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Research article

Three-Dimensional Numerical Modelling of Pre-Support System in front of Tunnel by Different Approaches, Case Study

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Keywords

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Equivalent Zone
Tunnel
Ecvantion-induced Deformation

English Extended Abstract

Summary

This paper investigates the effect of the method of applying pre-support in the numerical modeling of tunnel and ground interaction. Two main numerical approaches of linear pile and equivalent zone elements were considered for the modeling of pre-support in front of the advancing tunnel face. Both of these approaches were applied for one of the Tehran-Shomal Freeway as the case study of numerical modeling. The results of numerical models were compared to investigate the effect of pre-support modeling approaches. The vertical deformation of numerical models with different approaches shows a meaningful consistency; therefore, it is concluded that both of these methods of linear pile element and equivalent zone element can be applied to numerical modeling demands for other studies.

Introduction

This study focuses on the numerical modeling of the umbrella arc in front of the tunnel crown as one of the pre-support or head ground reinforcement techniques of tunneling in weak grounds. The pre-support method consists of installing a set of sub-horizontal pipes above the tunnel crown face from the inside of the tunnel before the excavation advancement. This method is practically and widely applied for ground improvement ahead of tunnel face to manage and control the induced deformation (i.e. settlement), instability risks, and operation safety. Wide practical implementation of the umbrella arc demonstrates the requirement of a standard design method, which cannot be found in scientific literature. In this regard, several previous studies utilized the numerical modeling of ground-umbrella arc interaction. The method of modeling the umbrella arc through numerical models can be classified into two different methods of a linear structural element (i.e. pile, cable, and beam) [1-3], and an equivalent ground element around the tunnel boundary [4-6]. Each of these methods has different advantages and disadvantages respecting simplicity in numerical modelling, efficiency of numerical calculation, and applicability in 2D numerical models. However, the comparison of these methods concerning the accuracy of calculation results has been not studied yet. This issue is the main subject of the present study.

Methodology and Approaches

Three-dimensional finite difference numerical models by FLAC3D software were utilized to investigate the effect of pre-support element type on induced displacement by tunnel face advance. The numerical model was generated based on the topography of the study area and the as-built construction procedure of a real case study in the Tehran-Shomal freeway, Lot 1. The numerical modeling of tunneling advance was performed for different cases of pre-support element types including 1) no pre-support, 2) linear pile element for pre-support, and 3) equivalent zone around tunnel crown for pre-support. These models are shown in Fig. 1. In addition to these models, an

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intermediate model of the second type with little changes in the application of pre-support in the limited length of the tunnel (as experienced in the real work advances of construction) was utilized for verification of the numerical model.

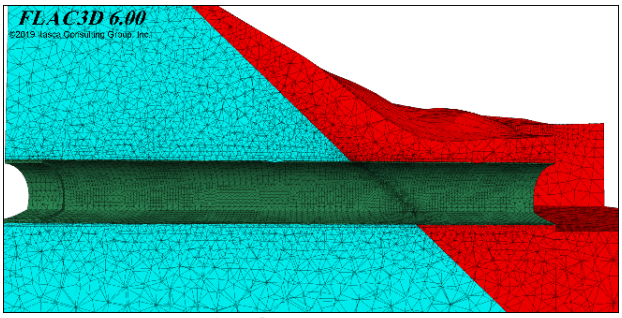
Results and Conclusions

Results and Conclusions should include (1) the principles and generalizations inferred from the results, (2) any exceptions to, or problems with these principles and generalizations, (3) theoretical and/or practical implications of the work, and (5) conclusions drawn and recommendations.

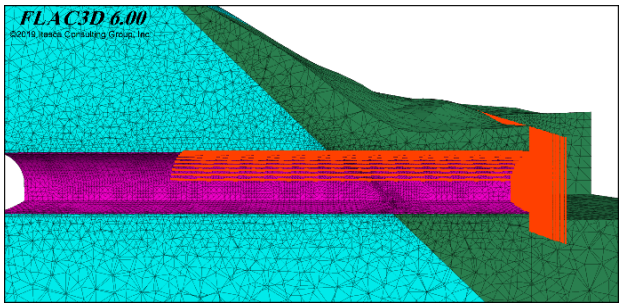
Figures, Tables and Images

The results of this study show that applying the pre-support on the numerical model meaningfully improves the state of tunnel-induced deformation around the face. In the case of no pre-support applied in the numerical model, the vertical displacement of the tunnel crown reaches more than 65 cm. In this case, the vertical displacement gradually decreases from the tunnel crown to the ground surfaces, which causes a notable and unacceptable induced ground settlement (more than 50 cm). In this case, the pre-support shall be reasonably applied to control the ground surface settlement and stability of the tunnel crown at the face. In addition, the results of numerical without local pre-support (in short distances of tunnel length) indicate a sudden increase of tunnel induced deformation in front of the tunnel face and the support installed near the face. These prediction results of the numerical model consist of the instability locations and other evidence of instability near the tunnel face in the area without pre-support application during the tunnel construction. Therefore, the proposed numerical model can be utilized for parameter study demands.

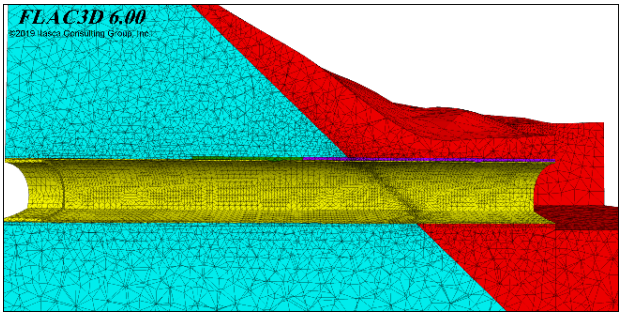
The results of numerical models with different approaches for pre-support applied in the calculations in the format of vertical displacement induced by tunnel are very similar (both values and spatial variation). The predicted vertical displacements of numerical models with different approaches show a meaningful consistency, where the average relative error is obtained at about 2.7% and 5.1% for right and left tunnels, respectively. Due to the negligible relative error between different approaches of linear pile element and equivalent zone element, it is concluded that both of these methods can be applied for numerical modeling demands for other studies.



a) without pre-support



b) linear pile element for pre-support



c) equivalent zone around tunnel crown for pre-support

Fig. 1. General view of different approaches of pre-support numerical modeling

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