11.1 Footing Types

Footings may be classified as deep or shallow. If depth of the footing is equal to or greater than its width, it is called deep footing, otherwise it is called shallow footing. Shallow footings comprise the following types:

**Isolated Footings:**

An isolated footing is used to support the load on a single column. It is usually either square or rectangular in plan. It represents the simplest, most economical type and most widely used footing. Whenever possible, square footings are provided so as to reduce the bending moments and shearing forces at their critical sections. Isolated footings are used in case of light column loads, when columns are not closely spaced, and in case of good homogeneous soil. Under the effect of upward soil pressure, the footing bends in a dish shaped form. An isolated footing must, therefore, be provided by two sets of reinforcement bars placed on top of the other near the
bottom of the footing. In case of property line restrictions, footings may be designed for eccentric loading or combined footing is used as an alternative to isolated footing. Figure 11.1 shows square and rectangular isolated footings.

**Wall Footings:**

![Figure 11.2: Wall footing](image)

A wall footing is a strip of reinforced concrete, usually wider than the wall, used to support the loads that the wall carries at the top surface level of the footing. Under the action of soil pressure, it bends in the transverse direction. Thus, main reinforcement is provided in the short direction near the bottom of the footing. Secondary reinforcement is provided in the longitudinal direction to satisfy shrinkage and temperature requirements. Figure 11.2 shows a wall footing.

**Combined Footings:**

In some cases, a column is to be provided near the edge of property and it may not be permissible to extend the footing beyond a certain limit. In such a case, the load on the footing will be eccentric and hence this will result in uneven distribution of load to the supporting soil. Hence, an alternative design would be to provide a common footing to the edge column and to an interior column close to it. Combined footings under two or more columns are used under closely spaced, heavily loaded interior columns where individual footings, if they were provided, would be either very close to each other, or overlap each other. This footing is called “combined footing”. The
shape of combined footing in plan shall be such that the centroid of the foundation plan coincides with the centroid of the loads in the two columns. Combined footings are either rectangular or trapezoidal. Rectangular footings are favored due to their simplicity in terms of design and construction. However, rectangular footings are not always practicable because of the limitations that may be imposed on its longitudinal projections beyond the two columns or the large difference that may exist between the magnitudes of the two column loads. Under these conditions, the provision of a trapezoidal footing is more economical. Figure 11.3 and Figure 11.4 show combined footings supporting two and three column loads respectively.

Figure 11.3.a: Rectangular combined footing;

Figure 11.3.b: Trapezoidal combined footing
Combined footings behave as inverted beams spanning between the columns and subjected to the upward soil pressure. Reinforcement must, therefore, be provided in the longitudinal direction and placed near the tension sides. In addition to this main reinforcement, secondary reinforcement is provided in the short direction and concentrated under each column.

When the spacing between the columns is relatively large, a spine beam is provided to reduce the thickness of the base slab.

**Strap (Cantilever) Footings:**

A strap footing, shown in Figure 11.5, is used wherever the property lines of the building site do not permit a reasonable or no extension of the footing beyond the face of an exterior column. It is also used when the distance between this column and the nearest internal column is long that a combined footing will be too narrow. It consists of two separate footings, one under each column, connected together by a beam called “strap beam”. The purpose of the strap beam is to prevent overturning of the eccentrically loaded footing. It is always subjected to a linearly varying negative moment and constant shear, thus called “cantilever footing”. Its main reinforcement must be provided near its topside.

This type of footing is more economical than combined footings where distance between the columns is long.
Raft (Mat)Footing:
This is a footing that covers the entire area under the structure. This footing is used when very heavy loads of building are to be transmitted to the underlying soil having very low and differential bearing capacities. Due to its rigidity, it minimizes differential settlement.

There are several types of raft foundation in use. The most common types are; the flat slab and the slab-beam types, shown in Figure 11.6.

Where the ground water table is high, rafts are often placed over piles to control buoyancy.
Figure 11.6.a: Raft foundation (Slab type)

Figure 11.6.b: Raft foundation (Slab-beam type)
11.2 Concentrically loaded Footings

If the resultant of the loads acting at the base of the footing coincides with the centroid of the footing area, the footing is concentrically loaded and a uniform distribution of soil pressure is assumed in design, as shown in Figure 11.7. The magnitude of the pressure intensity is given by

\[ q = \frac{P}{A} \]  

(11.1)

where \( A \) is the bearing area of the footing, and \( P \) is the applied load.
11.3 Eccentrically Loaded Footings

Although it is always desirable to load footings axially to ensure uniform settlement and to minimize soil pressures, footings are often designed for both axial load and moment. Moment may be caused by lateral forces due to wind or earthquake, and by lateral soil pressures.

If the resultant of the loads acting at the base of the footing does not coincide with the centroid of the footing area, the footing will be eccentrically loaded and the distribution of the soil pressure will not be uniform. Depending on the extent of the eccentricity of the load relative to the dimensions of the base area, one of the following cases may occur:

**Case (a):** $e \leq L/6$

The resultant lies within the middle third of the length of the footing. In this case the pressure distribution on the soil is given by

$$q_{\text{max}} = \frac{P}{A} \left(1 + \frac{6e}{L}\right)$$  \hspace{1cm} (11.2)

$$q_{\text{min}} = \frac{P}{A} \left(1 - \frac{6e}{L}\right)$$  \hspace{1cm} (11.3)

where $L$ is the length of the footing, and $e$ is the eccentricity of load.

In this case, compressive stresses develop over the entire base of the footing, as shown in Figure 11.8.

![Figure 11.8: Eccentrically loaded footings (e ≤ L/6)](image-url)
Case (b): $e > L/6$

Large eccentricities cause tensile stresses on part of the base area of the footing. Since soil cannot resist tensile stresses, redistribution of stresses is necessary to maintain equilibrium. The maximum pressure associated with this stress redistribution is established by knowing that the centroid of the soil pressure is located directly under the vertical component of the applied load. With the dimensions of the footing established and the eccentricity of the vertical load known, the distance between the resultant of the applied load $P$ and the outside edge $a$ can be established. The length of base on which the triangular distribution of soil pressure acts is equal to $3a$.

Equating the resultant of the soil pressure to the applied forces gives

$$\frac{q_{\text{max}} \times 3aB}{2} = P$$

(11.4)

Solving for $q_{\text{max}}$, one gets

$$q_{\text{max}} = \frac{2P}{3aB}$$

(11.5)

where $a = L/2 - e$, and $B$ is the width of footing, as shown in Figure 11.9.

![Eccentrically loaded footing (e > L/6)](image-url)