**Syllabus for First Semester, B Tech, Civil Engineering**
**BASIC CIVIL ENGINEERING**

**Module-I**

Introduction to Civil Engineering – Various disciplines of Civil engineering, Importance of Civil engineering in infrastructure development of the country. Introduction to types of buildings as per NBC, Selection of site for buildings, Components of a residential building and their functions, Introduction to Industrial buildings and types.
Building Planning – Basic requirements, elements, introduction to various building area terms, computation of plinth area, carpet area.

**Module-II**

Surveying – Principle and objectives, Instruments used, Horizontal measurements, Ranging (direct ranging only), Instruments used for ranging, Leveling – Definition, Principles, Instruments, Preparation of level book, problems on leveling, Modern surveying instruments – EDM, Total station, GPS (Brief discussion) Building Materials – Bricks, properties and specifications, Cement – Types, properties, grades, other types of cement and uses, Cement mortar – Constituents, Preparation, Concrete – PCC and RCC, Grades, Steel – Use of steel in buildings, types.

**Module-III**

Building Construction – Foundations, Classification, Bearing Capacity of Soil and related terms (definition only), Masonry Works – classifications, definition of different technical terms, Brick masonry – types, bonds, general principle, Roofs – functional requirements, basic technical terms, roof covering material, Floors – function, types, flooring materials (brief discussion), Plastering and Painting – objectives, types, preparation and procedure of application.

**Module-IV**

Basic Infrastructure services – air conditioning & purpose, fire protection & materials, Ventilation, necessity & functional requirements, Lifts, Escalators. Introduction to planning and design aspects of transportation engineering, Transportation modes, Highway engineering – historical development, highway planning, classification of highway, Railway Engineering – cross section of rail track, basic terminology, geometric design parameter (brief discussion only).

**Module-V**

Airport engineering – development, types, definition, characteristics of aircraft, basic terminology, Traffic engineering – traffic characteristics, traffic studies, traffic operations (signals, signs, markings), Urban engineering – classification of urban road. Irrigation & Water Supply Engineering – Introduction, Types of Irrigation, different types of hydraulic structures, dam and weirs, types of dam, purpose and functions.

**Text Books:**


- Basic Civil engineering, Gopi, S., Pearson Publication
- Basic Civil Engineering, Bhavikatti, S. S., New Age.


**Reference Books:**


- Construction Technology, Chudley, R., Longman Group, England
- Basic Civil and Environmental Engineering, C.P. Kausik, New Age.
- American Society of Civil Engineers (2011) ASCE Code of Ethics – Principles Study and Application

# Module-I

***Introduction to Civil Engineering –*** *Various disciplines of Civil engineering, Importance of Civil engineering in infrastructure development of the country.*
*Introduction to types of buildings as per NBC, Selection of the site for buildings, Components of a residential building and their functions, Introduction to Industrial buildings and types.*

***Building Planning –*** *Basic requirements, elements, introduction to various building area terms, computation of plinth area, carpet area.*

## 1.1 INTRODUCTION TO CIVIL ENGINEERING :-

Civil engineering is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including public works such as roads, bridges, canals, dams, airports, sewage systems, pipelines, structural components of buildings, and railways.

Civil engineering is traditionally broken into a number of sub-disciplines. Civil engineering is the application of physical and scientific principles for solving the problems of society, and its history is intricately linked to advances in the understanding of physics and mathematics throughout history. Because civil engineering is a broad profession, including several specialized sub-disciplines, its history is linked to knowledge of **structures**, **materials science**, **geography**, **geology**, **soils**, **hydrology**, **environmental** science, **mechanics**, **project management**, and other fields.

## 1.2 DISCIPLINES OF CIVIL ENGINEERING

The various disciplines of civil engineering are-

### 1. ARCHITECTURE AND TOWN PLANNING

An art of **shaping** and **guiding** the **physical growth** of the town creating buildings and environments to meet the various needs such as social, cultural, economic and recreational etc. and to provide healthy conditions for both rich and poor to live, to work, and to play or relax, thus bringing about the social and economic well-being for the majority of mankind is known as town planning.

### OBJECTIVES OF TOWN PLANNING-

- To create and promote **healthy conditions and environments** for all the people.
- To make **right use of the land** for the right purpose by zoning
- To ensure **orderly development**
- To **avoid encroachment** of one zone over the other.

## 2. BUILDING MATERIALS TECHNOLOGY

All the building structures are composed of various types of materials. These materials are either referred to as building materials or materials of construction.
A builder, perhaps an architect or engineer, or a contractor needs to become familiar totally with these building materials. These are some of the most commonly used building materials -

1. Stones
2. Bricks
3. Cement
4. Sand
5. Mortar
6. Concrete
7. Timber
8. Metals
9. Glass
10. Ceramics
11. Miscellaneous Building Materials

**3. CONSTRUCTION TECHNOLOGY AND MANAGEMENT**

It focuses on the knowledge and skills required for the **planning**, **coordination** and successful **implementation of large Projects** such as design and construction of structures and buildings, ship structures, aircraft, dams, roads, and bridges etc. It is a fusion of **engineering** and **management**.

**4. ENVIRONMENTAL ENGINEERING:-**

- This field is concerned with the study of the necessary methods and techniques of **environment protection** as well as the availability of the basic life elements such as water and air with a specific level of quality to protect the mankind health and environment.
- This includes design and construction of **water distribution networks, wastewater and storm water collection systems**, **water treatment plants and wastewater treatment** for reuse in industrial and agricultural fields.
- Environmental engineering involves also the study of the different techniques of **controlling air, water and soil pollution** as well as the **proper disposal or recycle of solid and hazardous wastes**.

## 5. GEOTECHNICAL ENGINEERING:-

- This field is concerned with the study of the **soil properties** of the construction site and its **bearing capacity**.
- Geotechnical engineering is concerned also with the **suitable solutions for any problem in the soil** as well as the choice of the best and secured methods of design and construction of the foundation of engineering structures.

## 6. HYDRAULICS AND WATER RESOURCES ENGINEERING-

- This field covers the basic concepts of **water science** and its related theorems and applications. This includes the methods of **transporting water from sources to distribution sites** through channels and pipelines, water sources and storage system, types of dams and their design methods.
- It involves also the study of **seawater movements and shore protection**. 
- Hydraulic engineering consists of the application of fluid mechanics to water flowing in an isolated environment (pipe, pump) or in an open channel (river, lake, ocean).

## 7. REMOTE SENSING ENGINEERING

Remote sensing is the process of **detecting and monitoring the physical characteristics** of an area by measuring its **reflected and emitted radiation** at a distance (typically from satellite or aircraft).
Some specific uses of remotely sensed images of the Earth include:

- **Large forest fires** can be mapped from space, allowing rangers to see a much larger area than from the ground.
- **Tracking clouds** to help predict the weather or watching erupting volcanoes, and help watching for dust storms.
- **Tracking the growth of a city and changes in farmland or forests** over several years or decades.
- Discovery and mapping of the rugged topography of the ocean floor (e.g., huge mountain ranges, deep canyons, and the "magnetic striping" on the ocean floor).

## 8. STRUCTURAL ENGINEERING:-

- This discipline deals with the **analysis and design of concrete and steel structures**, such as multi-story buildings, bridges, towers....etc. It deals also with the study of the **durability** and **resistibility** of such structures for live loads, wind and earthquake.
- The study involves also the study of the properties of building materials according to the international specifications.

## 9. SURVEYING:-

**Surveying** typically involves measurements of **horizontal and vertical distances** between points. It also includes descriptions of the **exact characteristics of the land structure and surface**.
A **surveying engineer** also works to:

- provide the proper design and development of infrastructure
- protect the surrounding natural environment
- maximize the efficiency of the proposed structures

## 10. TRANSPORTATION ENGINEERING:-

Transportation engineering is a branch of civil engineering that involves the **planning, design, operation, and maintenance of transportation systems** to help build smart, safe, and liveable communities.
Any system that moves people and goods from one place to another falls under the scope of transportation engineering, which includes:

- Highways and roadways
- Railways
- Oil pipelines
- Public transport systems
- Traffic control systems
- Automated transport systems
- Space transport systems

## 1.3 Importance of Civil Engineering in Infrastructure Development of the Country:-

Civil Engineers play a major role in the **infrastructure development** of a country. All structures constructed in the past exhibit the path of civilization and current infrastructures development express the practices followed by civil engineers. Infrastructure can be defined as activities that provide society with services necessary to conduct daily life and to engage in productive activity and development in a country's economy.

In a country like India, the major infrastructural. Factors that are most significant in accelerating the pace of economic development are energy, transport, irrigation, finance, communications, education, and health.

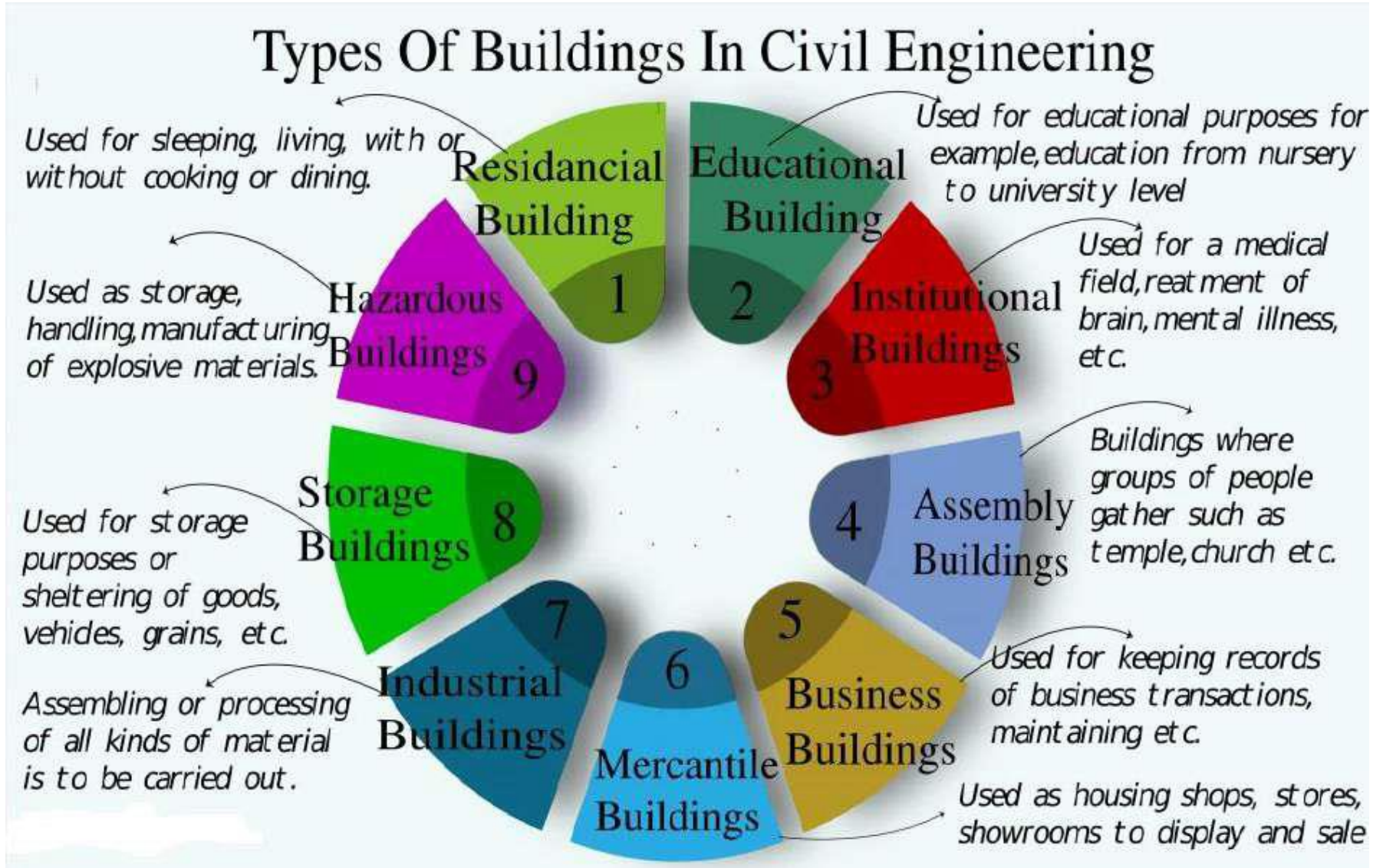
The knowledge of basic areas of civil engineering can be of great use in providing the infrastructural facilities where constructional aspects are involved for development of regions.

- Good surface communication links such as tar or concrete roads.
- Provision of water supply distribution system i.e., construction of water storage reservation or sumps, laying of underground pipes etc.
- Provision of a drainage system which may include construction of surface drains as subsurface drains for the disposal of wastewater.
- Supply of electrical power for which construction of transmission line towers, construction of electrical substations.
- Providing inland communications lines, i.e., telephone lines etc.
- Construction of recreational places e.g., gardens, parks etc.

## 1.4 TYPES OF BUILDING AS PER NBC (NATIONAL BUILDING CODE):-

Any structure made for whatsoever purpose with any material, used for human habitation or not which included foundation, plinth, walls, floor, roofs, chimney, plumbing, and building services, Verandah, Balcony, and cornice, etc. is called a building. Buildings are classified
based on **occupancies** and **type of construction**:

**A.** RESIDENTIAL
**B.** EDUCATIONAL
**C.** INSTITUTIONAL
**D.** ASSEMBLY
**E.** BUSINESS
**F.** MERCANTILE (included **retail** and **wholesale** store)
**G.** INDUSTRIAL (low, moderate and high fire hazards)
**H.** STORAGE
**I.** HAZARDOUS


Types Of Buildings In Civil Engineering
Used for sleeping, living, with or without cooking or dining.
Residancial Building
1
Educational Building
2
Used for educational purposes for example, education from nursery to university level
Used for a medical field, reatment of brain, mental illness, etc.
Institutional Buildings
3
Used as storage, handling, manufacturing of explosive materials.
Hazardous Buildings
9
Buildings where groups of people gather such as temple, church etc.
Assembly Buildings
4
Used for storage purposes or sheltering of goods, vehicles, grains, etc.
Storage Buildings
8
Used for keeping records of business transactions, maintaining etc.
Business Buildings
5
Assembling or processing of all kinds of material is to be carried out.
Industrial Buildings
7
Mercantile Buildings
6
Used as housing shops, stores, showrooms to display and sale

**Basic Civil Engineering**

**Lecture- 2**

**1. Residential Buildings-**

Any building in which **sleeping accommodation** is provided for **normal residential purposes with or without cooking/dining**. These are further classified as:

Group A-Residential

A1: Lodging or rooming houses.

A2: One or two-family private dwellings

A3: Dormitories

A4: Apartment houses

A5: Hotels (upto 4 star category)

A6: Hotels (**Starred**- five star and above)

(i) **Lodging and rooming houses**- These are buildings in which separate **sleeping accommodation with or without a dining facility** but **without a cooking facility** is provided. For instance, Inns, Clubs, Motels, and Guesthouses.

(ii) **One or two-family private dwelling**- A private dwelling which is occupied by members of one or two-family. Maximum sleeping accommodation is provided for **20 persons**.

(iii) Dormitories- Any building in which group sleeping accommodation is provided with or without dining facilities. e.g., School and College Dormitories, Hostels, and Military Barracks.
(iv) Apartment Houses- Buildings in which living quarters are provided for **three or more families** having independent cooking facilities and living independently of each other. e.g., apartments, Mansions, and Chowls.
(v) Hotels -Buildings in which sleeping accommodation is provided with or without dining facilities for up to four-star categories (hotels).
(vi) Hotels (**Starred)** Normally five star and above by local authority.

**2. Educational Buildings**
Any building used for school, college, and other training institutions having a minimum of 20 students.
(i) Schools up to Senior Secondary level Minimum students should be 20.
(ii) All others/training institute Minimum students should be 100.

**3. Institutional Buildings-**
Buildings that are used for medical or other treatment, care of persons suffering from physical and mental illness, care of infants, for inmates etc. are called institutional buildings

(i) Hospital and Sanatoria -Any building which is used for the treatment of patients e.g., hospitals, sanatoria, infirmaries, and nursing homes.
(ii) Custodial Institutions Any building used for custody and care of a person for instance children, old age homes, orphanages, etc.
(iii) Penal and mental institutions Any building which is used for housing persons whose liberty is restricted e.g., jails, prisons, mental hospitals, etc.

**4. Assembly Buildings**

Any building in which a minimum of **50 persons** gathers for recreational, amusement, social, religious, patriotic purposes e.g., theatres, assembly halls, exhibition halls, museums, restaurants, places of worship, etc.
These are classified into 7 types:

(i) The building having **theatrical or motion pictures** or any other stage having fixed seats for **over 1000** persons.
(ii) The building having **theatrical or motion pictures** or any other stage having fixed seats for **up to 1000** persons.
(iii) Buildings without a **permanent stage** having an accommodation for **300** or more persons but no permanent seating arrangements.
(iv) All other structures including **temporary structures** designed for assembly of peoples.
(v) Buildings having **mixed occupancies** of assembly and mercantile
(vi) **Underground and elevated mass rapid transit** system.

**5. Business Buildings**

Any buildings used for the **transaction of business, professional establishments, service facilities**, etc. are termed as business buildings.

These are further divided into 5 types –

(i) Offices, Banks, Professional establishments etc.

(ii) Laboratories, clinics, research establishments and libraries etc.

(iii) IT parks, call centers etc.

(iv) Telephone exchange

(v) Broadcasting stations, TV stations and air traffic control towers.

**6. Mercantile Buildings**

Any building which is used as **a shop, store, market**, etc. is known as mercantile buildings.

These are further classified as:

(i) Shops, stores, departmental stores, markets (covered area **up to 500 sq. m** ).

(ii) Shops, stores, departmental stores, markets (covered area **more than 500 sq. m**).

(iii) Underground shopping centres, storage and service facilities

**7. Industrial Buildings**

Any building in which products or materials are **fabricated, assembled, manufactured, or processed**. For instance, assembly plants, industrial laboratories, power plants, pumping stations, etc.

- Buildings for **low hazard industry** –
  - Buildings in which those things are manufactured that have low combustibility.

- Buildings for **moderate hazard industry**-
  - Buildings in which those things are manufactured which will burn with moderate rapidity.

- Buildings for **high hazard industry**-
  - Buildings in which those things are manufactured which will burn with extreme rapidity and results in hazardous situations.

**8. Storage Buildings**

- Any building which is used for **storage of goods**, ware or merchandise, vehicles or animals. e.g., warehouse, cold storage, garages, stables, etc.

**9. HAZARDOUS BUILDINGS**

- Buildings which are used for storage, handling, manufacture, or processing of highly combustible or explosive material. For instance, manufacture of explosives and fireworks, storage of highly flammable liquids, storage of LPG, rocket propellants, etc.

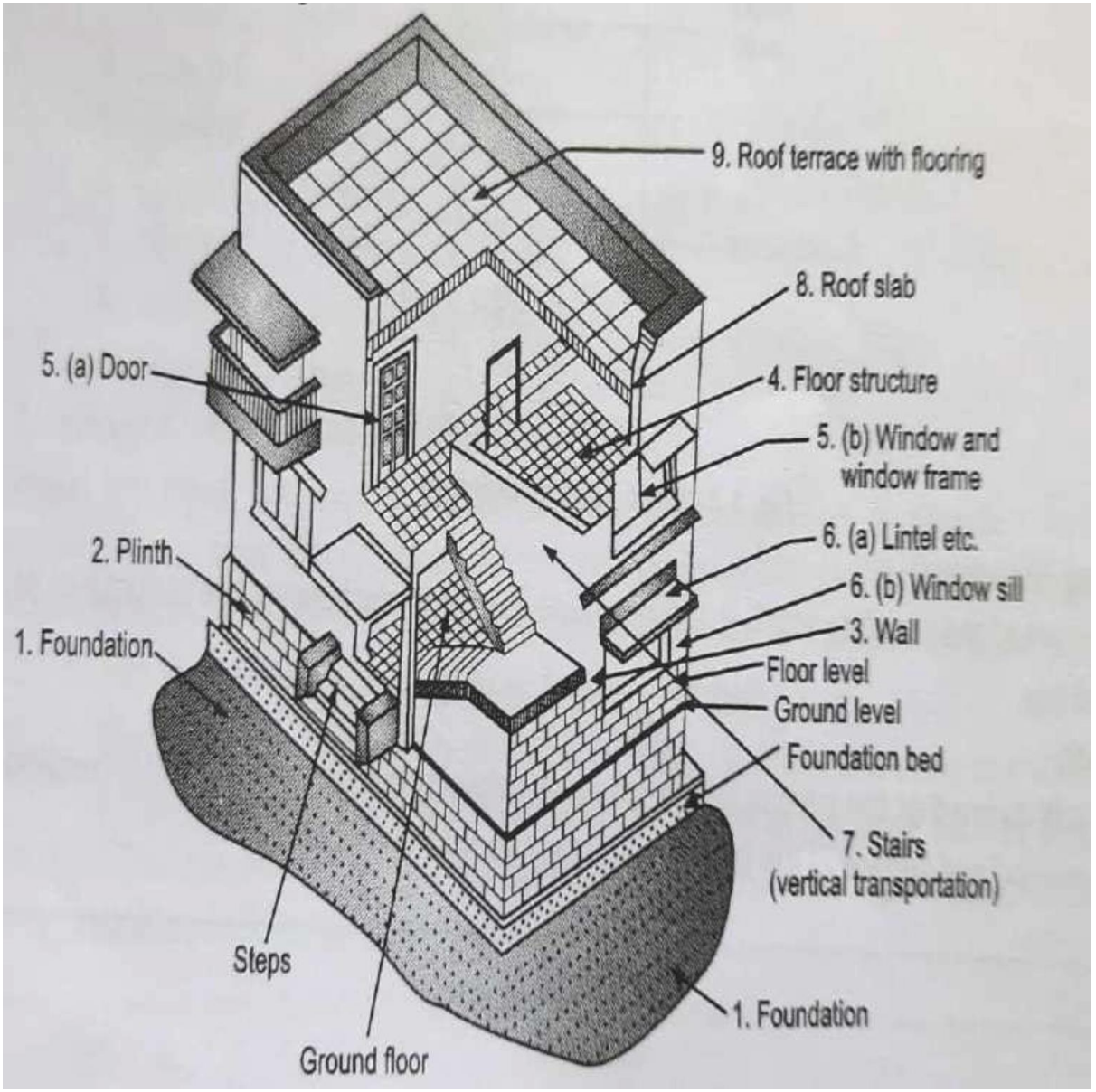
## 1.5 SELECTION OF SITE FOR BUILDINGS :-

1. The soil of site should have good bearing capacity. Hard strata should be available at reasonable depth, around 1.2m to1.5m depth from ground level.
2. The site should be on elevated ground. It should have slope towards front street to afford good facility of drainage.
3. Sites nearer to ponds ,pools of water, water logged areas must be avoided as they remain in damp condition .
4. Sites near to high voltage power transmission lines are avoided.
5. Sites very nearer to big shopping complexes , markets, railway station ,airport are avoided
6. The surrounding of site should be pleasing and calm.
7. The orientation of site should be such that it receives natural light and air in plenty.
8. The location of site is such that the common facilities like school, transportation, medical facilities etc are within reasonable range.
9. Sites in developed colonies should be preferred.
10. The layout of the colony should be approved by local authorities. This will help in getting essential facilities like water , drainage ,electricity, telephone connection etc easily.

## 1.6 COMPONENTS OF RESIDENTIAL BUILDING

Building component means any subsystem, subassembly, or other system designed for use in,
or as part of, a structure, which may include structural, electrical, mechanical, plumbing, and
fire protection systems and other systems affecting health and safety.

The basic function of a building is to provide **structurally sound and environmentally controlled spaces** to **house and protect** occupants and contents.A building is combination of various components. A Civil Engineer should have good knowledge of execution of each and every component with respect to design layouts given by Architect.



The following are the basic component parts of a **residential building**:-

1. Foundation
2. Plinth
3. Walls and columns
4. Sills, lintels and chejjas
5. Doors and windows
6. Floors
7. Roofs
8. Steps, stairs and lifts
9. Finishing work
10. Building services.
11. Parapet

# Basic Civil Engineering

## Lecture- 3

The Roof

The Lintel

The Window

The Door

The Cill

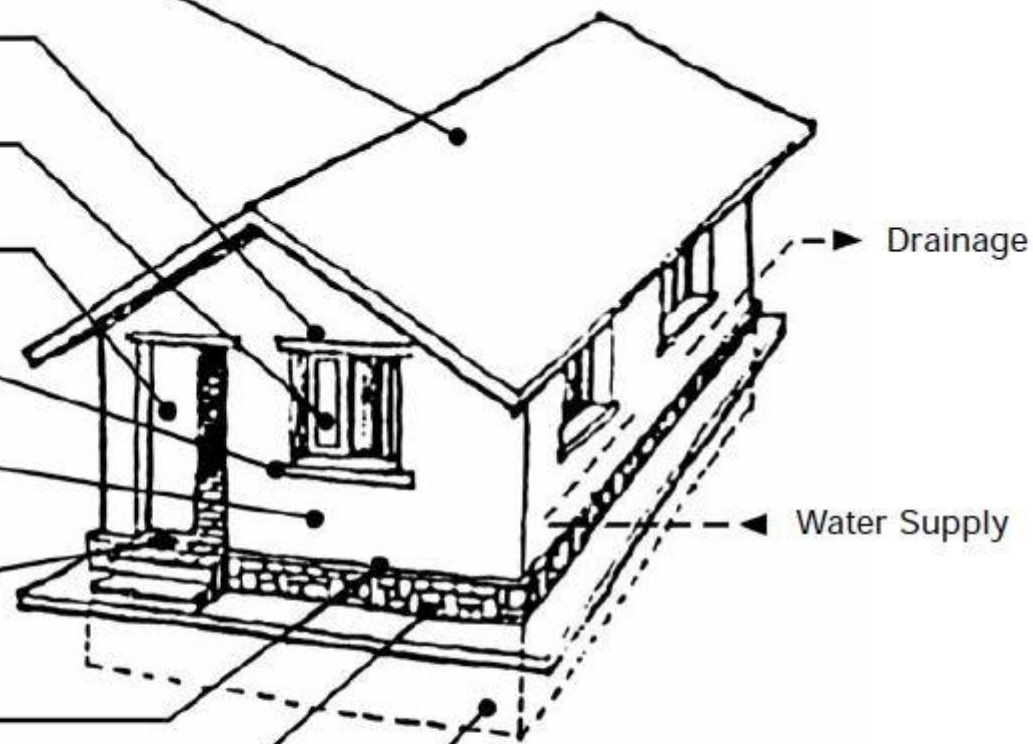
The Wall

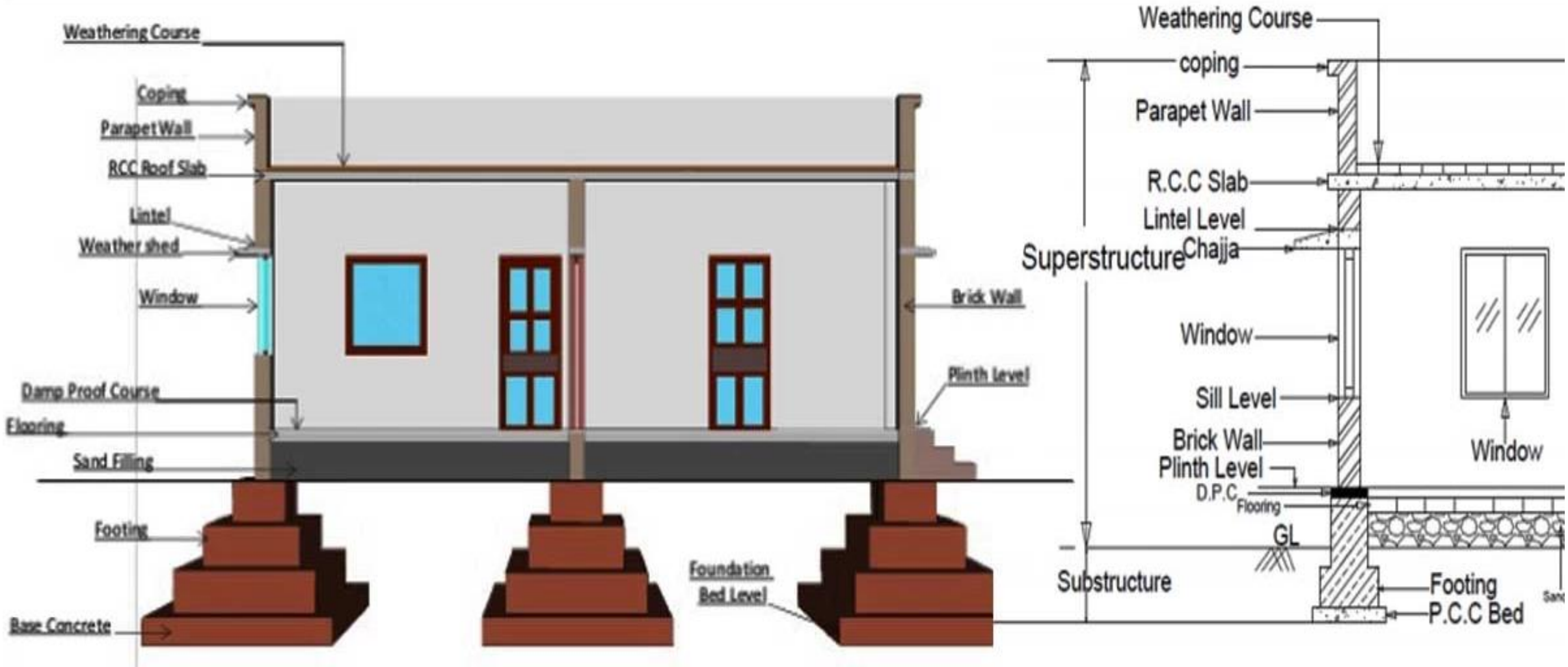
The Floor

The DPC lies at the Floor Level right below the Walls (not under any openings like Doors)

The Plinth lies between the Floor and the Ground

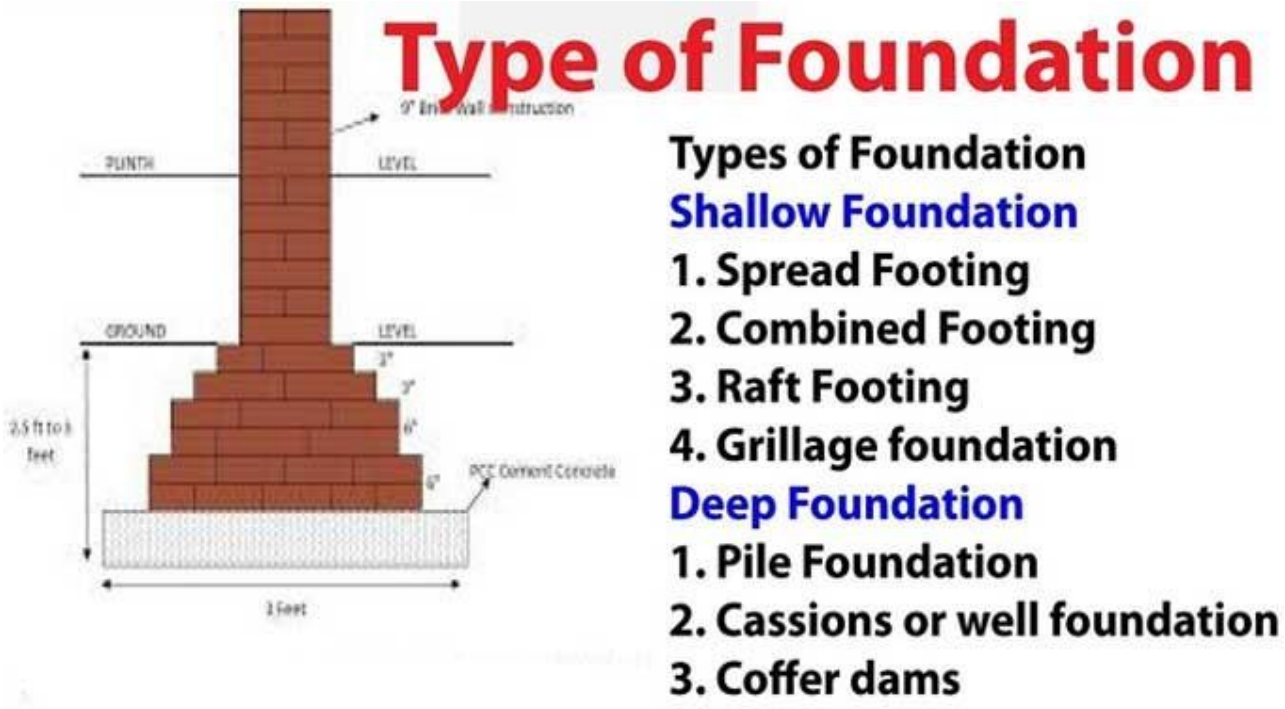
The Foundation is invisible and lies below the Ground, just beneth the Walls

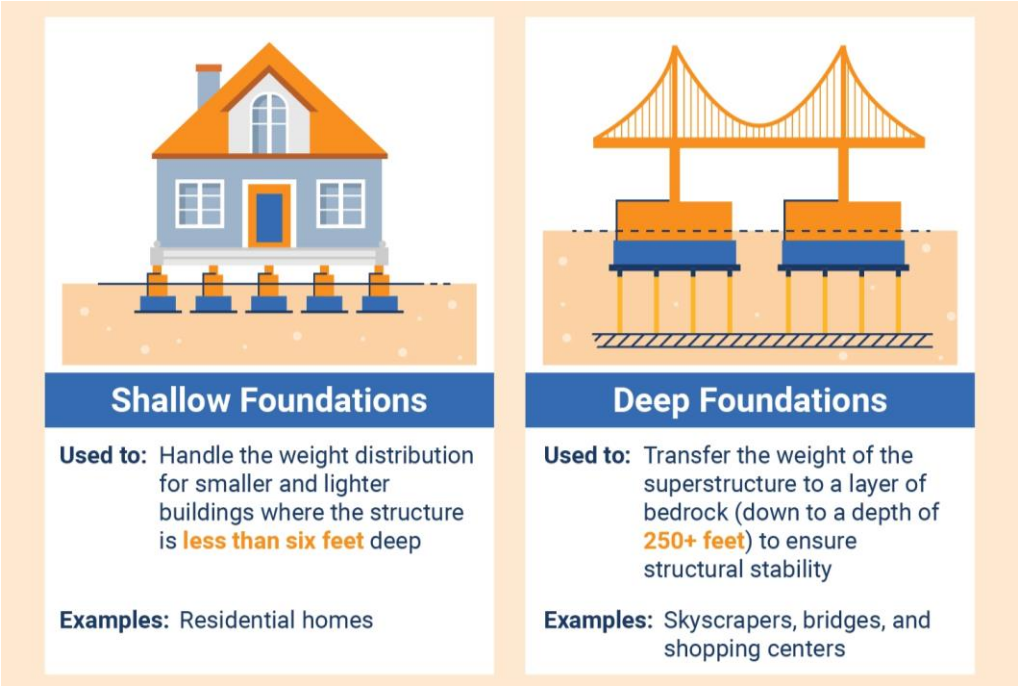



Weathering Course
Coping
Parapet Wall
RCC Roof Slab
Lintel
Weather shed
Window
Brick Wall
Plinth Level
Damp Proof Course
Flooring
Sand Filling
Footing
Foundation Bed Level
Base Concrete
Weathering Course
coping
Parapet Wall
R.C.C Slab
Lintel Level
Chajja
Superstructure
Window
Sill Level
Brick Wall
Plinth Level
D.P.C
Flooring
GL
Substructure
Footing
P.C.C Bed
Window

**Foundation**:
Foundation is the most important part of the building. Building activity starts with digging the ground for foundation and then building it. It is the lower most part of the building. It transfers the load of the building to the ground. Its main functions and requirements are:

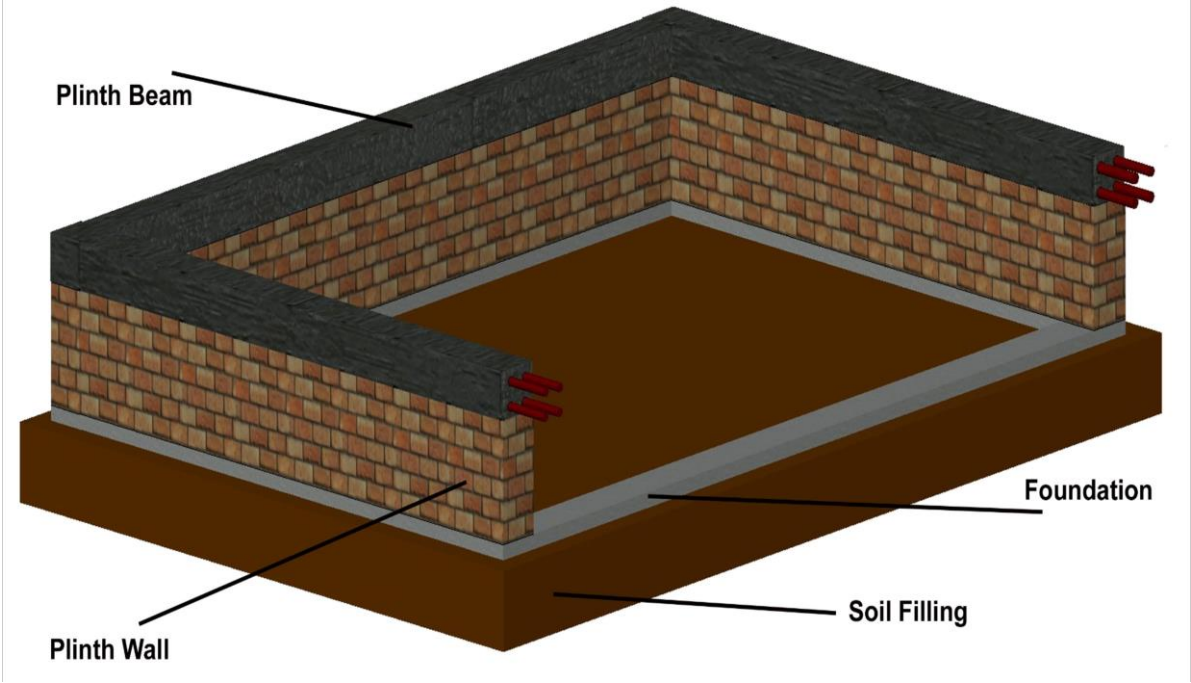
(a) Distribute the load from the structure to soil evenly and safely.
(b) To anchor the building to the ground so that under lateral loads building will not move.
(c) It prevents the building from overturning due to lateral forces.
(d) It gives level surface for the construction of super structure.



**Plinth:**

- The portion of the wall between the **ground level** and the **ground floor level** is called **plinth**. It is usually of stone masonry. If the foundation is on piles, a plinth beam is cast to support wall above floor level. At the top of plinth, a damp proof course is provided. It is usually 75 mm thick plain concrete course.
- The function of the plinth is to keep the **ground floor above ground level**, **free of dampness**. Its height is **not less than 450 mm**. It is required that plinth level is at least **150 mm above the road level**, so that connections to underground drainage system can be made.



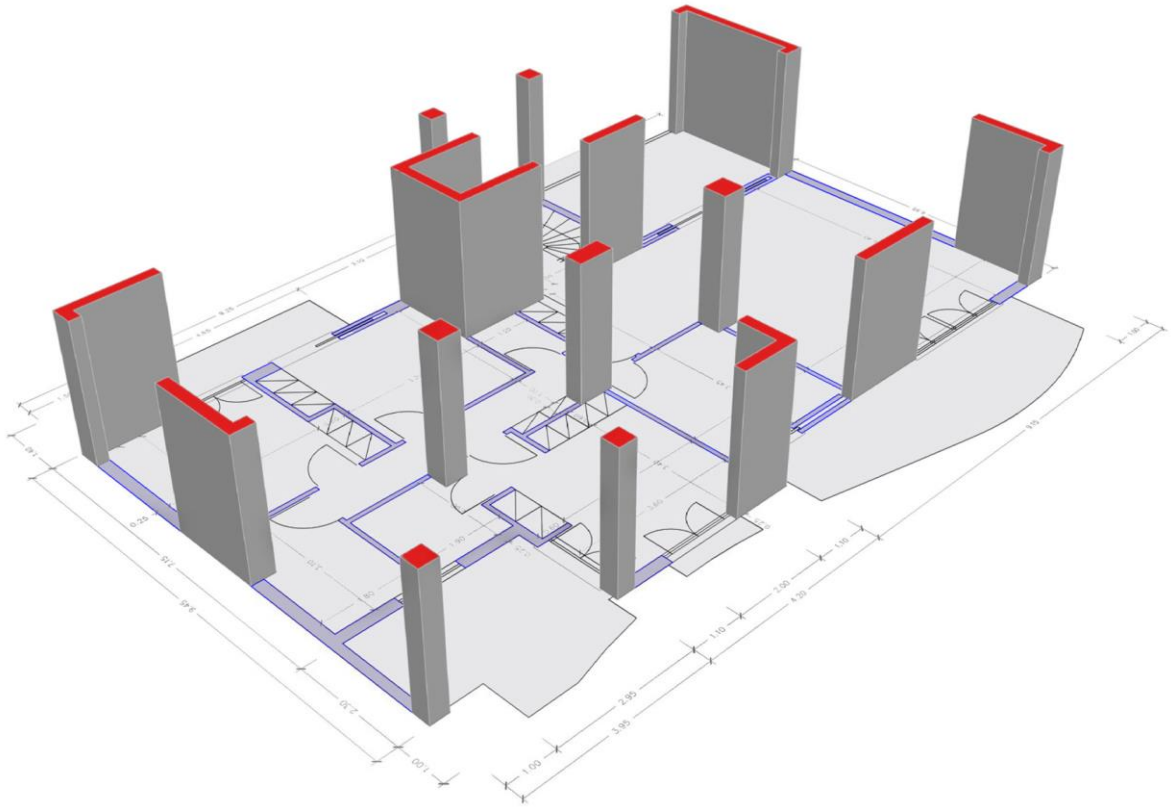
**Walls and Columns:-**

The function of walls and columns is to transfer the load of the structure vertically downwards to transfer it to foundation. Apart from this wall performs the following functionsalso:

(a) It encloses building area into different compartments and provides privacy.

(b) It provides safety from burglary and insects.

(c) It keeps the building warm in winter and cool in summer.

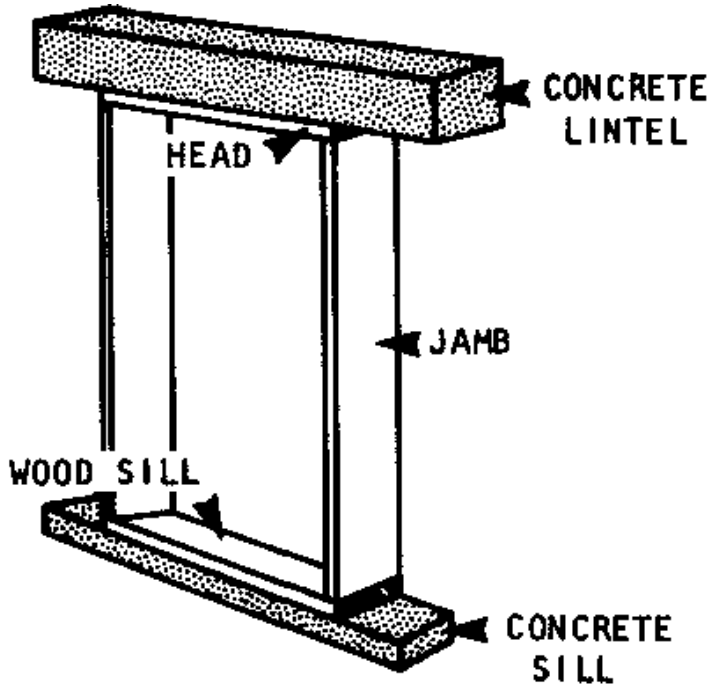


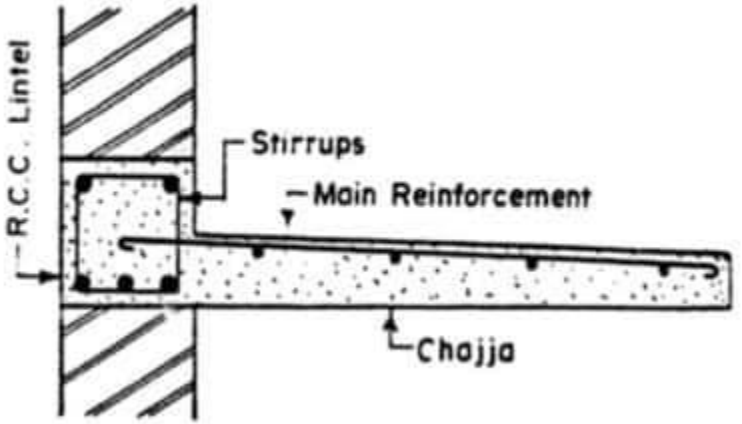
**Sills, Lintels and Chejjas:-**

- A **window frame should not be directly placed** over masonry. It is placed over **50 mm to 75 mm thick plain concrete course** provided over the masonry. This course is called as **sill**.

• **Lintels** are the **R.C.C. or stone beams** provided **over the door and window openings** to **transfer the load transversely** so as to see that door or window frame is **not stressed unduly**. The width of lintels is equal to the width of wall while thickness to be provided depends upon the opening size.

**Chejja** is the projection given **outside the wall to protect doors and windows** from the rain. They are usually made with R.C.C. In low cost houses stone slabs are provided as chejjas. The projection of chejja varies from 600 mm to 800 mm. Sometimes drops are also provided to chejjas to improve **aesthetic** look and also to get additional protection from sun and rain.



**Doors and Windows:-**

- The function of a **door** is to give access to different rooms in the building and to deny the access whenever necessary. Number of doors should be minimum possible. The size of the door should be of such dimension as will facilitate the movement of the largest object likely to use the door.
- **Windows** are provided to get light and ventilation in the building. They are located at a height of 0.75 m to 0.9 m from the floor level. In hot and humid regions, the window area should be 15 to 20 per cent of the floor area. Another thumb rule used to determine the size and the number of windows is for every 30 sq. m of inside volume there should be 1 sq. m window opening.

**Floors:-**

- Floors are the important component of a building. They give working/useful area for the occupants. The ground floor is prepared by filling brick bats, waste stones, gravel and well compacted with not less than 100 mm sand layer on its top. A lean concrete of 1 : 4 : 8, 100 mm thick is laid. On this a damp proof course may be provided. Then floor finishing is done as per the requirement of the owner.
- Cheapest floor finish for a moderate house is with 20 to 25 mm rich mortar course finished with red oxide. The costliest floor finish is mosaic or marble finishing. Other floors are usually of R.C.C. finished as per the requirements of the owner.

**Roof**:-

- Roof is the top most portion of the building which provide top cover to the building. It should be leak proof. Sloping roof like tiled and A.C. sheet give leak proof cover easily. But they do not give provision for the construction of additional floor. Tiled roof gives good thermal protection. Flat roofs give provision for additional floors.

Terrace adds to the comfort of occupants. Water tanks can be easily placed over the flat roofs.

**Step, Stairs and Lifts:-**

- **Steps** give convenient access from ground level to ground floor level. They are required at doors in the outer wall. 250 to 300 mm wide and 150 mm rise is ideal size for steps. In no case the size of two consecutive steps be different. Number of steps required depends upon the difference in the levels of the ground and the floor.
- **Stairs** give access from floor to floor. They should consist of **steps of uniform sizes**.

In all public buildings lifts are to be provided for the conveniences of old and disabled persons.

- In hostels **G + 3 floors can be without lifts**. Lift is to be located near the entrance. Size of the lift is decided by the number of users in peak hours. Lifts are available with capacity 4 to 20 persons.

**Finishing:-**

- Bottom portion of slab (ceiling), walls and top of floor need smooth finishing with plaster. Then they are provided with white wash, distemper or paints or tiles.

The function of finishing work is:

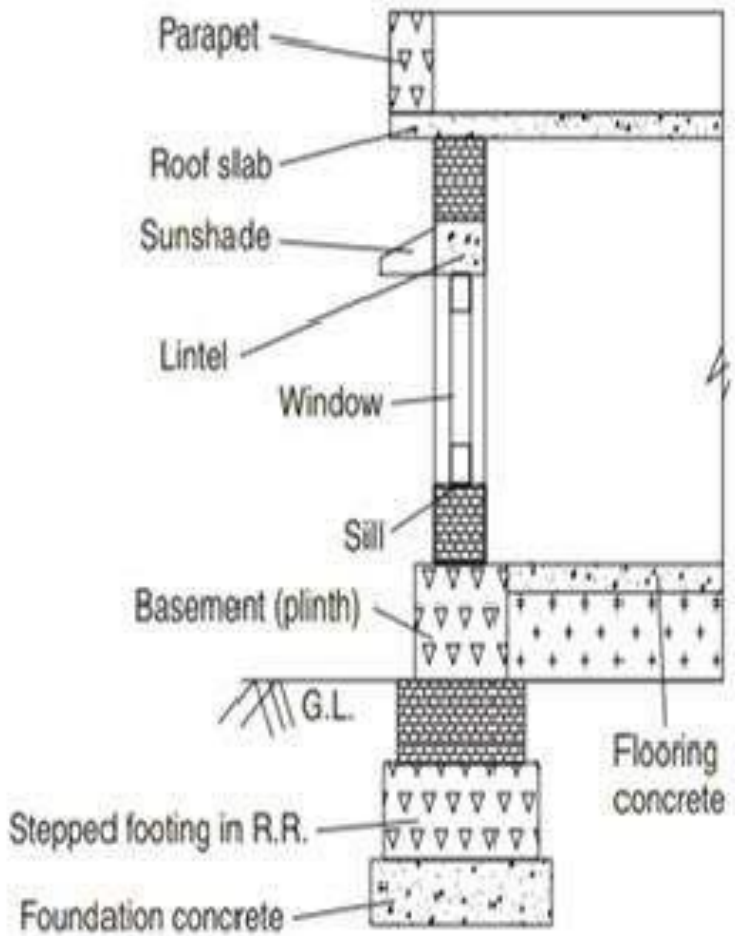
- Give protective cover
- Improve aesthetic view
- Rectify defective workmanship
- Finishing work for plinth consists in pointing while for floor it consists in polishing.

**Building Services:-**

- **Water supply, sanitation and drainage works, electric supply work and construction of cupboards and show cases** constitute major building services.
- For storing water from municipal supply or from tanker a **sump** is built in the house property near street. From the sump water is pumped to overhead tanks placed on or above roof level so as to get water all the 24 hours. Plumbing work is made so as to get water in kitchen, bathrooms, water closets, sinks and garden taps. For draining rain water from roofs, down take pipes of at least 100 mm diameters should be used. Proper slopes should be given to roof towards down take pipe. These pipes should be fixed at 10 to 15 mm below the roof surface so that rain water is directed to the down take pipe easily.
- The **sanitary fittings** are to be connected to stone ware pipes with suitable traps and chambers. Stone ware pipes are then connected to underground drainage of municipal lines or to the septic tank.
- Many **carpentry works** are required for building service. They are in the form of showcases, cupboards, racks etc.
- **Electric supply** is essential part of building services. The building should be provided with sufficient points for supply of lights, fans and other electric gadgets.

**Parapet:-**

- The parapet is a minor wall around the edge of a roof, balcony, terrace, or stairway, usually covering the roof's perimeter. It protects the top and pre-built structures from corrosion and degradation.



**Lecture- 4**

## INTRODUCTION TO INDUSTRIAL BUILDING AND TYPES-

Any building structure used by the industry to s**tore raw materials or for manufacturing products** of the industry is known as an industrial building.

- Industrial buildings are generally used for steel plants, automobile industries, utility and process industries, thermal power stations, warehouse, assembly plants, storage, garages, etc.

**Factors Considered while Selecting Site For Industrial Building:-**

- Site should be located on an arterial road.
- Local availability of raw material.
- Facilities like water supply, electricity
- Topography of an area
- Soil conditions with respect to foundation design
- Waste disposal facilities
- Transportation facilities
- Sufficient space for storage of raw materials

**Types of Industrial Building**

**1.** Warehouses
**2.** Cold Storage Buildings
**3.** Telecom Centres or Data Hosting Centres
**4.** Flex Buildings
**5.** Light Manufacturing Buildings
**6.** Research And Development Set up

**Warehouse**

- There are buildings that are used for **storing goods on behalf of other companies**. These are called warehouses. Although warehouses can be of different sizes, they are usually large and are located outside city limits. They can have more than one storey and can have loading docks, huge parking lots of big trucks. They can also have a small office set up inside the premises.
- These typical single-story warehouses range in size from 5,000 to hundreds of thousands of square feet and are used for the storage and transport of goods. Ceilings are generally at least 60 feet high because of the necessary racking and storage systems concealed beneath its roof. Loading docks, big truck doors, and parking areas for semi-trailers used for distribution are among the other important elements of an industrial building.

**Cold Storage Buildings-**

• Refrigeration and cold storage facilities are distribution centres dedicated to food items like meat, produce, and dairy. These buildings provide rooms for cooling and freezing in order to maintain goods at the right temperatures before they are sent out.

Other key features include docks with special seals to keep products cool, as well as insulated overhead doors that keep them frozen.

• These are especially built to store large amounts of food products and keep them under refrigerated conditions for long periods. These buildings are located mostly along state and national highways and in places where there is good supply of electricity.

**Telecom/Data Hosting Centers (Switching Centers, Cyber Centers, Web Hosting Facilities, Telecom Centers )**

These highly specialized industrial buildings are located close to major communications trunk lines to allow for access to an extremely large and redundant power supply capable of powering extensive computer servers and telecom switching equipment.

**FLEX BUILDING:-**

- This is the newest addition to the category of industrial segment of industrial real estate and is a result of the evolving needs of modern times. These flex building have **more than one usage and can accommodate a R and D facility**, an office set up, light manufacturing and even showroom spaces. They are flexible in nature and some of the uses can be changed by making simple modifications.

**FLEX Building** Systems is committed to providing flexible, superior building systems for a variety of applications. Flex buildings often incorporate different areas or spaces in a design, optimized for different purposes and needs. This can be either an uninsulated or insulated **warehouse, workshop, garage or even a showroom**, often in combination with one or more offices. The buildings often have to balance complex solutions for production, cold storage and heating. Flex space buildings are mainly of three types - **Research and Development buildings, Data centre buildings, and Show rooms.**

**LIGHT MANUFACTURING BUILDING:-**

These buildings can be used in processing **food items or assembly of light machinery like fans, water pumps, gadgets,** etc. These are generally small in size as compared to heavy industrial buildings and do not have blast furnace, high capacity exhaust systems etc. These buildings can sometimes find alternative uses like a unit making water pumps can be converted in to assembly unit for gadget by making changes in the some of the installed machinery.

**RESEARCH AND DEVELOPMENT BUILDING:-**

Research and Development (R&D) forms an integral part of many businesses and they like to set up their own R&D centres which cater to their specific requirements. A lot of life sciences companies have their R&D centres which are usually owned by them. These centres are generally not in the centre of the city. Companies can house their scientists and other staff in these centres and hence there are residential elements in this kind of a set up. There can also be elements of office buildings in a R&D centre. Sometimes these centres run on rented buildings also but the lease period is usually long.

**SHOWROOM BUILDINGS:-**

A showroom, also referred to as a gallery, is a large space used to display products or show entertainment. A showroom is a large space used to display products for sale, such as automobiles, furniture, appliances, carpet or apparel. It is a retail store of a company in which products are on sale in a space created by their brand or company. There are many types of showroom buildings like jewelry shops, malls, large vehicle showroom, furniture showrooms etc.

**Lecture-5**

## BUILDING PLANNING AND BASIC REQUIREMENTS:-

Every family needs a building to reside in. Apart from residential purposes, buildings are required for educational, institutional, business, assembly, and industrial purposes. Buildings are necessary for the storage of materials also. This article will discuss the basic requirements of a building concerning **orientation**, the **utility** of space, **energy efficiency**, and other **requirements**, etc.

"The concept of positioning all the elements and units of a building in a systematic and practical manner to have the **maximum and best utilization of the available space, area and facilities** is termed as **Principles of Building Planning**."

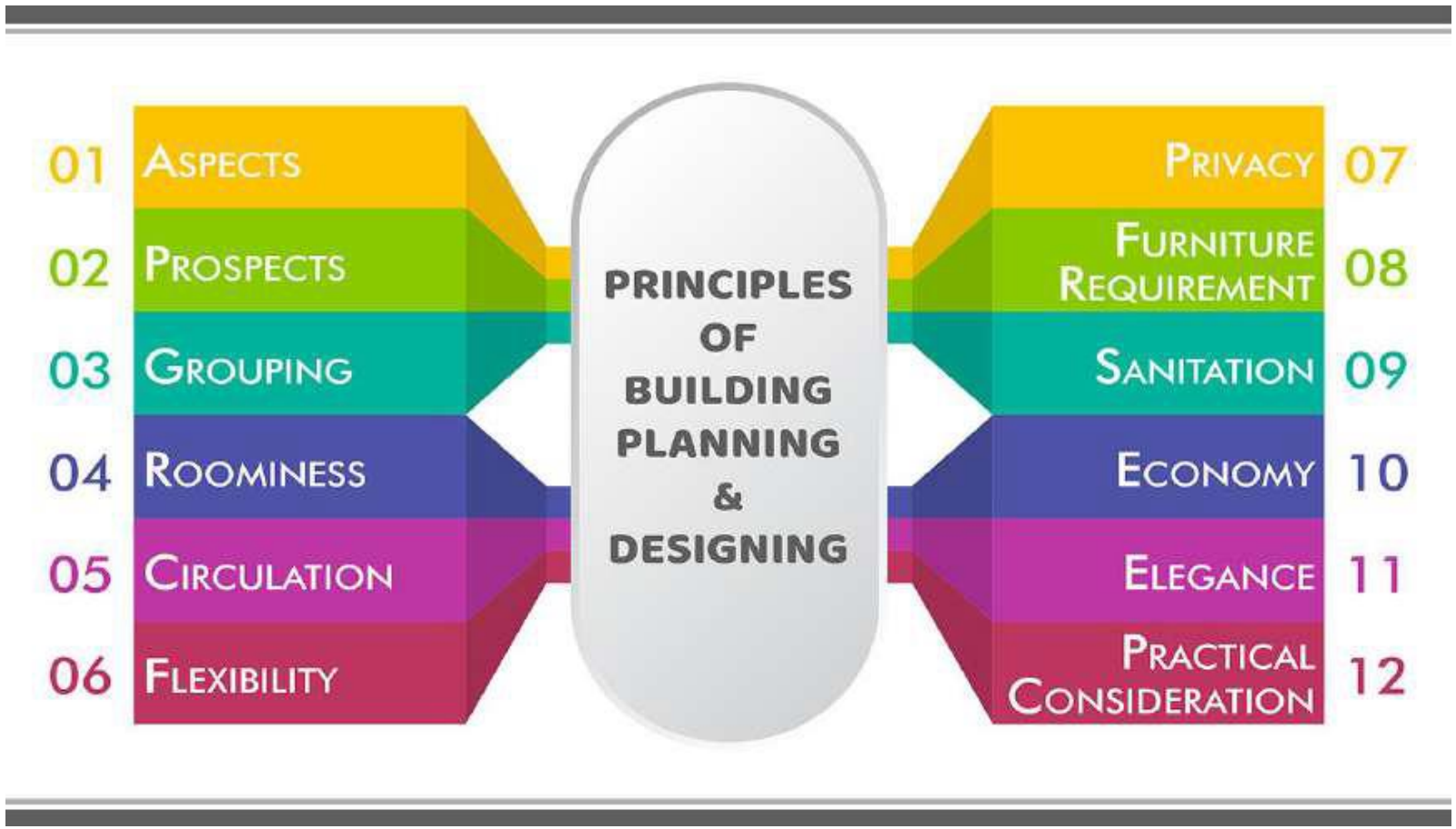
## PRINCIPLES OF BUILDING PLANNING:-

“The concept of positioning all the elements and units of a building in a systematic and practical manner to have the **maximum and best utilization of the available space**, **area** and **facilities** is termed as **Principles of Building Planning**.” There are several principles that affect the planning of a building. This article will give you a brief knowledge of all those principles.

## FACTORS AFFECTING THE PLANNING OF THE BUILDING:

1. The **function** of the building e.g. residential, industrial, public, commercial, etc.
2. **Shape and size of the plot**
3. **Topography**
4. **Climatic** condition
5. Building by-Laws etc.

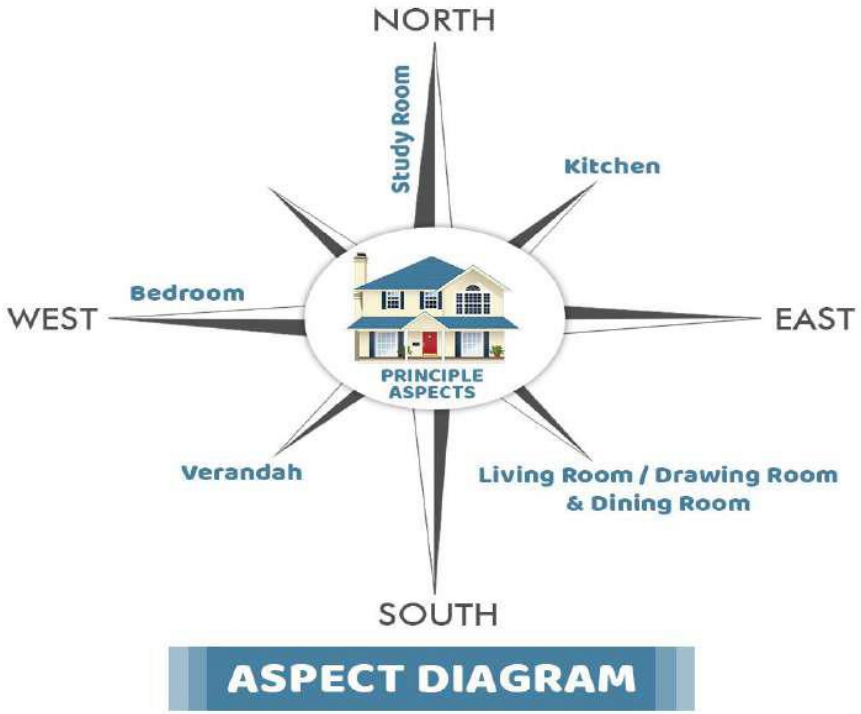
**REQUIREMENTS OF BUILDING PLANNING AND THE CONSTRUCTION:**



**What is an ASPECT in building planning?**

A building is a complete constitute of different rooms and blocks in it. All the rooms are located according to the standard **use** of components considering the **proper access of natural resources,** i.e., **sunlight** and **wind**. ASPECT is defined as a significant **arrangement of doors and windows** in abuilding, which are enough and efficient to provide **sunlight**, **hygiene**, **wind**, and **eco-friendly environment**. There must be sufficient **light** and **ventilation** in each room and across the house.

The aspect of building can be achieved by **arranging** the rooms, kitchen, veranda, and many other components in **proper directions**. The ways to cover the direction with advisable aspect is given below:



ASPECT DIAGRAM

The above diagram indicates the appropriate directions which should be preferred for the **positioning** of various rooms in a house.

## What are the PROSPECT principles in building planning?

In these modern times, all the buildings and constructions are aimed to achieve an **aesthetically appealing look** from both **exteriors** and **interior** considerations. The appearance of a house or a building is defined as **PROSPECT.** The standards are raised to accomplish the building's **pleasant look** by locating doors and windows at an **accurate location** to view nature's beauty and avoid unwanted attributes from getting entry into the house.

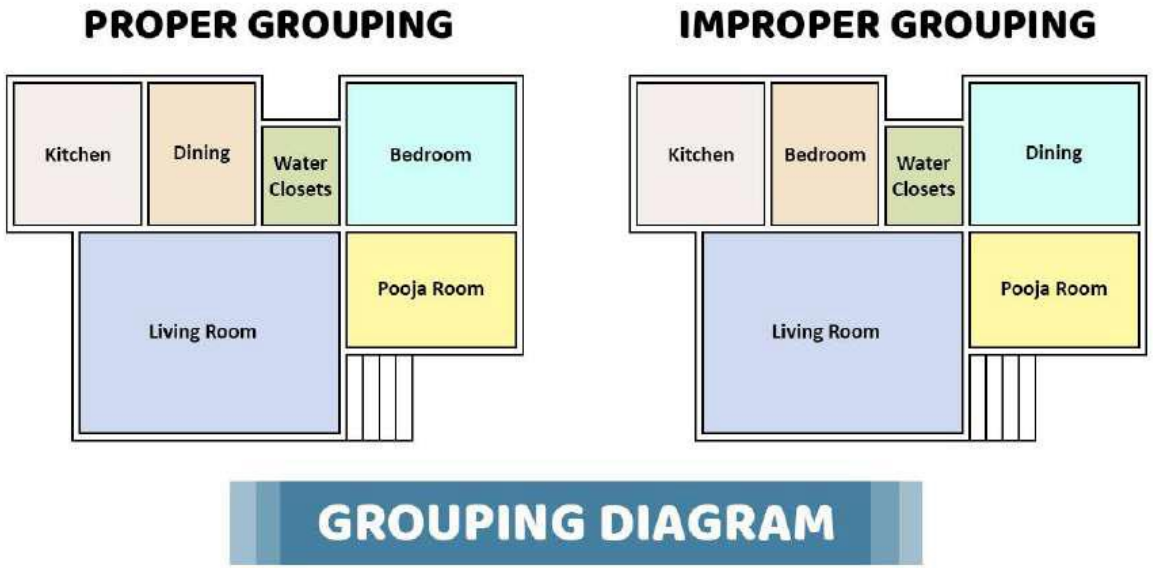
One of the other factors of the prospect is to have a pleasant view outside a house from doors, windows, balconies as clearly as possible, as shown in the above image.

## What does the GROUPING mean in building planning?

GROUPING: It is to organize the different rooms in such a way that they are adequately **interconnected with each other** to form a functional and practical layout of the house. The **accessibility** of all the rooms is **interlinked** with each other, and this provision can be satisfied by grouping.

To understand the theory of grouping, let us consider an example. In a simple sense, the dining room should be near to the kitchen so that both the units can be easily used for the service. Similarly, water closets should be close to the bedrooms and living room but not close to the kitchen.

An idea of the grouping is applicable not only in a residential building but also applies to commercial and industrial buildings. In industries, the storage rooms must be near the road to ease the loading and unloading of the goods.



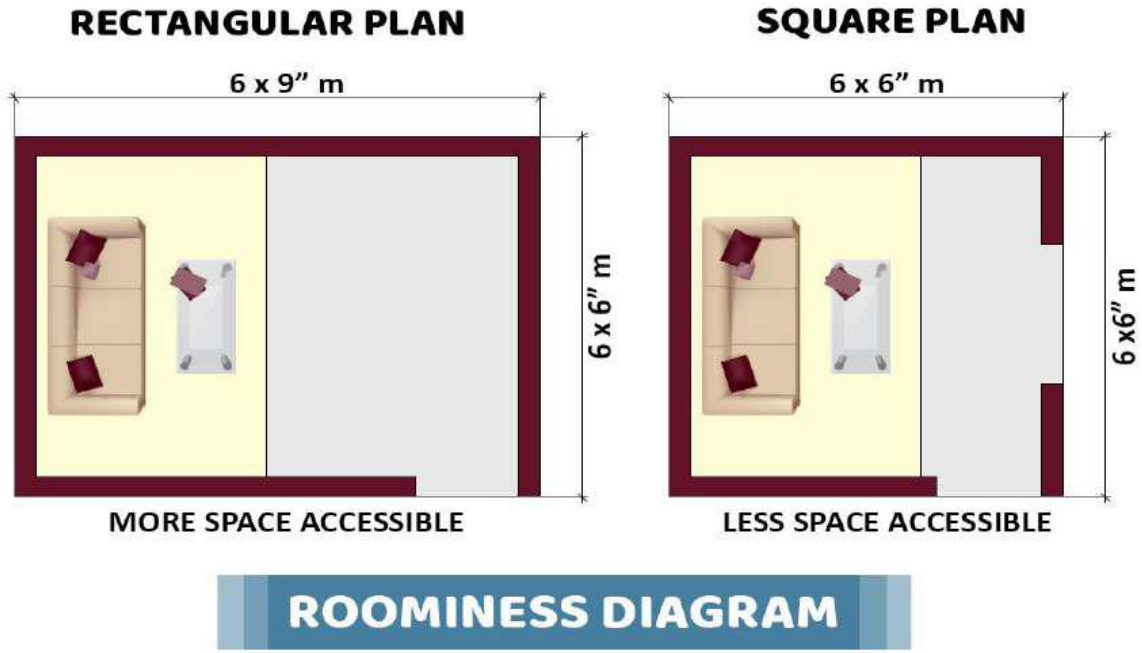

The above figure indicates the common groups of rooms, which should be combined together while planning a residential building.

**How ROOMINESS can be a principles of building planning?**

- The meaning of ROOMINESS is to **maximize the advantage of the available space** from the **minimum dimension** of a room. Both the size and shape of the room play a vital role in providing roominess.

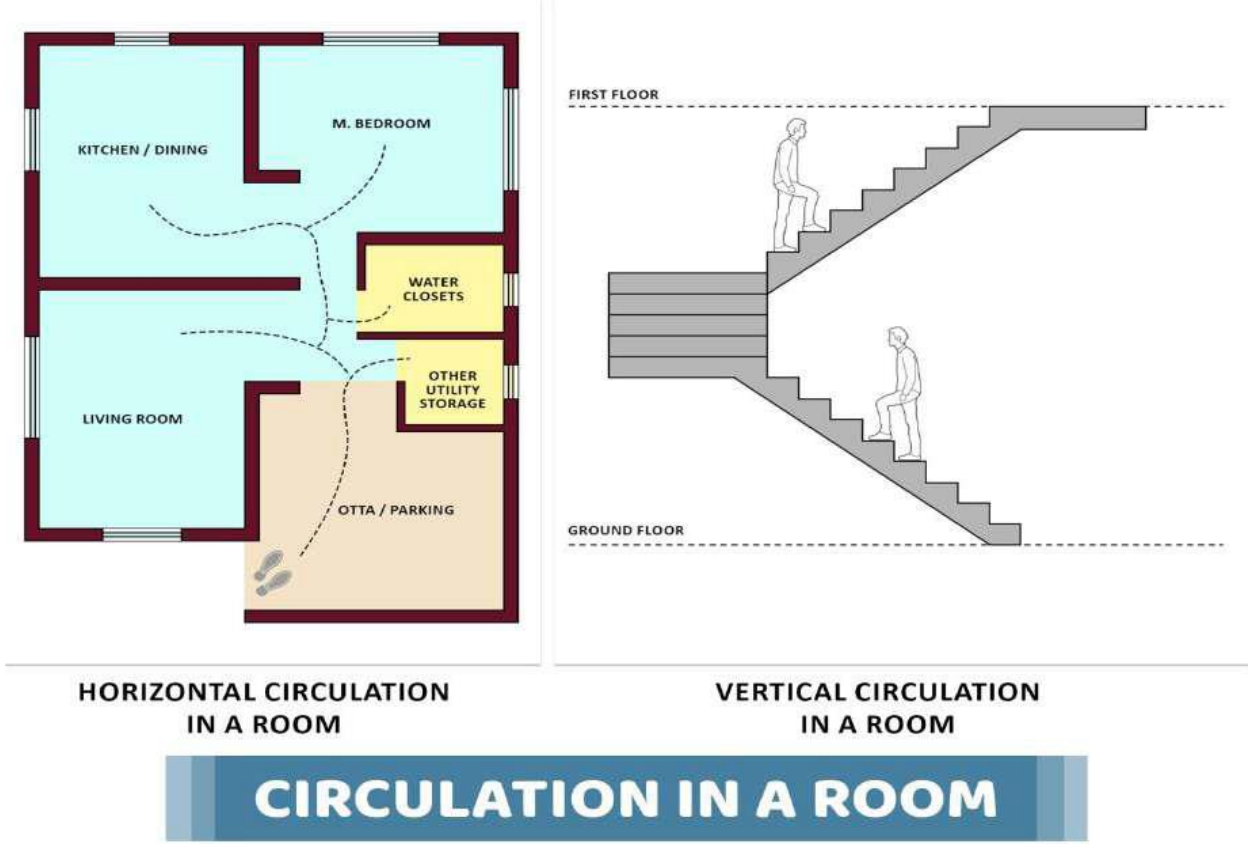
**POINTS TO UNDERSTAND THE ROOMINES**

- A square room seems small in size when compared to a rectangular room.
- It is always advisable to plan a rectangular room with a proportion of 1.2 to 1.5 times the ratio of the length to the breadth. The increase in ratio due to length gives the tunnel experience as it looks longer.
- Also, the height should neither be too high nor too less that the ceiling becomes a hindrance.
- Floors, ceilings, walls, ceiling, lifts, furniture, and all such elements should be appropriately placed to offer more space in the rooms.




ROOMINESS DIAGRAM

The **internal access in a room in both ways** i.e. in **horizontal and vertical** directions of a building is defined as **CIRCULATION**. The movement from one room to another on the same floor can be described as **horizontal circulation**. Likely, the movement from one floor to the other floor is termed as vertical circulation. To have the efficient circulation in a building, passages, corridors and foyer etc should be provided in such a way that these elements are neither too **narrow nor too large**. They must have **good lighting and ventilation**. Some better options are highlighted in the diagram which reflects the ways of good circulation in a house.



## What is Flexibility in building planning?

Flexibility means “to **allow use of the particular element in another way possible to fulfil a specific purpose.** An element is initially designed for one **particular reason**, but later the same element is **used differently**.”

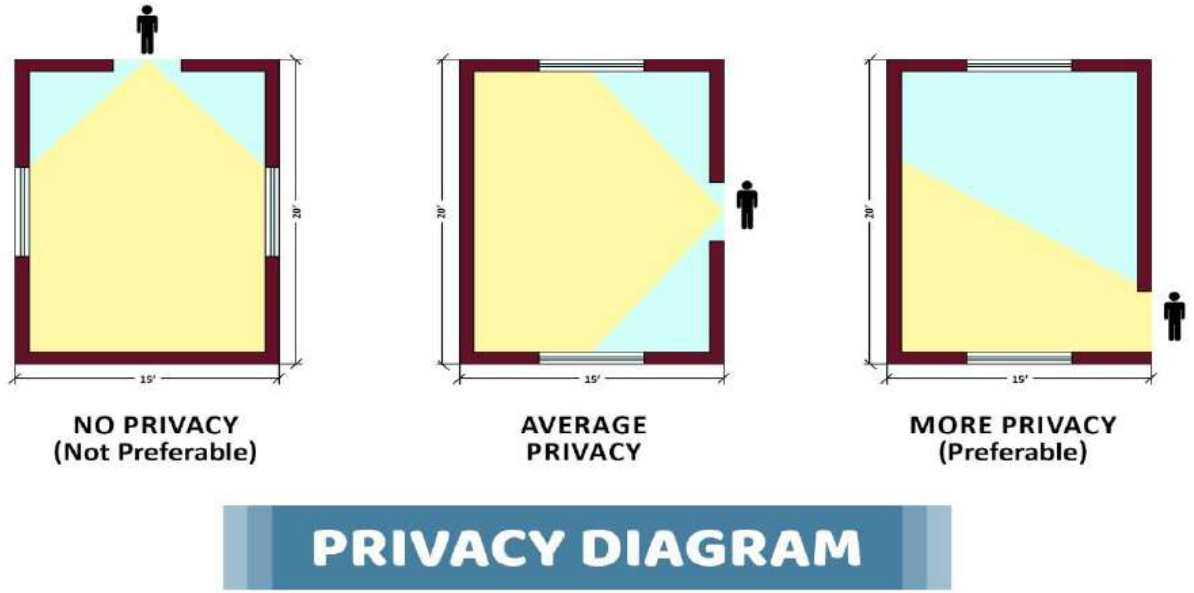
Let us take an example to understand the concept of the flexibility. One storey residential house has a dining and drawing hall on the ground floor, separated with a fibre partition wall in it. For various events and gatherings, both **dining** and **drawing** hall can be **combined** and converted into a **banquet hall** by removing partition wall. Also, future expansions of converting one unit to another must be kept in mind as it is one of the basic principles of construction.

## What does Privacy means in building planning?

Privacy is an important factor that needs prior attention. Usually, the privacy can be considered in two ways:

**01. Internal Privacy**: This deals with the privacy inside a house, amongst the rooms. It covers the privacy between rooms and water closets, corridors, passage lobbies etc.

**02. External Privacy:** Privacy of a building with respect to other buildings and the things outside the building- such as streets, roads, etc., is external privacy.




**How FURNITURE influence principles of building planning?**

According to rooms' functions, the type of furniture varies. The architects and planner must consider the **furniture's relative positions** to **avoid the congestion** of space. The furniture should match the purpose of the room and justify the **effective use of a room and furniture** as well. There are many points to consider while choosing furniture for your house.

## What is SANITATION in building planning?

The **hygiene maintenance** in a building is crucial. **Light, ventilation**, and **sanitary conveniences**, are essential factors that provide good sanitation in a building. Adequate sanitation can be achieved by placing **doors**, **windows**, and **ventilators** appropriately. Installing **exhaust fans, lighting lamps, suitable absorbent flooring, and improvised plumbing equipment** can lead to better sanitation. It is studied that for **proper lighting**, the **least area of window** should **not be less** than **1/10th of floor area** in residential building. This ratio can be raised to **1/5th for buildings other than residential** ones.

## What is the importance of ECONOMY in building planning?

The economy is also one of the major factors to keep in mind while planning a structure. The building should not be **too expensive**. However, having said that, the cost cutting should not happen by **compromising on the safety and the building principles**. Often, the cost of the construction at the initial stage is higher as standard designs and materials are used, but it reduces the cost of maintenance and repair in the future.

## What is ELEGANCE in building planning?

The elegance has a direct connection with the **appearance and layout** of a plan. It has become a trend nowadays to construct **attractive elevations**, which gives a pleasant sense of visibility. Straight, it depends on the **materials used** for construction in the exterior portion and relies on the positions of the door, windows, chajja, balconies, and many such factors. All these components aim to enhance the look and thus it is necessary to give more footage to it while building planning.

## What are the PRACTICAL CONSIDERATIONS in building planning?

While **designing and planning** a building, there are several practical points to be considered for better results. These practical considerations are briefly mentioned as follows:


**Life of a Building:**

Having considered all the above important attributes a common question that arises is how long a building will survive and sustain and will remain serviceable? It is generally said that, a building has a **100 years life**, but this is not always true. The life of a building does not only deal with the **physical life** but also focuses on **economic** as well as **functional life**.

**Lecture-6**

**BUILDING AREA TERMS:-**

**Plot area:**

The area which is **surrounded by a boundary line** (fencing) is called as Plot Area.

**Plinth area or Built-up area**

The **total building area** in plot area is referred as **Built up area**. In simple, Area **excluding empty space** around the building is called Built up area or Plinth area.

**Built up Area = Carpet area+ Thickness of All walls + balcony**

The **plinth area** is the area that lies within the **outer-to-outer dimensions** of the walls of the building and is obtained by multiplying the out-to-out dimensions of the building at any floor level. The **space** covered by **pillars**, **pilasters**, and other **intermediate support** are not calculated in the floor area.

The built-up area and plinth area may or may not same.

**Carpet Area**:

It is the area that can **actually be covered by a carpet**, or the area of the apartment **excluding the thickness of inner walls**. Carpet area does **not include** the space covered by common areas such as **lobby**, **lift**, **stairs**, **play area**, etc. **Carpet area** is usually around **70%** of the **built-up area**.

**Setback area:**

The **empty space** around the building is called **Setback area**. The setback area is decided by Municipal Authority. In India, we **leave 4 ft. from all the sides of the building**. The reason behind leaving setback area is to make ease for moving **vehicles, ventilation and during emergency purposes**. However set back area increases for High rise building and may go up to several meters.

**Setback area = Plot area – Built-up Area**

**Built-Up Area:**

Built-up area is the area that comes after adding **carpet area (70%) and wall area (30%)**. Now, the **wall area** does not mean the surface area, but the **thickness of the inner walls** of a unit. The area constituting the **walls is around 20% of the built-up area** and totally changes the perspective.

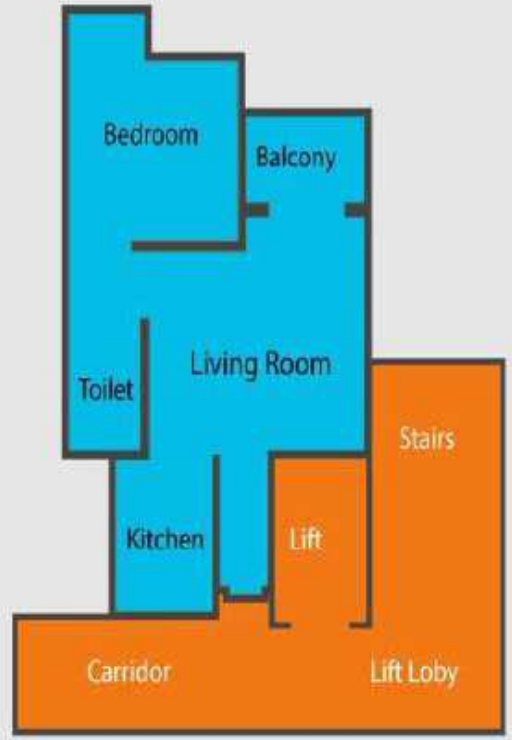
The built-up area also consists of other areas mandated by the authorities, such as a **dry balcony, flower beds,** etc., that add up to **10%** of the built-up area. So, when you think about it, the usable area (carpet area) is only **70% of the built-up area**.

**Super Built-Up Area**:-

It is the area calculated by adding the **built-up area and common area** that includes the **corridor**, **lift lobby, lift**, etc. In some cases, builders even include amenities such as a **pool**, **garden** and **clubhouse** in the common area. A developer/builder charges you on the basis of the **super built-up area** which is why it is also known as '**saleable' area.**


**Carpet Area** = Area That Can Be Covered by Carpet
(House's Net Usable Floor Area)

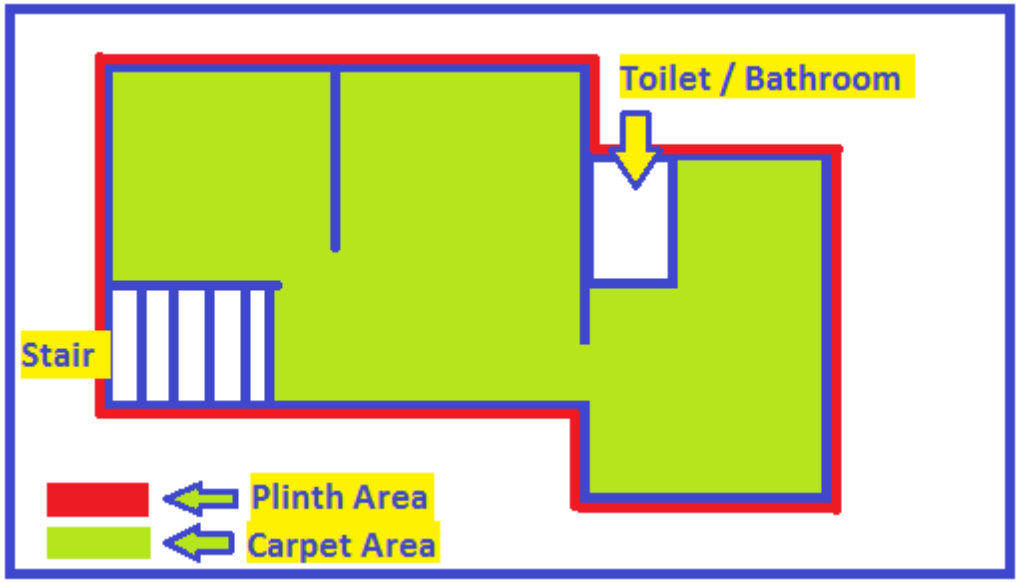

Carpet Area + Wall Area = **Built Up Area**




Built-Up Area + Common Areas = **Super Built-up Area**

**COMPUTATION OF PLINTH AREA/BUILT UP AREA -**

- Plinth area = building carpet area + wall area (both internal and exterior walls) + parasitic area + elevator openings, etc.
- The plinth area is the space between the building's exterior and outer bounds or its walls.
- The **plinth area is 10 to 20% greater than the carpet area**.




**COMPUTATION OF CARPET AREA/LIVABLE AREA-**

- Calculated by subtracting the area of the **outer and inner walls** of the building from the **total floor area of the building**. **Carpet Area = Built-up area – Area of walls**.
- For example, if the built area of a property is 2000 sq. ft., then its carpet area would be 1400 sq. ft.
- The carpet area is the sum of the **actual areas of the rooms that you can carpet.**
- The carpet area is smaller than the plinth area by 10 to 20%.

***Lecture-7***

# Module-II

***Module II Syllabus***

***Surveying*** *- Principle and objectives, Instruments used, Horizontal measurements, Ranging (direct ranging only), Instruments used for ranging, Leveling – Definition, Principles, Instruments, Preparation of level book, problems on leveling, Modern surveying instruments – EDM, Total station, GPS (Brief discussion)*

***Building Materials -*** *Bricks, properties, and specifications, Cement – Types, properties, grades, other types of cement and uses, Cement mortar – Constituents, Preparation, Concrete – PCC and RCC, Grades, Steel – Use of steel in buildings, types.*

**SURVEYING**

Surveying is the art of determining the **relative positions on, beneath, or above the surface of the ground or earth** by the direct or indirect way of measurements of **distance, direction**, and **elevation**.

## Surveying principle:-

Two basic principles of surveying are:

• Always work from **whole to the part**

• To locate a **new station** by **at least two measurements** (Linear or angular) from a fixed reference points. The area is first enclosed by main stations (i.e. Control stations) and main survey lines.

## Objectives of Surveying

Surveying is the means of determining the **relative position of points** and the **relative distances**. It is very important in the field of Civil Engineering. We can find uses of surveying in all civil engineering projects. The objectives of surveying may very depending on the type of project. The main objectives of surveying are discussed below.

- To determine the **relative position** of any objects or points of the earth.
- To determine the **distance** and **angle** between different objects.
- To prepare a **map** or **plan** to represent an area on a horizontal plan.
- To develop methods through the knowledge of modern science and the technology and use them in the field.
- To solve **measurement problems** in an optimal way.

**Station:** A **definite point on the Earth** whose **location** has been **determined** by surveying methods. Usually, but not always, **marked on the ground** using a monument of special construction, or by a natural or-artificial structure. The station's origin or purpose is usually described in its name.

**Datum:** An **assumed surface** used as a **reference** for the measurement of heights and depths. A line to which dimensions are referred on engineering drawings, and from which measurements are calculated **Horizontal datums** measure **positions** (latitude and longitude) on the **surface of the Earth**, while **vertical datums** are used to measure **land elevations** and **water depths**.

**Bench mark:** A **post** or other **permanent mark** established at a **known elevation** that is used as the **basis for measuring** the **elevation** of other topographical points.

**Reduce level:** Reduced level refers to **equating elevations of survey points with reference to a commonly assumed datum**. It is a vertical distance above or below the datum plane. The most common datum used is Mean Sea Level. This reduced level is the term used in levelling.

## Surveying Instruments

Surveying instruments are used to assist in measuring land, including vertical distance, horizontal distance, and volume of excavated material. A land surveyor uses surveying instruments to make precise measurements of the earth's surface. Instruments used in surveying include:

**HORIZONTAL MEASUREMENTS**

A. DIRECT LINEAR SURVEYING
B. SETTING OUT RIGHT ANGLES
C. SETTING OUT DIRECTIONS
D. SETTING OUT ANGLES

## A. Instruments for DIRECT LINEAR SURVEYING

### 1. MEASURING TAPES

It is made up of cotton, coated linen, or any other synthetic material. Centimeters or decimeters are marked on the tape. They are available in lengths of 20, 30, or 50 meters.

**Measuring Tape**

**Metallic tape:** Available in lengths 2, 5, 10, 20, 30, and 50 meters. Except for 2 and 5-meter tapes, other tapes have a small ring fastened at the ends which is of the same width as that of the tape for protection and are supplied in a leather or metal case with a winding device.
**Steel tape**: Available in lengths 1, 2, 10, 20, 30, and 50 meters. Except for 1 and 2-meter tapes, other tapes have a small brass ring fastened at the ends. These tapes are supplied in a corrosion-resistant metal case or a leather case with a winding device.
**Invar tape**: Available in lengths of 20, 30, and 100 meters. Made up of an alloy of nickel and steel with a low thermal coefficient of expansion.

Used for linear measurements that require high precision. It should be kept on reels of high diameter as they can be easily bent and damaged.

## 2. SURVEYING CHAINS

### Use

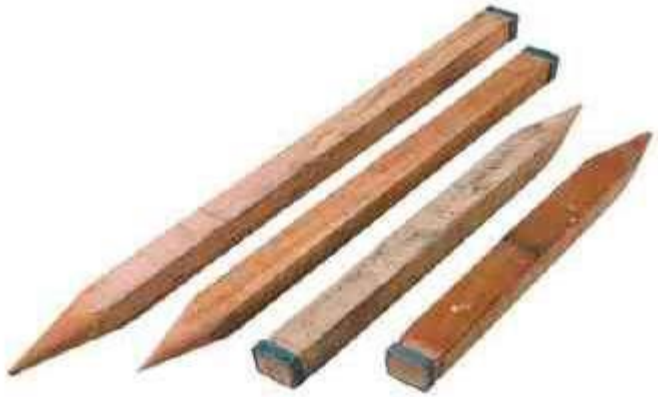
- The chain is used to measure the distance on the **ground**. It gives much **more accurate measurements** as compared to tape.
- A chain is a surveying instrument that is made up of connecting **links** of galvanized mild steel. The mild steel wire is bent into a ring and joined to each other with three small circular or oval rings. Each connecting link measures 20 cm.
- A tally marker or a special joint is also installed sometimes to mark the distance of 5 meters.
- The total length of the chain is 20 meters or 30 meters, which also includes a **brass handle** on each end. The handles are provided with swivel joints so they can be easily turned during surveying without being twisted.

## 3. ARROW:-

### Use

- Arrows are used for **marking** and are made up of hardened, and tempered **steel wire** of good quality.
- **10 arrows are usually sold with a chain**. Its length is about **25-50 cm**. One of its ends is **sharpened** while the other end is bent into a **circular loop**.
- To mark the chain length on the ground, an arrow is inserted at the end of the chain.

## 4. PEG



### Use

- Pegs are mostly made of **timber**. They are also used to **mark** out the locations on the ground at terminal points or the end of the survey line.
- They are 2.5-3 square centimeters and are of **15cm** length with a tapered end. A **hammer** is used to drive the peg into the ground.

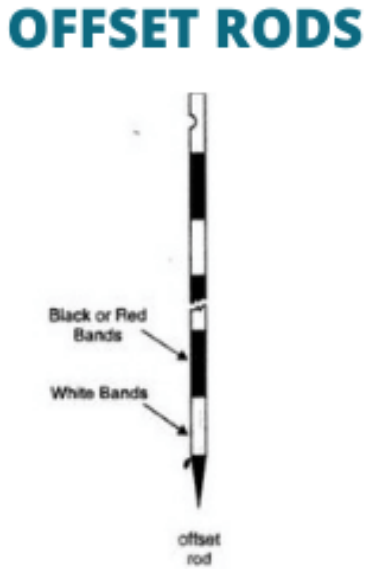
## 5. RANGING RODS

- Ranging rods are **2-3 meters** in length and are painted with **alternate bands** of **two colors** like **white and black**, **red and white** in succession. Each band is kept at a length of 20 centimeters.
- Ranging rods are made of **well-seasoned timber**. Their cross-section is kept either circular or octagonal with a 3 cm nominal diameter.
- They are used to **range** an **intermediate point** on a **survey line**.

Ranging Rods

## 6. OFFSET RODS

- It is similar to a ranging rod but is of a **3 m length**. They are also wooden rods, circular in cross-section. Its one end is pointed with an iron shoe and at the other, a notch or hook is provided.
- It is used to take **rough offsets** in the nearby regions. Also, the **right angles** can be set out with its help as it has **two narrow slots** at its center.



### 7. PLUMB BOB

- It is used to **transfer** the **points** to the **ground** on a slope while **chaining**. It is also used to make the **ranging poles vertical**.
- In theodolites, compasses, plane tables, and other surveying instruments, it is used for **centering purposes**.

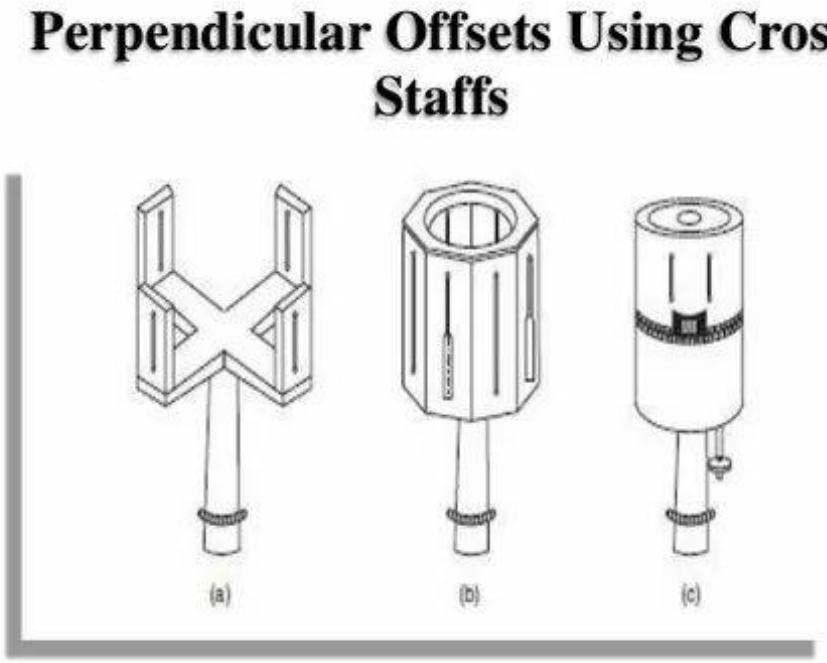
## B. Instruments for SETTING OUT RIGHT ANGLES

### 1. CROSS STAFF

It is the simplest instrument for **setting out right angles** on a survey line. It has a frame containing **two pairs of opposite slits** mounted on a pole. The pole can be used to fix the instrument on the ground.

**Types of cross staff:**

- **Open cross-staff**: Two pairs of vertical slits are present which gives two lines of sight at right angles.
- **French cross-staff**: It has a hollow octagonal box set up on a pole. On each face, vertical slits are cut in the middle for sighting. The lines of sight are at an angle of 45° to one another.
- **Adjustable cross-staff**: It has two cylinders of equal diameter with sighting slits placed on each other. The upper box can be rotated and is provided with a vernier to take measurements. The lower box has graduations of degrees and subdivisions. Any angle can be set out with the help of this instrument.





## 2. OPTICAL SQUARE

- It is **more accurate** than a cross-staff. Also, it is convenient to use for setting out right angles. It has a circular box with three slits.
- The instrument is set on the line whose perpendicular is to be set out. Two slits point towards the ranging rod at the end of the survey line.
- Then another ranging rod is to be set at such a point that the two images coincide with each other. This point is perpendicular to the initial line.

## 3. PRISM SQUARE

- The principle of the prism square is similar to that of the optical square. However, it is **more precise** as compared to the optical square.
- It can be used in a similar manner as an optical square. Unlike the optical square, **adjustment is not required**, as the angle between the reflecting surfaces does not vary.

*Lecture-9*

## FOUNDATION:

It is a part of structural system that supports and anchors the superstructure of a building and transmits its loads directly to the earth. Foundation of a building as the name implies is the starting of a building construction on site really. Types of building, nature of soil and environmental conditions are the major determinant of type of foundation. Choosing a kind of foundation depends on, ground conditions, groundwater conditions, site – the environment (the buildings nearby) and structure of our building.

## Purpose:-

There are numerous reasons a foundation is provided, some of which are:

- The most crucial purpose of providing Foundation is Structural Stability. Strength of the foundation determines the stability of the structure to be constructed.
- A properly designed and the constructed foundation provide an even surface for the development of superstructure at a proper level at over a firm bed.
- A well-designed foundation prevents the lateral movement of the supporting material (which is the soil in this case) and thus ensuring the safety of the superstructure from the detrimental effects of the lateral movements of soil.
- The foundation serves the purpose of completely distributing the loads from the structure to a large base area, and then the soil underneath. This uniform transfer of loads helps in avoiding unequal settlement of the building, which is one of the detrimental defects in building construction.

## Types of Foundation:-

1. Shallow foundation: If the depth of foundation is less than the width of foundation then it is known as Shallow or stepped Foundation. It can be used where the bearing capacity of soil on which the structure is to be constructed is maximum. Minimum depth of this Foundation is 800mm and maximum depth not to be taken more than 4 meters.
2. Deep foundation: If the depth of footing greater or equal to the Width of footing, it is known as the deep Foundation. Deep Foundation is used where the bearing capacity of the soil is very low. The load coming from the superstructure is further transmitted vertically to the soil.

**Difference between Foundation and Footing**:

- Foundation is a structure which transfers the loads from the superstructure to the ground, while footing is the foundation which is in contact with the earth.

- A foundation can be shallow and deep, while a **footing** is a type of a **shallow foundation**. so, all footings are foundations but all foundations cannot be footings.

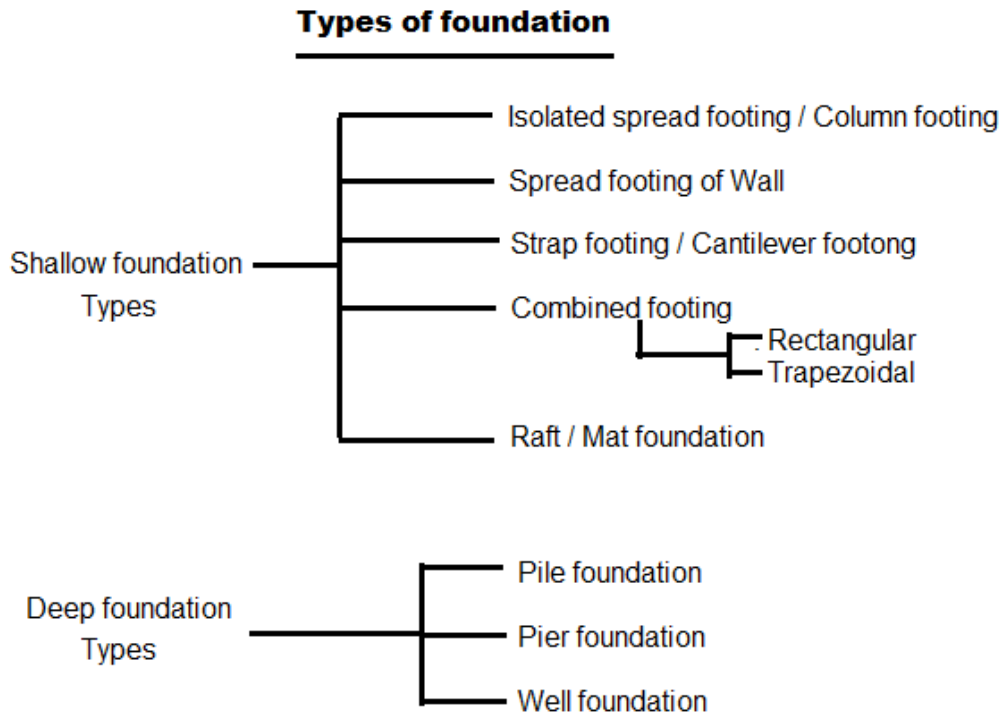
## SHALLOW FOUNDATIONS

- They are usually located no more than 6 ft below the lowest finished floor.
- A shallow foundation system generally used when

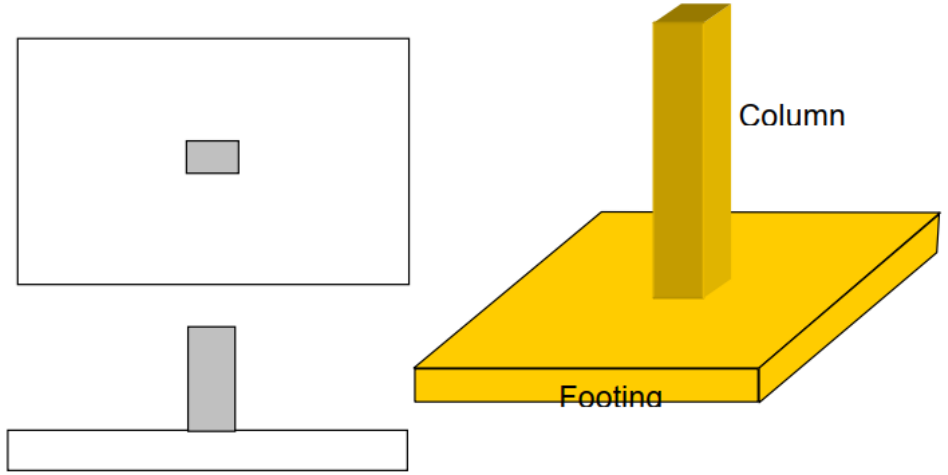
• The soil closes the ground surface has sufficient bearing capacity
• Underlying weaker strata do not result in excessive settlement.

- The shallow foundations are commonly used most economical foundation systems
- **Types of spread footing: (either for Column or for Wall)**

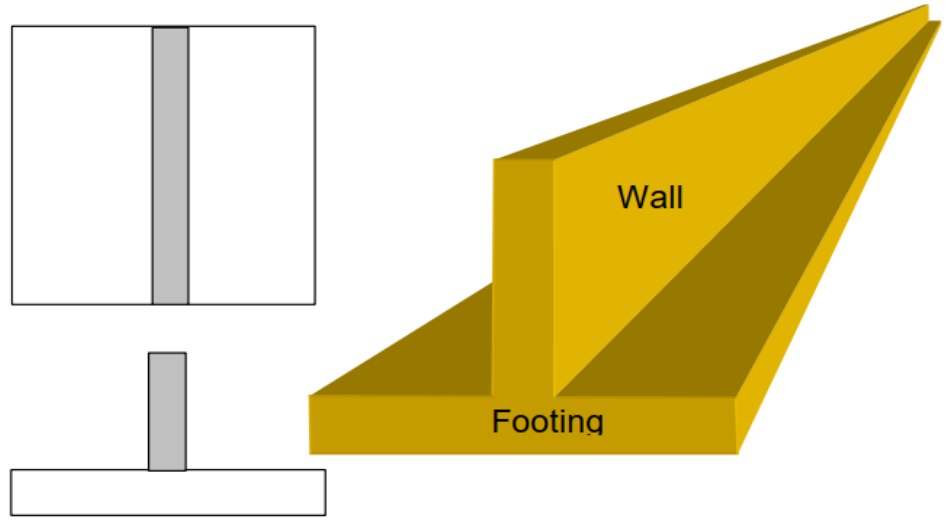
a) Single pad footing.
b) Stepped footing for a column.
c) Sloped footing for a column.
d) Wall footing without step.
e) Stepped footing for walls.
f) Grillage foundation.



**(a) Isolated spread footings** under individual columns which can be square, rectangular or circular.




**(b) Wall footing** is a continuous slab strip along the length of wall



**(c) Combined footings** support two or more columns. These can be rectangular or trapezoidal in plan.

➢ A combined footing is necessary in following **three reasons**:

• Columns are placed **very close to each other** so that their individual footings overlap each other.

• When **bearing capacity of soil is less** so it is required to have a more spread area for footing and so footing of adjacent column may overlap.

• When external column is **close to property line**, it is not possible to provide isolated footing for that column because it may be extended beyond the property line and so combined footing solves the problem.

➢ The **essential condition** to satisfy in **combined footing** is that, c**entroid of footing area should coincide with resultant of column loads** so that **soil pressure distribution is uniform under soil.**

**Types of combined footing**:

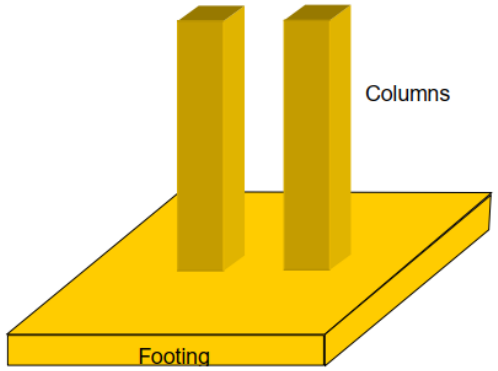
• Combined footing (Rectangular):

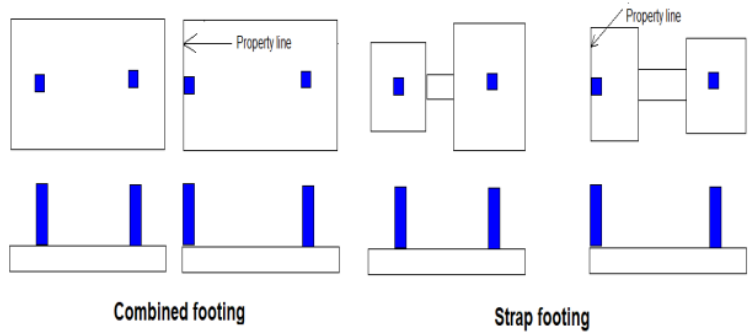
• Combined footing (Trapezoidal):

If outer column near property line carries a heavier load

• Strap footing

• Raft / mat foundation




**Combined footing**

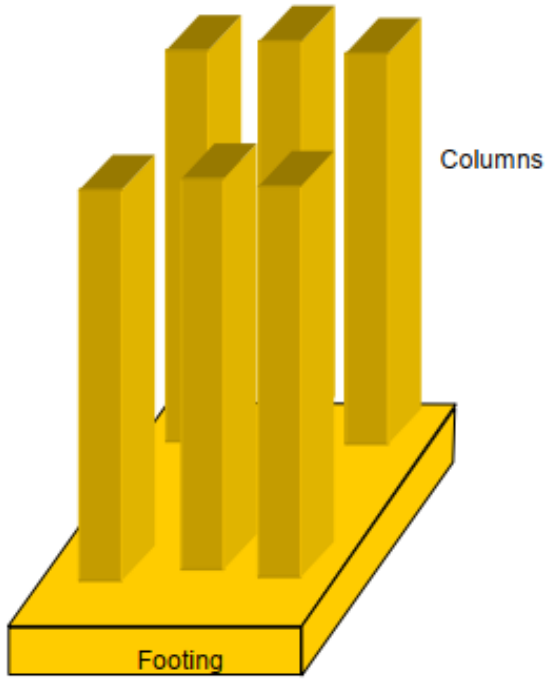
**(d) Strap or Cantilever Footing**

- Strap footings are similar to combined footings.
- Reasons for considering or choosing strap footing are identical to the combined one.
- In *strap footing*, the foundation under the columns is built individually and connected by a **strap beam**.
- Generally, when the **edge of the footing cannot be extended beyond the property line**, the **exterior footing is connected by a strap beam with interior footing**.

**(e) Raft / mat foundation:**

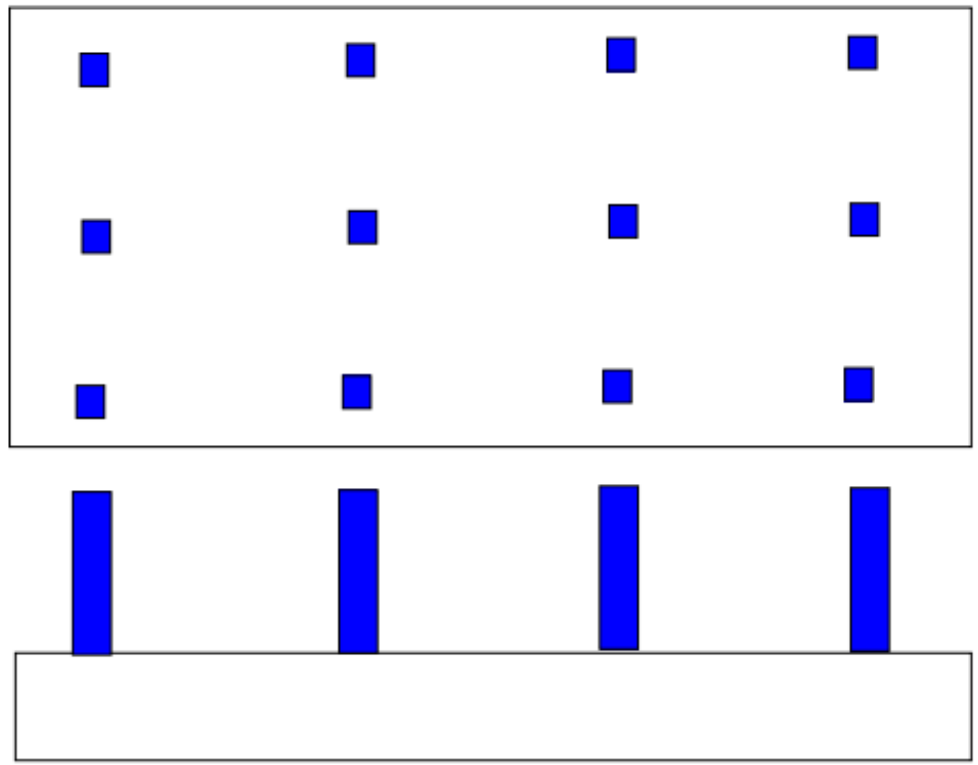
- This is a large continuous footing supporting all the columns of the structure.
- This is used when soil conditions are poor but piles are not used.
- Raft foundation is provided
- When **load** transmitted by **columns** are so **heavy** or **allowable soil pressure** are so small that individual footings if provided would **cover more than about half** of the area, then it is better to provide a continuous footing called raft foundation under all columns and walls
- Raft foundations are used to reduce settlement of structure located above heavy compressible deposits i.e. they control differential settlement

- **Types of raft foundation**:
- **Solid raft** (A continuous slab covering all the columns)
- **Ribbed raft** (mat with a central hollow region when all the columns are connected by a continuous beam which gets supported on the raft slab




**Raft foundation**

**Mat or Raft**



**DEEP FOUNDATION**

**DEEP FOUNDATION**

**1. PILE FOUNDATION**

- A **pile** is a **slender column** provided with a **cap** to receive the **column load** and transfer it to **undelaying soil layer / layers**.
- Pile **foundation** is a common type of deep foundation.
- Pile is a slender member with a small cross-sectional area compared to its length.
- It is used to transmit foundation loads to a deeper soil or rock strata when the bearing capacity of soil near the surface is relatively low.
- Pile transmits load either by skin friction or bearing.
- Piles are also used to resist structures against uplift and provide structural stability against lateral and overturning forces.
- They are used to reduce cost, and when as per soil condition considerations, it is desirable to transmit loads to soil strata which are beyond the reach of shallow foundations.
- Pile foundations are economical when
  - Soil with higher **bearing capacity** is at a greater depth.
  - When the foundation is subjected to a **heavily concentrated load**
  - The foundation is subjected to **strong uplift force**
  - Lateral forces are relatively pre dominant
  - When there are chances of construction of **irrigation canals** in the nearby area.

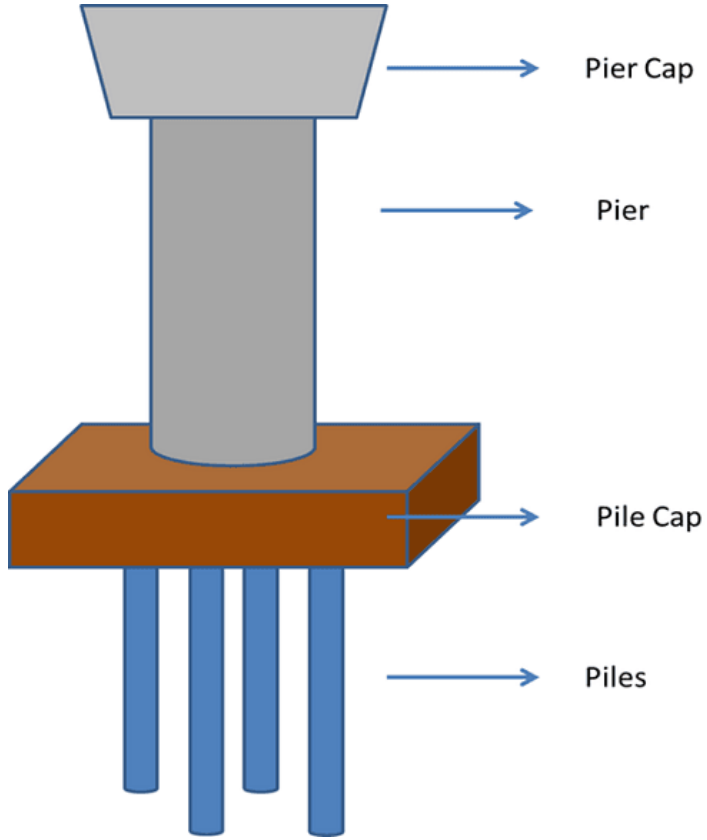
- Expansive soil like **black cotton soil** are present at the site
- In **marshy places** where soil is wet soil/ soft soil/ water logged/ low laying area
- When the **topsoil laye**r is **compressible** in nature.
- In the case of bridges, when the **scouring** is **more** in the **river bed**.
- When it is very expensive to provide **raft** or **grillage**.

## 2. PIER FOUNDATION

• Pier is a deep foundation structure above ground level that transmits a more massive load, which cannot be carried by shallow foundations.
• It is usually shallower than piles.
• Pier foundation is a cylindrical structural member that transfer heavy load from superstructure to the soil by end bearing.
• Unlike piles, it can only transfer load by **end bearing** only and by **not skin friction**.

## Difference between Pile and Pier foundation

| Pile | Pier |
|---|---|
| Piles are always below the ground level | Piers are always above the ground |
| Larger in length and smaller in diameter | Smaller in length and larger in diameter |
| Adopted when there is no hard bearing strata of soil available at reasonable depth | Adopted when there is hard bearing strata of soil available at reasonable depth but other types of foundation construction is not economical |
| Piles are driven through overburden soil into load bearing strata | Pier is drilled by drilling machine |
| Transfers full load through both bearing and friction action only | Transfers full load through bearing action only |
| Constructed at greater depth | Constructed at shallower depth |
| Resist greater intensity of load | Resist smaller intensity of load |




**PIER foundation with PILE**

3.WELL / CAISSON FOUNDATION

- Caisson foundation is a watertight retaining structure used as a bridge pier, construction of the dam, etc.
- It is generally used in structures that require foundation beneath a river or similar water bodies.
- The reason for choosing the caisson is that it can be floated to the desired location and then sunk into place.
- Caisson foundation is a ready-made hollow cylinder depressed into the soil up to the desired level and then filled with concrete, which ultimately converts to a foundation.
- It is mostly used as bridge piers.
- Caissons are sensitive to construction procedures and lack construction expertise.
- There are several types of caisson foundations.

1. Box Caissons.
2. Floating Caissons.
3. Pneumatic Caissons.
4. Open Caissons.
5. Sheeted Caissons.
6. Excavated Caissons.

**CAISSON Foundation**

**Lecture-10**

# DETAILS OF PILE AND PILE CAP

## Classification of Pile foundation:

### 1. Based on Function or Use:

a) **End Bearing Piles:**

These are the pile used to transfer loads through water or soft soil to a suitable bearing stratum.

b) **Friction Piles:**

This type of pile utilizes the frictional resistance force between the pile surface and adjacent soil to transfer the superstructure load.

**c) Combined end bearing and friction pile:**

This pile transfers the super-imposed load both through side friction as well as end bearing. Such piles are more common, especially when the end bearing piles pass through granular soils.

d) C**ompactor Piles:**

These are used to compact loose granular soil thus increasing their bearing capacity.

**e) Batter pile:**

A pile driven at an angle with the vertical to resist a lateral force

**f) Sheet Piles:**

Used as impervious cut-off to reduce seepage and uplift under hydraulic structures. They are rarely used to furnish vertical support but are used to function as retaining wall

**g) Anchor pile:**

It provides anchorage against horizontal pull from sheet piling

Anchor piles can transfer both **compressive** and **tensile** forces as well as **bending moments** to the ground, making them ideal as anchors for offshore moorings, basements, and tunnels, etc. Moored floating offshore structures impose a variety of load conditions on the anchor system.

h) **Tension/uplift pile:**

It anchors down the structures subjected to uplift due to hydro static pressure, seismic activity or due to overturning moment

**2. Based on Materials:**

a) Timber Piles

b) Concrete Piles

c) Steel Piles

d) Composite Piles

**3. Based on construction process:**

**a) Bored Piling:**

Bored piles are installed by auguring into the ground forming a hole into which concrete can be poured, thereby casting the pile in position.

**b) Driven Piling:**

Driven piles are driven or hammered into the ground with the use of vibration

**c) Screw Piling**

Screw piles are wound into the ground, much like a screw is wound into wood. This is an efficient means of installation and coupled with their mechanism of dispersing load, provides effective in-ground performance in a range of soils, including earthquake zones with liquefaction potential

**d) Mini Piling**

Mini piling is a variation on piling that uses a narrower diameter. This makes them light and inexpensive whilst still being able to support considerably heavy loads. For the most common type of mini piling a hollow steel shaft is screwed or drilled into the ground

**e) Sheet Piling**

Sheet pile walls are retaining walls constructed to retain earth, water or any other filling materials. These walls are thinner in section compared to masonry walls. Sheet pile walls are generally used for following: Water front structures, i.e. in building wharfs, quays and piers

**4. Classification of Piles based on the effect of Installation:**

a) **Displacement** pile:(eg: **Driven** Cast in Situ concrete pile and Driven Precast concrete pile)
b) Non- Displacement pile: (eg: **Bored** Cast in Situ concrete pile, Bored Precast concrete pile)

**5. Classification of Concrete piles:**

a) Driven cast in-situ (CIS) piles (IS 2911-P1-S1-2010)
b) Bore cast in-situ (CIS) piles (IS 2911-P1-S2-2010)
c) Driven precast (PC) piles (IS 2911-P1-S3-2010)
d) Precast (PC) pile in pre bore hole (IS 2911-P1-S4-2010)

Pile foundation:

In this type of foundation, the load is transmitted by a vertical member. This vertical member is known as a pile. These piles are generally made of steel, concrete and wooden. These days precast members are used but we can create these members on site as well.

According to function pile foundation are of following types.

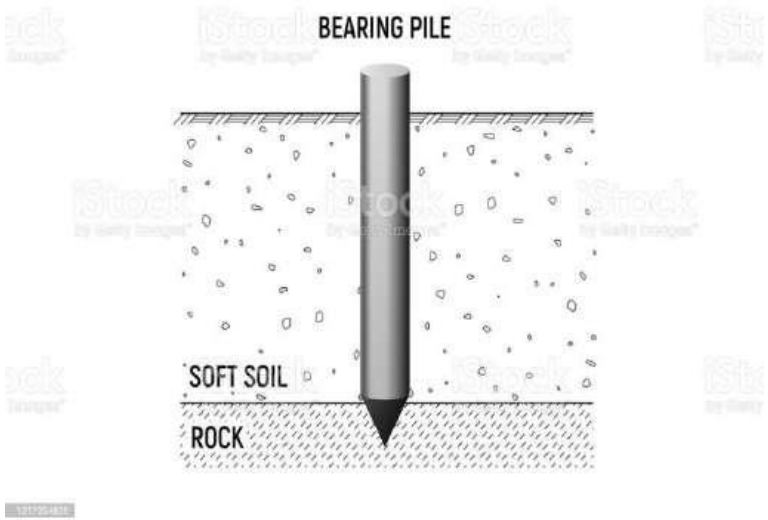
a) Bearing pile

b) Friction pile

Bearing pile:

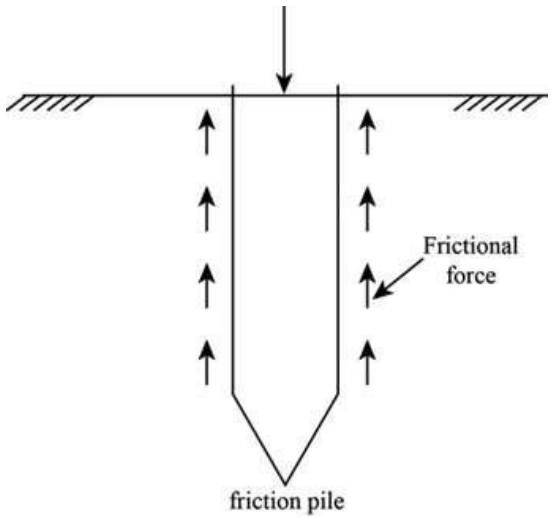
They are driven till hard Strata or layer of Rock beds.

The load is transmitted by columns to the hard layer of soil.




Friction pile:

These piles are used where the soil is soft at a considerable depth. The load is transferred to the soft soil due to the friction produced between the soft soil which is in contact with these piles



According to material piles are as follow
a) Concrete pile
b) Wooden pile or Timber pile
c) Steel pile
d) Composite pile

Concrete pile:
These piles are made up of concrete. The diameter of these pile varies from 30 to 50 cm. Minimum length of these pile is not taken less than 20 meters and maximum it can be taken till 30 meters. Concrete piles are manufactured either by precast or cast in situ method.

Wooden pile or Timber pile:
As the name suggests these piles are made up of wood. For these piles, seasonal Timber wood is used. The diameter of the timber pile varies in between 20 to 50 cm. Length of a pipe is taken 20 times that of its diameter. The maintenance cost of these piles is more because as it is wood if it comes in contact with water then it can be damaged by fungus or white ants. So care has to be taken.

Steel pile:

These files are generally in shape of ‘I’ or hollow section. It can be easily driven in the soil because it has a very small cross-sectional area. These piles can be used as a bearing pile but cannot be used as friction piles because if we use them as a friction pile it can sunk in the soil due to structural load.

Composite pile:

When the piles are made from more than one material they are known as composite pile. These piles are made from concrete and wood. These piles are used in those areas where the water table is up. These piles are used in such conditions just because concrete and wood both are good water absorbers.

## Bearing Capacity of Soil

✓ When subjected to stress from loading, the soil has a tendency to distort. The soil's ability to resist displacement is influenced by a number of different variables, including its moisture content, relative density, internal friction angle and the way in which force is transmitted to the soil.

✓ The term "bearing capacity of soil" refers to **the maximum weight per unit area** that soil can support without succumbing or being displaced.

✓ If the soil underneath a building cannot support the weight of the structure being constructed, the structure may become unstable, which can result in fractures and other forms of damage.

✓ As a result, in order to circumvent this problem, the bearing capacity of soil must be taken into consideration while designing the foundation.

| Soil Type | Allowable Bearing Capacity |
|---|---|
| Rock | 3240 |
| Soft Rock | 440 |
| Course Sand | 440 |
| Medium Sand | 245 |
| Fine Sand | 440 |
| Stiff Sand | 100 |
| Soft Clay | 100 |
| Very Soft Clay | 50 |

## Types of Bearing Capacity of Soil

**1. Ultimate bearing capacity (qu)**
The **gross pressure** at the base of the foundation at which soil fails is called ultimate bearing capacity.

**2. Net ultimate bearing capacity (qnu)**
By **neglecting the overburden pressure** from ultimate bearing capacity we will get net ultimate bearing capacity.

**3. Net safe bearing capacity (qns)**
By considering only shear failure, **net ultimate bearing capacity** is **divided** by certain **factor of safety** will give the **net safe bearing capacity**.
qns = qnu/ F

**4. Gross safe bearing capacity (as)**
When **ultimate bearing capacity** is **divided** by **factor of safety** it will give gross safe bearing capacity.
qs = qu/F

**5. Net safe settlement pressure (anp)**
The pressure with which the soil can carry without exceeding the allowable settlement is called net safe settlement pressure.

**6. Net allowable bearing pressure (qna)**
This is the pressure we can used for the design of foundations. This is equal to net safe bearing pressure if gnp > qns. In the reverse case it is equal to net safe settlement pressure.

## *Factors Affecting Bearing Capacity of Soil*

### 1. Foundation width

Soil with little cohesiveness might have its bearing capacity reduced if the foundation is too narrow. In cohesionless soil, where internal friction contributes significantly to soil shear strength, a wider foundation will support a greater load. Soil with infinite depth, consistent shear strength, and cohesive properties may support loads of any width foundation.

### 2. Foundation depth

A deeper foundation is necessary for increased bearing capacity. This is most noticeable in cohesive-free soil when the texture is homogeneous. The opposite is true if the foundations are pushed into a poor soil layer, which reduces their carrying ability.

Unless the building is anchored by under-consolidated soil or compressible soil that is vulnerable to wetness, appropriate bearing capacity is typically assured by foundations set at depths where the weight of the structure matches the weight of the displaced soil.

### 3. Surcharge and soil weight

One cannot exclude the bearing capacity contribution of water table-influenced surcharge and subsurface soil. Construction, seepage, and elevation issues may be avoided if the water table is kept below the foundation's base. There will be no effect on the bearing capacity of soil from water table levels below the failure surface.

### 4. Spacing between foundations

When designing a foundation, it is advised that a minimum separation between footings that is 1.5 times the width of the foundation be taken into consideration. This will help prevent a loss in the foundation's carrying capacity.

### 5. Dynamic motion and earthquake

The bearing capacity of soil might diminish due to repeated movement, which would raise pore pressure. Earthquakes, vibrating equipment, and several other factors such as transportation,
explosion, and pile driving all contribute to cyclic motions.
When pore pressures are higher than the soil confining tension, the foundation soil may become liquefied. The effective stress drops to zero due to liquefaction, leading to significant deformation and a decrease in bearing capacity.

### 6. Frost action

Changes in the bearing capacity of soil may occur gradually over time due to frost heave in particular soils that are in proximity to water and are exposed to subzero weather. Materials with a low cohesiveness, such as those made up of a lot of silt-sized particles, are more vulnerable to the effects of frost.

### 7. Subsurface voids

The bearing capacity of soil is diminished when subsurface voids are present within a crucial depth under the foundation. The critical depth is determined by the depth at which the pressure exerted by the foundation on the soil is no longer significant.

### 8. Collapsible and expansive soils

When the soil is somewhat dry, its sturdiness and bearing capacity may increase significantly, despite its tendency to collapse and expand. However, because of changes in moisture content, the proportion of these soils might shift. As a result, there will be shifts in the structure’s base on a global and regional scale. Soil movement brought on by rain and dry spells may cause long-term, severe damage to buildings.

## 9. Potential heave

Consolidometer testing, carried out in line with ASTM D 4546, may reveal the presence of a possible heave. The findings of this test are taken into account when deciding how to prepare the foundation soils so that they are better able to resist or isolate the anticipated soil heave.

## 10. Soil reinforcement

The bearing capacity of weak or soft soil may be significantly boosted by the installation of different types of reinforcement in the soil. These reinforcements can take the shape of metal links, strips, arrays, geotextile fabrics, or coarse aggregates.

## 11. Seepage and soil erosion

Seepage and erosion of the soil surrounding and beneath foundations may both lower the bearing capacity of the foundation soil and ultimately lead to its collapse.

**Lecture-11**

**Module-II**

## Fundamental Properties of Construction Materials

Building materials or construction materials are the major requirement in this modern age of technology. There are many types of building materials used for different construction works.

## Properties of Building Materials

For a material to be considered as building material, it should have required engineering properties suitable for construction works. These properties of building materials are responsible for its quality and capacity and helps to decide applications of these material. Such properties of building materials are categorized as follows.

- Physical properties
- Mechanical properties
- Chemical properties
- Electrical properties
- Magnetic properties
- Thermal properties

## Physical Properties of Building Materials

These are the properties required to estimate the quality and condition of the material without any external force. The physical properties of engineering materials are as follows.

- Bulk density
- Porosity
- Durability
- Density
- Density index
- Specific gravity
- Fire resistance
- Frost resistance
- Weathering resistance
- Spalling resistance
- Water absorption
- Water permeability
- Hygroscopicity
- Coefficient of softening
- Refractoriness

## Bulk Density of Building Materials

Bulk density is the ratio of mass to the volume of the material in its natural state that is including voids and pores. It is expressed in $kg/m^3$. Bulk density influences the mechanical properties of materials like strength, heat and conductivity etc. bulk density values of some of the engineering materials are given below.

| Building material | Bulk density ($kg/m^3$) |
|---|---|
| Brick | 1600 - 1800 |
| Sand | 1450 - 1650 |
| Steel | 7850 |
| Heavy concrete Light concrete | 1800 – 2500 500 - 1800 |
| Granite | 2500 – 2700 |

## Porosity of Building Materials

Porosity gives the volume of the material occupied by pores. It is the ratio of volume of pores to the volume of material. Porosity influences many properties like thermal conductivity, strength, bulk density, durability etc.

### Durability of Building Materials

The property of a material to withstand against the combined action of atmospheric and other factors is known as durability of material. If the material is more durable, it will be useful for longer life. Maintenance cost of material is dependent of durability.

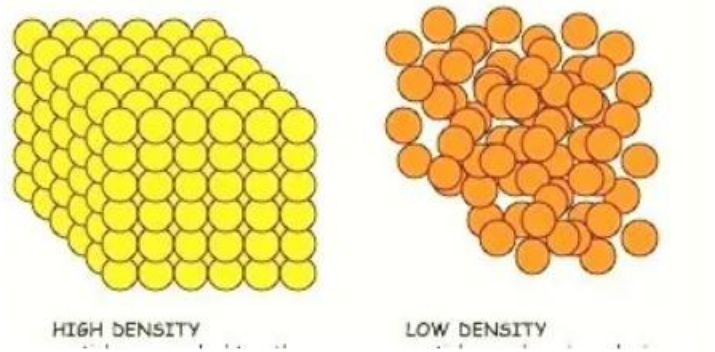
### Density of Building Materials

Density is the ratio of mass of the material to its volume in homogeneous state. Almost all the physical properties of materials are influenced by its density values. Density values of some building materials are given below.

| Material | Density ($kg/m^3$) |
|---|---|
| Steel | 7800 – 7900 |
| Brick | 2500 -2800 |
| Granite | 2600 – 2900 |

## Density Index

Ratio of bulk density of material to its density is termed as density index. Hence it gives the volume of solid matter in the material. In nature, fully dense material is not available so, density index is always less than 1 for any building material.




## Specific Gravity of Building Materials

Specific gravity is the ratio of mass of given substance to the mass of water at 4°C for the equal volumes. Specific gravity of some materials is listed below.

| Material | Specific gravity |
|---|---|
| Steel | 7.82 |
| Cast iron | 7.20 |
| Aluminum | 2.72 |

## Fire Resistance of Building Materials

The ability to withstand against fire without changing its shape and other properties. Fire resistance of a material is tested by the combined actions of water and fire. Fireproof materials should provide more safety in case of fire.

**Frost Resistance**

The ability of a material to resist freezing or thawing is called frost resistance. It is depends upon the density and bulk density of material. Denser materials will have more frost resistance. Moist material have low frost resistance and they lose their strength in freezing and become brittle.

**Weathering Resistance**

The property of a material to withstand against all atmospheric actions without losing its strength and shape. Weathering effects the durability of material. For example corrosion occurs in iron due to weathering. To resist this paint layer is provided.

**Spalling Resistance**

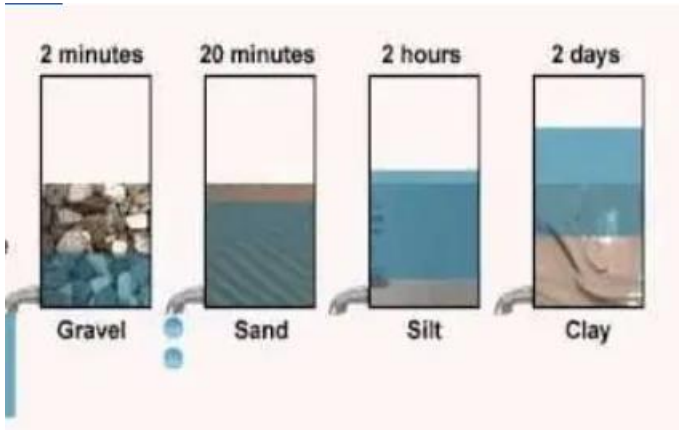
The ability of a material to undergo certain number of cycles of sharp temperature variations without failing is known as spalling resistance. It is the dependent of coefficient of linear expansion.

**Water Absorption**

The capacity of a material to absorb and retain water in it is known as water absorption. It is expressed in % of weight of dry material. It depends up on the size, shape and number of pores of material.

**Water Permeability**

The ability of a material to permit water through it is called water permeability. Dense materials like glass metals etc. are called impervious materials which cannot allow water through it.



**Hygroscopicity**

Hygroscopicity is the property of a material to absorb water vapor from the air. It depends on the relative humidity, porosity, air temperature etc.

**Coefficient of Softening**

Coefficient of softening of a material is the ration of compressive strength of a saturated material to its compressive strength in dry state. It affects the strength of water absorbent materials like soil.

**Refractoriness**

The property of a material which cannot melts or lose its shape at prolonged high temperatures (1580$^{o}$C or more). Example: fire clay is high refractory material.

**Mechanical Properties of Building Materials**

Mechanical properties of the materials are find out by applying external forces on them. These are very important properties which are responsible for behavior of a material in its job. The mechanical properties are,

- Strength
- Hardness
- Elasticity
- Plasticity
- Brittleness
- Fatigue
- Impact strength
- Abrasion resistance
- Creep

**Strength of Building Materials**

The capacity of a material to resist failure caused by loads acting on it is called as strength. The load may be compressive, tensile or bending. It is determined by dividing the ultimate load taken by the material with its cross sectional area. Strength is an important property for any construction materials. So, to provide maximum safety in strength, factor of safety is provided for materials and it is selected depending on nature of work, quality of material, economic conditions etc.

**Hardness of Building Materials**

The property of a materials to resist scratching by a herder body. MOHS scale is used to determine the hardness of a materials. Hardness is most important to decide the usage of particular aggregate. It also influences the workability.

**Elasticity of Building Materials**

The capacity of a material to regain its initial shape and size after removal of load is known as elasticity and the material is called as elastic material. Ideally elastic materials obey Hooke's law in which stress is directly proportional to strain. Which gives modulus of elasticity as the ratio of unit stress to unit deformation. Higher the value of modulus of elasticity lower the deformations.

**Plasticity**

When the load is applied on the material, if it will undergo permanent deformation without cracking and retain this shape after the removal of load then it is said to be plastic material and this property is called as plasticity. They give resistance against bending, impact etc. Examples: steel, hot bitumen etc.

**Brittleness**

When the material is subjected to load, if it fails suddenly without causing any deformation then it is called brittle material and this property is called as brittleness. Examples: concrete, cast-iron etc.

**Fatigue**

If a material is subjected to repeated loads, then the failure occurs at some point which is lower than the failure point caused by steady loads. This behavior is known as fatigue.

**Impact Strength**

If a material is subjected to sudden loads and it will undergo some deformation without causing rupture is known as its impact strength. It designates the toughness of material.

**Abrasion Resistance**

The loss of material due to rubbing of particles while working is called abrasion. The abrasion resistance for a material makes it durable and provided long life.

**Creep**

Creep the deformation caused by constant loads for long periods. It is time dependent and occurs at very slow rate. It is almost negligible in normal conditions. But at high temperature conditions creep occur rapidly.

**Chemical Properties of Building Materials**

•The properties of materials against the chemical actions or chemical combinations are termed as chemical properties. And they are

•Chemical resistance

•Corrosion resistance

**Chemical Resistance of Building Materials**

The ability of a construction materials to resist the effects by chemicals like acids, salts and alkalis is known as chemical resistance. Underground installations, constructions near sea etc. should be built with great chemical resistance.

**Corrosion Resistance**

Formation of rust (iron oxide) in metals, when they are subjected to atmosphere is called as corrosion. So, the metals should be corrosive resistant. To increase the corrosion resistance proper measures should be considered. Otherwise it will damage the whole structure.

**Electrical Properties of Building Materials**

The properties of a material to conduct or to resist electricity through them are electrical properties of material. For example, wood have great electric resistance and stainless steel is a good conductor of electricity.

**Magnetic Properties of Building Materials**

The magnetic properties of materials like permeability, hysteresis etc. are required in the case of generators etc. iron is magnetic material and aluminum is non-magnetic material.

**Thermal Properties of Building Materials**

- Thermal capacity
- Thermal conductivity
- Thermal resistivity
- Specific heat

**Thermal Capacity of Building Materials**

Thermal capacity is the property of a material to absorb heat and it is required to design proper ventilation. It influences the thermal stability of walls. It is expressed in J/N $^{o}$C and it is calculated by below formula. Thermal capacity, $T = [H/(M(T_2 - T_1))]$ Where H = quantity of heat required to increase the temperature from $T_1$ to $T_2$ $T_1$ = Initial temperature $T_2$ = Final temperature M = Mass of material in N.

## Thermal Conductivity

The amount of heat transferred through unit area of specimen with unit thickness in unit time is termed as thermal conductivity. It is measured in kelvins. It depends on material structure, porosity, density and moisture content. High porous materials, moist materials have more thermal conductivity.

## Thermal Resistivity

It is the ability to resist heat conduction. And it is the reciprocal of thermal conductivity. When it is multiplied by thickness of material it gives thermal resistance. Thermal resistivity of soil varies from 30 to 500 $^0$C-cm/W.

## Specific Heat

Specific heat is the quantity of heat required to heat 1 N of material by 1$^o$C. Specific heat is useful when we use the material in high temperature areas. Specific heat values of some engineering materials are given below.

| Material | Specific heat J/N $^o$C |
|---|---|
| Steel | 0.046 x $10^3$ |
| Wood | 0.239 to 0.27 x $10^3$ |
| Stone | 0.075 to 0.09 X $10^3$ |

**Lecture-12**

# STONES

## Introduction:

All the building structures are composed of different types of materials. These materials are either called building materials or materials of construction. It is very essential for a builder, may be an architecture or engineer or contractor, to become conversant thoroughly with these building materials. The knowledge of different types of material, their properties and uses for different purposes provides and important tool in the hands of the builders in achieving economy in material cost. The material cost in a building ranges 30 to 50 percent cost of total cost construction. In addition to material economy, the correct use of material results in better structural strength, functional efficiency and aesthetic appearance.

## Classification of Rocks:

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

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

## Geological Classification:

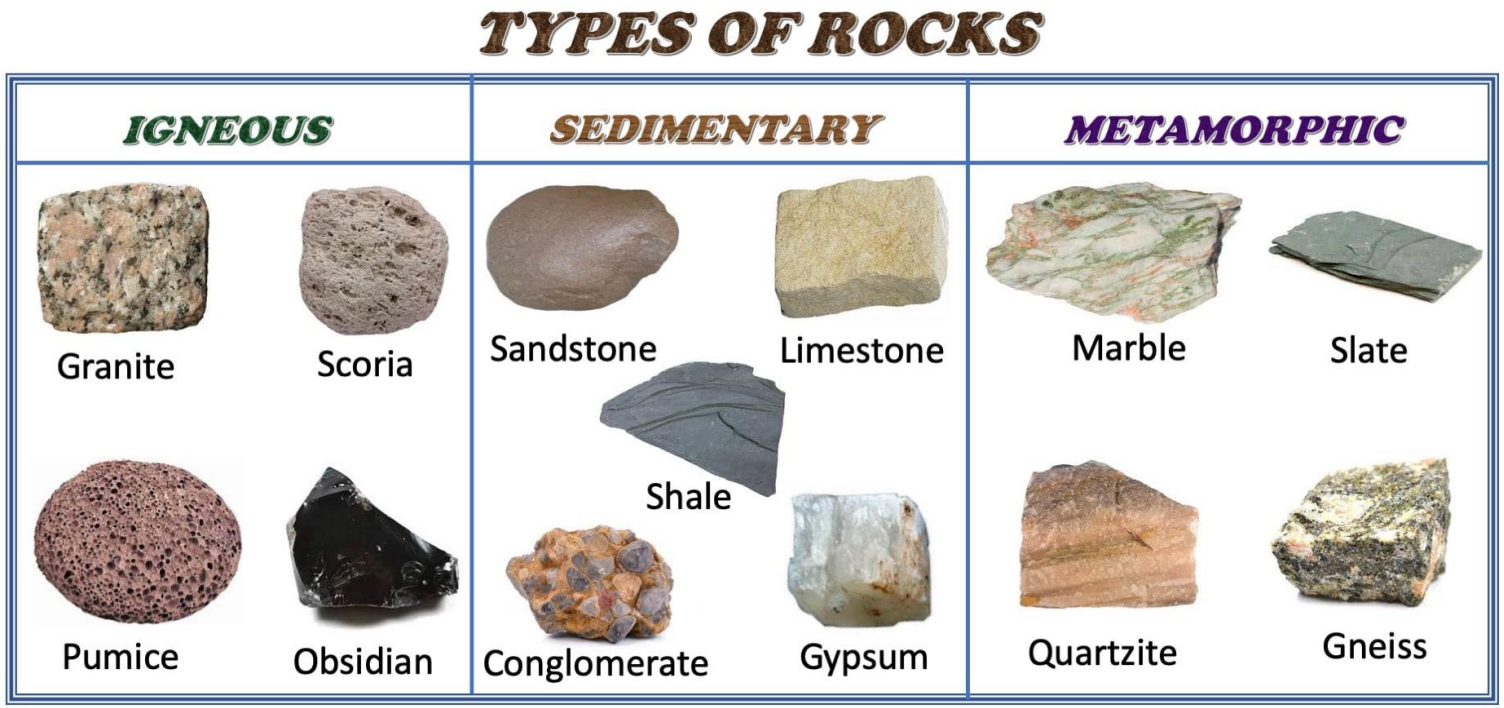
According to this classification, the rocks are of the following types.

**a. Igneous rocks:** Rocks that are formed by cooling of Magma (molten or pasty rocky material) are known as igneous rocks.

Eg: Granite, Basalt and Dolerite etc.

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

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



**Physical Classification:**

This classification based on general structure of rocks. According to this, the rocks are classified into three types

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

Ex: sedimentary rocks

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

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

**Chemical Classification:**

According to this classification rocks are classified into three types.

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

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

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

**Uses of stones:**

1.**Structure**: Stones are used for foundations, walls, columns, lintels, arches, roofs, floors, damp proof course etc.

2.**Face works.** Stones are adopted to give massive appearance to the structure. Wall are of bricks and facing is done in stones of desired shades. This is known as composite masonry.

3.**Paving stones:** These are used to cover floor of building of various types such as residential, commercial, industrial etc. They are also adopted to form paving of roads, foot paths etc.

4.**Basic material**: Stones are disintegrated and converted to form a basic material for cement concrete, morum of roads, calcareous cements, artificial stones, hallow blocks etc.

5.**Miscellaneous**: Stones are also used for (i) ballast for railways (ii) flux in blast furnace (iii) Blocks in the construction of bridges, piers, abutments, retaining walls, light houses, dams etc.

**Qualities of a good building stone:**

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

**1. Crushing strength:** For a good building stone, the crushing strength should be greater than l000kg per cm2.

**2. Appearance:** Good building stone should be a uniform colour, and free from clay holes, spots of other colour bands etc capable of preserving the colour for longtime.

**3. Durability:** A good building stone should be durable. The factors like heat and cold alternative wet and dry, dissolved

gases in rain, high wind velocity etc affect the durability.

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

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

**6. Percentage wear:** For a good building stone, the percentage wear should be equal to or less then 3 percent.
**7. Resistance to fire:** A good building stone be fire proof. Sandstone, Argillaceous stone resists fire quite well
**8. Specific gravity:** For a good building stone the specific gravity should be greater then 8.7 or so.
**9. Texture:** A good building stone should have compact fine crystalline structure should be free from cavities, cracks or patches of stuff or loose material.

**10. Water absorption:** For a good building stone, the percentage absorption by weight after 24 hours should not exceed 0.60.
**11. Seasoning:** Stones should be well seasoned before putting into use. A period of about 6 to 12 months is considered to be sufficient for proper seasoning.
**12. Toughness Index:** Impact test, the value of toughness less than 13 – Not tough, between 13 and 19 – Moderate, greater than 19- high

**Characteristics of stones**

In order to ensure suitable selection of stone of particular work, one must be conversant with its composition, characteristics, uses and place of availability.

**Granite**

1. Igneous rock
2. Composed of quart, felspar and mica and minerals
3. Available in grey, green, brown and pink and red
4. Hard and durable
5. High resistance to weathering
6. The texture varies with its quality
7. Specify gravity 2.7 and compressive strength 700 to 1300 kg/cm$^2$
8. Used for ornamental, road metal, railway ballast, aggregate for concrete; for construction of bridges, piers and marine works etc.

**Basalt**

1. Igneous rock
2. It is compact, hard and heavy
3.Available in red, yellow grey, blue and greenish black colour
4. Specific gravity is 3 and compressive strength varies 1530 to 1890 kg/cm$^2$.
5. Used for ornamental, rail road ballast, aggregates for concrete etc.

**Sand Stone:**

1. Sedimentary rock
2. It is available in variety of formations fine grained, coarse grained compact or porous
3. Available in white, green, blue, black, red and yellow.
4. Specific gravity 2.65 to 2.95
5. Compressive strength is 650kgs / $cm^2$
6. Used for ashlar works

**Lime Stone:**

1. Sedimentary rock: It is available in a variety of forms which differ from one another in colour Compaction, texture, hardness and durable

a. Compact lime stone
b. Granular lime stone
c. Magnesia lime stone
d. Kanker lime stone
f. Used for paving, road metal, etc.

**Marble**

1. Metamorphic rock
2. Available in white, blue, green, yellow black and red colour
3. High compactness,
4. Suitable for decorative works, wall lining columns, pile, table slabs, hearths, tiled floors, steps of stair case etc.

**Slate:**

1. Metamorphic rock

1. Non absorbent, compact fine grained and produce metallic ringing sound when struck
2. Available in black, dark blue, grey, reddish brown etc.
3. Used for providing damp proof course, paving dados etc

**Selection of stones**

In contemplating the use of stone for various engineering works, the selection of the nature and quality of stone is governed by the purpose in view, cost of stone, its ornamental value and durability Suitability various types of stones for different purposes and situation is briefly discussed below

**a.** For face work, in general marble, granite and close-grained sand stone are used in the form of thin slabs (veneers) where the structure subjected to adverse weather effects.
**b.** For pillars, balustrade, pedestals, columns statues and door and window sill and paving stone, granite marble and compact lime stone can be recommend because they can take good polish.
**c.** For ornamental works such as moulding and carvings, fine grained sand stone, fine grained marble and fine grained granite are used.
**d.** For bridges, piers, docks, break-waters and other marine structures the stone should be very hard, heavy, strong and durable granite and gneiss are recommended for this purpose
**e.** For road metal, stones should be hard, tough, resistant to abrasion and durable. Basalt and course-grained granite are generally recommended for this purpose.
**f.** For railway ballast, the stone should be hard, dense, durable, tough and easily workable sandstone, compact lime stone, trap and quartzite are commonly used
**g.** In situation like steps, doors sills, pavings etc. where there is a regular flow of traffic, stone should be hard, dense, easily workable and durable. Marble, slates and sand stones are commonly use in such places.
**h.** In fire proof construction, compact sand stone should always be preferred.

**Artificial stones:** These are also known as cast stones or reconstructed stones. Artificial stones may take up various forms such as

**a. Cement concrete:** This is the mixture of cement, fine aggregates, coarse aggregates and water. It may be cast in site or pre-cast if steel is used with cement concrete, it is known as reinforced cement concrete.

**b. Mosaic tiles:** Pre-Cast concrete tiles with marble chips at top surface are known as tiles. They are available in different shades and widely adopted at present.

**c. Terrazo :** This is a mixture of marble chips and cement. It is used for bathrooms residential buildings, temples etc.

**Advantages of artificial stones:**

1. Cavities may be kept in artificial stones to convey pipes, electric wires etc.
2. Grooves can be kept in artificial stone while it is being cast which are useful for fixing various fittings.
3. It can cast in desired shape
4. It can be made in a single piece and hence trouble of getting large blocks of stone for lintels, beams etc is avoided.
5. It can be made stronger than natural stone
6. It is cheap and economical
7. It is more durable than natural stone
8. Natural bed is absent in artificial stones and hence, the question of taking precautions with respect to the natural bed of stones does not arise.

**BRICK**: A **brick** is a type of block used to build walls, pavements and other elements in masonry construction. Properly, the term brick denotes a block composed of dried clay, but is now also used informally to denote other chemically cured construction blocks. Bricks can be joined using mortar, adhesives or by interlocking them. Bricks are produced in numerous classes, types, materials, and sizes which vary with region and time period, and are produced in bulk quantities.

## Percentage of Constituents of Brick (Weight Basis)

There are six major ingredients of brick. The general percentage of these ingredients in brick is given below:

| Ingredient | Percentage in brick |
|---|---|
| Silica ($SiO_2$) | 55% |
| Alumina ($Al_2O_3$) | 30% |
| Iron Oxide ($Fe_2O_3$) | 8% |
| Magnesia (MgO) | 5% |
| Lime(CaO) | 1% |
| Organic Matter | 1% |

## Chief Ingredients of Brick and Their Functions

**Silica (Sand)** and **Alumina (Clay),** these two are the most prominent ingredients in brick clay. When **mixed with water** in proper proportions, it gains **plasticity**. The plastic mass can be easily molded and dried. It should not go through **cracking**, **shrinkage** or **warping**.

### Alumina

Alumina is the main constituent of clay. It acts as a cementing material in raw brick. Brick clay is plastic due to the presence of alumina. This plasticity ensures that bricks can be molded. An excess amount of alumina in clay may cause the bricks to shrink, warp or crack on drying and burning as any other cementing material.

Figure: Clay for Brick formation

### Silica

Good quality bricks contain 50-60% silica. It is present in both free and combined form. As frees sand, it remains mechanically mixed with clay. In combined form, it reacts with alumina to form aluminosilicates. Silica prevents raw bricks from cracking, shrinking and warping. The higher the proportion of sand, the more and shapely and uniform in texture will be the brick. Although, excess silica destroys cohesion between the brick clay particles and makes brick brittle and weak. The durability of bricks largely depends upon the proper proportion of silica and alumina.

Figure: Sand

## Lime

Bricks should contain a little amount of finely powdered lime. It enables silica (of a required portion) to melt at the furnace temperature of 165$^{o}$C and binds the particles of brick together resulting in strong and durable bricks. At about 1100$^{o}$ C, lime acts as a catalyst to elevate the furnace temperature to 1650$^{o}$C at which silica fuses. This slightly fused silica works as a strong cementing material. Excess lime in brick clay will cause vitrification of bricks. It causes bricks to melt, as more than the required amount of silica will fuse. The bricks then lose their shape and become disfigured.

Figure: Powdered Lime

## Iron Oxide

Bricks contain a small quantity of Iron Oxide. Iron Oxide acts a flux like lime, thus helps silica to fuse at low temperature. It imparts a red color to bricks upon burning. Iron also increases the durability and impermeability of the bricks.

Figure: Iron Oxide powder

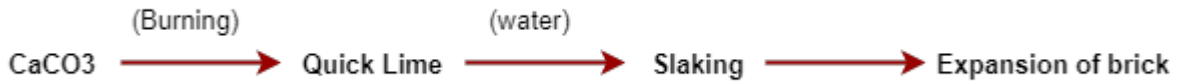
## Magnesia

A small proportion of magnesium decreases shrinkage and gives a yellow tint to the bricks. An excess amount of it causes bricks to decay.

### Harmful Ingredients of Brick

## Lime

**Excess lime** melts the bricks and disfigures it. If $CaCO_3$ exists (in the purest form, i.e., if it contains at least 95% CaO) in lime-lump in brick clay, it converts into quicklime on burning. When these bricks come in contact with water, quicklime slakes and expands. And causes **disintegration of bricks**.




## Alkalis

Alkalis are mainly salt of Sodium (Na) and Potassium (K). It acts as a flux in the kiln and causes **fusion**, **warping**, and **twisting** of bricks. Alkalis absorb moisture from the atmosphere and cause **dampness** and **efflorescence** in bricks (because of the presence of hygroscopic salts, e.g., $CaCl_2$, $MgCl_2$, etc.).

## Pebbles, Stones & Gravels

Their presence does not allow thorough **mixing of earth**, thus the bricks produced are weaker. Such bricks cannot be broken at the desired section and they break very irregularly.

## Iron Pyrites (FeS)

Iron Pyrites causes **crystallization** and **disintegration** of bricks while burning. It discolors bricks in the form of black slag.

## Organic Matter

Organic matter in bricks makes bricks porous resulting in low density and weaker bricks.

**Raw Materials for Brick**

Sufficient samples of the earth available must be tested to check if the soil is suitable for composition of bricks and available abundantly in neighborhood. It is reasonable uniformity of composition in the soil. Mechanical composition of the soil may preferably confirm the following requirements.

- Clay 20 to 35 %
- Silt 20 to 35%
- Sand 35 to 45 %

**Manufacture of bricks:**

The manufacturing of brick, the following operations are involved

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

## CLASSIFICATION OF BRICKS:

- Sun-dried bricks
- Burnt clay bricks
- Fly ash bricks
- Concrete bricks
- Engineering bricks
- Calcium silicate bricks
- Eco bricks

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

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

a. **First Class bricks:** These bricks are table moulded and of standard shape. The surface and edges of the bricks are sharp, square, smooth and straight. The comply all the qualities of good bricks and used for superior work of permanent nature.

b. **Second class bricks:** These bricks are ground moulded and they are burnt in kilns. The surface of bricks is some what rough and shape is also slightly irregular. These bricks are commonly used at places where brick work is to be provided with a coat of plaster.

c. **Third class bricks:** These bricks are ground moulded and they burnt in clamps. These bricks are not hard and they have rough surfaces with irregular and distorted edges. These bricks give dull sound when struck together. They are used for unimportant and temporary structures and at places where rainfall is not heavy.

**d. Fourth class bricks:** These are over burnt bricks with irregular shape and dark colour. These bricks are used as aggregate for concrete in foundation, floors, roads, etc because of the fact that the over burnt bricks have compacted structure and hence, they are some times found stronger than even first class bricks.

**Fly ash bricks:**
Also called Self-cementing brick, these bricks contain Class F or Class C fly ash as a part of the formula.
**Concrete bricks**:
These bricks are made using solid concrete. The concrete is prepared using sand, coarse aggregates, water, and cement.
**Engineering bricks**:
This type of brick offers high compressive strength. They are used for construction where low porosity, frost resistance, acid resistance, and strength are mandatory.

**Calcium silicate bricks**:
Also called sand lime bricks, they are made by mixing fly ash, lime, and sand. It is used for masonry and ornamental works in different construction projects.
**Eco bricks**:
Porotherm **hollow bricks** are suitable walling solutions. They offer significant thermal insulation and make walls stronger.

**Qualities of Good Brick:**
(i) Bricks should be table moulded, well burnt in kilns, copper coloured, free from cracks and with sharp and square edges.
(ii) Bricks should be uniform shape and should be of standard size.
(iii) Bricks should give clear ringing sound when struck each other.
(iv) Bricks when broken should show a bright homogeneous and compact structure free from voids.
(v) Bricks should not absorb water more than 20 percent by weight for first class bricks and 22 percent by weight for second class bricks, when soaked in coldwater for a period of 24 hours.

(vi) Bricks should be sufficiently hard no impression, should be left on brick surface, when it is scratched with finger nail.
(vii) Bricks should be low thermal conductivity and they should be sound proof.
(viii) Bricks should not break when dropped flat on hard ground from a height of about one meter.
(ix) Bricks, when soaked in water for 24hours, should not show deposits of white salts when allowed to dry in shade.
(x) No brick should have crushing strength below 55kg/cm$^2$

# Specification of Bricks

A brick is small block of burnt clay with a size that can be held in one hand conveniently. Brick should be thoroughly burnt, of uniform color, having plane rectangular faces, sharp straight, right angle edges.

- Standard **Modular size** of common building brick is **190X90X90** mm
- The size of a **Non-Modular brick** is 9"X4-3/8"X2-11/16" (229X111X70 mm).But it is specified as **230X110X70** mm.
- The weight of a brick is about **3 to 4 kg**

### Recommended Sizes of Bricks

| Type of Bricks | Normal Size (mm) | Actual Size (mm) |
|---|---|---|
| Modular Bricks | 200x100x100 mm | 190x90x90 mm |
| Non -Modular Bricks | 229x114x70 mm | 230x110x70 mm |

Tests for bricks :

A brick is generally subjected to following tests to find out its suitability of the construction work.

ii. Absorption

iii. Crushing strength or compression strength

iv. Hardness

v. Presence soluble salts

vi. Shape and size

vii. Soundness

viii. Structure

1) **Absorption:** A good should not absorb not more than 20 percent of weight of dry brick

2) **Compressive strength:** crushing or compressive strength of brick is found out by placing it in compression testing machine. It is pressed till it breaks. Minimum crushing strength of brick is 35kg/cm2 and for superior bricks, it may vary from 70 to 140 $kg/cm^2$.

3) **Hardness:** No impression is left on the surface the brick is treated to be sufficiently hard

4) **Presence of soluble salts:** The bricks should not show any grey or white deposits after immerted in water for 24 hours

5) **Shape and size:** It should be standard size and shape with sharp edges

6) **Soundness:** The brick should give clear ringing sound struck each other

7) **Structure:** The structure should be homogeneous, compact and free from any defects

## Cement

Cement is a commonly used building material, obtained by burning a mixture of calcareous (calcium-rich) and argillaceous (clay) material at a very high temperature and then grinding the clinker so produced to a fine powder. When cement is mixed with fine aggregate, mortar is produced for masonry; and when mixed with sand & gravel, concrete is produced. Cement can be characterized as either hydraulic or non-hydraulic, depending on its ability to set in the presence of water.

## Uses of the Cement

These days the utility of cement has increased as it can be used for all kinds of works and in all conditions. Cement sets very quickly and does not need any slaking. It can be used for the construction of underwater structures. The various uses of cement in construction work are:

- To prepare mortar that can be used for Masonry work, plaster, pointing, etc.
- To prepare concrete that can be used for laying floors, roofs, construction of lintels, beams, weather sheds, stairs, pillars, etc. Besides, it is used for the construction of important engineering structures such as bridges, culverts, dams, tunnels, storage reservoirs, lighthouses, docks, etc.
- It can be used for creating fire-proof, acid-resistance, and waterproof structures such as kilns, chimneys, structures exposed to certain
organic and inorganic chemicals, or tanks for their storage.
- It can be used as grouting material for the filling of cracks and joints in structures.
- It can be used for manufacturing precast pipes, garden seats, artistically designed urns, flower pots, dust bins, fencing posts, etc.
- Coloured cement can be used for decorating or colouring structures.

Despite so many uses of cement, it has a few demerits as follows:

● The structure, once built using cement, is difficult to displace or reuse.

They can’t be easily recycled like plastics or steel.

● Cement structure is very heavy. So, while building skyscrapers, it can’t be built on cement. Instead, steel structures are placed.

## Chemical Composition

| Components | Percentage of mass |
|---|---|
| Calcium Oxide (Cao) | 66.33 |
| Silica($SiO_2$) | 18.6 |
| Ferric Oxide($Fe_2O_3$) | 4.03 |
| Alumina($Al_2O_3$) | 3.77 |
| Sulphuric anhydride ($SO_3$) | 2.67 |
| Magnesium oxide (MgO) | 2.13 |
| Sodium oxide ($Na_2O$) | 1.39 |
| Potassium Oxide ($K_2O$) | 0.46 |

**Compressive Strength and Grades of Cement**

Compressive strength is one of the important properties of cement. When cement is used for important structures, the compressive strength test is always carried out to ascertain the quality of cement. For this mortar, cubes are made with standardized sand and tested in a compression testing machine as per the specifications of the IS code. The cement is available in three grades, namely 33-Grade, 43-Grade and 53-Grade, depending upon the compressive strength of the cement mortar cubes at 28 days. The following table shows the compressive strength of different grades of cement.

| Grades of Cement | Minimum compressive strength in MPa at the end of (IS 269-1976) | | |
|---|---|---|---|
| | 3 days | 7 days | 28 days |
| 33-Grade | 16 | 22 | 33 |
| 43-Grade | 23 | 33 | 43 |
| 53-Grade | 27 | 37 | 53 |

## Types of Cement

- Ordinary Portland Cement (OPC) is the most common cement used for general construction purposes. It has a low resistance to chemical attack, and it has a medium rate of hardening. The colour of ordinary Portland cement is grey or greenish-grey. Its name is derived from its similarity to Portland stone, which was quarried on the Isle of Portland in Dorset, England. It was named by Joseph Aspdin, who had invented this in 1824.
- Ordinary Portland cement consists of lime (60-65%), silica (20-25), alumina (3-8%), iron oxide (3-4%), gypsum (3-4%), magnesia (0.1-3%), sulphur (1-3%), alkalis (0.2-1%) etc. If the proportion of lime is more in cement, then it sets slowly. On the contrary, if the amount of lime is less, then cement becomes weak. Silica imparts strength to cement. Excess of silica increases the strength but causes a slow setting of cement.
- Alumina is responsible for a quick setting. On the other hand, if alumina is in excess, the strength of cement reduces. Iron oxide imparts the characteristics of grey colour to the cement. Besides, it reduces the fusion temperature of the ingredients during cement manufacturing.
- Gypsum is added to the cement to increase the initial setting time of the cement and to avoid flash setting. Magnesia imparts hardness and colour to the cement, but the excess of it reduces the soundness of the cement.
- A high percentage of sulphur makes the cement unsound while a high percentage of alkali causes efflorescence and cracking of cement.
- In addition to ordinary Portland cement, there are many varieties of cement available in the market. Each type of cement has its own properties, uses, and advantages. Some of the most common varieties of cement are as follows:

| Type | Properties | Uses |
|---|---|---|
| Portland Pozzolana Cement | It is manufactured by blending OPC cement with fly ash and grinding them together. It has a high resistance to aggressive waters and sulphates. It continues to gain compressive strength with age. | Marine works, mass concreting , watertight structure |
| Rapid Hardening Cement | It attains high strength in the early days. It is used in concrete where formworks need to be removed at an early stage | Road pavement, precast concrete casting |
| Quick Setting Cement | It sets into a stony mass in less than 30 minutes from laying it. | Underwater constructions, in cold and rainy weather conditions |

| Type | Properties | Uses |
|---|---|---|
| Low Heat Cement | A Low amount of heat or hydration is liberated during setting and hardening of this cement | Mass concreting in mega structures like gravity dams |
| Blast furnace slag cement | It is manufactured by blending OPC cement with blast-furnace slag obtained from the steel industry and grinding them together. It has a slow rate of hardening and lower heat evolution. | Useful for mass concreting and marine structures. |
| Sulphate Resisting Cement | It can resist sulphate attack on concrete and thus is used in the construction of foundations where the soil has high sulphate content. | Pile foundation, coastal area works, sewage and water treatment plants |

| | | |
|---|---|---|
| High Alumina Cement | Its initial setting time is 3.5 hours, while the final setting time is 5 hrs. It can sustain a very high temperature. | Used in the construction of refineries and kilns, for binding fie bricks. |
| White Cement | The properties of this cement are very similar to the OPC except for the colour, which is white. It is manufactured by adding high-quality raw materials with very low iron oxide compounds. | Plaster and other decorative works, for manufacturing coloured cement by adding colouring pigments. |

| Type | Properties | Uses |
|---|---|---|
| Coloured Cement | It is manufactured by adding different colouring pigments to the white cement. | Artificial marble floor finishing |
| Air Entraining Cement | Entrain airs in the form of air bubbles of diameter 0.075 mm to 1.25 mm. This makes the concrete more plastic and workable. | Used in frost-resistant concrete construction |
| Hydrophobic Cement | It repels water and remains unaffected during monsoons or rains | Construction of water retaining structures like a tank, reservoir, retaining wall, or swimming pool |

# Construction Aggregates

The construction aggregates, or simply "aggregates," are a broad category of coarse to medium grained hard and granular materials suitable for use either on their own or with the addition of cement, lime, or a bituminous binder for construction works. Aggregates are the base material for every construction, be it a building or bridge, road or railway. The aggregates help in building a strong foundation and a stable foundation. They bind the expensive cement and other materials together for long-lasting results. Aggregates are used to add strength to the concrete. Because of their relatively high hydraulic conductivity value, they also help in proper drainage.

**Uses of aggregates**

The following are some of the important uses of aggregates:

- Aggregate is used in road construction, as a basic component of granular base, sub-base, and bituminous courses.
- Used as ballast for construction of railway lines.
- In concrete the aggregate is used for economy, reduces shrinkage and cracks, and strengthens the structure.
- Aggregates allow easy drainage of the rainwater off the road surface

and protect the founding soil from damage.

- Used for stabilization of weak soils.
- They are used in water filtration and sewage treatment processes.
- They are used for landfill purposes.
- Used as backfilling material.

**Classification of Aggregates**

The aggregates may be classified based on the source of production or based on their size.

A. Classification based on its source of production: Depending on the source of production, the aggregates may be classified as primary, secondary, or recycled aggregates.

**Primary aggregates:** Primary aggregates, otherwise known as natural aggregates are produced from naturally occurring mineral deposits, explicitly extracted for use as aggregates and used for the first time. Most construction aggregates are produced from hard, strong rock formations by crushing them or from naturally occurring particulate deposits such as sand and gravel. The most important sources of crushed rock in India are limestone (including dolomite), igneous rock and sandstone. Sand and gravel can be either land-won or river or marine dredged.

**Secondary aggregates:** Secondary aggregates are usually defined as (a) aggregates obtained as a by-product of other quarrying and mining operations, such as china clay waste, slate waste and colliery spoil, or (b) aggregates obtained as a by-product of other industrial processes, such as blast furnace/steel slag, coal-fired power station ash, incinerator ash, and spent foundry sand. The by-product aggregates derived from industrial processes are also otherwise known as manufactured aggregates.

**Recycled aggregates:** Such aggregates result from the processing of inorganic materials previously used in construction, e.g., construction and demolition waste. Other forms of recycled aggregates are asphalt pavements from resurfacing roads and railway track ballast. ‘Recycling’ involves the removal of deleterious materials, such as fines, wood, plastic, or metal, and processing by crushing and screening as required so that it can be reused, often for less demanding applications. Once the material is processed into a saleable product, it becomes a resource rather than a ‘waste.’

B. Classification based on size: Based on the particle size, aggregates are classified into fine aggregates and coarse aggregates. The main differences between fine and coarse aggregates are given in the following table:

**Comparison of Fine and coarse aggregates**

| Scopes | Fine Aggregate (FA) | Coarse Aggregate (CA) |
|---|---|---|
| Definition | Fine aggregates are small-size filler materials in construction. | Coarse aggregates are larger-size filler materials in construction. |
| Size of Particles | Fine aggregates are the particles that pass through a 4.75 mm sieve and retain on a 150-micron sieve. | Coarse aggregates are the particles that retain on a 4.75 mm sieve. |
| Materials | Sand, surkhi, stone screenings, burnt clays, cinders, fly ash, etc. are used as fine aggregate in concrete. | Brick chips (broken bricks), stone chips (broken stones), gravels, pebbles, clinkers, cinders, etc. are used as coarse aggregate in concrete. |
| Sources | River sand or machine sand, crushed stone sand, and crushed gravel sand are the major sources of fine aggregate. | Dolomite aggregates, crushed gravel or stone, and the natural disintegration of rock are the major sources of coarse aggregate. |
| Surface Area | The surface area of fine aggregates is higher. | The surface area of the coarse aggregate is less than fine aggregates. |
| Uses | Fine aggregates are used in mortar, plaster, concrete, filling of road pavement layers, etc. | Coarse aggregates are mainly used in concrete, railway track ballast, etc. |

Aggregates that are collected from the pit or river bed may contain significant representations of particle sizes corresponding to the fine aggregate and the coarse aggregate. These are known as all-in Aggregate or mixed aggregate. It is mainly used for unimportant works and landfilling without separating it into different sizes.

## Mortar

Mortar is defined as a paste prepared by adding water in a required quantity to a mixture of a bonding material such as cement or lime and inert materials like sand, cinder or surkhi. Mortar is used as a binding material in stone and brick masonry constructions or as a plastering material to provide smooth, hard, and decorative walls and surfaces.

## Types of Mortar

**A. Cement Mortar:** In this type of mortar cement is used as binding material and sand is used as fine aggregate. Depending upon the desired strength, the cement to the sand proportion of cement mortar varies from 1:2 to 1:6 (cement: sand).

**B. Lime mortar:** Lime mortar is composed of lime (hydraulic, or nonhydraulic), water and an aggregate such as sand. With the introduction of Portland cement, the use of lime mortar gradually declined. Nowadays, lime mortar is primarily used in the conservation of existing old buildings or the construction of new ones using traditional materials such as natural stone and terracotta.

**C. Gypsum mortar:** The mortars are prepared from gypsum binding materials such as building gypsum and anhydrite binding materials.

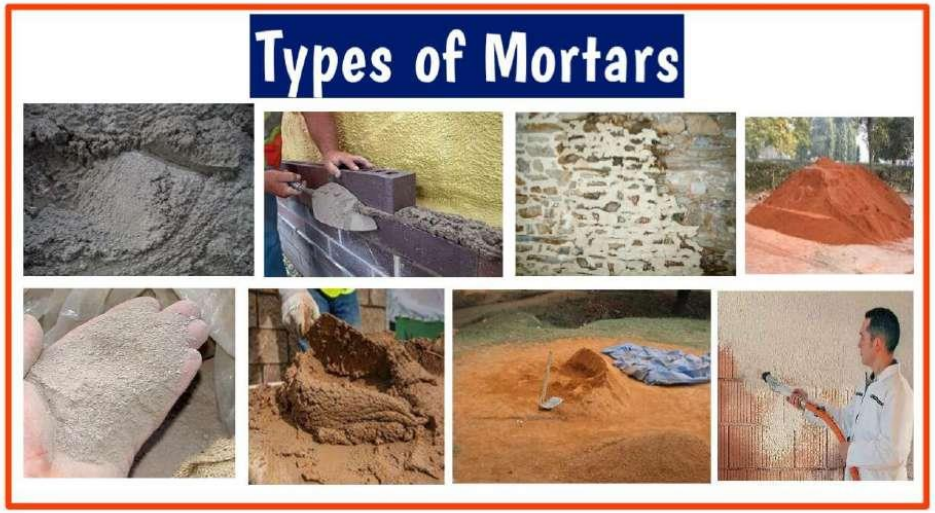
**D. Fireproof mortar:** This type of mortar is made with fire-resistant materials, such as refractory cement or fire clay. It is used in fireplaces, chimneys, and industrial furnaces, where high temperatures are expected.

E. Polymer-modified mortar: This is a modern mortar made by adding polymer resins to the cement and sand mixture. The polymer improves the adhesion, flexibility, and water resistance of the mortar, making it suitable for tiling, paving, and repair work.

**F. Surkhi Mortar:** This type of mortar is prepared using surkhi as the fine inert material and lime as the binding material. Surkhi is prepared by finely grinding well-burnt, good-quality bricks free from under- burnt particles of soluble salts, pyrites and adherent coatings of soil or silt. The maximum quantity of clay, fine silt, and fine dust present shall not exceed five percent by weight. Surkhi mortar is used for ordinary masonry works in all kinds of foundations and superstructure. The surkhi mortar is used as the binding material for ordinary masonry work of all kinds in foundations and superstructures.

**G. Gauged Mortar:** Gauged mortar is a type of mortar where cement and lime both are used as binding material and sand are used as fine aggregate. The cement is added to gain higher strength. The process is known as gauging. Gauging makes lime mortar stronger economical and dense.

**H. Mud mortar:** Mud mortar is a type of mortar where mud is used as binding material and sawdust, rice husk or cow dung is used as fine aggregate. Mud mortar is useful where lime or cement is not available. It is also used for the construction of kaccha houses.



## Concrete

Concrete is one of the most widely used construction materials throughout the world. It is obtained by mixing together cement, aggregates, water and sometimes admixtures. The mixture when placed in forms and allowed to cure, hardens into a rock-like mass. Concrete has the ability to be placed in forms to create almost any shape. In building construction, concrete is used for the construction of foundations, columns, beams, slabs and other load- bearing elements.

## Advantages and Limitations of Concrete

Concrete as a building material offers the following advantages:

- Concrete can be manufactured to the desired strength and can be cast in any required shape at the construction site.
- The Compressive strength of concrete is high and comparable to natural stones. But, unlike natural stone, the concrete is free from defects and flaws. Additionally, with the combination of steel reinforcement concrete can be used for the construction of several other structures which are not possible using natural stone.
- The concrete is highly durable, and fire and water-resistant. The deterioration of concrete is not appreciable with age. Therefore, the maintenance cost of concrete is negligible.
- The main ingredients are cheap and easily available throughout the world. Further, the procedure of casting construe structures is simple and requires less technical manpower.

Additionally, concrete has the following limitations:

- The strength-to-weight ratio for concrete is relatively more in comparison to steel and wood.
- In comparison to other binding materials, the tensile strength and ductility of concrete are relatively less.
- Concrete may contain soluble salts which may cause efflorescence and subsequent disfiguring of the structure.

## Types of Concrete

**A. Plain cement concrete (PCC):** Plain cement concrete (PCC) is a mixture of cement, fine aggregate (sand), and coarse aggregate without steel reinforcement. It is a strong material in compression but weak in tension. Hence PCC is used when the structural member is subjected only to the compressive forces but not used if it is subjected to tensile and bending forces. PCC is commonly used in the construction of foundations, pavements, and other structures where reinforcement is not required. It is also used as a base for other types of concrete, such as reinforced concrete.

**B. Reinforced cement concrete (RCC):** Reinforced concrete is a composite material made of concrete and steel. Concrete is strong in compression but weak in tension, while steel is strong in both compression and tension. By combining concrete and steel, reinforced concrete is able to resist both compressive and tensile forces. RCC is made by pouring concrete around a steel reinforcement cage. The steel reinforcement cage is made up of steel bars or rods that are arranged in a specific pattern to provide the necessary strength and durability.

Once the concrete has been poured and cured, the steel reinforcement cage becomes bonded to the concrete, forming a strong and durable composite material. RCC is one of the most widely used construction materials in the world. Reinforced cement concrete is used for almost all structures, great or small such as buildings, bridges, pavements, dams, retaining walls, tunnels, drainage and irrigation facilities, tanks, and so on.

There are numerous advantages of using RCC as follows:

**C. Pre-stressed concrete:** Pre-stressed concrete is a type of concrete that has been strengthened by the application of compressive stresses before it is put into service. The purpose of pre-stressing is to improve the performance of concrete structures by counterbalancing the tensile stresses (opposite of compressive stress). Pre-stressed concrete can be achieved by two methods: pre-tensioning and post-tensioning. In pre-tensioning, steel cables or tendons are stretched before the concrete is cast. After the concrete hardens, the tendons are released to transfer the compressive force to the concrete.

In post-tensioning, steel tendons are placed inside ducts or sleeves within the concrete. After the concrete hardens, the tendons are tensioned and anchored to the ends of the concrete member. The tendons apply a compressive force to the concrete through friction or bonding. Prestressed concrete has many advantages over conventional reinforced concrete, such as higher strength, lower deflection, better crack control, thinner
sections, longer spans, and reduced reinforcement. Prestressed concrete is widely used in bridges, buildings, dams, tanks, pavements, and nuclear containment structures.

**D. Precast concrete;** Precast concrete or prefabricated concrete is a construction product produced by casting concrete in a reusable mould or "form" which is then cured in a controlled environment, transported to the construction site and manoeuvred into place. This method of construction offers many potential advantages over onsite casting. Precast concrete production can be performed on ground level, which maximizes safety during its casting. There is greater control over material quality and workmanship in a precast plant compared to a construction site. The forms used in a precast plant can be reused hundreds to thousands of times before they have to be replaced, often making it cheaper than onsite casting in terms of cost per unit of formwork. However, there are certain aspects that may discourage the use of precast concrete units under certain conditions such as the need for special types of equipment for handling, transportation, and erection, particularly for large-size units like beams, slabs, columns, etc. Further, there is more chance of damage to the precast units while loading, transporting, and erecting.
Examples include precast beams, railway sleepers, telephone and electric poles, wall panels, etc.

# Cement vs. Concrete vs. Mortar

- Binding element in both concrete & mortar
- Made of limestone, clay, shells, & silica sand
- Sets & hardens when combined with water

- Made of cement, sand, & gravel
- Used for building: foundations, slabs, patios, & masonry
- Most flexible, forming into any mold & rock hard

- Made of cement & sand
- Used as the glue to hold bricks, blocks, etc. together
- Various types available for specific applications

**Steel**

Steel is an alloy of iron containing 0.25 to 1.5 percent carbon which is present in the form of carbides of iron. Carbon has the maximum influence on the mechanical properties of steel. Steel with low carbon content has properties nearly similar to that of iron. An increase in carbon percentage in steel increases its tenacity and hardness with a corresponding decrease in its ductility and toughness. The tensile strength, hardness, yield point, and elastic limit of steel increase with a corresponding increase in carbon percentage up to 1% of carbon. Depending upon specific requirements, a variety of elements such as chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium or zirconium, etc. are added to improve the mechanical and durability properties of steel. On the basis of its carbon content, the presence of other alloying elements and its structural application; the steel can be classified as follows:

Carbon Steel

Carbon steel is a variety of steel where the main alloying constituent is carbon. Other elements in carbon steel are incidental and are not addressed in its formulation, and that is too small in the amount to affect its properties. The specified minimum limit for copper is 0.40 percent, and the maximum limit for the elements like manganese is 1.65%, silicon is 0.60%, and copper is 0.60%. There are generally 3 classes depending on carbon content: mild steel, medium carbon steel, and high carbon steel.

A. Mild Steel (or low carbon steel): Mild Steel is a type of carbon steel with a low carbon content, which is why it is also known as 'low carbon steel.' It has a carbon content ranging from 0.05% to 0.25%, making it malleable and ductile. Additionally, it is alloyed with manganese, typically in the range of 0.70% to 0.90%, while the remaining composition consists of silicon, which can measure up to 0.40%. Mild steel is known for its toughness, ductility, malleability, and its equal strength in compression and tension. It can be easily joined and welded. However, mild steel has poor resistance to corrosion. Owing to its strength and versatility, mild steel finds numerous applications in various industries. It is widely used for structural steel sections in construction projects, concrete reinforcement, roof covering materials, and in the production of tools, equipment, rail tracks, transmission towers, and industrial buildings.

B. Medium Carbon Steel: Medium carbon steel has carbon content in the range of 0.31 to 0.60 percentage, and a manganese content ranging from 0.60% to 1.65%. It is stronger than low-carbon steel and more difficult to form, weld, and cut. Medium carbon steels are quite often hardened and tempered using heat treatment. It is primarily used for manufacturing rails, tires, hammers, large stamping and pressing dies, etc.

C. High Carbon Steel (or tool steels): High Carbon Steel, also known as 'tool steel,' contains a carbon percentage ranging from 0.55 to 1.5. It is more elastic and tougher than mild steel, exhibiting greater strength in compression than in tension. Welding high-carbon steel can be challenging. However, it possesses the ability to withstand shocks and vibrations. High carbon steel is commonly used in the production of tools such as drills, files, and chisels, as well as in the manufacturing of machine components that require a hard, tough, and durable material capable of enduring shocks and vibrations.

**Alloy Steel**

The alloy steel is steel alloyed with a variety of alloying elements (other than carbon) in a range between 1 to 50 percent by weight. Common alloying elements are molybdenum, manganese, nickel, chromium, vanadium, silicon, and boron. This steel has specific properties that are not found in regular carbon steel. Alloy steels have greater strength, hardness, hot hardness, wear resistance, hardness, or toughness compared to carbon steel.

**A. Stainless Steel:** Stainless steel (or inox steel) generally contains between 10-20% chromium as the main alloying element and is valued for high corrosion resistance. Stainless steel does not stain, corrode, or rust as easily as ordinary steel (it stains less, i.e., it is not stain-proof). Carbon steel rusts when exposed to air and moisture. However, chromium present in stainless steel forms a passive film of chromium oxide, which prevents further surface corrosion and blocks corrosion from spreading into the metal's internal structure. Stainless steel is used where the properties of steel and resistance to corrosion are required.

B. High tension steel: High tension steel is made with 0.8 % carbon and 0.6 % manganese apart from small percentages of silicon, sulphur, and phosphorous. It has high tensile strength. It resists atmospheric corrosion better than mild steel. It is tough and more elastic but brittle and less ductile than the mild steel. High-tension steel wires are extensively used as tendons in prestressed concrete structures.

**Steel as Concrete Reinforcement Material**

Concrete and steel reinforcing work together beautifully in reinforced concrete structures. The advantages of each material seem to compensate for the disadvantages of the other. For instance, the great shortcoming of concrete is its lack of tensile strength, but tensile strength is one of the great advantages of steel. Reinforcing bars have tensile strengths equal to approximately 100 times that of the usual concretes used. The two materials bond together very well so there is little chance of slippage between the two; thus, they will act together as a unit in resisting forces. The excellent bond obtained is the result of the chemical adhesion between the two materials, the natural roughness of the bars, and the closely spaced rib-shaped deformations rolled onto the bars' surfaces. Reinforcing bars are subject to corrosion, but the concrete surrounding them provides them with excellent protection. The strength of exposed steel subjected to the temperatures reached in fires of ordinary intensity is nil, but enclosing the reinforcing steel in concrete produces very satisfactory fire ratings. Finally, concrete and steel work well together with temperature changes because their coefficients of thermal expansion are quite close. For steel, the coefficient is 0.0000065 per unit length per degree Fahrenheit, while it varies for concrete from about 0.000004 to 0.000007 (average value: 0.0000055). Four varieties of steel bars are used as follows:

**A. Mild steel (MS) bars:** The mild steel bar is manufactured from mild steel containing 0.20-0.25% carbon. The yield trength of MS bars is 250 MPa. The surface of these bars is plain and does not contain ribs, due to which they are also called plain bars. MS bars have high ductility. Nowadays, these bars are used for the construction of structures that are primarily subjected to impact or shock loads.

B. High Yield Strength Deformed (HYSD) bars: As the name suggests, HYSD bars have strength more than the MS bars and have surface deformations in the form of lugs and ribs. These deformations inhibit the longitudinal movement of the bar relative to the surrounding concrete and ensure a better bond between reinforcement and concrete. HYSD bars are available in three grades: Fe 415, Fe 500, and Fe 550, where the numeric value denotes its yield strength in MPa.

**C. Thermo Mechanically Treated (TMT) bars:** TMT bars take their name from the process of manufacturing, called thermomechanical treatment, where hot steel billets are quenched by cold water. This technique hardens the outer surface, enhancing its tensile strength, while the core remains at a higher temperature and increases the ductility. TMT bars don't go through any deformation or twisting processes. Hence its surface does not form cracks. Like HYSD bars, TMT bars are also available in three grades: Fe 415, Fe 500, and Fe 550. TMT bars offer better Bendability, Weldability, fire resistance, corrosion resistance, and high dimension tolerance than HYSD bars. Due to high ductility, these bars are commonly used for construction in earthquake-prone zones.

**D. Prestressing Steel Bars:** The prestressing steel bars are used in the form of strands or tendons. Multiple strands are employed in concrete in order to perform the prestressing action. The strands are made of multiple wires, either 2 or 3 or 7 wire strands. The wires used here are cold-formed and have a high tensile strength ranging from 1750 MPa – 1850 Mpa. This high strength helps to prestress the concrete effectively.

## Timber

Timber can be defined as the wood from a tree of sufficient girth (usually more than 0.6 m) that is used for building, carpentry, or other engineering purposes. Until the Industrial Revolution and the wide adoption of cast iron, timber was used as the only material for the construction of the building and structural frames. When the timber is in the form of a living tree, it is called “standing timber’. Just after the felling of the tree, it is ‘Rough timber,’ and lastly, when it is sawed and cut into pieces of suitable sizes, it is called ‘converted timber.’

## Classification of Timber

Wood may be classified in different manners based on their mode of growth, strength elasticity, durability, grading, etc. Commercially, the wood is classified into two categories: Softwood and hardwood. The following table presents the main differences between the two categories:

| Characteristics | Softwood | Hardwood |
|---|---|---|
| Source | Softwood is collected from conifer trees, which are evergreen and have needle-shaped leaves. | Hardwood is obtained from deciduous trees (lose leaves in autumn). |
| Growth of tree | Fast | Slow |
| Structure | Resinous, fibers are straight and less dense. | Dense and close-grained |
| Weight and hardness | Lightweight and soft | Heavyweight and hard |
| Colour | Light | Dark |
| Resistance to fire | Poorer than hardwood. | Better than softwood. |
| Weather resistance | Need special treatment to impart weather resistance. | They have better weather resistance than softwood. |
| Durability | Less durable. | Highly durable. It may last for several decades. |
| Strength | Good strength in the fibre direction. Less strength in other directions. Weak in shear. | Uniformly good strength in all directions. Strong in shear. |
| Cost | Less expensive. | More expensive. |
| Workability | Easier to carve. | Difficult to curve. |
| Use | For the preparation of decorative wood pieces, wooden furniture, and non-load bearing members such as doors, windows, and wooden flooring. | For manufacturing wooden furniture, and load-bearing members in buildings like columns, beams, rafters, etc. |
| Examples | Cedar, Fir, Juniper, Pine, Redwood etc. | Maple, Oak, Teak, Sal, Mango, etc. |

## Characteristics of Good Timber

A good timber has the following characteristics:

- They have a shining appearance
- Uniform colour and texture.
- High density and modulus of elasticity.
- It should be hard and durable and capable of resisting shock.
- It should have sufficient abrasion resistance (resistance to wear).
- Good timber should be strong in bending, shear, and direct compression.
- It should not warp under changing environmental conditions.
- It should have better fire resistance, low permeability, and be easily workable.
- Good timber is free from defects like dead knots, shakes, and cracks.

## Common Indian Timbers Used in Construction

There are over 200 species of trees used for the production of construction timbers. The few most important varieties of timbers used for construction purposes are as follows:

| Sl. No. | Purpose | Requirement | Important Trees |
|---|---|---|---|
| 1 | Bridge | The timber should have good strength, durability, and resistance to water and salts | Babul, Bakul, Red cedar, Ironwood, Jarul, Sal, Sissoo. |
| 2 | Houses | It should be lightweight, tough, and durable. The grains must be closely spaced have pleasing colour and good texture and must be able to take a good polish. | Sissoo, Teak, Babul, Bel, Mango, Redwood, Walnut |
| 3 | Joists, Beams, Door frame etc. | Should be strong, hard, and durable. | Arjun, Mango, Sal |
| 4 | Column, Rafter | Should be strong, heavy, and durable. Must be able to take a heavy load in axial directions. | Sal, Bamboo, Palm, Coconut. |
| 5 | Furniture | Close grained, light, soft, and durable. Must be able to take a good polish | Teak, Deodar, Walnut, Shisham, Oak, Aini |
| 6 | Piles | Hard, Strong, and Durable. Must be able to resist the actions of soil and water. | Sal, Bijasal, Ironwood, Banyan, Nageswar |
| 7 | Railway sleepers | Cheap, Hard, Tough, durable. Must have a high damping capacity. | Sundari, Sal, Bel, Deodar |
| 8 | Railways/Bus carriage | Hard, durable, close-grained, should be able to take a good polish | Ironwood, Redwood, Teak |
| 9 | Scaffoldings | Flexible, strong, and durable. | Bamboo, Casuarinas |
| 10 | Shuttering | Hardness, Durability against the attack of cement and water, Easy to work. Smooth | Mango, Nageswar, Gambhir |

## Paints

Paint is a type of material that is commonly used to add colour, protection, and decoration to various surfaces, including walls, ceilings, furniture, and metal or woodwork. Paint consists of three primary components: pigment, binder, and solvent. The pigment provides colour, while the binder holds the pigment together and attaches it to the surface, and the solvent helps to keep the paint in a liquid form until it is applied.

## Functions of Paint

The following are the functions of paint:

- To protect the surface from weathering effects of the atmosphere and actions by other liquids, fumes and gases.
- To check corrosion of metals, decay of wood or formation of bacteria and fungus.
- To check penetration of water through RCC.
- To provide a smooth surface with a good appearance.

## Types of Paints

There are many different types of paint available, each with its unique properties and applications. When choosing a type of paint, it is important to consider the surface you are painting, the desired finish, and the environmental conditions. It is also important to follow the manufacturer's instructions for application and safety. Some of the most common types of paint include

**A. Oil paint:** Oil paints are made with an oil or solvent base and are known for their durability and smooth finish. They dry slowly, have a strong odour, and are difficult to clean up, but they are well-suited for use on woodwork, metal, and exterior surfaces.

**B. Aluminium paint:** Aluminium paint is made with finely ground aluminium suspended in a varnish. It is highly visible in the dark, heat- resistant, electrical-resistant, corrosion free, and impervious to moisture. It is often used to paint metallic surfaces such as gas tanks, water pipes, oil storage tanks, and electric poles.

**C. Cement paint:** Cement paint is made with white cement, colouring pigments, and an accelerator. It has excellent waterproofing and durability properties and is often used to paint plastered brick and stone masonry, concrete works, and iron sheets.

**D. Asbestos paint:** Asbestos paint is made with fibrous asbestos as the main ingredient. It has fire-retarding and water-resistant properties and is often used to paint public buildings, gutters, and spouts.

**E. Cellulose paint:** Cellulose paint is made with pigments suspended in cellulose nitrate lacquers. It provides a flexible, hard, and smooth surface, and can withstand extreme heat and cold. It is often used to paint motor cars, aeroplanes, and other superior works.

**F. Emulsion paint:** Emulsion paint is made with vehicles such as polyvinyl acetate and synthetic resins. It has excellent alkali resistance, quick drying, good workability, and durability. It is often used on stucco, bricks, and masonry surfaces containing free alkali.

**G. Plastic paint:** Plastic paint contains a variety of plastics as the base. It is quick-drying, has high covering power, and provides a decorative appearance. It has good adhesion to the surface and is often used to paint showrooms, auditoriums, offices, and cinema halls.

**H. Enamel paint:** Enamel paint contains bases like metallic oxide (white lead or zinc white) ground with a small quantity of oil, which is mixed with petroleum spirit vehicle. It is acid and alkaline-resistant, waterproof, and can provide a durable and hard surface. It is used for painting both internal and external surfaces and woodwork.

**I. Anti-corrosive paint:** Anti-corrosive paint uses linseed oil as a vehicle and dry red lead, sublimed blue lead, zinc oxide, iron oxide and zinc chromate as pigments. It obstructs corrosion by reducing direct access of air and water to the metals. It is often used for the preservation of steel against acid fumes and adverse weather conditions.

**Non-Ferrous Metals**

Non-ferrous metals are metals that do not contain iron as their primary component. They have several properties that make them useful in the construction industry, including their strength, durability, and corrosion resistance. Here are some examples of non-ferrous metals that are commonly used in the construction industry:

**A. Aluminium:** Aluminium is a lightweight metal and offers better corrosion resistance and strength-to-weight ratio. It is used for window frames, roofing, siding, and building facades.

**B. Copper:** Copper is a highly conductive metal that is used in electrical applications. It is also used in roofing, gutters, and flashing because of its resistance to corrosion and its aesthetic appeal.

**C. Zinc:** Zinc is a highly corrosion-resistant and highly malleable metal. It is often used in roofing and cladding systems, building facades or as a decorative element.

**D. Nickel:** Nickel is a highly corrosion-resistant metal. It is often used in the construction of chemical plants, refineries, and other industrial facilities.

**Alloys**

Alloys are materials made by combining two or more different metals or a metal with a non-metallic element. Alloys are widely used in the construction industry, because of their unique properties such as strength, durability, and resistance to corrosion. Apart from steel, some other commonly used alloys are:

**A. Aluminium alloys:** Aluminium alloys are made by combining aluminium with other metals such as copper, zinc, or magnesium. Aluminium alloys are commonly used in the construction of buildings, bridges, and other structures because of their lightweight, corrosion resistance, and high strength-to-weight ratios.

**B. Copper alloys:** Copper alloys are made by combining copper with other metals such as zinc or tin. Copper alloys are used for applications such as plumbing and electrical systems because of their excellent thermal and electrical conductivity, as well as their resistance to corrosion.

**C. Titanium alloys:** Titanium alloys are made by combining titanium with other metals such as aluminium, vanadium, or iron. Titanium alloys are used for applications such as building structures, bridges, and pipelines because of their high strength-to-weight ratios, resistance to corrosion, and excellent durability.

**D. Zinc alloys:** Zinc alloys are made by combining zinc with other metals such as copper, aluminium, or magnesium. Zinc alloys are used for applications such as roofing and cladding because of their resistance to corrosion, durability, and ease of installation.

**Glass**

Glass is a versatile and amorphous solid material that is commonly used in construction, transportation, and consumer products. It is known for its transparency, durability, and customizable nature. Glass is produced by melting silica, soda ash, and lime in a furnace, and then cooling it rapidly to prevent the formation of crystals. While it has some limitations, such as being prone to breaking under extreme conditions, glass continues to be a valuable material in many applications, contributing to the functionality and aesthetic appeal of modern structures. There are various types of glass that are commonly used in the construction industry for different purposes. Here are some of the most common types of glass used in construction:

**A. Annealed Glass:** Annealed glass is a basic type of glass that is used in many different construction applications. It is also known as float glass or plate glass. It is the most common type of glass used in windows and doors, and it is relatively inexpensive.

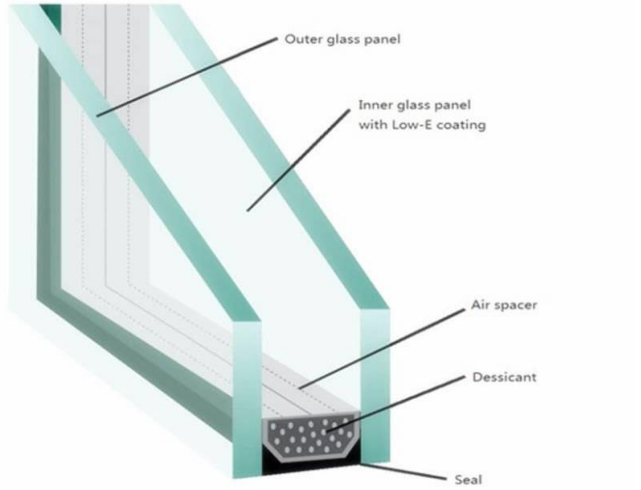
**B. Tempered Glass:** Tempered glass is stronger and more durable than annealed glass. It is made by heating annealed glass to a very high temperature and then rapidly cooling it. Tempered glass is four to five times stronger than annealed glass and is often used in areas where safety is a concern, such as in shower doors, partitions, and railings.

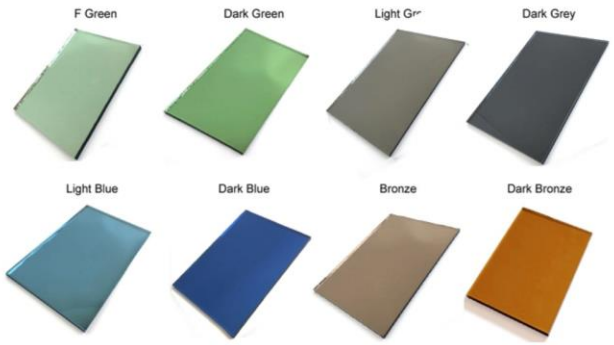
**C. Laminated Glass:** Laminated glass is made by sandwiching a layer of plastic between two or more layers of glass. The plastic layer helps to hold the glass together if it is broken. Laminated glass is often used in areas where safety is a concern, such as in skylights, curtain walls, and exterior glass panels.

**D. Insulated Glass:** Insulated glass is made by sealing two or more panes of glass together with a spacer bar. The space between the panes is filled with air or an insulating gas, such as argon or krypton. Insulated glass provides better insulation and noise reduction than single-pane glass and is often used in windows and doors.

**E. Low-E Glass:** Low-emissivity (Low-E) glass has a special coating that reflects heat back into a room, reducing heat loss and improving energy efficiency. Low-E glass is often used in areas with extreme temperatures, such as in cold climates or hot climates.

**F. Tinted Glass:** Tinted glass is glass that has been treated with a special film or coating that reduces the amount of light that passes through it. Tinted glass is often used in areas where privacy is a concern, such as in office buildings, and it can also help to reduce glare and heat gain.

**Plastic**

Plastics have been increasingly used in the construction industry due to their durability, versatility, low cost, and lightweight. It is made from polymers and can be manufactured in a variety of forms, such as sheets, films, fibres, and moulded parts. Some common uses of plastic in construction include pipes, insulation, roofing, and flooring. The following are different types of plastics used in the construction industry.

**A. PVC:** Polyvinyl chloride, or PVC, is a type of plastic that is widely used in construction for its strength, durability, and resistance to moisture and chemicals. It is often used for plumbing and electrical applications, as well as for flooring and roofing.

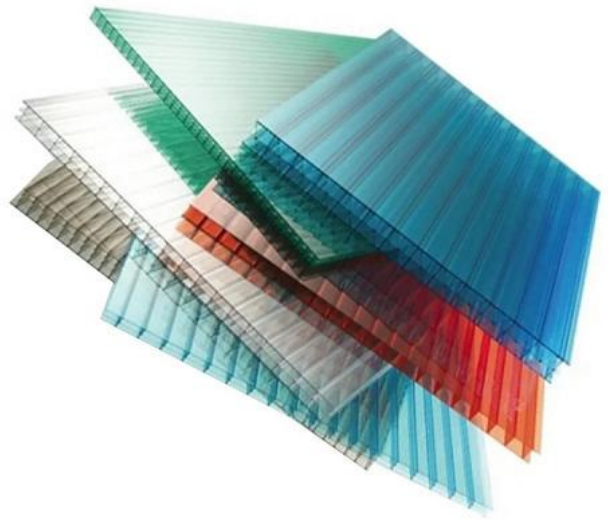
**B. Polyethylene:** Polyethylene is a lightweight, flexible plastic that is often used in construction for insulation, packaging, and moisture barriers. It is also used in the production of plastic pipes and films.

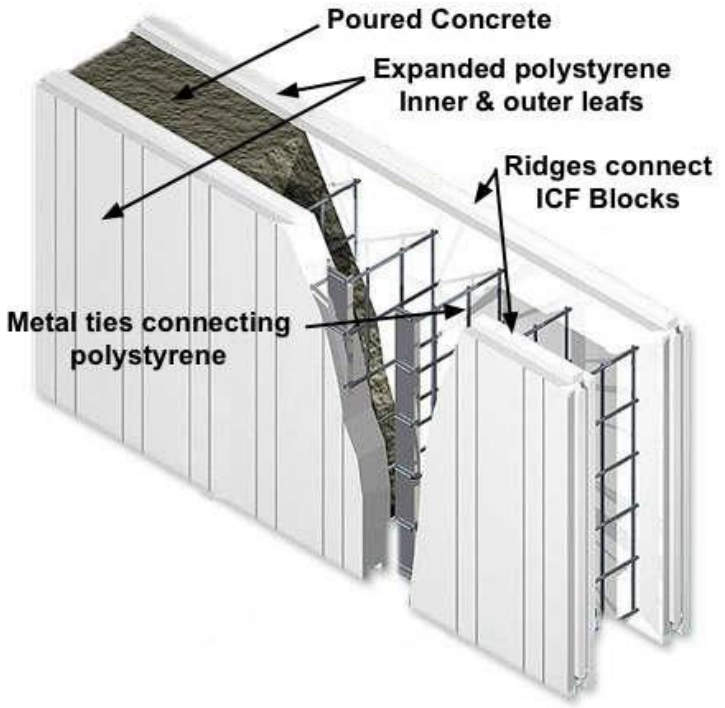
**C. Polycarbonate:** Polycarbonate is a strong, transparent plastic that is commonly used in construction for its impact resistance and UV stability. It is often used for skylights, greenhouse panels, and roofing.

**D. Acrylic:** Acrylic, also known as Plexiglas, is a clear, lightweight plastic that is often used as a glass replacement in construction. It is highly resistant to impact and UV light and is often used for windows, partitions, and signs.

**E. Nylon:** Nylon is a strong, durable plastic that is often used in construction for its strength and resistance to wear and tear. It is often used for heavy-duty applications, such as ropes and cables.

**F. Insulated concrete forms:** Insulated Concrete Forms (ICFs) are made from expanded polystyrene foam, which is a plastic material. ICFs are used to construct walls, provide excellent insulation properties and can reduce energy consumption.




Poured Concrete
Expanded polystyrene
Inner & outer leafs
Ridges connect
ICF Blocks
Metal ties connecting
polystyrene

**Rubber**

Rubber is a versatile material that has a wide range of applications in various industries. It is an elastic substance that can be stretched and bent and then returned to its original shape. Rubber is produced from the sap of rubber trees or from synthetic sources. The unique properties of rubber, including its elasticity, durability, and resistance to water and chemicals, make it an essential material for many applications including the construction field. Some of the common types of rubber used in the construction industry include:

**A. Natural rubber:** This is a naturally occurring rubber that is extracted from the sap of rubber trees. It is highly elastic and has good tear resistance. It is often used in flooring, insulation, and vibration- damping applications.

**B. Synthetic rubber:** Synthetic rubber is made from petroleum-based products and is used in a wide range of construction applications, including roofing, waterproofing, and insulation.

**C. Neoprene rubber:** This is a synthetic rubber that is highly resistant to oil, chemicals, and weather. It is often used in gaskets, hoses, and seals.

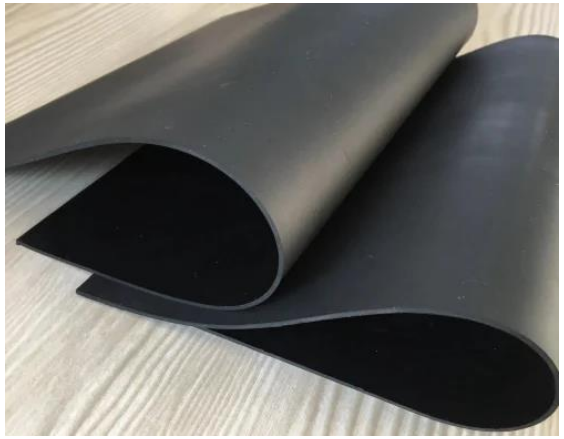
**D. EPDM** (Ethylene Propylene Diene Monomer): This is a synthetic rubber that is highly durable and resistant to weather, heat, ozone, and UV radiation. It is commonly used in roofing and waterproofing systems.

**E. Silicone rubber:** This is a synthetic rubber that is highly resistant to temperature. It is often used in roofing and sealing applications.

**F. Butyl rubber:** This is a synthetic rubber that is highly impermeable to gases and liquids. It is often used in roofing and waterproofing applications.

**G. Nitrile rubber:** This is a synthetic rubber that is highly resistant to oil and grease and used in gaskets, hoses, and seals.


Synthetic Rubber



**Adhesive**

The adhesive is a substance that is used to join or bond two surfaces together. It can come in many forms, including liquids, pastes, tapes, or films, and it can be made from a variety of materials such as synthetic polymers, natural resins, or animal collagen. Adhesives can provide a strong and durable bond that is often superior to other joining methods such as screws or nails. Following are some examples of adhesives used in the construction industry:

**A. Epoxy adhesives:** Epoxy adhesives are widely used in construction because they provide strong, durable bonds. They can be used to bond a wide range of materials and are particularly useful in high-stress applications. Epoxy adhesives also have excellent resistance to chemicals and water.

**B. Polyurethane adhesives:** Polyurethane adhesives are often used in construction because they are very strong and can bond a wide range of materials. They are particularly useful for bonding wood and other porous materials. Polyurethane adhesives also have good moisture resistance and can be used in outdoor applications.

**C. Acrylic adhesives:** Acrylic adhesives are often used in construction because they are strong and durable. They are particularly useful for bonding plastics, metal, and glass. Acrylic adhesives are also resistant to UV light and weathering, making them a good choice for outdoor applications.

**D. Cyanoacrylate adhesives:** Cyanoacrylate adhesives, also known as superglues, are often used in construction because they provide a fast and strong bond. They are particularly useful for bonding small parts or for applications where fast curing is required.

**E. Silicone adhesives:** Silicone adhesives are often used in construction for sealing and bonding. They can be used to bond a wide range of materials, including glass, metal, and plastics. Silicone adhesives are also resistant to UV light and temperature extremes, making them useful for outdoor applications.


Permabond
PT 326
2-Component PU Adhesive


TA435
TA436
TA439
Permabond


Permabond
910
799
POP


ALSTONE
995

## Composite Materials

Composite materials are materials made by combining two or more different materials to create a new material with improved properties. The individual materials that make up the composite are called the constituent materials. Composite materials are designed to take advantage of the unique properties of each of their constituent materials and to overcome the limitations of those materials when used alone. For example, a composite material made of a lightweight polymer matrix and strong fibres can be much stronger and more durable than either material used alone.

The use of composite materials has many advantages over traditional materials, including high strength-to-weight ratios, corrosion resistance, and improved fatigue resistance. Due to such benefits, these materials have been used in a wide range of applications in various industries, including aerospace, automotive, and marine. In the construction industry, composite materials are increasingly being used as a replacement for traditional materials such as steel, concrete, and wood. Different types of composite materials used in the construction industry are:

**A. Fiber reinforced polymers (FRP):** FRPs are made by combining a matrix material, such as epoxy, with a reinforcing material, such as carbon fibres, glass fibres, or aramid fibres. These materials have high strength-to-weight ratios, making them ideal for applications such as bridges, columns, and beams.

**B. Wood-plastic composites (WPCs):** WPCs are made up of a mixture of wood fibres and plastic, typically polyethylene or polypropylene. These composites have good dimensional stability, are resistant to rot, and have a natural appearance. WPCs are commonly used in the construction of decking, railing, and fencing.

**C. Metal matrix composites (MMCs):** MMCs are made up of a metal matrix reinforced with fibres such as carbon, silicon carbide, or aluminium oxide. These composites have high strength, are wear- resistant, and have excellent thermal properties. MMCs are commonly used in the construction of heat sinks, cladding panels, and structural components.

**D. Ceramic matrix composites (CMCs):** these are composites where the matrix material is ceramic, and the reinforcing material can be a ceramic or a fibre such as carbon or silicon carbide. CMCs are used forhigh-temperature applications.

**Smart Materials**

Smart materials are those materials with the ability to sense changes in their environment and respond to those changes in a predictable and controllable way. In the construction industry, smart materials have many potential applications, including:

**A. Shape memory alloys (SMAs):** These are alloys that have the ability to return to their original shape when heated. SMAs can be used in the construction of self-healing concrete, which can repair cracks when heated.

**B. Self-healing materials:** These materials have the ability to repair themselves when damaged. Self-healing concrete, for example, contains microcapsules filled with healing agents that can be released to repair cracks in the concrete.

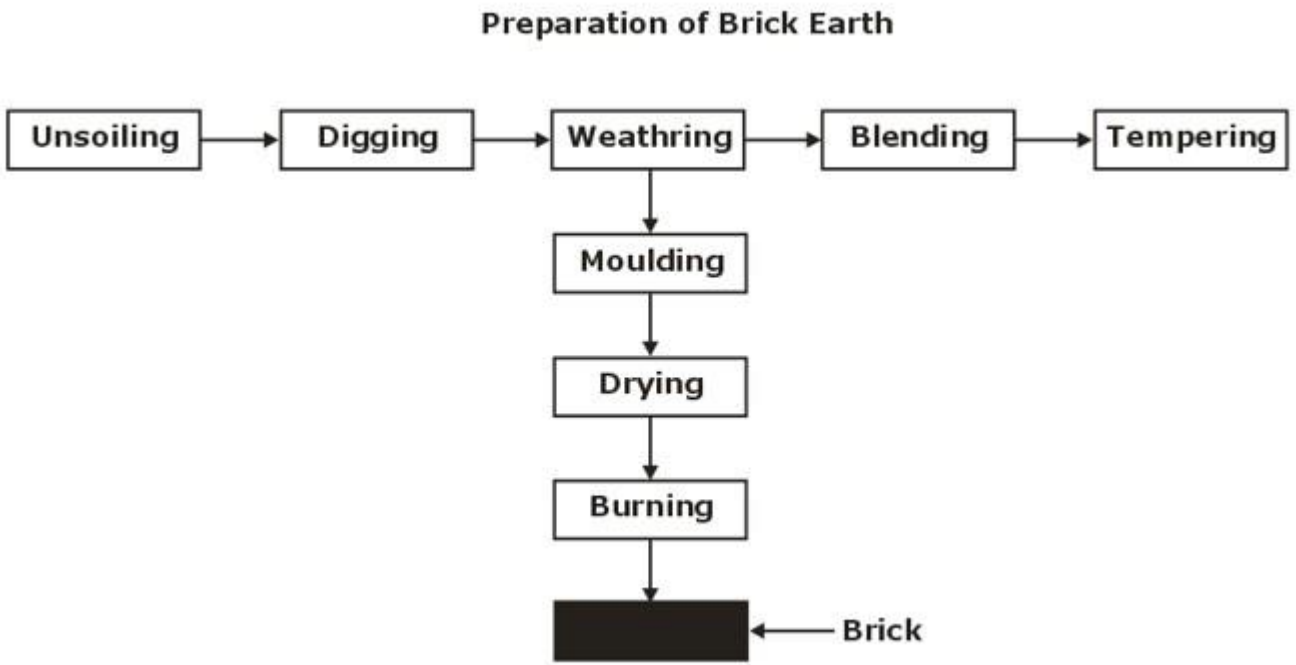
**C. Electrochromic materials:** These materials have the ability to change colour or opacity in response to an electrical signal. Electrochromic windows, for example, can be used to control the amount of light and heat that enters a building.

**D. Piezoelectric materials:** These materials generate an electrical charge when they are mechanically deformed. Piezoelectric materials can be used in the construction of energy-harvesting systems, which can generate electricity from the motion of the building or its occupants.

**E. Smart coatings:** These are coatings that can change their properties in response to changes in their environment. For example, smart coatings can be used to control the temperature and humidity inside a building.

## Flow Chart of Manufacturing of Bricks

The flow chart for brick manufacturing consists of the steps involved in the process of making bricks. These brick manufacturing processes may include the preparation of clay material, moulding of clay, drying of bricks and burning of bricks, etc. The clay preparation involves many steps like unsoiling, digging, weathering, etc.




**Flow Chart of Manufacturing of Bricks**

**Process of Making Bricks**

Brick material consists of silica, alumina, manganese and iron oxides. The process of making bricks consists of the following operations.

•**Unsoiling:** In this process, the soil is prepared to form bricks. It should be free from gravel, coarse sand, organic matter etc. Earth material for manufacturing bricks should be free from pebbles, roots, etc.

•**Digging:** After removing the top layer of the earth, proportions of additives such as fly ash, sandy Loam, rice husk ash, stone dust etc., should be spread over the plane ground surface on a volume basis. The digging operation should be done before the rains.

•**Weathering:** it is the process of removing large particles like gravel, pebbles etc. It is done to develop homogeneity in the mass of soil, particularly if they are from different sources, and also to eliminate the impurities which get oxidized. Soluble salts in the clay would also be eroded by rain, which otherwise could have caused scumming when burning the bricks in the kiln. The soil should be turned over at least twice and ensured that the entire soil is wet throughout the period of weathering.

•**Blending:** The earth is mixed with sandy and calcareous earth in suitable proportions to modify soil composition. A moderate amount of water is mixed to obtain the correct mould consistency. The addition of water to the soil at the dumps is necessary for easy mixing and workability, but the addition of water should be controlled so that it may not create a problem in moulding and drying. Moisture content in excess amounts may affect the shape and size of the finished brick.

•**Tempering:** Tempering consists of kneading the earth to make the mass stiff and plastic (by plasticity, we mean wet clay’s property of being permanently deformed without cracking). It should preferably be carried out by storing die soil in a cool place in layers of about 30 cm thickness for not less than 36 hours. It will ensure homogeneity in the mass of clay for subsequent processing.

•**Vitrification:** To convert the mass into a glass-like substance — the temperature ranges from 900-1100°C for low-melting clay and 1000-1250°C for high-melting clay. Cooling the bricks below the cherry red heat requires great care to avoid checking and cracking. The vitrification period may further be divided into incipient vitrification, complete vitrification, and viscous vitrification.

# TRANSPORTATION ENGINEERING

## 5.1 What is Transportation?

Transportation refers to systems that are designed to move people and goods. It is a central part of how people live their lives, build economies, and interact with the environment. Transportation is vital for the economic development of any region. It provides personal mobility, reduces travel time, and provides access to education, food, recreation, and other essentials.

The transportation system contains three essential components: the mode of transportation, fuel type, and technology. The mode of transportation defines personal or goods mobility via car, bus, bicycle, train, truck, pipeline, plane or ship, etc. across land, air, or sea routes. Fuel is the crucial element that propels the transportation systems. It includes human and animal powers, petroleum, coal, biofuel, electricity, renewable energy, etc. The systems for the storage and distribution of these fuels among transport vehicles constitute an important part of the transport infrastructure. The technology component defines specifications for different modes of transportation such as their speed, capacity, proportion mechanism, systems for their management and control, etc. Technology not only affects and improves the efficiency of the existing system but is also poised to transform future systems. With the advancement in technology, intelligent transportation systems (ITS), self-driving automobiles, hyperloop, unmanned air vehicles (UAVs), and urban aerial mobility (UAM) systems may turn into the leading mode of transportation in the near future. Therefore, the scope of the transportation system spans various disciplines of engineering.

However, the role of a civil engineer is very specific and limited to the planning, construction, and management of different transportation facilities and fixed installations. It includes physical links such as roads, railways, conveyor belts and pipelines, and terminals such as airports, seaports, harbours, railway stations, and bus stands.

## 5.2 Importance of Transportation

Transportation is linked to each commercial and social activity in one way or another. It is associated with living in such a way that we cannot imagine even a single day where we don't use any mode of transportation. For example, the water we use and the food we cook use different transportation systems to reach our homes. We use transportation to go to the office, school, bank, post office, market, etc. Transportation is required to carry raw materials used in the construction of the house we live in and the furniture therein.

Transportation contributes to the economic, industrial, social, and cultural development of any country. Every commodity produced needs transportation for carrying raw materials and for the distribution of finished products among consumers. Transportation also enhances the pool of customers as there is the possibility to do business at the national as well as international levels. The availability of rapid, safe, economic, and efficient transportation facilities in a country provides a good indication of its social and economic progress. Transportation offers several benefits:

- Transportation increases business profits by providing inexpensive raw materials from different locations and by supplying your end products to distant customers.

- It ensures enough goods of different varieties are always available in the market. This avoids monopoly that in turn reduces the price. Further, transport has a major impact on the stability of prices of various basic products by moving goods from surplus areas to deficits.

- As their commodity can reach distant places, the companies may upscale their production to satisfy the demands of the large customer base. This contributes to the growth of the industry and results in additional job creation.

- It enhances the social and commercial corporations between different countries to meet each other's needs.

- It enhances mobility and allows people to move larger distances in a shorter period. It is now normal to travel nearly 1800 km from New

Delhi to Chennai, complete the work and return on the same day. Can you imagine the same about 100 years ago?

- It enhances employment opportunities as distant places become reachable. New opportunities are also created in the form of taxi services.

- Transportation results in the development of backward regions and hence helps in the removal of regional imbalance.

- Transportation encourages people to live in places away from their work and hence helps in decreasing population concentration at urban centres.

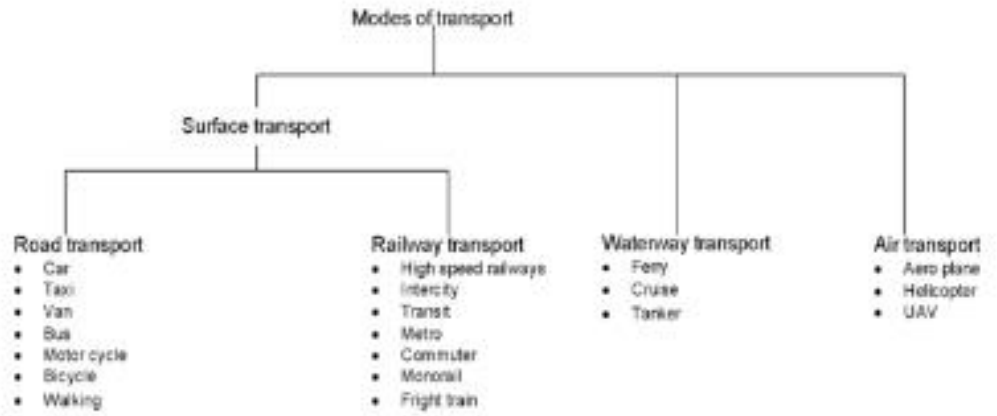
- It helps in the facilitation of aid in the areas affected by an emergency. It is essential for strategic movements for the defence of the country and to maintain better law and order.

## 5.3 Modes of Transportation

For convenience, transportation can be classified into surface transport, water transport, and air transport as shown in the figure. Surface transport can be divided into road transport or railway transport. Other modes like pipelines, cable or ropeways, and belt conveyor systems also exist. Each mode of transport has its importance and limitations and takes place through a separate environment. The selection of a suitable mode of transportation is decided considering the following factors: length of the haul, weight, and size of the consignment, traffic density, nature of the route, and quality of the service.

### 5.3.1 Road Transportation

Road transport means the transportation of goods and personnel from one place to the other on roads. The road is a route between two destinations, which has been either paved or worked on to enable transportation by way of motorized and non-motorized carriages.




**Different Modes of Transportation**

Road transportation is one of the two traditional modes of transportation. The other one is the waterway transportation. Since the dawn of civilization animals and animal-driven carts have been used for the transportation of goods and people. However, during the past century, the mode of road transport became enormously diversified with the inclusion of motorized vehicles such as a car, buses, trucks, scooters, etc. Today, the road transport sector alone accounts for about 87% of passenger traffic and 60% of freight traffic movement in the country.

**Advantages of road transport**

- Road transportation offers maximum service flexibility in terms of availability and adaptability of a vehicle of any type and any capacity, the route chosen, the time and the speed of travel, etc.
- In particular, for short-distance travel, road transport saves time.
- It can enable door-to-door delivery of goods and materials and provide a very cost-effective means of cartage, loading, and unloading.
- Road Transport has the highest level of penetration into populated areas in any country. Sometimes road transport is the only way for carrying goods and people to and from rural areas which are not catered to by rail, water or air transport. Hence, the delivery of goods

between cities, towns and small villages is made possible only through road transport.

- Road Transport is considered one of the most cost-effective modes of transport. The investment required in road transport is much less compared to other modes of transport such as railways and air transport. Further, the cost of construction, operating costs, and maintaining roads are cheaper than that of the railways, the other mode of surface transport.

- Road transport also acts as a feeder service to the railway, shipping, and air traffic.

**Limitations of road transport**

- For instance, there are more chances of accidents and breakdowns in the case of road transport. So, motor transport is not as safe as other means of transport.

- Road transport is also quite less organized in comparison with other modes. It is irregular and undependable.

- Rates for road transportation are also unstable and unequal, while the speed of road transport is slow and limited, which is a major drawback.

- Transporting bulky goods over long distances is also unsuitable and costly.

- In modern days, road transport has a serious negative impact on the environment. Building roads requires the melting of tar or formulation of concrete, which may harm the associated environment. Since roads have been a major enabler of motorized transport, these vehicles also emit a lot of pollution in the form of Nitrogen dioxide, volatile organic compounds, carbon monoxide, and various harmful air pollutants, including benzene, which have adverse respiratory health effects and a serious threat to global warming.

### 5.3.2 Rail Transportation

Rail transport is also known as train transport. It is a means of transport, on vehicles which run on tracks known as rails. It is one of the most important, commonly used, and very cost-effective modes of transportation over long distances. It includes passenger trains, urban metro railways, and goods carriages.

The first public railway transportation system was introduced in 1825 in England by the pioneer of railways, George Stephenson (1781-1843). Within a short period, it was adopted by several countries throughout the world. The first railway on the Indian sub-continent ran for a stretch of 32 km from Bombay to Thane in 1843. This modest beginning in due course developed into the fourth-largest network of railway lines next to the United States, China, and Russia.

#### Advantages of rail transport

- With time, rail transport has emerged as one of the most dependable modes of transport in terms of safety. Trains are fast and the least affected by usual weather turbulence like rain or fog, compared to other transport mechanisms.

- Rail transport is better organized than any other medium of transport. It has fixed routes and schedules. Its services are more certain, uniform and regular compared to other modes of transport. Rail transport is also one of the fastest modes of land transport.

- The system runs on metal (usually steel) rails and wheels. Thus, it has the inherent benefit of lesser frictional resistance. This helps to attach more load in terms of wagons or carriages to a single-engine.

- Rail transport is one of the cheapest modes of transport, especially for carrying heavy and bulky goods over long distances.

- The carrying capacity of a train is larger for any other mode of surface transport. Further, the carrying capacity is elastic that is it can be increased by just adding additional wagons to the train.

**Limitations of rail transport**

- One of the biggest constraints of rail transport is the heavy cost. Trains need high capital to build and maintain and the cost is magnified when a whole rail network is to be built. The cost of construction, maintenance, and overhead expenses are very high compared to other modes of transport.

- Rail transport is tied to a particular track. Hence, it cannot provide door-to-door service. Further, the rail transport service is not flexible, as its routes and timings cannot be adjusted to individual requirements.

- Rail transportation may require intermediate loading or unloading due to the unavailability of direct trains or due to gauge changes. Such, intermediate loading or unloading involves greater cost, more wear and tear, and waste of time.

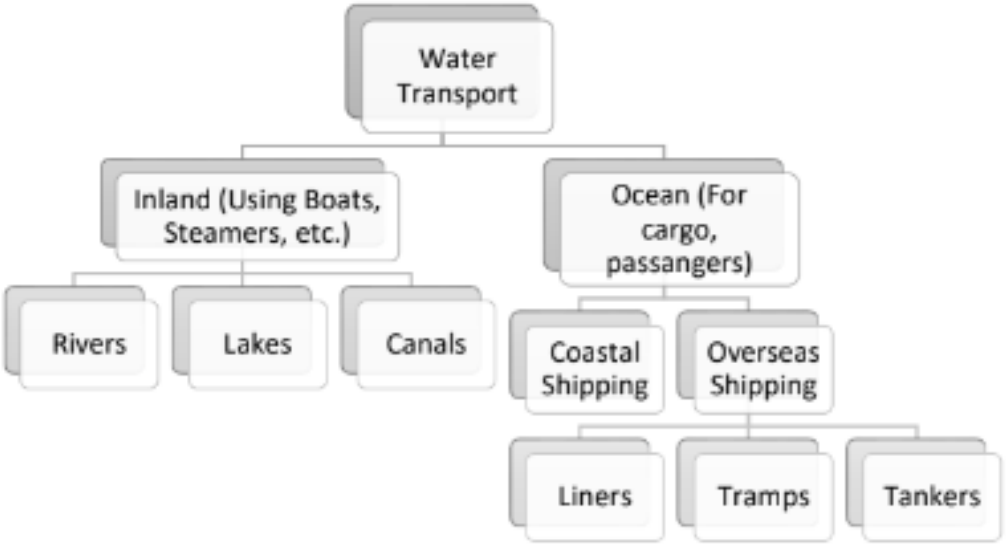
### 5.3.3 Water Transportation

In water transportation, the conveyance of people and goods takes place through the vehicles that float on water. This mode of transportation holds historical significance as the premier mode of transportation that facilitated international trade cultural relations and intercontinental movements. Even today, it remains the primary mode of transportation for international trade relations and accounts for around 80 percent of international trade in tons.

Water transport is the cheapest and oldest mode of transport. It operates on a natural track such as stream, river, lake, sea, ocean, etc. and hence does not require huge capital investment in the construction and maintenance of these tracks. The cost of the operation of water transport is also very low. It has the largest carrying capacity and is most suitable for carrying bulky goods over long distances.

Water transportation can broadly be classified into two categories, such as inland water transportation and oceanic water transportation. The figure below represents the different methods and vehicles used in water transport. Inland water transportation takes place on rivers, lakes, and

canals within the mainland. It takes place through barges, boats, steamers, etc. Similarly, oceanic transportation takes place for the conveyance of people and goods across the ocean between continents and islands. It takes place through ocean liners, cargo vessels, tankers, cruises, etc.




### Advantages of water transport

- Water transport has the capacity of conveying bulky and heavy cargoes such as coal, oil, minerals, etc.
- It is the cheapest mode of transportation for bulkier cargo over a long distance. Its operational expense is relatively cheap as it can transport a huge amount of cargo at a time thus reducing per-unit cost.
- Water transportation takes place through nature-gifted routes such as rivers, lakes, seas, etc. therefore no additional expense is incurred to construct waterways like roads or railways. Additionally, it allows for flexible service with little to no congestion.
- Water transportation causes the lowest pollution among all modes of transportation for the conveyance of the unit weight of cargo.

- During natural calamities like floods and rains, rail and road transport may have been disrupted. Hence, relief operations can be carried out through water transport.

### Limitations of water transport

- It is also unsuitable for short-distance journeys, due to being costly and time-consuming. It is the slowest mode of transport. Sometimes there are delays in shipment at docks and locks, which hinders navigation. Poor weather conditions might also cause this.

- Water transport is also risky as poor weather and sea storms may cause an accident leading to significant economic loss and casualty.

- Vessel oil spillage, noise, smoke, and fumes cause pollution and endanger marine life.

- Water transport is not suitable for the transportation of perishable goods.

- Canals can also be very expensive to construct, maintain, as well as dredge.

## 5.3.4 Air Transportation

Air travel is a form of conveyance in vehicles such as helicopters, aeroplanes, jet planes, balloons, or anything else that can sustain flight. Air transport is the fastest-growing transportation for carrying passenger traffic. It has grown at present to be the primary mode of international travel of peoples. Air transportation is the preferred mode of transportation for valuable and high-end products. Although, Air transportation's share of world trade in goods is less than 1% measured by weight but more than 35% by value.

The air transport system generally consists of three primary elements such as airports, airspace, and air traffic control (ATC) systems. The airport represents the ground part of the system and is responsible for the accommodation of the aircraft at the beginning and end of their flights, and serving the passengers and freight cargo shipments. The organized and

controlled airspace between the airports represents the air part of the air transport system. The ATC system guides aircraft while flying through the controlled airspace between airports and during their ground movements at the airports. The ATC is responsible for the prevention of conflicts that cause air traffic incidents and accidents, significant aircraft delays, and additional airline and passenger costs.

### Advantages of air transport

- Air transport is the fastest mode of transport that can fly at a speed that is sometimes more than the speed of sound. This, in turn, has resulted in a tremendous saving of travel time.
- It is the safest mode of transportation.
- It can occur over both land and water without loss of time, unlike other modes of transport.
- The air transport can reach areas inaccessible by other means of transportation.
- The air service is extremely useful in emergencies like floods, earthquakes, etc. for airlifting the affected people, dropping packets, or assessing the gravity of the situation.

### Limitations of air transport

- Hefty cost is incurred for the procurement, construction, operation, and maintenance of aeroplanes, construction of airports, ATC systems, meteorological stations, etc. The additional cost is involved in providing special training to the pilots. Therefore, the operation cost for air transport is the most expensive among different modes of transportation.
- The weight-carrying capacity of aircraft is the lowest among all modes of transport. As a result, the number of passengers traveling by air as well as the quantity of freight cargo that can be accommodated is the smallest as compared to the other modes of transportation. High cost to low capacity thus increases the per-unit cost for air transport.

- The operation of air transport is highly dependent on the weather. The landing and taking off of an aeroplane is not possible in foggy or high wind conditions.

### 5.3.5 Pipe Transportation

Pipeline transport is the long-distance transportation of liquid, and gas through a system of pipes known as pipelines. Its route is practically unlimited as it can be laid on land or underwater. At present, it has become the main mode of transportation for onshore oil, gas, and granular coal transportation. The pipelines for conveying solid materials are mainly seamless steel pipes, and fluids are often used for casings pipes. About 67 lakh km of pipeline has been laid in the world out of that 75% is laid in three premier countries such as the USA, Russia, and Canada. India has made a late start in this mode of transportation. The total pipe length in India at present is about 36,000 km.

### Advantages of pipeline transport

- Pipeline transportation only needs to lay pipelines and build pumping stations. The amount of earth and stone works is much smaller than that of road or railway construction. Moreover, most of the plain areas are buried underneath and do not require the acquisition of farmland and traverse through difficult terrains.

- The transportation volume is large. For example, a coal pipe with a diameter of 720 mm can transport 20 million tons of coal a year, which is almost equivalent to the single-direction conveying capacity of a single-track railway.

- It can be transported continuously and transportation is not affected by the weather. Further, the pipeline can take shortcuts due to which the transportation distance is short.

- It is a safe, reliable, pollution-free mode of transport. It consumes the lowest energy among all modes of transportation.

- As transportation takes place through a closed environment, the losses due to transportation are much less compared to other modes of transport.

### Limitations of pipeline transport

- Though operational and maintenance costs are minimal, the capital cost for laying the pipeline is much higher than other modes of transport.

- It is not flexible, as it can be used in a limited area of work. Further, its capacity can not be increased once it is laid.

- The pipelines are more susceptible to enemy or terrorist attacks as they shall stop the supply and halt the production activities thus jeopardizing the entire nation. Moreover, it is difficult to make security arrangements for the entire pipeline.

- Damages and leakages in the underground pipeline are difficult to detect and repair. Additionally, leakages from the oil or gas pipeline may cause explosions and fires, resulting in casualties, environmental damage, and material loss.

## 5.4 Types of Roads

The different types of roads can be grouped in the following methods:

- **Depending on their usability throughout the year**: all-weather road (usable throughout the year) and fair weather road (usable only during certain months of the year depending on weather conditions).

- **Topography:** Plain area roads and hilly roads.

- **Traffic type:** Pedestrian road, cycle track, and motorized roads

- **Material of construction:** earthen road, murram road, bituminous road, concrete road, etc.

- **Pavement type:** paved road (provided with a hard pavement course) and unpaved roads (not provided with hard pavement course, e.g., earthen roads and gravel roads)

- **Based on location and function**: Highway (road system connecting important towns and industrial bases through the country), urban roads (road system within a particular urban conglomeration), and rural roads (runs within a village or connects a group of villages and to the nearest city centre).

## 5.5 Indian Road Transport System

Road transport is the most important mode of transport in India that reaches every corner of the country. It provides the basic infrastructural facilities to the agricultural and industrial sectors alike. Roads have existed in India since the beginning of Indo-Aryan civilizations. Documented proofs are available to suggest that starting from the Mauryan period various kings of India have prioritized road buildings. During the Mughal and subsequent British rule, a lot of progress was made. Most of the present trunk routes follow their routes.

During the time of independence, India had 4 lakh kilometres of roads out of which about 1.5 lakh kilometres of roads were developed. Now India has the second largest road network system in the world with a total length of the developed road of about 5 lakh kilometers. Out of this, the total length of the expressway is approximately 1600 km, the national and state highway is approximately 132,000 km, and the rest are major district and rural roads.

### 5.4.1 Classification of Indian Roads

Depending on the location, function, importance, traffic volume, and earmarked administrative jurisdictions Indian roads are classified into the following three categories:

A. **Primary systems**: The primary systems include all national highways and expressways in the country. These roads connect important towns and centres of economic activities on a national and regional level.

Primary systems approximately constitute 3% of India's total road network but carry more than 40 percent of road traffic.

- **Expressway:** Expressways are the high-speed (more than 120 km/hr) road network systems of India. Expressways have superior facilities and design standards than any other national highway or state highway. These roads contain four or more lanes with divided carriageways, with access control at entry and exit, grade separations at crossroads, and total fencing. Parking, loading, and unloading of goods and pedestrian traffic is not allowed on expressways. Most of the existing expressways in India are toll roads, i.e., fees are assessed for the passage of a vehicle through the road. Expressways are owned by the central government or a state government depending on whether the route is a national highway or state highway.

- **National Highway:** These are the main highways running through the length and breadth of India connecting major ports, important cities, state capitals, economic and industrial conglomerates, foreign highways and the roads required for the strategic movement of defence forces. The National Highway Authority of India (NHAI) under the Ministry of Road Transport and Highways of Govt. of India is responsible for the development, maintenance, and management of these roads.

**B. Secondary systems**: The secondary system includes all state highways and major district roads. These roads connect cities, production, and market centres of a region or state. Secondary systems act as the main feeders for routing traffic to primary roads.

- **State Highway**: State highways are the major arterial roads within a state that connect district headquarters, important cities, and economic centres within the state, national highways, and highways of neighbouring states. These highways are built and maintained by respective state governments through the state public works departments.

- **Major District Roads**: Major district roads (MDR) are important roads within a district that connect important town centres, block and tehsil headquarters, major production centres, and highways passing

through the district. These highways are maintained through the state public works departments.

C. **Tertiary systems**: These include other district roads and village roads. It provides access to properties and through routes within a district or village level. As secondary connectors, they mainly feed traffic to secondary road systems.

- **Other District Roads**: Other district roads (ODR) are the roads that connect villages to important towns, districts, block and tehsil headquarters, and other main roads within a district. These are rural roads managed by District councils (i.e., Zillah Parishad) primarily under the Pradhan Mantri Gram Sadak Yojana (PMGSY) scheme.

- **Village Roads**: Village roads (VR) are the roads that connect a village or a group of villages with each other and to the nearest roads of a higher category. These are maintained by Panchayat Samitis through the PMGSY scheme.

## 5.6 Urban Road

Urban roads are part of urban infrastructure. These roads are required for both intra-city and intercity movement and render a much higher level of service compared to Regional Roads, State Highways and National Highways. Quality of life in urban areas depends on efficient and effective urban Road systems in addition to other infrastructural services such as water supply, sewerage, drainage, electricity, telephones etc. An urban transportation network is required to facilitate the movement of people and goods and therefore efficient network is necessary for their efficient movement. Urban roads being the most important mode of transportation, these are required to establish a reliable, efficient and attractive transportation system for vehicles and individuals.

### 5.6.1 Objectives of Urban Road

The objectives of urban roads are as follows:

- To facilitate communication of men and materials between the various centres of the town

- To provide air and light to the properties situated on their edges, and
- To provide space for laying the public utility services like water mains, drainage pipes, electric cables, telephone lines, etc.

### 5.6.2 Classification of Urban Roads

Urban roads constitute the road systems, excluding the highways, within the limits of an urban area. The development and maintenance of the urban roads is the duty of respective urban authorities. Urban roads are classified as arterial roads, sub-arterial roads, collector streets, and local streets.

Arterial and sub-arterial roads are meant for through traffic for the basic movements inside the town. The shape of these roads broadly sets the development pattern of the town. The sub-arterial road has a lower level of traffic mobility than the arterial streets. The collector street provides access to the arterial streets, and they collect and distribute traffic from and to local Streets.

Apart from this, large urban areas may also contain through roads, bypass roads, and ring roads. When a highway or main road passes through the congested portion of the town then it is called a through road. It results in a sharp reduction in the speeds of vehicles and the smooth flow of traffic on the through road. To maintain an easy flow of traffic on through roads and to give convenience and comfort to the road users, a loop road is constructed on the highways that go around a town or village so that traffic passing that town does not have to go through the town centre. Such a loop road is known as a bypass road.

On the other hand, a road or a series of or a series of connected roads that goes all the way around the town in a large circle is called a ring road. The most common purpose of a ring road is to reduce traffic in the city centre, by offering an alternate route around the city for drivers who do not have any business in the town.

### 5.6.3 Urban Road Patterns

A pattern means a design or form. In town planning, the roads form the pattern or design and the buildings, parks, open spaces etc. form the blocks

- As transportation takes place through a closed environment, the losses due to transportation are much less compared to other modes of transport.

### Limitations of pipeline transport

- Though operational and maintenance costs are minimal, the capital cost for laying the pipeline is much higher than other modes of transport.
- It is not flexible, as it can be used in a limited area of work. Further, its capacity can not be increased once it is laid.
- The pipelines are more susceptible to enemy or terrorist attacks as they shall stop the supply and halt the production activities thus jeopardizing the entire nation. Moreover, it is difficult to make security arrangements for the entire pipeline.
- Damages and leakages in the underground pipeline are difficult to detect and repair. Additionally, leakages from the oil or gas pipeline may cause explosions and fires, resulting in casualties, environmental damage, and material loss.

## 5.4 Types of Roads

The different types of roads can be grouped in the following methods:

- **Depending on their usability throughout the year**: all-weather road (usable throughout the year) and fair weather road (usable only during certain months of the year depending on weather conditions).
- **Topography:** Plain area roads and hilly roads.
- **Traffic type:** Pedestrian road, cycle track, and motorized roads
- **Material of construction:** earthen road, murram road, bituminous road, concrete road, etc.

- **Pavement type:** paved road (provided with a hard pavement course) and unpaved roads (not provided with hard pavement course, e.g., earthen roads and gravel roads)

- **Based on location and function:** Highway (road system connecting important towns and industrial bases through the country), urban roads (road system within a particular urban conglomeration), and rural roads (runs within a village or connects a group of villages and to the nearest city centre).

## 5.5 Indian Road Transport System

Road transport is the most important mode of transport in India that reaches every corner of the country. It provides the basic infrastructural facilities to the agricultural and industrial sectors alike. Roads have existed in India since the beginning of Indo-Aryan civilizations. Documented proofs are available to suggest that starting from the Mauryan period various kings of India have prioritized road buildings. During the Mughal and subsequent British rule, a lot of progress was made. Most of the present trunk routes follow their routes.

During the time of independence, India had 4 lakh kilometres of roads out of which about 1.5 lakh kilometres of roads were developed. Now India has the second largest road network system in the world with a total length of the developed road of about 5 lakh kilometers. Out of this, the total length of the expressway is approximately 1600 km, the national and state highway is approximately 132,000 km, and the rest are major district and rural roads.

### 5.4.1 Classification of Indian Roads

Depending on the location, function, importance, traffic volume, and earmarked administrative jurisdictions Indian roads are classified into the following three categories:

A. **Primary systems**: The primary systems include all national highways and expressways in the country. These roads connect important towns and centres of economic activities on a national and regional level.

Primary systems approximately constitute 3% of India's total road network but carry more than 40 percent of road traffic.

- **Expressway:** Expressways are the high-speed (more than 120 km/hr) road network systems of India. Expressways have superior facilities and design standards than any other national highway or state highway. These roads contain four or more lanes with divided carriageways, with access control at entry and exit, grade separations at crossroads, and total fencing. Parking, loading, and unloading of goods and pedestrian traffic is not allowed on expressways. Most of the existing expressways in India are toll roads, i.e., fees are assessed for the passage of a vehicle through the road. Expressways are owned by the central government or a state government depending on whether the route is a national highway or state highway.

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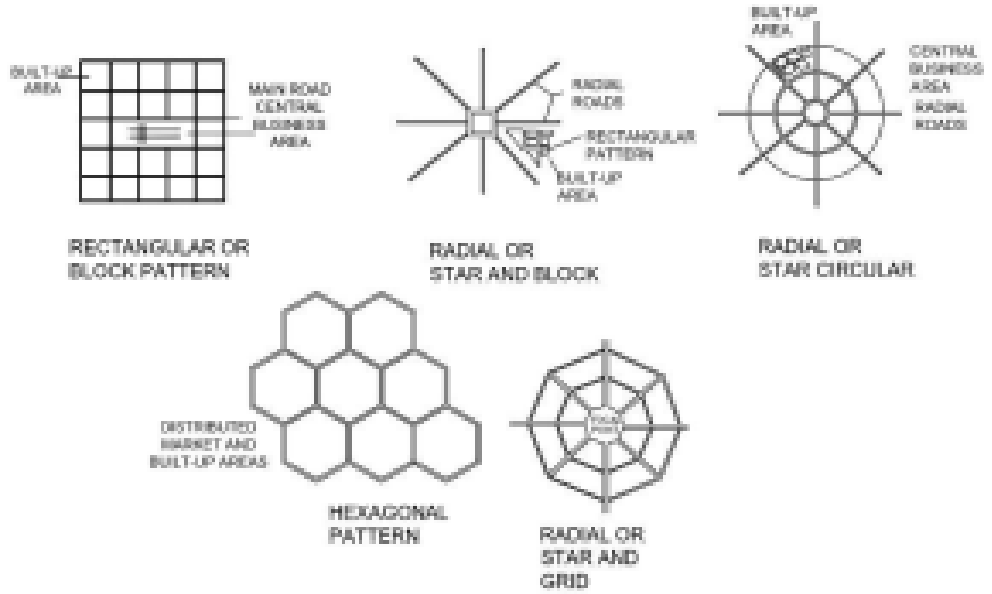
### 5.6.3 Urban Road Patterns

A pattern means a design or form. In town planning, the roads form the pattern or design and the buildings, parks, open spaces etc. form the blocks

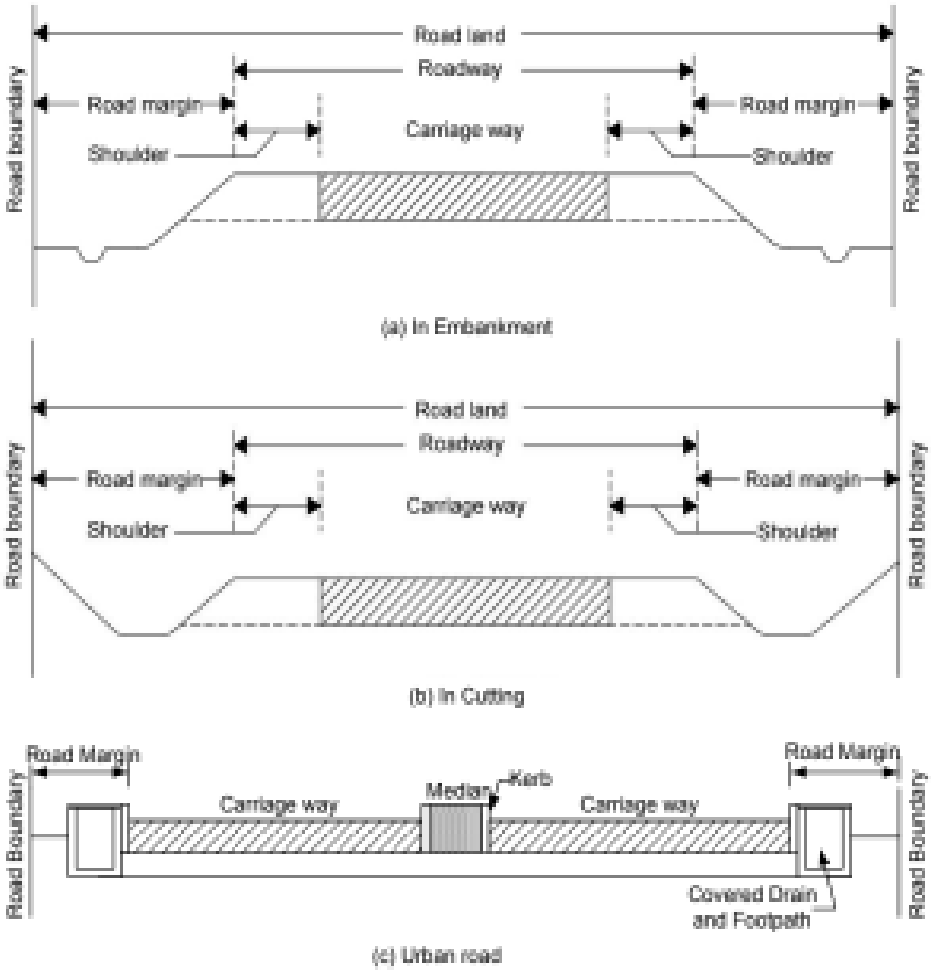
surrounded by these patterns. The streets might form squares, triangles, radial, hexagonal or any odd shapes between them, depending on how their layout is designed. This combination of shapes formed by the streets is the road pattern'. Road Pattern also plays a vital role in the management of city traffic and helps to reduce the time and distance that the vehicle takes to reach the destination place. There are five types of road patterns that are mostly used: (*i*) rectangular or block pattern, (*ii*) radial or star and block pattern, (*iii*) radial star and circular pattern, (*iv*) radial star and grid pattern, and (*v*) hexagonal pattern.




**Urban road patterns**

## 5.7 Basic Components of a Road

Highways consist of several basic components such as road width, cross slope, pavement, road margins, traffic separators, and curbs. These components are meticulously designed based on factors such as driver psychology, vehicle characteristics, and regional traffic patterns and efficient design of these elements is paramount to ensuring highway safety and functionality. The figure below shows typical highway cross sections in embankment, cutting and urban areas.




**Basic components of a road**

### 5.7.1 Cross Slope or Camber

Cross slope, also known as camber, refers to the transverse slope of the pavement or carriageway, as depicted in Figure 1. It facilitates drainage of rainwater from the road surface. Insufficient cross slope can lead to water accumulation on the pavement, ultimately causing highway deterioration. The specific angle of the slope depends on the road construction materials and the regional rainfall patterns, typically ranging from 1 in 60 to 1 in 25.

### 5.7.2 Carriageway or Pavement

The carriageway or pavement represents the paved section of the highway designated for vehicle traffic. Its width is determined by the number of traffic lanes and the desired lane width for construction. A traffic lane is a designated path for a single line of traffic. Generally, for single lanes a lane width of 3.75 meters is recommended. For pavements designed with two or more lanes, a width of 3.5 meters per lane is provided.

### 5.7.3 Medians

Medians are traffic separators whose function is to prevent collisions between vehicles travelling in opposite directions on adjacent lanes.

### 5.7.4 Kerbs

Road kerbs are the raised visible barriers at the edges of the road that separate the footpath or median from the street or roadway. The materials used for road kerbs include natural stone, precast concrete, and cast in-situ concrete. They are typically constructed on urban roads and serve various purposes, such as providing a boundary between the footpath and pavement, preventing vehicles from parking beside the road, providing structural support to the pavement, and facilitating the longitudinal drainage system.

### 5.7.5 Road Margins

Road margins encompass various elements, such as:

- ✓ **Shoulders**: These are provided along the road edge. This area serves the purpose of accommodating vehicles that are compelled to be taken out of the pavement or the roadway. These also act as a service lane for the vehicles that have broken down.

- ✓ **Footpaths or Sidewalks**: When the vehicular and pedestrian traffic is heavy, a special area is allotted for the movement of pedestrians. The area is called footpaths or sidewalks. This is provided to protect the pedestrian thus decreasing accidents.

- ✓ **Parking Lanes**: Parking lanes are provided on urban roads to accommodate parked vehicles.

- ✓ **Bus Bays**: These are the designated spaces provided on urban roads for bus traffic to onboard and deboard passengers.

### 5.7.6 Width of Roadway

The width of the roadway or the width of the formation is equal to the sum of the width of the pavement (including the separators if any) and the shoulders.

### 5.5.7 Right of Way

The right of way refers to the width of land acquired for the road along its alignment. The right of way is dependent on the importance of the road and the possibility of future development.

## 5.7 Road Pavement

A road pavement structure is made of multiple layers of processed and compacted road materials, in different thicknesses, which together form a structure to support the vehicle and provide a smooth riding quality. Two types of pavement are laid in India: rigid pavement and flexible pavement. In a flexible pavement system, a layer of bituminous concrete is laid and compacted over a bed of granular materials. Whereas, in a rigid pavement system, a layer of cement concrete (plain, or reinforced) is laid and compacted over the bed of granular materials.

### 5.7.1 Flexible Pavement

A typical flexible pavement consists of a bituminous surface course over the base course and sub-base course. The surface course may consist of one or more bituminous or hot mix asphalt (HMA) layers. These pavements have negligible flexure strength and hence undergo deformation under the action of loads. Due to this, it is named as flexible pavement.

The structural capacity of flexible pavements is attained by the combined action of the different layers of the pavement. The wheel load is

directly applied on the wearing course, and gradually distributed to a wider area, and the stress decreases with the depth. Since the stress induced by traffic loading is highest at the top, this layer has to be best in quality to sustain maximum compressive stress, besides, wear and tear. The lower layers will experience the lesser magnitude of stress and low-quality material can be used. Taking advantage of these stress distribution characteristics, flexible pavements normally have many layers: surface course, binder course, base, sub-base, subgrade, and ultimate ground.

- **Surface course:** The surface course is the layer directly in contact with traffic loads and generally contains superior quality materials. They are usually constructed with dense graded asphalt concrete (AC). The functions of the surface course to provide a a smooth and skid-resistant riding surface, and to prevent the entrance of excessive quantities of surface water into the underlying base, subbase, and subgrade

- **Binder course:** This layer provides the bulk of the asphalt concrete structure. Its primary purpose is to distribute the load to the base course. The binder course generally consists of aggregates having less asphalt and doesn't require quality as high as the surface course, so replacing a part of the surface course with the binder course results in a more economical design.

- **Base course:** The base course is the layer of material immediately beneath the surface of the binder course and it provides additional load distribution and contributes to the sub-surface drainage It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials.

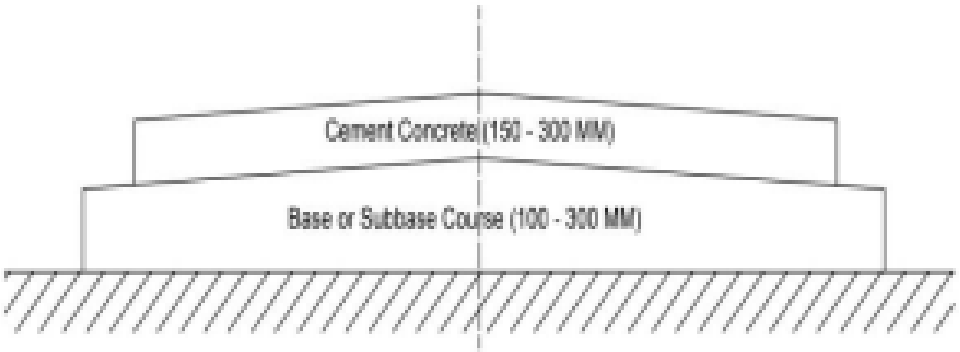
- **Sub-base course:** The sub-base course is the layer of material beneath the base course and the primary functions are to provide structural support, improve drainage, and reduce the intrusion of fines from the sub-grade in the pavement structure If the base course is open-graded, then the sub-base course with more fines can serve as a filler between subgrade and the base course A sub-base course is not always needed or used. For example, a pavement constructed over a high-quality, stiff subgrade may not need the additional features offered by a sub-base course. In such situations, sub-base courses may not be provided.

- **Subgrade:** The topsoil or subgrade is a layer of natural soil prepared to receive the stresses from the layers above. At any time, soil subgrade must not be overstressed. It should be compacted to the desired density, near the optimum moisture content.


**Typical cross-section of a flexible pavement**

### 5.7.2 Rigid Pavement

Rigid pavements have high flexural rigidity due to which they deflect very little under loading due to the high modulus of elasticity of their surface course. Compared to flexible pavement, rigid pavements are placed either directly on the prepared subgrade or a single layer of granular or stabilized material. Since there is only one layer of material between the concrete and the subgrade, this layer can be called a base or sub-base course.




**Typical Cross-section of rigid pavement**

### 5.7.3 Difference Between Flexible and Rigid Pavement

| Sl. No. | Flexible Pavement | Rigid Pavement |
|---|---|---|
| 1. | It consists of a series of layers with the highest quality materials at or near the surface of the pavement | It consists of one layer of Portland cement concrete slab or relatively high flexural strength |
| 2. | Reflects the localized failures and deformations of subgrade and subsequent layers on the surface layer. | It can bridge over localized failures and areas of inadequate strength. |
| 3. | Its stability depends upon the aggregate interlocking, particle friction, and cohesion. | Its structural strength is provided by the pavement slab through the beam action. |
| 4. | The area of load distribution on the subgrade depends on its depth from the surface layer. | The load is distributed over a wide area of the subgrade due to the high elasticity modulus of concrete. |
| 5. | Additional stress is not produced in flexible pavements due to temperature variations. | Temperature variation may induce heavy stresses in rigid pavements. |

### 5.7.4 Pavement Type Selection

Selecting a pavement type is an important decision for any road designer. Different parameters that are considered while selecting suitable pavement types include the type and characteristics of traffic plying over the pavement, anticipated pavement life, cost, availability of finances, and local conditions.

- **Traffic**: Various traffic characteristics such as the weight of the vehicle, weight per axle, speed, etc. determine the thickness of the pavement required the extent and rate of damage and the need for maintenance. Generically rigid pavements are more suitable for busy roads and roads subject to heavy traffic.

- **Service life**: The need for frequent maintenance and the anticipated service life is better for rigid pavements than flexible pavements. Hence, it is preferred for the construction of busy roads and urban streets where it is not possible to carry out frequent maintenance works that may result in the temporary closing of the road.

- **Cost**: The cost is the most important factor that affects the selection of the pavement type. The common cost components are the cost of materials, construction and subsequent maintenance charges over a selected analysis period such as 20 or 30 years. Generally, the initial cost of construction for flexible pavement is less than the rigid pavements. But the service life for flexible pavement is about 15 years which is less than the rigid pavements which has a service life of about 30 years. Further, the maintenance requirement for rigid pavement is far less than the flexible pavement. As a result, in the long term, the cost of rigid pavement comes less.

- **Funds available**: If sufficient fund is not available for the construction of rigid pavement then flexible pavement is selected.

- **Other local factors**: Besides the economic considerations, local conditions are also considered while deciding the pavement type. The local conditions may include local availability of materials, equipment, experience and expertise. Considering the specific site design conditions (for example, the condition of the subgrade, level of water table, existing road geometry etc.), weather conditions (for example, freeze-thaw, rainfall, etc.), or safety conditions, certain types of pavements may assume more weightage in the process of decision making.

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# WATER SUPPLY ENGINEERING

## 6.1 Introduction

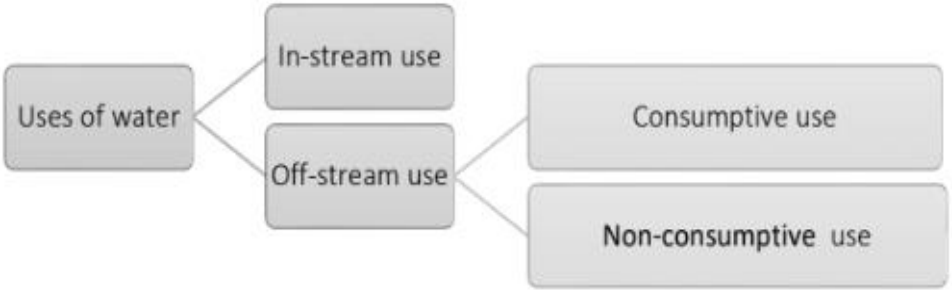
Water is among the most essential requirements for the existence of life: not only human beings but also plants, animals, and even microbes. Without water, there cannot be any life. Further, it is necessary that the water required for their needs must be good, and must not be contaminated with any undesirable and harmful impurities, and chemicals.

Water covers about 71% of the total surface of the earth in the form of ocean and sea. But, being saline in nature, they are not suitable for public consumption purposes. Water also exists in ice caps and glaciers and is not available for consumption. The water for consumption purposes is mainly collected as ground water from wells, hand pumps, bore wells, etc., or as surface water from rivers, lakes, ponds, etc. Moreover, water for consumption purposes can also collected by reclamation of seawater through desalination or reuse of treated waste water. However, the quality and quantity of water available from each source differ.

### 6.1.1 Uses of Water

The water can be used in-stream or off-stream. The **in-stream use** includes the use of river water for navigation, hydroelectric power generation, fishing and recreational purposes. On the other hand, **off-stream use** refers to the withdrawal of water from the surface, underground or reservoirs. The off-stream use is of two types: non-consumptive use and consumptive use.

**Non-consumptive use** refers to the withdrawal of water from surface and underground flows and reservoirs, wherein part of the water may be returned after use to the same source and can be used again, e.g., water used for a bath or for washing clothes. **Consumptive use** refers to the use in which water does not return to the stream or groundwater source immediately after use, e.g., water used for irrigation.




## 6.2 Public Water Supply System

Public water supply refers to the supply and distribution of water to domestic, commercial, and industrial users by any public or private supplier. Examples of public water-supply systems include systems that serve cities and towns, and apartment complexes and industries.

Since the dawn of civilization, water supply schemes have been considered a basic necessity where there is a density of population. It is evident from the piped water supply and sanitation system of Mesopotamia (4000 BCE), Indus Valley (3000 BCE), and Egypt civilizations (2500 BCE), "Qanats" of Persian civilization (700 BC) and "Aqueducts" of Roman civilization (300 BC). General health in a city cannot be maintained if the water supply is not introduced maintained and supervised.

### 6.2.1 Necessity of Public Water Supply System

- The growth of new industries for various pipe appurtenances such as air valves, etc. takes place in the locality granting employment opportunities.

- The industries which require pure water for their work are saved from the expenditure of installing their own water purification plant.

- The installation and maintenance of the water supply scheme grant opportunities for employment to the local people.

- The public in general gets treated reliable water for consumption and other uses.

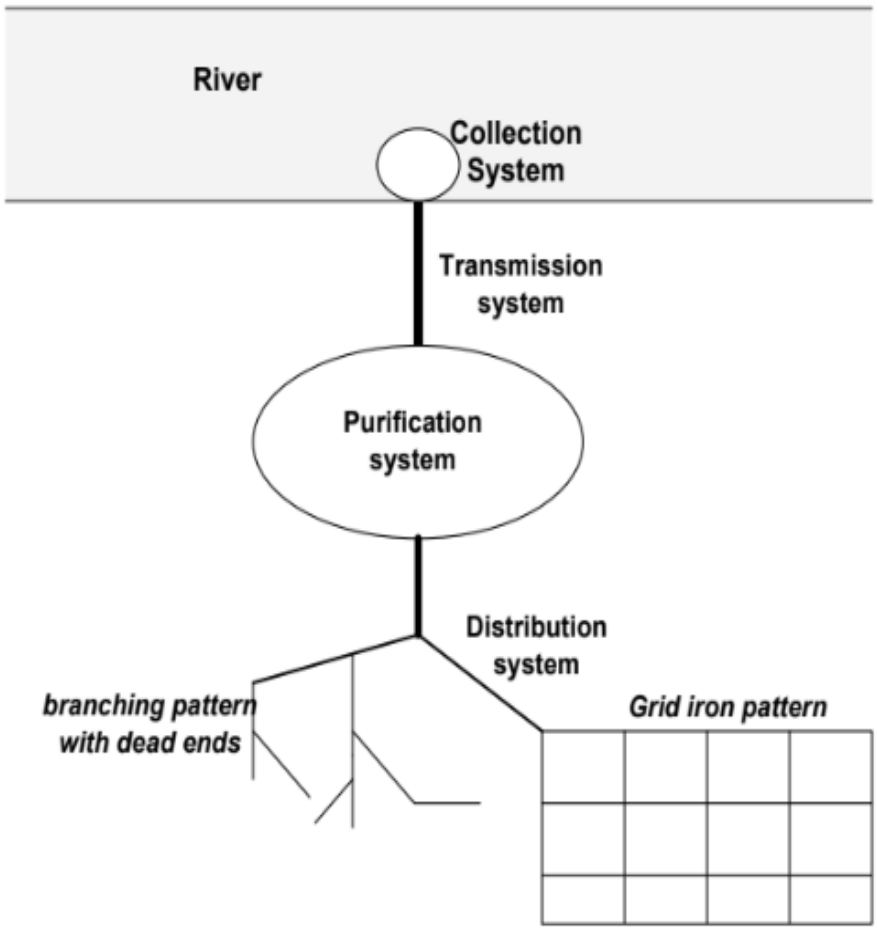
- The sanitation of the area is considerably improved by the adequate water supply.

- There are fewer chances of waterborne diseases to occur resulting in saving of human lives and working hours.

- The available water in the locality is used in the best possible manner and its misuse and wastage are avoided to a considerable extent.

### 6.2.2 Basic Layout of a Public Water Supply System

A public water supply system consists of *i*) collection systems, *ii*) Transmission systems, *iii*) purification systems, and *iv*) distribution systems as shown below.




**Basic layout of public water supply system**

A. **Collection system**: Collection works are meant for the collection of surface and groundwater. For major cities, water is mostly collected from a river or a lake. If the river is perennial, then the intake structure is built directly on the river bank. In non-perennial rivers, occasionally a dam is built to store water. The collection works therefore involve storage, diversion and/or intake structures.

B. **Transmission system**: For several cities, the collection works may be far away from the city where water is to be supplied. In that case, water is conveyed to the city through the transmission systems. Hence, the transmission system forms the connecting link between the collection and purification works. The water is generally conveyed through conduits and canals. However, depending on the topography of the area between the collection and purification sites, the transmission system may also contain intermediate pumping stations.

C. **Purification system**: The collected water may not be safe for consumption directly as it may be contaminated with several physical, chemical, or biological impurities. Therefore, the basic aim of the purification systems is to supply hygienic, clean, attractive and palatable water. The common components of a water purification system are:

- Filtration plants: for removal of suspended particles, colour, odour, turbidity, bacteria, and other harmful organisms.
- Deferrization and demaganization plats: for removal of excessive amounts of iron, manganese etc.
- Softening plants: to remove excessive amounts of scale-forming, soap-consuming ingredients like calcium and magnesium ions.

D. **Distribution system**: The treated and purified water is finally sent to the consumers through a suitable distribution system. In order for water to flow in the water supply pipes under pressure, the purified water is normally stored in an elevated service reservoir. More than one reservoir may be needed in large systems. There are two patterns of water distribution system: branching pattern with dead ends, and grid iron pattern. The plan, topography and location of the area with

respect to the service reservoir establish the type of distribution system and character of the flow.

## 6.3 Water Demand

The design of a water supply system involves the estimation of the quantity of water required by the public. This is then followed by finding sources to fulfil that demand. Various types of water demands that a city may have are as follows:

a. Domestic water demand
b. Institutional, and Industrial Water Demands
c. Demand for public and civic uses
d. Fire demand
e. Distribution System Losses

Hence, the total water demand of a city or town is the summation of all individual water demands.

### 6.3.1 Domestic Water Demand

It includes the water required for domestic uses such as drinking, cooking, bathing, washing, flushing of toilets, gardening etc. The amount of domestic water consumption per person varies according to the living standards of the consumer, their habit, and climatic conditions. The recommended per capita water consumption for a town with a full flushing system is 200 litres per capita per day (lpcd); although, for economically weaker sections it can be reduced to 135 lpcd.

### 6.3.2 Institutional, and Industrial Water Demands

Institutional water demand includes the water requirements of hospitals, schools, colleges, offices, airports, railway stations, hotels, restaurants and other institutional and commercial establishments. Similarly, the industrial water demand represents the water demand of industries existing in or near the city. These water demands need to be assessed separately in addition to

domestic water demand and necessary provisions should be made in the planned water supply system.

### 6.3.3 Water Demands for Public and Civic Use

This water demand includes water required for washing roads, flushing sewers, watering public parks, gardens, fountains, etc. Usually, the provision of 5% of the total water demand is made for in the water supply scheme.

### 6.3.4 Fire Demand

Fire may break out accidentally leading to serious damages if not controlled immediately. For this, a large quantity of water is required in a short period of time. Hence, the per capita fire demand is very low, but the rate at which water is required is significant. Hence, the fire demand significantly affects the design of the distribution system composed of storage tanks, pipes etc.

### 6.3.5 Distribution System Losses

It includes the water lost due to leakage in the distribution system, installation of defective meters, or stolen water through unauthorized connection, etc. The amount of water thus lost and wasted needs to be considered while estimating the total water demand of a town or city. Generally, an allowance of 15% of the total water demand is made for this purpose.

### 6.3.6 Total Water Requirement for a City

The quantity of water required per day to satisfy various demands of a town or city is calculated by multiplying per capita demand with the probable future population of the city. Hence, it involves the determination of the rate of water demand, and the future population of the city.

### 6.3.7 Per Capita Water Demand

The per capita water demand is the annual average amount of daily water required by one person for different uses. It is estimated considering the

water demand for domestic, industrial, commercial and public uses along with waste and thefts. Mathematically,

$$Per\ capita\ demand\ = \frac{Total\ yearly\ water\ demand\ of\ the\ city\ in\ liters}{Design\ population\ \times 365}$$

As per Ministry of Housing and Urban Affairs, government of India, the per capita water demand suggested for urban water supply schemes is 135 litre per capita per day (lpcd). For rural areas, minimum service delivery of 55 lpcd has been fixed under the Jal Jeevan Mission, which may be enhanced to a higher level by states.

### 6.3.8 Factors Affecting per Capita Demand

The factors affecting per capita water demand are:

A. **Size of the city**: The per capita water demand in bigger cities is generally higher than the smaller cities as the bigger cities require more water for maintaining a clean and healthy environment and sanitation. However, the fluctuations in water demand may be narrow in larger cities in comparison to the smaller cities.

B. **Type of the city**: The water demand in industrial cities is in general more. However, it actual demand depends upon the type of industry present in the city.

C. **Standard of living**: The higher the standard of living is, the higher the water demand and the greater the variation in demand.

D. **Development of sewerage facility**: The water demand increases, if the city is provided with a modern sewerage system.

E. **Climatic conditions**: The water demand in hot and dry cities is higher. Similarly, in extremely cold cities, people tend to keep their taps open to prevent the freezing of pipes. It leads to the wastage of water and increasing water demand.

F. **Quality of water**: Good quality and taste of water increases the demand.

G. **Pressure in the distribution system**: High pressure in the distribution pipe increases wastage due to leaks, leading to increased water demand.

H. **Metering and method of charging**: The consumption of water decreases if its supply is metered or its rate is increased.

### 6.3.9 Variations in Water Demand

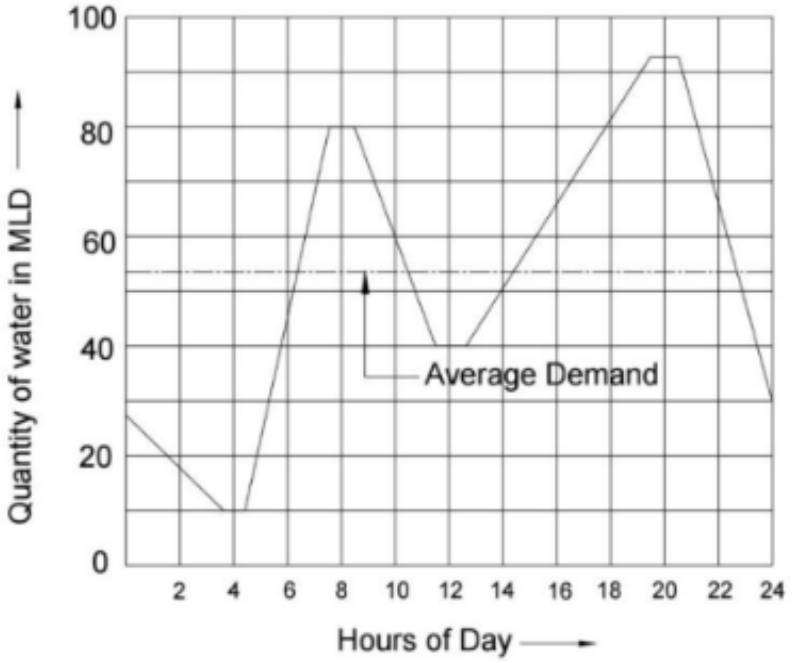
The water demand of a city is not constant but varies significantly from season to season, on a daily basis and even on an hourly basis. These variations are expressed as a percentage of annual average daily consumption. Accordingly, the variations are:

- Seasonal variations
- Daily variations, and
- Hourly variations

A. **Seasonal variations**: About 30% more water is required in summer than the annual average rate of demand as a significant amount of water is utilized for drinking, bathing, washing, cooling purposes etc.

B. **Daily variations**: The water requirement varies from day to day. It changes due to variations in climatic conditions. Moreover, people consume more water on Sundays and festival days. The maximum daily consumption may be as high as 80% of the annual average rate of demand.

C. **Hourly variations**: Water demand is at the peak during active household working hours i.e., during six to ten in the morning and four to eight in the evening. During other hours the demand is comparatively less. The figure below shows the variation in consumption throughout the day. The maximum hourly consumption is 150% of the average consumption for that day. The maximum hourly consumption on the maximum day of the maximum month of the year is denoted as the absolute maximum hourly demand.




D. **Peak factor**: Peak factor is a ratio expressed in terms of peak water demand divided by average daily water demand. The recommended peak factors are as follows:

| Type of the city | Peak factor |
|---|---|
| Rural water supply and small cities with population < 50,000 | 3.0 |
| For cities with population 50,000 - 2,00,000 | 2.5 |
| For cities with population > 2,00,000 | 2.0 |

## 6.4 Water Treatment

The purpose of water treatment is to make the water suitable for a particular use, such as drinking, industrial use, etc. During the water treatment process, contaminants are removed or reduced to meet the required levels.

The water used for drinking purposes could be potable, or palatable. 'Potable' refers to water that is safe to drink and does not contain harmful microorganisms or organic compounds that could react adversely with the human body. On the other hand, palatable water is one that is free of turbidity, colour, odour, and taste problems.

Water can be characterized according to its physical, chemical and biological compositions, which vary considerably from industry to industry. Depending on the level of pollutants under different categories and local regulations; specific treatment techniques are used before its discharge. Hence, it is evident from the above that the first step is the design of wastewater treatment facilities.

### 6.4.1 Physical Characteristics

These characteristics describe the physical appearance of the water. It includes:

- **Turbidity**: Used to measure water clarity. Turbid water signifies the presence of a large quantity of fine suspended particles like clay or silt.

- **Colour**: Colour indicates the presence of dissolved organic and inorganic materials or growth of algae or microbes.

- **Taste and odour:** It indicates the presence of dissolved organic materials, inorganic salts or dissolved gases such as hydrogen sulphide ($H_2S$), Methane ($CH_4$), etc.

- **Suspended particles**: Suspended particles are measured by quantity and sizes in the range 1 – 60 µm. They are generally not visible to the eyes and may adsorb toxic metals or synthetic organic chemicals. Particles are called suspended solids if their sizes are more than µm, or referred to as colloidal particles if their sizes are 0.001 - 1 µm, and dissolved particles if their sizes are less than 0.001 µm.

- **Temperature**: Water temperature is very important and changes with seasons, which affects water's physical, chemical and biological properties.

### 6.4.2 Chemical Characteristics

Chemical characteristics is used to describe various chemical constituents in water, as follows:

- **Hydrogen potential (pH-value):** pH value indicates the acidity or alkalinity of a solution. It ranges from 0 to 14. A solution with a pH less

than 7 is considered acidic; a solution with a pH greater than 7 is considered basic, or alkaline. Neutral water has a pH equal to 7.

- **Hardness**: Hardness indicates the presence of dissolved calcium and magnesium in water. Hard water prevents the formation of sufficient foam formation in soapy water, and results breakdown of boilers and water cooling systems.

- **Chloride concentration**: Chloride is generally present in the form of common salts i.e., sodium chloride; mostly due to mixing with seawater.

- **Nitrogen concentration**: Nitrogen may be found in surface and groundwater in the forms namely ammonia, nitrites or nitrate. The presence of nitrogen may be caused due to agricultural runoff from ammonia-based fertilizers or the decomposition of organic materials.

- **Other minerals**: Some other metals and minerals may be available in water including irons, manganese, copper, lead, lithium, cadmium, arsenic, fluorine, sulphur, etc. The amount of these chemicals in drinking water should be limited within permissible limits to avoid any harmful effects.

- **Dissolved gases**: Gases such as oxygen, nitrogen, carbon dioxide, methane, hydrogen sulphide etc. may be present in the dissolved form. The extent of these dissolved gasses provides an idea of water quality and extent of contamination. Dissolved oxygen (D.O.) refers to the level of oxygen present in water in free and noncompound form. DO is important for the survival of aquatic life including fish, invertebrates and microbes that use it in respiration.

- **Organic matters:** Natural Organic Matter (NOM) is anything that contains carbon compounds formed by living organisms, and covers a wide range of things like leaves, branches, moss, algae, manure, sewage sludge, microbes, etc. The concentration of organic carbon present per litre of water is denoted by Total Organic Carbon (TOC). On the other hand, Synthetic Organic (SO) chemicals include those carbon compounds resulting from industrial activities, urban runoff, etc.

Some of the dissolved oxygen is required by the aerobic bacteria to decompose waste organic materials; resulting in self-cleaning of a stream or storage water. The biological decomposition continues for several months and its rate depends on the temperature. Hence, for standardization purposes, the amount of oxygen required during the first five days and at 20 °C is known as *Biochemical Oxygen Demand (B.O.D.)*.

*Chemical Oxygen Demand or COD* is an indicator to measure the total quantity of organic materials present in water. It is defined as the amount of dissolved oxygen required to oxidize organic materials and inorganic chemicals like ammonia and nitrite present in water. This results in a higher COD value than BOD for the same water sample, as only organic compounds are consumed during BOD testing. Determination of DO, TOC, BOD and COD is important for the treatment and disposal of wastewater.

### 6.4.3 Biological Characteristics

It is used to describe the presence of pathogenic microorganisms such as bacteria, viruses, protozoa and helminths, which cause sickness or disease in their hosts. Since there are many different pathogens, it is not practical to monitor all of them. As a result, a few indicator bacteria belonging to the coliform group such as *E. coli* are used to assess biological contamination. It is generally presumed that water that contains no or little coliform bacteria is safe and free from pathogenic bacteria. Clearly, indicator organisms cannot provide a direct assessment and hence if doubt arises other methods must be used to confirm the absence of various pathogens.

## 6.5 Water Quality Requirements

To ensure safety to public health, and to ensure its usability in industries, and for irrigation purposes, it is necessary to ensure that the supplied water satisfies certain quality standards depending upon the type of use. A standard is a definite rule, principle, or measurement which is established by statutory authority. The specification for water suitable for drinking purposes as per IS 10500:2012 is given in the table below. Some of the important requirements of water fit for drinking purposes are as follows:

1. The water should be colourless, odourless, sparklingly clear and free from any suspended particles.
2. It should be tasty, and reasonably soft.
3. It should be free from disease-producing bacteria and organisms.
4. It should be free from objectionable dissolved gases such as hydrogen sulfide, methane, carbon dioxide etc., but should contain sufficient dissolved oxygen.
5. The amount of dissolved minerals and salts such as iron, magnesium, manganese sodium, chloride etc. should be within permissible limits.
6. It should be free from harmful salts and heavy metals like lead, arsenic and radioactive metals.
7. It should not lead to scale formation and corrode the metals.

**Specifications for drinking water (IS 10500:2012)**

| Parameter | Desirable Value | Maximum Permissible Value | Effect if not controlled |
|---|---|---|---|
| Colour | Colorless | 25 in Hazen unit | Unacceptable by people |
| Odour | Odourless | Odourless | Unacceptable by people |
| Turbidity | 5 NTU | 10 NTU | Unacceptable by people |
| Soluble Salts/TDS | 500 mg/l | 2000 mg/l | Stomach Ache |
| pH | 6.5-8.5 | 6.5-8.5 | Intestinal Problem |
| Hardness | 300 mg/l | 600 mg/l | Not appropriate for cooking, washing clothes, flaking in pipes |

| Parameter | Desirable Value | Maximum Permissible Value | Effect if not controlled |
|---|---|---|---|
| Calcium | 75 mg/l | 200 mg/l | Not appropriate for cooking |
| Chlorides | 250 mg/l | 1000 mg/l | Corrosion, taste differs |
| Sulphate | 200 mg/l | 400 mg/l | Indigestion, stomach problems |
| Magnecium | 30 mh/l | 100 mg/l | Schomach Ache |
| Nitrates | 45 mg/l | 100 mg/l | Can lead to blue baby disease (1-6 month babies) |
| Fluorides | 1.00 mg/l | 1.5 mg/l | Fluorosis of teeth, bones and muscles |
| Alkalinity | 200 mg/l | 600 mg/l | Taste differs |
| E. coli bacteria | 0 in 100 ml | 0 in 100 ml | Infectious disease and intestinal problems |

## 6.6 Basic Treatments for Drinking Water

Water from ground or surface sources is not always potable for drinking and needs some level of water treatment prior to supply for the water supply system. Following are some of the quality issues that are seen in various types of water sources:

| Water source | Water Quality Issues |
|---|---|
| Lakes and ponds | ✓ Development of algae on top, development of micro-organisms, high turbidity in bottom layers.<br>✓ May be affected by organic and chemical pollutants by disposal of wastewater. |

Some of the dissolved oxygen is required by the aerobic bacteria to decompose waste organic materials; resulting in self-cleaning of a stream or storage water. The biological decomposition continues for several months and its rate depends on the temperature. Hence, for standardization purposes, the amount of oxygen required during the first five days and at 20 °C is known as *Biochemical Oxygen Demand (B.O.D.)*.

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| Water source | Water Quality Issues |
|---|---|
| River and Irrigation canals | ✓ Presence of organic debris, mineral salts.<br>✓ May be affected by organic and chemical pollutants by disposal of wastewater. |
| Well, tube well, hand pumps etc. | ✓ Salinity, fluoride, alkalinity, hardness.<br>✓ Chemical contaminations due to disposal of industrial waste, and fertilizers etc. nearby. |

Normally, water supplied for drinking is treated at the head works under the water supply system. However, water needs treatment even at the household level as there may be chances of water contamination while transmission of water. The type of treatment depends on the quality of raw water and the source. The common methods of water treatment used in water supply system are as follow:

**A.** **Screening**: It is a pretreatment process where water is allowed to pass through screens fixed in the intake works or at the entrance of the treatment plant. This process removes bigger suspended particles that could make the whole system less efficient, and damage expensive and essential water treatment equipment.

**B.** **Aeration**: It is the process of adding air to the water which is done through an aerator. Aeration removes dissolved gases, and increases dissolved oxygen content and oxides dissolved metals. As a result, the taste and the odour of the water improve.

**C.** **Sedimentation**: In this process, the flow of water is retarded to a nearly still condition due to which suspended solids settle by gravity. The tank designed to reduce the velocity of water so as to permit sedimentation is known as a settling tank, sedimentation tank or clarifier.

Most of the impurities settle by gravity alone. This process is known as plain sedimentation. However, when raw water contains very fine clay and colloidal impurities, chemical coagulants may be added to the

water to hasten aggregation and faster settlement. This process is known as sedimentation with coagulation or clarification.

D. **Filtration**: This process involves the treatment of water by passing it through a bed of granular materials such as sand and stones (known as filters). During filtration, the leftover particulate matter from the sedimentation process is removed. This system is useful in the removal of bacteria, and improvement in colour, odour, and taste.

E. **Softening**: Softening is the process of removing hardness from water. Hardness could be temporary or permanent. Temporary hardness arises due to the presence of sulfates and carbonates of calcium and magnesium and can be removed by boiling. On the other hand, permanent hardness is caused by nitrates, calcium chlorides, and magnesium chlorides in the water and may be removed using the zeolite method.

F. **Disinfection**: The water coming out of the filter plants may still contain some harmful bacteria and microbes. It is therefore necessary to disinfect water before use. This is done by adding one or more chemical disinfectants such as chlorine, chloramines, and ozone or passing the water through UV light. Chlorination or disinfection of water using chlorine is the cheapest form of disinfection for public water supply. It is applied to the water in any of the following from that includes bleaching powder, chloramines, free chlorine, or chlorine dioxide.

## 6.7 Sewerage and Sanitary Engineering

A sewerage system is the infrastructure consisting of pipes, pumping stations, and appurtenances to collect, treat, and finally dispose the sewage safely into the environment. Sewage is the waste and wastewater generated in homes and municipalities. Sanitary engineering or wastewater engineering is the branch of civil engineering that is concerned with the planning, operation and maintenance of community sanitation infrastructures related to the removal and disposal of waste, and the supply of safe potable water.

Depending on the origin there are primarily three types of sewages, namely domestic sewage, industrial sewage and storm sewage.

- **Domestic Sewage**: It consists of liquid wastes originating from households from the urinals, latrines, bathrooms, kitchen sinks, wash basins and institutional or commercial establishments such as hotels, hospitals, business houses etc. This sewage is generally extremely foul.

- **Industrial Sewage**: It consists of liquid wastes originating from industrial processes of various industries, such as dyeing, paper making, brewing etc. The quality of industrial sewage largely depends upon the types of industry and the chemicals used in the process. The industrial sewage may be highly acidic or alkaline in nature and may contain inert, organic or toxic materials. Sometimes, they may be very foul and require extensive treatment before discharge.

- **Storm sewage or storm drainage**: The runoff resulting from the rain and storms is sometimes referred to as storm sewage. But, it is now more popularly called storm drainage, or simply drainage, to differentiate it from domestic and industrial sewage (*collectively referred to as sewage*) which are fouler and require treatment before disposal. The storm drainage mainly carries sand and other gritty materials, oils and greases from automobiles, bitumen and various suspended inorganic and organic materials generated from streets. Storm discharge generally does not require any treatment and can be discharged directly.

### 6.7.1 Types of sewerage system:

Sewerage systems are three types as follows:

- **Combined system**: When the storm drainage is taken along with the sewage in the same piped network, then it is called a combined system. However, in the combined system, the drainage water gets mixed with sewage. Hence, the entire flow needs treatment before discharge. This on the other hand necessitates a larger treatment plant, thereby making it costlier. Further, the velocity of sewage flow in the sewers can be significantly less in non-monsoon seasons which in turn may result in frequent silting.

- **Separate system**: In this system, the stormwater drainage and sewage are taken independently through two different sets of conduits. The separate system although necessitates smaller treatment plants leading to some cost savings. But it requires the lying of two different sets of conduits. This may sometimes eclipse the above cost saving.

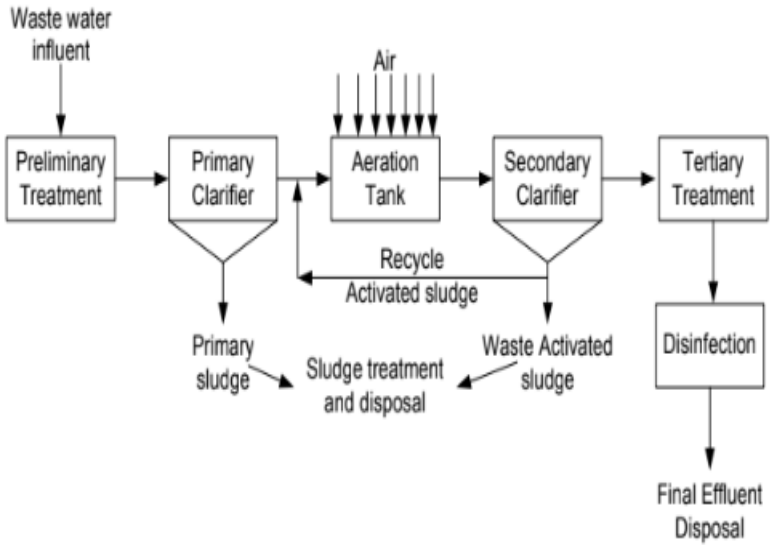
- **Partly combined and partly separate system**: In this system, the rainwater originating from the roofs or buildings, may be allowed to be admitted into the sewers; similarly, at the times the sewer capacity becomes insufficient, then the excess sewage may be diverted to the stormwater drains.

### 6.7.2 Wastewater Treatment Process

Wastewater treatment is the process of converting wastewater into effluent that can be reused or returned to the water cycle. The main purpose of wastewater treatment is to control pollution of the receiving water bodies such as rivers, lakes, groundwater or sea.

There are two wastewater treatment plants namely the physio-chemical wastewater treatment plant, and the biological wastewater treatment plant. Biological waste treatment plants use biological matter and bacteria to break down waste matter. Physio-chemical waste treatment plants use chemical reactions as well as physical processes to treat wastewater. Biological treatment systems are ideal for treating wastewater from households and business premises. Whereas, physio-chemical wastewater treatment plants are mostly used to treat wastewater from industries, factories and manufacturing firms. This is because most of the wastewater from these industries contains chemicals and other toxins that can largely harm the environment.

To design an effective treatment system, it is important to 1) identify the characteristics of raw wastewater; 2) set treatment objectives; 3) integrate unit treatment operations; 4) assess the system in view of green engineering, life cycle thinking and sustainability. A typical treatment plant consists of the following units: pre-treatment, primary treatment, secondary treatment, tertiary treatment, disinfection and sludge treatment.




**Wastewater treatment through activated sludge process**

- **Preliminary treatment**: Preliminary treatment consists of the removal of large floating particles, and heavy settleable grits, oils, fats, greases etc.

- **Primary treatment**: It includes sedimentation with or without the addition of coagulants to separate suspended materials. About 60% of suspended solids and 30% of BOD are removed in this stage.

- **Secondary treatment**: It includes the removal of dissolved organic matter using biological treatment. The most common biological treatment system is the activated sludge process. Here, the effluent from primary treatment is sent to an aeration tank and mixed with a diverse mass of microorganisms such as bacteria, fungi, rotifers and protozoa. The dissolved oxygen level is maintained at about 2mg/L by forcing air into the system. After the process is finished, effluent is sent to the next stage and the settled sludge is removed from the system. Microorganism seeds required to continue the process are added to the aeration tank by pumping a small portion of the effluent back in. After this process, biologically degradable organic matter is decomposed, and microorganisms are amassed for reuse as activated sludge.

- **Tertiary treatment:** Tertiary treatment is provided mainly to remove nitrogen and phosphorus-rich compounds. Removal of nitrogen

involves nitrification (conversion of ammonia ⇒ nitrites ⇒ nitrates), followed by denitrification reactions (conversion of nitrates to nitrogen gas). Phosphorus can be removed either biologically or chemically. The biological phosphorus removal method uses polyphosphate bacteria that can accumulate large amounts of phosphorus from the wastewater in their cells. These bacteria are removed and used as fertilizers. Contrary, phosphorus also can be removed by means of chemical precipitation using alum. This process comparatively is simpler and more reliable than biological phosphorus removal.

- **Disinfection**: It is carried out to remove pathogenic microorganisms using disinfectants like ozone, chlorine, ultraviolet light, or sodium hypochlorite. However, unlike drinking water, any disinfectant residual is not desirable in the effluent of a wastewater treatment plant.

- **Sludge treatment**: The sludge generated from the secondary treatment process needs treatment to reduce unpleasant odour and pathogens. It can be achieved by either aerobic digestion or anaerobic digestion. In aerobic treatment or composting, oxygen and bacterial biomass are used to convert the organic matter or other pollutants like nitrogen and phosphorus into carbon dioxide, water, and other compounds. On the other hand, anaerobic treatment involves breaking down organic impurities in the absence of oxygen to produce methane, carbon dioxide, and other materials. Dewatering is adopted to reduce the water in the sludge before disposal. It is carried out using a natural drying bed with an underneath drainage system, or using a mechanical device.

- **Disposal**: Depending upon the nature, the dewatered sludge may be buried in landfills, incinerated, or used as fertilizers. To prevent harmful contamination, it is necessary to tightly control the sludge generated from industry and households. The sludge applied in public areas like city parks is provided with heat or chemical treatments to control pathogens.

sunlight, temperature, filtration, adsorption, sedimentation, and biodegradation are used to treat wastewater or faecal sludge. The naturally occurring physicochemical and ecological processes due to the interaction between microorganisms, aquatic plants, substrates, solar energy, and wind help to reduce and remove pollutants from wastewater. Waste stabilization ponds (WSPs) and constructed wetlands (CWs) are common natural wastewater treatment systems.

### 6.7.3 Septic Tank

A septic tank is a small-scale sewage treatment system in areas with no connection to main sewage pipes, usually in suburbs and small towns as well as rural areas. The term "septic" refers to the anaerobic bacteria environment that develops in the tank to decompose or mineralize the waste discharged into the tank. A septic tank generally consists of a tank connected to an inlet wastewater pipe at one end and a septic drain field at the other. The septic tank requires no power. A properly designed and normally operated septic system is odour-free. Waste left by the anaerobic digestion has to be removed from the septic tank by pumping, which is taken every few years. In areas with high population density, groundwater pollution from septic tanks may be a problem.

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# ENVIRONMENTAL ENGINEERING

## 7.1 Environment

The environment is the natural world around us, including all living and nonliving things. It encompasses the air we breathe, the water we drink, the land we live on, and the organisms with which we share the planet. The environment includes all of the ecosystems, such as forests, deserts, oceans, and wetlands that support life on Earth.

The environment provides the basic resources such as air, water, food, energy, and shelter that are essential for life. It helps to regulate the Earth's climate and weather patterns, through processes such as the water cycle, carbon cycle, and atmospheric circulation and plays a critical role in the purification of air and water. It helps in maintaining biodiversity and controlling natural hazards like floods and landslides.

## 7.2 Effect of Infrastructure Development on the Environment

Infrastructure development can have significant impacts on the environment. While it can bring about economic growth and social development, it often requires the alteration of natural habitats and the clearing of land, which can lead to the loss of biodiversity and fragmentation of ecosystems. Construction activities can also generate noise and air pollution, contributing to health problems for nearby communities. Increased traffic and energy consumption associated with infrastructure development can lead to increased greenhouse gas emissions, contributing to climate change. Additionally, the use of natural resources, such as water and raw materials, can result in increased pollution and degradation of natural landscapes.

On the other hand, properly planned and managed infrastructure development can have positive effects on the environment. For example, the implementation of green infrastructure, such as green roofs and

bioswales, can help to reduce stormwater runoff and improve air quality, while also providing habitat for wildlife. Promoting sustainable transportation options, such as public transit and cycling, can reduce reliance on cars and lower greenhouse gas emissions, while also promoting physical activity and improving public health. The use of renewable energy sources, such as solar and wind power, can help to reduce reliance on fossil fuels and lower greenhouse gas emissions. Additionally, well-planned infrastructure development can contribute to economic growth and social development, which can help to promote environmental stewardship and conservation efforts. By incorporating sustainable practices into infrastructure development, we can help to create a more resilient and equitable future for both people and the environment.

## 7.3 Environmental Impacts of Major Infrastructure Development Projects

### 7.3.1 Development of Towns and Cities

Towns and cities can significantly impact the environment, both through their direct impact on local ecosystems and their contribution to global environmental issues. Here are some of the key ways in which cities can impact the environment:

- **Land use and habitat loss:** The development of towns and cities requires large amounts of land for their infrastructure, including buildings, roads, and other infrastructure. This can lead to habitat loss and fragmentation, which can negatively impact biodiversity.

- **Air pollution:** Towns and cities are a major source of air pollution, including particulate matter, nitrogen oxides, and other pollutants. This can contribute to respiratory illnesses, cardiovascular disease, and other health problems.

- **Water use and pollution:** A large amount of water is required for the residents and businesses, which can put pressure on local water resources. Wastewater treatment and discharge can also impact water quality.

- **Greenhouse gas emissions:** Towns are a major source of greenhouse gas emissions, including from transportation, buildings, and industry. This contributes to global warming and climate change.

- **Waste generation and management:** Cities generate significant amounts of waste, which must be managed through landfilling, incineration, or other methods. These processes can generate greenhouse gas emissions and other pollutants.

### 7.3.2 Highway and Transportation Projects

- **Greenhouse gas emissions:** Transportation is a major contributor to greenhouse gas emissions, which are a leading cause of climate change. Cars, trucks, buses, trains, ships, and aeroplanes all emit carbon dioxide and other greenhouse gases into the atmosphere, contributing to global warming.

- **Air pollution:** It also generates significant amounts of air pollution, including particulate matter, nitrogen oxides, and other pollutants. This can contribute to respiratory illnesses, cardiovascular disease, and other health problems.

- **Water pollution:** It may also lead to water pollution, through oil spills, chemical leaks, and other releases of pollutants. For example, runoff from roads can carry pollutants into waterways and impact aquatic ecosystems.

- **Land use and habitat loss:** Transportation infrastructure, such as roads and highways, can require significant amounts of land, which can lead to habitat loss and fragmentation, and disrupt ecosystems.

- **Noise pollution:** Transportation can also generate significant amounts of noise pollution, which can negatively impact human health and wildlife.

### 7.3.3 Dams and River Valley Projects

River valley projects, which include large hydroelectric dams, can have the following impacts on the environment:

- **Habitat Loss and Fragmentation:** River valley projects can result in the flooding of large areas of land, which can result in the loss of habitat for plants and animals. This can have a significant impact on local ecosystems and biodiversity. River valley projects can also result in the fragmentation of natural habitats, which can have a negative impact on the movement and survival of wildlife.

- **Water Quality:** The impoundment of water behind dams can result in changes in water quality, such as increased sedimentation and changes in water temperature and oxygen levels. This can harm aquatic ecosystems and fish populations.

- **Erosion and Sedimentation:** River valley projects can result in the trapping of sediment, which can lead to erosion downstream. This can negatively affect the river and coastal ecosystems, as well as water quality.

- **Climate Change:** River valley projects can contribute to climate change through the release of greenhouse gases from the decomposition of organic matter in the reservoir, as well as through changes in land use patterns and deforestation.

- **Social and Economic Impacts:** River valley projects can have significant social and economic impacts on local communities. For example, the construction of large hydroelectric dams can result in the displacement of communities and the loss of cultural heritage sites.

### 7.3.4 Thermal Power Plants

Thermal power plants can have significant negative impacts on the environment, mainly through their contribution to climate change and air pollution.

- **Climate change:** Thermal power plants generate electricity by burning fossil fuels such as coal, oil, and natural gas. This process releases carbon dioxide and other greenhouse gases into the atmosphere, contributing to global warming and climate change.

- **Air pollution:** Thermal power plants can also generate significant amounts of air pollution, including particulate matter, sulfur dioxide, nitrogen oxides, and other pollutants. These can contribute to respiratory illnesses, cardiovascular disease, and other health problems.

- **Water use and pollution:** Thermal power plants require large amounts of water for cooling purposes. The discharge of this water can raise water temperatures and impact aquatic ecosystems, while leaks and spills can result in water pollution.

- **Land use and habitat loss:** Thermal power plants require large amounts of land for their infrastructure, including coal mines and power transmission lines. This can lead to habitat loss and fragmentation, which can negatively impact biodiversity.

- **Waste generation:** The operation of thermal power plants generates large amounts of waste, including fly ash and bottom ash. These waste products can contain heavy metals and other pollutants, and require careful management to avoid environmental contamination.

### 7.3.5 Mining and Metallurgical Industries

The extraction of minerals and metals often involves the removal of large amounts of soil and rock, which can result in soil erosion, land degradation, and habitat destruction. Mining can also generate large quantities of waste, which can result in the contamination of nearby water sources and soil.

The production of metals often involves the use of high amounts of energy and water, which can result in increased greenhouse gas emissions and water depletion. Additionally, the use of toxic chemicals, such as cyanide and mercury, in the production of metals can result in pollution of nearby water sources and soil.

Furthermore, mining and metallurgical industries can also have social impacts on nearby communities, including displacement, loss of cultural heritage, and impacts on health and safety.

### 7.3.6 Manufacturing Industries

Manufacturing industries involve the production of physical goods, typically using machines, tools, and other equipment. This sector includes but is not limited to the manufacturing of automobiles, electronics, pharmaceuticals, food and beverage, chemicals, textiles, aerospace, construction materials etc. Some of the key ways in which the manufacturing industry impacts the environment include:

- **Air pollution:** Manufacturing processes often involve the emission of pollutants such as volatile organic compounds, nitrogen oxides, and sulphur dioxide, which can contribute to poor air quality and health problems.

- **Water pollution:** Manufacturing processes can generate wastewater containing heavy metals, chemicals, and other pollutants that can contaminate rivers and groundwater, and harm aquatic ecosystems and human health.

- **Land use:** Manufacturing activities can contribute to deforestation, loss of natural habitats, and other forms of land use change, which can have negative impacts on biodiversity and ecosystem services.

- **Waste generation:** Manufacturing processes generate a significant amount of waste, such as hazardous waste, electronic waste, and plastic waste, which can contribute to pollution and health problems.

- **Resource depletion:** Manufacturing activities often require the use of natural resources such as water, minerals, and energy, which can contribute to resource depletion and contribute to climate change.

## 7.4 Environmental Impact Assessment (EIA)

Environmental Impact Assessment (EIA) is a process that is used to identify and evaluate the potential environmental impacts of a proposed project or development work. The process involves the collection and analysis of data related to the environmental, social, and economic impacts of the project, and the development of strategies to mitigate any negative impacts. The main goal of EIA is to ensure that the proposed project or development

work does not have significant negative impacts on the environment or local communities. The EIA process typically involves the following steps:

- **Scoping:** The first step is to define the scope of the EIA, including the proposed project, the environmental and social issues that need to be addressed, and the methods that will be used to assess the impacts.

- **Baseline data collection:** The next step is to collect baseline data about the existing environmental and social conditions in the area where the proposed project will take place.

- **Impact assessment:** This step involves the identification and evaluation of potential environmental, social, and economic impacts of the proposed project.

- **Mitigation measures**: Once the impacts have been identified, the EIA process moves on to developing strategies to minimize or mitigate the negative impacts of the proposed project. This can involve changing the project design, modifying construction methods, or implementing environmental management plans.

- **Review and approval:** The final step involves the review and approval of the EIA report by regulatory agencies or other stakeholders.

The EIA process is important for ensuring that proposed projects are developed sustainably and responsibly and that negative impacts on the environment and local communities are minimized. The process can also help to identify opportunities for incorporating sustainable practices into the project design and management and can help to build stakeholder trust and support for the proposed development.

## 7.5 Ecological Impact Assessment (EcIA)

Ecological impact refers to the effect that human activities and natural phenomena have on the environment, including living and non-living organisms and ecosystems. Examples of ecological impact include pollution, habitat destruction, introduction of invasive species, climate change, and overexploitation of natural resources. These impacts can have

far-reaching consequences, including loss of biodiversity, degradation of ecosystem services, and disruption of ecological processes.

Ecological Impact Assessment (EcIA) is a process used to identify, assess, and manage the potential impacts of a proposed development project on the environment and natural resources. EcIA aims to evaluate the potential ecological impacts of a project, including impacts on biodiversity, ecosystems, and the natural resources that support human societies.

## 7.6 Social Impact Assessment (SIA)

Social impact refers to the effect that an action or project has on people and communities, including social and cultural norms, values, and institutions. Social impact can be positive, negative, or neutral, and can occur at the individual, community, or societal level. It can be influenced by a wide range of factors, such as demographic characteristics, social structures, power dynamics, and cultural practices.

Social Impact Assessment (SIA) is a process used to identify, analyze, and manage the potential social impacts of a proposed development project. The goal of SIA is to identify and evaluate the potential social impacts of the proposed project, including impacts on local communities, social institutions, and cultural heritage. The SIA process is typically conducted as part of an Environmental Impact Assessment (EIA) and is designed to complement the environmental assessment with a focus on the social and cultural impacts of the project.

## 7.7 Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) is a methodology used to evaluate the environmental impacts associated with the entire life cycle of a product, process, or service. It is a comprehensive approach that takes into account all stages of a product's life cycle, including raw material extraction, manufacturing, transportation, use, and disposal.

The life cycle assessment process typically involves four main stages: goal and scope definition, inventory analysis, impact assessment, and interpretation. The goal and scope definition stage establishes the purpose

and boundaries of the assessment, while the inventory analysis stage identifies and quantifies the inputs and outputs associated with each stage of the product's life cycle. The impact assessment stage evaluates the potential environmental impacts of the product or process and the interpretation stage summarizes the results and draws conclusions.

Consider an example of an LCA for a building. It would involve evaluating the environmental impacts associated with the construction, use, and disposal of the building over its entire life cycle as follows:

- **Goal and scope definition:** In this first stage, the objectives of the LCA are established and the scope of the study is defined. This may include the functional unit of the building, such as its total floor area or energy use, as well as the building's expected life span and location. The objective of the study should be clear and specific, and the scope should include all relevant stages of the product or service life cycle.

- **Inventory analysis:** The inventory analysis stage involves gathering data on the materials, energy, and resources used during the building's life cycle. This includes the extraction of raw materials, manufacturing of building components, transportation of materials, construction, use of energy, water and other resources, and end-of-life disposal or recycling of building components. This information is typically collected through data gathering, such as surveys, literature reviews, and company reports.

- **Impact assessment:** During this stage, the environmental impacts associated with the building's life cycle are evaluated. This may include impacts on climate change, water and air quality, land use, biodiversity, and human health.

- **Interpretation:** In the final stage of the LCA, the results of the assessment are reviewed and interpreted to identify opportunities for improving the environmental performance of the building. This may include evaluating alternative building materials and construction methods, improving energy efficiency and water management, and optimizing the use of renewable energy sources.

### 7.7.1 Approaches for LCA

Several LCA approaches can be used to assess the environmental impact of a product or process. The choice of approach will depend on the specific objectives and scope of the LCA study, as well as the availability of data and resources. Some of the commonly used approaches are:

- **Cradle-to-grave approach:** This approach evaluates the environmental impact of a product or service from the beginning of its life cycle, starting with the extraction of raw materials, through manufacturing and use, to its final disposal.

- **Cradle-to-gate approach:** This approach evaluates the environmental impact of a product or service from the beginning of its life cycle up to the point where it leaves the manufacturing facility. This approach is useful for assessing the environmental impact of manufacturing processes.

- **Gate-to-gate approach:** This approach evaluates the environmental impact of a product or service from a specific point in the life cycle, such as the transportation or distribution stage, to another specific point, such as the end-of-life stage.

- **Attributional approach:** This approach evaluates the environmental impact of a product or process as it exists today, without considering potential changes or improvements.

- **Consequential approach:** This approach evaluates the environmental impact of a product or process based on potential changes or improvements. It considers the environmental impacts that may result from changes in the supply chain, market demand, or other factors that may result from the change.

- **Hybrid approach:** This approach combines two or more of the above approaches to provide a more comprehensive assessment of the environmental impact of a product or process.

### 7.7.2 Applications of LCA

Life Cycle Assessment (LCA) has a wide range of uses and applications, including but not limited to:

- **Environmental management:** LCA can help organizations identify the environmental impacts of their products, processes, and services and develop strategies to reduce those impacts.

- **Product development:** LCA can be used to evaluate the environmental impact of a product or service at each stage of its life cycle, from raw material extraction to disposal. This information can be used to guide the development of more sustainable products and services.

- **Policy-making:** LCA can be used to support the development of environmental policies and regulations by providing a quantitative assessment of the environmental impact of different options.

- **Marketing and communication:** LCA can be used to communicate the environmental performance of a product or service to customers, stakeholders, and investors. This information can help build trust and demonstrate the organization's commitment to sustainability.

- **Supply chain management:** LCA can be used to assess the environmental impact of the products and services that are sourced from suppliers, helping organizations make more informed decisions about which suppliers to work with.

- **Environmental labelling and certification:** LCA can be used to support environmental labelling and certification schemes, such as eco-labels, that provide consumers with information about the environmental impact of products and services.

## 7.8 Sustainability

Sustainability of a product or service refers to the ability of that product or service to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. A sustainable

product or service is that which is produced, used, and disposed of in a way that minimizes its impact on the environment, society, and the economy. Sustainability is often defined in terms of three interconnected and interdependent pillars: environmental, social, and economic sustainability. Achieving sustainability requires a balance between these three pillars.

- Environmental sustainability involves protecting natural resources and the environment for future generations. This includes reducing waste and pollution, conserving biodiversity, and mitigating the impacts of climate change.

- Social sustainability involves promoting equity, social justice, and quality of life for all members of society. This includes access to education, healthcare, and fundamental human rights, as well as opportunities for community engagement and empowerment.

- Economic sustainability involves creating a prosperous and resilient economy that supports long-term well-being for individuals and society as a whole. This includes creating jobs and economic opportunities, promoting innovation and entrepreneurship, and ensuring equitable distribution of resources and benefits.

### 7.8.1 Sustainability and Construction

Sustainability is an increasingly important consideration in the construction industry. Attaining sustainability in the construction industry requires a multi-faceted approach that takes into account the environmental, social, and economic impacts of construction activities. Here are some ways to attain sustainability in the construction industry:

- **Adaptation of sustainable design:** The design of buildings can have a significant impact on their environmental performance. Sustainable design principles can include maximizing natural light and ventilation, reducing energy consumption through efficient building systems, and using sustainable and non-toxic building materials.

- **Using sustainable construction methods:** Minimize construction waste, use recycled materials, and adopt prefabrication techniques that reduce construction time and minimize waste. Use construction

materials that have low embodied energy and are durable, long-lasting, and easy to maintain.

- **Achieving resource efficiency:** The construction industry can reduce its environmental impact by improving resource efficiency. This can include reducing waste during construction, using recycled materials, and designing buildings for adaptability and reuse.

- **Conserving water:** Conserving water is an important aspect of sustainable construction. This can be achieved through the use of water-efficient fixtures and landscaping, as well as through the use of water recycling systems.

- **Sustainable site selection and development:** Choose sites that have minimal environmental impact, minimize site disturbance during construction, and protect nearby ecosystems. Use permeable paving and landscaping techniques that reduce water runoff and promote natural filtration.

- **Adopt sustainable construction management practices:** Use project management practices that minimize waste, reduce energy use, and promote sustainable practices. Use life cycle assessment (LCA) methods to evaluate the environmental impact of construction projects and to identify areas for improvement.

- **Consider social and economic sustainability:** Promote worker safety, pay fair wages, and provide opportunities for local workers and suppliers. Ensure that the building design meets the needs of the community and enhances the local environment.

- **Certification and verification:** Use third-party certification and verification programs such as Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM) to certify that buildings and construction processes meet sustainability criteria.

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# IRRIGATION ENGINEERING

## 8.1 Irrigation

Water is the most important element for the growth of plants. Different types of plants require different quantities of water at different times during their growing period. The water requirement of plants is naturally fulfilled through the rain. However, rainwater may not always fulfil the water demand. In such cases, the water has to be applied artificially. This process of applying water artificially to the agricultural fields is termed Irrigation.

### 8.1.1 Importance of Irrigation

The period of rain is restricted to only four months in a year in India, i.e., June to September when the monsoon arrives. The other eight months are mostly dry excepting unsure and irregular rainfall during December and January months. Even during monsoon, the rainfall may be inadequate and undependable in some parts of the country. Such, insufficient, unsure, and irregular rain causes uncertainty in agriculture. In such cases irrigation system is essential for the satisfactory growth of crops.

Some perennial crops like sugarcane, cotton, etc. need water throughout the year. However, the precipitation is restricted largely to four rainy months in a year. For the remaining duration of the year, the irrigation becomes vital. Further, the provision of irrigation facilities helps in growing two or three crops in a year on the same agricultural land.

Out of the 160 million hectares of cultivated land in India, about 83 million hectares can reliably water either naturally or through irrigation. About 50% of cultivated land in India is poorly irrigated due to which the crop yield decrease substantially. The provision of irrigation facilities can increase yields from such lands. Further, proper irrigation may also bring additional barren lands and desert areas under cultivable land.

### 8.1.2 Merits and Demerits of Irrigation

Irrigation has following merits:

- It increases the productivity of the land.
- As crop production improves; irrigation helps in preventing feminine situations in a country.
- Irrigation makes it possible to cultivate crops, pulses, vegetables, etc. throughout the year. Due to irrigation, the cultivation of cash crops like cotton, jute, grass, flowers, fruits, etc. becomes profitable. As a result, farmers can earn more money and improve their living standards.
- As agriculture becomes profitable, more people are attracted to it. This, in turn, results in the reduction of unemployment.
- Taxes are generally levied on the supply of irrigation water. Hence, it is another source of income for the government.
- Irrigation systems may have some indirect benefits as follows:
  - ✓ Dams, barrages, and canal systems built for irrigation may also be used for flood control.
  - ✓ Dams may be used for hydroelectric power generation
  - ✓ Irrigation canals may be used for inland navigation and domestic and industrial water supply.
  - ✓ Reservoirs and canals may be utilized for the development of fisheries projects.

Apart from the above excessive irrigation has certain ill-effects too. Excess water may ruin the crop yield, result in waterlogging and form marshy lands. Therefore, irrigation should be optimum for effective cultivation.

## 8.2 Types of Irrigation System

The irrigation system may be classified into two categories such as lift irrigation and flow irrigation.

### 8.2.1 Lift Irrigation

Lift irrigation is a method of irrigation in which water instead of being transported by natural flow as in the case of rivers or canals is lifted from a water source using animal-driven, mechanical or electrical pumps and directly supplied to the cropland.

For a viable lift irrigation scheme, the prime necessities are the availability of a stable water source for the entire crop season and the feasibility of lifting water to the intended crop field. The source is mainly groundwater, river streams, contour canals, ponds, and lakes. The source is primarily groundwater, river streams, contour canals, ponds, and lakes. Lift irrigation first lifts water using pumps from the water source to the main distribution chamber, located at the topmost point in the command area. Then they are distributed to the lands of the beneficiary farmers through a suitable and right distribution system.

**Advantages of lift irrigation**: The following are the advantages of lift irrigation:

- Due to lift irrigation cultivation on an elevated land high becomes possible.
- Water is supplied directly to the agricultural land due to that water loss is minimal.
- Initial and maintenance cost in lift irrigation is low as the construction of structures like dams, barrages, canals, canal head regulators, etc. are not necessary.
- Lift irrigation at water logging areas lowers water table levels and prevents waterlogging.
- Land requirement for lift irrigation is minimal as the construction of the networks of the canal is not required.

**Disadvantages of lift irrigation:** The following are the disadvantages of lift irrigation:

- Lift irrigation needs a suitable pumping system and power supply to operate the pump. This increases the operating cost of lift irrigation. Moreover, in interior most areas, the unavailability of continuous power may hinder lift irrigation.

- In summer sources surface water may dry up and groundwater table may go down. This may cause the failure of the lift irrigation system during summer.
- Underground water may have less manorial silt contents that are vital for plant growth. As a result, the yield of the crop depends on costly chemical fertilizers.

### 8.2.2 Flow Irrigation

Flow irrigation or gravity irrigation is a system of irrigation where the water flows from its source to the crop field due to gravity force. In this system, the head of the canal is at a higher elevation than the land to be irrigated. Flow irrigation is further classified into two categories such as direct irrigation and storage irrigation.

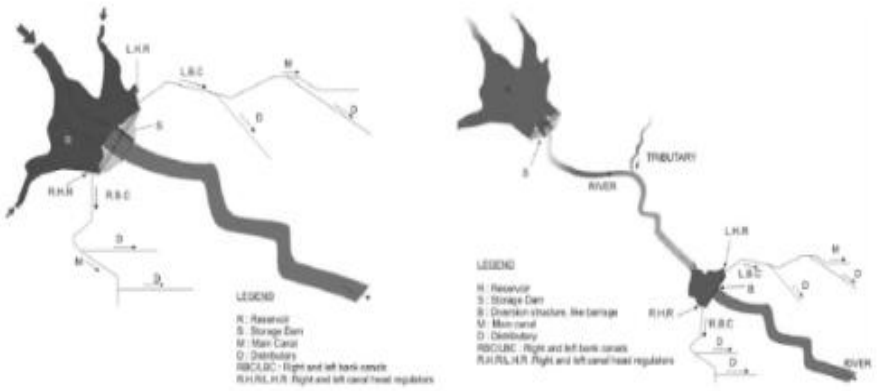
A. **Direct Irrigation**: In direct irrigation methods, the river water is directly diverted into the canal without attempting to store water. This method is practised where the river has an adequate perennial supply to feed the canal system at the times of crop periods. The direct irrigation method can be achieved in two methods as follows:

   **Construction of diversion headworks:** In this method, the river water is directly diverted into the canal by constructing a diversion structure like a weir or barrage across the river to raise the water level on the upstream side and to take care of diurnal variations. It also results in raising the water level in the river to a certain limit due to which it into the off-taking channel by gravity. The flow in the channel is usually controlled by a gated structure which is known as a head regulator. The entire set of hydraulic structures including the gated structures constructed at the head of the irrigation system is known as diversion headworks. Such an irrigation system is called a perennial irrigation system if water from such headwork is available throughout the crop period.

   **Inundation system of irrigation:** In this system, the canal takes off from the bank of an inundation river that overflows in the rainy seasons and nearly dries in the remaining seasons. The bed level of the canal is kept at such a level that, the water can flow through the canal

during the rainy seasons when the water level rises in the river. Similarly, the flow of water through the canal automatically stops once, the water level in the river falls below the canal bed level. An inundation canal usually doesn't have any head regulators to control the flow of water. As a result, there might be over-irrigation resulting in damage to crops.

B. **Storage irrigation:** In this type of irrigation system, a dam is constructed across a river to form a storage reservoir on the upstream side. This reservoir stores a part of the excess water flowing during monsoon which otherwise would have passed down to the ocean even occasionally flooding a vast area in the downstream side. Apart from irrigation, the stored water can be used for multiple purposes including water supply for domestic and industrial uses, hydroelectric power generation, and fishery, etc.




Typical Storage Irrigation system  Bhakra-Nangal Project

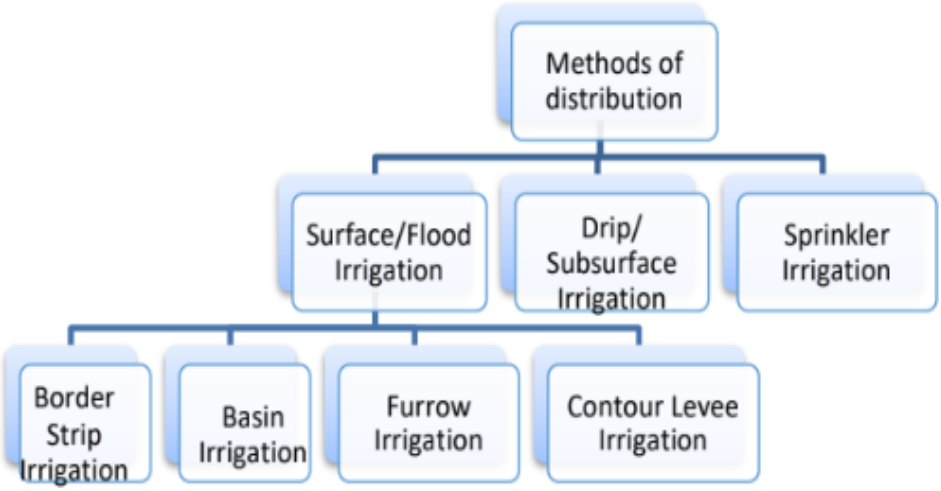
**Typical storage irrigation system**

The main canals are taken off from both sides of the dam as shown in the figure above. Sometimes a storage reservoir is associated with a barrage constructed at some downstream location, where the canals take off as usual for direct irrigation method. An example of such a composite system is the Bhakra-Nangal project on the river Sutlej. The main dam is constructed at Bhakra and a barrage is constructed at Nanga as shown in the figure below. The dam holds excess water during the monsoon and provides a regulated release during the year. The Nangal barrage constructed at comparatively flatter terrain some 13 km downstream side of the main dam serves as

a balancing reservoir for taking up daily fluctuations and distributes the water to the main canals.

## 8.3 Methods of Field Water Distribution

Different methods of field water distribution systems may be classified as follows:




### 8.3.1 Surface Irrigation

In surface irrigation or flooding, method water is distributed to the croplands through the small channels that flood the land up to a required depth. No irrigation pump is involved in this method and water flows simply by gravity. Surface irrigation is of the following types:

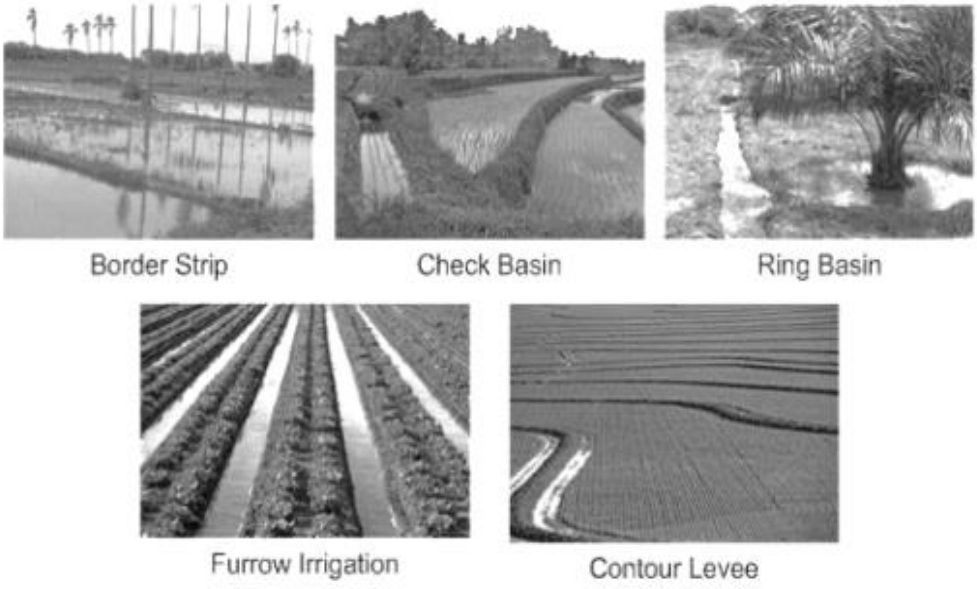
A. **Border Irrigation**: Border irrigation method, the agricultural area is divided into a series of long narrow strips (known as Border strips) by small bunds known as levees. The strips are aligned along the slope of the land. Water is introduced at the upper end of the strip and flows throughout the area and down the strip. This method is suitable when the field is even with a gentle slope. Border irrigation is suited to all crops that are not damaged by inundation for short periods.

B. **Basin Irrigation**: Basins are flat areas of land surrounded by low bunds. The bunds prevent the water from flowing to the adjacent

fields. There are two types of basins namely check basin and ring basin. The basins are filled to the desired depth and the water is retained until it infiltrates into the soil. This method is employed for watering orchards and paddy fields where water needs to be maintained for considerable periods.

C. **Furrow Irrigation**: In this method, narrow channels or furrows are dug between crops at regular intervals. The water is supplied through the furrows that infiltrate into the soil and recharge the soil water. Flow to each furrow is separately controlled. Furrow irrigation is suitable for crops that grow in trees and that are planted in rows such as plantation of vegetables. As water does not directly contact the plants it will not damage the crops.

D. **Contour levee Irrigation**: This method is adopted in hilly areas where the land has a steep slope. Here, the land is divided into a series of horizontal strips which are known as terraces. The procedure of irrigation is more or less similar to the border irrigation method. The shapes of the strips or terrace are not rectangular, rather they follow the contour lines of the hill. Small bunds are provided at the end of each terrace to hold water up to a required depth.




**Different surface irrigation systems**

### 8.3.2 Drip Irrigation

In drip irrigation or, subsurface irrigation method the water is directly applied at the root zone of the plants through an underground network of perforated pipes. The perforated pipes permit the water to drip slowly, moist the soil beneath the root zone which is then ingested by the crops directly. Water is applied close to the plants so that only part of the soil in which the roots grow is wetted as a result a lot of saving in water is achieved. Further saving is achieved as the water evaporation rate is the minimum in the drip irrigation system. This method is suitable for permeable soil like sandy soil.

**Drip Irrigation**

### 8.3.3 Sprinkler Irrigation

In this method, the water is applied to the land in the form of spray similar to natural rainfall but spread over the land surface and at a time when required. The sprinkling of water is achieved by distributing water through a system of pipes usually by pumping which is then sprayed into the air through sprinklers so that it breaks up into small water drops that fall to the ground. The rate of sprinkling is such that, all the water applied to the field gets infiltrated and does not result in surface runoff. The system of irrigation is suitable for undulating lands, with poor water availability, sandy or shallow soils, or where the uniform application of water is desired. No land levelling is required as with the surface irrigation methods. The water that is pumped through the pump pipe sprinkler system must be free of suspended sediments. As otherwise there would be chances of blockage of the sprinkler nozzles. The following are different types of sprinklers used for irrigation purposes:

- Perforation on lateral pipes
- Fixed nozzles on lateral pipes
- Rotating sprinklers.

Perforation on lateral pipes

Fixed nozzles on lateral pipes

Rotating sprinklers

## 8.4 Classification of Irrigation Projects

Irrigation projects in India are classified into three categories such as major, medium and minor according to the area cultivated.

- **Major irrigation project:** Major irrigation projects are those which have a culturable command area (CCA) of more than 10,000 ha. The total area that can be irrigated using the water from the canal system assuming an unlimited quantity of water is available is called a gross command area (GCA) for the irrigation system. The culturable command area (CCA) is the area of the cultivable land within the GCA of an irrigation project. The major irrigation project usually consists of huge multipurpose storage reservoirs and flow diversion structures.

- **Medium irrigation project:** Medium irrigation projects are those which have a culturable command area (CCA) of less than 10,000 ha but more than 2,000 Ha. Such projects include medium-sized storage reservoirs and diversion structures.

- **Minor irrigation project:** Minor irrigation projects are those which have a culturable command area (CCA) of less than 2,000. The source of water is either groundwater or surface water lifted by pumps or by gravity flow from tanks, ponds, or small canals.

## 8.5 Multipurpose River Valley Projects

As the name implies Multi-purpose river valley projects are carried on to serve more than one requirement such as irrigation, electricity generation, water supply for domestic and industrial uses, flood control, recreation, inland navigation, and fish breeding. For example, the Bhakra Nangal Project was constructed with the prime objective of irrigation and power generation. Similarly, the Hirakud project was intended for flood control, irrigation, and power generation.

After the independence of India, several multipurpose river valley projects were launched. Those projects are not only serving as the vehicle to lead the development of agriculture and the village economy but also acting as a catalyst for rapid industrialization and growth of the urban economy.

## 8.6 Dams

A dam is an impervious barrier constructed across a river or natural watercourse to stop or restrict the flow of water in it. Dams and reservoirs normally go together. When the barrier is constructed across the river it forms a reservoir or artificial lake that stores water for future use. The dam is the central structure in a multipurpose river valley project. Multipurpose dams hold special importance in developing countries, where a single dam may bring significant benefits related to hydroelectric power production, agricultural development, and industrial growth.

### 8.6.1 Purpose of Dam Construction

- **Flood control**: Dams can impound the floodwaters into the reservoir behind it, allowing it to be released under control or stored for future use.

- **Irrigation and water supply:** The water stored in the dam can be used for irrigation, domestic use, and industrial use.

- **Power generation:** Dams provide a source of clean and renewable energy in the form of hydroelectric power.

- **Inland water navigation**: Dams help to raise and maintain a stable water level on the rivers this facilitates inland water transportation.

- **Fishery**: The Lake formed behind the dam may be used for fishery farming.

- **Recreational activities**: The Lake that formed behind the dam can be used for recreational such as water sports and pleasure activities. Moreover, large dams are on their own become a major tourist attraction.

### 8.6.2 Types of Dams

The dams can be classified according to their size, intended purpose, or structural behaviour in the following ways:

A. **Based on size:** Based on their height measured from the lowest portion of its foundation to the crest the dams can be classified into three categories namely: major dams, large dams, and small dams.

   - **Major dams**: Major dams have a height of over 150 m.

   - **Large dams**: Large dams have a height above 15 m. A dam between 10 m to 15 m in height may be classified as a large dam if it satisfies at least one of the following conditions: (a) the length of the crest is not less than 500 m; (b) The capacity of the storage reservoir formed by the dam is not less than 1 million cubic meters; (c) The maximum flood discharge dealt with by the dam is not less than 2000 cumec (cubic meter per second); (d) The dam has special difficult foundation problems; and (e) The dam is of unusual design.

   - **Small Dam:** A dam less than 15 m in height and which does not fulfil any of the conditions of a large dam.

B. **Based on intended purpose:** Based on their intended purpose the dams can be divided into the following major types:

- **Storage dams:** This dam impounds water in periods of surplus supply for use in periods of deficient supply. These periods may be seasonal, annual, or longer.

- **Detention Dam**: A dam whose principal purpose is to temporarily detain all or part of the runoff and enable its release at controlled rates, as and when required to prevent the downstream area from sudden flooding.

- **Diversion Dam:** A fixed dam built to divert parts or all of the water from a stream out of and away from its course for irrigation, water supply, power generation, etc.

- **Levee:** An earthen embankment extending generally parallel to the river channel and designed to protect the area, behind it from overflow by floodwaters.

- **Check Dam:** A check dam is a small, sometimes temporary, dam constructed across a shallow, drainage ditch, or waterway to counteract erosion by reducing water flow velocity. A check dam may also be constructed to retain debris. It is generally built of inexpensive and temporary materials such as brush, logs, timber, loose rock, masonry, concrete, etc.

- **Coffer Dam**: It is a temporary structure built with sheet piles to exclude water during the construction of a foundation in a waterlogged area such as a river bed.

C. **Based on the materials of construction:** Based on the materials of construction the dams can be classified into earthen dams, masonry dams, concrete dams, steel dams, timber dams or rockfill dams, etc.

D. **Based on the structural behaviour:** Based on the structural behaviour the dams are the following main types:

- **Gravity dam**: A gravity dam is a solid concrete or masonry dam that is designed and shaped in such a way that its weight is sufficient to resist all forces acting on it.

- **Arch Dam:** A curved solid masonry or concrete dam, convex upstream, that depends principally on arch action to resist the forces acting on it.

- **Buttress Dam:** A dam consisting of water supporting upstream face or deck, usually reinforced concrete slab, supported by buttresses generally in the form of equally spaced triangular reinforced concrete or masonry walls or counterforts. The buttress transmits the water load and weight of the deck to the foundation.

### 8.6.3 Selection of Suitable Dam Sites

There are several factors that affect the selection of a suitable site for a dam. These are:

- **Topography:** The river valley should be deep, narrow, and well-defined so that the capacity of the storage shall be large with minimum surface area and length of the dam.

- **Geological and foundation conditions:** A good rocky foundation such as granite having strong bearing capacity is suitable for dam construction. The basin should be free from cracks, fissures, etc. to avoid percolation. If unavoidable, the area should be located and necessary measures should be taken to make it leakproof. Further, if the site is located in a seismic-prone area then its design must be capable of resisting additional forces for the earthquake.

- **Availability of materials:** For the economy, the materials required for dam construction must be available locally or at short distances from the construction site.

- **Accessibility of the site:** Further, the site should be easily accessible by road or railways for the transport of construction materials, equipment, etc.

- **Settlement:** The dam site should be selected in such a way that, after its construction, the submersion of valuable property, or lands shall be as less as possible.

- **Sedimentation**: The River at the dam site should not carry large quantities of sediment. The necessary measures must be taken to reduce the sedimentation before the water reaches the dam site.

### 8.6.4 Problems Caused by Dam Construction

- The dam itself blocks fish migrations, which for some species engender the spawning habitats. Similarly, due to the regulation of the natural flow; dams trap sediments resulting in rockier stream beds and poorer habitats for aquatic life even on the downstream side.

- Irrigation has also changed the cropping pattern of many regions with farmers shifting to water-intensive and commercial crops. It may cause great ecological consequences like the salinisation of the soil.

- The reservoir created by the construction of dams submerges a very large area. This destroys its natural environment, fauna, and flora. Construction of the dam also results in rising water table levels and dampness. This results in the salinisation of soil and damage to structures and monuments.

- The construction of large dams can cause serious geological troubles. For example, the building of the Hoover Dam, USA, and Koyna Dam, India triggered earthquakes.

- A vast land area is required for the construction of dams, storage reservoirs, canals, and other hydraulic structures. It results in large-scale displacement of local peoples who often had to give up their land, and livelihood for the greater benefit of the nation.

- The dams may create conflicts between people: farmers, industrialists, local villagers, and urbanites. It is because their need and uses are different, simultaneously they try to derive the maximum benefits for them from the same water resources.

- Dams block the flow of water from one state to another or from one country to another. This means that the water supply from the same river in the following state or country is reduced. This can lead to serious Interstate and inter-country disputes between them.

- The breaching of a dam may cause flooding and damage in a vast area on the downstream side. This makes the dam a soft target for attracts by the enemy or terrorists.

## 8.7 Canal Irrigation

Canal irrigation is one of the significant techniques adopted throughout the world. In India, it is the second most important source of irrigation following wells and tube wells. The main canal-irrigated areas are in the northern plains of India where Uttar Pradesh, Punjab, Haryana, Rajasthan, and Bihar account for about 60 percent of the canal-irrigated area of the country.

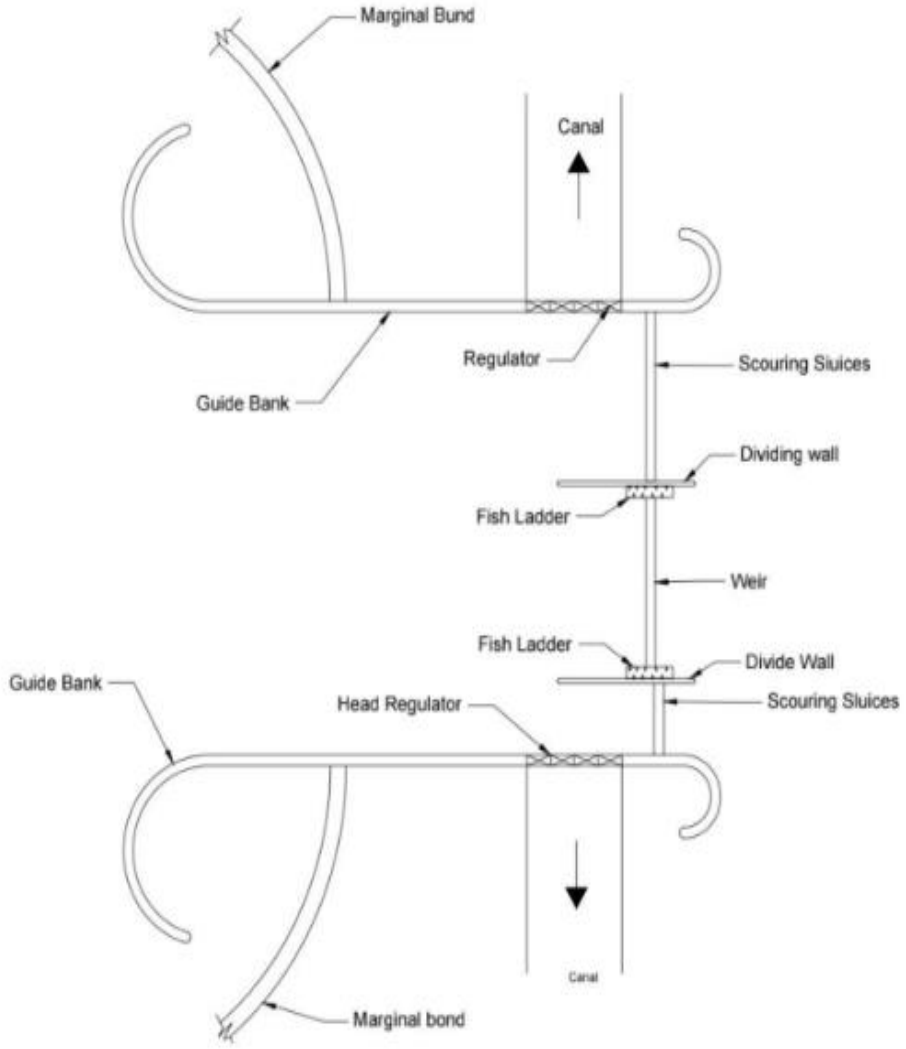
The canal irrigation involves:

- ✓ Construction of diversion head work
- ✓ The excavation of a network of canal systems.

### 8.7.1 Diversion Head Works

Diversion head works consist of structures constructed across a river so that the water level in the river may be raised and diverted into the off-taking canals. The objectives of the diversion headworks are:

- Raising the water level at the upstream side of the river
- To form a small storage pond so that water is available throughout the year.
- It controls the entry of silt into canals
- To control the fluctuations of water level in the river during different seasons.




**Canal Diversion Headwork**

The following are important components of diversion headworks.

A. **Weir/ Anicut:** Weir is an impervious barrier made up of masonry, concrete, or rocks, which is constructed across a river to raise the water level to a required height and the surplus water flows over its crest. It is aligned at right angles to the direction of flow in the river and is primarily built to divert the water into a canal, make the river navigable, or measure flow in the river.

B. **Barrage:** Barrage is a permanent barrier provided with a series of gates across the river to regulate water surface level and pattern of flow upstream and for other purposes. A barrage provides maximum

control on the river as the adjustable gates help to maintain the water surface at different levels at different times of the year.

The difference between a barrage and a weir is only qualitative. In the former, the gates or shutters provide the larger part of the ponding, while in the latter the solid crest carries out most of the raising of water level or ponding and the top shutters are relatively small in height.

Weir

Barrage

C. **Divide wall:** It is a long wall constructed at a right angle to the axis of the weir or barrage. It is extended well beyond the main structure of the canal head regulator on the upstream side and up to the launching apron on the downstream side. In the case of one canal off-take from each bank of the river, one divide wall is provided in front of each of the head regulators.

The dividing wall separates the under sluices from the weir or barrage proper since the crest level of the under sluices is lower than that of the weir proper, the two must be separated and this is being done by the divided wall. Further, it helps in providing a comparatively less turbulent pocket near the canal head regulator, resulting in the deposition of silt in this pocket and thus helping in the entry of silt-free water into the canal.

D. **Fish ladder**: It is the nature of several fishes to migrate from downstream to upstream during monsoon and vice versa during winter. This movement is necessary for spawning and survival. Diversion structures such as barrages and weirs are provided with a device, known as a fish ladder, which facilitates the smooth passage of fish from upstream to downstream and vice versa.

Fish ladders usually consist of an inclined chute from the dam, or diversion works to the downstream river bed and are divided into compartments by cross walls. Each cross wall has a small hole at its bottom and in one corner for the fish to pass through. The holes in the adjacent walls are staggered to reduce the velocity of water passing through the chute. The difference in water levels between the upstream and downstream sides is thus divided into water steps by these cross walls.

E. **Silt excluder:** A silt excluder is a device by which silt is precluded from entering the canal. It usually consists of a series of R.C.C. rectangular tunnels, known as still pockets, located in front of the intake/head regulator, and at right angles to the axis of the barrage.

The roof slab of the excluder is kept at the same level as the rectangular crest. The bottom layer of water, which is heavily loaded, thus passes down the tunnel into the river, leaving clear water at the top that passes down in the canal.

F. **Under sluices/ scouring sluices:** The under sluices are controlled gated openings provided at the base of the dams, barrages, or weirs. As the velocity of water is less at the upstream side of diversion work, the silt deposition is more there. When silt deposition becomes appreciable they are loosened with an agitator mounted on a boat and then the gates are opened to wash away the muddy water containing the silt.

G. **Canal head regulators:** It is a structure built at the head of the canal to divert, control and regulate water supplies from the pond into the canal. It consists of several spans separated by piers. Each span consists of several tiers on which adjustable gates are placed that are operated by a suitable mechanical device. A road is usually provided on the top of the piers.

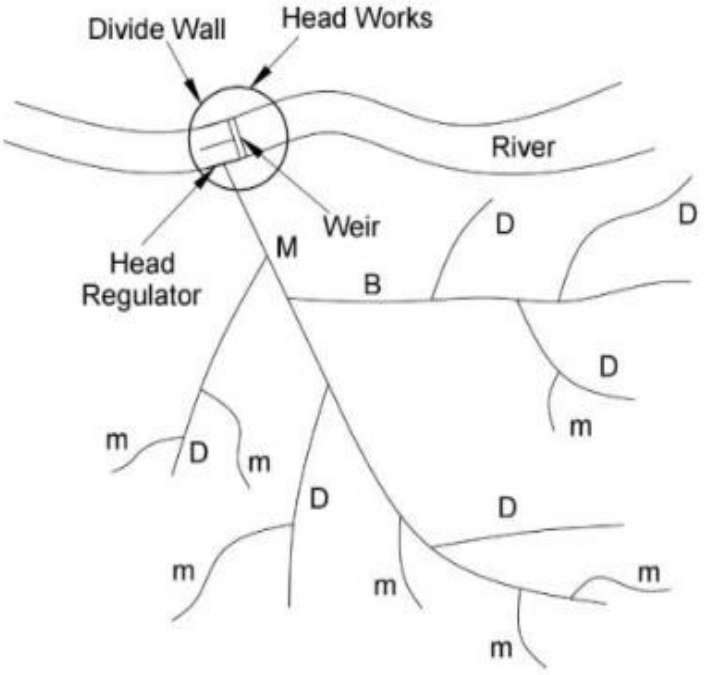
H. **Guide bank:** When the flow of water is restricted due to the construction of a weir, barrage, or bridge across an alluvial river it starts scouring the river banks. It can be prevented by guiding and narrowing down the flow through the waterway. Guide bunds are provided for this purpose.

The guide banks are the earthen embankments with curved heads on both ends. To prevent erosion of the material from the river-side surface of the guide bank, the surface is stone-pitched. This pitching is continued up to the rear side of the curved head and the thickness of stone pitching is more for the curved head region.

I. **Marginal Bunds or dikes**: They are earthen bonds whose face towards the river is generally pitched. They are constructed parallel to river banks to protect the surrounding area from inundation caused by floods. They should be located at the limiting line of meandering of the river i.e. beyond the meander belt of the river.

### 8.7.2 Canal Systems

Canal irrigation is achieved through a network of channels. It carries maximum discharge when a canal takes off from the headwork. As it traverses it goes on satisfying the water demands. Due to this canal's discharge continues to decrease. Naturally, it is not appropriate to maintain the same section when the canal carries small amounts of water. Hence, the sectional dimensions of the canal decrease as its traverse length increases. Accordingly, the canal systems are divided as follow:




**Components of a canal system**

A. **Main canal (M):** This canal takes off from the river and derives water through the head regulator. For a certain length, in the beginning, the water level in the canal may be below the general ground surface. Hence, direct flow irrigation is not possible from the main canals. The prime function of the main canal is to take the total water required for irrigation from the head and to deliver it to the branch canals and distributaries.

B. **Branch canals (B):** To distribute the water over the entire commanded area main canal is bifurcated at regular intervals. The bifurcated canals are called branch canals or simply branches. From the branch canals, direct irrigation is very rarely done. The main function of the branches is to make the water available in different parts of the tract for further distribution.

C. **Major distributaries or, Rajbaha (D):** Major distributaries are smaller in section than the branches. They are taken off mainly from the branches to distribute the water through outlets to minor distributaries or watercourses for direct irrigation purposes. Major distributaries may take off directly from the main canal.

D. **Minor distributaries or minors (m):** If the distance of the farmer's field from the major distributary outlet is about 3 km or more, then minor distributaries are introduced to reduce the length of the field channels. They are taken off from the major distributaries and sometimes from the branch canals.

E. **Water Courses, or field channels**: Field channels are small channels that are excavated mostly by the farmer to take water from the outlet point provided in the distributary, or the minor. The amount of water discharged through one outlet is in proportion to the area to be irrigated below that point. The length of a watercourse should not be more than 3 km to ensure minimum loss of water.

**Typical discharges for different canal type**

| Type | Discharging capacity in cumec ($m^3/sec$) |
|---|---|
| Minor | Less than 0.7 |
| Major distributary | Less than 5.5 |
| Branch | More than 5.5 |
| Main Canal | Whole discharge of a canal system |

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