ASSIGNMENT

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SUBJECT	Advanced Design of Reinforced Concrete Structures
PROGRAMME	M.S (STRUCURE ENGINNERING)
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ASSIGNMENT

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Example :

Design a raft footing for five storey building having dimension 23×20.The Raft has x side spacing of 7m and y side spacing of 6m.The plan of the raft is shown.

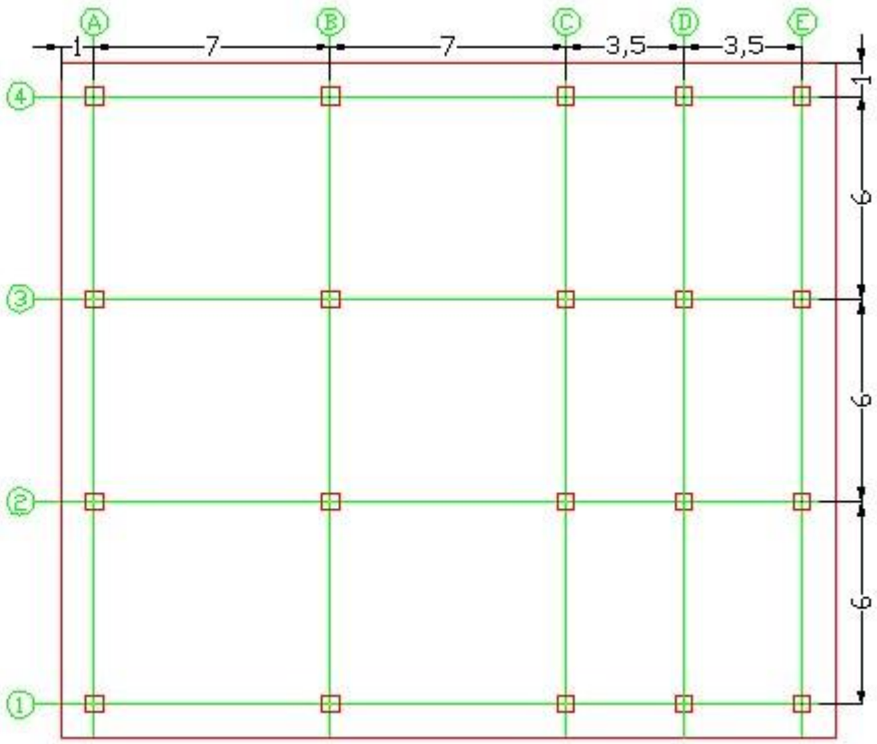


Figure 1, Raft layout

Step # 01

The total area of the raft =

$$((3*7)+1+1)*((3*6)+1+1)$$

$$= 23*20 = 460\ m^2$$

Step # 02
Columns loads in Raft:

This raft is designed for has 5 stories industrial building with dead and live loads which are shown in table 2.

Load type	Load case	Load value (kN/m^2)
Services	Dead	2.5 kN/m^2
Slab own weight assumed	Dead	(25kN/m^3)(0.2m) = 5 kN/m^2
Flooring	Dead	1 kN/m^2
Live loads	Live	7 kN/m2

Table 2, design loads

Figure 2 shows the columns notation and the yellow lines shows the turbidity areas that are covered by the columns.

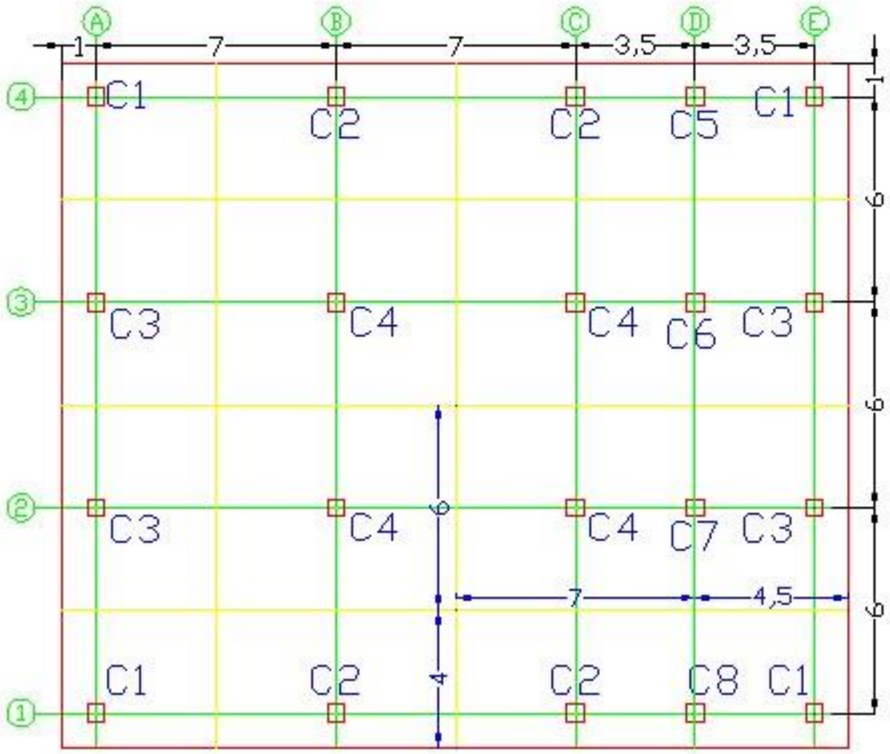


Figure 2, Raft dimension and column spacing

Loads per square meter are calculated as:

$$General\ Dead\ load\ stress = (5+2.5+1)\frac{kN}{m2} * no.of\ floors$$

$$General\ Dead\ load\ stress = (5+2.5+1)\frac{kN}{m2} * 5 = 42.5\ kN/m^2$$

$$General\ Life\ load\ stress = (7)\frac{kN}{m2} * 5 = 35\ kN/m^2$$

Columns loads:

Axial Dead load = *Stess per unit area*
KN/m^2 ∗ *Turbidity area*

Column type (1):

Axial unfactored Dead load = 42.5 kN/m^2 ∗ (4 ∗ 4.5)m^2 = 765 KN
Axial unfactored Live load = 35 kN/m^2 ∗ (4 ∗ 4.5) m^2 = 630 KN
TotalSevice Axial load = 765 + 630 KN = 1395 KN
Ultimate axial load = 1.2 (765) + 1.6 (630) = 1926 KN

Column type (2):

Axial unfactored Dead load = 42.5 kN/m^2 ∗ (4 ∗ 7)m^2 = 1190 KN
Axial unfactored Live load = 35 kN/m^2 ∗ (4 ∗ 7)m^2 = 980 KN
TotalSevice Axial load = 1190 + 980 KN = 2170 KN
Ultimate axial load = 1.2 (1190) + 1.6 (980)= 2996 KN

Column type (3):

Axial unfactored Dead load = 42.5 kN/m^2 ∗ (4.5 ∗ 6) m^2 = 1148 KN
Axial unfactored Live load = 35 kN/m^2 ∗ (4.5 ∗ 6) m^2 = 945 KN
TotalSevice Axial load = 1148 + 945 KN = 2093 KN
Ultimate axial load = 1.2 (1148)+ 1.6 (945) = 2889 KN

Column type (4):

Axial unfactored Dead load = 42.5 kN/m^2 ∗(7 ∗ 6) m^2 = 1785 KN
Axial unfactored Live load = 35 kN/m^2 ∗(7 ∗ 6) m^2 = 1470 KN
TotalSevice Axial load = 1785 + 1470 KN = 3255 KN
Ultimate axial load = 1.2 (1785) + 1.6 (1470) = 4494 KN

Extra Column loads:

These columns are placed in the right edge of the raft, and they are external columns that are carried by the raft and will cause moments around x-axis and y-axis as will be shown. The axial loads of the original columns and extra columns are shown in the table 3.

Column no.	Dead load (kN)	Live load (kN)	Total service load(kN)	Total factoredload (kN)
C1	765	630	1395	1926
C2	1190	980	2170	2996
C3	1148	945	2093	2889
C4 (maximum)	1785	1470	3255	4494
C5 (extra)	500	300	800	1080
C6 (extra)	450	250	700	940
C7 (extra)	400	200	600	800
C8 (extra)	350	150	500	660

Table 3, all columns loads

Columns Dimensions and Reinforcement:

Columns have been designed using the PCA columns. All columns have dimensions of 500 mm by 500 mm with $12\emptyset22$ as shown in figure 3. This design of column will resists all columns loads up to the maximum load of 4494 KN

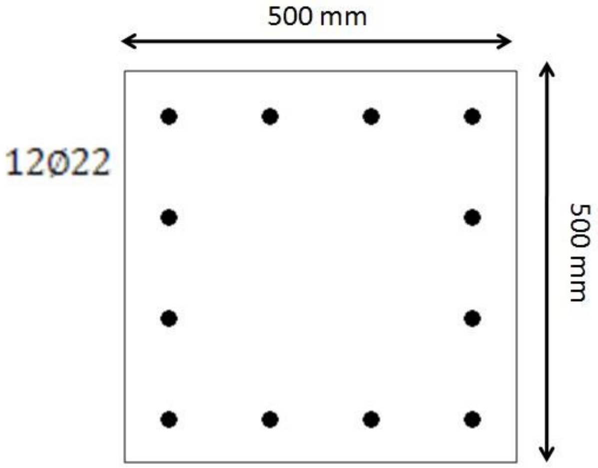


Figure 3, Column design

$$Pc = \emptyset P_n = (0.7)(0.8)\left[(0.85 f_c' A_g + F_y A_{st})\right]$$
$$Pc = \emptyset P_n = (0.7)(0.8)[(0.85(30)(500)(500) + (400)(4562)]$$

Pc = 4592 KN > Pu = 4494 KN

. The properties used in the analysis and the design of this raft foundation are shown in table 4.

Soil type	Loose sand
Effective bearing stress for the soil	$q_e = 100\ \mathrm{kN/m^2}$
Sub-grade modules	20,000 $\mathrm{kN/m^3}$
Concrete strength of raft	30 MPa
Reinforcement Steel strength	400 MPa

Table 4, Properties taken in Raft Design

$$q_e = 100\ \mathrm{kN/m^2}$$
$$\text{Total Maximum Sevice Axial load} = 1785 + 1470\ \mathrm{kN} = 3255\ \mathrm{kN}$$
$$\text{Area of single sqaure footing} = \frac{1.1(3255)}{100} = 35.8\ \mathrm{m^2}$$
$$\mathrm{B\ X\ B} = 35.8 \longrightarrow \mathrm{B} = \sqrt{35.8} = 6\ \mathrm{m\ by\ 6\ m}$$

This area is considered to be very big to be excavated under one column. So the raft foundation will be much efficient and more economical for this foundation.

Raft thickness:

In Raft foundation, the thickness can be determined by checking the diagonal tension shear that will be imposed in the raft. The maximum ultimate column load will be used in the calculation.

$U = (b_o)(d)(\emptyset)(0.34)\sqrt{f_c'}$ 11.12.2.1.c

Where,

U = factored column load

$\emptyset$ = Reduction factor = 0.85

b_o = The parameter of the sheared area d = effective depth of raft

f_c' = Compressive strength of concrete

In this Raft,

$$U = 4494\,\text{kN} = 4.494\,\text{MN}$$
$$b_o = 4(0.4 + d) = 1.6 + 4d$$

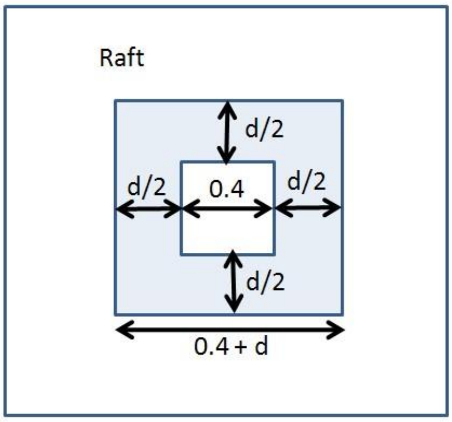


Figure 4, Diagonal tension shear area

And by using the equation above, the required depth of the raft can be determined.

$U = (b_o)(d)(\emptyset)(0.34)\sqrt{f_c'}$ ACI-05 11.12.2.1.c

$$4.494 = (1.6 + 4d)(d)(0.75)(0.34)\sqrt{30}$$
$$4.494 = (1.6d + 4d^2)(1.397)$$
$$3.2169 = 1.6d + 4d^2$$
$$0 = 4d^2 + 1.6d - 3.2169$$
$$0 = 4d^2 + 1.6d - 3.2169$$

Solving equation for d

d = 0.689 m = 689 mm = 700 mm

Thickness of the raft = 700 + 75 + 25 (assumed bar diameter)

Thickness = 800 mm

Raft Depth check:

One way shear:

$$V_u = Maximum\ shear - (d)(w_{soil})$$

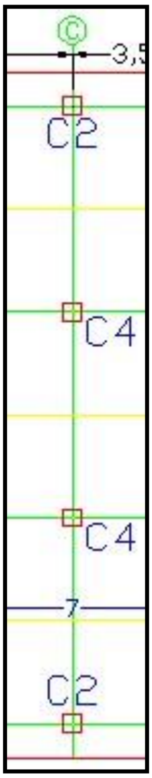


Figure 6, maximum shear in strips CSY3

To determine the w_{soil}, the average soil pressure should be determined in the maximum loads stripes.

For the y-strips, CSY4 have maximum shear value in C4. Which is equal to 2173.51 KN

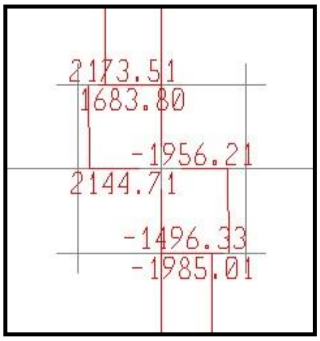


Figure 5, C4 shear diagram

CSY3 will be analyzed separately to calculate the ultimate bearing stress of the soil.

$$q_{alt} = \frac{Total\ factored\ loads\ in\ strip\ CSY3}{Area\ of\ the\ strip}$$

$$q_{alt} = \frac{C2 + C4 + C4 + C2}{(width\ of\ strip)(length\ of\ strip)}$$

$$q_{alt} = \frac{2996 + 4494 + 4494 + 2996}{(3.5)(20)} = 214\ kN/m^2$$

$$q_{alt} = 214\ kN/m^2$$

$$w_{soil} = (214\ kN/m^2)(width\ of\ strip) = (214\ kN/m^2)(3.5)$$

$$w_{soil} = 749kN/m$$

Assuming

$$d = 800 - 75 = 725\ mm$$

$$V_u = Maximum\ shear - (d)(w_{soil})$$

$$V_u = 2173.5 - (0.725)(749)$$

$$V_u = 1630.5\ kN$$

$$d = \frac{(V_u)(1000)}{(0.75)(\sqrt{f_c'})\left(\frac{1}{6}\right)(B)} = \frac{(1630.5\ )(1000)}{(0.75)(\sqrt{30})\left(\frac{1}{6}\right)(3500)} = 680.4\ mm$$

$$d = 680.4\ mm < d = 725\ ok$$

Two way shear (interior column):

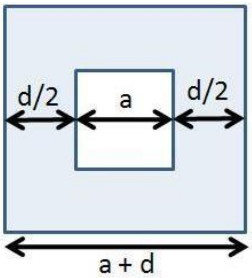


Figure 7, two way shear area

$$V_u = Column\ Axial\ Load - (d + a)^2(w_{soil})$$

To determine the w_{soil}, the average soil pressure should be determined in the maximum loads stripes.

$$q_{alt} = 214\ kN/m^2$$

$$d = 800 - 75 = 725\ mm$$
$$V_u = Column\ Axial\ Load - (d + a)^2 (w_{soil})$$
$$V_u = 4494 - (0.725 + 0.5)^2 (214) = 4172.9\ kN$$
$$b_o = 4(a + d) = 4(500 + 725) = 4900\ mm$$
$$d_{III} = \frac{(V_u)(1000)}{(0.75)\left(\sqrt{f_c'}\right)\left(\frac{1}{3}\right)(b_o)} = \frac{(4172.9)(1000)}{(0.75)\left(\sqrt{30}\right)\left(\frac{1}{3}\right)(4900)}$$
$$d_{III} = 622.6\ mm$$
$$d = 622.6\ \ mm < d = 725\ ok$$

3.5.2 SAFE Punching Shear check:

Safe software has command of checking the punching shear of the raft or any slab that is modelled in safe. And in this project, the punching shear has been checked using the SAFE software and all the factors are less than 1. This means that the load shear is less than the raft shear resistance. The punching shear factors are shown in the following figure:

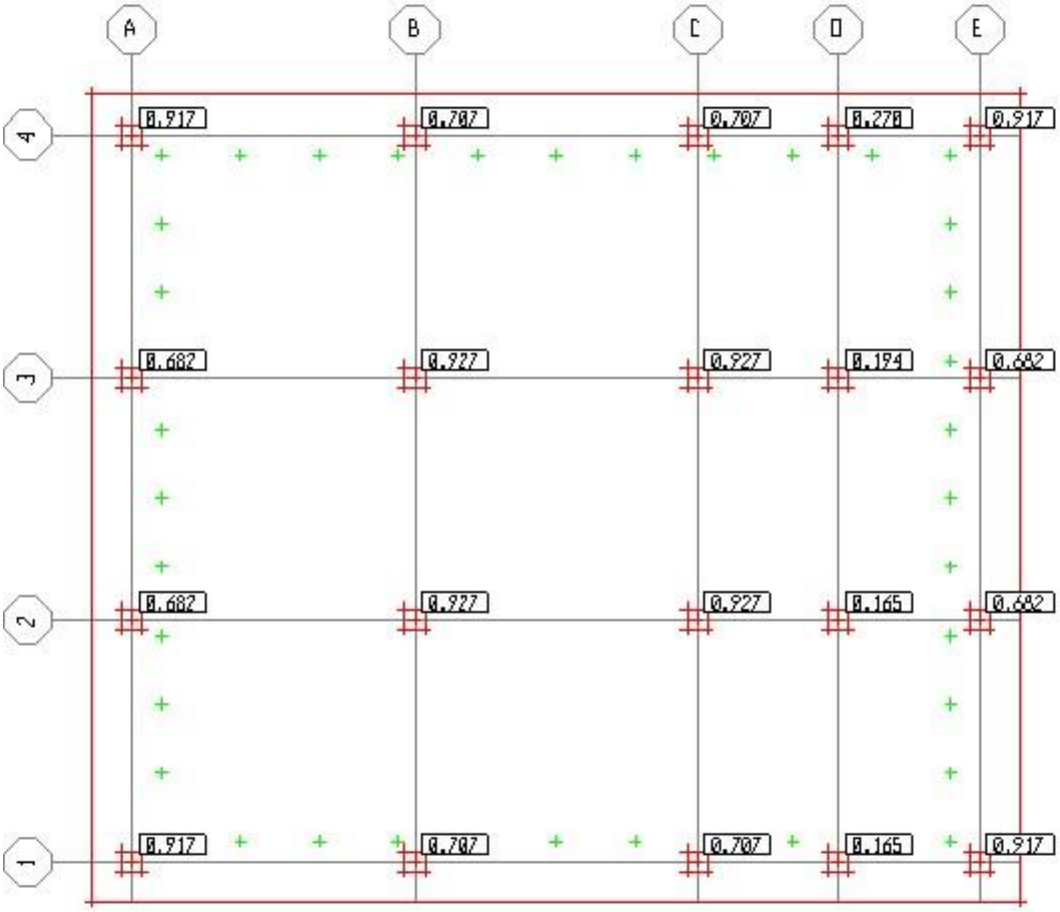


Figure 8, punching shear factors for the raft

Soil Pressure Check:

In this section, the soil net pressure should be checked in each point of the raft foundation. The raft foundation is not symmetric around x-axis nor y-axis due to difference in the columns positions and loads. Moments effects on the raft should be checked to assure that the stresses of the raft under all columns are less than the net allowable stress which is equal to $100\ \mathrm{kN/m^2}$.

$$q = \frac{Q}{A} \mp \frac{M_y x}{I_y} \mp \frac{M_x y}{I_x}$$

$$A = Area\ of\ the\ mat = \big((7)(3) + 1 + 1\big) * \big((6)(3) + 1 + 1\big) = (23) * (20)$$

$$A = 460\mathrm{m}^2$$

$$I_x = \frac{bh^3}{12} = \frac{23(20)^3}{12} = 15333.3\ \mathrm{m}^4$$

$$I_y = \frac{bh^3}{12} = \frac{20(23)^3}{12} = 20278.3\ \mathrm{m}^4$$

$$Q = sum\ of\ all\ service\ colums\ loads$$

$$Q = 4(C1) + 4(C2) + 4(C3) + 4(C4) + extra\ column\ loads$$

$$Q = 4(1395) + 4(2170) + 4(2093) + 4(3225) + 800 + 700 + 600 + 500$$

$$Q = 38252\ kN$$

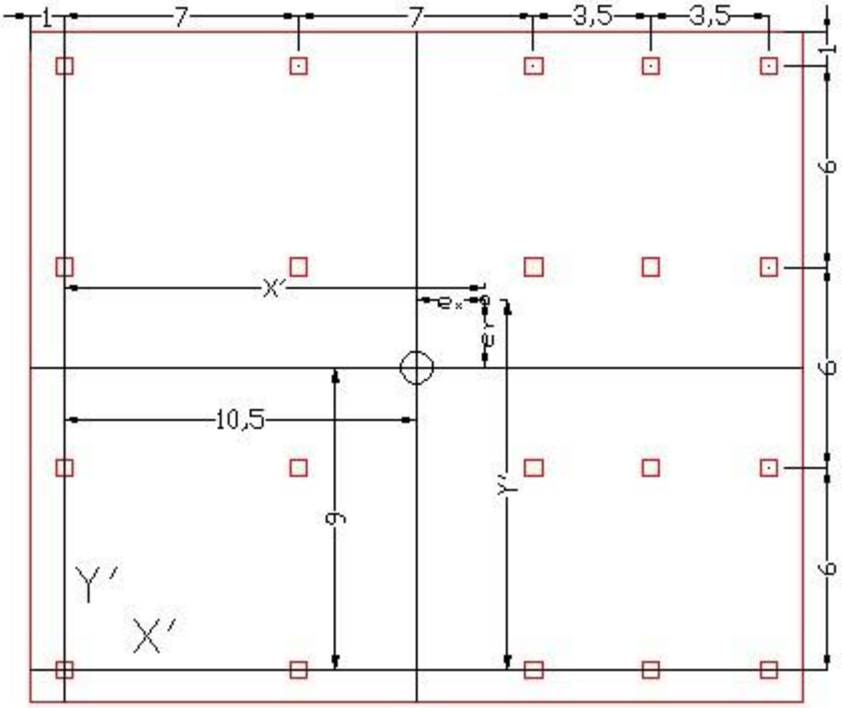


Figure 9, resultant position due to column loads

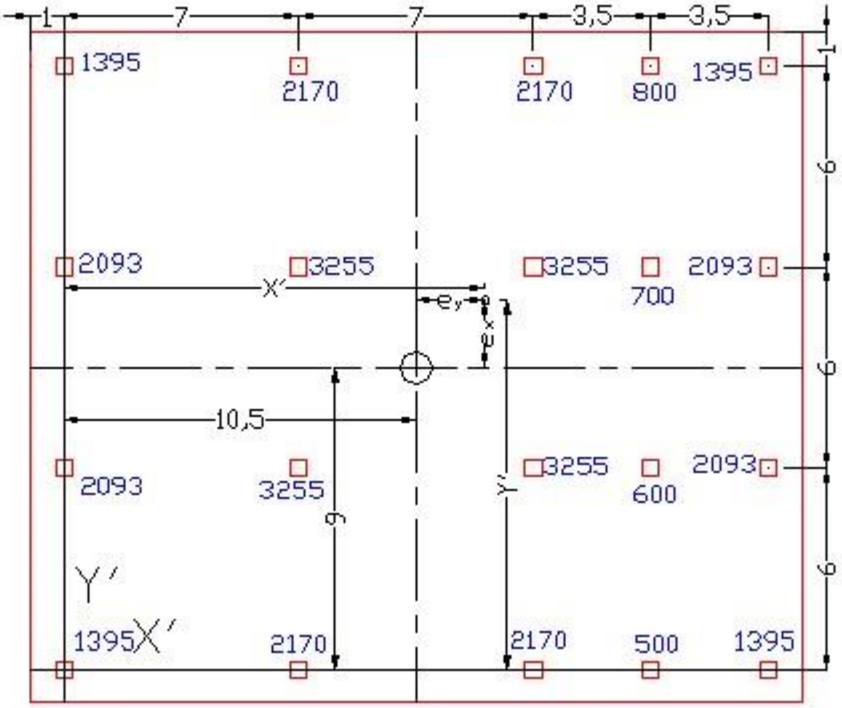


Figure 10, columns total service loads (DL+LL)

Calculate M_y:

$$e_x = X' - 10.5$$
$$Q * X' = Q1(x'1) + Q2(x'2) + \cdots$$
$$X' = \frac{Q1(x'1) + Q2(x'2) + \cdots}{Q}$$
$$X' = \frac{1}{38252}[(7)(2170 + 3255 + 3255 + 2170) + (14)(2170 + 3255 + 3255 + 2170) + (17.5)(800 + 700 + 600 + 500) + (21)(1395 + 2093 + 2093 + 1395)]$$
$$X' = \frac{1}{38252}[227850 + 45500 + 146496]$$
$$X' = 10.976\,m$$
$$e_x = 10.976 - 10.5 = 0.4758\,m$$
$$M_y = Qe_x = 38252 * 0.4758 = 18200\,kN.m$$

Calculate M_x:

$$e_y = Y' - 9$$
$$Q * Y' = Q1(y'1) + Q2(y'2) + \cdots$$
$$Y' = \frac{Q1(y'1) + Q2(y'2) + \cdots}{Q}$$
$$Y' = \frac{1}{38252}[(18)(1395 + 2170 + 2170 + 800 + 1395) + (12)(2093 + 3255 + 3255 + 700 + 2093) + (6)(2093 + 3255 + 3255 + 600 + 2093)]$$
$$Y' = \frac{1}{38252}[142740 + 136752 + 67776]$$
$$Y' = 9.07843\,m$$
$$e_y = 9.07843 - 9 = 0.07843\,m$$
$$M_x = Qe_y = 38252 * 0.07843 = 3000\,kN.m$$

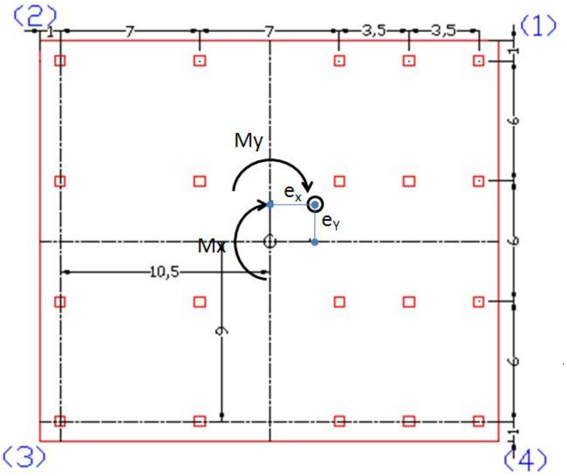
Calculate Soil pressure due to total service axial loads and moments:

$$q_i = -\frac{Q}{A} \mp \frac{M_y x}{I_y} \mp \frac{M_x y}{I_x}, i = 1, 2, 3 \text{ and } 4$$

where (-) minus signs refers to compression stress.

Soil pressure will be checked in the four corners of the raft. Soil pressure should not be more than the allowable stress of the soil and not less than 0 kN/m^2, to make sure that no tension could occur in any part of the raft

$$q_i = -\frac{Q}{A} \mp \frac{M_y x}{I_y} \mp \frac{M_x y}{I_x}$$
$$q_1 = -\frac{38252}{460} - \frac{18200(11.5)}{20278.3} - \frac{3000(10.5)}{15333.3}$$



$$q_1 = -\frac{38252}{460} - \frac{18200(11.5)}{20278.3} - \frac{3000(10.5)}{15333.3}$$

$$q_1 = -83.157 - 10.321 - 2.054$$

$$q_1 = -95.532 < q_{net} = 100\ kN/m^2$$ Ok

$$q_2 = -\frac{38252}{460} + \frac{18200(11.5)}{20278.3} - \frac{3000(10.5)}{15333.3}$$

$$q_2 = -83.157 + 10.321 - 2.054$$

Figure 11, corners of raft

$$q_2 = -75.265 < q_{net} = 100\ kN/m^2$$ ok

$$q_3 = -\frac{38252}{460} + \frac{18200(11.5)}{20278.3} + \frac{3000(10.5)}{15333.3}$$

$$q_3 = -83.157 + 10.321 + 2.054$$

$$q_3 = -70.89 < q_{net} = 100\ kN/m^2$$ Ok

$$q_4 = -\frac{38252}{460} - \frac{18200(11.5)}{20278.3} + \frac{3000(10.5)}{15333.3}$$

$$q_4 = -83.157 - 10.321 + 2.054$$

$$q_4 = -91.424 < q_{net} = 100\ kN/m^2$$ Ok

All pressure values are in compression and they are less than the net bearing stress of the soil which is equal to $100\ kN/m^2$

Table 5 shows the analysis outputs for x-strip moments. Negative moments will be designed for Top Reinforcement, and Positive moments will be designed for Bottom Reinforcement.

Strip notation	Strip Field	Maximum Moment Value (kN.m)	
		Positive	Negative
CSx1	Column strip	1144	1049.3
MSx1	Middle strip	319.1	1063.0

CSx2	Column strip	**1532**	1142.0
MSx2	Middle strip	476.6	1039.0
CSx3	Column strip	1523	**1142.3**
MSx3	Middle strip	303.4	1064.3
CSx4	Column strip	1119	1052.2

Table 5, x-strips moments values

Table 6 shows the analysis outputs for Y-strip moments. Negative moments will be designed for Top Reinforcement, and Positive moments will be designed for Bottom Reinforcement.

Strip notation	Strip Field	Maximum Moment Value (kN.m)	
		Positive	Negative
CSY1	Column strip	943	960.3
MSY1	Middle strip	26.1	927.7
CSY2	Column strip	**1450**	1107.3
MSY2	Middle strip	166.2	948.3
CSY3	Column strip	1445	**1230.3**
CSY4	Middle strip	344	1193.0
CSY5	Column strip	939.7	1117.5

Table 6, y-strips moments values

X -strip Design:

Positive moments (Bottom Reinforcement):

Design of reinforcement will be based on one meter unit of the strip. The distance to the rebar center is equal to 75 mm, so effective raft depth equal to

$d = 800 - 75 = 725\ mm$

$M_u^+(maximum) = 1532\ kN\ .m$/m

$$\frac{M_u^+}{\emptyset b d^2} = \frac{1532e6}{(0.9)(1000)(725)^2} = 3.238$$

$\rightarrow Go\ to\ q_u\ table \rightarrow\ \rho = 0.0088 > \rho_{min}\ = 0.0035$

$\rightarrow\ \rho = 0.0088 < \rho_{max}\ = 0.0244$

$A_s = 0.0088(b)(d) = 0.0088(1000)(725)$

$A_s = 6380\ mm^2$/m

use 13Ø25/m $A_s = 6381\ mm^2$/m

$$S = \frac{1000}{13-1} = 83 \; use \; S = 80 \; mm < S_{max} = 450 \; mm$$

Use $\varnothing 25@80mm$

Check Mc:

$$a = \frac{As * Fy}{0.85 * fc * b} = \frac{6381 * 400}{0.85 * 30 * 1000} = 100.1 \text{ mm}$$

$$c = \frac{a}{B1} = \frac{100.1}{0.85} = 117.7 \text{ mm}$$

$$d = h - cover - = 800 - 75 = 725 \text{ mm}$$

$$\epsilon_t = \left(\frac{d-c}{c}\right) \times 0.003 = \left(\frac{725 - 117.7}{117.7}\right) \times 0.003 = 0.0154 > 0.005 \;\; (\text{Tension Control})$$

then use $\varnothing = 0.9$

$$M_c = \varnothing(As)(Fy)\left(d - \frac{a}{2}\right)$$

$$M_c = (0.9)(6381)(400)\left(725 - \frac{100.1}{2}\right)e^{-6}$$

$M_c = 1550.4 \text{ kN.m} > Mu = 1532 \text{ kN.m}$ ok

Use $\varnothing 25@80\text{mm for positive moments x} - \text{direction} - \text{bottom Reinforcement}$

Negative moments (Top Reinforcement):

Design of reinforcement will be based on one meter unit of the strip. The distance to the rebar center is equal to 75 mm, so effective raft depth equal to

$$d = 800 - 75 = 725 \; mm$$

$$M_u^-(maximum) = 1142.3 \;\; kN.m/\text{m}$$

$$\frac{M_u^{\pm}}{\varnothing bd^2} = \frac{1142.3e6}{(0.9)(1000)(725)^2} = 2.415$$

$$\rightarrow Go \; to \; q_u \; table \rightarrow \; \rho = 0.0064 > \rho_{min} = 0.0035$$

$$\rightarrow \; \rho = 0.0064 < \rho_{max} = 0.0244$$

$$A_s = 0.0064(b)(d) = 0.0064(1000)(725)$$

$$A_s = 4640 \; mm^2/\text{m}$$

use $10\varnothing 25/\text{m}$ $\quad A_s = 4909 \; mm^2/\text{m}$

$$S = \frac{1000}{10-1} = 111.1 \; use \; S = 110 \; mm < S_{max} = 450 \; mm$$

Use $\varnothing 25@110 \; mm$

Check Mc:

$$a = \frac{As * Fy}{0.85 * fc * b} = \frac{4909 * 400}{0.85 * 30 * 1000} = 77\ mm$$

$$c = \frac{a}{B1} = \frac{77}{0.85} = 90.6\ mm$$

$$d = h - cover - stirrups - \frac{d_b}{2} = 800 - 75 = 725\ mm$$

$$\epsilon_t = \left(\frac{d - c}{c}\right) \times 0.003 = \left(\frac{725\ - 90.6}{90.6}\right) \times 0.003 = 0.021 > 0.005\ \ (\text{Tension Control})$$

then use $\emptyset = 0.9$

$$M_c = \emptyset(As)(Fy)\left(d - \frac{a}{2}\right)$$

$$M_c = (0.9)(4909)(400)\left(725 - \frac{77}{2}\right)e^{-6}$$

$M_c = 1213.2\ kN.m > Mu = 1532\ kN.m$ Ok

Use $\emptyset 25@110mm$ for negative moments x − direction − top Reinforcement

Y-strip Design:

Positive moments (Bottom Reinforcement):

Design of reinforcement will be based on one meter unit of the strip. The distance to the rebar center is equal to 75 mm + 25 mm, because y-direction reinforcement will be under the reinforcement of x-direction, so effective raft depth equal to

$d = 800 - (75 + 25) = 700\ mm$

$M_u^+(maximum) = 1532\ kN.m$/m

$$\frac{M_u^+}{\emptyset b d^2} = \frac{1450e6}{(0.9)(1000)(700)^2} = 3.288$$

$\rightarrow Go\ to\ q_u\ table \rightarrow\ \rho = 0.009 > \rho_{min}\ = 0.0035$

$\rightarrow\ \rho = 0.009 < \rho_{max}\ = 0.0244$

$A_s = 0.009(b)(d) = 0.009(1000)(700)$

$A_s = 6300\ mm^2$/m

use 13Ø25/m $\quad A_s = 6381\ mm^2$/m

$$S = \frac{1000}{13 - 1} = 83\ use\ S = 80\ mm < S_{max}\ = 450\ mm$$

Use $\emptyset 25@80mm$

Check Mc:

$$a = \frac{As * Fy}{0.85 * fc * b} = \frac{6381 * 400}{0.85 * 30 * 1000} = 100.1 \text{ mm}$$

$$c = \frac{a}{B1} = \frac{100.1}{0.85} = 117.7 \text{ mm}$$

$$d = h - cover - = 800 - 75 = 725 \text{ mm}$$

$$\epsilon_t = \left(\frac{d - c}{c}\right) \times 0.003 = \left(\frac{725 - 117.7}{117.7}\right) \times 0.003 = 0.0154 > 0.005 \ \text{(Tension Control)}$$

$$\text{then use } \emptyset = 0.9$$

$$M_c = \emptyset(As)(Fy)\left(d - \frac{a}{2}\right)$$

$$M_c = (0.9)(6381)(400)\left(725 - \frac{100.1}{2}\right) e^{-6}$$

$$M_c = 1550.4 \text{ kN.m} > Mu = 1450 \text{ kN.m}$$ ok

Use $\emptyset 25@80\text{mm}$ for positive moments $Y - \text{direction} - \text{bottom Reinforcement}$

Negative moments (Top Reinforcement):

Design of reinforcement will be based on one meter unit of the strip. The distance to the rebar center is equal to 75 mm + 25 mm, because y-direction reinforcement will be under the reinforcement of x-direction, so effective raft depth equal to

$$d = 800 - (75 + 25) = 700 \ mm$$

$$M_u^{-}(maximum) = 1532 \ kN.m/\text{m}$$

$$\frac{M_u^{\pm}}{\emptyset b d^2} = \frac{1230.3e6}{(0.9)(1000)(700)^2} = 2.790$$

$$\rightarrow Go \ to \ q_u \ table \rightarrow \ \rho = 0.0076 > \rho_{min} = 0.0035$$

$$\rightarrow \ \rho = 0.0076 < \rho_{max} = 0.0244$$

$$A_s = 0.0076(b)(d) = 0.0076(1000)(700)$$

$$A_s = 5300 \ mm^2/\text{m}$$

use $11\emptyset 25$/m $\quad A_s = 5400 \ mm^2$/m

$$S = \frac{1000}{10 - 1} = 100 \ use \ S = 100 \ mm < S_{max} = 450 \ mm$$

Use $\emptyset 25@100 \ mm$

Check Mc:

$$a = \frac{As * Fy}{0.85 * fc * b} = \frac{5400 * 400}{0.85 * 30 * 1000} = 84.7 \text{ mm}$$

$$c = \frac{a}{B1} = \frac{84.7}{0.85} = 99.6 \text{ mm}$$

$$d = h - \text{cover} - \text{stirrups} - d_b = 800 - 75 - 25 = 700 \text{ mm}$$

$$\epsilon_t = \left(\frac{d - c}{c}\right) \times 0.003 = \left(\frac{700 - 99.6}{99.6}\right) \times 0.003 = 0.0181 > 0.005 \text{ (Tension Control)}$$

$$\text{then use } \emptyset = 0.9$$

$$M_c = \emptyset(As)(Fy)\left(d - \frac{a}{2}\right)$$

$$M_c = (0.9)(5400)(400)\left(700 - \frac{84.7}{2}\right) e^{-6}$$

$$M_c = 1278.5 \text{ kN.m} > Mu = 1230.3 \text{ kN.m ok}$$

Use $\emptyset 25@100$mm for negative moments Y − direction − top Reinforcement

Comparison Table:

	Moment Value kN.m/m	Manual Design		SAFE design
X-strip				
Bottom As	1532	$\emptyset 25@80mm$	$6381\ mm^2/m$	$13\emptyset 25 = 6381\ mm^2/m$
Top As	1142.3	$\emptyset 25@110mm$	$4909\ mm^2/m$	$10\emptyset 25 = 4909\ mm^2/m$
Y-strip				
Bottom As	1450	$\emptyset 25@80$mm	$6381\ mm^2/m$	$12\emptyset 25 = 5890 mm^2/m$
Top As	1230.3	$\emptyset 25@100$mm	$5400\ mm^2/m$	$11\emptyset 25 = 5400 mm^2/m$

Table 7, comparison between manual and computer design