THE EFFECT OF SLIDING GAPS ON THE LINING OF TUNNELS

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ABSTRACT

Tunneling in squeezing rocks presents some special challenges to the geotechnical engineer because in these rocks it is often necessary to install support as close as possible to the tunnel face to ensure the safety of the workers. If linings are installed before much deformation has occurred, these supports will be subjected to very large stresses as the tunnel deforms and the supports may fail. The sliding gaps can be added to the steel sets. These gaps allow the lining to easily deform and an amount of deformation occurs and therefore is not subjected to very high stresses. The effect of the sliding gaps on the lining of tunnels was analyzed by means of modeling the circular tunnels in shale rocks using the finite element program Phase2. The sliding gaps are allowed to undergo about 4 percent of circumferential strain. The results of the evaluations show that using the steel sets with sliding gap, the displacement and yielded elements around tunnels somewhat has been reduced while the axial force of steel sets largely has been decreased.

KEYWORDS

Sliding gaps; Circular tunnel; Lining; Steel sets

1. INTRODUCTION

The strength of squeezing rocks is generally very low and failures can easily be induced by excavation of tunnels. Large deformations of rocks around tunnels are often encountered during excavations in rocks with squeezing characteristics. Hoek and Marinos (2000) have discussed the characterization of weak rock masses, the estimation of strength and deformation specifications and the analysis of squeezing problems in weak rock tunnels. According to Barla (1995), squeezing around the tunnel may stop the construction process or it may prolong for a significant amount of time.

It is difficult to estimate ground movement and tunnel support pressures in squeezing rocks. Many researchers used to measure ground deformations around tunnels to determine ground, squeezing and contact pressures (Phien-Wej and Cording, 1991; Panet, 1996; Steiner, 1996).

The factors such as the rock mass characteristics, in situ stress conditions, groundwater conditions, excavation and lining installation sequence, relative stiffness between the lining and the ground around tunnel, influence on the ground deformation and the loads on the support system in squeezing rocks. Ignoring these factors in squeezing rocks may greatly delay the construction program. When designing a support system in squeezing rocks, time dependent deformations should be highly considered because a large amount of deformation and contact pressure may take place with them (Shalabi, 2005).

In squeezing rocks it is often necessary to install support as close as possible to the tunnel face to ensure the safety of the workers. If the linings are installed before much deformation has occurred, these spots will be subjected to very large stresses as the tunnel deforms and the supports may fail. The steel sheets with sliding gaps allow a squeezing tunnel to contract with little resistance until the gaps to be closed. After the gap closes, the steel set ring locks and axial load can be transmitted through the lining. These gaps allow linings to be installed close to an advancing tunnel face without overloading the lining.

This paper attempts to evaluate the effects of circular steel set lining which includes sliding gaps and undergo about 4 percent of circumferential strain. These steel sets are installed in circular tunnels with different diameters excavated in shale rocks and is compared with steel sets without sliding gaps.

2. The Physical And Mechanical Characteristics Of The Shale Rocks

The physical and mechanical properties of the shale rocks are determined from cores obtained of boreholes in Hamro tunnel in Iran. The specific gravity of these rocks is equal to 2.65 and the minimum and maximum of UCS varies from 31 to 35 MPa, respectively, and the average value is equal to 33 MPa.

The rock mass properties such as the rock mass, strength (σ_{cm}), the rock mass deformation modulus (Em) and the rock mass constants (MB, s and a) were calculated by the RocLab program defined by (Hoek et al., 2002) (Fig. 1). This program has been developed to provide a convenient means of solving and plotting the equations presented by (Hoek et al., 2002).

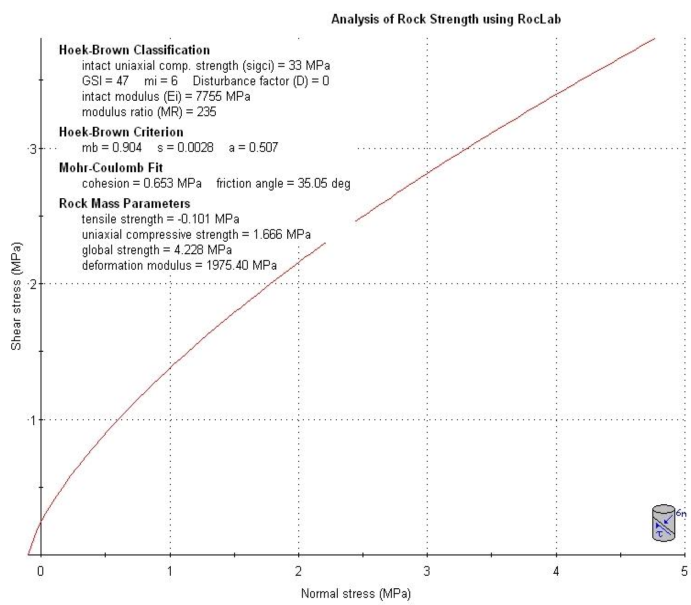
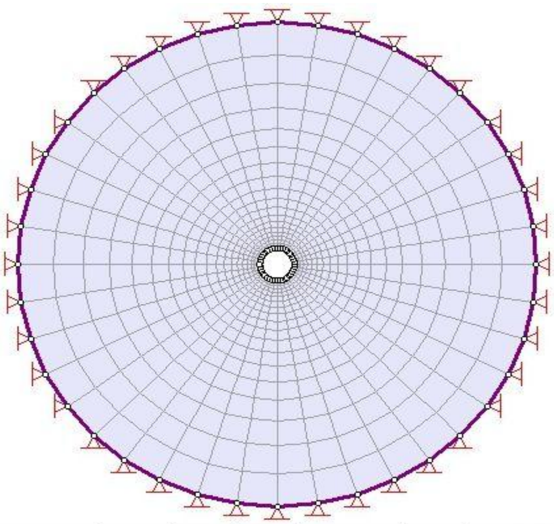


Fig. 1. Geomechanical parameters of shale rocks

In RocLab program, both the rock mass, strength and deformation modulus were calculated using equations of (Hoek et al., 2002). In addition, the rock mass constants were estimated using equations of the Geological Strength Index (GSI) (Hoek et al., 2002) together with the value of the shale material constant (me). Also, the value of disturbance factor (D) that depends on the amount of disturbance in the rock mass associated with the method of excavation, was considered zero for the shale rocks, it means these rocks would not be disturbed more than this during blasting.

3. The Circular Tunnels Modeling

For the modeling of tunnels in shale rock masses a finite element model for circular tunnels with diameters of 2, 4, 6, 8, 10 and 12 meters are used. The external boundary of models is located in distance 7 times of tunnel radius and radial meshes with 4 nodes are used in finite element meshing (Fig. 2).



Material Name	Elastic Type	Young's Modulus (MPa)	Poisson's Ratio	Failure Criterion	Material Type	Intact Compressive Strength (MPa)
Shale	Isotropic	1975.4	0.3	Generalized Hoek-Brown	Plastic	33

Fig. 2. The modeling of circular tunnel with diameter of 2 m

Numerical analysis of sliding gaps in the lining of tunnels includes analysis of displacement and number of yielding elements around tunnels and also the values of axial force in the lining of tunnels. These analyses are accomplished for 3 modes: no lining, lining without sliding gaps and lining with sliding gaps.

4. Numerical Analysis Of Sliding Gaps In Circular Tunnels

This analysis about the tunnel with a diameter of 2 m is as follows:

4.1. Modeling of tunnel in the case of no lining

In this case, the maximum of radial displacement around the tunnel is equal to 0.162 m (Fig. 3) And displacement in different excavation phases is shown in Fig. 4. Furthermore, the number of yields elements exhibiting extent of plastic zone around the tunnel is equal to 358 points.

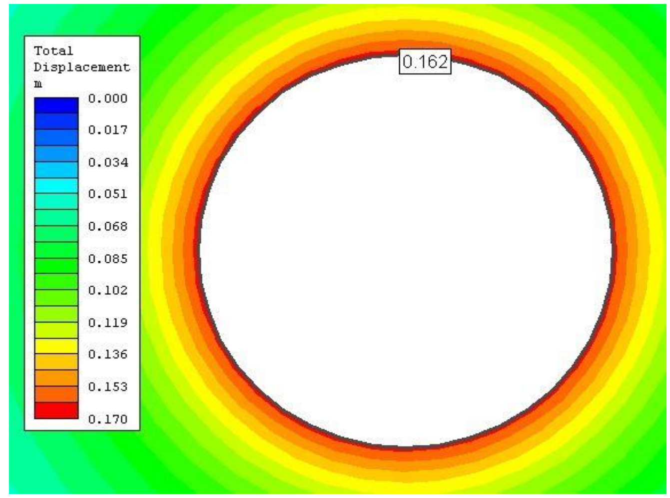


Fig. 3. The maximum of radial displacement around the tunnel in the case of without lining

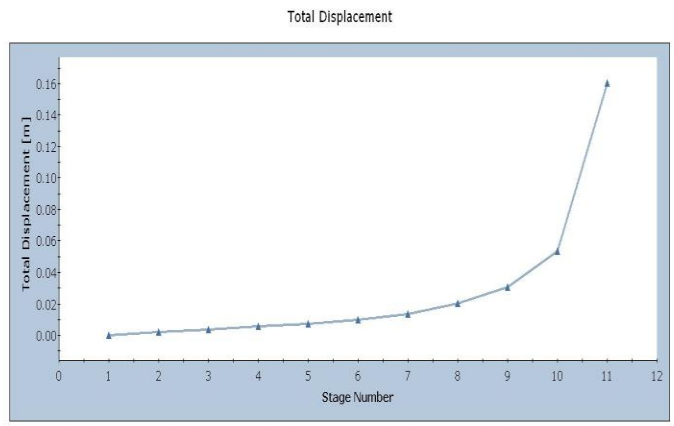


Fig. 4. The diagram of displacement around tunnel in various stages of excavation in the case of without lining

4.2. Modeling of tunnel in the case of lining without sliding gaps

In this case, a lining composed of steel set with Young's modulus of 3133 Mpa and Poisson's ratio of 0.2 and a thickness of 0.25 m is installed in the fifth stage of excavation. This lining is without sliding gaps and is constructed from integrated beam. In this case, the maximum of radial displacement around the tunnel is equal to 0.018 m (Fig. 5) And displacement in various stages of excavation is shown in Fig. 6. The number of yielding points is equal to 159 that show a considerable reduction of plastic zone around the tunnel. Furthermore, the maximum axial force in lining is equal to 9.995 MN (Fig. 7).

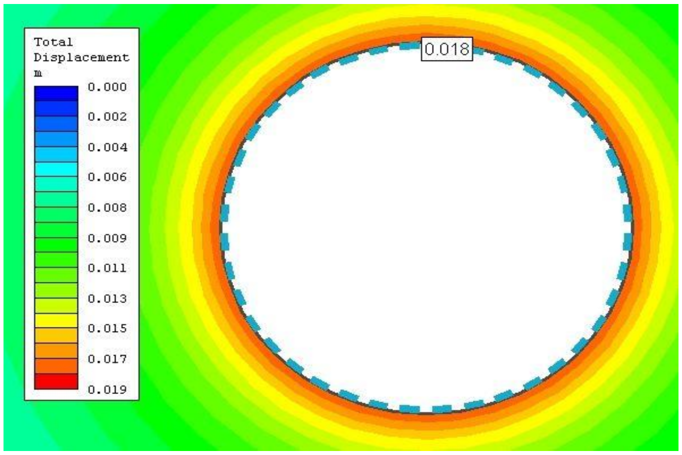


Fig. 5. The maximum of radial displacement around the tunnel in the case of lining without sliding gaps

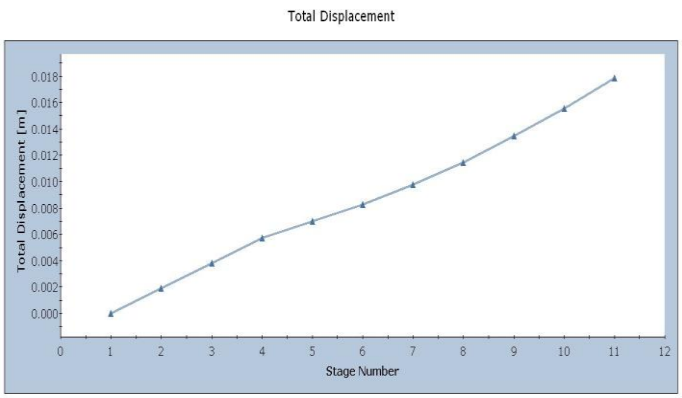


Fig. 6. The diagram of displacement around tunnel in various stages of excavation in the case of lining without sliding gaps

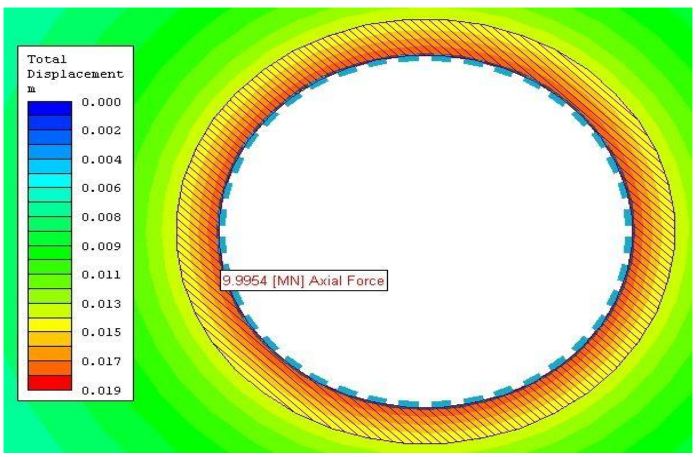


Fig. 7. The maximum axial force in lining in the case of lining without sliding gaps

4.3. Modeling of tunnel in the case of lining with sliding gaps

In this case, the lining with formerly characteristics is installed in the fifth stage of excavation with the difference that the steel set have sliding gaps which enable to undergo about 4 percent of circumferential strain. The maximum of radial displacement around the tunnel is equal to 0.057 m (Fig. 8) And displacement in various stages of excavation is shown in Fig. 9. The maximum of radial displacement relation to the case of without sliding gap somewhat has increased due to deformation of lining in sliding gaps. The number of yielded points in this case is equal to 262 that showing a slight increase in plastic zone around the tunnel. The maximum axial force in lining is equal to 2.833 MN (Fig. 10). In this case, the axial force in lining has decreased relation to mode of without sliding gaps which this is due to strain in sliding gaps. Table 1 summarizes key results for the 3 different cases for tunnel with a diameter of 2 m.

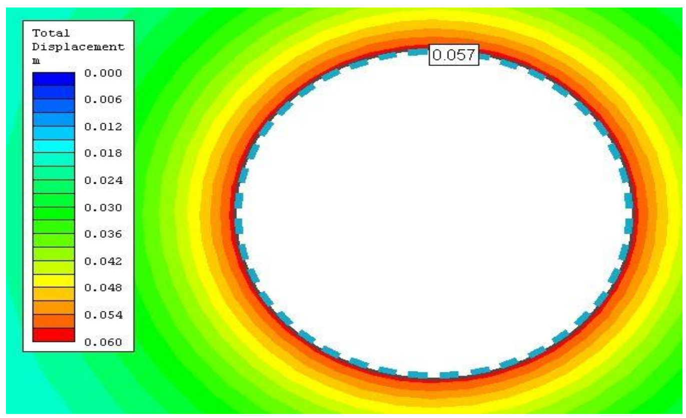


Fig. 8. The maximum of radial displacement around the tunnel in the case of lining with sliding gaps

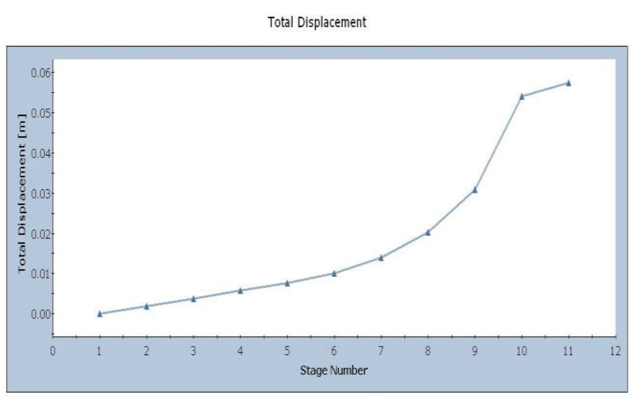


Fig. 9. The diagram of displacement around tunnel in various stages of excavation in the case of lining with sliding gaps

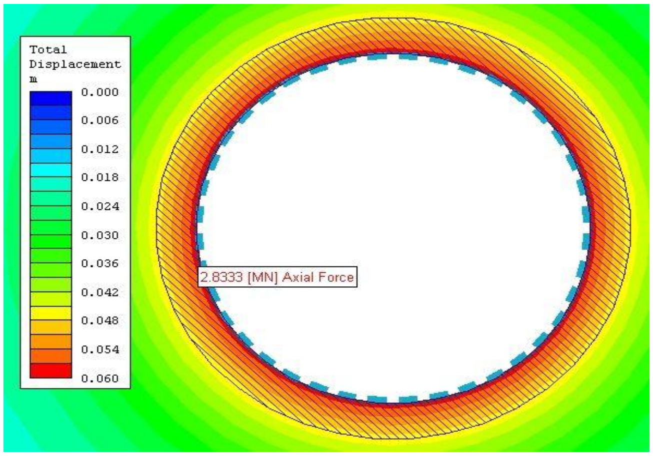


Fig. 10. The maximum axial force in lining in the case of lining with sliding gaps

Table 1. The obtained results for tunnel with a diameter of 2 m

Tunnel (Diameter of 2 m)	Maximum radial displacement (m)	Maximum axial force in lining (MN)	Number of yielded elements
No lining	0.162	n/a	358
Lining without sliding gaps	0.018	9.99	159
Lining with sliding gaps	0.057	2.83	262

The numerical analysis in the other tunnels is done similarly and the obtained results are shown in diagrams presented in Figs. 11 to 13.

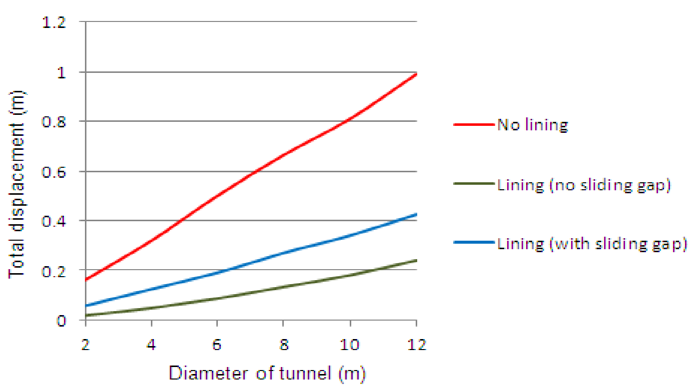


Fig. 11. The maximum radial displacement around circular tunnels with different diameters in the cases: no lining, lining without sliding gaps and lining with sliding gaps

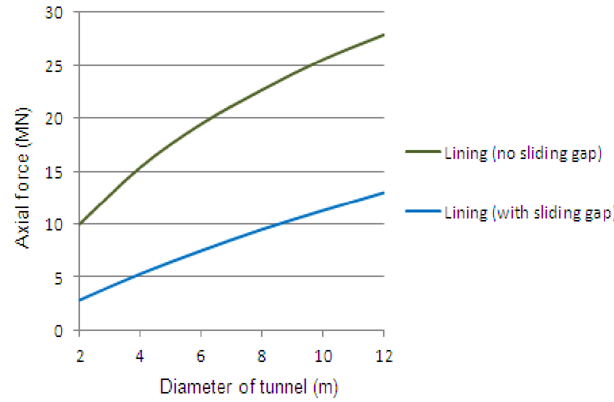


Fig. 12. The maximum axial force in lining in circular tunnels with different diameters in the cases: no lining, lining without sliding gaps and lining with sliding gaps

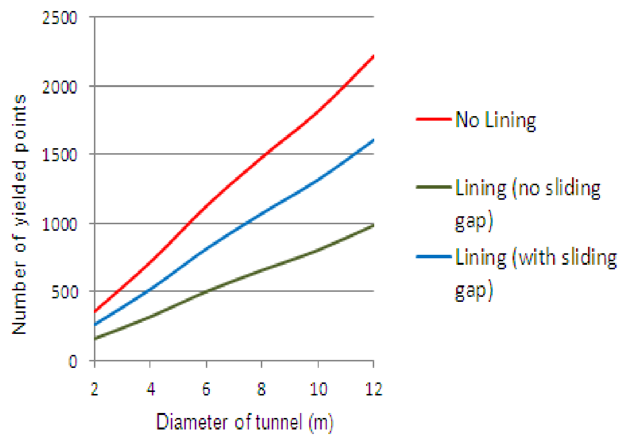


Fig. 13. The number of yielded points around circular tunnels with different diameters in the cases: no lining, lining without sliding gaps and lining with sliding gaps

The diagram in Fig. 11 shows the maximum displacement around of tunnels in 3 cases above mentioned. As the seen, in all tunnels with the installing of lining, the displacement around tunnels greatly has been decreased, but in the case of use the lining with sliding gaps, the displacement less has decreased. This suggests that lining with sliding gaps while controlling the convergence around tunnels, to the wall of the tunnel to allow some will be displaced and thereby the pressure on the lining will decrease. Therefore, the possibility installing lining near the advancing tunnel face in the squeezing rocks will be possible.

The diagram in Fig. 12 shows the maximum axial force in lining. As the seen, in all tunnels with installing of lining with sliding gaps, the axial force in lining has considerably decreased. This indicates that in the case of use lining with sliding gaps while controlling the convergence around tunnels, the axial force in lining has decreased and therefore, the possibility yielding it will reduce.

The diagram in Fig. 13 shows the number of yields points around of tunnels in 3 cases above mentioned. As the seen, in all tunnels with the installing of lining, the yielded elements around tunnels has been greatly decreased but in the case of use the lining with sliding gaps, the yielded elements less have decreased. This suggests that lining with sliding gaps allows some of induced stresses around tunnels release, but the releasing all of stresses prevent.

5. CONCLUSIONS

This study has investigated effect sliding gaps in the lining of tunnels. The sliding gaps play an important role in reducing axial forces in lining and in such way the possibility installing lining near the advancing tunnel face in the squeezing rocks will be possible. In this case, the following conclusions could be noted:

- In all tunnels installing of lining with sliding gaps cause the displacement and yielded elements around tunnels seem to be reduced.
- Installing of lining with sliding gaps in tunnels causes the axial forces in lining considerably to be decreased.
- The effect of sliding gaps in reducing loads on lining in tunnels with different diameters is nearly same.

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