

GOVERNMENT POLYTECHNIC, BHUBANESWAR



DEPARTMENT OF CIVIL ENGINEERING LECTURE NOTE

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SUBJECT CODE & NAME : TH-1, BUILDING CONSTRUCTION

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INTRODUCTION TO BUILDING CONSTRUCTION:

Shelter is the most important need the human beings after food and clothes. Even the birds, animals, and other creatures also need shelter for survival. The buildings in a nation represent its level of development. Human shelters have changed significantly with time. Humans have reached from the caves to these comfortable homes with the advancement of time. A good shelter gives confidence and reason to live with dignity to human beings.

CLASSIFICATION OF BUILDINGS (AS PER NBC):

You would have observed many types of buildings in your vicinity. Some are used for storing goods and others are used as shops. You are also living in a structure called home. Have you ever thought, how many types of buildings are there? According to the National Building Code (NBC) of India, a building is classified into nine categories depending on its usage. The buildings as per NBC criteria are classified into the following categories:

- A. Residential Buildings
- B. Educational Buildings
- C. Institutional Buildings
- D. Assembly Buildings
- E. Business Buildings
- F. Mercantile Buildings
- G. Industrial Buildings
- H. Storage Buildings
- I. Hazardous Buildings

Group A: Residential Buildings

The buildings which have sleeping arrangements with or without cooking and dining facilities are known as residential buildings. According to NBC, Residential buildings are further divided into five sub-categories as follows:

A-1: Lodging and rooming houses: This type of building consists of a sleeping arrangement for fewer than 40 persons and doesn't have any cooking facility. The building or group of buildings with 40 beds or fewer lies in this category.

A-2: One or two-family private dwelling: The buildings which provide accommodation to one or two families with a bed capacity of 20 or less are known as A-2 type of residential buildings.

A-3: Dormitories: In dormitories, a group of sleeping accommodations is provided for public use. The users in the case of A-3 type residential buildings don't belong to the same family.

A-4: Apartment houses: Apartment houses are also known as flats. The buildings which have three or more quarters for living independently are known as apartments or flats. The cooking and dining facilities are provided in such types of buildings.

A-5: Hotels: The buildings which provide sleeping accommodations with or without dining facilities are classified as hotels.

Group B: Educational Buildings

The buildings which are used for providing education or training are known as educational buildings. Schools, colleges, and universities come under the category of education buildings. Group B buildings are further divided into two categories.

B-1: The schools up to the senior secondary class system come under the B-1 category of educational institutions

B-2: The teaching and training institutions that do not belong to the B-1 category are categorized under the B-2 category.

Group C: Institutional Buildings

The buildings which are used for care, treatment, imprisonment, etc. are known as institutional buildings. The institutional buildings consist of sleeping arrangements. Group C buildings are further divided into the following three sub-categories:

C-1: Hospital and Sanatoria: The buildings which are used for accommodating people who are suffering physically. Hospitals, nursing homes, healthcare centers, etc. come in this category.

C-2: Custodial Institutions: The buildings which are used for the protective care of children, old age people, teenagers, etc. are known as custodial institutions. The orphanage, old age homes, juvenile homes, etc. lie under the C-2 category of institutional buildings.

C-3: Penal and Mental Institutions: The buildings which are used for accommodating persons for restriction of their liberty are called penal and mental institutions. C-3 type institutional buildings include mental asylums, prisons, jails, etc.

Group D: Assembly Buildings

The buildings which are used for accommodating the gathering of 50 or more people are known as assembly buildings. The people can gather for social, religious, recreational purposes, etc. According to NBC, the assembly buildings are further classified into the following seven categories:

D-1: The building which has a stage and fixed seats with an accommodating capacity of more than 1000 viewers are classified under the D-1 category of assembly buildings. Theatres, exhibition rooms, cinema halls, auditoriums, etc. are the D-1 category of assembly buildings.

D-2: The building which has a stage and fixed seats with an accommodating capacity of fewer than 1000 viewers are classified as a D-2 category assembly building.

D-3: The buildings which neither have a permanent stage nor fixed seats but have an accommodating capacity of 300 persons or more are known as D-3 assembly buildings.

D-4: The buildings which have the same characteristics as D-3 buildings but an accommodating capacity is less than 300, are known as D-4 assembly buildings.

D-5: All the other structures for the gathering of people which are not covered in the D-1 to D-4 subcategories lie in D-5 assembly buildings.

D-6: The buildings which have mixed facilities of shopping, theatre, gaming, etc. lie under the D-6 category of assembly buildings. Modern-day shopping malls and multiplexes are examples of D-6 assembly buildings.

D-7: Any underground or elevated structure for the gathering of people for different purposes which is not covered by D-1 to D-6 categories is kept under the D-7 assembly building category.

Group E: Business Buildings

The buildings which are used for business transactions, and for maintaining the records and accounts are known as business buildings. Libraries, banks, offices, laboratories, etc. lie in this category of buildings. Group E buildings are further divided into three categories:

E-1: The buildings which are used as offices, banks, and other establishments are categorized as E-1 type of business buildings.

E-2: The buildings which are used as laboratories, research laboratories, testing houses, etc. are categorized as E-2 business buildings.

E-3: The buildings where groups of computers are installed are known as E-3 business buildings.

E-4: Telephone exchanges are categorized in this category.

E-5: Television stations and radio broadcasting stations lie in this category.

Group F: Mercantile Buildings

The buildings which are used as shops, retail stores, markets, wholesale shops, etc. are known as mercantile buildings. Mercantile buildings are further divided into the following three categories:

F-1: The shops or stores having an area equal to or less than 500 m² are known as F-1 mercantile buildings.

F-2: The shops or stores with an area of more than 500 m² are known as F-2 mercantile buildings.

F-3: The underground structures which are used as shops or stores are categorized as F-3 mercantile Buildings.

Group G: Industrial Buildings

The buildings in which manufacturing, fabricating, assembling, and processing of materials and products are known as industrial buildings. The buildings used by various industries like dairies, tanneries, dry cleaning plants, pump stations, etc. the examples of group G buildings. Industrial buildings are further classified into the following three categories:

G-1: The buildings which are used for low hazard industry come in this category. The materials and products accommodated in the G-1 type of building comparatively have low combustibility and there are very less chances of self-propagating fires.

G-2: The buildings which are used for moderate hazard industry come in this category. The material and products accommodated in such type of building burn at a medium speed but toxic fumes or explosions during a fire are not generated.

G-3: The buildings which are used for high hazard industry come in this category. The materials and products accommodated in such a type of building burn rapidly. Toxic fumes and explosions during the fire can be generated.

Group H: Storage Buildings

The building or part of the building that is used to store the goods, products, merchandise, etc. except the hazardous material is known as a storage building. Storehouses, grain storage, fruit stores, garages, cold storage, animal shelters, etc. are examples of group H buildings.

Group I: Hazardous Buildings

The buildings which are used to store and process extremely inflammable material or goods are termed as hazardous buildings. These hazardous materials can produce excessive toxic fumes or explosions during a fire. Group I buildings may store the explosives or chemicals which are to be kept with great care at specific pressure or temperature. Acetylene, rocket fuel, liquefied petroleum gas (compressed natural gas (CNG), etc. are accommodated in hazardous buildings.

CLASSIFICATION OF BUILDINGS (AS PER TYPES OF CONSTRUCTION):

A building has many components like walls, floor, roof, etc. The load is transferred to the foundation from the components of the building. The buildings can be classified into the following three categories based on the construction:

- 1 Load Bearing Structures
- 2 Framed Structures
- 3 Composite Structures

1. Load-bearing Structures:

The structure in which a load of the roof is transferred through the walls to the foundation. The loadbearing structures are used for the construction of small buildings. Small structures like temples, small houses, rural buildings, and low-rise buildings are examples of load-bearing structures.

Advantages

The major advantages of load-bearing structures are as follows:

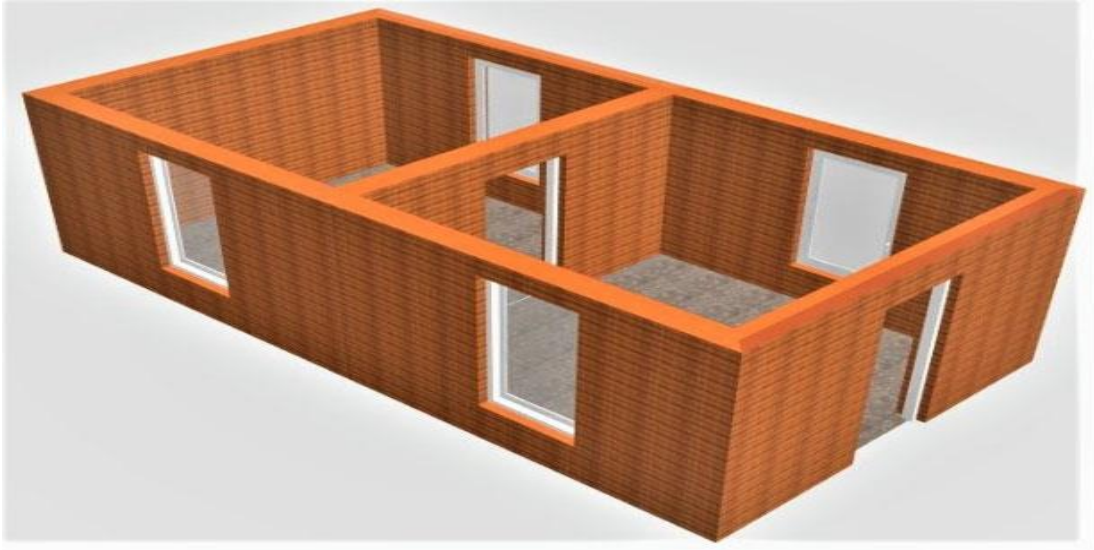
- a. If the soil conditions are favorable, the load-bearing structures prove to be very cost-effective.
- b. The masonry used in load-bearing structures offers good fire resistance characteristics.
- c. The load-bearing structure has good sound insulation properties.

Disadvantages

The major disadvantages of load-bearing structures are as follows:

- a. The load-bearing structures are suitable only for up to two to three-floor buildings.

- b. These types of structures are not earthquake resistant and less preferred than framed structures.
- c. Long spans are not possible for load-bearing structures.
- d. This approach reduces the floor area of the building.



2. Framed Structures:

The building components like beams, columns, and slabs are integrated to form a framed structure. A framed structure consists of a combination of these building components. This process of combining the structural components is known as framing.

In the framed structure, the load is transferred through this frame to the foundation. the framed structure.

The frames can be made of materials like concrete, timber, and steel.

Concrete frames are used commonly for framed building structures.

Concrete structures are very durable and cost-effective. The wooden frames are light in weight and flexible. They are good insulators of electricity and sound. The only problem with wooden frames is their durability. The wooden frames are prone to insect attack. Steel frames provide good resistance to fire. The steel frames are also light in weight and provide higher tensile strength.

The framed structures offer the following advantages:

- a. The framed structure offers good stability and strength. These structures can easily withstand earthquake loads and wind loads.
- b. These structures can be used to construct multi-story buildings.
- c. These structures can absorb the shocks and vibrations in a better way as compared to loadbearing structures.



3. Composite Structures:

The load-bearing and framed structures are combined to form the composite structures. The composite structures are used for long spans.

The advantages of load-bearing structures and framed structures are coined in composite structures.

The walls in the composite buildings act as load-bearing structures while the columns run through the structure as framed structures. Some examples of composite structures are long shed diaries, storage houses, workshops, etc

COMPONENTS OF BUILDINGS:

The building components are the structures that serve the purpose of load transfer, supporting, and protecting the building. A building can be divided into the following two parts:

a. Substructure: Substructures or foundations can be defined as all lower structures of building below ground level which helps in transmitting loads of superstructures to the soil. A foundation is that part of the building structure which is in direct contact with the supporting soil and transfers structural loads.

b. Superstructure: The superstructure can be defined as all the structures that lie above the ground level both internally and externally.

1 Substructure:

A substructure transfers the load from the various building components to the earth. The substructure remains beneath the ground.

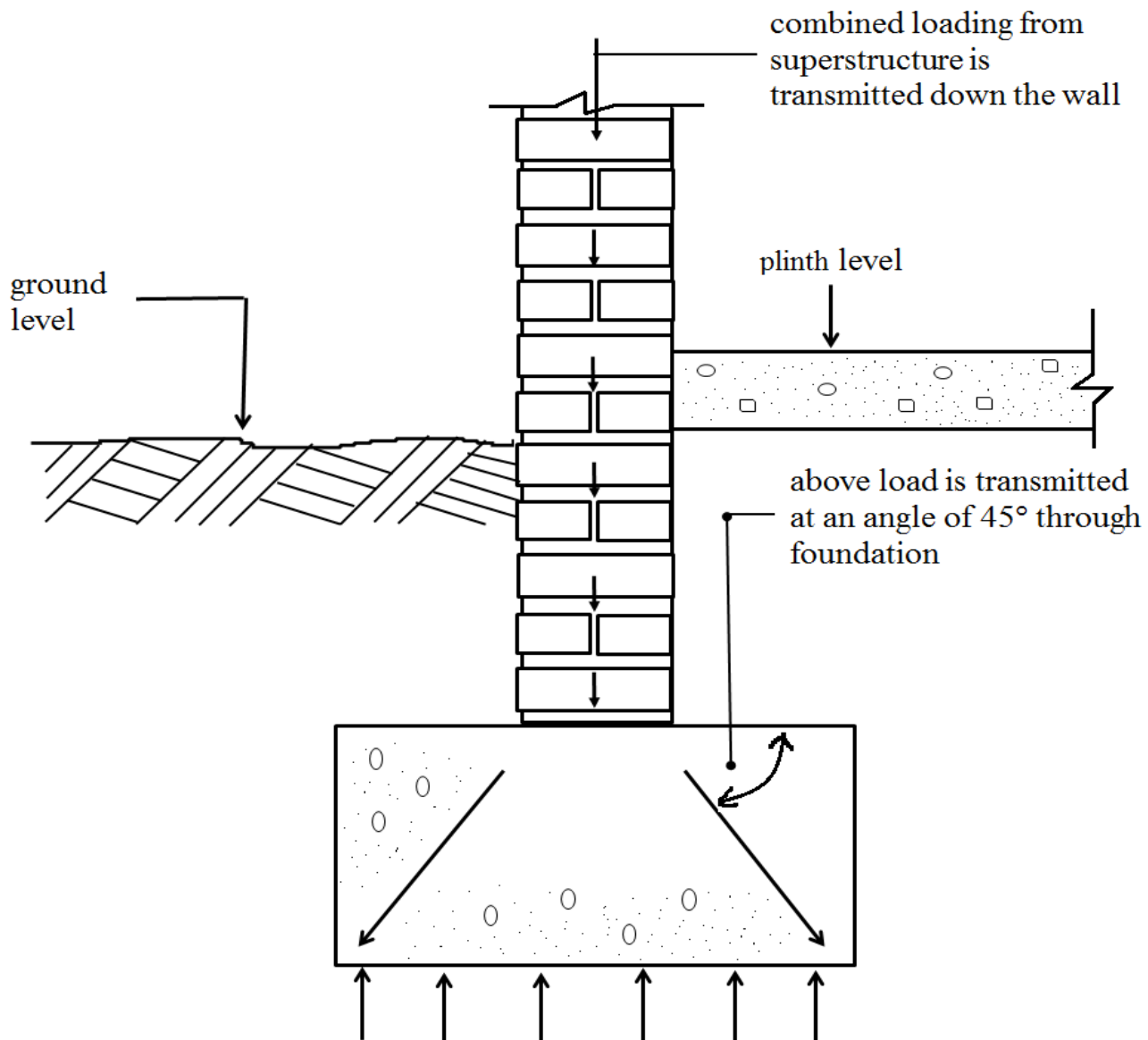
The substructure of a building consists of the following two parts:

a. Foundation: The basic function of the foundation is to prevent the building from collapsing by transferring the dead load, live load, wind load, earthquake load, and any other type of load to the subsoil in such a manner that it doesn't cause any settlement or shear failure of soil.

Foundation should have sufficient bearing capacity and stability. It is therefore designed very carefully as the failure of the foundation cannot be noticeable till it affects the building.

b. *Plinth*: The part of the structure between the surface of the surrounding subsoil and the surface of the raised floor of the building, immediately above the ground is known as a plinth. The width of the plinth beam should be equal to the width of the foundation at the ground level. It should have a minimum depth of 20 cm and the concrete used for construction should have a minimum of 20 MPa strength. Some of the important advantages of the plinth in building construction are as follows:

- The plinth distributes loads of the superstructure evenly to the foundation.
- It acts as a barrier to the dampness and moisture reaching the superstructure.
- The plinth protects from water seepage in a framed structure.
- It protects the building from cracks at the time of settlement of the foundation.
- It provides durability and stability to the superstructure.
- It gives a better aesthetic appeal to the structure.



2. Superstructure:

The superstructure is the visible part of a building. The components of the superstructure are visible and you can see them at your home too. Doors, windows, floor, roof etc. are the parts of the superstructure.

The various components of the superstructure are discussed in the subsequent sections.

a) Walls:

Walls are the most important parts of the building's superstructure. A wall can be used for the transfer of load or for just partition purposes. The walls which are used to transfer the loads are known as load-bearing walls while the walls which don't act as a load-bearing structure are known as nonload-bearing walls. Some of the salient features of a wall in building construction are given as follows:

- It should be strong to carry its own weight.
- It must be capable of carrying and transmitting the load of the roof to the substructure.
- It must be strong enough to support the opening of doors and windows.
- It helps in the space management of buildings to make them more useful.
- It protects the occupants from heat, rain, and cold and provides privacy.
- It acts as a sound barrier.
- It should be fire-resistant.
- Walls are of different types depending on their usage and location such as cavity walls, partition walls, retaining walls, compartment walls, dwarf walls, parapet walls, and curtain walls.

b) Cavity wall:

Cavity walls are types of walls made up of two different walls joined with the help of wall ties. In this type of wall, an outer wall is attached with the help of ties to the inner wall separated by cavity/airspace. Metal strips are used as wall ties. Generally, wall ties are placed at the gap of 90 cm along the length and 45 cm in the direction of height. The thickness of the external wall is kept at 10 cm and the thickness of the inner wall is as per the imposed load. The cavity wall protects the building from external wall moisture and rainwater and also provides space for the installation of thermal insulation. Buildings with cavity walls face a lesser impact of external temperature. This type of building remains cooler in summer and warm in winter. As the inner wall is protected from the external atmosphere, the life of the building also increases. The cavity starts from the floor level to the roof of the building and is covered from the top to prevent the penetration of rainwater.

c) Partition wall:

These types of walls are generally non load-bearing walls that are used to separate the internal common space of the building. This type of wall only carries its own weight. So, no foundation is required as in the case of a normal wall. It can be raised directly from the floor level. If the partition wall is not constructed up to the height of the roof and has a height of around 5 feet to 6 feet, then it is called a curtain wall. The partition walls can be easily seen in banks, railway stations, offices, hospitals, hotels etc. Materials used for the construction of partition walls are brick, timber, plywood, glass, aluminum sheets, PVC board, etc.

In modern-day buildings, where the construction is carried out as framed structures, the utility of the partition wall has increased. These types of walls provide flexibility as wall positions can be easily reconfigured and inexpensive without impacting the structure of the building. They can be easily designed and constructed with openings for doors, windows, sockets, etc. The partition wall specification depends on the availability of materials, cost, ease of construction, and finishing.

d) Sill:

Sill is a horizontal surface made up of mortar located below the window and having a width equal to the width of the wall below the window. It provides a smooth finished surface and support to the window. Materials used for the construction of sill are reinforced cement concrete, plain cement concrete, wood, steel, etc. Sill helps in preventing the moisture and passage of water to reach up to the window.

e) Lintel:

Lintels are horizontal stripes such as beams or any structural member, which are used to cover the opening and supporting the structure above the opening of the doors and windows. Materials used for constructing lintel are wood plank, bricks, reinforced cement concrete, stone, and rolled steel section infused in cement concrete.

The width of the lintel is provided equally to the width of the building wall. The vertical load above the opening of the door and window is carried by the lintel and transmitted to the side wall from its end.

f) Doors and windows:

A door is a moving structure within the wall of the building used to allow the entrance or block the passage of the building or a room. The door is designed in such a way that any person can enter without any complications. They are generally located at the corner of the room in such a way that they cover the minimum floor area of the room while opening and provide security to the building or room on closing.

The door is attached to the wall with the help of a frame and shutter. The wood used for the construction of the door should conform to IS 12896 (1990). Commonly used woods for the door are teak, cedar, kail, etc. Nowadays, different materials are available in the market for the construction of the doors like aluminum, PVC, glass, soft steel, etc.

A window is installed in the building to properly flow light and ventilation. If there is more than one window in the room, then wherever possible windows are kept opposite to each other for better circulation of air. The window shutter in the external wall of the building should open outside. The sill of the window is kept at 75 to 100 cm above the floor level for better natural light.

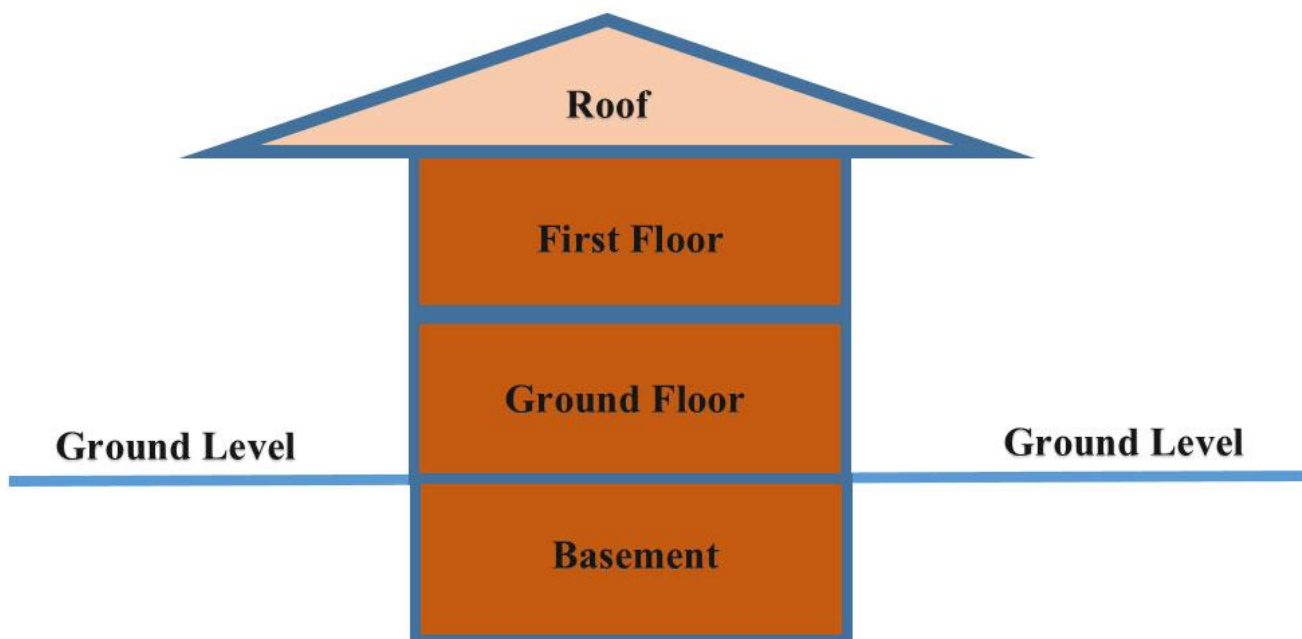
g) Floor:

A floor may be defined as the vertical partition of a building one over the other to increase the accommodating capacity of the building in a limited area. A floor is a flat and smooth surface that is designed to support the occupants, furniture, equipment, etc. the floor at the ground is called 'ground floor' and the floor at the first storey is called 'first floor'. A floor has the following two components:

- i. Sub-floor: A sub-floor provides sufficient support to the floor covering and the load on the floor covering. A sub-floor imparts the necessary strength to bear the superimposed load.
- ii. Floor covering: Floor covering is a flat, even, smooth and durable surface that provides the face of the floor. The floor covering is impervious in nature and aesthetically pleasing.

The floors are classified as ground floor and upper floors. In the ground floor, the floor rests on the ground while in the case of upper floors the floors are supported by some other means like slab action, timber framing, etc.

The ground floors can be further divided into three categories which are suspended floors, solid floors, and basement floors. The suspended floors do not rest on the ground and have blank space underneath. The solid floor rests on the ground and can take more load compared to the suspended floor. The floor covering rests on a floor of solid concrete. The solid ground floor has more strength and shows less movement as compared to the other floors. The basement ground floor is provided where the underground structure is provided in the building.



h) Mezzanine floor:

The mezzanine floor may be defined as an intermediate floor that lies between the floor and the ceiling. Mezzanine floors are temporary or semi-permanent structures that are used to maximize the use of the space in the building. These floors only extend to some portion and are not counted as main floors. The minimum size of the mezzanine floor is to be 9.5 m². The height of the mezzanine floor should be from 2.20 m to 2.70 m.

i) Roof:

A roof may be defined as the uppermost part of the building that acts as a structural covering to the building and protects it from the impact of weather and external impacts. The roofs are constructed as the floors but the shapes remain different. The roofs can be of the following three types:

- a. Flat roof
- b. Sloping roof
- c. Curved roof

a. Flat roof :

A roof may be defined as the uppermost part of the building that acts as a structural covering to the building and protects it from the impact of weather and external impacts. The roofs which have a very gentle slope known as flat roofs. The flat roofs have a slope gradient of less than 10°. These types of roofs are suitable for the regions where the rainfall quantity remains less throughout the year. The flat roof can be used as a terrace. It is necessary to provide some slope in the flat roofs for the proper drainage during the rainfall season. The flat roofs require less material for construction. These types of roofs are stable against the action of winds. In multi-storey buildings, only flat roofs can be constructed as it is easy to construct the upper floor on flat roofs.

b. Sloping roof :

If the slope of the roof is more than 10°, it is known as the sloping roof. The sloping roofs are more suitable for regions where the quantity of rainfall is high. These roofs are cost-effective and can be provided for long spans. The regions where snowfall is a common phenomenon, sloping roofs are mandatory. The snow is easily drained out from the sloping roofs.

c. Curved roofs:

Curved roofs are relatively new types of roofs. These types of roofs are relatively durable and look aesthetically pleasing. The curved roofs have very good drainage properties. These types of roofs are more suitable for the storage buildings as these increase the accommodating capacity of the storage buildings. The curved roofs are designed by specialists and require skilled labour. These types of roofs require less maintenance. The curved roofs require very sophisticated design capabilities and the cost may be higher due to the specific design requirements.

j) Structural Members of Building:

The structural members of the building provide stability and strength to the building. The load from the building is transferred to the foundation through the structural members of the building. There are three structural members in a typical building: slabs, beams, and columns.

Slabs are the flat horizontal members which take the load of the people, goods, equipment, etc., and transfer it to the beams. The slabs are used to make flat surfaces like floors and roofs. The slabs are made of concrete generally and can be prefabricated too.

Beams are the horizontal members which take the load from the slabs and transfer it to the columns. The beams take the vertical loads.

Columns are the vertical members which take the load from the beams and transfer it to the foundation. The column is a compression member of the building as it counteracts the compressive load from the building components.

h) Parapet:

A parapet wall may be defined as a wall that is constructed along the perimeter of the roof. These are short in height. The parapet walls are used to provide safety to roof users. The parapet wall helps in the prevention of accidents. It is aesthetically pleasing and provides the users with privacy. A parapet wall can be constructed of masonry, steel, stones, etc. The parapet walls can be provided in the form of railing too.

Functions of the building components:

The building components must fulfill the following conditions:

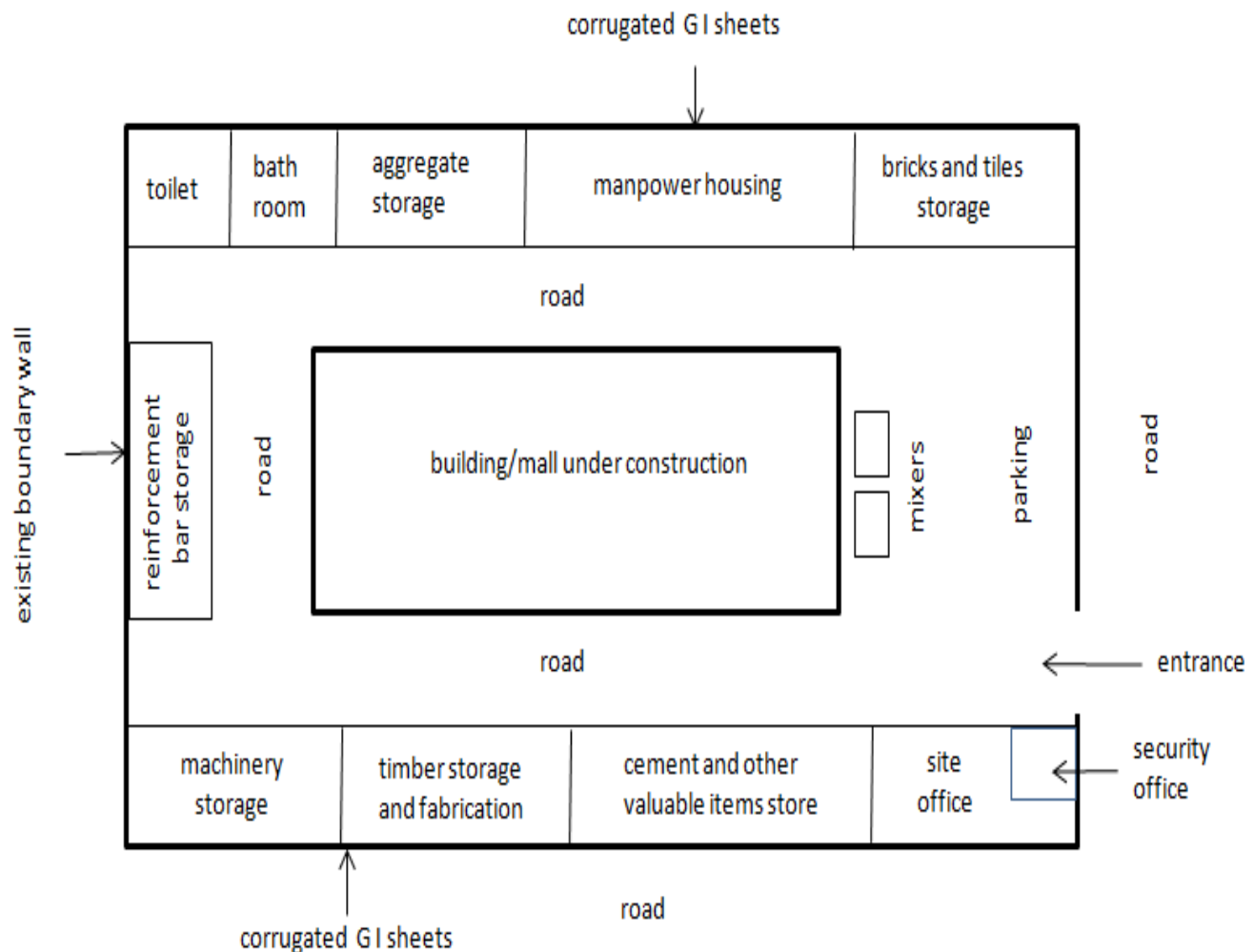
- (a) They should satisfy the function for which they were constructed. For example, load-bearing components should transfer the load to the other members.
- (b) They must be stable to resist the loads coming on them.
- (c) They must be durable to serve their function and continue till their life.
- (d) They must be economical and can be achieved with minimum resources available.

JOB LAYOUT :

Job layout can be defined as a drawing of the proposed construction site which shows different locations such as entry point, exit point, equipment, and material stores, temporary facility, site office, and place where workers will stay.

Job layout helps us to plan the construction site in such a way that different construction resources like tools, machinery, materials, manpower, etc. can be arranged easily and optimal uses of construction space can be achieved. More complex the construction project or larger in scale detailed job layout is necessary as it helps in detailing and managing space on site. Following are the main purpose of job layout:

- It helps in reducing the completion time for the construction.
- It provides easy movement of equipment from one point to another.
- It helps in reducing wastage and deterioration of the material.
- It saves time by delivering and making a uniform flow of material at the site.
- It provides more safety to the worker at the site.
- The output from manpower and equipment can be increased using the job layout.



Site Clearance:

Site clearance is the process taken to prepare a building site for its construction. It involves the clearance of vegetation, dead root mats, living or dead trees, and subsoil for a minimum depth of 30 cm from the ground surface. Site clearance also involves the work related to the demolition of any prior structure before the actual construction takes place.

The following recommendations are considered during the process of the site clearance:

- (1) The area to be cleared is marked properly.
- (2) The trees and vegetation on the site are to be cleared off. The details of the trees to be cut should be listed and the trees and vegetation are removed manually or mechanically.
- (3) The topsoil is excavated using the excavating equipment. The excavators are used for the removal of the soil
- (4) All the depressions and pits created during the process of clearing the trees and during the removal of the vegetation must be filled and compacted properly. The excavated soil is used for this purpose.
- (5) The water can be used during the compaction of the pits. The density of the compacted pits should be near the surrounding area.
- (6) If the structures exist in the area, these should be demolished mechanically. The demolition waste is dumped at the approved dumping sites, and the useful waste is stored properly. The soil that is excavated must be stored properly. These materials can be removed using tractors and dumpers
- (7) The ground can be leveled using the dozers if required.

EARTHWORK:

The process of the excavation and deposition of excavated material is known as earthwork. The earthwork includes the excavation, loading, transportation, deposition, compaction, and improvement of the soil. After the clearance of the site, the earthwork begins. Earthwork can be defined as engineering work that involves moving the soil or processing the soil from the earth's desired shape required for construction purpose. Earthworks mainly required heavy machinery equipment for the excavation of soil and backfill. Heavy machinery is generally used due to the involvement of large quantities of the material which has to be moved.

Excavation for Foundation:

Excavation can be defined as a process that helps in transferring subsoil, rock, or any other material using machinery and tools. It includes trenching, tunneling, earthworks, and wall shafts. One of the common practices using excavation is building construction. Excavation is primarily used in foundation for digging, trenching, and site development.

Excavation for small buildings is done manually using pick axes, spades, crowbars, etc. For deep foundations and for large buildings, excavation is carried out by using machinery for earth cutting. Setting out is done first to carry out excavation at the site. The Excavation is done on hard soil where the depth of the foundation is less than 1.5 m, trench sides don't require external support. In case of loose soil or deeper excavation, some type of support is required from preventing the sides to fall. Strutting and timbering are done continuously depending on the type of soil and foundation depth. In general, excavation trench width is kept equal to the width of foundation concrete, because wider excavation is not good for the strength and economy of the building as wider excavation is to be filled later by losing soil. The foundations should be checked for depth and width while excavating.

Earthwork for Embankment:

Earthwork is the engineering work using machinery and tools for moving or processing subsoil and underground rocks. The subsoil may be transported from one location to another or formed into any shape that is required for the construction. Earthwork generally involves cutting and filling and machine excavation at the site.

Materials for Plinth:

- Soil
- Murum Soil
- Sand

Tools and Plants for Excavation:

- Spade
- Shovel
- Hoe
- Trowel
- Pickaxe
- Rammer
- Crow bar
- Basket



(a)



(b)



(c)



(d)



(e)

❖ Different types of machine tools used in construction are as follows:

- Tracked Excavator
- Bulldozer
- Roller
- Backhoe Excavator
- Loader



Tracked Excavator



Backhoe

FOUNDATION:

The word 'foundation' has emerged from the Latin word 'fundare'. The word 'fundare' means to 'set on a solid base'. Foundation is the lowermost part of the structure which transfers the load of the superstructure and other loads to the ground. A foundation may be defined as a solid base on which the structure rests.

The foundation plays a major role in the stability and strength of the structure. As the ultimate load from all the building components is to be transferred through the foundation, it is essential to construct the foundation carefully.

FUNCTIONS OF FOUNDATION:

The foundation is one of the most important parts of the building. The structural elements like columns, , and slabs transfer the load to each other but it is the foundation that ultimately transfers beams the load of the whole structure to the earth. So, the foundation plays a vital role in the safety and serviceability of a structure. The major functions of the foundation are discussed as follows:

- (1) A foundation provides a hard and level surface that is suitable for the construction of a superstructure over it.
- (2) The foundation distributes the load from the structure to a larger area which helps in reducing the load intensity. We know that pressure is the ratio of force to area. If the area is larger the pressure reduces. The foundation acts on the same principle. The load of the structure is distributed by the foundation and transferred to the ground. The larger the area of the foundation, the lesser will be the load intensity and the safer will be the structure.
- (3) The load is distributed uniformly by the foundation. If the load is distributed non-uniformly or unevenly, there can be differential settlements in the base. The differential settlements can cause cracks in the building components. In extreme cases, even failure of building components can occur.

(4) There is a significant impact of winds and earthquakes on the buildings. The wind and earthquake loads have a tendency to overturn the building due to their horizontal impact. The foundation binds the superstructure and provides lateral stability to the structure.

(5) The foundations save the components of the building from the cracks during the movement of the soil. The soils can expand or contract which can cause the cracking of the structural components of the buildings. Special measures during the construction of the foundation are taken to save the structure from cracking.

(6) The foundation reduces the impact of undermining and scouring on the building.

TYPES OF FOUNDATION:

- The foundations can be classified into two types which are the **shallow foundation** and **deep foundation**.

SHALLOW FOUNDATION:

A footing is the part of the foundation that transfers the load to a larger area. The base of the column or wall is enlarged to increase the area at the bottom, known as footing. Foundation is the combination of footings. Shallow foundations can be further classified into the following categories:

- Spread footings
- Combined footings
- Strap footings
- Mat (Raft) foundations

Spread footings:

As the name suggests, the spread footings are the footings that distribute the load to the earth by spreading the load over a larger area. The area at the base of columns or walls can be spread in different ways. Based on the different shapes of the spread footings, the spread footings can be further divided into the following six types:

- Single column footing
- Stepped column footing
- Sloped column footing
- Strip wall footing
- Stepped wall footing
- Grillage footing

Grillage foundation:

A grillage foundation consists of a combination of beams laid over each other resting on the layer of concrete. The area is spread at the bottom of the column by the combination of beams to spread the superimposed loads. The grillage foundation provides more stability and strength and can take very high loads.

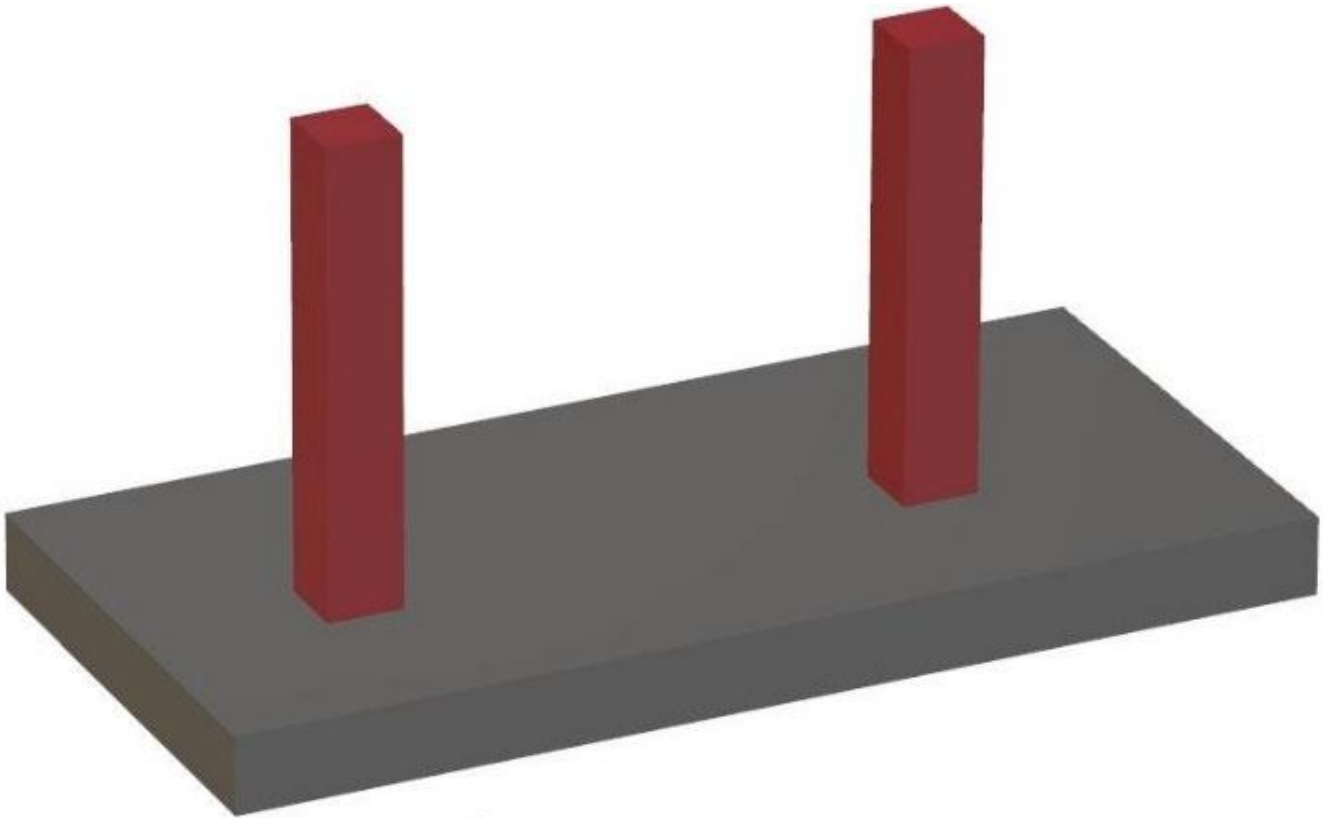
During the construction of the grillage footing, the following recommendations are considered:

- The grillage foundation is provided for the heavy load of columns or steel stanchions if the bearing capacity of the soil is poor.
- The depth of the grillage foundation is kept from 1 m to 1.5 m.
- In the steel grillage foundation, the steel beams are separated by pipe separators of 25 mm diameter and spacers of 20 mm diameter. The distance between the steel beams should be sufficient so that concrete can get compacted easily. The minimum clearance between the beams can be kept 8 cm.
- The minimum concrete cover of 15 cm is provided to the lower beams and 10 cm for the upper beams.
- In case of timber grillage foundation, the timber boards of 8 m to 10 cm thickness are stacked form the timber grillage. The maximum spacing between the timber beams can be 38 cm.

Combined footings:

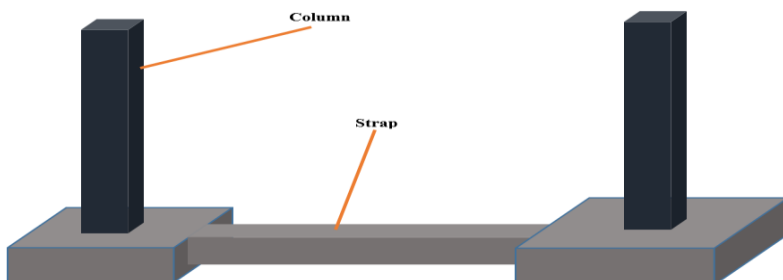
Sometimes if the columns are constructed near to each other, it is not possible to provide the individual footings. So, a combined footing for two or more columns is provided. The combined footings are more economical as compared to the individual footing for each column. The combined footing can be of the following three types:

- Rectangular combined footing
- Trapezoidal combined footing
- Combined column wall footing



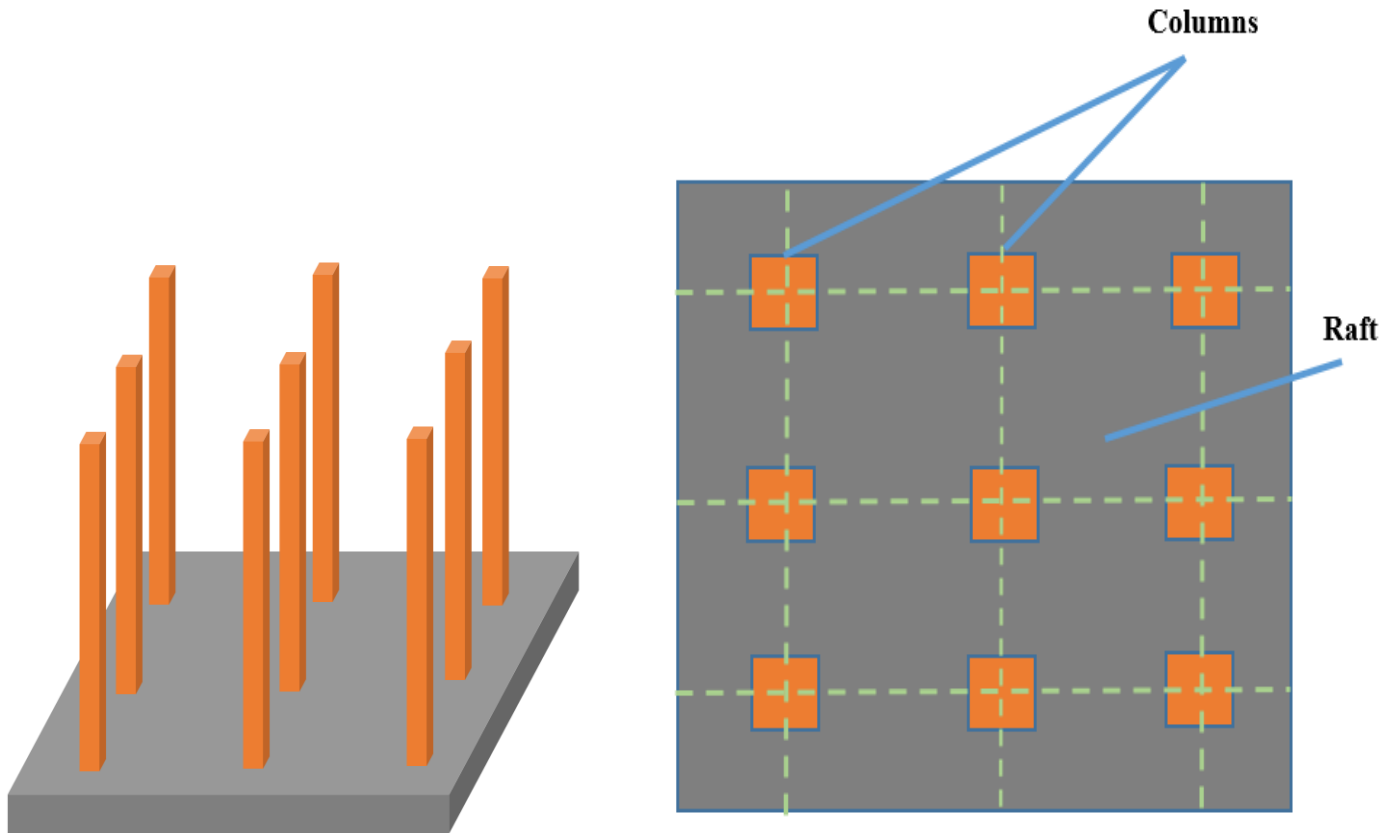
Strap footings:

A strap footing is a special type of combined footing. The combined footing can only be used if the columns are not much far from each other. If the columns have a larger distance between them, the trapezoidal footings become narrow. In this case, the bending moments can increase significantly, leading the structure to fail. The strap may be defined as a beam connecting the column's individual footings.



Raft foundations:

The raft foundation is also known as the mat foundation. The raft foundation is provided throughout the base of the superstructure as a mat. It is a continuous slab that supports a number of columns. The mat foundation transfers the load of all the components of the building to the earth. The raft foundation also reduces the differential settlements.



DEEP FOUNDATION

We know that the shallow foundations transfer the load to the hard stratum below the ground by means of footings. Sometimes the hard stratum under the ground lies at a significant depth. In this case, it is not feasible to provide a shallow foundation. If the hard stratum lies deep below the ground, a deep foundation can be provided. A deep foundation is the type of foundation that has more depth than its width. Deep foundations are of the following three types:

- Pile foundation
- Well foundation or caissons
- Cofferdams

Pile foundation:

A pile may be defined as a slender long column made of timber, concrete, steel, or composite material that is used to transfer the load of the structure through its bottom or friction action or by a combination of both. The diameter of the piles is generally equal to or less than 0.6 m. Based on the mechanism of transfer of the load, the piles may be classified further into the following three types:

- End bearing piles
- Friction piles
- Combined piles

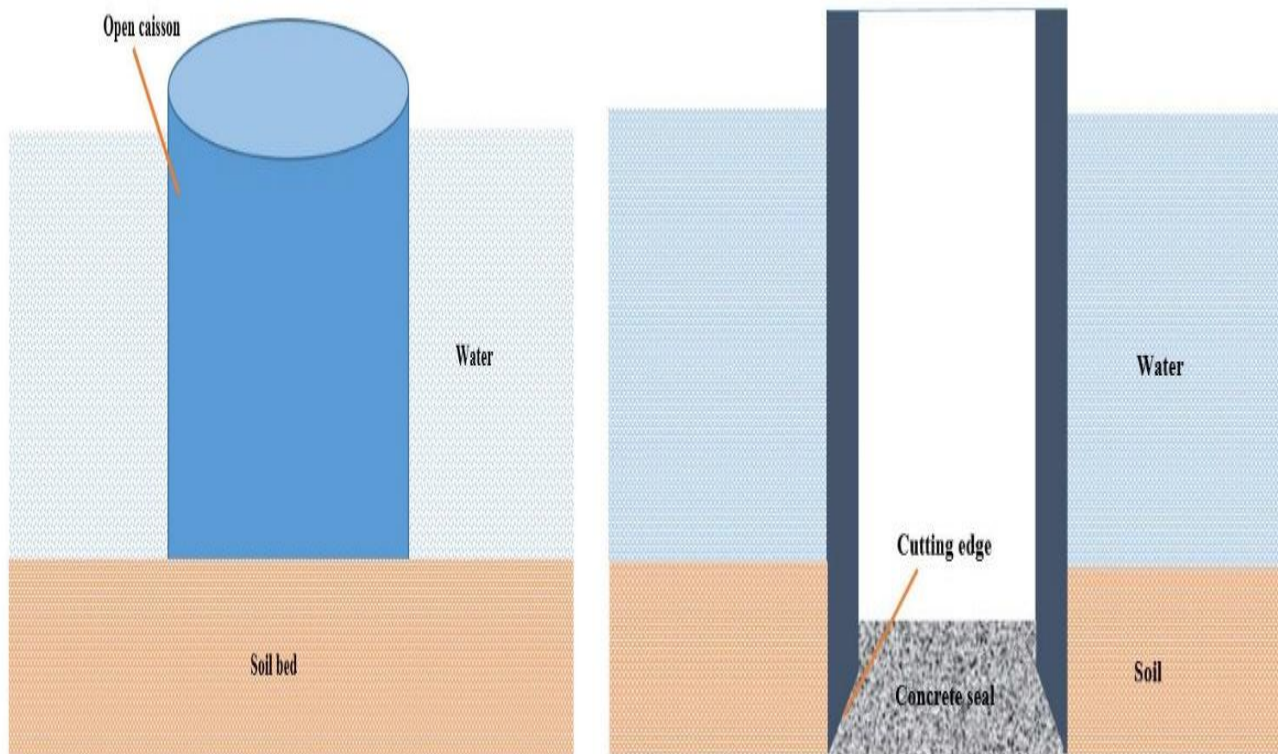
The piles can be made of different materials. The piles can be classified into the following four categories based on the material:

- Timber piles
- Steel Piles
- Concrete Piles
- Composite piles

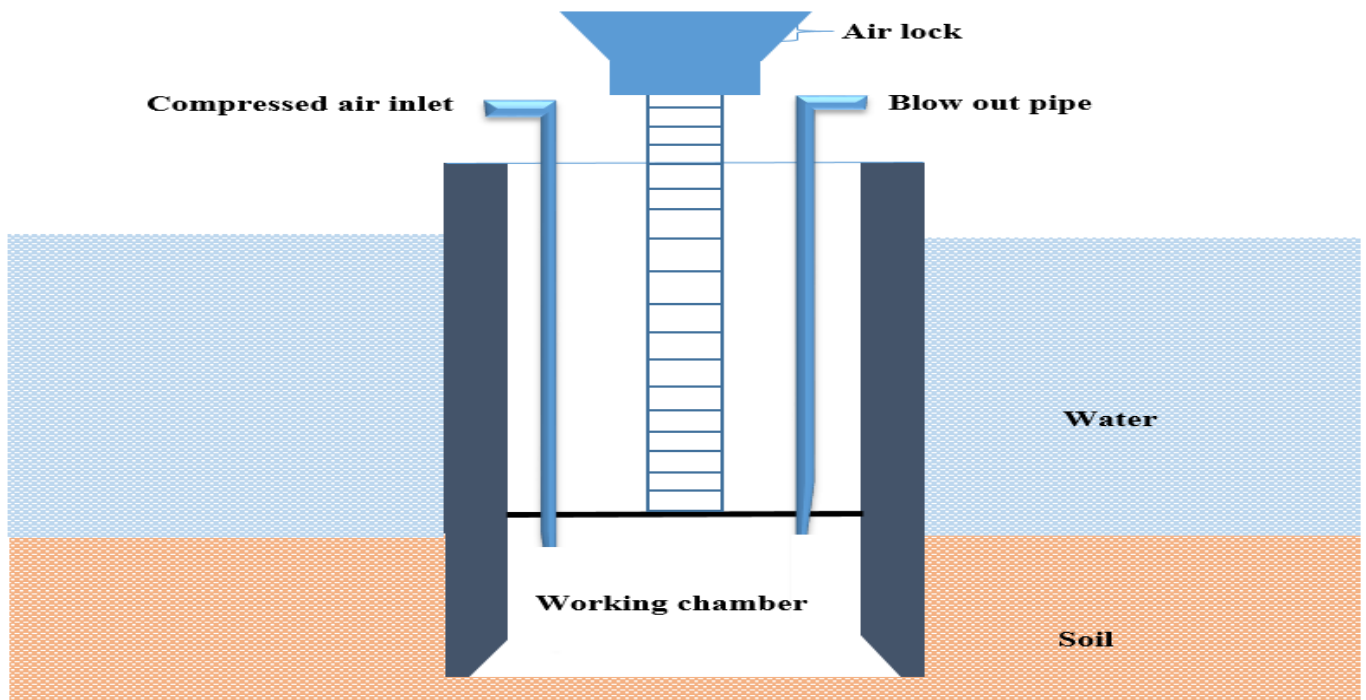
Caissons:

Caissons are box or cylindrical type structures that are hollow in nature. The caissons are fabricated on ground and penetrated at the waterbed. The caissons are used to support the bridges in the water bodies. The caissons are of the following three types:

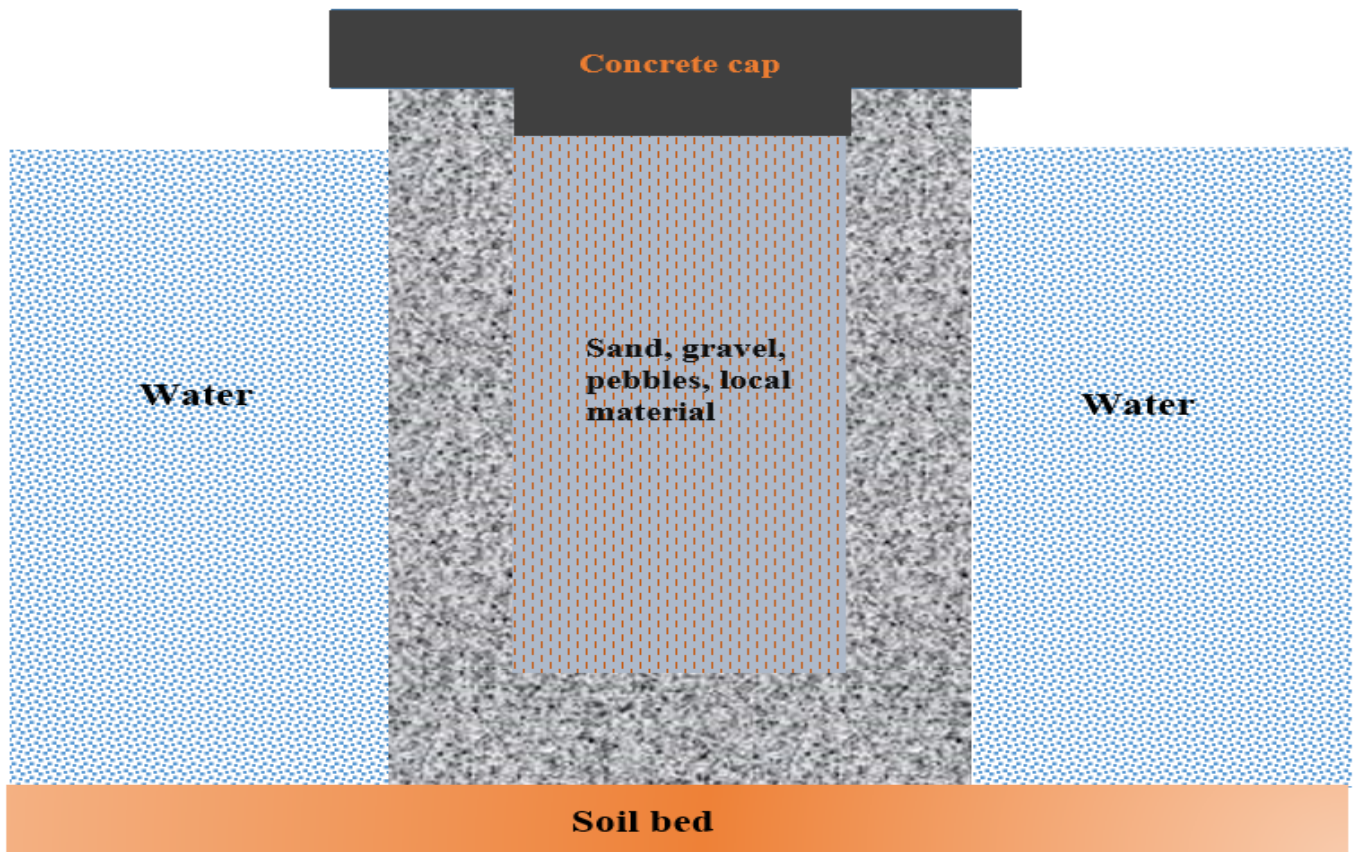
- Open caissons or well foundation
- Floating or closed caissons
- Pneumatic caissons



Open Caisson



Pneumatic caisson



Floating or closed caisson

Cofferdams:

A cofferdam is a temporary, watertight enclosure built in a body of water to allow the enclosed area to be pumped dry, creating a dry working environment for construction. These structures are used for projects like building bridge piers, docks, or dams, and they can be made from various materials like earth, rock, steel sheet piles, or concrete.

Purpose:

- To create a dry space for construction work in an area that is normally underwater.
- To protect workers and equipment from water and soil during construction.
- To allow for the construction of permanent structures, such as foundations for bridges, in rivers, lakes, or on coastlines.
- To be used in areas with high groundwater tables where deep excavations are required.

Types of cofferdams

- Earth-fill cofferdams: Used in shallow water, these consist of earthen embankments.
- Sheet pile cofferdams: A common type that uses interlocking steel sheets driven into the ground to form a wall.
- Rock-fill cofferdams: Constructed by filling a contained area with rocks.
- Cellular cofferdams: Large, circular or D-shaped structures formed by connecting multiple sheet piles, used for deeper water.
- Crib cofferdams: Use a horizontal framework of timbers to create pockets that are filled with earth or stones, often used in deep water.



❖ **Difference between Shallow and Deep Foundation:**

Feature	Shallow Foundation	Deep Foundation
Depth	Close to the ground surface	Extends to deeper, more stable soil or rock layers
Load Transfer	Transfers load to the soil near the surface	Transfers load through weaker upper soils to a stronger layer below
Typical Use	Lighter structures on stable, near-surface soil	Heavy structures or unstable, weak surface soils
Depth Metric	Usually less than three meters deep, with depth generally less than the width	Often extends beyond three meters, with depth greater than the width
Cost	Generally cheaper and easier to construct	More expensive and time-consuming due to complex construction

❖ **Difference between Caisson and Cofferdam:**

Feature	Caisson	Cofferdam
Purpose	To provide a permanent, stable foundation for structures	To create a temporary, dry working environment for construction below water level
Lifespan	Permanent	Temporary; removed after construction is complete
Construction Method	Often prefabricated offsite and sunk into place, or sunk in stages and filled with material	Built on-site from materials like sheet piles, earth, or timber to surround an area
Role in Final Structure	Becomes part of the finished structure (e.g., a bridge pier)	Is removed after the permanent work is done
Examples	Bridge piers, docks, and deep foundations	Building permanent dams, bridge piers, or oil platforms