

Module 1: Introduction to Civil Engineering

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1. Overview of Civil Engineering

1.1 Definition

Civil Engineering is the branch of engineering that deals with the planning, design, construction, operation and maintenance of the physical infrastructure required by society – buildings, roads, railways, bridges, dams, canals, water supply and sanitation systems.

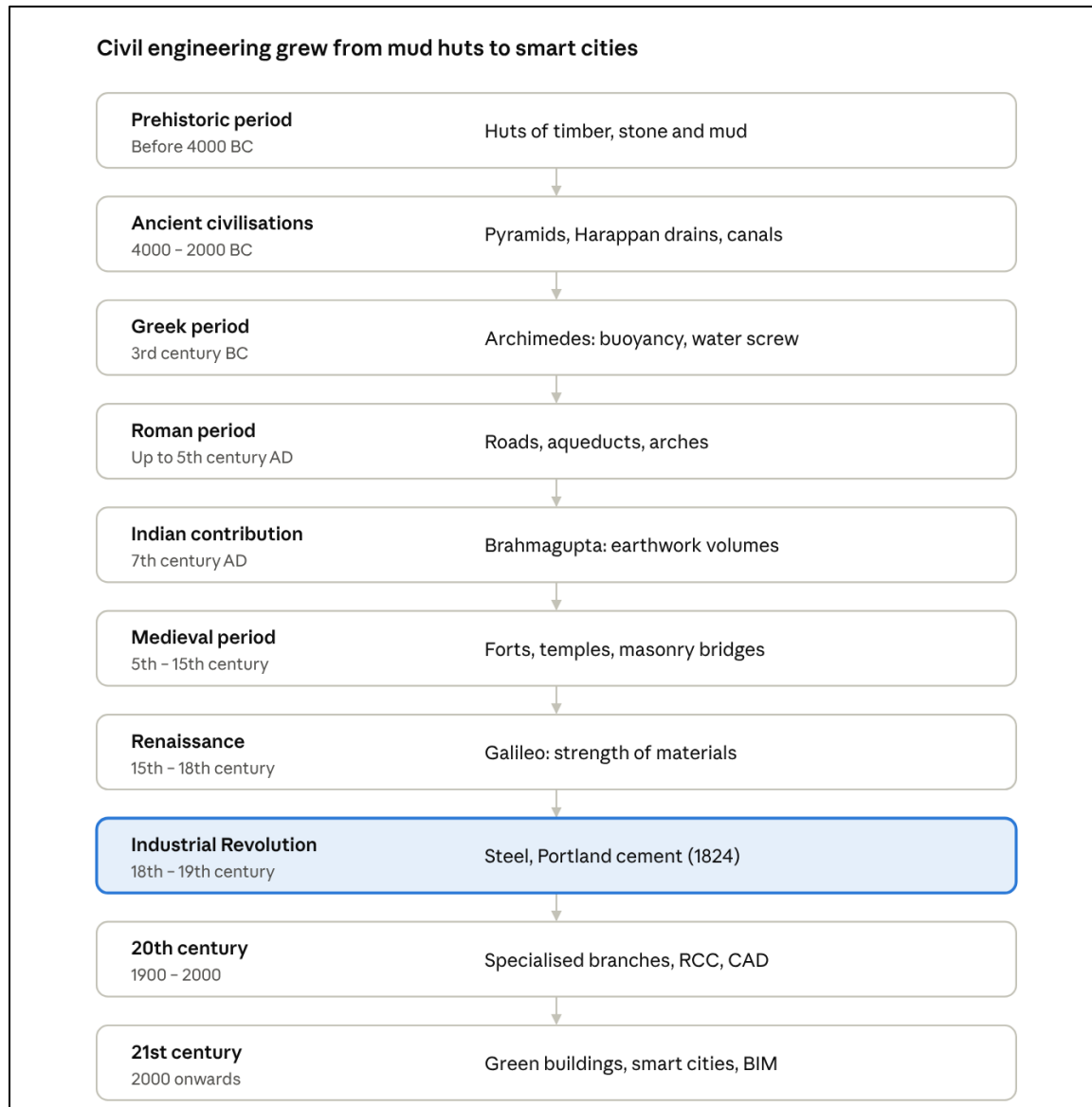
Standard definition (Royal Charter of the Institution of Civil Engineers, London, 1828): Civil engineering is *"the art of directing the great sources of power in nature for the use and convenience of man."*

Definition by the American Society of Civil Engineers (ASCE), *"Civil engineering is the profession in which a knowledge of the mathematical and physical sciences, gained by study, experience and practice, is applied with judgement to develop ways to utilise, economically, the materials and forces of nature for the progressive well-being of humanity – in creating, improving and protecting the environment, in providing facilities for community living, industry and transportation, and in providing structures for the use of humanity."*

Civil engineering is the branch of engineering that deals with the **planning, design, construction, maintenance and operation** of infrastructure such as buildings, roads, bridges, dams, water supply and sanitation systems, for the safety and well-being of society.

The word *civil* distinguishes it from *military* engineering. It is the oldest engineering discipline after military engineering and is often called the **mother of all engineering branches**.

1.2 Brief History of Civil Engineering



Flowchart: History of civil engineering

The Industrial Revolution (highlighted) is the turning point: steel and Portland cement made modern construction possible.

1. **Prehistoric period (before 4000 BC):** Early humans built simple huts using timber, stone, mud and leaves. Construction was by trial and error, without any science.

2. **Ancient civilisations (4000 – 2000 BC):** People settled in river valleys and built permanent houses, canals and drains. Examples: Egyptian pyramids and the planned cities of Harappa and Mohenjo-daro.
3. **Greek period (3rd century BC):** Archimedes gave the principle of buoyancy and the Archimedes screw for lifting water. Engineering started to use scientific principles.
4. **Roman period (up to 5th century AD):** Romans built durable roads, aqueducts, bridges and domes. They used the semicircular arch and lime concrete.
5. **Indian contribution (7th century AD):** Brahmagupta used arithmetic and geometry to calculate the volume of excavations. This helped in earthwork calculations.
6. **Medieval period (5th – 15th century):** Forts, castles, cathedrals, temples and masonry bridges were built. Stone masonry and arches were widely used.
7. **Renaissance (15th – 18th century):** Scientists like Galileo studied the strength of materials. Construction moved from rule-of-thumb to scientific design.
8. **Industrial Revolution (18th – 19th century):** Iron and steel were mass-produced and Portland cement was invented (Joseph Aspdin, 1824). Railways, long bridges and factories were built.
9. **20th century:** Civil engineering divided into branches such as structural, geotechnical and transportation engineering. RCC, prestressed concrete and computer-aided design (CAD) came into use.
10. **21st century:** The focus is on sustainable and smart construction. Examples: green buildings, smart cities, Building Information Modelling (BIM).

2. Relevance of Civil Engineering in the Infrastructural Development of a Nation

Infrastructure is defined as the basic physical and organisational structures and facilities (buildings, roads, power supply, etc.) needed for the operation of a society and for its economic development.

Infrastructure is broadly grouped as:

- **Economic (physical) infrastructure:** roads, railways, bridges, airports, ports, dams and canals, power stations, factories, industrial townships.
- **Social infrastructure:** schools, hospitals, housing, water supply, sanitation, community buildings.

Role of the civil engineer (points for the examination)

1. **Planning, design and maintenance:** Civil engineers plan, design, construct, supervise, operate and maintain infrastructure projects in the public and private sectors.
2. **Economic development:** Roads, railways, ports and power projects increase production and trade; infrastructure growth directly raises a nation's GDP.
3. **Social infrastructure:** Housing, schools, hospitals and water supply improve the quality of life and indirectly support economic growth.

4. **Transportation:** Design and construction of highways, railways, airports, harbours and metro systems for movement of people and goods.
5. **Water resources management:** Dams, reservoirs, canals and groundwater schemes ensure water supply for drinking, irrigation and hydropower throughout the year.
6. **Urban planning:** Planned development of towns, smart cities and vertical growth to handle rapid urbanisation and high land cost.
7. **Rural development:** Low-cost housing, rural roads (e.g. PMGSY), minor irrigation and drinking water schemes.
8. **Environmental protection and pollution control:** Water and wastewater treatment, solid waste management, and control of air, water and land pollution.
9. **Disaster mitigation:** Earthquake- and cyclone-resistant structures, flood control works and retaining structures.
10. **Research and training:** Development of new materials, construction technology and codes of practice; training of skilled manpower.

3. Building Materials and Their Significance

3.1 Cement

Definition: Cement is a finely ground **hydraulic binding material** which, when mixed with water, undergoes a chemical reaction (hydration), sets and hardens, and binds sand and coarse aggregate into a solid mass.

Important technical terms

Term	Meaning
Hydration	Chemical reaction of cement with water that makes it set and harden
Setting time	Initial ≥ 30 min; final ≤ 600 min (10 h) for OPC
Grade of cement	28-day compressive strength in N/mm^2 – OPC 33, 43, 53 grades

Common types of cement: Ordinary Portland Cement (OPC), Portland Pozzolana Cement (PPC – with fly ash), Portland Slag Cement (PSC – with GGBS), Rapid Hardening Cement, Sulphate Resisting Cement, Low Heat Cement, White Cement.

Uses of cement

1. Preparation of **mortar** for masonry, plastering and pointing.
2. Preparation of **concrete** for foundations, columns, beams, slabs, lintels and stairs.
3. Construction of important structures – bridges, culverts, dams, tunnels, lighthouses.
4. Manufacture of precast products – pipes, piles, poles, fencing posts, paver blocks.
5. Construction of water-retaining structures – tanks, wells, swimming pools.
6. Making joints in drains and pipes, and for water-tightness of structures.

7. Construction of roads, footpaths and floors.

Significance of cement

Point	Significance
Binding material	Binds aggregates into a strong, solid mass
Strength	Gives strength to concrete and mortar (33, 43, 53 grades)
Hydraulic property	Sets and hardens even under water – dams, foundations
Durability	Long-lasting structures that resist weather and loads
Mouldability	Fresh concrete can be cast into any shape
Economy	Supports construction and employment; India is the 2nd largest producer

Mortar

Definition: Mortar is a workable paste prepared by mixing a **binding material** (cement or lime), **fine aggregate** (sand) and **water** in suitable proportions. It is used to **bind masonry units** (bricks, stones, blocks) together and for plastering and pointing.

When cement is the binding material, the mix is called **cement mortar**. Its proportion is written as cement : sand, e.g. **1 : 4** means 1 part cement to 4 parts sand by volume.

Mixture	Name	Typical use
Cement + water	Cement paste (neat cement)	Binding agent inside mortar and concrete
Cement + water (thin, flowing)	Cement slurry / grout	Filling cracks and joints, bonding old and new concrete
Cement + sand + water	Cement mortar	Brick and stone masonry (1 : 4 to 1 : 6), plastering (1 : 3 to 1 : 6), pointing (1 : 2 to 1 : 3)
Lime + sand + water	Lime mortar	Masonry and plastering in old and heritage buildings
Cement + sand + coarse aggregate + water	Cement concrete	Foundations, beams, columns, slabs

Key point: Cement becomes **mortar** only when **sand (fine aggregate)** is added to cement paste. When **coarse aggregate** is also added, it is no longer mortar – it is **concrete**.

3.2 Aggregates

Definition: Aggregates are **inert granular materials** such as sand, gravel, crushed stone and recycled concrete, which are bound together by cement paste to form concrete or mortar. They are obtained by natural disintegration or artificial crushing of rocks. Aggregates occupy about **60–75 % of the volume** (70–85 % of the mass) of concrete.

Classification based on size

Type	Standard definition (based on IS sieve)	Size range	Examples
Fine aggregate	Aggregate passing through a 4.75 mm IS sieve and retained on a 75 micron IS sieve	0.075 mm to 4.75 mm	River sand, manufactured sand (M-sand), crushed stone sand
Coarse aggregate	Aggregate retained on a 4.75 mm IS sieve	4.75 mm and above (commonly 10, 12.5, 20, 40 mm; up to 80 mm)	Crushed stone (jelly), gravel, broken brick

Note: material finer than 75 μm is called silt/clay (fines) and is not treated as fine aggregate.

Sources

- **Fine aggregate:** Natural river sand formed by weathering and water action, washed to remove silt and organic impurities; or manufactured sand (M-sand) produced by crushing hard rock.
- **Coarse aggregate:** Obtained from quarries, where rock is blasted and crushed in crushers into required sizes, giving better control over size and shape.

Important technical term

Term	Meaning
Grading	Distribution of particle sizes, found by sieve analysis

Uses of aggregates

1. Principal ingredient of concrete and mortar.
2. Base and sub-base layers of roads and railway ballast.
3. Filter media in water treatment and drainage.
4. Foundations, flooring and landscaping.

Significance of aggregates

Point	Significance
Economy	Cheaper than cement and fill 60–75 % of volume – lower cost
Strength	Form a strong skeleton that gives strength and stiffness
Less shrinkage	Restrain shrinkage of cement paste; fewer cracks
Durability	Resist wear and weathering
Proper grading	Fewer voids, less cement and water needed
Workability	Shape, texture and grading control workability and density

3.3 Concrete

Definition: Concrete is a **composite construction material** obtained by mixing cement (binder), fine aggregate, coarse aggregate and water, with or without admixtures, in suitable proportions. The mix is placed in moulds (formwork), compacted and cured, and it hardens into a stone-like mass.

Concrete is **strong in compression but weak in tension** (tensile strength is only about 10 % of its compressive strength).

Types of concrete

Type	One-line definition	Typical uses
Plain Cement Concrete (PCC)	Concrete made of cement, sand, coarse aggregate and water without any reinforcement ; it resists only compressive loads.	Levelling course (bed concrete) below foundations, floors, pavements
Reinforced Cement Concrete (RCC)	Concrete in which steel bars are embedded so that concrete resists compression and steel resists tension.	Beams, columns, slabs, footings, bridges, water tanks

Important technical terms

Term	Meaning
Grade (e.g. M20)	M = mix; 20 = compressive strength of 150 mm cube at 28 days (N/mm ²)

Term	Meaning
Water–cement ratio	Weight of water ÷ weight of cement; lower ratio gives higher strength
Workability	Ease of placing and compacting fresh concrete (slump test)
Curing	Keeping concrete moist (min. 7 days) so it gains strength

Uses of concrete

1. **Foundations and footings** – stable base that spreads load to the soil.
2. **Beams, columns and slabs** – the structural frame of buildings.
3. **Pavements** – roads, highways, runways and footpaths.
4. **Bridges and flyovers.**
5. **Dams, canals and retaining walls.**
6. **Water tanks** and other water-retaining structures.
7. **Precast products** – pipes, poles, panels, paver blocks, kerbs.
8. **Architectural and decorative work** – façades, jaalis, garden furniture.

Significance of concrete

Point	Significance
High compressive strength	Supports heavy loads
Durability	Long life, little maintenance
Mouldability	Can be cast into any shape and size
Economy	Locally available ingredients
Fire resistance	Non-combustible; protects embedded steel
Monolithic construction	Members cast together give rigidity
Sustainability	Can be recycled as aggregate

3.4 Steel

Definition: Steel is an **alloy of iron and carbon**, with carbon content generally between about 0.05 % and 1.5 % (always less than 2 %), along with small amounts of manganese, silicon, sulphur and phosphorus. It has **high tensile and compressive strength** and is ductile.

Carbon is added to iron mainly to **increase hardness and tensile strength**; however, more carbon reduces ductility and weldability.

Important technical terms

Term	Meaning
Mild steel	Low-carbon steel; ductile and easily welded
Ductility	Ability to stretch a lot before breaking
TMT / HYSD bars	Reinforcement bars graded Fe 415, Fe 500, Fe 550 (yield strength, N/mm ²)

Uses of steel

1. **Reinforcement (rebars)** in RCC beams, columns, slabs and footings.
2. **Structural members** – trusses, beams, columns, steel bridges, towers, industrial sheds.
3. **Non-structural works** – grills, doors, windows, gates, railings.
4. **Pipes and tanks** – water pipes, overhead tanks.
5. **Sanitary and plumbing fittings**, rainwater goods.
6. **Roofing** – corrugated galvanised sheets.
7. **Prestressing wires and strands** in prestressed concrete.

Significance of steel

Point	Significance
High strength	High tensile and compressive strength (410–550 MPa)
Complements concrete	Takes tension in RCC; same thermal expansion as concrete
Strength-to-weight ratio	Light sections for long spans and tall buildings
Ductility	Bends before failure – vital in earthquakes
Speed of construction	Prefabricated, quickly erected
Recyclability	Can be recycled repeatedly without loss of quality

3.5 Sustainable Materials

Definition: Sustainable materials are materials that are sourced, manufactured, used and disposed of in a way that **minimises environmental impact**, conserves natural resources and reduces energy consumption and carbon emissions over their life cycle. Examples: bamboo, fly ash bricks, CSEB, recycled aggregate, crumb rubber modified bitumen, reclaimed wood.

Technical terms

Term	Meaning
Embodied energy	Total energy used to produce and transport a material
Carbon footprint	Total greenhouse gases released by a material

Significance of sustainable materials

Point	Significance
Less pollution	Lower greenhouse gas emissions and deforestation
Saves resources	Conserves river sand, fossil fuels and minerals
Uses waste	Recycles industrial and construction waste (fly ash, tyres, debris)
Low energy	Low embodied energy in production
Healthy buildings	Better indoor air quality and thermal comfort
Green rating	Helps buildings earn IGBC / GRIHA green certification

3.5.1 Compressed Stabilized Earth Blocks (CSEB)

Definition: CSEB are masonry blocks made from **local soil mixed with a small quantity of stabiliser** (cement about 5 % or lime), sand and water, **compressed** in a manual or motorised press and then **cured** (not burnt) for about 28 days.

Technical terms

Term	Meaning
Stabilization	Adding cement or lime to soil to improve strength and water resistance
Curing	Keeping blocks moist (about 28 days) to develop strength

Significance of CSEB

Point	Significance
Local material	Uses site soil – saves transport cost
Not burnt	No kiln firing – low energy and low carbon emission
Thermal comfort	Good insulation keeps buildings cool
Durability	Stabiliser gives better strength and rain resistance than mud blocks
Good finish	Uniform size; often no plastering needed

Point	Significance
Economy	Low cost – ideal for rural and affordable housing

Applications: Load-bearing and partition walls, low-cost and rural housing, compound walls, schools and community buildings, eco-resorts and restoration works.

3.5.2 Crumb Rubber Modified Bitumen (CRMB)

Definition: CRMB is bitumen modified by blending it with **crumb rubber** – fine rubber particles obtained by grinding **waste tyres** – along with additives, to improve its elasticity and performance.

Technical terms

Term	Meaning
Bitumen	Black binder from petroleum, used in road surfacing
Crumb rubber	Fine rubber powder from waste tyres
Rutting	Permanent grooves formed along wheel paths on roads

Significance of CRMB

Point	Significance
Elasticity	Resists cracking and rutting under heavy traffic
Temperature resistance	Performs well in both hot and cold weather
Longer pavement life	Better bond with aggregates; resists water damage
Waste utilisation	Uses scrap tyres that would otherwise pollute
Life-cycle economy	Lower maintenance cost, though initial cost is higher

Applications: National and state highways and busy city roads, airport runways, industrial roads, and waterproofing of roofs, tanks and reservoirs.

4. Structural Elements of a Building

A building is divided into two parts: the **substructure** – the part below ground/plinth level (foundation) – and the **superstructure** – the part above plinth level (walls, columns, beams, slabs, roof). Load passes from **slab** → **beam** → **column (or wall)** → **foundation** → **soil**.

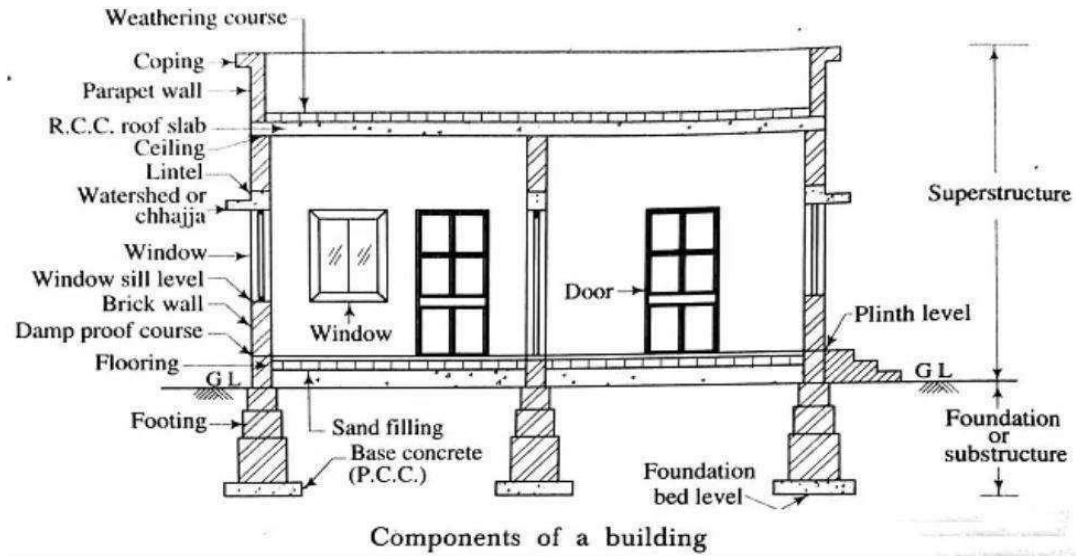


Figure 1: Components of a building (substructure and superstructure)

Sl. No.	Structural element	Definition	Function
1	Foundation	The lowest part of a building, below ground level, which rests on the soil.	Carries the whole load of the building safely to the soil and keeps the building stable.
2	Plinth	The part of the building between ground level and the ground floor level.	Raises the floor above ground level and keeps out rain water, dampness and insects.
3	Plinth beam	An RCC beam provided at plinth level over the foundation.	Spreads wall load evenly on the foundation and stops cracks from reaching the walls.
4	Damp Proof Course (DPC)	A layer of waterproof material laid at plinth level across the wall.	Stops moisture from the ground rising into the walls.
5	Masonry wall	A wall built of bricks, stones or blocks joined with mortar.	Encloses and divides rooms, carries loads and protects from weather.
6	Sill	The horizontal member at the bottom of a window opening.	Supports the window frame and drains rain water away from the wall.

7	Lintel	A horizontal beam placed over a door or window opening.	Carries the wall above a door or window opening and transfers the load to the side walls.
8	Chajja (sunshade)	A projecting slab provided over an outside door or window.	Protects doors and windows from rain and direct sunlight.
9	Column	A vertical member that carries loads mainly in compression.	Carries loads from beams and slabs down to the foundation.
10	Beam	A horizontal member that carries loads by bending.	Supports slabs and walls and transfers their load to the columns.
11	Slab	A flat, thin horizontal RCC plate forming a floor or roof.	Provides floor and roof surfaces and transfers loads to beams or walls.
12	Staircase	A series of steps connecting one floor to another.	Gives safe and easy movement from one floor to another.
13	Parapet	A low wall built along the edge of a roof or terrace.	Prevents people from falling off the roof or terrace.
14	Roof	The topmost covering of a building.	Covers the building and protects it from rain, sun and wind.

5. Building Byelaws

Definition: Building byelaws are the **rules and regulations framed by local authorities** (municipal corporations, development authorities, panchayats), based on the **National Building Code of India (NBC 2016)**, to control the planning, design, construction and use of buildings. They ensure safety, health, convenience, adequate light and ventilation, and orderly development of an area.

5.1 Planning Regulations

Definition: Planning regulations are the rules that control **land use, plot size, access, open spaces, building area, height and parking** so that towns develop in a planned manner (NBC 2016, Part 3 – Development Control Rules).

Objectives

1. Planned and systematic development of urban areas.
2. Regulation of land use for residential, commercial, industrial and other activities.
3. Safe and convenient access to buildings.
4. Adequate natural light and ventilation.
5. Sufficient open space around buildings.
6. Control of building height, coverage and density.
7. Public health, safety and fire safety.
8. Adequate parking and traffic facilities.

Main components

1. **Land use classification** – residential, commercial, industrial, educational, public and semi-public, etc.
2. **Requirements of plots** – minimum plot size, frontage and shape.
3. **Means of access** – minimum width of roads and entrances.
4. **Open spaces** – front, rear and side setbacks.
5. **Area and height limitations** – ground coverage, FAR and maximum height.
6. **Parking requirements** – parking space in proportion to built-up area or dwelling units.

5.2 Open Space Requirements

Definition: Open space is an area forming an integral part of a plot, **left open to the sky**, between the building and the plot boundaries. It is also called **setback**.

Types of open spaces

1. **Front open space (front setback):** Between the front boundary (road side) and the building; gives access for people and vehicles and improves appearance.
2. **Rear open space (rear setback):** Between the rear boundary and the building; gives light, ventilation and space for services and maintenance.
3. **Side open space (side setback):** Between the side boundaries and the building; gives ventilation, privacy and access around the building.

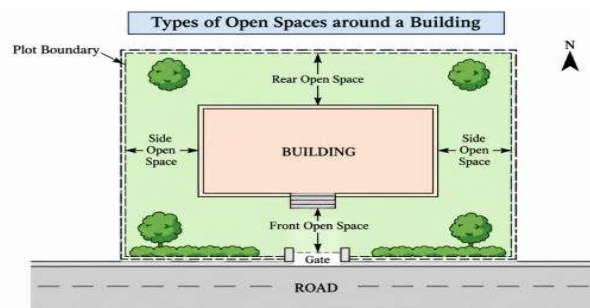


Figure 11: Types of open spaces around a building

The front open space faces the road; rear and side open spaces are left along the other three boundaries of the plot.

Importance of open spaces (points for the examination)

1. Natural light inside the building.
2. Air circulation and natural ventilation.
3. Access for fire tenders and emergency services.
4. Movement around the building for occupants and maintenance.
5. Privacy between neighbouring buildings.
6. Prevents overcrowding and congestion.
7. Space for landscaping, gardens and recreation.
8. Improves appearance and the health and comfort of occupants.

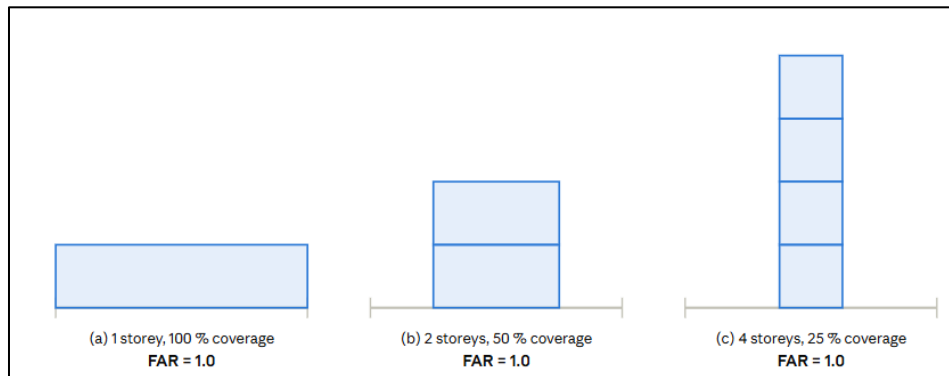
5.3 Floor Area Ratio (FAR)

Definition: Floor Area Ratio (FAR), also called **Floor Space Index (FSI)**, is the ratio of the **total covered floor area of all floors** of a building to the **area of the plot** on which it is built.

$$\text{FAR} = \frac{\text{Total covered area of all floors}}{\text{Plot area}}$$

The same FAR of 1.0 can be built wide and low or narrow and tall

Same plot in all three cases (elevation); FAR = total floor area ÷ plot area



FAR fixes the total floor area allowed, not the shape: *a wider building must be lower, a narrower one can be taller.*

Importance of FAR

1. Efficient use of land by regulating the quantity of construction on a plot.
2. Controls building density and prevents overcrowding.
3. Ensures adequate open spaces, light and ventilation.

4. Controls the size and height of buildings.
5. Reduces pressure on roads, water supply, drainage and electricity.
6. Helps traffic and parking management.
7. Promotes planned, safe and sustainable urban development.

Factors affecting permissible FAR (as per NBC)

1. Population density of the area.
2. Road width and traffic load.
3. Parking requirements.
4. Availability of public services – water supply, drainage, sewerage, electricity.
5. Type of occupancy – residential, commercial, educational, industrial.
6. Type of construction and structural system.
7. Fire-fighting facilities available.

6. Self-Study: Scope of Different Fields of Civil Engineering

6.1 Structural Engineering

Definition: Structural engineering is the branch of civil engineering that deals with the **analysis and design of structures** so that they safely resist all the loads acting on them (dead load, live load, wind load, earthquake load) during their lifetime.

Scope

1. Analysis and design of buildings, bridges, towers, chimneys, water tanks and industrial structures.
2. Design of structures in different materials – RCC, prestressed concrete, steel, masonry and timber.
3. Earthquake- and wind-resistant design of tall buildings.
4. Design of special structures – dams, offshore platforms, transmission towers, stadiums.
5. Repair, rehabilitation and retrofitting of old and damaged structures.
6. Structural health monitoring using sensors and software (e.g. STAAD Pro, ETABS).

6.2 Geotechnical Engineering

Definition: Geotechnical engineering (soil mechanics and foundation engineering) is the branch of civil engineering that deals with the **engineering properties and behaviour of soil and rock**, and their use in supporting structures.

Scope

1. Soil investigation – finding the type of soil and its bearing capacity before construction.
2. Design of shallow and deep foundations (footings, rafts, piles, wells).
3. Design of retaining walls, embankments and earth dams.
4. Slope stability and landslide control.

5. Ground improvement techniques for weak soils (compaction, grouting, geosynthetics).
6. Design of tunnels and underground structures.

6.3 Transportation Engineering

Definition: Transportation engineering is the branch of civil engineering that deals with the **planning, design, construction, operation and maintenance of transport facilities** for the safe, quick, comfortable and economical movement of people and goods.

Scope

1. Highway engineering – planning, geometric design and pavement design of roads.
2. Railway engineering – track, stations and signalling.
3. Airport engineering – runways, taxiways and terminals.
4. Harbour and dock engineering – ports and waterways.
5. Traffic engineering – traffic control, signals, road safety and parking.
6. Urban transportation – metro rail, bus rapid transit and intelligent transport systems.

6.4 Environmental Engineering

Definition: Environmental engineering is the branch of civil engineering that deals with **protecting public health and the environment** by providing safe water supply, proper sanitation and control of pollution.

Scope

1. Water supply engineering – collection, treatment and distribution of safe drinking water.
2. Sanitary engineering – collection, treatment and disposal of sewage and wastewater.
3. Solid waste management – collection, recycling and safe disposal of municipal and industrial waste.
4. Air and noise pollution control.
5. Environmental Impact Assessment (EIA) of projects.
6. Rainwater harvesting and recycling of treated water.