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PARAMETRIC STUDY ON PILE WALL USED AS RETENTION SYSTEM FOR DEEP EXCAVATIONS

Chavda Jitesh, Desai A.K., Solanki C. H.

ABSTRACT: ***Inadequate space in urban area has set forth a challenging trend to go deeper into the ground, and increase the space required for providing public amenities, parking space and for housing utilities. Closely spaced structures in the vicinity of excavation, soft and compressible landfills, presence of underground utilities, and restriction of lateral ground movements have made the supporting systems a formidable task to execute [3]. Deep excavations are supported by systems like conventional retaining walls, sheet pile walls, braced walls, diaphragm walls and pile walls. In urban areas noise and vibration creating supporting systems are avoided and hence Pile wall can be used effectively. In this work, numerical modelling of Pile Wall using PLAXIS – 3D is conducted in order to carry out parametric studies, effect of stage wise excavation on ground and pile wall deformation.***

Keywords : Deep excavations, Pile wall, FEM analysis

1. INTRODUCTION

Urban settings pose unique challenge to the construction Industry. Special features of urban areas are restricted movements, inadequate space for equipment, soil heterogeneity (including fill and remains of old foundations or other unexpected obstructions); effects of changes in the water table; foundation interaction (the detrimental effects of construction of new structures on the surrounding buildings). Heavy traffic and lack of adequate space has compelled Civil engineers to excavate deeper into the ground to create additional floor space to meet increasing space requirements for amenities, parking and for housing of building utilities. As the number of deep excavations in city is seen to increase exponentially so are the problems associated with their construction. Structures in the immediate vicinity of excavations, dense traffic scenario, presence of underground obstructions and utilities have made excavations a formidable task to execute. Clearly, deep excavations are posing mounting problems that demand a site specific and tailor made retaining solution. Even in complicated urban settings, deep retaining systems have been deployed successfully by overcoming construction challenges.

Chavda Jitesh *
PG Student, Applied Mechanics Department,
S.V. National Institute of Technology - Surat, India

Solanki C. H.
Professor, Applied Mechanics Department,
S.V. National Institute of Technology - Surat, India

Desai A. K.
Professor, Applied Mechanics Department,
S.V. National Institute of Technology - Surat, India

1.1 General – Piled Retaining Systems

There are different types of pile walls like contiguous pile wall, tangent pile wall, secant pile wall and micro-pile wall. Diameter and spacing of the piles is decided based on soil type, ground water level and magnitude of design pressures. Large spacing is avoided as it can result in caving of soil through gaps. In Contiguous bored pile construction, centre to centre spacing of piles is kept slightly greater than the pile diameter. Secant bored piles are formed by keeping this spacing of piles less than the diameter. Tangent piles are used when secant piling or diaphragm-walling equipment is not available.

1.2 Contiguous Piles - Merits and Demerits [3]

Contiguous piles serving as retaining walls are popular since, traditional piling equipments can be resorted for their construction. They are considered more economical than diaphragm wall in small to medium scale excavations due to reduction in cost of site operations. Common pile diameters adopted are 0.6, 0.8 and 1.0m. These piles are connected with a capping beam at the top, which assists equitable pressure distributions in piles. These retaining piles are suitable in areas where water table is deep or where soil permeability is low. However, some acceptable amount of water can be collected at the base and pumped out. Contiguous piles are suitable in crowded urban areas, where traditional retaining methods would otherwise congest the adjoining land, leaving less space for working. Provision of contiguous piles restricts ground movements on the backfill side, and thus protects the neighbouring structures, foundations and boundary walls from the detrimental effects of the excavation. Contiguous piles facilitate deployment of several independent sets of equipment and gangs along its alignment which can speed up its execution. They can be constructed using even the conventional piling equipments and also can be constructed in hard and rocky sub-soil conditions, where diaphragm wall construction is difficult. Such retaining systems has advantage of employing varying diameter of piles in lieu of change in sub-surface conditions, or on encountering competent stratum at a depth which is different than that anticipated during design. Further, unlike the diaphragm wall – which relies on the orthogonal geometry of the excavated area – contiguous pile retaining system can constructed to form any shape in the excavated area.

They are however, not considered suitable for construction in areas of high water table, as retention and containing water is not possible in contiguous piles. Perfect alignment of piles is often difficult to achieve at site, and this in turn is found to affect the dimension and alignment of the Capping beams. In design parlance, only the portion of concrete and steel away from the neutral axis is known to offer resisting moment. As a result, some concrete and steel area remains under-utilized.

2. NUMERICAL MODELING USING PLAXIS - 3D

Finite element analysis is one of the most accurate numerical methods to find an approximate solution for engineering problems. In short, finite element analysis creates partial differential equations to be solved numerically. With the aid of finite element software which can perform high number of iterations, the accuracy of finite element analysis approximately matches the actual condition of Pile wall problems. In this work, numerical modelling using PLAXIS – 3D is conducted in order to carry out parametric studies. Table 1 and Fig. 1 show the parameters and geometries used in PLAXIS modelling. The medium dense sand properties were taken from Fang. H, Kulhawy. F, Foundation Engineering Handbook, 1990.

2.1 Geometrical inputs for Pile wall: The length of wall is taken as 16m, diameter of pile = 750mm, Capping beam of 750 x 375 mm considering same properties of pile, height of excavation is up to 8m with stage-wise excavation of every 2m, 3D model of 30m x 3m x 20m (X,Y & Z) having pile wall at distance of 20m. In order to discard the effect of pore water pressure, modelling is done considering no water table i.e. dry soil.

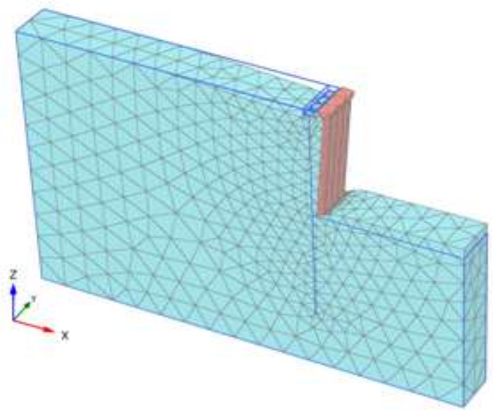

Fig. 1 FE model used in the analysis (deformed mesh after excavation)

Table 1: Parameters used for modelling of Pile wall in PLAXIS-3D

Item	Sand	Pile
Model	Mohr–Coulomb	Linear Elastic
Drainage condition	Drained	Non porous
Soil unit weight – Dry (kN/m^3)	16	25
Friction angle, Ø (^{o})	30	-----
Cohesion, c (kN/m^2)	1	-----
Elastic Modulus	35Mpa	30Gpa
Poisson ratio, υ	0.25	0.15

2.2 Settlement of Ground Surface around Foundation Excavation

The stage wise excavation is done in phases to stimulate actual site condition on field. The depth of excavation in each phase is of 2m with total 4 phase, excavation depth of 8m is done. The settlement of the ground surface around foundation excavation is explained by Fig. 2 shows that the surface settlement appears to take a triangular distribution, and the closer the measuring points to foundation excavation, the larger the settlement value. As the excavation deepens, the settlement increases. According to numerical analysis, for distance range of 0 to 10 m from the foundation excavation is the area of influence, and then away from the excavation, influence on surface settlement is negligible. Furthermore, there appears to be concave increasing zone along line in the range of 15–30 m. Fig. 3 shows the effect of every 2m excavation on lateral deformation of pile wall. As the excavation increases, the deformation of wall increases.

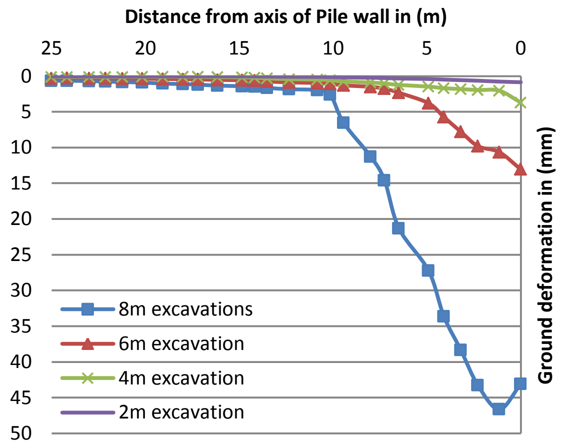

Fig. 2 Effect of stage wise excavation on Ground Deformation

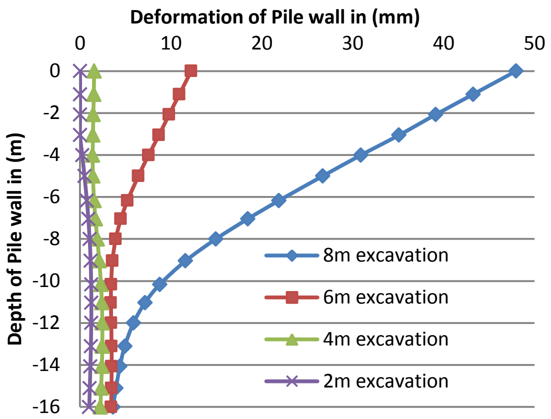

Fig. 3 Effect of stage wise excavation on deformation of Pile wall

3. PARAMETRIC STUDIES – PILE WALL

3.1 Soil friction angle

First parametric study is carried out on varying soil friction angle (Ø), the soil friction angle used in previous section is 30°, Therefore, model of Ø=30° is used as the control model. The values of Ø used in this part are 20°, 25°, 30°, 35° and 40°. Figure 4 shows the deformation of pile wall for different Ø values. From Fig. 4, when the friction angle increases from Ø = 20° to 40°, the deformation of pile wall reduces, the active pressure acting on every depth of the pile wall decreases.

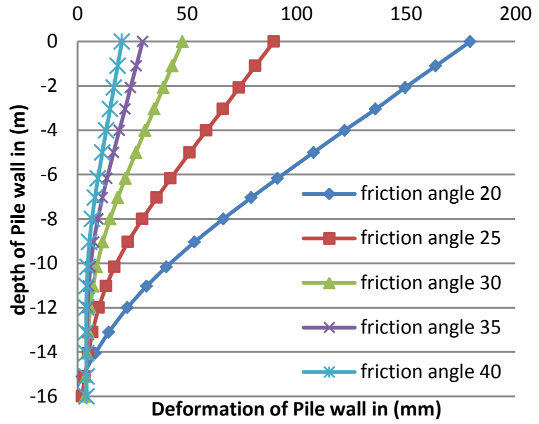

Fig. 4 Effect of friction angle of soil on lateral deformation of Pile wall

This is due to the increasing internal shear strength within the soil with increasing soil friction angle. Hence, active earth pressure developed on the wall is reduced.

3.2 Soil unit weight

Second parametric study is carried out by varying unit weight of soil (γ). Similar to the first parametric study, PLAXIS model in previous section with unit weight of 16 kN/m^3 is used as control model. Deformation of pile wall with varying unit weight is shown in Fig 5. In this parametric study, the unit weights used are 14, 15, 16, 17 and 18 kN/m^3

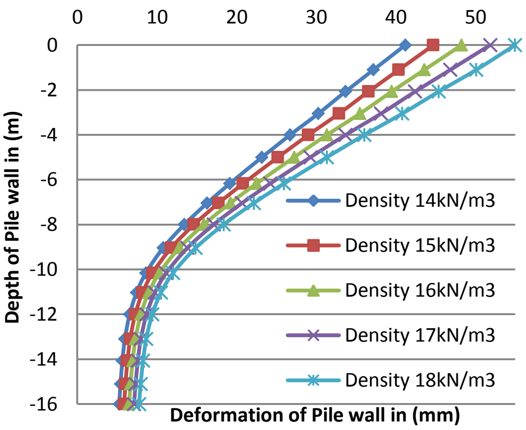

Fig. 5 Effect of soil unit weight on lateral deformation of Pile wall

From Fig.5, deformation of pile wall increases with increase in unit weight of soil. When soil unit weight increases, vertical stress acting on a soil mass increases, and eventually causes lateral active stress to increase. Therefore, this can be explained that when unit weight of soil increases, the active earth pressure acting on retaining wall increases and deformation of pile wall increases.

3.3 Height of Pile wall

Third parametric study is height of wall, *H*. In control model from previous section, the height of wall used is 16 m. In this parametric study, the values of height of wall used are 14, 15, 16, 17 and 18m. Figure 6 shows the results from PLAXIS-3D analysis, shows the normalize Pile wall lateral deflections $\delta h/H_e$ in % along the normalized depth h/H_w, where δh is the lateral deflection along wall and *h* is the depth below the ground surface. The maximum excavation depth H_e is 8 m and the wall length H_w is 16m.

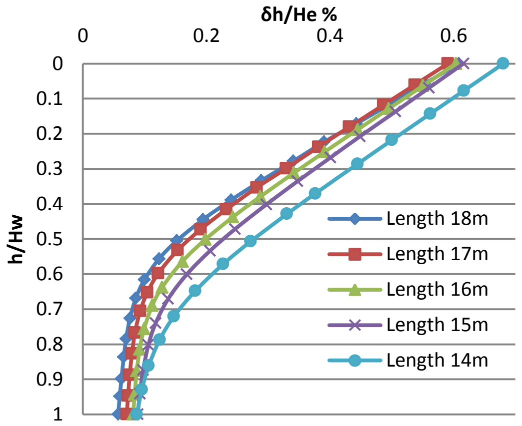

Fig. 6 Effect of length of Pile on lateral deformation of Pile wall

From fig.6, as the height of wall is increased deformation of pile wall reduces up to certain height. At height of 18m increases in deformation is noticed. This is due to increases in slenderness ratio and it cannot take passive resistance from the back bottom portion of pile wall. Hence increase in height of pile wall up to certain limit reduces deformation of the pile wall.

3.4 Diameter of Pile wall

The diameter of pile wall is increased from 750 to 1500 mm, i.e. change in structural stiffness is done in fourth parametric study. In PLAXIS-3D pile wall is modelled with diameter of pile of 750mm, 1000mm, 1200mm and 1500mm. Figure 7 shows the results from PLAXIS-3D analysis.

From Fig. 7, increase in diameter of pile wall reduces the deformation of pile wall. This is due to increases in structural stiffness.

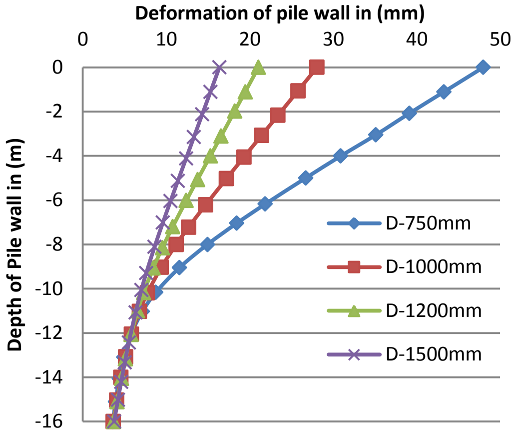

Fig. 7 Effect of Diameter of Pile on deformation of Pile wall

4. CONCLUSIONS

1) With progress in excavations, the ground deformation increases and the settlement value becomes larger and larger as the excavation deepens. According to numerical analysis, a distance range of 0 m to 10 m from the foundation excavation is the main influence area, and then away from the excavation, there is less influence on surface settlement.

2) In parametric studies, when soil friction angle increases, the deformation of Pile wall decreases, this is due to the increasing internal shear strength within the soil with increasing soil friction angle. Hence, active earth pressure developed on the wall is reduced.

3) When the soil unit weight increases the deformation of Pile wall increases. When soil unit weight increases, vertical stress acting on a soil mass increases, and eventually causes lateral active stress to increase.

4) With increase in height of Pile wall from 14m to 17m, there is decrease in deformation of pile wall. At a wall height of 18m there is increase in deformation of pile wall is observed, this is due to increases in slenderness ratio and it cannot take passive resistance from the bottom portion of pile wall when it rotates.

5) With increase in diameter of pile reduces the deformation of pile wall. This is due to increase in structural stiffness.

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About Author:

Author is pursuing Post Graduation in Soil Mechanics and Foundation Engineering, from S.V.National Institute of Technology – Surat, India

His Research area : Deep Excavations, Retention systems, Micropile, Fibre Reinforced soil, Physical Modelling in Geotechnical engineering