LECTURE 1


Green Building – Detailed Notes (Diploma Level)
Definition of Green Building
A Green Building is a structure designed, constructed, and operated to reduce environmental impact and improve the health and comfort of occupants
• Energy Efficiency
• Water Conservation
• Eco-Friendly Materials
• Eco-Friendly Materials
• Waste Reduction
• Better Indoor Air Quality
Benefits of Green Building
Environmental Benefits
Energy & Water Conservation
Reduced Pollution
Economic Benefits
Lower Costs
Higher Property Value
Health Benefits
Better Indoor Air Quality
Improved Comfort
Key Features of Green Building
Renewable Energy
Solar Panels & Wind Turbines
Water Efficiency
• Rainwater Harvesting
• Low-Flow Fixtures
Sustainable Materials
• Recycled & Local Materials
Indoor Air Quality
• Natural Ventilation & Low VOC Paints
Waste Management & Landscaping
Recycle
Compost
Waste Management
Green Spaces
Green Spaces

Definition of Green Building

A **Green Building** is a structure that is **designed, constructed, and operated** in a way that **reduces negative impacts on the environment** and **improves the health and comfort of occupants** throughout its life cycle.

It focuses on:

- Efficient use of **energy**
- Efficient use of **water**
- Use of **eco-friendly materials**
- Reduction of **waste and pollution**
- Better **indoor air quality**

Simple Definition:
A green building is an environmentally responsible and resource-efficient building from planning to demolition.

Objectives of Green Building

- To **conserve natural resources**
- To **reduce energy consumption**
- To **minimize pollution and waste**
- To provide **healthy living conditions**
- To promote **sustainable development**

Benefits of Green Building

A. Environmental Benefits

1. **Energy Conservation** – Use of solar panels, LED lights, natural lighting reduces electricity consumption.
2. **Water Conservation** – Rainwater harvesting and low-flow fixtures save water.
3. **Reduced Pollution** – Less emission of harmful gases.
4. **Waste Reduction** – Recycling and reuse of materials.
5. **Protection of Ecosystem** – Less damage to forests and natural habitats.

B. Economic Benefits

1. **Lower Operating Cost** – Reduced electricity and water bills.

2. **Higher Property Value** – Green buildings have better market demand.
3. **Reduced Maintenance Cost** – Durable and quality materials are used.
4. **Long-Term Savings** – Initial cost may be high but lifecycle cost is low.

C. Social / Health Benefits

1. **Better Indoor Air Quality**
2. **Improved Comfort** – Proper ventilation and lighting.
3. **Increased Productivity** – Healthier environment improves efficiency.
4. **Reduced Health Problems** – Less allergies and respiratory issues.

Components / Features of Green Building

1. Site Selection and Planning

- Choose site with **minimum environmental damage**.
- Near public transport to reduce fuel use.
- Preserve natural trees and landscape.

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2. Energy Efficiency

- Use of **solar panels** and renewable energy.
- Proper **building orientation** for sunlight and wind.
- **LED lighting** and energy-efficient appliances.
- **Insulation** to reduce heat gain/loss.

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3. Water Efficiency

- **Rainwater Harvesting**
- **Low-flow taps and dual-flush toilets**
- **Grey water recycling** for gardening.
- Drip irrigation systems.

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4. Sustainable Building Materials

- Use of **locally available materials**
- Recycled steel, fly ash bricks, bamboo.

- Non-toxic paints and adhesives.
- Materials with **low embodied energy**.

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5. Indoor Environmental Quality

- Adequate **natural lighting**
- Proper **ventilation**
- Use of **low VOC paints**
- Noise control measures.

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6. Waste Management

- Segregation of waste.
- Recycling and reuse of construction waste.
- Composting organic waste.

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7. Renewable Energy Use

- Solar water heaters.
- Wind energy (where possible).
- Biogas plants.

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8. Landscaping and Green Areas

- Roof gardens and vertical gardens.
- Plantation of native plants.
- Reduction of heat island effect.

Green Building Rating Systems

- **LEED (Leadership in Energy and Environmental Design)**
- **GRIHA (India)**
- **IGBC (Indian Green Building Council)**

These systems **certify buildings** based on sustainability performance.

Conclusion

Green buildings are essential for **sustainable development**. They help in **saving energy, water, and resources**, reduce pollution, and provide a **healthy and comfortable environment**. Though the initial construction cost may be slightly higher, the **long-term environmental and economic benefits** are significant.

LECTURE 2

ENERGY EFFICIENCY

Definition

Energy Efficiency means **using less energy to perform the same work** without reducing comfort or performance.

Example:
Using LED bulb instead of incandescent bulb → same light but less electricity.

Objectives

- Reduce electricity consumption
- Lower energy bills
- Reduce pollution & carbon emission
- Conserve natural resources (coal, oil, gas)

Methods to Improve Energy Efficiency

1. Building Design

- Proper orientation of building
- Maximum natural lighting
- Cross ventilation
- Use of shading devices

2. Efficient Appliances

- LED lights

- 5-Star rated AC, Refrigerator, Fans
- Inverter technology

3. Insulation

- Wall insulation
- Roof insulation
- Double glazed windows

4. Renewable Energy Use

- Solar panels
- Solar water heaters
- Wind energy

ENERGY BENCHMARK

Definition

Energy Benchmark is a **standard value or reference point** used to compare the energy performance of buildings.

It answers:
"Is this building using more or less energy compared to similar buildings?"

Purpose

- Measure building performance
- Identify energy wastage
- Improve efficiency
- Certification (LEED, GRIHA, BEE ratings)

Common Units

- **kWh/m²/year** (Kilowatt hour per square meter per year)
- Energy Use Intensity (EUI)

Example

If two buildings have:

- Building A = 150 kWh/m²/year
- Building B = 80 kWh/m²/year

Building B is more energy efficient.

WATER EFFICIENCY

Definition

Water Efficiency means **using minimum water without waste** and maintaining performance.

Objectives

- Reduce water consumption
- Save groundwater
- Lower water bills
- Sustainable development

Methods

1. Low Flow Fixtures

- Low flow taps
- Dual flush toilets
- Sensor taps

2. Leak Prevention

- Regular maintenance
- Proper plumbing

3. Smart Irrigation

- Drip irrigation
- Sprinkler systems

4. Reuse Systems

- Grey water recycling
- Rainwater harvesting

RAIN WATER USE (RAINWATER HARVESTING)

Definition

Rainwater Harvesting is the process of **collecting, storing, and using rainwater** for future use.

Uses

- Drinking (after filtration)
- Gardening
- Toilet flushing
- Groundwater recharge

Components

1. Catchment Area (Roof)
2. Gutters & Pipes
3. Filter Unit
4. Storage Tank / Recharge Pit

GREY WATER USE

Definition

Grey Water is **wastewater from bathrooms, sinks, washing machines** (NOT from toilets).

It can be treated and reused.

Sources of Grey Water

- Hand wash basins
- Showers
- Laundry
- Kitchen sink (sometimes)

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Uses After Treatment

- Gardening
- Toilet flushing
- Cleaning floors
- Landscaping

Topic	Main Aim	Benefit
Energy Efficiency	Save Electricity	Lower bills
Energy Benchmark	Measure Energy Use	Performance comparison
Water Efficiency	Save Water	Sustainability
Rainwater Use	Collect Rain	Groundwater recharge
Grey Water Use	Reuse Wastewater	Reduce fresh water demand

LECTURE 3

MATERIAL EFFICIENCY

Definition

Material efficiency means **using construction materials in such a way that minimum waste is produced and maximum life and performance are achieved.**

Objectives

- Reduce consumption of natural resources.
- Reduce construction cost.
- Minimize waste generation.
- Increase durability of building.

Methods to Achieve Material Efficiency

1. **Use of Recycled Materials**
    - Fly ash bricks
    - Recycled steel
    - Reused wood and tiles
    - Plastic recycled boards
2. **Use of Local Materials**
    - Reduces transportation cost and pollution.
    - Example: local stone, sand, bricks.
3. **Modular Design**
    - Designing rooms in standard sizes.
    - Reduces cutting and wastage of materials.
4. **Durable Materials**
    - Materials with long life like RCC, treated wood, aluminium.
    - Less maintenance cost.
5. **Construction Waste Management**
    - Segregation of waste.
    - Reusing concrete debris for road base.

Advantages

- Cost saving
- Environmental protection
- Better building life
- Reduced landfill waste

INDOOR AIR QUALITY (IAQ)

Definition

Indoor Air Quality refers to the **quality and cleanliness of air inside buildings** which affects human health and comfort.

Factors Affecting IAQ

- Ventilation
- Humidity
- Dust and pollutants
- Chemicals from paints and furniture
- Smoking and cooking fumes

Methods to Improve IAQ

1. **Proper Ventilation**
    - Cross ventilation through windows.
    - Exhaust fans in kitchen and toilets.
2. **Air Filtration Systems**
    - HVAC filters.
    - Air purifiers.
3. **Low VOC Materials**
    - VOC = Volatile Organic Compounds.
    - Use low-VOC paints, adhesives, varnishes.
4. **Indoor Plants**
    - Snake plant, money plant, aloe vera.
    - Absorb CO_2 and pollutants.
5. **Moisture Control**
    - Prevent leakage.
    - Avoid fungus and mold growth.

Effects of Poor IAQ

- Headache
- Allergies
- Asthma
- Fatigue
- Sick Building Syndrome

THERMAL COMFORT (TEMPERATURE CONTROL)

Definition

Thermal comfort means **maintaining a comfortable indoor temperature so that occupants feel neither too hot nor too cold.**

Factors Affecting Thermal Comfort

- Outdoor climate
- Building orientation
- Insulation
- Air movement
- Sunlight exposure

Methods to Achieve Thermal Comfort

1. **Insulation**
   - Roof insulation sheets.
   - Cavity walls.
   - False ceilings.
2. **Glazing**
   - Double-glazed windows.
   - Reflective glass reduces heat entry.
3. **Passive Design**
   - Building orientation towards north/south.
   - Shading devices like chajjas and louvers.
   - Courtyards for airflow.
4. **Efficient HVAC Systems**
   - Air conditioners with high star rating.
   - Ceiling fans and ventilators.
5. **Cool Roof Techniques**
   - White coating.
   - Green roofs.

Benefits

- Reduced electricity consumption.
- Increased occupant comfort.
- Improved productivity.

VISUAL COMFORT (LIGHTING COMFORT)

Definition

Visual comfort means **providing sufficient and glare-free lighting so that people can see clearly without eye strain.**

Elements of Visual Comfort

- Natural daylight
- Artificial lighting
- Glare control
- Color contrast
- Outside view

Methods to Improve Visual Comfort

1. **Maximize Natural Light**
   - Large windows.
   - Skylights.
   - Glass doors.
2. **Quality Artificial Lighting**
   - LED lights.
   - Proper placement of fixtures.
3. **Glare Reduction**
   - Curtains, blinds.
   - Matte wall finishes.
4. **Proper Color Selection**
   - Light colors reflect light.
   - Dark colors absorb light.
5. **View to Outdoors**
   - Windows facing gardens or open spaces.

Benefits

- Reduced electricity cost.
- Better eyesight comfort.
- Increased productivity in offices and classrooms.

ACOUSTICS (SOUND COMFORT)

Definition

Acoustics deals with **control of sound inside buildings to reduce noise and improve clarity of speech and sound.**

Sources of Noise

- Traffic
- Machinery
- Neighbors
- Construction activities
- Echo inside rooms

Methods to Improve Acoustics

1. **Sound Insulation Materials**
    - Acoustic panels.
    - Gypsum boards.
    - Rock wool.
2. **Double Glazed Windows**
    - Reduce external noise.
3. **Soft Furnishings**
    - Curtains, carpets, sofas absorb sound.
4. **Wall and Ceiling Treatment**
    - False ceiling.
    - Perforated boards.
5. **Room Shape and Design**
    - Avoid large empty halls.
    - Use irregular surfaces to reduce echo.

Benefits

- Quiet environment.
- Better concentration.
- Improved communication in classrooms and offices.


Sustainable Building Design Notes
Material Efficiency
• Use recycled & sustainable materials.
• Reduce construction waste.
• Optimize building design to minimize resource use.
• Ensure durability & longevity.
Indoor Air Quality
• Proper Ventilation & Air Filtration
• Low-VOC paints & finishes.
• Control humidity & moisture.
• Avoid allergens & pollutants.
Thermal Comfort
• Optimal Insulation & Glazing.
• Effective HVAC Systems.
• Passive Design Strategies.
• Maintain Stable Indoor Temperature.
Visual Comfort
• Maximize Natural Daylight.
• Quality Artificial Lighting.
• Reduce Glare & Reflections.
• Good Views to the Outdoors.
Acoustics
• Sound Insulation & Absorptive Materials.
• Reduce Noise Transmission.
• Control Reverberation.
• Create Quiet Interior Spaces.
Holistic Sustainable Design Improves Comfort, Health & Efficiency.

LECTURE 4

Site Selection Strategies –

(Green / Sustainable Building Planning)

Site selection strategy means **choosing and planning a building site in such a way that energy consumption, environmental damage, and cost are reduced while comfort and efficiency are increased.** It is an important topic in Green Building and Building Planning.

The main components are:

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1. Landscaping

Landscaping means planning trees, plants, lawns, pathways, and water bodies around the building.

Objectives

- Improve micro-climate around building
- Reduce heat and dust
- Provide shade and beauty
- Control wind and noise

Strategies

- **Use Native Plants:** Plants that grow naturally in the region need less water and maintenance.
- **Tree Plantation:**
  - Trees on **west and south sides** reduce heat gain.
  - Tall trees act as windbreakers.
- **Green Spaces:** Lawns and gardens reduce surface temperature.
- **Water Features:** Ponds, fountains improve humidity and cooling.
- **Permeable Surfaces:** Use grass pavers instead of full concrete to allow rainwater absorption.

Benefits

- Lowers surrounding temperature by 2–5°C
- Reduces energy for cooling
- Improves air quality

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2. Building Form

Building form refers to the **shape, size, and mass of the building.**

Strategies

- **Compact Shape:** Square or rectangular buildings lose less heat compared to irregular shapes.
- **Surface Area to Volume Ratio:** Lower ratio = less heat transfer.
- **Height Consideration:**
  - Low-rise buildings are better in hot climates.
  - High-rise buildings are better in dense urban areas.

Examples

- **Hot Climate:** Courtyard buildings allow air circulation.
- **Cold Climate:** Compact box shape retains heat.

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3. Building Orientation

Orientation means the direction in which the building faces with respect to the sun and wind.

Strategies

- **East–West Orientation:** Long side facing north–south reduces direct sunlight.
- **Maximize North Light:** North side gets uniform daylight without heat.
- **Control West Sun:** Provide minimum openings on west side.
- **Use Prevailing Wind Direction:** Windows placed in wind direction improve ventilation.

Benefits

- Natural lighting
- Reduced artificial lighting cost
- Better thermal comfort

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4. Building Envelope

Building envelope is the outer covering of the building including **walls, roof, windows, and doors.**

Components

- Walls
- Roof
- Doors
- Windows
- Insulation layers

Strategies

- **Thermal Insulation:** Use materials like glass wool, foam boards.
- **Air Barriers:** Prevent air leakage.
- **Moisture Barriers:** Protect from dampness.
- **Cool Roofs:** Reflect sunlight using white or reflective paint.
- **Thermal Mass:** Thick walls store heat and release slowly.

Benefits

- Reduces heating/cooling load
- Energy efficient building
- Increased life of structure

LECTURE 5

6. Fenestration

Fenestration means arrangement of **windows, ventilators, skylights, and glass openings.**

Strategies

- **Window Size & Placement:**
  - Larger windows on north side.
  - Smaller windows on west side.
- **Double Glazed Glass:** Reduces heat transfer.
- **Shading Devices:**
  - Chajjas
  - Louvers
  - Sunshades
  - Vertical fins
- **Skylights:** Provide daylight but should have shading.

Benefits

- Natural daylight
- Reduced electricity usage
- Improved ventilation

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6. Materials

Building materials greatly affect sustainability and energy performance.

Strategies

- **Local Materials:** Reduce transportation cost and pollution.
- **Recycled Materials:** Fly ash bricks, recycled steel.
- **Low VOC Paints:** Reduce indoor air pollution.
- **Eco-friendly Materials:** Bamboo, mud blocks, compressed earth blocks.
- **Durable Materials:** Increase life span and reduce maintenance.

Benefits

- Environmental protection
- Cost saving
- Healthier indoor environment

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7. Land Use and Consumption

This refers to **how efficiently land is used without damaging natural resources.**

Strategies

- **Minimum Site Disturbance:** Avoid cutting too many trees.
- **Preserve Natural Features:** Hills, ponds, vegetation.
- **Rainwater Harvesting:** Store rainwater for reuse.
- **Waste Management:** Proper disposal and recycling.
- **Reduce Building Footprint:** Multi-storey instead of spreading horizontally.

Benefits

- Conservation of natural resources
- Reduced soil erosion
- Better ecological balance


Site Selection Strategies
(Diploma Level Notes)
Landscaping
• Use native plants.
• Tree plantation for shading & wind control.
• Create green spaces & water features.
• Permeable surfaces for rainwater absorption.
• Lowers temperature by 2-5°C
• Reduces energy for cooling
• Improves air quality.
Benefits
• Lowers temperature by 2-5°C
• Reduces energy for cooling
• Improves air quality.
Building Form
• Compact shape like square or rectangle loses less heat.
• Lower surface area to volume ratio.
• Height consideration: Low-rise in hot, high-rise in urban.
Compact Shape
Less heat transfer
Energy efficient heating & cooling
Hot Climate
Cold Climate
Building Orientation
• Use thermal & moisture barriers to prevent heat transfer.
• Cool roofs reflect sunlight.
• Thermal mass increases stability.
Proper Orientation
Poor Orientation
• Use thermal & moisture barriers to prevent heat transfer.
• Cool roofs reflect sunlight.
• Use prevailing wind for natural ventilation.
Cold Climate
Benefits
• Reduces heating/ cooling load
• Energy efficient building.
Fenestration
• Optimize window size & placement.
• Use energy-efficient, double glazed windows.
• Install shading devices: chajjas, louvers, skylights.
Materials
• Use local & recycled materials (fly ash bricks, bamboo, etc.)
• Low VOC paints for better indoor air quality.
Land Use & Consumption
• Reduce site disturbance & footprint.
• Preserve natural features (hills, ponds, trees, etc..)
• Manage water & waste: rainwater harvesting, recycling.
Fenestration
• Provide aluteal glass
• Shading devices.
Materials
• Use local & recycled materials (fly ash bricks, bamboo, etc.)
• Low VOC paints for better indoor air quality.
Land Use & Consumption
• Conserves natural resources.
• Reduces soil eresion.
• Achieves better ecological balance.
Green / Sustainable Building Planning

LECTURE 6

CONSTRUCTION TECHNIQUES

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1. ROOFS (छत निर्माण तकनीक)

1.1 Definition

A **roof** is the topmost covering of a building which protects the structure from **sun, rain, wind, heat, and snow**.

1.2 Functions of Roof

- Protection from weather.
- Thermal insulation (heat control).
- Sound insulation.
- Structural stability.
- Aesthetic appearance.

1.3 Types of Roofs

A. Flat Roof

- Slope: 1 in 40 to 1 in 60.
- Used in **urban buildings**.
- Easy for water tank, solar panels, terrace use.
- Materials: RCC slab, waterproofing layers.

Advantages

- Usable terrace.
- Easy maintenance.
- Modern look.

Disadvantages

- Water leakage risk if waterproofing is poor.

B. Pitched Roof

- Slope more than 10°.
- Used in **high rainfall or snowfall areas**.
- Materials: Tiles, GI sheets, shingles, slate.

Advantages

- Quick water drainage.
- Good thermal performance.

Disadvantages

- Less usable space.
- Higher construction cost.

C. Curved / Shell Roof

- Used in stadiums, auditoriums.
- Modern architectural style.
- RCC or steel structures.

1.4 Roof Components

- **Rafters** – Sloping beams.
- **Purlins** – Horizontal support.
- **Truss** – Framework for load transfer.
- **Waterproofing layer** – Prevents leakage.
- **Insulation layer** – Heat reduction.

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2. WALLS (दीवार निर्माण तकनीक)

2.1 Definition

Walls are **vertical structural members** that divide spaces and carry loads.

2.2 Functions

- Load bearing.
- Space division.

- Thermal & sound insulation.
- Privacy & security.
- Weather protection.

2.3 Types of Walls

A. Load Bearing Wall

- Carries roof/floor load.
- Thickness: 230 mm or more.
- Used in low-rise buildings.

B. Non-Load Bearing Wall

- Only partition.
- Thickness: 100–150 mm.
- Materials: Bricks, gypsum boards, glass.

C. Cavity Wall

- Two parallel walls with air gap.
- Provides thermal insulation.
- Prevents dampness.

D. Shear Wall

- Used in high-rise buildings.
- Resists earthquake forces.

2.4 Wall Materials

- Burnt Clay Bricks
- Fly Ash Bricks
- Concrete Blocks
- AAC Blocks
- Stone Masonry
- Timber / Glass Panels

LECTURE 7

3. FENESTRATION (खिड़की-दरवाज़े की व्यवस्था)

3.1 Definition

Fenestration refers to the arrangement and design of **windows, doors, ventilators, and skylights** in a building.

3.2 Objectives

- Natural lighting.
- Ventilation.
- Thermal comfort.
- Aesthetic appeal.
- Energy efficiency.

3.3 Types of Fenestration

Windows

- **Casement Window** – Hinged open.
- **Sliding Window** – Moves horizontally.
- **Fixed Window** – Does not open.
- **Louvered Window** – Air passage with slats.
- **Bay Window** – Projects outward.

Doors

- Panel Door
- Flush Door
- Glass Door
- Sliding Door

Skylights

- Installed on roof.
- Provides daylight.
- Saves electricity.

3.4 Design Considerations

- Orientation (North light preferred).
- Window-to-Wall Ratio (WWR).
- Cross ventilation.
- Height and sill level.
- Shading devices.

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4. SHADED FINISHES (छाया युक्त सतह उपचार)

4.1 Definition

Shaded finishes are **external surface treatments** that reduce heat gain and improve durability.

4.2 Purpose

- Reduce solar heat.
- Improve building life.
- Enhance aesthetics.
- Protect from rain & dust.

4.3 Types of Shaded Finishes

A. Sunshades / Chajjas

- RCC or metal projection.
- Placed above windows/doors.
- Blocks direct sunlight.

B. Louvers

- Horizontal/Vertical slats.
- Allow air, block sunlight.

C. Pergolas

- Open roof shading structure.
- Used in terraces & gardens.

D. Textured Exterior Paints

- Reflective paints reduce heat.
- Weather-resistant coatings.

E. Cladding Materials

- Stone cladding.
- ACP panels.
- Wooden panels.
- Ceramic tiles.

4.4 Advantages of Shaded Finishes

- Energy saving.
- Comfort improvement.
- Moisture protection.
- Better building appearance.

Integrated Design Concept

A good construction technique combines:

- **Strong walls**
- **Efficient roof design**
- **Proper fenestration**
- **Effective shaded finishes**

This results in:

- Energy efficient buildings
- Comfortable interiors
- Long structural life
- Reduced maintenance cost

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LECTURE 8

Advanced Passive Heating and Cooling Techniques –

Introduction

Passive heating and cooling techniques are **design strategies used in buildings to maintain comfortable indoor temperature without using mechanical equipment** like ACs, heaters, or fans.
They depend on **natural energy sources** such as **sunlight, wind, shade, thermal mass, and ventilation**.

These techniques help in:

- Reducing electricity consumption
- Improving thermal comfort
- Lowering carbon emissions
- Increasing building sustainability

Passive Heating Techniques

Passive heating is mainly required in **cold climates** or **winter seasons**. The objective is to **capture, store, and distribute solar heat** inside the building.

2.1 Direct Solar Gain

- Sunlight enters through **south-facing windows** (in India).
- Floors and walls absorb heat and release it slowly at night.
- Use **large glass windows** with double glazing.

Advantages:

- Simple and low cost
- Immediate heating effect

Limitations:

- Risk of overheating in summer
- Needs shading devices

2.2 Indirect Solar Gain (Thermal Storage Wall / Trombe Wall)

- A **thick masonry or concrete wall** painted dark is placed behind glass.
- Sunlight heats the wall during the day.
- Heat slowly moves inside at night.

Materials Used: Brick, stone, concrete, adobe.

Benefits:

- Delayed heat release
- Stable indoor temperature

2.3 Sunspaces / Solar Greenhouses

- A **glass-enclosed room** attached to the south side.
- Acts as a heat collector.
- Warm air enters living spaces through vents.

2.4 Thermal Mass Heating

- Use of **high heat-capacity materials** like:
  - Concrete
  - Brick
  - Stone
  - Mud blocks
- These materials store heat during day and release at night.

Passive Cooling Techniques

Passive cooling is essential in **hot climates**. Aim is to **reduce heat gain and increase heat loss naturally**.

3.1 Building Orientation

- Long axis east-west.
- Minimize west-side openings.
- Maximize north-south airflow.

3.2 Natural Ventilation

Uses wind and temperature differences.

(a) Cross Ventilation

- Windows on **opposite walls**.
- Air flows across rooms.

(b) Stack Ventilation

- Hot air rises and exits through **roof vents/skylights**.
- Cool air enters from lower openings.

3.3 Shading Devices

- **Overhangs**
- **Louvers**
- **Pergolas**
- **Vertical fins**
- **Trees and vegetation**

Purpose: Block direct sunlight, especially west sun.

3.4 Insulation

- Reduces heat transfer.
- Used in **roofs, walls, and floors**.
- Materials: Glass wool, rock wool, foam boards, cellulose.

3.5 Cool Roofs / Reflective Surfaces

- White or light-colored roof paints.
- Reflect solar radiation.
- Reduce indoor temperature by **3–5°C**.

3.6 Courtyards

- Central open space improves airflow.
- Creates pressure difference and cooling.
- Common in **traditional Indian architecture**.

3.7 Evaporative Cooling

- Uses water evaporation to cool air.
- Methods:
    - Water bodies
    - Fountains
    - Wet curtains
    - Roof ponds

3.8 Earth Air Tunnel / Earth Cooling

- Air is passed through **underground pipes**.
- Soil temperature is cooler than outside air.
- Air gets naturally cooled before entering building.

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4. Advanced Passive Techniques

4.1 Double Skin Facade

- Two layers of glass with air gap.
- Air gap acts as insulation and ventilation channel.

4.2 Phase Change Materials (PCM)

- Materials that **absorb/release heat during phase change**.
- Maintain constant indoor temperature.

4.3 Green Roofs and Green Walls

- Vegetation layer on roof/walls.
- Provides insulation and evaporative cooling.

4.4 Solar Chimney

- Tall vertical shaft painted black.
- Heats up and pulls hot air out.

- Improves natural ventilation.

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5. Design Considerations

- Climate analysis (hot, cold, composite)
- Site orientation
- Building materials
- Window-to-wall ratio
- Landscaping
- User behavior

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6. Advantages of Passive Heating & Cooling

- Energy saving (30–60%)
- Low maintenance
- Environment friendly
- Improved indoor air quality
- Increased comfort

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7. Limitations

- Higher initial design effort
- Climate dependent
- Space requirement for courtyards/sunspaces
- Needs proper planning at early stage

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Lecture 9

WASTE REDUCTION DURING CONSTRUCTION – GREEN BUILDING

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1. Introduction

Waste Reduction during Construction means minimizing the amount of material that is wasted, discarded, or sent to landfills while constructing a building.
In **Green Building**, waste reduction is a very important principle because it helps in:

- Saving natural resources
- Reducing environmental pollution
- Lowering construction cost
- Improving site cleanliness and safety
- Increasing project efficiency

Construction waste includes **cement bags, bricks, concrete debris, steel scraps, wood pieces, packaging materials, plastics, glass, and soil waste.**

---

2. Types of Construction Waste

1. **Material Waste** – Broken bricks, extra cement, unused sand, tiles.
2. **Packaging Waste** – Plastic covers, cardboard boxes, thermocol.
3. **Demolition Waste** – Concrete debris, old steel, wood.
4. **Hazardous Waste** – Paint cans, chemicals, adhesives.
5. **Excavation Waste** – Extra soil and stones.

---

3. Causes of Construction Waste

- Poor planning and design changes

- Ordering excess materials
- Improper storage of materials
- Skilled labor shortage
- Transportation damage
- Cutting errors and measurement mistakes
- Weather conditions (rain, wind)

---

4. Principles of Waste Reduction (3R Concept)

Green building follows **3R Principle**:

1. Reduce

- Use only required quantity of materials.
- Accurate estimation and budgeting.
- Modular design to avoid cutting waste.

2. Reuse

- Reuse wooden formwork.
- Reuse bricks and steel.
- Reuse packaging materials.

3. Recycle

- Recycle concrete into aggregates.
- Recycle steel scrap.
- Recycle plastics and glass.

---

5. Methods of Waste Reduction during Construction

A. Proper Planning & Design

- Prepare detailed drawings.
- Use **standard dimensions** to reduce cutting.
- Adopt **prefabrication** methods.

B. Material Management

- Order materials in correct quantity.
- Follow **First-In First-Out (FIFO)** method.
- Store cement in dry areas and steel off the ground.

C. Use of Prefabricated Components

- Precast slabs, doors, windows, wall panels.
- Reduces on-site waste and saves time.

D. Efficient Construction Techniques

- Ready Mix Concrete (RMC).
- Machine cutting instead of manual cutting.
- Use of modular bricks/blocks.

E. On-Site Waste Segregation

Separate waste into:

- Metal
- Plastic
- Wood
- Concrete
- Hazardous waste

This makes recycling easier.

F. Reuse of Materials

- Reuse shuttering plywood.
- Reuse soil for landscaping.
- Use broken bricks for filling.

G. Recycling Facilities

- Provide bins for recyclable waste.
- Tie up with recycling agencies.

H. Training & Awareness

- Train workers about waste control.
- Display instruction boards on site.

---

6. Benefits of Waste Reduction in Green Buildings

- **Environmental Benefits**
  - Reduced landfill burden
  - Lower pollution
  - Conservation of resources

- **Economic Benefits**
  - Reduced material cost
  - Less transportation cost
  - Increased profit margin
- **Social Benefits**
  - Cleaner site
  - Improved worker safety
  - Better public image

---

7. Green Building Rating Systems & Waste Reduction

Green rating systems like **IGBC, GRIHA, LEED** give points for:

- Construction waste management plan
- Recycling percentage
- Use of recycled materials
- Low-waste technologies

---

8. Example Practices

- Using **Fly Ash Bricks** instead of clay bricks.
- Using **Recycled Steel**.
- Converting concrete waste into paver blocks.
- Digital drawings instead of paper prints.

---

9. Conclusion

Waste reduction during construction is a key element of **Green Building**.
By proper planning, 3R principles, efficient material management, and worker awareness, construction waste can be significantly minimized. This results in **sustainable, economical, and eco-friendly buildings**, which is the main goal of green construction.

LECTURE 10

Meaning of Energy Audit

An **Energy Audit** is a **systematic inspection, survey, and analysis of energy use** in a building, industry, or facility.
The main aim is to **identify areas where energy is wasted** and to **suggest measures to reduce energy consumption** without affecting productivity or comfort.

In Simple Words

Energy Audit = **Checking how much energy is used + where it is wasted + how to save it.**

Key Points

- It studies **electricity, fuel, water, lighting, HVAC systems, machinery, etc.**
- Conducted by **Energy Auditors / Engineers.**
- Focus is on **efficiency, conservation, and cost saving.**

---

2. Necessity / Importance of Energy Audit

Energy audit is necessary due to increasing energy demand, high electricity bills, and environmental concerns.

Why Energy Audit is Important

1. Reduction in Energy Cost

- Helps in lowering electricity and fuel bills.
- Identifies unnecessary consumption.

2. Energy Efficiency Improvement

- Improves performance of equipment and systems.
- Reduces energy loss.

3. Environmental Protection

- Decreases carbon emissions.
- Supports green building concepts.

4. Better Resource Utilization

- Efficient use of electricity, water, gas, and fuel.

5. Increased Equipment Life

- Proper maintenance and optimized use extend machinery life.

6. Compliance with Government Norms

- Many industries must follow energy efficiency standards.

---

3. Types of Energy Audit

1. Preliminary Energy Audit

- Basic and quick review.
- Uses existing data like electricity bills.
- Identifies major problem areas.

2. Detailed Energy Audit

- In-depth analysis.
- Includes measurements, monitoring, and calculations.
- Provides accurate recommendations and payback analysis.

---

4. Objectives of Energy Audit

- To **reduce energy consumption**
- To **identify energy saving opportunities**
- To **optimize system performance**
- To **reduce operational cost**
- To **protect environment**
- To **improve sustainability**

---

5. Procedures / Steps of Energy Audit

Energy audit is performed in a systematic manner.

Step 1: Preliminary Assessment

- Collect past energy bills.
- Study building layout and equipment list.
- Identify high energy consuming areas.

Step 2: Data Collection

- Record electricity usage.

- Check lighting systems, HVAC, motors, appliances.
- Note operating hours.

Step 3: Detailed Analysis

- Use instruments like **lux meter, clamp meter, power analyzer, thermometer.**
- Measure actual energy consumption.
- Compare with standard values.

Step 4: Identification of Energy Saving Opportunities

Examples:

- Replacing incandescent bulbs with LEDs.
- Installing solar panels.
- Improving insulation.
- Using energy efficient motors.

Step 5: Cost–Benefit Analysis

- Calculate investment cost.
- Estimate payback period.
- Determine savings.

Step 6: Reporting & Recommendations

- Prepare audit report.
- Suggest corrective actions.
- Provide implementation plan.

Step 7: Implementation & Monitoring

- Apply recommended measures.
- Monitor results regularly.

---

6. Instruments Used in Energy Audit

- **Lux Meter** – measures light intensity.
- **Power Analyzer** – measures electrical parameters.
- **Clamp Meter** – measures current.
- **Thermometer / Thermal Camera** – checks heat loss.
- **Anemometer** – measures air velocity.
- **Flow Meter** – measures water or gas flow.

7. Benefits of Energy Audit

- **Cost Savings**
- **Improved Energy Efficiency**
- **Environmental Protection**
- **Better Building Performance**
- **Reduced Carbon Footprint**
- **Long-term Sustainability**
- **Improved Comfort & Productivity**

---

8. Explanation of Energy Audit Diagram (Conceptual Understanding)

An energy audit diagram generally shows:

Top Section – Meaning

A building with an auditor inspecting energy usage → represents **inspection and analysis**.

Middle Section – Importance

Icons such as factory, bulb, money sign → show **cost saving, efficiency, and environmental benefits**.

Lower Section – Steps

Usually displayed in **4–5 boxes**:

1. **Preliminary Assessment**
2. **Detailed Measurement**
3. **Identification of Opportunities**
4. **Reporting & Recommendations**
5. **Implementation**

Bottom Section – Benefits

Symbols like piggy bank, globe, leaf, growth chart → indicate **financial savings, eco-friendliness, and performance improvement.**

LECTURE 11

Objectives of Energy Audit

- Reduce electricity and fuel bills
- Improve efficiency of equipment
- Reduce environmental pollution
- Increase life of machines
- Optimize energy use
- Promote green building concepts

Need of Energy Audit

- Rising energy costs
- Limited natural resources
- Government energy regulations
- Environmental protection
- Better operational control

Types of Energy Audit

Energy audits are mainly classified into **three types**:

Preliminary Energy Audit (Walk-Through Audit)

Meaning:
A simple and quick inspection of the building or facility.

Features:

- Short duration
- Low cost
- Basic data collection
- Visual inspection only
- No complex instruments

Purpose:

- Identify major energy wastage areas
- Understand energy consumption pattern
- Suggest simple improvements

Example Suggestions:

- Switching off lights when not needed
- Replacing old bulbs with LED
- Fixing leakage in air conditioners

Simple Representation

Building Visit
↓
Check Lights, Fans, AC
↓
Note High Energy Areas
↓
Give Basic Suggestions

Detailed Energy Audit

Meaning:
A **comprehensive and technical study** of energy consumption.

Features:

- Long duration
- High accuracy
- Use of instruments and meters
- Detailed data collection
- Cost–benefit analysis

Activities:

- Measuring voltage, current, power factor
- Studying energy bills
- Load analysis
- Efficiency testing of equipment
- Thermal imaging, insulation checks

Outcome:

- Exact energy saving potential
- Investment requirement

- Payback period calculation

Concept Diagram

Data Collection → Measurement → Analysis → Report → Implementation

---

Investment Grade Energy Audit

Meaning:
An audit done before **large financial investments**.

Purpose:

- Used for industries or big buildings
- Accurate financial analysis
- Risk assessment
- Return on Investment (ROI)

Used When:

- Installing solar plants
- Upgrading HVAC systems
- Major renovation projects

Steps in Energy Audit Process

1. **Planning and Preparation**
2. **Data Collection**
3. **Site Inspection**
4. **Measurement and Monitoring**
5. **Data Analysis**
6. **Report Preparation**
7. **Implementation of Measures**
8. **Monitoring & Verification**

Instruments Used in Energy Audit

- Lux Meter – Measures light intensity

- Clamp Meter – Measures current
- Power Analyzer – Measures power consumption
- Thermometer – Temperature measurement
- Anemometer – Air velocity
- Thermal Camera – Heat loss detection

Energy Management Program

Definition

Energy Management Program (EMP) is a planned and continuous effort to **monitor, control, and conserve energy** in a systematic way.

Objectives of Energy Management

- Reduce energy waste
- Improve efficiency
- Lower operational cost
- Environmental protection
- Sustainable development

Components of Energy Management Program

1. Energy Policy

- Written statement by organization
- Commitment to energy saving

2. Energy Planning

- Setting energy targets
- Budget allocation

3. Implementation

- Use of energy efficient equipment
- Staff training
- Awareness programs

4. Monitoring

- Tracking monthly energy bills
- Meter readings

5. Review and Improvement

- Periodic audits
- Updating technologies

Energy Management Cycle (PDCA Cycle)

PLAN → DO → CHECK → ACT

Plan: Set targets
Do: Implement measures
Check: Monitor results
Act: Improve and standardize

Energy Conservation Measures

- Use LED lighting
- Install solar panels
- Proper insulation
- Use energy efficient motors
- Automatic sensors for lights
- Maintain HVAC systems
- Use natural ventilation

Benefits of Energy Audit & Management

- Cost savings
- Reduced carbon emission
- Better comfort
- Increased equipment life
- Sustainable development
- Compliance with green building norms

LECTURE 12

Types of Energy Audit

Energy audits are mainly classified into **three types**:

1. **Preliminary Energy Audit (Walk-through Audit)**
2. **Detailed Energy Audit**
3. **Investment Grade Energy Audit**

Preliminary Energy Audit (Walk-through Audit)

Definition

A preliminary energy audit is a **simple and quick study** of energy usage. It provides a general understanding of energy consumption and identifies major energy-saving opportunities.

Features

- Basic inspection of energy systems
- Limited data collection
- Short duration
- Low cost
- Provides overall energy consumption pattern

Steps Involved

1. Collection of past energy bills and records
2. Walk-through inspection of plant or building
3. Identification of major energy-consuming equipment
4. Identification of obvious energy wastage areas
5. Preparation of initial energy-saving recommendations

Tools Used

- Visual inspection
- Basic measuring instruments
- Utility bill analysis

Advantages

- Quick and economical
- Helps in identifying major problem areas
- Requires less technical analysis

Limitations

- Does not provide detailed technical analysis
- Energy-saving estimates are approximate

LECTURE 13

Detailed Energy Audit

Definition

A detailed energy audit is a **comprehensive and systematic study** of energy consumption. It provides accurate data and detailed analysis of energy-saving opportunities.

Features

- Extensive data collection
- Detailed performance analysis of equipment
- Accurate energy-saving calculations
- Includes technical and financial evaluation

Steps Involved

Step 1: Pre-Audit Preparation

- Collection of design and operational data
- Study of previous energy consumption records
- Identification of audit scope

Step 2: Field Study

- Measurement of energy consumption
- Performance testing of equipment
- Monitoring operating conditions

Step 3: Data Analysis

- Energy balance calculation
- Identification of energy losses
- Comparison with standard values

Step 4: Identification of Energy Conservation Measures (ECMs)

- Improvement in equipment efficiency

- Process modification
- Waste heat recovery
- Installation of energy-efficient systems

Step 5: Economic Evaluation

- Cost-benefit analysis
- Payback period calculation
- Return on investment

Step 6: Report Preparation

- Detailed audit report
- Recommendations for energy savings
- Implementation plan

Advantages

- Accurate and reliable results
- Helps in major energy savings
- Provides financial feasibility

Limitations

- Time-consuming
- Expensive
- Requires skilled professionals

Investment Grade Energy Audit

Definition

An investment grade audit is the **most detailed and comprehensive type** of audit. It is conducted before implementing large energy conservation projects.

Features

- Highest level of accuracy
- Detailed financial and risk analysis
- Used for project investment decisions

Steps Involved

1. Detailed energy consumption analysis
2. Advanced monitoring and testing

3. Simulation and modeling of energy systems
4. Detailed cost estimation
5. Risk assessment
6. Preparation of implementation strategy

Advantages

- Provides precise energy-saving estimates
- Helps investors and management in decision making
- Ensures successful project implementation

Limitations

- Very expensive
- Requires long time
- Requires advanced technical expertise

LECTURE 14

LECTURE15

Environmental Impact Assessment (EIA)

1. Introduction

Environmental Impact Assessment (EIA) is a systematic process used to identify, predict, and evaluate the environmental effects of proposed projects before they are carried out. It helps decision-makers understand the environmental consequences of development activities such as industries, dams, highways, mining, and power plants.

Objectives of EIA:

- To predict environmental impacts at an early stage.
- To suggest measures to reduce or eliminate negative impacts.
- To promote environmentally sustainable development.
- To help government authorities in decision making.
- To involve public participation in project planning.

Importance of EIA:

- Protects natural resources.
- Prevents environmental pollution.
- Improves project planning and design.
- Helps maintain ecological balance.
- Reduces project risks and costs in the long term.

2. EIA Regulations (India)

Environmental Impact Assessment in India is governed by the **Environment (Protection) Act, 1986**. The Government of India introduced EIA regulations through notifications to control environmental damage from development projects.

Major EIA Notification

- The first EIA notification was issued in **1994**.
- It was replaced and updated by the **EIA Notification, 2006** (currently followed with amendments).

Projects Requiring Environmental Clearance

Projects such as:

- Mining and quarrying
- Thermal power plants
- Highways and airports
- River valley and hydroelectric projects
- Chemical industries
- Construction and infrastructure projects

Categories of Projects (As per EIA 2006)

1. **Category A Projects**
    - Large scale projects.
    - Clearance given by the **Ministry of Environment, Forest and Climate Change (MoEFCC)**.
2. **Category B Projects**
    - Medium scale projects.
    - Clearance given by the **State Environment Impact Assessment Authority (SEIAA)**.
    - Further divided into:
        - **B1** – Requires detailed EIA study.
        - **B2** – Does not require detailed EIA study.

LECTURE 16

Stages of EIA Process

1. **Screening**
   - Determines whether a project needs EIA or not.
2. **Scoping**
   - Identifies important environmental issues and prepares Terms of Reference (ToR).
3. **Public Consultation**
   - Public and stakeholders give opinions and suggestions.
4. **Environmental Impact Analysis**
   - Assessment of environmental effects of the project.
5. **Preparation of EIA Report**
   - Detailed documentation of environmental impacts and mitigation measures.
6. **Appraisal**
   - Expert committee reviews the report and gives recommendations.
7. **Environmental Clearance**
   - Final approval or rejection of the project.

LECTURE 17

Benefits of Environmental Impact Assessment (EIA):

1. **Environmental Protection**
   - Helps identify potential environmental damage before starting a project.
   - Suggests measures to reduce pollution, deforestation, and habitat destruction.
2. **Better Project Planning**
   - Provides information about environmental risks, helping planners design safer and more sustainable projects.
3. **Supports Decision Making**
   - Helps government and authorities decide whether a project should be approved, modified, or rejected.
4. **Promotes Sustainable Development**
   - Ensures development activities balance economic growth with environmental conservation.
5. **Public Awareness and Participation**
   - Encourages involvement of local communities and stakeholders in decision-making.
6. **Cost Savings**

   - Identifies environmental problems early, reducing expensive corrective actions later.
7. **Legal Compliance**
   - Helps projects follow environmental laws and regulations.
8. **Protection of Human Health**
   - Reduces harmful effects of pollution and environmental degradation on people.

LECTURE 18

Environmental Clearance for Civil Engineering Projects

Environmental Clearance (EC) is an official approval required before starting certain civil engineering and infrastructure projects. It ensures that the project does not cause unacceptable damage to the environment and follows sustainable development principles.

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1. Meaning of Environmental Clearance

Environmental Clearance is permission granted by government environmental authorities after assessing the environmental impact of a proposed project. It ensures that the project follows environmental protection laws and minimizes pollution.

---

2. Objectives of Environmental Clearance

- To protect natural resources such as air, water, land, and forests
- To reduce environmental pollution
- To promote sustainable development
- To ensure proper waste management
- To safeguard public health and biodiversity

---

3. Projects Requiring Environmental Clearance

Environmental clearance is usually required for large civil engineering projects such as:

- Highways and road construction
- Dams and irrigation projects
- Airports and railways
- Mining projects

- Industrial plants
- Large residential and commercial buildings
- Power plants
- Ports and harbours

---

4. Authorities Responsible for Clearance (India)

In India, Environmental Clearance is granted by:

- **MoEFCC** – Ministry of Environment, Forest and Climate Change (Central Government)
- **SEIAA** – State Environment Impact Assessment Authority

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5. Steps in Environmental Clearance Process

Step 1: Screening

Determines whether the project requires Environmental Impact Assessment (EIA).

Step 2: Scoping

Identifies key environmental issues and prepares Terms of Reference (TOR).

Step 3: Environmental Impact Assessment (EIA)

- Study of environmental effects such as air pollution, water pollution, noise, soil erosion, etc.
- Suggests mitigation measures.

Step 4: Public Hearing

- Public and local communities give their opinions and objections.

Step 5: Appraisal

- Expert committee reviews the project and EIA report.

Step 6: Grant or Rejection of Clearance

- Approval is given with environmental conditions or the project is rejected.

---

6. Documents Required

- Project report
- EIA report
- Environmental Management Plan (EMP)
- Risk assessment report
- Public hearing report

---

7. Importance in Civil Engineering

- Helps engineers design eco-friendly projects
- Reduces environmental damage
- Ensures legal compliance
- Improves project sustainability
- Prevents future environmental hazards

UNIT-V

Chapter 5

RATING SYSTEM FOR GREEN BUILDING

Weightage 12 Hours, 18 Marks

Syllabus

5.1 Leadership in energy and environmental design (LEED) criteria.

5.2 Indian green building council (IGBC) green rating.

5.3 Green rating for integrated habitat assessment (GRIHA) criteria.

5.4 HVAC unit in green building.

Learning Objectives

This chapter will enable students to

(5a) Select the relevant rating system for assessment of given green building.

(5b) Compare the different rating system such as GRIHA, IGBC, EDGE, BEE adopted in the country.

(5c) Explain salient provisions used in IGBC green rating system for the given building.

(5d) Explain the role of HVAC unit in the given type of green building.

One can define Green Buildings as structures that ensure efficient use of natural resources like building materials, water, energy and other resources with minimal generation of non-degradable waste. Technologies like efficient cooling systems have sensors that can sense the heat generated from human body and automatically adjust the room temperature, saving energy. It applies to lighting systems too. Green buildings have a smarter lighting system that automatically switches off when no one is present inside the rooms. Simple technologies like air based flushing system in toilets that avoids water use by 100%, Use of energy efficient LED's and CFL's instead of conventional incandescent lamp, new generation appliances that consume less energy, and many other options help in making the buildings green and make them different from conventional ones.

Whether Green buildings are really green is to be decided against the predefined rating systems. There are three primary Rating systems in India :

- GRIHA
- IGBC
- BEE

5.1 Leadership in Energy and Environmental Design (LEED) Criteria

LEED, or Leadership in Energy and Environmental Design, is the most widely used green building rating system in the world. Available for virtually all building, community and home project types, LEED provides a framework to create healthy, highly efficient and cost-saving green buildings. LEED certification is a globally recognized symbol of sustainability achievement.

- 2.2 million + square feet is LEED certified every day with more than 90,000 projects using LEED.
- LEED works for all building types anywhere. LEED is in 165 countries and territories.
- LEED buildings save energy, water, resources, generate less waste and support human health.
- LEED buildings attract tenants, cost less to operate and boost employee productivity and retention.

5.1.1 LEED for Every Project

LEED is for all building types and all building phases including new construction, interior fit outs, operations and maintenance, and core and shell. There's a LEED for every type of building project.

5.1.1.1 LEED for Building Design and Construction

LEED for Building Design and Construction (LEED BD + C) provides a framework for building a holistic green building, giving you the chance to nail down every sustainability feature, maximizing the benefits.

LEED works for all project types from hospitals to manufacturing plants, showrooms and office buildings. LEED BD+C has options to fit every project. Use a specialty option for unique needs or use New Construction and Major Renovations for everything else.

- **New Construction and Major Renovation**. Addresses design and construction activities for both new buildings and major renovations of existing buildings that do not primarily serve k-12 educational, retail, data center, warehouse and distribution center, hospitality, healthcare or residential uses. These projects include major HVAC improvements, significant building envelope modifications and major interior rehabilitation. (Teams using LEED v4 may also use this option for multifamily residential projects that have nine or more stories).
- **Core and Shell Development**. For projects where the developer controls the design and construction of the entire mechanical, electrical, plumbing and fire protection system—called the core and shell—but not the design and construction of the tenant fit-out. Use this option for projects that are less than 60% complete at the time of certification. (LEED v4 and LEED v4.1)
- **Data Centers**. Specifically designed and equipped to meet the needs of high-density computing equipment, such as server racks, used for data storage and processing. (LEED v4 and LEED v4.1)
- **Healthcare.** For hospitals that operate twenty-four hours a day, seven days a week and provide inpatient medical treatment, including acute and long-term care. (LEED v4 and LEED v4.1)
- **Hospitality.** Dedicated to hotels, motels, inns or other businesses within the service industry that provides transitional or short-term lodging with or without food. (LEED v4 and LEED v4.1)
- **Retail**. Addresses the unique needs of retailers—from banks, restaurants, apparel, electronics, big box and everything in between. (LEED v4 and LEED v4.1)
- **Schools.** For buildings made up of core and ancillary learning spaces on K-12 school grounds. Can also be used for higher education and non-academic buildings on school campuses. (LEED v4 and LEED v4.1)
- **Warehouses and Distribution Centers**. For buildings used to store goods, manufactured products, merchandise, raw materials or personal belongings, like self-storage. (LEED v4 and LEED v4.1)

5.1.1.2 LEED for Interior Design and Construction

LEED for Interior Design and Construction (LEED ID+C) enables project teams, who may not have control over whole building operations, the opportunity to develop indoor spaces that are better for the planet and for people.

Who it's for

- **Commercial Interiors**. For interior spaces dedicated to functions other than retail or hospitality.
- **Retail**. Guides retailers interior spaces used to conduct the retail sale of consumer product goods. Includes both direct customer service areas (showroom) and preparation or storage areas that support customer service.
- **Hospitality**. Designed for interior spaces dedicated to hotels, motels, inns, or other businesses within the service industry that provides transitional or short-term lodging with or without food.

5.1.1.3 LEED for Building Operations and Maintenance

LEED for Building Operations and Maintenance (O+M) offers existing buildings an opportunity to pay close attention to building operations.

Who it's for

- **Existing Buildings :** Specifically projects that do not primarily serve K-12 educational, retail, data centers, warehouses and distribution centers, or hospitality uses.
- **Retail :** Guides existing retail spaces, both showrooms, and storage areas.
- **Schools :** For existing buildings made up of core and ancillary learning spaces on K-12 school grounds. Can also be used for higher education and non-academic buildings on school campuses.
- **Hospitality :** Existing hotels, motels, inns, or other businesses within the service industry that provide transitional or short-term lodging with or without food.
- **Data Centers :** Existing buildings specifically designed and equipped to meet the needs of high density computing equipment such as server racks, used for data storage and processing.
- **Warehouses and Distribution Centers :** Existing buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).

5.1.1.4 LEED for Neighborhood Development

LEED for Neighborhood Development (LEED ND) was engineered to inspire and help create better, more sustainable, well-connected neighborhoods. It looks beyond the scale of buildings to consider entire communities. Why? Because sprawl is a scary thing. Here's the antidote.

Who it's for

- **Plan :** Certification is available to your neighborhood-scale project if it's currently in any phase of planning and design and up to 75% constructed. We designed this offering to help you or your developers' market and fund your project among prospective tenants, financiers, public officials, etc. by affirming your intended sustainability strategies.
- **Built project :** Designed for neighborhood-scale projects that are near completion or were completed within the last three years.

5.1.1.5 LEED for Homes Design and Construction

A home is more than just shelter : homes are the most important buildings in our lives. We think that every building should be a green building – but especially homes. Why? LEED homes are built to be healthy, providing clean indoor air and incorporating safe building materials to ensure a comfortable home. Using less energy and water means lower utility bills each month. And in many markets, certified green homes are now selling quicker and for more money than comparable non-green homes.

Who it's for

LEED for Homes is available for building design and construction projects for single family homes and multifamily projects up to eight stories.

- **Homes and Multifamily Low rise**. Designed for single family homes and multifamily buildings between one and three stories.
- **Multifamily Midrise**. Designed for midrise multifamily buildings four stories and higher.

5.1.1.6 LEED for Cities and Communities

LEED for Cities and LEED for Communities provide cities and communities with a globally consistent way to measure and communicate performance.

The LEED v4.1 for Cities and LEED v4.1 for Communities certification programs revolutionize the way cities and communities are planned, developed and operated in order to improve the quality of life of people around the world. The programs provide a framework for planning, designing, measuring and managing the performance of social, economic and environmental conditions on a city-wide or community level.

LEED v4.1 for Cities and LEED v4.1 for Communities helps cities and communities develop responsible, sustainable and specific plans for natural systems, energy, water, waste, transportation and many other factors that contribute to quality of life.

5.1.1.7 LEED Recertification

Applies to all occupied and in-use projects that have previously achieved certification under LEED – including BD + C and ID + C, regardless of their initial rating system or version.

5.1.1.8 LEED Zero

What happens when the built environment goes beyond lessening its impact on the environment? For more than two decades, LEED has provided a framework for high performance buildings and spaces, and reduced greenhouse gas emissions through strategies impacting land, energy, transportation, water, waste and materials. Building on that work, the U.S. Green Building Council has developed LEED Zero, a complement to LEED that verifies the achievement of net zero goals and signals market leadership in the built environment.

- **LEED Zero Carbon** recognizes buildings or spaces operating with net zero carbon emissions from energy consumption and occupant transportation to carbon emissions avoided or offset over a period of 12 months.
- **LEED Zero resources**
  - **Energy** recognizes buildings or spaces that achieve a source energy use balance of zero over a period of 12 months.
  - **Water** recognizes buildings that achieve a potable water use balance of zero over a period of 12 months.
  - **Waste** recognizes buildings that achieve GBCI's **TRUE Zero Waste certification** at the Platinum level.

LEED Zero represents a new level of achievement in green building that is not just attainable but is the goal of LEED certified projects around the world.

5.1.2 LEED Works for Groups of Multiple Buildings

LEED offers several options designed for companies and organizations seeking certification for multiple buildings.

5.1.2.1 Volume Certification

LEED works for groups of multiple buildings through options designed for companies and organizations seeking certification for multiple buildings. There are two options for certifying multiple buildings : Volume or Campus.

For 25 or more projects : Volume

For organizations planning to certify a large number of new construction projects, the LEED volume program simplifies LEED documentation and speeds up the process. Using this option streamlines the LEED certification process by focusing on similarities in building design, operations and delivery - no matter where they are in the world. For organizations that certify multiple buildings within a given timeframe, this option offers valuable economies of scale for both new construction and existing buildings seeking certification of their operations and maintenance.

For less than 25 projects : Campus

The campus program is for projects not necessarily uniform in design or operations but located on a single campus location. The campus program was designed to simplify the certification process for multiple buildings while maintaining the technical integrity and rigor of LEED. It can be used for the following LEED 2009 rating systems : New Construction, Existing Buildings : Operations and Maintenance, Commercial Interiors, Core and Shell, Schools, Retail, and Healthcare.

LEED campus and multiple building certification is available for multiple buildings on a single site and offers a number of options to help project owners determine the best, most cost effective way to reach their goals. In some cases it's one single certification that applies to many buildings and in others it might be reviewing credits once to be utilized by a number of certifications. This process can be used with any of the LEED commercial rating systems. (A campus can be any shared site; it doesn't have to be a traditional university or corporate campus. This path has been used by hospitals, universities, commercial property management and even a zoo.)

5.1.2.2 LEED for Federal Agencies

GBCI offers options for government projects to meet the Guiding Principles for Federal Leadership in High Performance in Sustainable Building requirements.

5.1.3 Achieve Better Buildings with LEED

Projects pursuing LEED certification earn points across several categories : Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation and more. Based on the number of points achieved, a project then earns one of four LEED rating levels : Certified, Silver, Gold or Platinum.

Certified	Silver	Gold	Platinum
40-49 points earned	50-59 points earned	60-79 points earned	80+ points earned
(a)	(b)	(c)	(d)

Fig. 5.1

The process is designed to inspire project teams to seek innovative solutions that support public health and our environment, while saving building owners money over a project's life cycle.

5.1.4 LEED Criteria

The LEED standards are comprised of categories :

- Integrative Process.
- Location and Transportation.
- Sustainable Sites.
- Water Efficiency.
- Energy and Atmosphere.
- Materials and Resources.
- Indoor Environmental Quality.

Within these categories, there are specific strategies or goals, called credits. Each credit is worth a number of points. If you've heard about the four levels of LEED Certification – Certified, Silver, Gold, Platinum – this is what those levels are referring to. Each level corresponds with a point range.

In order to earn a LEED Certification label, project teams must develop a plan at the outset to determine which level of LEED Certification they want to achieve and which credits will make the most difference for their project. They can pick and choose from the credit options, so long as they demonstrate proficiency in fulfilling that credit's requirements.

At the end, documentation will show which credits were chosen and how the team met the corresponding requirements. The Green Business Certification Institute, or GBCI, will determine whether the team's efforts were sufficient and will therefore award certification.

LEED Certification Minimum Requirements

The LEED certification process needs to meet at a minimum these requirements :

- Be in compliance with environmental regulations and standards.
- Must meet the threshold of floor area requirements.
- Meet a minimum of building occupancy in terms of number of users.
- Maintain a reasonable site boundary.
- Be a permanent building.
- Share energy and water usage data.
- Must have a minimum building to site area ratio.

LEED Certification Criteria

In order to earn credits to achieve one of the above categories, the project must meet certain criteria and goals within the following categories :

- **Location and transportation :** You should take into consideration the location of your project and how it can be combined with the transportation option within the area, in other words how the users of the facility can get in and out of the facility.
- **Materials and Resources :** Earn credits by using sustainable and earth-friendly products, while reducing waste promoting better indoor **air quality**.
- **Water efficiency :** The building must be designed in such a way that potable water usage is reduced or resources can be reused, minimizing the needs of water inside the building.
- **Energy and atmosphere :** The building must enhance energy performance and promote great indoor air and environmental quality.
- **Sustainable sites :** Design the project in such a way that the natural resources and ecosystems nearby can naturally take part of the design minimizing environmental pollution.
- **Indoor environmental quality :** Increase daylight usage and promote natural ventilation.
- **Innovation :** Any idea that is not covered under the five LEED main areas.
- **Regional priority credits :** Addressing any particular concern based on the regional or geographical location.

LEED for Neighborhood Development provides for a couple of additional credit categories such as smart location and linkage, neighborhood pattern and design and green infrastructure and buildings

5.2 Indian Green Building Council (IGBC)

The Leadership in Energy and Environmental Design (LEED) is the rating system developed for certifying Green Buildings. LEED is developed by the U.S. Green Building Council (USGBC), the organization promoting sustainability through Green Buildings. LEED is a framework for assessing building performance against set criteria and standard points of references. The benchmarks for the LEED Green Building Rating System were developed in year 2000 and are currently available for new and existing constructions.

Confederation of Indian Industry (CII) formed the Indian Green Building Council (IGBC) in year 2001. IGBC is the non profit research institution having its offices in CII-Sohrabji Godrej Green Business Centre, which is itself a LEED certified Green building. Indian Green Building Council (IGBC) has licensed the LEED Green Building Standard from the USGBC. IGBC facilitates Indian green structures to become one of the green buildings.

IGBC has developed the following green building rating systems for different types of building in line and conformity with US Green Building Council. Till date, following Green Building rating systems are available under IGBC:

1. LEED India for New Construction
2. LEED India for Core and Shell
3. IGBC Green Homes
4. IGBC Green Factory Building
5. IGBC Green SEZ
6. IGBC Green Townships

5.2.1 Rating System

IGBC Green New Buildings rating system addresses green features under the following categories :

- Sustainable Architecture and Design
- Site Selection and Planning
- Water Conservation
- Energy Efficiency
- Building Materials and Resources
- Indoor Environmental Quality
- Innovation and Development

The guidelines detailed under each mandatory requirement and credit enables the design and construction of new buildings of all sizes and types. Different levels of green building certification are awarded based on the total credits earned. However, every green new building should meet certain mandatory requirements, which are non-negotiable.

5.2.1.1 Sustainable Architecture and Design

5.2.1.1.1 Integrated Design Approach

Encourage integrated design approach to construct a high performance building, thereby reducing negative environmental impacts.

5.2.1.1.2 Site Preservation

Encourage retaining the site features to minimise site damage and associated negative environmental impacts.

5.2.1.1.3 Passive Architecture

Adopt passive architectural design features to minimise negative environmental impacts.

5.2.1.2 Site Selection and Planning

5.2.1.2.1 Local Building Regulations

Ensure that the building complies with necessary statutory and regulatory codes.

5.2.1.2.2 Soil Erosion Control

Control soil erosion and sedimentation, thereby, reducing negative impacts to the site and surroundings.

5.2.1.2.3 Basic Amenities

Provide access to basic amenities, so as to reduce negative impacts caused from automobile use

5.2.1.2.4 Proximity to Public Transport

Encourage use of public transport, so as to reduce negative impacts caused from automobile use.

5.2.1.2.5 Low-emitting Vehicles

Encourage the use of non-fossil fuel vehicles, thereby reducing negative impacts resulting from fossil fuel based automobiles.

5.2.1.2.6 Natural Topography or Vegetation

Minimise disturbances or restore the site so as to reduce long-term negative environmental impacts, thereby promoting habitat and biodiversity.

5.2.1.2.7 Preservation or Transplantation of Trees

Preserve existing fully grown trees and plant new tree saplings, so as to promote habitat and biodiversity.

5.2.1.2.8 Heat Island Reduction, Non-roof

Minimise heat island effect so as to reduce negative impact on micro-climate.

5.2.1.2.9 Heat Island Reduction, Roof

Minimise heat island effect so as to reduce negative impact on micro-climate.

5.2.1.2.10 Outdoor Light Pollution Reduction

Reduce light pollution to increase night sky access and enhance the nocturnal environment.

5.2.1.2.11 Universal Design

Ensure that the building design caters to differently abled and senior citizens.

5.2.1.2.12 Basic Facilities for Construction Workforce

Promote welfare of the construction workforce by providing safe and healthy work conditions.

5.2.1.2.13 Green Building Guidelines

Provide building occupants, prospective tenants, and the facility team with descriptive guidelines that educate and help them implement and maintain green design features.

5.2.1.3 Water Conservation

5.2.1.3.1 Rainwater Harvesting, Roof and Non-roof

Enhance ground water table and reduce municipal water demand through effective rainwater management.

5.2.1.3.2 Water Efficient Plumbing Fixtures

Enhance efficiency of plumbing fixtures, thereby minimising potable water use.

5.2.1.3.3 Landscape Design

Design landscape to ensure minimum water consumption.

5.2.1.3.4 Management of Irrigation Systems

Reduce water demand for irrigation through water efficient management systems and techniques.

5.2.1.3.5 Waste Water Treatment and Reuse

Treat waste water generated on-site, so as to avoid polluting the receiving streams by safe disposal. Use treated waste water, thereby reducing dependence on potable water.

5.2.1.3.6 Water Metering

Encourage sub-metering to improve water performance of the building, and thereby save potable water.

5.2.1.4 Energy Efficiency

5.2.1.4.1 Ozone Depleting Substances

Encourage use of eco-friendly refrigerants and halons in the building, thereby minimizing negative impact on the ozone layer.

5.2.1.4.2 Minimum Energy Efficiency

Optimise energy consumption, to reduce negative environmental impacts from excessive energy use.

5.2.1.4.3 Commissioning Plan for Building Equipment and Systems

Verify and ensure that the building's equipment and systems are commissioned to achieve performance as envisaged during the design stage.

5.2.1.4.4 Eco-friendly Refrigerants

Encourage use of eco-friendly refrigerants in the facility, thereby minimising impact on the ozone layer.

5.2.1.4.5 Enhanced Energy Efficiency

Optimise energy consumption, to reduce negative environmental impacts from excessive energy use.

5.2.1.4.6 On-site Renewable Energy

Encourage the use of on-site renewable technologies, to minimise the environmental impacts associated with the use of fossil fuel energy.

5.2.1.4.7 Off-site Renewable Energy

Encourage the use of off-site renewable technologies, to minimise the environmental impacts associated with fossil fuel energy use.

5.2.1.4.8 Commissioning, Post-installation of Equipment and Systems

Verify and ensure that the building equipment and systems are commissioned to achieve performance as envisaged at the design stage.

5.2.1.4.9 Energy Metering and Management

Encourage sub-metering and continuous monitoring to identify improvement opportunities in building's energy performance.

5.2.1.5 Building Materials and Resources

5.2.1.5.1 Segregation of Waste, Post-occupancy

Facilitate segregation of waste at source to encourage reuse or recycling of materials, thereby avoiding waste being sent to landfills.

5.2.1.5.2 Sustainable Building Materials

Encourage the use of building materials to reduce dependence on materials that have associated negative environmental impacts.

5.2.1.5.3 Organic Waste Management, Post-occupancy

Ensure effective organic waste management, so as to avoid domestic waste being sent to landfills and to improve sanitation and health.

5.2.1.5.4 Handling of Waste Materials, During Construction

Facilitate segregation of construction and demolition waste at source to encourage reuse or recycling of materials, thereby avoiding waste being sent to landfills.

5.2.1.5.5 Use of Certified Green Building Materials, Products and Equipment

Use certified green building materials, products, and equipment, so as to reduce dependence on materials that have associated negative environmental impacts.

5.2.1.6 Indoor Environmental Quality

5.2.1.6.1 Minimum Fresh Air Ventilation

Provide adequate outdoor air ventilation, so as to avoid pollutants affecting indoor air quality.

5.2.1.6.2 Tobacco Smoke Control

Minimise exposure of non-smokers to the adverse health impacts arising due to passive smoking in the building.

5.2.1.6.3 CO_2 Monitoring

Continuously monitor and control carbon dioxide level in the building to ensure occupant comfort and well-being.

5.2.1.6.4 Daylighting

Ensure connectivity between the interior and the exterior environment, by providing adequate daylighting.

5.2.1.6.5 Outdoor Views

Ensure connectivity between the interior and the exterior environment, by providing adequate views.

5.2.1.6.6 Minimise Indoor and Outdoor Pollutants

Minimise the exposure of building occupants and maintenance team to hazardous indoor and outdoor pollutants, which adversely affect indoor air quality and occupant health.

5.2.1.6.7 Occupant Well-being Facilities (Not applicable for Tenant-occupied Buildings)

Provide occupant well-being facilities, so as to enhance physical, emotional and spiritual well-being of building occupants

5.2.1.6.8 Indoor Air Quality Testing, After Construction and Before Occupancy

Avoid occupant's exposure to indoor airborne contaminants before occupying the premises, so as to reduce the adverse health impacts on building occupants.

5.2.1.6.9 Indoor Air Quality Management, During Construction

Reduce indoor air quality problems resulting from construction activities, and promote comfort and well-being of construction workers and building occupants.

5.2.1.7 Innovation and Development

5.2.1.7.1 Innovation in Design Process

Provide design teams and projects an opportunity to be awarded points for innovative performance in green building categories not specifically addressed by the IGBC Green New Buildings rating system and / or exemplary performance above the requirements set by the IGBC Green New Buildings rating system.

5.2.1.7.2 Optimisation in Structural Design (Developmental Credit)

Encourage optimum structural design to reduce dependence on natural resources.

5.2.1.7.3 Water Use Reduction for Construction (Developmental Credit)

Enhance water use efficiency, thereby minimising the use of potable water for construction activities.

5.2.1.7.4 IGBC Accredited Professional

Support and encourage involvement of IGBC Accredited Professional in green building projects, so as to integrate appropriate design measures and streamline the certification process.

5.3. Green Rating for Integrated Habitat Assessment (GRIHA)

The following aspects of a green building design are looked into in an integrated way.

- Site planning.
- Building envelope design.
- Building system design (HVAC [heating ventilation and air conditioning], lighting, electrical, and water heating).
- Integration of renewable energy sources to generate energy on-site.
- Water and waste management.
- Selection of ecologically sustainable materials (with high recycled content, rapidly renewable resources with low emission potential, and so on).
- Indoor environmental quality (maintain indoor thermal and visual comfort and air quality).

5.3.1 Synopsis of the criteria for rating (Mandatory and optional/non mandatory clauses as per GRIHA rating system)

The criteria have been categorized as follows :

(A) Conservation and efficient utilization of resources :

Objective is to maximize the conservation and utilization of resources (land, water, natural habitat, avid fauna, and energy) and enhance efficiency of the systems and operations. Under this following criteria are there :

Criterion 1 ***Site selection (1 Point)*** **:** The site should be located within ½ km radius of an existing bus stop, commuter rail, light rail or metro station and/or the proposed site must be a Brownfield site (to rehabilitate damaged sites where development is hindered by environmental contamination, thereby reducing pressure on undeveloped land). The site plan must be in conformity with the development plan/master plan/UDPFI guidelines (mandatory)

Criterion 2 ***Preserve and protect landscape during construction (5 Points)*** **:** Proper timing of the construction, preserve topsoil and existing vegetation, staging and spill prevention, and erosion and sedimentation control. Replant on-site trees in the ratio of 3 :1 to those removed during construction, for every removal one tree plant 3 saplings.

Criterion 3 ***Soil conservation (till post-construction) (2 points)*** **:** Proper topsoil laying, stabilization of the soil, and maintenance of adequate fertility of the soil to support vegetative growth.

Criterion 4 ***Design to include existing site features (4 points)*** **:** Minimize the disruption of the natural ecosystem and design to harness maximum benefits of the prevailing micro-climate.

Criterion 5 ***Reduce hard paving on-site and/or provide shaded hard-paved surfaces (2 Points)*** **:** Minimize storm water run-off by reducing hard paving on-site.

Criterion 6 ***Enhance outdoor lighting system efficiency and use renewable energy system for meeting outdoor lighting requirements (3 Points)*** **:** Meet minimum allowable luminous efficacy (as per lamp type) and make progressive use of a renewable-energy-based lighting system.

Criterion 7 ***Plan utilities efficiently and optimize on-site circulation efficiency (3 Points)*** **:** Minimize road and pedestrian walkway length by appropriate planning and provide aggregate corridors for utility lines.

Criterion 8 ***Provide minimum level of sanitation/safety facilities for construction workers (2 Points)*** **:** Ensure cleanliness of workplace with regard to the disposal of waste and effluent, provide clean drinking water and latrines and urinals as per applicable standard.

Criterion 9 ***Reduce air pollution during construction (2 Points)*** **:** Ensure proper screening, covering stockpiles, covering brick and loads of dusty materials, wheel washing facility, and water spraying facility.

(B) Building planning and construction

Criterion 10 *Reduce landscape water requirement* (3 Points) : Landscape using native species and reduce lawn areas while enhancing the irrigation efficiency and reducing the water requirement for landscaping purposes.

Criterion 11 *Reduce water use in the building* (2 Points) : Reduce building water use by applying low-flow fixtures and other similar tools.

Criterion 12 *Efficient water use during construction* (1 Points) : Use materials such as pre-mixed concrete for preventing loss during mixing. Use recycled treated water and control the waste of curing water.

Criterion 13 *Optimize building design to reduce conventional energy demand* (8 Points) : Plan appropriately to reflect climate responsiveness, including adequate day-lighting as well as efficient artificial lighting.

Criterion 14 *Optimize energy performance of building within specified comfort limits* (16 Points) : Ensure that the building complies with the mandatory compliance requirement of ECBC 2007 and meet thermal comfort conditions as per NBC 2005 as well as minimum benchmark for EPI as per GRIHA. Ensure reduction in EPI up to 40% under a specified category.

- Meet thermal comfort conditions as per National Building Code 2005 and, minimum benchmark for energy performance index as per GRIHA
- Ensure that energy consumption in building under a specified category is 10%–40% less than that benchmarked through a simulation exercise.

Criterion 15 *Utilization of fly-ash in building structure* (6 Points) : Use of fly-ash for RCC (reinforced cement concrete) structures with in-fill walls and load bearing structures, mortar, and binders.

Criterion 16 *Reduce volume, weight, and construction time by adopting efficient technologies (such as pre-cast systems)* (4 Points) : Replace a part of the energy-intensive materials with less energy-intensive materials and/or utilize regionally available materials, which use low-energy/energy-efficient technologies.

Criterion 17 *Use low-energy material in interiors* (4 Points) : Minimum 70% in each of the three categories of interiors (internal partitions, panelling/false ceiling/ interior wood finishes/in-built furniture door/window frames, flooring) from low-energy materials/finishes to minimize the usage of wood.

Criterion 18 *Renewable energy utilization* (5 points) : Rated capacity of proposed renewable energy systems is equal to or more than 1% of internal lighting and space conditioning connected loads and meets energy requirements for a minimum of 5% of the internal lighting consumption (for general lighting or its equivalent from renewable energy sources[solar, wind, biomass, fuel cell and others). Energy requirements will be calculated based on realistic assumptions which will be subject to verification during appraisal

Criterion 19 *Renewable-energy-based hot water system* (3 Points) : Meet 20% or more of the annual energy required for heating water through renewable energy based water-heating systems

Criterion 20 *Waste water treatment* (2 Points) : Provide necessary treatment of water for achieving the desired concentration of effluents.

Criterion 21 *Water recycle and reuse (including rainwater)* (5 Points) : Provide on-site waste water treatment for achieving prescribed concentration, rainwater harvesting, reuse of treated waste water and rainwater for meeting the building's water and irrigation demands.

Criterion 22 *Reduction in waste during construction* (1 Point) : Ensure maximum resource recovery and safe disposal of wastes generated during construction and reduce the burden on landfill.

Criterion 23 *Efficient waste segregation* (1 Point) : Use different coloured bins for collecting different categories of waste from the building.

Criterion 24 *Storage and disposal of wastes* (1 Point) : Allocate separate space for the collected waste before transferring it to the recycling/disposal stations.

Criterion 25 ***Resource recovery from waste (2 Points)*** : Employ resource recovery systems for biodegradable waste as per the Solid Waste Management and Handling Rules, 2000 of the MoEF. Make arrangements for recycling of waste through local dealers.

Criterion 26 ***Use low-VOC paints/adhesives/sealants (3 Points) :*** Use only low VOC paints in the interior of the building. Use water–based rather than solvent-based sealants and adhesives.

Criterion 27 ***Minimize ozone depleting substances (1 Point) :*** Employ 100% zero ODP (ozone depletion potential) insulation, HCFC (hydrochloro-fluorocarbon)/ and CFC (chlorofluorocarbon), free HVAC, and refrigeration equipment/and halon-free fire suppression and fire extinguishing systems.

Criterion 28 ***Ensure water quality (2 Points) :*** Ensure water from all sources (such as groundwater, municiapal water, treated wastewater) meets the water quality norms as prescribed in the Indian Standards for various applications (Indian Standards for drinking [IS 10500-1991], irrigation applications [IS 11624-1986]), cooling towers (as given in NBC 2005). In case the water quality cannot be ensured, provide necessary treatment of raw water for achieving the desired concentration for various applications.

Criterion 29 ***Acceptable outdoor and indoor noise levels (2 Points) :*** Ensure outdoor noise level conforms to the CPCB (Central Pollution Control Board)– Environmental Standards–Noise (ambient standards) and indoor noise level conforms to the NBC (National Building Code of India) 2005 (BIS 2005a).

Criterion 30 ***Tobacco smoke control (1 Point) :*** Zero exposure to tobacco smoke for non-smokers, and exclusive ventilation for smoking rooms.

Criterion 31 ***Provide at least the minimum level of accessibility for persons with disabilities (1 Point) :*** To ensure accessibility and usability of the building and its facilities by employees, visitors, and clients with disabilities

(C) Building operation and maintenance

Criterion 32 ***Energy audit and validation (0 Point) :*** Energy audit report to be prepared by approved auditors of the Bureau of Energy Efficiency (BEE), Government of India.

Criterion 33 ***Operation and maintenance (2 Points) :*** Validate and maintain 'green' performance levels/adopt and propagate green practices and concepts. Ensure the inclusion of a specific clause in the contract document for the commissioning of all electrical and mechanical systems to be maintained by the owner, supplier or operator. Provide a core facility/service management group, if applicable, which will be responsible for the OandM of the building and the electrical and mechanical systems after commissioning. Owner/builder/ occupants/service or facility management group to prepare a fully documented operations and maintenance manual, CD, multimedia or an information brochure listing the best practices/dos and don'ts/maintenance requirements for the building and the electrical and mechanical systems along with the names and addresses of the manufacturers/suppliers of the respective system.

(D) Innovation points

Criterion 34 ***Innovation points (4 Points) :*** Four innovation points are available under the rating system for adopting criteria which enhances the green intent of a project, and one can apply for the innovation points. Some of the probable points are as follows.

- alternative transportation
- environmental education
- company policy on green supply chain
- life cycle cost analysis
- any other criteria proposed by applicant

Please note that these innovation points are beyond the 100 points and a project can apply for 104 points in all, while the scoring shall be given on a 100-point scale only.

(D) Evaluation system of GRIHA

GRIHA has a 100-point system consisting of some core points, which are mandatory to be met while the rest are non mandatory or optional points, which can be earned by complying with the commitment of the criterion for which the point is allocated. Different levels of certification (one star to five stars) are awarded based on percentage of points earned. The minimum percentage required for certification is 50. Buildings scoring 50–60 percentage points, 61–70 percentage points, 71–80 percentage points, and 81–90 percentage points will get one star, two stars, three stars, and four stars, respectively. A building scoring 91–100 percentage points will receive the maximum rating, which is five stars.

5.4 HVAC Unit in Green Building

Energy conservation, indoor air quality, and comfort are among the core green building issues covered by heating, air-conditioning and ventilation design. These interrelated systems can be complex, expensive to install, and costly to operate but green building also offers many opportunities to simplify and save :

- HVAC is more than a few pieces of mechanical equipment. It's a system designed as part of the house.
- An HVAC system works best when it takes local climate and building designs into account.
- In a green-built home, heating and cooling equipment can be smaller, less costly, and less complicated.

5.4.1 Design the System

- Great energy savers are the many passive solar features that are built into a green house.
- HVAC design follows many fundamental building design steps that can collectively reduce the size of the heating and cooling system by 30-50%.
- Solar orientation, insulation, window placement and design, even vegetation on the building site all directly affect heating and cooling loads.
- Designing a system based on real demand, not conventional practice, is essential.
- Incorporate HVAC systems early in the design phase so that it :
  - Makes installation easier and more efficient. Dedicated efforts will cut down on labor costs and project complexity.
  - One or two meetings with the architect or engineer early in the building process.
  - Systems can often be smaller in green homes with increased insulation saving money
- System is sized appropriately for actual home needs. Reduced heating bills and protects air quality.
- Careful calculations based on room and home size. The home's orientation, insulation and window placement affect the heating and cooling load.
- Some software can be used for the purpose
- HVAC systems - chiller, VRV systems, primary and secondary water pumps, cooling tower, AHU fans, fresh air fans and flow settings, fresh air treatment units, heat recovery wheel, VFDs
- Demonstrate that refrigerants used in the buildings Heating, Ventilation and Air-conditioning (HVAC) equipment are eco-friendly and have low or no Ozone Depletion Potential (ODP) and Global Warming Potential (GWP)
- Use high efficiency AC/Heating systems
- Seal around electrical outlets and all wall penetrations
- Ducts are sized appropriately for actual room by room needs. Heat or cooling is efficiently blown to all rooms of the house effectively.
- Ducts are installed and sized for maximum performance
- Leaky ductwork looses pressure and wastes as much as 20% of conditioned air as it travels.
- Brush mastic over any joints or bends
- Recovers heat from exhausted indoor air and transfers it to the incoming fresh air stream Necessary if the house has less than 0.35 natural air changes per hour.

- System installed in conjunction with the furnace or A/C unit.
- Efficient, properly designed and sized HVAC equipment increases comfort and reduces energy costs for residents, reduces complaints for building owners and benefits the environment through reduced greenhouse gas emissions.
- Considering the entire building design when designing HVAC systems allows easier installation and maintenance, reduces resistance to airflow, and increases efficiency.
- Well sealed duct systems and proper filtration improve indoor air quality.
- Sealed and balanced systems improve air quality and safety by reducing the possibility of back drafting.

Important Points

- One can define Green Buildings as structures that ensure efficient use of natural resources like building materials, water, energy and other resources with minimal generation of non-degradable waste.
- Available for virtually all building, community and home project types, LEED provides a framework to create healthy, highly efficient and cost-saving green buildings. LEED certification is a globally recognized symbol of sustainability achievement.
- LEED is for all building types and all building phases including new construction, interior fit outs, operations and maintenance, and core and shell. There's a LEED for every type of building project.
- Indian Green Building Council (IGBC) has licensed the LEED Green Building Standard from the USGBC. IGBC facilitates Indian green structures to become one of the green buildings.
- Objective of GRIHA is to maximize the conservation and utilization of resources (land, water, natural habitat, avid fauna, and energy) and enhance efficiency of the systems and operations.
- HVAC is more than a few pieces of mechanical equipment. It's a system designed as part of the house.
- An HVAC system works best when it takes local climate and building designs into account.

Practice Questions

1. Define Green Buildings.
2. What are three primary Rating systems in India?
3. What is LEED?
4. Explain 'LEED for every project'.
5. Explain 'LEED for BUILDING DESIGN AND CONSTRUCTION'.
6. Explain 'LEED for Interior Design and Construction'.
7. Explain 'LEED for Building Operations and Maintenance'.
8. Explain 'LEED for Neighborhood Development'.
9. Explain 'LEED for Homes Design and Construction'.
10. Explain 'LEED for Cities and Communities'.
11. Explain 'LEED Zero'.
12. Explain 'LEED works for groups of multiple buildings'.
13. Explain 'Achieve better buildings with LEED'.
14. Explain LEED criteria.
15. Explain 'LEED Certification Minimum Requirements'.
16. What is Indian Green Building Council (IGBC)?
17. Explain 'IGBC Green New Buildings rating system'

18. Describe the components of SUSTAINABLE ARCHITECTURE AND DESIGN.
19. Describe the components of SITE SELECTION AND PLANNING.
20. Describe the components of WATER CONSERVATION.
21. Describe the components of ENERGY EFFICIENCY.
22. Describe the components of BUILDING MATERIALS AND RESOURCES.
23. Describe the components of INDOOR ENVIRONMENTAL QUALITY.
24. Describe the components of INNOVATION AND DEVELOPMENT.
25. Explain 'Green Rating for Integrated Habitat Assessment (GRIHA)'.
26. Describe the criteria of Conservation and efficient utilization of resources.
27. Describe the criteria of Building planning and construction.
28. Describe the criteria of Building operation and maintenance.
29. Describe the criteria of Innovation points.
30. Describe Evaluation system of GRIHA.
31. Explain HVAC Unit in Green Building.
32. Describe the Design of the System for HVAC.

UNIT-III

Chapter 3

ENERGY AND ENERGY CONSERVATION

Weightage 8 Hours, 12 Marks

Syllabus

3.1 **Renewable energy resources :** Solar energy, wind energy, ocean energy, hydro energy, biomass energy.

3.2 **Non-renewable energy resource :** Coal, petroleum, natural gas, nuclear energy, chemical sources of energy, fuel cells, hydrogen, biofuels.

3.3 **Energy conservation :** Introduction, specific objectives, present scenario, need of energy conservation, LEED india rating system and energy efficiency.

3.4 **Functions** of government organization working for energy conservation and audit (ECA) :
- National productivity council (PC).
- Ministry of new and renewable energy MNRT).
- Bureau of energy efficiency (BEE).
- Maharashtra energy development agency (MEDA).

3.5 Salient features of energy conservation act – 2001.

Learning Objectives

This chapter will enable students to

(3a) Use the given source of renewable and non-renewable energy for energy conservation.

(3b) Justify the need of energy conservation in the given civil project.

(3c) Describe present practices adopted in energy conservation in the country.

(3d) Justify the role of MEDA in energy conservation in the given city/town.

(3e) Implement the relevant provisions of energy conservation act 2001 for the purpose of energy conservation in the given project.

In physics, energy is an indirectly observed quantity that is often understood as the ability of a physical system to do work on other physical systems. Since work is defined as a force acting through a distance (a length in space), energy is always equivalent to the ability to exert pulls or pushes against the basic forces of nature, along a path of a certain length. In simple language, energy can be defined as the capacity to do the work.

Energy Resources : A natural resource that can be converted by humans into forms of energy in order to do useful work!

- **Non-renewable Resources of Energy :** These are energy resources that cannot be replaced after they have been used or need thousands to millions of years to be replaced. **Fossil fuels** are energy resources that formed from the buried remains of plants and animals that lived millions of years ago. The plants stored energy from the sun during photosynthesis. Animals stored this same energy by eating the plants. So, fossil fuels are concentrated forms of the sun's energy and are termed as Non-renewable Resources of Energy.
- **Renewable Resources of Energy :** An energy resource that can be used and replaced in nature in a short period of time. Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). About 16% of global final energy consumption comes from renewable, with 10% coming from traditional biomass, which is mainly used for heating, and 3.4% from hydroelectricity. New renewable (small hydro, modern biomass, wind, solar, geothermal, and bio-fuels) accounted for another 3% and are growing very rapidly. The share of renewable in electricity generation is around 19%, with 16% of global electricity coming from hydroelectricity and 3% from new renewable.

3.1 Renewable Energy Resources

Renewable energy flows involve natural phenomena such as sunlight, wind, tides, plant growth, and geothermal heat, as the International Energy Agency explains :

Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources.

Renewable energy resources and significant opportunities for energy efficiency exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid deployment of renewable energy and energy efficiency, and technological diversification of energy sources, would result in significant energy security and economic benefits.

Renewable energy replaces conventional fuels in four distinct areas : electricity generation, hot water/space heating, motor fuels, and rural (off-grid) energy services :

Power generation : Renewable energy provides 19% of electricity generation worldwide. Renewable power generators are spread across many countries, and wind power alone already provides a significant share of electricity in some areas : for example, 14% in the U.S. state of Iowa, 40% in the northern German state of Schleswig-Holstein, and 20% in Denmark. Some countries get most of their power from renewables, including Iceland and Paraguay (100%), Norway (98%), Brazil (86%), Austria (62%), New Zealand (65%), and Sweden (54%). Renewable sources used for power generation are only about 12 % in India.

Heating : Solar hot water makes an important contribution to renewable heat in many countries, most notably in China, which now has 70% of the global total (180 GWth). Most of these systems are installed on multi-family apartment buildings and meet a portion of the hot water needs of an estimated 50–60 million households in China. Worldwide, total installed solar water heating systems meet a portion of the water heating needs of over 70 million households. The use of biomass for heating continues to grow as well. In Sweden, national use of biomass energy has surpassed that of oil. Direct geothermal for heating is also growing rapidly. According to estimates, 35 MW of power could be generated from 1 sq km.

Transport fuels : Renewable biofuels have contributed to a significant decline in oil consumption in the United States since 2006. The 93 billion liters of biofuels produced worldwide in 2009 displaced the equivalent of an estimated 68 billion liters of gasoline, equal to about 5% of world gasoline production.

In international public opinion surveys there is strong support for promoting renewable sources such as solar power and wind power, requiring utilities to use more renewable energy (even if this increases the cost), and providing tax incentives to encourage the development and use of such technologies. There is substantial optimism that renewable energy investments will pay off economically in the long term.

India has more than 50 million Ha of wasteland, which could be utilized for cultivating plants. Jatropha is one of the options thought of by many minds for producing bio-fuels. It is a kind of plant which can come up on arid land, albeit with lower yield. There are concerns such as low supply of quality seeds, technical advice, low knowledge of agencies which would buy seeds etc. But recently such agencies have come up and are offering technical advice as well as buying for further processing.

Another option is coming up in bio-fuels which will beat Jatropha once the research on it is successful and scalable is algae. Lot of it is being talked about around the world in the field of bio-fuels and is so attractive theoretically that anyone could go for it. If the output is compared in terms of oil in liter per acre, it is said to be better than Jatropha by about 100 times.

3.1.1 Solar Energy

Solar energy, radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar energy technologies include solar heating, solar photo-voltaic, solar thermal electricity and solar architecture, which can make considerable contributions to solving some of the most urgent problems the world now faces.

Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favourable thermal mass or light dispersing properties, and designing spaces that naturally circulate air.

In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating climate change, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared".

The Earth receives 174 petawatts (PW = 10^{15} watt) of incoming solar radiation (insolation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet.

Earth's land surface, oceans and atmosphere absorb solar radiation, and this raises their temperature. Warm air containing evaporated water from the oceans rises, causing atmospheric circulation or convection. When the air reaches a high altitude, where the temperature is low, water vapour condenses into clouds, which rain onto the Earth's surface, completing the water cycle. The latent heat of water condensation amplifies convection, producing atmospheric phenomena such as wind, cyclones and anti-cyclones. Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14°C. By photosynthesis green plants convert solar energy into chemical energy, which produces food, wood and the biomass from which fossil fuels are derived.

The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 exajoules (EJ) per year. In 2002, this was more energy in one hour than the world used in one year. Photosynthesis captures approximately 3,000 EJ (10^{18} joules) per year in biomass. The amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined.

Solar energy can be harnessed in different levels around the world. Depending on a geographical location the closer to the equator the more "potential" solar energy is available.

3.1.1.1 Principle of Flat Plate Collector

A solar thermal collector is a solar collector designed to collect heat by absorbing sunlight. The term is applied to solar hot water panels, but may also be used to denote more complex installations such as solar parabolic, solar trough and solar towers or simpler installations such as solar air heat. The more complex collectors are generally used in solar power plants where solar heat is used to generate electricity by heating water to produce steam which drives a turbine connected to an electrical generator. The simpler collectors are typically used for supplemental space heating in residential and commercial buildings. A collector is a device for converting the energy in solar radiation into a more usable or storable form. The energy in sunlight is in the form of electromagnetic radiation from the infrared (long) to the ultraviolet (short) wavelengths. The solar energy striking the Earth's surface depends on weather conditions, as well as location and orientation of the surface, but overall, it averages about 1,000 watts per square meter under clear skies with the surface directly perpendicular to the sun's rays.

The principle underlying the solar collector is that 'visible light' falling onto a dark object is converted into tangible warmth. The colour of the object does not in fact need to be black; it is rather the absorptive qualities of the material which determine the effect. A painted plate can be warmed, but so can a suitable fibrous material such as charred rice chaff. The cover is of secondary importance, but still has a decisive influence on the total working efficiency; it prevents the created warmth from being blown away and also limits the warmed-up objects' heat loss through re radiation. Moreover it allows a controlled airstream over the warmed objects, which would not otherwise be possible. To exploit the warmth in the heated objects or surface a medium (water, air) is directed alongside which takes up the warmth and takes it to wherever it is needed. When air is used, it can pass under the collector, above it, or through canals embedded within it. It can be a 'forced' or a 'natural' current. In drying, the relative and absolute humidity are of great importance. Air can take up moisture, but only up to a limit. This limit is the absolute (= maximum) humidity, and is temperature dependent. In practice, however, the air is very rarely fully saturated with moisture. The degree of saturation at a given temperature is called the relative humidity and is expressed as a percentage of the absolute humidity at that temperature. If air is passed over a moist substance it will take up moisture until it is virtually fully saturated, that is to say until absolute humidity has been reached. However, the capacity of the air for taking up this moisture is dependent on its temperature. The higher the temperature, the higher the absolute humidity, and the larger the uptake of moisture. If air is warmed the amount of moisture in it remains the same, but the relative humidity falls; and the air is therefore enabled to take up more moisture from its surroundings. If fully-saturated air is warmed and then passed over the objects to be dried, the rise in absolute humidity (and the fall in relative humidity) allows still more water to be taken up.

Solar collectors fall into two general categories : non-concentrating and concentrating. In the non-concentrating type, the collector area (i.e., the area that intercepts the solar radiation) is the same as the absorber area (i.e., the area absorbing the radiation). In these types the whole solar panel absorbs the light. Flat-plate and evacuated-tube solar collectors are used to collect heat for space heating, domestic hot water or cooling with an absorption chiller.

3.1.1.1.1 Working of Flat Plate Collector

Flat-plate collectors, developed by Hottel and Whillier in the 1950s, are the most common type. They consist of (1) a dark flat-plate absorber of solar energy, (2) a transparent cover that allows solar energy to pass through but reduces heat losses, (3) a heat-transport fluid (air, antifreeze or water) to remove heat from the absorber, and (4) a heat insulating backing. The absorber consists of a thin absorber sheet (of thermally stable polymers, aluminium, steel or copper, to which a matte black or selective coating is applied) often backed by a grid or coil of fluid tubing placed in an insulated casing with a glass or polycarbonate cover. In water heat panels, fluid is usually circulated through tubing to transfer heat from the absorber to an insulated water tank. This may be achieved directly or through a heat exchanger. Most air heat fabricators and some water heat manufacturers have a completely flooded absorber consisting of two sheets of metal which the fluid passes between. Because the heat exchange area is greater they may be marginally more efficient than traditional absorbers.

Sunlight passes through the glazing and strikes the absorber plate, which heats up, changing solar energy into heat energy. The heat is transferred to liquid passing through pipes attached to the absorber plate. Absorber plates are commonly painted with "selective coatings," which absorb and retain heat better than ordinary black paint. Absorber plates are usually made of metal - typically copper or aluminium - because the metal is a good heat conductor. Copper is more expensive, but is a better conductor and less prone to corrosion than aluminium. In locations with average available solar energy, flat plate collectors are sized approximately one-half- to one-square foot per gallon of one-day's hot water use.

3.1.1.2 Principle and Working of Photovoltaic Cell

Photovoltaics are best known as a method for generating electric power by using solar cells to convert energy from the sun into a flow of electrons. The photovoltaic effect refers to photons of light exciting electrons into a higher state of energy, allowing them to act as charge carriers for an electric current. The photovoltaic effect was first observed by Alexandre-Edmond Becquerel in 1839. The term photovoltaic denotes the unbiased operating mode of a photodiode in which current through the device is entirely due to the transduced light energy. Virtually all photovoltaic devices are some type of photodiode.

Solar cells produce direct current electricity from sun light, which can be used to power equipment or to recharge a battery. The first practical application of photovoltaics was to power orbiting satellites and other spacecraft, but today the majority of photovoltaic modules are used for grid connected power generation. In this case an inverter is required to convert the DC to AC. There is a smaller market for off-grid power for remote dwellings, boats, recreational vehicles, electric cars, roadside emergency telephones, remote sensing, and cathodic protection of pipelines.

Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photovoltaics include mono-crystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide. Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years.

Cells require protection from the environment and are usually packaged tightly behind a glass sheet. When more power is required than a single cell can deliver, cells are electrically connected together to form photovoltaic modules, or solar panels. A single module is enough to power an emergency telephone, but for a house or a power plant the modules must be arranged in multiples as arrays.

A significant market has emerged in off-grid locations for solar-power-charged storage-battery based solutions. These often provide the only electricity available. The first commercial installation of this kind was in 1966 on Ogami Island in Japan to transition Ogami Lighthouse from gas torch to fully self-sufficient electrical power.

Solar photovoltaics is growing rapidly, albeit from a small base, to a total global capacity of 67,400 megawatts (MW) at the end of 2011, representing 0.5% of worldwide electricity demand. The total power output of the world's PV capacity run over a calendar year is equal to some 80 billion kWh of electricity. This is sufficient to cover the annual power supply needs of over 20 million households in the world. More than 100 countries use solar PV. World solar PV capacity (grid-connected) was 7.6 GW in 2007, 16 GW in 2008, 23 GW in 2009, and 40 GW in 2010. Installations may be ground-mounted (and sometimes integrated with farming and grazing) or built into the roof or walls of a building (building-integrated photovoltaics).

A number of solar panels may also be mounted vertically above each other in a tower, if the zenith distance of the Sun is greater than zero, and the tower can be turned horizontally as a whole and each panels additionally around a horizontal axis. In such a tower the panels can follow the Sun exactly. Such a device may be described as a ladder mounted on a turnable disk. Each step of that ladder is the middle axis of a rectangular solar panel. In case the zenith distance of the Sun reaches zero, the "ladder" may be rotated to the north or the south to avoid a solar panel producing a shadow on a lower solar panel. Instead of an exactly vertical tower one can choose a tower with an axis directed to the polar star, meaning that it is parallel to the rotation axis of the Earth. In this case the angle between the axis and the Sun is always larger than 66 degrees. During a day it is only necessary to turn the panels around this axis to follow the Sun.

3.1.2 Wind Energy

Wind Energy is generated by harnessing the kinetic energy of atmospheric air. Wind Energy has had been in use for centuries for several other purposes such as sailing, irrigation and for grinding grain. Wind power systems transform kinetic energy of the wind into useful sources of power.

During ancient times, wind power systems were used for both milling and irrigation. It was during the early years of the 20th century that wind power was started to be harnessed for generation of electricity. Windmills have also been used in several countries to pump water.

Wind turbines work by transforming the Wind Energy into mechanical power that can be used for conversion to electricity or for other mechanical purposes like grinding. Wind turbines are used either as stand-alone units or in groups known as Wind Farms. Small-sized wind turbines, known as aero generators are used for charging large-sized batteries.

More than 80% of the global Wind Energy capacity is installed in 5 countries with India at the 5th position. Wind power is the fastest growing source of renewable energy globally with an established capacity in excess of 14,000

3.1.2.1 Principle

Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity. The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses, schools, and the like.

3.1.2.2 Wind Turbines

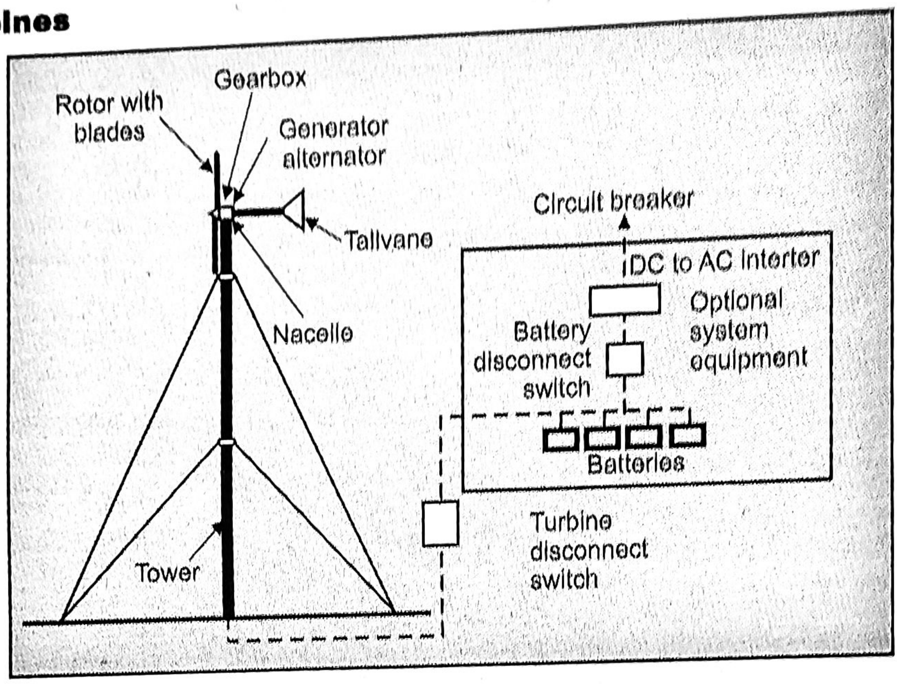

Fig. 3.1

Wind turbines, like aircraft propeller blades, turn in the moving air and power an **electric generator** that supplies an electric current. Simply stated, a wind turbine is the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity.

Modern wind turbines fall into two basic groups; the **horizontal-axis** variety, like the traditional farm windmills used for pumping water, and the **vertical-axis** design, like the eggbeater-style Darrieus model, named after its French inventor. Most large modern wind turbines are horizontal-axis turbines.

Horizontal turbine components include :

- **blade** or **rotor**, which converts the energy in the wind to rotational shaft energy;
- a **drive train**, usually including a gearbox and a generator;
- a **tower** that supports the rotor and drive train; and
- other equipment, including controls, electrical cables, ground support equipment, and interconnection equipment.

Wind turbines are often grouped together into a single wind power plant, also known as a **wind farm**, and generate bulk electrical power. Electricity from these turbines is fed into a utility grid and distributed to customers, just as with conventional power plants.

Wind turbines are available in a variety of sizes, and therefore power ratings. The largest machine has blades that span more than the length of a football field, stands 20 building stories high, and produces enough electricity to power 1,400 homes. A small home-sized wind machine has rotors between 8 and 25 feet in diameter and stands upwards of 30 feet and can supply the power needs of an all-electric home or small business. **Utility-scale turbines** range in size from 50 to 750 kilowatts. Single small turbines, below 50 kilowatts, are used for homes, telecommunications dishes, or water pumping.

3.1.3 Ocean Energy

Oceans can fulfill our needs of energy partially by three ways :

1. By way of Tidal Power.
2. By way of Wave Power.
3. By way of Ocean Thermal Energy Conversion (OTEC).

3.1.3.1 Tidal Power

Harnessing the power of the tides can be achieved by placing bi-directional turbines in the path of the tidal water flow in bays and river estuaries. To be viable, it needs a large tidal range and involves creating a barrier across the bay or estuary to funnel the water through the turbines as the tide comes in and goes out. Although tidal energy captured in tidal ponds have been used since Roman times to power mills, there are few modern installations. The first plant to utilise tidal energy on a large scale for electricity generation was built at Rance in France in1966. Others followed in Canada and Russia.

Electric power from tidal flows

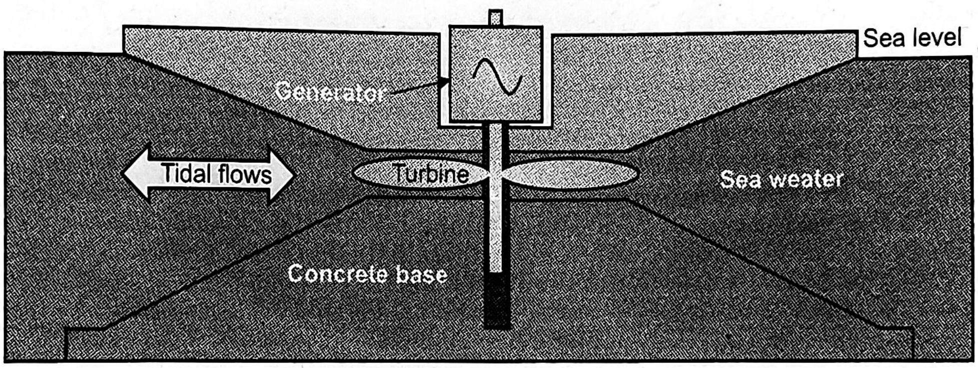

Fig. 3.2

Tidal power comes closest of all the intermittent renewable sources to being able to provide an unlimited, continuous and predictable power output but unfortunately there are few suitable sites in the world and environmental constraints have so far prevented their general acceptance.

Shrouded water turbines placed in deep water tidal currents show better potential for exploitation, though the associated civil works are more complicated, and several projects are under development.

Power is available for only six to twelve hours per day depending on the ebb and flow of the tides.

3.1.3.2 Wave Power

The energy available from the ocean's surface wave motion is almost unlimited, but it has proved frustratingly difficult to capture. Many ingenious systems have been proposed but, except for very small installations, very few are generating electricity commercially and most have been thwarted by practical problems.

Some of these proposals are outlined below. Most are still in an experimental phase and many are not scalable into high capacity systems.

- **Energy Conversion Systems**
- **Oscillating Float System**

One of the simplest and most common solutions is the oscillating float system in which a float is housed inside a cylinder shaped buoy which is open at the bottom and moored to the seabed. Inside the cylinder the float moves up and down on the surface of the waves as they pass through the buoy.

Various methods have been employed to turn the motion of the float into electrical energy. These include :-

- Hydraulic systems in which air is compressed in a pneumatic reservoir above the float during its upward movement on the crests of the waves. After the crests have passed, the air expands and forces the float downwards into the following troughs of the waves. A hydraulic system then uses the reciprocating movement of the float to pump water through a water turbine which drives a rotary electrical generator..
- Pneumatic systems in which the air displaced in the cylinder is used to power an air turbine which drives the generator.
- Linear generators to turn the reciprocating motion of the float directly into electrical power.
- Instead of generating the electricity on board the buoy, some systems pump the hydraulic fluid ashore to power shore based generators.
- **Oscillating Paddle System**

This system uses large paddles moored to the ocean floor to mimic the swaying motion of sea plants in the presence of ocean waves. The paddles are fixed to special hinged joints at the base which use the swaying motion of the paddles to pump water through a turbine generator.

- **Oscillating Snake System**

The snake system uses a series of floating cylindrical sections linked by hinged joints. The floating snake is tethered to the sea bed and maintains a position head on into the waves. The wave-induced motion at the hinges is used to pump high-pressure oil through hydraulic motors via smoothing accumulators. The hydraulic motors in turn drive electrical generators to produce the electrical power.

- **Oscillating Water Column**

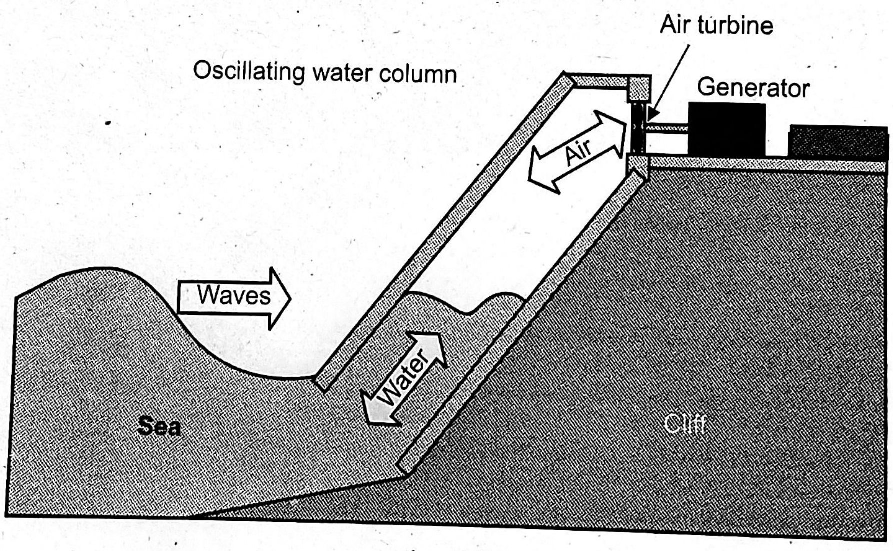

Fig. 3.3

Water columns are formed within large concrete structures built on the shore line or on rafts. The structure is open at both the top and the bottom. The lower end is submerged in the sea and an air turbine fills the aperture at the top. The rising and falling of the water column inside the structure moves the air column above it driving the air through the turbine generator. The turbine has movable vanes which rotate to maintain unidirectional rotation when the movement of the air column reverses.

- **Pressure Transducer System**

The hydraulic pump system uses a submerged gas-filled tank with rigid sides and base and a flexible, bellows-like, top. The gas in the tank compresses and expands in response to pressure changes from the waves passing overhead causing the top to rise and fall. A lever attached to centre of the top drives pistons, which pump pressurized water ashore for driving hydraulic generators.

- **Wave Capture Systems**

Wave capture systems use a narrowing ramp to funnel waves into an elevated reservoir. Waves entering the funnel over a wide front are concentrated into a narrowing channel which causes the amplitude of the wave to increase. The increased wave height coupled with the momentum of the water is sufficient to raise a quantity of water up a ramp and into a reservoir situated above the sea level. Water form the reservoir can then be released through a hydroelectric turbine located below the reservoir to generate electricity.

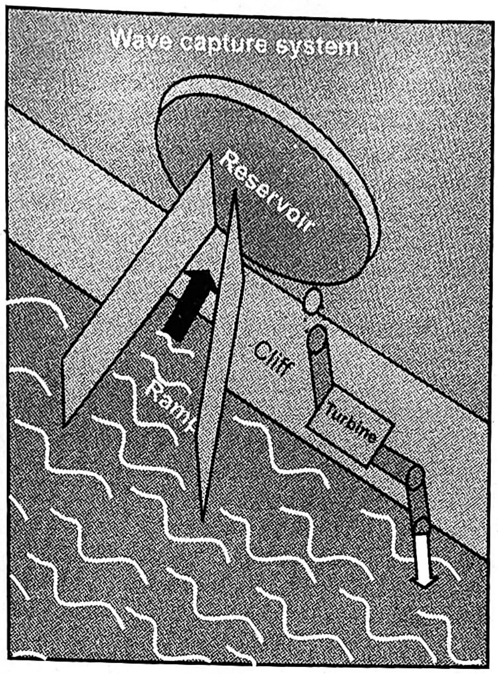

Fig. 3.4

- **Overtopping Wave Systems**

T hese are floating systems similar to the land based system described above. They focus waves onto a tapered ramp which causes their amplitude to increase. The crests of the waves overtop the ramp and spill into a low dam. Water from the low dam then flows through hydroelectric turbines back into into the sea beneath the floating structure.

- **Lever Systems**

Various lever based energy capture systems have been developed. Long levers may be mounted on steel piles or on floating platforms. Large floats or buoys are attached to the extremities of the levers which move up and down with the waves.

Movement of the lever arms forces fluid into a central hydraulic accumulator and through to a generator turbine. Alternatively high-pressure water can be pumped ashore to power shore based generators.

3.1.3.3 Ocean Thermal Energy Conversion (OTEC)

Sea water is heated by energy both from the Sun and from the Earth below. The solar energy falling on the water surface is greater than the heat flow emanating from the Earth so that the temperature at the surface is greater than the temperature in the depths of the water. OTEC systems convert the heat energy of the surface water into electrical energy using Binary Electric Generating Plants.

The available energy depends on the temperature gradient in the water. Warm water at the surface vaporises a working fluid such as ammonia or butane and the vapour is used to drive a turbine generator. Cold water, pumped up from the depths (down to 1000 metres), condenses the vapour.

3.1.4 Hydro Energy

The use of falling water as a source of energy is known for a long time. In the ancient times waterwheels were used already, but only at the beginning of the nineteenth century with the invention of the hydro turbine the use of hydropower got a new impulse.

Small-scale hydropower was the most common way of electricity generating in the early 20th century. In 1924 for example in Switzerland nearly 7000 small scale hydropower stations were in use. The improvement of distribution possibilities of electricity by means of high voltage transmission lines caused fainted interest in small scale hydropower.

Renewed interest in the technology of small scale hydropower started in China. Estimates say that between 1970 and 1985 nearly 76,000 small scale hydro stations have been built there!

Hydel energy is a renewable energy resource because it uses the Earth's water cycle to generate electricity. Water evaporates from the Earth's surface, forms clouds, precipitates back to earth, and flows toward the ocean. The movement of water as it flows downstream creates kinetic energy that can be converted into electricity. 2700 TWH (terawatt hours) is generated every year. Hydropower supplies at least 50% of electricity production in 66 countries and at least 90% in 24 countries. Out of the total power generation installed capacity in India of 1,76,990 MW (June, 2011), hydro power contributes about 21.5% i.e. 38,106 MW. A capacity addition of 78,700 MW is envisaged from different conventional sources during 2007-2012 (the 11th Plan), which includes 15,627 MW from large hydro projects. In addition to this, a capacity addition of 1400 MW was envisaged from small hydro up to 25 MW station capacity. The total hydroelectric power potential in the country is assessed at about 150,000 MW, equivalent to 84,000 MW at 60% load factor. The potential of small hydro power projects is estimated at about 15,000 MW.

Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy, accounting for 16 percent of global electricity consumption, and 3,427 terawatt-hours of electricity production in 2010, which continues the rapid rate of increase experienced between 2003 and 2009.

Hydropower is produced in 150 countries, with the Asia-Pacific region generating 32 percent of global hydropower in 2010. China is the largest hydroelectricity producer, with 721 terawatt-hours of production in 2010, representing around 17 percent of domestic electricity use. There are now three hydroelectricity plants larger than 10 GW : the Three Gorges Dam in China, Itaipu Dam in Brazil, and Guri Dam in Venezuela.

The cost of hydroelectricity is relatively low, making it a competitive source of renewable electricity. The average cost of electricity from a hydro plant larger than 10 megawatts is 3 to 5 U.S. cents per kilowatt-hour. Hydro is also a flexible source of electricity since plants can be ramped up and down very quickly to adapt to changing energy demands. However, damming interrupts the flow of rivers and can harm local ecosystems, and building large dams and reservoirs often involves displacing people and wildlife. Once a hydroelectric complex is constructed, the project produces no direct waste, and has a considerably lower output level of the greenhouse gas carbon dioxide (CO_2) than fossil fuel powered energy plants.

3.1.4.1 Principle

The basic principle of hydropower is that if water can be piped from a certain level to a lower level, then the resulting water pressure can be used to do work. If the water pressure is allowed to move a mechanical component then that movement involves the conversion of the potential energy of the water into mechanical energy. Hydro turbines convert water pressure into mechanical shaft power, which can be used to drive an electricity generator, a grinding mill or some other useful device.

To know the power potential of water in a river it is necessary to know the flow in the river and the available head. The flow of the river is the amount of water (in m^3 or litres) which passes in a certain amount of time a cross section of the river. Flows are normally given in cubic meters per second (m^3/s) or in litres per second (l/s). Head is the vertical difference in level (in meters) the water falls down.

3.1.4.2 Hydroelectric Power Generation

Hydro energy is available in many forms, potential energy from high heads of water retained in dams, kinetic energy from current flow in rivers and tidal barrages, and kinetic energy also from the movement of waves on relatively static water masses. Many ingenious ways have been developed for harnessing this energy but most involve directing the water flow through a turbine to generate electricity.

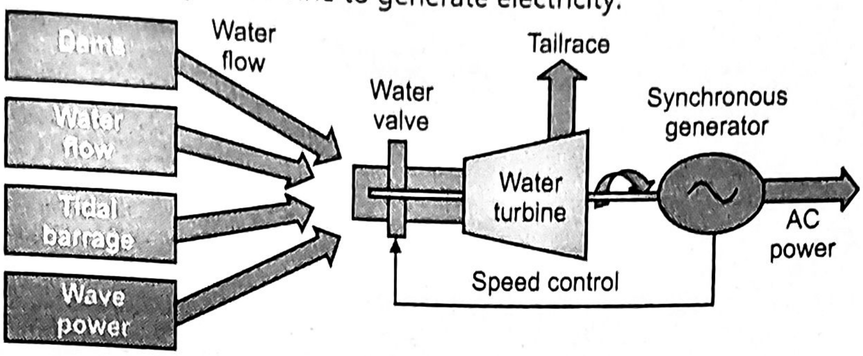

Fig. 3.5

3.1.4.3 Power from Dams (Potential Energy)

A hydroelectric dam installation uses the potential energy of the water retained in the dam to drive a water turbine which in turn drives an electric generator. The available energy therefore depends on the head of the water above the turbine and the volume of water flowing through it. Turbines are usually reaction types whose blades are fully submerged in the water flow.

The diagram opposite shows a typical turbine and generator configuration as used in a dam.

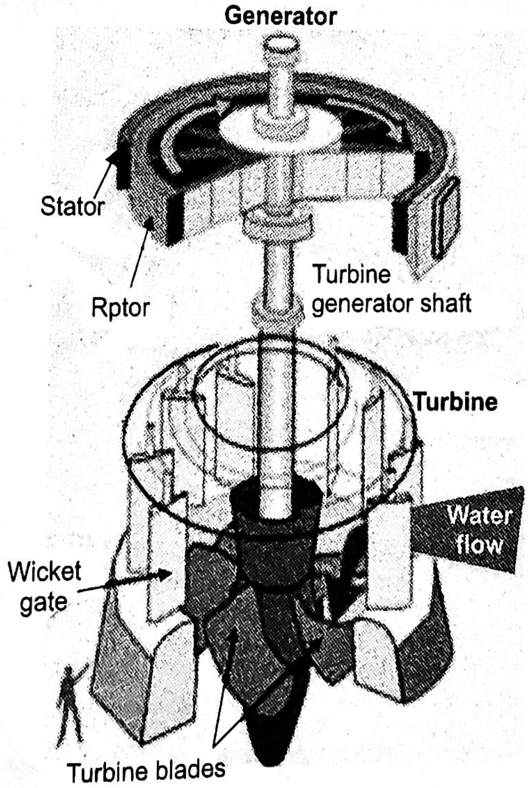

Fig. 3.6

The civil works involved in providing hydro-power from a dam will usually be many times the cost of the turbines and the associated electricity generating equipment. Dams however provide a large water reservoir from which the flow of water, and hence the power output of the generator, can be controlled. The reservoir also serves as a supply buffer storing excess water during rainy periods and releasing it during dry spells.

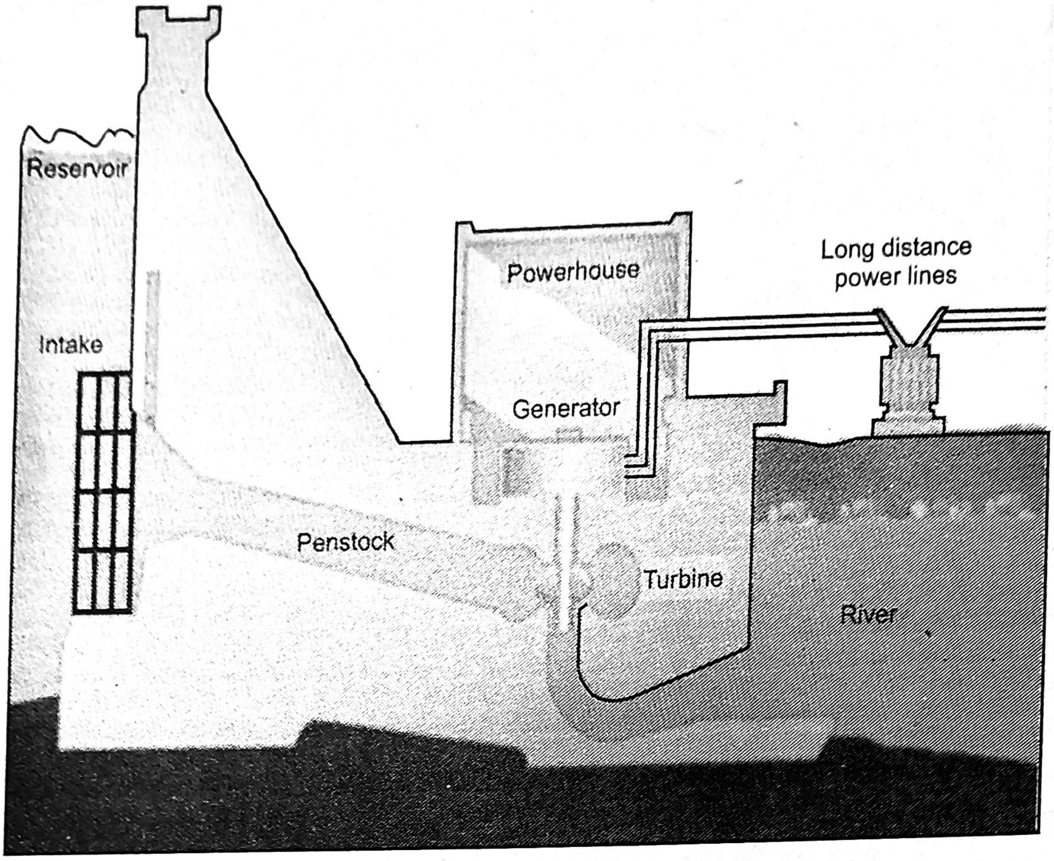

Fig. 3.7

3.1.4.4 "Run of River" Power (Kinetic Energy)

"Run of river" installations are typically used for smaller schemes generating less than 10 MegaWatts output. Water from a fast flowing river or stream is diverted through a turbine, often a Pelton wheel which drives the electrical generator. The head of water is essentially zero and the turbine converts the kinetic energy of the flowing water into the rotational energy of the turbine and the generator. The available energy therefore depends on the quantity of water flowing through the turbine and the square of its velocity. Impulse turbines which are only partially submerged are more commonly employed in fast flowing run of river installations while In deeper, slower flowing rivers, submerged Kaplan turbines may be used to extract the energy from the water flow.

Run of river projects are much less costly than dams because of the simpler civil works requirements. They are however susceptible to variations in the rainfall or water flow which reduce or even cut off potential power output during periods of drought. During flood conditions the installation may not be able to accommodate the higher flow rates and water must be diverted around the turbine losing the potential generating capacity of the increased water flow. Because of these limitations, if the construction of a dam is not possible, run of river installations may need to incorporate some form of supply back-up such as battery storage, emergency generators or even a grid connection.

Tidal Power and Wave Power are already explained in earlier sections.

3.1.5 Biomass Energy

Biomass is organic material that comes from plants and animals, and it is a renewable source of energy.

Biomass contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. When biomass is burned, the chemical energy in biomass is released as heat. Biomass can be burned directly or converted to liquid biofuels or biogas that can be burned as fuels.

Examples of biomass and their uses for energy :

- Wood and wood processing wastes - burned to heat buildings, to produce process heat in industry, and to generate electricity,

- Agricultural crops and waste materials - burned as a fuel or converted to liquid biofuels,
- Food, yard, and wood waste in garbage - burned to generate electricity in power plants or converted to biogas in landfills,
- Animal manure and human sewage - converted to biogas, which can be burned as a fuel.

3.1.5.1 Converting Biomass to Energy

Solid biomass, such as wood and garbage, can be burned directly to produce heat. Biomass can also be converted into a gas called biogas or into liquid biofuels such as ethanol and biodiesel. These fuels can then be burned for energy.

Biogas forms when paper, food scraps, and yard waste decompose in landfills, and it can be produced by processing sewage and animal manure in special vessels called digesters.

Ethanol is made from crops such as corn and sugar cane that are fermented to produce fuel ethanol for use in vehicles. Biodiesel is produced from vegetable oils and animal fats and can be used in vehicles and as heating oil.

3.1.5.2 How much biomass is used for fuel?

Biomass fuels provided about 5% of total primary energy use in the United States in 2017. Of that 5%, about 47% was from biofuels (mainly ethanol), 44% was from wood and wood-derived biomass, and 10% was from the biomass in municipal waste. (Sum of percentages is greater than 100% because of independent rounding) Researchers are trying to develop ways to use more biomass for fuel.

3.1.5.3 Biomass Energy in India

With serious concern globally and in India on the use of fossil fuels, it is important for India to start using renewable energy sources. India is the 7th largest country in the world spanning **328 million hectares** and amnlv bestowed with renewable sources of energy. Among the renewable energy sources, biomass plays a vital role especially in rural areas, as it constitutes the major energy source to majority of households in India. Biomass energy is the utilization of organic matter present and can be utilized for various applications.

- Biomass can be used to produce heat and electricity, or used in combined heat and power (CHP) plants.
- Biomass can also be used in combination with fossil fuels (co-firing) to improve efficiency and reduce the build up of combustion residues.
- Biomass can also replace petroleum as a source for transportation fuels.
- Biomass is a complex class of feed stocks with significant energy potential to apply different technologies for energy recovery. Typically technologies for biomass energy are broadly classified on the basis of principles of thermo chemistry as combustion, gasification, pyrolysis and biochemistry as anaerobic digestion, fermentation and trans-esterification. Each technology has its uniqueness to produce a major calorific end product and a mixture of by-products.
- India produces about 450-500 million tonnes of biomass per year. Biomass provides 32% of all the primary energy use in the country at present.
- As per estimates, the potential in the short term for power from biomass in India varies from about 18,000 MW, when the scope of biomass is as traditionally defined, to a high of about 50,000 MW if one were to expand the scope of definition of biomass.
- The current share of biofuels in total fuel consumption is extremely low and is confined mainly to 5% blending of ethanol in gasoline, which the government has made mandatory in 10 states.
- Currently, biodiesel is not sold on the Indian fuel market, but the government plans to meet 20% of the country's diesel requirements by 2020 using biodiesel.
- Plants like Jatropha curcas, Neem, Mahua and other wild plants are identified as the potential sources for biodiesel production in India.

- There are about 63 million ha waste land in the country, out of which about 40 million ha area can be developed by undertaking plantations of Jatropha. India uses several incentive schemes to induce villagers to rehabilitate waste lands through the cultivation of Jatropha.
- The Indian government has targeted a Jatropha plantation area of 11.2 million ha by 2012.
- The Ministry of New and Renewable Energy (MNRE) provides Central Financial Assistance (CFA) in the form of capital subsidy and financial incentives to the biomass energy projects in India. CFA is allotted to the projects on the basis of installed capacity, energy generation mode and its application etc. Financial support will be made available selectively through a transparent and competitive procedure.
- One of the most critical bottlenecks for biomass plants (based on any technology) is the supply chain bottlenecks that could result in non-availability of feedstock. A related problem is the volatility, or more precisely increase, in the feedstock price. Both these could render the project unviable. There is other concerns and bottlenecks as well such as :
- Lack of adequate policy framework and effective financing mechanisms
- Lack of effective regulatory framework
- Lack of technical capacity
- Absence of effective information dissemination
- Limited successful commercial demonstration model experience

Biomass to Transportation fuels

Biodiesel

- One of the main problems in getting the biodiesel programme rolling is the difficulty linked to initiating large-scale cultivation of Jatropha. The following problems have been cited by farmers regarding Jatropha cultivation :
- Lack of confidence in farmers due to the delay in notifying, publicizing and explaining the government biodiesel policy.
- No minimum support price.
- In the absence of long-term purchase contracts, there are no buy-back arrangements or purchase centres for Jatropha plantations.
- Lack of availability certified seeds of higher yield containing higher oil content.
- No announcement of incentives/subsidy and other benefits proposed to be provided to farmers

Bioethanol

- The overwhelmingly dominant factor in the production of ethanol in India is the price and availability of molasses.
- The Central government sets the policy regarding ethanol blending, but the State governments control the movement of molasses and often restrict molasses transport over State boundaries. State governments also impose excise taxes on potable alcohol sales, a lucrative source of revenue.

3.2 Non-renewable Energy Resources

A **non-renewable energy resource** (also called a **finite energy resource**) is a resource of energy of economic value that cannot be readily replaced by natural means at a quick enough pace to keep up with consumption. Natural resources such as coal, petroleum (crude oil) and natural gas take thousands of years to form naturally and cannot be replaced as fast as they are being consumed. Eventually it is considered that fossil-based resources will become too costly to harvest and humanity will need to shift its reliance to other sources of energy such as solar or wind power. Coal, crude oil, and natural gas are all considered fossil fuels because they were formed from the buried remains of plants and animals that lived millions of years ago. Uranium ore, a solid, is mined and converted to a fuel used at nuclear power plants. Uranium is not a fossil fuel, but it is classified as a nonrenewable fuel.

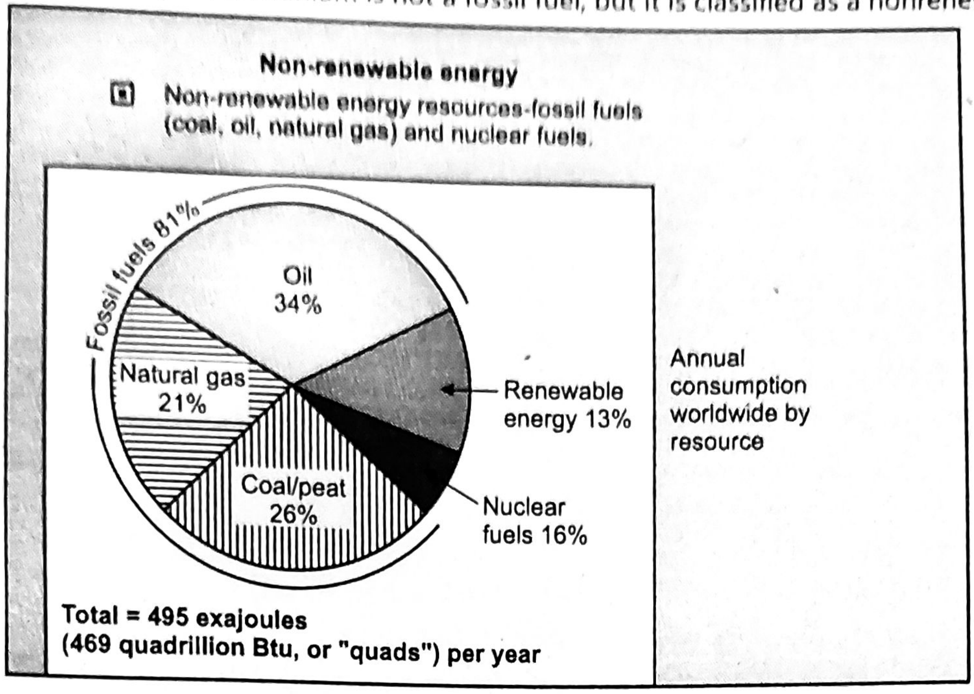

Fig. 3.8

The major nonrenewable energy sources are As follows :

1. Coal
2. Petroleum
3. Natural Gas
4. Nuclear Energy
5. Chemical Sources of Energy
6. Fuel Cells
7. Hydrogen
8. Bio-fuels

3.2.1 Coal

Coal is the main source of energy in India as it fulfils almost 67 per cent of the total commercial energy consumed in the country. This fossil fuel is found in a form of sedimentary rocks and is often known as 'Black Gold'. Coal is a combustible black or brownish-black sedimentary rock with a high amount of carbon and hydrocarbons. Coal is classified as a nonrenewable energy source because it takes millions of years to form. Coal contains the energy stored by plants that lived hundreds of millions of years ago in swampy forests. Layers of dirt and rock covered the plants over millions of years. The resulting pressure and heat turned the plants into the substance we call coal.

Types of coal

Coal is classified into four main types, or ranks : anthracite, bituminous, subbituminous, and lignite. The ranking depends on the types and amounts of carbon the coal contains and on the amount of heat energy the coal can produce. The rank of a coal deposit is determined by the amount of pressure and heat that acted on the plants over time.

Anthracite contains 86%–97% carbon and generally has the highest heating value of all ranks of coal. It is the best quality of coal which ignites slowly with a blue flame. It has the highest calorific value. It is found in small quantity in Jammu and Kashmir.

Bituminous coal contains 45%–86% carbon. It carries 60 to 80 per cent of carbon content and a low level of moisture content. It is widely used and has high calorific value. It is found in Jharkhand, West Bengal, Odisha, Chhattisgarh and Madhya Pradesh.

Lignite contains 40%–55% carbon and has quite low energy content. Lignite coal deposits tend to be relatively young and were not subjected to extreme heat or pressure. Lignite is crumbly and has high moisture content, which contributes to its low heating value. Lignite is often brown in colour. It is an intermediate stage which happens during the alteration of woody matter into coal. It has high moisture content so it gives smoke when burnt. It is found in Rajasthan, Lakhimpur (Assam), and Tamil Nadu.

Peat has less than 40 per cent carbon content. It is in the first stage of transformation from wood to coal. It has low calorific value and burns like wood.

3.2.2 Petroleum (Crude Oil)

It is a liquid fossil fuel. It is also called oil or crude oil. Crude oil is a mixture of hydrocarbons that formed from plants and animals that lived millions of years ago. Crude oil is a fossil fuel, and it exists in liquid form in underground pools or reservoirs, in tiny spaces within sedimentary rocks, and near the surface in tar (or oil) sands. Petroleum products are fuels made from crude oil and other hydrocarbons contained in natural gas. Petroleum products can also be made from coal, natural gas, and biomass.

After crude oil is removed from the ground, it is sent to a refinery where different parts of the crude oil are separated into useable petroleum products. These petroleum products include gasoline, distillates such as diesel fuel and heating oil, jet fuel, petrochemical feedstocks, waxes, lubricating oils, and asphalt.

3.2.3 Natural Gas

Natural gas is a fossil energy source that formed deep beneath the earth's surface. Natural gas contains many different compounds. The largest component of natural gas is methane, a compound with one carbon atom and four hydrogen atoms (CH_4). Natural gas also contains smaller amounts of natural gas liquids (NGL; which are also hydrocarbon gas liquids), and non-hydrocarbon gases, such as carbon dioxide and water vapor. We use natural gas as a fuel and to make materials and chemicals.

Millions to 100's of millions of years ago and over long periods of time, the remains of plants and animals (such as diatoms) built up in thick layers on the earth's surface and ocean floors, sometimes mixed with sand, silt, and calcium carbonate. Over time, these layers were buried under sand, silt, and rock. Pressure and heat changed some of this carbon and hydrogen-rich material into coal, some into oil (petroleum), and some into natural gas.

In some places, natural gas moved into large cracks and spaces between layers of overlying rock. The natural gas found in these types of formations is sometimes called *conventional natural gas*. In other places, natural gas occurs in the tiny pores (spaces) within some formations of shale, sandstone, and other types of sedimentary rock. This natural gas is referred to as *shale gas* or *tight gas*, and it is sometimes called *unconventional natural gas*. Natural gas also occurs with deposits of crude oil, and this natural gas is called *associated natural gas*. Natural gas deposits are found on land and some are offshore and deep under the ocean floor. A type of natural gas found in coal deposits is called *coalbed methane*.

To reach natural gas, some companies use a process called "hydraulic fracturing," or fracking. Hydraulic means they use water, and fracturing means to "split apart." The process uses high-pressure water to split apart the rocks underground. This releases the natural gas that is trapped in rock formations. If the rock is too hard, they can send acid down the well to dissolve the rock. They can also use tiny grains of glass or sand to prop open the rock and let the gas escape.

We use natural gas for heating and cooking. Natural gas can also be burned to generate electricity. We rely on natural gas to give power to lights, televisions, air conditioners, and kitchen appliances in our homes.

Natural gas can also be turned into a liquid form, called liquid natural gas (LNG). LNG is much cleaner than any other fossil fuels. Liquid natural gas takes up much less space than the gaseous form. The amount of natural gas that would fit into a big beach ball would fit into a ping-pong ball as a liquid! LNG can be easily stored and used for different purposes. LNG can even be a replacement for gasoline.

3.2.4 Nuclear Energy

Nuclear energy is usually considered another non-renewable energy source. Although nuclear energy itself is a renewable energy source, the material used in nuclear power plants is not.

Nuclear energy harvests the powerful energy in the nucleus, or core, of an atom. Nuclear energy is released through nuclear fission, the process where the nucleus of an atom splits. Nuclear power plants are complex machines that can control nuclear fission to produce electricity. The material most often used in nuclear power plants is the element uranium. Although uranium is found in rocks all over the world, nuclear power plants usually use a very rare type of uranium, U-235. Uranium is a non-renewable resource.

Nuclear energy is a popular way of generating electricity around the world. Nuclear power plants do not pollute the air or emit greenhouse gases. They can be built in rural or urban areas, and do not destroy the environment around them.

However, nuclear energy is difficult to harvest. Nuclear power plants are very complicated to build and run. Many communities do not have the scientists and engineers to develop a safe and reliable nuclear energy program.

Nuclear energy also produces radioactive material. Radioactive waste can be extremely toxic, causing burns and increasing the risk for cancers, blood diseases, and bone decay among people who are exposed to it.

3.2.5 Chemical Sources of Energy

Energy is of different types like mechanical energy, kinetic energy and sound energy. One such type of energy is chemical energy. Chemical energy is obtained by rearrangement of molecules and atoms of any substance. Coal, natural gas, batteries, explosives, food, gasoline, photosynthesis and electrolysis are example of chemical energy.

3.2.6 Fuel Cells

A fuel cell uses the chemical energy of hydrogen or another fuel to cleanly and efficiently produce electricity. If hydrogen is the fuel, electricity, water, and heat are the only products. Fuel cells are unique in terms of the variety of their potential applications; they can provide power for systems as large as a utility power station and as small as a laptop computer.

Fuel cells can be used in a wide range of applications, including transportation, material handling, stationary, portable, and emergency backup power applications. Fuel cells have several benefits over conventional combustion-based technologies currently used in many power plants and passenger vehicles. Fuel cells can operate at higher efficiencies than combustion engines, and can convert the chemical energy in the fuel to electrical energy with efficiencies of up to 60%. Fuel cells have lower emissions than combustion engines. Hydrogen fuel cells emit only water, so there are no carbon dioxide emissions and no air pollutants that create smog and cause health problems at the point of operation. Also, fuel cells are quiet during operation as they have fewer moving parts.

Fuel cells are classified primarily by the kind of electrolyte they employ. This classification determines the kind of electro-chemical reactions that take place in the cell, the kind of catalysts required, the temperature range in which the cell operates, the fuel required, and other factors. These characteristics, in turn, affect the applications for which these cells are most suitable. There are several types of fuel cells currently under development, each with its own advantages, limitations, and potential applications.

A fuel cell is a device that converts chemical potential energy (energy stored in molecular bonds) into electrical energy. A PEM (Proton Exchange Membrane) cell uses hydrogen gas (H_2) and oxygen gas (O_2) as fuel. The products of the reaction in the cell are water, electricity, and heat. This is a big improvement over internal combustion engines, coal burning power plants, and nuclear power plants, all of which produce harmful by-products.

Since O_2 is readily available in the atmosphere, we only need to supply the fuel cell with H2 which can come from an electrolysis process (see Alkaline electrolysis or PEM electrolysis).

The anode, the negative post of the fuel cell, has several jobs. It conducts the electrons that are freed from the hydrogen molecules so that they can be used in an external circuit. It has channels etched into it that disperse the hydrogen gas equally over the surface of the catalyst.

The cathode, the positive post of the fuel cell, has channels etched into it that distribute the oxygen to the surface of the catalyst. It also conducts the electrons back from the external circuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to form water.

The electrolyte is the proton exchange membrane. This specially treated material, which looks something like ordinary kitchen plastic wrap, only conducts positively charged ions. The membrane blocks electrons. For a PEMFC, the membrane must be hydrated in order to function and remain stable.

The catalyst is a special material that facilitates the reaction of oxygen and hydrogen. It is usually made of platinum nano-particles very thinly coated onto carbon paper or cloth. The catalyst is rough and porous so that the maximum surface area of the platinum can be exposed to the hydrogen or oxygen. The platinum-coated side of the catalyst faces the PEM.

As the name implies, the heart of the cell is the proton exchange membrane. It allows protons to pass through it virtually unimpeded, while electrons are blocked. So, when the H_2 hits the catalyst and splits into protons and electrons (remember, a proton is the same as an H+ ion) the protons go directly through to the cathode side, while the electrons are forced to travel through an external circuit. Along the way they perform useful work, like lighting a bulb or driving a motor, before combining with the protons and O_2 on the other side to produce water.

How does it work? Pressurized hydrogen gas (H_2) entering the fuel cell on the anode side. This gas is forced through the catalyst by the pressure. When an H_2 molecule comes in contact with the platinum on the catalyst, it splits into two H+ ions and two electrons (e^-). The electrons are conducted through the anode, where they make their way through the external circuit (doing useful work such as turning a motor) and return to the cathode side of the fuel cell.

Meanwhile, on the cathode side of the fuel cell, oxygen gas (O_2) is being forced through the catalyst, where it forms two oxygen atoms. Each of these atoms has a strong negative charge. This negative charge attracts the two H^+ ions through the membrane, where they combine with an oxygen atom and two of the electrons from the external circuit to form a water molecule (H_2O).

All these reaction occurs in a so called cell stack. The expertise then also involves the setup of a complete system around core component that is the cell stack.

The stack will be embedded in a module including fuel, water and air management, coolant control hardware and software. This module will then be integrated in a complete system to be used in different applications.

Due to the high energetic content of hydrogen and high efficiency of fuel cells (55%), this great technology can be used in many applications like transport (cars, buses, forklifts, etc) and backup power to produce electricity during a failure of the electricity grid.

3.2.7 Hydrogen

Hydrogen is the simplest element. Each atom of hydrogen has only one proton. Hydrogen is also the most abundant element in the universe. Stars such as the sun consist mostly of hydrogen. The sun is essentially a giant ball of hydrogen and helium gases.

Hydrogen occurs naturally on earth only in compound form with other elements in liquids, gases, or solids. Hydrogen combined with oxygen is water (H_2O). Hydrogen combined with carbon forms different compounds - or hydrocarbons - found in natural gas, coal, and petroleum.

Energy carriers allow the transport of energy in a useable form from one place to another. Hydrogen, like electricity, is an energy carrier that must be produced from another substance. Hydrogen can be produced - separated - from a variety of sources including water, fossil fuels, or biomass and used as a source of energy or fuel. Hydrogen has the highest energy content of any common fuel by weight (about three times more than gasoline), but it has the lowest energy content by volume (about four times less than gasoline).

It takes more energy to produce hydrogen (by separating it from other elements in molecules) than hydrogen provides when it is converted to useful energy. However, hydrogen is useful as an energy source/fuel because it has high energy content per unit of weight, which is why it is used as a rocket fuel and in fuel cells to produce electricity on some spacecraft. Hydrogen is not widely used as a fuel now, but it has the potential for greater use in the future.

3.2.8 Biomass-Biofuel

Biomass energy, a renewable energy source, can also be a non-renewable energy source. Biomass energy uses the energy found in plants.

Biomass energy relies on biomass feed stocks - plants that are processed and burned to create electricity. Biomass feed stocks can include crops such as corn or soy, as well as wood. If people do not replant biomass feed stocks as fast as they use them, biomass energy becomes a non-renewable energy source.

Bio-fuels are transportation fuels such as ethanol and biodiesel that are made from biomass materials. These fuels are usually blended with petroleum fuels (gasoline and diesel fuel), but they can also be used on their own. Using ethanol or biodiesel means less gasoline and diesel fuel is burned, which can reduce the amount of crude oil imported from other countries. Ethanol and biodiesel are also cleaner-burning fuels than pure gasoline and diesel fuel.

Ethanol is an alcohol fuel made from the sugars found in grains such as corn, sorghum, and barley.

Sources of sugars to produce ethanol include :

- switch grass
- Sugar cane
- Sugar beets
- Potato skins
- Rice
- Yard clippings
- Tree bark

Most of the fuel ethanol used is distilled from corn. Scientists are working on ways to make ethanol from all parts of plants and trees rather than just grain. Farmers are experimenting with fast-growing woody crops such as small poplar and willow trees and switchgrass to see if they can be used to produce ethanol. Ethanol is blended with gasoline

Biodiesel is a fuel made from vegetable oils, fats, or greases—such as recycled restaurant grease. Biodiesel fuel can be used in diesel engines without changing the engine. Pure biodiesel is non-toxic, biodegradable, and produces lower levels of most air pollutants than petroleum-based diesel fuel. Biodiesel is usually sold as a blend of biodiesel and petroleum-based diesel fuel. A common blend of diesel fuel is B20, which is 20% biodiesel.

3.3 Energy Conservation

People use energy for transportation, cooking, heating and cooling rooms, manufacturing, lighting, entertainment, and many other uses. The choices people make about how they use energy—turning machines off when they're not using them or choosing to buy fuel-efficient vehicles and energy-efficient appliances—affects the environment and people's lives.

- **Energy efficiency** is using technology that requires less energy to perform the same function. Using a light-emitting diode (LED) light bulb or a compact fluorescent light (CFL) bulb that requires less energy than an incandescent light bulb to produce the same amount of light is an example of energy efficiency.
- **Energy conservation** is any behavior that results in the use of less energy. Turning the lights off when leaving the room and recycling aluminum cans are both ways of conserving energy.

3.3.1 Introduction

Whether it's turning off a light when leaving a room, checking the tire pressure on a car or adding insulation to an attic, every contribution towards energy conservation helps preserves Earth's finite natural resources. Conservation helps slow down the effects of climate change as well. The world runs on energy, most of which is supplied through the burning of fossil fuels that release harmful gases. Cutting back on energy use and using energy more efficiently results in fewer emissions entering the atmosphere.

Energy conservation is the effort made to reduce the consumption of energy by using less of an energy service. This can be achieved either by using energy more efficiently (using less energy for a constant service) or by reducing the amount of service used (for example, by driving less). Energy conservation is a part of the concept of eco-sufficiency. Energy conservation reduces the need for energy services and can result in increased environmental quality, national security, personal financial security and higher savings. It is at the top of the sustainable energy hierarchy. It also lowers energy costs by preventing future resource depletion.

Energy can be conserved by reducing wastage and losses, improving efficiency through technological upgrades and improved operation and maintenance. On a global level energy use can also be reduced by the stabilization of population growth.

Energy can only be transformed from one form to other, such as heat energy to motive power in cars, or kinetic energy of water flow to electricity in hydroelectric power plants. However machines are required to transform energy from one form to other. The wear and friction of the components of these machine while running cause loss of quadrillions of BTU and $500 billions in industries only in USA. It is possible to minimize these losses by adopting green engineering practices to improve life cycle of the components.

3.3.2 Specific Objectives

1. *Energy Independence :* In today's modern world, where the economies of the world are interlinked, regional events have global consequences. Just the rumor of potential conflict in an oil-producing country has the power to drive up gas prices worldwide. Lessening a dependence on foreign oil through conservation offers a measure of financial and national security.
2. *Countering Rising Energy Demands :* The US Energy Information Administration (EIA) predicts that global demand for energy will double by the year 2035. Energy prices are predicted to rise as well. It has been reported that while energy-efficient appliances have been effective in conserving energy, an increase in the number of electronics in homes has offset those savings. While the number of televisions might have dropped per household, homes now have more than one computer. For every rupee that a household spends on electricity, 20 paisa goes towards powering home electronics and appliances.
3. *Conservation Benefits :* By reducing the amount of carbon dioxide that is emitted into the atmosphere due to conservation, cities, rivers and oceans are less polluted. Conservation can slow the effect of climate change, reducing the occurrence of disastrous weather events. Beyond the basic goal of conserving the planet's resources, conservation has economical, political and cultural benefits. Conservation is personally empowering as well. Every citizen can takes steps to conserve energy, and a unified effort can result in significant, positive results.
4. *Encourage the preferential use of renewable energy*
5. *Debate the best technical and sustainable options for increasing renewable energy and energy efficiency*
6. *Facilitate Research and Development in renewable energy and energy efficiency*
7. *Disseminate information on renewable energy and energy efficiency*
8. *Lobby on the strategic issues affecting the development of a renewable energy sector*
9. *Keep mottos as "Energy saved is energy generated"; "Save energy to reduce pollution" and "Save our money when we save energy"*

3.3.3 Present Scenario

- The World is in a transition phase and energy is central to it. India has been responsible for almost 10% of the increase in global energy demand since 2000. India's energy demand in this period has almost doubled, pushing the country's share in global demand up to 5.7% in 2013 from 4.4% at the beginning of the century.
- The primary energy demand in India has grown from about 441 Mtoe (Million Tonnes of Oil Equivalent) in 2000 to about 775 Mtoe in 2013. This demand is expected to increase to about 1250 (estimated by International Energy Agency) to 1500 (estimated in the Integrated Energy Policy Report) million toe in 2030. India's energy consumption has almost doubled since 2000 and the potential for further rapid growth is enormous. Yet the increase in domestic energy production is far below than India's consumption needs.
- By 2040 more than 40% of primary energy supply will be imported, up from 32% in 2013. It may also be noted that no country in the world has been able to achieve a Human Development Index of 0.9 or more without an annual energy supply of at least 4 toe per capita. Consequently, there is a large latent demand for energy services that needs to be fulfilled in order for people to have reasonable incomes and a decent quality of life.
- Improving the energy efficiency meets the dual objectives of promoting sustainable development and of making the economy competitive. Recognizing the formidable challenges of meeting the energy needs and providing adequate and varied energy of desired quality in a sustainable manner and at reasonable costs, improving efficiency have become important components of energy policy. In addition, the environmental and health burdens arising out of the use of hydrocarbons may also force mankind towards energy efficiency and clean energy systems. Energy Conservation has also assumed enhanced importance with a view to conserve depleting energy resources.
- Government of India has undertaken a two pronged approach to cater to the energy demand of its citizens while ensuring minimum growth in CO2 emissions, so that the global emissions do not lead to an irreversible damage to the earth system. On one hand, in the generation side, the Government is promoting greater use of renewable in the energy mix mainly through solar and wind and at the same time shifting towards supercritical technologies for coal based power plants. On the other side, efforts are being made to efficiently use the energy in the demand side through various innovative policy measures under the overall ambit of Energy Conservation Act 2001.
- The Energy Conservation Act (EC Act) was enacted in 2001 with the goal of reducing energy intensity of Indian economy. Bureau of Energy Efficiency (BEE), a statutory body under Ministry of Power is responsible for spearheading the improvement of energy efficiency in the economy through various regulatory and promotional instruments. Bureau of Energy Efficiency (BEE) was set up as the statutory body on 1st March 2002 at the central level to facilitate the implementation of the EC Act. The Act provides regulatory mandate for : standards and labelling of equipment and appliances; energy conservation building codes for commercial buildings; and energy consumption norms for energy intensive industries. In addition, the Act enjoins the Central Govt. and the Bureau to take steps to facilitate and promote energy efficiency in all sectors of the economy. The Act also directs states to designate agencies for the implementation of the Act and promotion of energy efficiency in the state.
- Ministry of Power, through Bureau of Energy Efficiency (BEE), has initiated a number of energy efficiency initiatives in the areas of household lighting, commercial buildings, standards and labelling of appliances, demand side management in agriculture/municipalities, SME's and large industries including the initiation of the process for development of energy consumption norms for industrial sub sectors, capacity building of SDA's (State Designated Agency) etc.

3.3.4 Need for Energy Conservation

- The increasing demand for power has led to considerable fossil fuels burning which has in turn had an adverse impact on environment. In this context, efficient use of energy and its conservation is of paramount importance. It has been estimated that nearly 25,000 MW can be saved by implementing end-use energy efficiency and demand side management measures throughout India. Efficient use of energy and its conservation assumes even greater importance in view of the fact that one unit of energy saved at the consumption level reduces the need for fresh capacity creation by 2 times to 2.5 times. Further, such saving through efficient use of energy can be achieved at less than one-fifth the cost of fresh capacity creation. Energy efficiency would, therefore, significantly supplement our efforts to meet power requirement, apart from reducing fossil fuel consumption.
- The economic development of a country is often closely linked to its consumption of energy. Although India ranks sixth in the world as far as total energy consumption is concerned, it still needs much more energy to keep pace with its development objectives. India's projected economic growth rate is slated at 7.4 % during the period 1997-2012. This would necessitate commensurate growth in the requirement of commercial energy, most of which is expected to be from fossil fuels and electricity.
- India's proven coal reserves may last for more than 200 years, but the limited known oil and natural gas reserves may last only 18 years to 26 years, which is a cause of concern. The continued trend of increasing share of petroleum fuels in the consumption of commercial energy is bound to lead to more dependence on imports and energy insecurity.
- India's energy intensity per unit of GDP is higher as compared to Japan, U.S.A. and Asia by 3.7 times, 1.55 times and 1.47 times respectively. This indicates inefficient use of energy but also substantial scope for energy savings. The increasing global trade liberalization and growing global competition have made productivity improvement, including energy cost reduction, an important benchmark for economic success. Therefore, a paradigm shift in our approach to energy policy issues is needed – a shift from a supply dominated one to an integrated approach. This integrated approach would have to incorporate a judicial mix of investment in the supply side capacity, operational efficiency improvements of existing power generating stations, reduction of losses in transmission and distribution, end-use efficiency and renewable technologies.
- The policy goals and concepts would have to be shifted from "energy conservation" to "energy efficiency", and from "energy inputs" to the "effectiveness of energy use" and "energy services". Creation of new power generation capacity is costly and necessitates long gestation period whereas energy efficiency activities can make available additional power at comparatively low investments within a short period of time.

3.3.6 LEED India Rating System and Energy Efficiency

For the past few years, the word 'Green Buildings' is continuously hogging limelight in the media. Now the question comes up – what exactly are these structures? How are different from other buildings? And why are they green?

We can define Green Buildings as structures that ensure efficient use of natural resources like building materials, water, energy and other resources with minimal generation of non-degradable waste. Technologies like efficient cooling systems have sensors that can sense the heat generated from human body and automatically adjust the room temperature, saving energy. It applies to lighting systems too. Green buildings have a smarter lighting system that automatically switches off when no one is present inside the rooms. Simple technologies like air based flushing system in toilets that avoids water use by 100%, Use of energy efficient LED's and CFL's instead of conventional incandescent lamp, new generation appliances that consume less energy, and many other options help in making the buildings green and make them different from conventional ones.

Whether Green buildings are really green is to be decided against the predefined rating systems. There are three primary Rating systems in India.

1. Green Rating for Integrated Habitat Assessment (GRIHA).
2. Indian Green Building Council (IGBC)/Leadership in Energy and Environmental Design (LEED).
3. Bureau of Energy Efficiency (BEE).

3.3.6.1 LEED India Rating System

The Leadership in Energy and Environmental Design (LEED) is the rating system developed for certifying Green Buildings. LEED is developed by the U.S. Green Building Council (USGBC), the organization promoting sustainability through Green Buildings. LEED is a framework for assessing building performance against set criteria and standard points of references. The benchmarks for the LEED Green Building Rating System were developed in year 2000 and are currently available for new and existing constructions.

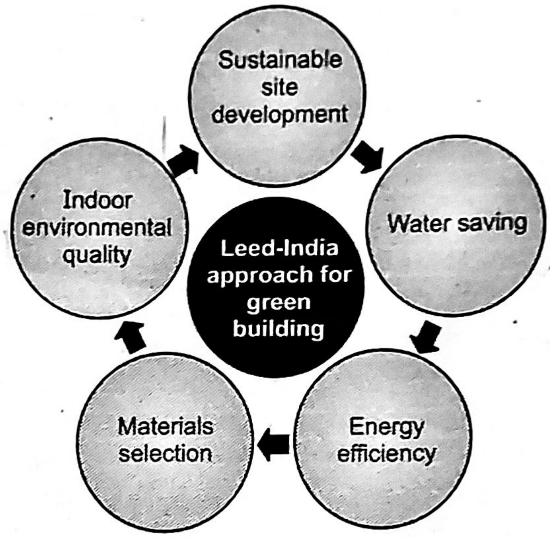

Fig. 3.9

Confederation of Indian Industry (CII) formed the Indian Green Building Council (IGBC) in year 2001. IGBC is the non profit research institution having its offices in CII-Sohrabji Godrej Green Business Centre, which is itself a LEED certified Green building. Indian Green Building Council (IGBC) has licensed the LEED Green Building Standard from the USGBC. IGBC facilitates Indian green structures to become one of the green buildings.

IGBC has developed the following green building rating systems for different types of building in line and conformity with US Green Building Council. Till date, following Green Building rating systems are available under IGBC :

1. LEED India for New Construction.
2. LEED India for Core and Shell.
3. IGBC Green Homes.
4. IGBC Green Factory Building.
5. IGBC Green SEZ.
6. IGBC Green Townships.

3.3.6.2 Energy Efficiency

BEE developed its own rating system for the buildings based on a 1 to 5 star scale. More stars mean more energy efficiency. BEE has developed the Energy Performance Index (EPI). The unit of Kilo watt hours per square meter per year is considered for rating the building and especially targets air conditioned and non-air conditioned office buildings. The Reserve Bank of India's buildings in Delhi and Bhubaneshwar, the CII Sohrabji Godrej Green Business Centre and many other buildings have received BEE 5 star ratings.

Indians were aware of Green Building concepts from the beginning. Conventional homes with baked red colour roof tiles and clay made walls is a really good example of energy efficient structures that are used to keep cool during summers and warm during the winters. Most of rural India is still attached to this building technology with naturally available materials like clay, wood, jute ropes, etc. Today we have advanced technologies that create smarter systems to control inside temperature, lighting systems, power and water supply and waste generation. Green buildings might be a bit heavy on the purse but are good for the environment. In this rapidly changing world, we should adopt the technology that helps us to save precious natural resources. This would lead us to true sustainable development.

3.4 Functions of Government organization working for Energy Conservation and Audit (ECA)

3.4.1 National Productivity Council

NPC is national level organization to promote productivity culture in India. Established by the Ministry of Industry, Government of India in 1958, it is an autonomous, multipartite, non-profit organization with equal representation from employers' and workers' organizations and Government, apart from technical and professional institutions and other interests. NPC is a constituent of the Tokyo-based Asian Productivity Organisation (APO), an Inter Governmental Body, of which the Government of India is a founder member.

NPC teams up with its clients to work out solutions towards accelerating productivity, enhancing competitiveness, increasing profits, augmenting safety and reliability and ensuring better quality. It provides reliable database for decision-making, improved systems and procedures, work culture as well as customer satisfaction both internal and external. The solutions can be all-encompassing or specific depending on the nature of the problem. The council also helps monitor, review and implement the identified strategies. Promotional and catalytic in nature, NPC's services have bearings on economic growth and quality of life. The Council promotes a comprehensive view of productivity focused on improving triple bottom line – economic, environmental and social and adds value for all the stakeholders through generation and application of advanced knowledge for inclusive Growth.

3.4.1.1 Competencies

NPC provides consultancy services and training programs in the following fields :

1. AGRI BUSINESS SERVICES
2. ECONOMIC SERVICES
3. ENERGY MANAGEMENT
4. ENVIRONMENT MANAGEMENT
5. HUMAN RESOURCE MANAGEMENT
6. INFORMATION TECHNOLOGY
7. INDUSTRIAL ENGINEERING
8. TECHNOLOGY MANAGEMENT

But this chapter concerns energy conservation which is a part of energy management; therefore, ENERGY MANAGEMENT activities/consultancy/training under NPC is relevant to the chapter.

3.4.1.2 Energy Management (EM)

Energy Management (EM) Division of NPC offers Consultancy / Training services since 1964. NPC has core strength of 30 EM professionals which include about 20 BEE certified Energy Auditors. The areas of expert services of this division are enlisted as follows :

- Energy Management and Audit in all types of Industries, Commercial buildings and establishment, Power-generating plants, Distribution system.

- Demand side Management potential with focus on the industrial sector.
- To strengthen policy aspects and increase public awareness of Energy Conservation issues through modular training programmes for Senior, Middle and Shop floor level executives.
- Technological Up gradation and Resource Conservation in SME's through cluster approach.
- Providing Technical Expertise Services to Asian Productivity Organization (APO) member Countries in Energy Efficiency.
- Providing hands on training at Centre Excellence for Training in Energy Efficiency and Indo- Japan project on Regional Energy Efficiency Centre at Dr. Ambedkar Institute of Productivity, Chennai, sponsored by Department of Industrial Policy and Promotion (DIPP), with support from BEE and New Energy and Industrial Technology Development Organization (NEDO), Japan.
- NPC has been conducting the prestigious National Certification Examination for Energy Managers and Energy Auditors on behalf of the Bureau of Energy Efficiency (BEE), Ministry of Power, India, since 2004.
- "Assessment of Energy Conservation Potential in identified sectors in all 28 Stales and 7 UT's" for B.E.E.
- Preparation of Energy Conservation Action Plan (ECAP) and conduct of awareness programme on EC for State Designated Agency (SDAs) of 16 states and 7 UT's, for B.E.E.
- Project on Green House Emission Reduction in Asia Pacific (GERIAP); funded by Swiss Industrial Development Agency (SIDA) and executed by UNEP, Bangkok, NPC India as served as the lead agency to assist 8 member countries in providing technical assistance.
- EU sponsored project for BEE, on "Strengthening State Designated Agencies in Implementing Energy Conservation Act-2001, covering six states in India.
- As Advisor Cum Consultants to Ministry of Power, NPC carried out Accelerated Power Distribution Reforms Programme (APDRP), in the states of West Bengal, Assam and Himachal Pradesh.
- As Third Party Independent Energy Audit Agency, NPC is assisting PFC, MOP, GOI in Restructured Accelerated Power Distribution Reforms Programme (RAPDRP).
- NPC has carried out Impact Assessment Studies of Renewable Energy (RE) Schemes of Ministry of New and Renewable Energy (MNRE).
- Third Party Evaluation of Report on verifiable energy savings
- Energy Audit and Demand Side Management (DSM) studies in Hydro Power Projects.
- Assisting neighboring countries like Nepal, Bangladesh, Dubai on capacity building hands holding third party independent evaluator Assessor on Energy Efficiency.
- Study and conduct of baseline energy audit i.e. Energy intensive industrial sectors towards fixation of target and energy efficiency improvement.

3.4.2 Ministry of New and Renewable Energy (MNRE)

The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India for all matters relating to new and renewable energy. The broad aim of the Ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of the country. **Creation CASE, DNES and Ministry :**

1. Commission for Additional Sources of Energy (CASE) in 1981.
2. Department of Non-Conventional Energy Sources (DNES) in 1982.
3. Ministry of Non-Conventional Energy Sources (MNES) in 1992.
4. Ministry of Non-Conventional Energy Sources (MNES) renamed as Ministry of New and Renewable Energy (MNRE) in 2006.

The role of new and renewable energy has been assuming increasing significance in recent times with the growing concern for the country's energy security. Energy self-sufficiency was identified as the major driver for new and renewable energy in the country in the wake of the two oil shocks of the 1970s. The sudden increase in the price of oil, uncertainties associated with its supply and the adverse impact on the balance of payments position led to the establishment of the Commission for Additional Sources of Energy in the Department of Science and Technology in March 1981. The Commission was charged with the responsibility of formulating policies and their implementation, programmes for development of new and renewable energy apart from coordinating and intensifying RandD in the sector. In 1982, a new department, i.e., Department of Non-conventional Energy Sources (DNES), that incorporated CASE, was created in the then Ministry of Energy. In 1992, DNES became the Ministry of Non-conventional Energy Sources. In October 2006, the Ministry was re-christened as the Ministry of New and Renewable Energy.

Functions :

Facilitate research, design, development, manufacture and deployment of new and renewable energy systems/devices for transportation, portable and stationary applications in rural, urban, industrial and commercial sectors through :

1. Technology Mapping and Benchmarking;
2. Identify Research, Design, Development and Manufacture thrust areas and facilitate the same;
3. Lay down standards, specifications and performance parameters at par with international levels and facilitate industry in attaining the same;
4. Align costs of new and renewable energy products and services with international levels and facilitate industry in attaining the same;
5. Appropriate international level quality assurance accreditation and facilitate industry in obtaining the same;
6. Provide sustained feed-back to manufacturers on performance parameters of new and renewable energy products and services with the aim of effecting continuous upgradation so as to attain international levels in the shortest possible time span;
7. Facilitate industry in becoming internationally competitive and a net foreign exchange earner especially through (ii) to (v) above and related measures;
8. Resource Survey, Assessment, Mapping and Dissemination.
9. Identify areas in which new and renewable energy products and services need to be deployed in keeping with the goal of national energy security and energy independence;
10. Deployment strategy for various indigenously developed and manufactured new and renewable energy products and services; and
11. Provision of cost-competitive new and renewable energy supply options

3.4.3 Bureau of Energy Efficiency (BEE)

The Government of India set up Bureau of Energy Efficiency (BEE). on 1st March 2002 under the provisions of the Energy Conservation Act, 2001. The mission of the Bureau of Energy Efficiency is to assist in developing policies and strategies with a thrust on self-regulation and market principles, within the overall framework of the Energy Conservation Act, 2001 with the primary objective of reducing energy intensity of the Indian economy.

Role of BEE

BEE co-ordinates with designated consumers, designated agencies and other organizations and recognize, identify and utilize the existing resources and infrastructure, in performing the functions assigned to it under the Energy Conservation Act. The Energy Conservation Act provides for regulatory and promotional functions.

The Major Functions of BEE include :

- Create awareness and disseminate information on energy efficiency and conservation
- Arrange and organize training of personnel and specialists in the techniques for efficient use of energy and its conservation
- Strengthen consultancy services in the field of energy conservation
- Promote research and development
- Develop testing and certification procedures and promote testing facilities
- Formulate and facilitate implementation of pilot projects and demonstration projects
- Promote use of energy efficient processes, equipment, devices and systems
- Take steps to encourage preferential treatment for use of energy efficient equipment or appliances
- Promote innovative financing of energy efficiency projects
- Give financial assistance to institutions for promoting efficient use of energy and its conservation
- Prepare educational curriculum on efficient use of energy and its conservation
- Implement international co-operation programmes relating to efficient use of energy and its conservation

3.4.4 Maharashtra Energy Development Agency (MEDA)

- Registered as a society under Societies Registration Act, 1860 (in 1985) and Bombay Public Trust, 1950 (in 1987)
- Under the aegis of MNRE, GoI
- Assistance to state and central govt to promote and develop new and renewable sources of energy and technologies and to promote and implement energy conservation.
- Working as State Nodal Agency in renewable energy sector and state designated agency in energy conservation sector
- Committed to explore the resources such as Wind, Bagasse Cogen, Hydro, Biomass, Geothermal, Wave which are clean and eco-friendly in nature.

Functions :

- To propagate, promote and develop new and renewable sources of energy and technologies and to implement energy conservation schemes
- To encourage power generation through renewable sources of energy
- To create mass awareness about the increasing need for energy conservation and use of renewable sources of energy
- To implement the renewable energy programs of the state government and The Ministry of New and Renewable Energy (MNRE)

3.5 Salient features of the Energy Conservation Act 2001

An Act to provide for efficient use of energy and its conservation and for matters connected therewith or incidental thereto. BE it enacted by Parliament in the Fifty second Year of the Republic of India as follows :—"

Chapter 01 : Short title, extent and commencement

Chapter 02 : Establishment and incorporation of Bureau of Energy Efficiency

Chapter 03 : Transfer of assets, liabilities and employees of Energy Management Centre

Chapter 04 : Powers and functions of Bureau

Chapter 05 : Power of Central Government to enforce efficient use of energy and its conservation

Chapter 06 : Power of State Government to enforce certain provisions for efficient use of energy and its conservation

Chapter 07 : Grants and loans by Central Government

Chapter 08 : Penalty

Chapter 09 : Establishment of Appellate Tribunal

Chapter 10 : Power of Central Government to issue directions to Bureau

- The Act empowers the Central Government and, in some instances, State Governments to :
- Specify energy consumption standards for notified equipment and appliances;
- Direct mandatory display of label on notified equipment and appliances;
- Prohibit manufacture, sale, purchase and import of notified equipment and appliances not conforming to energy consumption standards;
- Notify energy intensive industries, other establishments, and commercial buildings as designated consumers;
- Establish and prescribe energy consumption norms and standards for designated consumers;
- Prescribe energy conservation building codes for efficient use of energy and its conservation in new commercial buildings having a connected load of 500 kW or a contract demand of 600 kVA and above;
- Direct designated consumers to :
  - Designate or appoint certified energy manager in charge of activities for efficient use of energy and its conservation;
  - Get an energy audit conducted by an accredited energy auditor in the specified manner and interval of time;
  - Furnish information with regard to energy consumed and action taken on the recommendation of the accredited energy auditor to the designed agency;
  - Comply with energy consumption norms and standards;
  - Prepare and implement schemes for efficient use of energy and its conservation if the prescribed energy consumption norms and standards are not fulfilled;
- Get energy audit of the building conducted by an accredited energy auditor in this specified manner and intervals of time;

State Governments may :

- Amend the energy conservation building codes prepared by the Central Government to suit regional and local climatic conditions;
- Direct every owners or occupier of a new commercial building or building complex being a designated consumer to comply with the provisions of energy conservation building codes;
- Direct, if considered necessary for efficient use of energy and its conservation, any designated consumer to get energy audit conducted by an accredited energy auditor in such manner and at such intervals of time as may be specified.

Important Points

- Energy Resources is a natural resource that can be converted by humans into forms of energy n order to do useful work.
- Non-renewable Resources of Energy are energy resources that cannot be replaced after they have been used or need thousands to millions of years to be replaced.
- Renewable Resources of Energy are energy resources that can be used and replaced in nature in a short period of time.
- Energy efficiency is using technology that requires less energy to perform the same function. Using a light-emitting diode (LED) light bulb or a compact fluorescent light (CFL) bulb that requires less energy than an incandescent light bulb to produce the same amount of light is an example of energy efficiency.

- Energy conservation is any behaviour that results in the use of less energy. Turning the lights off when leaving the room and recycling aluminum cans are both ways of conserving energy.
- NPC teams up with its clients to work out solutions towards accelerating productivity, enhancing competitiveness, increasing profits, augmenting safety and reliability and ensuring better quality.
- The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India for all matters relating to new and renewable energy. The broad aim of the Ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of the country.
- The mission of the Bureau of Energy Efficiency is to assist in developing policies and strategies with a thrust on self-regulation and market principles, within the overall framework of the Energy Conservation Act, 2001 with the primary objective of reducing energy intensity of the Indian economy.
- MEDA provides assistance to state and central govt to promote and develop new and renewable sources of energy and technologies and to promote and implement energy conservation.

Practice Questions

1. Define Energy, Non-renewable Resources of Energy and Renewable Resources of Energy.
2. Describe four distinct areas in which renewable energy replaces conventional.
3. Describe solar energy as renewable resources of energy.
4. State the Principle of flat plate collector.
5. Explain the Working of flat plate collector.
6. Explain the Principle and working of Photovoltaic cell.
7. Explain Wind Energy as renewable resources of energy.
8. Explain the principle of wind energy.
9. Explain tidal power generation.
10. Explain wave power generation.
11. What is Oscillating Float System?
12. What is Oscillating Paddle System?
13. What is Oscillating Snake System?
14. What is Oscillating Water Column?
15. What is Pressure Transducer System?
16. What is Wave Capture Systems?
17. Explain Overtopping Wave Systems and lever system.
18. Explain OTEC.
19. Explain the principle of Hydro Energy.
20. Explain power generation from Dams.
21. What is "Run of River" Power?
22. Explain the position of Biomass Energy in India
23. Explain the use of Biomass as Transportation fuels
24. List the major nonrenewable energy sources.

25. Describe coal as nonrenewable energy sources.
26. Describe petroleum as nonrenewable energy sources.
27. Describe natural gas as nonrenewable energy sources.
28. Describe uranium as nonrenewable energy sources.
29. Describe Bio-fuels as nonrenewable energy sources.
30. Describe fuel cells as nonrenewable energy sources.
31. Describe hydrogen as nonrenewable energy sources.
32. List the sources of sugars to produce ethanol.
33. What is Biodiesel?
34. Differentiate between Energy efficiency and Energy conservation.
35. Define energy conservation and its specific objectives.
36. Describe the present scenario of energy conservation in India.
37. Explain the need for energy conservation.
38. Explain LEED India rating system.
39. Explain Energy Efficiency rating system by BEE.
40. State the functions of NPC for for Energy Conservation and Audit (ECA).
41. Explain the functions of MEDA for Energy Conservation and Audit (ECA).
42. Explain the functions of Ministry of New and Renewable Energy (MNRE) for Energy Conservation and Audit (ECA).
43. Explain the functions of Bureau of Energy Efficiency (BEE) for Energy Conservation and Audit (ECA).
44. State salient features of the Energy Conservation Act 2001.

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UNIT-III

Chapter 4

GREEN BUILDING

Weightage 14 Hours, 16 Marks

Syllabus

4.1 **Introduction :** Definition of green building, benefits of green buldings.

4.2 **Principles :** Principles of green building – planning concept of green building,.

4.3 **Features :** Salient features of green building environmental design (ED) strategies for building construction.

4.4 **Process :** Improvement in environmental quality in civil structure.

4.5 **Materials :** Green building materials and products – Bomboo, rice husk ash concrete, plastic bricks, bagasse particle board, insulated concrete forms. Reuse of water material – plastic, rubber, newspaper wood, non-toxic paint, green roofing.

Learning Objectives

This chapter will enable students to

(4a) Identify the components of the given green building.

(4b) Explain the principles of green building used in given building.

(4c) Improve the quality of environment in the given civil structure.

(4d) Suggest the strategies for design of the given building to have green building construction.

(4c) Identify the relevant materials required for the given building to have green building construction.

Green buildings are becoming an integral part of modern India. Over the years, green buildings have taken the front seat in many government initiatives like Smart Cities Mission, Pradhan Mantri Awas Yojana (PMAY) and Atal Mission for Rejuvenation and Urban Transformation (AMRUT). The real estate sector in India has taken note of the benefits of going green and hence many famous green buildings have been built in the country over the last decade.

The built environment has a vast impact on the natural environment, human health, and the economy. By adopting green building strategies, we can maximize both economic and environmental performance. Green construction methods can be integrated into buildings at any stage, from design and construction, to renovation and deconstruction. However, the most significant benefits can be obtained if the design and construction team takes an integrated approach from the earliest stages of a building project.

4.1 Introduction

The buildings in which we live, work, and play protect us from nature's extremes, yet they also affect our health and environment in several ways. As the environmental impact of buildings becomes more obvious, a new field called "green building" is gaining momentum.

Green, or sustainable, building is the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition.

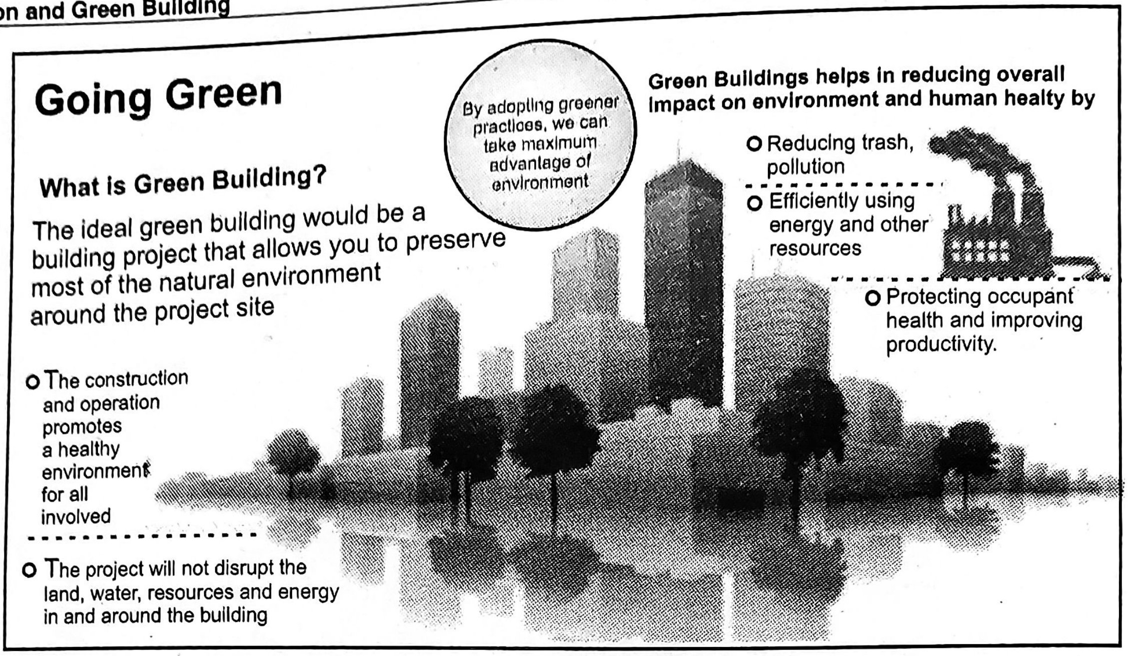


Fig. 4.1

4.1.1 Definition of Green Building

1. A green building is one which uses less water, optimizes energy efficiency, conserves natural resources, generates less waste and provides healthier spaces for occupants, as compared to a conventional building.

2. Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high performance building.

4.1.2 Benefits of Green Building

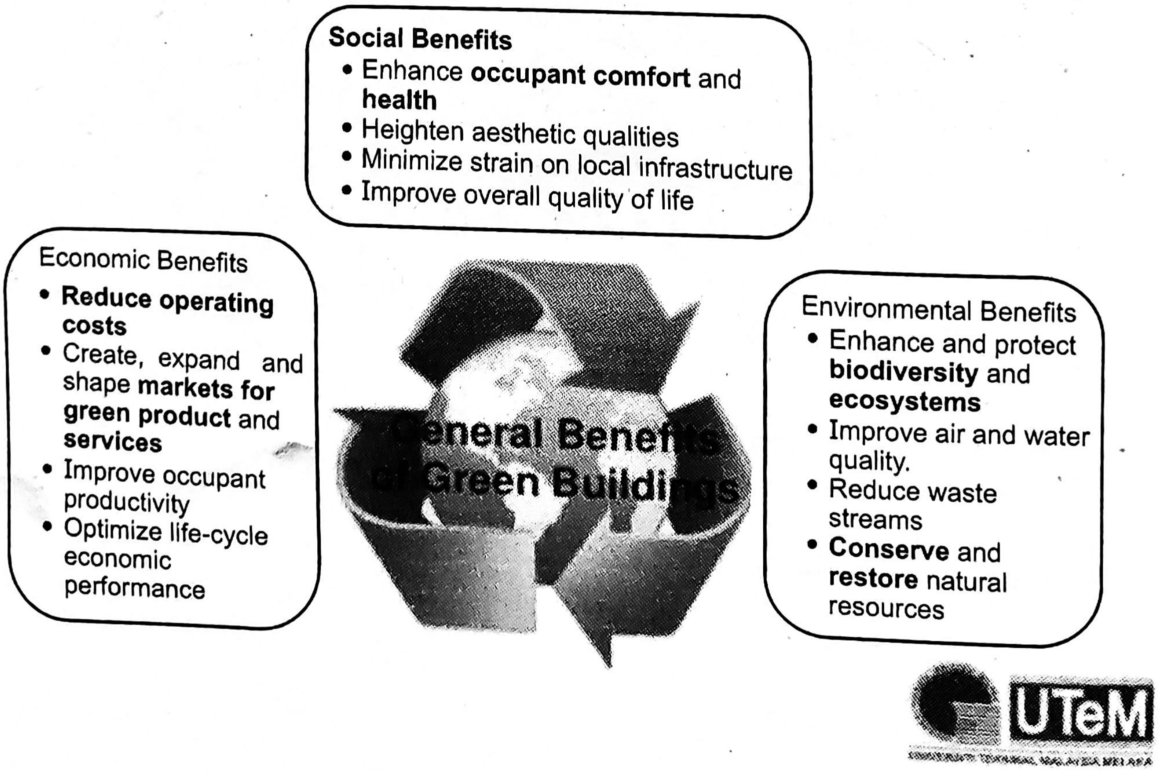


Fig. 4.2

A green building has lower resource consumption as compared to conventional buildings. The following is the percentage reduction of various resources in a building and their respective reasons :

- Green buildings consume 40% to 60% (depending on the range of measures adopted) lesser electricity as compared to conventional buildings. This is primarily because they rely on passive architectural interventions in the building design, and high efficiency materials and technologies in the engineering design of the building.
- Green Buildings also attempt to work towards on-site energy generation through renewable energy utilization to cater to its energy needs. For instance, solar thermal systems can help generate hot-water and replace the conventional electrical geyser in buildings. Solar PV panels can help generate electricity which can reduce the buildings dependence on grid power.
- Green buildings consume 40% to 80% (depending on the range of measures adopted) lesser water as compared to conventional buildings. By utilizing ultra low-flow fixtures, dual plumbing systems, waste-water recycling systems and rain-water harvesting, green buildings not only reduce their demand for water use but also look at on-site supply options to cater to its internal and external (landscape) water demands.
- Green buildings generate lesser waste by employing waste management strategies on site. They may also employ waste to energy or waste to resource (like manure, or compost) strategies on site, to minimize their burden on municipal waste management facilities and land fills.
- Green buildings generate lesser pollution both during construction as well as while in use.
- Through best-practices such as proper storage of construction materials, barricading of the site to prevent air and noise pollution during construction, proper storage and disposal of waste during construction and operation, and so on, ensures reduced impact on the surrounding environment.
- Green buildings ensure proper safety, health and sanitation facilities for the labourers (during construction) and the occupants (while in use).
- Green buildings restrict the use of high ODP (ozone depleting potential) substances in their systems as well as in finishes.
- Green buildings offer higher image and marketability.

The world over, evidence is growing that green buildings bring multiple benefits. They provide some of the most effective means to achieving a range of global goals, such as addressing climate change, creating sustainable and thriving communities, and driving economic growth. The benefits of green buildings can be grouped within three categories : environmental, economic and social. Here is a range of **facts and statistics** that provide evidence of the various benefits :

4.1.2.1 Environmental

One of the most important types of benefit green buildings offer is to our climate and the natural environment. Green buildings can not only reduce or eliminate negative impacts on the environment, by using less water, energy or natural resources, but they can - in many cases - have a positive impact on the environment (at the building or city scales) by generating their own energy or increasing biodiversity.

At a global level :

- The building sector has the largest potential for significantly reducing greenhouse gas emissions compared to other major emitting sectors.
- This emissions savings potential is said to be as much as 84 gigatonnes of CO_2 ($GtCO_2$) by 2050, through direct measures in buildings such as energy efficiency, fuel switching and the use of renewable energy.
- The building sector has the potential to make energy savings of 50% or more in 2050, in support of limiting global temperature rises to 2°C (above pre-industrial levels).

At a building level :

- Green buildings achieving the Green Star certification in Australia have been shown to produce 62% fewer greenhouse gas emissions than average Australian buildings, and 51% less potable water than if they had been built to meet minimum industry requirements.

- Green buildings certified by the Indian Green Building Council (IGBC) results in energy savings of 40 - 50% and water savings of 20 - 30% compared to conventional buildings in India.
- Green buildings achieving the Green Star certification in South Africa have been shown to save on average between 30 - 40% energy and carbon emissions every year, and between 20 - 30% potable water every year, when compared to the industry norm.
- Green buildings achieving the LEED certification in the US and other countries have been shown to consume 25 per cent less energy and 11 per cent less water, than non-green buildings.

4.1.2.2 Economic

Green buildings offer a number of economic or financial benefits, which are relevant to a range of different people or groups of people. These include cost savings on utility bills for households (through energy and water efficiency); lower construction costs and higher property value for building developers; increased occupancy rates or operating costs for building owners; and job creation

At a global level :

- Global energy efficiency measures could save an estimated €280 to €410 billion in savings on energy spending (and the equivalent to almost double the annual electricity consumption of the United States) - European Commission, 2015.

At a country level :

- Canada's green building industry generated $23.45 billion in GDP and represented nearly 300,000 full-time jobs in 2014 – Canada Green Building Council / The Delphi Group, 2016.
- Green building is projected to account for more than 3.3 million U.S. jobs by 2018 – US Green Building Council / Booz Allen Hamilton, 2015.

At a building level :

- Building owners report that green buildings - whether new or renovated - command a 7 per cent increase in asset value over traditional buildings – Dodge Data and Analytics, 2016.

4.1.2.3 Social

Green building benefits go beyond economics and the environment, and have been shown to bring positive social impacts too. Many of these benefits are around the health and wellbeing of people who work in green offices or live in green homes.

- Workers in green, well-ventilated offices record a 101 per cent increase in cognitive scores (brain function) - Harvard T.H. Chan School of Public Health/Syracuse University Center of Excellence/SUNY Upstate Medical School, 2015.
- Employees in offices with windows slept an average of 46 minutes more per night - American Academy of Sleep Medicine, 2013.
- Research suggests that better indoor air quality (low concentrations of CO_2 and pollutants, and high ventilation rates) can lead to improvements in performance of up to 8 per cent–Park and Yoon, 2011.

4.2 Principles : Principles of Green Building - Planning concept of Green Building and Related Strategies

The energy demands vary over different stages of the construction. The energy consumed by a building throughout the construction phase and later in its life depends on multiple factors. The five principles of green building practices have been established that cover the life cycle performance of green buildings. For integrated and comprehensive approach, the principles encompass each of the green building phases/stages, including construction, operation, maintenance, and decommissioning. Due to the high energy demand, it is challenging for architects, civil engineers and builders to design environment-friendly and resource-efficient buildings. These challenges, however, can be met by adopting green building practices. The five principles, on which the green building design depends, are as follows :

1. Sustainable Siting

This principle optimizes land use and development to reduce adverse impacts and minimize the building's ecological footprint. A conscious effort is made by architects and planners to keep the urban area to minimum. Open space, green habitat, and other valuable parts of the land are used creatively to add more beauty and functionality to the entire construction site. Instead of going for sprawl, urban planners and architects focus on developing the land more compactly as compact constructions or high density urban planning leaves room for more walk-able, bike and transit friendly cities. The key environmental assets inside or in proximity to the construction site are persevered carefully. This principle may include one/more/all the activities/strategies for the sustainable site design for a green building as follows :

(A) Protect or enhance site's ecological integrity and biodiversity :

- *Minimize the development footprint* : This includes parking, building, roads. Cluster/group buildings together.
- *Locate building to preserve the site's natural areas* : Do an inventory of the site's ecology. If there are concerns, send in a map of the site to an expert to have it assessed for rare or endangered species. Avoid making major changes to sensitive landscapes, wildlife habitat, or topography.
- *Re-establish* : damaged native ecosystems. Plant native species and take out ecologically harmful non-native or invasive species. Plant native species along streams to act as buffers. Use landscaping to control erosion.
- *Preserve, establish, or re-establish* : native biodiversity (diversity of native plant and animal species). During construction, salvage native plants to be replanted on the site or elsewhere.
- *Preserve, establish, or re-establish* : wildlife habitat by providing shade, shelter, food and water to sustain the desired wildlife.
- *Make connections* : between the natural ecology of the site and natural systems both within and beyond the site.
- *Build support for urban greenways* : that can be used by wildlife, pedestrians, cyclists, and others. This can be done by working with the relevant local or regional government agencies to help you establish, connect with or further develop a greenway.

(B) Reduce or eliminate disturbance to water system :

- *Minimize storm water run-off* : Increase site infiltration where soil conditions allow by maintaining the natural pervious landscape or designing a pervious landscape. Use pervious surfaces for as much as possible of the surfaces that are usually paved (For example : roads, parking, courtyards and pathways), where soil conditions permit.
- *Use organic storm water management features* : like vegetative swales, filter strips, vegetative buffers, infiltration basins, or drywells instead of subsurface storm drains to treat storm water run-off from fields, roofs and roads, where soil conditions permit.
- *Celebrate these natural water management techniques* : by making them into attractive landscape elements.
- *Install oil/water separators* : to treat run-off from parking lots (do not use them for run-off from fields or roofs). On impervious areas that do exist, capture rainwater for site or building use.
- *Design roads and parking lots* : without curbs or with curb cuts or openings that drain to storm water treatment and infiltration measures.

(C) Prevent or reduce the use of potable water for irrigation :

- *Harvest rainwater* : or use recycled storm water, or site treated grey or waste water for irrigation.
- *Use water-efficient plants* : These are often native species, or species that have adapted.
- *Use water-efficient irrigation* : including micro irrigation, moisture sensors and weather data based controllers.

(D) Reduce urban heat islands :

- *Maximize green space :* through use of native gardens, trellises, roof gardens etc.
- *Maximize pervious surfaces :* for parking areas, paths, courtyards etc.
- *Use light coloured, high-albedo materials :* for all non-pervious surfaces. Drawings and specifications must record expected albedo requirements.
- *Provide shade :* on impervious surfaces where high-albedo materials cannot be used.

(E) Design infrastructure to support alternative transportation :

- *Locate building :* to have access to public transit, bike routes, and pedestrian routes.
- *Encourage :* walking and bicycling by designing attractive, safe pedestrian and cycling infrastructure. These features can be centrally located and grouped with landscape features. Site features such as walking and cycling paths, public squares, and outdoor seating can be located to optimise the solar access and access to attractive landscape features. Internal infrastructure can also be important to encourage walking and cycling. Central, attractive staircases can encourage the use of stairs over elevators.
- *Maximize bicycle :* parking spaces and minimize carparking spaces. Internal covered bike parking may be appropriate in some cases, and can be designed to be an attractive feature of the building. At other times, external bike parking, or a combination of both, will be more appropriate. Whether inside or out, bike parking can be made more desirable by being covered from the rain and located centrally.
- *Build :* changing facilities and showers for cyclists and joggers.
- *Give :* preferred parking to carpool cars.

2. Energy Efficiency

This principle/technique focuses on the establishment of performance targets that account for intended use, occupancy and other energy operations for new construction and renovation projects. By adopting advanced energy conservation measures, we can reduce our reliance on over-consuming energy and creating energy for our everyday needs from low energy sources. This principle may include one/more/all the activities/strategies with regard to energy efficiency for a green building as follows :

(A) Use site resources to reduce building loads and enhance indoor environmental quality :

- *Use existing and proposed trees and plantings* to reduce heating, cooling and lighting loads. Plantings can reduce summer solar gain, channel summer breezes, and block winter winds, while still allowing daylighting. Deciduous trees, for example, let winter sun through while shading summer sun, and therefore are useful. Evergreen trees are particularly useful for blocking winter wind.
- *Orient the building to optimize prevailing winds and solar opportunities.* Prevailing winds should be used to create appropriate air pressures in the building if natural ventilation is being used. However thermal loses due to infiltration of prevailing winds should be minimized. The building should be sited and oriented to optimize the site's solar resources. Winter solar gain and summer shading are often important, but sun studies and energy computer simulations will need to be done to develop strategies appropriate for each building and site.
- *Use existing and proposed topography to create thermal mass around the building.* Earth berms and other topographical features can be used to enhance the building's energy performance.
- *Assess the feasibility of using on-site renewable or alternate energy.* Consider geothermal or ground source energy, co-generation, passive and active solar energy, passive and active wind energy, and other energy sources.

(B) Configure internal layout to reduce loads and enhance energy efficiency :

- *Reduce heating, cooling, lighting and ventilation loads through careful placing of internal uses.* This can be done in a number of ways.
- *Locate internal spaces to optimize natural ventilation, daylighting, and site resources* like trees or topography for shading. Create operable windows where air quality is good and where prevailing winds will create desired internal pressures. Locate highly occupied spaces close to exterior windows.

- *Uses that do not need windows can be located on the side.* Locating gyms, theatres or other uses that do not require windows on such face which usually has the least potential for daylighting and passive solar gain. In addition, such exterior wall has the greatest heat loss from any windows located there, so avoiding this is beneficial to the overall energy performance of the building. The energy simulation should act as a check of whether this is the appropriate strategy for your building.
- *Create zones :* Spaces with similar functions should be grouped together so that heating and cooling demands can be combined into HVAC zones. The building's orientation and relationship to the outdoors should be taken into consideration when selecting zones.
- *Use circulation areas as buffers :* public areas and circulation areas can be design to experience wider temperature ranges, because they are occupied less, and are occupied when people are moving.
- *Be as space efficient as possible.* Building less space means using fewer materials and maintaining and operating less space over time

(C) Design and select all building systems to meet energy targets

- *Conduct an energy simulation* The energy simulation provides the energy and cost information required to make the "best" selection of building systems. The "best" selection will be the one that provides the lowest life-cycle cost within approved cost budget. This is the most iterative phase of the overall design process. The goal is to investigate energy and cost savings resulting from the synergies between the various building systems and their components.
- Once energy loads are optimized through the selection of the best combination of structural, envelope, ventilation, water, and lighting systems, the design team will select the most appropriate mechanical system to meet this load. This process will generally lead to the selection of a smaller mechanical system than would normally be the case.

(D) Design envelope to reduce heating, cooling, lighting, and ventilation loads

- *Design an energy efficient envelope :* appropriate insulation, tight construction and high-performance, low-e windows.
- *Avoid thermal bridges in walls* (use continuous insulation, or eliminate metal studs in outside walls, or otherwise ensure thermal break).
- *Optimize solar heat gain and reduce glare.* The design options include : selecting glazing with appropriate ratio of visible light transmittance to solar heat gain coefficient; using trees and plantings to reduce summer solar gain; and ensuring windows have appropriate exterior shading.
- *Locate and size fenestration* to capture the wind and fresh air available on site. This can reduce the need to mechanically heat, cool, and move air.

(E) Use passive and active renewable energy

- *Design building for solar heat and light.* Optimize solar gains to offset heating and lighting needs.
- *Control solar heat gain and glare.* This can be done by selecting glazing with appropriate ratio of visible light transmittance to solar heat gain coefficient, and by ensuring windows have appropriate exterior and/or interior shading. Shading devices range from trees to solar electric (PV) panels (that double as shading devices) to blinds. Deciduous trees can provide excellent sunshading, allowing light through in the winter and blocking unwanted lighting the summer.
- *Design building to incorporate the site's wind and air resources.* Plan air openings where air is cleanest. Design with the wind speeds and directions in mind to optimize natural ventilation if feasible.
- *Assess the feasibility of incorporating renewable* energy into the envelope, using : passive solar technologies like solar-wall, or/and active solar technologies like photovoltaic panels

3. Water Efficiency

This principle emphasizes the value of decreasing demands for fresh water and reducing the generation of waste water through optimized landscaping, integrated rainwater catchments, gray water recycling, and wastewater treatment systems. Water conservation is an integral part of every sustainable construction. Popular water-saving ideas like collecting rain-water, reusing indoor wash water and other methods to ensure on-site supply of water are increasingly becoming popular.

Many residential and commercial buildings also focus on methods to recharge ground water, recycle and reuse water. The sanitary fixtures in the apartments should be designed to minimize water consumption. It is also critical to treat and reuse the sewage on-site. Some of the most energy-efficient buildings in the world excel in waste management by segregating organic and recyclable wastes. This minimizes the burden on landfills and makes the environment cleaner and greener.

(A) Reduce or prevent the use of potable water to treat human waste

- *Install water-efficient toilet fixtures.* This could include :
  - Water closets with a maximum of 6 litres per flush.
  - Wastewater piping with a generous pitch to account for smaller water flows.
  - Waterless urinals or urinals with a maximum of 3.6 litres per flush (use individual-flush urinals).
- *Install alternative wastewater technologies.* Often these options allow the water to be treated on site to tertiary standards. This also meets the Site Design and Planning goal of reducing or eliminating disturbance to the natural water system, as it returns water to the ground in as good as or better condition than the water would have otherwise been treated.

  Options include :
  - constructed wetlands
  - composting toilets
  - biological waste water technologies
  - aerobic treatment.

  Grey water and black water systems can treat water to be reused for toilet flushing and irrigation. Once treated, the water can recharge groundwater if conditions are appropriate.

(B) Select water efficient fixtures

Install the following where appropriate :

- Lavatory and kitchen faucets with max 9.5 litres per minute.
- Public lavatory faucets with 2 litres per minute or less.
- Self-closing, time-activated (5 second shut-off) or motion detecting public faucets.
- Showers with a maximum of 9.5 litres per minute
- Public showers self-closing time-activated (1 minute shut off).
- Dishwashers with a maximum of 27 litres on normal cycle (for non-industrial use).
- Clothes washers that are energy and water efficient (for example, horizontal axis)
- HVAC water that is made-up of recycled or storm water.

(C) Monitor water use

- *Install water meters* to allow measurement of potable water consumption.

(D) Reduce or eliminate disturbance to water system

- *Minimize storm water run-off.* Increase site infiltration where soil conditions allow by maintaining the natural pervious landscape or designing a pervious landscape. Use pervious surfaces (ones which allow water to penetrate) for as much as possible of the surfaces that are usually paved (for example : roads, parking, courtyards and pathways), where soil conditions permit.
- *Use organic stormwater management* features like vegetative swales, filter strips, vegetative buffers, infiltration basins, or drywells instead of subsurface storm drains to treat stormwater run-off from fields, roofs and roads, where soil conditions permit.
- *Celebrate these natural water management techniques* by making them into attractive landscape elements.
- *Install oil/water separators* to treat run-off from parking lots (do not use them for run-off from fields or roofs). On impervious areas that do exist, capture rainwater for site or building use.
- *Design roads and parking lots without curbs* or with curb cuts or openings that drain to stormwater treatment and infiltration measures.

4. Sustainable Construction Materials

By using sustainable construction materials and resources, green building materials have aided the reduction of extraction, processing, transportation, solid waste, and consumption. The choice of construction material is important in safeguarding the health of the occupants and to make the building safe and sturdy. The focus should be on using quality products that meet the highest standards of safety and health. Many buildings utilize recycled engineered materials and recycled construction debris to create marvelous structures, thereby minimizing the environmental impacts.

- Facilitate segregation of waste at source to encourage reuse or recycling of materials, thereby avoiding waste being sent to landfills.
- Encourage the use of building materials to reduce dependence on materials that have associated negative environmental impacts.
- Ensure effective organic waste management, so as to avoid domestic waste being sent to landfills and to improve sanitation and health.
- Ensure use of salvaged, recycled and efficient materials as much as possible. The GVRD's Directory of Resource and Efficient Building Products can be used to find appropriate materials. See the glossary for definitions and standard examples of these materials.
- Use local materials. Avoid the environmental and economic costs of transportation by specifying local materials, products, services and systems as much as possible.
- Use rapidly renewable materials.
- Use minimally processed products. Use materials that have not been highly processed, as they will have less embodied energy, and there will be little risk of chemical emissions from the manufacturing process. Examples include natural stone and slate shingles, wood products and plant products (agricultural or non-agricultural).
- Use low-emissions products. This includes zero- and low-VOC paints, caulks, and adhesives. It also includes other reduced-emissions materials or products, like non-formaldehyde manufactured wood. Specify alternatives to ozone-depleting substances. Many building materials still utilize HCFCs, including rigid and blown foam insulations, some carpet pad and compression-cycle HVAC equipment. Alternatives should be specified.
- Use alternatives to PVC, polycarbonates, and other hazardous components. There are many alternatives available to vinyl, PVC cabling and PVC pipes. Other alternatives to hazardous materials include low mercury fluorescent lamps and chromium-free solar collectors.
- Use durable and low maintenance materials and products. These include products such as fibre glass windows, fibre cement siding, slate shingles, and vitrified clay waste pipe.

5. Healthy Indoor Environmental Quality

Healthy indoor environment is critical to good health and well-being of residents. To maintain a healthy atmosphere, efforts should be taken to improve the indoor air quality and ventilation. Instead of depending on artificial lighting, maximum utilisation of daylight should be done. This principle includes the processes that have enhanced the sustainable communities through ventilation and thermal comfort, moisture control, daylighting, environmental tobacco smoke control, and protecting indoor air quality during construction.

(A) Optimize indoor environmental quality

- *Optimize daylighting and views.* Design the envelope to bring in daylight and views to as much of the inhabited floor area as possible.
- *Design the envelope to provide adequate fresh air.* In addition, users should be provided with as much comfort and control as possible.

(B) Provide adequate fresh air

- *Separate air intakes from pollution.* Trees, waterways, forested areas, fields and other planting options can improve outside air quality. The intake must be far enough away to eliminate exposure to contaminated air.

- *Use carbon dioxide sensors* to monitor ventilation rates and to provide ongoing information concerning air quality.
- *With the help of building users and owner, reduce pollution sources.* For pollution generating sources that cannot be eliminated from the building, create isolated zones that are separately ventilated.
- *Ensure that indoor air is free of pollution.*

(C) Provide users comfort and control

- *Provide individual controls for ventilation.* Operable windows, in addition to individual controls for airflow, encourage users to turn-off ventilation when needed, and also allow a high level of comfort and control. Individual controls should therefore be provided where feasible.

(D) Reduce ventilation loads

- *Select an efficient mechanical or natural ventilation system.* Buildings with access to clean air and a quiet outdoor environment may benefit from use of natural ventilation systems at least in swing seasons.
- *Assess the potential for heat recovery systems.* Heat can be recovered from both sensible and latent heat.
- *Consider using zones* to group areas with similar occupancies and ventilation needs.
- *Weigh the benefits of VAV* (variable air volume) air distribution systems. When there is reduced demand, reduce the system load.

(E) Design envelope to reduce heating, cooling, lighting, and ventilation loads

- *Design an energy efficient envelope* : appropriate insulation, tight construction and high-performance, low-e windows.
- *Avoid thermal bridges in walls* (use continuous insulation, or eliminate metal studs in outside walls, or otherwise ensure thermal break).
- *Optimize solar heat gain and reduce glare.* The design options include : selecting glazing with appropriate ratio of visible light transmittance to solar heat gain coefficient; using trees and plantings to reduce summer solar gain; and ensuring windows have appropriate exterior shading.
- *Locate and size fenestration* to capture the wind and fresh air available on site. This can reduce the need to mechanically heat, cool, and move air.

(F) Minimize exposure of non-smokers to the adverse health impacts arising due to passive smoking in the building

4.3 Features

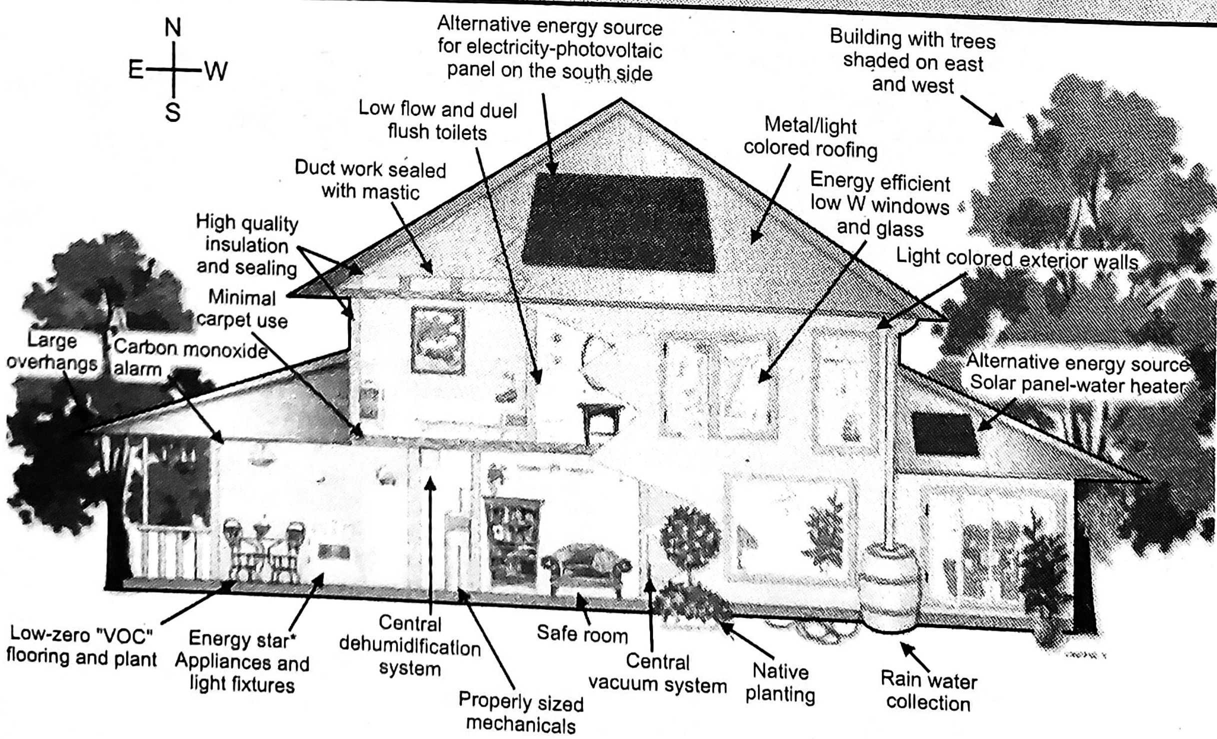


Fig. 4.3

4.3.1 Salient Features of Green Building

- Green Building can Design, Build and Operate a Building that Delivers High Performance Inside and outside.
- Building annually consumes more than 20% of electricity used in India.
- Green Building practices can substantially reduce or eliminate negative environmental impacts and can improve existing unsustainable design, construction and operational practices.
- Green Building reduces Operational costs, enhances Building marketability, Increase worker productivity, Improves Indoor Environment Quality, and Reduces potential liability resulting from Indoor Air Quality problems.
- People Friendly GREEN Building design gains productivity by 16%, Reduction in Absenteeism and improved work quality, which benefits building stakeholders, including owner, occupants and general public.
- In development circles, Green has gone from a boutique idea to a mandatory part of the Architecture and Construction.
- Almost all Construction waste is recycled or reused.
- Green Buildings consumes about 25% less energy than conventional buildings.
- In Green Buildings Interiors are done with low V.O.C. content materials, adhesives, sealants, paints and carpets, which reduces allergies and illness.

Typical Features of Green Building

1. Sustainable Development

- Site Development - Protect and Restore habitat - Maximize Open space.
- Heat Island Effect - Roof and Non-Roof.
- Basic Amenities.
- Parking.
- Transportation and Alternate Transportation.
- Design for Differently Able.
- Storm water design - Quality and Quantity control.
- Development Density and Community Connectivity.
- Light Pollution Reduction.
- Green Home Guidelines - Design and Post occupancy.

2. Water Efficiency

- Water Efficient Landscape.
- Innovative waste water technologies.
- Gray water treatment.
- Use of treated Gray water.
- Water Use reduction.
- Ground water recharge.
- Roof rain water recharge/harvesting.
- Rain water harvesting.
- Water efficient fixtures.

3. Energy Efficiency

- Passive Cooling System.
- Passive ventilation System.
- Energy in Building Construction.
- Advanced Windows and Energy Savings.

- Fundamental Building System Commissioning.
- Enhanced Building System Commissioning.
- Minimum Energy Performance.
- Optimize Energy Performance.
- Active Energy Efficiency.
- CFC reduction in HVAC Equipment.
- Fundamental Refrigerant Management.
- Enhanced Fundamental Refrigerant Management.
- Building Energy simulation.
- Building Envelope Design.
- On-site Renewable Energy.
- Hybrid Energy.
- Building Integrated renewable Energy technologies.
- Measurement and Verification.
- Building Automation and Control.
- Green Power.

4. Materials and Resources

- Storage and Collection of Recyclables.
- Building Reuse.
- Construction Waste management.
- Material Use.
- Regional Material.
- Rapidly renewable Materials.
- Certified Wood.

5. Indoor Environmental Quality

- Minimum Indoor Air Quality Performance.
- Outdoor Air Delivery Monitoring.
- Increased Ventilation.
- Low Emitting Building Materials.
- Control ability of Systems – Light and Thermal Comfort.
- Thermal Comfort Design and Verification.
- Daylight and Views – Daylight.
- Daylight and Views – Views.

6. Innovation in Design Process

- Vastu Principles.
- Bio dynamic Farming.
- Three tier Cooling System.
- Three grade Cooling System.
- A pert of building to be Net Zero.

- Zero Discharge.
- Geo Thermal Cooling.
- Wind Towers.
- Bio-fence.
- Thermal fence.
- Green Walls.
- Hydroponics.

7. **Regional Priority**
   - Energy Conservation.
   - Water Conservation.
   - Disaster Management Plan.
   - Meditation Room.
   - Environmental Tobacco Smoke Control.

4.3.2 Environmental Design (ED) Strategies for Building Construction

- Site Selection and Design.
- Architectural Design for Sustainability.
- Indoor Environmental Quality.
- Building Energy Use - Mechanical Systems.
- Building Lighting, Equipment, Energy Management and Utilities.
- Water Management.
- Materials and Resources.
- Construction.
- Commissioning.

4.4 Process : Improvement in Environmental Quality in Civil Structure

Indoor environmental quality and occupant comfort can be achieved with improved air quality. Occupants typically experience a greater sense of well-being if they have greater control over their immediate environment as well as access to windows that provide daylight and a visual connection to the outdoors.

4.4.1 Air Quality

Reduce air quality problems at the source.

- Reduce potential water problems. Design surface grades, drainage systems and HVAC condensate collection systems to prevent accumulation of water under, in or near buildings.
- Control unwanted moisture. Prevent condensation of water vapour inside the building envelope by proper use of air retarders, vapour retarders, proper location and amount of thermal insulation; control of indoor-to outdoor pressure differences; and control of moisture-generating activities at the source.
- Specify non-offgassing materials. Specify construction materials with low volatile organic compounds and low odor emissions.
- Isolate exhaust and plumbing systems in rooms with contaminants.
- Install permanent architectural entryway systems such as grills or grates to prevent occupant-borne contaminants from entering the building.

- Segregate chemical use areas. Where chemical use occurs (including housekeeping areas, laboratories, art rooms, floor cleaning machine recharging area and copying/printing rooms), provide segregated areas and separate outside exhaust. Provide heat recovery or other efficiency strategy where cost-effective.
- Design the building to maximize views for students, faculty, staff and other personnel through direct line-of-sight-to-perimeter glazing in all regularly occupied spaces. Such views are important to physiological as well as psychological well-being.
- Consider interior material color and reflectance. Choose light-colored flooring (a trade-off, as it requires greater cleaning and maintenance) to enhance lighting levels. Ceilings should be white for high reflectance. Walls adjacent to windows should be light in color. Avoid saturated colors except as accents or special effects in corridors.
- Provide lamps with high color rendering index.
- Use photometric analysis for lighting design of all significant spaces.

4.4.2 Control of Building Systems

Provide a high level of control for thermal comfort, lighting and ventilation systems.

- Where possible, provide temperature and lighting controls for each occupied space to manage comfort variation according to orientation and other factors as well as occupant preferences.
- Provide interlock controls with HVAC to turn-off heating and cooling when windows are open.
- Consider workstation-based ventilation (fan) and heat (radiant panel) controls.

4.4.3 Acoustic Quality

Control noise.

- Reduce exterior noise (traffic, other loud noise) through appropriate building orientation, landscaping, insulation or other means of attenuating sound.
- Isolate equipment. Locate noisy mechanical equipment and functions (for example, shops, music rooms) away from noise-sensitive spaces.
- Use offset studs and deck-to-deck partitions around noisy functions, incorporating sound-attenuating insulation, floating floor slabs and sound absorbent ceiling systems as appropriate.
- Use internal insulation or sound attenuators for sound control on ducts. Do not use internal lining to prevent airborne fibers and IAQ problems.
- Select appropriate surfaces (ceilings, floors, walls) to achieve good classroom acoustics for resonance and reverberation time between.
- Abate corridor noise through use of resilient floor surfaces, ceiling tiles and other interior surface materials that minimize noise.

4.5 Materials : Green Building Materials and Products

In building, environmentally-friendly materials (also known as green building materials) are those in which, for their production, placing and maintenance, actions of low environmental impact have been performed.

The aim of using green building materials is to construct energy-efficient structures and to build those structures one should be aware of different green building materials, their properties and how they contribute into saving energy.

4.5.1 Bamboo

- Bamboo is one of the most used multipurpose and durable materials used in construction.
- These trees grow faster irrespective of climatic conditions. So, it makes it economical as well.
- They can be used to construct frames or supports, walls, floors etc.
- They provide a good appearance to the structures.
- Bamboo as a building material has high compressive strength and low weight has been one of the most used building material as support for concrete, especially in those locations where it is found in abundance.

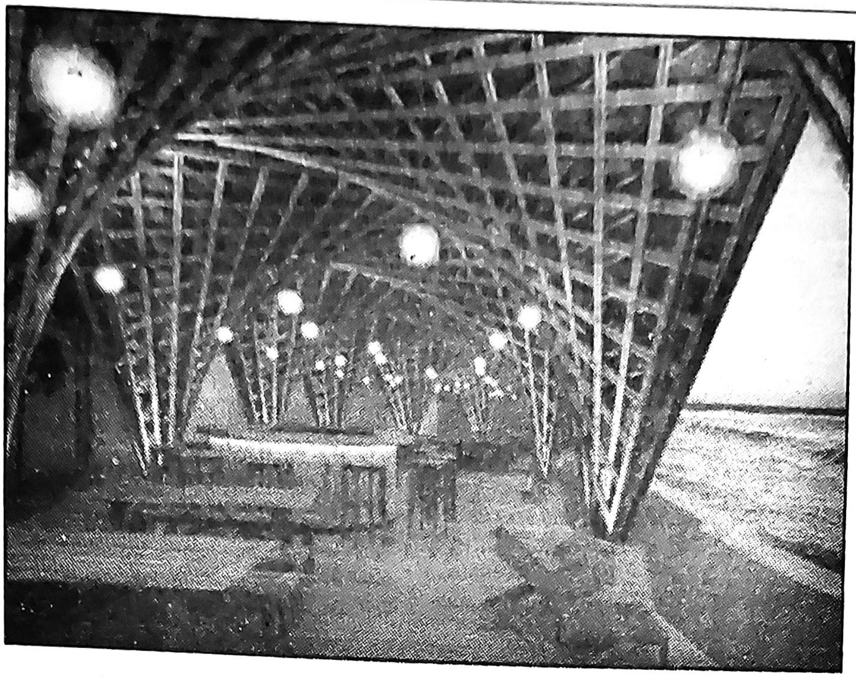


Fig 4.4 : Bamboo Structure

Bamboo as a building material is used for the construction of scaffolding, bridges and structures, houses.

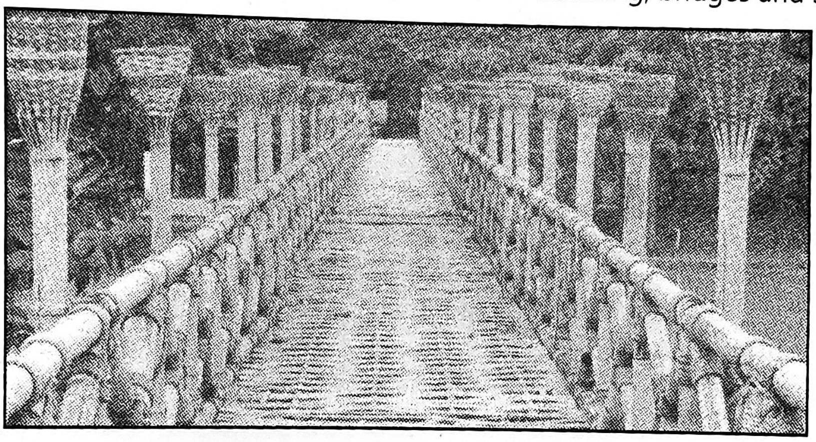


Fig. 4.5

Due to a distinctive rhizome-dependent system, bamboos are one of the fastest-growing plants in the world and their growth is three times faster than most other species of plants. They are renewable and extremely versatile resource with multi-purpose usage. Among many uses of bamboo, Housing is one of the major areas applications especially in the wake of residential shortages around the globe.

Bamboo as a building material is conventionally associated with the region of Southeast Asia and South America where climate is best suitable for its cultivation. In many of the nations, bamboo is used to hold-up suspension bridges or simply make places of dwelling.

4.5.2 Rice Husk Ash Concrete

The rice paddy milling industries give the by-product rice husk. Due to the increasing rate of environmental pollution and the consideration of sustainability factor have made the idea of utilizing rice husk. About 100 million tons of rice paddy manufacture by-products are obtained around the world. They have a very low bulk density of 90 to 150 kg/m^3. This results in a greater value of dry volume.

The rice husk ash has good reactivity when used as a partial substitute for cement. These are prominent in countries where the rice production is abundant. The properly rice husk ashes are found to be active within the cement paste. So, the use and practical application of rice husk ash for concrete manufacturing are important.

The incorporation of rice husk ash in concrete convert it into an eco-friendly supplementary cementitious material. The following properties of the concrete are altered with the addition of rice husk :

- The **heat of hydration** is reduced. This itself help in drying shrinkage and facilitate durability of the concrete mix.
- The reduction in the **permeability of concrete** structure. This will help in penetration of chloride ions, thus avoiding the disintegration of the concrete structure.
- There is a higher increase in the chloride and sulfate attack resistance.

The rice husk ashes in the concrete react with the calcium hydroxide to bring more hydration products. The consumption of calcium hydroxide will enable lesser reactivity of chemicals from the external environment.

Applications of Rice Husk Ash

The rice husk ash is a green supplementary material that has applications in small to large scale. It can be used for waterproofing. It is also used as the admixture to make the concrete resistant against chemical penetration.

The main applications of rice husk ash in the construction are :

- High-performance Concrete.
- Insulator.
- Green concrete.
- Bathroom floors.
- Industrial factory floorings.
- Concreting the foundation.
- Swimming pools.
- Waterproofing and rehabilitation.

4.5.3 Plastic Bricks

Plastic waste is increasing due to increase in population, urbanization and development. The disposal of waste plastic has become a serious problem globally due to their non-biodegradability Annually approximately 500 billion plastic bags are used worldwide. Over one million sea birds and 100,000 marine mammals are killed annually from plastic in our oceans. To overcome these defects we can use the plastic in construction sector as raw materials in different ways. Like by preparing bricks, tiles and can be used for civil engineering projects.

With 15 × 30 cm dimension, the plastic bricks are as strong as normal bricks used in construction. Plastic, irrespective of their quality and density are melted at a certain temperature and other materials such as sand and ash are added to it. Once the mixture then goes into a "crude machinery" (which is basically a compartment customized by the manufacturer), the bricks will be made in 2 hours' time. After its curating time of seven days, the bricks are good to use.

Hence, the technology is very simple. A person has to just heat-up a mixture (up to 110 to 140 degrees) of plastic and fibrous materials in a mould with the chemical and then let it cool for some time. A nice tile or a brick would be ready for use

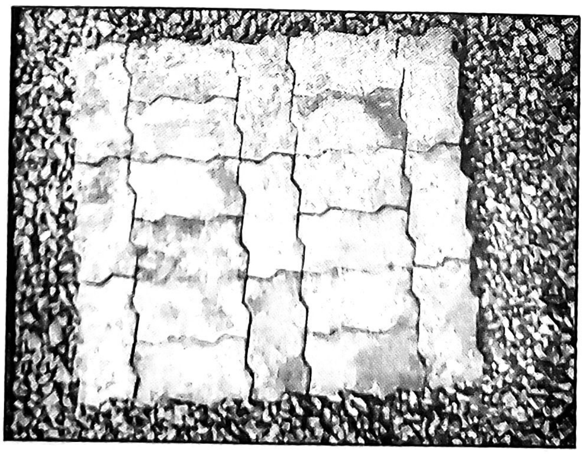


Fig. 4.6

4.5.4 Bagasse Plastic Board

Bagasse is the dry pulpy fibrous residue that remains after sugarcane or sorghum stalks are crushed to extract their juice. It is used as a biofuel for the production of heat, energy, and electricity, and in the manufacture of pulp and building materials. For every 10 tonnes of sugarcane crushed, a sugar factory produces nearly three tonnes of wet bagasse. Since bagasse is a by-product of the cane sugar industry, the quantity of production in each country is in line with the quantity of sugarcane produced.

These boards are used for interior application for the area, which is not exposed to moisture and high humidity. Owing to their homogeneous structure, uniformity and equal strength in all directions, these boards are widely demanded by the users.

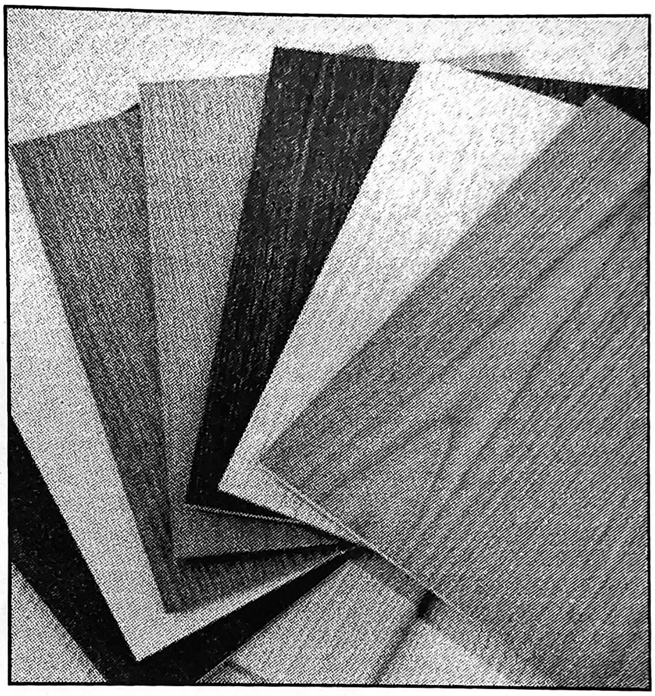


Fig. 4.7

4.5.5 Insulating Concrete Forms (ICFs)

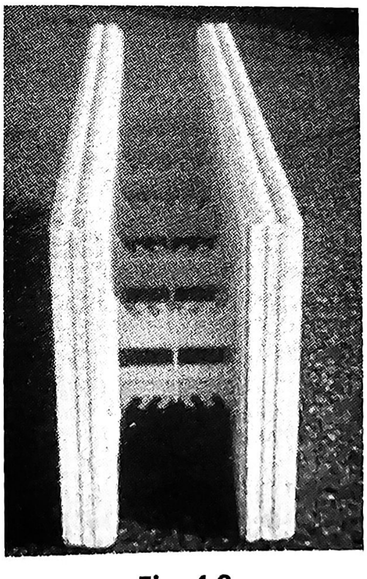


Fig. 4.8

Insulating concrete forms (ICFs) result in cast-in-place concrete walls that are sandwiched between two layers of insulation material. These systems are strong and energy efficient. Common applications for this method of construction are low-rise buildings, with property uses ranging from residential to commercial to industrial. Traditional finishes are applied to interior and exterior faces, so the buildings look similar to typical construction, although the walls are usually thicker.

Insulating concrete forms provide following benefits :

- strong walls
- disaster resistance and safety
- mold, rot, mildew, and insect resistance (below grade can require termite protection)
- sound-blocking ability
- overall comfort
- energy efficiency and resultant cost savings
- fast, easy construction
- flexibility
- light weight for easy shipping and erection
- compatibility with carpenter trades

4.5.6 Reuse of Waste Material

4.5.6.1 Plastic Rubber

Plastic Rubber or Thermoplastic elastomers (TPE), sometimes referred to as thermoplastic rubbers, are a class of copolymers or a physical mix of polymers (usually a plastic and a rubber) that consist of materials with both thermoplastic and elastomeric properties.

Plastic rubber has the potential to be recyclable since they can be molded, extruded and reused like plastics, but they have typical elastic properties of rubbers which are not recyclable owing to their thermosetting characteristics. Depending on the environment, these have outstanding thermal properties and material stability when exposed to a broad range of temperatures and non-polar materials. These consume less energy to produce, can be coloured easily by most dyes, and allow economical quality control.

Plastic rubber are used where conventional elastomers cannot provide the range of physical properties needed in the product. These materials find large application in the automotive sector and in household appliances sector. In 2014 the world market for Plastic rubber reached a volume of ca. 16.7 billion US dollars. About 40% of all Plastic rubber products are used in the manufacturing of vehicles. For instance co-polyester Plastic rubber are used in snowmobile tracks where stiffness and abrasion resistance are at a premium. Thermoplastic olefins (TPO) are increasingly used as a roofing material. Plastic rubber are also widely used for catheters where nylon block copolymers offer a range of softness ideal for patients. Thermoplastic silicone and olefin blends are used for extrusion of glass run and dynamic weather stripping car profiles. Styrene block copolymers are used in shoe soles for their ease of processing, and widely as adhesives. Plastic rubber is commonly used to make suspension bushings for automotive performance applications because of its greater resistance to deformation when compared to regular rubber bushings. Thermoplastics have experienced growth in the heating, ventilation, and air conditioning (HVAC) industry due to the function, cost effectiveness and adaptability to modify plastic resins into a variety of covers, fans and housings. Plastic rubber may also be used in medical devices and is also finding more and more uses as an electrical cable jacket and inner insulation. You'll also be able to find Plastic rubber used in some headphone cables.

Properties

- Dense rubber
- Slip resistance
- Excellent weather resistance

- Shock absorption
- Outstanding ozone resistance
- Flexibility
- Soft texture
- Benefit of being co-extruded
- UL and NSF approval with certain TPE grades

Advantages

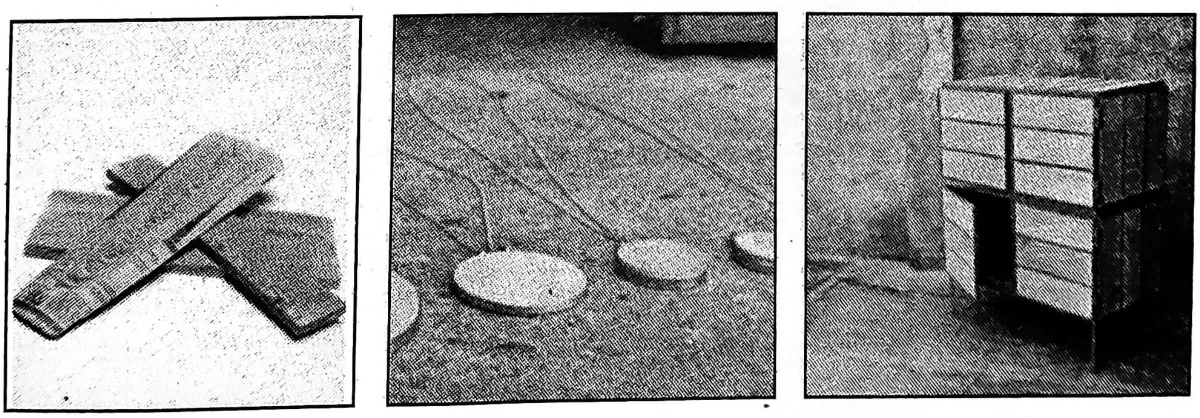
- Simplified processing - no mixing or vulcanization involved.
- Lower part costs through lower density and thinner wall sections.
- TPEs are colorable.
- Recyclable scraps and parts.
- Long-lasting.

4.5.6.2 Newspaper Wood

As the name suggests, this is 'wood' made from newspaper. The individual pages are rolled together using a specially developed machine to produce tabloid sized 'logs', which can then be milled into planks, drilled and sanded just as real wood might. Neatly, the Newspaper Wood also replicates the grain of wood, with streaks of text or color photographs revealed in the new planks when it is cut.

The designers are currently refining the Newspaper Wood design and working to develop further products from it. The relatively small size of the logs will probably limit its applications to a certain extent, but it is easy to imagine attractive pieces of furniture or other heirloom quality objects being made from it.

Large amounts of newspaper are recycled every day so the raw product for Newspaper Wood is both cheap and widely available. Additionally the product has also been developed with an eye on how it could be recycled at the end of its life. The glue that binds the sheets of newspaper together has been selected for its ability to be separated from the paper in an eventual recycling process.



(a) (b) (c)

Fig. 4.9

4.5.6.3 Non-Toxic Paint

Indoor air is three times more polluted than outdoor air, and according to the EPA, is considered one of the top five hazards to human health. Paints and finishes are among the leading causes.

Paints and finishes release low level toxic emissions into the air for years after application. The source of these toxins is a variety of volatile organic compounds (VOCs) which, until recently, were essential to the performance of the paint.

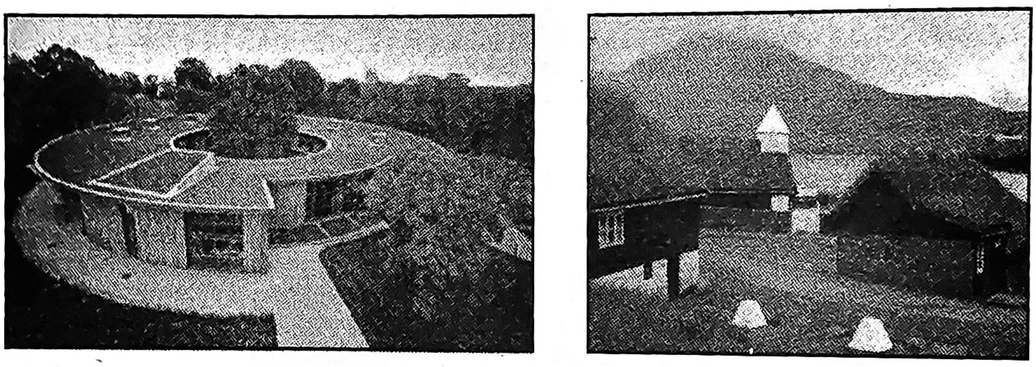
New environmental regulations and consumer demand have led to the development of low-VOC and zero-VOC paints and finishes. Most paint manufacturers now produce one or more non-VOC variety of paint. These new paints are durable, cost-effective and less harmful to human and environmental health.

The term "non-toxic" is used here in its broadest sense. With paints and finishes, it is more a matter of degree. Even Zero-VOC formulations contain some small amounts of toxins. Here are three general categories of non-toxic (or low-toxic) paints : **Natural Paints, Zero VOC, and Low VOC.**

Benefits

1. **Health :** Reduced toxins benefit everyone, including those with allergies and chemical sensitivities.
2. **Environment :** Reduces landfill, groundwater and ozone depleting contaminants.
3. **Effective :** Low-VOC products perform well in terms of coverage, scrubbability and hideability (covering flaws on previous coats).
4. **Water-Based :** Easy clean-up with soap and warm water.
5. **Little or No Hazardous Fume :** Low odour during application; no odor once cured. No off-gassing. Painted areas can be occupied sooner, with no odour complaints.
6. **Not Deemed Hazardous Waste :** Cleanup and disposal greatly simplified.

4.5.6.4 Green Roof

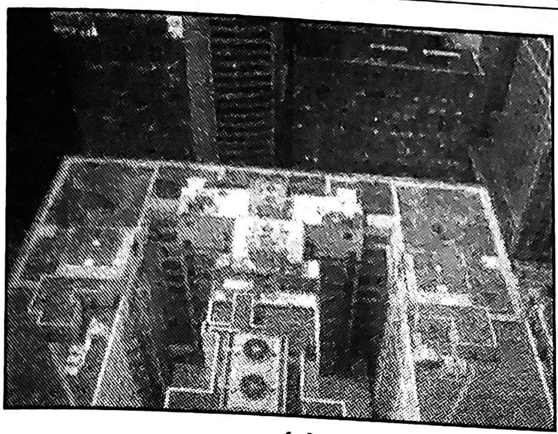


(a) (b)

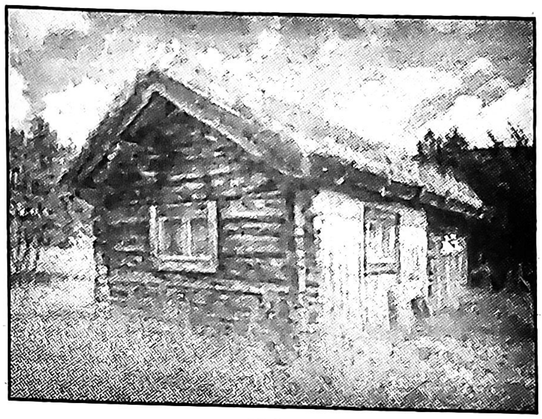
Fig. 4.10

A green roof or living roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. It may also include additional layers such as a root barrier and drainage and irrigation systems. Container gardens on roofs, where plants are maintained in pots, are not generally considered to be true green roofs, although this is debated. Rooftop ponds are another form of green roofs which are used to treat grey water. Vegetation, soil, drainage layer, roof barrier and irrigation system constitute green roof.

Green roofs serve several purposes for a building, such as absorbing rainwater, providing insulation, creating a habitat for wildlife, increasing benevolence and decreasing stress of the people around the roof by providing a more aesthetically pleasing landscape, and helping to lower urban air temperatures and mitigate the heat island effect. Green roofs are suitable for retrofit or redevelopment projects as well as new buildings and can be installed on small garages or larger industrial, commercial and municipal buildings. They effectively utilize the natural functions of plants to filter water and treat air in urban and suburban landscapes. There are two types of green roof : intensive roofs, which are thicker, with a minimum depth of 12.8 cm (5.0 in), and can support a wider variety of plants but are heavier and require more maintenance, and extensive roofs, which are shallow, ranging in depth from 2 cm (0.79 in) to 12.7 cm (5.0 in), lighter than intensive green roofs, and require minimal maintenance.



(a)



(b)

Fig. 4.11

Benefits of Green Roofs

As land continues to be replaced with impervious surfaces due to population growth and urbanization, the necessity to recover green space is becoming increasingly critical to maintain environmental quality. Installing green roofs is one option that can reduce the negative impact of development while providing numerous environmental, economic, and social benefits. They can improve storm water management by reducing run-off and improving water quality, conserve energy, mitigate the urban heat island, increase longevity of roofing membranes, reduce noise and air pollution, sequester carbon, increase urban biodiversity by providing habitat for wildlife, provide space for urban agriculture, provide a more aesthetically pleasing and healthy environment to work and live, and improve return on investment compared to traditional roofs.

The mitigation of stormwater run-off is considered by many to be the primary benefit because of the prevalence of impervious surfaces in urban areas. Rapid runoff from roof surfaces can exacerbate flooding, increase erosion, and may result in raw sewage that is discharged directly into our rivers. The larger amount of run-off also results in a greater quantity of water that must be treated before it is potable. A major benefit of green roofs is their ability to absorb stormwater and release it slowly over a period of several hours. Green roof systems have been shown to retain 60-100% of the stormwater they receive. In addition, green roofs have a longer life-span than standard roofs because they are protected from ultraviolet radiation and the extreme fluctuations in temperature that cause roof membranes to deteriorate. Vegetation helps cool the membrane and the building during the summer as the plants and growing substrate act as an insulation layer, they shade the roof, and through evapotranspiration. Furthermore, the construction and maintenance of green roofs provide business opportunities for roofing contractors, plant producers, landscape designers and contractors, and other green industry members while addressing the issues of environmental stewardship

4.5.7 Earthen Materials

- Earthen materials like adobe, cob, and rammed earth are being used for construction purposes since ages.
- For good strength and durability- chopped straw, grass and other fibrous materials etc. are added to earth.
- Even today, structures built with adobe or cob can be seen in some remote areas.

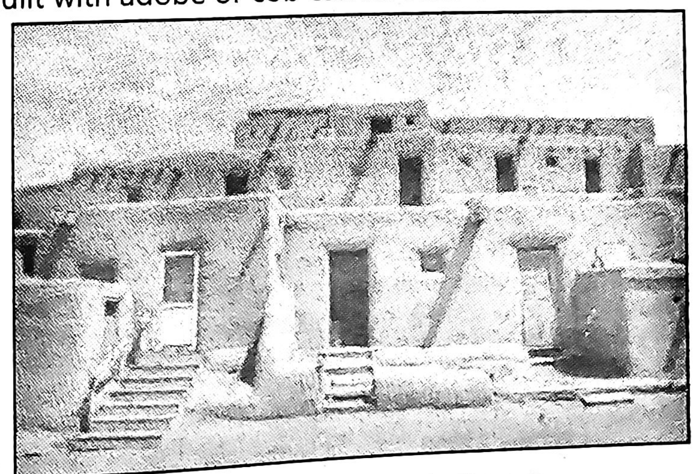


Fig 4.12 : Adobe Made Structure

4.5.8 Engineered Wood

- Wood is one of the most famous building materials used around the world.
- But in the process of conversion of raw timber to wood boards and planks, most percentage of wood may get wasted.
- This wastage can also be used to make structural parts like walls, boards, doors etc. in the form of engineered wood.
- Unlike solid wood, engineered wood contains different layers of wood, usually the middle layers are made of wood scraps, softwoods, wood fibers etc.

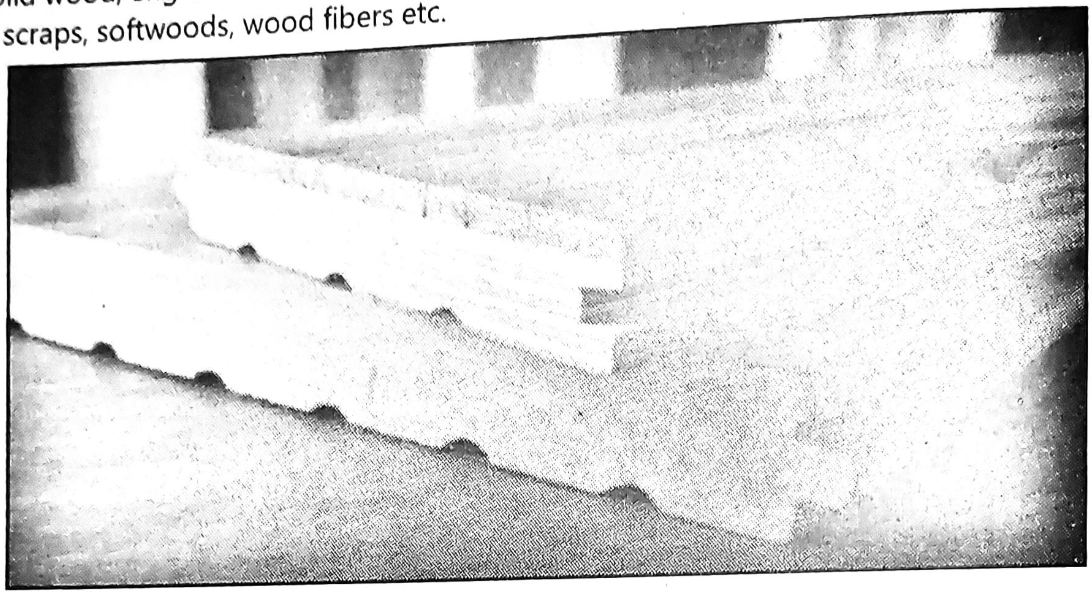


Fig. 4.13 : Engineered Wood Board Over Solid Wood Board

4.5.9 SIPs

- Structural insulated panels (SIPs) consist of two sheets of oriented strand boards or flake board with a foam layer between them.
- They are generally available in larger sizes and are used as walls for the structure.
- Because of their large size, they need heavy equipment to install however, they provide good insulation.

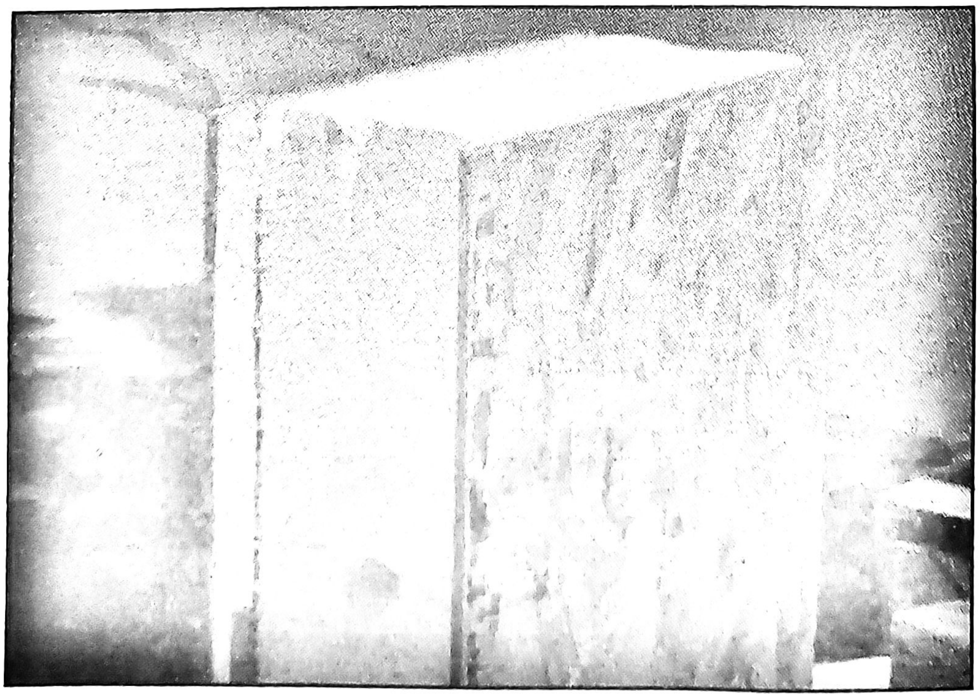


Fig. 4.14 : Structural Insulated Panel (SIP)

4.5.10 Insulated Concrete Forms

- Insulated concrete forms contain two insulation layers with some space in between them. This space contains some arrangement for holding reinforcement bars, after placing reinforcement, concrete is poured into this space.
- They are light in weight, fire resistant, low dense and have good thermal and sound insulation properties.

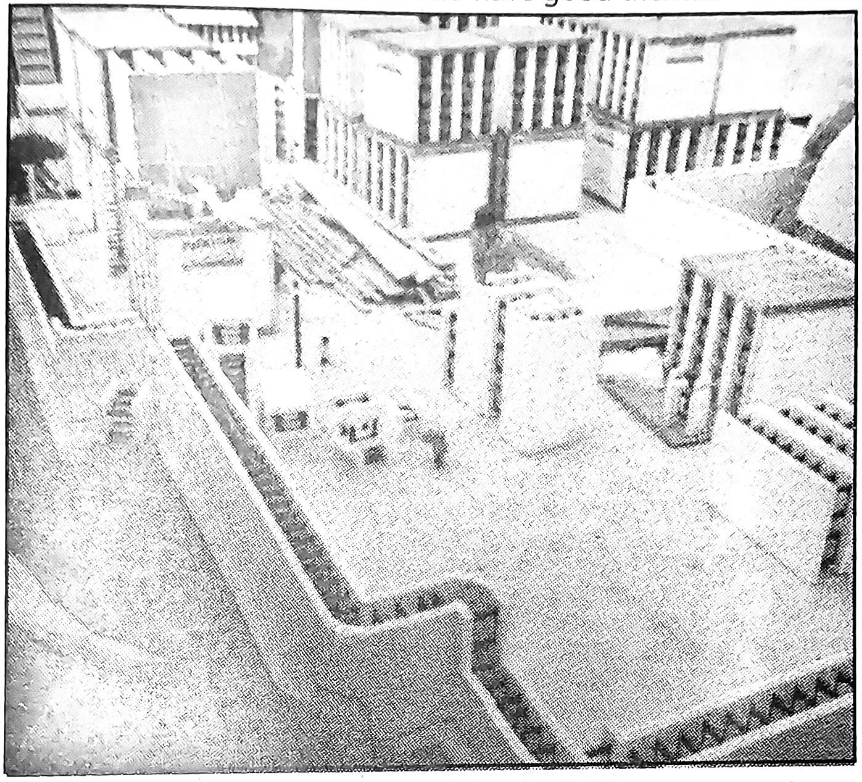


Fig. 4.15 : Insulated Concrete Forms

4.5.11 Cordwood

- If wood is abundantly available and easily accessible to the site of construction, cordwood construction is recommended.
- It requires short and round pieces of wood which are laid one above the other, width wise, and are bonded together by special mortar mix.
- They are strong, environmental friendly and also give good appearance to the structure.

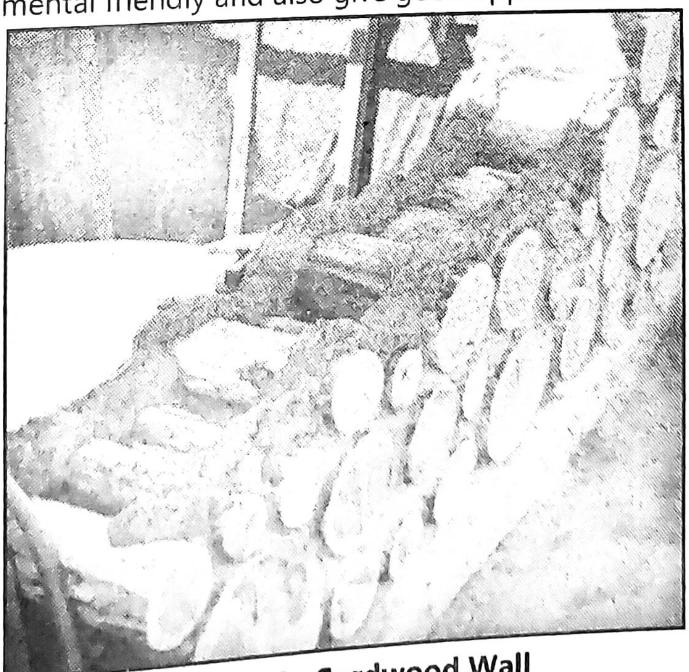


Fig. 4.16 : Cordwood Wall

4.5.12 Straw Bale

- Straw bale is another green building material which can be used as framing material for building because of good insulating properties. They can also act as soundproof materials.
- Non-load bearing walls of straw bale can be used as fill material in between columns and; in beams framework is recommended.
- Since air cannot pass through them, straw bales also have some resistance to fire.

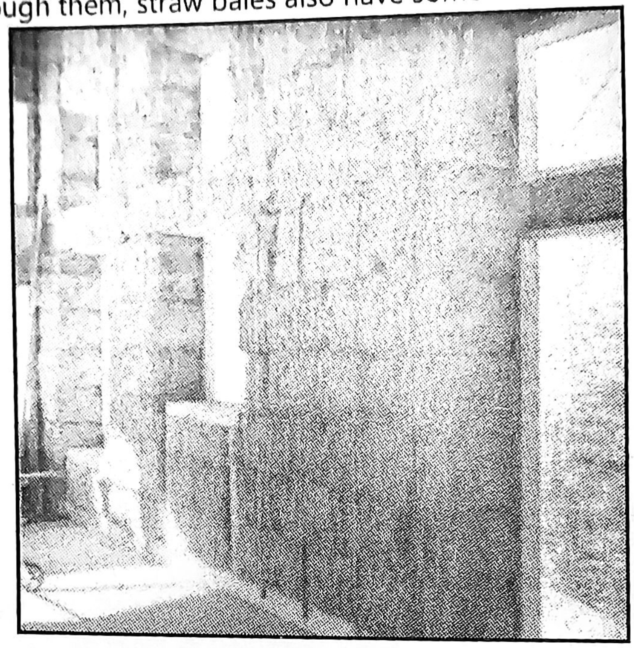


Fig. 4.17 : Straw Bale Wall

4.5.13 Earth Bags

- Earth bags or sand bags are also used to construct walls of a structure.
- These types of structures can be seen in military bases, near banks of water resources etc.
- Generally, bags made of burlap are recommended but they may rot very easily and hence, polypropylene bags are used nowadays.

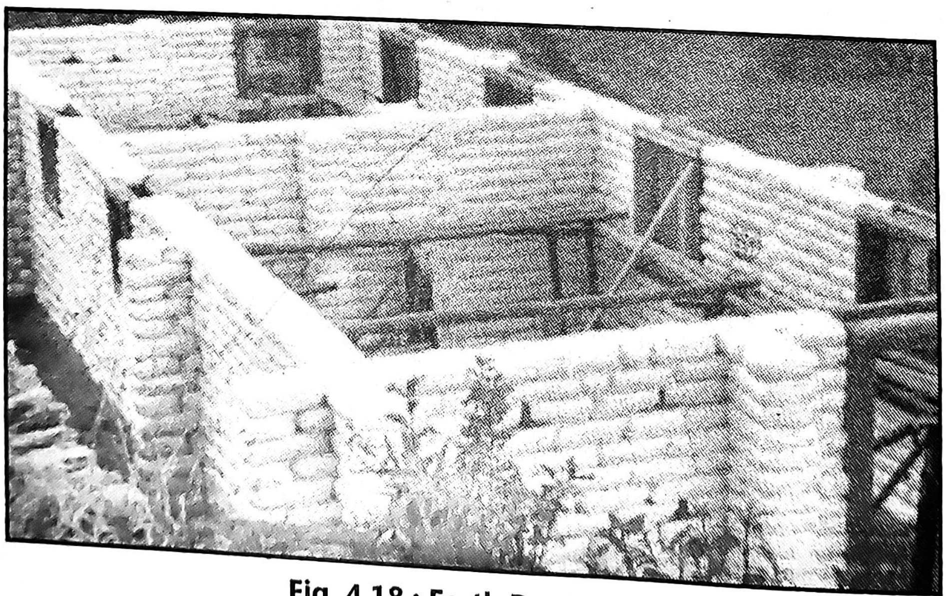


Fig. 4.18 : Earth Bag Walls

4.5.14 Slate Roofing

- Slate is naturally formed rock which is used to make tiles.
- Slate tiles have high durability and they are used as roofing materials.
- Slate roofing is preferred when it is locally or cheaply available.

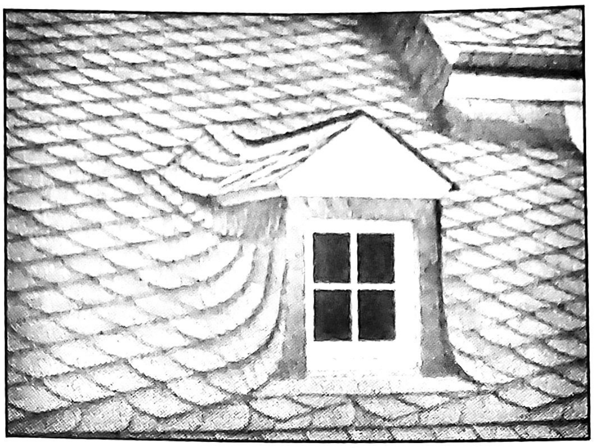


Fig. 4.19 : Slate Roofing

4.5.15 Steel

- Steel roof panels and shingles are highly durable and they can be recycled again and again. So, these are the best choices for green roofing materials.

Fig. 4.20 : Steel Roofing

4.5.16 Thatch

- Thatch is nothing but dry straw, dry water reed, dried rushes etc. These are the oldest roofing materials which are still in use in some remote locations of the world and even in cities for aesthetic attractions.
- It is cheaply available for roofing and a good insulator too.

Fig. 4.21 : Thatch Roofing

4.5.17 Composites

- Roof panels made of composite materials such as foam or cellulose layer sandwiched between two metal sheets or two plastic sheets also come under green building materials.
- They are light in weight, inexpensive and provide good insulation for the structure and save energy.

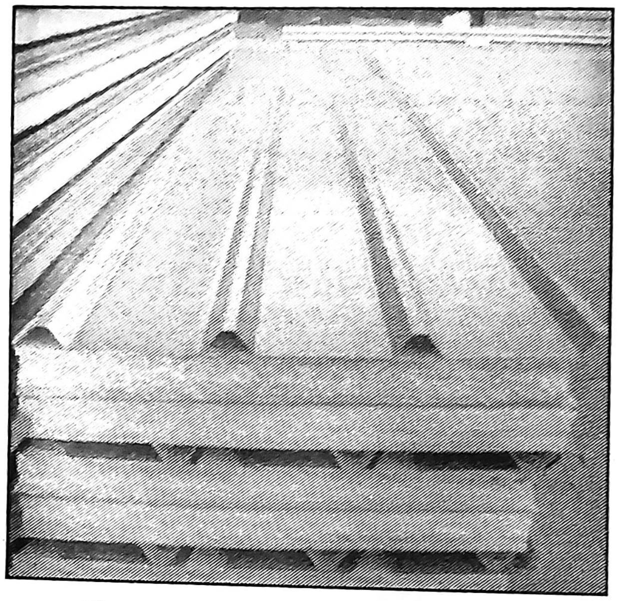


Fig. 4.22 : Composite Roof Panels

4.5.18 Natural Fiber

- Natural fibers like cotton, wool can also be used as insulation materials.
- Recycled cotton fibers or wool fibers are converted into a batt and installed in preformed wooden frame sections.

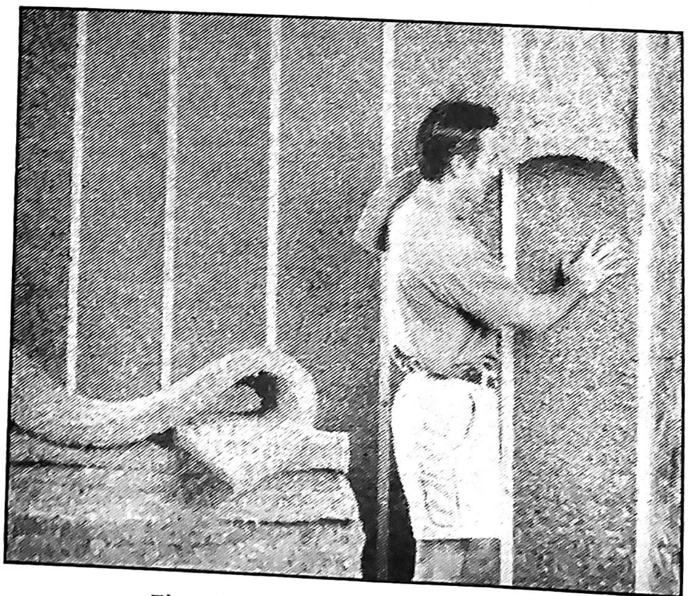


Fig. 4.23 : Cotton Insulation

4.5.19 Polyurethane

- Polyurethane foam is available in the form of spray bottles. They are directly sprayed onto the surface or wall or to which part insulation is required.
- After spraying it expands and forms a thick layer which hardens later on.
- They offer excellent insulation and prevent leakage of air.

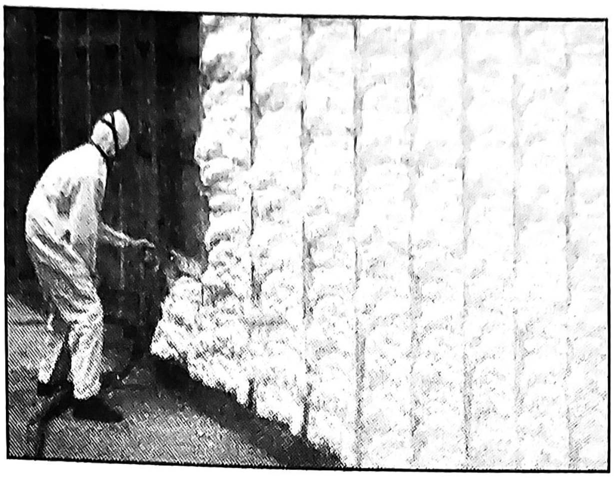


Fig. 4.24 : Polyurethane Foam Spray

4.5.20 Fiberglass

- Fiberglass is also used for insulation purposes in the form of fiberglass batts.
- Even though it contains some toxic binding agents, because of its super insulation property at low cost it can be considered as a green building material.

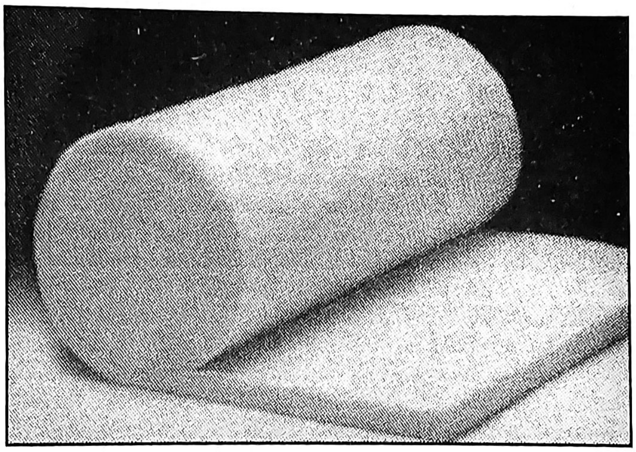


Fig. 4.25 : Fibreglass batt

4.5.21 Cellulose

- Cellulose is a recycled product of paper waste and it is widely used around the world for insulation purposes in structure.
- It acts as good sound insulator and available for cheap prices in the market.

Fig. 4.26 : Installing Cellulose Insulation

4.5.22 Cork

- Cork is also a good insulator. Boards or panels made of cork are available in markets.
- A great amount of electrical energy can be saved by corkboard insulation in winter.
- These cork boards are also good for sound insulation.

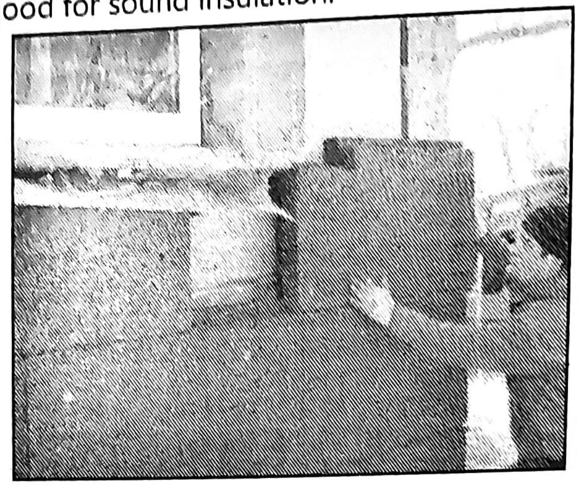


Fig. 4.27 : Installing Cork Boards

4.5.23 Polystyrene and Isocyanurate

- Polystyrene and isocyanurate foam sheets are another type of insulation materials which are available in the form of boards or sheets.
- These are generally provided as insulators on exterior sides of a structure, below the grade etc.

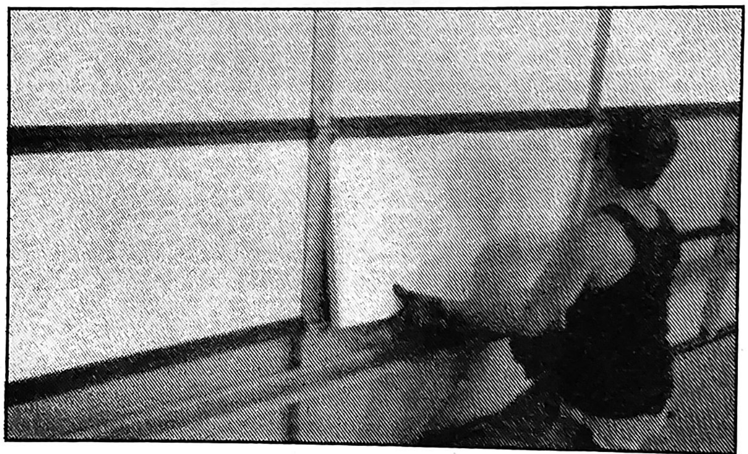


Fig. 4.28 : Installation of Polystyrene Foam Sheets

4.5.24 Natural Clay

- Plastering of walls can be done using natural clay rather than other gypsum-based plasters.
- Natural clay plaster with proper workmanship gives a beautiful appearance to the interior.

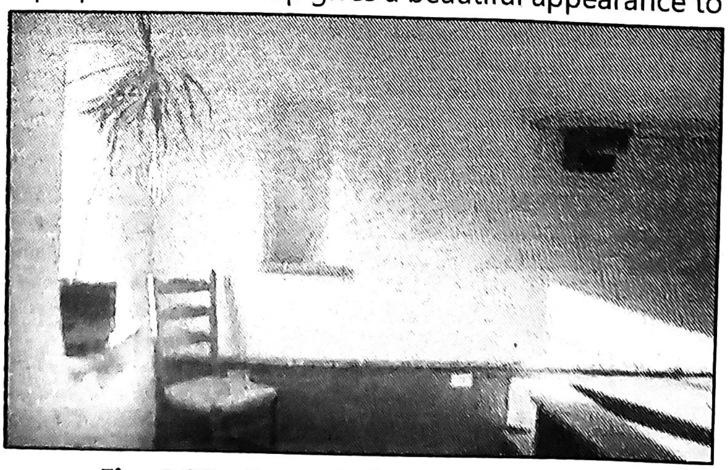


Fig. 4.29 : Natural Clay Plastered Wall

4.5.25 Non-VOC Paints

- Non-VOC paint or green paint is recommended over VOC containing paints.
- Presence of Volatile Organic Compounds (VOC) in paint reacts with sunlight and nitrogen oxide resulting in the formation of ozone which can cause severe health problems for the occupants.
- If non-VOC paint is not available then try the paint with very low-VOC content in it.

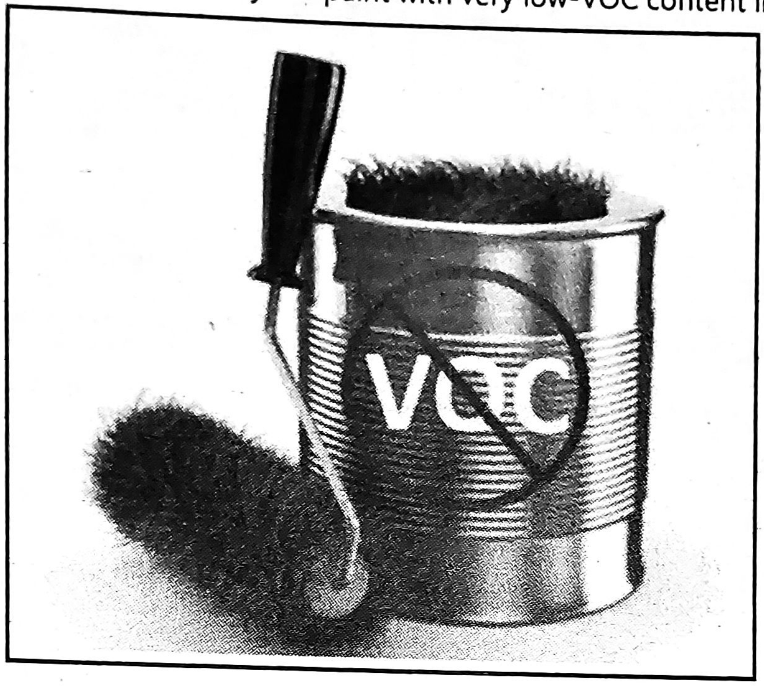


Fig. 4.30 : Non-VOC Paint

4.5.26 Natural Fiber Floor

- Naturally occurring materials like bamboo, wool and cotton fiber carpets, cork etc. can be used for flooring purposes.

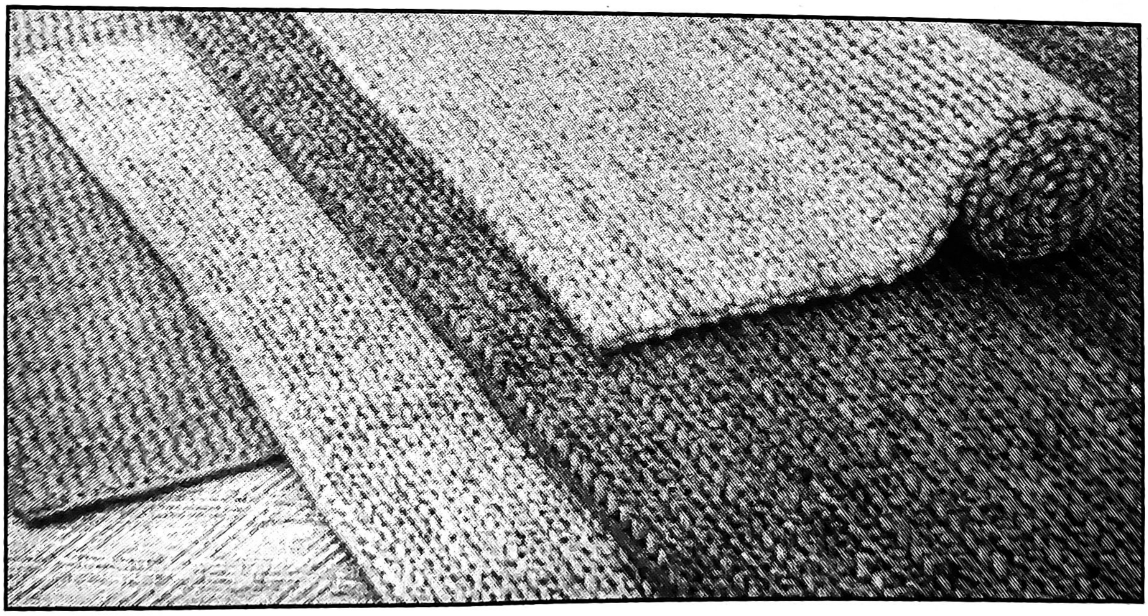


Fig. 4.31 : Natural Fiber Flooring Rugs

4.5.27 Fiber Cement

- Fiber cement boards are made of cement, sand and wood fibers.
- For exterior siding, fiber cement boards are good choice because of their cheap price, good durability and good resistance against fire.

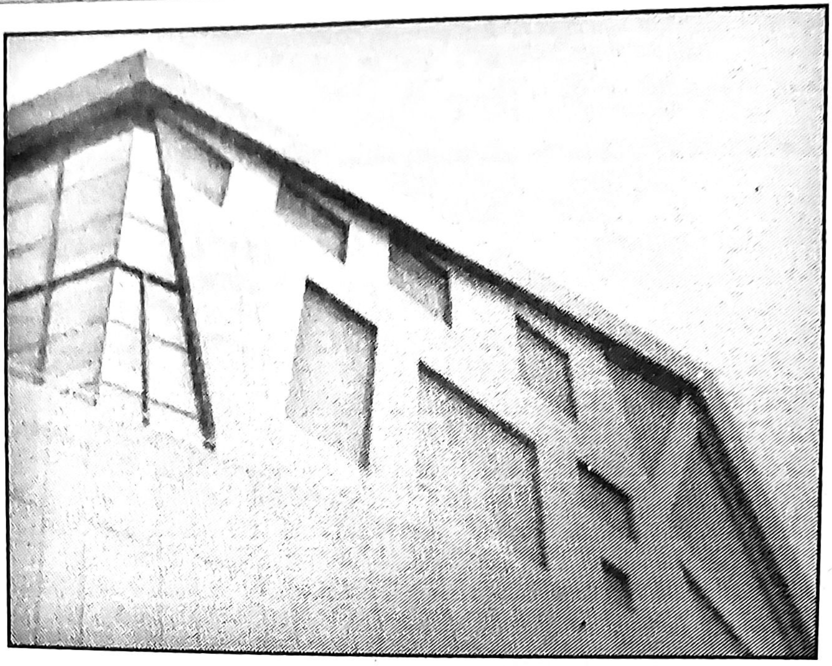


Fig. 4.32 : Exterior Siding with Fiber Cement Boards

4.5.28 Stone

- Stone is a naturally occurring and a long-lasting building material. Some Stone structures built hundreds of years ago are still in existence without much abrasion.
- Stones are good against weathering hence they can be used to construct exterior walls, steps, exterior flooring etc.

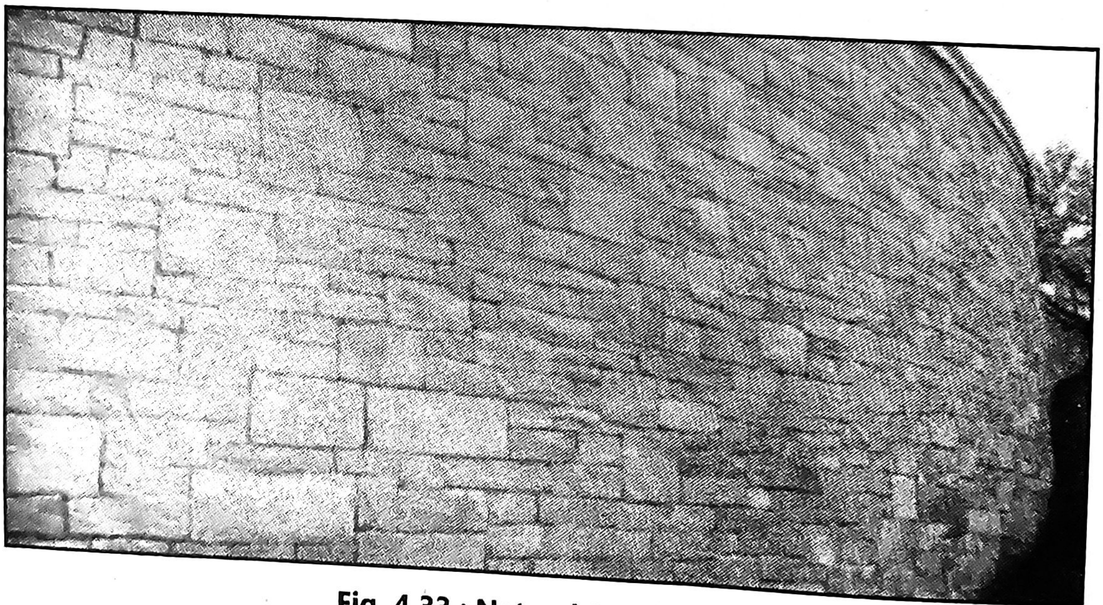


Fig. 4.33 : Natural Stone Wall

Important Points

- Green, or sustainable, building is the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition.
- The benefits of green buildings can be grouped within three categories : environmental, economic and social.
- Sustainable siting principle optimizes land use and development to reduce adverse impacts and minimize the building's ecological footprint.

- Energy efficiency principle/technique focuses on the establishment of performance targets that account for intended use, occupancy and other energy operations for new construction and renovation projects.
- Water efficiency principle emphasizes the value of decreasing demands for fresh water and reducing the generation of waste water through optimized landscaping, integrated rainwater catchments, gray water recycling, and wastewater treatment systems.
- By using sustainable construction materials and resources, green building materials have aided the reduction of extraction, processing, transportation, solid waste, and consumption.
- Healthy indoor environment is critical to good health and well-being of residents. To maintain a healthy atmosphere, efforts should be taken to improve the indoor air quality and ventilation.
- In building, environmentally-friendly materials (also known as green building materials) are those in which, for their production, placing and maintenance, actions of low environmental impact have been performed.
- A green roof or living roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane.

Practice Questions

1. Define Green Building and state its benefits.
2. Describe Principles of Green Building – Planning concept of Green Building and Related Strategies.
3. How to Protect or enhance site's ecological integrity and biodiversity?
4. What is Sustainable Siting?
5. How to reduce or eliminate disturbance to water system?
6. How to reduce the use of potable water for irrigation?
7. How to reduce urban heat islands?
8. How to design infrastructure to support alternative transportation?
9. What is Energy Efficiency?
10. How to use site resources to reduce building loads and enhance indoor environmental quality?
11. How to configure internal layout to reduce loads and enhance energy efficiency?
12. How to design and select all building systems to meet energy targets?
13. How to design envelope to reduce heating, cooling, lighting, and ventilation loads?
14. How to use passive and active renewable energy?
15. What is water efficiency?
16. How to reduce or prevent the use of potable water to treat human waste?
17. How to select water efficient fixtures?
18. How to eliminate disturbance to water system?
19. What are sustainable Construction Materials and their benefits?
20. How is Healthy Indoor Environmental Quality ensured?
21. How to reduce ventilation loads?

22. How to design envelope to reduce heating, cooling, lighting, and ventilation loads?
23. What are the Salient Features of Green Building?
24. Describe Typical Features of Green Building.
25. What is the Process : Improvement in environmental quality in civil structure?
26. How to reduce air quality problems at the source?
27. How to Control noise indoor?
28. Describe any four Green building materials and products.
29. What is green roof?

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