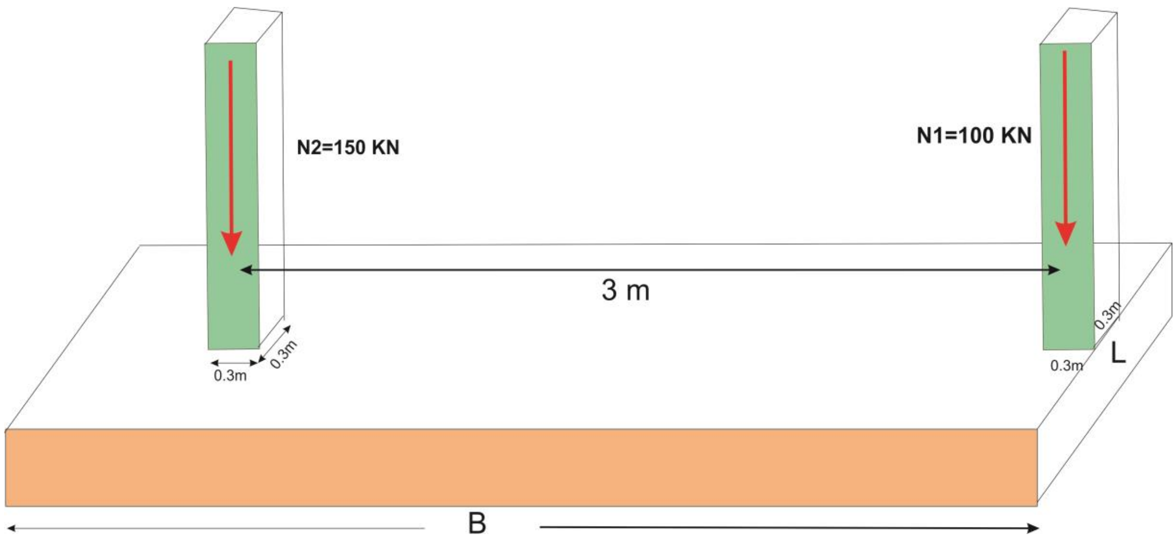
Eccentric combined footing design

Example: A rectangular eccentric combined footing shown in the figure is required to be fully designed. The allowable bearing capacity of the underlying soil is $q_a = 50$ KN/m2. The distance between the two column is 3m. $f_{\acute{c}} = 25\ Mpa, \qquad f_y = 450\ Mpa$



The first step is to transmit the forces system to the center. This is may be done as follows:-
For simplify the problem, suppose the center of the right column is at the edge of the footing.

$M = 50B - (450 - 75B) = 125B - 450$ clockwise

$$q = \frac{N}{LB} + \frac{6M}{LB^2}$$

$$q_1 = \frac{250}{LB} + \frac{6(125B-450)}{LB^2}$$

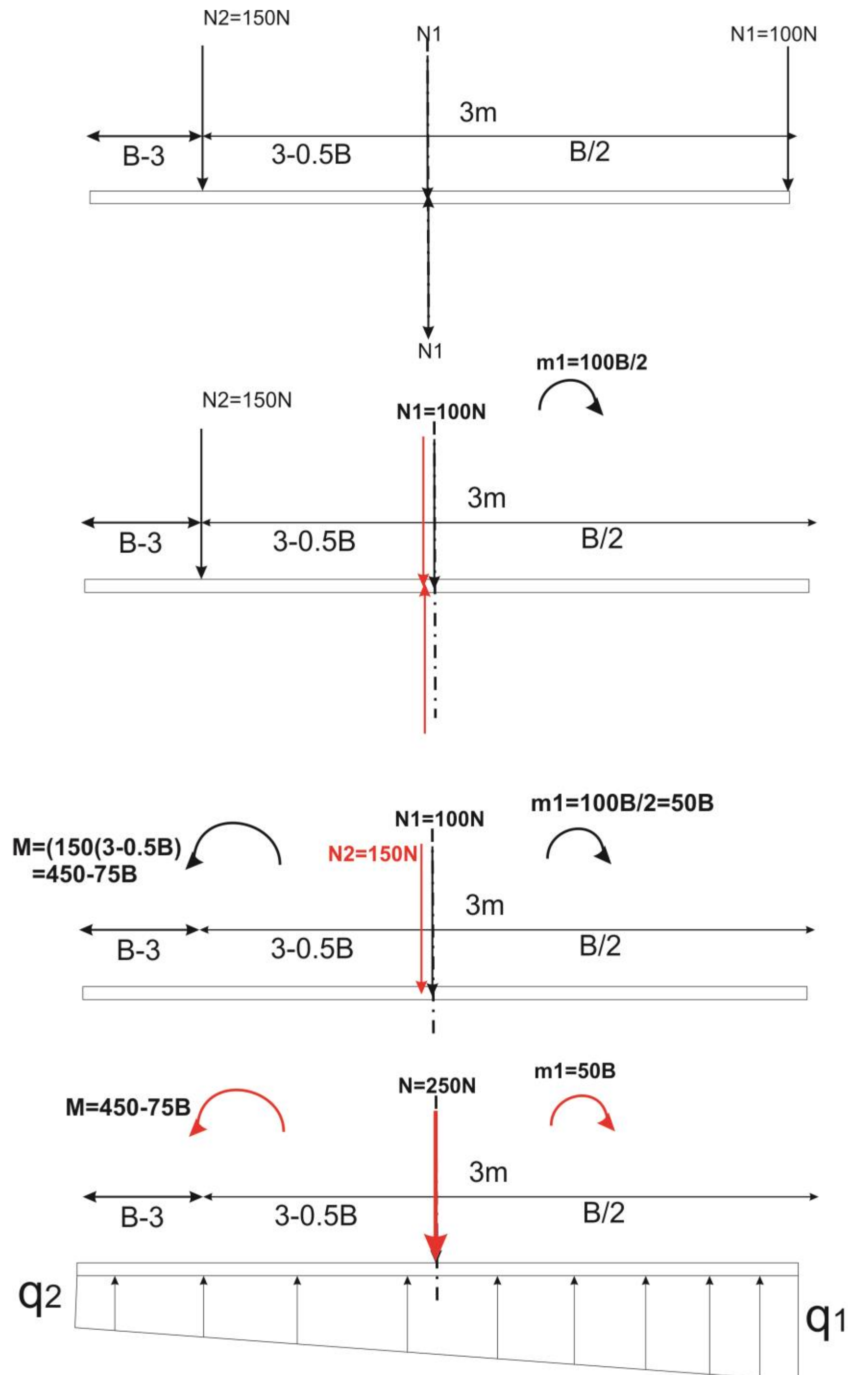
$$q_2 = \frac{250}{LB} - \frac{6(125B-450)}{LB^2}$$

Let the footing is rectangular and suppose B=2L, this leads to

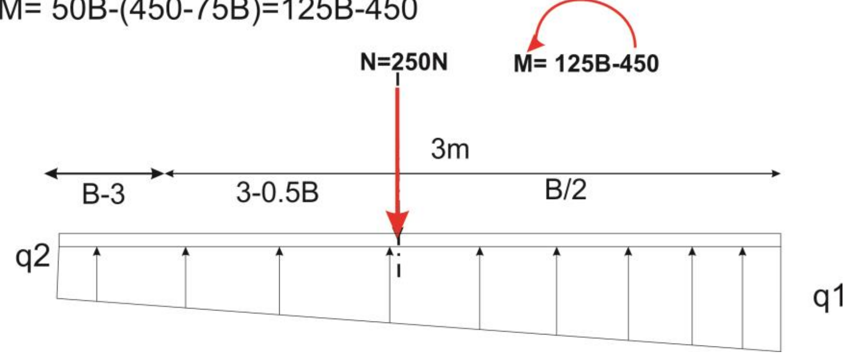
$$q_1 = \frac{250}{L*2L} + \frac{6(125*2L-450)}{L*(2L)^2} = \frac{125}{L^2} + \frac{6(250L-450)}{4L^3}$$

$$q_2 = \frac{250}{L*2L} - \frac{6(125B-450)}{LB^2} = \frac{125}{L^2} - \frac{6(250L-450)}{4L^3}$$

Analysis of eccentricity



M= 50B-(450-75B)=125B-450



In all cases q2 is larger than q1, therefore q2 should be used for footing dimension design

Let;

$$\frac{125}{L^2} - \frac{6(250L-450)}{4L^3} = 50\ KN/m2$$

$$125L \quad + 675 - 375L = 50L^3$$

$$-200L - 50L^3 = -675$$

L=1.835m≅ 1.85, B=3.67m≅ $3.7m$ Footing dimensions

$M = 125B - 450 = 125 * 3.7 - 450 = 12.5KN.m$ clockwise

$$q_2 = = \frac{125}{1.85^2} - \frac{6(250*1.85-450)}{4\ (1.85)^3} = 33.56KN/m2$$*1.85m=62 KN/m

$$q_1 = \frac{125}{(1.85)^2} + \frac{6(250*1.85-450)}{4(1.85)^3} = 39.48KN/m2$$

$$q_1 = 39.48\frac{KN}{m2} * 1.85 = 73KN/m$$

Checking of eccentricity

$$e = \frac{12.5}{250} = 0.062m, \quad e = \frac{B}{6} = \frac{3.7m}{6} = 0.616m$$

0.062 < 0.61 OK

Shear force diagram

1- Shear force left a = 62*0.7+$\frac{11}{3.7} * 0.7^2/2$=44.128 KN
2- Shear force right a = 44.128 – 150 = -105.871 KN
3- Shear force left d = (62+73)/2*3.7-150=100KN
4- Shear force right d= 0

Zero shear point

$$62 * X + \frac{11}{3.7} * \frac{X^2}{2} - 150 = 0$$

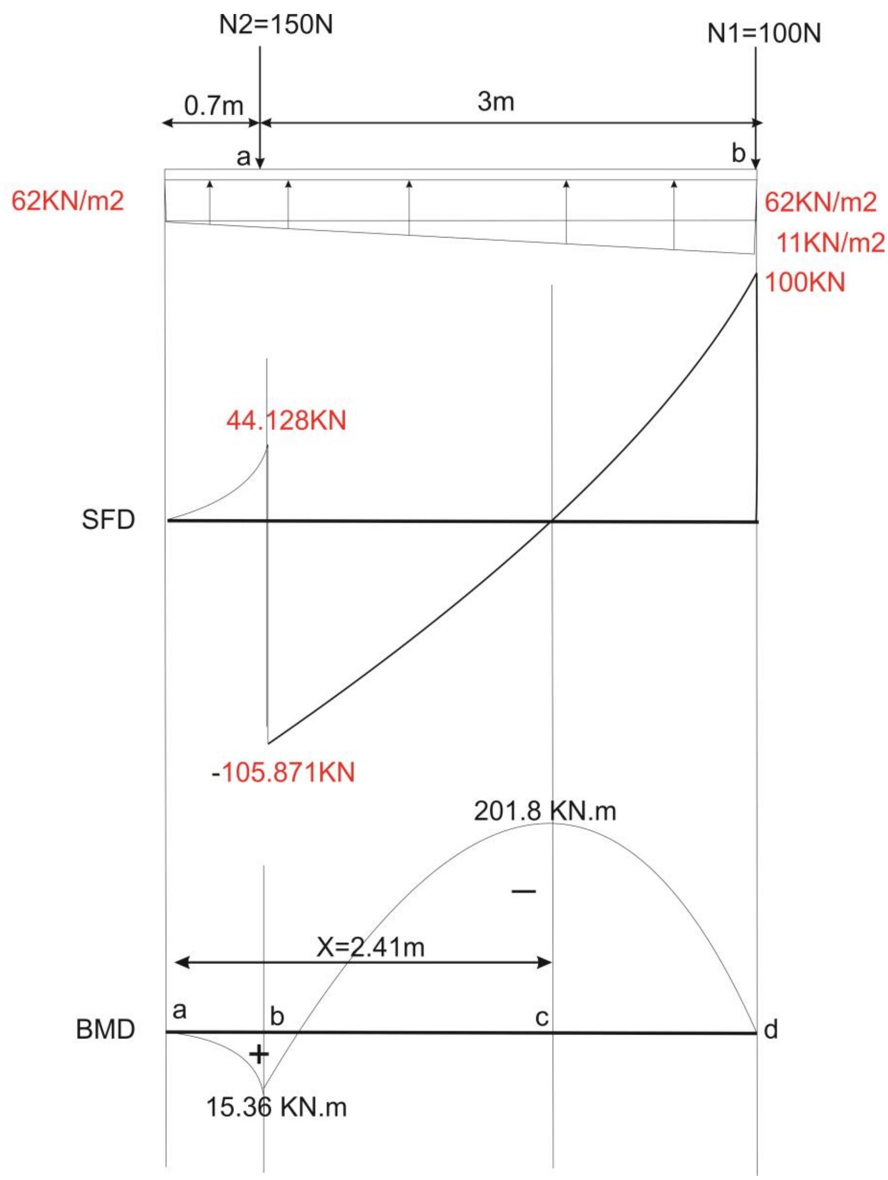
$62X + 0.14864X^2 = 150$, $X = 2.41$(Zero shear point and max moment)

Maximum moment

$$M_a = 62 * \frac{0.7^2}{2} + \frac{11}{3.7} * \frac{0.7^3}{6} = 15.36KN.m$$

$$M_{max} = 62 * \frac{2.41^2}{2} + \frac{11}{3.7} * 2.41 * \frac{2.41}{2} * \frac{2.41}{3} - 150 * 1.71$$

$$M_{max} = 47.74 + 6.9357 - 256.5 = 201.8\ KN.m$$



SFD and BMD

H determination

$v_U = 0.8\sqrt{f_{\acute{c}}}$ $=0.8\sqrt{25} = 4\ N/mm2$

$d = \frac{2N_U}{perimeter.v_U} = \frac{2*1.6*150*1000}{1200*4} = 200mm$, take $d = 300mm\ minimum$

$H = 300 + 50\ cover + 20mm\ bar = 370mm$, approximate to 400mm

Real d = 400-50cover-20∅ =330 mm

Reinforcement design

Reinforcement at maximum moment

$$K = \frac{M_{max}}{f_{\acute{c}}Ld^2} = \frac{201.8 * 10^6}{25 * 1850 * 300^2} = 0.04848$$

$$\frac{Z}{d} = 0.5 + \sqrt{0.25 - \frac{0.04848}{0.9}} = 0.942 < 0.95 \quad OK$$

$$Z = 0.942 * 330 = 310.5$$

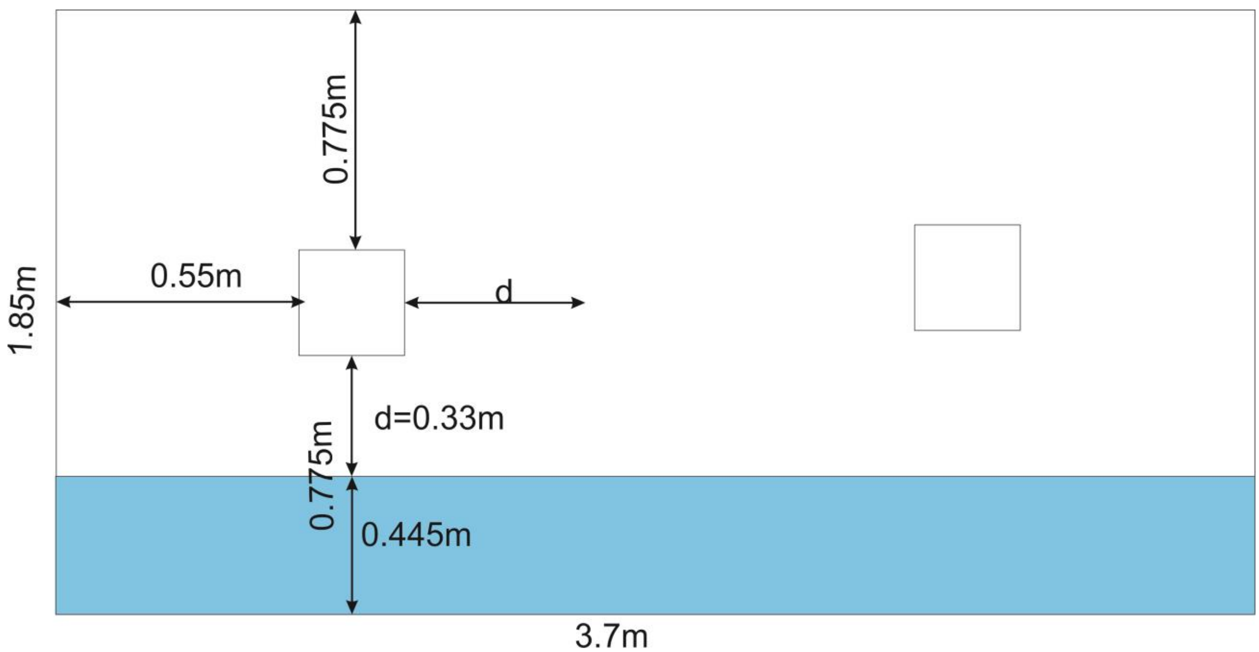
$$A_s = \frac{M}{0.95f_yZ} = \frac{1.5 * 201.8 * 10^6}{0.95 * 450 * 310.5} = 2,280.4mm2$$

Minimum reinforcement = 0.13 L d =0.13 * 1850*330/100 = 793.65mm2   OK

$No\ of\ bars = \frac{2,280.4}{314.1} = 7.26$, use 8 Ø20 for Negative side.

Spacing = $\frac{185}{8} = 23.125, use\ 20cm$, use   9Ø20 to keep the distance between the bars 20cm

Shear Check



$$Shear\ force \quad v = \frac{\frac{39.5KN}{m}+33.5KN/m}{2} * 3.7m * 0.445m = 60\ KN$$

$$\text{Shear stress} = \frac{v}{Bd} = \frac{60*1000}{3700*330} = 0.049$$

$$V_C = [0.79\left(\frac{100A_S}{Ld}\right)^2 \frac{400}{d}\left(\frac{f_{\bar{C}}}{25}\right)^{\frac{1}{3}} /1.25$$

If $\frac{400}{d} < 1\ take\ it\ 1$

$$V_C = [0.79\left(\frac{100*\mathbf{2{,}280.4}}{1850*330}\right)^2 \frac{400}{330}\left(\frac{25}{25}\right)^{\frac{1}{3}} /1.25 = 0.10688 > 0.049 \text{ OK}$$

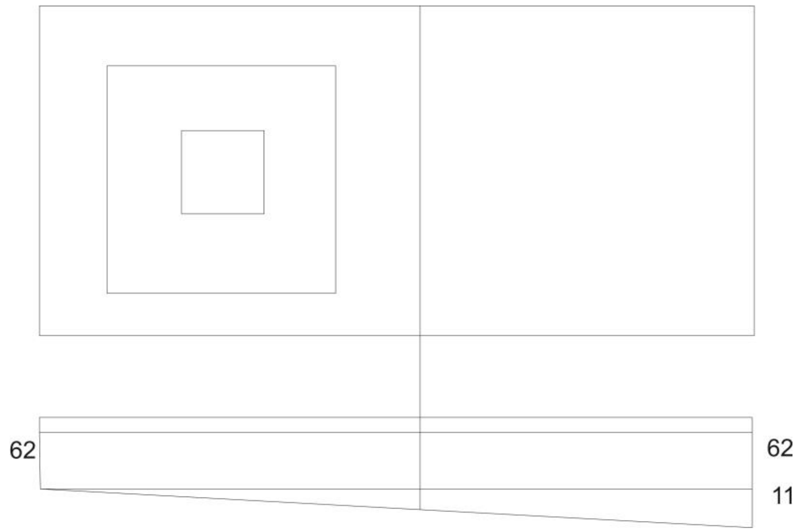
Check Punching

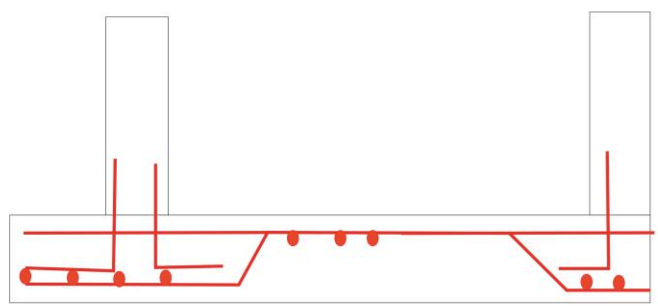
Perimeter of punching, $U = 300*4+8*1.5*330 = 5{,}160mm$

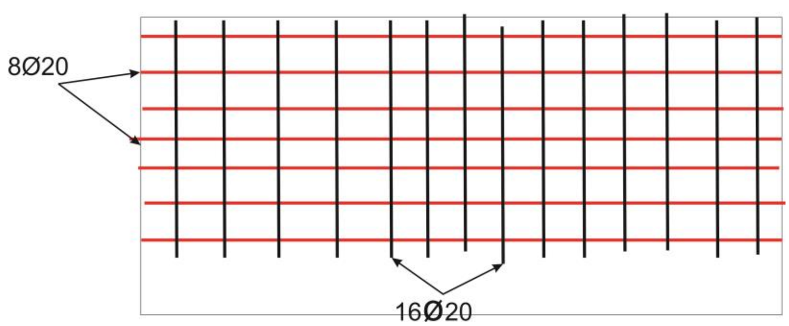
$$A_p = 1.85^2 - (3*0.33+0.3)^2 = 1.7584m^2$$

$$Punching\ force, V_p = 1.785 * \frac{33.5+\frac{6}{3.7}*1.85}{2} = 32.57KN$$

Punching stress, $v_p = \frac{32.57*1000}{5160*330} = 0.019n/mm2 < V_C$


62
62
11




8Ø20
16Ø20