

# Effect of Deep Excavation Adjacent to Pile Structure

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**ABSTRACT:**In urban area where land is scarce and buildings are closely spaced, deep excavation for basement construction and other underground facilities like cut- cover tunnels are unavoidable.. As many high rise buildings are supported on pile foundation, there is concern that lateral ground movement resulting from the soil excavation, may adversely affect the nearby pile foundation systems. The lateral load imposed by the soil movements impose the bending moment and deflections in the pile, which may lead to structural distress and failure. This paper aims at investigating the effect of excavation induced movements on the lateral deflection and bending moments on pile situated near the excavation in layered soil.

**KEYWORDS:**Pile, Deep excavation, Side supported excavation, Layered soil.

## I. INTRODUCTION

In dense urban environments where land is scarce and buildings are closely spaced, deep excavation for basement construction and other underground facilities like cut- cover tunnels are unavoidable. As these excavations are usually carried out close to existing buildings, a major concern is to prevent or minimize damage to adjacent building and underground utilities. As many high rise buildings are supported on pile foundation, there is concern that lateral ground movement resulting from the soil excavation, may adversely affect the nearby pile foundation systems. The lateral load imposed by the soil movements impose the bending moment and deflections in the pile, which may lead to structural distress and failure.

In deep excavation soil supported wall get deflected by the moment induced due to soil movement. Several researches have used numerical modelling and centrifuge test modelling to evaluate the performance of pile adjacent to the side supported excavation. .Several experimental studies have also been conducted to explore the effect of various parameters like diameter of pile, length of pile, distance of pile from excavation, excavation depth to pile length ratio, stiffness of wall, and stiffness of pile on the deflection and bending moment of pile and deflection and bending moment of wall supported to the excavation.They established that for piles in sand, the induced pile bending moment and deflection increase with increase in excavation depth. As clay rather than sand is the predominant subsurface material in many cities, the analysis of pile response in clay near the excavation is carried out by using centrifuge model test and results in reduction in pile response with increasing the distance of pile from excavation. The common results from the literature included significant effect of the increase in distance of pile from excavation and depth of excavation on the deflection and bending moment of pile.

## II. RELATED WORK

Polous *et.al* (1997)<sup>[1]</sup>conducted study of finite element and boundary element method for pile response due to excavationinduced moment in clay.They concluded that pile response increases with increasing undrained shear strength and decreases with stiffer excavation support conditions and struts stiffness.

Leung *et.al*(2000)<sup>[2]</sup>conducted a study of centrifuge model tests on unstrutted deep excavation in dense sand and its influence on an adjacent single pile foundation.The test result revealed that the induced maximum bending moment and

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deflection on the pile decreased with increasing distance between the pile and the wall.

Goh *et al* (2003)<sup>[3]</sup> conducted the result of an actual full scale instrumented study that was carried out to examine the behaviour of existing pile due to the nearby excavation activities of tunnel. A simplified numerical procedure based on finite element method (BCPILE) was used to analyze the pile response.

Ong *et al* (2006)<sup>[4]</sup> presented study of series of centrifuge model test to investigate the behaviour of pile group of various sizes and configuration behind the retaining wall in very soft clay. The test result revealed that behind an unstable retaining wall, the extent of soil deformation zone is much larger than behind a stable wall.

Elkady T.<sup>[5]</sup> conducted a study of finite element analysis by ABAQUS to assess the effect of excavation depth, distance of pile from side supported excavation, pile stiffness and wall stiffness. Results indicated that distance of pile from excavation and excavation depth have a significant effect on the lateral deformation and bending moment on pile.

Kulkarni.S.R.<sup>[6]</sup> presented a study of deep basement excavation for 33 stored high rises Tower by Finite element software (Plaxis 2D). Contiguous bored piles are provided as earth retention system with anchorage at three levels.

A Finite element software (Plaxis 2D) was used to evaluate the bending moment of wall and settlement of ground. Result indicates that as the depth of excavation increase moment on wall also increase.

### III. MATERIALS AND METHOD

Generally in deep excavation soil profile consist of number of layers of soil having different geotechnical properties. The previous study deals with the investigation of pile response in particularly clay and soil. Practically at site it is difficult to find out full sand layer or clay layer. The earlier studies are therefore extended to investigate the behavior of single pile due to excavation induced soil movement in layered soil. The parametric study should be carried out with Finite element software (PLAXIS2D). The analysis have been performed to assess the effect of diameter of pile, length of pile, distance of pile from excavation, excavation depth to pile length ratio on the adjacent pile in two layers of soil either weak over strong or vice a versa.

#### 1. Model Preparation:

Model for analysis selected by performing number of analysis of different references for different size of model. Model selected for analysis gives maximum deflection value. The model consists of three parts; namely soil, pile and wall. Pile and walls are defined by plate element on model. Main features and dimensions of the finite element model is shown in Figure 1.

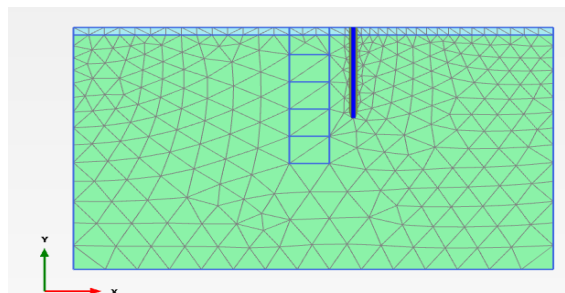


Figure 1: Finite Element Mesh generated to model

#### 2. Input parameters and model variables:

Input parameters considered in the analysis included soil mechanical properties (density, shear strength parameters, and elastic modulus) as well as pile and wall material properties. The soil considered for this study was in two layer as mixed soil modelled as an isotropic elasto-plastic material with a Mohr coulomb failure criterion as provided in Table 1. The pile and wall were modelled as isotropic linearly-elastic materials defined by modulus of elasticity, density, and poisson's ratio shown in table 2.

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Model variables considered in assessing the effect of pile stiffness, excavation depth- to pile length ratio (H/L), and distance of pile from the wall (X) are summarized in Table 3. It should be noted that pile diameter (d) was considered as a representation of pile stiffness.

Table no 1: Input parameters of soil Table no 2: Input parameters of pile and wall

Parameter	Name	Layer 1	Layer 2	Unit
Material mode	Model	Mohr-Coulomb	Mohr-Coulomb	-
Unit weight above pheratic level	$\gamma_{sat}$	17.6	18.2	kN/m <sup>3</sup>
Unit weight below pheratic level	$\gamma_{sat}$	19.39	20.05	kN/m <sup>3</sup>
Young's modulus	E	7.5	10.5	MPa
Cohesion	$C_{ref}$	20	35	kN/m <sup>2</sup>
Friction angle	$\phi$	17	17.5	Degree
Possion ratio	$\mu$	0.1	0.15	-

Component	Density	Elastic modulus	Poisson's ratio
Pile	24 kg/m <sup>3</sup>	25 Mpa	0.15
Wall	25 kg/m <sup>3</sup>	200 Mpa	0.30

Table no 3: Modeling Variables

Variables	Values
Diameter of pile(D)	300mm, 600mm 900 mm
Length of pile(L)	5m, 10m, 15m
Distance of pile from excavation	X=0.2L,0.4L,0.6L,,8L
Excavtion Depth	H=0.3L,0.6L,0.9L,1.2L

### 3. Modelling approach:

The finite element modelling was executed in three stages. The first stage involved the generation of model, second is assigning the soil, wall and pile properties and third is mesh generation and analysis.

## IV. RESULTS AND DISCUSSION

This section summarizes main findings obtained from the finite element analysis. Firstly analysis was performed without support to excavation. Figure no 2 shows deflection of 5m long and 300mm diameter pile with varying distance of pile from excavation's shown in figure deflection decreases with increase in distance from pile (X=0.2L to 0.8L).After certain depth of excavation, pile fails due to soil body collapse as excavation is not supported by wall.

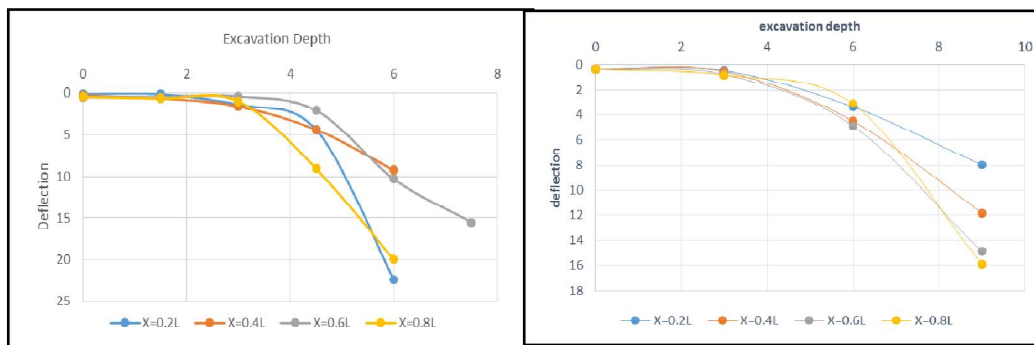


Figure 2: Lateral deflection along pile vs Distance of pile from excavation (for 300 dia, 5m long pile)

Figure 3: Lateral deflection along pile vs Distance of pile from excavation (for 300 dia, 10m long pile)

Figure no. 3 and Figure no. 4 shows that for 10m and 15m long and 300 mm diameter pile, soil body collapse at 9 m excavation depth. Pile shows maximum deflection at 0.8L distance from excavation depth.

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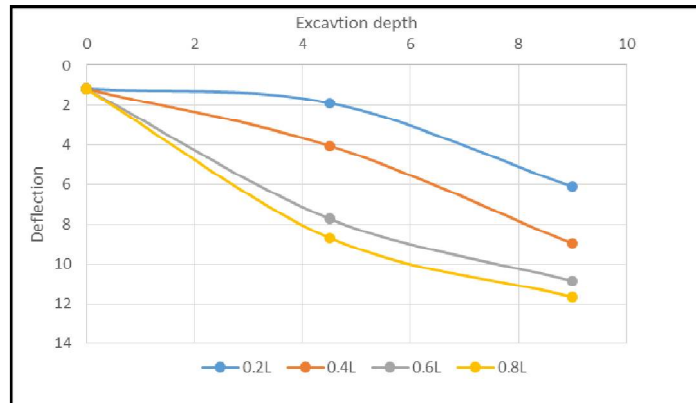


Figure 4: Lateral deflection along pile vs Distance of pile from excavation(for 300 dia, 15m long pile)

Graphs of 300mm diameter pile are illustrated below. Further results for (dia 300mm, 600mm, 900mm) presented with the help of bar chart (fig no. 5, 6, 7,8) for 5m, 10m and 15m length of pile. Results are presented for ratio of pile length to excavation depth  $X=0.2L, 0.4L, 0.6L, 0.8L$ . The soil is considered as two layered soil in which thickness of first layer is considered as  $h_1=0.25L$ .

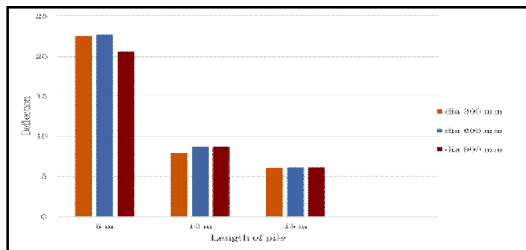


Figure 5: Representation of lateral deflection of pile according to various diameter at  $X=0.2L$ .

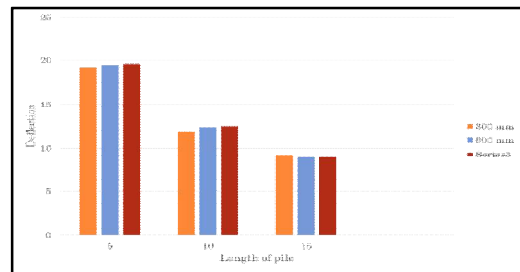


Figure 6: Representation of lateral deflection of pile according to various diameter  $X=0.4L$ .

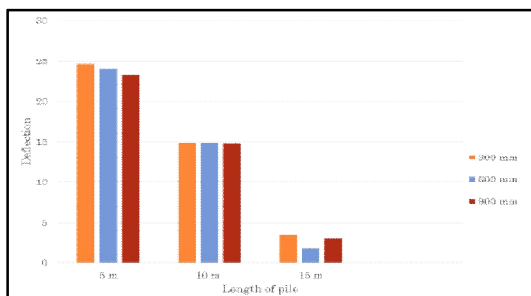


Figure 7: Representation of lateral deflection of pile according to various diameter  $X=0.6L$ .

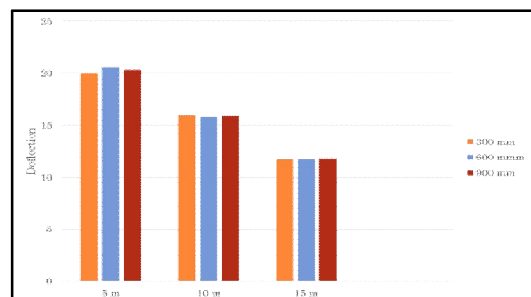


Figure 8: Representation of lateral deflection of pile according to various diameter  $X=0.8L$ .

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Similarly considering the first soil layer thickness  $h_1=0.5L$  following graphs are plotted for 300mm,600mm,900mm diameter.

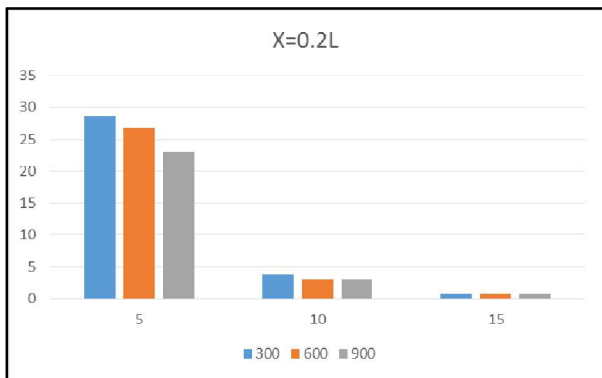


Figure 9: Representation of lateral deflection of pile according to various diameter at  $X=0.2L$

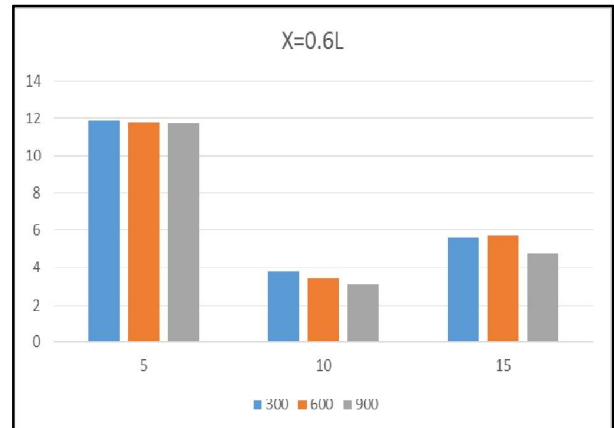


Figure 10: Representation of lateral deflection of pile according to various diameter at  $X=0.6L$

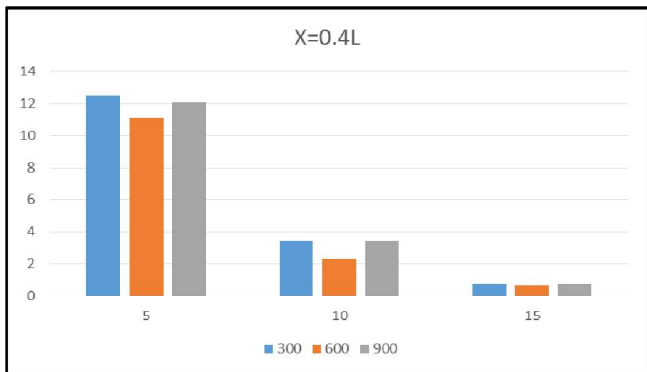


Figure 11: Representation of lateral deflection of pile according to various diameter at  $X=0.4L$

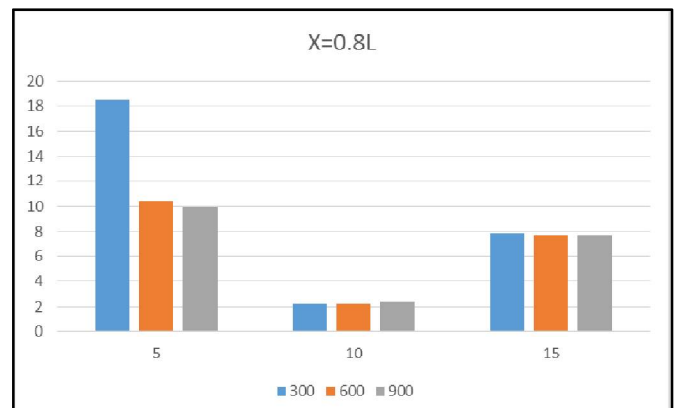


Figure 12: Representation of lateral deflection of according to various diameter  $X=0.8L$

From the results it is concluded that as the thickness of first layer increases soil body collapse occurs earlier than above case. It is observed that for the 900 mm diameter as pile stiffness is greater the deflection of pile is low. Deflection observed for 10m and 15m pile is only due to collapse of soil during excavation. As the distance of pile increases from excavation, deflection of pile decreases.

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### V. CONCLUSION

Based on software analysis following are some of the conclusions obtained.

- i) Distribution of lateral pile deflection along the pile length is maximum upto 20 mm. This deflection was observed due to soil body collapse as the excavation is unsupported. Hence the deflection shown by pile is due to only collapse of soil body, not by load.
- ii) In multilayer soil deflection of pile depends on the properties of each layer of soil. As the thickness of soil increases with respect to pile length, deflection of pile decreases.
- iii) The induced maximum bending moment and deflection on the pile decrease as the distance between the pile and the excavation increases.

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