# VISVESVARAYA TECHNOLOGICAL UNIVERSITY
# BELGAUM

## GREEN BUILDINGS

## (Subject Code: BETCK105B)

## LECTURE NOTES

## (MODULE-1)

### I-SEMESTER


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# Module -1

## Introduction to the Concept of Cost-Effective Construction

### Uses of different types of materials and their availability

### STONE

Stone is a 'naturally available building material' which has been used from the early age of civilization.

It is available in the form of rocks, which is cut to required size and shape and used as building block.

It has been used to construct small residential buildings to large palaces and temples all over the world. Red Fort, TajMahal, VidhanSabha at Bangalore and several palaces of medieval age all over India are the famous stone buildings.

**Classification of Rocks:**

Building stones are obtained from rocks occurring in nature and classified in three ways.

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

**1. Geological Classification:**

According to this classification, the rocks are of the following types.

a. **Igneous rocks:** Rocks that are formed by cooling of Magma (molten or pasty rocky material) are known as igneous rocks.Eg: Granite, Basalt and Dolerite etc.

b. **Sedimentary rocks:** these rocks are formed by the deposition of production of weathering on the pre-existing rocks. Examples: gravel, sandstone, limestone, gypsum, lignite etc.

c. **Metamorphic rocks.** These rocks are formed by the change in character of the pre-existing rocks. Igneous as well as sedimentary rocks are changed in character when they are subject to great heat and pressure. Known as metamorphism. Examples: Quartzite, Schist, Slate, Marble and Gneisses.

**2. Physical Classification:**

This classification based on general structure of rocks.

According to this, the rocks are classified into three types

a. **Stratified Rocks:** These rocks possess planes of stratification or cleavage and such rocks can be easily split along these planes.

Ex: sedimentary rocks

b. **Unstratified rocks:** The structure may be crystalline granular or compact granular. Examples: Igneous rocks and Sedimentary rocks affected by movements of the earth.

c. **Foliated Rocks:** These rocks have a tendency to split up in a definite direction only. Ex: Metamorphic rocks.

**3. Chemical Classification:**

According to this classification rocks are classified into threetypes.

a. **Siliceous rocks:** In these rocks, silica is predominating. The rocks are hard; durable and not easily effected by weathering agencies. Ex: Granite, Quartzite, etc.

b. **Argillaceous Rocks:** In these rocks, clay predominates. The rocks may be dense and compact or may be soft.

Ex: slates, Laterites etc.

c. **Calcareous rocks:** In these rocks, calcium carbonate predominates. The durability to these rocks will depend upon the constituents present in surrounding atmosphere. Ex: Lime Stone,marble etc.

**Uses of stones:**

- **Structure**: Stones are used for foundations, walls, columns, lintels, arches, roofs, floors, damp proof course etc.
- **Face works.** Stones are adopted to give massive appearance to the structure. Wall are of bricks and facing is done in stones of desired shades. This is known as composite masonry.
- **Paving stones:** These are used to cover floor of building of various types such as residential commercial, industrial etc. They are also adopted to form paving of roads, foot paths etc.
- **Basic material**: Stones are disintegrated and converted to form a basic material for cement concrete, morum of roads, calcareous cements, artificial stones, hallow blocks etc.

- **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.

**Qualities of a good building stone**: The following are the qualities or requirements of a good building stone.

**1. Crushing strength**: For a good building stone, the crushing strength should be greater than l000kg per $cm^2$.

**2. 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 long time.

**3. Durability**: A good building stone should be durable. The factors like heat and cold alternative wet and dry, dissolved gases in rain, high wind velocity etc affect the durability.

**4. Fracture:** For good building stone its fracture should be sharp, even and clear.

**5**. **Hardness:** The hardness greater than 17, treated as hard used in road works. If it is between 14 to 17, medium hardness, less than 14 is said be poor hardness.

**6. Percentage wear**: For a good building stone, the percentage wear should be equal to or less than 3 percent.

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

**8**. **Specific gravity:** For a good building stone the specific gravity should be greater than 8.7 or so.

**9. Texture**: A good building stone should have compact fine crystalline structure should be free from cavities, cracks or patches of stuff or loose material.

**DETERIORATION OF STONE:**

Deterioration of stone occurs due to the following reasons

1. Rain
2. Frost
3. Wind

4. Temperature change
5. Mutual decay
6. Chemical agent
7. Vegetation growth

(1) **Rain:** Rain water acts both physically and chemically on stones. The physical action is due to the erosive and transportation powers and the latter due to the decomposition, oxidation and hydration of the minerals present in the stones.

(2) **Frost:** In cold places frost pierces the pores of the stones where it freezes, expands and creates cracks.

(3) **Wind:** Since wind carries dust particles, the abrasion caused by these deteriorates the stones.

(4) **Temperature change:** Expansion and contraction due to frequent temperature changes cause stone to deteriorate especially if a rock is composed of several minerals with different coefficients of linear expansion.

(5) **Mutual decay**: When different types of stones are used together mutual decay takes place. For example, when sandstone is used under limestone, the chemicals brought down from limestone by rain water to the sandstone will deteriorate it.

(6) **Chemical agent**: Smokes, fumes, acids and acid fumes present in the atmosphere deteriorate the stones. Stones containing $CaCO_3$, $MgCO_3$ are affected badly.

(7) **Vegetation growth:** Roots of trees and weeds that grow in the masonry joints keep the stones damp and also secrete organic and acidic matters which cause the stones to deteriorate. Dust particles of organic or nonorganic origin may also settle on the surface and penetrate into the pores of stones. When these come in contact with moisture or rain water, bacteriological process starts and the resultant micro-organism producing acids attack stones which cause decay.

**PRESERVATION OF STONE:**

- Stones should be kept dry with blow lamp and applied coat of paraffin, linseed oil, light paint, etc.
- Stones should be washed with water and steam to remove dirt and salt.
- In industrial towns stones are preserved by application of solution of barite, $Ba(OH)_2$ to form insoluble barium sulphate.

- Preservative treatment only slows down the decay but does not stop it. All have harmful side effects also.

**Laterite Blocks**

Laterite stones are manual or machine-cut block pieces from quarries or mines containing lateritic crusts.

Laterite is a soft rock composed of iron & aluminum oxides as the main ingredient. Due to the weathering actions, in hot & wet tropical areas, lateritic soil gradually gains strength to become a hard mass.

These hard layers of laterite are cut into blocks of required sizes & transported for the building construction works.

**Advantages:**

1. They keep the building cool in the summer season as they are quarried natural stones.
2. Laterite stones have good thermal insulation properties.
3. The stone provides a rustic natural look to the building.
4. The stone hardens & gains strength as time progresses.
5. Due to its larger size, it is cost-effective by reducing labor & other material charges.
6. Plastering is not compulsory for laterite masonry works.
7. Environment friendly as they do not emit CO2 & greenhouse gases.

**Disadvantages:**

1. The strength of the block is not uniform.
2. Laterite stone blocks are available in limited regions.
3. Stone dressing is needed before masonry work to match the sizes.
4. Laterite stones are avoided in multistory buildings due to their weight & chemical composition.

**Burned Bricks**

Brick is obtained by moulding good clay into a block, which is dried and then burnt. This is the oldest building block to replace stone. Manufacture of brick started with hand moulding, sun drying and burning in clamps. A considerable amount of technological development has taken place with better knowledge about to properties of raw materials, better machineries' and improved techniques of moulding drying and burning. The size of the bricks is of 190 mm × 90 mm × 90 mm and 190 mm × 90 mm × 40 mm. With mortar joints, the size of these bricks is taken as 200 mm × 100 mm × 100 mm and 200 mm × 100 mm × 50 mm.

## Composition - Manufacture Process.

Composition – Following are the constituents of good brick earth.

**Alumina**: - It is the chief constituent of every kind of clay. A good brick earth should contain 20 to 30 percent of alumina. This constituent imparts plasticity to earth so that it can be moulded. If alumina is present in excess, raw bricks shrink and warp during drying and burning.

**Silica-**A good brick earth should contain about 50 to 60 percent of silica. Silica exists in clay either as free or combined form. As free sand, it is mechanically mixed with clay and in combined form; it exists in chemical composition with alumina. Presence of silica prevents crackers shrinking and warping of raw bricks.

**Lime –** A small quantity of lime is desirable in finely powdered state to prevents shrinkage of raw bricks. Excess of lime causes the brick to melt and hence, its shape is lost due to the splitting of bricks.

**Oxide of iron**- A small quantity of oxide of Iron to the extent of 5 to 6 percent is desirable in good brick to imparts red colour to bricks. Excess of oxide of iron makes the bricks dark blue or blackish.

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

**Manufacture of bricks**: The manufacturing of brick, the following operations are involved

1. Preparation of clay
2. Moulding
3. Drying
4. Burning

**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

**Classification**: Bricks can broadly be divided into two categories.

(i) Unburnt or sundried bricks
(ii) Burnt bricks

**Un burnt or Sun-dried bricks**- Un burnt or sun dried with the help of heat received from sun after the process of moulding. These bricks can only be used in the constructions of temporary and cheap structures. Such bricks should not be used at places exposed to heavy rains.

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

**i.) 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. The comply all the qualities of good bricks and used for superior work of permanent nature.

**ii.) Second class bricks**: These bricks are ground moulded and they are burnt in kilns. The surface of bricks is somewhat 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.

**iii.) 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.

**iv.) 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.

**Qualities of Good Brick**:

(i) Bricks should be table moulded, well burnt in kilns, copper coloured, free from cracks and with sharp and square edges.
(ii) Bricks should be uniform shape and should be of standard size.
(iii) Bricks should give clear ringing sound when struck each other.
(iv) Bricks when broken should show a bright homogeneous and compact structure free from voids.

(v) Bricks should be low thermal conductivity and they should be sound proof.

(vi) Bricks should not break when dropped flat on hard ground from a height of about one meter.

**Concrete Blocks**

A Concrete Block is a 'Building Block' composed entirely of concrete that is then mortared together to make an imposing, long-lasting construction. These construction blocks can be 'Hollow' or 'Solid,' formed of ordinary or lightweight concrete in various specified sizes, depending on the precise requirements. Concrete blocks come in various shapes and sizes, and they can be solid or hollow. 39cm x 19cm x (30cm or 20 cm or 10cm) or 2-inch, 4-inch, 6-inch, 8-inch, 10 inch, and 12-inch unit configurations are the most popular concrete block sizes. Concrete blocks are made from cement, aggregate (sand, gravel), and water. In concrete blocks, the cement-aggregate ratio is 1:6. Concrete block construction has gained importance and has become a valid alternative to fired clay bricks. Concrete blocks are produced in a large variety of shapes and sizes. They can be produced manually or with the help of machines.

**Types of Concrete Blocks:**

There are two types of concrete blocks:

1. Solid Concrete Blocks
2. Hollow Concrete Blocks

Solid concrete blocks, which are highly heavyweight and formed by aggregate, are primarily utilized in construction projects. They're sturdy and give structures a lot of solidities. These solid blocks are ideal for large-scale projects such as force-bearing walls. They're compared to bricks that come in big sizes. As a result, constructing concrete masonry takes less time than brick masonry.

Solid blocks have no cavities, or- according to US standards- have no voids amounting to not more than 25% of the gross cross-sectional area.

In masonry construction, hollow concrete blocks are typically employed. It reduces labour costs on the job site while also speeding up the construction process and saving cement and steel. These blocks reduce the natural weight of masonry structures while also improving physical wall qualities like noise and thermal insulation. Standard hollow concrete blocks come in two sizes: Full size and half size. Half-sized blocks are cubical and have one core, while full-sized blocks are rectangular and have two cores. The nominal size of concrete

blocks, according to the 'Research Designs & Standards Organization of Indian Railways,' is as follows:

i) 400, 500, or 600 mm in length ii) 200 or 100 mm in height iii) 50, 75, 100, 150, 200, 250, or 300 mm in width.

Hollow concrete blocks come in various shapes, sizes, and designs, depending on the shape, needs, and design.

Hollow blocks are the most common type of concrete blocks, having one or more holes that are open at both sides. The total void area can amount to 50% of the gross cross-sectional area.

**Advantages of Concrete Blocks**

- The reduced wall thickness due to narrower Concrete Blocks than a traditional brick masonry wall makes the space is larger by increasing the carpet surface.
- Concrete block building is more systematic, faster, and stronger than brick masonry because of the vast size of the blocks.
- Better thermal insulation is provided.
- It effectively absorbs sound and protects the interiors from noise pollution. Using concrete blocks provides additional fire protection.
- Protects precious agricultural land that is extensively mined to produce clay bricks.
- Individual pieces can be manufactured to a larger customized size and shape, allowing for a quick building cycle turnaround.
- Concrete Blocks, unlike traditional bricks, have a consistent size that lowers the need for plaster, making them a more cost-effective solution. The mortar consumption rate is lower than in traditional masonry construction, but the overall strength of the structure is increased.

**Disadvantages of Concrete Blocks**

- The expense of constructing a residence out of concrete blocks is significantly higher.
- Some of the blocks may need to be cut to reach critical systems.
- Concrete block homes aren't usually attractive from the outside.
- Over time, concrete blocks may be subject to water seepage.
- Some regional preferences may not be compatible with this material.
- Windows and doors can easily detract from the environmental benefits.

**Uses of Concrete Blocks**

- Concrete Blocks are a great option for partition walls because they are quick and easy to install. The inclusion of steel reinforcement adds to the structure's strength.
- Exterior and Interior Load-bearing Walls, Partition Walls, Panel Walls, and Boundary Walls are common uses for Hollow Concrete Blocks.
- Solid Concrete Blocks are perfect for Chimney and Fireplace building, but they also work well for Non-load Bearing Walls and Garden Walls.
- Concrete blocks are also used in a variety of smaller landscaping projects. Many Outdoor Furniture & Patio ideas, for example, include Outdoor Seating, Decorative screens, Outdoor Bar, Flower Bed, and many others.
- Concrete blocks can cover stored commodities from the effects of changing weather. It's no surprise that engineers prefer it to construct Material Bins.

**Stabilized Mud Blocks**

Earth block is a construction material made primarily from soil. Types of earth block include compressed earth block (CEB), compressed stabilized earth block (CSEB), and stabilized earth block (SEB).

Stabilized mud block (SMB) or pressed earth block is a building material made primarily from damp soil compressed at high pressure to form blocks. If the blocks are stabilized with a chemical binder such as Portland cement, they are called compressed stabilized earth block (CSEB) or stabilized earth block (SEB). Creating SMBs differs from rammed earth in that the latter uses a larger formwork into which earth is poured and manually tamped down, creating larger forms such as a whole wall or more at one time rather than building blocks and adobe which is not compressed. Stabilized mud block uses a mechanical press to form block out of an appropriate mix of fairly dry inorganic subsoil, non-expansive clay, aggregate, and sometimes a small amount of cement.

Soil is very widely available on earth. And soil have good properties of thermal insulating, and strength. Therefore, the soil is used as a construction material which provides cheaper construction and improve building strength. Also improve thermal control in a building and provide high efficiency to users.

This stabilized mud block used in wall for the filling of gap of reinforced beam and column. This block is also used in different ways. This stabilized mud block is also known as mud brick.

In a developing country, to provide better housing with great performance is very difficult. Because of the increase in price of material and reduction in the land for construction of building. Therefore, it is required to use cheaper material for cheaper construction. Therefore, the stabilized mud block is very important and provide better performance and cheaper compared to brick.

The stabilized mud block made by different material like, Soil mud, coir, straw, fibres and cement as stabilization. The straw and other fibres are used to improve tensile strength of stabilized mud block. Because the fibres have great tensile strength and this material is available naturally with lowest price. These fibres are connected to mud and improves tensile strength of block.

The compressive strength of fibres mud block is higher compared to normal mud block. Because the fibres are strong against stress. Soil is very widely used in India for the construction of earthen houses in village area because soil is easily available and easy to use. But soil have tendency to erosion easily and allow water through it.

Also, soil require high routine maintenance to improve durability of construction. The cement is used to improve compressive strength of building. Low amount of cement increases 50 to 60% of compressive strength.

All material which are used in mud block, naturally available and naturally renewable. Due to that this material are not affect to environment and does not produce green gases which make healthy environment. Therefore, we say the blocks are eco-friendly.

Mud block also have good sound insulation material and easy to cast. Therefore, for casting the blocks does not require good skilled labour.

**Soil Identification**

A very few laboratories can identify soils for building purposes. But soil identification can be performed by anybody with sensitive analyses. The main points to examine are:

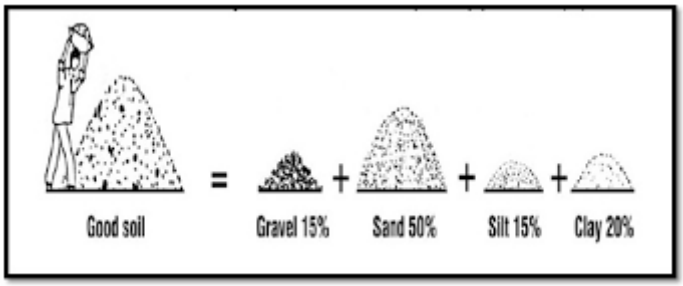
- Grain size distribution, to know quantity of each grain size
- Plasticity characteristics, to know the quality and properties of the binders (clays and silts)
- Compressibility, to know the optimum moisture content, which will require the minimum of compaction energy for the maximum density.
- Cohesion, to know how the binders bind the inert grains.
- Humus content, to know if they are organic materials which might disturb the mix.

## Soil stabilization

Many stabilizers can be used. Cement and lime are the most common ones. Others, like chemicals, resins or natural products can be used as well. The selection of a stabilizer will depend upon the soil quality and the project requirements. Cement will be preferable for sandy soils and to achieve quickly a higher strength. Lime will be rather used for very clayey soil, but will take a longer time to harden and to give strong blocks. give strong blocks.

## Soil Suitability and Stabilization

Not every soil is suitable for earth construction and CSEB in particular. But with some knowledge and experience many soils can be used for producing CSEB. Topsoil and organic soils must not be used. Identifying the properties of a soil is essential to perform, at the end, good quality products. Some simple sensitive analysis can be performed after a short training. A soil is an earth concrete and a good soil for CSEB is more sandy than clayey. It has these proportions:




According to the percentage of these 4 components, a soil with more gravel will be called gravely, another one with more, sand, sandy, others silty or clayey, etc. The aim of the field tests is to identify in which of these four categories the soil is. From the simple classification it will be easy to know what to do with this soil.

## OBJECTIVES

- Stabilized mud blocks (SMBs) are manufactured by compacting a wet mixture of soil, sand, and stabilizer in a machine into a high-density block. Such blocks are used for the construction of load-bearing masonry.
- For the purpose of providing alternate for burnt bricks.
- To investigate present soils to find their suitableness in stable earth block production.
- Use naturally available material in construction work.
- For eco-friendly construction and decrease greenhouse effect.
- For the purpose of achieving cheaper construction.

- For providing thermal insulation in building.
- To improve sound absorption in building.
- To meet the economic requirements of the local situation by: reducing dependence on outside sources and ensuring low-cost alternatives.

## ADVANTAGES

- The stabilized mud blocks are 20 to 40% cheaper compared to bricks.
- For casting of block, materials are locally available.
- Natural materials are used in mud block; therefore, this block is environment friendly.
- Does not require skilled labour.
- The blocks can be easily cast on a site
- Provide better aesthetic view
- This block produces low solid waste which is very important.
- All materials are naturally renewable.
- The compressive strength of stabilized mud block is 40 to 50% more compare to normal mud block.
- The water absorption of block is very less.
- These blocks produce less green gases.
- Mud block provide better sound absorption.
- Thermal insulating property is good of this block.
- These blocks are very good for hot climate and cold climate region.
- This block is best alternative of burnt bricks
- Block is reusable.

## DISADVANTAGES

- In high rainfall region, where high rainfall occurs these blocks are not used.
- This block is less durable compare to bricks.
- Blocks are affected by water, and due to that blocks destroy easily.
- The compressive strength of block is less compared to bricks.
- These blocks are affected by environment.
- Proper maintenance is required.
- The blocks are affected by termite. Therefore, anti-termite protection is required.
- For casting and drying of this block, it requires more time.

- These blocks are easily affected by nature like, wind, sun heat, rain, snow etc.

**Lime Pozzolana Cement**

Lime-pozzolana cement is one of the earliest building materials, widely used in the masonry construction during Roman times. Slow strength development with ambient temperature curing condition is one of the disadvantages of lime- pozzolana cement (LPC). In 19th century, its use was significantly reduced because of the invention of ordinary Portland cement (OPC) which was the faster setting and had higher early strength development.

LPC has been used for manufacturing construction products because of low cost and excellent durability than OPC in the past 50 years. The advantageous properties of pozzolanas consisted of the reduction of cost, heat evolution, alkali-aggregate expansion, concrete drying shrinkage and permeability as well as the improvement of the properties of fresh concrete and chemical resistance.

The Lime–pozzolana (LP) cement is made by mixing calcium hydroxide (lime) and pozzolana in the ratio of 1: 1.5 or 1: 2. Secondary grade lime available locally in many areas can also be used by adjusting the mix proportions. Variety of pozzolonas like burnt clay pozzolona, rice husk ash, good quality fly ash or combination of pozzolonas can be used. Ideally lime and pozzolana have to be inter ground in a ball mill. But such mixtures have poor shelf life (15 days). Volume proportions of 1: 3 or 1: 4 (LP cement: sand) can be used. The strength of the mortar mix can be easily manipulated by adjusting the proportions of various materials. LP cements are low energy consuming materials and can be used for a majority of secondary applications except for reinforced concrete works.

Lime pozzolana cement (LPC) is a type of blended cement that is made by mixing pozzolanic materials, such as fly ash or volcanic ash, with lime. Pozzolanic materials are materials that, when mixed with lime, will react chemically to form a cementitious material. This reaction is known as pozzolanic reaction.

LPC is often used in the construction of buildings and other structures where a low-cost, durable, and strong cement is required. It has several advantages over traditional Portland cement, including:

1. Lower cost: LPC is generally less expensive to produce than Portland cement, making it a cost-effective alternative.

2. Lower greenhouse gas emissions: The production of LPC generates fewer greenhouse gases than the production of Portland cement, making it a more environmentally friendly option.
3. Greater durability: LPC is more resistant to chemical attack and weathering than Portland cement, which makes it more durable.
4. Greater strength: LPC can achieve higher strength at a faster rate than Portland cement, which makes it useful for constructing structures that require a high level of strength.
5. Greater flexibility: LPC can be used in a wider range of applications than Portland cement due to its greater flexibility.
6. Improved workability: LPC has a higher workability than Portland cement, which makes it easier to mix and work with.
7. Improved finishing: LPC has a finer texture than Portland cement, which results in a smoother finish when used in concrete.

There are a few disadvantages of using lime pozzolana cement (LPC) in construction projects:

1. Limited availability: LPC is not widely available in many parts of the world, which can make it difficult to obtain.
2. Shorter shelf life: LPC has a shorter shelf life than Portland cement, which means it must be used more quickly once it is mixed.
3. Lower initial strength: LPC has a lower initial strength than Portland cement, which means it may take longer to achieve the desired strength in a structure.
4. Shrinkage: LPC is more prone to shrinkage than Portland cement, which can lead to cracking in structures if not properly compensated for.
5. Lower heat of hydration: LPC has a lower heat of hydration than Portland cement, which means it generates less heat when it is curing. This can be a disadvantage in cold weather conditions, as the lower heat of hydration may not be sufficient to keep the concrete at an optimal curing temperature.

Despite these disadvantages, LPC can still be a useful construction material in certain applications due to its lower cost and improved workability and finishing compared to Portland cement.

## Gypsum Board

Gypsum Board is one of the widely used construction materials mainly in interior design works. Due to its properties and various product of gypsum, its uses have become vast in construction industries.

Gypsum Board is used as surface material and its applications are prominent in wall and ceiling construction. The use of gypsum can also be done in the field in the form of plaster.

It is designed to be used without the addition of plaster of walls, ceilings, or partitions and provides a surface suitable to receive either paint or paper.

Gypsum board is extensively used in drywall construction, where the plaster is eliminated. It is also available in the market with one surface covered with aluminium and another surface covered with the heat-reflecting type of foil or with imitation wood grain or another pattern on the exterior surface so that no extra decoration is required.

The different types of gypsum board generally available in the market are clued wallboard, backing board, core board, fire-resistant gypsum board, water–resistant gypsum board, and gypsum form board.

Gypsum board also known as drywall, plasterboard, or wallboard is used to form panels made of gypsum plaster pressed between two thick sheets of paper. Gypsum board possesses many attributes that make it an attractive construction material.

The home-building and remodelling industry has seen many construction materials utilized to improve a building's functioning and aesthetic appeal. Gypsum board is one such product. A collection of panel goods is referred to as "gypsum board." These have a non-combustible gypsum core with paper surfacing front, back, and long edges. The term "gypsum panel products" refers to the various gypsum boards used in building and construction. The basis of all gypsum board products is gypsum, but the surface can be wrapped in various materials, including paper and fiberglass matting.

Drywall, wallboard, and plasterboard are used to describe gypsum boards. They differ from other panel-type shelters, and road and building products, such as plywood, hardboard, and fiber board, due to their non-combustible core and paper facers. Gypsum wallboard creates a continuous surface suited for various interior design projects, both residential and commercial when their seams and fastener heads are covered with a joint compound system.

## Properties of Gypsum Board

### 1. Gypsum is Fire – Resistant

Gypsum boards are fire resistant and safeguard the structure from fire threats by preventing the fire from spreading further. Due to chemically bound water in the gypsum, it possesses a fire-resistant quality. When gypsum boards are exposed to fire, the water contained within the gypsum evaporates, forming a protective layer. Gypsum plasterboard of 15mm thickness would possess almost liters of crystal water within it.

### 2. Thermal Properties of Gypsum

Gypsum can regulate variables such as humidity and temperature in the home. The insulating characteristics of gypsum plasterboard or formwork used in buildings are improved.

The thermal properties rendered by the gypsum construction would enable a good balancing of indoor humidity and temperature.

Gypsum construction includes cavities, like plasterboard or formwork construction with gypsum that gives extra insulation properties. By using plasterboards in interior construction act as a vapor barrier preventing indoor humidity.

### 3. Acoustic Property of Gypsum

Sound isolation is prioritized in the design of gypsum materials. Other methods, such as masonry, would work well, as it is commonly used in a thicker thickness and is no less demanding than gypsum. Gypsum plasterboard is designed to absorb sound and reduce reverberation. Adding an air space between two solid gypsum walls improves acoustic performance by preventing noise from passing through. For example, instead of a 110mm thick brick wall, we can use 75mm thick drywall to obtain the same sound performance.

### 4. Non-combustible Property of Gypsum

The heating of gypsum products causes the water crystals in the gypsum material to heat up. Calcinations is the process of dehydrating gypsum with heat. Calcinations creates a protective layer over the components, preventing them from combusting and allowing the materials around them to retain a lower, safer temperature.

The residue will act as an insulating layer until it is separated, even after the water crystals

have been entirely calcined. Because of its non-combustible quality and capacity to slow fire development for hours depending on the extent to which gypsum products are utilized, gypsum is regarded as an effective fire retarder.

**Uses of Gypsum Board**

- Gypsum and glass are also utilized to make various lightweight architectural ornaments.
- The ceilings of the buildings are similarly made of gypsum tiles.
- Partitions, lining, ceilings, roofs, and floors are made of gypsum fireboards.
- Gypsum is also used to control the setting time in cement manufacture.
- In the building of partition walls, gypsum blocks are employed.
- The ability of gypsum to give a comfortable and aesthetic ambiance as a construction material increases the demands of gypsum.
- It is a natural product that is commonly available. It is free of odour.
- Nowadays most of the interior and exterior construction features are mostly prepared by gypsum construction or gypsum products.
- The advancement of gypsum construction in a continuous process is due to its time and cost of construction.
- With an increase in time, gypsum products gain more properties like increased fire resistance, acoustic properties for noise insulation, etc.

**Types of Gypsum Board:**

**1. Fire Resistant Gypsum Boards**

Due to the particular behaviour of the gypsum core when exposed to fire, a fire-resistant gypsum board provides good fire protection in buildings. The chemically mixed water is gradually released in the form of water vapor when a fire-resistant gypsum board protects building materials exposed to fire. This situation develops when a board or gypsum finish is continuously exposed to a temperature above 49°C.

**Uses of Fire-Resistant Gypsum Boards**

When a high level of fire protection is required in ceilings and drywall, this product is ideal.

**2. Water-Resistant Gypsum Board**

This type has water-repellent face paper and a water-resistant gypsum core. It can be used as a foundation for wall tiles in bathtubs, showers, and other wet places.

**Uses of Water-Resistant Gypsum Boards**

- In wet spaces like bathrooms and kitchens, it's best for both ceiling and drywall partitions.
- In sheltered locations, it's used as a base for external soffits.
- Interior walls and ceilings in residential and commercial buildings are covered with this material.
- Also, specialized moisture or water-related assembly is required.

**3. Backing Gypsum Board**

The backing gypsum comprises various layers in the construction process, where several layers of gypsum boards are utilized as a soundproofing material to give the walls strength and fire resistance. Walls and ceilings are covered with backing gypsum boards, also used for self-levelling screeds. The boards come in 16 to 48 inch wide, 4 to 16 feet long, and ¼ to 1 inch thick.

**Uses of Backing Gypsum Boards**

- For the walls and ceilings.
- Gypsum-based fiber board
- Partitions and tiles made of gypsum plaster blocks
- Screeds with self-levelling properties.

**4. Drywall White Board**

Drywall is made out of thin gypsum board panels used to build walls. The board comprises two layers of special paper with a layer of gypsum rock sandwiched between them. Drywall is a far more efficient form of a building than applying wet plaster to a gypsum lath, which was once standard.

Drywall is normally white on one side and brown on the other side. It is probably the most economical drywall type and comes in different sizes ranging in thickness from 3/8 inches to one inch.

This is the most usual type used and is normally available in the market in four by eight feet panels.

**Uses of Drywall White Boards**

- It's also used as a tile backer in wet conditions, including in bathrooms, water closets, basement walls, kitchens, and laundry and utility rooms.
- It is moisture-resistant and has a strong resistance power.

**Advantages of Gypsum Board**

- Gypsum is also used in plaster to provide a smooth, crack-free surface. Gypsum boards give a smooth, continuous surface to which you can apply paint directly.
- Gypsum has the property of balancing the building's indoor temperature and humidity. Gypsum is a low-emission building material that provides excellent thermal and acoustic insulation.
- The use of gypsum goods within the budget boosts the creativity of architects. It offers a wide range of attractive design options.
- The gypsum products are simple to install and do not necessitate the use of trained staff. The installation is simple, clean, and quick.
- The gypsum plaster does not need to be painted, and it can be utilized as a final finish. It provides the surface of the wall with a white shine.
- A wide range of gypsum products is available to meet a variety of practical and aesthetic needs.

**Disadvantages of Gypsum Board**

- It's a hassle to keep the temperature consistent for both the mechanical and adhesive applications of gypsum board.
- Maintain adequate ventilation in the working area during the installation and cure process.
- Although it is not required, always read the manufacturer's instructions for temperature control during the joint treatment, texturing, and ornamentation.
- The risk of exposing the gypsum board to high temperatures is substantial.
- Never use gypsum board in areas where moisture is present in large amounts or regularly.

## Light Weight Beams

Lightweight beams are structural elements that are designed to have a lower weight-to-strength ratio than traditional beams. They are used in construction to support loads, such as the weight of a building or a bridge, while minimizing the amount of material used.

There are several types of lightweight beams that are used in construction, including:

1. Hollow core beams: These beams have a hollow center section, which reduces their weight while maintaining their strength.
2. Composite beams: These beams are made by combining two or more materials, such as steel and concrete, to create a beam that is stronger and lighter than a beam made from a single material.
3. Foam core beams: These beams have a foam core that is surrounded by a concrete or other material shell. The foam core reduces the weight of the beam while the concrete shell provides strength.
4. Timber beams: Timber beams can be made lightweight by using smaller cross-sections or by laminating thin layers of wood together.

Lightweight beams are often used in the construction of buildings, bridges, and other structures where weight is a concern, such as in high-rise buildings or long-span bridges. They can also be used to reduce the overall weight of a structure, which can make it more cost-effective to build and easier to transport.

### Advantages of Light Weight Beams

There are several advantages to using lightweight beams in construction:

1. Reduced weight: The most obvious advantage of lightweight beams is their reduced weight, which can make a structure easier to transport and handle during construction.
2. Increased load capacity: Lightweight beams can have a higher load capacity than traditional beams of the same size, which means they can support more weight with less material.
3. Lower material cost: Because lightweight beams use less material, they can be more cost-effective to produce than traditional beams.
4. Increased design flexibility: Lightweight beams can be designed in a variety of shapes and sizes, which gives architects and engineers more design flexibility when creating a structure.

5. Improved energy efficiency: Because lightweight beams require less material to produce, they can also result in lower energy consumption during the manufacturing process.
6. Increased sustainability: The use of lightweight beams can help to reduce the overall environmental impact of a structure by using less material and requiring fewer resources to produce.

Lightweight beams are often used in the construction of buildings, bridges, and other structures where weight is a concern, such as in high-rise buildings or long-span bridges. They can also be used to reduce the overall weight of a structure, which can make it more cost-effective to build and easier to transport.

**Disadvantages of Light Weight Beams**

There are a few potential disadvantages to using lightweight beams in construction:

1. Reduced strength: Lightweight beams may not be as strong as traditional beams of the same size, which means they may not be suitable for certain applications where a high level of strength is required.
2. Increased deflection: Lightweight beams may deflect more under load than traditional beams, which can result in increased bending and swaying of a structure. This can be a concern in buildings where occupants may feel discomfort due to the movement.
3. Limited availability: Some types of lightweight beams, such as composite beams, may not be widely available in certain regions, which can make them difficult to obtain.
4. Higher cost: Some types of lightweight beams, such as foam core beams, can be more expensive to produce than traditional beams, which may make them less cost-effective in certain applications.

Overall, the decision to use lightweight beams in a construction project should be based on a careful analysis of the specific needs and requirements of the project. In some cases, lightweight beams may be the best choice, while in other cases traditional beams may be more suitable.

**Uses of Light Weight Beams**

Lightweight beams are used in a variety of construction applications where weight is a concern. Some common uses of lightweight beams include:

1. Buildings: Lightweight beams are often used in the construction of high-rise buildings and other structures where weight reduction is important to reduce the load on the foundation.
2. Bridges: Lightweight beams can be used in the construction of bridges to reduce the overall weight of the structure, which can make it easier to transport and install.
3. Roofs: Lightweight beams can be used in the construction of roofs to reduce the weight of the structure and make it easier to install.
4. Industrial structures: Lightweight beams are often used in the construction of industrial structures, such as warehouses and factories, where weight reduction is important to reduce the load on the foundation.
5. Transportation: Lightweight beams are used in the construction of transportation infrastructure, such as airports and train stations, where weight reduction is important to reduce the load on the foundation.
6. Recreational structures: Lightweight beams are used in the construction of recreational structures, such as sports arenas and concert venues, where weight reduction is important to reduce the load on the foundation.

Overall, lightweight beams are used in a variety of construction applications where weight reduction is important to reduce the load on the foundation and make the structure easier to transport and install.

**Fiber Reinforced Cement Components**

Fiber Reinforced Concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibers. Fiber reinforced concrete are of different types and properties with many advantages. Continuous meshes, woven fabrics, and long wires or rods are not considered to be discrete fibers. Fiber is a small piece of reinforcing material possessing certain characteristics properties. They can be circular or flat. The fiber is often described by a convenient parameter called "aspect ratio". The aspect ratio of the fiber is the ratio of its length to its diameter. The typical aspect ratio ranges from 30 to 150. 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, the

character of fiber reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities.

Fibre-reinforcement is mainly used in shotcrete, but can also be used in normal concrete. Fiber-reinforced normal concrete is mostly used for on-ground floors and pavements, but can be considered for a wide range of construction parts (beams, pliers, foundations, etc) either alone or with hand-tied rebars Concrete reinforced with fibers (which are usually steel, glass or "plastic" fibers) is less expensive than hand-tied rebar, while still increasing the tensile strength many times. The shape, dimension, and length of fiber is important. A thin and short fiber, for example, short hair-shaped glass fiber, will only be effective the first hours after pouring the concrete (reduces cracking while the concrete is stiffening) but will not increase the concrete tensile strength.

**Effect of Fibers in Concrete**

Fibers are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce the 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, so it cannot replace moment resisting or structural steel reinforcement. Some fibers reduce the strength of concrete. The amount of fibers added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibers) termed volume fraction ($V_f$). $V_f$ typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d).

Fibers with a non-circular cross-section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fiber is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. An increase in the aspect ratio of the fiber usually segments the flexural strength and toughness of the matrix. However, fibers that are too long tend to "ball" in the mix and create workability problems. Some recent research indicated that using fibers in concrete has a limited effect on the impact resistance of concrete materials. This finding is very important since traditionally people think the ductility increases when concrete reinforced with fibers. The results also pointed out that the microfibres are better in impact resistance compared with the longer fibers.

## Necessity of Fiber Reinforced Concrete

1. It increases the tensile strength of the concrete.
2. It reduces the air voids and water voids the inherent porosity of gel.
3. It increases the durability of the concrete.
4. Fibers such as graphite and glass have excellent resistance to creep, while the same is not true for most resins. Therefore, the orientation and volume of fibres have a significant influence on the creep performance of rebars/tendons**.**
5. Reinforced concrete itself is a composite material, where the reinforcement acts as the strengthening fibre and the concrete as the matrix. It is therefore imperative that the behavior under thermal stresses for the two materials be similar so that the differential deformations of concrete and the reinforcement are minimized.
6. It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to concrete would act as crack arrester and would substantially improve its static and dynamic properties.

## Factors Affecting Properties of Fiber Reinforced Concrete

Fiber reinforced concrete is the composite material containing fibers in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously, depends upon the efficient transfer of stress between matrix and the fibers. The factors are briefly discussed below:

### 1. Relative Fiber Matrix Stiffness

The modulus of elasticity of matrix must be much lower than that of fiber for efficient stress transfer. Low modulus of fiber such as nylons and polypropylene are, therefore, unlikely to give strength improvement, but they help in the absorption of large energy and therefore, impart greater degree of toughness and resistance to impart. High modulus fibers such as steel, glass and carbon impart strength and stiffness to the composite. Interfacial bond between the matrix and the fiber also determines the effectiveness of stress transfer, from the matrix to the fiber. A good bond is essential for improving tensile strength of the composite.

### 2. Volume of Fibers

The strength of the composite largely depends on the quantity of fibers used in it. Use of higher percentage of fiber is likely to cause segregation and harshness of concrete and mortar.

### 3. Aspect Ratio of the Fiber

Another important factor which influences the properties and behavior of the composite is the aspect ratio of the fiber. It has been reported that up to aspect ratio of 75, increase on the aspect ratio increases the ultimate concrete linearly. Beyond 75, relative strength and toughness is reduced.

### 4. Orientation of Fibers

One of the differences between conventional reinforcement and fiber reinforcement is that in conventional reinforcement, bars are oriented in the direction desired while fibers are randomly oriented. To see the effect of randomness, mortar specimens reinforced with 0.5% volume of fibers were tested. In one set specimens, fibers were aligned in the direction of the load, in another in the direction perpendicular to that of the load, and in the third randomly distributed. It was observed that the fibers aligned parallel to the applied load offered more tensile strength and toughness than randomly distributed or perpendicular fibers.

### 5. Workability and Compaction of Concrete

Incorporation of steel fiber decreases the workability considerably. This situation adversely affects the consolidation of fresh mix. Even prolonged external vibration fails to compact the concrete. The fiber volume at which this situation is reached depends on the length and diameter of the fiber. Another consequence of poor workability is non-uniform distribution of the fibers. Generally, the workability and compaction standard of the mix is improved through increased water/ cement ratio or by the use of some kind of water reducing admixtures.

### 6. Size of Coarse Aggregate

The maximum size of the coarse aggregate should be restricted to 10mm, to avoid an appreciable reduction in the strength of the composite. Fibers also in effect, act as aggregate. Although they have a simple geometry, their influence on the properties of fresh concrete is complex. The inter-particle friction between fibers and between fibers and aggregates controls the orientation and distribution of the fibers and consequently the properties of the composite. Friction-reducing admixtures and admixtures that improve the cohesiveness of the mix can significantly improve the mix.

### 7. Mixing

Mixing of fiber reinforced concrete needs careful conditions to avoid balling of fibers, segregation and in general the difficulty of mixing the materials uniformly. Increase in the

aspect ratio, volume percentage and size and quantity of coarse aggregate intensify the difficulties and balling tendency. Steel fiber content in excess of 2% by volume and aspect ratio of more than 100 are difficult to mix. It is important that the fibers are dispersed uniformly throughout the mix; this can be done by the addition of the fibers before the water is added. When mixing in a laboratory mixer, introducing the fibers through a wire mesh basket will help even distribution of fibers. For field use, other suitable methods must be adopted.

**Different Types of Fiber Reinforced Concrete**

Following are the different type of fibers generally used in the construction industries.

1. Steel Fiber Reinforced Concrete
2. Polypropylene Fiber Reinforced (PFR) cement mortar & concrete
3. GFRC Glass Fiber Reinforced Concrete
4. Asbestos Fibers
5. Carbon Fibers
6. Organic Fibers

**1. Steel Fiber Reinforced Concrete**

A number of steel fiber types are available as reinforcement. Round steel fiber the commonly used type, are produced by cutting round wire in to short length. The typical diameter lies in the range of 0.25 to 0.75mm. Steel fibers having a rectangular c/s are produced by silting the sheets about 0.25mm thick. Fiber made from mild steel drawn wire. Conforming to IS:280-1976 with the diameter of wire varying from 0.3 to 0.5mm have been practically used in India. Round steel fibers are produced by cutting or chopping the wire, flat sheet fibers having a typical c/s ranging from 0.15 to 0.41mm in thickness and 0.25 to 0.90mm in width are produced by silting flat sheets. Deformed fiber, which are loosely bounded with water-soluble glue in the form of a bundle are also available. Since individual fibers tend to cluster together, their uniform distribution in the matrix is often difficult. This may be avoided by adding fibers bundles, which separate during the mixing process.

**2. Polypropylene Fiber Reinforced (PFR) cement mortar and concrete**

Polypropylene is one of the cheapest & abundantly available polymers. Polypropylene fibers are resistant to most chemical & it would be cementitious matrix which would deteriorate first under aggressive chemical attack. Its melting point is high (about 165 degrees

centigrade), so that a working temperature as (100 degree centigrade) may be sustained for short periods without detriment to fiber properties. Polypropylene fibers being hydrophobic can be easily mixed as they do not need lengthy contact during mixing and only need to be evenly distressed in the mix. Polypropylene short fibers in small volume fractions between 0.5 to 15 commercially used in concrete.

**3. GFRC - Glass Fiber Reinforced Concrete**

Glass fiber is made up of 200-400 individual filaments which are lightly bonded to make up a stand. These stands can be chopped into various lengths, or combined to make cloth mats or tape. Using the conventional mixing techniques for normal concrete it is not possible to mix more than about 2% (by volume) of fibers of a length of 25mm. The major appliance of glass fiber has been in reinforcing the cement or mortar matrices used in the production of thin-sheet products. The commonly used varieties of glass fibers are e-glass used. In the reinforced of plastics & AR glass E-glass has inadequate resistance to alkalis present in Portland cement where AR-glass has improved alkali-resistant characteristics. Sometimes polymers are also added in the mixes to improve some physical properties such as moisture movement.

**4. Asbestos Fibers**

The naturally available inexpensive mineral fiber, asbestos, has been successfully combined with Portland cement paste to form a widely used product called asbestos cement. Asbestos fibers here thermal mechanical & chemical resistance making them suitable for sheet product pipes, tiles and corrugated roofing elements. Asbestos cement board is approximately two or four times that of unreinforced matrix. However, due to relatively short length (10mm) the fiber has low impact strength.

**5. Carbon Fibers**

Carbon fibers from the most recent & probability the most spectacular addition to the range of fiber available for commercial use. Carbon fiber comes under the very high modulus of elasticity and flexural strength. These are expansive. Their strength & stiffness characteristics have been found to be superior even to those of steel. But they are more vulnerable to damage than even glass fiber, and hence are generally treated with resign coating.

**6. Organic Fibers**

Organic fiber such as polypropylene or natural fiber may be chemically more inert than either steel or glass fibers. They are also cheaper, especially if natural. A large volume of vegetable

fiber may be used to obtain a multiple cracking composite. The problem of mixing and uniform dispersion may be solved by adding a superplasticizer.

**Advantages of Fiber-reinforced concrete**

- Fiber reinforced concrete may be useful where high tensile strength and reduced cracking are desirable or when conventional reinforcement cannot be placed.
- It improves the impact strength of concrete, limits the crack growth and leads to a greater strain capacity of the composite material.
- For industrial projects, macro-synthetic fibers are used to improve concrete's durability. Made from synthetic materials, these fibers are long and thick in size and may be used as a replacement for bar or fabric reinforcement.
- Adding fibers to the concrete will improve its freeze-thaw resistance and help keep the concrete strong and attractive for extended periods.
- Improve mix cohesion, improving pumpability over long distances.
- Increase resistance to plastic shrinkage during curing.
- Minimizes steel reinforcement requirements.
- Controls the crack widths tightly, thus improving durability.
- Reduces segregation and bleed-water.
- FRC, toughness is about 10 to 40 times that of plain concrete.
- The addition of fibers increases fatigue strength.
- Fibers increase the shear capacity of reinforced concrete beams.

**Disadvantages Of Fibre Reinforced Concrete**

- Fibers are costly.
- The fibers should be uniformly distributed in concrete because they may not mix well and form lumps.
- The size of the coarse aggregate is restricted to 10 mm.
- Mixing fibers in large volumes could be tedious.
- Construction with FRC requires skilled labor.

**Applications of Fiber Reinforced Concrete**

The type of FRC used can vary based on the particular construction project. In general, most civil engineering projects utilize FRC. For example:

- Walls

- Flooring
- Dams
- Runways
- Roads
- Concrete pipes
- Bridges
- Warehouse floors
- Manholes
- Tunnels
- Pavements

**Fiber Reinforced Polymer Composite**

Fiber reinforced polymer (FRP) composites are lightweight, high strength, corrosion-resistant materials. In fabric form, they offer unprecedented flexibility since fibers can be oriented to provide strength in any given direction.

Fibre-reinforced plastic (FRP; also called fibre-reinforced polymer) is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass (in fibre glass), carbon (in carbon-fibre-reinforced polymer), aramid, or basalt. Rarely, other fibres such as paper, wood, or asbestos have been used. The polymer is usually an epoxy, vinyl ester, or polyester thermosetting plastic, though phenol formaldehyde resins are still in use.

FRPs are commonly used in the aerospace, automotive, marine, and construction industries. They are commonly found in ballistic armour and cylinders for self-contained breathing apparatuses.

Fiber-Reinforced Polymer (FRP) materials are composite materials that typically consist of strong fibers embedded in a resin matrix. The fibers provide strength and stiffness to the composite and generally carry most of the applied loads. The matrix acts to bond and protect the fibers and to provide for transfer of stress from fiber to fiber through shear stresses. The most common fibers are glass, carbon, and synthetic fibers. FRP composites have very high strength characteristics and are nonconductive, noncorrosive, and lightweight.

FRP composites are different from traditional construction materials like Steel and Aluminum. FRP composites are anisotropic whereas Steel and Aluminum are isotropic. Therefore, their properties are directional, meaning that the best mechanical properties are in the direction of the fibre placement.

These materials have a high ratio of strength to density, exceptional corrosion resistance and convenient electrical, magnetic and thermal properties. However, they are brittle and their mechanical properties may be affected by the rate of loading, temperature and environmental conditions.

The primary function of fibre reinforcement is to carry the load along the length of the fiber and to provide strength and stiffness in one direction. It replaces metallic materials in many structural applications where load-carrying capacity is important.

The use of FRP in engineering applications enables engineers to obtain significant achievements in the functionality, safety and economy of construction because of their mechanical properties.

**Components of Composite Materials**

**1. Fibres**

The choice of fibre frequently controls the properties of composite materials. Carbon, Glass, and Aramid are three major types of fibres which are used in construction. The composite is often named by the reinforcing fibre, for instance, CFRP for Carbon Fibre Reinforced Polymer. The most important properties that differ between the fibre types are stiffness and tensile strain.

**2. Matrices**

The matrix should transfer forces between the fibres and protect the fibres form detrimental effects. Thermosetting resins (thermosets) are almost exclusively used. Vinyl ester and epoxy are the most common matrices.

Epoxy is mostly favoured above vinyl ester but is also more costly. Epoxy has a pot life around 30 minutes at 20 degree Celsius but can be changed with different formulations. Epoxies have good strength, bond, creep properties and chemical resistance.

## Types of Fibre Reinforced Polymer (FRP)

### 1. Glass Fibre Reinforced Polymer (GFRP)

Glass fibres are basically made by mixing silica sand, limestone, folic acid and other minor ingredients. The mix is heated until it melts at about 1260°C.

The molten glass is then allowed to flow through fine holes in a platinum plate. The glass strands are cooled, gathered and wound. The fibres are drawn to increase directional strength. The fibres are then woven into various forms for use in composites.

Based on an aluminium lime borosilicate composition, glass produced fibres are considered as the predominant reinforcement for polymer matrix composites due to their high electrical insulating properties, low susceptibility to moisture and high mechanical properties.

Glass is generally a good impact resistant fibre but weighs more than carbon or aramid. Glass fibres have excellent characteristics equal to or better than steel in certain forms.

### 2. Carbon Fibre Reinforced Polymer (CFRP)

Carbon fibres have a high modulus of elasticity, 200-800 GPa. The ultimate elongation is 0.3-2.5 % where the lower elongation corresponds to the higher stiffness and vice versa.

Carbon fibres do not absorb water and are resistant to many chemical solutions. They withstand fatigue excellently and neither corrode nor show any creep or relaxation.

### 3. Aramid Fibre Reinforced Polymer (AFRP)

Aramid is the short form for aromatic polyamide. A well-known trademark of aramid fibres is Kevlar but there does exist other brands as well such as Twaron, Technora and SVM.

The modulii of the fibres are 70-200 GPa with an ultimate elongation of 1.5-5% depending on the quality. Aramid has a high fracture energy and is therefore used for helmets and bullet-proof garments.

They are sensitive to elevated temperatures, moisture and ultraviolet radiation and therefore not widely used in civil engineering applications. Finally, Aramid fibres do have problems with relaxation and stress corrosion.

## Applications of FRP

1. Carbon FRPs are used in prestressed concrete for applications where high resistance to corrosion and electromagnetic transparency of CFRP are important.
2. CFRP composites are employed for underwater piping and structural parts of offshore platform. Added to that, FRP declines the risk of fire.

3. Carbon fibre reinforced polymers are used to manufacture underwater pipes for great depth because it provides a significantly increased buoyancy (due to its low density) compared to steel.
4. The stairways and walkways are also made of composites for weight saving and corrosion resistance.
5. It is used in high-performance hybrid structures.
6. FRP bars are used as internal reinforcement for concrete structures.
7. FRP bars, sheets, and strips are used for strengthening of various structures constructed from concrete, masonry, timber, and even steel.
8. FRPs are employed for seismic retrofitting.
9. Fibre reinforced polymers are used in the construction of special structures requiring electrical neutrality.
10. The high energy absorption of aramid fibre reinforced polymer (AFRP) composites makes them suitable for strengthening engineering structures subjected to dynamic and impact loading.

**Bamboo**

Bamboo is a strong, fast growing and very sustainable material, having been used structurally for thousands of years in many parts of the world. In modern times it has the potential to be an aesthetically-pleasing and low-cost alternative to more conventional materials such as timber, as demonstrated by some visually impressive recent structures.

Bamboo which is considered as the poor man's timber is one of the most important forestry species with wide distribution throughout India. India has the largest area and second largest reserves of bamboo in the world today, yet its industries are swinging in shortage of raw material availability. The bamboo economy of the country is still in nascent stage that is 4% of the global bamboo economy. Major consumers of bamboo in the country include paper industry, construction sector, handicrafts and small and cottage industries.

Bamboo has more than 1,500 documented uses, ranging from fuelwood to light bulbs, medicine, poison and toys to aircraft manufacturing (Forest Research Institute, 2008). The products made from bamboo can be broadly classified into:

- Industrial Use and Products, (paper and pulp, bamboo charcoal for fuel, bamboo-based gasifier for electricity)
- Food Products (consumption of bamboo shoots)

- Construction and Structural Applications (Bamboo housing)
- Wood Substitutes and Composites (Bamboo based panels, Veneers, Bamboo Flooring, mat boards, fiber boards, particle boards, medium density boards, combinations of these, and combinations of these with wood and other ligno-cellulose materials and inorganic substances).
- Cottage and Handicraft Industry

Bamboo is one of the greatest environmentally friendly construction materials.

- The self-generation rate is unbelievably rapid, and some have reportedly grown to three feet over 24 hours.
- It continues to expand and cultivate without replanting after harvest.
- On every continent except in Europe and Antarctica, Bamboo is an eternal grass and does not grow wood.
- It also has a very lengthy strength to weight ratio, even more, comprehensive strength than concrete and brick. Therefore, it is the ideal choice for floors and enclosures.
- Regrettably, bamboo needs to be resistant to insects and redness.
- Bamboo containing starch that attracts insects to expand and fracture after water absorption if left untreated.

**Advantages of Bamboo as a Building Material**

The various advantages of bamboo are as mentioned below:

1. **Tensile strength**: Bamboo has higher tensile strength than steel because its fibers run axially.
2. **Fire Resistance**: Capability of bamboo to resist fire is very high and it can withstand temperature up to 4000 C. This is due to the presence of high value of silicate acid and water.
3. **Elasticity**: Bamboo is widely preferred in earthquake prone regions due to its elastic features.
4. **Weight of bamboo**: Bamboos due to their low weight are easily displaced or installed making it very easier for transportation and construction.
5. Unlike other building materials like cement and asbestos, bamboo poses no danger to health.
6. They are cost effective and easy to use.
7. They are especially in great demand in earthquake prone areas.

**Disadvantages of Bamboo**

Bamboos come with their own set of drawbacks such as:

1. They require preservation
2. Shrinkage: Bamboo shrinks much greater than any other type of timber especially when it loses water.
3. **Durability**: Bamboo should be sufficiently treated against insect or fungus attack before being utilized for building purposes.
4. **Jointing:** Despite prevalence of various techniques of jointing, structural reliability of bamboo is questionable.

**Recycling of building materials**

Recycling building materials refers to the process of reusing materials that have been used in the construction or demolition of buildings. This can include materials such as concrete, brick, wood, steel, and drywall.

There are several benefits to recycling building materials:

1. Conservation of natural resources: Recycling building materials reduces the demand for new materials, which helps to conserve natural resources such as timber, water, and minerals.
2. Reduction of waste: Recycling building materials reduces the amount of waste that is sent to landfills, which can help to reduce the environmental impact of construction and demolition projects.
3. Cost savings: Recycling building materials can be more cost-effective than using new materials, as it can reduce the cost of disposal and the cost of purchasing new materials.
4. Energy savings: Recycling building materials can also save energy, as it takes less energy to process and manufacture recycled materials than it does to produce new materials from raw materials.

**Brick**

Recycled brick is brick that has been used in the construction or demolition of a building and then processed for reuse in new construction projects. Recycled brick is often used as an

alternative to new brick in order to reduce the demand for new materials and the environmental impact of construction.

There are several benefits to using recycled brick in construction:

1. Conservation of natural resources: Using recycled brick reduces the demand for new brick, which helps to conserve natural resources such as clay and water.
2. Reduction of waste: Using recycled brick reduces the amount of waste that is sent to landfills, which can help to reduce the environmental impact of construction and demolition projects.
3. Cost savings: Using recycled brick can be more cost-effective than using new brick, as it can reduce the cost of disposal and the cost of purchasing new brick.
4. Energy savings: Using recycled brick can also save energy, as it takes less energy to process and manufacture recycled brick than it does to produce new brick from raw materials.

**Concrete**

Recycled concrete is concrete that has been used in the construction or demolition of a building and then processed for reuse in new construction projects. Recycled concrete is often used as an alternative to new concrete in order to reduce the demand for new materials and the environmental impact of construction.

Concrete is globally the most widely used material in the construction industry. Basically, concrete is a manufactured product consisting of cement, aggregates, water and admixture. The composition of aggregates forms a major portion of the mixture consisting of sand, crushed stones and gravel which are inert granular materials. Construction aggregates make up more than 80 percent of the total aggregate market and are used mainly for building constructions and pavements.

Recycled aggregates are aggregates derived from the processing of materials previously used in construction. Examples include recycled concrete from construction and demolition waste material (C&D), reclaimed aggregate from asphalt pavement and scrap tyres. Coarse Recycled Concrete Aggregate (RCA) is produced by crushing sound, clean demolition waste of at least 95% by weight of concrete, and having a total contaminant level typically lower than 1% of the bulk mass. Other materials that may be present in RCA are gravel, crushed stone, hydraulic-cement concrete or a combination deemed suitable for pre-mix concrete production.

Recycled concrete can be used in a variety of construction applications, including foundations, walls, and other structural elements. It is often used in the construction of roads, sidewalks, and other infrastructure projects. Recycled concrete can also be used as a base material for landscaping projects, such as creating retaining walls or as a filler for low-lying areas.

**Steel**

Steel is one of the most popular construction materials available. It's non-flammable and a better choice in areas that might be prone to earthquakes or other natural disasters as it is less likely to warp. It is also stable enough to sustain high winds, which makes it a great option for areas that are often affected by hurricanes.

In fact, it is one of the most durable construction materials available. But its strength and long-life span isn't the only important thing about steel. Its sustainable features make recycled steel one of the best materials available for construction projects.

One of steel's best features is that it can be recycled. In fact, over 90% of a steel building or fixture can be recycled and reused for another project. This is a far higher recycling rate than other common building materials, like concrete or wood. As a result, the steel industry has reduced greenhouse gas emissions by an estimated 36% in the past 30 years.

Recycling steel is fairly easy. The steel is magnetically separated from other materials and then shipped to steel mills or other factories for recycling. It is then melted down and recreated into the manufacturer's desired moulds. In 2019, recycled steel accounted for about 600 million tons of all steel produced.

The primary issue when recycling steel is identifying and separating different steel grades from one another during demolition. According to the Institute of Scrap Recycling Industries, there are 316 different grades of steel.

The majority of construction demolition are heavy bulk wastes like concrete which are generally downcycled into general fill. However, many companies are seeing the benefits of using sustainable materials like steel instead of or in pair with concrete.

Nowadays, ninety-three percent of all steel used in construction projects is recycled. Because it poses many benefits for companies as well as the environment including reducing waste by diverting it from landfills and back into other projects.

**It reduces waste and is eco-friendly.** One major benefit of reusing steel from buildings and structures is that beams, columns, and other structural pieces can be used without having to

be re-melted or processed. Scrap pieces of steel, on the other hand, can be melted down and made into something new. In fact, 98 percent of a building's steel is recycled back into other steel projects after the building's life-cycle ends.

**It retains its quality.** Steel's quality is not compromised, even after it is recycled. Reusing steel doesn't degrade the products' strength or value and it has a great weight capacity.

**It saves money.** While recycled steel is no different in quality than new steel, it is however cheaper. Its lightweight nature means less use of heavyweight equipment and lifts. Additionally, builders save money on maintenance and repair due to steel's long life span and durability.

When construction projects have the chance to cost millions of dollars, saving on one of your primary building materials is a huge win. Plus, it conserves primary resources and raw materials by using recycled components.

**Plastics**

Plastic recycling is the reprocessing of plastic waste into new products. When performed correctly, this can reduce dependence on landfill, conserve resources and protect the environment from plastic pollution and greenhouse gas emissions. Although recycling rates are increasing, they lag behind those of other recoverable materials, such as aluminium, glass and paper. Since the beginning of plastic production in the 20th century, until 2015, the world has produced some 6.3 billion tonnes of plastic waste, only 9% of which has been recycled, and only ~1% has been recycled more than once. Additionally, 12% was incinerated and the remaining 79% disposed of to landfill or to the environment including the sea.

Recycling is necessary because almost all plastic is non-biodegradable and thus builds-up in the environment, where it can cause harm.

**Benefits of Plastic Recycling**

**1. Roofing Tiles**

A roof is an essential part of a house, so when it comes to home building, there have been many innovations in roofing methodologies over the years. Using recycled plastics to build roofing tiles is a great way to resemble other more expensive materials, while providing the same high-quality you can expect with materials such as slate.

Other undeniable benefits from recycled plastic roofs include:

- Lighter material
- Easier, quicker installation
- Lower carbon footprint

**2. Concrete**

Recycled plastics can be used to make stronger concrete structures in the form of sidewalks, driveways and more. Experiments have been conducted with recycled plastic by exposing small amounts of it to gamma radiation, mixing it into a powder and then mixing that into cement paste.

Doing so can produce concrete that is up to 15% stronger than regular concrete, allowing this form of construction to be both long-lasting and more eco-friendly.

**3. Indoor Insulation**

Insulation is another essential factor in homebuilding and buying because it keeps your home's temperature regulated all year-round.

Various insulation companies have begun developing insulation with recycled plastic inside of it because only a minimum amount of plastic will maximize your home's energy efficiency levels.

Additional benefits for insulation from recycled plastics include:

- Easy installation
- Durability
- Long-term energy savings

**4. Structural Lumber**

Using recycled plastic as the main ingredient in structural lumber as an alternative to other materials such as steel, comes with indisputable advantages.

By using plastic to make lumber instead of wood, you no longer have to spray wood with toxic preservatives to protect it from aspects such as insects and weather. Rather, the polyethylene from recycled plastics does not necessitate such requirements, and have now been used to make materials like picnic tables and benches.

**5. PVC Windows**

PVC Windows have grown in popularity because they are easy to design and can adapt to many varying styles. A bonus is that because they are made primarily from plastics, the frames are 100% recyclable. Other benefits include:

- Longer lifetime (up to 40 years)

- Surplus of production material
- Same insulation quality as regular plastic

**6. Bricks**

Bricks are a stable material to build a home with, and more and more companies are embracing the idea of building bricks with recycled plastic.

Recycled bricks can be put together in a LEGO-like way, making a home's building time much quicker than it would be with traditional brick. This plastic product can also be fire-resistant, is cheaper, and, of course, is more eco-friendly.

**7. Fences**

Another part of a home-building journey may include fencing in a backyard or adding a white picket fence to your front yard. Homeowners can prioritize sustainability by designing fences from recycled plastic.

Additional advantages of building fences with recycled plastic are:

- Longevity (can be exposed to many weather elements without rotting)
- Durability
- No need for paint (color can be added in during recycling process)

**8. Floor Tiles**

The floor covering in your house is one of the most essential aspects in creating your dream home, and it has become more common to utilize floor tiles that contain recycled plastics.

Some of their benefits include:

- Easy installation process
- Easy to clean
- Quiet and warm
- Affordable

**9. Carpeting**

Along with floor tiles, your comfy carpet is very important to your home. Oddly enough, the water bottle you drank from this morning could wind up recycled into some of the best carpets out there.

Homeowners are installing these carpets made from recycled materials because they are more stain resistant and color fast. Also, recycling your carpet after years of use provides plastics with another way to be incorporated into more products.

### 10. Ceiling Tiles

Utilizing recycled plastic ceiling tiles is a great way to do it. Since plastic is easy to work with, the installation process is quite simple.

Some other pros include:

- Low maintenance (no painting, varnishing, or additional coats required once installed)
- Long lasting
- Affordable
- Great insulation material

### Environmental issues related to quarrying of building materials

Rapid growth of construction activity, to meet the modern-day requirements of increasing population and housing and infrastructure development needs of the society, has immensely boosted the demand for building materials. Stone quarrying continues to play major role in this process. However, the activity has caused serious environmental degradation and socio-economic conflicts. The major environmental and socio-economic problems related to quarrying revealed during this study include, landscape alteration, hill cutting affecting local biodiversity, generation of unproductive wastelands, dust pollution, noise pollution, illegal stone extraction, accidents and in some areas lowering of groundwater table.

A mineral is a naturally occurring substance of chemical composition. They are formed in different types of geological environments, under different conditions by natural processes. They can be identified based on their physical characteristics. The process of extracting minerals from rocks buried beneath the earth's surface is called "Mining". Minerals that lie near the surface are simply dug out, by the process known as "Quarrying". There are two types of quarrying processes done by humans on earth, one is mountain quarrying and the other is river quarrying.

### Quarrying Process

**Stage 1:** Identifying the mine site and planning the map to extract the mines from the operational site.

**Stage 2:** Remove the top layer of the Quarry site through the overburden.

**Stage 3:** Drill holes, insert explosions, and blast the rocks on mining sites.

**Stage 4:** Transport material for processing.

**Stage 5:** Process materials using crushing and screening technologies.

**Stage 6:** Addition of added value to processed materials using additional processing methods.

**Stage 7:** Transporting finished mining products to customers and partner companies.

**Major Environmental Concerns**

Quarrying has a significant impact on the environment. It can become a major environmental concern because it destroys the flora and fauna around it.

**Land Degradation**

The quarrying Process exclaves large land areas to extract the mineral ore and on the other hand, there is a requirement of huge areas to dump the mine spoils. Quarrying process of change in topography results in drastic changes in drainage patterns and a reduction in aesthetic value. While the extraction is underway, the landscape is visibly disfigured and habitat loss can be extensive. Quarrying destroys natural vegetation by scraping the upland soil and thereby also destroys the habitats of many wild animals. It cleans the surface vegetation, which destroys the humus in the soil which is essential for plant growth. Fine dust particles spread in the air around a quarrying site destroy natural vegetation.

**Erosion**

Quarrying in hilly areas causes erosion of hillsides, mine dumps, and tailings dams, which can result in the siltation of canals, streams, and rivers, which significantly affects surrounding areas. Due to quarrying, soil erosion reduces the availability of water for plant growth, which may result in population decline in plant ecosystems. Quarrying also causes coastal erosion, resulting in flooding in coastal areas. In the agricultural sector, it can disturb or destroy productive grazing and cropland. It can also destroy ecosystems and habitats in wildlife sanctuaries and national parks. River Quarrying transforms the river beds into large and deep pits, and as a result, the groundwater table drops leaving the drinking water wells.

**Air Pollution**

Deep Quarrying activities can affect local hydrology causing the water flow as well as quality. The quarrying process generates a lot of dust which causes air pollution. That means dust from quarry sites is a major source of air pollution, although the intensity depends on factors such as local microclimatic conditions, dust particle size, and their

chemistry. Limestone quarries produce highly alkaline and reactive specks of dust on the other hand coal mines produce acidic dust. Air pollution affects human health, mainly effects on the respiratory system. Air pollution also has physical effects on surrounding plants by depositing dust particles on the surface of plants, blocking and damaging their internal structure, and abrasion of leaves and cuticles.

**Water Pollution**

Quarrying activities cause pollution of surrounding water resources and groundwater. High concentrations of chemicals such as arsenic, sulfuric acid, and mercury produced from quarrying operations spread over the water surface. This sewage containing the above-mentioned chemicals leads to the destruction of the surrounding vegetation. If this runoff water is dumped into the forest areas, it will create a bad situation for the environment.

**Noise Pollution**

Quarrying operations involve many activities that generate significant levels of noise. those preparatory activities are the establishment of the road to the quarry site, rail access, drilling activities, blasting activities, hydraulic excavator truck operations, and product processing activities. Quarrying site involves the use of explosives to break huge chunks of rocks, which leads to massive noise pollution. And also blasting done for quarrying generates great vibrations that can damage nearby constructions like civilian buildings, dams, etc. the use of powered machinery which involves the transport of materials and processing crushing of the products contributes more noise to the environment.

**Damage to Biodiversity**

One of the biggest concerns of quarrying on the environment is the damage to biodiversity. Although habitats are not directly removed by quarrying activities, they are indirectly affected and damaged by environmental impacts such as groundwater depletion that causes some habitats to dry out or others to flood. Even noise pollution can also have a significant impact on some species and affect their successful reproduction.

**Sinkholes**

At the time of quarrying activities, overburden at the quarry site can develop cavities in the subsoil or rock, which can refill with sand and soil from overlying strata, when sudden

failure of the earth creates a large depression at the surface without warning can cause serious hazards to life and property nearby by quarry site.

**Improper disposal of Quarry Waste**

Many man-made activities and machinery activities on a quarry site generate significant amounts of waste. Dumping of quarry waste without a proper site can harm the environment, And the severity of impacts depends on the method of quarrying and the natural topography surrounding the quarry sites. Furthermore, the treatment, storage of waste products, and disposal of waste may produce more negative impacts on the environment. Even the chemicals involved in the Quarry operations may increase dangerous particles in the wastage which may imbalance the freshwater ecosystem when the query wastage is disposed of in nearby lakes or rivers. when waste material has to be dumped on the adjacent land, it is chemically contaminated and affects the hydrological instability of plant growth as it is carried to the watercourses and degraded environment near the land.

## REVIEW QUESTIONS

1. Explain the classification and uses of stones.
2. What are the qualities of a good building stone?
3. Write the advantages and disadvantages of laterite blocks.
4. Write the advantages and disadvantages of concrete blocks.
5. What are the advantages and disadvantages of LPC?
6. Explain the benefits of plastic recycling.
7. Explain the environmental issues related to quarrying.
8. What are the advantages and disadvantages of bamboo?
9. Explain the following building materials:
   a) Stabilized Mud Blocks
   b) Gypsum Board
   c) Lime Pozzolana Cement
   d) Light Weight Beams
10. Explain the different types of fibre reinforced concrete.