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The Releasing Stress in Tunnels and Support Capacity Plots in the Other Tunnels

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Abstract- This paper presents numerical analysis of the effect of releasing stress in tunnels on the support capacity plots in the other tunnels by means of elasto-plastic finite element method. In numerical analysis, a 2D finite element program with software Phase2 in the shale rocks is utilized. First, the circular tunnel with different diameters is modeled and reinforced with lining. Then, a new tunnel is excavated at various distances from the first tunnel and the effect of new tunnel is investigated on the axial force of lining and support capacity of the old tunnel. The results of the evaluations show that by increasing the values of releasing stress in the new tunnel, the changes of axial force in the lining of old tunnel at the whole depths have increased. Furthermore, by increasing distance of tunnels, the changes of axial force of lining has somewhat increased and these changes are more in high level of releasing stress. By increasing the values of releasing stress in the new tunnel, the factor of safety of tunnel lining has decreased.

Keywords- *Releasing stress; Tunnel; Lining forces; Support capacity plots*

I. INTRODUCTION

The urban development requires the construction of new tunnels close to the existing ones. Because, the relative position of tunnels affects the internal forces in the lining, it is better to study the influence of tunnels on each other.

In tunnel design, the interaction between the support system and the rock surrounding the tunnel are studied (Panet and Guenot 1982; Panet 1995). One problem in tunnels design is the measurement and interpretation of stresses in the lining of tunnels, particularly when a new tunnel to be excavated in the vicinity of the old tunnel. In geo technic projects, different methods are used to calculate lining stresses (Nunes and Meguid 2009). Therefore, tunnel design requires a proper estimate of pressures on the tunnel lining. Tunneling may induce significant different magnitudes of deformation to the surrounding ground, resulting as well in different ground pressures on tunnel linings. For the design of the tunnel lining, the excavation and support sequence needs to be taken into consideration.

One method for define a factor of safety for tunnel design, is described by Kaiser (1985), and Sauer et al (1994) and it involves the use of support capacity diagrams. The support capacity diagrams are based on elastic analyses and is recognized that this method have a simplification compared to much more sophisticated non-linear models that are used in structural engineering. Furthermore, in developing the elastic support capacity diagrams, the aim is to provide the tunnel designer with a set of tools of comparable accuracy to the input data.

This paper attempts to evaluate the effect of releasing stress in tunnels on the support capacity plots in the shale rocks.

II. THE GEOMECHANICAL PROPERTIES OF THE SHALE ROCKS

The rock mass properties such as the rock mass strength (σcm), the rock mass deformation modulus (Em) and the rock mass constants (mb, s and a) are calculated by the Rock-Lab program defined by Hoek et al. (2002). This program has been developed to provide a convenient means of solving and plotting the equations presented by Hoek et al. (2002). The geomechanical parameters of shale rock masses is obtained and presented in Figure 1.

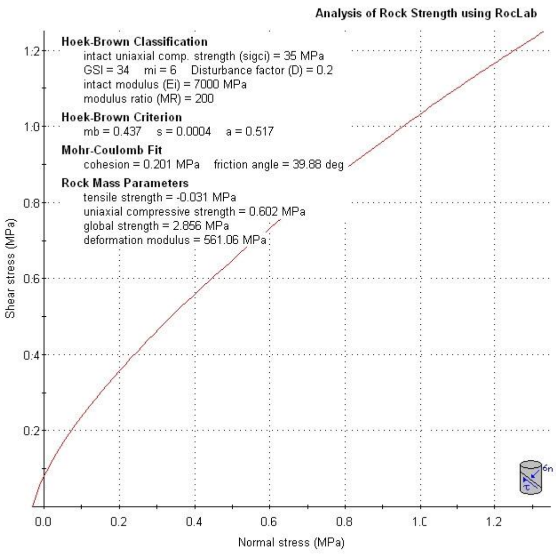

Figure 1. The geomechanical parameters of shale rock masses

III. NUMERICAL ANALYSIS OF RELEASING STRESS IN THE TUNNELS

Numerical analyses of the releasing stress in the circular tunnels are done 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. In this finite element simulation, based on the elasto-plastic analysis, deformations and stresses are computed. These analyses used for evaluations of the tunnel stability in the rock masses. The geomechanical properties for these analyses are extracted from Fig. 1. The generalized Hoek and Brown failure criterion is used to identify elements undergoing yielding and the displacements of the rock masses in the tunnel surrounding.

To simulate the excavation of tunnels in the shale rock masses, a finite element models is generated for the circular tunnel (old tunnel) with diameter of 8 meters that reinforced with lining (for example Fig. 2). The lining is composed of 20 cm shotcrete, reinforced with lattice girders. The outer model boundary is set on a scale of 100 and 200 meters and three-nodded triangular elements are used in the finite element mesh. The circular tunnel is modeled at depths of 10, 20, 30, 40 and 50 meters. By run of model, the value of axial force in the lining of tunnel is determined (for example Fig. 3).

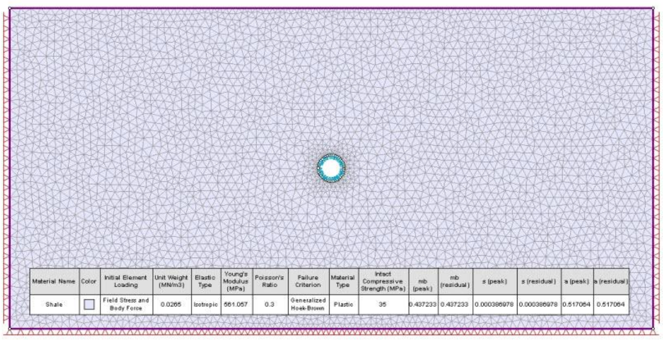

Figure 2. The modeling of circular tunnel with diameter of 8 meters and at a depth of 50 meters that reinforced with lining

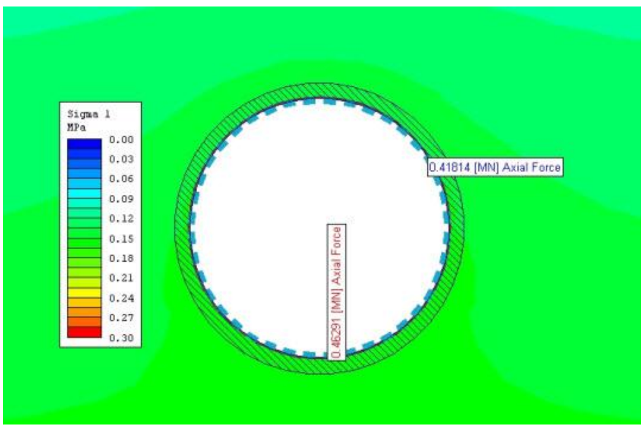

Figure 3. The values of axial force in the lining of circular tunnel with diameter of 8 meters and at a depth of 50 meters

Then, a circular tunnel with diameter of 8 meters (new tunnel) is modeled at distances of 20, 30, 40 and 50 meters from the previous tunnel (for example Fig. 4). The induced stresses in new tunnels are released with the value of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 percent and the effect of it is investigated on the lining forces of the old tunnel.

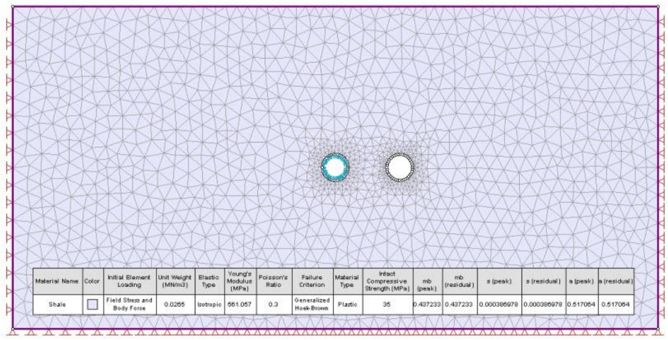

Figure 4. The modeling of a circular tunnel (new tunnel) with diameter of 8 meters at a distance of 20 meters from the previous tunnel

By run of models, the value of axial force in the lining of old tunnel is measured and the changes it is shown in Figs. 5 to 9.

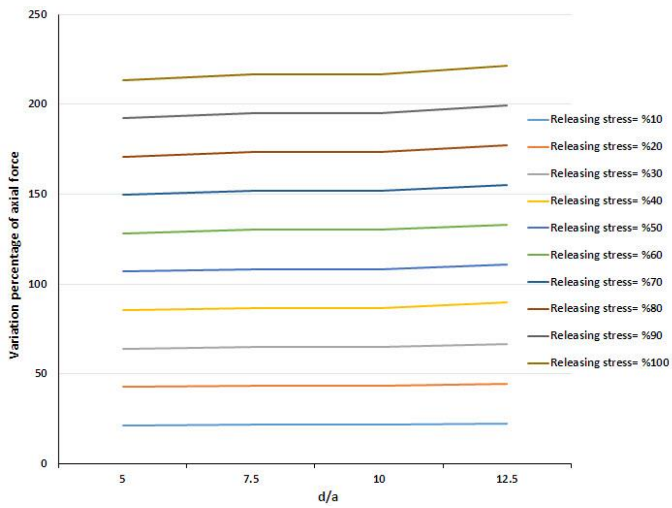

Figure 5. The diagram shows the effect of releasing stress in the new tunnel on the axial force of lining in the old tunnel at a depth of 10 meters (d=tunnels distance; a=tunnel radius)

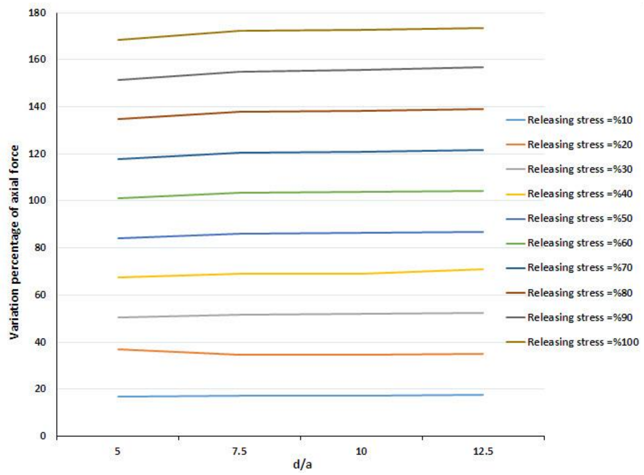

Figure 6. The diagram shows the effect of releasing stress in the new tunnel on the axial force of lining in the old tunnel at a depth of 20 meters (d=tunnels distance; a=tunnel radius)

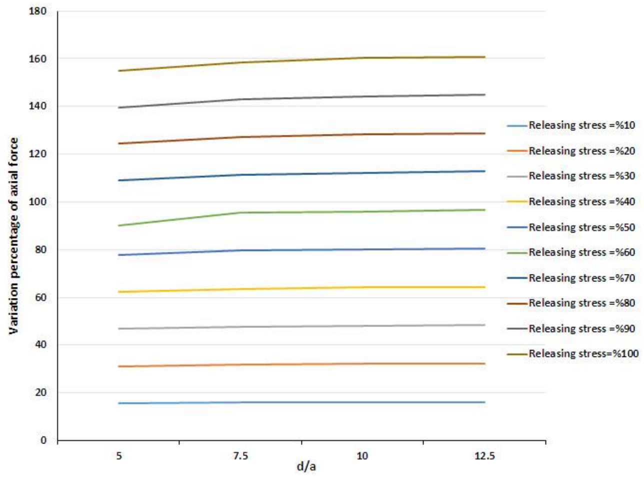

Figure 7. The diagram shows the effect of releasing stress in the new tunnel on the axial force of lining in the old tunnel at a depth of 30 meters (d=tunnels distance; a=tunnel radius)

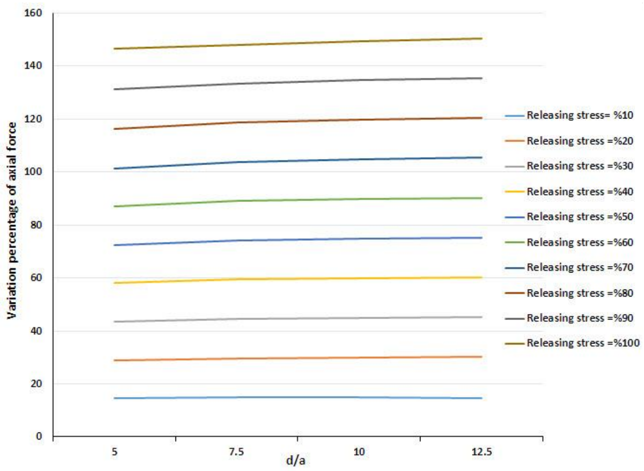

Figure 8. The diagram shows the effect of releasing stress in the new tunnel on the axial force of lining in the old tunnel at a depth of 40 meters (d=tunnels distance; a=tunnel radius)

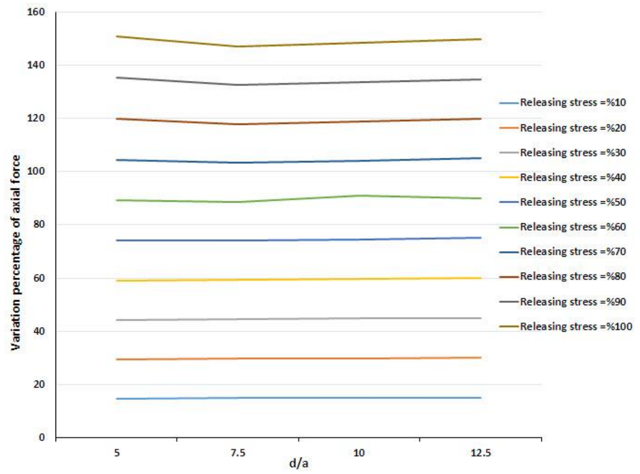

Figure 9. The diagram shows the effect of releasing stress in the new tunnel on the axial force of lining in the old tunnel at a depth of 50 meters (d=tunnels distance; a=tunnel radius)

As the above diagrams show, by increasing the values of releasing stress in the new tunnel, the changes of axial force in the lining of old tunnel at the whole depths have increased and the maximum of these changes is related to depth of 10 meters. Also, by increasing distance of tunnels, the changes of axial force of lining has somewhat increased and these changes are more in high level of releasing stress. Moreover, by increasing depth of tunnels, the changes of axial force of lining have decreased.

Now, the support capacity diagrams have been investigated for different values of releasing stress. The support capacity diagrams are based on elastic analysis of the support elements and this implies that no tensile cracking or compressive crushing of the lining elements is acceptable. These diagrams for depth of 10 meters and values of releasing stress of 10, 50 and 100 percent are shown in Figs. 10 to 12.

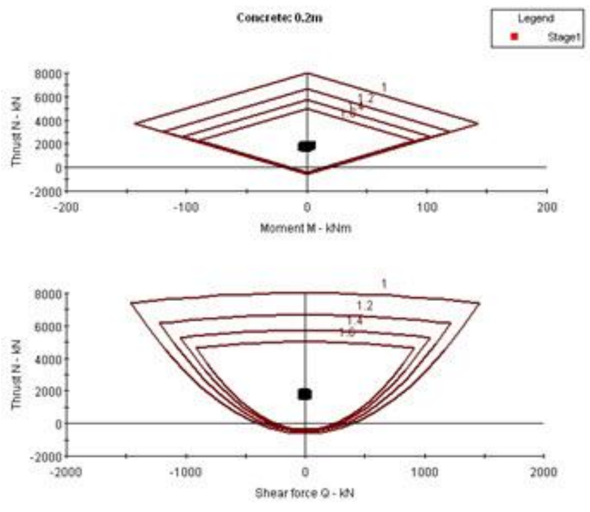

Figure 10. Support capacity diagrams for tunnel lining (releasing stress in adjacent tunnel is equal to 10 percent)

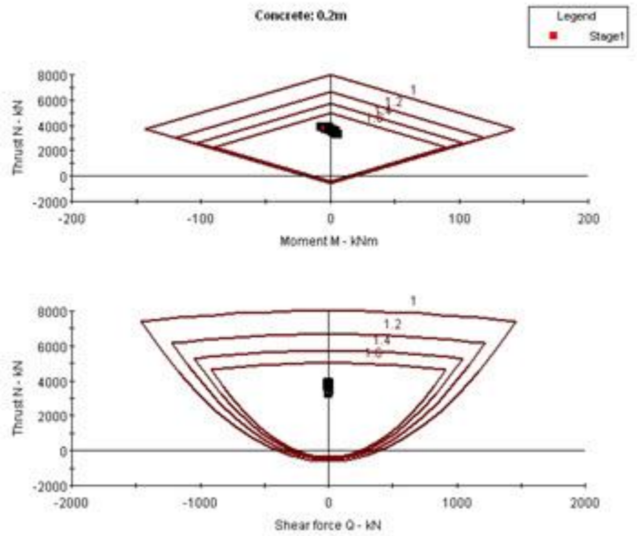

Figure 11. Support capacity diagrams for tunnel lining (releasing stress in adjacent tunnel is equal to 50 percent)

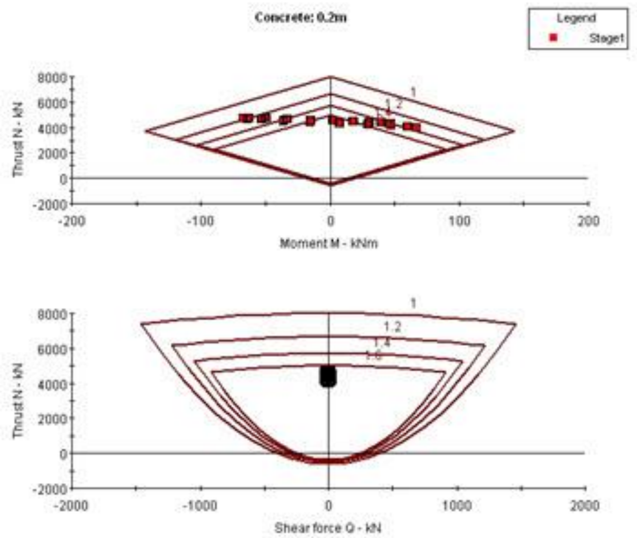

Figure 12. Support capacity diagrams for tunnel lining (releasing stress in adjacent tunnel is equal to 100 percent)

As the diagrams in Figs 10 to 12 shows, by increasing the values of releasing stress in the new tunnel, the factor of safety of tunnel lining has decreased so that by releasing stress of 100 percent, this factor for shotcrete is reached to less than 1.2. This implies that may be tensile cracking in the shotcrete section.

IV. CONCLUSIONS

This study provides an estimation of the effect of releasing stress in tunnels on the support capacity plots in the shale rocks. The following conclusions could be noted:

- By increasing the values of releasing stress in the new tunnel, the changes of axial force in the lining of old tunnel at the whole depths have increased.

- By increasing distance of tunnels, the changes of axial force of lining has somewhat increased and these changes are more in high level of releasing stress.

- By increasing depth of tunnels, the changes of axial force of lining have decreased.

- By increasing the values of releasing stress in the new tunnel, the factor of safety of tunnel lining has decreased.

REFERENCES

[1] E. Hoek and T. Brown, “Underground structures in rock”, Translated by Fahimifar-Ahmad, Technical Lab and Soil mechanics Publisher of Road and Transportation ministry,1998.

[2] E. Hoek and T. Brown, “Practical estimates of rock mass strength”. Int. J. Rock Mech. Min. Sci. 34 (8), 1165–1186, 1997.

[3] E. Hoek, C. Carranza-Torres and B. Corkum, “Hoek–Brown Failure Criterion—2002 Edition”. Rocscience, 2002.

[4] P.K. Kaiser, “Rational assessment of tunnel liner capacity”. Proc. 5th Canadian Tunnelling Conference. Montreal,1985.

[5] M.A. Nunes and M.A. Meguid, “A study on the effects of overlying soil strata on the stresses developing in a tunnel lining”, Tunnelling and Underground Space Technology (24), 716–722, 2009.

[6] M. Panet and A. Guenot, “Analysis of convergence behind the face of a tunnel”. Proceedings of the International Conference on Tunnelling, 197-204. Brighton: The Institution of Mining and Metallurgy,1982.

[7] M. Panet, “Le Calcul des Tunnels par la Méthode Convergence-Confinement”. Paris: Presses de l'École Nationale des Ponts et Chaussées. (in French), 1995.

[8] Rocscience, “A 2D finite element program for calculating stresses and estimating support around the underground excavations”. Geomechanics Software and Research. Rocscience Inc., Toronto, Ontario, Canada, 1999.

[9] G. Sauer, V. Gall, E. Bauer and P. Dietmaier, “Design of tunnel concrete linings using limit capacity curves”. in Computer Methods and Advances in Geomechanics, Eds.: Siriwardane & Zaman, Rotterdam, NL. 2621 – 2626, 1994.