Effect of Ground Movement on the Performance of Pile Foundation

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ABSTRACT: This paper presents the results of model tests conducted on piles embedded in loose and medium dense sand behind a retaining wall. It is observed that the maximum pile head deflection is higher for shorter pile (L/D = 10) in loose sand whereas it is higher for longer pile (L/D = 27) in medium dense sand. The induced bending moment in piles is more for longer piles than shorter piles irrespective of the density of sand bed. It is also found that the pile head deflection and the bending moment are found to decrease exponentially with increasing distance between the pile and the wall. In case of pile groups, the test results reveal that the piles arranged in a line perpendicular to retaining wall show lesser deflection than single pile and also for the piles of pile group arranged in a row parallel to retaining wall.

1. INTRODUCTION

Pile foundations are used to transfer the load to deeper soil of high bearing capacity avoiding shallow soil of lower bearing capacities. They subjected to both lateral and vertical loads. In most of the situations lateral load govern the pile design and the condition is critical when piles are subjected to ground movement (lateral spread). The lateral movement of soil may be attributed to ground instability and change in stress state. In many cases the piles are not designed to sustain lateral soil movements. Moreover soil movement brings in more complexity in the pile analysis and design is becoming difficult. Though the geotechnical engineers know about the problems to the foundation due to ground movement, their attention is not drawn to these problems until recently except the situations like construction of berthing structures and foundation on or in sloping ground. Of late in urban areas like Chennai where construction of high rise buildings with multiple basements are quite common, and foundations of neighbouring structures are subjected to ground movement because of deep excavations. In order to understand the response of foundations due to ground movement numerous researchers have worked on the problem of pile subjected to lateral movement of ground. Experimental studies through 1g models and centrifuge model tests on piles behind supported excavations were conducted by Poulos & Chen (1997), Chen et al. (1997), Leung et al. (2000 and 2003). Tests were conducted on simulated field conditions and the influence of depth of excavation and distance between the pile (or pile of pile group) and face of excavation were brought out. But influence of pile length, relative stiffness and density of soil on response of pile is not adequately dealt in the literature. In the theoretical studies of Poulos & Chen (1997) some of these efforts have been addressed through boundary element method (PALLAS) and design charts were proposed for various relative stiffness of pile-soil system. However, research contribution in this field is very limited since difficulty involved in simulating the field condition for conducting tests and complexity involved in numerical modeling.

In the present study, tests were carried out on model piles to examine the influence of ground movement on the behaviour of piles and to bring out the influence of parameters such as distance between the pile and the excavation face, depth of cut versus length of pile, relative stiffness of pile etc. on the displacement and moment on pile. The performance of pile groups (two piles) were also studied by varying the spacing between the piles. The test results thus obtained are interpreted and presented in detail in this paper.

2. EXPERIMENTAL SETUP AND PROCEDURE

Model tests were conducted on steel tank of size 650 mm × 400 mm × 600 mm which was stiffened at different levels to avoid volume change during preparation of sand bed. The tank was fabricated using steel plates of 6 mm thickness and one long side of the tank (650 mm × 600 mm) was made transparent by fixing perspex sheet of 10 mm thick. Figure 1 shows the schematic setup of the model. Hollow aluminium tubes of various diameter were selected as model piles. The
length and diameter of piles are varied to perform tests at different L/D ratios. Aluminum sheets of 0.5 mm thickness were used as retaining wall. The piles of diameters (D) 25.4 mm, 19.05 mm and 15 mm and lengths 254 mm, 381 mm and 405 mm are used as model piles.

Air dried sand was compacted in layers in the tank by adopting sand raining or combination of raining and tamping technique depending on the density required. The sand bed up to the base of the pile was prepared and model pile was placed in position. Preparation of sand bed was continued up to the base level of retaining wall and the retaining wall was installed in position. Further preparation of sand bed was continued up to the top level of the model pile in layers of 100 mm thick for medium dense sand beds; for loose sand beds sand raining technique was adopted. Sufficient thickness of sand bed below the pile was always provided in all the experiments. The deformation dial gauges were set in position much before the commencement of excavation. The output cables of the strain gauges were connected to the strain indicator. The strain indicator reading was made to zero before starting the excavation. The strain gauges were calibrated to obtain the relationship between bending moment and strain. Ground movement was induced by excavating the soil in the front face of retaining wall. The removal of wooden planks in stages induced soil movement. The displacement of the pile and the retaining wall at the top (at the surface level of the sand bed) and their strains for each excavation depth were recorded at predetermined time intervals (i.e. at the interval of ten minutes).

3. RESPONSE OF PILE

The first series of tests were conducted on piles of three L/D ratios such as 10, 20 and 27. The tests were carried out in both loose and medium dense sand beds for piles placed at distances of 2d, 3d and 4d from the face of retaining wall. The retaining wall was located at 20 cm from the excavation face. The Figure 2 shows the variation of retaining wall deflection with the excavation depth in loose sand and medium dense sand bed. It can be observed that the deflection of wall increases as the excavation depth increases. The responses also shows that the deflection is more in loose sand compared to medium dense sand bed.

![Fig. 2: Variation of Retaining Wall Deflection with The Excavation Depth in Loose Sand and Medium Dense Sand](image)

3.1 Pile Head Deflection

Figure 3 shows the variation of pile head deflection with excavation depth for pile of three L/D ratios embedded in loose sand at a distance of 2d from the retaining wall. It can be observed that the rate of increase in deflection is high for pile of L/D = 10 when compared to 20 and 27 in case of piles embedded in loose sand. This indicates that short pile deflects more when compared to long pile. And the pile deflection decreases exponentially as the distance from the retaining wall increases. It is also observed that the pile deflection increases gradually upto the depth of excavation of 140 mm (h/H = 0.35) and rate of increase of pile deflection is reduced thereafter.

![Fig. 3: Variation of Pile Head Deflection with Excavation Depth for Pile in Loose Sand](image)
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Figure 4 shows the variation of pile head deflection with excavation depth for pile of three L/D ratios embedded in medium sand at a distance of 2d from the retaining wall. The results show that the higher L/D exhibits higher deflection in case of pile embedded in dense sand whereas in case of piles in loose sand the lower L/D ratio exhibits higher deflection. This may be attributed to higher resistance of medium sand against excavation induced soil movement and resistance offered by the larger diameter pile.

3.1.1 Variation of Maximum Pile Deflection with Distance of Pile from Retaining Wall

Figures 5 and 6 show the variation of maximum pile deflection with distance of pile from retaining wall for piles tested with L/D ratios 10, 20 and 27 in loose and medium dense sands respectively. It can be observed that on increase in the distance from the retaining wall, the magnitude of maximum deflection of pile head reduced almost linearly irrespective of the density and distance from the wall and the pile tested.

3.2 Bending Moment

Figure 7 shows the variation of bending moment along the pile length with excavation depth for a pile of L/D = 10 embedded in loose sand. The pile is located at 2d from retaining wall. The bending moment in the pile increased with excavation depth and the location of maximum bending moment was observed at a length of 190 mm from the pile head for pile embedded in both loose and medium dense sand. The piles placed at 3d and 4d from the face of retaining wall also showed similar behaviour as that of piles placed at a distance of 2d from the retaining wall. The response observed in the test conducted in medium dense sand is similar to that of test conducted in loose sand with identical test conditions. The basic difference is only in the magnitude of bending moment of pile for the given depth of excavation.

Figure 8 shows the variation of maximum pile bending moment with the L/D ratios of piles embedded in loose and medium dense sands. It is observed that the piles of higher L/D ratio exhibits higher bending moment than the piles of lower L/D ratios irrespective of the density of sand. It can be noted that the pile which are at a distance of 2d from the retaining wall shows higher bending moment than the piles at the distance of 3d and 4d as expected.
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4. CONCLUSIONS

The maximum pile head deflection is higher for shorter pile (L/D = 10) in loose sand whereas it is higher for longer pile (L/D = 27) in medium dense sand. The percentage decrease in maximum deflection is 6.6% and 12.1% for L/D of 20 and 27 respectively while comparing with the deflection of pile of L/D = 10 in loose sand. Similarly the reduction in maximum deflection is 7.5% and 12.5% for L/D of 20 and 10 respectively in medium sand while comparing with the pile of L/D = 27. The induced bending moment in piles is more for longer piles than shorter piles irrespective of the density of sand bed. The pile head deflection and the bending moment are found to decrease exponentially with increasing distance between the pile and the wall.

The response of a pile within a pile group due to excavation induced soil depends on its distance from the retaining wall and its orientation. The pile group arranged in a row parallel to retaining wall exhibit lesser deflection than the single pile. The pile deflection ratio is almost same for both loose and medium dense conditions for spacing less than 3.5d. In case of piles arranged in a line perpendicular to retaining wall, the pile group exhibits lesser deflection than single pile and the piles of pile group arranged in a row parallel to retaining wall.

REFERENCES


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