Structural Design of Raft Foundation For 30 story high rise building - A case study in Lucknow, Uttar Pradesh region, India

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Abstract. In this age of rapid growth in population in india, there is scarcity of land in prime locations especially in metro cities of the country. So, to overcome this problem we are moving towards vertical constriction (that is towards high rise buildings). The main problem in moving towards vertical construction is foundation system, if the foundation system in high rise buildings is not plan and designed smartly and economically then there are different problems related to foundation system that is going to arise, the soil in that area also plays a very important role in designing of economical and stable foundation system. It is always beneficial to have a raft foundation on alluvial soil for high rise buildings. But, however, it is a matter of great concern that what foundation will be proposed on such type of natural soils or man-made refills [12]. In this paper, an attempt has been made to design a raft foundation based on its geotechnical analysis. An extensive survey of research works devoted to study the geotechnical parameters affecting the behavior of raft foundation is carried out with detailed experiments raft foundations are increasingly being recognized as an economical and effective foundation system for high rise buildings. This paper sets out some principles of design for such foundations, including design for the geotechnical ultimate limit state, the structural ultimate limit state and the serviceability limit state. Attention will be focused on the improvement in the foundation performance due to the raft being in contact with, and embedded within, the soil.

KEY WORDS: raft foundation, high rise buildings, alluvial region

1. INTRODUCTION:

This Raft Foundation has been designed for (G+10) High Rise Building in Alluvial region. The Raft Foundation have been used for economical consideration. In column load section, justification has been given for using raft foundation

Raft foundation is a type of combined footing, in this the entire area under the structure is provided as one rigid body supporting several columns. In this, the total allowable bearing stress have been taken as 100 KN/m2, since the soil is alluvial, the bearing stress is around 100 KN/m2.and in this type of soil raft foundation is most suitable type for high rise buildings. Since the columns have high axial loads, if spread footings are used, it will require large area under columns, which is not practical and economical, so in this condition we prefer using raft foundation.

In this, the raft will be designed as flat plate, which has a uniform thickness and without any beams or pedestals.

2. THE FOUNDATION DESIGN FOR A HIGH-RISE BUILDING OF 30 STORIES.

DESIGN PARAMETERS

Parameter	Notation	Value
Young modules of elasticity	(E)	2000000
Strength of concrete	(f_c)	30 MPa
Yield strength of steel	(f_y)	400 MPa
Live load factor	(L.L.F)	1.6
Dear load factor	(D.L.F)	1.2
Allowable Bearing stress	(q_a)	100 KN/ m^2
Soil Unit weight	(γ soil)	15 KN/m^3
Concrete Unit weight	(γ concrete)	25 KN/ m^3

Table 1, PARMATERS USED IN RAFT DESIGN

3. GEOTECHNICAL PROPERTIES OF ALLUVIAL SOIL (SPACIALLY IN UTTAR PRADESH REGION)

ENGINEERING TEST	GEOTECHNICAL PROPERTIES	VALUE
Compaction Test	Maximum Dry Density	1.79 g/cc
	Optimum Moisture Content	12.49 %
Direct Shear Test	Cohesion (C)	8^0
	Angle of internal friction (φ)	11.8 KN/m2

Table 2, Geotechnical properties of Alluvial soil

4. CALCULATION OF BEARING CAPACITY

4.1 Using IS: 6403-1981,

$$\text{For } \varphi = 8°$$

Bearing capacity factors , $N_c = 6.63, N_q = 1.63, N_\gamma = 0.50$

$$Shape\ factors, S_C = S_q = 1.15, S_\gamma = 0.68$$

$$Depth\ factors, d_c = 1.01, d_q = d_\gamma = 1$$

$$Inclination\ factors, i_c = i_q = 0.97, i_y = 0.765$$

4.2 For local shear failure,

$$The\ net\ ultimate\ bearing\ capacity = \frac{2}{3}N_cS_cd_ci_c + q(N_q - 1)S_qd_qi_q + B_\gamma N_\gamma d_\gamma i_\gamma$$

$$The\ net\ ultimate\ bearing\ capacity = 143.70\ \frac{KN}{m^2}$$

$$Taking\ factor\ of\ safety\ (FOS) = 2.5$$

$$Safe\ Bearing\ Capacity\ (SBC) = \left(\frac{q_{nu}}{FOS}\right) + \ D_f = 100\frac{KN}{m^2}$$

5. RAFT ANALYSIS

5.1 RAFT DIMENSIONS

The spacing of raft in x- side is 6 meters and the spacing of the raft in y-side is also 6 meters. There is one meter of edge around the edge's columns. In figure 1, the plan of the raft has been shown

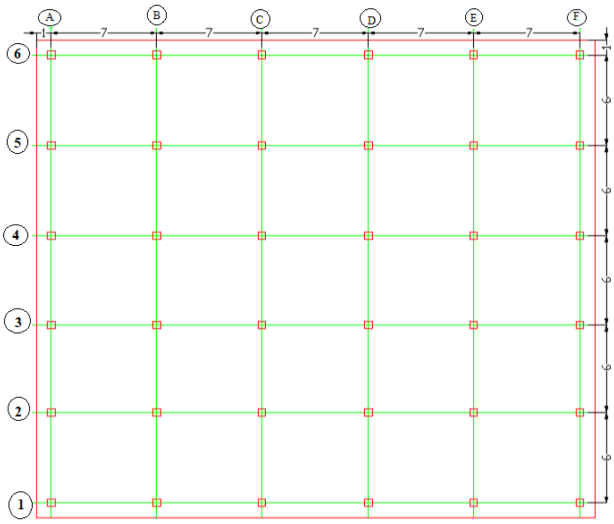


Figure 1, Raft layout

Total area of the raft under raft foundation = [(5x6) +1+1) x (5x7) +1+1)]

=(32x37)

=1184 m^2

5.2 LOADS OF COLUMNS IN RAFT:

This raft has been designed for a residential building of 30 stories, considering all the dead and live loads.

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

Table 3, design loads

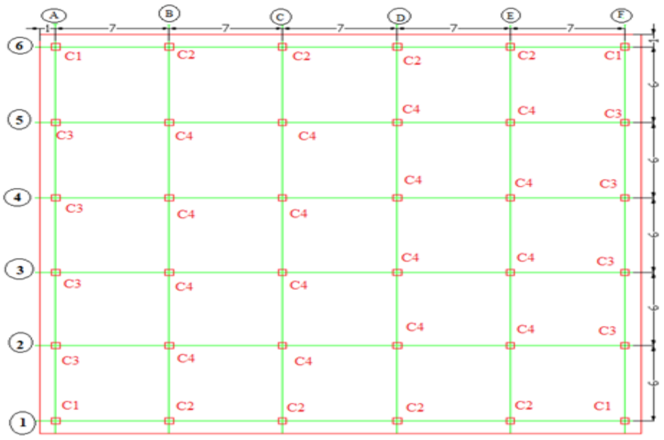


Figure 2, Raft dimension and column spacing

Loads per square meter are calculated as

$$General\ Dead\ load\ stress = (5 + 2.5 + 1)\frac{KN}{m^2} \times (number\ of\ floors)$$

$$General\ Dead\ load\ stress = (5 + 2.5 + 1)\frac{KN}{m^2} \times (30) = 255\frac{KN}{m^2}$$

$$General\ Life\ load\ stress = (2)\frac{KN}{m^2} \times (30) = 60\frac{KN}{m^2}$$

5.3 COLUMNS LOADS:

$$Axial\ Dead\ load = stress\ per\ unit\ area\frac{KN}{m^2} \times Turbidity\ area$$

Column type (1):

$$\text{Axial unfactored Dead load} = 255\frac{KN}{m^2} \times 4 \times 4.5m^2 = 4590\ KN$$

$$\text{Axial unfactored Live load} = 60\frac{KN}{m^2} \times 4 \times 4.5m^2 = 1080\ KN$$

$$\text{Total Service Axial load} = 4590\text{ KN} + 1080\text{ KN} = 5670\text{KN}$$

$$\text{Ultimate axial load} = 1.2(4590) + 1.6(1080) = 7236\text{KN}$$

Column type (2):

$$\text{Axial unfactored Dead load} = 255\frac{KN}{m^2} \times 4 \times 7m^2 = 7140\ KN$$

$$\text{Axial unfactored Live load} = 60\frac{KN}{m^2} \times 4 \times 7m^2 = 1680\ KN$$

$$\text{Total Service Axial load} = 7140\text{KN} + 1680\text{ KN} = 8820\text{ KN}$$

$$\text{Ultimate axial load} = 1.2(7140) + 1.6(1680) = 11256\text{KN}$$

Column type (3):

$$\text{Axial unfactored Dead load} = 255\frac{KN}{m^2} \times 4.5 \times 6m^2 = 6885\ KN$$

$$\text{Axial unfactored Live load} = 60\frac{KN}{m^2} \times 4.5 \times 6m^2 = 1620KN$$

$$\text{Total Service Axial load} = 6885 \text{ KN} + 1620\text{KN} = 8505 \text{ KN}$$

$$\text{Ultimate axial load} = 1.2(6885) + 1.6(1620) = 10854 \text{ K}$$

Column type (4):

$$\text{Axial unfactored Dead load} = 255\frac{KN}{m^2} \times 7 \times 6m^2 = 10710\ KN$$

$$\text{Axial unfactored Live load} = 60\frac{KN}{m^2} \times 7 \times 6m^2 = 2520KN$$

$$\text{Total Service Axial load} = 10710 \text{ KN} + 2520 \text{ KN} = 13230 \text{ KN}$$

$$\text{Ultimate axial load} = 1.2(10710) + 1.6(2520) = 16884\text{KN}$$

5.4 COLUMN LOADS:

Column no.	Dead load (KN)	Live load (KN)	Total service load (KN)	Total factored load (KN)
C1	4590	1080	5670	7236
C2	7140	1680	8820	11256
C3	6885	1620	8505	10854
C4	10710	2520	13230	16884

Table 4, all columns load

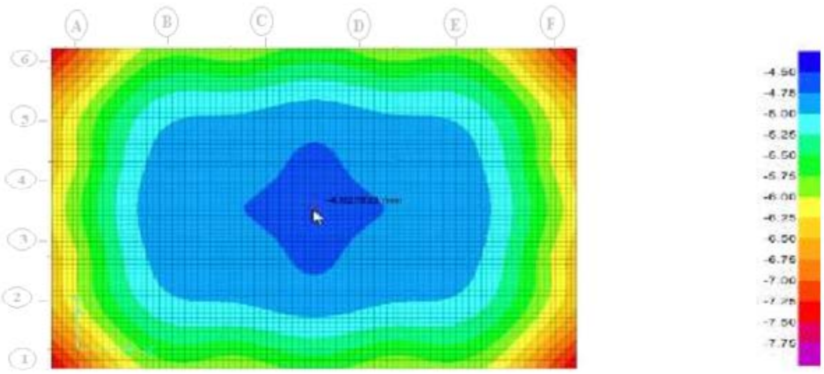


Figure 3, Columns Loads

5.5 DIMENSIONS OF COLUMNS AND REINFORCEMENT PROVIDED

The dimensions of columns are 650 mm by 650 mm with 12Ø22 as shown in the figure below. The maximum load that this design of column will resist is around 6432 KN.

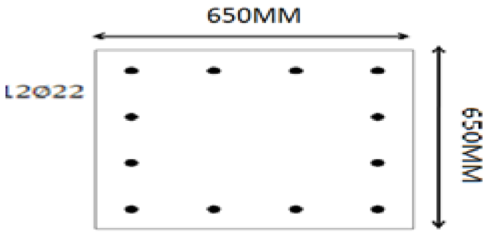


Figure 4, DIMENSIONS OF COLUMNS

$$Let's\ assume\ \%\ of\ steel\ as\ 1\%\ of\ A_g$$

$$A_{sc} = 0.01A_g$$

$$A_c = A_g - A_{sc}$$

$$A_c = 0.99A_g$$

$$P_U = (0.45\ f_{ck}A_c) + (0.67f_yA_{SC})$$

$$6432 \times 10^3 = \left(0.45 \times 30 \times 0.99A_g\right) + (0.67 \times 415 \times 0.01A_g)$$

$$A_g = 378352\ mm^2$$

$$Let\ Assume\ it\ as\ a\ Square\ column$$

$$S = \sqrt{378352}$$

$$S = 650$$

$$A_g = (650)^2 = 422500\ mm^2$$

$$\text{To find Area of steel} : -$$

$$P_u = (0.45f_{ck}A_c) + (0.67f_yA_{SC}$$

$$A_C = A_g - A_{SC}$$

$$6432 \times 10^3 = (0.45 \times 30 \times \left(A_g - A_{SC}\right) + (0.67 \times 415 \times A_{SC})$$

$$6432 \times 10^3 = (5703750 - 13.5A_{SC}) + (278.05A_{SC})$$

$$6432 \times 10^3 = (5703750 + 264.55A_{SC})$$

$$A_{SC} = 2743mm^2$$

$$P_C = \emptyset P_n = 0.7 \times 0.8(0.85f_{c'}A_g + f_yA_{st}$$

$$P_C = \emptyset P_n = (0.7)(0.8)[0.85(30)(650)(650)] + (415)(2743)$$

$$P_C = 7172KN > P_U = 6432KN$$

5.6 WHY RAFT SHOULD BE USED:

The maximum axial load is occurred in column type 3, and if we had to design a single square footing in alluvial region. The properties that are used in the analysis and design of raft foundation in alluvial soil are

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

Table 5, Properties taken in raft design

$$q_e = 100\frac{KN}{m^2}$$

$$\text{Total Maximum Service Axial load} = 4080\text{KN} + 960\text{KN} = 5040\text{KN}$$

$$\text{Area of single square footing} = \frac{1.1(5040)}{100}$$

$$\text{B} \times \text{B} = 55.44$$

$$\text{B} = \sqrt{55.44 m^2}$$

$$\text{B} = 8\text{m} \times 8\text{m}$$

As the area is very big that must be excavated under one column. So, the raft foundation will be more economical and efficient for this kind of foundation in alluvial region.

5.7 RAFT THICKNESS:

With the help of diagonal tension shear, the thickness of the raft in raft foundation can be determined. For calculation, maximum ultimate column load will be used.

$$U = (b_o)(d)(\emptyset)(0.34)f_{c'}$$
$$Where,$$
$$U = Factored\ column\ load$$
$$\emptyset = Reduction\ Factor = 0.85$$
$$b_o = The\ parametre\ of\ the\ sheared\ area$$
$$d = effective\ depth\ of\ raft$$
$$f_{c'} = Compressive\ strength\ of\ concrete$$

$In\ this\ Raft$
$U = 6432KN = 6.432MN$
$b_o = 4(0.4 + d) = 1.6 + 4d$
$And\ by\ using\ the\ equation\ above, the\ required\ depth\ of\ the\ raft\ can\ be\ determined$

$$U = (b_o)(d)(\emptyset)(0.34)f_{c'}$$
$$6.432 = (1.6 + 4d)(d)(0.75)(0.34)(30)$$
$$6.432 = (1.6d + 4d^2)(1.397)$$
$$4.604 = 1.6d + 4d^2$$
$$0 = 4d^2 + 1.6d - 4.604$$
$$0 = 4d^2 + 1.6d - 4.604$$

Solving equation for d = 0.860 m = 860 mm = 900 mm Thickness of the raft = 700 + 75 + 25 (assumed bar diameter)
Thickness = 1000 mm

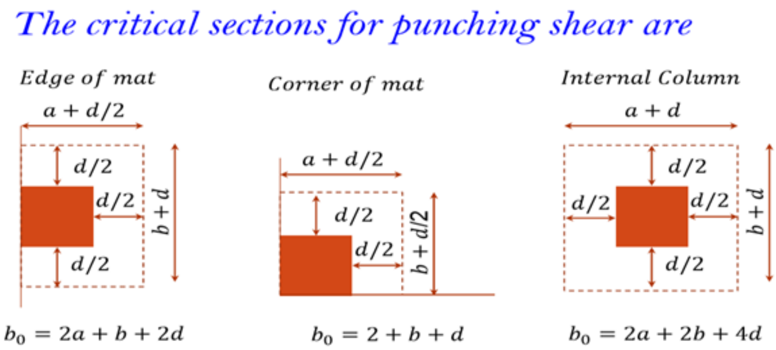


Figure 5, The critical sections for punching shear

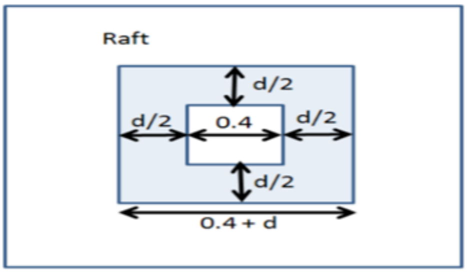


Figure 6, Diagonal shear area

5.8 RAFT DEPTH CHECK:

5.8.1 ONE-WAY SHEAR:

Vu = $Maximum\ shear$- (d) $(wsoil)$
To determine the $wsoil$, On the maximum load's stripe, the average soil pressure should be determined.
$\underline{\boldsymbol{Calculate\ the\ ultimate\ bearing\ stress\ of\ the\ soil}:-}$

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

$$q_{alt} = \frac{C_2 + C_4 + C_4 + C_2}{(width\ of\ strip)(length\ of\ strip)}$$

$$q_{alt} = \frac{(6432 + 3216 + 3216 + 6432)}{(6) \times (20)}$$

$$q_{alt} = \frac{(19296)}{120}$$

$$q_{alt} = 160.8 \frac{KN}{m^2}$$

$$q_{alt} = \frac{(6432 + 3216 + 3216 + 6432)}{(6) \times (20)}$$

$$q_{alt} = \frac{(19296)}{(120)}$$
$$q_{alt} = 160.8KN/m^2$$
$$W_{soil} = (160.8\ KN/m^2)(width\ of\ strip)$$
$$W_{soil} = (160.8\ KN/m^2)(6)$$
$$W_{soil} = 643.2KN/m$$

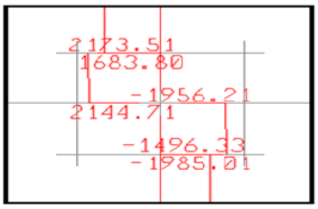
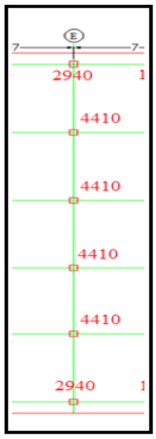


Figure 7, Shear diagram



Maximum shear in strips CSY5

Assuming d=1000−75=925 mm

$$V_u = Maximum\ shear - (d)(W_{soil})$$
$$V_u = (2173.5) - (0.925) \times (643)$$
$$V_u = 1578.72KN$$
$$d = \frac{V_u \times (1000)}{(0.75)(\sqrt{f'_c})(\frac{1}{6})(B)}$$
$$d = \frac{(V_u)(1000)}{(0.75)(\sqrt{30})(^1/_6)(6000)}$$
$$d = 431.13mm$$
$$d = 431.13mm < d = 725\ ok$$

5.8.2 TWO-WAY SHEAR (INTERIOR COLUMN):

Vu=$Column\ Axial\ Load$− $(d$+$a)^2$($wsoil$)

To determine the w_{soil}, On the maximum load's stripe, the average soil pressure should be determined.

$$q_{alt} = 160.8KN/m^2$$
$$Assuming\ d = 800 - 75 = 725mm$$

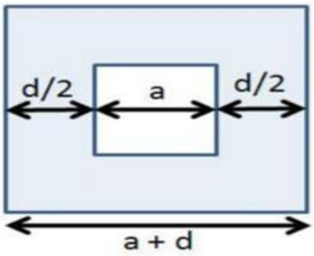


Figure 8, Two way Shear

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

$$V_u = (6432) - (0.725 + 0.65)^2 (643.2)$$

$$V_u = 5215.95KN$$

$$b_o = 4(a + d)$$

$$b_o = 4(650 + 725) = 5500mm$$

$$d = \frac{V_u \times (1000)}{(0.75)(\sqrt{f'_c})(\frac{1}{3})(b_o)}$$

$$d = \frac{(5212) \times (1000)}{(0.75)(\sqrt{30})(\frac{1}{3})(5500)}$$

$$d = 696.54mm$$

$$d = 696.54mm < d = 725ok$$

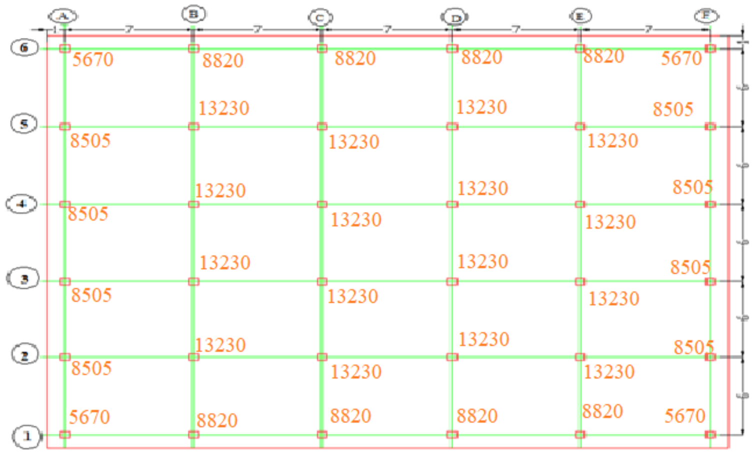


Figure 9, columns total service loads (DL+LL)

6. SOIL PRESSURE CHECK:

In soil pressure check, the net pressure must be checked at every point of the raft foundation. The effect of moments that is they're on the raft must be checked to make sure that the stresses on the raft under all columns are less than the net allowable stress, that is equal to 100KN/m2.

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

$$A = Area\ of\ the\ mat = [(5 \times 6) + 1 + 1) \times (5 \times 7) + 1 + 1)]$$

$$A = (32 \times 37) = 1184m^2$$

$$I_x = \frac{bh^3}{12}$$

$$I_x = \frac{(32) \times (37)^3}{12} = 135075\, m^4$$

$$I_y = \frac{bh^3}{12}$$

$$I_y = \frac{(37) \times (32)^3}{12} = 101035\, m^4$$

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

$$Q = 4(C1) + 8(\text{C2}) + 8\ (\text{C3}) + 16\ (\text{C4})$$

$$Q = 4(5670) + 8(8820) + 8\ (8505) + 16\ (13230)$$

$$Q = 22680 + 70560 + 68040 + 211680$$

$$Q = 372960KN$$

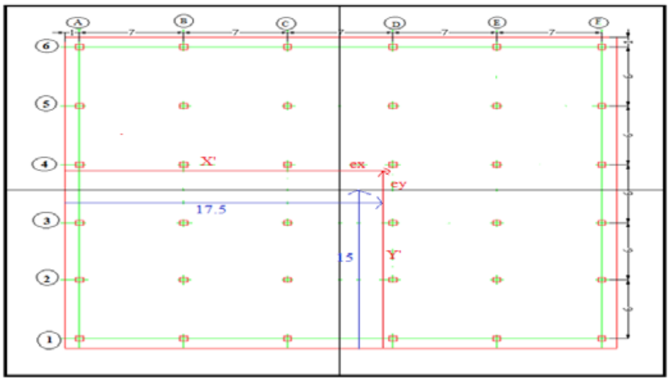


Figure 10. Resultant position due to column load

6.1 CALCULATE My:

$$e_x = X' - 15$$

$$Q \times X' = Q_1(x_1) + Q_2(x_2) + \cdots$$

$$X' = \frac{Q_1(x'_1) + Q_2\ (x'_2) + \cdots}{Q}$$

$$X' = \frac{1}{372960} \times [(7)(8820 + 13230 + 13230 + 13230 + 13230 + 8820) + (14)(8820 + 13230 + 13230 + 13230 + 13230 + 8820) + (21)(8820 + 13230 + 13230 + 13230 + 13230 + 8820) + (28)(8820 + 13230 + 13230 + 13230 + 13230 + 8820) + (35)\ (5670 + 8505 + 8505 + 8505 + 8505 + 5670)$$

$$X' = \frac{1}{372960} \times [164640 + 329280 + 493920 + 658560 + 529200]$$

$$X' = \frac{1}{372960} \text{x} [\ 2175600]$$

$$X' = 18.3m$$

$$e_x = 18.3 - 17.5 = 0.83m$$

$$M_y = Q_{ex} = 372960 \times 0.83m = 98479KN.m$$

6.2 CALCULATE Mx:

$$e_y = Y' - 9$$
$$Q \times Y' = Q_1(y_1) + Q_2(y_2) + \cdots$$
$$Y' = \frac{Q_1(y'_1) + Q_2(y'_2) + \cdots}{Q}$$

$$Y' = \frac{1}{372960} \times [(30)(5670 + 8820 + 8820 + 8820 + 8820 + 5670) + (24)(8505 + 13230 + 13230 + 13230 + 13230 + 8505) + (18)(8505 + 13230 + 13230 + 13230 + 13230 + 8505) + (12)(8505 + 13230 + 13230 + 13230 + 13230 + 8505) + (6)(8505 + 13230 + 13230 + 13230 + 13230 + 8505)]$$

$$Y' = \frac{1}{372960} \times [466200 + 559440 + 419580 + 279720 + 139860]$$
$$Y' = \frac{1}{372960} \text{x} [1864800]$$
$$Y' = 15.71 \text{ m}$$
$$e_y = 15.71 - 15 = 0.71 \text{ m}$$
$$M_x = Q_{ey} = 372960 \times 0.71\, m = 84241KN.$$

7. Soil pressure due to total service axial loads and moments

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

In the above equation (-) minus signs indicates compression stress. In all the four corners of the raft, soil pressure will be checked with the help of the above equation. The calculated soil pressure should not be more than the allowable stress of the soil and not less than 0 KN/m2, this is to make sure that no tension could occur in any part of the raft.

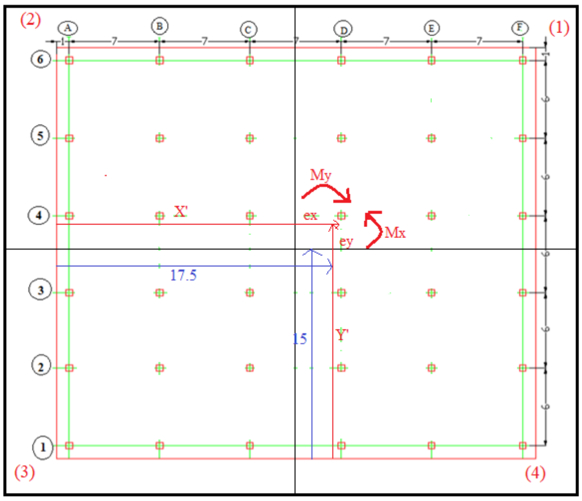


Figure 13. corners of raft

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

$$q_1 = -\frac{(372960)}{(1184)} - \frac{(98479) \times (17.5)}{(101035)} - \frac{(84241) \times (16.5)}{(135075)}$$

$$q_1 = -100 - 17 - 10$$
$$q_1 = -117 \ < q_{net} = 120\, KN/m^2\ OK$$
$$q_2 = -\frac{(372960)}{(1184)} + \frac{(98479) \times (17.5)}{(101035)} - \frac{(84241) \times (16.5)}{(135075)}$$
$$q_2 = -100 + 17 - 10$$
$$q_2 = -93 \ < q_{net} = 120\, KN/m^2\ OK$$
$$q_3 = -\frac{(372960)}{(1184)} + \frac{(98479) \times (17.5)}{(101035)} + \frac{(84241) \times (16.5)}{(135075)}$$
$$q_3 = -100 + 17 + 10$$
$$q_3 = -83 \ < q_{net} = 120\, KN/m^2\ OK$$
$$q_4 = -\frac{(372960)}{(1184)} - \frac{(98479) \times (17.5)}{(101035)} + \frac{(84241) \times (16.5)}{(135075)}$$
$$q_4 = -100 - 17 + 10$$
$$q_4 = -107 \ < q_{net} = 120\, KN/m^2\ OK$$

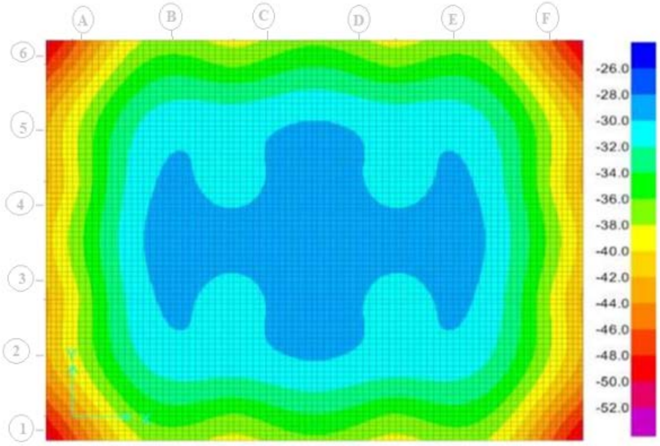


Figure 14, Soil Pressure

The pressure values that have been calculated above are in compression and all the values are coming less than the net bearing stress of the soil which is equal to 100 KN/m^2. So, from this it can be said that soil is safe against any type of soil failure.

8. SETTLEMENT ANALYSIS: -

The maximum settlement that was recorded was equal to 28.5 mm. This amount of settlement is acceptable, that is 28.5mm, because according to IS 1904-1986, the maximum allowable settlement is equal to 50 mm.

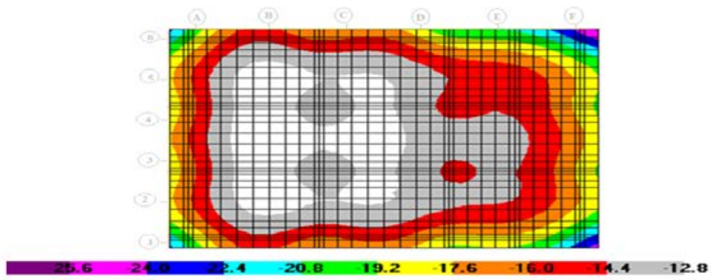


Figure 15, settlement of raft foundation

9.Moments Strips SAFE results:

In SAFE software, the raft is automaticity divided to different strips. Each direction has a column strip and middle strips. The moments analyzed by SAFE software are the strip moments per one meter width of the strip.

9.1 X direction strips

In x-strips, the column strips have a dimension of 2.5-meter width and the middle strips have a dimension of 3 meters width. Moments computed are analyzed based on one meter unit width of the strip. Moment Diagram of x-strips are shown in figure 13.

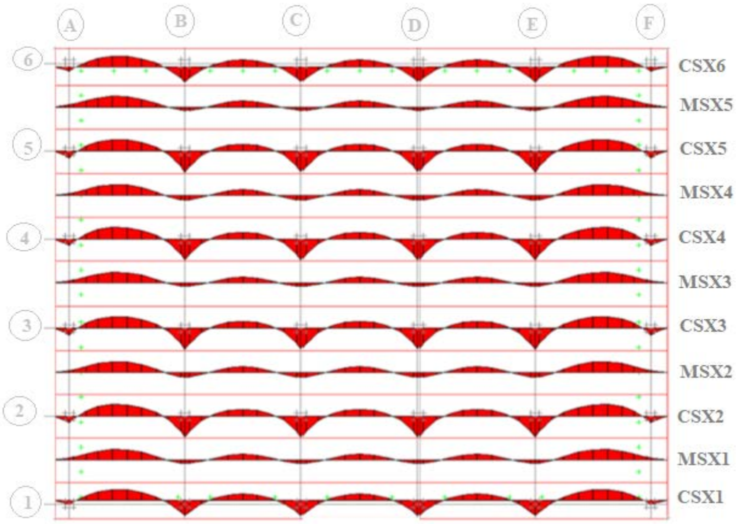


Figure 13. X-Strip moment diagram

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	1233	1259.3
MSx1	Middle strip	419.1	1313.0
CSx2	Column strip	1632	1242.0
MSx2	Middle strip	776.6	1339.0
CSx3	Column strip	1723	1442.3
MSx3	Middle strip	603.4	1264.3
CSx4	Column strip	**1858.7**	1252.2
MSx4	Middle strip	668	1335.2
CSx5	Column strip	1284.7	**1845.3**
MSx5	Middle strip	867	1406.7
CSx6	Column strip	665.7	1298.6

9.2 Y direction strips

In y-strips, the column strips have a dimension of 2.75-meter width and the middle strips have a dimension of 3.5 meters width. Moments computed are analyzed based on one meter unit width of the strip. Moment Diagram of x-strips are shown in figure 14.

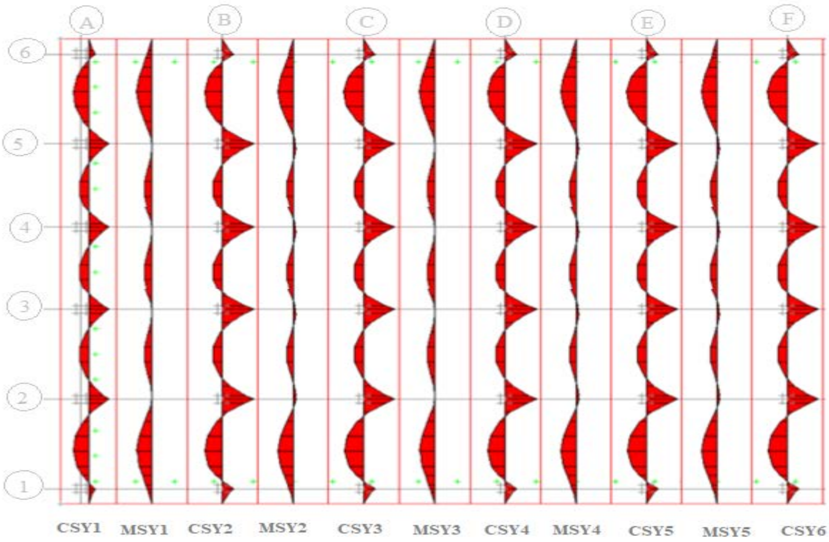


Figure 11. Y-Strip moment diagram

Strip notation	Strip Field	Maximum Moment Value (kN.m)	
		Positive	Negative
CSY1	Column strip	1043	1060.3
MSY1	Middle strip	426.1	1027.7
CSY2	Column strip	6450	1407.3
MSY2	Middle strip	466.2	1048.3
CSY3	Column strip	1645	1430.3
MSY3	Middle strip	844	1393.0
CSY4	Column strip	**1876**	1317.5
MSY4	Middle strip	954.4	1087.6
CSY5	Column strip	853.8	**2456.7**
MSY5	Middle strip	1102.1	1213.6
CSY6	Column strip	1023.5	979.5

10. Manual & Computer Design:

Using the SAFE software analysis, the moments of x and y strips will be used to design the top and the bottom reinforcement for the raft. The maximum moments in each direction will be used to design the reinforcement in all raft strips. SAFE software design output will be compared with the manual design for those maximum positive and negative moments

10.1.X-strip Design:

10.1.1 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

$$M_u^+(maximum\} = 1532\ KN.m/m$$

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

$$Go\ to\ q_u\ table \rightarrow p = 0.0088\ >\ p_{min} = 0.0035$$

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

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

$$A_s\ = 6380mm^2/m$$

$$use\ 13\emptyset 25/m\quad A_s = 6381mm^2/m$$

$$S = \frac{1000}{(13-1)} = 83$$

$$Use\ S = 80mm\ <\ S_{max} = 450mm$$

$$Use\ \emptyset 25@80mm$$

Check Mc:

$$a = \frac{A_s\ X\ F_y}{0.85\ X\ F_c\ X\ b} = \frac{6381\ X\ 400}{0.85\ X\ 30\ X\ 1000} = 100.1mm$$

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

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

$$\in_t = \left(\frac{d-c}{c}\right) X\ 0.003 = \left(\frac{725-117.7}{117.7}\right) X\ 0.003 = 0.0154 > 0.005(Tension\ control)$$

$$then\ use\ \emptyset\ \ =\ \ 0.9$$

$$M_c\ = \emptyset(A_S)(F_y)(d - \frac{a}{2})$$

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

$$Mc\ \ =\ \ 1550.4\ kN.m\ >\ Mu\ \ =\ \ 1532\ kN.m\ ok$$

$$Use\ \emptyset 25@80mm\ for\ positive\ moments\ x - direction - bottom\ Reinforcement$$

10.1.2. 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

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

$$M_u^-(maximum) = 1142.3kN.m/m$$

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

$$Go\ to\ qu\ table\ \rightarrow \rho\ =\ 0.0064\ >\ \rho min\ =\ 0.0035$$

$$\rho\ =\ 0.0064 < \ \rho max\ =\ 0.0244$$

$$A_S = \ 0.0064(\ b)(\ d)\ \ =\ 0.0064\ (1000)(\ \ 725\ )$$

$$A_S = 4640\ mm2/m$$

$$use\ 10\emptyset 25/m\quad As\ \ =\ 4909\ mm2/m$$

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

$$Use\ \emptyset 25@110\ mm$$

Check Mc:

$$a = \frac{A_S\ X\ F_y}{0.85\ X\ F_c\ X\ b} = \frac{4909\ X\ 400}{0.85\ X\ 30\ X\ 1000} = 77mm$$

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

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

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

$$then\ use\ \emptyset\ \ =\ 0.9$$

$$M_c = \emptyset(A_S)(F_y)(d - \frac{a}{2})$$

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

$$Mc\ \ =\ 1213.2\ kN.m\ >\ Mu\ \ =\ 1532\ kN.m\ ok$$

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

10.2.0 Y-strip Design

10.2.1 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 + 25mm, because y-direction reinforcement will be under the reinforcement of x-direction, so effective raft depth equal to

d = 800−(75+25) = 700 mm

$$M_u^+(maximum\} = 1532\ KN.m/m$$

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

$$Go\ to\ q_u\ table \rightarrow p = 0.009\ >\ p_{min} = 0.0035$$

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

$$A_s\ =\ 0.009(\ b)\ \ (d)\ \ =\ 0.0009\ (1000)\ \ (700)$$

$$A_s\ = 6300mm^2/m$$

$$use\ 13\emptyset 25/m \quad A_s = 6381mm^2/m$$

$$S = \frac{1000}{(13-1)} = 83$$

$$Use\ S = 80mm\ \ <\ S_{max} = 450mm$$

$$Use\ \emptyset 25@80mm$$

Check Mc:

$$a = \frac{A_s\ X\ F_y}{0.85\ X\ F_c\ X\ b} = \frac{6381\ X\ 400}{0.85\ X\ 30\ X\ 1000} = 100.1mm$$

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

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

$$\in_t = \left(\frac{d-c}{c}\right) X\ 0.003 = \left(\frac{725-117.7}{117.7}\right) X\ 0.003 = 0.0154 > 0.005(Tension\ control)$$

$$then\ use\ \emptyset\ \ =\ \ 0.9$$

$$M_c\ = \emptyset(A_s)(F_y)(d - \frac{a}{2})$$

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

$$Mc\ \ =\ \ 1550.4\ kN.m\ \ >\ \ Mu\ \ =\ \ 1532\ kN.m\ ok$$

$$Use\ \emptyset 25@80mm\ for\ positive\ moments\ x - direction - bottom\ Reinforcement$$

10.2.2. 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

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

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

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

$$Go\ to\ qu\ table\ \rightarrow \rho\ =\ 0.0076\ >\ \rho min\ =\ 0.0035$$

$$\rho\ =\ 0.0076 <\ \rho max\ =\ 0.0244$$

$$A_S =\ 0.0076(\ b)(\ d)\ \ =\ 0.0076\ (1000)(\ \ 700\ )$$

$$A_S = 5300\ mm2/m$$

$$use\ 10\emptyset 25/m\quad As\ =\ 5400\ mm2/m$$

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

$$Use\ \emptyset 25@110\ mm$$

Check Mc:

$$a = \frac{A_s\ X\ F_y}{0.85\ X\ F_c\ X\ b} = \frac{5400\ X\ 400}{0.85\ X\ 30\ X\ 1000} = 84.7mm$$

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

$$d\ =\ h - cover - strrups - \frac{d_b}{2} =\ 800 - 75 - 25\ =\ 700\ mm$$

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

$$then\ use\ \emptyset\ =\ 0.9$$

$$M_c = \emptyset(A_S)(F_y)(d - \frac{a}{2})$$

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

$$Mc\ =\ 1278.5\ kN.m\ >\ Mu\ =\ 1532\ kN.m\ ok$$

$$Use\ \emptyset 25@100mm\ for\ negative\ moments\ x - direction - top\ Reinforcement$$

10.3.0 Comparison Table:

	Moment Value kN.m/m	Manual Design		SAFE design
X-strip				
Bottom As	1532	$\emptyset 25@80mm$	$6381\ mm2/m$	$13\emptyset 25 = 6381\ mm2/m$
Top As	1142.3	$\emptyset 25@110mm$	$4909\ mm2/m$	$10\emptyset 25 = 4909\ mm2/m$
Y-strip				
Bottom As	1450	Ø25@80mm	$6381\ mm2/m$	$12\emptyset 25 = 5890mm2/m$
Top As	1230.3	Ø25@100mm	$5400\ mm2/m$	$11\emptyset 25 = 5400mm2/m$

Table 7, comparison between manual and computer design

10.CONCLUSION

1. As per the Indian Standards, safety requirements were provided while designing the Raft foundation corresponding to Alluvial type of soil. In this paper, the design of the raft foundation along with its reference to various geotechnical aspects are studied and implemented in the design required to be completed.
2. For loose soil bending moment is sagging in nature, over entire of raft. However, as soil stiffness increases tension zone is created. From the edge as we proceed toward center the intensity and extent of tension zone goes increasing. However, the effect is more in X direction as compared to Y direction.
3. For loose soil, pressure distribution beneath the raft is lower at edge and goes on increasing towards the center. In the central zone, in between column, it remains almost constant. For medium soil, at the edge, pressure distribution is high and goes on reducing towards the center with very mild rate. For hard soil, pressure distribution at the edges is high, reduces under the edge columns and then after increases in the central part.
4. The punching shear factors are less than 1 and settlement is less than 50 mm.

11.Index

a = *depth of rectangular stress distribution from compression fiber to distance* $\beta 1c$

As = *area of tension steel*
Ab = *area of individual bar*
As,min = *minimum tension reinforcement*
b = *width of compression face*
bo = *perimeter of critical section for two −way shear in slabs and footings, mm*
Ca = *coefficient of aticve earth pressure*
Cc = *clear cover from the nearest surface in tension to the surface of the flexural tension reinforcement, mm*
Cm = *factor relating the actual moment diagram of a slender column to an equivelant uniform moment diagram*
Cm = *moment coefficient*
Cp = *coefficient of passie earth pressure*
d = *effective depth from compression surface to center of steel in tension zone.*
d' = *distance from extreme −compression fiber to centroid of comression renforcement,mm*
db = *nominal diameter of bar ,wire ,or prestressing strand ,mm*
D = *dead load*

e = $eccentricity$
Ec = $modulus\ of\ elasticity\ of\ concrete\ MPa$
EI = $Flexural\ stiffness\ of\ compression\ member,\ N-mm2$
Es = $modulus\ of\ elasticity\ of\ reinforcement\ MPa$
$f\ c'$ = $compressive\ strength\ in\ concrete\ due\ 28-day,\ psi\ or\ MPa$
$f\ s$ = $calculated\ stress\ in\ reinforcement\ at\ service\ loads,\ MPa\ or\ N/mm2$
fy = $yeild\ strength\ of\ nonprestressed\ reinforcement$
h = $overall\ depth\ or\ thickness\ of\ slab\ or\ beam$
I = $moment\ of\ inertia\ of\ a\ section,\ mm4$
jd = $distance\ between\ the\ resultants\ of\ the\ internal\ compressive\ and\ tensile$ $force\ on\ cross\ section$
k = $effectivr\ length\ factored\ for\ compression\ member$
l = $span\ length\ of\ beam\ or\ one-way\ slab,\ generally\ center\ to\ center\ of$ $supports$
ld = $development\ length$
ln = $clear\ span\ measured\ face\ to\ face\ of\ supports.$
M = $moment$
Mc = $factored\ moment\ to\ be\ used\ for\ design\ of\ a\ slender\ compression\ member$ $KN-m$
Mu = $factored\ moment\ due\ to\ factored\ load$
PE = $buckling\ load\ of\ an\ elastic,\ hinged-end\ column$
Pn = $nominal\ axial\ load\ strength\ at\ given\ eccentricity$
$P\ o$ = $nominal\ axial\ load\ strength\ at\ zero\ eccentricity$
Pu = $axial\ force\ due\ to\ factored\ load$
S = $spacing\ between\ bars$
$V\ c$ = $Nominal\ shear\ strength\ of\ concrete$
W = $weight$
$\beta 1$ = $ratio\ of\ depth\ pf\ rectangular\ stress\ block,\ a,\ to\ depth\ to$ $neutral\ axis,c$
γ = $ratio\ of\ the\ distance\ between\ the\ outer\ layers\ of\ reinforcement\ in\ a\ column$ $to\ the\ overall\ depth\ of\ the\ column.$
ρ = $ratio\ of\ tension\ steel$

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