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EXTENDED ABSTRACT

Studying the area of soil loosening and arching in the urban tunnel adjacent to the unstable zone

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1. Introduction

Basically, the interaction behavior of urban tunnels in cohesive and granular soils is different. Various studies have been conducted on the behavior of tunnel structures in granular soils such as sandy soil. For example, tunnel model and sandy soil layer failures including various cases such as ground displacements (Sun and Liu, 2014; Shao et al., 2021) and types of tunnel front ruptures (Wong et al., 2012) have been studied. Also, ground surface failures and settlements (Sohaei et al., 2020; Pabodha et al., 2021) and issues related to deep tunnels (Wan et al., 2019) and the problems associated with shallow tunnels including partial failures in the excavation front (Li et al., 2019) have also been researched in previous researches. Anyway, according to the investigations carried out in the relevant technical literature, so far, the issue of facing or proximity of tunnel excavation operations to unstable soil zones with the ability to creep and time-dependent deformations has been less studied in the field of arching and deformation of the earth's surface. And the purpose of this research is to evaluate and study these cases at the same time. In this study, in the framework of two- and three-dimensional finite element models and numerical simulation of a case study following the occurrence of a tunnel excavation accident, these goals have been pursued.

2. Methodology

2.1. Numerical study

In this research, the effects of changing the thickness and position of the *unstable soil zone* on the interaction behavior of the tunnel and soil layers have been evaluated. In this regard, for the numerical simulation of the soil around the tunnel in the stable zone, the Mohr-Coulomb (MC) elastic-perfect plastic model has been used, and the SSC soft soil creep model has been used to define the soil in the unstable zone. In order to model the different stages of tunnel boring and defining the tunnel, its lining mechanism and the activation of the soil layers and building surcharges in the two and three dimensional finite element programs of this research, the number of 10 different and consecutive phases or stages has been defined. Also, to define the reinforced concrete lining of the tunnel, an elastic model with structural concrete specifications (elastic modulus E_c=25GPa) has been used.

2.2. FE modeling

The FEM-based software packages, PLAXIS 2D and PLAXIS 3D TUNNEL, were used for the numerical modeling and analysis. In this study, parametric studies have been defined with changes in the thickness of the unstable zone, the over-consolidation ratio of the soil, numerical analysis type (plastic or consolidation) and the surface building surcharge (Fig. 1).

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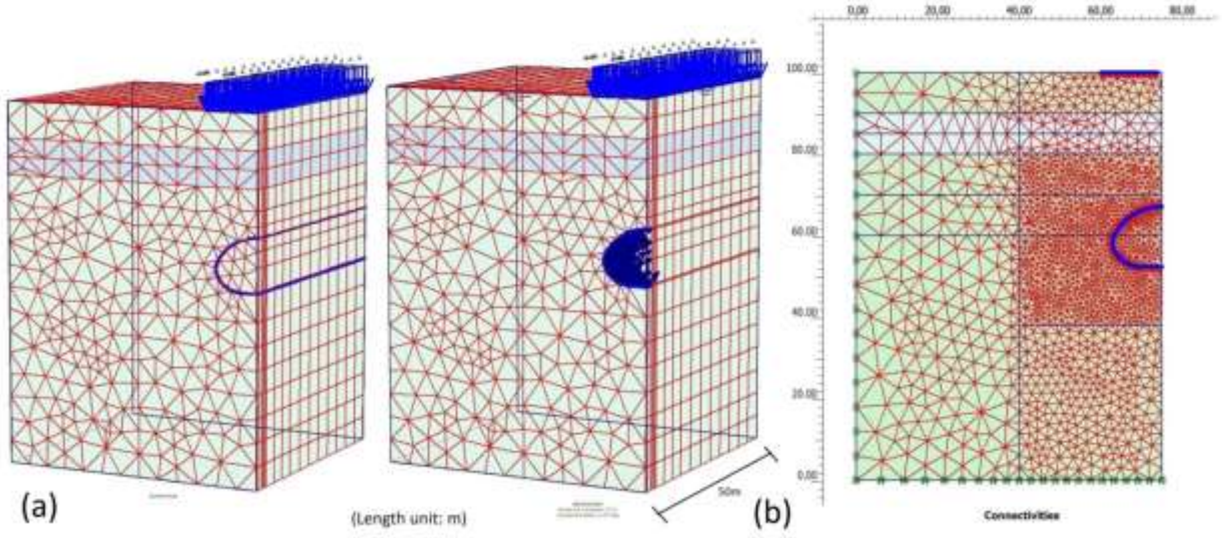

Fig. 1. Geometry of 2D and 3D finite element models, building surcharge and unstable zone.

3. Results and discussion

3.1. Effect of surcharge load and unstable zone thickness (H_{uz})

In Fig. 2, the changes in the loosening zone at the top of the tunnel for the application of q=200kPa overhead and the execution of plastic analyzes in over-consolidation states including OCR=1 and OCR=10 are drawn.

According to Fig. 2(a), in the presence of surcharge q=200kPa and NC soil, the largest dimensions of the loosening zone are related to H_{uz}=0m, as in the cases in the previous state (i.e., case q=0). It is also similar to the case of the previous state, despite the surcharge, again the smallest dimension of the loosening zone is related to the case of H_{uz}=100m (Fig. 2(a)). with the difference that in the case of q=200kPa compared to q=0, the dimensions of the loosening zone are limited exactly to the area under the surface surcharge. On the other hand, in Fig. 2(b) and for OC soil at H_{uz} values >30m, the shape and pattern of the loosening zone changes and breaks compared to the position of the unstable zone. In this case, for H_{uz} values greater than 30m (that is, the expansion of the dimensions of the unstable zone after the tunnel crown), in all cases, the upper part of the loosening zone approaches the location of the starting and ending points of the surface surcharge location. In such a way that in the case of H_{uz}=100m, the loosening zone passes exactly from the starting and ending points of the equivalent surface overhead of the building (Fig. 2(b)). By comparing Figs. 2(a) and 2(b), it is clear that over-consolidation of soil in plastic analysis causes changes in the shape, pattern, location and range of the loosened soil area above the tunnel crown.

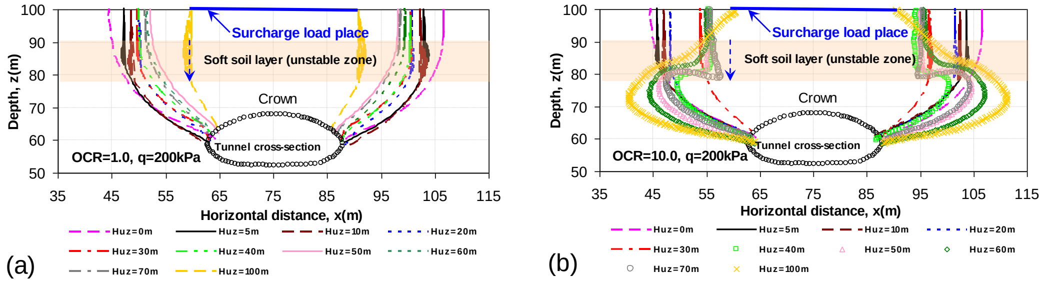

Fig. 2. Surcharge q=200kPa and plastic analysis in over-consolidation states including: (a) OCR=1 and (b) OCR=10.

4. Conclusions

In this study, the effect of the geometric and strength characteristics of the unstable zone on the interaction of the urban tunnel in the soil was evaluated in the form of two- and three-dimensional finite element simulations. According to the findings of this article, changes in surface building surcharge q cause changes in the dimensions, appearance, and starting and ending points of the loosening zone versus changes in the thickness of the unstable zone. The results of two-dimensional finite element analyzes are usually between 5 and 35% larger than the results of three-dimensional analyzes. This makes two-dimensional analyzes more conservative. Plastic analysis gives less ground settlement than consolidation analysis. Because, in the consolidation analysis, a part of the vertical displacement of the soil is caused by the occurrence of consolidation and the reduction of the volume of consolidated soft soil.

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