ate:

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Design of raft foundation

Data :

F_y = 400 MPa

F_c = 30 MPa

E = 2000000

DL-factor = 1.2

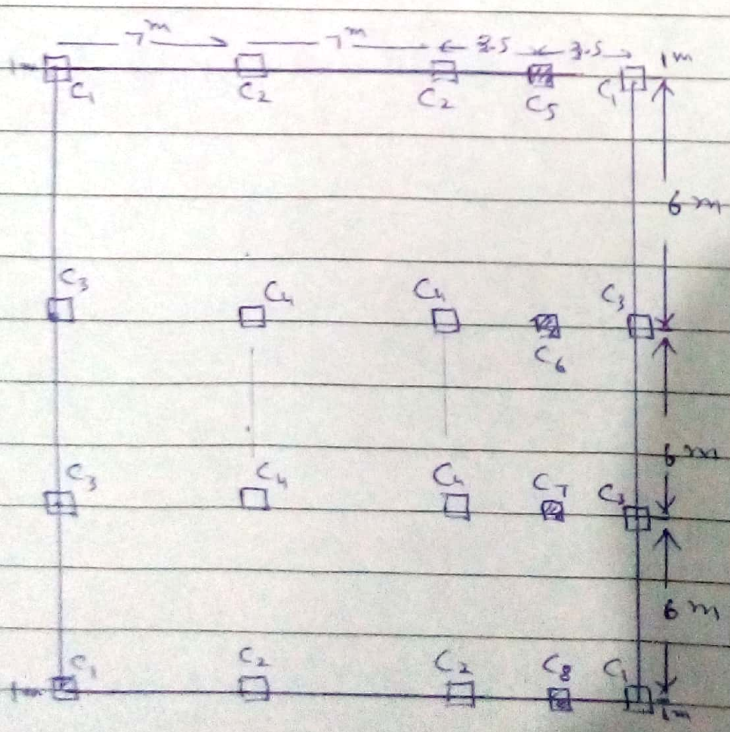
LL- " = 1.6

γ_{soil} = 15 KN/m^3

q_a = 100 KN/m^3

$\gamma_{concrete}$ = 25 KN/m^3

Multistory building



Step 1: Raft dimensioning

Total area of raft = $\{(3\times7)+1+1\} \times \{(3\times6)+1+1\}$

Total area of raft = 23×20

Total area of raft = $460\ m^2$

Step 2: Loads in Raft.

Load type	Load Case	Load value
Service	Dead	$2.5\ KN/m^2$
Slab own weight	"	$(25KN/m^3)(0.2m) = 5\frac{KN}{m^2}$
Flooring	"	$1\ KN/m^2$
Live loads	Live	$7\ KN/m^2$

Load /m^2 are Calculated as

General dead load stress = $(5+2.5+1)\ KN/m^2 \times$ (no. of floors)

General dead load stress = $(8.5)\ KN/m^2 \times 5 = 42.5\ KN/m^2$

General live load stress = $7\ KN/m^2 \times 5 = 35\ KN/m^2$

Columns loads:

Axial dead Load = stress per unit area $\frac{KN}{m^2}$ x Turbsidity area

Column type 1

Axial unfactored dead Load = $42.5 \times (4\times4.5)m^2 = 765\ KN$

" " live Load = $35\ KN/m^2 \times (4\times4.5) = 630\ KN$

Total Service axial load = 765+630 = 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 x (4x7) = 1190 KN

" " live load = (35 KN/m^2) x (4x7) = 980 KN

Total Service axial load = 980+1190 = 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 x (4.5x6) = 1148 KN

" " live load = 35 x (4.5x6) = 945 KN

Total Service axial load = 1148+945 = 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 x (7x6) m^2 = 1785 KN

" " live load = 35 KN/m^2 x (7x6) m^2 = 1470 KN

Total Service axial load = (1785+1470) KN = 3255 KN

Ultimate axial load = 1.2(1785)+1.6(1470) = 4494 KN

Extra Columns load:

These column are placed at right edge of raft includes C-5, C-6, C-7, C-8

	DL	LL	Total load	factored load
C-5	500	300	800	1080
C-6	450	250	700	940
C-7	400	200	600	800
C-8	350	150	500	660

Column dimension:

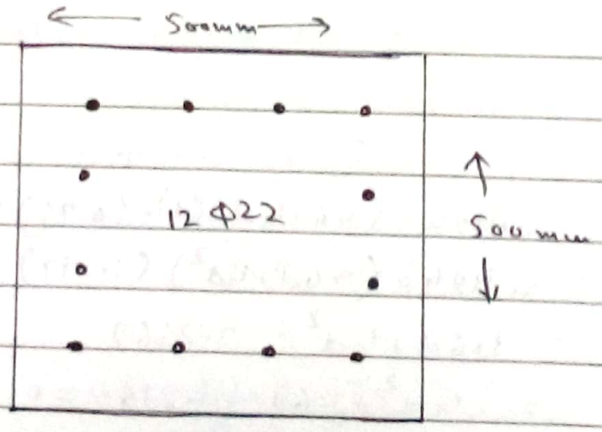
Columns have dimension of 500mm x 500mm with 12 Φ22 bars. This design column will resist all maximum load of 4494 KN

$$P_c = \Phi P_n = 0.7\times 0.8\{(0.85 f_c' A_g + F_y A_{st})\}$$

$$P_c = \Phi P_n = 0.7\times 0.8\times\{(0.85\times 30\times 500\times 500 + 400\times 4562)\}$$

$$P_c = 4592 > P_u = 4494$$

Column figure:



· Also

Since given that $q_e = 100\ KN/m^2$

Total maximum axial Load = 1785 + 1470 = 3255 KN

Area of Single Square footing = $\frac{1.1(3255)}{100} = 35.8\ m^2$

$B\times B = 35.8 \Rightarrow B = \sqrt{35.8} = B \approx 6\ m$

So ⇒ $B\times B = 6\times 6\ m$.

So it means our assumed area of footing is sufficient enough

Step 3- Raft Thikness

Maximum ultimate Column load will be used in this Calculation

Acording to ACI-05 11.12.2.1.C

$$U = b_o \times d \times \Phi \times (0.34)\sqrt{f_c'} \longrightarrow Ⓐ$$

$U = 4494$ KN $= 4.494$ MN

b_o = Parameter of sheared area

d_o = effective depth of raft

Φ = Reduction factor

Eq Ⓐ becomes

$$4.494 = (1.6+4d)(d) \times (0.75)(0.34)\sqrt{30}$$

$$\therefore 4.494 = (1.6d+4d^2)(1.397)$$

$$= 1.6d+4d^2 = 3.2169$$

$$= 4d^2+1.6d-3.2169=0$$

By using quadratic formula

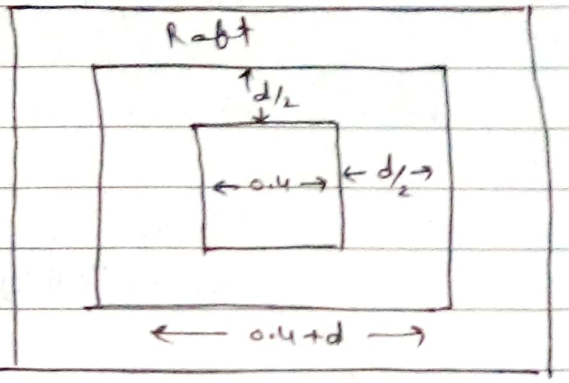
$d = 0.689$ m $= 689$ mm ≈ 700 mm

Thikness of the raft = 700+75+25 (assumed bar Φ)

Thikness = 800 mm

figur

diagnol tension shear area



Step 4 - Raft depth check

One way shear:

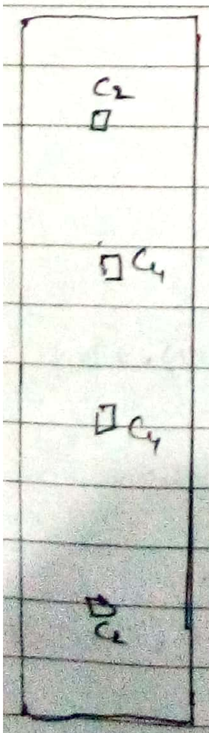
As we know

$$V_u = \text{Max-shear} - (d)(W_{soil}) \rightarrow (B)$$

To determine (W_{soil}), the average soil pressure should be determined in the max load stripes

Since C-4 have maximum shear value = 2173.5 KN

fig- strip



Max shear strip

$$q_{alt} = \frac{\text{Total factored load in strip}}{\text{Area of strip}}$$

$$q_{alt} = \frac{C_2 + C_4 + C_4 + C_2}{\text{width} \times \text{length of strip}}$$

$$q_{alt} = \frac{2996+4494+4494+2996}{3.5 \times 20} = 214\ KN/m^2$$

$$W_{soil} = q_{alt} \times \text{width of strip}$$

$$W_{soil} = (214)(3.5) = 749\ KN/m$$

Assuming

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

Eq (B) becomes

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

$V_u = 1630.5$ KN

$d = \dfrac{V_u \times 1000}{0.75 \times \sqrt{f_c} \times (1/6)(B)} = \dfrac{1630.5 \times 1000}{0.75 \times \sqrt{30}\,(1/6)(3500)}$

$d = 680.4$ mm < 725 $\underline{\underline{OK}}$

Two way shear (Interior column)

As given that

$$\longrightarrow ⓒ$$

$V_u =$ Column axial load $- (d+a)^2 (W_{soil})$

To determine Wsoil, Average soil pressure should be determine in the maximum load strips

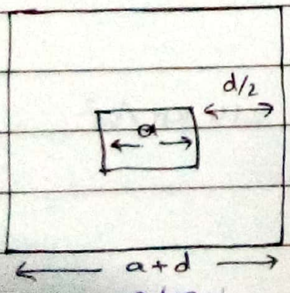
Since

$q_{ult} = 214$ KN/m^2

Assuming

$d = 800 - 75 = 725$ mm

fig:



Eq ⓒ becomes

$V_u = 4494 - (0.725 + 0.5)^2 (214) = 4172.9$ KN

$b_o = 4(a+d) = 4(500 + 725) = 4900$ mm

Now

$d = \dfrac{V_u \times 1000}{0.75 \times \sqrt{f_c} \times (1/3)(b_o} \Rightarrow \dfrac{4172.9 \times 1000}{0.75 \times \sqrt{30} \times 1/3\,(4900)}$

$d = 622.6$ mm < 725 mm

So ok

Step 5 – soil pressure check

As we know

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

Area of Mat/Raft = 460 m^2

$$I_x = \frac{bh^3}{12} \Rightarrow \frac{23 \times (20)^3}{12} = 15333.3 \text{ in}^4$$

$$I_y = \frac{b^3h^3}{12} \Rightarrow \frac{20\,(23)^3}{12} \rightarrow 20278.4 \text{ in}^4$$

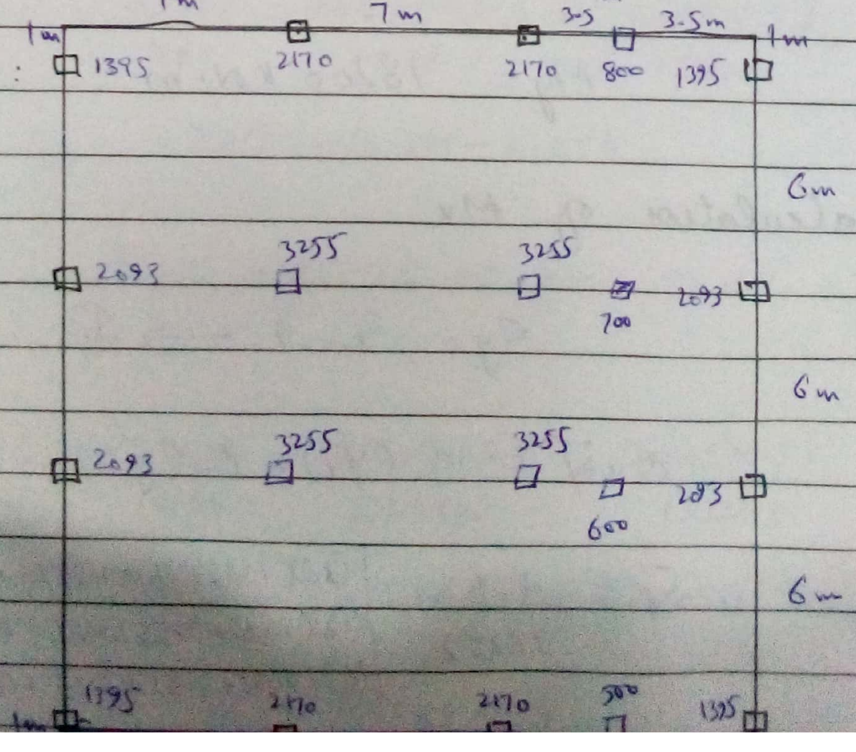
Q = Sum of all Service colum Loads

$$Q = 4C_1 + 4C_2 + 4C_3 + 4C_4 + \text{Extra Column Load}$$

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

$$Q = 38252 \text{ KN}$$

figure:



Calculation of My

$$e_x = \bar{X} - 10.5 \longrightarrow ⓐ$$

$$Q.\bar{x} = Q_1(\bar{x}1) + Q_2(\bar{x}2) + \cdots$$

$$\cancel{Q}\times\bar{X} = \frac{1}{38252}\begin{cases}(7)(2170) + 3255 + 3255 + 2170) + (14)(2170 + \\ +3255 + 3255 + 2170) + (17.5)(800 + 700 + 600 + 500) \\ + 21(1395 + 2093 + 2093 + 1395)\end{cases}$$

$$\bar{X} = \frac{1}{38252}(227850 + 45500 + 146494)$$

$$\bar{X} = 10.976\ m$$

$$e_x = \bar{X} - 10.5$$
$$e_x = 10.976 - 10.5$$
$$e_x = 0.4758$$

$$\Rightarrow My = Q e_x \Rightarrow 38252 \times 0.4758$$

$$My = 18200\ kN.m$$

Calculation of Mx

$$e_y = \bar{Y} - 9 \longrightarrow ⓑ$$

$$Q\times\bar{Y} = Q_1(y'1) + Q_2(y'2) + \cdots$$

$$\bar{Y} = \frac{1}{38252}\begin{cases}(18)(1395 + 2170 + 2170 + 800 + 1395) + \\ (12)(2093 + 3255 + 3255 + 700 + 2093) + \\ (6)(2093 + 3255 + 3255 + 600 + 2093)\end{cases}$$

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$$\bar{Y} = \frac{1}{38252}\left(142740+136752+67776\right)$$

$$\bar{Y} = 9.07843\ m$$

$$e_y = 9.07843 - 9 = 0.07483$$

2)

$$M_x = Q e_y \Rightarrow 38252 \times 0.07483$$

$$M_x = 3000\ KN.m$$

Calculation of soil pressure due to total Service axial load and moments

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

$i = 1, 2, 3, 4 \ldots$

$$q_1 = -\frac{38252}{460} - \frac{18200(11.5)}{20278.3} - \frac{3000(10.5)}{15333.5}$$

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

$$q_1 = -95.532 < q_a = 100\ KN$$ OK

$$q_2 = -\frac{38252}{460} + \frac{18200(11.5)}{20278.30} + \frac{3000(10.5)}{15333.3}$$

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

$$q_2 = 75.625 < q_a$$ OK

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

$$q_3 = -70.89 < 100 \text{ KN} \qquad \underline{\text{OK}}$$

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

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

$$q_4 = -91.424 < q_{net} = 100 \qquad \underline{\text{OK}}$$

step 6- Analysis

for detailed analysis raft footing is devided into vertical and horizontal strips- and the moments are find

strips Moment - (X- direction strips)
(Findings)

	Max: moment value	
strip field	+	-
Column strip (CS)	1144	1047.3
Middle strip (MS)	319.1	1063
CS	1532	1142
MS	476.6	1039
CS	1523	1142.3 →
MS	303	1064.3
CS	1119	1052.2

Strips Moment (Y-direction)
(findings)

strip field	Max: moment value +	Max: moment value −
CS	943	960.3
MS	261	927.7
CS	$\boxed{1450}$	1107.3
MS	166.2	948.3
CS	1445	$\boxed{1230.3}$
MS	347.1	1193.3
CS	939.7	1117.5

Design:

X- Strips Deign

+ve Moments: (bottom reinforcement)

Distance to the rebar Centre = 75 mm

So effective raft depth = $d = (800-75)\,mm = 725\,mm$

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

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

As $\rho = 0.0088 > \rho_{min} = 0.0035$

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

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

$A_s = 6380\ mm^2/m$

Use 13 #25 bar / meter $A_s = 6381$

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

So ⟹ 13 #25 bar at 80mm

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Check Mc

$$a = \frac{A_s f_y}{0.85 f_c \times b} \Rightarrow \frac{6381 \times 400}{0.85 \times 30 \times 1000} = 100.1\ mm$$

$$c = \frac{a}{B_1} \Rightarrow \frac{100.1}{0.85} = 117.7\ mm$$

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

$$\epsilon_t = \left(\frac{d-c}{c}\right) \times 0.003 = \left(\frac{725-117.7}{117.7}\right) 0.003$$

$\epsilon_t = 0.0154 > 0.005$ (Tension Control)

then use $\phi = 0.9$

$M_c = \phi A_s f_y (d - a/2)$

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

$M_c = 1550.4$ KN.m $> M_u = 1532$ KN.m

OK

So use $\phi 25$ @ 80mm for +ve moment x-direction (bottom)

Now

x-strip design

-ve Moments (Top reinforcement)

$d = 725$ mm

$M_u^-(\max) = 1142.3$ KN.m/m

$$\frac{M_u}{\phi b d} = \frac{1142.3\ e^{6}}{(0.9)(1000)(725)^2} = 2.415$$

from Ru table

$\rho = 0.0064 > \rho_{min} = 0.0035$

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

$A_s = 0.0064 \times b \times d = 4640 \ mm^2/m$

Use 10 Φ25 /m (As = 4909 mm²/m)

Spacing

$\frac{1000}{10-1} \Rightarrow 111.1$ use 110mm < Smax 450mm

Use Φ25 @ 110 mm

Check Mc

$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{4909 \times 400}{0.85 \times 30 \times 1000} = 77 \ mm$

$c = \frac{a}{B_1} \Rightarrow \frac{77}{0.85} = 90.6 \ mm$

$d = 725 \ mm$

$\epsilon_t = \left(\frac{d-c}{c}\right) 0.003 \Rightarrow \left(\frac{725-90.6}{90.6}\right) 0.003$

$\epsilon_t = 0.021 > 0.005$

Then use $\Phi = 0.9$

$M_c = \Phi A_s f_y (d - a/2)$

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

$M_c = 21213.2$ KN.m $> M_u = 1532$ KN.m

$\underline{\underline{ok}}$

Use Φ25 @ 110mm for -ve Moments x-direction
(top reinforcement)

Design

Y- strip design

+ve moments (bottom reinforcement)

Distance to the rebar centre = (75+25) mm because y-direction reinforcement is under the reinforcement of x-direction

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

$$M_u^{+}\ (max) = 1450\ KN.m/m$$

$$\frac{M_u^{+}}{\Phi b d} = \frac{1450 \times e^{6}}{0.9 \times 1000 \times (700)^2} = 3.288$$

from R_u table $\rho = 0.009 > \rho_{min} = 0.0035$

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

$A_s = 0.009\ bd \Rightarrow A_s = 6300\ mm^2/m$

Use 13 $\Phi 25$ /m ($A_s = 6381\ mm^2/m$)

$$Spacing = \frac{1000}{13-1} \rightarrow 83 \text{ use } 80mm$$

Use $\Phi 25$ @ 80mm

Check M.C

$$a = \frac{A_s f_y}{0.85 \times f_c \times b} = \frac{6381 \times 400}{0.85 \times 30 \times 1000} = 100.1mm$$

$$c = \frac{a}{\beta_1} = \frac{100.1}{0.85} = 117.7\ mm$$

$$d = h - Cover = 725\ mm$$

$$\epsilon_t = \left(\frac{d-c}{c}\right) 0.003 = 0.0154 > 0.005$$

Use $\Phi = 0.9$

$$M_c = \Phi A_s f_y (d - a/2) \bar{e}^{6} = 1550.4 > M_u = 1450KN.m$$

So use $\Phi 25$ @ 80mm for +ve Moments Y-direction (bottom reinfment)

Y-strip design

-ve Moments (top reinforcement)

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

$M_u\ (max) = 1230.3$

$$\frac{M_u}{\Phi b d} = \frac{1230.3e^{6}}{0.9\times1000\times(700)^2} = 2.790$$

from R_u table

$\rho = 0.0076 > \rho_{min} = 0.0035 < \rho_{max} = 0.0244$

$A_s = 0.0076bd = 0.0076\times1000\times700$

$A_s = 5300\ mm^2/m$

Use 11 $\Phi25/m$ ($A_s = 5400\ mm^2/m$)

$$Spacing = \frac{1000}{11-1} = 100$$

Use $\Phi25$ @ 100 mm

Check M_c

$$a = \frac{A_s f_y}{0.85 f_c \times b} \Rightarrow \frac{\cancel{0.85}\ 5400\times400}{0.85\times30\times1000}$$

$a = 84.7\ mm$

$$c = \frac{a}{\beta_1} \Rightarrow \frac{84.7}{0.85} \Rightarrow 99.6\ mm$$

$d = 700\ mm$

$$\varepsilon_t = \left(\frac{d-c}{c}\right)\cdot0.003 = 0.0181 > 0.005$$

Then use $\Phi = 0.9$

$M_c = \Phi A_s f_y (d - a/2)$

$$M_c = 0.9\times5400\times400\left(700 - \frac{84.7}{2}\right)$$

$M_c = 1278.5 > 1230.3$ OK

So use $\Phi25$ @ 100mm for -ve Moment in y direction top reinforcement.

X- strip	Moment value KN.m/m	Design
Bottom As	1532	Φ25 @ 80mm
Top As	1142.3	Φ25 @ 110mm
Y- strip		
Bottom As	1450	Φ25 @ 80mm
Top As	1230.3	Φ25 @ 100 mm