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An Experimental Investigation into the Excavation Using Pile-anchorage System

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1-Introduction

Deep excavation, as one of the most common problems in construction industry, has a huge effect on the alternation of the stress distribution of soil layers and ground displacement. Excavations can lead to the deviation of lateral walls and damages to the adjacent buildings. Up to now, a few researchers have focused on the effect of excavations in sand. Physical modeling is one of the valid methods, which may be employed to model geotechnical problems and also to verify the results of numerical analyses.

In the present research, efforts were made to model the excavation behavior using a combined pile and anchorage system (with pre-stressed anchorage), in the laboratory to investigate the influence of deep excavation on the vicinity of adjacent properties.

2-Test Program

To study the behavior of excavation in a sandy physical model, a metal box with dimensions of 2×1×1 m was made as the space of excavation. The walls of this box were covered with transparent talc to facilitate the observation of the changes process. For the modeling of piles in the retaining structure system, a number of pipes made of polypropylene were utilized. The dimensions and rigidity of the piles were scaled relative to the real model. This led to the selection of polypropylene pipes for the physical model. Fig. (1) shows the scaled test box model and the building adjacent to the excavation. Moreover, in this Figure, a schematic design of the test box and equipment used in the experiments is shown. It should be noted that for modeling the process of excavation, ten gates of 10 cm high were installed in front of the test box. By removing any of these gates, one stage of excavation is modelled.

To assess the behavior of retaining structures in the laboratory model, three main parameters including the distance between the center of piles (S/D), the surcharge in the vicinity of the excavation and the end fixity in the model piles were studied. It is worth noting that the retaining structure system was modeled from the bored pile retaining wall with anchorage. In the present study, eight tests with a unique code were conducted. The code stars with the letter T. The second letter of each code is S or N (with or without surcharge in the vicinity of the excavation). The third letter, F (free) or X (fixed), shows the end fixity of model piles. The three-digit number at the end of each code represents the center-to-center distance of piles (mm).

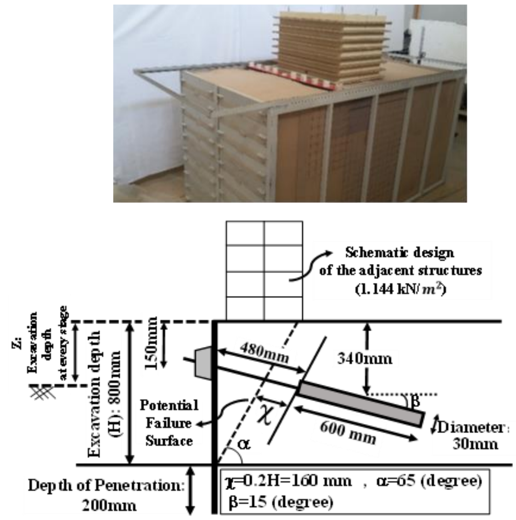

Fig. 1 (a) real view, (b) a view of anchors used in the model (c) cross-section of the physical model

3- Anchor pre-stressing test

To determine the pre-stressing force for a ground anchor, a tensile test was conducted. The test involved stretching prestressed reinforcing elements and measuring the load and its corresponding displacement. It was carried out under laboratory conditions by means of a cable and pulley system. Accordingly, changes of axial force (F) in an anchor proportional to the applied displacement (Δ) are depicted in Fig. (2). As shown, the ultimate resistance of anchor is about 0.88 kN. Finally, with regard to operational conditions in real projects, a prestressing anchor force (lock-off load or applied load) equaling 45% of the ultimate resistance of anchor was applied.

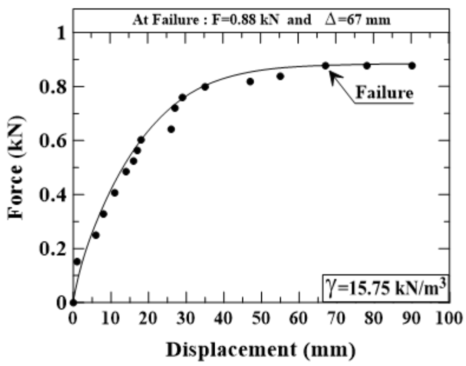

Fig. 2 Force-Displacement variations for tensile test of strut

4- Relation between δ_{vm} and δ_{hm}

Table (1) represents the ratio of maximum ground surface settlement to the maximum lateral displacement of wall (δ_{vm}/δ_{hm}). These values are based on the test results reported in this study. As shown in Table 1, δ_{vm}/δ_{hm} ratio was in the range of 0.78 to 2.35. These results are

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consistent with the reports provided by other different case studies.

Table (1) Relation between δ_{vm} and δ_{hm}

Code of test	δ_{hm}(mm)	δ_{vm}(mm)	δ_{vm}/δ_{hm}
TNX150	1.84	1.7	0.92
TNF150	1.16	0.9	0.78
TSX150	2.4	3.5	1.46
TSF150	1.34	2.3	1.72
TNX100	3.1	5.5	1.77
TNF100	1.7	4	2.35
TSX100	4.1	6.1	1.49
TSF100	2.2	4	1.82

Figure (3) illustrates the relationship between the maximum ground surface settlement and maximum lateral displacement of the wall. The upper and lower bound values of maximum ground surface settlement (δ_{vm}) were in the range of 1.28 to 1.87 δ_{hm} (with the mean value of 1.58 δ_{hm}).

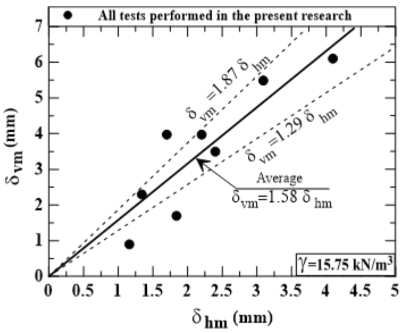

Fig. 3 Maximum ground surface settlement vs. maximum lateral displacement

5 Ground surface settlement patterns

Figure (4) shows the relationship between ground surface settlement normalized by the excavation depth (δ_v/H) and the distance from the excavation normalized by the excavation depth (d/H) for tests No.1 to 8.

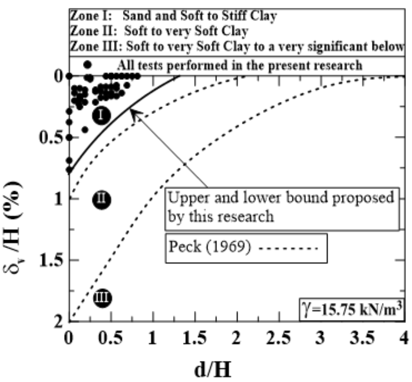

Fig. 4 Distribution of ground settlement normalized by excavation depth

Generally, the distribution of ground surface settlement was extended to a distance of about 1.2*H* from the excavation edge caused due to the excavation (Figure 4). This bound could be used to estimate the maximum deformation pattern of the ground level in the vicinity of excavation for the purpose of laboratory studies.

Figure (5) shows the normalized ground settlement (δ_v/δ_{vm}) and normalized distance from the wall (d/H). As can be seen, for experiments No.4 to 8, the maximum ground surface settlement is achieved near the walls (d/H = 0). In other words, in this case, it is δ_v/δ_{vm}. However, in experiments No.1 to 3, the ground surface settlement near the wall was in the range of zero to -0.86 δ_{vm}. The distribution of ground surface settlement obtained in experiments shown in Figure 5 where the ABC boundary line is proposed for this distribution. Two settlement zones in the trapezoid envelope can be distinguished. At $0 \leq d/H \leq 0.5$, there is a zone in which the maximum ground surface settlement occurs. While at $0.5 \leq d/H \leq 1$, there is a transition zone in which the ground surface settlements decrease from maximum values to negligible ones.

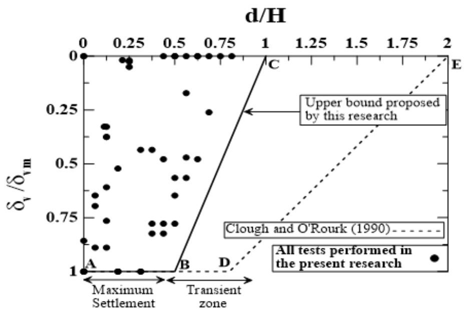

Fig. 5 The relationship between ground settlement normalized by maximum settlement and normalized distance from wall

6- Conclusion

1. The maximum lateral displacement of the wall increases as the excavation progresses. When the distance between the centers of piles is 150 mm, the value of δ_{vm}/H ratio is in the range of 0.145% to 0.3%; and when the distance is 100 mm, it is in the range of 0.21% to 0.51%.
2. The maximum ground surface settlement increases with the progress of the excavation. When the distance between the centers of piles is 150 mm, the value of δ_{vm}/H is in the range of 0.11% to 0.44%; and when the distance is reduced to 100 mm, it is in the range of 0.50% to 0.76%.
3. By increasing the distance between the piles of wall, ground movements and wall deflection declined to 45-71% and 72-355%, respectively.
4. According to the results, in the case of fixed earth support, the lateral displacement of the wall and ground surface settlement will be 59% ~ 80% and 38% ~ 91% higher than the free earth support mode, respectively.
5. According to the results, the ratio of δ_{vm}/δ_{hm} was in the range of 0.78 to 2.35.
6. In this study, the distribution curves of the ground surface settlement were plotted based on the test results. Overall, the ground surface settlement distribution was extended to a distance of about 1.2H from the excavation. In this curve, two AB and ABC boundaries for the purpose of estimating the maximum deformation pattern of the ground in the vicinity of excavation were suggested for laboratory studies, especially large-scale physical models.