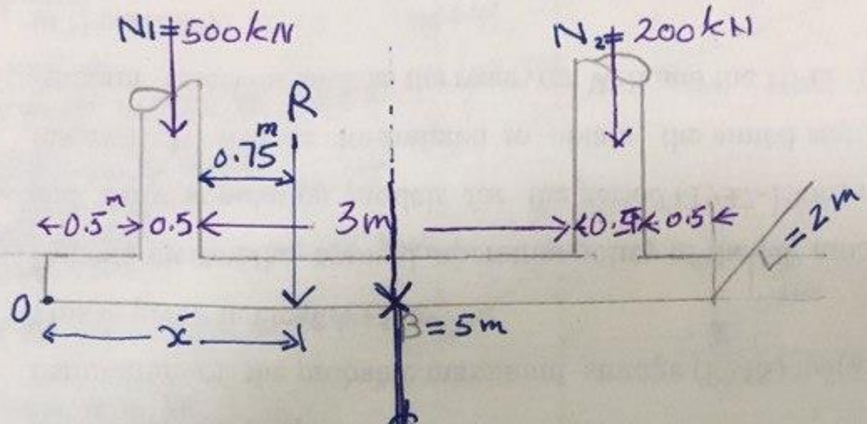
Design of eccentric combined foundation

Example: design the rectangular footing shown in the figure below, if $f'_c = 20$ mpa and $f_y = 415$ mpa. The allowable bearing capacity $q_{all} =$



step 1: Find the location of the resultant (R)

$R = 500 + 200 = 700$ kN

$\Sigma M_o = 0$

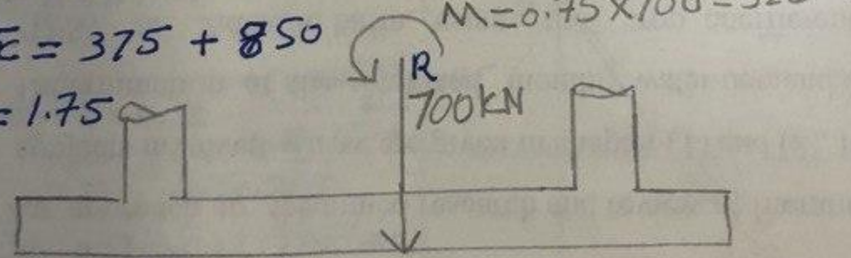
$R\bar{x} = N_1 * 0.75 + N_2 * 4.25$

$700\bar{x} = 0.75 * 500 + 4.25 * 200$

$700\bar{x} = 375 + 850$

$\bar{x} = 1.75$

$M = 0.75 \times 700 = 525$ kN.m



$q = \frac{R}{BL} \mp \frac{6M}{LB^2}$

$q_1 = \frac{700}{5*2} + \frac{6*525}{2*5^2}$

$= 133$ kN/m²

$q_2 = \frac{700}{5\times2} - \frac{6*525}{2*5^2}$

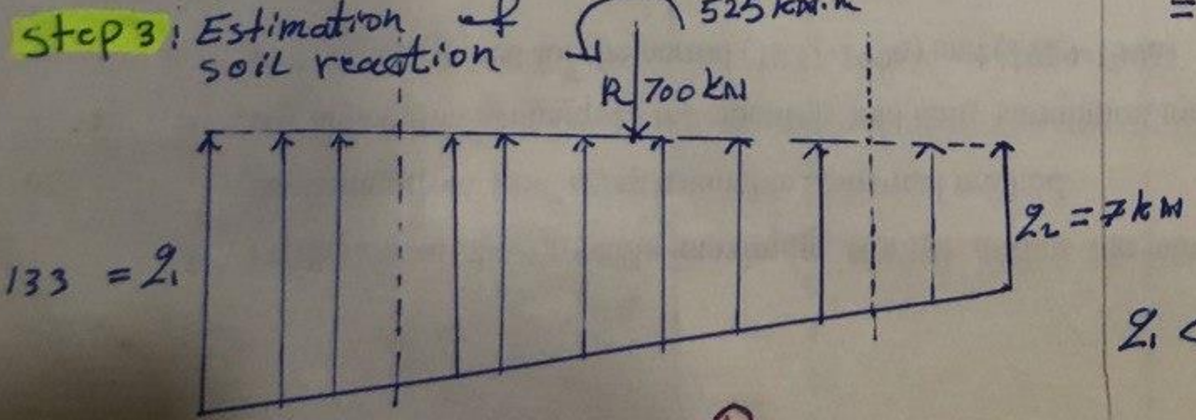
$= 7$ kN/m²

step 2: Check the eccentricity

$e = \frac{525}{700} = 0.75$ m

$\frac{B}{6} = \frac{5}{6} = 0.83 \quad \therefore e < \frac{B}{6}$ o.k

step 3: Estimation of soil reaction



$q_1 < q_{all}$ (200 kN/m²)

o.k

Step 4: Draw SFD and BMD

divide the loads over 2 to obtain the shear and bending moments per 1m ⊥ paper

Shear: left a

square $= 7 \times 0.75 = 5.25$

Trapezoid $= \dfrac{\left(\frac{126}{5} \times 4.25 + 126\right)}{2} \times 0.75$

$= 87.4125$

$V = 87.4125 + 5.25 = 92.66$ kN/m

$V_{right\ a} = 92.66 - 250 = -157.33$ kN/m

Area between a – b

$A_{rectangular} = 7 \times 3.5 = 24.5$

$A_{trapezoid} = \dfrac{\left(\frac{126}{5} \times 4.25 + \frac{126}{5} \times 0.75\right)}{2} \times 3.5$

$= 220.5$

$V_{a-b} = 24.5 + 220.5 = 245$

$V_{left\ b} = -157.33 + 245 = 87.67$

$V_{right\ b} = 87.67 - 100 = -12.33$

$V_{between\ b-c} = \dfrac{0.75 \times 7 + \left(\frac{126}{5} \times 0.75\right)}{(\times 0.75/2)}$

$= 12.375$

$V_c = -12.3375 + 12.3375 = 0$

Zero shear point

$-157.33 + 7x + \left[\frac{126}{5}(4.25) + \frac{126(4.25 - x)}{5}\right]\frac{x}{2} = 0$

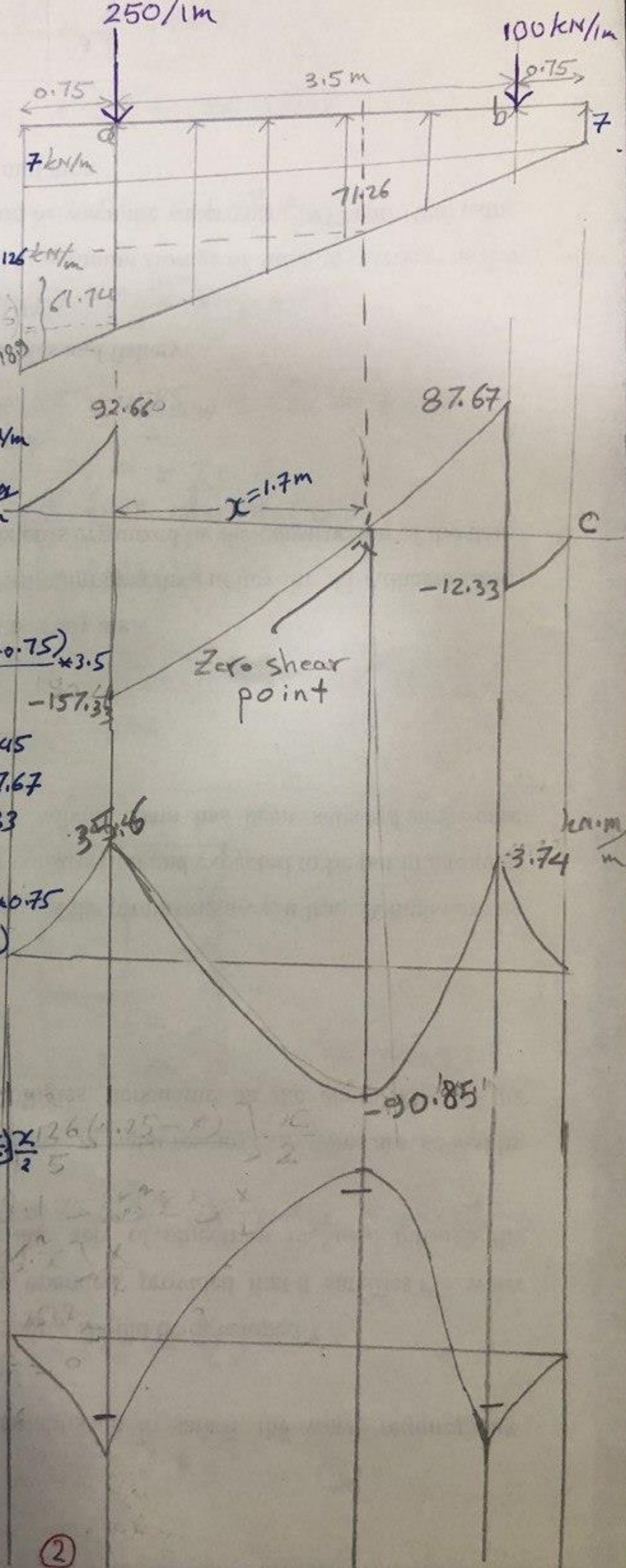
$x = 1.7$m

Bending Moment

$M_b = 7\dfrac{0.75^2}{2} + \dfrac{126}{5} \times \dfrac{0.75^2}{6}$

$M_{max} = 7 \times \dfrac{2.55^2}{2} + \dfrac{126}{5} \times \dfrac{2.55^2}{6} - 100 \times 1.8 = -130$

$M_a = 7 \times \dfrac{4.25^2}{2} + \dfrac{126}{5} \times \dfrac{4.25^2}{6} - 3.5 \times 100$



$$M_a = \frac{114.1 \times 0.75^2}{2} + \frac{18.9 \times 0.75}{2} * \frac{2}{3} 0.75$$

$$M_{max} = \left(\frac{126}{5} * \frac{2.55^3}{2} \times \frac{1}{3}\right) + 7 \frac{2.55^2}{2} = 180$$

$$337.4 - 250 * 1.7 =$$

$$M_b = 7 \frac{0.75^2}{2} + \frac{126}{5} * 0.75 * \frac{0.75}{2} * \frac{1}{3} 0.75$$

$= 3.74$

$$M_a = 7 \frac{4.25^2}{2} + \frac{126}{5} \times 4.25 \times \frac{4.25}{2} * \frac{4.25}{3} - 350$$

$= 63.218 + 322.4 - 350 = 35.6$

step5: Determination of effective depth (d)

the diagonal tension shear (U) is

$$U = b_o d \, \phi (0.34)(0.85) \sqrt{f'_c}$$

$U = 1.7 *$ Max column load

$= 1.7 \times 500 = 850$ kN $= 0.85$ MN

$0.85 = (4d+2) d (0.85) 0.34 \sqrt{20}$

$0.7 = (4d+2) d$

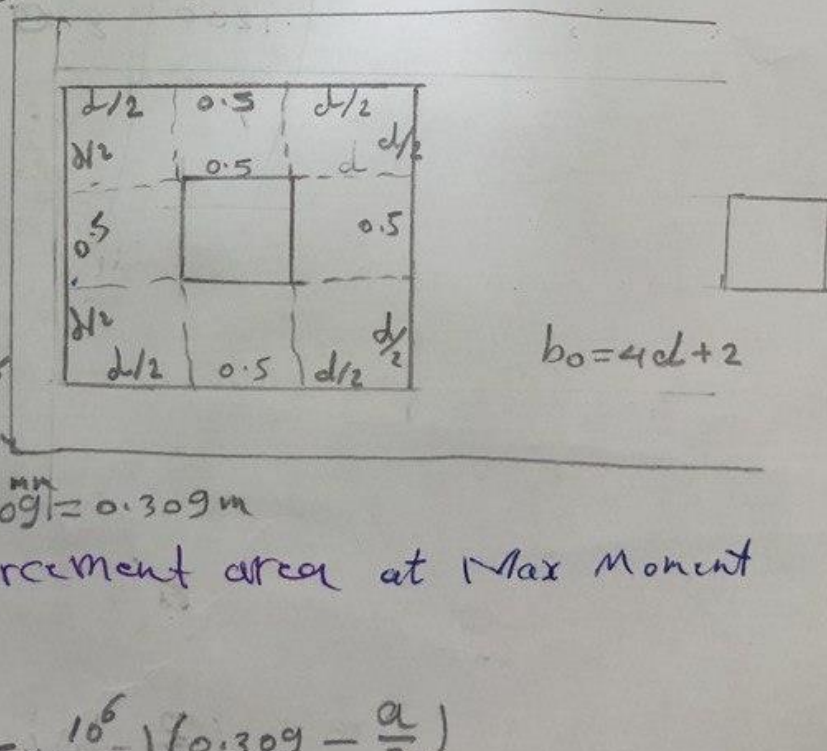
$d = 0.24$ m $= 240$ mm

240 mm < 300 mm

take $d = 300$ mm

$H = 300 + 75$ cover $+ \phi 16$

$= 391$ mm take 400 mm



$b_o = 4d + 2$

net $d = 400 - 75 - 16 = 309$ mm $= 0.309$ m

step 6: Estimate reinforcement area at Max Moment

$$M_u = \phi A_s f_y \left(d - \frac{a}{2}\right)$$

$$1.7 * 90.85 = 0.9 A_s \left(415 \times \frac{10^6}{10^3}\right)\left(0.309 - \frac{a}{2}\right)$$

$8.27 \times 10^{-4} = A_s (0.618 - a)$ — ①

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{A_s 415}{0.85 \times 20 * 1} = 24.4 A_s$$ — ②

sub in (1)

$8.27 \times 10^{-4} = A_s(0.618 - 24.4 A_s)$

$8.27 * 10^{-4} = 0.618 A_s - 24.4 A_s^2$ $\quad * 10000$

$8.27 = 6180 A_s - 244000 A_s^2$

$A_s = 0.00143 \, m^2 = 1430 \, mm^2/m$

A_s	8.27
0.01	37.44
0.005	24.8
0.0025	13.925
0.0015	8.721
0.00145	8.44799
0.0014	8.1737
0.00143	

$\text{min reinforcement} = \frac{0.13 L H}{100}$

$= \frac{0.13 * 1000 * 400}{100} = 520 \, mm$

= $\quad$ o.k

$\text{no. of bars} = \frac{1430}{201} = 7.11 \simeq$

use $8 \phi 16 / 1m \perp$ paper

provid 16 mm diameter bars at 125 mm

$A_s \text{ provided} = (201 * \frac{1000}{125}) = 1608 \, mm^2$

step 7 : Estimate reinforcement at b

$M_u = \phi A_s f_y (d - \frac{a}{2})$

$1.7 * 35.6 = 0.9 A_s * (415 * \frac{10^6}{10^3})(d - \frac{a}{2})$

$1.62 \times 10^{-4} = A_s(0.309 - \frac{a}{2})$

$3.24 \times 10^{-4} = 0.618 A_s - a A_s$ ←

$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{A_s * 415}{0.85 * 20 * 1} = 24.4 A_s$

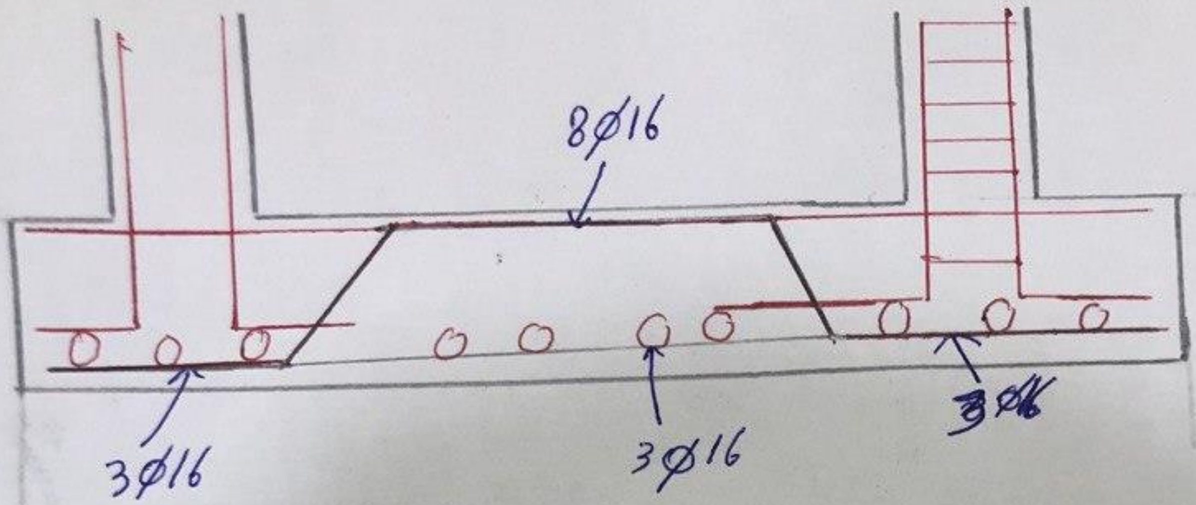
$3.24 \times 10^{-4} = 0.618 A_s - 24.4 A_s^2$

$3.24 = 6180 A_s - 244000 A_s^2$

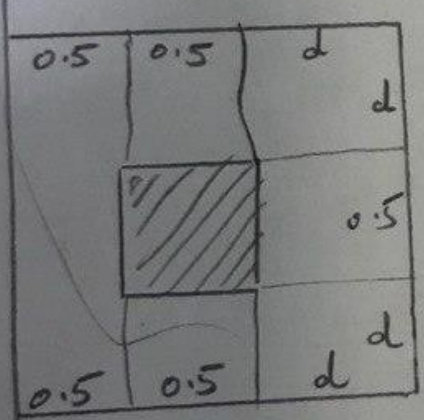
$A_s = 0.00053 \, m^2 = 530 \, mm^2$

A_s	3.24
0.0007	4.2
0.0006	3.6
0.00055	3.325
0.00053	3.206

$\text{No. of bars} = \frac{530}{201} = 2.636$ use $3 \phi 16 / m$



Step 8: punching check



$$V_p = \frac{1.7 * 500 \times 1000}{(2.5 + 4d)1000 * d} = \frac{850}{(2.5 + 4 * 0.309) * 309} = 0.525\ N/mm^2$$

$$V_c = \left\{0.79\left(\frac{100 A_s}{Ld}\right)^{1/3}\left(\frac{400}{d}\right)\left(\frac{f_c'}{25}\right)^{1/3}\right\} / 1.25$$

$$= \left\{0.79\left(\frac{100 \times 1430}{1000 \times 309}\right)^{1/3}\left(\frac{400}{309}\right)\left(\frac{20}{25}\right)^{1/3}\right\} / 1.25 = 0.587$$

$V_p < 0.587$ o.k