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Full 3D Modeling of Tunnel Excavation and Lining with Emphasis on Sequence Excavation,Comparison of 3D and 2D Analysis

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ABSTRACT: In this paper 3D and full tunnel modeling with considering step by step excavation and installation of lining, will be discussed. Full 3D modeling of tunnel by finite element method (FEM) can be ideally represents the behavior of longitudinal and transverse ground settlement by progress of excavation and installation of lining. Results of numerical analysis showed good agreement with empirical formulations for longitudinal settlement. It is also seen that the effect of boundary condition of the model, there are up to five times the diameter of the tunnel and then reaches its maximum and steady-state condition. With increasing the tunnel depth, ground surface settlement decreases before the tunnel face and increases after the tunnel face. Also according to the results, settlement longitudinal curves of different depths intersect in the tunnel face, which means ground surface settlements in the tunnel face are the same for different depths. In the other section of the paper transverse settlement curve obtained by 2D analysis compared with the corresponding trough from 3D analysis, by comparing these two profiles area, can be reached to the stress release factor, that is one of the key parameters in the 2D analysis.

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1- Introduction

Tunnel excavation process is a three-dimensional operation in which the length of tunnel and the length of the unsupported part of the tunnel are the important factors that affect the ground surface settlement. In addition to the empirical and analytical approaches for estimating the ground surface settlement, numerical models are more useful considering the important factors in the analysis such as the interaction of soil and structure. The purpose of this article is to study the effect of sequence excavation and lining on longitudinal settlement trough emphasizing the length of excavation. In order to consider the excavation and sequence of excavation process, the so-called step-by-step method introduced by Hanafy and Emery (1980) has been used. First, the longitudinal ground surface settlement derived from numerical analysis was compared with Panet-Guento and Unlu-Gercek's empirical methods. The effect of tunneling depth and ground stiffness on longitudinal settlement trough and also comparison between settlement cross-sectional troughs obtained by 3D analysis and the ones obtained by 2D analysis are the other cases that have been discussed in this article.

2- Numerical Modeling

The numerical modeling was conducted using the Finite Element Analysis and ABAQUS software. The simulation and excavation procedures were conducted in a 3D and step by step model respectively. The dimensions 80m, 50m, and 140m were chosen for length, width, and depth respectively. It must be noted, the tunnel excavation was simulated at the length of 80m and the round length d=2m.

In order to compare the longitudinal settlement trough derived by the numerical method and the one calculated by empirical method, (for excavated sections of tunnel before the tunnel face) Equations 1 and 2 were used for empirical methods Panet-Guento and Unlu-Gercek, respectively.

$$S_v(x) = S_{v\max}(x)\left(0.28+0.72\left[1-\left(\frac{0.84}{0.84+x^*}\right)^2\right]\right) \qquad (1)$$

$$S_v(x) = S_{v\max}(x)\times \times\left[(0.22\upsilon+0.19)+A_b\left(1-\left(\frac{B_b}{(A_b+x^*)^2}\right)\right)\right] \qquad (2)$$

For comparing the two-dimensional and three-dimensional models, the cross-sectional settlement trough for 3D analysis in the length of steady-state displacements reaches has been drawn.

3- Simulation Results

For the longitudinal settlement trough, a good agreement between the results of 3D analysis and empirical formulations was observed, as it is shown in Figure 1.

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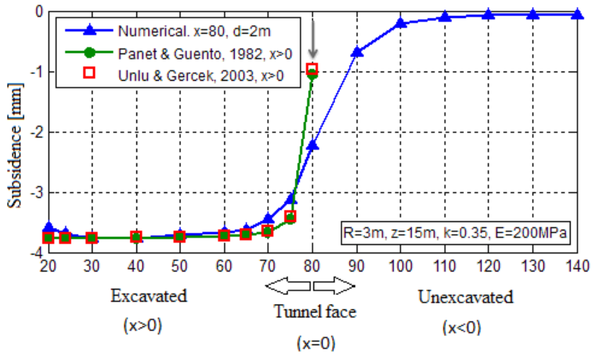

Figure 1. Comparison of longitudinal settlement trough with empirical relations

According to Figure 2, the effect of boundary condition of the model was up to five times of the diameter of the tunnel and after reaching this length, it gets to its maximum and steady-state condition. Also by increasing the ground stiffness, ground surface settlement decreases.

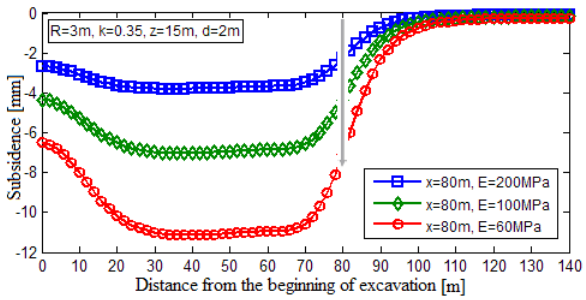

Figure 2. Comparison of longitudinal settlement trough for different elasticity modulus of ground

By increasing the tunnel depth, ground surface settlement decreases before the tunnel face and increases after the tunnel face (Figure 3). Also, by increasing the round length, ground surface settlement increases (Figure 4).

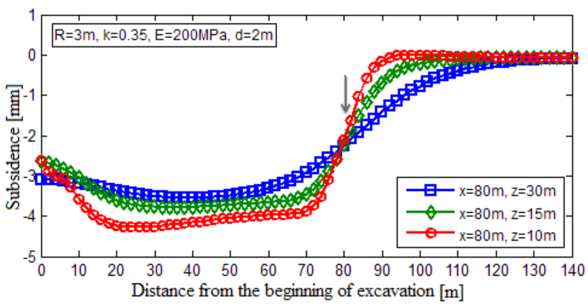

Figure 3. Comparison of longitudinal settlement trough for different tunnel depth

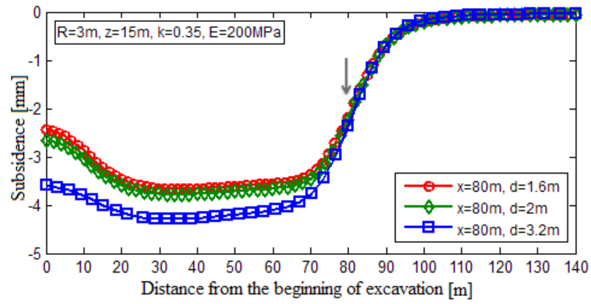

Figure 4. Comparison of longitudinal settlement trough for different length of excavation

At the end of this article, the transverse settlement curve obtained by 2D analysis is compared with the corresponding trough derived by 3D analysis, by comparing these two profiles area, one can achieve the stress release factor which is one of the key parameters in the 2D analysis.

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