Journal of Civil Engineering and Environmental Technology
Print ISSN : 2349-8404; Online ISSN : 2349-879X; Volume 2, Number 11; April – June, 2015 pp 31 – 36
Krishi Sanskriti Publications
http://www.krishisanskriti.org/jceet.html

Structural Design Of Raft Foundation Based On Geotechnical Analysis

Nabanita Sharma[1], ,Jitendra Deka[2], Ankita Gogoi[3],Dipankar Borpuzari[4] , Biki Hussain[5]

Royal Group of Institutions
[1]nabanita@india.com, [2]jitend.dek93@gmail.com, [3]1ankitagogoi@gmail.com
[4]dpnkrborpuzari10@gmail.com
[5]b.messi11@gmail.com

Abstract:
In this age of rapid urbanization, due to scarcity of the space in prime locations especially in major cities, constructions are proposed even on refilled areas, which may be of natural fill or engineering fill. In the present scenario, the major problem in focus is the geotechnical issues acting as the barrier in the construction of tall buildings in such areas. Basically in engineering refill, proper precaution is taken for the selection of the refill material and utmost care is taken for the compaction too with the understanding that some construction may be taken in future on such areas. It is always beneficial to have foundations on engineering refilled soil. But, however, it is a matter of great concern that what foundation will be proposed on such type of natural or man-made refills. 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.

1. INTRODUCTION

Raft foundation is an essential type of foundation. It is constructed for many multistoried buildings. Hence, it is necessary to get acquainted with the analysis and design of a raft foundation.

2. STUDY AREA

The site of the foundation which is to be designed in this paper is in the Eastern zone to the Royal Group of Institutions, Guwahati, Assam. Currently this place is used as a parking lot.
Figure 1. Proposed site for the foundation design (inside the white ellipse)

3. DETERMINATION OF GEOTECHNICAL PROPERTIES

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/m^2

Table 1. Results of Engineering Tests

4. CALCULATION OF BEARING CAPACITY

Using IS: 6403-1981, for $\phi = 8^o$, 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, $i_c = i_q = 0.97$, $i_\gamma = 0.765$
For local shear failure, the net ultimate bearing capacity = $\frac{2}{3} c N_c\, s_c\, d_c\, i_c + q\,(N_q - 1)\, s_q\, d_q\, i_q + B\,\gamma\, N_\gamma\, s_\gamma\, d_\gamma\, i_\gamma$
=143.70 KN/m^2

Taking a Factor of safety (FOS) = 2.5, Safe Bearing Capacity,

SBC = $(q_{nu} / FOS) + \gamma D_f$ = 60.51KN/m^2

5. ANALYSIS OF THE RAFT FOUNDATION

5.1 Plan of the Foundation

The size of the available land for the proposed construction is considered as 30m X 60m. The design of the raft foundation will be done for a size of 25m X 30m. The plan is illustrated in the following figures.

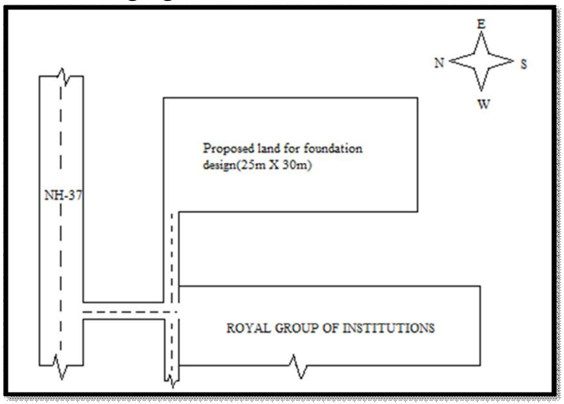


Fig 2. Illustration of the proposed land concerned with the design of the foundation.

5.2 Data Assumptions

The foundation is of length 30m and breadth 25m. Columns are provided at a centre to centre distance of 5m for both longitudinal and transverse directions. It covers a total of 7 columns along its length and 6 columns along its breadth in the exterior sides. The total number of columns at the exterior side is 22 and the total number of columns for interior side is 20. Further it has been considered that the load carried by the exterior columns is 500KN and load carried by interior columns is 700KN. The size of the columns is considered to be 400mm X 400mm.

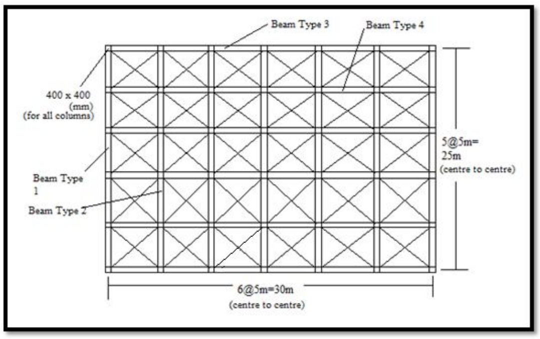


Fig 3. Illustration of the applications of areas according to IS Code 456:2000 regarding calculation of the loads on the beams.

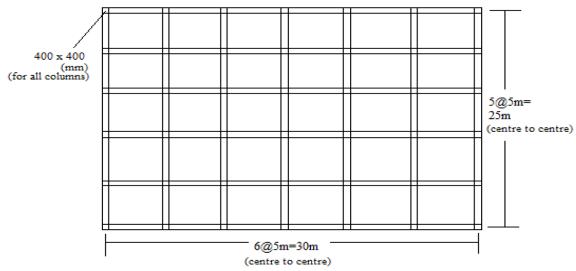


Fig 4. Plan of the beam and slab type raft foundation

5.3 Calculations of the Imposed Load

Total column load =(22x500)+(20x700) = 25000 kN

Self-weight of the raft = 10% of the Total column load = 2500KN

Therefore Total Load =25000 +2500 =27500KN

Therefore, Imposed load = $\frac{27500}{\text{Length x Breadth}}$

$$= \frac{27500}{(30+0.2+0.2)(25+0.2+0.2)}$$

$= 35.61KN/m^2 < 60.51KN/m^2$

Here, 200mm(=0.2m) is considered for the existing columns at the ends of the figure.

Thus, we have seen that total imposed load is less than safe bearing capacity.

5.4 Load on Supporting Beams

Type 1 and 3

Area= (1/2) base X height = 0.5 X 5 X 2.5 = 6.25 m^2

Therefore, load on the beam in the form of point load =Area X imposed load = 222.56KN

Therefore, load in the form of uniformly distributed load=(point load/distance) = 222.56/5 =**44.51KN/m**

Point load at the ends = 222.56/2 = **111.28KN**

Point load at the mid-supports=2X111.28=**222.56 kN**

Type 2 and 4

Area= (1/2) base X height =2(0.5 X 5 X 2.5)=12.5 m^2

Therefore, load on the beam in the form of point load =Area X imposed load = 12.5X35.61 = 445.125 kN

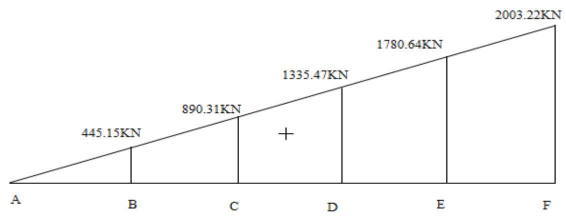
Therefore, load in the form of uniformly distributed load=(point load/distance)=445.125/5=**89.025 KN/m**

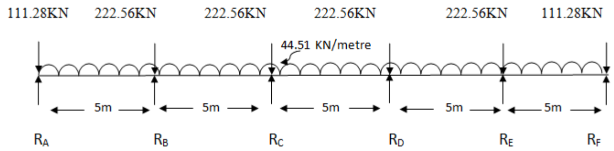
Point load at the ends = **222.56 KN**

Point load at the mid-supports=2X222.56=**445.12 kN**

5.5 Analysis of the Beams

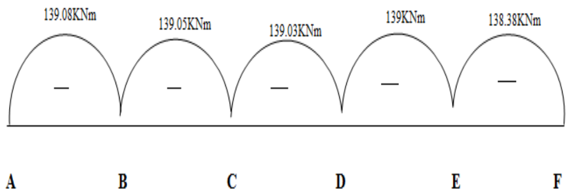
Type 1





$R_A = R_F = 111.28 + (44.51 \times 2.5) = 222.55$ KN

$R_B = R_C = R_D = R_E = 222.56 + (2 \times (44 \times 2.5)) = 445.11$



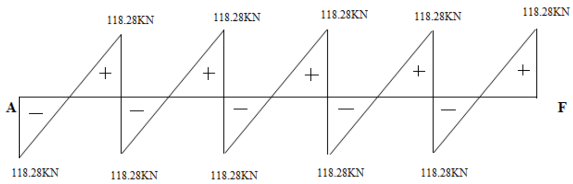
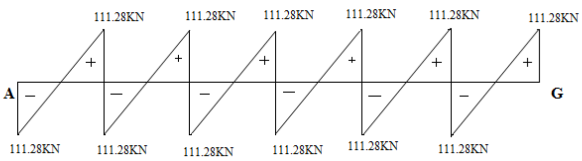


Fig 5. Bending moment diagram

Type 2



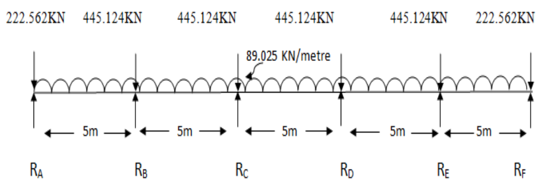


Fig 6. Shear Force diagram

Type 3

$R_A = R_F = 222.562 + (2.5 \times 89.025) = 445.124$ kN

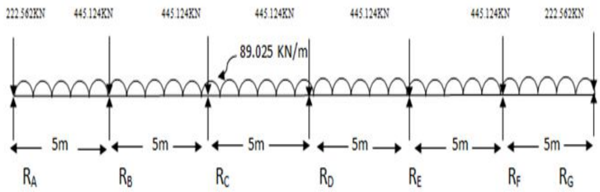
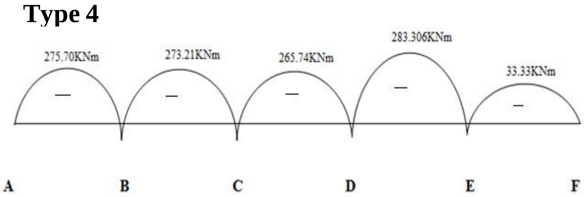


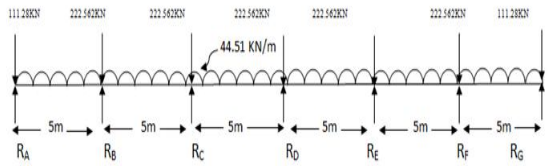
Fig 7. Bending moment diagram

Type 4



$R_B = R_C = R_D = R_E = R_F = 445.12 + (2.5 \times 89.025 \times 2) = 890.25$ KN

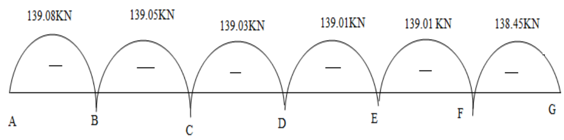
Fig 8. Shear Force diagram



$R_A = R_G = 222.562 + (2.5 \times 44.51) = 222.555$ kN

$R_B = R_C = R_D = R_E = R_F = 222.562 + (44.51 \times 5) = 445.112$ kN

Fig 9. Bending moment diagram



$R_A = R_G = 222.562 + (2.5 \times 89.025) = 445.124$ kN

$R_B = R_C = R_D = R_E = R_F = 445.129 + (2.5 \times 89.025 \times 2) = 890.254$ kN

Fig 10. Shear Force diagram

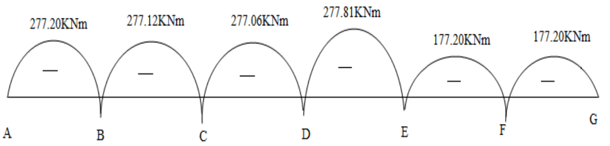


Fig 11. Bending moment diagram

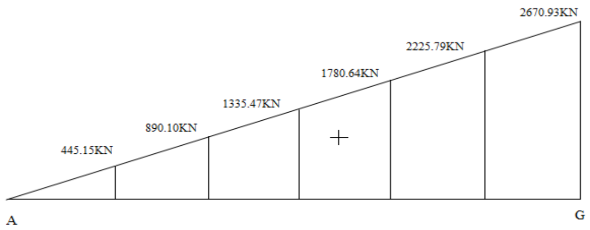


Fig 12. Shear Force diagram

6. DESIGN OF THE BEAMS

6.1 Design of Type 1 beam:

Clear Span = 5000-200-200 = 4600mm
Effective span = Clear Span + effective depth (d)
Let, 16mm Ø bar is provided with a nominal cover of 50mm with overall depth (D) 500mm.
Therefore, d= 500-50- $\frac{16}{2} = 442$ mm.
For Fe415 and M20 concrete,
$BM_{modified}(=M_u)$=1.5x139.08=208.62 kNm
According to IS 456:2000, Annex G, clause 38.1(G-1.1)
$BM_{'lim} = 0.36\, f_{ck} \frac{Xu'max}{d}(1 - 0.42\frac{Xu'max}{d})bd^2$
$=0.36x20x0.48(1-0.42x0.48)x400x(442)^2$= 215.5KNm
Since , $M_u < BM_{'lim}$, hence, single reinforcement will be provided. Now, from IS 456:2000, Annex G, clause 38.1(G-1.1), $M_u = 0.87\, f_y A_{st} d\, (1- \frac{Ast\ fy}{bd\ fck})$
This gives a quadratic equation in terms of A_{st}, the solution of which works out as under:

$$A_{st} = \frac{0.5\ fck}{fy}\left(1-\sqrt{1-\frac{4.6\ Mu}{fck\ bd(^\wedge 2)}}\right)bd$$

$$=\frac{0.5 \times 20}{415}\left(1-\sqrt{1-\frac{4.6 \times 208.62\times10(^\wedge 6)}{20\times400\times 442(^\wedge 2)}}\right)400x442$$

$= 1613.45\ mm^2$

Taking 20mm Ø bars, no. of bars = $\frac{1613.45}{\frac{\pi}{4}(20 \times 20)}$ = 6

Hence, 6 numbers of 20mm Ø bars will be provided.

6.1.1 Check for Shear reinforcement. The critical section for shear is at a distance of d = (0.400m) from the face of the support.

$V_{uD} = \frac{Wl}{2} - w(d + \frac{d}{2})$

Where, w = uniformly distributed load over the entire beam= 44.51KN/m
l = 5m
$d + \frac{d}{2} - 442 + (\frac{442}{2}) - 663mm - 0.663m$

Therefore, $V_{uD} = \frac{Wl}{2} - w(d + \frac{d}{2})$

$=\frac{44.51\times10^3\times5}{2} - 44.51 \times 10^3 \times 0.663$

= 81764.87 KN

Now, $\tau_v = \frac{Vu}{bd} = \frac{81764.087}{400}$ = 0.462 N/mm^2

$100\frac{Ast}{bd} - \frac{628.31}{442 \times 400} \times 100 - 0.35$

Where, $A_{st} = 2 \times \frac{\pi}{4} \times (20)^2$ =628.31mm^2

Now, using table 19 of IS 456:2000, design shear strength of concrete $\tau_{c} = 0.552\ N/mm^2 > \tau_v$
Hence, the design is safe.

6.2 Design of Type 2 beam:

Clear Span = 5000-200-200 = 4600mm
Let, 16mm Ø bar is provided with a nominal cover of 50mm with overall depth (D) 700mm.
Therefore, Effective span,d=700-50- $\frac{16}{2} = 642$ mm.
For Fe415 and M20 concrete,
M_u =1.5x283.306=424.96 kNm
According to IS 456:2000, Annex G, clause 38.1(G-1.1) ,$BM_{'lim} = 0.36\, f_{ck} \frac{Xu'max}{d}(1 - 0.42\frac{Xu'max}{d})bd^2$
$=0.36x20x0.48(1-0.42x0.48)x400x(642)^2$= 454.9KNm
Since , $M_u < BM_{'lim}$
Hence, single reinforcement will be provided.
Now, from IS 456:2000, Annex G, clause 38.1(G-1.1), $M_u = 0.87\, f_y A_{st} d\, (1- \frac{Ast\ fy}{bd\ fck})$
This gives a quadratic equation in terms of A_{st}, the solution of which works out as under:

$$A_{st} = \frac{0.5\ fck}{fy}\left(1-\sqrt{1-\frac{4.6\ Mu}{fck\ bd(^\wedge 2)}}\right)bd$$

$$= \frac{0.5 \times 20}{415}\left(1-\sqrt{1-\frac{4.6 \times 424.959\times10(^\wedge 6)}{20\times400\times 642(^\wedge 2)}}\right) 400 \times 642$$

$= 2239.52\ mm^2$

Taking 20mm Ø bars, No. of bars = $\frac{2239.52}{\frac{\pi}{4}(25 \times 25)}$ = 5

Hence, 5 numbers of 25mm Ø bars will be provided.

6.2.1 Check for Shear reinforcement. The critical section for shear is at a distance of d = (0.400m) from the face of the support.

$V_{uD} = \frac{Wl}{2} - w(d + \frac{d}{2})$

Where, w = 89.025KN/m, l = 5m

$d + \frac{d}{2} = 642 + \left(\frac{642}{2}\right) = 963mm = 0.963m$

Therefore, $V_{uD} = \frac{Wl}{2} - w(d + \frac{d}{2})$

$= \frac{89.025 \times 10^3 \times 5}{2} - 89.025 \times 10^3 \times 0.963$

= 136831.425 N

Now,

$\tau_v = \frac{Vu}{bd} = \frac{136831.425}{400 \times 642}$ = 0.53 N/mm^2

$100\frac{Ast}{bd} = \frac{981.75}{400 \times 642} \times 100 = 0.38$

Where, $A_{st} = 2 \times \frac{\pi}{4} \times (25)^2$ =981.75mm^2

Now, using table 19 of IS 456:2000, design shear strength of concrete τ_c =0.422 N/mm^2

Since $\tau_c < \tau_v$, as per IS :456:2000, clause B-5.4, we provide shear reinforcement to carry a shear force equal to ($V_u - \tau_c$ bd).

The strength of the shear reinforcement will be calculated as ,

$V_S = \sigma_{st}\frac{Asv\ d}{Sv} = 136831.425 - 0.422 \times 400 \times 642 = 28461.83KN$

Taking 8mm dia bars, $A_{sv} = 2 \times \frac{\pi}{4} \times (8)^2$ = 100.5 mm^2, $S_v = \frac{Asv\ d}{Vs}\sigma_{sv} = \frac{100.5 \times 642}{28461.83} \times 230$ =521.39 mm

According to table 22 of IS 456:2000, for High Yield strength deformed bars confirming to IS 1786(Grade Fe-415), σ_{st} =230 N/mm2

Now, from page number 47 of IS 456:2000, shear reinforcements of 8mm diameter will be provided at a c/c spacing of 226.78$\cong 226mm$. Also we provide 2 nos of 10mm diameter holding bars at the top.

7. DESIGN OF SLAB

While designing the slabs, three different types of slabs come into account. Hence, only one design will represent the design of other slabs, being design methodology same for all.

Design of the interior slab:

Computation of loading and bending moment:

From deflection point of view, from IS456:2000, $\frac{span}{effective\ depth} = 20$ (as shorter span > 3.5m) for simply supported slab.

Here, longer span = shorter span = $5 - 0.4 = 4.6m = 4600mm$

Now, let us assume % of steel P_t =0.35% and the corresponding modification factor from IS456:2000, page 38, fig 4 gives that m_f=1.31

Therefore, $\frac{span}{effective\ depth} = 20 \times m_f = 20 \times 1.31$

Therefore, effective depth = $\frac{4600}{20 \times 1.31} = 176mm$

Providing 20mm nominal cover by considering the exposure condition to be normal from IS 456:2000 page 47 table 16 and considering 10mm diameter bars,

Overall depth, D = 176+20+$\frac{10}{2} = 201mm$.

Hence, assuming an overall depth of 350 mm for the purpose of computing dead weight of the slab.

Computation of loads:

1. Self weight of slab =0.35 $\times 25000 = 8750$ N/m^2
2. Imposed load= 36000 N/m^2

Therefore total load = 8750 + 36000 = 44750 N/m^2

Therefore, factored load,(Wu) = 1.5 $\times 44750$ =67125 N/m^2

Now, taking effective depth of 300 mm we have,

Effective l_y = 4.6 + 0.3 = 4.9m

Effective l_x = 4.6 + 0.3 = 4.9m

Therefore, r = (l_y / l_x)=1

Required depth by bending:

$M_{ux} = R_u\, bd^2$

Therefore, d= $\sqrt{\frac{Mux}{Ru \times b}} = \sqrt{\frac{52 \times 10^6}{2.761 \times 1000}}$ = 137.24 mm

Overall depth = 350mm

Now, for 8mm dia. Bars with nominal cover 20mm,

Therefore, effective depth (d_S) for short span = 350-20-$\frac{8}{2} = 326mm$

Therefore, effective depth (d_L) for short span = 326-8 = 318mm

For the interior panel, α_x, α_y from IS 456:2000, page 91, table 26 (case-1):

Short span co-efficient , α_{x+} =0.032 and α_{x-} = 0.024

Longer span co-efficient , α_{y+} =0.032 and α_{y-}= 0.024

$M_{ux+} = \alpha_{x+} Wu l_x^2 = 0.032 \times 67125 \times 4.9^2 = 52 \times 10^6$ Nmm

$M_{ux-} = \alpha_{x-} Wu\, l_x^2 = 0.024 \times 67125 \times 4.9^2 = 39 \times 10^6$ Nmm

$M_{uy+} = \alpha_{y+} Wu\, l_x^2 = 0.032 \times 67125 \times 4.9^2 = 52 \times 10^6$ Nmm

$M_{uy-} = \alpha_{y-} Wu\, l_x^2 = 0.024 \times 67125 \times 4.9^2 = 39 \times 10^6$ Nmm

Computation of steel reinforcement for short span using 8 mm ∅ bars and ($d_S = 326mm$):

$(Ast)_x = \frac{0.5 fck\ bd}{fy} \times (1 - \sqrt{1 - \frac{4.6Mux}{fck\ bd^2}})$

$= \frac{0.5 \times 20 \times 1000 \times 326}{415}[1 - \sqrt{\frac{4.6 \times 52 \times 10^6}{20 \times 1000 \times 326^2}}]$ = 455.2mm^2

Spacing for 8mm bars = $\frac{\pi \times \frac{8 \times 8}{4} \times 1000}{455.2}$ = 100mm c/c

Therefore, no. of bars = $\frac{455.2}{50.3}$ = 9.1 ≈ 10 bars.

Therefore, use 8mm Φ bars @ 100mm c/c for the middle strip of width 3.675m.

Computation of steel reinforcement for long span using 8 mm ∅ bars and (d_L= 318mm):

$(Ast)_y = \frac{0.5 fck\ bd}{fy} \times (1 - \sqrt{1 - \frac{4.6 Mux}{fck\ bd^2}})$

$= \frac{0.5\times20\times1000\times318}{415} [1 - \sqrt{\frac{4.6\times52\times10^6}{20\times1000\times318^2}}]$

$= 467.4 mm^2$

Spacing for 8mm bars = $\frac{50.3\times1000}{467.4}$ = 100mm c/c

Therefore, no. of bars = $\frac{467.4}{50.3}$ = 9.3 ≈ 10 bars.

Therefore, use 8mm Φ bars @ 100mm c/c for the middle strip of width 3.675m.

Design of Corner Slab:

$(Ast)_x$ = 637mm^2

Spacing for 8mm bars = $\frac{50.3\times1000}{637}$ = 70mm c/c

Therefore, no. of bars = $\frac{637}{50.3}$ = 12.7 ≈ 13 bars.

Therefore, use 8mm Φ bars @ 70mm c/c for the middle strip of width 3.6m.

$(Ast)_y$ = 655mm^2

Spacing for 8mm bars = $\frac{50.3\times1000}{655}$ = 70mm c/c

Therefore, no. of bars = $\frac{655}{50.3}$ = 12.9 ≈ 13 bars.

Therefore, use 8mm Φ bars @ 70mm c/c for the middle strip of width 3.6m.

Design of End Slabs:

Computation of steel reinforcement for short span using 8 mm ∅ bars and (d_S =326 mm):

$(Ast)_x$ = 506.8mm^2

Spacing for 8mm bars = $\frac{50.3\times1000}{506.8}$ = 90mm c/c

Therefore, no. of bars = $\frac{506.8}{50.3}$ = 10.1 ≈ 11 bars.

Therefore, use 8mm Φ bars @ 90mm c/c for the middle strip of width 3.615m.

$(Ast)_y$ = 520.5mm^2

Spacing for 8mm bars = $\frac{50.3\times1000}{520.5}$ = 90mm c/c

Therefore, no. of bars = $\frac{520.5}{50.3}$ = 10.4 ≈ 11 bars.

Therefore, use 8mm Φ bars @ 90mm c/c for the middle strip of width 3.615m.

8. CONCLUSION

At the very outset, a study and observations of the soil which undergoes a local shear failure are made. As per the Indian Standards, safety requirements were provided while making the design of the foundation corresponding to this type of soil. In this paper, the basics of 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.

9. REFERENCES

[1] Haytham Adnan Sadeq, Mohammed Saleem Taha, *Structural Design of Raft Foundation* ,QATAR UNIVERSITY COLLAGE OF ENGINEERING, 01-01-2009.

[2] IS 456: 2000, Indian Standard Plain and Reinforced Concrete, Bureau of Indian Standards, New Delhi, 2000.

[3] IS 6403: 1981, Indian Standard Code of Practice for Determination of Bearing Capacity of Shallow Foundations, Bureau of Indian Standard, New Delhi, 2006.

[4] Punmia B. C., Jain K. A., Jain K. A., *R.C.C. DESIGNS (Reinforced Concrete Structures, as per IS 456:2000)*, Laxmi Publications(P) Ltd, New Delhi-110002, 2006.

[5] Ramamrutham S, *Design of Reinforced Concrete Structures,* Dhanpat Rai Publishing Company(P) Ltd, New Delhi-110002 ,2013.

[6] Ramamrutham S. ,Narayan R. , *Theory of Structures*, Dhanpat Rai Publishing Company(P) Ltd, New Delhi-110002, Ninth Edition, 2010.

[7] Ranjan Gopal, Rao A S R, *Basic and Applied Soil Mechanics*, New Age International Publishers, Delhi, Second Edition, 2000.

[8] Saran Swami, *Analysis and Design of Substructures,* Oxford & IBH Publishing Company, Delhi, 2006.