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Research article

Investigation of time-dependent effects on the convergence of circular tunnels

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Keywords

Circular tunnels
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Ground reaction curve
Time-dependent behavior

English Extended Abstract

Summary

A numerical solution based on the finite difference method is presented in this study which employs time-dependent parameters of surrounding rock mass of a circular tunnel. Applying the solution, the effect of time on induced stress and displacement is investigated. Moreover, the impact of support installation under time-dependent deformation of the surrounding mass is studied for various plastic behaviors.

Introduction

Nowadays, due to the development of urban areas, huge investments are made in creating infrastructures and their maintenance. Consequently, there is an increasing demand for the construction of underground structures such as tunnels. One of the most important issues in designing tunnels as an underground construction is its stability. On the contrary, the evaluation of induced stress and deformation fields is the most crucial matter after underground excavation. This excavation could change the initial stress components and produce an induced stress field causing further displacements around the underground structure. This evolution in stress and deformation regime may not occur instantly, instead it might develop over long periods of time. A ground reaction curve is a beneficial approach to describe these deformations based on the convergence-confinement method. For simplicity, it is assumed in this method that rock mass mechanical properties are isotopic, and in situ hydrostatic stress field exists making the problem as an axisymmetric problem. In the majority of the analytical solutions for the ground reaction curve, the rock mass constitutive model is assumed as elastic perfectly plastic and elastic brittle plastic which simplifies the solving process. Moreover, in some other solutions, strain softening constitutive model is implemented. Nonetheless, considering all this research, the actual rock mass behavior which is affected by time is neglected.

Methodology and Approaches

In this paper, an investigation is carried out into the time effects on the convergence of circular tunnels assuming viscos-elastoplastic behavior, along with proposing a numerical solution for finding stress and deformation fields around the tunnels. This numerical solution, which is based on the finite difference method, with a discretizing rock domain, is able to simulate various rock mass behaviors including perfect plastic, strain softening, and brittle plastic models, as well as employing viscous deformation. By using the proposed solution, assuming homogenous, isotropic surrounding mass under hydrostatic initial stress, the magnitude of time-dependent stress components and displacements, along with the ground reaction curve, is calculated for different time periods after excavation. Finally, by employing rock mass data, the ground reaction curve is illustrated for various time intervals, and a comparison is carried out for values predicted from the solution by assuming perfectly plastic, strain softening, and brittle plastic models of rock mass behavior.

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Results and Conclusions

It is demonstrated that due to different influences of the plastic zone development, and the magnitude of second invariant of deviator stress, the induced displacement and ground reaction curve exhibit different behaviors over time. Within a short period of time (less than 70 days), the brittle plastic constitutive model produces the largest displacement, while for a long period of time (more than 70 days), strain softening model develops the largest displacement between constitutive models. Rock-support interaction shows that in a long period of time after support installation, amongst all the models, strain softening constitutive model results in a higher load on the supports. The failure criterion applied in the proposed solution is Mohr-Coulomb yield criterion.

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