

MODULE-2

SUSTAINABLE BUILT ENVIRONMENT

SMART CITY CONCEPT

1. Definition

A Smart City is defined as:

“A city that uses digital technologies to enhance performance, well-being, and reduce costs and resource consumption across urban sectors while engaging more effectively and actively with its citizens.”

2. Smart City Components

a) Smart Governance

- Online grievance redressal systems.
- E-governance portals for licenses, taxes, and payments.
- Real-time data dashboards for decision-making.
- Citizen feedback applications.

b) Smart Mobility

- Intelligent Traffic Management Systems (ITMS).
- Integrated public transport (metro, buses, bicycles).
- Smart parking and electric vehicle (EV) infrastructure.
- Use of GPS and sensors for real-time route planning.

c) Smart Energy

- Smart grids and meters for efficient power distribution.
- Solar rooftop installations and renewable energy integration.
- Street lighting using motion sensors and LEDs.

d) Smart Water and Waste Management

- Smart water metering and leak detection systems.
- Automated waste collection and segregation.
- Recycling and reuse of wastewater.

e) Smart Environment

- Monitoring of air and water quality through sensors.
- Green buildings and energy-efficient designs.

- Urban forestry, green roofs, and parks.

f) Smart Economy

- Support for startups, innovation hubs, and IT industries.
- E-commerce, fintech, and tourism promotion.
- Digital payment and financial inclusion.

g) Smart Living

- Accessible healthcare through telemedicine.
- Smart education platforms and digital classrooms.
- Recreation, safety, and cultural heritage preservation.

3. Features of a Smart City

- Citizen-centric planning.
- Real-time data monitoring.
- Integrated transport and mobility solutions.
- Efficient and transparent governance.
- Smart utility management (energy, water, waste).
- Inclusive development and safety.
- Sustainable urban design and green buildings.

4. Benefits Of Smart Cities

1. Improved quality of life for citizens.
2. Efficient and transparent governance.
3. Optimized use of resources (energy, water, waste).
4. Reduced pollution and enhanced sustainability.
5. Safer and cleaner urban environments.
6. Boost to economic growth and job creation.
7. Better disaster management and resilience.

EMERGING MATERIALS IN CONSTRUCTION

Modern construction focuses on using eco-friendly, sustainable, and cost-effective materials that reduce environmental impact while maintaining durability and performance. Some key emerging materials include AAC blocks, Bamboo, and Recycled Plastics.

1. Autoclaved Aerated Concrete (AAC) Blocks

Definition:

AAC blocks are lightweight, precast, foam concrete building materials made from cement, lime, sand (or fly ash), water, and a small amount of aluminum powder. They are cured in an autoclave under high pressure and temperature, producing a cellular structure filled with air voids.

Manufacturing Process:

1. Mixing of raw materials (cement, lime, fly ash/sand, gypsum, aluminum powder).
2. Pouring into molds — aluminum reacts to form hydrogen bubbles → air voids.
3. Pre-curing and cutting into block sizes.
4. Steam curing in autoclave at 180°C and 12 bar pressure.

Types of AAC Blocks:

Types of Autoclaved Aerated Concrete (AAC) Blocks:

1. Low-Density AAC Blocks
 - Density: 400–500 kg/m³
 - Uses: Suitable for partition walls and insulation panels; ideal for non-load-bearing applications where lightweight material is preferred.
2. Standard AAC Blocks
 - Density: 550–650 kg/m³
 - Uses: Used for external and internal non-load-bearing walls; provides good insulation and easy handling.
3. High-Density AAC Blocks
 - Density: 700–800 kg/m³
 - Uses: Appropriate for load-bearing walls and structural works; provides higher strength and stability.
4. Reinforced AAC Panels
 - Density: Not specified (varies based on reinforcement)

- Uses: Used for floor and roof panels, lintels, and façade panels; reinforced for structural performance.

Properties:

- Lightweight (1/4th weight of conventional brick)
- High thermal and sound insulation
- Fire resistant up to 6 hours
- Pest and mold resistant
- Easy to cut and handle

Uses:

- Wall construction in residential, commercial, and industrial buildings
- Partition walls and infill panels
- Roof and floor slabs (with reinforcement)
- High-rise structures (reduces dead load)
- Fire-rated walls (kitchens, ducts, staircases)

Advantages:

- Faster construction (larger block size)
- Reduces dead load → smaller foundation size
- Eco-friendly (uses fly ash, less energy)
- Excellent insulation → energy savings
- Precision in size, smooth surface finish

2. Bamboo

Definition:

Bamboo is a naturally renewable, fast-growing grass with a woody stem used as a structural and finishing material in buildings.

Bamboo is a fast-growing, renewable natural material widely used in construction, especially in rural and tropical areas. It is often called the “green steel” because of its high strength-to-weight ratio and versatility.

2. Uses of Bamboo in Construction

Structural Uses

1. Load-Bearing Structures:
 - Temporary shelters, huts, and low-cost houses.
 - Light frame structures such as trusses, roofs, and scaffolding.
2. Bridges and Walkways:
 - Pedestrian bridges and lightweight modular structures.
3. Reinforcement:
 - In some regions, treated bamboo is used as reinforcement in low-cost concrete structures.

Non-Structural Uses

1. Flooring and Wall Panels:
 - Bamboo strips or laminated bamboo panels for flooring, partitions, and walls.
2. Ceilings and Roofing:
 - Bamboo mats, thatches, and reinforced bamboo panels.
3. Furniture and Decorative Elements:
 - Chairs, tables, ladders, window blinds, and railings.
4. Scaffolding:
 - Temporary support structures in construction sites, widely used in Asia.

3. Advantages of Bamboo in Construction

1. High Strength-to-Weight Ratio:
 - Comparable to mild steel in tension, making it strong yet lightweight.
2. Rapid Growth and Renewable:

- Bamboo matures in 3–5 years, unlike timber that takes decades.
- 3. Flexibility and Ductility:
 - Can bend without breaking, making it suitable for earthquake-resistant structures.
- 4. Sustainable and Eco-Friendly:
 - Absorbs CO₂, reduces environmental impact, and is biodegradable.
- 5. Cost-Effective:
 - Locally available in many tropical regions, reducing transportation costs.
- 6. Versatility:
 - Can be used in structural, non-structural, and decorative applications.
- 7. Thermal and Acoustic Insulation:
 - Provides natural insulation, keeping interiors cool and reducing noise.

4. Limitations of Bamboo in Construction

- 1. Durability Issues:
 - Susceptible to decay, fungi, and termite attack if untreated.
- 2. Moisture Sensitivity:
 - Absorbs water and swells; untreated bamboo can crack or warp.
- 3. Limited Standardization:
 - Variations in species, quality, and size make design calculations challenging.
- 4. Short Span Load-Bearing Limit:
 - Suitable mainly for small to medium-span structures; not ideal for heavy buildings without engineering reinforcement.
- 5. Fire Risk:
 - Highly combustible if not properly treated or coated.
- 6. Maintenance Requirement:
 - Requires regular treatment (chemical, heat, or smoke treatment) to enhance durability.

3. Recycled Plastics

Introduction:

Recycled plastics are obtained from post-consumer or industrial plastic waste which is processed and converted into construction materials. Using recycled plastics in construction reduces environmental pollution, landfill waste, and the demand for virgin raw materials.

These materials are increasingly being used in infrastructure, building components, and interior finishes due to their durability and versatility.

2. Uses of Recycled Plastics in Construction

Structural and Semi-Structural Applications

1. Plastic Waste Bricks:

Plastics blended with other materials to make lightweight bricks or blocks.

2. Plastic Roads:

Roads with bitumen-plastic composite are flexible, water-resistant, and long-lasting.

3. Modular Housing Components:

Recycled plastic panels used in prefabricated homes, partitions, and furniture.

4. Composite Decking & Outdoor Furniture:

Resistant to termites, moisture, and rot; widely used in parks, balconies, and gardens.

5. Plastic Lumber/Composites:

- Made from recycled plastic combined with wood fibers or fillers.
- Used for decking, fencing, window frames, and outdoor furniture.

6. Roofing Sheets and Panels:

- Lightweight, water-resistant, and corrosion-free plastic sheets for temporary or permanent roofs.

7. Pipes and Drainage Systems:

- Polyethylene (PE) and Polypropylene (PP) pipes for water supply, sewage, and drainage.

8. Insulation and Panels:

- Plastic-based panels or boards for partition walls and insulation.

Non-Structural Uses

1. Tiles and Flooring:

- Recycled plastic tiles for flooring, walkways, and playgrounds.

2. Road Construction:

- Plastic waste mixed with bitumen for paving roads (enhances flexibility and durability).
- 3. Furniture and Decorative Items:
 - Chairs, tables, cabinets, railing, and fencing materials.
- 4. Packaging for Construction Materials:
 - Plastic crates, pallets, and molds for concrete casting.

3. Advantages of Using Recycled Plastics

1. Environmental Benefits:
 - Reduces plastic waste in landfills and oceans.
 - Conserves natural resources like wood, sand, and gravel.
2. Durability and Longevity:
 - Resistant to corrosion, moisture, chemicals, and rot.
 - Longer life compared to some timber or metal components.
3. Lightweight and Easy to Handle:
 - Simplifies transportation and reduces labor effort.
4. Low Maintenance:
 - Does not require painting, polishing, or chemical treatments.
5. Versatility:
 - Can be molded into various shapes, panels, boards, and structural components.
6. Cost-Effective:
 - Production often cheaper than using virgin materials.
7. Energy Efficiency in Production:
 - Recycling plastics consumes less energy than producing new plastics or metals.

4. Limitations of Using Recycled Plastics

1. Limited Load-Bearing Capacity:
 - Not suitable for heavy structural members; mainly used for non-load-bearing applications.
2. UV and Heat Sensitivity:
 - Some plastics degrade under prolonged exposure to sunlight (UV) or high temperatures.
3. Chemical Compatibility:

- Certain plastics may react with solvents, oils, or alkaline materials in concrete.
- 4. Quality Variability:
 - Performance depends on the type and grade of recycled plastic used.
- 5. Fire Hazard:
 - Many plastics are combustible; need fire retardants for safety.
- 6. Aesthetic Limitations:
 - May fade, discolor, or warp over time; may require coating or finishing for aesthetics.

MATERIAL SELECTION CRITERIA, DURABILITY, AND SUSTAINABILITY

1. MATERIAL SELECTION CRITERIA

Definition:

Material selection in construction refers to the process of choosing suitable materials for a structure based on their performance, strength, cost, appearance, availability, and environmental impact. The goal is to ensure safety, functionality, and long service life of the structure at an economical cost.

Main Factors Affecting Material Selection:

1. Strength and Load-bearing Capacity:

The material should have sufficient strength to withstand the applied loads without failure. For example, concrete, steel, and stone are selected for structural members such as beams, columns, and foundations.
2. Durability:

Materials must resist weathering, wear, and chemical attacks over time. Durable materials reduce maintenance costs and extend the life of the structure. Examples include well-cured concrete, burnt clay bricks, and treated wood.
3. Workability and Ease of Handling:

The material should be easy to shape, transport, and install. Materials like bricks, timber, and AAC blocks are easy to handle during construction.
4. Availability and Cost:

Locally available materials are preferred as they reduce transportation costs and environmental impact. For example, laterite stones and clay bricks are economical where

available locally.

5. Aesthetic Appearance:

The material should provide a pleasing appearance and finish, especially for visible surfaces. Decorative materials like marble, glass, and tiles are used to improve the aesthetic value of buildings.

6. Maintenance Requirements:

Materials that need less maintenance are preferred for long-term use. UPVC windows and powder-coated steel sections require minimal upkeep.

7. Thermal and Acoustic Properties:

Good materials should provide insulation against heat and sound, improving comfort and energy efficiency. Examples include insulating blocks, gypsum boards, and cavity walls.

8. Fire Resistance:

In fire-prone areas, materials with high fire resistance are essential. Concrete, bricks, and AAC blocks are good fire-resistant materials.

9. Environmental Impact:

Materials should have low embodied energy and cause minimal harm to the environment. Fly ash bricks, bamboo, and recycled steel are eco-friendly options.

10. Compatibility with Other Materials:

Materials used together should not chemically or physically react in an undesirable way. For example, steel reinforcement must be compatible with concrete.

Guidelines for Selecting Materials:

- Choose materials suitable for the function and type of building.
- Prefer locally available and sustainable materials.
- Evaluate not just the initial cost, but also maintenance and life-cycle cost.
- Follow relevant IS codes and material standards.
- Consider environmental conditions such as humidity, temperature, and exposure.

2. DURABILITY

Definition:

Durability is the ability of a construction material to resist deterioration due to environmental, mechanical, or chemical effects over time, while maintaining its strength, appearance, and performance.

Importance of Durability:

Durable materials ensure a long service life of structures, reduce repair and maintenance costs, and improve safety and sustainability. Using durable materials conserves resources and reduces waste.

Factors Affecting Durability:

1. Material Properties:

The porosity, permeability, and composition of materials affect their resistance to moisture, chemicals, and physical wear. For example, dense concrete is more durable than porous concrete.

2. Environmental Conditions:

Materials exposed to rain, heat, frost, or saltwater deteriorate faster. Structures near the sea need corrosion-resistant materials or protective coatings.

3. Design and Detailing:

Good design prevents water stagnation and ensures proper drainage and ventilation, which increases durability.

4. Workmanship and Quality Control:

Proper mixing, compaction, and curing are essential for materials like concrete. Poor workmanship reduces strength and lifespan.

5. Maintenance:

Regular inspection and preventive maintenance such as painting, waterproofing, or coating help extend the life of materials.

Ways to Improve Durability:

- Apply protective coatings, paints, or sealants to prevent corrosion and water entry.
- Use proper curing and compaction techniques during construction.
- Ensure good drainage design to avoid standing water.
- Select materials that are suited for the local environment and exposure conditions.

3. SUSTAINABILITY

Definition:

Sustainability in construction means using materials and methods that minimize environmental impact, conserve resources, and ensure long-term performance without compromising the needs of future generations.

Principles of Sustainable Material Use:

1. Resource Efficiency:

Materials should require minimal raw resources and energy to produce. Using industrial by-products like fly ash in concrete is one example.

2. Renewable and Recyclable Materials:

Preference should be given to materials that can be renewed or recycled after use. Bamboo, recycled steel, and reclaimed wood are good examples.

3. Low Embodied Energy:

Materials with low energy consumption in manufacturing and transportation are more sustainable. Locally available materials are preferred for this reason.

4. Reduced Environmental Impact:

Sustainable materials should produce less pollution, generate minimal waste, and have a smaller carbon footprint.

5. Long Life and Reusability:

Durable materials that last longer and can be reused reduce the need for frequent replacement and save resources.

6. Health and Safety:

Non-toxic and safe materials should be used to ensure healthy indoor environments. Low-VOC paints and natural finishes are examples.

Sustainable Construction Practices:

- Use energy-efficient and insulating materials to reduce heating and cooling loads.
- Reuse and recycle construction waste wherever possible.
- Design buildings for maximum use of natural light and ventilation.
- Conduct a life-cycle assessment of materials before selection.
- Adopt green building certification systems such as LEED or GRIHA.

Examples of Sustainable Materials:

Sustainable materials include fly ash or slag-based cement, recycled aggregates, bamboo, timber from certified forests, recycled plastics, mud blocks, lime plasters, and reflective roofing materials.

Benefits of Using Sustainable Materials:

Using sustainable materials reduces energy consumption and carbon emissions, conserves natural resources, lowers overall building costs, and improves indoor air quality. It also contributes to achieving green building standards and helps create environmentally responsible structures.

GREEN BUILDING

1. Introduction

A Green Building (also called a sustainable or eco-friendly building) is one that is designed, constructed, and operated to minimize its negative impacts on the environment while maximizing resource efficiency and occupant well-being.

A green building uses energy, water, and materials efficiently, produces less waste and pollution, and provides a healthy indoor environment.

2. Objectives of Green Buildings

1. Reduce energy and water consumption.
2. Use renewable and recyclable materials.
3. Minimize waste generation during construction and operation.
4. Protect natural resources and biodiversity.
5. Improve indoor air quality and occupant comfort.
6. Promote sustainable site planning and efficient building management.
7. Reduce greenhouse gas (GHG) emissions and environmental impact.

3. Advantages of Green Buildings

1. Energy Efficiency: Lower operational energy consumption through passive design and efficient systems.
2. Water Conservation: Rainwater harvesting, low-flow fixtures, and greywater recycling reduce water use.
3. Waste Reduction: Efficient material use and recycling during and after construction.

4. Health and Comfort: Better indoor air quality and natural lighting improve occupant productivity.
5. Economic Benefits: Reduced energy and maintenance costs over the building's life cycle.
6. Environmental Protection: Reduced carbon footprint and greenhouse gas emissions.
7. Enhanced Market Value: Certified green buildings often attract higher occupancy and resale value.

4. Green Building Materials

Green building materials are eco-friendly materials that have a low environmental footprint throughout their life cycle — from production to disposal.

Characteristics of Green Materials:

- Non-toxic and low emission of volatile organic compounds (VOCs).
- Locally available and renewable.
- Require low energy during production and transportation.
- Durable and recyclable.
- Support energy efficiency (for example, insulation materials).

Examples of Green Building Materials:

1. Fly ash and slag-based cement – reduces CO₂ emissions from cement production.
2. Bamboo – renewable and rapidly growing structural material.
3. Recycled steel and aluminium – reduce mining and energy consumption.
4. Autoclaved Aerated Concrete (AAC) blocks – lightweight, insulating, and low embodied energy.
5. Low-VOC paints and adhesives – improve indoor air quality.
6. Recycled plastic composites – used for flooring, panels, and outdoor decks.
7. Solar reflective roofing tiles – reduce heat absorption.
8. Timber from certified forests – ensures sustainable forest management.
9. High-performance glass and insulation panels – minimize heat transfer and save energy.
10. Permeable paving blocks – help recharge groundwater.

GREEN BUILDING RATING SYSTEMS

To assess and certify how “green” a building is, several rating systems have been developed worldwide. They evaluate the building’s performance based on various sustainability parameters.

The three main rating systems used in India are:

1. IGBC – Indian Green Building Council
2. LEED – Leadership in Energy and Environmental Design
3. GRIHA – Green Rating for Integrated Habitat Assessment

1. INDIAN GREEN BUILDING COUNCIL (IGBC)

Purpose:

- Established by the Confederation of Indian Industry (CII) in 2001.
- Promotes sustainable building practices and certifies green buildings in India.
- Aims to enable a sustainable built environment for all and to make India a global leader in green buildings.

Key Highlights of IGBC System:

- Applicable to residential, commercial, institutional, factory, and township projects.
- Voluntary and performance-based rating system.
- Encourages energy, water, and material efficiency.
- Focuses on environmental design and occupant well-being.
- Certification is valid for a defined period and may require renewal after major renovations.

Major Rating Categories:

1. Sustainable Architecture and Design
2. Site Selection and Planning
3. Water Conservation
4. Energy Efficiency
5. Building Materials and Resources
6. Indoor Environmental Quality
7. Innovation and Design Process

Point System and Certification Levels:

Each category has a certain number of points. Based on total points scored, certification levels are

awarded:

- Certified: 50–59 points
- Silver: 60–69 points
- Gold: 70–79 points
- Platinum: 80–100 points

Differential Weightage:

- Energy and water efficiency carry higher weightage (since they directly reduce resource use and carbon emissions).
- Innovation and design carry lower weightage, but add bonus points for unique sustainable strategies.

2. LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN (LEED)

Purpose:

LEED is an international green building certification system developed by the U.S. Green Building Council (USGBC). It is used globally to evaluate environmental performance and promote sustainable design.

Key Highlights of LEED:

- Focuses on the entire life cycle of buildings — design, construction, operation, and maintenance.
- Encourages efficient energy and water use, material conservation, and indoor air quality improvement.
- Adapted in India as LEED India by IGBC with localization of criteria.

Major Rating Categories:

1. Sustainable Sites
2. Water Efficiency
3. Energy and Atmosphere
4. Materials and Resources
5. Indoor Environmental Quality
6. Innovation and Design Process
7. Regional Priority Credits

Point System and Certification Levels:

Buildings earn points (maximum 110) based on performance in various categories.

- Certified: 40–49 points
- Silver: 50–59 points
- Gold: 60–79 points
- Platinum: 80+ points

Differential Weightage:

- Energy efficiency and renewable energy credits have the highest weightage.
- Water efficiency and material management have moderate weightage.
- Site planning and innovation provide bonus points.

3. GREEN RATING FOR INTEGRATED HABITAT ASSESSMENT (GRIHA)

Purpose:

GRIHA is India's national green building rating system, jointly developed by TERI (The Energy and Resources Institute) and the Ministry of New and Renewable Energy (MNRE), Government of India. It evaluates buildings based on their environmental performance across the life cycle — from design to operation.

Key Highlights of GRIHA:

- Suitable for new and existing buildings in Indian climatic conditions.
- Based on the five elements of nature (Panchabhutas) — Earth, Water, Fire, Air, and Space.
- Promotes energy conservation, renewable energy use, waste reduction, and occupant comfort.
- Mandatory for certain government and public buildings.

Major Assessment Categories:

1. Site Planning
2. Energy Efficiency
3. Renewable Energy Use
4. Water Management
5. Waste Management
6. Materials and Resources

7. Indoor Environment Quality
8. Innovation and Health Well-Being

Point System and Certification Levels:

- Total points: 100
- Certification Levels:
 - 1 Star: 25–40 points
 - 2 Star: 41–55 points
 - 3 Star: 56–70 points
 - 4 Star: 71–85 points
 - 5 Star: 86–100 points

Differential Weightage:

- Energy and water management receive the highest priority.
- Materials and waste management have moderate importance.
- Innovation and occupant well-being receive additional bonus points.

4. COMPARISON BETWEEN IGBC, LEED, AND GRIHA (Summary in Words)

- IGBC is industry-driven and flexible, suitable for a variety of building types in India.
- LEED is internationally recognized and focuses on global sustainability standards.
- GRIHA is government-recognized and specifically tailored to Indian climatic and regulatory conditions.
- All systems reward buildings that save energy, conserve water, use sustainable materials, and provide good indoor environments.
- The rating levels (Certified, Silver, Gold, Platinum or Star levels) depend on total points achieved, with differential weightage based on the environmental impact of each category.