9. FOOTINGS

ISOLATED FOOTINGS

Footings are structural elements that transfer loads from the building or individual columns to the earth. If these loads are to be properly transmitted, foundations must be and to provide adequate safety against sliding and overturning.

Theoretically speaking isolated footings must be designed for both axial load and moment but practically isolated footings are designed only for axial load.

Foundations may be broadly classified under two heads: *shallow foundation* and *deep foundation*.

According to Terzaghi, a foundation is shallow if its depth is equal to or less than it width. In the case of deep foundation, the depth is greater than the width. Apart from deep strip, rectangular or square foundations, other common forms of deep foundations are; pier foundations, pile foundation and well foundation. The shallow foundations are of the following types: Spread footing, strap footing, combined footing and mat or raft footing.

Spread footings: A spread footing or simply footing, is a type of shallow foundation used to transmit the load of an isolated column, or that of a wall, on the subsoil. In the case of wall, the footing is continuous while in the case of column, is a isolated.

Combined footings: A spread footing which supports two or more columns is termed as a combined footing. Such a footing is provided when the individual footings are either very near to each other, or overlap. Combined footings may either be rectangular or trapezoidal.

Strap or Cantilever footings: A strap footing consists of spread footings of two columns connected by a strap beam. The strap beam does not remain in contact with soil, and thus does not transfer any pressure to the soil.

Mat or Raft foundation: A mat or raft is a combined footing that covers the entire area beneath a structure and supports all the walls and columns. When the available soil pressure is low or the building loads are heavy, the use of spread footings would cover more than one-half of the area and it may prove more economical to use mat or raft foundation.

Pile foundation: Pile foundation is a deep foundation used where the top soil is relatively weak. Piles transfer the load to a lower stratum of greater bearing capacity, by way of end bearing, or to the intermediate soil though skin friction. This is more common type of deep foundation generally used for buildings where a group of piles transfer the load of the super-structure to the sub-soil.

DESIGN OF ISOLATED FOOTING

Rectangular footing

Given values

1. Load = P or P_u
2. Bearing capacity of soil = q_u
3. Size of column
4. Grade of concrete and steel

Design Steps

(i) Size of foundation

Load from column = P

Add weight of foundation (P_F) = 0.1P

∴ Total load P_T = 1.1P (even for limit state method use unfactored load for calculation of area)

∴ Area of footing, $$A = \frac{P_T}{q_u} = \frac{\text{Total load}}{\text{Bearing capacity of soil}}$$

Choose L and B such that A = L × B

Net soil pressure,

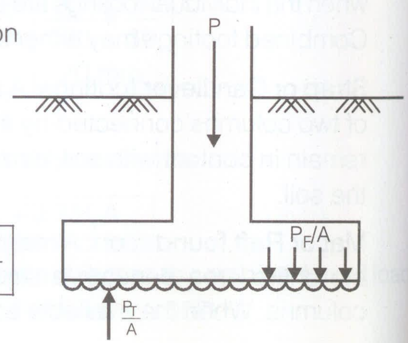
$$w = \frac{P}{A} = \frac{\text{Load from column without self weight}}{\text{Area provided}}$$

Net soil pressure over foundation

$$w = \frac{P_T - P_F}{A} = \frac{P}{A}$$

For LSM

Net soil pressure $$(w_u) = \frac{1.5P}{A}$$



(ii) Check for bending moment

Critical section for bending moment is at the face of the column

Consider 1 m strip of foundation

Bending moment about X_1X_1

$$O_{y_1} = \frac{B-b}{2}$$

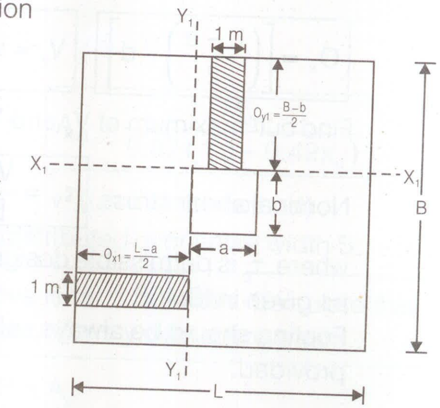
∴ Maximum bending moment

$$\frac{w}{2} \times \left(\frac{B-b}{2}\right)^2 = \frac{w(B-b)^2}{8}$$

Similarly moment about Y_1Y_1

$$O_{x_1} = \frac{L-a}{2}$$

Maximum BM $$M_y = \frac{w}{2} \times \left(\frac{L-a}{2}\right)^2 = \frac{w(L-a)^2}{8}$$



NOTE: Use $w = w_u = 1.5$ w for Limit State Method.

(iii) Depth required $$d = \sqrt{\frac{M_{max}}{QB}}$$ Where, B = 1000 mm

For LSM $$d = \sqrt{\frac{M_{umax}}{QB}}$$

(iv) Check for single shear (one-way shear)

Critical section for one-way shear is at 'd' distance from the face of the column.

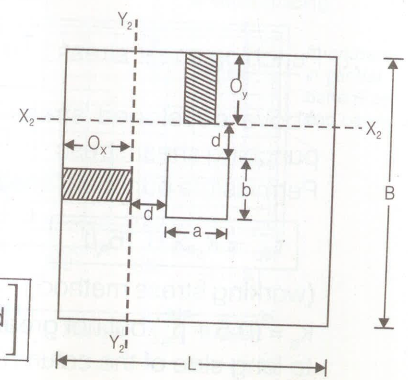
Shear at X_2X_2

Overhang,

$$O_y = \left[\left(\frac{B-b}{2}\right) - d\right]$$

Shear force,

$$V_x = w.1 \times O_y = w\left[\left(\frac{B-b}{2}\right) - d\right]$$



Similarly Shear force at Y_2Y_2

Overhang,

$$O_x = \left[\left(\frac{L-a}{2}\right) - d\right] \qquad V_y = w.1 \times O_x = w\left[\left(\frac{L-a}{2}\right) - d\right]$$

Find out maximum of V_x and V_y

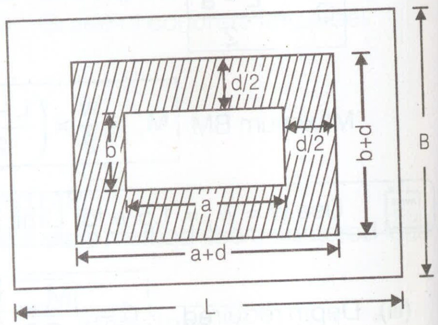
Nominal shear stress $\tau_V = \dfrac{V_{max}}{Bd} < \tau_C$

where, τ_c is permissible design shear strength of concrete in N/mm^2 as given in IS:456

Footing should be always safe in shear. No shear reinforcement is provided.

(v) Check for two-way (Punching Shear).

Critical section for punching shear also called two-way shear is at (d/2) distance from face of the column all around.



Net punching force

$$P_{net} = P - w(a+d)(b+d)$$

$$\text{Punching shear stress developed} = \frac{\text{Net punching force}}{\text{cross-section area of resisting section}}$$

$\therefore$ Cross-section area = perimeter × depth

Now perimeter = 2[(a+ d) + (b+ d)], Depth = d

$$\therefore \text{ Punching shear stress } \tau_{vp} = \frac{P - w(a+d)(b+d)}{2[(a+d)+(b+d)] \times d}$$

Above developed stress should be less than the permissible punching shear stress

Permissible punching shear stress

$$\tau_{cp} = k_s \times 0.16\sqrt{f_{ck}} \qquad \tau_{cp} = k_s \times 0.25\sqrt{f_{ck}}$$

(working stress method) (Limit state method)

$k_s = (0.5 + \beta_c)$ but not greater than 1, β_c being the ratio of short side to long side of the column

(vi) Area of steel for longer span

The area of steel A_{st} of long bars parallel to direction L is calculated as under

For M_y moment

$$A_{st} = \frac{M_y}{\sigma_{st} jd} \qquad A_{st} = \frac{M_{uy}}{0.87 f_y (d - 0.42x_u)}$$

(Working stress method) (Limit state method)

This reinforcement is equally distributed over entire width B.

NOTE Area of steel calculated above is for 1 m, width. Calculate this area for width B and distribute uniformly over entire width

For B m, total area of steel = B × A_{st}

(vii) Area of steel for shorter span

The area of steel A_{st} of short bars parallel to direction B is calculated as under

$$A_{st} = \frac{M_x}{\sigma_{st} jd} = \frac{M_{ux}}{0.87 f_y (d - 0.42x_u)} \quad \text{for 1 m}$$

For L m, total area of steel = L × A_{st}

This area is provided in two distinct band widths:

- The central band B of width B, and
- The end bands A, each of width $\frac{1}{2}(L-B)$

The reinforcement in central band width = $\dfrac{2}{\beta + 1}$ × total reinforcement in short direction.

Where, β = ratio of long side to the short side of the footing

The remainder of reinforcement shall be uniformly distributed in outer portions of the footing.