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Experimental study of time-dependent deformation of the wall deformation Nailing during excavation operations

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Abstract

Today, with the cities expansion and population growth, the need for high-rise buildings and deep excavations for their implementation is increasingly felt. Under constant loading conditions, soil undergoes deformations over time which is called time-dependent deformations. This is of particular importance in terms of safety in the long run. In this study, based on the physical modelling technique, the long term behaviour of stabilized deep excavation in silty sand, using the nailing method, has been investigated. The test results indicated that with increasing the depth of excavation the lateral displacements, the surface settlements behind the excavation wall and also the time-dependent deflections increase as well. In addition, if the excavation operation is brought to a temporary halt or is led to the abandonment, it results in a significant increase in the time-dependent deflections. Finally, the recorded data revealed that the rate of the experienced deformations over time decreases which is due to the gradual mobilization of forces in the nails.

Keywords: *Experimental study, Ground settlement, Nailing, Time-dependent deflections, Wall deflection*

Extended Abstract:

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1. Introduction

One of the most common problems that tall buildings faces in the world is the need for deep excavation in urban areas. Deep excavation has a significant influence on the stress distribution of soil layers and ground displacement. It could lead to the deviation of lateral walls and landslide and dramatic damages to the adjacent buildings. Deep excavation, especially in the adjacent of a building, is among the major challenges in civil engineering. Inaccuracies in the design, calculation and execution of excavations and retaining structures in urban areas or in the vicinity of buildings can inflict considerable damage on people's life and properties. It is therefore of vital importance to estimate the damage of excavation on the adjacent structures. The extent and shape of the wall displacement, caused by deep excavation, is dependent on various factors. During last decades many researches have focused on the behaviour of soil affected by deep excavations. Moreover, several published studies have examined ground movements induced by excavations in clay, but very few have explored the effect of excavations in the sandy soil. Physical modeling is one of the common methods used for the assessment and verification of calculations. It refers to the construction of a scaled model of geotechnical structure and carrying out the loading required to simulate real conditions. Physical modelling can also be used to verify the results of numerical analyses. With development of a physical modelling, the present research aims to evaluate the evaluation the side deformation of deep excavation stabilized based on the nailing method.

2. Materials and methods

The developed physical model included a 2-meter-long, 1-meter-wide, and 1-meter-high metal box as the excavation environment. The box also had enough space to minimize the side effects and to apply the surcharge in the vicinity of the excavation. Physical modelling in geotechnics includes the development of a model of the structure and applying the necessary loading to simulate the phenomenon. In order to model the surcharge in the vicinity of the excavation site and given the dimensional similarity and dead and live loads, the weight of the roof was considered to be 0.143 kN/m^2. The desired building in the physical model included eight roofs, each with a dimension of 0.70 by 0.50 square meter with the surcharge equivalent with 1.144 kN/m^2. The walls of this box were covered with transparent sheet to observe the deformation trend. It should be noted that in order to model the excavation steps, 10 openings with a height of 10 cm were embedded in the front of the test box. The nail space was selected in accordance with the procedures taken in the previous studies based on the case and field studies. Moreover, in addition to the above cases, the criteria and recommendations presented in FHWA as well as the safety factor of approximately 1.5 and allowable deformation were employed. Finally, an optimal nail spacing with respect to the dimensional similarity was used in the physical model.

3. Tests results

Since the excavation process was conducted with a 2-hour time interval in the performed tests, the lateral side wall deformation could be due to the excavation and the soil time-dependent deformations. When the excavation process is proceeding, the side wall deformation increases steadily. The wall displacement was initially in a cantilever form, but with the progress in excavation process, it changed into the stable cantilever form. The maximum values of the instantaneous lateral displacement of the side wall were 0.79 to 3.37 mm (0.10 to 0.42% of the total depth of excavation).

As the excavation and the lateral deformation of the wall began, the soil behind the wall moved forward and downward, resulting in the ground subsided. With the progress in the excavation stages, the maximum values of the vertical displacement (maximum settlement) increased. The maximum instantaneous settlement and the ratio of the maximum instantaneous settlement to the excavation depth were in the intervals 0.5 to 1.18 mm and 0.06 to 0.15%, respectively. The maximum values of settlement were in the range 0.24 δ_{hm} to 0.64 δ_{hm} with an average value of 0.44 δ_{hm}. Furthermore, the ratios of maximum settlement due to time-dependent deformations to the excavation depth (δ_{vmcb}/H) in the first, second, third, and finally fourth stages of excavation were in the range of 0 to 0.013%, 0.008 to 0.038%, 0.020 to 0.070%, and 0.038 to 0.112%, respectively.

The settlement distribution was extended from the edge of the excavation to a distance of about 1.4 times the height of the excavation from the excavation edge, with the maximum dimensionless settlement value being equal to 0.25.

4. Conclusion

1) The time-dependent deformation phenomenon may be due to the particle rearrangement or particle breakage and crushing. In the tests, the stress level was not so high to cause the particles to break; therefore, the time-dependent deformations and the resulting displacements seem to be due to particle rearrangement. In accordance with the investigations, the time-dependent deformation led to a maximum 31% increase in the lateral displacements and a 100% increase in the instantaneous settlement during the excavation operations. Therefore, any delay in the excavation process increases the lateral defomation and settlement and may damage to the adjacent buildings and equipment.
2) Increasing the excavation depth increases the lateral displacements and the settlement caused by the time-dependent deformations. This can be attributed to the increased lateral pressure of the soil and, hence, the increase in the tangential forces among the particles and their slippage.
3) The time-dependent deformation phenomenon caused a significant increase in the lateral displacements as well as during the 2-hour excavation operation. Additional deformations were significant and should be considered in executive projects.
4) The measurements revealed that the deformations occurring over time continued at a decreasing rate due to the increase compaction of soil. When deformations occur as the time-dependent deformations, the particles undergo a little rearrangement, reducing the tangential components and increasing the vertical components of the tangential forces. As a result, the inter-particle slip rate decreases, leading to the decrease in the overall rate of the time-dependent deformations.
5) The findings suggested that the presence of surcharge in the vicinity of the excavation increases the displacement level. This seems to be due to the increase in the lateral pressure of the soil, the stress reliefe, and the increase in the tangential force and slip of the soil particles. With an increase in the nail spacing, the brace stiffness in the unit width decreased. This in turns, increases the values of the instantaneous displacement as well as the time-dependent deformations. With an increase in the soil compaction, the magnitudes of the instantaneous displacements and the time-dependent deformations decrease.

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