Unit 3
Role of Civil Engineering in Built Environment

STRUCTURAL ENGINEERING

Structural Engineering is a core sub-discipline of Civil Engineering concerned with the analysis, planning, design, construction, and maintenance of load-bearing structures. It ensures that buildings, bridges, and other infrastructure are safe, serviceable, and durable under various physical loads and environmental conditions.

PURPOSE OF STRUCTURAL ENGINEERING IN BUILT ENVIRONMENT

- To design structures that can safely withstand loads such as dead loads, live loads, seismic loads, wind loads, and snow loads.
- To ensure the stability and serviceability of structures during their lifespan.
- To resist environmental factors including earthquakes, floods, and soil settlement.

STRENGTH AND STABILITY

- **Strength**: The ability of a structure or its component (like a beam or column) to resist external forces without failing. Strength is typically calculated using allowable stress methods or ultimate strength concepts, depending on the design philosophy.
  - Example: The maximum bending moment (M) a simply supported beam can resist is calculated by the flexure formula: $M = f \times Z$, where f is permissible stress and Z is the section modulus.
- **Stability**: The ability of a structure to retain its position and shape when subjected to loads without undergoing unacceptable deformations, buckling, or collapse. Stability analysis often involves slenderness ratio, Euler buckling load ($P_{cr} = \pi^2EI/L^2$), and lateral-torsional buckling checks.

Design Philosophies

1. *Working Stress Method (WSM):*
   - Based on elastic theory and factor of safety
   - Service loads considered
   - Used for low-rise RCC buildings and masonry structures
2. *Limit State Method (LSM):*
   - Considers ultimate strength and serviceability
   - Widely adopted in IS 456:2000
   - Ensures safety, economy, and usability
3. *Ultimate Load Method (ULM):*
   - Strength-based approach
   - Load factors are used to estimate failure loads

4. *Load and Resistance Factor Design (LRFD):*
    - Adopted globally (like in ACI, AISC codes)
    - Introduces partial safety factors for both load and material strength
    - Formula: Factored load ≤ $\phi \times$ Nominal resistance

These philosophies govern how we translate real-world loads into design forces and how we check the adequacy of structural components against failure modes.

GEOTECHNICAL ENGINEERING

Geotechnical Engineering is a crucial branch of civil engineering that deals with the analysis of soil and rock behaviour under various loading conditions. It forms the basis for safe and economical design of foundations, slopes, retaining structures, tunnels, and pavements.

Importance in the Built Environment

- Provides data for safe foundation design
- Identifies potential geohazards like liquefaction, landslides
- Ensures long-term performance and stability of structures

SOIL EXPLORATION TECHNIQUES

Before any design or construction begins, site investigations are performed:

1. *Reconnaissance Survey* – Initial visual inspection
2. *Borehole Drilling* – Rotary, percussion, auger drills to extract soil samples
3. *Trial Pits and Trenches* – Used for shallow investigations
4. *Geophysical Methods* – Resistivity and seismic refraction
5. *SPT/CPT Tests* – In-situ tests to determine strength and classification

TYPES OF SOIL

- **Gravel**: Coarse particles > 2 mm, excellent drainage, high shear strength
- **Sand**: Granular, 0.06 mm–2 mm, good compaction
- **Silt**: Finer than sand, poor drainage, high frost susceptibility
- **Clay**: Fine-grained < 0.002 mm, high plasticity, poor drainage
- **Loam**: Balanced mix of sand, silt, clay – ideal for construction
- **Peat**: Organic, highly compressible, unsuitable for structures

Additional Classifications

- *IS Soil Classification System:* Based on particle size and Atterberg limits
- *Unified Soil Classification System (USCS)*
- *AASHTO Classification:* Used in highway engineering

SOIL BEHAVIOUR UNDER LOAD

Soil behaves differently under various loads. Primary behaviours include:

1. *Compression and Settlement*
    - Immediate settlement: Elastic compression of soil
    - Consolidation: Expulsion of pore water from saturated clay
    - Secondary settlement: Long-term creep
2. *Shear Strength*
    - Defined by Mohr-Coulomb equation: $\tau = c + \sigma \tan \phi$

- Affected by confining pressure, drainage, and loading rate

3. *Bearing Capacity*
    - Ultimate bearing capacity is the maximum load soil can sustain
4. *Liquefaction*
    - Occurs in saturated loose sands during seismic activity
    - Causes ground to behave like a liquid

MOISTURE CONDITIONS AND EFFECTS

1. *Water Table Position*
    - High water table reduces bearing capacity
2. *Moisture Content*
    - Optimal Moisture Content (OMC) gives maximum compaction
3. *Shrink-Swell Behaviour*
    - Clays expand when wet and shrink when dry
4. *Capillarity*
    - Upward movement of water causes dampness in structures

Common Soil Tests

- *Atterberg Limits* – Liquid, Plastic, and Shrinkage limits
- *Proctor Compaction Test* – Determines OMC and maximum dry density
- *Permeability Test* – Falling head and constant head methods
- *Triaxial Test* – Accurate measurement of shear strength under controlled drainage
- *Unconfined Compression Test (UCT)* – Strength of cohesive soil without confinement
- *SPT & CPT* – Measure soil resistance and stratification
- *Plate Load Test* – On-site method for determining bearing capacity

FOUNDATION TYPES

What is a Foundation?

A foundation is the lowermost supporting part of a structure that transmits the building loads to the underlying soil or rock in a safe and uniform manner. It ensures the stability, durability, and safety of the entire superstructure.

Classification of Foundations

Foundations are broadly classified based on depth:

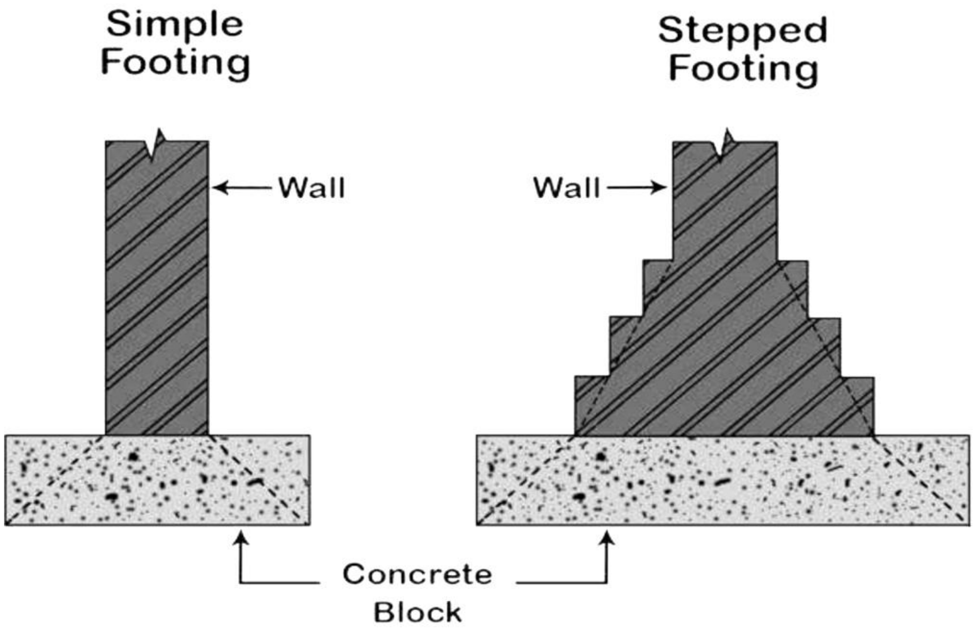
Type	Description	Typical Depth
Shallow Foundations	Transfer load to soil at a relatively small depth	Up to 3 meters
Deep Foundations	Transfer load to deeper soil strata or rock	More than 3 meters

Shallow Foundations

Used where good bearing soil is available near the ground surface and load intensity is moderate.

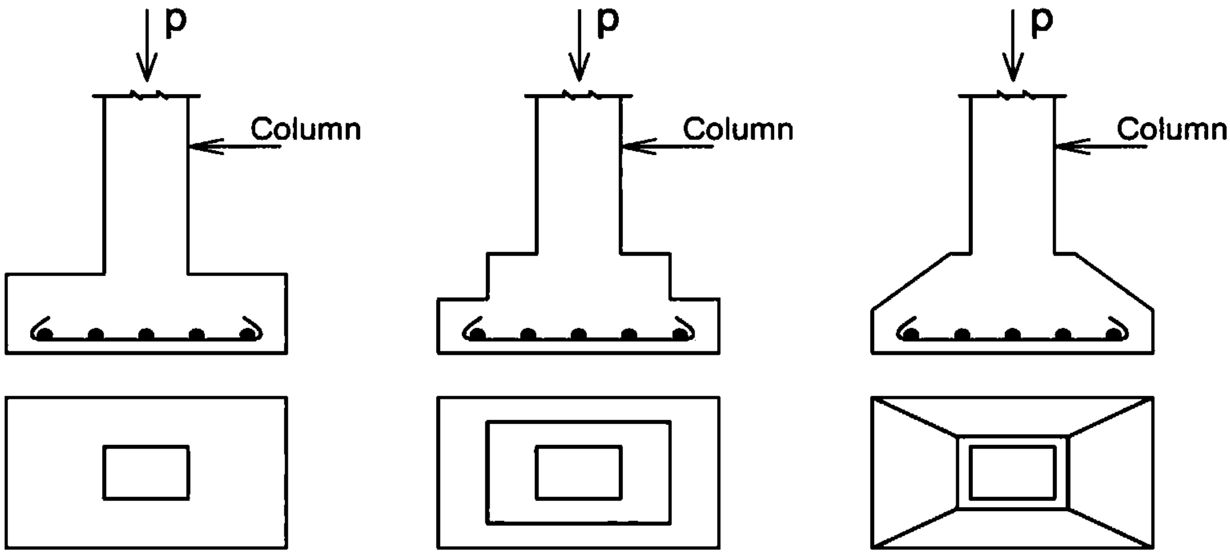
a) Simple Wall Footing

- Simple wall footing is a type of shallow foundation.
- Shallow foundations are those foundations whose depth is smaller the width of the foundation.
- The wall footings support the structural and non-structural walls.
- Wall footings are also known as strip footing and it is continuous over the entire wall.
- The construction of wall footing is done as either masonry wall footing or as RCC wall footing.



b) Isolated Footing (Pad Footing)

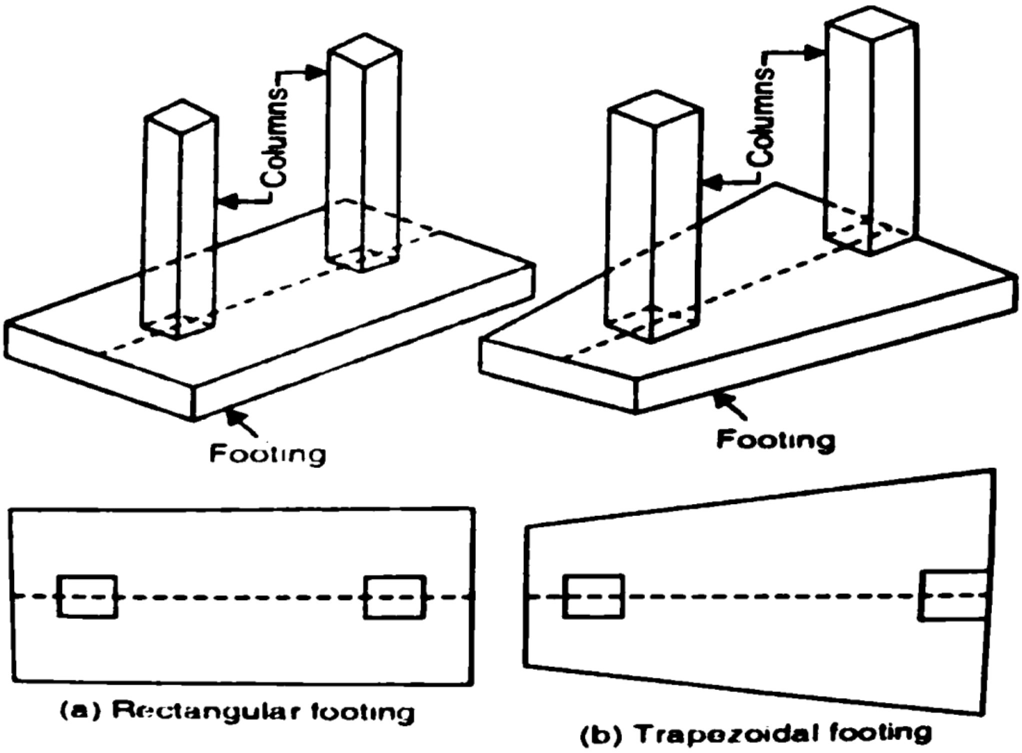
- Use: Under a single column
- Shape: Square, rectangular, circular
- Materials: Plain or Reinforced Concrete
- Features:
    - Simple and economical
    - Load is distributed over a small area
- Example: Columns of residential buildings



(a) Pad Footing (b) Stepped Footing (c) Sloped Footing

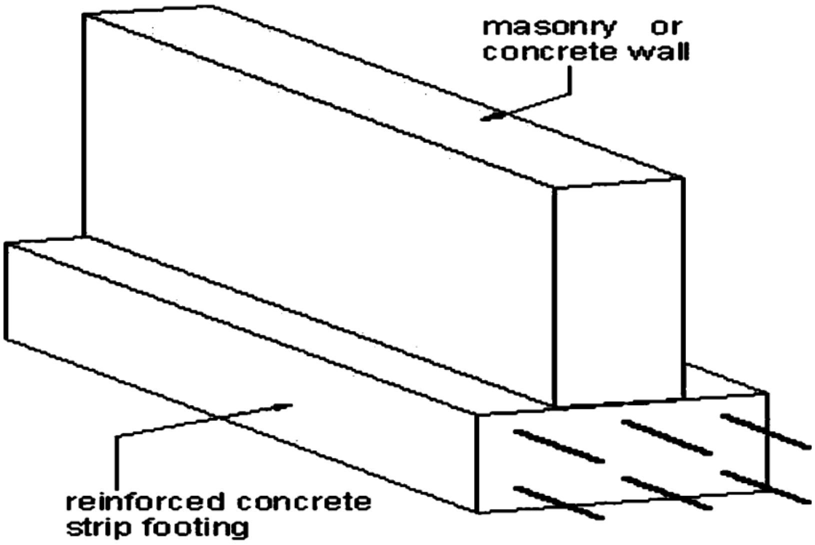
c) Combined Footing

- Use: Supports two or more columns
- Types:
    - Rectangular
    - Trapezoidal (used when one column is near the boundary)
- Features:
    - Load from both columns is shared
    - Reduces differential settlement
- Example: Industrial buildings or constrained plot boundaries



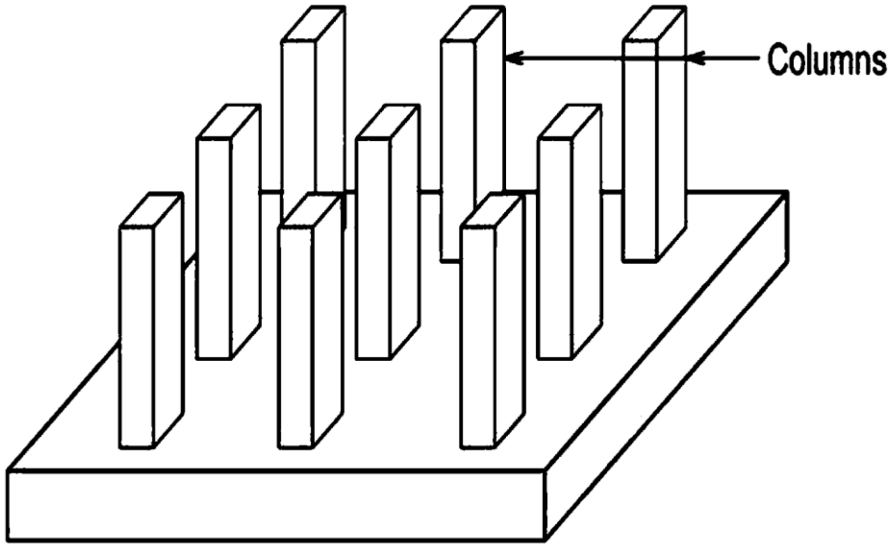
d) Strip Footing

- Use: For load-bearing walls or rows of columns
- Shape: Long continuous footing
- Features:
  - Distributes load along the length
  - Often reinforced longitudinally
- Example: Boundary walls, small commercial buildings



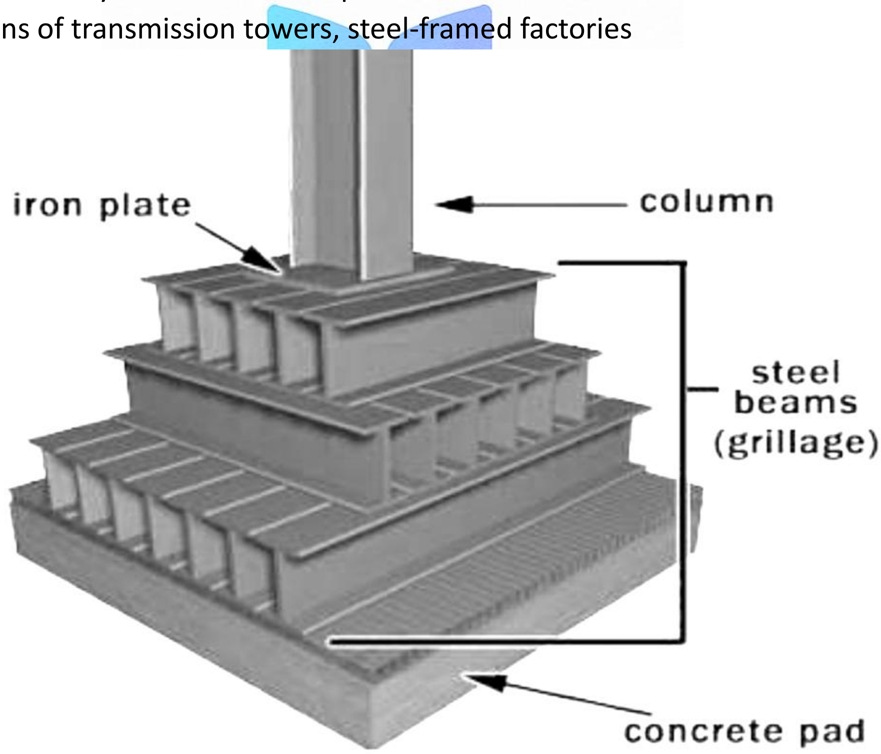
e) Mat or Raft Foundation

- Use: When soil has low bearing capacity or structure is heavily loaded
- Structure: One thick slab covers entire building area
- Features:
  - Reduces differential settlement
  - Acts as floor slab
  - Costly but safer in poor soils
- Example: High-rise apartments, water tanks, basements



f) Grillage Foundation

- Use: Heavy point loads on weak soils
- Structure: Multiple layers of steel beams at right angles embedded in concrete
- Features:
    - Distributes heavy load without deep excavation
- Example: Columns of transmission towers, steel-framed factories

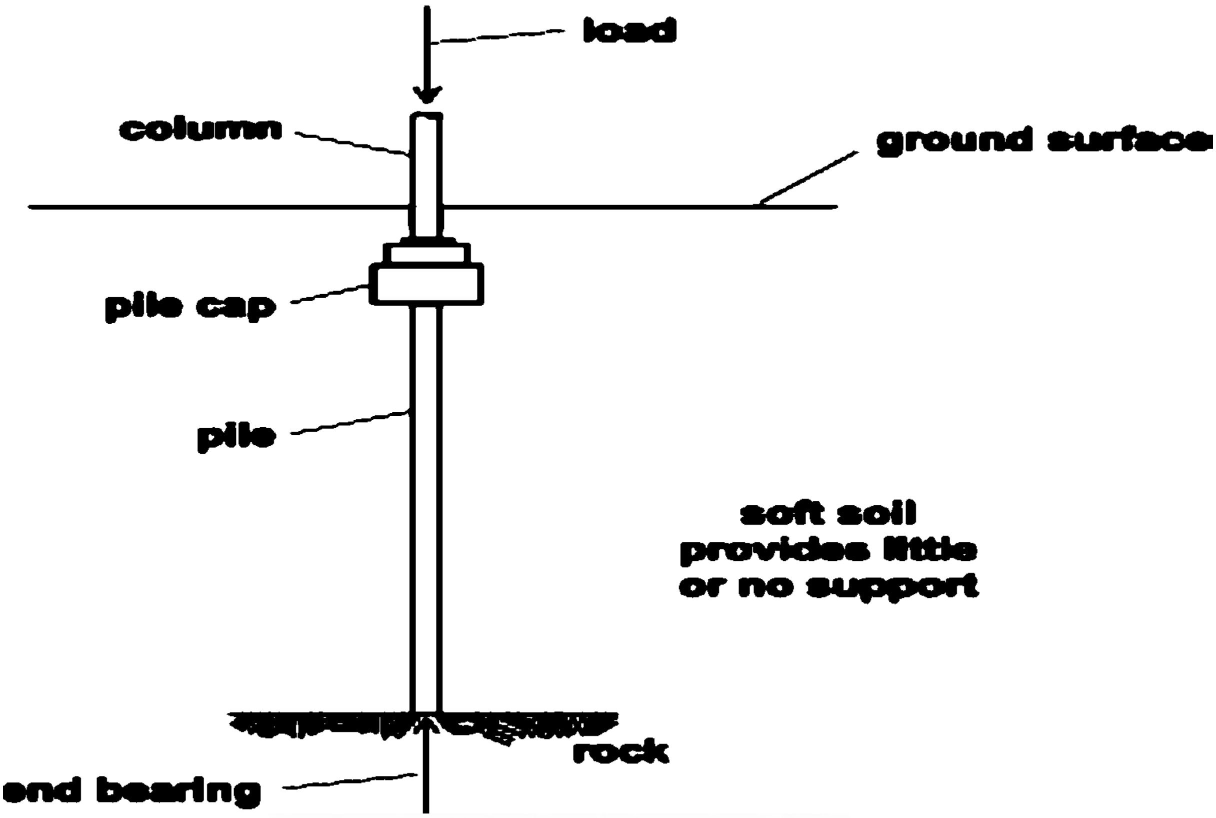


Deep Foundations

Used when bearing strata lies deep below the surface or when superstructure loads are very high.

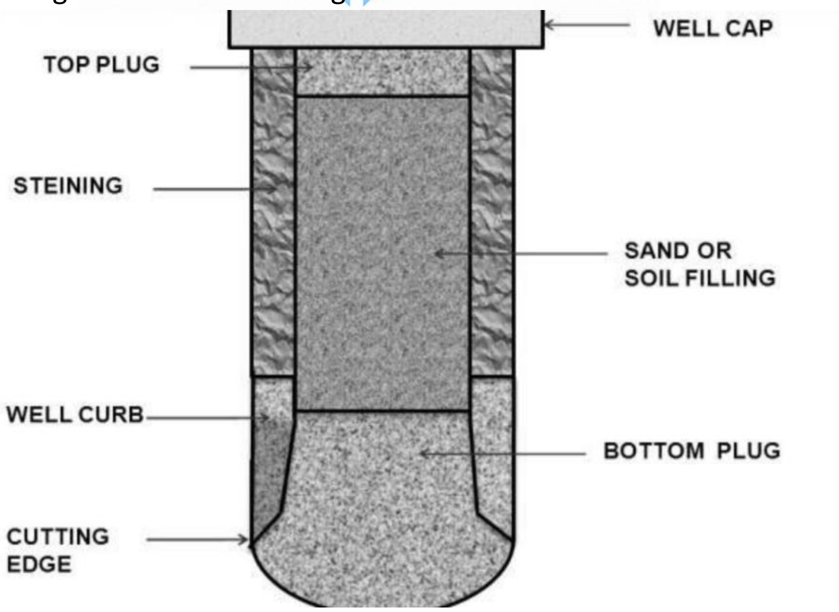
a) Pile Foundation

- Pile foundation is a type of deep foundation which is used to transfer heavy loads from the structure to a hard rock stratum much deep below the ground level.
- Pile foundations are used to transfer heavy loads of structures through columns to hard soil strata which is much below ground level.



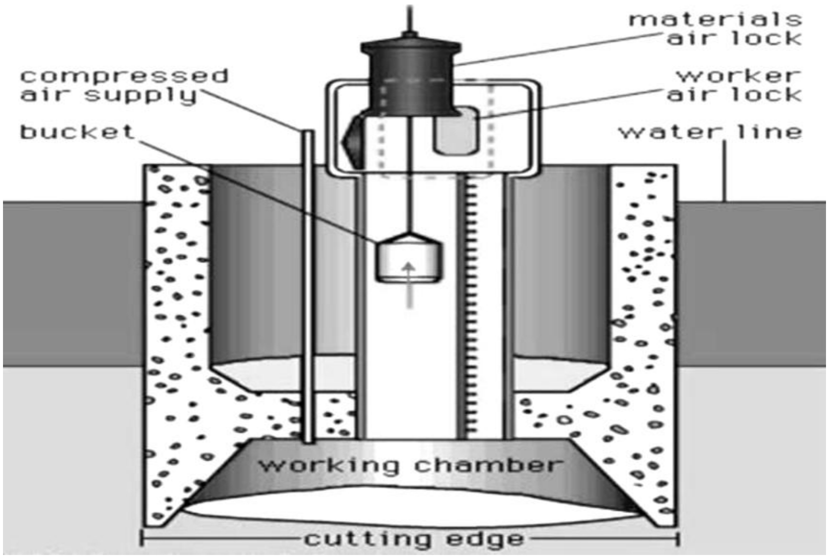
b) Well Foundations (Caissons)

- Use: In deep rivers for bridge piers
- Construction:
  - Large hollow structure (brick/concrete)
  - Sunk gradually by excavation from inside
- Sinking Methods: Open, pneumatic
- Example: Railway bridges like Godavari Bridge



c) Drilled Caissons

- Used In: Offshore structures, towers
- Features:
  - Very large diameter
  - Constructed using special boring equipment
- Example: Wind turbines, oil platforms



SOIL STABILIZATION TECHNIQUES

- *Mechanical Stabilization* – Compaction, adding aggregates
- *Chemical Stabilization* – Lime, cement, fly ash
- *Geosynthetics* – Use of geotextiles, geomembranes for reinforcement
- *Grouting* – Injection of cementitious or chemical solutions into soil

Geotechnical Engineering is essential to ensure that civil infrastructure is well-founded on stable and safe ground. Its comprehensive approach to analysing, testing, and improving soil behaviour forms the very base upon which every structure is built.

TRANSPORTATION ENGINEERING

TYPES OF TRANSPORTATION SYSTEMS

Transportation systems facilitate the mobility of people and goods and are categorized based on the mode of movement:

Land Transportation

1. *Roadways*
    - Examples: National Highways, Expressways, Rural Roads
    - Vehicles: Buses, Trucks, Cars, Two-wheelers
    - Infrastructure: Bridges, Tunnels, Flyovers
    - Roads classified by traffic volume, location, and construction material
2. *Railways*
    - Types: Metro Rail, High-speed Rail (Vande Bharat), Suburban Rails
    - Components: Tracks, Sleepers, Stations, Signals
    - Benefits: High capacity, reliable, lower emissions
3. *Pipelines*
    - Used for transporting oil, natural gas, water, and sewage
    - Can be underground, overground, or underwater

Waterways (Maritime Transport)

- Used for heavy and bulk cargo (e.g., coal, iron, grains)
- Includes rivers (inland waterways), oceans, and seas
- Ports: Vishakhapatnam, Mumbai, Kandla
- Vessels: Ships, Boats, Barges

Airways

- Fastest means of transport over long distances
- Airports, Airstrips, Terminals
- Aircraft types: Passenger (commercial), Cargo, Private jets
- Expensive and weather-sensitive

ROLE OF TRANSPORTATION IN SOCIO-ECONOMIC DEVELOPMENT

Transportation plays a **central role in economic growth, urbanization, and integration**:

Economic Impacts

- Reduces cost of goods through faster delivery
- Improves employment in logistics, construction, and vehicle sectors
- Promotes industrial growth by connecting factories to markets

Social Impacts

- Enhances connectivity between rural and urban areas
- Improves access to education, healthcare, and jobs
- Encourages migration, tourism, and cultural exchange

National Benefits

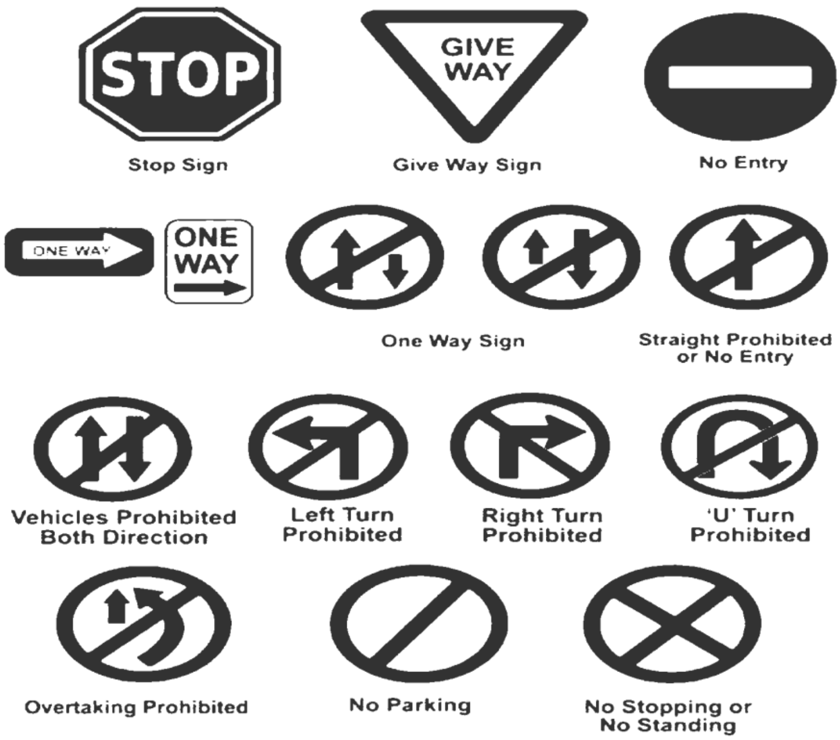
- Strengthens defence logistics
- Ensures supply chain stability in disasters
- Boosts GDP through transport infrastructure investment

ROAD TRAFFIC SIGNS

Road traffic signs are standardized visual indicators used to regulate, warn, or guide road users. As per Indian Road Congress (IRC):

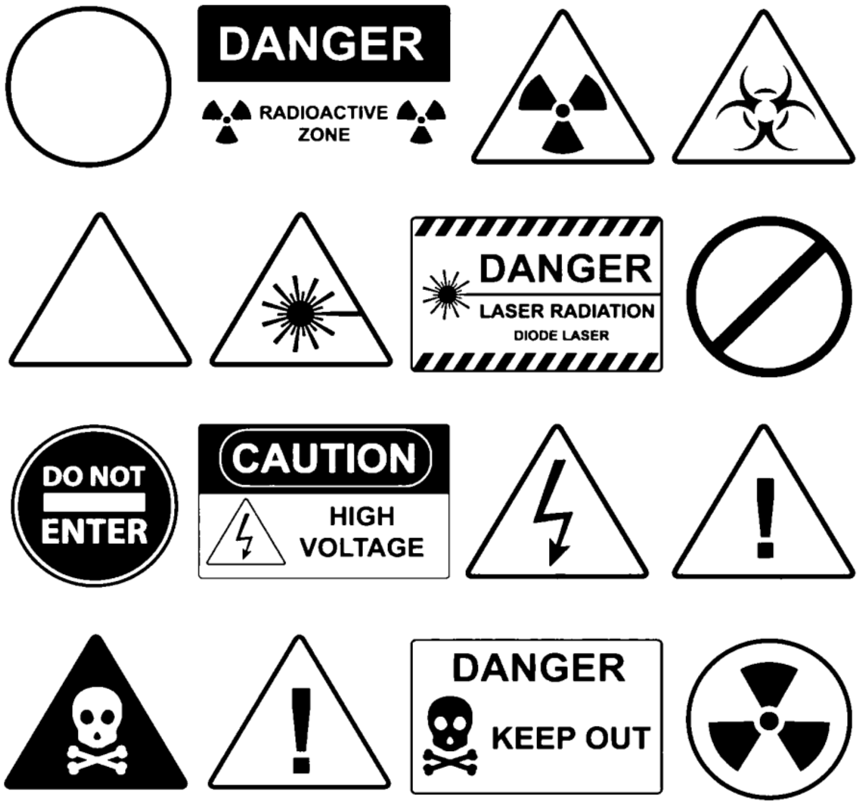
Regulatory Signs (Mandatory)

- Purpose: Enforce traffic laws
- Shape: Circular, red border
- Examples: Stop, Speed Limit, No Entry, One-Way, No Parking, Weight/Height Limits etc.



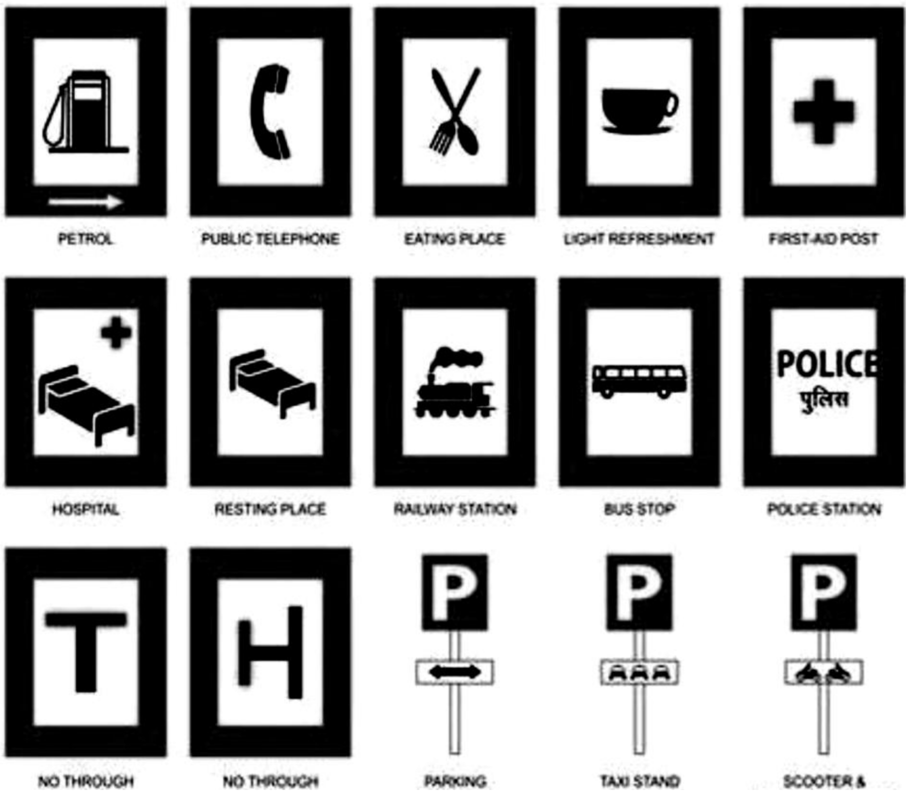
Warning Signs (Cautionary)

- Purpose: Warn about road conditions ahead
- Shape: Triangular, red border
- Examples: Curve Ahead, Slippery Road, Pedestrian Crossing, Steep Descent, School Zone etc.



Informatory Signs (Guide)

- Purpose: Guide to services or locations
- Shape: Rectangular or square, blue background
- Examples: Direction Signs, Distance Boards, Public Facility Signs (e.g., Hospital, Parking) etc.



ACCIDENT PREVENTION & ROAD SAFETY MEASURES

India records the highest number of road fatalities globally. Prevention focuses on human behaviour, vehicle condition, and road design.

Causes of Road Accidents

1. *Human Factors*
    - Over-speeding, drunk driving
    - Ignoring signals, overtaking
    - Distracted driving (mobile phones)
2. *Vehicle Defects*
    - Brake failure, tire burst
    - Faulty lighting or steering
3. *Road Design Flaws*
    - Blind curves
    - Potholes, poor drainage
    - Lack of signage and lighting
4. *Environmental Conditions*
    - Fog, rain, ice
    - Poor visibility

Road Safety Measures

- Drive Left, Overtake Right
- Always use seat belts and helmets
- Adhere to speed limits
- Avoid use of mobile phones while driving
- Give way to emergency vehicles
- Use indicators while changing lanes
- Install reflectors and blinkers on vehicles
- Ensure regular vehicle maintenance
- Never block pedestrian crossings or zebra zones

TRAFFIC CALMING TECHNIQUES

Traffic calming involves physical and visual modifications in roadway layout to reduce speed and enhance pedestrian safety:

Engineering-Based Measures

- *Speed Bumps and Humps* – Force drivers to slow down
- *Rumble Strips* – Alert inattentive drivers
- *Raised Crosswalks* – Make pedestrian presence obvious
- *Chicanes* – Narrow the road path to reduce speed

Visual Design Techniques

- Color-coded lanes
- Road narrowing with markings or landscaping
- Use of contrasting textures (brick paving, cobblestone)

Urban Planning Elements

- Zebra crossings at critical locations
- Roundabouts instead of 4-way stops
- Bollards to prevent vehicle entry into pedestrian-only zones

HYDRAULIC AND WATER RESOURCE ENGINEERING

GROUNDWATER: OCCURRENCE AND MOVEMENT

What is Groundwater?
Groundwater is water that fills the pores and cracks in underground soil and rock layers. It is stored in aquifers and is an essential resource for drinking, agriculture, and industry.

Zones in Subsurface

1. *Zone of Aeration (Vadose Zone):* Unsaturated, pores contain both air and water
2. *Zone of Saturation:* Fully saturated with water — the water table lies here
3. *Capillary Zone:* Water moves upward due to surface tension

Types of Aquifers

- *Unconfined Aquifer:* Water table aquifer, open to atmosphere
- *Confined Aquifer:* Sandwiched between two impermeable layers
- *Perched Aquifer:* Localized water above main water table

PLANNING OF WATER RESOURCES

Water resource planning ensures that water is used sustainably, equitably, and efficiently.

Objectives

- Satisfy domestic, industrial, irrigation, environmental demands
- Manage floods and droughts
- Promote inter-basin transfer of water
- Minimize conflicts among regions and states

Key Steps in Planning

1. Resource assessment (rainfall, surface flow, aquifers)
2. Storage and supply capacity estimation
3. Environmental and social impact analysis
4. Cost–benefit analysis
5. Prioritization of sectors: agriculture, domestic, industry

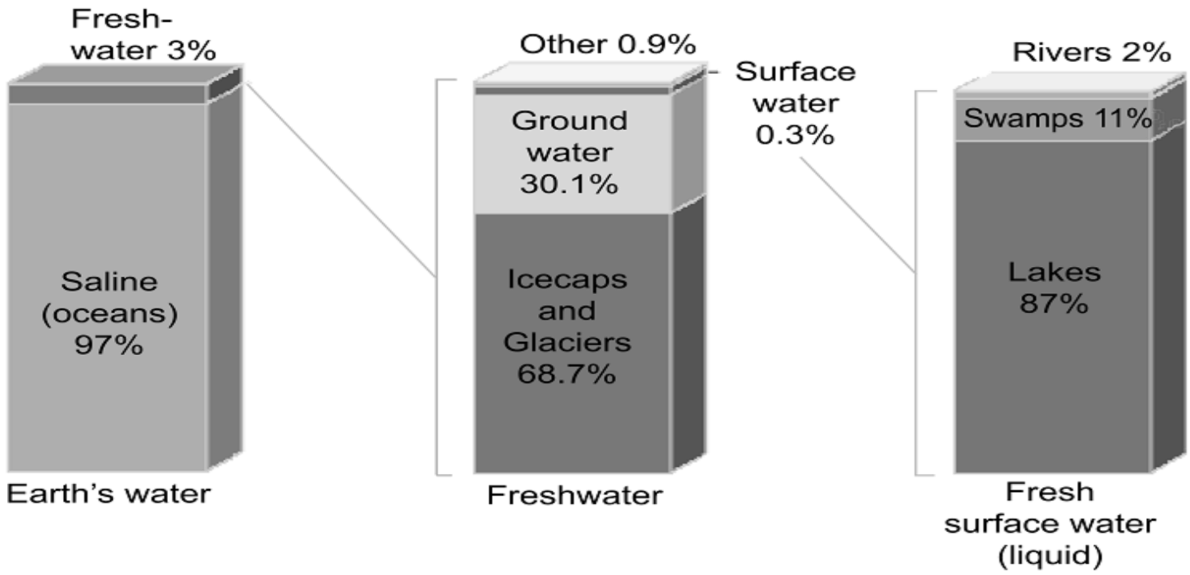
Institutions Involved

- Central Water Commission (CWC)
- Ministry of Jal Shakti
- State Water Boards
- BIS (Bureau of Indian Standards)

FIELD-LEVEL WATER STORAGE STRUCTURES

These structures help in rainwater collection, storage, irrigation, and groundwater recharge:

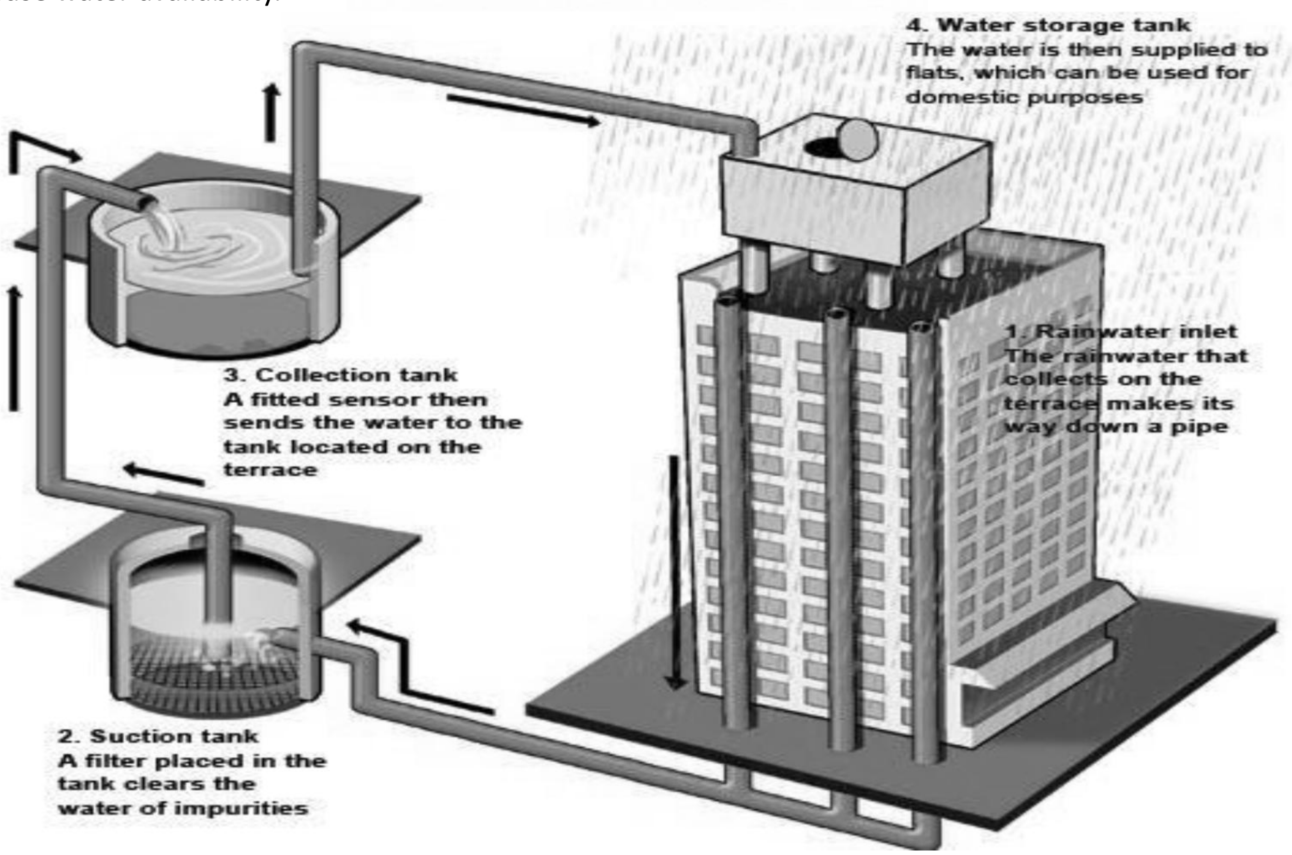
Structure Type	Purpose	Common Materials
Check Dams	Slow surface flow, recharge	Concrete, stone masonry
Percolation Tanks	Recharge groundwater	Earthen bunds, lined pits
Farm Ponds	Irrigation and cattle use	Earth-lined or plastic
Earthen Embankments	Rain runoff storage	Earth compacted walls
Nala Bunding	Prevent soil erosion	Stone/concrete weirs



RAINWATER HARVESTING (RWH)

Definition

The collection and storage of rainwater for future use. Helps recharge aquifers, reduce urban flooding, and increase water availability.



Techniques

1. *Rooftop Rainwater Harvesting*
   - Rain from roof is diverted to storage tanks or recharge pits
   - Uses PVC/HDPE pipes, mesh filters
   - Ideal for homes, schools, and offices
2. *Surface Runoff Harvesting*
   - Captures rainwater from paved/unpaved areas
   - Stored in ponds or tanks for irrigation or recharge

3. *Recharge Wells/Trenches*
    - Used in conjunction with filters to percolate clean rainwater
    - Improves the quality and quantity of groundwater

Benefits

- Reduces water bills and dependency on public supply
- Controls soil erosion and flooding
- Recharges wells and boreholes

WATER POLLUTION AND STANDARDS

Major Sources of Water Pollution

- *Domestic sewage*
- *Industrial effluents* (tanneries, textiles, chemicals)
- *Agricultural runoff* (pesticides, fertilizers)
- *Thermal pollution* (from power plants)

Effects

- Waterborne diseases (cholera, typhoid)
- Aquatic ecosystem disruption
- Bioaccumulation of heavy metals

BIS Standards (IS 10500:2012)

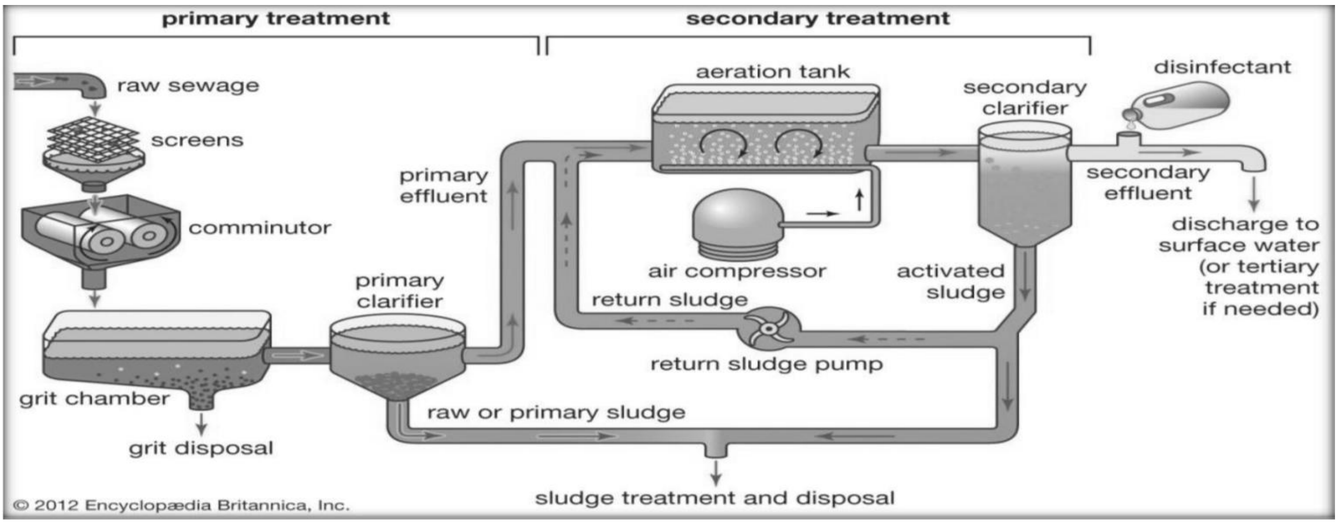
Parameter	Permissible Limit
pH	6.5 – 8.5
Total Dissolved Solids (TDS)	500 mg/L
Nitrate	45 mg/L
Fluoride	1.0 mg/L
Chloride	250 mg/L

Classification of Water Bodies (CPCB)

- *Class A:* Drinking water without treatment
- *Class B:* Outdoor bathing
- *Class C:* Drinking after conventional treatment
- *Class D:* Propagation of wildlife/fisheries
- *Class E:* Irrigation and industrial use

WASTEWATER TREATMENT

Stages of Treatment



Primary Treatment:

- Screening: Removal of floating solids
- Sedimentation: Removes settleable particles
- Grit Chambers: Sand and gravel separation

Secondary Treatment:

- Biological process using aerobic bacteria
- Methods: Activated Sludge Process, Trickling Filters
- Removes BOD (Biological Oxygen Demand) and pathogens

Tertiary Treatment:

- Advanced treatment for disinfection and nutrient removal
- UV, Chlorination, Membrane Filtration
- Makes water suitable for reuse

WATER REUSE AND SAVING

Water Reuse

- *Treated greywater* reused in:
    - Landscape irrigation
    - Flushing toilets
    - Cooling towers
    - Construction activities

Water Saving Methods

- Low-flow taps and dual-flush toilets
- Drip and sprinkler irrigation
- Leak detection systems in pipelines
- Awareness campaigns and incentives

ENVIRONMENTAL AND ENERGY ENGINEERING

ENVIRONMENTAL POLLUTION

Pollution is the introduction of harmful substances or products into the environment, affecting air, water, soil, and living organisms.

A. Air Pollution

- *Sources:* Industrial emissions, vehicular exhaust, burning of fossil fuels, construction dust
- *Pollutants:* CO, NOx, SO_2, PM2.5, PM10, VOCs
- *Health Effects:* Asthma, cancer, cardiovascular disease
- *Control Measures:*
    - Electrostatic precipitators
    - Scrubbers
    - Use of CNG vehicles
    - Plantation and green belts

B. Water Pollution

- *Sources:* Sewage discharge, industrial effluents, chemical fertilizers, oil spills
- *Pollutants:* BOD, COD, heavy metals, nitrates, phosphates
- *Control Measures:*
    - Effluent Treatment Plants (ETPs)

- Sewage Treatment Plants (STPs)
- Rainwater harvesting and wastewater recycling
- Safe disposal of chemicals

C. Soil Pollution

- *Sources:* Pesticides, fertilizers, industrial waste, heavy metals
- *Effects:* Reduced soil fertility, groundwater contamination
- *Control Measures:*
    - Use of bio-fertilizers
    - Ban on single-use plastics
    - Proper landfill design

D. Noise Pollution

- *Sources:* Traffic, construction, industrial machinery, loudspeakers
- *Measurement:* Decibel (dB)
- *Acceptable Limits (CPCB):*
    - Residential: 55 dB (day), 45 dB (night)
    - Industrial: 75 dB (day), 70 dB (night)
- *Control:* Noise barriers, zoning, green buffers, timing restrictions

ENVIRONMENTAL PROTECTION ACTS

India has several legislative measures to safeguard the environment:

Act / Rule	Year	Purpose
Environment Protection Act	1986	Umbrella law for all pollution control
Water (Prevention & Control)	1974	Prevent pollution of water bodies
Air (Prevention & Control)	1981	Regulate air pollution
EIA Notification	2006	Mandatory Environmental Impact Assessments
National Green Tribunal Act	2010	Specialized court for environmental issues
Noise Pollution Rules	2000	Sets decibel limits
Hazardous Waste Rules	2016	Controls hazardous industrial waste

FUNCTIONAL ECOLOGY

Ecology is the study of interactions among living organisms and their environment. Functional ecology focuses on processes and roles in ecosystems.

Key Concepts

- *Biotic Components:* Plants (producers), animals (consumers), microbes (decomposers)
- *Abiotic Components:* Soil, water, sunlight, temperature
- *Trophic Levels:*
    1. Primary Producers (Plants)
    2. Primary Consumers (Herbivores)
    3. Secondary Consumers (Carnivores)
    4. Decomposers (Fungi, Bacteria)

TYPES OF ECOSYSTEMS

Ecosystems can be classified into:

A. Natural Ecosystems:

- *Forest Ecosystems* – Rich biodiversity, high carbon absorption
- *Desert Ecosystems* – Dry climate, cacti, reptiles

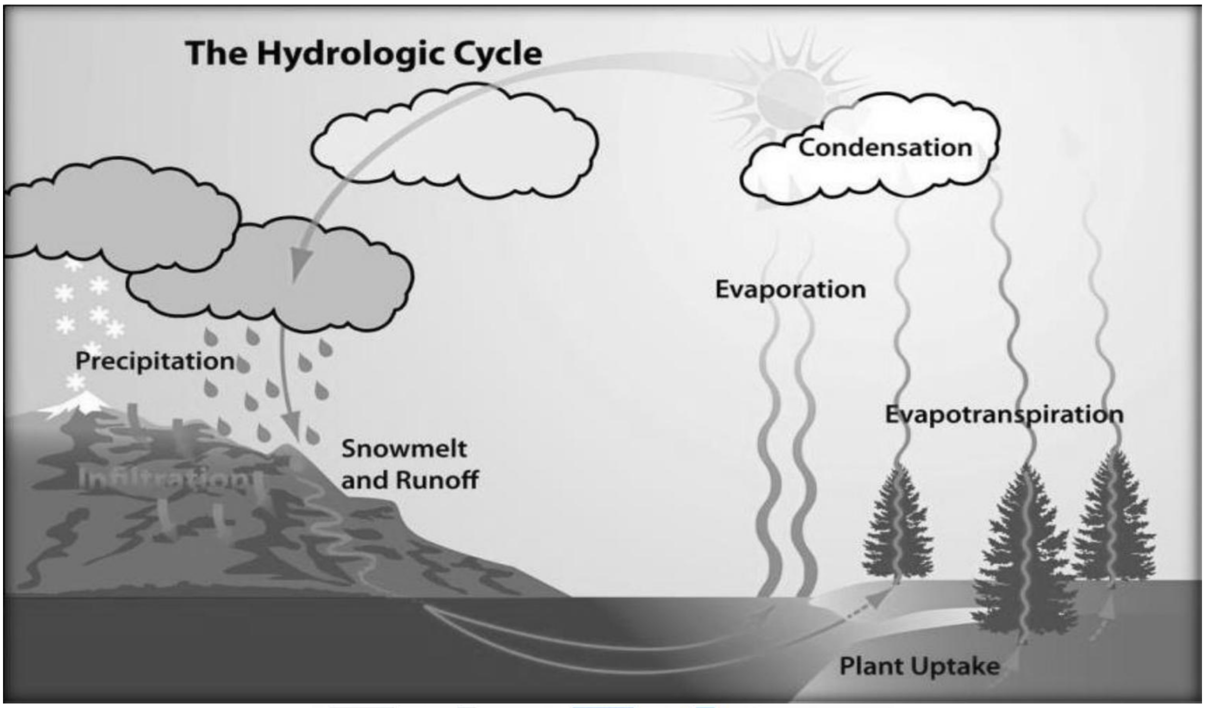
- *Grassland Ecosystems* – Prairies, Savannahs
- *Aquatic Ecosystems* – Oceans, lakes, rivers, wetlands

B. Artificial Ecosystems:

- *Agricultural Lands* – Cropland ecosystems managed by humans
- *Urban Ecosystems* – Cities and towns with human-altered landscapes
- *Reservoirs and Parks* – Human-made for water, recreation, and conservation

HYDROLOGICAL (WATER) CYCLE

The hydrological cycle describes the continuous movement of water on, above, and below the Earth's surface.



Stages

1. *Evaporation:* Sun heats surface water
2. *Condensation:* Vapor forms clouds
3. *Precipitation:* Rain/snow falls to Earth
4. *Infiltration:* Water enters soil and aquifers
5. *Runoff:* Water flows to rivers/oceans
6. *Transpiration:* Plant evaporation

Importance

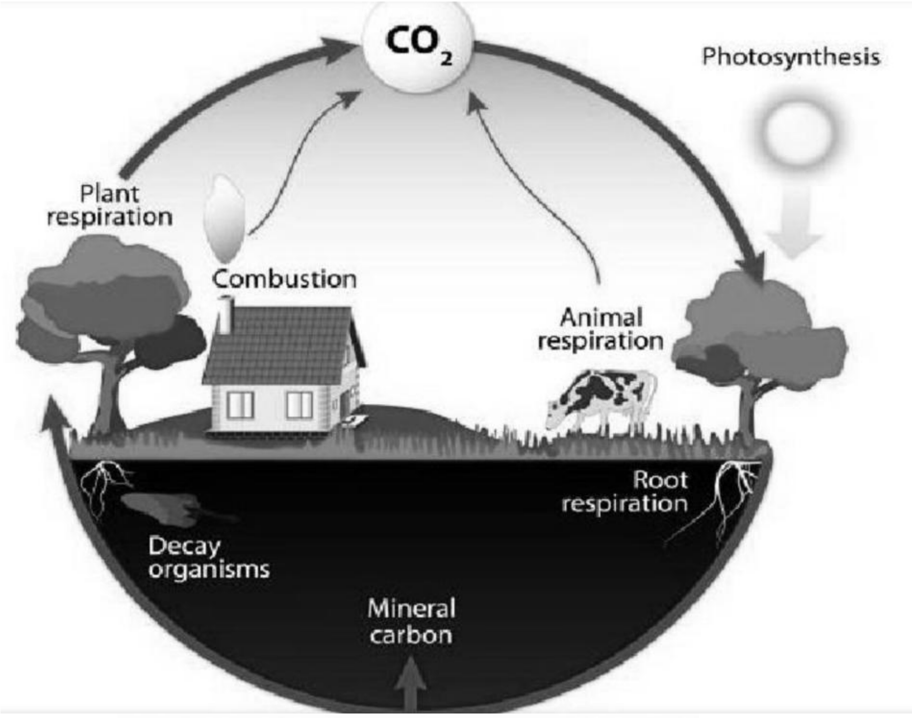
- Maintains water availability
- Regulates climate and weather
- Recharges groundwater and reservoirs

CHEMICAL (BIOGEOCHEMICAL) CYCLES

These are natural recycling systems that move essential nutrients through ecosystems.

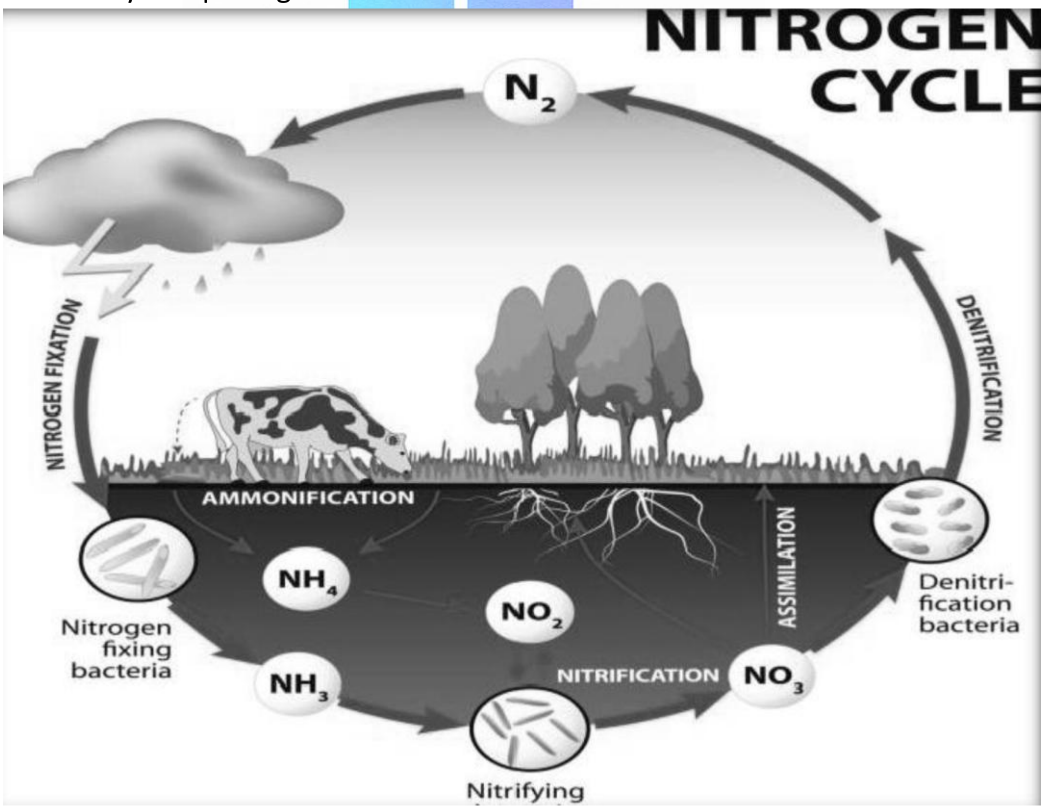
A. Carbon Cycle:

- Photosynthesis: Plants absorb CO_2
- Respiration: Organisms release CO_2
- Combustion & Decomposition return CO_2 to the atmosphere
- Oceans act as carbon sinks



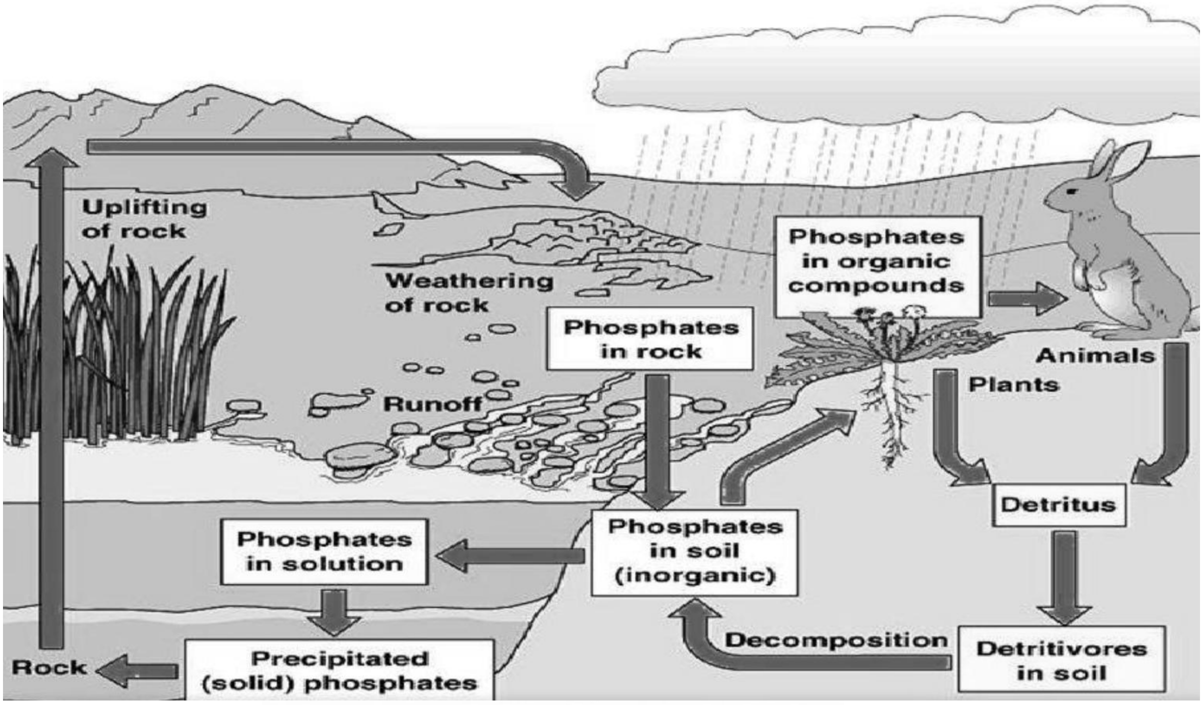
B. Nitrogen Cycle:

- Nitrogen Fixation (lightning, bacteria)
- Nitrification ($NH_3 \rightarrow NO_2^- \rightarrow NO_3^-$)
- Assimilation by plants
- Ammonification and Denitrification by bacteria
- Balances soil fertility and plant growth



C. Phosphorus Cycle:

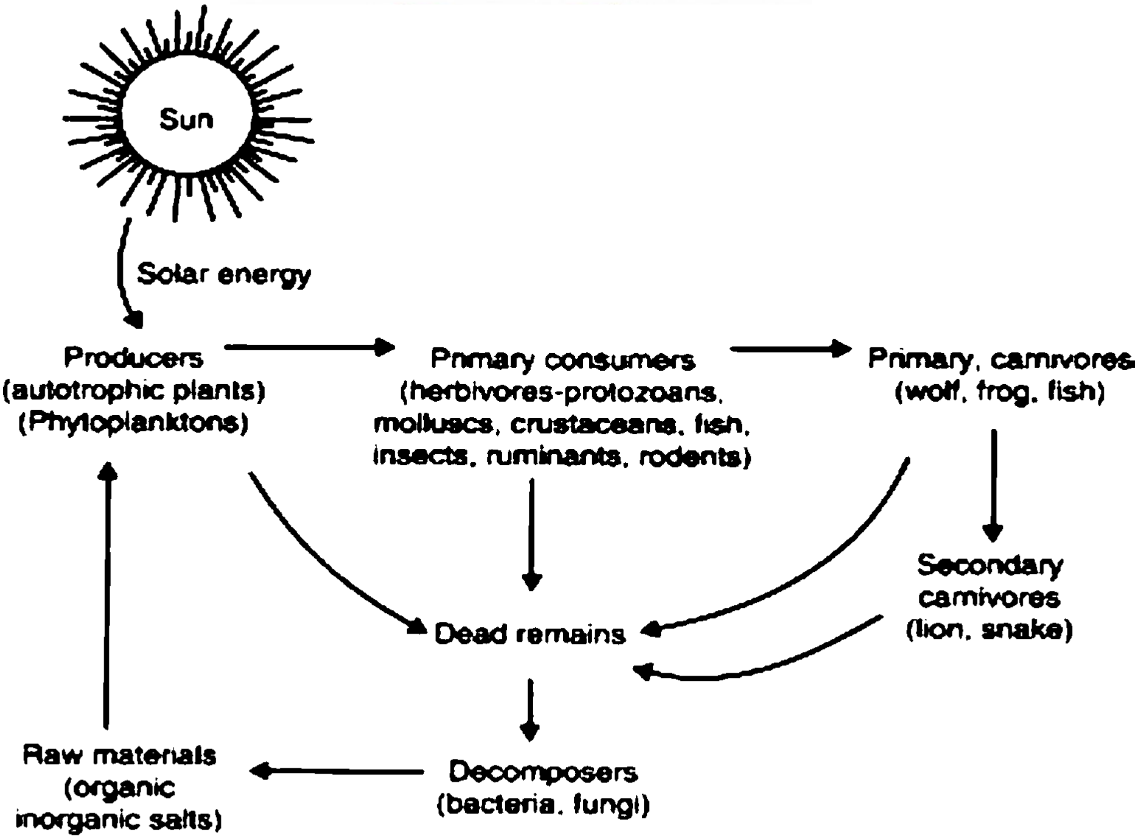
- Moves through rocks → soil → plants → animals → decomposers
- Unlike carbon/nitrogen, does not involve atmosphere
- Essential for DNA, ATP, bone formation



ENERGY FLOW IN ECOSYSTEMS

Source

- All energy in ecosystems originates from the **Sun**



Flow Path

- Sunlight → Plants (Producers) → Herbivores → Carnivores → Decomposers
- Governed by Laws of Thermodynamics:
    1. *First Law:* Energy cannot be created or destroyed
    2. *Second Law:* Energy decreases as it moves up trophic levels (10% rule)

Food Chains and Webs

- *Food Chain:* Linear flow (e.g., Grass → Deer → Tiger)
- *Food Web:* Network of interconnected food chains

RENEWABLE AND NON-RENEWABLE ENERGY SOURCES

A. Renewable Energy

- Naturally replenished, eco-friendly, long-term sustainable

Source	Features
Solar	Solar panels, rooftop systems
Wind	Wind turbines in coastal/plateau
Hydropower	Dams, run-of-river, tidal energy
Biomass	Organic waste → biofuels/gas
Geothermal	Heat from Earth's crust

B. Non-Renewable Energy

- Finite sources formed over millions of years

Source	Drawbacks
Coal	Major air pollutant (CO_2, SO_2)
Petroleum	Prone to spills, CO_2 emission
Natural Gas	Cleaner fossil fuel but limited
Nuclear	Radioactive waste and high risk

SUSTAINABLE ENGINEERING PRACTICES

- *Green Buildings:* Use of daylighting, passive ventilation, energy-efficient design
- *LEED Certification:* Rating for energy-efficient buildings
- *Rainwater Harvesting:* Integrating RWH in architecture
- *Net Zero Buildings:* Produce as much energy as they consume
- *Smart Meters:* Monitor energy consumption