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Establishing Correlation of Different Failure Parameters for Driven Pile in Silty Clay Soil Using All Pile Software

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Abstract

Pile foundation is considered as one of the state-of-art areas of the geotechnical engineering which is effective for all kinds of soil conditions. Pile bearing capacity includes toe bearing & friction bearing. Despite of several techniques, taking in account the effect of underground water, the problem of choosing the right calculating approach of bearing capacity becomes very complex. Pile load testing is an expensive and time-consuming performance and in order to escape it, many empirical or semi-empirical methods have been developed and used. In this study, numerical model was developed using AllPile software to predict the ultimate pile capacity of driven pile (DPC) when embedded in silty clayey soils. This work will give idea about the performance of bored piles embedded in silty clayey soils to make proper design of piled foundation. The soil lateral pressure was found to be decreased as depth increased until a certain depth of penetration is reached. This may be due to the fact that the soil near surface is usually weak and could not carry higher loads compared to soil at deeper elevations. Since the investigated soil profile was soft silty clay, the frictional resistance offered by the surrounding soil of the pile periphery was found to be dominated over the tip resistance and consequently increased gradually as the depth increased. Finally, a graphical correlation between lateral loads on pile embedded in silty clayey soils with pile top deflection was also developed to reach a certain degree pile top deflection corresponding to lateral loads.

Keywords: *Driven precast concrete; Numerical Analysis; Axial Force; Lateral Loads; Silty Clayey Soils.*

1 Introduction

Pile foundation is considered as one of the important areas of the geotechnical engineering. In most of the civil engineering projects loads coming from the superstructure are transferred to soil through foundation that can be either spread or pile. Pile foundations typically extent to depths in the order of 15m below ground surface but in some areas, they can be deep as 45m (Canakci, 2007). The need for deep foundations on any project typically results from many factors, including subsurface conditions, foundation loads, and allowable foundation settlement criteria (Bell, Davie et al. 2002). Selection of the pile type, in addition to local experience and practice, is frequently based on subsurface conditions, while the preliminary choice of pile size and length is usually determined by static pile capacity calculations. Soft soil deposits of low shear strength and high compressibility are found worldwide. In the past, construction on these deposits was avoided because of their adequacy in as a foundation ground due to their low bearing capacity to support buildings, road, etc. Pile load carrying capacity depends on several factors including pile characteristics such as pile length, cross section, and shape, soil configuration and short and long-term soil properties and pile installation method (Li, Wang, Guo, & Yu, 2019).

This paper proposes an analytical approach to evaluate the time-dependent bearing capacity of an in-situ pile in clayey soils by taking the pile installation and reconsolidation effects into consideration. The process of pile installation is modeled by untrained expansion of a spherical cavity at the pile tip and a cylindrical cavity around the pile shaft. The cavity expansion solution, which is based on a K0-consolidated anisotropic modified Cam-clay model (K0-AMCC), is used to capture the pile installation effects. After pile installation, the dissipation of the excess pore water and the increase of the effective stress in the surrounding soil are evaluated by the radial consolidation theory. Based on the effective stress, the strength of the remolded soil is quantified by the modified Cam-clay (MCC) model and the spatially mobilized plane (SMP) criterion (Li, Li, Sun, & Gong, 2016).

2 Significance of our study

The pile foundation is used when it is necessary to transfer the loads from the superstructure and abutment to a stronger soil beneath the weak soil near the ground surface, which is not capable of carrying the loads (Mohti & Khodair, 2014). However, with skyscrapers becoming increasingly tall together with the excavation becoming increasingly deep, the civil engineer must face the difficult challenge of foundation design. The huge building load and safety issues make the adoption of a pile foundation a necessity. In a pile foundation design the pile carries the total upper load without taking the contact pressure into account even in the areas with good stratigraphic conditions (Xiao & Zhao, 2019). Numerical analysis of the behavior of piled seated on uniform soil with low bearing capacity has been important to support the project design. The calibration of the numerical model with instrumented load test allows usage of the results, in given conditions, in the foundation design of small and medium-sized buildings built on soils with the same mechanical properties should be analyzed (Oliveira, Justino, & Garcia, 2022).

3 Materials and methodology

The details of materials selection, properties of soil used, pile profile and properties used, numerical modeling and experimental procedure of this research work.

3.1 Materials Selection

3.1.1 Properties of Soil Used

The soft silty clay was modelled with the parameters as shown in Table 1.

Table 1. Properties of Soils Used in this Investigation.

Zs (m)	Soil Data Input	G (kN/m^3)	Phi (Φ)	C (KN/m^2)	K (MN/m^3)	E50 or Dr	N_{spt}	Type
0	Soft Clay [W]	5.3	0.00	4.2	2.6	4.38	1	1
2	Sand/Gravel [W]	6.0	27.2	0.00	1.2	8.69	2	4
3.1	Silt (Φ+C) [W]	8.9	27.6	15.0	25.9	1.33	5	3
4	Silt (Φ+C) [W]	9.8	28.6	20.9	48.9	1.08	7	3
6	Silt (Φ+C) [W]	10.8	30.9	38.9	123.6	0.74	13	3
11	Silt (Φ+C) [W]	10.1	29.1	24.5	62.9	0.98	8	3
12	Stiff Clay [W]	10.8	0.00	77.8	123.6	0.74	13	2
15	Stiff Clay [W]	10.5	0.00	59.9	85.0	0.87	10	2

3.1.2 Soil Depth (Zs)

First, the top depth of the soil layer was inputted. The top is the distance from ground surface to the top of the layer. The depth of the first row (layer) is zero. The top of the second layer is the bottom of the first layer. The top depth of the last layer is defined as the last row.

3.1.3 Unit weight of soil (G)

If the soil is under the water table, buoyant weight must be input. (This is why it is necessary to divide a layer into two if the GWT sits within this layer.) Buoyant weight is the total unit weight of the soil minus the unit weight of the water. Input total unit weight above GWT and buoyant weight below GWT.

3.1.4 Modulus of Subgrade Reaction (K)

Modulus of Subgrade Reaction of soil (for lateral analysis only). If we only run vertical analysis, we don't have to input this value.

3.1.5 Relative Density, Dr or e50

If soil is silt, rock, or clay, e50 is strain at 50% deflection in p-y curve (only used for cohesive soil in lateral analysis). If soil is sand, Dr is the relative density from 0 to 100 (%). It is for reference only and is not used in the analysis.

3.1.6 Standard Penetration Test (N_{spt}) value

Standard Penetration Test (N_{spt}) value is the number of blows to penetrate 12 inches in soil (304.8 mm) with a 140-lb (622.72 N) hammer dropping a distance of 30 inches (0.762 m).

3.1.7 Soil Parameter Screen

The soil parameter screen is for inputting or modifying the soil parameters. The program provides correlation between SPT value and the other parameters. N sliding bar was used to modify all the parameters or move each bar individually.

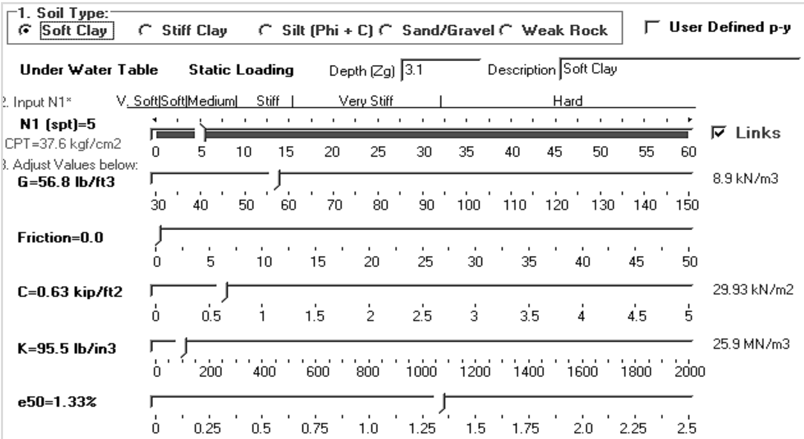


Figure 1: Soil Parameter Screen.

3.1.8 Pile profile and properties used

In this study, bored cast in-situ pile of 15m length and 40 cm diameter resting on silty clayey soils was modelled in AllPile commercial program. The pile properties used in this investigation is presented in Table 2.

Table 2. Pile properties used in this investigation

Depth (m)	Width (cm)	Area (cm^2)	Perimeter (cm)	I (cm^4)	E (MP)	Weight (kN/m)
0.0	40	1256.6	125.7	125663.7	20683	2.963
15.0	40	1256.6	125.7	125663.7	20683	2.963

Figure 2 represents the pile profile information. The diagram on the left side reflects the information input on the right side.

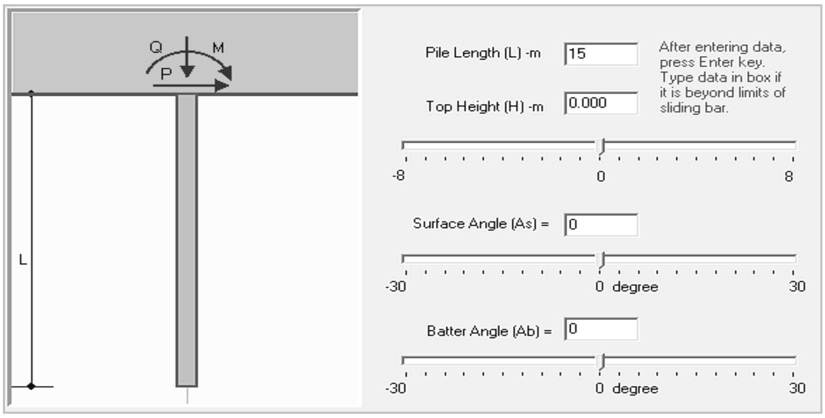


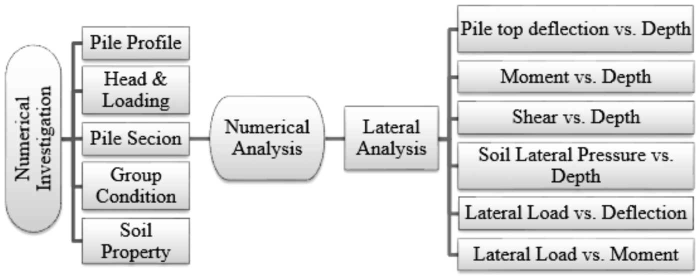
Figure 2: Pile profile

3.2 Numerical Modelling

AllPile analysis program was used to develop the numerical modeling as well as to analyze the pile load capacity efficiently and accurately. AllPile is a commercial program that has been utilized in many executive tasks and because of its ease of use in engineering, and in particular the analysis of different pile types under the influence of vertical, lateral, and bending loads and their combinations, as a single pile or pile group. The model consisted of a single pile of 15m length and 40 cm diameter resting on silty clayey soils.

3.3 Research Methodology

The steps followed for the research are shown in the following flowchart –



4 Results & Discussion

This section contains the numerical analysis results including variation of pile top deflection with depth, moment distribution along the embedded depth of pile and shear force with length of pile in silty clayey soils. This also includes variation of the lateral pressure in the soil adjacent to the bored cast in-situ pile in silty clayey soils, variation of lateral load with deflection and variation of lateral load with moment.

4.1 Lateral Analysis of Bored Cast in-situ (BCIS) pile embedded in silty clayey soils

4.1.1 Variation of Deflection with Depth

Figure 4 illustrates the fluctuation of deflection in the soil near the bored, driven pile with depth in silty clayey soils under lateral examination. Until a specific depth of penetration is attained, the deflection reduces as depth increases. When the depth was 0 m, the deflection initially reached a maximum of 0.80 cm. However, the pile top deflection is decreased to zero with the increase in depth at 5 m. The deflection stayed constant even while the depth was growing. This phenomenon is caused by the soil depth.

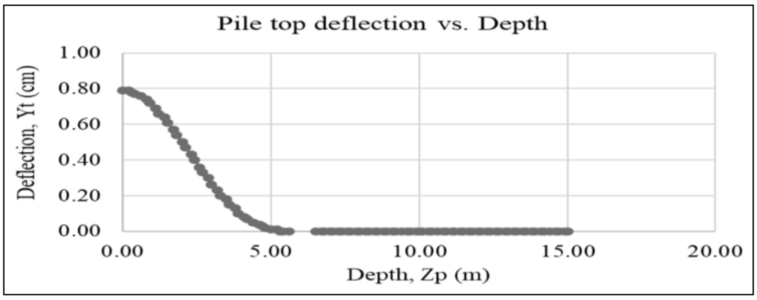


Figure 3: Variation of Deflection with Depth

4.1.2 Variation of Moment with Depth

Figure 5 represents the variation of shear of bored cast in-situ pile in silty clayey soils. From the start, the shear was about 45 KN when the depth was 0 m. Then the shear decreases to -25 KN as the depth increases to 5 m, although the shear increases again with the increase in depth. At 7 m, the shear remained 0 (KN), but the depth was increased to 15 m.

4.1.3 Variation of Shear Force with Depth

Under lateral analysis, Figure 6 depicts the variation of the shear in the soil adjacent to the bored, driven pile with depth in silty clayey soils. From the start, the shear was about 45 KN when the depth was 0 m. Then the shear decreases to -27 KN as the depth increases to 5 m, although the shear increases again with the increase in depth. At 7 m, the shear remained 0 (KN), but the depth was increased to 15 m.

4.1.4 Variation of Lateral Pressure with Depth

Figure 7 depicts the variation of the lateral pressure in the soil adjacent to the driven pile in silty clayey soils with pile length. At first, the pressure decreases as depth increases until a certain depth of penetration is reached. At maximum pressure of 10 (KN/m^2) when the depth was about 6 m. From then, it gradually began to decrease as the depth increased. From 9 m the pressure remains 0 (KN/m^2).

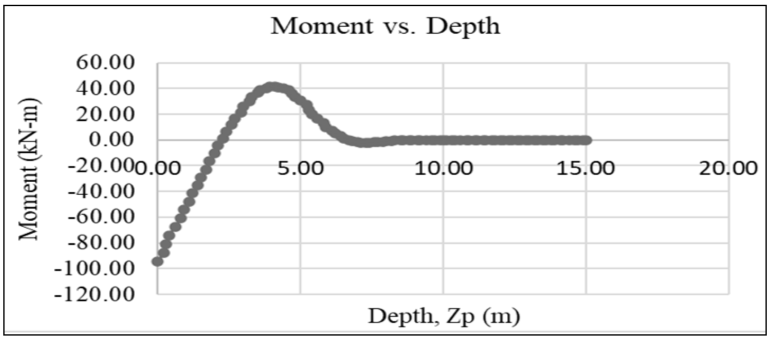


Figure 4: Variation of Moment with Depth

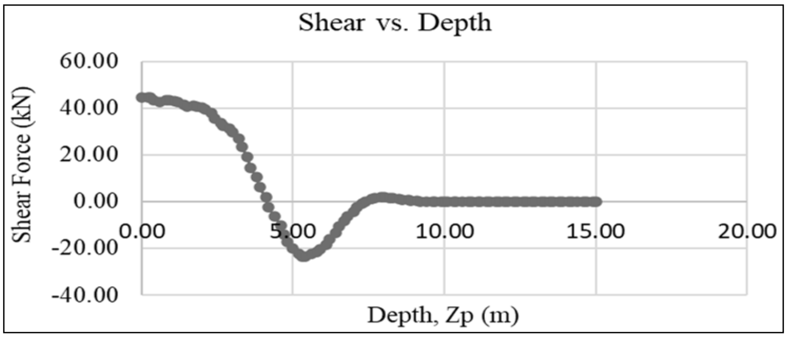


Figure 5: Variation of Shear Force with Depth

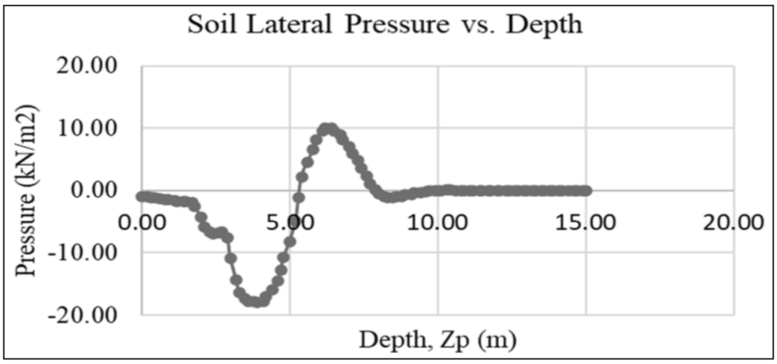


Figure 6: Variation of Soil Lateral Pressure with Depth

4.1.5 Variation of Lateral Load with Depth

In silty clayey soils, Figure 8 shows the variation of the lateral load in the soil next to the bored, driven pile with deflection under lateral analysis. The graph shows that both the lateral load and the deflection are flowing continuously upward. This increased lateral load depends mainly on the soil properties as well as the pile length. A straight-line equation could be used to explain their relationship.

4.1.6 Variation of Lateral Load in the Soil Adjacent to the pile with Moment

The variation of maximum bending moment with lateral load is presented in Figure 9. The magnitude of lateral load was found to be increased from 4.40 kN to 44.50 kN, for a fixed headed pile embedded in silty clayey soils, the maximum bending moment increased from 6.7 kN-m to 68.80 kN-m. It was observed from the above analysis that with an increase in lateral loads the magnitude of bending moment increases, irrespective of the soil type. This clearly occurs because of the increasing lateral load acting with the increasing lateral deflection.

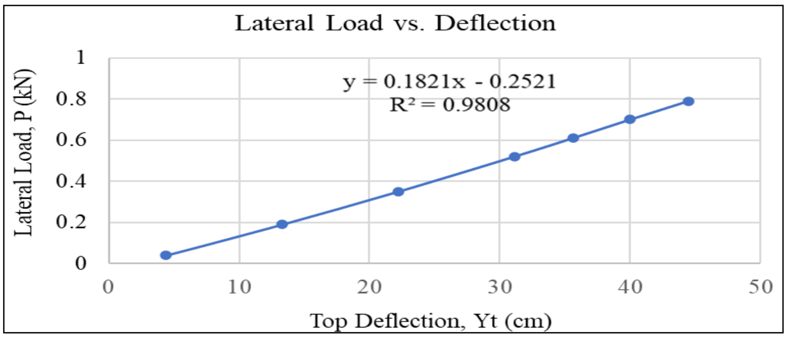


Figure 7: Variation of Lateral Load with Deflection

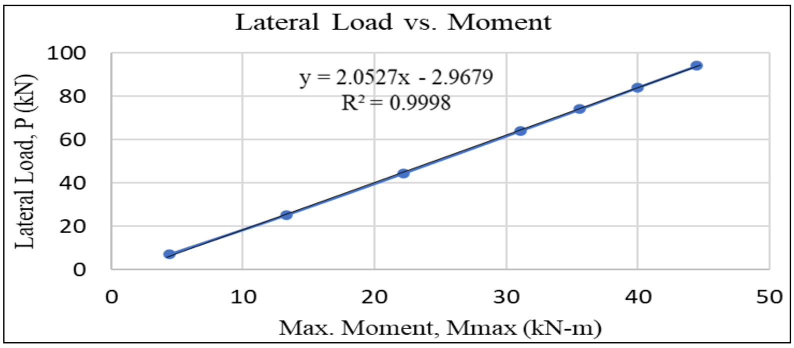


Figure 8: Variation of Lateral Load in the Soil Adjacent to the Pile with Moment

5 Conclusion

Initially, the pile top deflection was found to be a maximum of .80 cm when the depth was 0 m. Then the deflection decreased as depth increased until a certain depth of penetration (5 m) is reached when the pile top deflection is reduced to zero. The maximum negative moment was found to be -95 KN-m at pile top and then increased as the depth increased until it reached +45 KN-m at a depth of 5 m. After that, the moment decreased with the increased depth of pile and reduced to zero at a depth of 7 m. The maximum shear force was found to be 45 kN at pile top and then decreased as the depth increased until it reached -25 kN at a depth of 5 m. Beyond this the shear gradually reduced to zero at a depth of 7 m. The soil lateral pressure was found to be decreased as depth increased until a certain depth of penetration is reached. This may be due to the fact that the soil near surface is usually weak and could not carry higher loads compared to soil at deeper elevations. The lateral soil pressure increased when moving from the edge of pile to the center cross section and then gradually decreased to zero at a depth of 9 m. Since the investigated soil profile was soft silty clay, the frictional resistance offered by the soil surrounding the pile was found to be dominated over the tip resistance and consequently increased gradually as the depth increased. With an increase in lateral loads the magnitude of bending moment increased, irrespective of the soil type because of the increasing lateral load acting with the increasing lateral deflection.

6 References

Bell, K., Davie, J., Clemente, J., & Power, B. (2002). Proven Success for Driven Pile Foundations.

Canakci, H. (2007). Pile foundation design using Microsoft Excel. *computer Applications in Engineering Education* .

Poulos, H. G. and Davis, E. H. (1980). Pile Foundation Analysis and Design. Rainbom- Bridge Book Co.

Poulos, H. G., Small, J. C., & Chow, H. (2011). Piled raft foundations for tall buildings.

POULOS, H. G. (1980). *pile foundation analysis and design.*

Li, L., Li, J., Sun, D., & Gong, W. (2016). Analysis of Time-Dependent Bearing Capacity of a Driven Pile in Clayey Soils by Total Stress Method.

Wang, X. (2021). Research on Vertical Bearing Capacity of Pile Foundation under Wave Scouring. *Open Journal of Modelling and Simulation*, *9*(02), 124-134.