IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 7.105 ⁜ Vol. 9, Issue 5, May 2022

DOI: 10.17148/IARJSET.2022.9514

FLUCTUATING SOIL STIFFNESS IN PILED RAFT FOUNDATON

Salman A. Aziz Bagwan[1], Dr. Nagesh Shelke[2]

PG Student, Department of Civil Engineering, D. Y. Patil School of Engineering & Technology, Pune, India[1]

Head of Department, Department of Civil Engineering, D. Y. Patil School of Engineering & Technology, Pune, India[2]

Abstract: Nowadays piled raft foundations are widely used for the construction of high-rise buildings. Piled raft foundation can be used in both soft and hard soils. In this study, a high-rise building is analysed to estimate the varying effects of soil stiffness on a pile foundation. ETABS software is used for the analysis of superstructure. SAFE software is used for analysis of piled raft foundation. The analysis is carried out to determine the variation of settlements, differential settlements and load bearing capacity of pile and raft with different soil stiffness.

Keywords: Soil stiffness, piled raft foundation, settlements, differential settlements.

I.INTRODUCTION

In the past few years, the construction of high rise structures has become common and with them various new challenges occurs for both structural and geotechnical engineers. In the latest years many construction projects have been built on soft soil strata. Due to the characteristics of soft soil, structures built on it are subject to differential settlements. In such cases, the raft foundation alone cannot meet the upward pressure and differential settlement requirements. Layout is could be one of the ways in which differential settlement can be reduced. The piles are strategically provided with the raft foundations to reduce differential settlements and to satisfy the upward pressure. Such a foundation is called a piled raft foundation.

The main advantages of piled raft foundations are:

1. Settlements, differential settlements and inclinations can be reduced.
2. Enhances the overall stability of the foundation.
3. The number of piles required is reduced as compared to conventional pile foundation where the bearing effect of the raft is not taken into account.
4. The bending stress in the raft can be greatly reduced.
5. The overall cost of foundation is reduced.
6. Pile raft is effective in both hard and soft soils.

The following soil profiles are suitable for pile raft foundations:

- Soil profile with relatively hard clay.
- Soil profile with relatively dense sand.

The following soil profiles are not suited for pile raft foundations:

- Soil profile with soft soil near the surface.
- Soil profile with loose sand near the surface.
- Soil profile with soft compressive layers at relatively shallow depth.
- Soil profiles that are likely to cause swelling movements due to external causes.
- Consolidation of soil profile likely to pass through settlements.

II.METHODOLOGY

In this topic, the philosophy of pile raft modelling using a combined structural-geotechnical approach is explained. To observe the behaviour of the piled raft initially, the pile is treated as a spring and the raft as a beam on an elastic foundation as shown in Figure 1.

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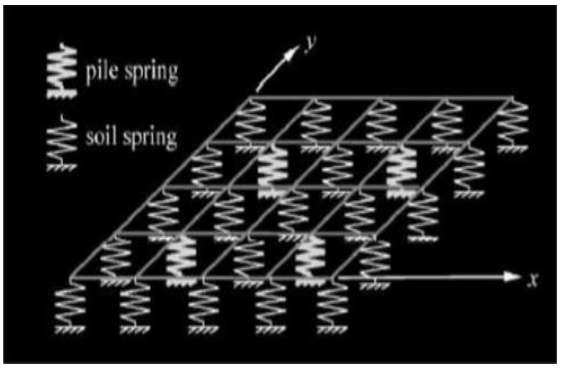

Fig. 1- Structural Idealization for Raft with Pile and Supporting Soil

For this study, Analysis of piled raft is done in SAFE software. With the help of ETABS software the superstructure is first analysed and following design parameters are considered:

Table 1 – Data considered for Modelling of Superstructure

Floor Finish	1.5 kN/m^2
Live Load	2 kN/m^2 for Rooms 3 kN/m^2 for Passage and Staircase
Wall Load	8 kN/m^2
Wind Load	According to IS: 875 - Part III (2015)
Earthquake Load	According to IS: 1893 (2016)
Method of Dynamic Analysis	Response Spectrum Method
No. of Stories	G + 40
Total Height of Building	143.5m
Grade of Concrete	M 60
Grade of Steel	Fe 550

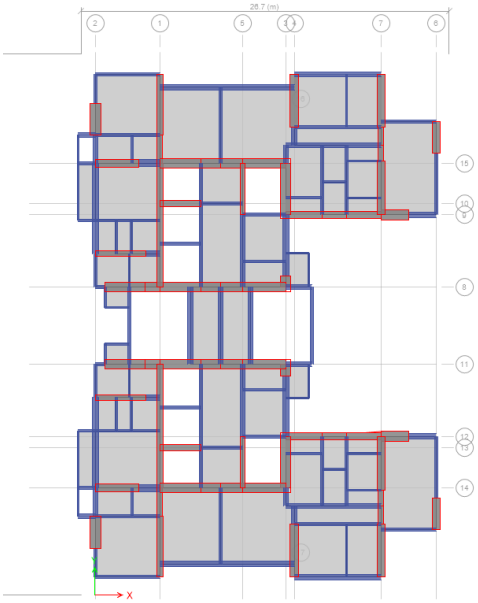

Fig. 2 - Typical Floor Plan of G+40 Storey Building

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Modelling of Piled Raft Foundation

Determination of No. of Piles Required for Piled Raft foundation:

- Load from superstructure = 985736 kN
- Safe bearing capacity of soil = 300 kN/m^2
- Permissible settlement = 8mm
- Subgrade modulus = SBC / Settlement
= 37500 kN/m^2/m
- Load taken by raft = Area of raft X SBC
= 269264 kN
- Load to be taken by piles = Load from superstructure – Load taken by raft
= 716472 kN
- No. of piles required = $\frac{716472}{10000}$ = 71.64 ~ 72 Nos

However, taking into account the geometry of the figure and the satisfactory requirements of the permissible settlement, provide 84 numbers of 1000mm diameter piles.

- Stiffness at point spring
$= \frac{\text{Capacity of one pile in kN}}{\text{Permissible Settlement in mm}} = \frac{10000}{8}$

= 1250 kN/mm

In order to consider the effect of soil structure interaction, piles are modelled as point springs. A spring stiffness value of 1250 kN/mm is applied to each spring. Fig. 3 shows the layout of the pile raft foundation. Fig. 4 and figs. 5 shows upward pressure and displacement respectively in a pile raft foundation.

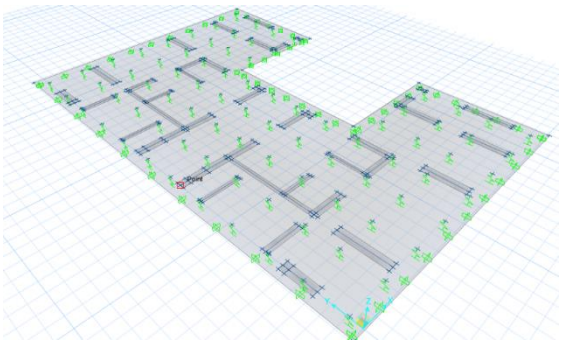

Fig. 3 – Layout of Piles into Piled Raft Foundation

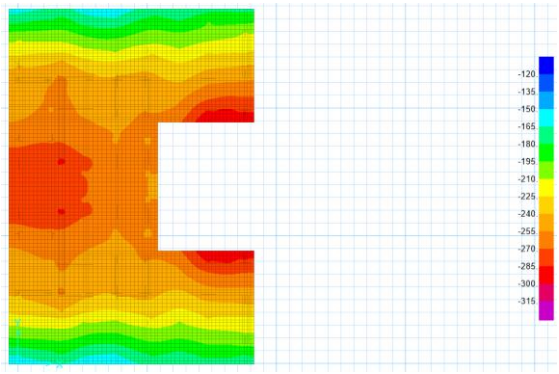

Fig. 4 – Upward Pressure in Piled Raft Foundation (300 kN/m^2)

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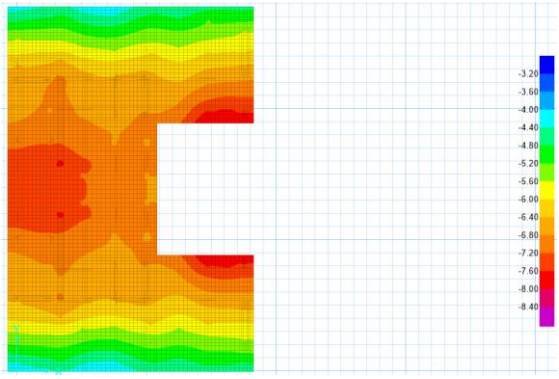

Fig. 5 – Displacement in Piled Raft Foundation (8.00 mm)

Determination of Effect of Varying Soil Stiffness:

Different soil stiffness are considered to determine the effect of soil stiffness on pile rafts for the same raft thickness, pile length and pile diameter. (18750KN/m^3, 37500 kN/m^3, 56250 kN/m^3 and 75000 kN/m^3). These effects are observed, the variation in soil stiffness in terms of settlements, differential settlements and load carrying capacity.

III.RESULTS AND DISCUSSIONS

Effect of variation in soil stiffness on piles and raft settlements and differential settlements:

The following table shows the variation in settlement and differential settlement in pile and raft along with variation in soil stiffness:

Table 2- Effect of variation in soil stiffness on raft and pile settlements and differential settlements

Stiffness of Soil	18750	37500	56250	75000
Max Settlement in Raft	9.04	8	7.2	6.56
Differential Settlement in Raft	4.38	3.96	3.65	3.43
Max Settlement in Piles	8.46	7.52	6.75	6.16
Differential Settlement in Piles	3.40	3.15	2.92	2.75

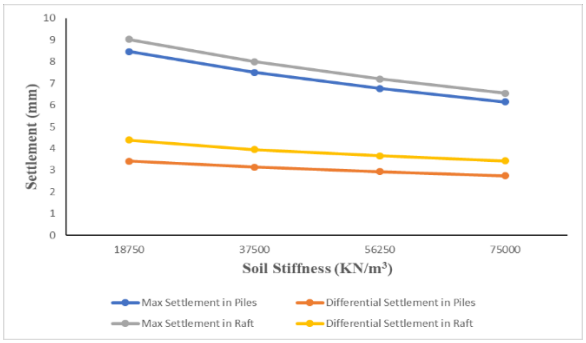

Fig. 6 – Graph of Soil Stiffness & Settlements in Raft and Piles

Effect of Varying Soil Stiffness on Load Carrying Capacity of Piles and Raft

For a G+40 storey building, an increase in the stiffness of the soil under the raft results in an increase in the load carried by the raft. Fig. 7 Shows the effect of soil stiffness on the load carrying capacity of a pile raft.

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Table 2- Effect of Soil Stiffness on Load Carrying Capacity of Raft and Piles

Stiffness of Soil (kN/m^3)	Load taken by Piles (kN)	Load taken by Raft (kN)	Load Taken by Piles (%)	Load Taken by Raft (%)
18750	741535	55505	93.10	6.90
37500	651320	145740	81.72	18.28
56250	580960	216080	72.89	27.11
75000	524550	272510	65.81	34.19

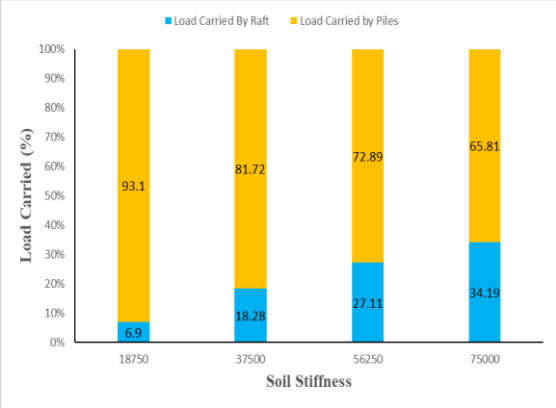

Fig. 7 – Graph of Soil Stiffness & Load Carrying Capacity of Raft and Piles

IV.CONCLUSIONS

The following points have been observed from the studies:

- The maximum settlement in the raft and pile decreases with increase in the hardness of the soil.
- Differential settlement in raft and pile decreases with increase in hardness of soil.
- The load shared by the raft increases with the increase in the hardness of the soil.

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