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[ijirset@gmail.com](mailto:ijirset@gmail.com)

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# A Parametric Study on Pile Foundation in Soft Clay Soil Considering Soil Structure Interaction

**Bidisha Dey<sup>1</sup>, Tuhin Roy<sup>2</sup>, Soumyadip Mondal<sup>3</sup>, Abhinaba Poddar<sup>4</sup>, Arnab Chatterjee<sup>5</sup>**

Student, Department of Civil Engineering, Shree Ramkrishna Institute of science and Technology, Kolkata, India<sup>1</sup>

Student, Department of Civil Engineering, Shree Ramkrishna Institute of Science and Technology Kolkata, India<sup>2</sup>

Student, Department of Civil Engineering, Shree Ramkrishna Institute of Science and Technology Kolkata, India<sup>3</sup>

Head of the Department, Department of Civil Engineering, Shree Ramkrishna Institute of Science and Technology  
Kolkata, India<sup>4</sup>

Assistant Professor, Department of Civil Engineering, Shree Ramkrishna Institute of Science and Technology  
Kolkata, India<sup>5</sup>

**ABSTRACT** : To bring new discernment into single pile responses to adjacent excavations in soft ground, numerical parametric studies are carried out. This paper aims at analysing the load deformation characteristics of a single pile of 1.1 m. length and varying diameter (0.3,0.45,0.6,0.9,1.2m) in soft clay (cohesive) soil. Varying cohesive values (137.3,0,53.93 kN/m<sup>2</sup>) and varying angle of internal friction (0,32,0)using Plaxis 2D software. The results of the analysis has been compared based on the Total Displacement and other results (effective principal stress, over consolidation ratio, active pore pressure, excess pore pressure & degree of saturation) of the pile under different conditions. As the study progresses it has been noticed that when angle of internal friction is less than cohesion, the soil collapse against the pile foundation.

**KEYWORDS** : Single Pile , Parametric Study, Total displacements, Effective Principal stress, Over consolidation Ratio, Active Pore Pressure, Excess Pore Pressure, Degree of Saturation.

## I. INTRODUCTION

Introduction of this paper has been divided and presented in the following two subsections.

### 1.1 Prologue

When any external load act on any structure, the structure deflects, which at the same time tends the foundation to deflect. The soil beneath the foundation as well as the deflects due to the deflection of foundation. This is known as Soil Structure Interaction (S.S.I). Piles or Pile Foundations are known as deep foundation and they are used when shallow foundations are unable to resist settlement or bearing capacity of the soil is questionable. We know that the load (both live and dead) of superstructure is transmitted to the sub soil through the foundation. Considering this, Pile Foundation is the first choice for any high rise building or any important critical structure because it carries vertical load as well as lateral loads. On the other hand underground constructions (i.e. basements, tunnels etc.) which are meant to make the transportation easier are also depended on Pile Foundation. Mat foundation (also known as Raft Foundation) is also supported by pile , which is built over highly compressible soil and is most popular one to resist settlement. Where water table is high rafts are often placed over piles to control buoyancy [ Bowles, E. J., (1997). Soil structure interaction is sometimes negligible for light structure but never for the important or heavy structures resting on relatively soft clayey soil.

Piles can be classified based on the a) material of the pile, b) properties during displacement and on the c) nature of load support. Properties of Pile, properties of soil, the methods of installation and loading conditions control the Pile load-displacement characteristics. Friction Pile and End Bearing Pile are the two classifications of Piles based on load support. Friction Pile transmits the load through the skin friction developed throughout the pile surface ; while End Bearing Pile transmits load directly through the soft strata to hard strata or deeper rock layer. The parameters of pile such as length, diameter, material of the pile depends on the bearing capacity of the soil which is determined by the following three methods- i) The Static Formula , ii) The Dynamic Formula & iii) The Field Load Tests. At the same time displacements of the piles in several cases can be shown by changing its other parameters.

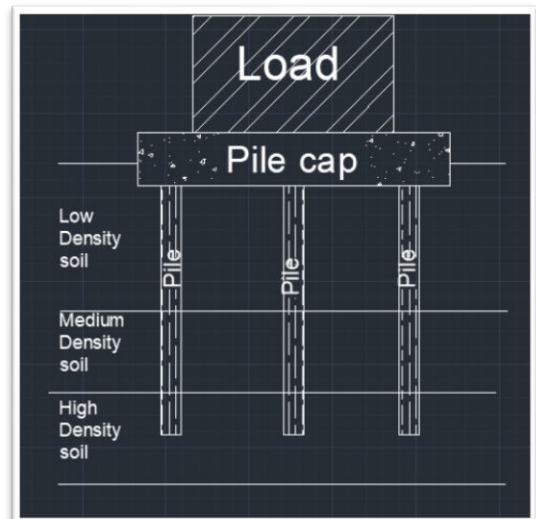
## 1.2 Pile Foundation

Pile Foundations are used when the soil near the surface is not capable of supporting the load of any structure effectively. Pile foundation is used when the soil is weak or unstable, structural loads are heavier, in those areas where soil is and water table is high. Designing a pile foundation is to provide adequate support to a structure when the hard strata is at a great depth. Currently pile foundations are very widely used in the construction of high-rise buildings as they are usually found to be economical in cases where the base soil has a low bearing capacity and column loads are very large. Pile foundation is the most effective deep foundation. It consists of long , slender columns (piles) driven or drilled into the ground.

According to Frank Lloyd Wright , “A building should have no unnecessary ornamentation; it should be one with the earth. The pile foundation, invisibly yet essential, mirrors the harmony between structure and soil.”

Meanwhile Fazlur Rahman Khan stated that, “ In the dance of loads and soil, the pile foundation performs a symphony of support, orchestrating stability for structures that aspire to touch the sky.”

Pile foundation design involves determining the appropriate type of piles, their dimensions, and the depth at which they should be installed to support the structure. Factors include soil conditions, structural loads, and environmental conditions. Engineers analyze geotechnical data, perform load calculations, and choose pile types such as driven piles or drilled shafts based on the project's requirements. The design aims to ensure stability, proper load distribution, and adherence to safety standards.



## II. FINITE ELEMENT METHOD & MODEL VERIFICATION

The finite element method is applied to analyze pile foundations by representing the soil-pile interaction through numerical modeling. In this method, the foundation soil and pile are divided into finite elements, and the governing equations are solved iteratively to simulate the behaviour under various loads and conditions.

In finite element method firstly the geometry of the pile and surrounding soil is defined and they are discretized into finite elements. Proper meshing should be done for accurate results. Then material properties to the soil and pile elements considering factors like stiffness, strength, and other relevant parameters are assigned. After that appropriate boundary conditions are provided to simulate the interaction with the surrounding environment i.e. fixed or prescribed displacements at certain points. Then gradually loads are provided and numerical analysis is done for the final outcomes. This approach allows to evaluate factors such as pile capacity, settlement, and lateral resistance, providing insights into the overall performance of the pile foundation under different conditions.

The present work is dealing with the designing of pile by the ‘Finite Element’ method and PLAXIS 2D Software is used in the present work. In the analysis, the software converts the object based model created by the user into a finite element model, called the analysis model. The finite element mesh used to find out the total displacement, effective principal stress, active pore pressure and other minor factors.



At first model verification is carried out to verify credibility and numerical ability of the finite element model. The various parameter of pile foundation i.e displacements, effective principal stress, active pore pressure are obtained from the literature which are tabulated below in table 3. A total six parameters are modelled and evaluated by field data. Based on available data numerical models are developed and solved by finite element approach. The design parameters are adopted from the values of Alzey Bridge Pile Load Test. The predicted values are tabulated in table 3. The results show that the predicted values of different parameters are almost same with measured values.

In the present study it is aimed to check outcomes of several important factors by changing the diameters of the pile alongwith the two parameters of soil i.e. cohesion and angle of internal friction. We are taking the piles of five different diameters (300, 450, 600, 900, 1200) and evaluating them by changing the cohesion and angle of internal friction thrice for each diameter of pile. The interaction among structures and their foundation and the soil below the foundation alter the actual behavior of the structure considerably than what is obtained from the consideration of structure alone. Finally design implications are suggested based on the influence of the several parameters on the observed responses.

**Table 1: Parameters for Soil**

Parameters	Values
Dry unit weight	20
Saturated unit weight	20
Cohesion	20
Poissons Ratio	0.2
Angle of internal friction	20 degree
Dialatancy angle	0 degree
Interface Ratio	1

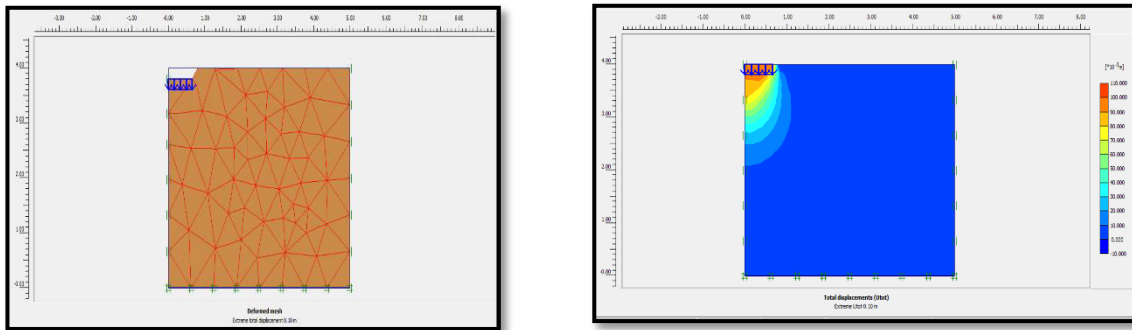
**Table 2: Parameters for Pile**

Parameter	Measured Value	Predicted Value
Total Displacement	0.1 m.	0.12 m.
Effective Principal Stress	-518.98 kn/m <sup>2</sup>	-560.77 kn/m <sup>2</sup>
Over Consolidation Ratio	0	0
Active Pore Pressure	1.00 X 10 <sup>-3</sup> kn/m <sup>2</sup>	1.00 X 10 <sup>-3</sup> kn/m <sup>2</sup>
Excess Pore Pressure	0	0
Degree of Saturation	0	0



Parameters	Values
Pile Length	9.5 m.
Pile Diameter	1.3 m.
Modulus of Elasticity	$1 \times 10^7 \text{ kN/m}^2$
Poissons Ratio	0.2
Skin Friction	1320 kn

**Table 3. Measured and predicted observations for different parameters of pile foundation.**



### III. RESULTS AND DISCUSSIONS

In our parametric study we have taken five piles of respective diameters – 300, 450, 600, 900 & 1200 mm. By using PLAXIS 2D Software we have calculated the Total Displacement, Effective Principal Stress, Over Consolidation Ratio, Active Pore Pressure, Excess Pore Pressure, Degree of Saturation. The two main soil parameters are Cohesion(C) and Angle of Internal Friction( $\phi$ ). For each pile of mentioned diameter three values of C and  $\phi$  is taken, which are marked as minimum, medium and maximum in the column charts displayed below.

For the all five cases when C is  $137.3 \text{ kN/m}^2$  and  $\phi$  is 0 , the condition is taken as minimum; when C is 0 v and  $\phi$  is 32, the state is taken as medium; and finally when C is  $53.93 \text{ kN/m}^2$  , the state is marked as maximum. The above mentioned results are evaluated by the change of diameter in every five cases.

**Fig.1** shows that Total Displacements are same in minimum and medium but it is extremely decreasing in the maximum condition for all the cases.

**Fig.-1 : Total Displacement**

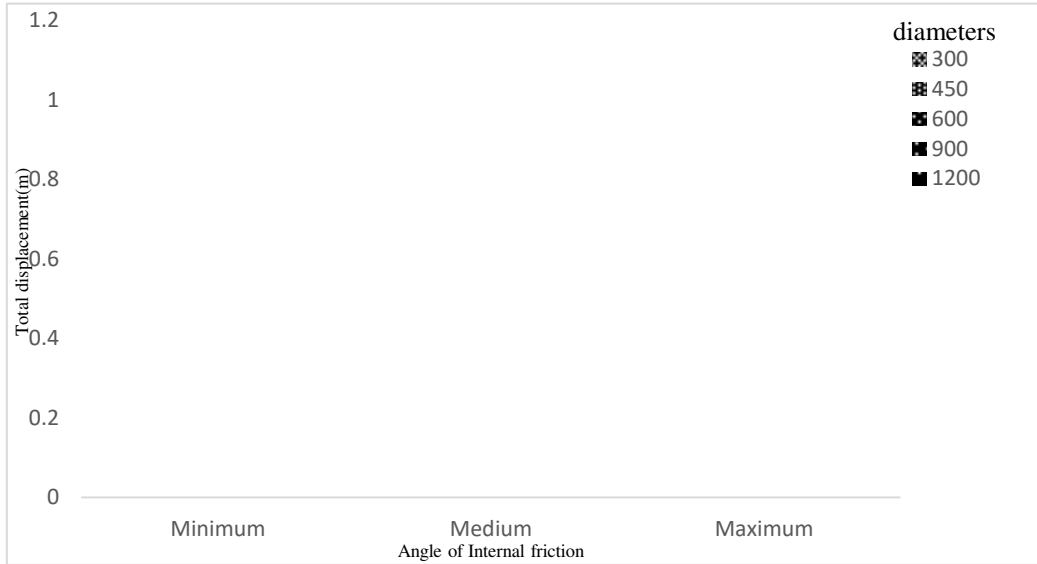


Fig. 2 shows that Effective Principal Stress is decreasing at about the rate of 25% from minimum to medium and in maximum state a sudden fall in the the effective stress is noticed.

**Fig.2 : Effective Principal Stress**

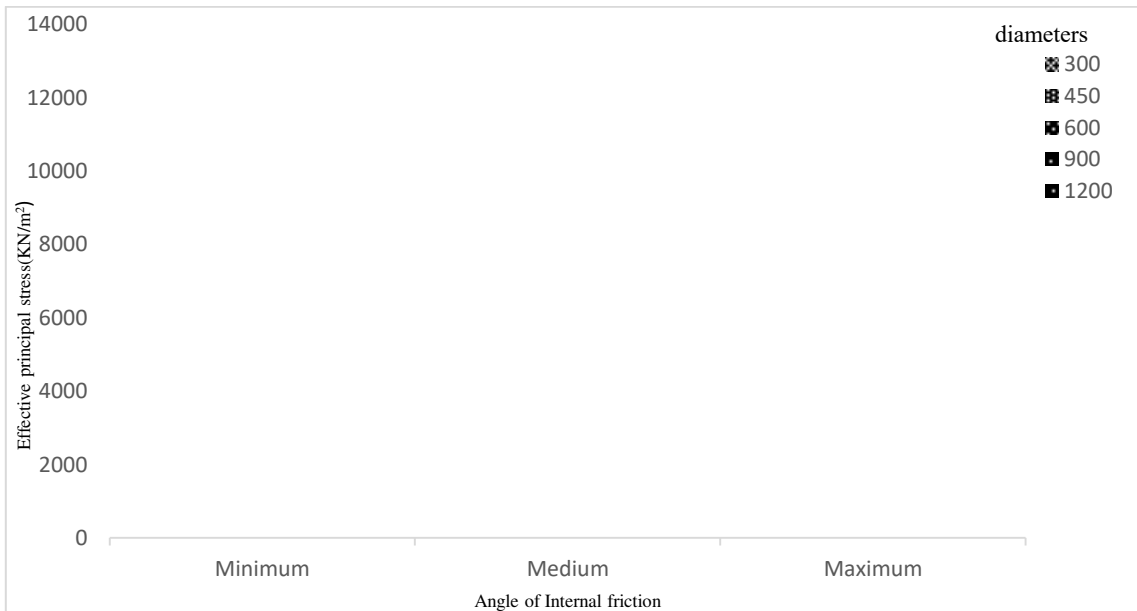
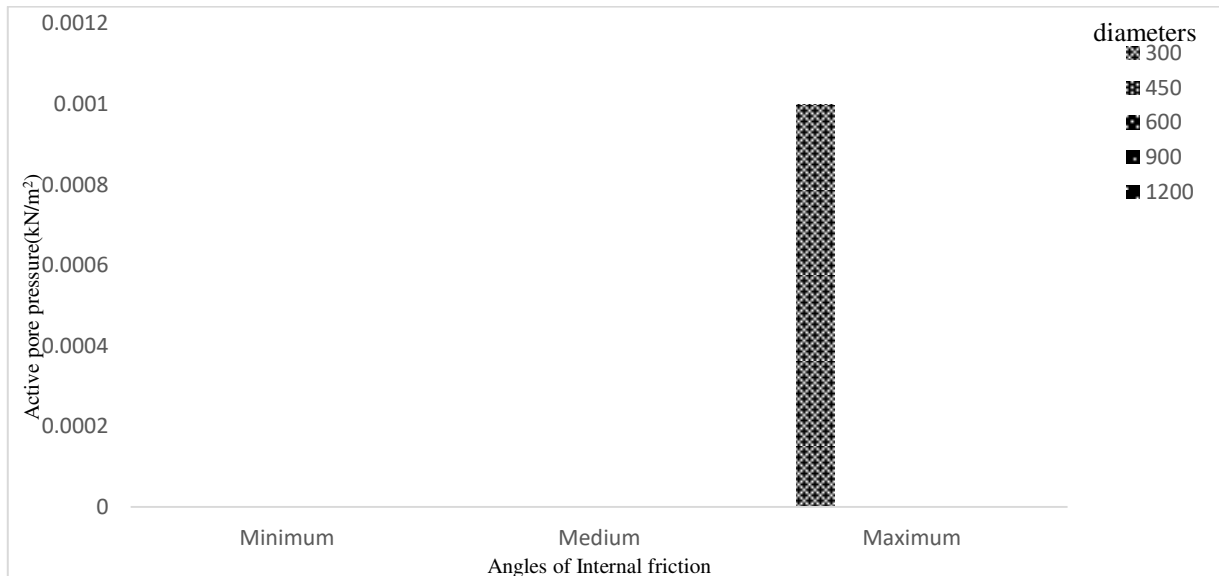


Fig. 3 shows that when C is 137.3 and  $\phi$  is 0 i.e. the minimum state and when C is 0 and  $\phi$  is 32 i.e. the medium state for the pile of 300 diameter the Active Pore Pressure is 0. But for the case of maximum state it is increased by 0.15% and for the rest of the cases the value is constant .

**Fig.3 : Active Pore Pressure**



Except these above discussed outcomes, the other values such as Over Consolidation Ratio, Excess Pore Pressure, Degree of Saturation is constant for all the before said cases.

#### IV. CONCLUSION

A parametric study is carried out for different parameters to determine the effect of soil structure interaction subjected to different parameters of pile and soil. The foundation is modelled using Plaxis 2D software considering the pile is of 1.1 m. depth for every cases. Based on the results, the following conclusions can be drawn.

- Measured parameters (such as displacements, effective principal stress, active pore pressure etc.) are in good agreement with predicted value.
- Displacement value is same for the minimum and medium phase for the all diameter of piles.
- It has been noticed that the soil will get collapsed for the value of cohesion and angle of internal friction at the maximum state.
- For every five cases, the effective principal stress is increasing when we are shifting from minimum to medium and the value falls at the maximum state.
- Over consolidation ratio, excess pore pressure and degree of saturation is same and constant for each and every cases.

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