UNIT V DESIGN OF FOOTINGS

Design of axially and eccentrically loaded Square, Rectangular pad and sloped footings

Design of Isolated Column Footing

The objective of design is to determine

1 Area of footing

2 Thickness of footing

3 Reinforcement details of footing (satisfying moment and shear considerations)

4 Check for bearing stresses and development length

This is carried out considering the loads of footing, SBC of soil, Grade of concrete and Grade of steel. The method of design is similar to the design of beams and slabs. Since footings are buried, deflection control is not important. However, crack widths should be less than 0.3 mm.

The steps followed in the design of footings are generally iterative. The important steps in the design of footings are;

- Find the area of footing (due to service loads)
- Assume a suitable thickness of footing
- Identify critical sections for flexure and shear
- Find the bending moment and shear forces at these critical sections (due to factored loads)
- Check the adequacy of the assumed thickness
- Find the reinforcement details
- Check for development length
- Check for bearing stresses

Limit state of collapse is adopted in the design pf isolated column footings. The various design steps considered are;

- Design for flexure

- Design for shear (one way shear and two way shear)

- Design for bearing

- Design for development length

The materials used in RC footings are concrete and steel. The minimum grade of concrete to be used for footings is M20, which can be increased when the footings are placed in aggressive environment, or to resist higher stresses.

Cover: The minimum thickness of cover to main reinforcement shall not be less than 50 mm for surfaces in contact with earth face and not less than 40 mm for external exposed face. However, where the concrete is in direct contact with the soil the cover should be 75 mm. In case of raft foundation the cover for reinforcement shall not be less than 75 mm.
Minimum reinforcement and bar diameter: The minimum reinforcement according to slab and beam elements as appropriate should be followed, unless otherwise specified. The diameter of main reinforcing bars shall not be less 10 mm. The grade of steel used is either Fe 415 or Fe 500.

Problem

Design an isolated footing of uniform thickness for RCC bearing a vertical load 600 KN and having a box of size 500mm x 500mm. The Safe Bearing Capacity of soil is take is 120 KN/m^2, M_{20} , Fe_{415}.

Step 1:

Size of column = 500 x 500 mm

Weight of column 'w' = 600 KN

S.B.C = 120 KN/m^2

f_y = 415 KN/mm^2

f_{ck} = 20 N/mm^2

Step 2:

Size of footing

W = 600 KN

Self weight of footing = 10% of column load

$= \frac{600 \times 10}{100}$

= 60 KN

Total load = 600 + 60

= 660 KN

Area of footing $= \frac{Load}{SBC}$

$= \frac{660}{120}$

$= 5.5m^2$

Area of Square $= a^2 = 5.5$

$\Rightarrow a = \sqrt{5.5}$

$= 2.35$m

Size of Footing = (2.35 x 2.35) m

Step 3:

Net upward pressure

$p_o = \frac{Load}{Width\ (Area\ of\ footing)}$

$= \frac{600}{5.5}$

$= 109.01\ KN/m^2$

Step 4:

a) Depth on basis of Bending Compression

$M = \frac{P_O}{8}$ (B – b) (B - b/4)

$= \frac{109.01}{8}$ [(2.35 – 0.5) (2.35 – 0.5/4)]

M = 56.08 KNm

Factored Moment = 1.5 x 56.08

M_u = 84.12 KNm

M_u lim $= \frac{0.36\ x_{u\,max}}{d} f_{ck} [1 - \frac{0.42\ x_{u\,max}}{d}]\ bd^2$

$= 0.36 \times 0.48 \times 20\ [1 – 0.42\ (0.48)]\ (bd^2)$

M_u lim $= 2.76\ bd^2$

` M_u lim = M_u

$(2.759 \times 2350)\ d^2 = 84.13 \times 10^6$

d = 113.91 ≅ 115mm

D = d + cover

= 115 + 60

D = 175mm

b) Depth on basis of two way shear

Assume, p_t = 0.3%

τ_c from IS 456 Pg No: 73 — 0.25 → 0.36

0.50 → 0.48

τ_c = 0.38

Permissible shear stress, τ_v = τ_c x K

D = 175 mm(IS 456 – 72 P) , K = 1.25

τ_v = 0.38 x 1.25

τ_v = 0.475

Critical section lies 'd' distance from the face of the unit,

$a = \frac{B}{2} - \frac{b}{2}$

$= \frac{2350}{2} - \frac{500}{2}$

a = 425 mm^2

V_u = 1.5 P_o a

= 1.5 x 109.01 x 0.925

V_u = 151.36 N/m^2

$\tau_v = \frac{Vu}{bd}$

$0.475 = \frac{355.44}{2350 \times d}$

d = 318.7mm ≅ 320mm

c) Depth on basis of two way shear,

$b_0 = \frac{d}{2} + \frac{d}{2} + b$

d = 320mm

b_0 = 820mm

Shear force, F = $P_o\ [B^2 - {b_0}^2]$

= $110\ [2.35^2 - 0.820^2]$

F = 532.61 KN ≅ 530 KN

F_u = 1.5 x 530

= 795 KN

Shear stress

τ_v = $\frac{Fu}{4 \times b_0 \times d}$

= $\frac{795 \times 10^3}{4 \times 820 \times 320}$

τ_v = $0.757\ N/mm^2$

Permissible shear stress

τ_v ≤ $k_s \tau_c$

k_s = $0.5 + B_c$

B_c = $\frac{shoter\ side\ of\ column}{Longer\ side\ of\ column}$

= $\frac{500}{500}$ = 1

k_s = 0.5 + 1

k_s = 1.5

Take, k_s = 1

τ_c = $0.25\sqrt{f_{ck}}$

= $0.25\sqrt{20}$

τ_c = $1.118\ N/mm^2$

k_s x τ_c = 1 x 1.118

= $1.118\ N/mm^2$

τ_v < $k_s \tau_c$

Hence Safe

Step 4: Design of Reinforcement

M_u = $0.87\ f_y\ Ast\ d\ [1- \frac{f_y Ast}{bd\ f_{ck}}]$

84.195×10^6 = $0.87 \times 415 \times Ast \times 320\ [1- \frac{415 \times Ast}{20 \times 320 \times 2350}]$

= $115536 \times Ast\ (1- 2.7 \times 10^{-5} Ast)$

Ast = 743.66 ≅ 745 mm

Provide 7nos of 12mm ∅ bars at 150mm spacing C/C.

Step 5:

Check for development length

i. L_d = $47 \times \emptyset$

= 47×12

= 564 mm

ii. Length of bar, L_o = $\frac{1}{2}(B - b) - d_c$

= $\frac{1}{2}(2350 - 500) - 60$

= 865 mm

$\because L_o > L_d$

Hence safe against development length.

Step 6:

Transfer of load at column base

$$\frac{2}{1} = \frac{b'}{385}$$

$b' = 770$mm

A_1 = $(500 + 770 + 770)^2 = 2040^2$

A_2 = 500^2

Adopt minimum value, $\sqrt{\frac{A_1}{A_2}} = 2$ ⇢ **(IS 456 pg: 65)**

$$= \sqrt{\frac{2040^2}{500^2}} = 4.08$$

Adopt value of $\sqrt{\frac{A_1}{A_2}} = 2$

Permissible bearing pressure = $0.45\, f_{ck} \sqrt{\frac{A_1}{A_2}}$

= $0.45 \times 20 \times 2$

= 18 N/mm^2

Step 7:

Actual bearing pressure

A.B.P = $\frac{Load}{Area}$ = $\frac{600 \times 10^3}{500 \times 500}$

= 2.8 N/mm^2

Check :

Actual bearing pressure & permissible bearing pressure

$2.4 < 18$

Hence safe

<u>Reinforcement Details</u>