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Settlement Analysis of Piled Raft System in Soft Stratified Soils

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Abstract: To compute and compare the effect of diameter of pile, number of piles and thickness of raft on the behavior of piled raft system. They are analyzed in two Cases:
Case I - developed small scale model in Plaxis 3D Software and compared Load-Settlement curves for different pile raft configurations. Case II - developed large Scale model and Compared Settlement analysis with Analytical Pile group with raft problem from Das, B.M [4]. The settlement was measured at the centre of the models of pile raft with (single, two, three, four and Group) piles. For case 1, the Settlement of piled raft decreases as the number of piles beneath the raft increases and the load carried by the piles increases with the increase in length of the pile. For case 2 the percentage difference between analytical and Plaxis results are 2 % which is considerable, in both the cases the settlement get reduced due to increase in number of piles beneath the raft.
Keywords: group piles, load-settlement, piled raft, and stratified.

I. Introduction

In a conservative method of design for pile foundations, once the decision to introduce piles to a raft foundation has been made because the differential settlement of the raft alone was large, the applied load is considered to be supported by piles and the capacity of the raft is ignored. A contribution of the raft resting on a soil surface to the capacity of the pile group or against the group settlement could be taken into account in design of piled raft foundations.

Valuable measurements of load distribution for piles and rafts were made by analytical methods. Settlement reducing piled, means to reduce the differential settlement of shallow foundations using friction piles, whose shaft capacity may be fully mobilized under working conditions. However, both the manner of the load transfer from the foundation to the soil and the settlement characteristics of piled raft systems are not well understood due to the complex system consisting of the piles, the raft and the surrounding soil.

II. Literature Review

A piled raft system is the composite structure which consists of the 3 elements: raft, pile and the ground. Applied uniform loads are transferred to the soil both through the toped raft and the beneath piles. This load transfer mechanism shown in figure 1 can be simply Load sharing between raft and piles are the main distinctive feature that diversifies this type of foundation from other type of piled foundations design.

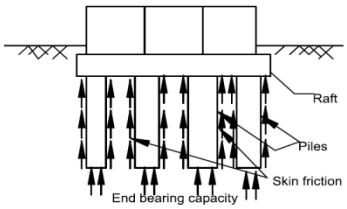

Fig. 1: Simple piled raft system with load transfer mechanism

2.1. Methods for the Analysis of Piled Raft Foundations

Poulos H.G [5] categorized the methods of analysis of piled raft foundations into 3 categories;

I. Simplified count strategies

According to Poulos H.G [5] overall stiffness equation is operative up to the fully mobilization of pile capacity.

II. Estimated PC based techniques

The approximate computer-based strategies are based on elastic hypothesis and mainly have two approaches as; strip on springs and plate on springs. In these methodologies, the raft is treated as a strip and as a

thin plate respectively. Also, piles are dealt with as springs and the soil as an elastic continuum, which are additionally rearranged into springs, for the foundation-structure interaction.

III. More thorough PC based techniques

More thorough strategies mainly include boundary element techniques and finite element strategies. In addition, for the different members of the foundation, combination of these strategies has been applied.

III. Methodology

3.1 Modeling of Pile Raft

For case –I, modeling of piled raft system with the single, two, three and four pile configurations are considered from Hameedi M.K.[4] are analysed and the settlements are considered and comparison made by varying number of piles in the Piled raft system, and the results plotted as load-settlement curves are shown in figures 5 and 6.

For case – II, The model of pile raft foundation with single configurations as shown in figures 2, 3 and 4 has been modeled by considering the raft and the pile are of concrete and with constant thickness, diameter and length respectively as given in the principles of foundation engineering by Braja M. Das [2].

Table 1: Properties of Pile & Raft

S. No	Material	Properties	Value
1	Pile and Raft (concrete)	Elastic Modulus, E (kN/m^2)	$2.9x10^5$
		Poisson's Ratio, υ *	0.2

Table 2: Material properties, pile and raft model used for the numerical model.

Material Properties	Type of Layer	Unsaturated & saturated Unit, γ (kN/m^3)	Elastic Modulus, E (kN/m^2)	Poisson's Ratio, υ	Undrained cohesion, C_u	Angle of Shearing Resistance, Ø (^{0})
	Soft Clay	18	7000	0.3	5	22
	Medium Clay	18.9	14000	0.3	8	23
	Stiff Clay	19	18000	0.3	10	24
Pile model	Pile Area = 7.26 m^2			Pile length = 15 m		
Raft Model	Raft Area = 10.24 m^2			Raft Thickness = 0.3 m		

The Properties of the Pile and Material (Table 1 & 2) were taken from the Page No: 628, Das B.M. (2011) [4].

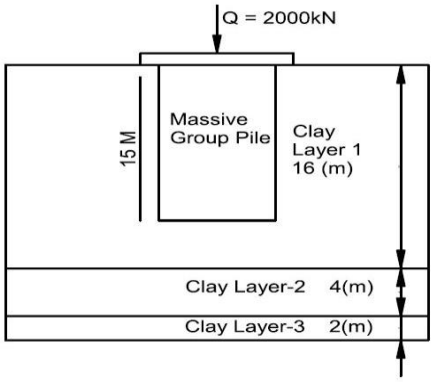

Fig.2: Modeling of Piled group for Numerical Analysis in layered soils

Figure 2; shows a piled raft foundation in normally consolidated clay, we can determine the settlement in the following manner

$$S = \left[\frac{CcxH}{1+e_0}\right]\log\left[\frac{\sigma_0 + \Delta\sigma}{\sigma_0}\right] \quad \text{_____ Equation (1)}$$

Where S= Total Settlement (mm).
H= total thickness of the soil media (m).
Cc = coefficient of consolidation.
e_0 =initial void ratio.
σ_0 = Initial over burden pressure (kN/m^2)
$\Delta\sigma$ = Incremental Pressure (kN/m^2)

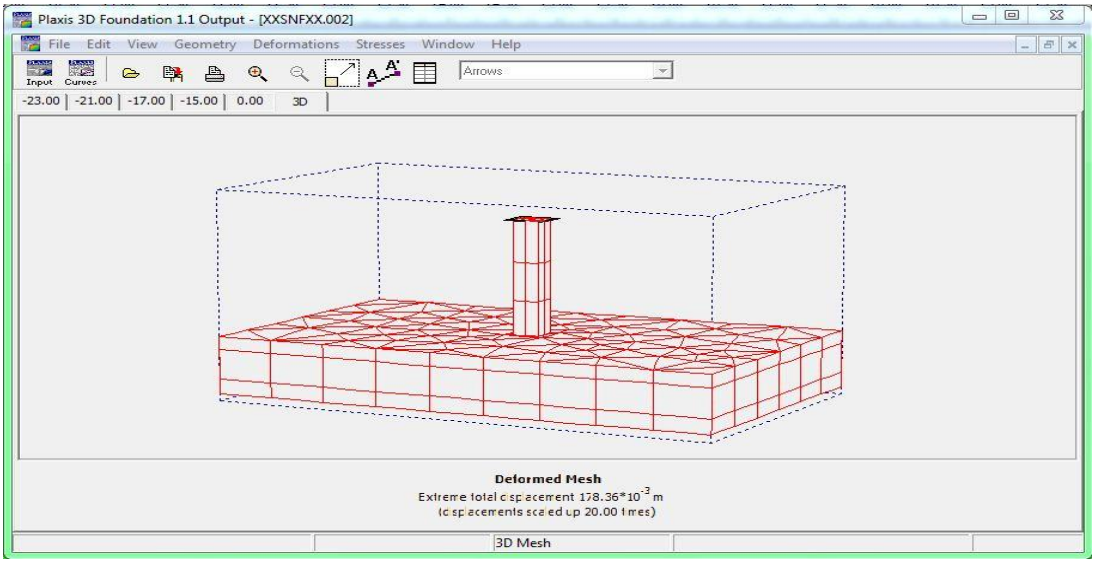

Fig.3: The massive Pile group Settlement in Layered clay with Soil Properties

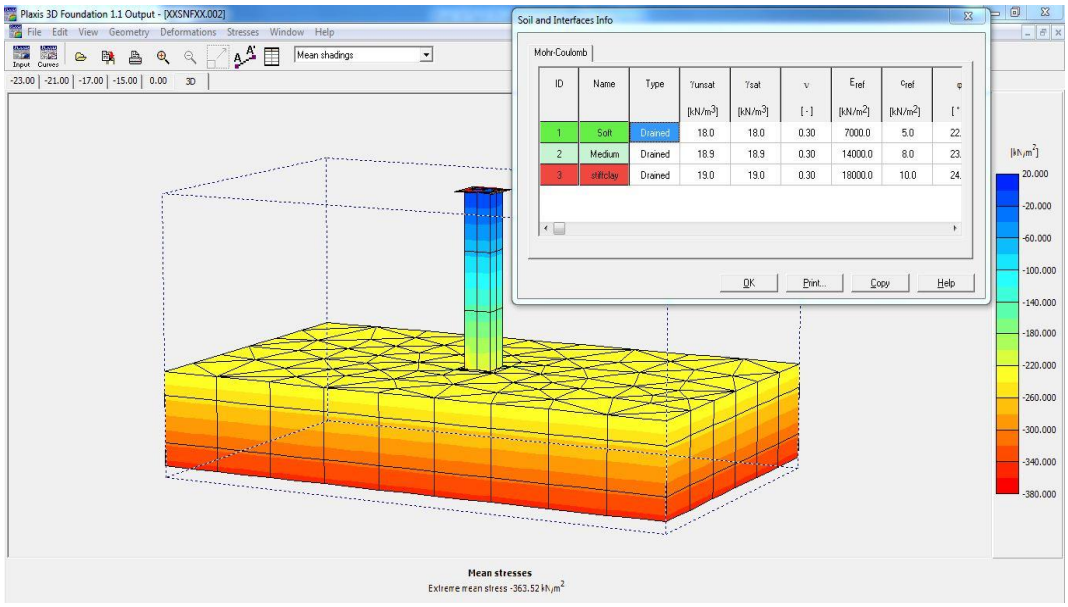

Fig.4: The massive Pile Group Stress Intensities

IV. Results and Discussion

4.1: For Case-I

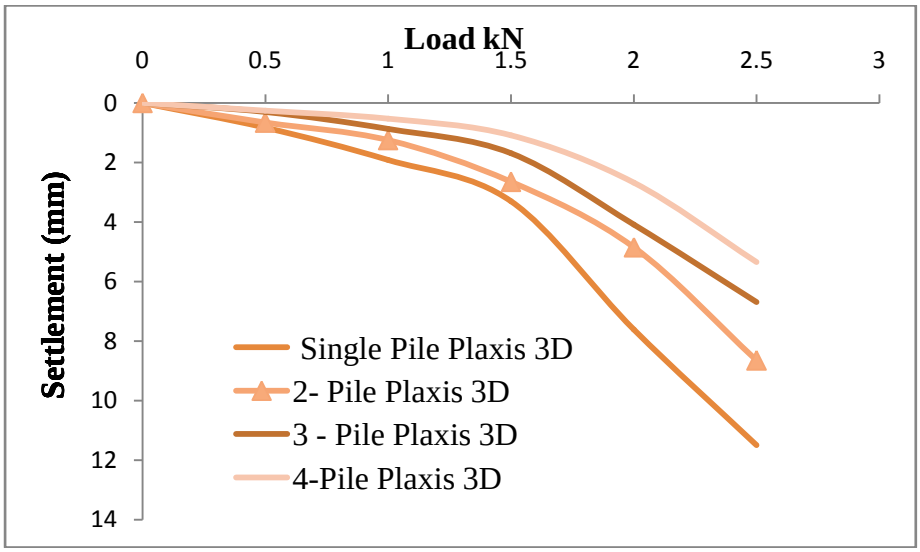

Fig.5: Load – Settlement Curves for one, two, three and four Piled Raft of Case – I Plaxis model.

From the above figure, it has been observed that the settlement of the Piled raft decreases with increase in number of the piles beneath the raft.

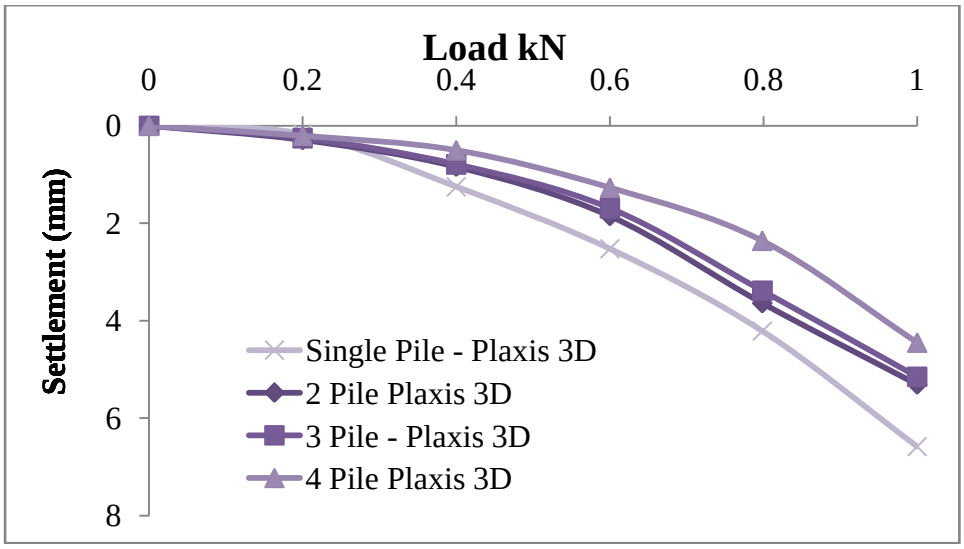

Fig.6**:** Load – Settlement Curves for one, two, three and four Piled Raft of Plaxis in case - I model.

From the above graph of the second model, it has been observed that the load carrying capacity of the Piled raft increases if the number of the piles beneath the raft increases.

For Case-II:

The analytical settlement analysis of a piled group raft in soft layered soil is estimated as 183.5 mm deformation by using 2:1 stress distribution method. The above settlement value is well compared with the settlement value (i.e. 178.5 mm) predicted from Plaxis 3D. With this comparison the percentage variation between analytical and Plaxis settlement values are found with 2 % deviation.

V. Conclusion

The numerical modeling of the piled raft problem considering the load effect using the finite element method through the program PLAXIS reveals the following conclusions:

1. The Settlement of piled raft decreases as the number of piles beneath the raft increases.
2. Piled raft system is beneficial to be used as settlement reducer in soft soils.

3. As the length of the pile increases the load carried by the piles increases.
4. The analytical method settlements are well compared with the FEM based results with a 2 % variation.
5. This study seems, the Plaxis 3D Numerical model can be a time effective tool to get fairly reliable results, hence the FEM based Software's can be used to analyze and execute real time Projects.

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