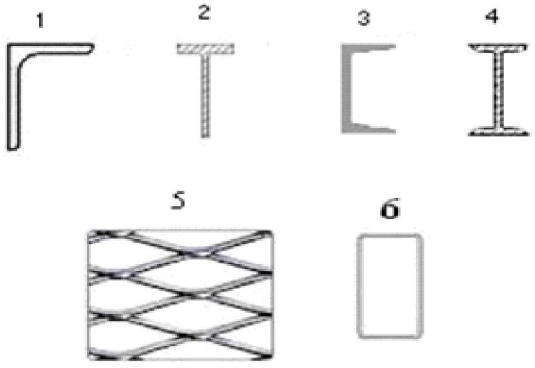
· Used for making reinforcing steel to be used in RCC works.

· Used for making power transmission towers, refrigerators, etc.

· The malleability of mild steel also allows it to be rolled or beaten into thin sheets.

11.5 Commonly Used Structural Steel Sections

1. Angle Sections: they may have equal or unequal legs. Widely used in the construction of steel roof trusses.
2. T-Sections: used as structural members in the steel roof trusses and also in the buildup sections.
3. Channel Sections: They consist of one web and two flanges. Used as structural members in steel framed structures.
4. I-Sections: popularly known as beams or rolled steel joists, these are used for floor beams, columns, lintels, etc.
5. Expanded Metal: Used for reinforcing concrete in foundations, roads, bridges, etc. It is also used for partitions.
6. Square Bars : Used in the grill work for gates, windows, etc. commonly used cross-sections vary from 5mm to 25mm.
7. Round Bars : Widely used as reinforcement in concrete structures, grill works, etc.
8. Flat Bars : Used in the grill work for gates, windows, etc.
9. Plates : Used to connect steel beams, roof trusses tension members, built-up sections, etc.
10. Ribbed Bars : Used as reinforcement in concrete structures.



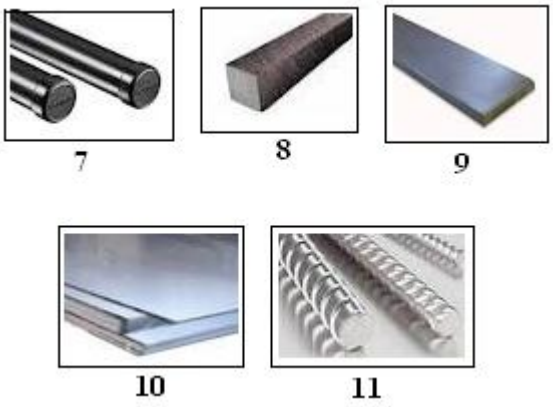


Fig. 11.1 Common Forms of Structural Steel Sections

11.6 Reinforcing Steel

HYSD Bars (High Yield Strength Deformed Bars):

These bars have projections or ribs on their surface. They are made up of high strength steel and are much stronger than plain bars. They are produced by controlled cold twisting of hot rolled bars. Each bar is twisted individually and tested. These bars are available in sizes varying from 6mm to 50mm. These bars are used for almost all concrete works.

Advantages of HYSD bars over Plain Bars:

- Due to high yield strength **HYSD** bars are used for saving steel. On account of increase in bond stress such bars normally do not need end hook. Transport, storage bending and fixing charges are less than 35% cost of mild steel bar.
- They have better structural qualities.
- These rods can be bent through 180^0 without any cracks formation on the outer surface.
- Some types of Ribbed HYSD bars can be welded.
- These bars have 40% more bond strength with concrete. Therefore, end hooks are not required.

Different types of steel reinforcement bars used as reinforcement in concrete structures

Mild steel bars conforming to IS: 432 (Part I) and Cold-worked steel high strength deformed bars conforming to IS: 1786 (grade Fe 415 and grade Fe 500, where 415 and 500 indicate yield stresses 415 N/mm^2 and 500 N/mm^2 respectively) are commonly used.

Grade Fe 415 is being used most commonly nowadays. This has limited the use of plain mild steel bars because of higher yield stress and bond strength resulting in saving of steel quantity.

TMT Bars

· TMT bar means thermo mechanically treated bar i.e. hot rolled steel wire is passed through cold water to make their surface harder as well as to keep the core softer.

· It serves two purposes corrosion resistance and weldability. Bars range in diameter from 6 to 50 mm. Cold-worked steel high strength deformed bars start from 8 mm diameter. For general house constructions, bars of diameter 6 to 20 mm are used.

TOR Steel

• Popular name of HYSD bars is tor steel, i.e., High Yield Strength Deformed bar. As the name implies it has comparatively high strength than Mild Steel. They are graded as Fe415, Fe500 i.e. Yield stress of 415 N/sq mm and 500 N/sq mm respectively. The HYSD bars may be hot / cold worked.

• As tor or HYSD steel is stronger, it saves cost. Strength of an 8 mm diameter tor steel bar is almost equal to 10 mm diameter plain steel bar. Similarly, a 10 mm dia tor steel bar has almost same strength as 12 mm plain steel bar. In actual, tor is a trade name belonging to Tata steel company.

• These bars can be used as a general purpose concrete reinforcement in all types of reinforced concrete construction (RCC).

Advantages

- Savings in Steel: minimum 25% compared to TMT bars of Grade Fe415
- Higher breaking load
- Higher bond strength due to scientific rib design
- Savings in construction Cost

11.7 Weights of steel bars of various diameters per meter

Nominal Diameter(mm)	Weight/unit Length(kg/m)	Cross-SectionalArea (mm^2)
6	0.222	28.3
8	0.395	50.3
10	0.617	78.5
12	0.888	113
14	1.21	154
16	1.579	201
20	2.467	314
25	3.855	491
28	4.83	616
32	6.316	804
40	9.868	1257
50	15.413	1963

11.8 Tests on Mild Steel

Mild steel bars are tested for their yield strength and compression strength in the laboratory using Universal Testing Machine.

Suppose that a metal specimen be placed in **tension-compression-testing machine**. As the axial load is gradually increased in increments, the total elongation over the gauge length is measured at each increment of the load and this is continued until failure of the specimen takes place. Knowing the original cross-sectional area and length of the specimen, the normal stress and the strain can be obtained. The graph of these quantities with the stress along the y-axis and the strain along the x-axis is called the stress-strain diagram. The stress-strain diagram differs in form for various materials. The diagram shown below is that for mild steel.

Proportional Limit (p) (Hooke's Law)

From the origin O to the point called proportional limit, the stress-strain curve is a straight line. This linear relation between elongation and the axial force

causing was first noticed by Sir Robert Hooke in 1678 and is called Hooke's Law that within the proportional limit, the stress is directly proportional to strain.

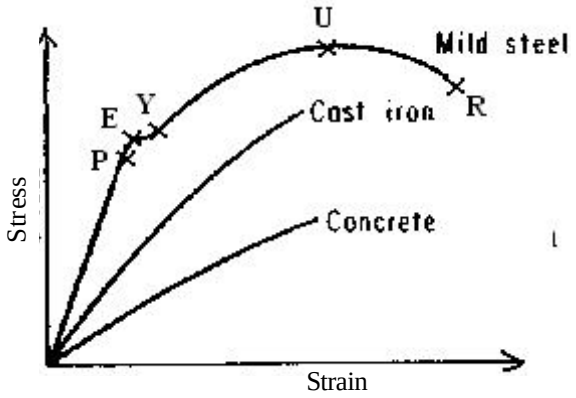


Fig. 11.2 Stress - Strain Curve of Mild steel compared with cast iron and concrete

The constant of proportionality is called the Modulus of Elasticity or Young's Modulus and is equal to the slope of the stress-strain diagram from O to P. Then

Stress=E * Strain

Proportional Limit - Stress above which stress is not longer proportional to strain.

Elastic Limit (E) - The maximum stress that can be applied without resulting in permanent deformation when unloaded.

Elastic and Plastic Ranges

The region in stress-strain diagram from O to P is called the elastic range. The region from P to R is called the plastic range.

Yield Point (Y) - Stress at which there are large increases in strain with little or no increase in stress. Among common structural materials, only steel exhibits this type of response.

Yield Strength - The maximum stress that can be applied without exceeding a specified value of permanent strain (typically .2% = .002 in/in).

Ultimate Strength – It is the maximum stress the material can withstand (based on the original area).The maximum ordinate in the stress-strain diagram is the ultimate strength or tensile strength.

Rapture Strength (R)

Rapture strength is the strength of the material at rupture. This is also known as the breaking strength.

Fixing Reinforcement

Bars in contact shall be firmly secured to each other with approved binding wire or proprietary clips of a type approved by the Engineer. Binding wires shall be 1.1-1.3 mm diameter soft annealed iron wire free from rust or other contaminants. The reinforcement shall be fixed accurately and securely in position so that the reinforcement is in the correct position in relation to the formwork to give the specified concrete cover and will not be displaced due to trafficking around site or during the placing and compaction of the concrete or any related operations.

The correct cover shall be maintained by the use of plastic spacers or other approved means. Concrete spacing blocks, if approved for use, shall be machine pressed well compacted and water cured for a minimum of seven days after casting and shall have a10 minute absorption of less than 2.5% by weight. Concrete spacers shall be comparable in strength, durability and appearance to the surrounding concrete. Any wire cast into the spacer blocks shall be positioned well away from the exposed surface and shall be galvanized. Spacers fixed to parallel reinforcement bars shall not be located in a line across a section. Timber, stone or metal spacers are not permitted.

Concrete shall be placed within 1 day of fixing reinforcement and the reinforcement shall be protected with plastic sheeting or tarpaulin in the interim period.

Bar Bending schedule

Bar bending schedule is a chart which describe the shape of bars, length of bars and total amount of steel is to be used in the specific design. Bar-bending-schedule is the schedule of reinforcement bars prepared in advance before cutting and bending of bars.

Checklist for steel reinforcement before the placement/pouring of concrete:

· Reinforcement should be free from loose rust, oil paints, mud etc. it should be cut, bent and fixed properly.

· The reinforcement shall be placed and maintained in position by providing proper cover blocks, spacers, supporting bars, laps etc.

· Reinforcements shall be placed and tied such that concrete placement is possible without segregation, and compaction possible by an immersion vibrator.

Lap or development length /Where and how should they be provided:

· Lap length is the overlap length of bars tied to extend the reinforcement length. Generally lap length of about 50 times the diameter of the bar is considered safe. Laps of neighboring bar lengths should be staggered and should not be provided at one level/line.

· At one cross section, a maximum of 50% bars should be lapped. In case, required lap length is not available at junction because of space and other constraints, bars can be joined with couplers or welded (with correct choice of method of welding).

Procedure

1) Study the given drawings carefully.

2) Finalise the items of the work with their units of measurements. Prepare the check list of the items.

3) Write brief description of each item of the work on the measurement sheet.

4) Calculate length, width & depth of different components for calculation of quantity of concrete & form work.

5) Calculate the quantity of form work for beam, column.

6) Enter the length, width/breath & depth/height in measurement sheet for concrete & form work item.

7) Prepare bar bending schedule.

8) Calculate the length of bars of different diameter in different components such as slab, beam, column, footing etc.

9) Calculate the number of bars of different diameter in different components.

10) Enter the number, length & weight of bar for different bars in different components in Bar bending schedule.

11) Calculate the quantities of items of the work in the measurement sheet.

Barb ending Schedule

S. No.	Diameter of bar in mm	Bar by sketch	Length of bar in 'm'	Number of bars	Total length of bar mm	Total weight of bar in kg
1.						
2.						
3.						
4.						
5.						
6.						

Summary / Synopysis

- The ferrous metals used for various engineering purposes cast iron, wrought iron and steel
- The non-ferrous metals which are generally used in engineering structures are Aluminium, cobalt, copper, lead, magnesium, nickel, tin, zinc etc
- Pig Iron is a crude impure iron extracted from iron ores.
- Cast iron is formed by remelting Pig Iron, and is useful for a variety of engineering purposes.
- Cast iron contains 3 to 4.5% of carbon; wrought iron contains about 0.1 to 0.15 percent. Whereas steel contains about 0.15 to 1.7 percent of carbon.
- Steel is often classified by its carbon content: Types of steel are: Low Carbon Steel, Medium Carbon Steel, High Carbon Steel and Very High Carbon Steel.
- Alloy steels, now most widely used, contain one or more other elements to give them specific qualities.
- Commonly Used Structural Steel Sections are Angle sections, Channel sections, I-sections, T-sections, Expanded metal, square bars, round bars, flat bars, plates, ribbed bars, etc.

Short Answer Type Questions

1. What are the uses of cast iron?
2. What are the uses of wrought iron?
3. What the properties of steel?
4. Name any four uses of steel.
5. List out the names of commonly used structural steel sections.
6. What are the Advantages of HYSD bars over Plain Bars?
7. What are different types of steel reinforcement bars used as reinforcements in concrete structures?

Long Answer Type Questions

1. Write the chemical composition, properties and uses of Cast Iron.
2. Write the chemical composition, properties and uses of Wrought Iron.
3. Explain the properties and uses of steel
4. Explain the properties and uses of cast iron
5. Explain different types of steel reinforcement used as reinforced in concrete structure
6. Briefly explain different market forms of steel.
7. Explain different types of steel reinforcement bars used as reinforcement in concrete structures.
8. Explain Stress-Strain Curve of Mild Steel.

OJT / Assignment

- Visit a Steel Shop and ascertain the current rates of different forms of steel.

UNIT 12

Surface Protective Materials

Learning Objectives

After studying this unit, you should be able to

- Explain what is Paint and different types of Paints.
- Known functions of Paints.
- Know different ingredients of Paints.
- Explain the characteristics of good paint.
- Explain what is a Varnish and different types of Varnishes.

12.1 Introduction

Finished surfaces of walls, ceiling, wood, furniture and metals need protection against weathering action. Paints, Varnishes and distemper are commonly used to protect color or provide texture to objects.

Any surface, in fact, which needs protection or decoration, will need a surface coating. Different formulations are used to produce the necessary properties, such as weather or chemical resistance, inhibition of the growth of algae, electrical insulation or lowered friction effects of the air at high speed, etc.

Paint is a liquid substance applied as a protective or decorative coating to various surfaces of timber and metals. Similarly, the varnishes are semi-transparent liquid substances applied on the surfaces of wood and paint.

Paint

Paint is defined as a liquid containing suspended pigment (colouring agent) applied to a solid surface to protect and decorate it.

12.2 Functions of Paint

Paint performs the following main functions:

- It **protect**s and increases the life of painted surface.
- It **imparts colour** and **attractive finish**.
- It **protects** the surface **from** the affects of **weathering**.
- It **prevents the corrosion** of metallic surface.
- It gives **pleasing appearance** to the surface.
- It provides a surface which can be **cleaned easily.**

12.3 Ingredients of Paint

An oil paint essentially consists of the following ingredients. These ingredients perform certain specific functions:

1. Base
2. Vehicle or Carrier
3. Drier
4. Colouring Pigment
5. Solvent

1. Base

Base is a solid substance in fine state which forms the **bulk of the paint**. It determines the quality of the paint and imparts durability to the painted surface. It reduces shrinkage and cracks on drying of the paint. It prevents the paint from entering the underlying surface.

Commonly used Bases in oil paints are Zinc Oxide, White Lead, Red Lead, Lithophane, and Oxides of Iron.

2. Vehicle or Carrier

Vehicle is a liquid substance that **holds the ingredients** of the paint **in liquid suspension**. It carries and spreads them over the painted surface. It acts as a binder for base and pigment.

Commonly used carriers are different types of Linseed Oil, Poppy Oil and Nut Oil (Walnut Oil).

3. Drier

Drier is a substance that **accelerates** the process of **drying**. These substances absorb oxygen from air and help in drying.

Commonly used driers are Litharge, Lead acetate, Manganese sulphate, and Cobalt compounds.

Functions of Drier

- It reduces the cost of paint.
- It prevents shrinkage and cracks on drying.
- It modifies weight of the paint.

4. Pigment

It is a finely powdered solid substance which **imparts colour** to the paint.

Some commonly used pigments for oil paints:

- Cobalt – for Blue colour.
- Chrome Yellow and Zinc chromate – for Yellow colour.
- Copper Sulphate, Chromium Oxide – for Green colour.
- Graphite – for Black Colour.
- Lithophane, White Lead – for White Colour.
- Red Lead and Iron Oxide – for Red Colour.

5. Solvent

The function of solvent is to **make the paint thin**, so that it can be easily applied on the surface. It is also known as thinner. The thinner evaporates quickly and **helps in drying**.

Commonly used solvents are Turpentine oil, Petroleum spirits, and Napthas.

Functions of Solvent:

- It increases the workability of paint.
- It improves the covering capacity of the paint.
- It helps in drying.

- It improves the penetration capacity of the paint.

12.4 Characteristics of Good Paint

Following are the characteristics of an ideal paint:

- Paint must be resistant to the wear and tear of the atmosphere and should maintain its color, smoothness and finish for a long time.
- It should have good spreading power and easily applied on the surface.
- It should dry in a reasonably short time.
- It should provide hard and durable surface for longer time.
- It should provide pleasing appearance.
- The dried painted surface should not show cracks.
- It should be cheap and economical.
- Paint should be environmentally friendly.

Failure of paint

The main reasons of paint failure after application on surface are the application defects and improper treatment of surface.

Application Defects can be attributed to:

- **Dilution**

This usually occurs when the dilution of the paint is not done as per manufacturer's recommendations. There can be a case of over dilution and under dilution, as well as dilution with the incorrect diluents.

- **Contamination**

Foreign contaminants results in various film defects.

- **Peeling/Blistering**

It is due to improper surface treatment before application and inherent moisture/dampness being present in the substrate.

- **Chalking**

Chalking is the progressive powdering of the paint film on the painted surface. The primary reason for the problem is polymer degradation of the paint matrix caused by UV radiation attack in sunshine.

- **Cracking**

Cracking of paint film is due to the unequal expansion or contraction of paint coats. It usually happens when the coats of the paint are not allowed to cure/dry completely before the next coat is applied.

- **Erosion**

Erosion is very quick chalking. It occurs due to external agents like air, water etc.

- **Blistering**

Blistering is due to improper surface exposure of paint to strong sunshine.

12.5 Types of Paints

Following are different types of paints used for various engineering purposes:

1. Oil paints
2. Enamel paints
3. Emulsion paints
4. Plastic Emulsion paints
5. Cement paints
6. Distemper
7. White wash and Colour Wash
8. Coal tar paint

12.5.1 Oil Paints

Oil paint is a type of **slow-drying paint** that consists of particles of **pigment** suspended in a **drying oil**, commonly linseed oil.

The viscosity of the paint may be modified to make it more workable by the addition of a solvent such as **turpentine** or **white spirit**. Varnish may be added to increase the glossiness of the dried oil paint film.

Common applications of oil paint include finishing and protection of **wood** in buildings and **exposed metal** structures such as bridges, grills, etc.

Its hard-wearing properties and availability in various colors make it desirable for both interior and exterior use on wood and metal. Time required for drying depends on thickness of coat: thin coats of oil paint dry relatively quickly.

12.5.2 Enamel Paint

Enamel paint is a common paint used for both residential and commercial purposes. It is an **oil-based paint** that provides a **glossy finish**.

Typically the term "enamel paint" is used to describe oil-based paints, usually with a significant amount of shine in them. However, recently many water-based paints are using the term as well. The term today means **"hard surfaced paint"** and usually it reference to paint brands of higher quality, high glossy finish or spray paints. Some enamel paints have been made by adding **varnish** to oil-based paint.

They contain **white lead** as base, **linseed** oil as carrier and **petroleum** as solvent. It also contains resinous materials.

They are used for coating surfaces that are **outdoors** or otherwise subject to variations in temperature, all types of **wood work**, structural members and wall of buildings. They are **easy to clean and dry quickly**.

Uses and categories of enamel paint

- Powder enamel – May be used for concrete, stairs, basements, etc..
- Fast dry enamel – Can dry within 10–15 minutes of application. Ideal for refrigerators, counters, and other industrial finishes.
- High-temp enamel – May be used for engines, brakes, exhaust, etc.
- Enamel paint is also used on wood.

12.5.3 Emulsion Paints

Emulsion or emulsion paint is a **water-based** paint, which is **not shiny** when it dries. It is generally used for **interior decoration** with an emphasis on painting walls and ceilings.

Unlike enamel paints that give a very glossy finish, these paints usually gives a **mat finish**.

Emulsion paints are water based and are made up from a mix of synthetic particles, a colour pigment and water. These paints work so well on walls and ceiling because they are easier to apply than many other paints and they have a longer life in terms of their colour hold and their durability. You can also **wash** down an emulsioned wall or ceiling to clean it without damaging the paint and it is easier to clean up spills and drips with this kind of paint than with other paints due to its water base.

One of the big advantages to using emulsion paint is that it can be painted on to just about **any surface** from brick to cement to lining papered walls. Special emulsion paints with a glossier finish are also available and these can be used to paint skirting boards and frames.

12.5.4 Plastic Emulsion Paints

Plastic emulsion paint is **water based** wall paint. It is based on acrylic (a substance made by a chemical process, for example fibres for cloth and paint) and provides a smooth matt finish to the walls. These paints are also **washable** and easy to maintain just as premium emulsions. It is extremely durable but is not suitable for application on external surfaces, wood and iron surfaces.

These paints are suitable for painting theatres, auditoriums and show-rooms.

Raw Materials for Plastic Emulsion Paint

· **Cement Primer:** A coat of cement primer is a base coat applied on the surface for painting.

· **Putty:** It's used to fill uneven surface and holes. It is prepared by mixing white lead chalk 'MITTI' and varnish together to form a thick paste.

Preparation of New Surface

· The surface should be thoroughly **cleaned** of mortar dropping, splashes of cement slurry, dust etc.

· **Primer coat** is applied on the surface.

· The surface should be **allowed to dry for at least 48 hours.**

· The surface should be **rubbed with sand paper** for getting smooth and even surface. Any unevenness should be leveled by applying **putty**.

12.5.5 Cement Paints

Cement Paint is a decorative waterproof cement coating used to beautify and protect outer surfaces.

Cement Paint is durable, economical, tough and can withstand all types of weather. Cement Paint is available in a variety of shades.

Cement paints are composed of the following ingredients: I) Pigments ii) Binder iii.) Additives and iv) Solvents—water, which is added before application.

Cement Paints is a material consisting of port land cement and other ingredients like lime, pigments, hydroscopic salts (Readily absorbing moisture),

water repellents and fungicides. The material readily **mixes with water** and is used on porous surfaces like masonry concrete, rough plaster **except gypsum plaster**.

Cement paints are **suitable for coating concrete as well as decorating indoor and outdoor walls** of the Building .It also imparts water repellent property to exterior surfaces.

Some important features are:

- Long lasting
- Available in different colors
- Reasonable rates

Difference between Cement Paint and Cement Wash:

Cement Paint is a paint made by mixing white cement, fillers, additives and extenders, and adding pigments to the mix to get the desired shade. Whereas **Cement Wash** is just a coating done with pure white cement and no additives are added. It's available only in **white colour.**

12.5.6 Distemper

Distemper is actually a kind of pain in which the binding agent is glue — typically from a mammal skin. Traditionally, in distemper, the animal-hide would be from rabbit. Distemper paint is formed by mixing whiting (fine chalk), hide derived glue, water and pigment.

Distemper is applied warm onto internal wall or ceiling surfaces and produces a durable soft sheen finish which tightens as it cools.

It is both a paint and if mixed stiffer, a form of filler. Traditionally this was used as the finish for lime and earthen plaster.

It is available in the form of paste also. These are cheaper. At the time of use, distemper is mixed with water and applied on the plastered wall and ceilings.

12.5.7 Whitewash

Whitewash, or lime paint is a low-cost type of paint made from **slaked lime** (calcium hydroxide), water and small quantity of gum or fevicol. Various other additives are also used. To improve whiteness, a small quantity of indigo is added.

Through a reaction with carbon dioxide in the atmosphere, whitewash form calcium carbonate in the form of calcite, a reaction known as **carbonatation**.

When the paint initially dries it is uncured and has almost no strength. It takes up to a few days, depending on climate, to harden.

It has been used throughout the world, indoors and out, on plaster, concrete, masonry, and stone. It is sometimes called limewash. It is a natural antiseptic and deters insects.

To make it a **colour wash**, a small quantity of pigment is added.

12.5.8 Coal – Tar Paint

It is prepared by mixing coal-tar in spirit. It resists moisture, corrosion and keeps the insects away.

It is used to protect wood and metal surfaces which are below the ground level or in contact with moisture.

12.6 Varnishes

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

This layer is transparent, and unlike paint, does not contain any pigment. The result is a shiny substance that covers the wood and protects it.

Resin varnishes "dry" by evaporation of the solvent and harden almost immediately upon drying. Acrylic and waterborne varnishes "dry" upon evaporation of the water but after an extended curing period.

12.6.1 Ingredients of Varnish

Resin

Resins that are used in varnishes include amber, kauri gum, dammar, copal, rosin (pine resin), sandarac, balsam, elemi, mastic, and others. It is a natural or synthetic organic substance which acts as a base and provides body to the varnish. The quality of varnish mainly depends upon the quality of resin.

Turpentine or solvent

Solvent acts as a vehicle of the varnish. It helps in spreading the resin over the varnished surface. Traditionally, natural (organic) turpentine was used as the thinner or solvent, but has been replaced by several mineral based turpentine substitutes such as white spirit or "paint thinner", also known as "mineral spirit".

Drying oil

It helps in drying of the varnish quickly. There are many different types of drying oils which include linseed oil, litharge. Walnut oil, etc. These contain high levels of polyunsaturated fatty acids.

Characteristics of a good varnish

- The film of varnish should be hard, tough and durable.
- It should dry rapidly.
- It should present a uniform and pleasing appearance.
- It should not develop cracks on drying.
- It should effectively resist weathering action and its colour should not fade.

Uses of Varnish

- They can be used to make the surface more matte or glossy.
- Varnishes offer protection for the underlying surface against weathering action.
- It allow for ease of cleaning of the painted object.
- Some varnishes offer additional protection against Ultra Violet Light radiation.
- It beautifies the appearance of painted surfaces and wooden furniture.

12.6.2 Types of Varnishes

Depending upon the type of **solvent** used, varnishes are classified into the following types:

1. Oil varnishes
2. Water varnishes
3. Turpentine varnishes
4. Spirit varnishes

(1) Oil varnishes

In this type of varnish, linseed oil is used as solvent. Hard resins such as amber and copal are dissolved in linseed oil. Small amount of turpentine is added to improve its workability.

They dry slowly and provide hard and durable layer.

Uses

- These are used for exposed surfaces.
- These are used on coaches and domestic fittings.

(2) Water varnishes

In this type of varnish, water is used as solvent. It is prepared by dissolving shellac in hot water. To accelerate dissolving of shellac, small quantity of either ammonia or borax or potash or soda is added.

Uses

- It is used to varnish pictures, maps, etc.
- It is also used for wall papers, etc.

(3) Turpentine varnishes:

In this type of varnish, turpentine is used as solvent. Soft variety of resins such as gum, dammar, mastic and rosin are used. They possess light colour and dry quickly. These are not durable as oil varnishes.

Uses

- Commonly used to give glossy shine to the painted surfaces.

(4) Spirit Varnishes

In this type of varnishes, spirit is used as solvent. Soft variety of resins such as lac or shellac is used. They dry quickly. They cannot withstand weathering action and are not durable.

Uses

- These are generally used for furniture.

French Polish:

It is the finest quality of spirit varnishes. It consists of soft resin like **Shellac** dissolved in **methylated spirit**.

It is made by dissolving 1 kg of shellac in 8 liters of methylated spirit without heat. The solution is then screened through a very fine cloth.

Small amount of pigment is added to obtain the desired colours.

Uses

It is used for ornamental furniture made from high quality wood, hand rails, etc.

Summary / Synopsis

· Paint is defined as a liquid containing suspended pigment

· An oil paint essentially consists of the following ingredients. These ingredients perform certain specific functions:

- Base
- Vehicle or Carrier
- Drier
- Colouring Pigment
- Solvent

Following are different types of paints used for various engineering purposes:

1. Oil paints
2. Enamel paints
3. Emulsion paints
4. Plastic Emulsion paints
5. Cement paints
6. Distemper
7. White wash and Colour Wash
8. Coal tar paint

· Varnish is a transparent, hard, protective film primarily used in wood finishing but also for other materials.

· Ingredients of Varnish are

- Resin
- Solvent
- Drying Oil

· Depending upon the type of **solvent** used, varnishes are classified into the following types:

1. Oil varnishes
2. Water varnishes
3. Turpentine varnishes
4. Spirit varnishes

Short Answer Type Questions

1. Define paint.
2. State the uses of paint.
3. List any four functions of paint.
4. List the ingredients of paint.
5. List out various types of paints.
6. What is varnish?
7. What are the ingredients of varnish?
8. What is Distemper?
9. What is White wash?

Long Answer Type Questions

1. What are the properties of a good paint?
2. What are the properties of a good varnish?
3. What are different types of paints and write their suitability?
4. What are different ingredients of paints? Explain the functions performed by them.
5. Explain briefly about a) Distemper & b) White wash.
6. What are different types of varnishes? Write their uses.

OJT / Assignments

1. Make a visit to hardware shop and find out the market rates of different varieties of paints and their coverage.

UNIT 13

Miscellaneous Materials

Learning Objectives

After studying this unit, you should be able to

- Know about Glass
- Know about Adhesives
- Know about Asbestos
- Know about Thermocol
- Know about Plaster of Paris
- Know about Fibre Reinforced Concrete
- Know about Wall Paper
- Know about P.V.C
- Know about Bitumen and Tar
- Know about Aluminium

13.1 Glass

Glass is usually a transparent or translucent material that has no crystalline structure, yet behaves like a solid. Common glass is generally made of a silicate (such as silicon oxide, or quartz) combined with other substances and melting the minerals at temperatures around 1700 degrees Celsius. Other materials that

can be added to produce different colours or properties include minerals like cobalt or sulphur, etc.

Glass used in windows and windshields, called **soda glass**, is made by melting a silicate with sodium carbonate (soda) and calcium oxide (lime).

Other types of glass are made by adding other chemical compounds. Adding boron oxide results in a tougher glass that remains solid at high temperatures, used for cooking utensils and scientific apparatus. Glass used for decorative purposes often has iron in it to alter its optical properties.

While it is still molten (a hot liquid), glass can be manipulated by glass blowers to form bottles and other decorative articles. They blow air into the liquid glass through a long pipe.

General Properties

1. It is a good heat, sound, and electric insulator.
2. It has no definite crystalline structure.
3. It is extremely brittle.
4. It can take up high polish.
5. It reflects, absorbs and transmits light.
6. It has no sharp melting point. It varies between $1400^0 - 1500^0$ C.
7. It is resistant to most of the chemicals.
8. It can be welded but difficult to be cast into large pieces.

Fig. 13.1 Glass Blocks used in Bathrooms

9. It is available in beautiful colours.

10. It can be reinforced with steel wires.

11. With modern technology, it can be made lighter than cork, softer than cotton and stronger than steel. It can be made bullet-proof.

12. It can be moulded into articles of desired shapes.

13. It is not usually affected by air or water.

Uses of different types of Glass

1. Soda Glass

It is the cheapest & most common glass. It is prepared by fusing soda ash, sand, and limestone. It is also called soft glass. It fuses at comparatively low temperatures. The major disadvantage of using this glass is that it is brittle & breaks easily. It cracks when subjected to sudden changes of temperature.

Soda glass is used for the manufacture of **window glass**, **mirrors**, **common glassware** etc. it is easily attacked by chemicals.

2. Hard Glass

It is obtained by fusing potassium carbonate & limestone. It is used for making hard glass apparatus. It is more resistant to the action of acids.

3. ead Crystal Glass

It is made from potassium carbonate, lead oxide & sand. Lead glass has high refractive index. It, therefore, sparkles & is used for making expensive glass ware. The surface of lead glass objects is often cut into decorative patterns to reflect light. Cut glass show extraordinary sparkle.

4. Pyrex Glass

It is made by fusing a mixture of sand, lime, borax ($Na_2B_4O_7.10H_2O$) & alkali carbonates. It is used to make good chemical laboratory apparatus, ampoules, pharmaceutical containers, et. In home, it is familiar with oven ware.

5. Opitcal Glass

It is specially made so as to be free of strains & defects. It is used for making lenses for spectacles, microscopes, cameras, telescopes & other optical instruments.

6. Photochromic Glass

It is a special variety of glass that temporarily darkens when exposed to bright light. It is, therefore, very useful as a sun-shield. This automatic darkling property of photo chromatic glass is because of the presence of silver bromide.

7. Safety Glass

It is prepared by placing a layer of transparent plastic between the two layers of glass by means of suitable adhesive. The 3 layers are joined together by the action of heat & pressure. The glass does not break easily under ordinary impact, & that is why it is known as safety glass. It is used in making wind screens of aero planes, automobiles, bulletproof glass etc.

8. Glass Fibres

It is in the form of fibres. It has varied applications in most of the industries. Glass wool is a bundle of loose glass fibres, which is an excellent heat insulator. it is used as insulating material in refrigerators, ovens etc. Another important class of glass fibre is optical fibres which are extensively used in telecommunication, surgical operation etc

9. Coloured Glass

These are obtained by adding certain colouring material, such as metallic oxides, to the molten mass. Different additions may produce different coloured glasses.

13.2 Adhesives

An adhesive is a substance used for sticking objects or materials together. It is usually in the form of liquid or semi-liquid state. Examples are Fevicol, Feviquick, Araldite, etc.

The types of materials that can be bonded are vast but they are especially useful for bonding thin materials. Adhesives cure (harden) by either evaporating a solvent or by chemical reactions that occur between two or more constituents.

Adhesives are advantageous for joining thin or dissimilar materials, minimizing weight. The main disadvantage of most adhesives is that they do not form an instantaneous joint because the adhesive needs time to cure.

Advantages

Following are the advantages of Adhesives over the conventional methods of Bolting, Riveting and Welding:

- Vast variety of materials can be bonded.
- Weight can be minimized by bonding either similar or dissimilar materials.
- It produces sufficient strength.
- Their application is easy, economical and quick.
- Corrosion between different metals joined can be prevented.
- Impermeable joints can be made.
- It creates a massive effect.

Disadvantages:

- They are not stable at high temperature and pressure.
- Sometimes they fail to attain desired strength.
- One single adhesive for all materials is not available. Suitable adhesive has to be selected for different materials.

13.3 Asbestos

Asbestos is the name given to a group of fibrous, naturally occurring **silicate minerals**. It is composed of hydrous silicates of calcium and magnesium. They generally exist in nature in metamorphic or igneous rocks.

Asbestos is resistant to heat and most chemicals (most forms are chemically inert). The fibers do not evaporate into air or dissolve in water. They have no odor or smell and do not migrate through soil. At least 5,000 different products have been manufactured from asbestos.

Long exposure to high concentrations of asbestos fibers will cause health problems.

Properties of Asbestos

- It has tremendous resistance to heat and electricity.
- It is chemically inert.
- It has no odor or smell and does not dissolve in water.
- Its tensile strength is better than that of steel.
- It is non-flammable.
- It binds very well with cement and other insulating materials which makes it an excellent building material.

- It is available in a range of shades, viz. blue, green and grey depending upon the composition.
- It is easily workable. It can be cut, drilled and screws can be fitted easily.
- It is flexible, smooth and non-porous.

Fig. 13.2 Asbestos

Fig. 13.3 Asbestos Fibers

Uses of Asbestos

Following are the uses of asbestos:

- The most popular use is asbestos-cement **roofing sheets**. They are prepared by mixing cement and asbestos fibers and moulded into corrugated or

flat sheets. **Corrugated sheets** are used as roofing material, whereas, **flat sheets** are used for door and window shutter panels, false ceiling, thermal insulation and for fire exits.

- Other important applications in construction include:
- Asbestos cement **sewage pipes**,
- Insulating cement, insulating block, pipe covering,
- Acoustical panels/plaster,
- Floor tile, ceiling tile,
- Insulation for Heating, Ventilation and Air Conditioning (HVAC) systems,
- Insulated electrical wire and panels,
- Fire bricks, fireproofing spray, fire door interiors, refractory and boiler insulation materials.

13.4 Thermocol

Thermocol contains a thermoplastic compound, called polystyrene. It is commercially manufactured from petroleum.

It is manufactured through a simple process. Thermoplastic granules are expanded through application of steam and air. Expanded granules become much larger in size but remain very light.

Thermocol is a good resister of cold and heat but since it is a petroleum product it dissolves in any solvent of petroleum.

Fig. 13.4 Thermocol

Properties of Thermocol:

- It contains 3-6 million discreet cells per liter giving it excellent insulating properties.
- It can be cut easily with simple tools like knife or a saw.
- It can be painted with Plastic Emulsion paints or water bound distemper.
- It has a high insulating efficiency, resistance to moisture, adequate structural strength and dimensional stability makes it easy to use.
- Thermocol insulation is permanent and lifelong.
- It is not environment friendly and proper care should be taken while disposing off.

All these attributes explain the outstanding insulation properties and remarkable resistance to moisture vapor penetration, making it the ideal low temperature insulation material with the best combination of desirable properties.

Availability in the Market:

The thermocol is available in the form of rectangular slabs, semi-circular pipe sections etc.

Uses of Thermocol

Thermocol Products work against heat, cold, sound and humidity. Thermocol is widely used as packaging material, roof & wall insulation material and for various industrial applications.

Insulation

In **Refrigeration,** it is used in industrial refrigeration, cold storage, cooled rooms, refrigerated trucks, domestic refrigerator and air-conditioning ducts.

In Building Construction:

In building construction, it is used for heat insulation for ceilings, false ceilings, roofs, walls, floors, floating floors, doors, partitions and cemented water tanks.

Acoustic Insulation:

It is used for sound insulation in cinema halls, factories, offices and residential buildings.

For Packaging:

It is used for packing fragile products and delicate equipments such as electronic goods, glassware (molded and hand cuts) and similar products.

It can also be used as a source of **display** in exhibitions and for multiple types of **decorations**.

13.5 Plaster of Paris (POP)

Plaster of Paris is basically a building material that consists of a fine, white-colored powder, known as calcium sulfate hemihydrate.

It is made by heating the mineral **gypsum**. Large deposits were originally found outside of Paris in France hence its name.

Unlike mortar and cement, plaster remains quite soft after setting, and can be easily manipulated with metal tools or even sandpaper. These characteristics make plaster suitable for a finishing, rather than a load-bearing material.

Fig. 13.5 Plaster of Paris

(i) When gypsum is heated to about 150°C, it losses water and produces the powdery white substance called plaster of Paris.

Gypsum + heat => Plaster of Paris + steam

$$2CaSO_4 \cdot 2H_2O + heat => 2CaSO_4 \cdot ½H2O + 3H_2O$$

(Two molecules of Calcium Sulphate together hold one water molecule. So no. of water molecules per molecule of Calcium Sulphate is said to be 1/2. So the formula is often written as $CaSO_4.1/2H_2O$.)

(ii) The process of making plaster of Paris is reversible; meaning that if the dry plaster powder is mixed with water, it re-forms into gypsum.

When water is added to the plaster of Paris powder it rehydrates (absorbs water) and quickly hardens.

Plaster of Paris + water ==> Gypsum

$2CaSO_4 \cdot ½H_2O + 3H_2O$ ==> $2CaSO_4 \cdot 2H_2O$ + heat

The chemical formula for plaster of Paris is **$CaSO_4 \cdot ½H_2O$** which means that there is one molecule of water around two molecules of $CaSO_4$ group.

Properties and Uses

It is used for construction purposes, either by mixing with other substances or as a finishing material. However, plaster of Paris is widely used in home decors; various designs can be made in the walls and ceilings. For many modern sculptors, it is a favorite sculpting material, mainly because of its easy occurrence and speed of setting. In addition to arts and architecture, plaster of Paris is also used in orthopedics to make smooth casts for broken limbs. In forensic science, molds of footprints and other important markings are made by using plaster of Paris for further investigation.

· It is resistant to fire and heat. It is used as an insulation to protect wood or metal columns and beams from high temperatures.

· It is light in weight. Sometimes, fillers such as saw dust, granules of cork, etc, are added to make it still lighter and to improve its sound and heat insulation qualities.

· It is practically unaffected by bacteria.

· It cannot be used for wet surfaces as it is slightly soluble in water.

· It sets in 5 to 10 minutes. That is why; small quantities should only be mixed. To prolong its setting time fillers are added to it. It should not be handled with bare hands. Rubber glows and goggles should be used.

· It shows negligible shrinkage upon drying. So moulds of actual dimensions can be used for castings.

· It seals thin cracks in the plastered surfaces.

· It is used in the ornamental plastering works. Gypsum boards are used for false ceiling, partition walls and internal linings. They are easy to use, repair, light in weight, and fire proof.

· Plaster of Paris (POP) is used in artwork, pottery, dentistry, and in orthopedics to make smooth casts for fractured bones.

- Large amounts of plaster of Paris placed directly onto the skin can cause serious burns because of the heat produced!

13.6 Fiber-reinforced concrete (FRC)

Fiber-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers. Within these different fibers that character of fiber-reinforced concrete changes with varying concretes, fiber materials and their shape, distribution, orientation and densities.

Effect of fibers in concrete

Fibers are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete.

Using fibers in concrete has limited effect on the impact resistance of the materials. The use of micro fibers offers better impact resistance compared with the longer fibers.

Benefits

Polypropylene and **Nylon fibers** can:

- Improve impact resistance
- Increase resistance to plastic shrinkage during curing
- Improve mix cohesion, improving pumpability over long distances(in case of Ready Mix Concrete)
- Improve freeze-thaw resistance (property of solids to resist cyclic freezing and melting)
- Improve resistance to explosive chipping in case of a severe fire

Steel fibers can:

- Improve structural strength
- Reduce steel reinforcement requirements
- Improve ductility

- Reduce crack widths and control the crack widths tightly thus improve durability
- Improve impact & abrasion resistance
- Improve freeze-thaw resistance

To take the advantages of benefits of both products, both steel and polymeric fibers are often used in combination in the construction projects.

In certain specific circumstances, steel fiber can entirely replace traditional steel reinforcement bar in reinforced concrete. This is most common in industrial flooring but also in some other precasting applications. These are subjected to the approval of laboratory testing to confirm performance requirements are met.

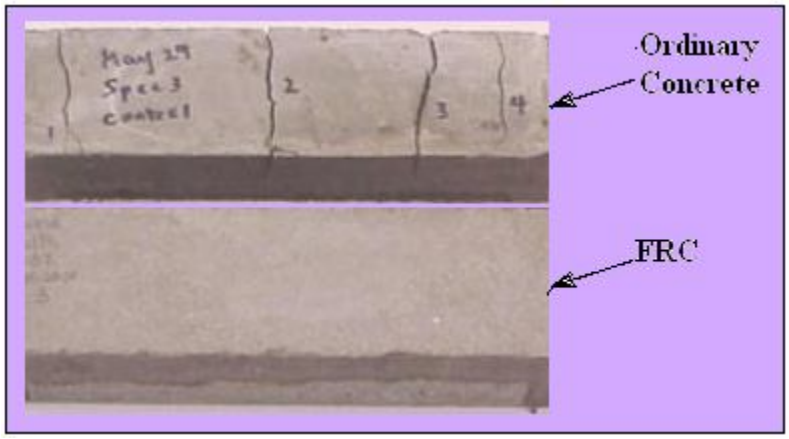


Fig. 13.6 Difference between Ordinary Concrete and FRC

Properties of some Fibers used as Reinforcement in Concrete

Fiber type	Tensile strength (MPa)	Tensile modulus (GPa)	Tensile strain (%)(max-min)	Fiber diameter (?m)	Alkali stability, (relative)
Asbestos	600-3600	69-150	0.3-0.1	0.02-30	excellent
Carbon	590-4800	28-520	2-1	7-18	excellent
Polypropylene	200-700	0.5-9.8	15-10	10-150	excellent
Rayon	450-1100	up to 11	15-7	10-50	fair
Polyvinyl Alcohol	800-1500	29-40	10-6	14-600	good

Polyacrylonitrile	850-1000	17-18	9	19	good
Polyethylene	400	2-4	400-100	40	excellent
Polyethylene pulp (oriented)	–	–	–	1-20	excellent
High Density Polyethylene	2585	117	2.2	38	excellent
Carbon steel	3000	200	2-1	50-85	excellent
Stainless steel	3000	200	2-1	50-85	excellent
AR- Glass	1700	72	2	12-20	good

13.7 Wall Paper

Wall papers are used to beautify the interior walls of the building. They are prepared exclusively with paper or in combination with other materials. They are either printed, coated or embossed and available in different colours.

Fig. 13.7 Wall Paper

Before pasting the wall paper, the surface has to be made free from loose matter and cracks. The surface should be leveled and dried. Wall putty is used to fill the cracks and level the surface. The wall paper is then pasted carefully using suitable paste.

The surface of the wall paper may be varnished for better appearance and to protect its surface. Washable and metal coated wall papers are also available in the market.

13.8 P.V.C Pipes

Polyvinyl chloride (PVC) is a versatile building material. Its popularity is increasing day by day. Pure polyvinyl chloride without any plasticizer is a white, brittle solid.

Fig. 13.8 P.V.C Pipes

It is insoluble in alcohol, but slightly soluble in **tetrahydrofuran (**A colorless liquid (**C_4H_8O**) used chiefly as a **solvent for plastics)**. It can be made softer and more flexible by the addition of plasticizers.

Its properties can be modified according to the strength requirements by adding other substances called additives.

It is used for door and window shutters and pipes in the building construction. The other applications of PVC include bottles, cables, bags, tubes, floor coverings, furniture, etc.

PVC Pipes

A polyvinyl chloride (PVC) pipe is made from a plastic and vinyl combination material. The pipes are durable, hard to damage, cheap and easily worked. A

PVC pipe does not rust, rot, or wear over time. For that reason, PVC piping is most commonly used in water systems, underground wiring, and sewer lines.

Due to the ability of PVC pipe to withstand extreme movement and bending, it is also increasingly used in earthquake prone areas; it can withstand the rigorous shaking of the earth without experiencing any damage. The smooth surface of the PVC pipe is also resistant to bacterial contamination, such as E. coli. Therefore, water can be kept free of contamination.

Advantages PVC Pipes

· Corrosion Resistance: PVC pipes are non-conductors of electricity and immune to electrochemical reactions caused by acids, bases, and salts that cause corrosion in metals.

· Chemical Resistance: PVC pipes exhibit resistance to a wide range of chemical reagents in temperatures up to 140 °F and are resistant to chemicals normally found or used in homes.

· Light Weight: A person can easily carry two 20-foot lengths of 4-inch PVC pipe, but could carry less than 5 feet of 4-inch iron pipe with the same effort.

· Flexibility: While PVC pipes are made from rigid (unplasticized) PVC compound, the pipe itself has the ability to yield under loading without fracturing.

· Long-Term Tensile Strength: The long-term hydrostatic design basis (HDB) for PVC is two or more times greater than that for other common thermoplastic pipe materials.

· Abrasion/Wear Resistance: PVC pipes exhibit outstanding resistance to wear and abrasion.

· Impact Strength: Under normal conditions, PVC pipes possess relatively high resistance to impact damage when compared to pipes made from clay, concrete, and most other conventional materials.

· Coefficient of Friction: PVC pipes provide smoother wall surfaces that reduce fluid friction and resistance to flow.

· Water Quality: PVC pressure pipes do not adversely alter water quality. There are no corrosion by-products with PVC pipe.

Disadvantages of PVC Pipes

· They cannot be used at high temperatures and pressures.

- They are liable to creep.
- Their strength is not comparable to Cast-Iron or Galvanized-Iron Pipes.
- They tend to expand more than C.I or G.I pipes.

PVC DOORS

Fig. 13.9 PVC Doors & Windows

Advantages of PVC Doors

- **Water Proof:** They are waterproof and do not expand, contract or warp when they come in contact with water.
- **Termite Proof:** Termites or other insects cannot harm them.
- **Maintenance Free:** Because of its smooth surface, it is easy to clean.
- **Easy to Install:** It is very quick & easy to install them.
- **Economical:** Their price is low.
- **Durability:** PVC Doors last around 12years.
- They are **resistant to fungal and bacterial growth**.
- **Resistance to Weathering:** Weather has no effect on PVC building materials. Problems like rotting, rust, etc. do not occur. They are suitable to coastal areas also.
- **Thermal Insulation:** They have low thermal conductivity. Thermal conductivity is the measurement of the speed at which heat travels through a material.
- **Availability in Different Sizes:** they are available in different sizes and colour in the market.

- They are **bendable** and **bondable.**

13.8 Bitumen and Tar

Bitumen

Bitumen is an oil based substance. It is a semi-solid hydrocarbon produced by removing the lighter fractions (such as liquid petroleum gas, petrol and diesel) from heavy crude oil during the refining process. The process is known as fractional distillation of petroleum. It is black or brownish black in colour. It is solid or semi-solid in state.

Bitumen is also commonly known as "asphalt cement" or "asphalt". Asphalt is the term used for a mixture of sand, filler and bitumen, which is used as a road paving material. The asphalt mixture contains approximately 5% bitumen. At ordinary temperatures bitumen is a stable, semi-solid substance.

Fig. 13.10 Bitumen

Uses of Bitumen

- It is used in the construction of roads and pavements.
- It is used as a waterproofing material for roofs, swimming pool, canal lining, dam construction and river bank protection.
- It is used to protect the wooden and metal surfaces which are below the ground level.
- It is used as a damp proof course.
- It is used in the manufacture of bitumen paints.

Tar

Tar is a dark black liquid with high viscosity. It is obtained by destructive distillation of carbonatious matter.

Tar may be classified into the following three categories depending upon its source:

1. Coal tar
2. Mineral tar
3. Wood tar.

1. Coal tar: Coal tar is a brown or black liquid of extremely high viscosity. Coal tar is among the by-products when coal is carbonized to make coke or gasified to make coal gas. It is used for road pavement construction and wood preservation.

2. Mineral Tar: it is obtained by distillation of bituminous shale. It is also called maltha.

3. Wood Tar: a dark viscous product obtained from wood by distillation or by slow burning without flame. It is used in its natural state to preserve timber, rope, etc. it is obtained by the distillation of pines and similar resinous wood.

13.9 Aluminium

Aluminium is a silvery white metal which is relatively soft, durable and light in weight. It is the most abundant metal in the Earth's crust. The chief ore of aluminium is **bauxite (Al_2O_3, $2H_2O$)**.

Fig. 13.11 Aluminium Sections

Properties

- Aluminium is a very light metal with a specific weight of 2.7 g/cm3, about a third that of steel.
- It is soft, ductile and malleable.
- It possesses great toughness and tensile strength.
- It is an excellent heat and electricity conductor.
- It is a good reflector of visible light as well as heat.
- It is highly corrosion resistant.
- It is very easy to machine. Ordinary machining equipment can be used such as saws and drills.
- It can be welded and riveted.
- Its melting point is 660.4^0C
- Aluminium is 100 percent recyclable with no downgrading of its qualities.

Uses

- It is used for window frames.
- It is used for hand railings.
- It is used for roofing, siding, and curtain walling, as well as for door handles, catches for windows, staircases, heating and air-conditioning systems.
- It is also used for other applications like aircraft industry, manufacture of electric cables, cooking utensils, surgical instruments, photographic flash lights, etc.

Summary / Synopsis

- **Glass** is a mixture of metallic silicates used for glass tubes, laboratory apparatus, window glass, artificial gems, electric bulbs, prisms, medicine bottles.

- **Common glass** is generally made of a silicate (such as silicon oxide, or quartz) combined with other substances and melting the minerals at temperatures around 1700 degrees Celsius.

- Different types of glass are: Soda Glass, Hard Glass, Lead Crystal Glass, Pyrex Glass, Optical Glass, Photochromatic Glass, Safety Glass, Coloured Glass & Glass Fibres.

· An **adhesive** is a substance used for sticking objects or materials together. It is usually in the form of liquid or semi-liquid state. Examples are Fevicol, Feviquick, Araldite, etc.

· **Asbestos** is the name given to a group of fibrous, naturally occurring **silicate minerals**. It is composed of hydrous silicates of calcium and magnesium.

· **Thermocol** contains a thermoplastic compound, called polystyrene. It is commercially manufactured from petroleum.

· **Plaster of Paris** is basically a building material that consists of a fine, white-colored powder, known as calcium sulfate hemihydrate. It is made by heating the mineral **gypsum**.

Gypsum + heat => Plaster of Paris + steam.

The process of making plaster of Paris is reversible:

Plaster of Paris + water ==> Gypsum

· **Fiber-reinforced concrete** (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers.

· **Wall papers** are used to beautify the interior walls of the building. They are prepared exclusively with paper or in combination with other materials.

· A **polyvinyl chloride** (PVC) pipe is made from a plastic and vinyl combination material. The pipes are durable, hard to damage, cheap and easily worked. A PVC pipe does not rust, rot, or wear over time.

· **Bitumen** is an oil based substance. It is a semi-solid hydrocarbon produced by removing the lighter fractions (such as liquid petroleum gas, petrol and diesel) from heavy crude oil during the refining process.

· **Linoleum** is mixture of oxidized unseed oil pulverized cork, wood flour, pigments and colour, all spread in a uniform layer on canvas the surface of which may be painted in different patterns, the surface is then water-proofed with the help of an oil paint.

Short Answer Type Questions

1. What are the properties of plastics?
2. Name any four uses of plastics.
3. What are the uses of glass?

4. What are the uses of adhesives?
5. Name any four uses of asbestos.
6. What are the uses of Thermocole?
7. What is the importance of plaster of paris in the building construction industry?
8. Name the uses of linoleum
9. What are the uses of wall paper?
10. Write the uses of bitumen & tar
11. What are the uses of plasticrete?

Long Answer Type Questions

1. What are the general properties of Glass?
2. What are the advantages and disadvantages of Adhesives?
3. What are the properties and uses of Asbestos?
4. What are the properties and uses of Thermocol?
5. What are the benefits of Fiber Reinforced Concrete?
6. What are the advantages and disadvantages of PVC pipes?
7. What are the properties and uses of Aluminium?
8. Write a short note on Bitumen and Tar?