Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 3159-0040
Vol. 2 Issue 10, October - 2015

The Bending Moment Changes Of Tunnel Lining Due To Karstification

Ashkan Rahmani[1*], Vahid Hosseinitoudeshki[2]

[1]Department of Civil Engineering, Zanjan Branch, Islamic Azad University, Zanjan, Iran
Corresponding e-mail address: ash.rahmani@yahoo.com

[2]Department of Civil Engineering, Zanjan Branch, Islamic Azad University, Zanjan, Iran
toudeshki@gmail.com

***Abstract*— Lining of tunnels in soluble rocks can create very problems to the geotechnical engineer. Therefore, it is necessary to examine some very basic concepts of how rock mass surrounding a tunnel behaves and how the lining acts to control these deformations. This study presents numerical analysis of the effect of karstification on the bending moment of lining in tunnels that formerly excavated in the limestone by means of elasto-plastic finite element method. The circular tunnels are modeled with diameter of 6, 8, 10, 12 and 14 meters and reinforced with lining. Then, the effect of circular and rhombus karsts is investigated on the bending moment of lining. The results of the evaluations show that by increasing distance of karsts from the tunnel, the bending moment changes of lining have decreased and the maximum of these changes has occurred by circular karstification at the bottom of tunnels.**

Keywords—Karstification; tunnel; Lining; Bending moment

1. INTRODUCTION

Bending moment is the reaction of a structural element when an external force is applied to the element causing the element to bend [1]. The internal reaction loads in a structural element can be resolved into a resultant force and a resulting couple. For equilibrium, the moment created by external forces must be balanced by the couple induced by the internal loads. The resulting internal couple is named the bending moment.

Soluble rock conditions are an important consideration in tunneling because of the numerous challenges in dealing with them. During the lifetime of tunnels, many failures happened as a result of the instability in the surrounding rock mass. All of these problems will generate considerations on the safety of the tunnel engineering [2]. Tunneling is associated with problems such as dissolution of the rock around the tunnel or karstification of them. Therefore, prediction of karstification and influence it on the lining of tunnels is considered as highly significant in the maintenance of tunnels.

The karstification is a result of the water erosion along the most open fractures under given tectonic conditions. The normal faults and the fissures are most favorable for the karst network evolution. The study of the mechanism of formation of fractures by [3, 4] shows which the vertical tensional and shear fractures and faults are formed as a result of residual elastic stresses during the post-tectonic uplifting of terrains. These structures can be formed only if horizontal tectonic extension exists.

The main purpose for this study is to investigate the effect of karstification on the bending moment of lining in tunnels that formerly excavated in the limestone.

2. GEOMECHANICAL PARAMETERS OF THE LIMESTONE

The study is related to the limestone with the following mechanical properties. The properties of rock mass including the strength of rock (σcm) deformation, modulus of rock (Em) and constants of rock (mb, s, a) have been calculated by Roclab software [5]. This software is provided by [6]. In this software constants are determined by means of geological strength index (GSI), the intact rock parameters (mi) 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 to Mohr-Coulomb and Hoek-Brown criterion. The results are shown in Table 1.

Table 1.Geomechanical properties of rock masses

Roclab program's input and output						
Hoek-Brown Classification				Hoek-Brown Criterion		
σ_{ci} (Mpa)	GSI	m_i	D	mb	s	a
Intact Uniaxial Compressive Strength	Pick GSI Value	Pick mi Value	Disturbance Factor			
75	44	8	0.2	0.867	0.0013	0.509
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	
0.529	48.40	-0.110	2.525	9.136	10519.41	

3. NUMERICAL ANALYSIS OF THE KARSTIFICATION AROUND TUNNELS

The numerical method using the computational code (phase2) has been applied in analyzing the sections of tunnel. Phase2 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.

The geomechanical properties for analyses of karstification around the tunnels are extracted from table1. 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 limestone rock masses, a finite element models is generated for circular tunnels with diameter of 6, 8, 10, 12 and 14 meters that reinforced with lining (for example Fig. 1). The outer model boundary is set at distances of 7 times the tunnel radius and six-nodded triangular elements are used in the finite element mesh.

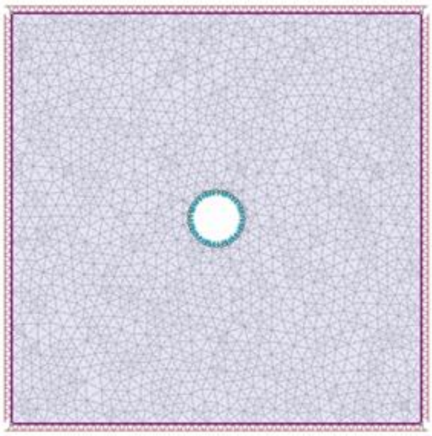

Fig. 1. The modeling of circular tunnel with diameter of 8 meters that reinforced with lining

By run of models, the value of bending moment in the lining is determined for each tunnel (for example Fig. 2). Then, the circular and rhombus karsts are modeled around tunnels (for example Figs. 3 and 4) and again the value of bending moment in the lining is measured and it changes is shown in Figs. 5 to 10.

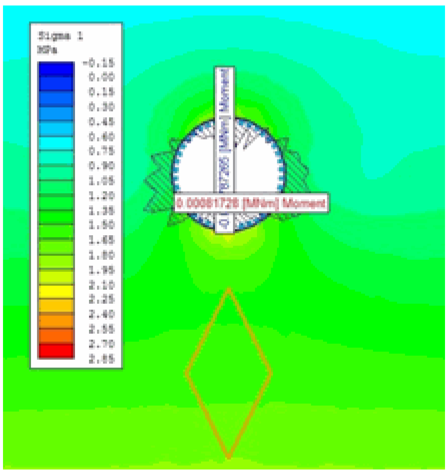

Fig. 2. The values of bending moment in the lining of circular tunnel with diameter of 8 meters

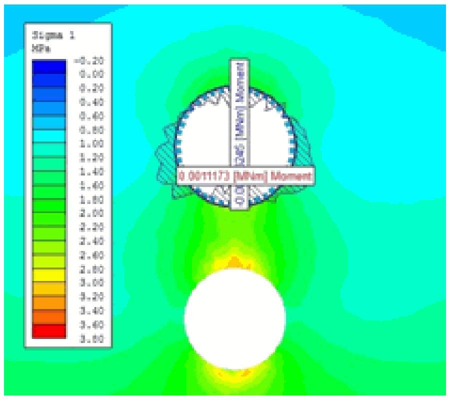

Fig. 3. The values of bending moment in the lining of circular tunnel with diameter of 8 meters in the case of circular karstification at the bottom of the tunnel

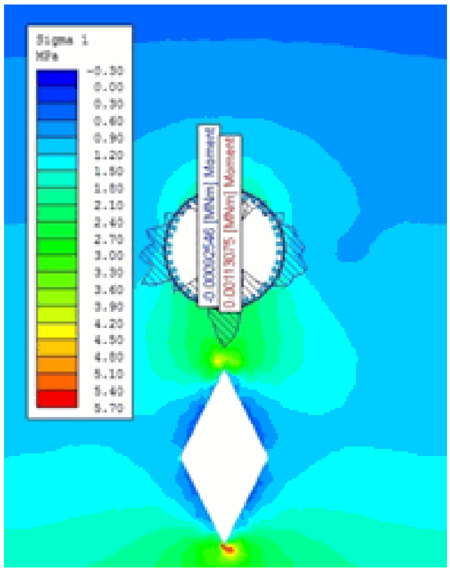

Fig. 4. The values of bending moment in the lining of circular tunnel with diameter of 8 meters in the case of rhombus karstification at the bottom of the tunnel

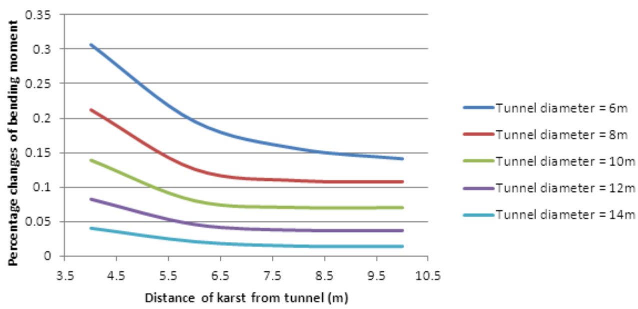

Fig. 5. The diagram shows the effect of circular karsts at the top of tunnels on the bending moment of lining

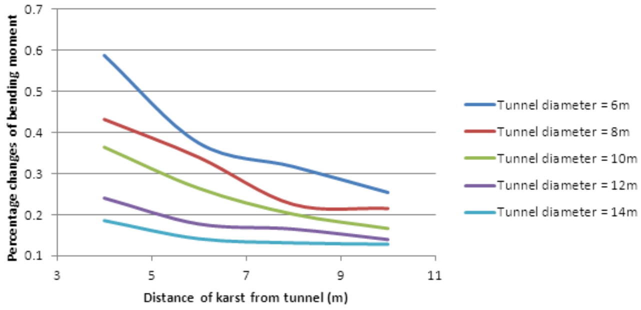

Fig. 6. The diagram shows the effect of circular karsts at the bottom of tunnels on the bending moment of lining

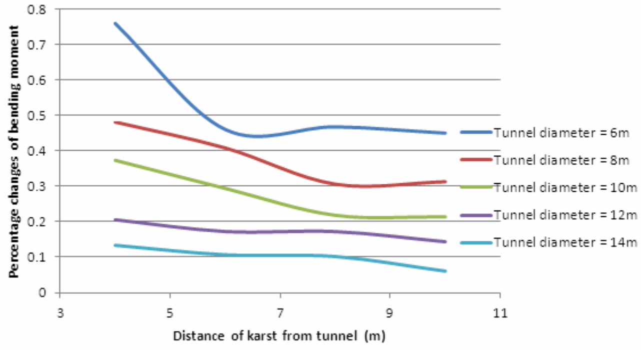

Fig. 7. The diagram shows the effect of circular karsts both at the top and bottom of tunnels on the bending moment of lining

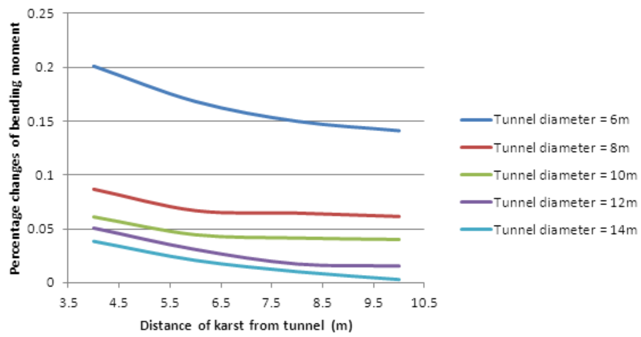

Fig. 8. The diagram shows the effect of rhombus karsts at the top of tunnels on the bending moment of lining

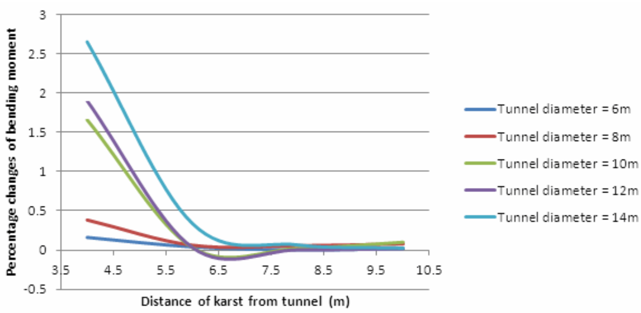

Fig. 9. The diagram shows the effect of rhombus karsts at the bottom of tunnels on the bending moment of lining

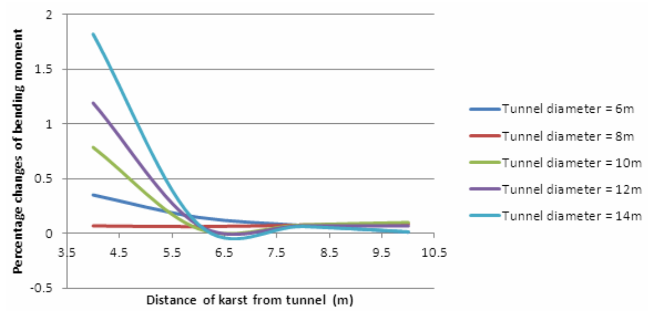

Fig. 10. The diagram shows the effect of rhombus karsts both at the top and bottom of tunnels on the bending moment of lining

As the above diagrams show, by increasing distance of karsts from the tunnel, the bending moment changes of lining have decreased so that, in distance of 10 meters from the tunnel, the changes is reached to the minimum value. Furthermore, by increasing diameter of tunnels, the ratio of the bending moment changes of lining due to karstification has reduced. The diagrams show that karsts form is effective on the bending moment of lining and the maximum bending moment changes of lining has occurred by circular karsts. Moreover, the karstification position relative to axis of tunnels is effective on the bending moment of lining and the maximum bending moment changes of lining has occurred by karstification at the bottom of tunnels.

4. CONCLUSION

This study provides an estimation of the effect of karstification on the bending moment of lining in tunnels that formerly excavated in the limestone. The following conclusions could be noted:

- By increasing distance of karsts from the tunnel, the bending moment changes of lining have decreased.
- By increasing diameter of tunnels, the ratio of the bending moment changes of lining due to karstification has reduced.
- By increasing the amount of karstification, the bending moment changes of lining have increased.
- The maximum bending moment changes of lining have occurred by circular karsts at the bottom of tunnels.
- The bending moment changes of lining due to karstification are less than that cause instability of lining.

REFERENCES

[1] J.M. Gere, and S.P. Timoshenko, “Mechanics of Materials” :Forth edition, Nelson Engineering, 1996.

[2] Y.Q. Wang, and Y.L. Xie, "The development and research of the arch tunnel in China, " Highway, 2008, 8, 216-219 (in Chinese).

[3] N.J. Price, "Mechanics of jointing in rocks," Geol. Mag. 1959, 96,149–167.

[4] N.J. Price, "Fault and joint development in brittle and semibrittle rock," Pergamon Press, Oxford, 1966.

[5] E. Hoek, C. Carranza-Torres, and B. Corkum, "Hoek–Brown Failure Criterion-2002 Edition," Rocscience, 2002.

[6] 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.