**TYPES OF FOUNDATION**

**Introduction:**

The lowest artificially built part of a structure which transmits the load of the structure to the soil lying underneath is called foundation.

- The supporting part of a structure; the foundation. (i.e.: footing / piling, pile cap, column stump)
- Sub-structure will include ground beams, ground floor column and ground floor slab.

**Purposes of foundation:**

1. To distribute loads of the structure over a large bearing area so as to bring intensity of loading within the safe bearing capacity of the soil lying underneath.
2. To load the bearing surface at a uniform rate so as to prevent unequal settlement.
3. To prevent the lateral movement of the supporting material.
4. To secure the level and firm bed for building operations.
5. To increase the stability of the structure as a whole.

**Factors affecting selection of foundations:**

1. Types and intensity of loads acting on various parts of the structure which may be dead load, live load, wind load, snow load, etc.
2. Nature and bearing capacity of the soil on which the structure directly rests.

Design and selection of foundation depends on:

1. Total load of building
2. Nature and bearing capacity of soil
**Causes of settlement**

1. Deformation of soils causing by an imposed load
2. Volume changes of soil cause by seasonal conditions.

Foundation failure: collapse or excessive *settlement* of a building supporting structure resulting from soil movement.
1. **Shallow Foundations** – are usually located no more than 6 ft below the lowest finished floor. A shallow foundation system generally used when (1) the soil close the ground surface has sufficient bearing capacity, and (2) underlying weaker strata do not result in undue settlement. The shallow foundations are commonly used most economical foundation system.

**Footings** are structural elements, which transfer loads to the soil from columns, walls or lateral loads from earth retaining structures. In order to transfer these loads properly to the soil, footings must be design to

- Prevent excessive settlement
- Minimize differential settlement, and
- Provide adequate safety against overturning and sliding.

a) **Isolated spread footing:** Isolated spread footings are used to support an individual point load such as that due to a structural column. These can be square, rectangular, or circular. They usually consist of a block or slab of uniform thickness, but they may be stepped or hunched if they are required to spread the load from a heavy column. Isolated spread foundations are usually shallow, but deep pad foundations can also be used.
b) **Wall footing:** Wall footing is a continuous slab strip along the length of wall.
c) **Combined footing:** Combined footings usually support two columns, or three columns not in a row. These can be rectangular or trapezoidal plan. Combined footings are used when two columns are so close that single footings cannot be used or when one column is located at or near a property line.

d) **Cantilever or strap footings:** Consist of two single footings connected with a beam or a strap and support two single columns. This type replaces a combined footing and is more economical.

e) **Rafted or mat foundation:** Rafted or mat foundation consists of one footing usually placed under the entire building area. They are used, when soil bearing capacity is low, column loads are heavy single footings cannot be used, piles are not used and differential settlement must be reduced.
2. **Deep Foundations** - Deep foundations are those founding too deeply below the finished ground surface for their base bearing capacity to be affected by surface conditions. This is usually at depths $>$3 m below finished ground level.

Fig. Pile Foundation- (a) Vertical Piles; (b) Battered Piles
• The foundations constructed below ground level with some arrangements such as piles, wells, etc. at their base are called deep foundations.

• Deep foundations are classified into the following types:
  – Pile foundation
  – Well foundation
  – Caisson foundation

a) Pile Foundation
When the upper soil layer(s) is (are) highly compressible and too weak to support the load transmitted by the superstructure, piles are used to transmit the load to underlying bedrocks or a stronger soil layer.

➢ Structures place on top of the piles.
➢ Piles + Pile Cap = Pile foundation
➢ Function : Distributes load to the individual piles.
➢ Pile Cap will connect the pile together and distributes the superstructure loads to the layer beneath.

When To Use Pile Foundations:
• Inadequate Bearing Capacity of Shallow Foundations
• To Prevent Uplift Forces
• To Reduce Excessive Settlement

Suitability:
Pile foundation is suitable under the following situations:
  i) When the soil is very soft and solid bed is not available at a reasonable depth to keep the bearing power within safe limits.
  ii) When provision of pad and raft foundations becomes very expensive.
  iii) When the structure carries heavy concentrated loads. When the structure carries heavy concentrated loads.
  iv) When it is necessary to construct a building along the sea-shore or river bed.
Classifications of Piles:

i) End Bearing
- End bearing piles are those which terminate in hard, relatively impenetrable material such as rock or very dense sand and gravel.
- These piles transfer their load on to a firm stratum
- The pile behaves as an ordinary column and should be designed as such.

ii) Skin Friction
- Friction piles obtain a greater part of their carrying capacity by skin friction or adhesion.
- This tends to occur when piles do not reach an impenetrable stratum.
- These piles transmit most of their load to the soil through skin friction

Classification of piles according to their composition or material of construction
1. Timber
2. Concrete
3. Steel
4. Composite piles
1. Timber Piles

- The piles made of wood, should be free of defects, decay, etc and it should be well seasoned.
- The piles can be circular or square in cross-section. Top of these piles is provided with an iron ring to prevent it from splitting under blows of hammer.
- The bottom is fitted with an iron shoe to facilitate sinking of piles.
- These piles are driven by blows of hammer of a pile driving machine.
- Used for buildings, bridges and cofferdams but is not recommended to be used in seawater.

**Advantages of timber piles:**
- Less expensive as timber available can be used after suitable treatment.
- Can be made longer in lengths by joining the individual pieces easily.
- Cutting of these piles is easy.
- Can be driven easily with lighter machinery.

**Disadvantages:**
- The piles deteriorate by action of water and insects.
- Lesser load bearing capacity
- A number of small individual units require to construct long piles; this entails lot of joining work as such the cost becomes high in constructing the piles.

2. Concrete Piles

- The piles are made of cement concrete, strong, durable and can bear more load than timber piles. They are free from defects and cannot be attacked by insect, white-ant, etc.
- The piles are fire-proof and water-proof.

Concrete piles are classified into two types:
1. Pre-cast piles.
2. Cast-in-situ piles.
a) Pre-cast piles:

These are R.C.C piles which are square, circular or octagonal in cross-section. It’s the heaviest, brittle and lack of tensile strength. The construction requires care in handling and driving to prevent pile damage.

Advantages of Pre-cast Concrete Piles

i. Best concrete can be prepared by proper workmanship. Any defect can be repaired immediately.
ii. The reinforcement remains in proper position and does not displace.
iii. The concrete only withstands loads after complete curing has taken place. They can be cast beforehand and quick driving progress can be ensured.
iv. More convenient when driven through wet conditions.
v. Suitable when part of their length is to remain exposed.
vi. Not affected by other additional forces which act on the piles while adjacent piles are driven.

Disadvantages:

i. Heavy and difficult to transport.
ii. Lapping of additional length means extra cost, labour and energy.
iii. Heavier in section to withstand holding stresses.
iv. The shocks of driving make the weaker.

b) Cast-in-situ piles:

This type of piles is constructed in its location in a bore hole prepared for this field. The operation consists of boring a hole, filling it with concrete or steel reinforcement and concrete. Examples are simplex pile, pedestal or bulb pile, Frankie pile, Raymond concrete pile, etc.

Advantages of Cast-in-situ piles:

i. Less wastage of material as exact length of pile is cast.
ii. Time spent on curing is saved.
iii. Can bear heavier loads by improving their X-sectional profile, eg, pedestal pile.
Disadvantages:

i. Good quality concrete cannot be easily obtained due to unusual height of dumping.
ii. The reinforcements are liable to get displaced.
iii. They cannot be used under water.
iv. The green concrete loses strength after coming in contact with the soil.
v. The shells are affected by casting additional piles adjacent to them.

3. Steel Piles

• Steel piles are of steel section. Useful where driving conditions are difficult and other types of piles are not suitable. Usually used for building and bridge foundations. The piles are in form of I, U, H sections.

• Steel piles are available in the following forms.

  a) Steel pin piles
  b) Sheet piles
  c) Disc piles
  d) Screw piles.
4. Composite piles

The upper and lower portions of composite piles are made of different materials. For example, composite piles may be made of steel and concrete or timber and concrete. Steel and concrete piles consist of a lower portion of steel and an upper portion of cast-in-place concrete. This type of pile is the one used when the length of the pile required for adequate bearing exceeds the capacity of simple cast-in-place concrete piles. Timber and concrete piles usually consist of a lower portion of timber pile below the permanent water table and an upper portion of concrete. In any case, forming proper joints between two dissimilar materials is difficult, and, for that reason, composite piles are not widely used.

b) Well foundation

Well foundation is a type of deep foundation which is generally provided below the water level for bridges.

The common types of well shapes are:

(i) Single circular
(ii) Twin circular
(iii) Dumb well
(iv) Double-D
(v) Twin hexagonal
(vi) Twin octagonal
(vii) Rectangular.

![FIG. 11.30 Different shapes of wells](image-url)
The choice of a particular shape of well depends upon the size of the pier, the care and cost of sinking, the considerations of tilt and shift during sinking and the vertical and horizontal forces to which well is subjected.

A circular well has the minimum perimeter of a given dredge area. Since the perimeter is equidistant at the points from the centre of dredge hole, the sinking is more uniform than the other shapes. However, the circular well is that in the direction parallel to the span of bridge, the diameter of the well is much more than required to accommodate minimum size of pier and hence circular well obstruct water way much in comparison to other shapes.

**Forces Acting On a Well Foundation:**

In addition to the self weight and buoyancy, it carries the dead load of superstructure, bearing and piers and subjected to the following horizontal forces:

(i) Braking effort of the moving vehicle.
(ii) Force due to the resistance of bearings against movement due to temperature variations.
(iii) Force of water current
(iv) Seismic forces
(v) Wind force
(vi) Earth pressure.
c) Caisson foundation:

Caisson is a French word which means “a large chest or a box”. Caisson is a water tight structure made of wood, steel, R.C.C. constructed in connection with excavation for foundation of bridges, piers in rivers, dock structures etc.

Types of Caisson:
There are three types of caisson as follows
- Open Caisson
- Box Caisson
- Pneumatic Caisson

Uses of Caisson:
1. Caissons are made suitable for the deep foundation under water where the foundation should be extended up to or below the river bed so as to obtain the proper stability.
2. Caissons as type of well foundation is constructed in rivers and lakes, bridges break water dock structures for the point of view of shore protection.
3. When depth of water in river, lake, or sea etc. is more, then caisson structure is used.
4. It is also used for pump house which are subjected to huge vertical as well as horizontal forces.
5. It is also occasionally used for large and multistory building and other structures.

Advantages:
1. The caisson can be extended up to large depth.
2. Caissons are more suitable for the deep foundation under water where the foundation should be extended up to or below the river bed so as to obtain the proper stability.
3. Cost of construction is relatively less on bed level or lower side.
4. Quality control of Pneumatic caisson is good because work is done in dry conditions. Concrete gain more strength due to dry conditions.
5. In-situ soil test is possible to determine the bearing capacity of pneumatic caisson.
6. There is direct and easy passage to reach the bottom of caisson, hence any obstruction can easily be removed.
Disadvantage:
1. In box caisson the placing of concrete is done for concrete is done for concrete seal under water, it may not be satisfactory.
2. If any obstructions of boulders or logs are encountered, then progress of work becomes slow.
3. The help of divers may be required for excavation near haunches at the cutting edges.
4. Construction of pneumatic caissons is much expensive than open caissons.
5. During working the various constructional activities, a proper care has to be taken; otherwise it may lead to fatal accidents.
6. Labor cost is high.

Difficulties:
- Sinking of Caisson
- Tilting of Caisson