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The effect of installation of support systems on the yielded elements in circular tunnels

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ABSTRACT: Yielding in around of tunnels when occurs that tangential stresses overcome to rocks strength so the yielded elements have important role in analysis of the stability of underground constructions which designed and implemented in rock. This study has been in weathered tuffs and in hydrostatic stress conditions where tunnels have been excavated. In tunnel modeling, several tunnels with different radiuses analyzed using phase2 software and the extent of plastic zone in around of the tunnels determined. In addition the effect of installation of support systems on the yielding in around of the tunnels is evaluated. The support systems which are used in this modeling are bolt and shotcrete. The obtain results show that installation of bolt and shotcrete has different influences on the yielded elements in around of the tunnels.

Keywords**:** Yielded elements, Support system, Circular tunnel.

INTRODUCTION

The rock masses whose strength is lower than the surrounding stress can be considered as weak rocks. The behavior of weak rocks in tunnels has led to problems during the construction of a number of projects. The ratio of rock mass strength to the in situ stress value specifies that deformations induce stability problems in the tunnel. The analysis of circular tunnels excavated in weak rocks under hydrostatic stress fields has been one of the principal sources of knowledge. The design of support systems in weak rocks can create very problems to the geotechnical engineer. Support of weak rock with grouted bolts and shotcrete (stille et al., 1989) and correlation between observed support pressure and rock mass quality (Singh et al., 1992) are among the studies that have been for support installation in weak rocks.

The results of a three-dimensional finite element analysis of the deformation and failure of the rock mass surrounding a circular tunnel excavating in a weak rock mass are shown in figure1.

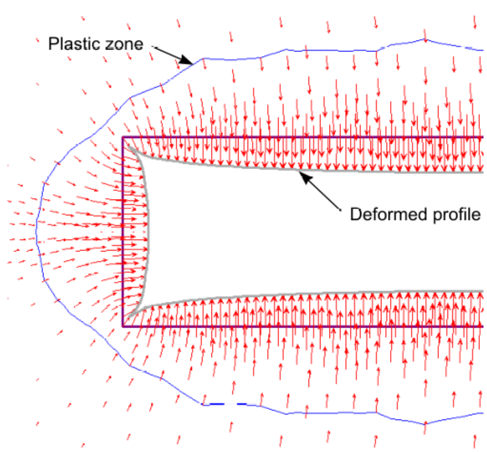

Figure 1. Shape of the plastic zone surrounding the tunnel

Numerical analysis of the plastic zone in around of the tunnels due to excavation with different support systems is presented in this paper. The effects of asynchronous and asynchronous installation rock bolt and shotcrete on the plastic zone in tunnels has been investigated. These tunnels have been excavated in weathered tuffs and in hydrostatic stress conditions have been analyzed.

MATERIALS AND METHODS

The numerical method using the computational code (phase2) has been applied in analyzing the sections of tunnel. Phase2 is a two dimensional program which planned based on infinite elasto-plastic elements that used for calculation the stresses and displacements around the underground excavations. In this paper, the tunnels are simulated in moderately weathered tuff rocks and radiuses from 2 to 7 meters. Numerical analysis was based on two dimensional analyzing and plane strain. The modeling for each diameter is in four stages. The first stage is modeling the tunnel without any support system. The second stage is the tunnel with bolts as a support system. The third stage is the tunnel with shotcrete as a support system. The fourth stage is synchronic installation the bolt and shotcrete and the fifth stage is asynchronic installation the bolt and shotcrete.

Rock mass in tunnel sections

The study area is related to the moderately weathered tuff rock with the following mechanical properties. The properties of rock mass including the strength of rock (σcm) deformation, modulus of rock (Em) and constants of rock (mb, s, a) have been calculated by Roclab software. This software is provided by Hoek et al, (2002). In this software constants are determined by means of geological strength index (GSI), the intact rock parameters (mi) and the distributed factor (D) that associated with existing disturbance as a result of excavation. Finally, shear strength and rock mass parameters (φ, C) are obtained with comparison Mohr-Coulomb and Hoek-Brown criterion. The results are shown in the figure 2 and Table 1.

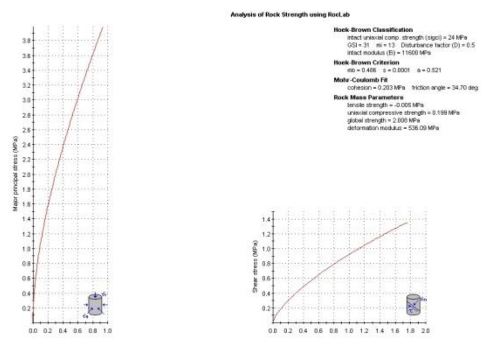

Figure 2. Rock mass parameters

Table 1.Geomechanical properties of rock masses

Roclab program's input and output						
Hoek Brown Classification				Hoek Brown Criterion		
σ_{ci} (Mpa)	GSI	m_i	D	mb	s	a
Intact Uniaxial Compressive Strength	Pick GSI Value	Pick mi Value	Disturbance Factor			
24	31	13	0.5	0.486	0.0001	0.521
Mohr-Coulomb Fit		Rock Mass Parameters				
C (Mpa)	φ(degree)	σ_t (Mpa)	σ_c (Mpa)	σ_{cm} (Mpa)	E_{dm}(Mpa)	
Cohesion	Friction angle	Tensile strength	Uniaxial compressive strength	Global strength	Deformation modulus	
0.203	34.70	-0.005	0.199	2.008	536.09	

Analysis of results

Through of numerical modeling, the yielded elements and radius of plastic zone in around of tunnels in five different moods of support (without support, with bolt, with shotcrete, with synchronous installation bolt and shotcrete, and with asynchronous installation bolt and shotcrete) is determined which for tunnel with a radius of 2 meters are shown in figures 3 to 7.

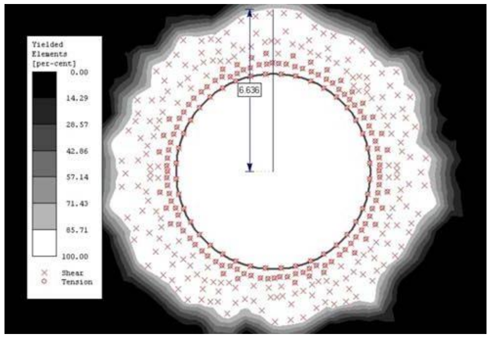

Figure 3. Yielded elements in around of the tunnel in mood of without support

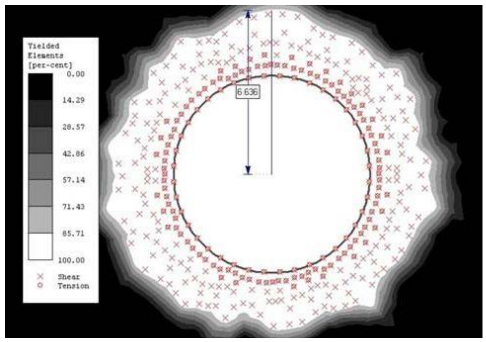

Figure 4. Yielded elements in around of the tunnel in mood of with bolt

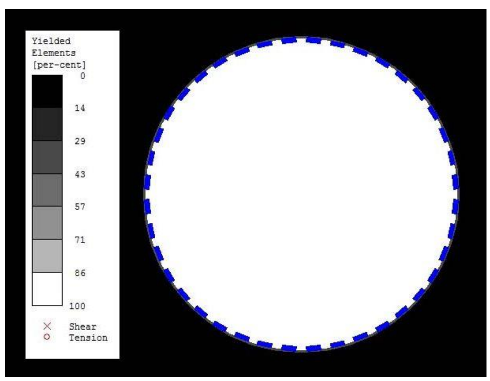

Figure 5. Yielded elements in around of the tunnel in mood of with shotcrete

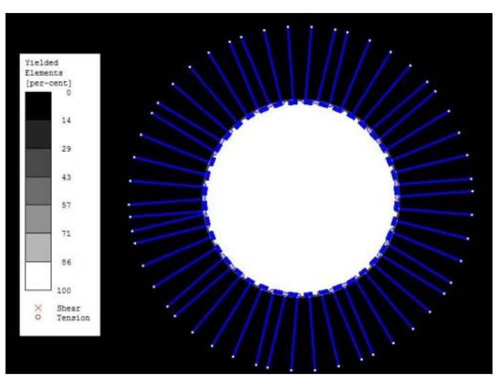

Figure 6. Yielded elements in around of the tunnel with synchronous installation bolt and shotcrete

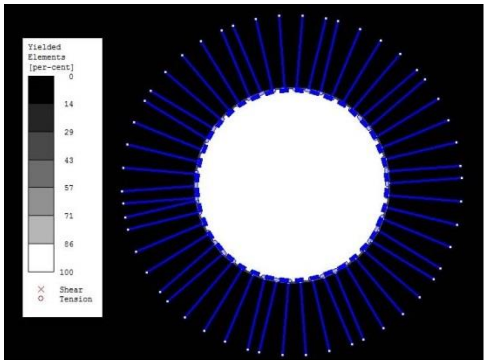

Figure 7. Yielded elements in around of the tunnel with asynchronous installation bolt and shotcrete

In the next stage, the radius of plastic zone for tunnels roof in five different moods of support are obtained and shown in the table 2.

Table 2. Plastic zone radius in different tunnels

Radius of tunnel	2m	3m	4m	5m	6m	7m
	Radius of plastic zone (m)					
No support	3.295	5	6.636	8.346	9.929	12.538
Shotcrete support	0	0	0	0	0	0
Bolt Support	2.491	3.435	4.557	5.669	7.204	8.366
Shotcrete & Bolt Support (synchronous installation)	0	0	0	0	0	0
Shotcrete & Bolt Support (asynchronous installation)	0	0	0	0	0	0

The above table shows that when the supporting systems are installed the radius of plastic zone is decreased. In tunnel with 2 meters radius after installing the bolt, radius of plastic zone decreases over 15% and with having the shotcrete or bolt and shotcrete as a supporting system no plastic zone is created around the tunnel. In tunnel with 3 meters radius the plastic zone reduce about 31% when the bolt is installed. In tunnels with 4 and 5 meters radius the plastic zone decreases closely 32% by having the bolt as a supporting system. In tunnels with 6 and 7 meters radius the plastic zone decreases nearly 33% by having the bolt as a supporting system.

The table indicates when shotcrete individually or shotcrete and bolt jointly are installed as a supporting system no plastic zone is created in all radiuses.

CONCULSION

In this study that with purpose of investigating the effects of installation support systems in tunnels accomplished the following results have been obtained:

- By increasing radius of tunnels, the plastic zone in around of tunnels is increased.
- The installation of bolt and shotcrete has different influences on the yielded elements in around of tunnels.
- The shotcrete is effective than the bolt in decreasing plastic zone in around of tunnels.

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