International Journal of Scientific & Engineering Research, Volume 6, Issue 12, December-2015
ISSN 2229-5518

APPROXIMATE ANALYSIS OF PILED RAFT

Rameez Gahlot[1], Roshni J John[2]

[1] PG Student, Dept of Civil Engg, Saraswati College of Engineering, Kharghar-410210, India
rameezgahlot@gmail.com
.[2] Head of Civil Engineering Department, Saraswati College of Engineering, Kharghar-410210, India
roshnijjohn@gmail.com

Abstract— Piled raft foundations provide an economical foundation option for circumstances where the performance of the raft alone does not satisfy the design requirements. Under these situations, the addition of a limited number of piles may improve the ultimate load capacity, the settlement and differential settlement performance, and the required thickness of the raft. An approximate method of analysis has been performed to estimate the settlement and load distribution of large piled raft foundation. In this method the raft is modelled as a thin plate and the pile and soils are treated as interactive springs. Both the resistance of the piles as well as raft base are incorporated into the model. Raft-soil-raft interaction are taken into account. The proposed method makes it possible to solve the problems of uniformly and large non-uniformly arranged piled rafts in a time saving way using computers. The computed settlements compared favourably with permissible value. This paper focuses the general effects of various parameters like raft thickness and soil on piled raft.

KEY WORDS: Piles, Raft, Foundation, Analysis**.**

INTRODUCTION

In the past few years, there has been an increasing recognition that the use of piles to reduce raft settlements and differential settlements can lead to considerable economy without compromising the safety and performance of the foundation. Such a foundation makes use of both the raft and the piles, and is referred to here as a pile-enhanced raft or a piled raft.

As a piled raft foundation takes into account both the pile and the cap acting as a raft footing in carrying the imposed load. The different design philosophies of piled raft foundations as stated by POULUS H.G. are

(a) Piles are mainly designed to take up the foundation loads and the raft only carries a small proportion.

(b) The raft is designed to resist the foundation loads and piles carry a small proportion of the total load. They are placed strategically to reduce differential settlement.

(c) The raft is designed to take up majority of the foundation loads. The piles are designed to reduce the net contact pressure between the raft and the soils to a level below the pre-consolidation pressure of the soil. Over the past decades, extensive research work has been done in order to improve the accuracy in predicting the behavior of piled rafts.

The main advantages of piled raft foundation are:

1. Reduction of settlements, differential settlements and tilts.
2. An increase of overall stability of foundation.
3. Reduces number of piles as compared to conventional piled foundation where bearing effect of raft is ignored which result in more number of piles.
4. A centralization of actions and resistances for the cases of large eccentricities.
5. A reduction of the bending stress for the foundation raft and
6. A cost optimization of the whole foundation.
7. Provides economical foundation where structural loads are carried partly by piles and partly by raft contact stresses.
8. Effective in stiff as well as soft clay.
9. Poulos (1991) has examined a number of idealized soil profiles, and has found that the following situations may be favorable for piled raft:

(a) Soil profiles consisting of relatively stiff clays.

(b) Soil profiles consisting of relatively dense sands In both circumstances, the raft can provide a significant proportion of the required load capacity and stiffness, with the piles acting to reduce the settlement of the foundation, rather than providing the major means of support. The situations those are unfavorable for piled raft includes:

1. Soil profiles containing soft clays near the surface.
2. Soil profiles containing loose sand near the surface.
3. Soil profiles that containing soft compressible layers at relatively shallow depths.
4. Soil profiles that are likely to undergo consolidation settlements.
5. Soil profiles that are likely to undergo swelling movements due to external causes.

EARLIER RESEARCH

According to Poulos (2001) has defined clearly three different design philosophies with respect to piled rafts:

- The "conventional approach", in which the piles are designed as a group to carry the major part of the load, while making some allowance for the contribution of the raft, primarily to ultimate load capacity.
- "Creep piling" in which the piles are designed to operate at a working load at which significant creep starts to occur, typically 70-80% of the ultimate load capacity. Sufficient piles are included to reduce the net contact pressure between the raft and the soil to below the pre-consolidation pressure of the soil.

- Differential settlement control, in which the piles are located strategically in order to reduce the differential settlements, rather than to substantially reduce the overall average settlement.

In addition, there is a more extreme version of creep piling, in which the full load capacity of the piles is utilized, i.e. some or all of the piles operate at 100% of their ultimate load capacity. This gives rise to the concept of using piles primarily as settlement reducers, while recognizing that they also contribute to increase the ultimate load capacity of the entire foundation system.[1]

Pastsakorn Kitiyodom and Tatsunori Matsumoto (2003), has developed simplified analytical method for the analysis of the deformation and the load distribution of axially and laterally loaded piled raft foundations embedded in non-homogeneous soils incorporated into a computer program PRAB. In this method, a hybrid model is employed in which the flexible raft is modelled as thin plates and the piles as elastic beams and the soil is treated as springs. The interactions between structural members, pile–soil–pile, pile–soil–raft and raft–soil–raft interactions, are approximated based on Mindlin's solutions for both vertical and lateral forces with consideration of non-homogeneous soils. The proposed method was verified through comparisons with the results from previous research and the results from the more rigorous finite element approach. [2]

Meisam Rabiei (2009) has considered a parametric study on pile configuration, pile number, pile length and raft thickness on piled raft foundation behaviour and it has been found that the maximum bending moment in raft increases with increase raft thickness, decrease pile number and decrease in pile length. Central and differential settlement decreases with increase raft thickness and uniform increase in pile length. It has also been found that pile configuration is very important in pile raft design. The program ELPLA for a piled raft with 9 piles supporting rafts of varying thicknesses. Except for thin rafts, the maximum settlement is not greatly affected by raft thickness, whereas the differential settlement decreases significantly with increasing raft thickness. Conversely, the maximum moment in the raft increases with increasing raft thickness. The design philosophy based on both ultimate load capacity and settlement criteria.[3]

Modeling of Piled Raft

In this topic, the philosophy of modeling piled raft has been explained using combined structural-geotechnical approach. Initially to observe the behaviour of piled raft, piles are modeled as spring and raft as beam on elastic foundation as shown in Figure

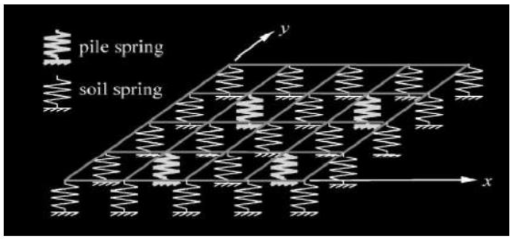

Fig Modeling of Piled Raft as a beam on elastic foundation

Here SAFE software is used for analysis of piled raft. The superstructure ia first analyzed in ETABS software and following design parameters are to be consider i.e. Dead load: 1.5KN/m^2

Live load: 2.0KN/m^2 (live load of 3kN/m^2 and 5kN/m^2 are provided for passage and stair case slab.)

Siporex blocks of density 8KN/$m^3$are used for walls.

Number of stories: 25.

Floor to floor height: 3 m.

Slab is modeled using rigid diaphragm.

Wind load is considered as per IS: 875. (Part III)

Earth quake load is considered as per IS: 1893-2002. (Moment resisting frame with response reduction factor of 4, zone III & 5% damping is provided.)

The building is analyzed for dynamic load using Response Spectrum Method.

The load combinations are considered as per IS: 875 (part 5) for DL, LL, WL & EQ loads. Twenty five percent of imposed load has been accounted along with dead load for seismic weight calculation of building as per IS: 1893(2002).

The maximum top storey displacements for wind in X & Y directions are 10 & 12 mm respectively. The maximum top storey displacements for earth quake in X & Y directions are 10mm and 10 mm respectively. Here is the 3d model of superstructure which is analyzed in ETABS software.

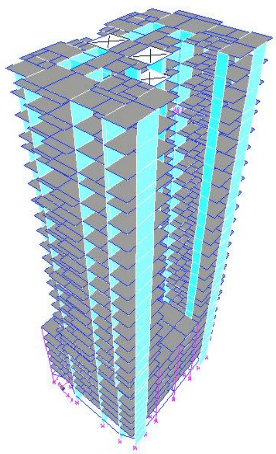

Fig. 1 3-D model of 25 storey building.

In SAFE software piled raft is analyzed , the piles are attached as point spring of equivalent stiffness as 418.2KN/mm and raft are modeled as usual, here length and diameter of pile is varied. The thickness of raftis consider as 2.5m. The piles are uniformly distributed with horizontal spacing of 2.2m and vertical spacing of 1.8m. Here soil bearing capacity is consider as 170KN/m^2 with the permissible settlement as 10mm and ultimate load carrying capacity of pile is consider as 1500KN the soil is consider as a dense sand with its approximate elastic modulus as 4.08 x10^4 KN/m^2.

For no. of pile in piled raft ,

N = [(load taken by conventional pile – load taken by raft) / pile capacity]

N = no. of pile

Therefore, the total no. of pile required in piled raft foundation is 240 nos. The length of pile is to be taken as 20m, 23m and 25m, along with this the diameter of pile is also varying i.e. 600mm, 650mm and 700mm. The piled raft foundation for the structure has been analyzed and corresponding settlement, differential settlement, maximum soil pressure and point reaction on pile are observed.

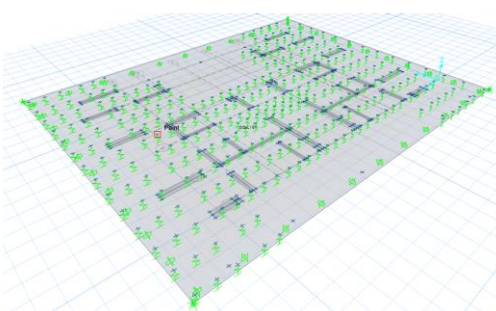

Fig 2 Layout of piled raft foundation.

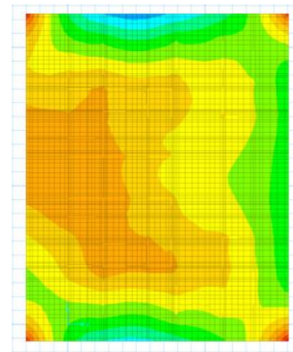

Fig 3 Displacement of piled raft foundation (in mm).

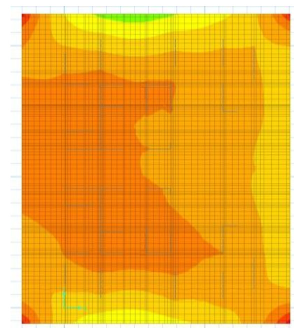

Fig 4 Soil pressure distribution in piled Raft foundation.

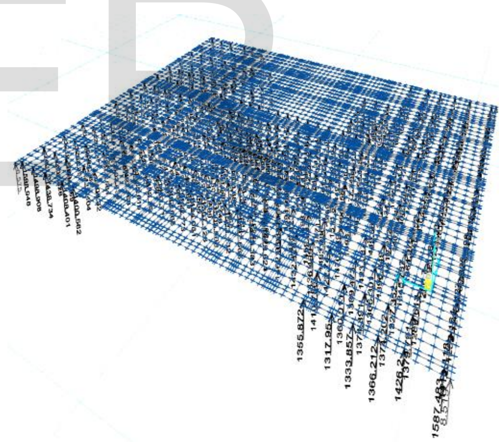

Fig 5 Point reaction acting on piles.

RESULTS AND DISCUSSION

Effect of varying thickness of raft on piled raft.

For a Twenty five storey building, increasing the raft thickness settlement reduces up to certain extent and beyond which further increase in raft thickness doesn't affect the settlement at all but with the increase in raft thickness the differential settlement reduces considerably. Initially the thickness of raft was 1.5m and the settlement was found to be 16mm and differential settlement was also 12.68mm. After increasing the thickness to 3.0m with an increment of 5000mm, it has been observed that the settlement reduces to 10.00mm, whereas differential settlement reduces to 3.14mm. It is also observed that with increase in raft thickness the dead load increase which results in increase in maximum bending moment. However increase in raft thickness is advantageous for punching shear. Figure shows the variation of maximum positive and negative moment with increase in raft thickness.

Table1: shows effect of varying raft thickness on pile raft

Thickness of raft (m)	Settlement (mm)	Differential settlement (mm)	Maximum +ve bending moment KN-m	Maximum –ve bending moment KN-m
1.5	**16**	**12.68**	**7019.66**	**2234.55**
2.0	**13**	**7**	**7619.20**	**2432.03**
2.5	**9.8**	**4.55**	**7990.17**	**3514.20**
3.0	**10**	**3.14**	**7999.7**	**3608.49**

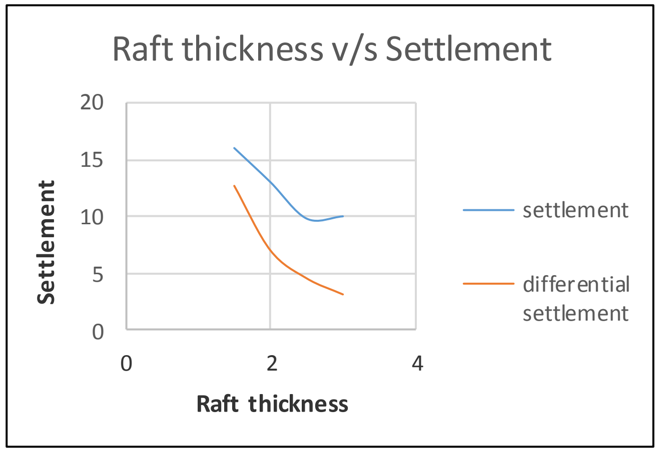

Fig 5.19 Graph shows Raft thickness v/s Settlement

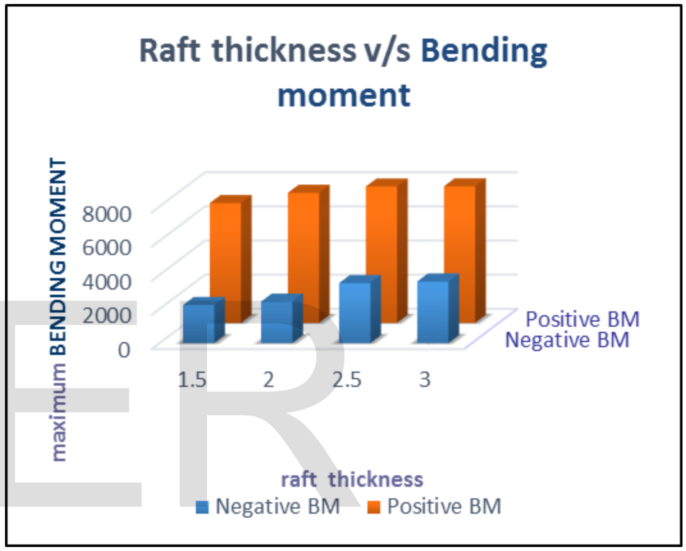

Fig 5.20 Graph shows raft thickness v/s bending moment

Effect of varying soil stiffness on load carrying capacity of raft for Twenty Five storey building

For a twenty five story building increase in stiffness of soil stiffness below raft results in increase in load taken by the raft as shown in Figure

Table2: Effect of soil stiffness on load carrying capacity of raft in piled raft.

Stiffness of soil (KN/m³)	Load taken by raft (KN)
17000	93369
20000	98608
25000	129159
30000	154527
35000	175953

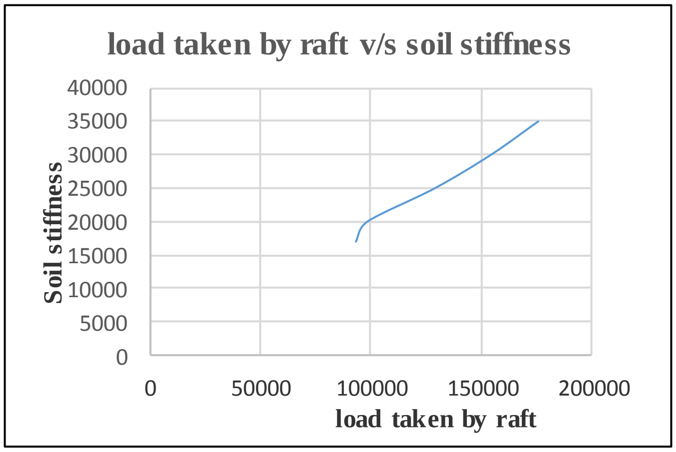

Fig 5.21 Graph shows load taken by raft v/s soil stiffness

Validation of results (in terms of Load transfer by pile and raft).

For validating the results obtained from analytical modelling as above, the problem of Chp. 4 i.e. Piled Raft was first analysed using SAFE software using Finite element method. This result is then compared with the result obtained from Analytical solution. For this purpose, the size of raft, soil property, end bearing resistance of pile, skin friction of pile, ultimate load carrying capacity of pile, length of pile and diameter of pile are to be considered.

Data

1. Size of raft = 43.5mx35m
2. Length of pile = 20m
3. Diameter of pile = 600mm
4. Soil bearing capacity = 17T/m^2
5. End bearing resistance of pile = 350KN/m^2
6. Skin friction of pile = 25KN/m^2
7. Assume permissible ultimate load carrying capacity of pile = 1500KN

Form IS 2911, the ultimate load carrying capacity is given by

$Q_u = \pi/4 \times d^2 \times$ end bearing resistance $+ \pi \times d \times L \times$ skin friction

$= \pi/4 \times 0.6^2 \times 350 + \pi \times 0.6 \times 20 \times 25$

= 1041.43 KN

No. of piles =242 nos.

Total load carrying capacity of Pile = 242 × 1041

= 252027.98 KN

Total permissible load carrying capacity of Pile = 363000 KN

Total load on foundation = 477898.5 KN (is taken from ETABS file)

Therefore, Load taken by the raft = 225870.52N

The load shared by pile and raft using SAFE software is 278985.3KN and 198913.2KN.

Summary

The results obtained simplified approach and results of SAFE software are compared and presented in Table 5

Method	Percentage load shared by pile	Percentage load shared by raft
Simplified approach	53%	47%
Software approach	58%	42%
% difference	5%	5%

It is observed that prediction of software approach overestimate by 5% as compared to simplified (Analytical) approach results. This deviation is observed due to dividing entire piled raft into number of strip and due to meshing entire piled raft in case of SAFE software whereas, analytical procedure the entire piled raft is consider for evaluation. Considering this, the software approach thus developed may be accepted.

CONCLUSION

The studies indicate that piled raft foundation concept has significant advantages in comparison to conventional foundation for the available soil strata. From the studies, the following points have been observed.

• With the increase in raft thickness the positive and negative bending moment of raft increases.

• It is observed that stiffer the soil more will be the load shared by the raft.

REFERENCES

[1] H.G.Poulos, "Methods of analysis of piled raft foundation". (International society of soil mechanics and geotechnical engineering, July 2001.)

[2] Pastsakorn Kitiyodom and Tatsunori Matsumoto, "A simplified analysis method for piled raft foundations in non-homogeneous soils" international journal for numerical and analytical methods in Geomechanics int. J. Numer. Anal. Meth. Geomech. 2003; 27:85–109 (DOI: 10.1002/nag.264).

[3] Meisam Rabiei, (2009). "Parametric Study for Piled Raft Foundations" Amirkabir University of Technology, Tehran, Iran.

[4]Combined piled raft foundation (CPRF). An approximate solution for the foundation design of high rise building by R. KATZENBACH, G. BACHMANN 2005/3 PAGES 19 – 29 RECEIVED 14. 2. 2005 ACCEPTED 18. 4. 2005

[5] Foundation engineering by P.C. Vergese

[6] IS 1904:1986 code for practice , Design and construction of foundations in soil