Journal of Novel Applied Sciences
Available online at www.jnasci.org
©2014 JNAS Journal-2014-3-1/78-83
ISSN 2322-5149 ©2014 JNAS

The effect of pretensioning in the rockbolts on the displacement around tunnels

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ABSTRACT: In this research the effect of pretensioning rockbolts on the displacements around tunnels has been evaluated. The rock mass parameters have been taken from Oroush dam tunnel in Turkey that excavated in weathered tuff rocks. In this regard, several tunnels with different diameters were modeled and rockbolts with different sizes were analysed. The tunnels in this research were analysed by Phase2 software and with a two-dimensional plane strain assumption. The obtained results show that by increasing the pretensioning force in rockbolts, the displacements around tunnels decrease until a specific force and then increase again.

***Keywords*:** Tunnel, Rock bolts, Pretensioning, Displacement.

INTRODUCTION

Rockbolt is one of the support tools which is used, to stabilize underground areas and rock slopes, and its role is to connect discontinuous rock masses and stabilize the tunnel. Using rockbolt and dovel has been common for many years and nowadays various types of them are being used.

To stabilize and consolidate the rock mass, four different mechanisms are used as bellow (Wittaker et al., 1990):

In relatively resistant or joint restraint rocks, the unstability is caused by small pieces of rock detached from excavation ceiling. This happens when the cohesion between rock joints is lower than the rock pieces weight which can be stabilized by rock bolts.

In weaker block rocks, condensation may happen in a tunnel because of rock torsion or slide. To stabilize these rock types tensional or non tensional rock bolts are used to maintain the shear strength along the discontinuity of rocks.

In laminated or layered rocks, the slide happens between the layers. In such cases by using injectable rockbolts, the strength between rock layers increases and the rock mass becomes stabil.

For stressed rock masses, increasing the minimum stress or confinement degree can stabilize the rock mass. In tunnels generaly the minimum main stress is perpendicular to the tunnel wall. So if the under tension rock bolts are installe immediately after the tunnel axcavation, the confinement stress increases so failure extension decreases.
The importance of the pre-tensioned force of rock bolts has been recognized by more and more researchers. In the roof, pre-tensioned rock bolts greatly increase vertical stress; as a result, the strength of the rock mass increased significantly which results in a greater capacity of bearing a large horizontal stress. The horizontal stress decreases in the upper section of the roof, indicating that pre-tensioned rock bolts significantly reduce the coefficient and the size of the region concentration of horizontal stress (Fu-qiang and Hong-pu, 2008).

Rock mass properties

The rock used in modeling the tunnel is called tuff which is extremely weathered and the Orush tunnel in Turkey has been excavated in this type of rock. By using Roclab the mechanical parameters of the rock mass, presented by Hoek et al. 2002 were calculated (Figure 1) and used as the input for Phase2.

The rock mass specifications such as (σ_{cm}) rock mass resistance, (E_m) rock mass elastic modulus and rock mass invariants like (a,s and mb), were calculated with the mentioned software. In Roclab the elastic modulus and the rock mass resistance are calculated according to the Hoek law. In addition the rock mass invarients are defined by the amounts of geology strength index (GSI) and the rock mass invariant (mi). Also the disorder factor (D) which is related to the disorder amount conducted by the excavation, meaning that how much are these rocks disordered by the excavation system and finally there shear resistance parameters (φ , C) are calculated due to the Hoek and Brown criteria (1997). So the failure curve of Hoek and Brown for the main stresses has been calculated and designed.

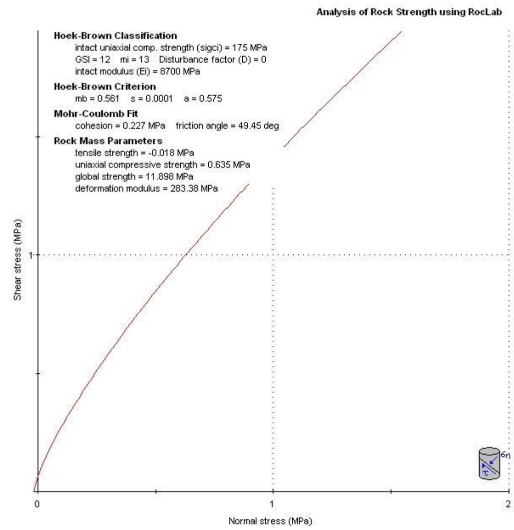

Figure 1. Rock mass parameters

Numerical modelling

Numerical analyses of tunnel deformations in the crushed rock masses were 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. As the excavations are all deep, the stress induced in the program is hydrostatic. The support system is also attached to tunnel walls. The rockbolts are used in spacing 1 m and with lengths 4, 5 and 6 m and diameter 30 cm.

In this research the rockbolts which are located around the tunnel with the mentioned specifications are changed to prestressed rockbolts and their results are evaluated. So at first the tunnel is analysed without pretensioning the rockbolts, then after each level the pretensioning force is increased. Afterwards all the phases are repeated for different tunnel models with different rockbolts according to their size, diameter and length. Because of the high number of models and tests conducted, in this paper just a model with the tunnel diameter of 12 m is shown. Different diameters and widths for other tunnels are shown in graphs. For example in Figure2 a general model of a tunnel with a 12m diameter and rockbolt length 4 m, rockbolt diameter 30mm and rockbolt spacing 1m is shown.

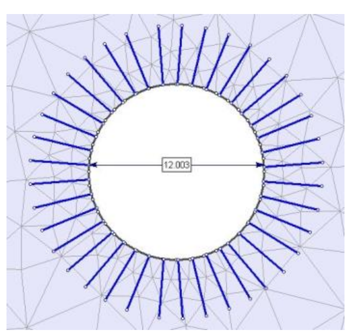

Figure 2. The model for a tunnel with diameter of 12m (rockbolt length: 4 m, rockbolt diameter: 30mm and rockbolt spacing: 1m)

Analyzing Results

The results of displacement differences by increasing the pretensioning force in each phase are measured in 4 points (roof, floor, left wall and right wall) of the circular tunnels with diameter of 12m and rockbolt length of 4 m are shown in Figs. 3 to 8. The output results indicate that in the pretensioning force of 90 KN the amount of displacements reaches to its minimum and afterwards increase and then suddenly the pretensioning effect of the rockbolts fades away.

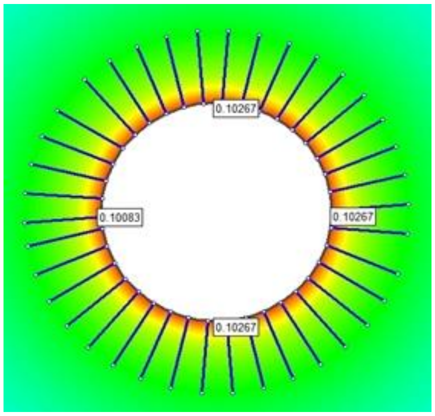

Figure 3. Tunnel displacement amounts with rockbolts non-pretensioned

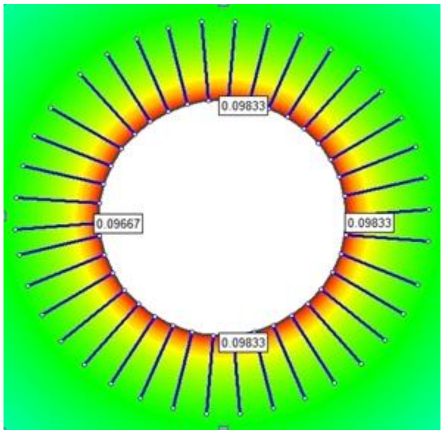

Figure 4. Tunnel displacement amounts with rockbolts that 20 KN pretensioned

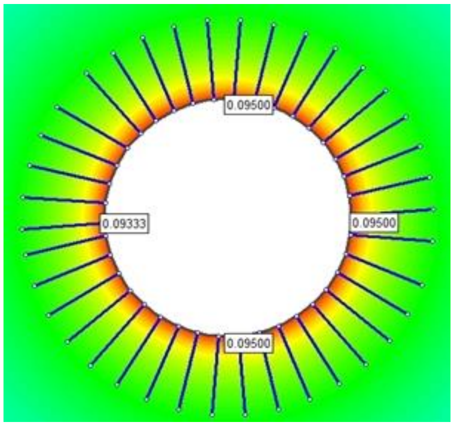

Figure 5. Tunnel displacement amounts with rockbolts that 40 KN pretensioned

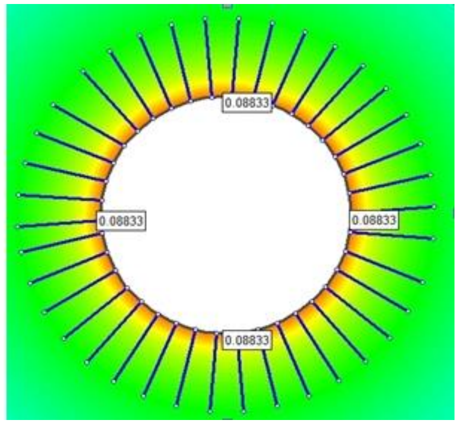

Figure 6. Tunnel displacement amounts with rockbolts that 80 KN pretensioned

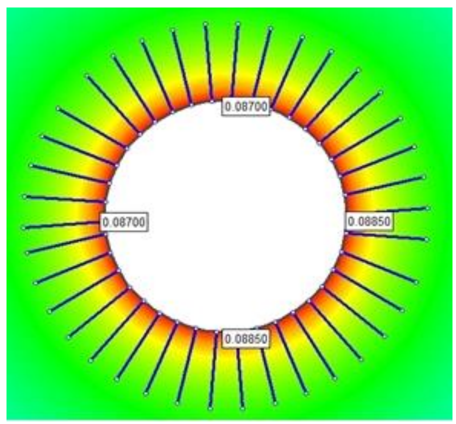

Figure 7. Tunnel displacement amounts with rockbolts that 90 KN pretensioned

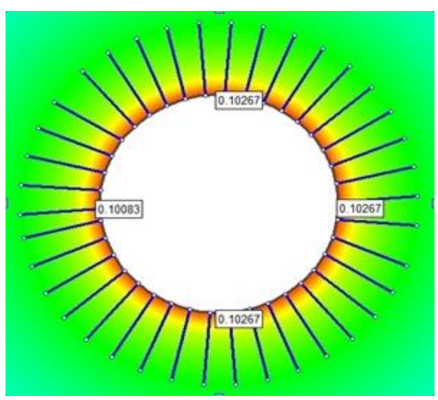

Figure 8. Tunnel displacement amounts with rockbolts that 100 KN pretensioned

In this paper different rockbolt length, spacing and diameter are chosen. The diameter chosen for tunnels are 8, 10, 12, 14 and 16 m. Some of the displacement results in roof of circlular tunnels are shown in the diagrams.

As it can be seen by increasing the pretensioning force the displacements reduce. This decresion continuous until a special force and afterwards the effect fades away (Figure 9). The 90KN is the optimum pretensioning force. This process is approximately same in all model types. It is obvious that by increasing the tunnel diameter the tunnel displacements increase.

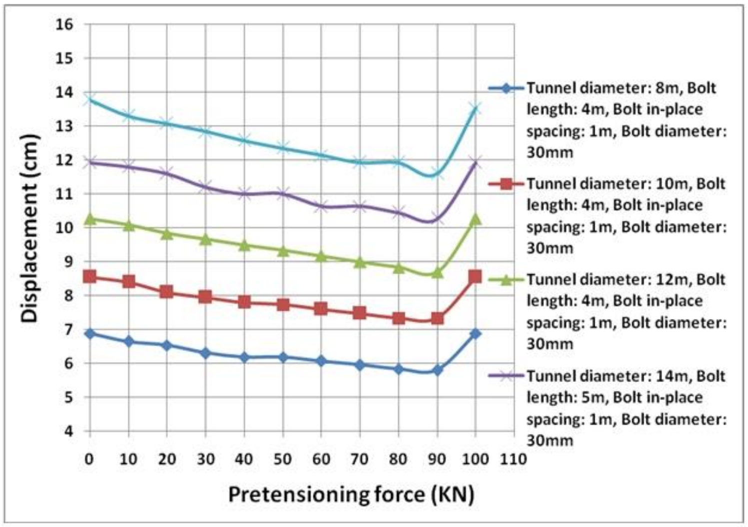

Figure 9. Diagram of displacement variations in the roof of circular tunnels according to increased pretensioning force (rockbolt length: 4 and 5m, rockbolt diameter: 30mm and rockbolt spacing: 1m)

In Figure 10 the rockbolt length is increased. The results indicate that increasing the rockbolts length, the displacements decreases in the roof of tunnels. In fact by increasing rockbolt length, the pretensioning effect increases.

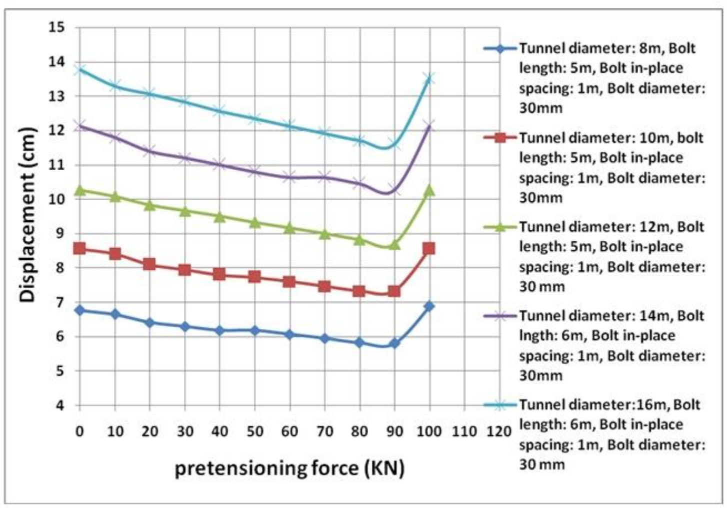

Figure 10. Diagram of displacement variations in the roof of circular tunnels according to increased pretensioning force (rockbolt length: 5 and 6m, rockbolt diameter: 30mm and rockbolt spacing: 1m)

CONCULSION

The technique In this paper the effect of pretensioning on rockbolt and displacement around circle tunnels are evaluated. The analyzing results are as the followings:

- By increasing the tunnel diameter the displacement around it and the effect of pretensioning rockbolts increase.
- By applying the pretensioning force on rockbolts, the displacement around the tunnels decreases until 90 KN and afterwards, it increases and the effect of pretensioning fades away.
- By increasing the length of pretensioning of rockbolts, the displacement reduction rate around the tunnel increases.

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