NUMERICAL MODELING OF SINGLE PILE IN A TWO-LAYERED SOIL

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Abstract- The purpose of this article is to elucidate the behavior of single pile under axial loading in a two-layered soil, as far as settlement and load transfer mechanisms are concerned. Design of axially loaded piles due to the load from the structure relies on a number of theoretical and numerical approaches. Finite element analysis offers an excellent way to study the soil-pile interaction and pile's response under the axial loading due to structural load. This paper presents the results of modeling in 2D finite element package Plaxis for the case of axially loaded single pile under axis-symmetric conditions, two-layered soil. The results are presented in the form of Load vs Settlement graphs for different slenderness ratio of the pile (L/D= 7.5, 10, 12.5). Two types of layering systems, i.e. soft clay overlying stiff sand and vice-versa are also considered. Results were also verified by using ALPA-XL spreadsheet designed by the researchers of Purdue University which is openly available on the web. Reasonable agreement has been achieved in comparing the single pile's response against the published results of the pile.

Index Terms- Axially loaded piles, Layering, Plaxis 2D, Soil-pile interaction, Two-layered soil.

I. INTRODUCTION

Piles are deep foundations, necessary when the bearing capacity of shallow foundations is not enough to ensure the support of the superstructure. This superstructure results in vertical forces, due to its weight as well as additional loads, which are axially transferred to the pile and, through its shaft and base, to the soil, possibly reaching a stiffer layer. The analysis of the load transfer mechanism in single piles under axial loading is therefore an essential basis for deep foundation design. It is very important that the physical interaction between pile and soil is carefully studied. The settlement analysis is also fundamental, for the maximum allowable settlement of a foundation is often the most important criterion in its design.
Thus, it should be estimated accurately. The behavior of single pile under axial loading, as far as load distribution and settlement along the pile are concerned, have been analyzed through numerous methods. One such method is numerical analysis using a commercial package, Plaxis. Numerical methods are powerful and very useful tools when used carefully and calibrated with the appropriate tests. They also constitute a valuable way of performing a sensitivity analysis of the soil parameters.

II. METHODOLOGY ADOPTED

In this work, the finite element method program Plaxis 2D 2015 is used to model single pile's behavior under axial loading in a two-layered soil. Instead of applying axial load on the pile pre-described settlement to the pile was provided for better comparison of the results.

The analyzed piles are cylindrical and isolated having diameter as 1m; and modeled as an axisymmetric case. The loading is provided axially through prescribed displacements equal to -10% of the pile diameter. Basically to understand the behavior of layering of the soil, analysis is done for two a two-layered soil i.e. soft clay overlying stiff sand and vice versa.

15-node triangular elements are used to create the mesh. Mesh with element size as medium is used as this will give us first insight into the problem. 15-node triangular elements is used as this is more precise than 6-node triangular elements. For the boundaries, standard fixities are used. Standard fixities means boundary x_{min} and x_{max} are normally fixed and y_{min} is fully fixed while y_{max} is free completely. The simulation is performed under drained conditions i.e. pheratic level is kept at the bottom of the soil.

Table 1 Parameters of soil and pile

Parameters	Clay	Sand	Pile
Model used	Mohr-Coulomb	Hardening Soil	Linear-elastic
Drainage Type	Undrained	Drained	Drained
γ_{unsat} (kN/m^3)	15	17	24
γ_{sat} (kN/m^3)	18	20	24
Stiffness (kN/m^2)	3000	4000	3.00E+08
kx (m/day)	0.0001	1	1.00E-05
ky (m/day)	0.0001	1	1.00E-05





Fig. 1 Pile and Soil Model

Calculations are carried out in two phases. In the modeling, the initial conditions determine the final solution. In the initial phase, activation of the actual weight of the soil and the initial radial constraint ($\sigma^{\circ}r = \sigma^{\circ}\theta = k_0 \gamma z$), which defines the initial state of stress. In this example, the installation effects are not taken into account. Initially, pore-water pressure due to the initial condition is calculated. In the second phase, pile and load on it is activated. Interface also gets activated. And all the calculation is done. Consolidation analysis is also done to study the long term behaviour.

III. RESULTS

Figure 2 shows the deformed mesh due to some settlement, and Fig. 3 shows the displacement around pile.

From the modeling results of the compression loading test of the pile (dilating interface and elasto-plastic soil), we can analyze the evolution of the displacement field around the pile. The displacement field is concentrated around the pile with a displacement of the pile head (0.1 m) and under the pile tip.

IV. ANALYSIS AND CONCLUSION

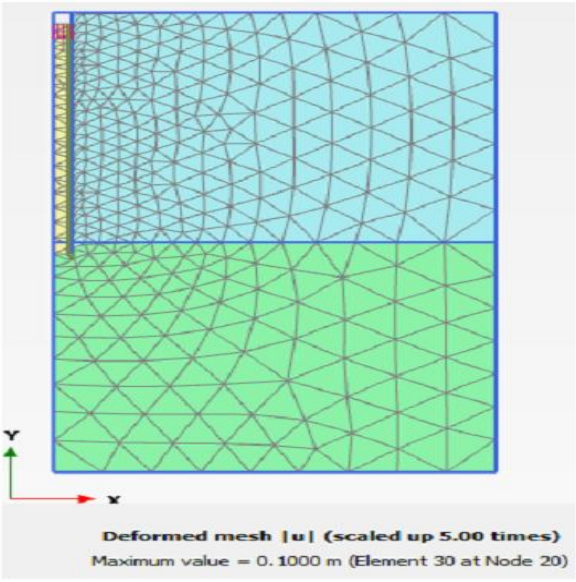


Fig. 2 Deformed Mesh

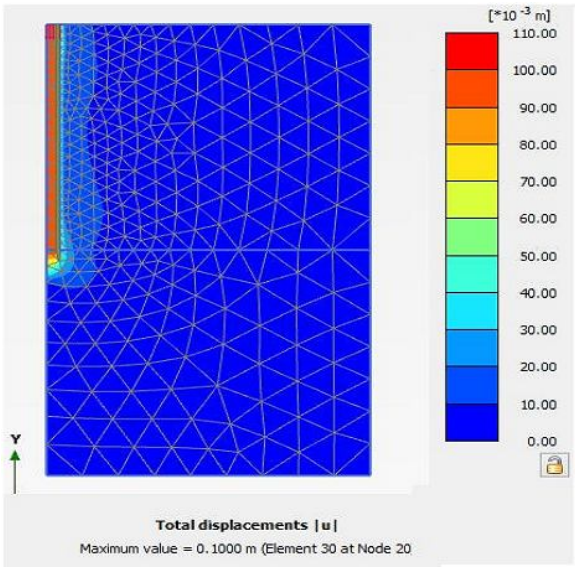


Fig. 3 Displacement field (Clay underlain by sand)

a) Clay layer underlain by sand

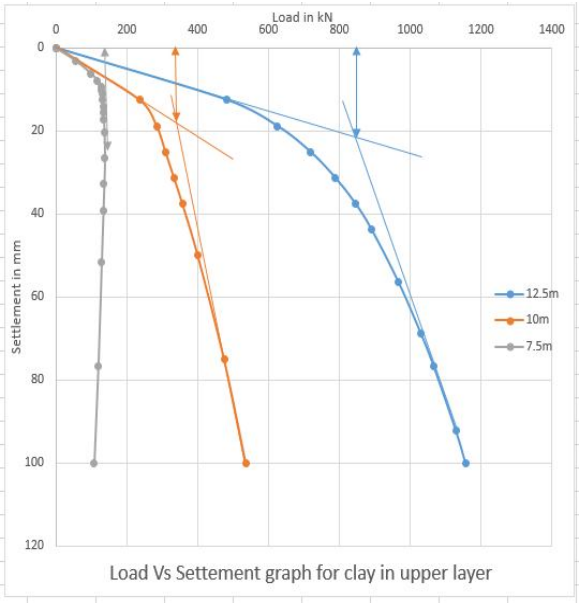


Fig. 4 Load-settlement curves

The results are presented in Fig. 4. From the load-settlement curves, it can be figured out that the pile of length 12.5m has the maximum capacity, followed by that of 10m, and 7.5m has the least.

This can be explained as the pile is surrounded by clay and resting on the sand and also is of the highest length; hence, has the highest capacity among all.

Table 2 Load carrying capacity

Length of pile (m)	Load Carrying Capacity (kN)
7.5	150
10.0	350
12.5	850

Sudden decrease in the bearing capapcity of pile of length 10m may be due to its smaller length and also the absence of frictional resistance which was available earlier in sand.
Finally, the pile of length 7.5m has very small capacity as there is little frictional resistance and a small bearing resistance.

b) Sand layer underlain by clay

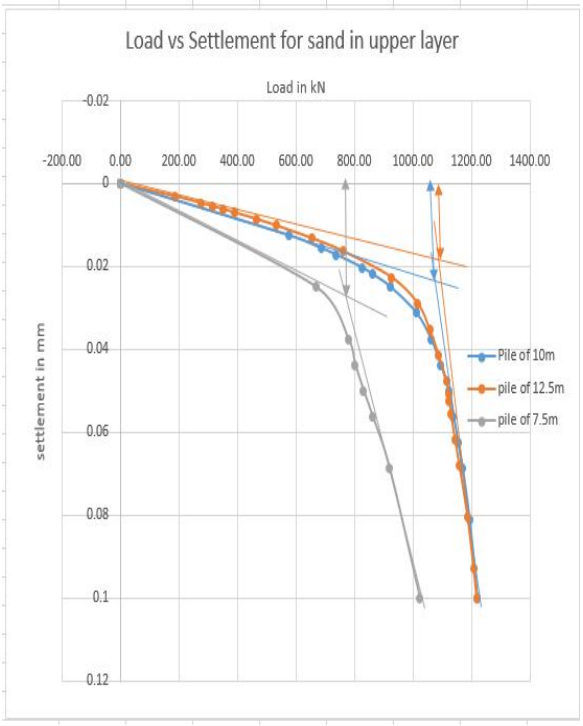


Fig. 5 Load-settlement curves

The results are presented in Fig. 5. From the load-settlement curves, it can be figured out that the piles of length 10m and 12.5m have almost same capacity. The pile of length 7.5m has the least capacity.

Table 3 Load carrying capacity

Length of pile (m)	Load Carrying Capacity (kN)
7.5	750
10.0	1050
12.5	1100

Graphs for piles of length 10m and 12.5m follow almost similar pattern. This might be because though the pile of 12.5m is longer, it is more slender and it has some length in clay and deriving resistance in both bearing and cohesion, unlike the case of pile of 10m length. Therefore, it has slightly higher capacity than pile having 10m length.
The pile of 10m length is placed completely in sand and has good capacity as compared to other piles. Finally, the pile of length 7.5m has the least capacity which is quite obvious because of its small length.

Finally, it can be observed that the pile in case of sand underlain by clay has significantly higher bearing capacity than the case in which clay is underlain by sand.

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