Journal of Novel Applied Sciences
Available online at www.jnasci.org
©2014 JNAS Journal-2014-3-1/84-88
ISSN 2322-5149 ©2014 JNAS

The effect of spacing and diameter of pretensioned rockbolts on the displacement around tunnels

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ABSTRACT: Rockbolts are support systems which increase the strength properties of rock masses. Nowadays rockbolts are vastly used in underground structures. For this reason a good design of the support system so that it can prepare an acceptable safety, is of great importance. In this paperthe effect spacing and diameter of pretensioningrockbolts on 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 parameters were analysed. The tunnels in this research were analysed by Phase2 software and with a two-dimensional plane strain assumption. The obtain results show that by increasing spacingof rockbolts, the reduction rate of displacements around the tunnels decreases. Furthermore with decreasing the diameter of rockbolts, the pretensioning effect increases.

Keywords: Tunnel, Rock bolts, Pretensioning, Displacement.

INTRODUCTION

Excavating underground structures in rock, causes stress changes in the underground environment and this phenomenan can cause displacements in these areas. Also the displacements caused by excavation may cause induced stress on the support system of the tunnels and finally can end in unstability of the tunnel surrounding area and will increase the plastic zone. Ground characterization and ground behavior evaluation are introductory steps in tunnel design. For a realistic evalution reflecting specific ground and site conditions, reasonable ground models and evalution tools are essential(Solak, 2009). Evaluating the underground excavation stability and specifying the cover has its own set of problems. Because soil and rock which cover the tunnels have complex structure, and no mathematical diagram can demonstrate their behavior.According to complex design and analysis of the tunnels, using simple methods for evaluating the interaction of soil and structure seems to be necessary to estimate the cover.

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-qiangand 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.

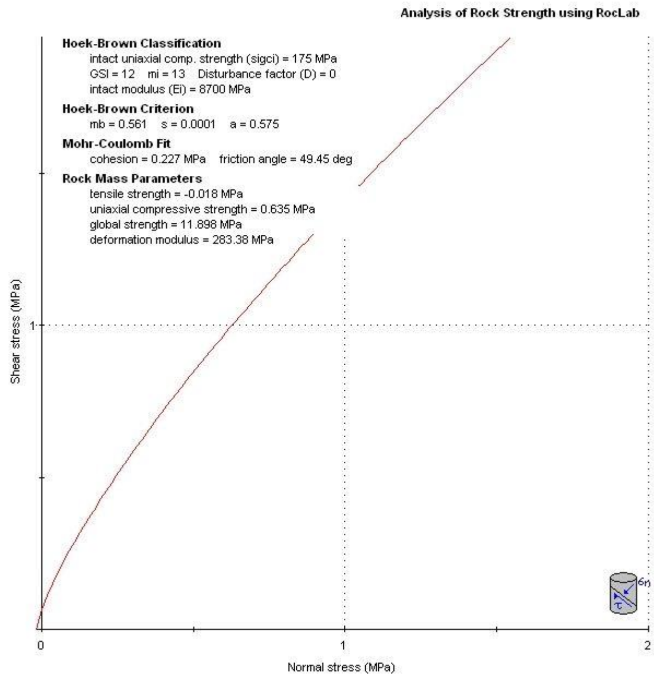

Figure 1. Rock mass parameters

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). As the excavations are all deep, the stress induced in the program is hydrostatic. The support system is also attached to tunnel walls. The rock bolts are used in spacing 1 and 2 m and with length 4 and 5 m and diameter 20 and 30 cm.

In this research the rockboltswhich are located around the tunnel with the mentioned specifications are changed to prestressedrockbolts and their results are evaluated. So at first the tunnel is analysed without pretensioning the rockbolts, then after each level the prestress is increased up to 10KN. Afterwards all the phases are repeated for different tunnel models with different rockbolts. For example in Figure 2 a general model of a tunnel with diameter of 12m, rockbolts with length of 4 m and spacing 1m is shown.

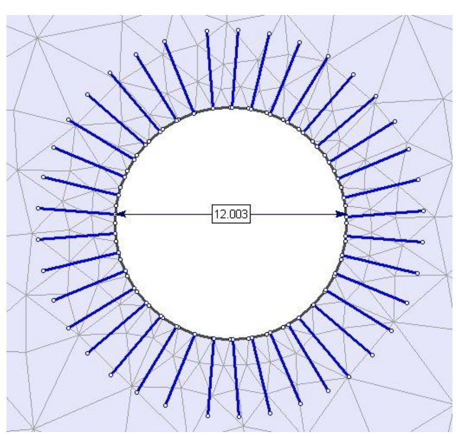

Figure 2. The model for a tunnel with 12m diameter (rockbolt length: 4 m, rockbolt diameter: 30mm and rockbolt spacing: 1m)

Diagram of displacement variations in the roof of circular tunnels (Figure 3) show that by increasing of pretensioning force, displacements in the roof of tunnels decrease until 90 KN and afterwards increases . By dicreasing diameter of rockbolts from 30 mm to 20 mm, the displacement around of tunnels slightly decrease and the optimum pretensioning force increases to 100 KN (Figure 4).

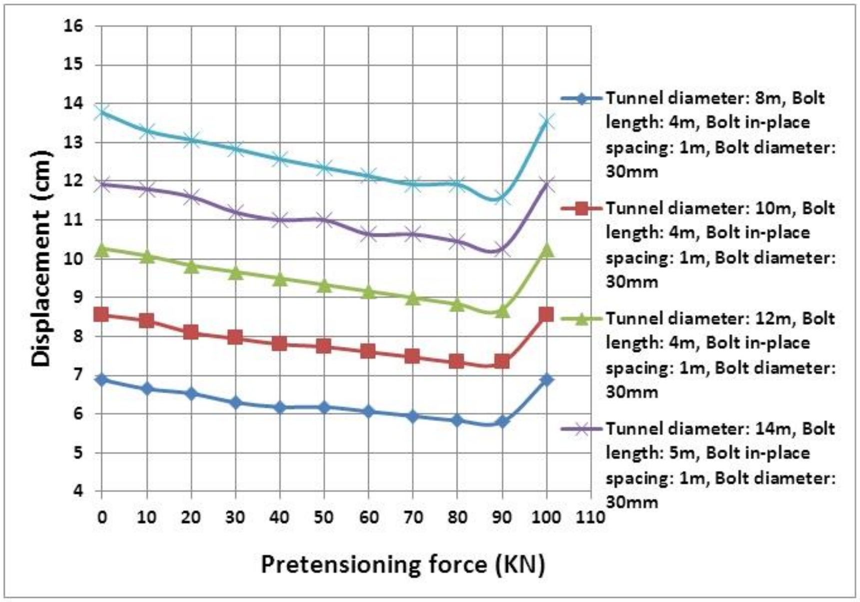

Figure 3. Diagram of displacement variations in the roof of circular tunnels according to increased pretensioning force (rockbolt length: 4 and 5 m, rockbolt diameter: 30mm and rockbolt spacing: 1m)

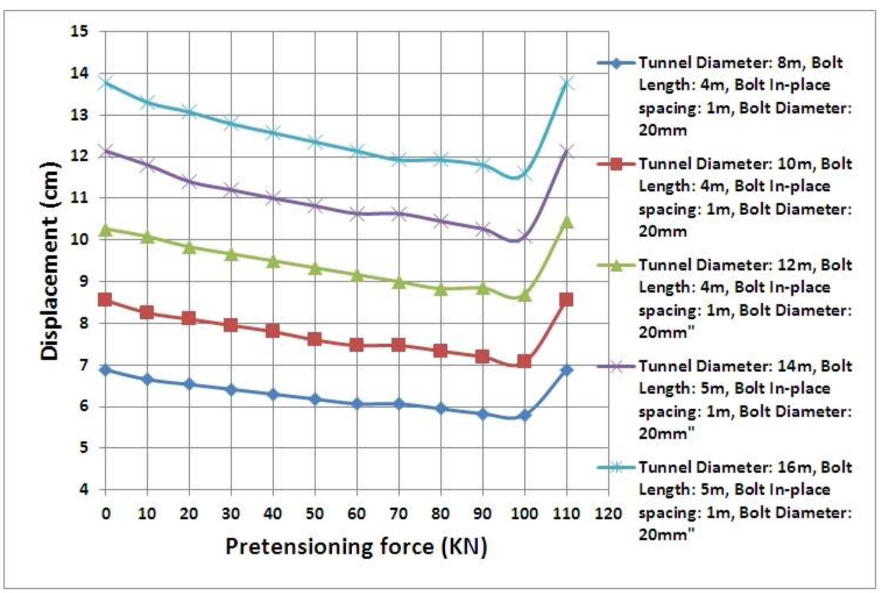

Figure 4. Diagram of displacement variations in the roof of circular tunnels according to increased pretensioning force (rockbolt length: 4 and 5m, rockbolt diameter: 20mm and rockbolt spacing: 1m)

In Figure5 a general model of a tunnel with diameter of 12m, rockbolts with length of 4 m and spacing of 2m is shown.

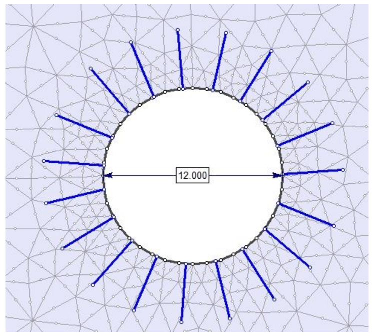

Figure 5. The model for a tunnel with 12m diameter (rockbolt length: 4 m, rockbolt diameter: 30mm and rockbolt spacing: 2m)

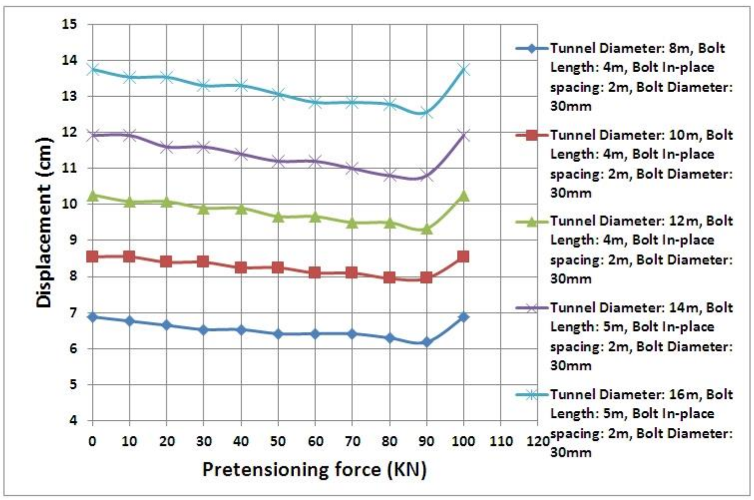

Figure 6. Diagram of displacement variations in the roof of circular tunnels according to increased pretensioning force (rockbolt length: 4 and 5 m, rockbolt diameter: 30mm and rockbolt spacing: 2m)

Diagram of displacement variations in the roof of circular tunnels (Figure 6) show that by increasing of pretensioning force, the rate of decreasing of displacements in the roof of tunnels decrease than rockbolt spacing of 1 m. By dicreasing diameter of rockbolts from 30 mm to 20 mm, the displacement around tunnels slightly decrease and the optimum pretensioning force increases to 100 KN (Figure 4).

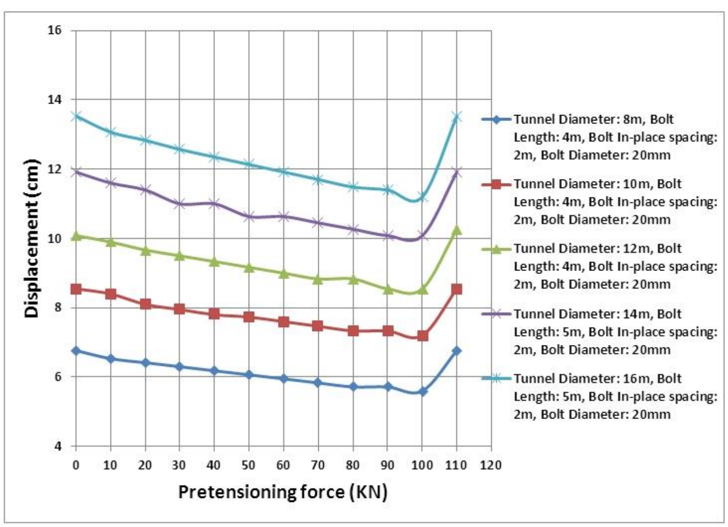

Figure 7. Diagram of displacement variations in the roof of circular tunnels according to increased pretensioning force (rockbolt length: 4 and 5 m, rockbolt diameter: 20mm and rockbolt spacing: 2m)

CONCULSION

In this paper the effect of spacing and diameter of pretensionedrockbolts on the displacement around tunnels are evaluated.The analyzing results are as the followings:

- By increasing the rockboltspacing, the reduction rate of displacements around the tunneldecreases.
- The effect of rockbolts diameter on displacements is negligible, but generaly it can be said that with decreasing the diameter of rockbolts, the pretensioning effect increases.
- The effect of pretensioning of rockbolts in tunnels with different diameter is all the same.

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