Journal of Novel Applied Sciences
Available online at www.jnasci.org
©2015 JNAS Journal-2014-4-3/340-344
ISSN 2322-5149 ©2015 JNAS

The effect of K_0 on the boundary conditions to tunnels

Aryan Maleki Dizaji*، Vahid Hosseinitoudeshki and Seyyed Amir Hossein Beheshti

Department of Civil Engineering، Zanjan Branch، Islamic Azad University، Zanjan، Iran

***Corresponding author*:** Aryan Maleki Dizaji

ABSTRACT: This paper presents the results of numerical analysis of K_0 on the boundary conditions in tunnels excavated in rock masses with strain-softening post-failure behaviour. Modeling of tunnels is done with software Phase2 that is a 2D finite element program. Three boundary types box, circle and hull and expansion factor of 7 are considered for modeling. The results of the evaluations show that in modeling of tunnels, the shape of the external boundary is important and with decreasing the values of K_0, the displacement around tunnels has increased but the style of deformation has maintained uniform. Furthermore, in the rocks with strain-softening behaviour, by increasing the values of GSI, the displacement around tunnels has strongly decreased for all boundary conditions.

***Keywords*:** Tunnel, Boundary conditions, K_0, Strain-softening.

INTRODUCTION

One of the most important tasks in rock mechanics and engineering geology is to estimate of the value of K_0 ($\sigma h/\sigma v$) and its effects on underground spaces. The K_0 is defined as the ratio between the major horizontal stress (σh) and the vertical stress (σv) (Goodman, 1989), being σv the weight of overburden. In this paper, the value of K_0 is estimated via the equation of Sengupta (1998, in Singh and Goel, 1999) that is applicable in compressive tectonic setting.

In general, strain-softening is the effect of localization of deformation and is founded in the incremental theory of plasticity (Hill, 1950; Kaliszky, 1989), that was developed in order to model plastic deformation processes, in which a material is characterized by a failure criterion and a plastic potential. The strain-softening behaviour is characterized by a gradual transition from a peak failure criterion to a residual one and can be seen in rocks with geological strength index between 25 and 75 (25<GSI<75) (Alejano. 2009).

Tunneling often disturbs the natural state of rock masses and produce interaction of different rock mass parameters and boundary conditions. Initial changes in rock mass parameters or boundary conditions will cause more changes of other parameters. The interaction of parameters is a dynamic and cyclic process, until a new equilibrium state is reached. For this purpose, a rock engineering interactive mechanism has been suggested to model the dynamic and cyclic behavior of rock mass and the boundary conditions (Hudson, 1991).

The three common external boundary types are box, circle and hull. The box external boundary will in general be a rectangle. The circle external boundary actually generates a regular 10-sided polygon approximating a circle around the excavation. The hull produces an external boundary which is a magnified version of the excavation. It will work for multiple excavations, although it is more appropriate for a single, convex excavation. (Rocscience, 1999).

The main purpose for this study is to analysis the tunnels in order to find efficacy of K_0 to tunnels on the boundary conditions.

Geomechanical properties of granitic rock masses

In this study, the geomechanical parameters of the granite rocks are obtained using Roclab software (Hoek. 2002). These parameters are obtained based on The Hoek-Brown failure criterion and it is presented in Fig. 1.

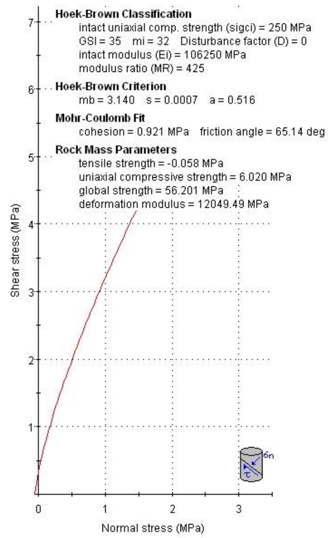

Figure 1. The geomechanical parameters of the granitic rock masses

Numerical analysis of K_0 to tunnels

Numerical analyses of boundary conditions in the rock masses are accomplished using a two-dimensional hybrid element model, called Phase2 Finite Element Program (Rocscience, 1999). This software is used to simulate the three-dimensional excavation of a tunnel. In three dimensions, the tunnel face provides support. As the tunnel face proceeds away from the area of interest, the support decreases until the stresses can be properly simulated with a two-dimensional plane strain assumption. In this finite element simulation, based on the elasto-plastic analysis, deformations and stresses are computed. These analyses used for evaluations of the tunnel stability in the rock masses. The geomechanical properties for these analyses are extracted from Fig. 1.

To simulate the excavation of tunnel in the granite rock masses, a finite element models is generated with three common external boundary types, namely box, circle and hull (Fig. 2 to 4). The outer model boundary is set at distances of 7 times the tunnel radius (expansion factor = 7) and six-nodded triangular elements are used in the finite element mesh and the tunnels diameter is 4 meters.

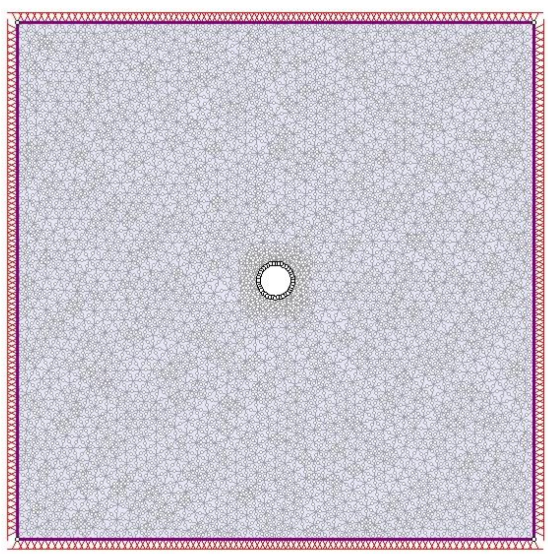

Figure 2. The modeling of circular tunnel with external boundary of box and expansion factor of 7

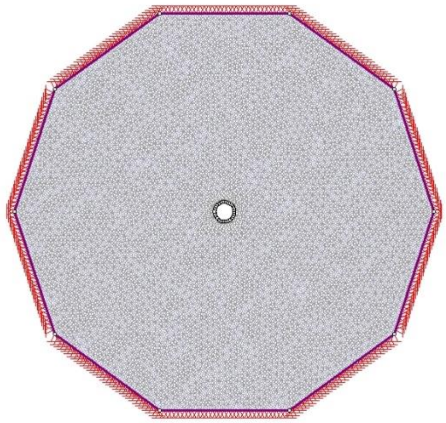

Figure 3. The modeling of circular tunnel with external boundary of circle and expansion factor of 7

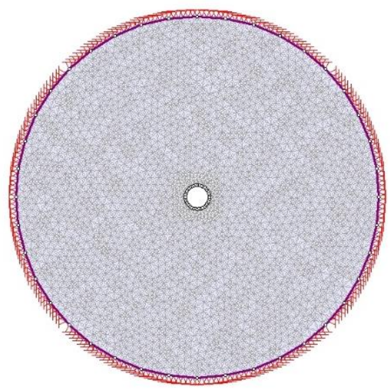

Figure 4. The modeling of circular tunnel with external boundary of hull and expansion factor of 7

First, the modeling of circular tunnels is performed with K_0 equal to 1.1, 1.2, 1.3, 1.4 and 1.5, and the maximum tunnel wall displacement far from the tunnel face is determined for each tunnel and the obtained results are shown in Figs. 5 to 7.

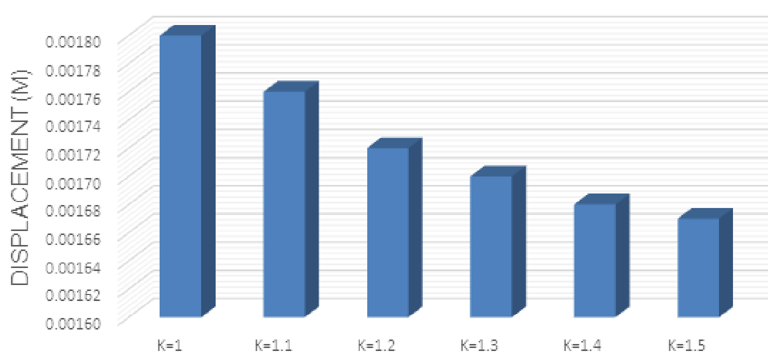

Figure 5. The displacement of circular tunnels with external boundary of box in different stress ratios

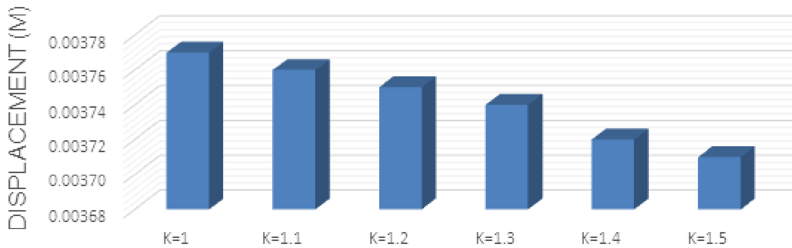

Figure 6. The displacement of circular tunnels with external boundary of circle in different stress ratios

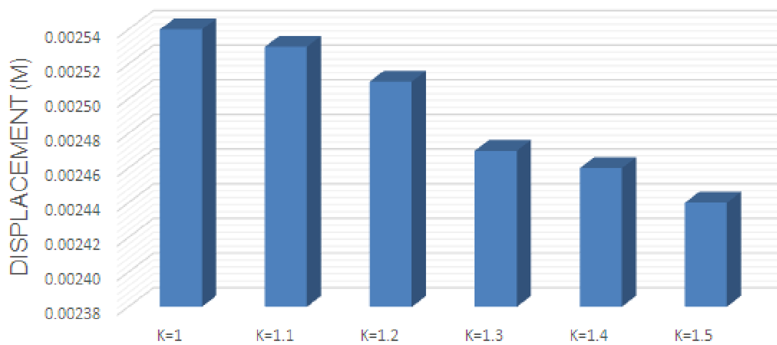

Figure 7. The displacement of circular tunnels with external boundary of hull in different stress ratios

As the above diagrams show, with increasing stress ratio (K_0), the displacement around tunnels has decreased and this is true for all shapes of external boundaries. Moreover, in this case, the maximum displacement of tunnels is related to external boundary of circle and then is related to external boundary of hull and box, respectively.
The next stage, the modeling of circular tunnels is performed with values of Geological Strength Index (GSI) equal to 25, 35, 45, 55, 65 and 75, and the maximum tunnel wall displacement is determined for each model and the obtained results are shown in Figs. 8 to 10.

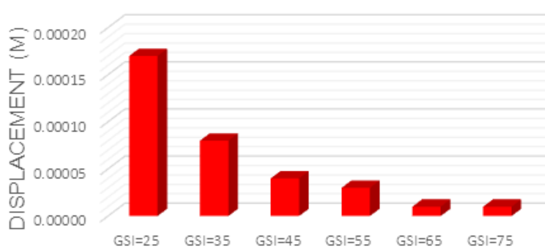

Figure 8. The displacement of circular tunnels with external boundary of box in different GSI

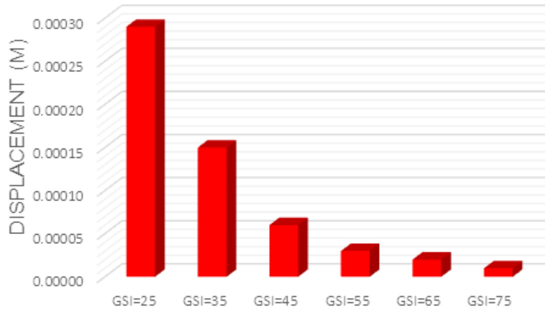

Figure 9. The displacement of circular tunnels with external boundary of circle in different GSI

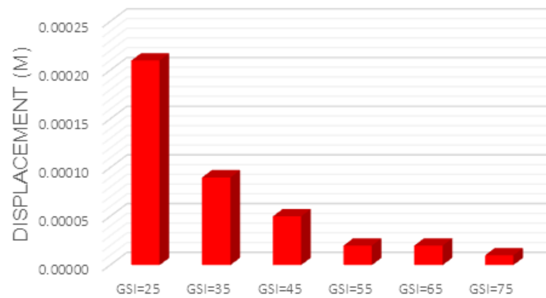

Figure 10. The displacement of circular tunnels with external boundary of hull in different GSI

As the above diagrams show, with increasing GSI, the displacement around tunnels has strongly decreased and this is true for all shapes of external boundaries. Also, the maximum displacement of tunnels is related to external boundary of circle and then is related to external boundary of hull and box, respectively.

CONCLUSION

In this study the effect of stress ratio (K_0) on the boundary conditions is investigated and could be used as initial parameter for modeling of tunnels. Overall, the rocks with strain-softening behaviour have the effect of localization of deformation and causes instability problems for underground openings. The following conclusions could be noted:

- Numerical analysis of K_0 in the tunnels shows that for all boundary conditions, with decreasing the values of K_0, the displacement around tunnels has increased.
- In modeling of tunnels, the shape of the external boundary is important and the external boundaries circle, hull and box to cause maximum displacement around tunnels, respectively.
- In the rocks with strain-softening behaviour, by increasing the values of GSI, the displacement around tunnels has strongly decreased for all boundary conditions.

REFERENCES

Alejano LR, Rodr´ıguez-Dono A, Alonso E and Fern andez Manin G. 2009. Ground reaction curves for tunnels excavated in different quality rock masses showing several types of post-failure behaviour. Tunnelling and Underground Space Technology 24 689–705.

Goodman RE. 1989. Introduction to Rock Mechanics, 2nd. Wiley.

Hill R. 1950. In: The mathematical theory of plasticity. New York: Oxford University Press.

Hoek E, Carranza-Torres C and Corkum B. 2002. Hoek–Brown Failure Criterion—2002 Edition. Rocscience.

Hudson JA. 1991. Atlas of rock engineering mechanisms: underground excavations. Int J Roc Mech Min Sci Geomech, 523–6.

Kaliszky S. 1989. Plasticity: Theory and Engineering Applications. Amsterdam, Elsevier.

Rocscience. 1999. A 2D finite element program for calculating stresses and estimating support around the underground excavations. Geomechanics Software and Research. Rocscience Inc., Toronto, Ontario, Canada.

Singh B and Goel RK. 1999. Rock Mass Classification, A Practical Approach in Civil Engineering. Elsevier, Amsterdam. 265 pp.