	SRI VIDYA COLLEGE OF ENGINEERING & TECHNOLOGY VIRUDHUNAGAR	

CE6505 DESIGN OF REINFORCED CONCRETE ELEMENTS

UNIT- V

LIMIT STATE DESIGN OF FOOTINGS

QUESTIONS & ANSWERS

PART – A

1. What are the causes of failure of foundation?

Any one or more of the following may causes failure of foundation

- Unequal settlement of the subsoil
- Horizontal movement of the soil adjoining the structure
- Shrinkage due to withdrawal of moisture from the soil below the foundation
- Lateral pressure tending to overturn the structure
- Action of atmosphere

2. What are the assumptions made in the design of footings?

The following are made

1. Foundation is rigid
2. The distribution of pressure from soil on the base is uniform

3. Name the common types of foundations?

The various types of foundations commonly used

1. Spread footings
2. Combined footings
3. Eccentricity loaded footings
4. Raft or Mat foundation
5. Pile Foundation

5. What are the causes of structural distress?

The various reasons for serviceability distress are attributed to the following factor

1. Large deflections of the floor slab and beam affecting the partition walls
2. Insufficient cover leading to corrosion of reinforcement and spilling of concrete
3. Improper slopes on roofs resulting in ponding of water and dampness due to poor drainage.
4. Local cracking of beams and slabs
5. Growth of algae and moss of wet surface of roof slabs leading to discoloration dampness.

6. What are the causes for the failure of a structure?

The ultimate failure or collapse of the structural concrete elements is due to the following reasons.

1. Improper design and detailing leading to primary of load bearing members.
2. Lack of quality control during construction may significantly reduce the design strength of concrete leading to sudden collapse of the member.
3. Use of poor quality materials.
4. Failure may also occur due to overloading or due to natural calamities like earthquake etc
5. Improper maintenance may lead to progressive collapse of the structure.

8. What are the guidelines to be followed while lapping the bars?

The following guide lines to be followed while lapping the bars.

1. Lapping should be avoided at points of maximum tensile stress such as the center of beams and slabs.
2. In structural concrete members, no more than 50% of the bars should be lapped at one place.
3. The lap length provided should be sufficient to transfer the entire force from one bar to the other.
4. The lap length should be based on the basis of smaller bars when two bars of different diameters are lapped.

9. What are the common shapes of reinforcement?

Reinforcements used in structural concrete members may be in different shapes as straight or cranked bars, single or double legged stirrups or bundled bars.

UNIT 5

LIMIT STATE DESIGN OF FOOTING

PROBLEM 1

A rectangular column 400 mm × 600 mm carries a live load of 2000 kN. The safe bearing capacity of the soil is 150 kN/m². Using M20 concrete and Fe415 steel design a rectangular footing to support the column. Adopt limit state design method.

(Anna Univ. Nov/Dec. 2010)

Solution

(i) Given Data

$P_u = 2000$ kN ; $f_{ck} = 20$ N/mm²

$b = 400$ mm ; $f_y = 415$ N/mm²

$D = 600$ mm

$q_s = 150$ kN/m²

$q_u = 1.5 \times 150$ kN/m²

(ii) Size of Footing

Load on column = 2000 kN

Assume self weight is ignored

Total factored load, $W_u = 2000$ kN

$$\text{Footing area} = \frac{2000}{1.5 \times 150} = 8.9 \text{ m}^2 \approx 10 \text{ m}^2$$

Footing is proportioned approximately in the same proportion as that of the column sides.

Hence $4x \times 6x = 10$

$x = 0.65$

Short side of footing $= 4x = 4 \times 0.65 = 2.63$ m ≈ 2.5 m

Long side of footing $= 6x = 5 \times 0.65 = 3.94$ m ≈ 4.0 m

Factored soil pressure,

$$q_u = \frac{2000}{2.5 \times 4.0} = 200 \text{ kN/m}^2 < 1.5 \times 150 = 225 \text{ kN/m}^2$$

Hence the footing area is adequate since the soil pressure developed at the base is less than the factored bearing capacity of the soil.

(iii) Factored Bending Moment

$$\left.\begin{array}{l}\text{Cantilever projection from the}\\ \text{short side face of the footing}\end{array}\right\} = 0.5\,(4 - 0.6) = 1.70 \text{ m}$$

$$\left.\begin{array}{l}\text{Cantilever projection from the}\\ \text{long side face of the footing}\end{array}\right\} = 0.5\,(2.5 - 0.4) = 1.05 \text{ m}$$

$$\left.\begin{array}{l}\text{Bending moment at short}\\ \text{side face of the column}\end{array}\right\} = \frac{q_u \times L_y^2}{2} = \frac{200 \times 1.7^2}{2} = 289 \text{ kN.m}$$

$$\left.\begin{array}{l}\text{Bending moment at long}\\ \text{side face of the column}\end{array}\right\} = \frac{q_u \times L_x^2}{2} = \frac{200 \times 1.05^2}{2} = 110.25 \text{ kN.m}$$

(iv) Depth of Footing

(a) From moment consideration

$$M_u = 0.138 f_{ck}\, b\, d^2$$

$$\therefore \qquad d = \sqrt{\frac{M_u}{f_{ck}\, b}} = \sqrt{\frac{289 \times 10^6}{0.138 \times 20 \times 10^3}} = 323.6 \text{ m}$$

(b) From shear stress consideration

For one-way shear the critical section is located at a distance d from the face of t

$$\left.\begin{array}{l}\text{Shear force per metre width}\\ \text{(longer direction)}\end{array}\right\} V_{uL} = q_u\left(\frac{L_y}{2} - \frac{600}{2} - d\right) N$$

$$V_{uL} = 200\left(\frac{4000}{2} - \frac{600}{2} - d\right) N = 200\,(1700 - d)\, N$$

Assuming shear strength $\tau_c = 0.36 \text{ N/mm}^2$ for M20 concrete with nominal of steel, $p = 0.25$

$$\tau_c = \frac{V_{uL}}{b\, d}$$

$$0.36 = \frac{200\,(1700 - d)}{1000 \times d}$$

$$360\,d = 140000 - 200\,d$$

$$d = 250 \text{ mm}$$

Adopt effective depth as 350 mm and overall depth as 400 mm.

(v) Reinforcement

(a) Longer Direction

$$M_u = (0.87\,f_y\,A_{st}\,d)\left[1 - \left(\frac{A_{st} f_y}{b\,d\,f_{ck}}\right)\right]$$

$$289 \times 10^6 = 0.87 \times 415 \times A_{st} \times 350\left[1 - \frac{A_{st} \times 415}{10^3 \times 350 \times 20}\right]$$

$$289 \times 10^6 = 126367.5\,A_{st} - 7.49\,A_{st}^2$$

$$A_{st}^2 - 16871.5\,A_{st} + 38584779.7 = 0$$

$$A_{st} = \frac{+\,16871.5 \pm \sqrt{(-\,16871.5)^2 - 4 \times 1 \times 38584779.7}}{2}$$

$$(A_{st})_l = \frac{16871.5 \pm 11415.3^2}{2} = 2728 \text{ mm}^2$$

$$\left.\begin{array}{l}\text{No. of bars per metre length}\\ \text{of 20 mm dia. bars}\end{array}\right\} = \frac{2728}{\pi \frac{20^2}{4}}$$

$$= 8.7$$

$$\text{Spacing } = \frac{1000}{8.7} = 114.9 \text{ mm} \approx 100 \text{ mm}$$

Adopt 20 mm diameter bars at 100 mm centres $((A_{st})_l = 314 \times 10 = 3140 \text{ mm}^2)$

(b) Shorter Direction

$$110 \times 10^6 = 0.87 \times 415 \times A_{st} \times 350\left[1 - \frac{415\,A_{st}}{10^3 \times 350 \times 20}\right]$$

$$A_{st}^2 - 16871.5\,A_{st} + 14686248.3 = 0$$

$$A_{st} = \frac{+16871.5 \pm \sqrt{(-16871.5)^2 - 4 \times 14686248.3}}{2}$$

$$(A_{st})_s = \frac{+16871.5 \pm 15030.1^2}{2} = 920.7 \text{ mm}^2$$

Provide 16 mm dia bars at 200 mm centres.

(c) Central Band

Central band width = Width of footing = 2.5 m.

$$\frac{\text{Reinforcement in central band}}{\text{Total reinforcement in short direction}} = \frac{2}{\beta + 1}$$

$$\beta = \frac{4}{2.5} = 1.6$$

$$\therefore \left.\begin{array}{l}\text{Reinforcement in the central}\\ \text{band of 2.5 m}\end{array}\right\} = \left(\frac{2}{1.6+1}\right) 920.7 \times 2.5$$

$$(A_{st})_{cb} = 1770.6 \text{ mm}^2$$

Minimum reinforcement $= 0.0012 \times 1000 \times 400$

$$= 960 \text{ mm}^2 < 1770.6 \text{ mm}^2$$

Hence provide 16 mm dia bars at 110 mm centres ($(A_{st})_{cb} = 1809 \text{ mm}^2$)

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

$$\left.\begin{array}{l}\text{Ultimate shear force per}\\ \text{metre width in the longer direction}\end{array}\right\} V_{uL} = 200\ (1700 - 350)/10^3$$

$$V_{uL} = 270 \text{ kN}$$

$$\frac{100\,(A_{st})_l}{b\,d} = \frac{100 \times 3140}{10^3 \times 350} = 0.90$$

From Table 19 of IS456-2000 the permissible stress in concrete is got as

$$k_s\,\tau_c = 1 \times 0.596 = 0.596 \text{ N/mm}^2$$

Nominal shear stress $\tau_v = \frac{V_u}{b\,d} = \frac{270 \times 10^3}{10^3 \times 350} = 0.77 \text{ N/mm}^2$

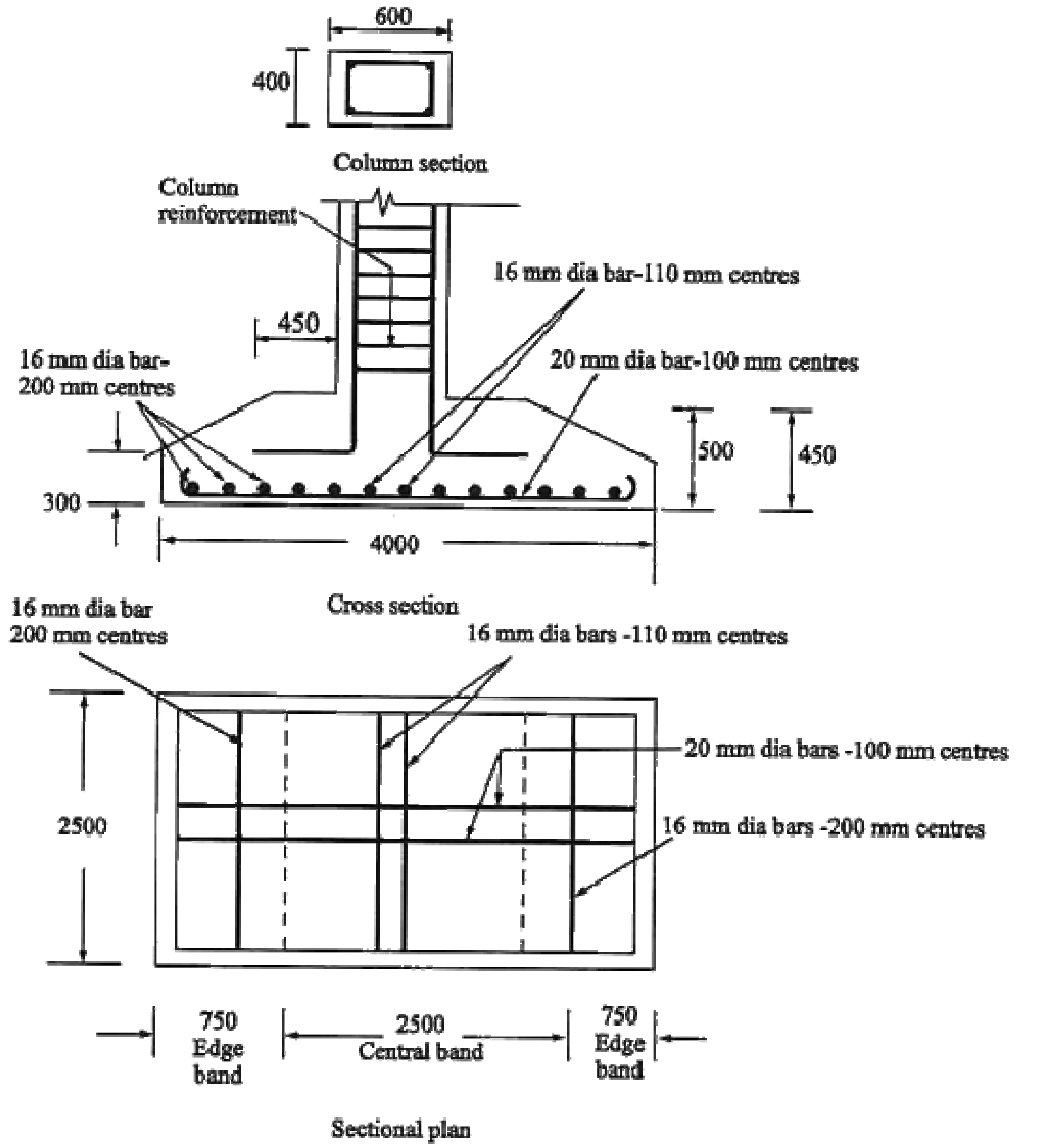
Making $k_s\,\tau_c = \tau_v = 0.596$ and the depth may be worked out as

$$\tau_v = 0.596 = \frac{270 \times 10^3}{10^3 \times d}$$

$\therefore \quad d = 453$ mm

Adopt a revised effective depth of 450 mm and overall depth of 500 mm.

(vi) Details of Reinforcement.



Details of reinforcement of the rectangular footing

PROBLEM 2

Design a suitable footing for a R.C. column of size 300 × 500 mm supporting a factored load of 1500 kN. Assume safe bearing capacity of the soil as 200 kN/m². Adopt M20 concrete and Fe415 grades. Sketch the details of reinforcements in footing.

(Anna Univ. May/June 2012)

Solution

(i) Given Data

$$P_u = 1500 \text{ kN}; \quad f_{ck} = 20 \text{ N/mm}^2$$

$$b = 300 \text{ mm}; \quad f_y = 415 \text{ N/mm}^2$$

$$D = 500 \text{ mm}$$

$$q_s = 200 \text{ kN/m}^2 \quad \text{Factored SBC} = 1.5 \times 200 = 300 \text{ kN/m}^2$$

(ii) Size of Footing

$$\text{Load on column} = 1500\, kN$$

$$\left.\begin{array}{l}\text{Self weight of the}\\ \text{footing (assumed)}\end{array}\right\} 10\% = 150 \text{ kN}$$

Total factored load $= W_u = 1650 \text{ kN}$

Footing area $= \dfrac{1650}{700} = 5.5 \text{ m}^2 \approx 6.0 \text{ m}^2$

Proportion the footing area in the same proportion as the sides of the column

Hence $(3x) \times (5x) = 6$

$\therefore \quad x = 0.63 \text{ m}$

Short side of footing $= 3 \times 0.63 = 1.89 \text{ m}$

Long side of footing $= 5 \times 0.63 = 3.25 \text{ m}$

Adopt a rectangular footing of size 2 m by 3 m.

Factored soil pressure at the base is given as

$$q_u = \frac{1650}{2 \times 3} = 275 \text{ kN/m}^2 < 300 \text{ kN/m}^2$$

Hence the footing area is adequate

$$360\,d = 275 \times 1250 - 275\,d$$

$$d = \frac{275 \times 1250}{(360 + 275)} = 541 \text{ mm}$$

Adopt effective depth of 550 mm and overall depth of 600 mm.

(v) Reinforcement Details

(a) Longer direction

$$M_u = (0.87 f_y A_{st}\, d)\left[1 - \frac{A_{st} f_y}{b\, d\, f_{ck}}\right]$$

$$214.8 \times 10^6 = 0.87 \times 415 \times 550\, A_{st}\left[1 - \frac{415 f_y}{10^3 \times 550 \times 20}\right]$$

$$214.8 \times 10^6 = 198577.5\, A_{st} - 7.49\, A_{st}^2$$

$$A_{st}^2 - 26512.4\, A_{st} + 28571428.6 = 0$$

$$(A_{st})_l = \frac{+26512.4 \pm \sqrt{(-26512.4)^2 - 4 \times 1 \times 28571428.6}}{2}$$

$$(A_{st})_l = \frac{26512.4 \pm 24261.5^2}{2} = 1125.5 \text{ mm}^2$$

Adopt 16 mm diameter bars at 160 mm centres $((A_{st})_l = 1257 \text{ mm}^2)$

(b) Shorter Direction

$$99.3 \times 10^6 = 0.87 \times 415 \times A_{st} \times 550\left[1 - \frac{415\, A_{st}}{10^3 \times 550 \times 20}\right]$$

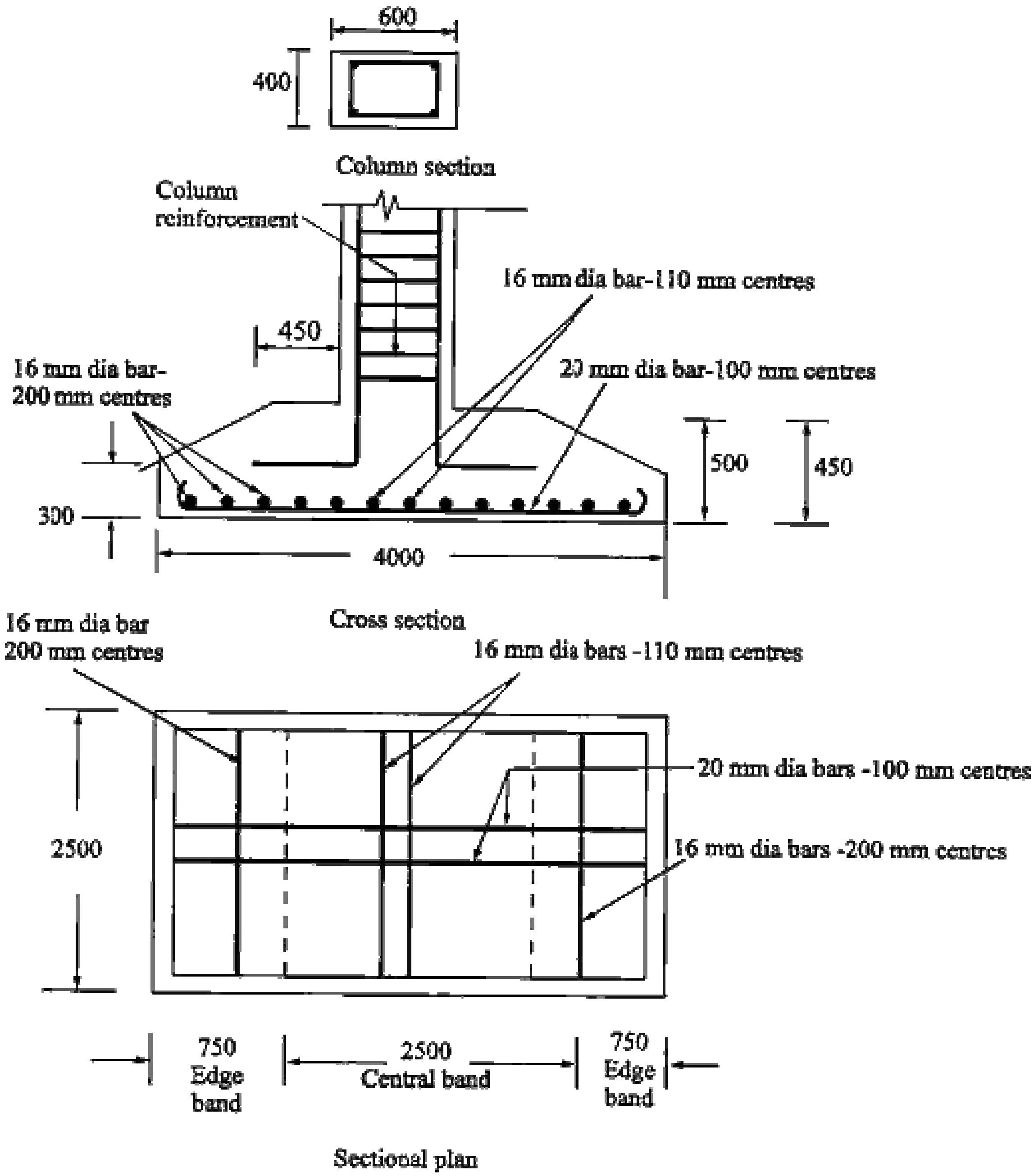
$$99.3 \times 10^6 = 198577.5\, A_{st} - 7.49\, A_{st}^2$$

$$A_{st}^2 - 26512.4\, A_{st} + 13257676.9 = 0$$

$$(A_{st})_s = \frac{+26512.4 \pm \sqrt{(-26512.4)^2 - 4 \times 1 \times 13257676.9}}{2}$$

$$(A_{st})_s = \frac{+26512.4 \pm 25492.7}{2} = 510 \text{ mm}^2$$

Provide 12 mm dia bars at 200 mm centres $[(A_{st})_s = 565 \text{ mm}^2]$



Details of reinforcement of the rectangular footing

PROBLEM 3

Design a footing for 250 mm thick masonry wall which supports a load of 200 kN/m a service state for the following data: Safe bearing capacity of soil = 150 kN/m²
Angle of repose of soil = 30°
Unit weight of soil = 20 kN/m³ **(Anna Univ. Nov/Dec. 2007**

Solution

(i) Given Data

Wall thickness = 250 mm

Service load = 200 kN/m

$q_s = 150$ kN/m², Unit wt. of soil = 20 kN/m³ Angle of repose = 30°

(ii) Depth of foundation

$$\text{Depth of foundation, } h = \frac{q_s}{\gamma_w}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

i.e.,

$$h = \frac{150}{20}\left(\frac{1-\sin 30°}{1+\sin 30°}\right)^2 = 0.83 \text{ m}$$

(iii) Width of Footing

Factored load, $w_u = 1.5 \times 200 = 300$ kN/m

Factored soil pressure, $q_u = 1.5 \times 150 = 225$ kN/m²

Considering one metre length of footing width,

$$B \times 1 = \frac{\text{Load}}{q_u} = \frac{300}{225} = 1.33 \text{ m}$$

Provide 1.5 m width of footing.

(iv) Depth of Footing

$$\text{Bending moment} = \frac{q_u \times L^2}{2} = \frac{225 \times (0.75 - 0.125)^2}{2}$$

$$= 43.95 \text{ kN.m}$$

$$M_u = 0.138 f_{ck}\, b\, d^2$$

$$d = \sqrt{\frac{M_u}{0.138 \times f_{ck} \times b}} = \sqrt{\frac{43.95 \times 10^6}{0.138 \times 20 \times 10^3}} = 126 \text{ mm} \approx 150 \text{ mm}$$

with cover provide a depth of 200 mm.

(v) Reinforcement

$$M_u = (0.87 f_y A_{st} d)\left[1 - \frac{A_{st} f_y}{b\, d\, f_{ck}}\right]$$

$$43.95 \times 10^6 = 0.87 \times 415 \times A_{st} \times 150\left[1 - \frac{415 \times A_{st}}{10^3 \times 150 \times 20}\right]$$

$$A_{st} = 931.6 \text{ mm}^2$$

PROBLEM 4

A square footing has to transfer a dead load of 900 kN and an imposed load of 500 kN for a square column of size 400 mm. Assume the safe bearing capacity of the soil as 200 kN/m². Design a square footing to support the above column. Adopt M20 grade concrete and Fe-415 grade steel. **(Anna Univ. Nov/Dec. 2007, April/May 2008, Nov/Dec. 2011)**

Solution

(i) Given Data

Dead load $= 900$ kN; $f_{ck} = 20$ N/mm^2

Imposed load $= 500$ kN; $f_y = 415$ N/mm^2

$b = D = 400$ mm

$q_u = 200$ kN/m^2; Factored $q_u = 1.5 \times 200 = 300$ kN/m^2

(ii) Size of Footing

Dead Load $= 900$ kN

Imposed Load $= 500$ kN

Total factored load, $W_u = 1400$ kN

Footing area $= \dfrac{1400}{1.5 \times 200} = 4.7$ m^2

Side of square footing $= \sqrt{4.7} = 2.17$ m ≈ 2.3 m

Adopt a square footing of size $2.3 \text{ m} \times 2.3 \text{ m}$

Factored soil pressure at the base $= \frac{1400}{2.3^2} = 264.7 \text{ kN/m}^2$

$$< 300 \text{ kN/m}^2$$

Hence the footing area is adequate since the soil pressure developed at the base is less than the factored bearing capacity of the soil.

(iii) Factored Bending Moment

Cantilever projection from the face of the column $\} = 0.5\,(2.3 - 0.4)$

$$= 0.95 \text{ m}$$

Bending moment on either side $\} = \frac{q_u L^2}{2} = \frac{1.5 \times 200 \times 0.95^2}{2} = 135.4 \text{ kN.m}$

(iv) Depth of Footing

(a) Depth from moment consideration

$$M_u = 0.138 f_{ck}\, b\, d^2$$

$$d = \sqrt{\frac{M_u}{0.13 f_{ck}\, b}} = \sqrt{\frac{135.4 \times 10^6}{0.138 \times 20 \times 10^3}} = 221.5 \text{ mm}$$

(b) Depth from shear consideration

Shear force per metre width

$$V_u = 264.7\left(\frac{2300}{2} - \frac{400}{2} - d\right) N$$

Assuming the shear strength of $\tau_c = 0.36 \text{ N/mm}^2$ for M-20 grade concrete with nominal percentage of reinforcement, $p = 0.25$

$$\tau_c = \frac{V_u}{b\,d}$$

$$0.36 = \frac{264.7\,(950 - d)}{1000 \times d}$$

$$360d + 264.7d = 264.7 \times 950$$

$$d = 402.5 \text{ mm}$$

Hence effective depth, $d = 450$ mm and overall depth, $D = 500$ mm.

(v) Reinforcement

$$M_u = (0.87 \times f_y \times A_{st} \times d)\left[1 - \left(\frac{A_{st} f_y}{b\, d f_{ck}}\right)\right]$$

$$135.4 \times 10^6 = (0.87 \times 415 \times A_{st} \times 450)\left[1 - \frac{415\, A_{st}}{10^3 \times 450 \times 20}\right]$$

$$135.4 \times 10^6 = 162472.5\, A_{st} - 7.49\, A_{st}^2$$

$$A_{st}^2 - 21691.9\, A_{st} + 18077436.6 = 0$$

$$A_{st} = \frac{21691.9 \pm \sqrt{(-21691.9)^2 - 4 \times 1 \times 18077436.6}}{2}$$

$$A_{st} = \frac{21691.9 \pm 19955.7}{2} = 868 \text{ mm}^2$$

Provide 16 mm diameter bars at 200 mm centres ($A_{st} = 1004.8 \text{ mm}^2$)

(vi) Check for Shear Stress

$$V_u = 264.7\,(950 - 450)\,10^{-3} = 132.4 \text{ kN}$$

$$p = \frac{100\, A_{st}}{b\, d} = \frac{100 \times 1004.8}{10^3 \times 450} = 0.223$$

From Table 19 of IS:456-2000 the permissible shear stress

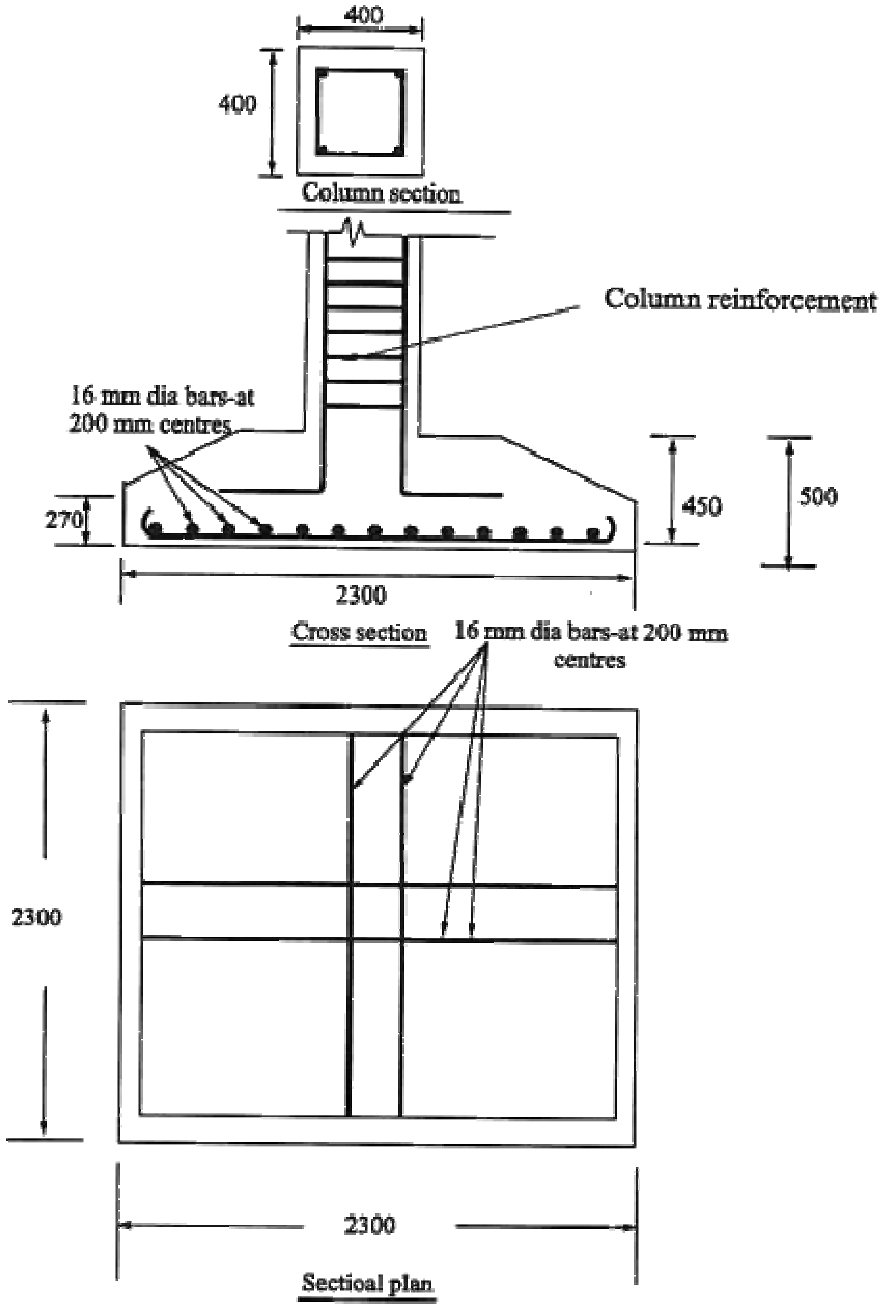
$$= k_s\, \tau_c = 1 \times 0.334 = 0.334 \text{ N/mm}^2$$

Nominal shear stress, $\tau_v = \dfrac{V_u}{b\, d}$

$$\tau_v = \frac{132.4 \times 10^3}{10^3 \times 450} = 0.294 \text{ N/mm}^2$$

Since $\tau_v < k_s\, \tau_c$ shear stresses are within the safe permissible limits.

(vii) Reinforcement Details.



Details of reinforcement of the square footing

PROBLEM 5

A circular column of 480 mm diameter transfers an axial dead load of 650 kN and an axial live load of 500 kN. The column is having 8 steel bars of 18 mm diameter. The safe bearing capacity of the soil is 140 kN/sq.m. Design a circular footing to support the circular column. Use M20 concrete and Fe-415 steel. **(Anna Univ. May/June 2007)**

Solution

(i) Given Data

Diameter of column, $D_c = 480$ mm

Axial dead load $= 650$ kN

Axial live load $= 500$ kN

Safe bearing capacity, $q_s = 140$ kN/sq.m

$f_{ck} = 20$ kN/m^2 $f_y = 415$ N/mm^2

Factored bearing capacity, $q_u = 1.5 \times 140 = 210$ kN/m^2

(ii) Size of Footing

Load on the column $= 650 + 500 = 1150$ kN

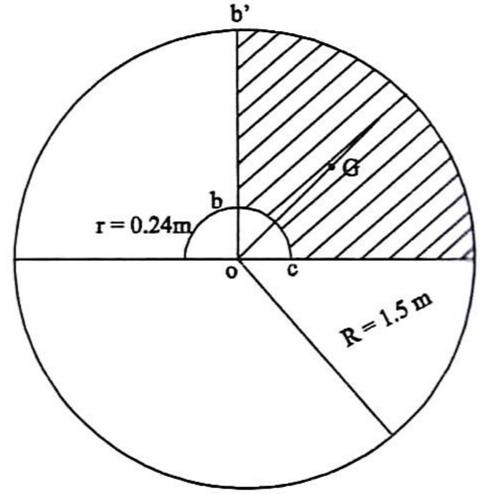
Factored load, $W_u = 1150$ kN

Let D_f be the diameter of the footing

Let A_f be the area of the footing

$$A_f = \frac{\pi D_f^2}{4} = \frac{W_u}{q_u} = \frac{1150}{210} = 5.48 \text{ m}^2$$

$$D_f = \sqrt{\frac{4 \times 5.48}{\pi}} = 2.64 \text{ m}$$



G-Centrid of quadrant bb' cc

Fig. 9.7

Adopt diameter of footing $= 3$ m

Upward soil pressure, $q_u = \dfrac{1150 \times 4}{\pi \times 3^2} = 162.8$ kN/m$^2 < 210$ kN/m^2

Hence the diameter of the footing is adequate.

Centre of gravity of quadrant of footing '*obc*' from '0'

$$= 0.6\left[\frac{R^2 + r^2 + R.r}{R + r}\right]$$

$$= 0.6\left[\frac{1500^2 + 240^2 + 1500 \times 240}{1500 + 240}\right]$$

$$= 920 \text{ mm}$$

Upward load on area $b\,b'\,c'\,c$

$$= \frac{\pi\,(1.5^2 - 0.24^2) \times 162.8}{4} = 280 \text{ kN}$$

(iii) Bending Moment

Maximum bending moment at the face of the column $\Big\}$ $M_u = 280\,(0.92 - 0.24)$

$$M_u = 190.4 \text{ kN.m}$$

Breadth of footing at column face (for one quadrant $c'\,b'$)

$$= \frac{\pi \times D_c}{4} = \frac{\pi \times 480}{4} = 376.8 \text{ mm}$$

Depth of footing, $d = \sqrt{\dfrac{M_u}{0.138 f_{ck}\, b}}$

$$d = \sqrt{\frac{190.4 \times 10^6}{0.138 \times 20 \times 376.8}} = 427.9 \text{ mm}$$

Depth requirement from shear considerations will be nearly 1.5 times that for moment considerations.

Hence adopt effective depth, $d = 640$ mm and Overall depth $= 700$ mm

(iv) Reinforcement

$$M_u = (0.87 f_y A_{st}\, d)\left[1 - \frac{A_{st} f_y}{b\, d\, f_{ck}}\right]$$

$$190.4 \times 10^6 = 0.87 \times 415 \times 640 \times A_{st}\left[1 - \frac{A_{st} \times 415}{376.8 \times 640 \times 20}\right]$$

$$190.4 \times 10^6 = 31072\, A_{st} - 19.9\, A_{st}^2$$

$$A_{st}^2 - 11611.7\,A_{st} + 9567839.2 = 0$$

$$A_{st} = \frac{11611.7 \pm \sqrt{(-11611.7)^2 - 4 \times 1 \times 9567839.2\,2}}{2}$$

$$A_{st} = 892.6 \text{ mm}^2$$

Minimum $A_{st} = 0.0012 \times 376.8 \times 700 = 316.5 \text{ mm}^2$

Provide 18 mm diameter bars at 250 mm centres (A_{st} = 1016 mm^2)

v) Check for Shear Stresses

Ultimate shear force at a distance d ($d = 640$ mm) from the face of the column

$$V_u = 162.8 \left\{ 3^2 - [2\,(0.640 + 0.24)]^2 \right\}$$

$$= 162.8\,(3^2 - 1.76^2)$$

$$= 960.5 \text{ kN}$$

Shear per metre width of perimeter

$$= \frac{960.5}{\pi \times 1.76} = 173.8 \text{ kN}$$

$$\tau_v = \frac{V_u}{b\,d} = \frac{173.8 \times 10^3}{10^3 \times 640} = 0.27 \text{ N/mm}^2$$

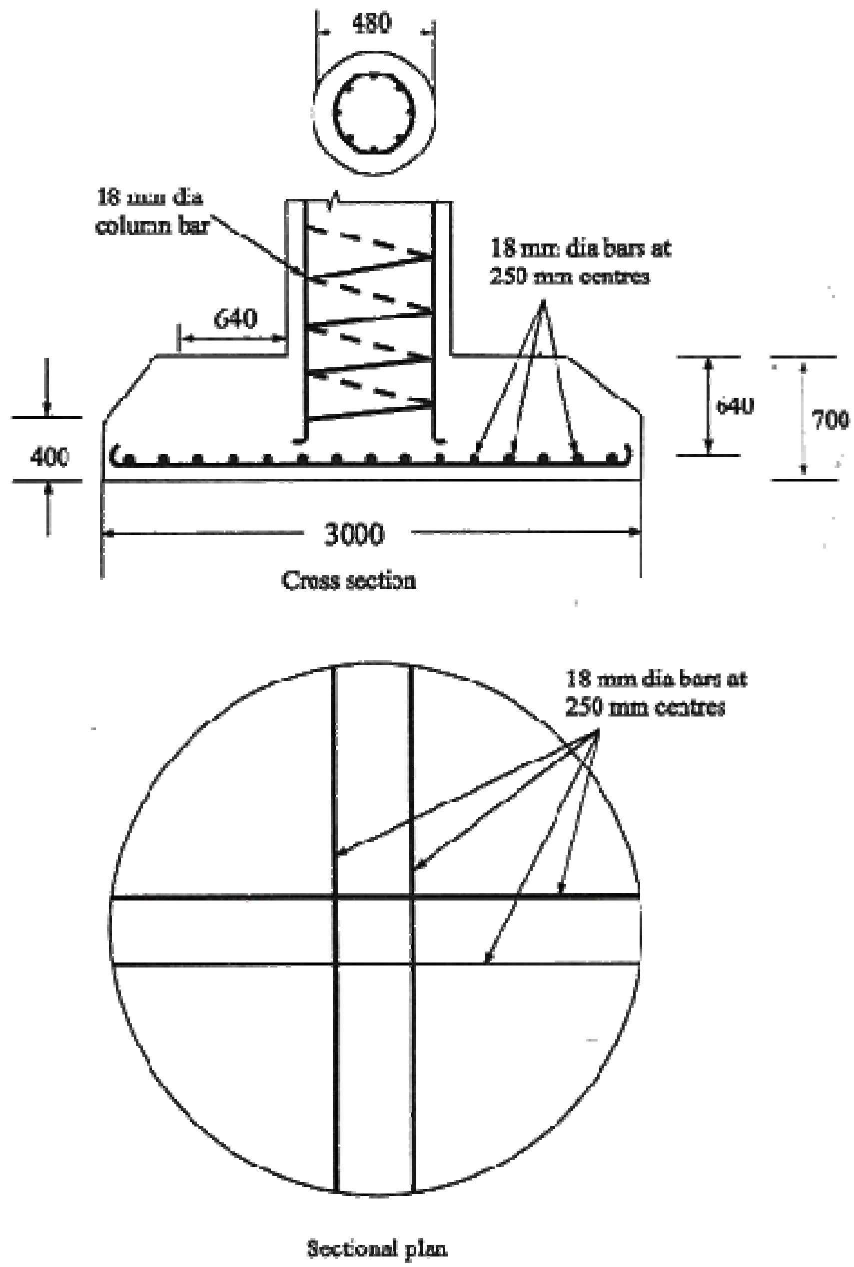
$$p = \frac{100\,A_{st}}{b\,d} = \frac{100 \times 1016}{10^3 \times 640} = 0.16$$

From Table 19 of IS:456-2000, the permissible shear stress is read as

$$k_s\,\tau_c = 1 \times 0.29 = 0.29 \text{ N/mm}^2$$

which is greater than $\tau_v = 0.27$ N/mm^2

(vi) Details of Reinforcement



Details of reinforcement of circular footing