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Research Paper

Numerical Modeling of Ground Improvement Methods Tehran Metro Line 6 Excavation

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Abstract: One of the most critical issues in weak grounds is soil improvement, which is considered reused in a new geotechnical structure or improves the current structure condition. In the present research, implementing a limited, finite element numerical method to predict the rate of ground settlement level before and after the implementation of ground improvement in the eastern access tunnel drilling process of Khorasan Square Station located in Tehran Metro Line 6. Since the tunnel route passes under residential buildings and shops, with the excavation of this part of the Khorasan Square Station project, large amounts of settlement exist on the ground surface, which cracked buildings and shop structures. Based on this, piling, fore poling, and anchoring improvement methods can be used for loose and fallen grounds that were modeled numerically by MIDAS GTS NZ software. In this research, in addition to investigating the performance of the mentioned methods, the effect of geometric parameters, including the covering of fore poling pipes, pile length, and the diameter of anchors, was investigated. The criteria for investigating, the Displacement occurred at ground level, and tunnel crown is considered. Results showed that all methods have been useful in reducing ground settlement and tunnel crown. Also, Among the above-mentioned improvement methods, the method of using the fore poling method with anchorage has reduced the plastic points surrounding the tunnel and also has a greater effect in reducing the settlement of the ground, so that it has reduced the maximum settlement of the ground surface by 50%.

Keywords: Fore poling pre-consolidation method, Numerical modeling, Anchoring improvement method, Piling method, Finite element method.

INTRODUCTION

Tunneling in urban environments has always had its difficulties and risks. The most important part of the design of such tunnels, especially in shallow conditions, is to study the issues associated with settlement; because most of these tunnels pass through residential and commercial infrastructure. Numerous studies

have been performed on settlement caused by tunneling as well as various methods to control and reduce the amount of deformation and damage to surface structures.

Loganathan et al. (2001) in their paper used an analytical method to estimate the displacements around the surface of the earth in the case of single and group piles. As the distance of the piles from the center of the tunnel increased, they examined the settlement amounts of the ground surface and the pile cap [1]. Kavitha et al. (2006) studied the prediction of the exact structural behavior of the interaction between pile-soil under loading. In a study, Lee and Yoo (2006) studied numerically the impact of deep excavation on soil settlement[2]. For this purpose, they used anchorage and nailing methods to stabilize the wall and improve the surrounding ground[3]. In other research, Aksoy and Onargan in 2010 analyzed the effect of the support method on the Izmir metro tunnel in Turkey. In this study, the role of tunnel pre-support and reinforcement methods consisting of fore poling were investigated by 3D analysis to prevent deformation and damage to the tunnel [4].

METHODS

In the present study, the eastern access tunnel of Khorasan Square station located in line 6 of Tehran metro has been modeled to investigate the stability of the tunnel and the settlement resulting from tunnel excavation. After that, the methods of improving the piling, fore poling pre-consolidation method, and anchoring improvement method to achieve the allowable settlement at the ground level and better stability of the tunnel have been studied. MIDAS GTS NX software based on the finite element method, which is a specialized software in the field of geotechnics and tunneling, has been used for modeling.

Khorasan Square Station, the case study, is one of the special stations in the crowded area of the city Tehran, which is of special importance in terms of passenger traffic. Underground excavation of this station has faced problems due to the relatively high groundwater level and has been carried out by special methods.

In numerical modeling for the verification of the model, the results of ground settlement in the model are compared with the data of surface settlement instrumentation. After that, the modeling methods of piling improvement, fore poling and anchorage methods were performed and evaluated.

Figure 1 shows the vertical displacement contour of the model after excavation and initial support. As seen, most settlement is obtained in the crown of the tunnel.

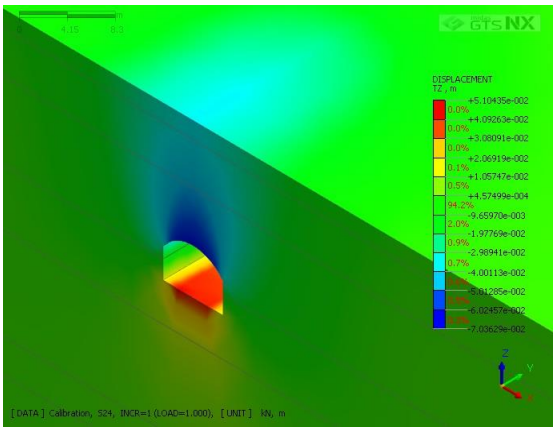

Figure 1. Vertical displacement contour of the model after excavation

FINDINGS AND ARGUMENT

To model the piling method from the ground, piles with a constant diameter of 1 meter and variable lengths have been studied. The performed piles with lengths of 10 and 15 meters increase the settlement of the ground compared to the state without piles. The reason for this is that these piles would be in the first and second layers. These layers have low cohesion parameters and modulus of elasticity, which reduces the shear strength and friction between the layer and the pile.

In modeling of fore poling ,modeling has been done first according to the design of the consulting

engineers .At each stage of the fore poling 27 ,pipes are placed at the top of the tunnel .In this study ,in addition to modeling the fore poling method ,the effect of overlap length on ground settlement has also been investigated .Figure 2 shows the modeling geometry of the fore poling method.

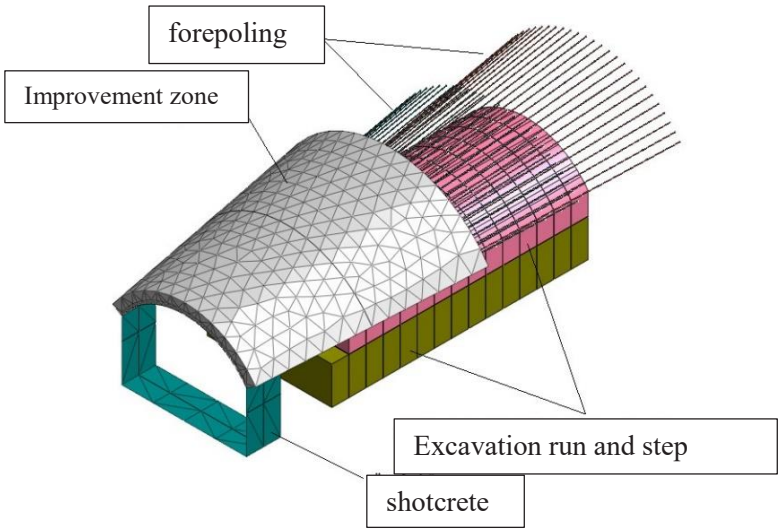

Figure 2. Modeling geometry of the fore poling method

The use of the fore poling has had a significant effect on reducing settlement; In a way that has reduced by 50% the maximum settlement at ground level (less than the allowable settlement). As expected, increasing the overlap length also reduces ground settlement; However, the downward trend is very small.

The study of fore poling method along with anchorage has also been examined numerically. To investigate the effect of anchorage diameter, modeling of anchorages with diameters of 25 and 38 mm has been performed. In addition, the effect of different improvement methods on the plastic area around the tunnel has been compared. With the onset of inelastic deformations and the expansion of the area with plastic behavior around the tunnel, the amount of pressure on the tunnel roof and wall increases due to the weight of the surrounding plastic area, which can play an important role in tunnel stability analysis. The weight of the plastic area leads to stress distribution and ultimately displacement around the tunnel. Deformation due to the plastic area increases the crown settlement and in layers that do not have high strength, it can even lead to the collapse of the crown and the tunnel wall.

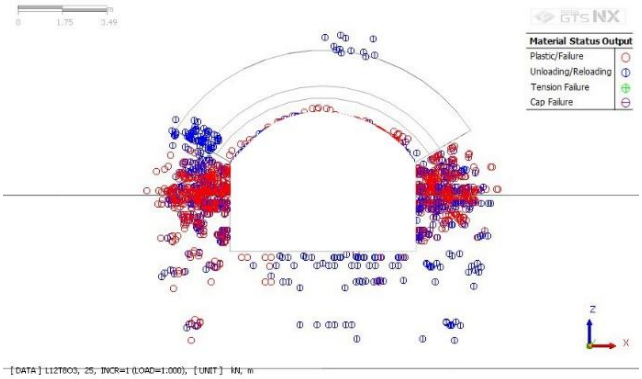

Figure 3. Plastic zone around the tunnel (fore poling with anchorage)

CONCLUSIONS

Since the selection of the Mohr-Columb constitutive model for soil layers provides an unrealistic output, the use of the modified Mohr-Columb model provided more realistic results than the actual conditions. In the piling method, changing the length of the pile changed the settlement of the ground and the crown of the tunnel. When the length of the piles is less than 18 meters, the amount of settlement of the ground and the crown of the tunnel increases. The use of the fore poling method has a significant effect on reducing ground settlement; In a way that has reduced the maximum settlement at ground level by about 50%. Increasing the overlap length also reduces ground settlement. When anchorages are used in the tunnel wall in addition to the fore poling method, the settlement of the ground surface and the crown of the tunnel is further reduced, as well as the plastic points around the tunnel. Also, the use of anchors in the wall is effective in reducing the elevation of the tunnel floor.

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