3.4 Proportion of footings:

- A structure is usually supported on a number of column .These column usually carry a different load depending on their location with respect to structure.
- Differential settlements are minimized by proportioning the footing for the various columns so as to equalize the average bearing pressure under all columns.
- But each column load consists of dead load (DL)+Live load(LL).The full LL does not act all the time(wind load)
- Hence DL+ full LL is not a realistic criterion for producing equal settlement.
- For ordinary building the actual load expected on the building is D.L+50% L.L.

Procedure:

i. DL inclusive self weight of column and estimated value for footing is noted for each column footing.

ii. LL for each column is calculated(IS code)

iii. The ratio of LL to DL is calculated for each column footing and the maximum value of ratio is noted.

iv. The allowable bearing pressure is calculated by Terazaghi equation.

v. For the footing with largest LL to DL ratio the area of footing required is calculated by total load by allowable bearing pressure.

$$A = \frac{Q}{allowable\ pressure}$$

vi. The service load for the column is calculated by adding appropriate fraction LL to DL.

vii. The design bearing capacity(q_d) is obtained by dividing the service load of maximum LL to DL ratio by the area of footing

$$q_d = \frac{Service\ load}{A}$$

viii. This pressure is less than the pressure computed in(iv)

ix. The area of footing for each of the column is obtained by dividing the corresponding service load by the allowable bearing pressure

$$A = \frac{\text{service load for that column}}{q_d}$$

Design Procedure for Proportioning of rectangular footing:

Consider dead load + reduced live load

Step1) To find column load

$$Q=Q_1+Q_2$$

Q_1=load in exterior column

Q_2= load in interior column

Step2) Find the area of footing

$$A = \frac{Q}{q_{na}} = \frac{Q}{q_s}$$

$$q_{na} = Allowable\ bearing\ pressure$$

Step3) Locate the line of action of the column loads measured from the centre of the exterior column

$$\bar{x}_1 = \frac{Q_2 x_2}{Q_1 + Q_2}$$

X_2=centre to centre distance between the column

Step4) Define the total length of the footing

$$L = 2(\bar{x} + e_1)$$

$$e_1 = projection\ of\ footing$$

Step 5) Find the width of the footing

$$B = \frac{A}{L}$$

Step6) Find the actual area provided(A_o)

Step 7)Find the actual pressure

Consider dead load +full live load

$$q_{max} = \frac{Q}{A_o}(1 + \frac{6e}{L})$$

$$q_{min} = \frac{Q}{A_o}(1 - \frac{6e}{L})$$

Step 8) Check the Pressure

Actual pressure<allowable pressure

1. Proportion a rectangular combined footing for a uniform pressure under DL+reduced LL with the following data allowable pressure

DL+reduced LL=180 KN/m^2

DL+LL=270 KN/m^2

Column Load

Load	Column A	Column B
DL	500KN	660KN
LL	400KN	840KN

C/C distance of column 5m,Projection of footing is 0.5m

Soln:

Column load	Column A	Column B	Total load
DL+reducedLL	=500+0.5x400 =700KN	$= 660 + \frac{50}{100} 840$ $= 1080KN$	=700+1080=1780KN
DL+LL	=500+400=900KN	=660+840=1500KN	=900+1500=2400KN

Consider full dead load+50% reduced live load

Step1) To find column load

$Q = Q_1 + Q_2 = 700 + 1080 = 1780KN$

Step2)Find the area of footing

$$A = \frac{Q}{q_{na}} = \frac{Q}{q_s} = \frac{1780}{180} = 9.88m^2$$

$$q_{na} = Allowable\ bearing\ pressure$$

Step3)Locate the line of action of the column loads measured from the centre of the exterior column

$$\bar{x}_1 = \frac{Q_2 x_2}{Q_1 + Q_2} = \frac{1080x5}{700 + 1080} = 3.03m$$

X_2=centre to centre distance between the column

Step4)Define the total length of the footing

$$L = 2(\bar{x}_1 + e_1)$$

$$L = 2(3.03 + 0.5) = 7.06m$$

$$e_1 = projection\ of\ footing$$

Step 5) Find the width of the footing

$$B = \frac{A}{L} = \frac{9.88}{7.06} = 1.39m = 1.4m$$

Step6) Find the actual area provided(A_o)

$$A_o = BxL = 1.4x7.06 = 9.88m^2$$

Step 7)Find the actual pressure

$$q_{max} = \frac{Q}{A_o}(1 + \frac{6e}{L})$$

$$q_{min} = \frac{Q}{A_o}(1 - \frac{6e}{L})$$

$$e = \bar{x}_1 - \bar{x}_2$$

Find uniform pressure under full DL+LL

$$\bar{x}_2 = \frac{Q_2 x_2}{Q_1 + Q_2}$$

$$\bar{x}_2 = \frac{1500x5}{900 + 1500} = 3.125m$$

$$e = 3.03 - 3.125 = 0.095 = 0.1m$$

$$q_{max} = \frac{(900 + 1500)}{9.89}(1 + \frac{6x0.1}{7.06}) = 263.04KN/m^2 < 270KN/m^2$$

$$q_{min} = \frac{(900 + 1500)}{9.89}(1 - \frac{6x0.1}{7.06}) = 222.7 < 270KN/m^2$$

Hence ok

Provide rectangular footing of size 7.06x1.4m

Proportioning of trapezoidal footing:

2. Proportion a trapezoidal combined footing for uniform pressure under a dead load +reduced live load with the following data

Allowable bearing pressure:

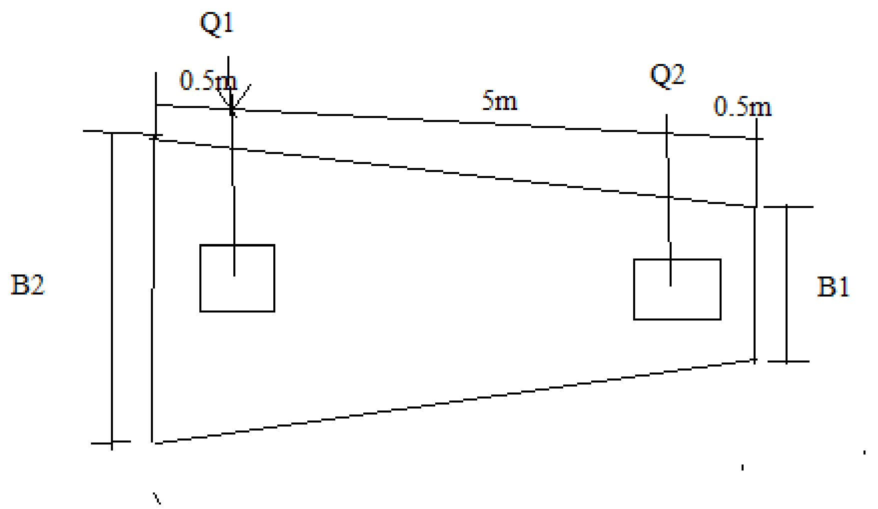
DL+reducedLL=180KN/m^2

DL+LL=280KN/m^2

Column load	A	B
DL	500KN	660KN
LL	400KN	840KN

Distance between c/c column=5m

Projection beyond column A=0.5m



Solution:

Column load	A	B	total
DL + reduced LL	700KN	1080KN	1780KN
DL+LL	900KN	1500KN	2400KN

For uniform pressure under DL+ reduced LL

Area:

$$A = \frac{Q}{q_{na}} = \frac{1780}{180} = 9.89m^2$$

$$\bar{x} = \frac{Q_2 x_2}{Q_1 + Q_2}$$

$$= \frac{1080x5}{1780} = 3.03m$$

Length of footing:

Length=C/c distance + projection on both sides

=5+0.5+0.5=6m

$$A = \frac{L}{2}(B_1 + B_2)$$

$$9.89 = \frac{6}{2}(B_1 + B_2)$$

$$B_1 + B_2 = 3.30 \ldots .(1)$$

We know that

$$\frac{L}{3}\left(\frac{B_1 + 2B_2}{B_1 + B_2}\right) = \bar{x} + e$$

$$\frac{6}{3}\left(\frac{B_1 + 2B_2}{B_1 + B_2}\right) = 3.03 + 0.5$$

$$\left(\frac{B_1 + 2B_2}{B_1 + B_2}\right) = 1.77$$

$$-B_1 + 0.43\ B_2 = 0 - - - (2)$$

Solve (1)&(2)

B_1=1m

B_2=2.40m

Total area provided= $\frac{2.40+1}{2}x6$=10.2 m^2

For dead load +live load calculations

$$\bar{x} = \frac{6}{3}\left(\frac{1 + 2x2.4}{1 + 2.4}\right) = 3.41m$$

Location of resultant DL+LL for exterior column

$$= \frac{Q_2 x_2}{Q} = \frac{1500x5}{2400} = 3.125m$$

Location of resultant from the outer edge of the footing

=3.125+0.5=3.625m

Eccentricity e=3.625-3.43=0.195m

Determination of pressure:

$$moment\ of\ inertia = \left[\frac{B_1^2 + 4B_1B_2 + B_2^2}{36(B_1 + B_2)}\right] L^3$$

$$moment\ of\ inertia = \left[\frac{1^2 + 4x1x2.40 + 2.4^2}{36(1 + 2.4)}\right] 6^3$$

$$= 28.87m^4$$

$$q_{max} = \frac{Q}{A} + \left[\frac{QxexX}{I}\right]$$

$$= \frac{2400}{10.2} + [\frac{2400x0.195x(6-3.41)}{28.87}] = 277 < 280KN/m^2$$

$$q_{max} = \frac{Q}{A} - [\frac{QxexX}{I}]$$

$$= \frac{2400}{10.2} - [\frac{2400x0.195x(6-3.41)}{28.87}]$$

$$= 193.3 < 280KN/m^2$$

Hence OK

Proportioning of strap footing:

3. Proportioning of strap footing for the following data:

Allowable pressure=150KN/m^2 for DL+reduced LL

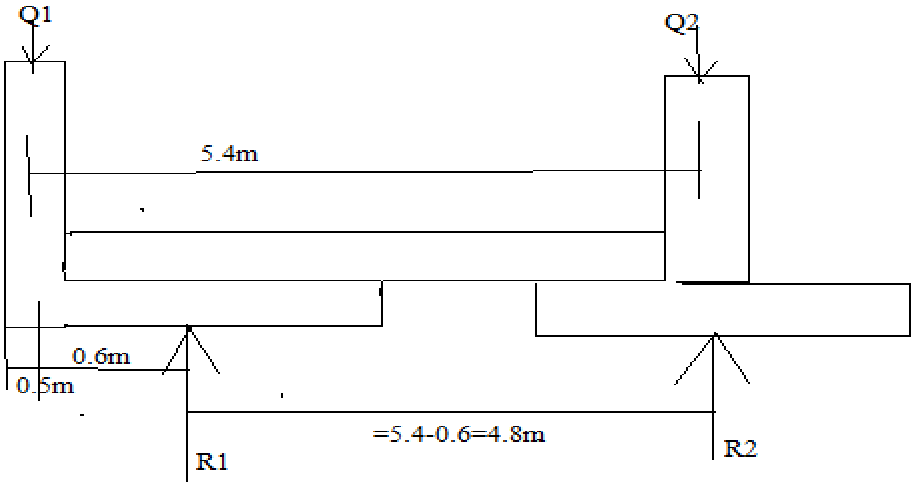
Allowable pressure=225KN/m^2 for DL+ LL

Column Load	A	B
DL	500KN	600KN
LL	450KN	800KN

Proportion the footing for uniform pressure under DL+reduced LL centre to centre spacing between column =5.4m.projection beyond column A should not exceed 0.5m

Solution:

Step 1:Assume eccentricity e=0.6m



Column load	A	B	total
DL+reduced LL	725KN	1000KN	1725KN
DL+LL	950KN	1400KN	2350KN

Step 2) Determine the length of footing of exterior column

$$L_1 = 2(e + 0.5b_1)$$

$$L_1 = 2(0.6 + 0.5x1) = 2.2m$$

Consider DL+reduced LL

Steps 3) compute the reaction R_1 by taking moment about the line of action of the reaction

$$R_1 = \frac{Q_1 x_2}{S} = \frac{725x5.4}{4.8} = 815KN$$

Steps 4) compute R_2

$$R_2 = (Q_1 + Q_2) - R_1$$

=1725-815=910KN

Steps 5) compute the area of footing A1

$$A_1 = \frac{R_1}{q_{na}} = \frac{815}{150} = 5.4m^2$$

$$A_2 = \frac{R_2}{q_{na}} = \frac{910}{150} = 6.07m^2$$

Step 6) calculate width of footing

$$B_1 = \frac{A_1}{L_1} = \frac{5.4}{2.2} = 2.45m$$

Provide a width of 2.50m

Consider B_1=B_2=2.5m

$$B_2 = \sqrt{A_2}$$

$$B_2 = \frac{A_2}{L_2}$$

$$L_2 = \frac{A_2}{B_2} = \frac{6.07}{2.5} = 2.43m$$

Provide the length is 2.5m

Step 7) calculate Pressure intensity

$$q_1 = \frac{R_1}{L_1 x B_1}$$

$$= \frac{815}{2.2x2.5}$$

$$= \frac{148.18KN}{m^2} < 150KN/m^2$$

$$q_2 = \frac{R_2}{L_2 x B_2}$$

$$= \frac{910}{2.5x2.5}$$

$$= \frac{145.6KN}{m^2} < 150KN/m^2$$

Provide the strap footing of size

2.2x2.5m and 2.5x2.5m