

OPSC-AEE 2020

Odisha Public Service Commission
Assistant Executive Engineer

Civil Engineering

Building Construction

Well Illustrated **Theory** with
Solved Examples and **Practice Questions**



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Building Construction

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2.1 Introduction

A foundation is that part of the structure which is in direct contact with the ground to which the loads are transmitted. The soil which is located immediately below the base of the foundation is called sub-soil or foundation soil, while the lower most portion of the foundation which is in direct contact with the sub-soil is called the footing.

The basic function of a foundation is to transmit the dead loads, superimposed loads (or live loads) and wind loads from a building to the soil on which the building rests, in such a way that:

- (a) Settlement are within permissible limits, without causing cracks in the superstructure.
- (b) The soil does not fail

When loads are transmitted to the sub-soil, it settles. If this settlement is slight and uniform throughout, no damage will be caused to the buildings. But if the settlement is excessive or unequal, serious damage may result in the form of cracked walls, distorted doors and window openings, cracked lintels, walls thrown out of plumb etc. and some times the complete collapse of the building.

The foundation is thus the most important part of a building. Since it remains below the ground level, the signs of failure of foundation are not noticeable till it has already affected the buildings. A foundation should be sufficiently strong to prevent excessive settlement as well as unequal settlement. Unequal settlement or differential settlement may be caused by

- (i) Weak sub-soils, such as made up of ground.
- (ii) Shrinkable and expansive soils such as clay.
- (iii) Frost action
- (iv) Movement of ground water and uplift pressure.
- (v) Excessive vibration due to traffic, machinery etc.
- (vi) Slow consolidation of saturated clays.
- (vii) Slipping of strata on sloping sites.

2.2 Objects of Foundation

The foundations are provided for the following purposes:

- (i) To distributed the total load coming on a structure on a larger area so as to bring down the intensity of load at its base below the safe bearing capacity of sub-soil.
- (ii) To support the structures.
- (iii) To give enough lateral stability to the structures against various disturbing horizontal forces such as wind, rain, earthquake etc.

- (iv) To prepare a level and hard surface for concreting and masonry work.
- (v) To transmit the superimposed loads through side friction and end bearing in case of deep foundations.
- (vi) To distribute the non-uniform load of the superstructure evenly to the subsoil.
- (vii) To provide structural safety against undermining or scouring due to animals, flood water etc.
- (viii) To prevent or minimise cracks due to movement of moisture in case of weak or poor soils.

2.3 Essential Requirements of a Good Foundation

Following are the three basic requirements to be fulfilled by a foundation to be satisfactory:

- (i) **Location :** The foundation structure should be so located that it is able to resist any unexpected future influence which may adversely affect its performance. This aspect requires careful engineering judgement.
- (ii) **Stability :** The foundation structure should be stable or safe against any possible failure. The foundation base should be rigid enough to bring down the differential settlement to a minimum extent specially when the superimposed loads are unevenly distributed.
- (iii) **Settlement :** The foundation structure should not settle or deflect to such an extent so as to impair its usefulness or the stability of buildings or the adjoining structures. It is however difficult to define the objectionable amount of settlement or deflection.

2.4 Types of Foundations

Foundations are broadly classified into two category:

- (a) Shallow foundation
- (b) Deep foundations.

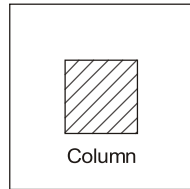
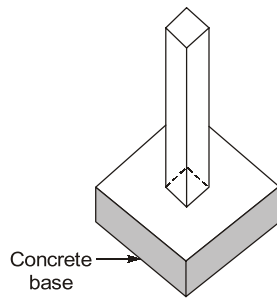
According to Terzaghi's, a foundation is shallow if its depth is equal to or less than its width. In case of deep foundation, the depth of foundation, is greater than width of foundation.

2.4.1 Shallow foundation

From the design point of view, shallow foundations may be of the following types:

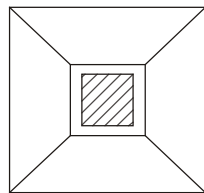
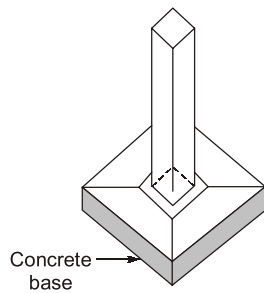
- (i) Spread footing
- (ii) Strip footing
- (iii) Combined footing
- (iv) Strap footings
- (v) Mat foundation

1. **Spread/isolated footing :** Spread footing are those which spread the superimposed load of wall or column over a larger area.
 - Spread footing supports either a column or wall.
 - Spread footing may be of the following kinds:
 - (i) Single footing for a column
 - (ii) Stepped footing for a column



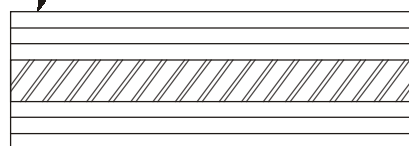
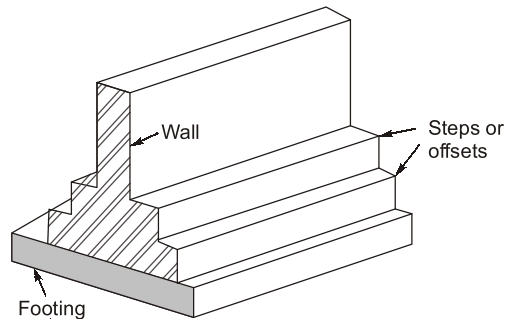
(a) Single footing

(iii) Sloped footing for a column

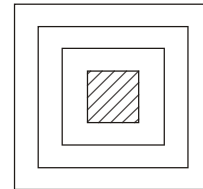
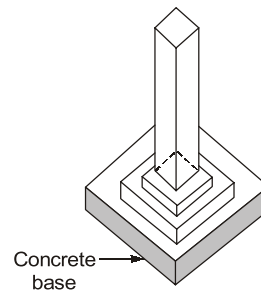


(c) Sloped footing

(v) Stepped footing for wall.

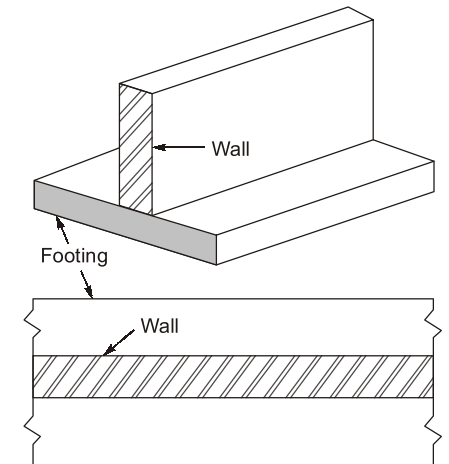


(e)



(b) Stepped footing

(iv) Wall footing without step



(d)

(vi) Grillage foundation:

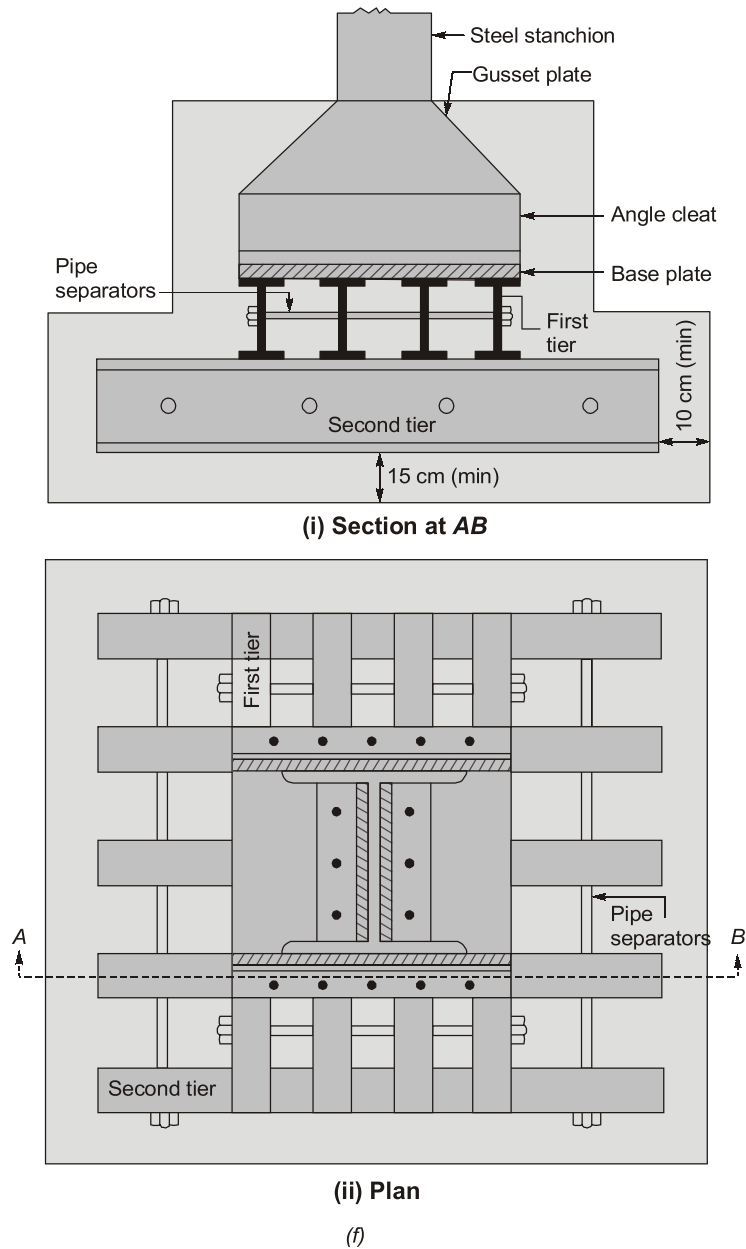
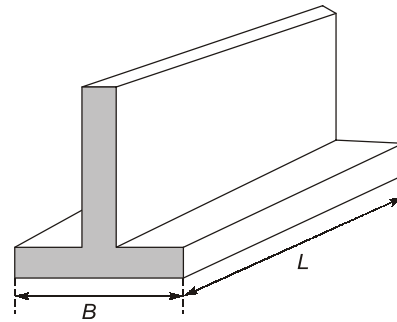


Figure shows a steel grillage foundation for an steel stanchion carrying heavy load.

- It is a special type of isolated footing generally provided for heavily loaded steel stanchion and used in those locations where bearing capacity of soil is poor. The depth of such a foundation is limited to 1 to 1.5 m.
- The load of the stanchion is distributed or spread to a very large area by means of two or more tiers of rolled steel joists, each layer being laid at right angles to the layer below it. Both the tiers of the joists are then embedded in cement concrete to keep the joists in position and to prevent their corrosion.

2. **Strip footing** : These are also known as wall footing to support wall.

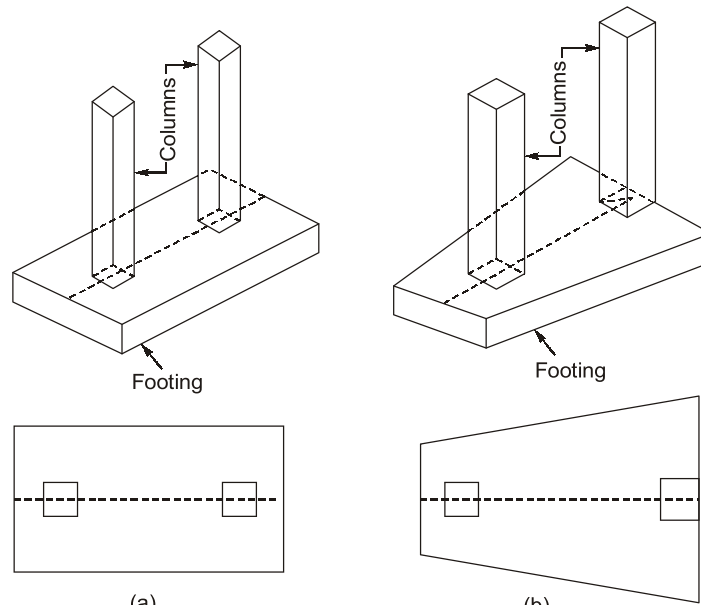
If $[L \gg B] \rightarrow$ Strip footing



Strip footing

3. **Combined footing** : These footings are usually constructed due to space limitations and supports two or more columns. They may be either rectangular or trapezoidal in shape.

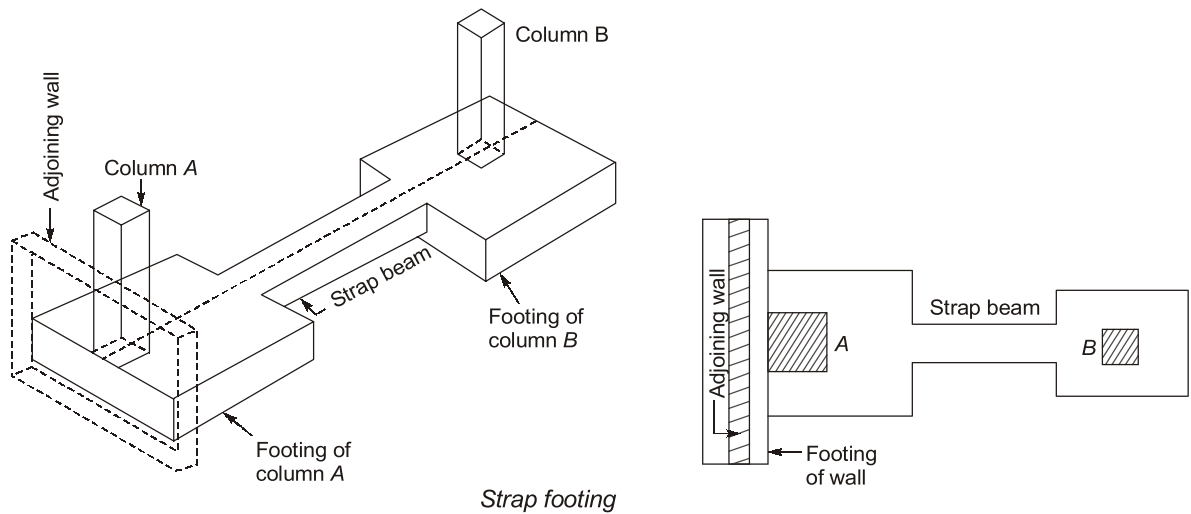
The combined footing for columns will be rectangular in shape if they carry equal loads. The design of rigid rectangular combined footing should be done in such a way that centre of gravity of column loads coincide with the centroid of the footing area. If the column carry unequal loads, the footing is of trapezoidal shape.



(a) Rectangular footing (b) Trapezoidal footing

4. **Strap footing** : If the independent footings of the two column are connected by a beam, it is called a strap footing.

- A strap footing may be used where the distance between the columns is so great that a combined trapezoidal footing become quite narrow, with high bending moments. In that case, each column is provided with its independent footing and a beam is used to connect the two footings.
- The strap beam does not remain in contact with the soil, and thus does not transfer any pressure to the soil. The strap, assumed to be infinitely stiff serves to transfer the column on the soil with equal and uniform pressure under both footings.



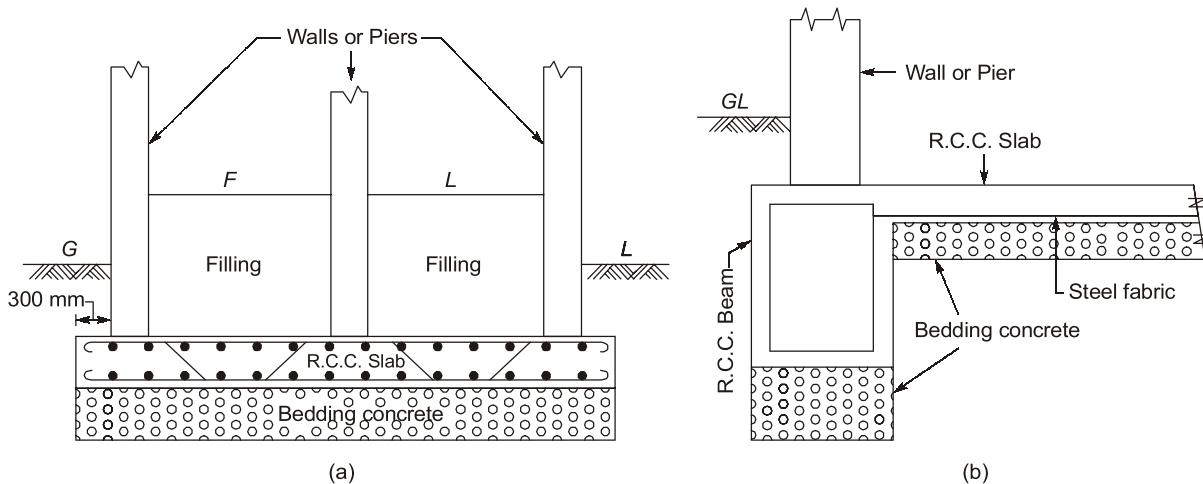
Strap footing

5. **Mat foundation/Raft foundation**

- A raft or mat is a combined footing that covers the entire area beneath a structure and supports all the walls and columns. When the allowable soil pressure is low, or the building loads are heavy, the use of spread footings would cover more than one half the area and it may prove more economical to use mat or raft foundation.
- They are also used where the soil mass contains compressible loss or the soil is sufficiently erratic. So that the differential settlement would become difficult to control. The mat or raft tends to bridge over the erratic deposits and eliminates the differential settlements.
- Raft foundation is also used to reduce settlement above highly compressible soils, by making the weight of structure and raft approximately equal to the weight of the soil excavated.
- Rafts may be divided into three types, based on their design and construction:

(i) Solid slab system (ii) Beam slab system (iii) Cellular system

All the three types are basically the same, consisting a large, generally unbroken area of slab covering the whole or large part of the structure. The thickness of the slab and the size of beams (if any) will be governed by the spacing and loading of the column and degree of rigidity required in the raft.



(a) R.C.C. raft with slab only (b) R.C.C. raft with slab and beam

- Sometimes the design of the raft is so adjusted that the weight of the excavated earth is just equal to the total load of the buildings. Thus the loading on the soils remains practically the same after the construction of the buildings. This is known as floating foundation and in such case the settlement is reduced to a minimum extent.

2.4.1.1 Shallow foundation for walls

Usually, spread footings, in which the width of foundations is gradually increased, are provided for walls. These foundations are built after opening trenches to the required depth.

The minimum depth required for such footings is determined using Rankine's formula

$$H = \frac{p}{w} \left(\frac{1 - \sin\phi}{1 + \sin\phi} \right)^2$$

where, p = safe bearing capacity of soil, w = unit weight of soil, ϕ = angle of repose of soil

However, the depth should not be less than 0.9 m in any case.

Width of foundation for wall is determined from the formula given below:

$$\text{Width of foundation} = \frac{\text{Load per unit length of wall}}{\text{SBC of soil}}$$

In any case, it shall not be less than the width of the wall plus 300 mm.

If the SBC of the soil is poor, inverted arch foundations may be provided to the walls. Between two walls, inverted arches are built with bricks or stone. The end walls should be sufficiently thick and strong to withstand the outward horizontal thrust due to arch action. Sometimes, outer walls are provided with buttress walls to strengthen them.

2.4.1.2 Shallow foundation for masonry columns

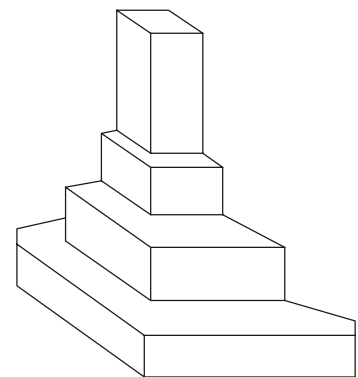
Figure shows a typical foundation for a masonry column. The area of footing required may be found from the formula.

$$\text{Area of footing} = \frac{\text{Load carried by column}}{\text{SBC of soil}}$$

Depth of the foundation is calculated from equation

$$H = \frac{p}{w} \left(\frac{1 - \sin\phi}{1 + \sin\phi} \right)^2$$

To provide footings for walls and masonry columns, trenches of required size are dug to the required depth and the soil is removed. Then a bed concrete of mix 1 : 4 : 8 of thickness 150-200 mm is provided. A stone masonry footing is built over this bed of concrete. It is built in suitable number of courses, each course projecting by 50-75 mm from the top course and height of each course varying from 150-200 mm. In case of wall footing, the projection is only in one direction while in case of columns the projections are in both directions. The projection of bed concrete need not extend beyond the face of the lowest course beyond its thickness.



Spread footing for masonry columns



Example - 2.1 For a proposed building, raft foundation, isolated footings and combined footings are being considered. These foundations are to be listed in the decreasing order of preference in terms of performance. Which one of the following is the correct order of listing?

- (a) Raft foundation - Combined footings - Isolated footings
- (b) Isolated footings - Raft foundations - Combined footings
- (c) Combined footings - Raft foundations - Isolated footings
- (d) Combined footings - Isolated footings - Raft foundations

[MPPSC]

Solution: (a)

As the size of foundation increases, the differential settlement decreases. Hence foundation bigger in sizes are preferred. Therefore Mat or Raft foundations are most desired and isolated footings are least desired.

2.4.2 Deep Foundation

Deep foundations may be of the following types:

1. Pile foundation
2. Pier foundation or drilled caisson foundation
3. Well foundation or caissons

1. Pile foundation

Pile foundation is that type of deep foundation in which the loads are taken to a low level by means of vertical members which may be of timber, concrete or steel.

Use of Pile: Pile foundation are relatively long, slender members and are either driven into the ground or bored cast-in-situ.

The situations which demand piles as foundations are as follows:

- (i) The load coming from the structure is very heavy and the distribution of load on soil is uneven.
- (ii) The subsoil water level is likely to rise or fall appreciably. This may be seasonal or occasional variation.
- (iii) The pumping of subsoil water is too costly for keeping the foundation trench in dry condition.
- (iv) The construction of raft or grillage foundations is likely to be very expensive or is practically impossible.
- (v) The firm bearing stratum exists at a greater depth. The piles upto 20 metres depths are common and under exceptional circumstances, they may even be taken to 30 metres depth. The piles are considered to be long when their length exceeds 30 metres.
- (vi) The timbering to excavations is too difficult to maintain the sides of the foundation trench.
- (vii) The pile foundation is to be adopted for the structures in the area where canals, deep drainage lines, etc. are to be constructed in near future.
- (viii) The structure is situated on sea-shore or river bed and the foundation is likely to be affected by the scouring action of water. Thus, the piles are useful for the marine structures.
- (ix) The piles are also used as anchors. They may be designed to give lateral support or to resist an upward pressure or uplift pressure.
- (x) The piles are used as fender piles in the construction of docks, piers and other marine structures. A fender pile protects the berthing ships from damage.