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The Effect of Seismic Load on the Displacement of Tunnel in the Jointed Rock Masses

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Abstrac: In this paper, the effect of seismic load on the displacement of tunnel excavated in the jointed rocks is surveyed. The numerical analysis has been performed in the case of static and quasi-static and the effects of increasing roughness joint coefficient (JCR) and joint compressive strength (JCS) on the displacement of tunnel is determined. This study used data from Tizhtizhgaran tunnel that have been excavated in the shale rocks. In this tunnel modeling, seven dips of joints analyzed using Phase 2 software and displacement diagrams are plotted on the sections of tunnel under static load and seismic loading. In addition, the effect of increasing joint compressive strength and dip of joints from 0 to 90 is evaluated on the joint roughness in around of tunnel. The obtained results showed that in both cases of the Static and quasi-static? the displacement around of the tunnel is increased with increasing dip of joints and in the mode of quasi-static, joints orientation play an important role in the displacement around of the tunnel. By increasing the joint roughness coefficient (JRC) of 0 to 15, the displacement in around of the tunnels is reduced and from15 to 20, the displacement in around of the tunnels increased. Furthermore, the Joints have weakened the rock mass and failure have occurred at the interface when the joint inclination is 15° to 70° with the major principal stress direction, whereas the failure have taken place in the intact rock when the inclination of joint is 0° or 90° with the major principal stress direction.

Key words: Quasi-static analysis · Joint roughness Coefficient (JRC) · Joint Compressive Strength (JCS) · Tunnel · Joint Dip

INTRODUCTION

Since structures such as tunnels, foundations and dams mainly constructed in the factual rock mass jointed and fractured, the mechanical properties of the rock mass must be accurately identified. The most important factor in reducing the strength and increasing the deformation properties of the rock mass is a joint. Therefore, joints can have a noticeable effect on the mechanical behavior of rock masses that it was observed in [1].

The factors such as roughness of joints, stretches, joints distance from each other, form filling and moisture are the important issues in classification of rock mass. And also the roughness of the joints (JRC), compressive strength (JCS) and dip of the joints are very important. One goal of this research is to survey the effects of joint roughness coefficient (JRC) and joint compressive strength (JCS) in tunnels in the static and quasi-static condition. The following is a summary of similar studies conducted by other investigators are listed:

The numerical study has dealt with compressive strength of the rock mass heterogeneity with several natural seams [2]. Joints have a significant effect on the cumulative strength of jointed rock masses. However seamless way that reduces the stability of the rock mass structure and properties of the rock mass will change. In this research, based on rock failure process analysis (RFPA), the evolutionary failure process is simulated of the rock mass with several natural seams. To simulate experiments of compressive strength of the rock mass in a large-scale, grid size used for modeling the elements with a size of 100 × 100 and 1000 × 1000 mm

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Table 1: Geomechanical properties of rock mass.

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 D	Hoek-Brown Criterion		
25	33	6	0.8	0.111	0.000039	0.518

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
0.086	27.38	-0.009	0.130	0.989	1127.30

respectively. The results of this study show that the number of natural joints in the rock mass increases, the compressive strength of jointed rock mass is reduced. In research conducted by [3] the effects of variable joints and seams along the direction parallel to the ultrasonic wave propagation in rocks is studied. For this purpose, experiments on prismatic samples of marble Dimensions 360 × 60 × 60, including seamless mode, 6 parallel seams and 6 variable seams have been studied. The wave propagation across fractured rock masses and the results [4] show that, under certain circumstances, transfer coefficient in failures will become larger.

Further research to determine the effects of cracks in rocks on wave transmission, which is an important parameter in solving problems related to earthquake engineering and seismic studies in a rock mass under dynamic loads, have been done that the results show the presence of any leaks or cracks in a rock, have a significantly influences in a seismic velocities in rocks and other rock properties, such as density, porosity, grain size and shape. To mention a few examples of this research [5], examined the relationship between sound speed and the number of joints on six different rock types and concluded that the values of the sound velocity with increasing number of joints is also reduced. The joint density effects on seismic velocities in the four types of rock [6] and have reached the conclusion that by increasing in density of the joints or cracks in the rock, wave speed will decreases.

MATERIALS AND METHODS

The numerical method using the phase2 software has been applied in analyzing the sections of tunnel. Phase 2 is a two - dimensional program which planned based on infinite elasto-plastic element that used for calculation the stresses and displacements around the underground excavations. In this paper tunnel which is used in order to numerical simulation includes Tizhtizhgaran tunnel that excavated in the jointed shale rock in depth of 41 m and diameter of 12 m in the northwest of Iran. Numerical analysis based on two dimensional analyzing and plane strain. The modeling has been with parallel joints in seven dips of joint (0, 15, 30, 45, 60, 75 and 90 degree). In addition, the values of JCS equal 5, 10, 15, 20, 25 and JRC equal 2, 5, 10, 15, 20 has been analyzed. Also in this study the model under quasi-static load with a horizontal acceleration of 0.3 g was done and the results are compared to the static case of this time.

Rock Mass in Tunnel Section: The study area is related to the jointed shale rock 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 [7]. In this software the strength of rock and deformation modulus are calculated by means of Hoek's equations. In addition, the constants are determined by means of geological strength index (GSI), the intact rock parameter (mi) and the disturbance factor (D) that associated with existing disturbance as a result of excavation. Finally, shear strength rock mass parameters (φ, c) are obtained with comparison Mohr-coulomb and Hoek - Brown criterion. The results are shown in Table 1 and Fig. 1.

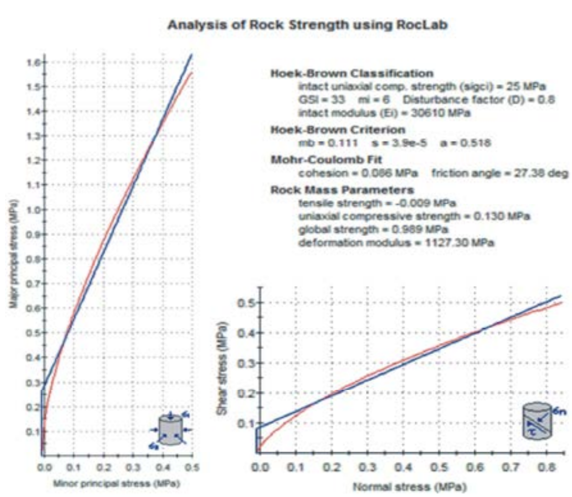

Fig. 1: Rock mass parameters.

RESULTS

According to the numerical analysis and the results obtained from diagrams in the tunnel, the effect of increasing dip of joints and also changes in roughness coefficient joints (JRC) and compressive strength joints are surveyed. Given the large number of diagrams obtained from analysis, in this study to clarify discussion the following charts are confining. The displacement diagrams in Figures 2,3,4,5 are for joints of tunnel roof at various angles. These graphs are results of the numerical analysis of tunnels in JCS equal to 10 and 15 and JRC equal to 2, 5, 10, 15 and 20 in the static and quasi-static conditions. With increasing dip of joints from 0 to 15 degree in the coefficients of different roughness the displacement is slightly reduced and for the dip of 15 to 30 degree, the displacement trendily is increased so the maximum displacement is occurred in the 30 degree dip of joints. From dip of 30 to 45 degree, the diagram moves downward so that the dip of 45 degree is caused the least amount of displacement in the tunnel. It can be said that if the orientation of joints is vertical or horizontal, the jointed rock mass behaves like a normal rock. This matter is truer in the dip of 90 degree. The trend of graphs in the static mode is the same with quasi-static mode and the displacement amount in quasi-static mode is more than static mode. Also by checking the graphs it specifies that the dip of joints has more changes in the quasi-static mode and they are exiting from the parallel mode (dip of joints 0 degree). So we can say that along the parallel joints, a wave moving in the rock will be easier and less attracted to rock but along non-parallel joints, a wave moving in the rock will be more attracted in the area of wave propagation and displacement increases.

Of the reasons for the increasing of displacement of joints is dilation that is created by the increasing of roughness coefficient (JRC) and compressive strength values (JCS). In order to create a necessary condition on the joint surface for generating dilation, first we should know that dilation occurs at low normal stresses and the existing normal stress (σn) should be lower than the shear normal stress of joint surface. Otherwise, if existing shear stress is higher than normal stress on the planar surfaces, the compressive strength continuously increases and the rock dilates. So because in higher roughness coefficients, the saw tooth surfaces become larger and rougher and with increasing the compressive strength, the saw-tooth stay intact and their strength against cracking decreases. Therefore, the only alternative for jointed rock mass is that at low normal stress acts as dilation (such as Figure 8) and increases the displacement.

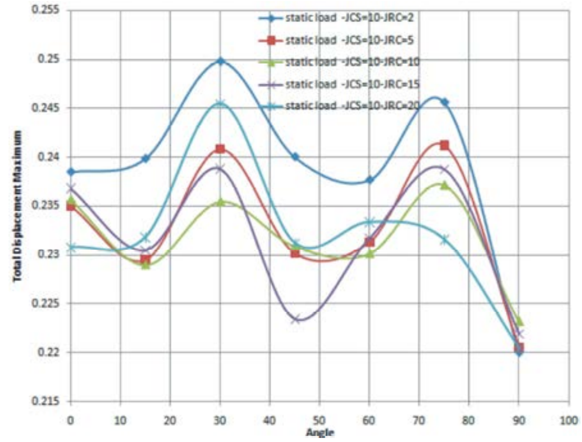

Fig. 2: Displacement diagram of tunnel roof in the dip of joint for static load JCS=10, JRC=2, 5, 10, 15, 20.

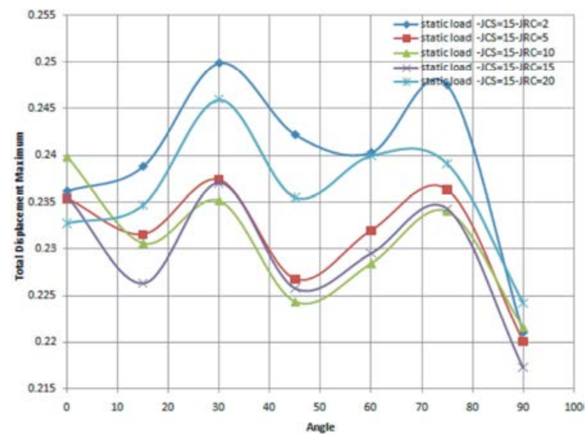

Fig. 3: Displacement diagram of tunnel roof in the dip of joint for static load JCS=15, JRC=2, 5, 10, 15, 20.

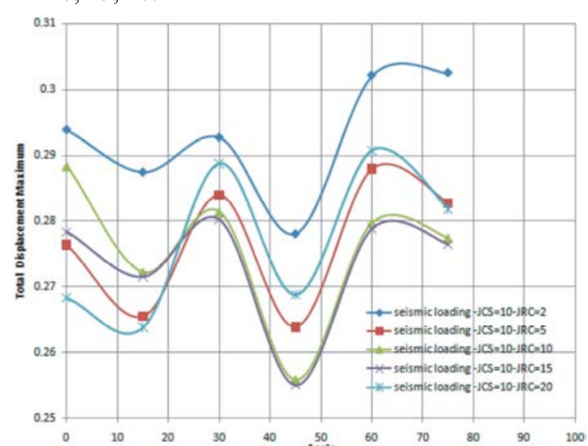

Fig. 4: Displacement diagram of tunnel roof in the dip of joint for seismic loading JCS=10, JRC=2, 5, 10, 15, 20

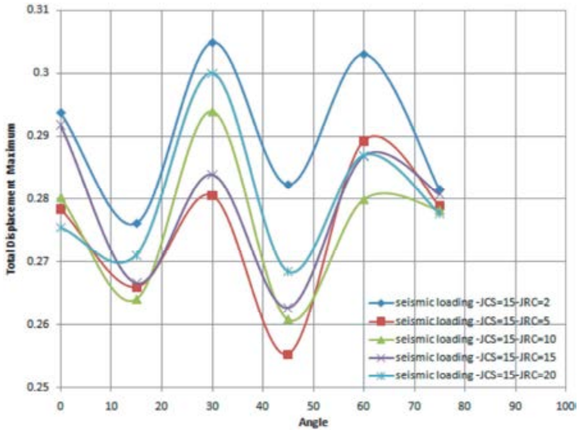

Fig. 5: Displacement diagram of tunnel roof in the dip of joint for seismic loading JCS=15, JRC=2, 5, 10, 15, 20.

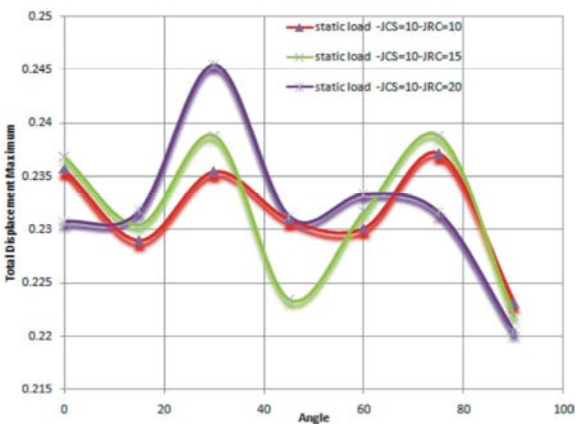

Fig. 6: Displacement diagram of tunnel roof in the dip of joint for seismic loading JCS=10, JRC=10, 15, 20.

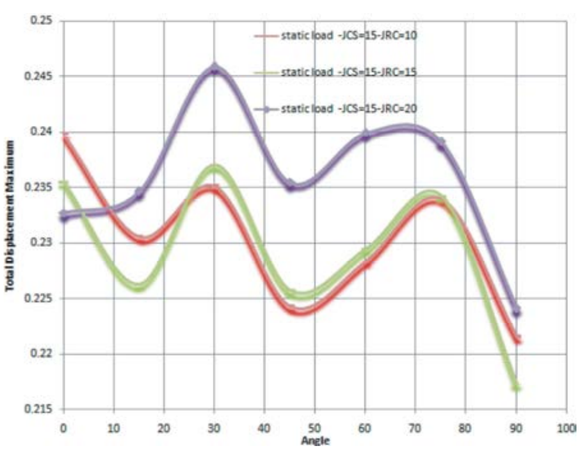

Fig. 7: Displacement diagram of tunnel roof in the dip of joint for seismic loading JCS=15, JRC=10, 15, 20.

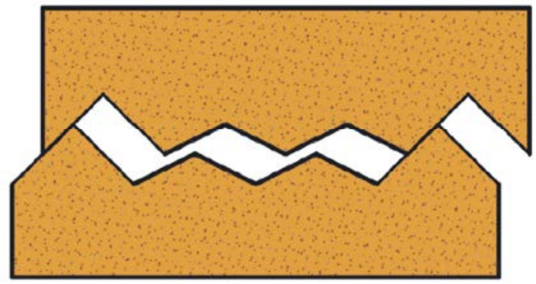

Fig. 8: Dilation and sliding of joints on each other and distancing the upper surface.

CONCLUSIONS

This study provides an estimation of the effect of joint roughness coefficient (JRC) and joint compressive strength (JCS) on the displacement in around of the tunnel in the mode of static and quasi-static. In this case, the following conclusions could be noted:

- In both cases the static and quasi-static, the displacement in around of the tunnel is increased with increasing dip of joints, the difference is that the increase in static mode is slower than the quasi-static.
- By increasing dip of joints from 0 to 90 degree, the JRC and JCS values have greater influence in displacement in around of the tunnel.
- In the case of quasi-static, joints orientation plays an important role in the displacement in around of the tunnel.
- In both cases the static and quasi-static, by increasing the joint roughness coefficient (JRC) from 0 to 15, the displacement in around of the tunnel is decreased and tunnel stability is increased.
- In both cases the static and quasi-static, by increasing the joint roughness coefficient (JRC) from 15 to 20, the displacement in around of the tunnel is increased and tunnel stability is decreased.
- If the joints orientation is vertical or horizontal, the jointed rock mass behaves like an intact rock.

The Joints have weakened the rock mass and failure have occurred at the interface when the joint inclination is 15° to 70° with the major principal stress direction, whereas the failure have taken place in the intact rock when the inclination of joint is 0° or 90° with the major principal stress direction.

REFERENCES

1. Hosseinitoudeshki, V., A.A. Vosoughikargazloo, M.H. Noori Gheidari and H. Sarveram, 2012. Influences of Crushed Fault Zone in the Stability of Zaker-Sorkhedizaj tunnel, NW Iran, Middle-East Journal of Scientific Research, 12(10): 1426-1434.
2. Han, F. and C. Tang, 2010. Numerical investigation for anisotropy of compressive strength of rock mass with multiple natural joints, J. Coal Sci. & Engin. 16: 246-248.
3. Kurtulus, C., M. Uckardes, U. Sari and S.O. Guner, 2012. Experimental studies in wave propagation across a jointed rock mass, Bull. Eng. Geol. Environ., 71: 231-234.
4. Zhao, X.B., J. Zhao, J.G. Cai and A.M. Hefny, 2008. UDEC modelling on wave propagation across fractured rock masses. Comput. & Geotech., 35: 97-104.
5. Kahraman, S., 2001. A correlation between P-wave velocity, number of joints and Schmidt hammer rebound number bit, J. Rock Mech. Min. Sci., 38: 729-773.
6. Altindag, R. and A. Guney, 2005. Evaluation of the relationships between P-wave velocity (VP) and joint density. The 19th International Mining Congress and Fair of Turkey, IMCET 2005, Izmit, Turkey.
7. Rocscience, 2002. Roclab user's guide. Rocscience Inc. Toronto, Ontario, Canada.