

The Effect of Asynchronous Installation of Composite Support System on the Convergence in Circular Tunnels

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Abstract: Total displacement and support systems have important role in analysis of the stability of underground constructions which designed and implemented in rock. So understanding the factors affecting the total displacement and yielded elements seems to be necessary. This study has been in weathered tuffs and in hydrostatic stress conditions where tunnels have been excavated. In tunnel modeling, six radiuses of tunnels in 2, 3, 4, 5, 6, 7 meters analyzed using phase2 software and ground reaction curves (GRC) are plotted on the sections of tunnel. In addition the effect of synchronic and asynchronous installation of support systems on the convergence in the tunnels is evaluated. The support systems which are used in this modeling are bolt and shotcrete. The obtain results show that the synchronous and asynchronous installation of bolt and shotcrete has different influences on the convergence of tunnels and the most effective way to install of support system in tunnels is synchronous installation of bolt and shotcrete.

Key words: Convergence • Support system • Displacement • Circular tunnel

INTRODUCTION

The design of support systems in weak rocks can create very problems to the geotechnical engineer. Therefore, the main purpose of a designer is to determine the most suitable and economical support system with a convenient excavation method. Support of weak rock with grouted bolts and shotcrete [1] and correlation between observed support pressure and rock mass quality [2] are among the studies that have been for support installation in weak rocks.

In order to understand the process of designing support for this type of tunnel it is necessary to examine some very basic concepts of how rock mass surrounding a tunnel deforms and how the support systems acts to control these deformations. Commonly, convergences of rock mass starts about one half a tunnel diameter ahead of the advancing face and reaches its maximum value about one half diameters behind the face. At the face position about one-third of the total radial displacement of the tunnel has already take placed and the tunnel face deforms inward.

The ratio of rock mass strength to the in situ stress value specifies that these deformations induce stability

problems in the tunnel. Therefore, deformation process takes place immediately upon excavation of the tunnel face. The basic input parameters for a safe tunnel design are tunnel size, characteristic of the rock masses surrounding the tunnels, geometry and the used support properties. During excavation, the numerical models allow the rapid choice, installation and control of the best solutions, after empirical adjustments for different situations [3].

By excavating a tunnel, the convergence and ground pressure on the tunnel lining increase with time. These are because the advance of the tunnel face and the time-dependent response of the surrounding rocks. In order to describe the time-dependent deformation in tunnels, multiple numerical methods have been developed [4-7]. Also a closed-form solution in order to determine tunnel wall displacements and ground pressure imposed on tunnel supports presented by [8].

The purpose of this study is to investigate the effects of asynchronous installation rock bolt and shotcrete in tunnels in order to achieve a specific pattern to installation practices of support systems in circular tunnels. In this regard, the convergence in circular tunnels in four cases namely; without support, with rock

bolt, with shotcrete and with rock bolt and shotcrete 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 (phase 2) has been applied in analyzing the sections of tunnel. Phase 2 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 and the fourth stage is synchronic installation the bolt and shotcrete as a composite support system.

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 (σ_{cm}) deformation, modulus of rock (E_m) and constants of rock (m_b , s , a) have been calculated by Roclab software. This software is provided by [9]. In this software constants are determined by means of geological strength index (GSI), the intact rock parameters (m_i) and the disturbance 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 Table 1.

Analysis of Results: Through of numerical modeling, the displacement in the around of total tunnels is determined which for tunnel with a radius of 2 meters are shown in Figures 1 to 5.

In the next stage, the ground reaction curves (GRC) for tunnels roof 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) are drawn and shown in Figures 6 to 11.

The ground reaction curves show that when the support systems are installed the amount of tunnel convergence is decreased. In tunnel with a radius of 2 meters, the reduction of convergence in moods of with bolt, with shotcrete, with bolt and shotcrete (asynchronous installation) and with bolt and shotcrete (synchronous installation) is 41%, 64%, 62% and 71% respectively.

In tunnel with a radius of 3 meters, the reduction of convergence in moods of with bolt, with shotcrete, with bolt and shotcrete (asynchronous installation) and with bolt and shotcrete (synchronous installation) is 37%, 59%, 56% and 61% respectively.

In tunnel with a radius of 4 meters, the reduction of convergence in moods of with bolt, with shotcrete, with bolt and shotcrete (asynchronous installation) and with bolt and shotcrete (synchronous installation) is 34%, 51%, 50% and 55% respectively.

In tunnel with a radius of 5 meters, the reduction of convergence in moods of with bolt, with shotcrete, with bolt and shotcrete (asynchronous installation) and with bolt and shotcrete (synchronous installation) is 31%, 47%, 45% and 50% respectively.

In tunnel with a radius of 6 meters, the reduction of convergence in moods of with bolt, with shotcrete, with bolt and shotcrete (asynchronous installation) and with bolt and shotcrete (synchronous installation) is 29%, 43%, 41% and 46% respectively.

Table 1: Geomechanical properties of rock masses

Roclab program's input and output				Hoek Brown Criterion		
Hoek Brown Classification						
σ_{ci} (Mpa)	GSI	m_i	D	m_b	s	a
Intact Uniaxial Compressive Strength	Pick GSI Value	Pick m_i 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	

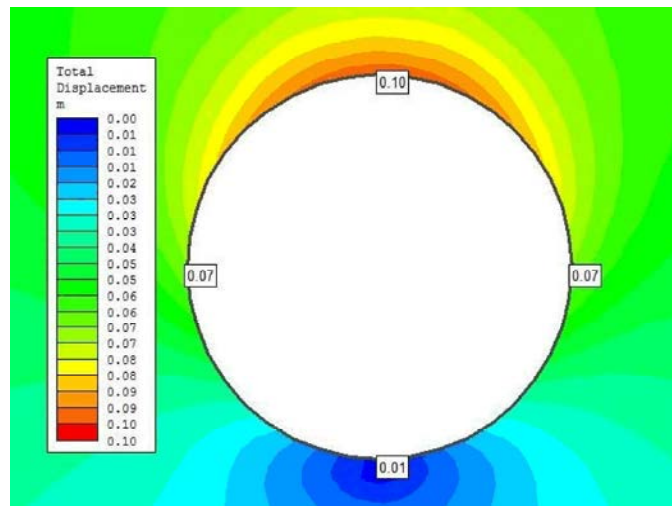


Fig. 1: Total displacement in around of the tunnel without support system

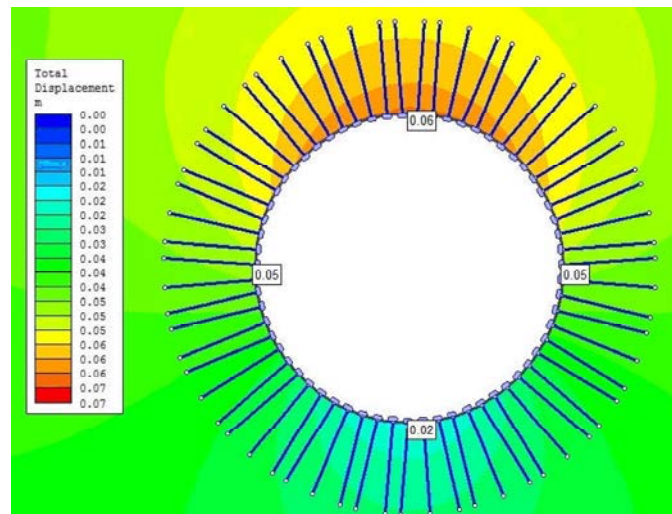


Fig. 2: Total displacement in around of the tunnel with bolt

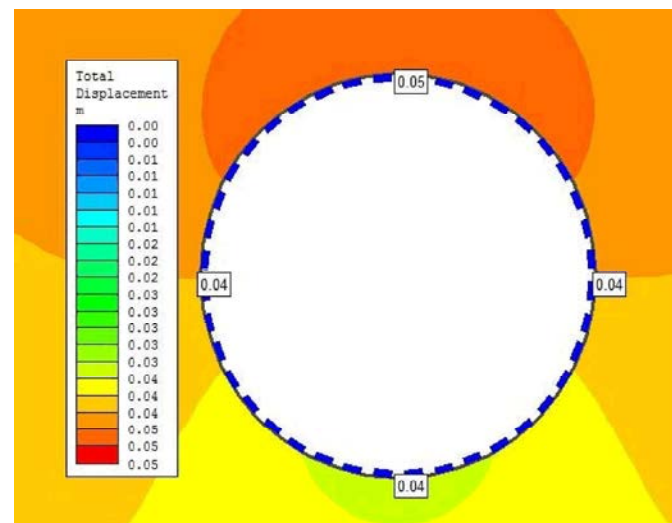


Fig. 3: Total displacement in around of the tunnel with shotcrete

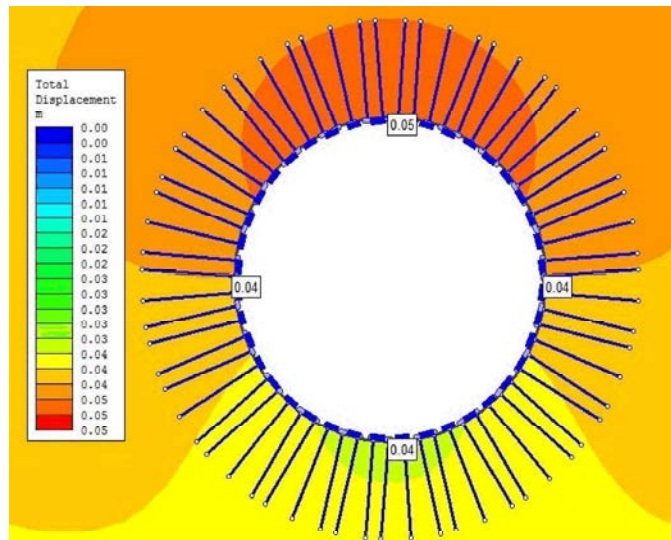


Fig. 4: Total displacement in around of the tunnel with bolt and shotcrete (synchronous installation)

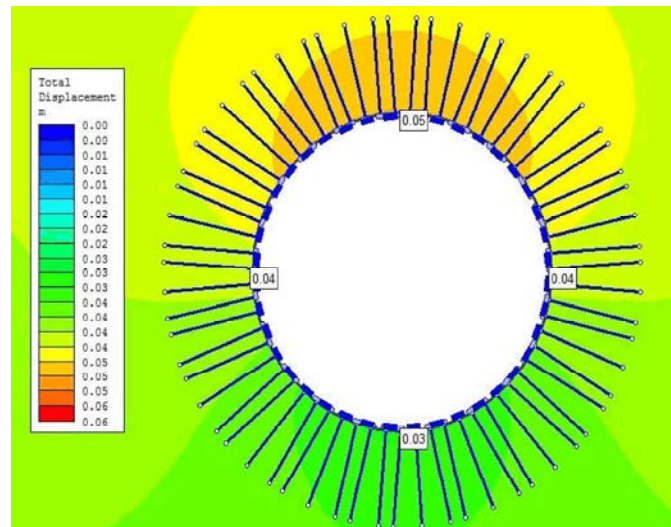


Fig. 5: Total displacement in around of the tunnel with bolt and shotcrete (asynchronous installation)

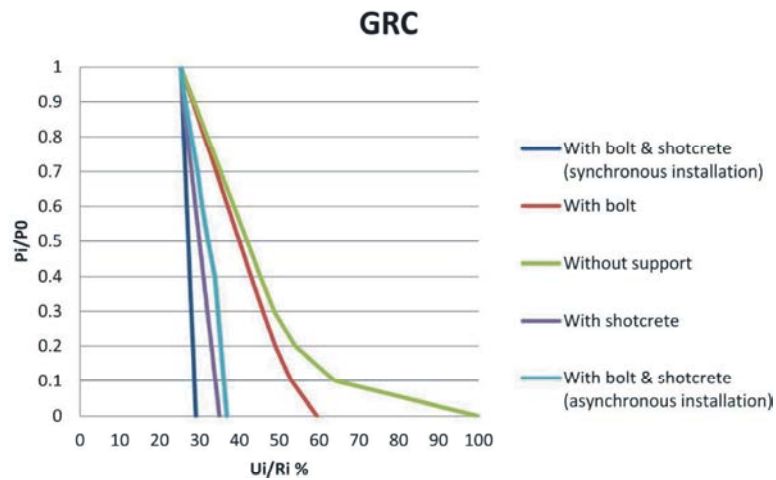


Fig. 6: The GRC diagram of tunnel roof with a radius of 2 m

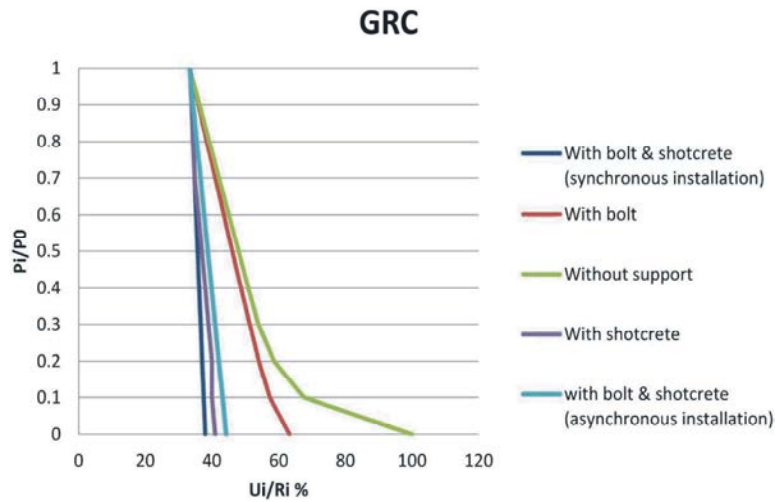


Fig. 7: The GRC diagram of tunnel roof with a radius of 3 m

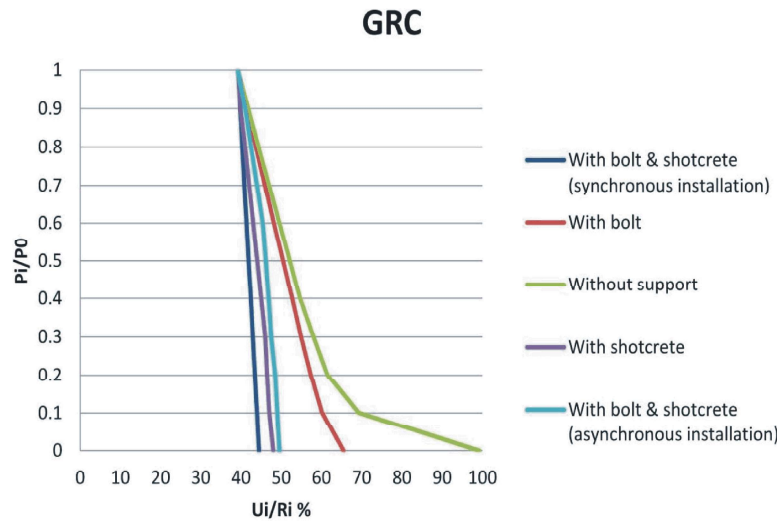


Fig. 8: The GRC diagram of tunnel roof with a radius of 4 m

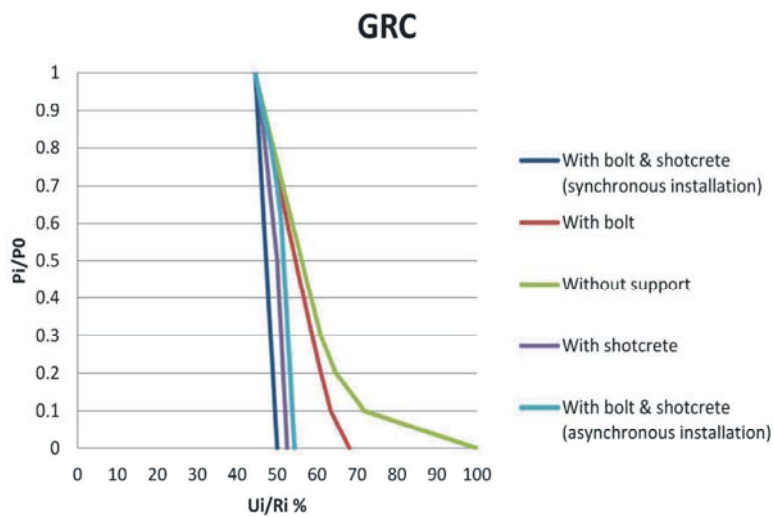


Fig. 9: The GRC diagram of tunnel roof with a radius of 5 m

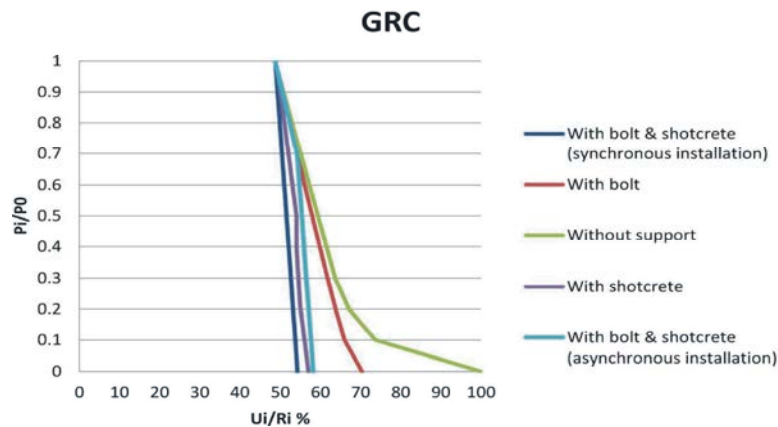


Fig. 10: The GRC diagram of tunnel roof with a radius of 6 m

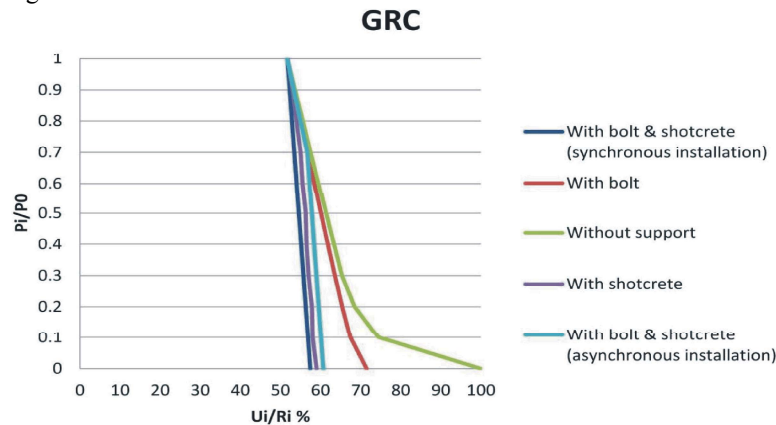


Fig. 11: The GRC diagram of tunnel roof with a radius of 7 m

Finally, in tunnel with a radius of 7 meters, the reduction of convergence in moods of with bolt, with shotcrete, with bolt and shotcrete (asynchronous installation) and with bolt and shotcrete (synchronous installation) is 28%, 41%, 39% and 43% respectively.

According to above mentioned it becomes clear that the most effective way to install of support system in tunnels is synchronous installation of bolt and shotcrete. Furthermore, the impact of asynchronous installation of bolt and shotcrete (first bolt and then shotcrete) on reducing the convergence is less than shotcrete that initially be installed. Therefore, in cases where there is no possibility to install the bolt and shotcrete synchronously, the most economical manner for supporting of tunnel is using of shotcrete solely.

CONCLUSIONS

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

- By increasing radius of tunnel, the effect of installing of support systems in reducing of convergence is decreased.
- The synchronous and asynchronous installation of bolt and shotcrete has different influences on the convergence of tunnels.
- In whole of tunnels, the shotcrete is effective than the bolt in decreasing convergence.
- The most effective way to install of support system in tunnels is synchronous installation of bolt and shotcrete.

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