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The effect of joint roughness coefficient (JRC) and joint compressive strength (JCS) on the axial force of rock bolts

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ABSTRACT: In this paper, the effect of joint roughness coefficient (JRC) and joint compressive strength (JCS) on the axial force of rock bolts are investigated. For this purpose, the rock slopes with different dips namely 30, 45, 60, and 75 degrees in jointed schist rocks are modeled using the Phase2 software. The joint pattern is parallel deterministic and in order to stabilizing slopes, the rock bolts with length of 7 meters and spacing of 25 meters are installed on the slopes. For different values of JRC and JCS, the axial force of rock bolts is measured and the obtained data are analyzed. The results show that by increasing dip of slopes, the axial force of rock bolts has been increased and in most slopes, the minimum axial force is related to JRC of 10 to 15. Furthermore, the maximum effect of JCS on the axial force of rock bolts is obtained for high value of JRC.

Keywords: Joint roughness Coefficient (JRC); Joint Compressive Strength (JCS); Axial force; Rock bolt.

INTRODUCTION

The joints in rock masses have an important role in the stability of the rock slopes and the stability of the slope is always of superior importance during the lifetime of the structures such as highways, railroads and power plants (Aydan , 1989). The undulations and asperities on a natural joint surface have a significant influence on its shear behaviour. Bartton studied the behaviour of natural rock joints and proposed that equation (1) could be rewritten as:

(1)

$$\tau = \sigma_n \tan\left[\phi_b + JRC \log_{10}\left(\frac{JCS}{\sigma_n}\right) \right]$$

Where JRC is the joint roughness coefficient and JCS is the joint wall compressive strength. Bartton and choubey (1977) provided the first non–linear strength criterion for rock joints on the basis of their direct shear test results for 130 samples of variably weathered rock joints (equation 2).

$$\tau = \sigma_n \tan\left[\phi_r + JRC \log_{10}\left(\frac{JCS}{\sigma_n}\right) \right] \quad (2)$$

Where ϕ_r is the residual friction angle.

The jointed and highly anisotropic rock masses in the underground construction have studied by Singh and Singh (2007). It has been shown in this study that the ratio of lateral to axial strain may be very high, especially, if the joints are critically oriented. The assumption of isotropic linearly elastic material is not applicable in such situations. This observation is based on the outcome of an extensive laboratory testing program, in which a large number of specimens of a jointed rock mass with various joint configurations were tested under uniaxial loading conditions. The trends of experimental results for both lateral strain ratio and rock mass strength have also been verified through distinct element modeling. The reason for high lateral strains has been attributed to the creation of voids and also to the fact that permanent deformations due to slip commence along rock joints right from the start to loading process. A simple mechanistic model has been suggested to explain the high values of lateral strain for rough and dilatant rock joints.

Du (2011) have studied the comparison between empirical estimation and direct shear test to measure the joint shear strength in rock. Comparison results show that for natural rock joints with joint surfaces closely matched, the average relative error of joint shear strength between empirical estimation and direct shear test is 9.9 percent. However, for natural rock joints surfaces with joint surface mismatched, the average relative error of joint shear strength between empirical estimation and direct shear test is 39.9 percent.

One of the ways to stabilizing of rock slopes is application of rock bolts. A rock bolt is a long anchor bolt, for stabilizing rock excavations, which may be used in rock slopes. It transfers load from the unstable exterior to the confined interior of the rock mass. The rock bolts are almost always installed in a pattern, the design of which depends on the rock quality designation and the type of excavation (Gale , 2004). Rock bolts work by knitting the rock mass together sufficiently before it can move enough to loosen and fail by unravelling. The rock bolts can become seized throughout their length by small shears in the rock mass, so they are not fully dependent on their pull-out strength.

In this Research in order to study the effect of joint roughness coefficient (JRC) and joint compressive strength (JCS) on the axial force of rock bolts, the slopes with different dips composed of schist rocks were modeled.

Geomechanical parameters of schist rocks

In this study, the geomechanical parameters of the jointed schist were obtained using Roclab software (Hoek 2002). These parameters are obtained based on The Hoek-Brown failure criterion and it is presented in Fig. 1.

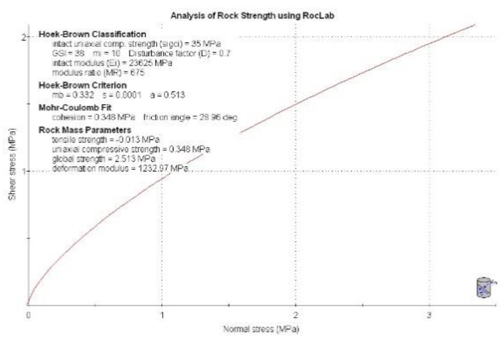

Figure 1. The geomechanical parameters of schist rocks

Modeling of rock slopes

To study the effect of joint roughness coefficient (JRC) and joint compressive strength (JCS) on the axial force of rock bolts, the slopes in different dips such as 30, 45, 60, and 75 are modeled (Fig. 2) by Phase2 software (Rocscience, 1999). In the models, the pattern of parallel deterministic joints is used in spacing of 10 meters, with the values JRC of 0, 5, 10, 15 and 20 and the values JCS of 1, 5, 10, 15, 20, 25, 30 and 35 Mpa. Moreover, the length of rock bolts and the distance of their places are selected equal to 7 meters and 25 meters, respectively. By run the made models, the axial force of rock bolts is obtained (for example, as Fig. 3).

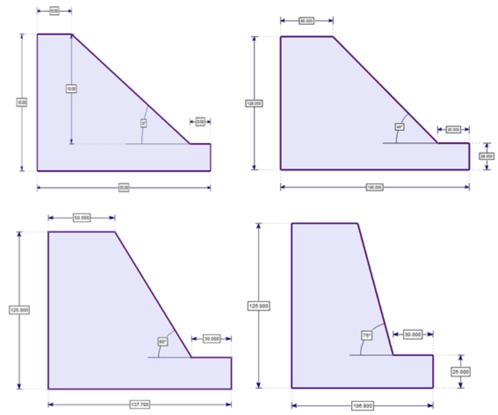

Figure 2. The slopes size modeled by Phase2 software

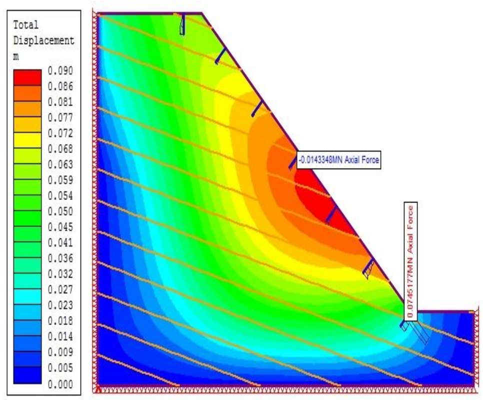

Figure 3. The axial force of rock bolts in the slope of 45 degrees that contains joints with dip of 30 degrees and JRC of 0 and JCS of 1Mpa

Similarly, the axial force of rock bolts for other slopes and also for other values of JRC and JCS are obtained and presented in Figs. 4 to 7.

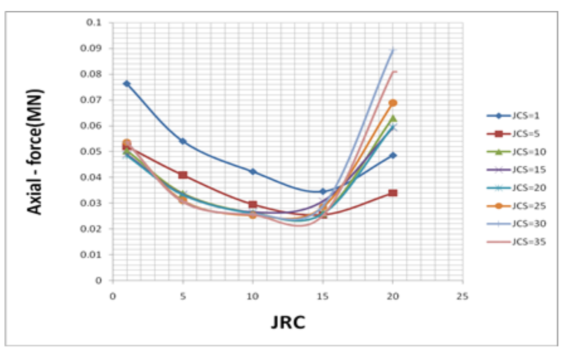

Figure 4. The diagram shows the axial force of rock bolts for the slope with dip of 30 degrees that contains joints with dip of 30 degrees

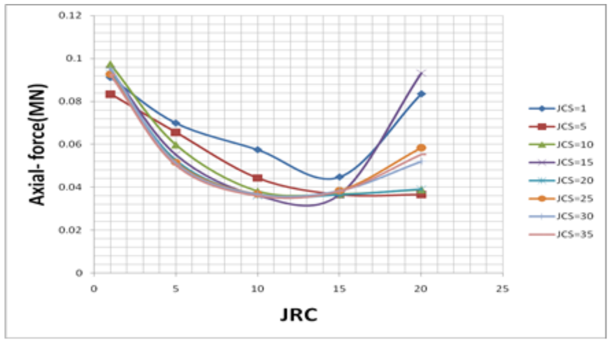

Figure 5. The diagram shows the axial force of rock bolts for the slope with dip of 45 degrees that contains joints with dip of 30 degrees

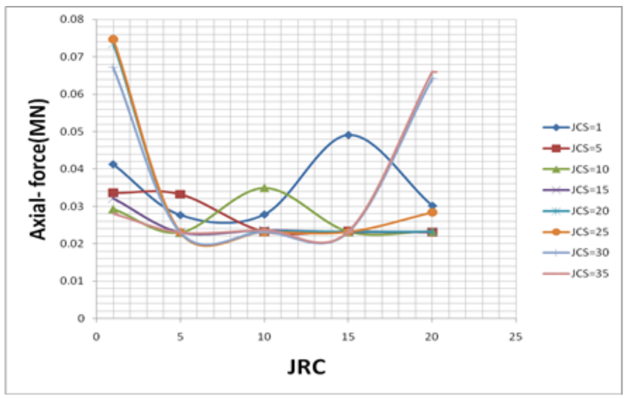

Figure 6. The diagram shows the axial force of rock bolts for the slope with dip of 60 degrees that contains joints with dip of 30 degrees

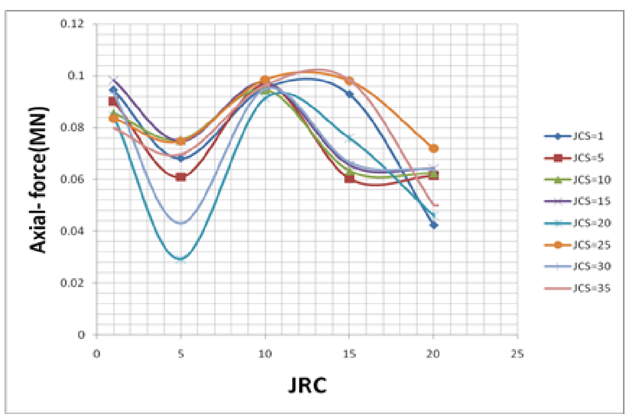

Figure 7. The diagram shows the axial force of rock bolts for the slope with dip of 75 degrees that contains joints with dip of 30 degrees

The diagrams in Figs. 4 to 7 show an increase in the axial force of rock bolts by increasing dip of slopes. The reason of increasing the axial force of rock bolts by an increase in dip of slopes is that by enhancing the dip of slopes, the state of stresses in the slopes has changed and gravity force is caused further instability of slopes. This issue is resulted in a bigger axial force of rock bolts. Moreover, the above diagrams show that when the values of JRC increases from 0 to 5, trend of the axial force is completely descending so that, the axial force of rock bolts in all slopes has decreased. This descending trend has continued for the values of JRC of 5 to 15 in the slopes with dips of 30 and 45 degrees, but this trend has changed in the slopes with dips of 60 and 75 degrees. However, the minimum axial force of rock bolts in the most of slopes is obtained in JRC of 10 to15.

In the JRC of 15 to 20, trend of the axial force is completely ascending and the axial force of rock bolts in all slopes has increased. Furthermore, the maximum effect of JCS on the axial force of rock bolts is obtained for high value of JRC. Dilation of joints is one of the reasons for the increasing of the axial force of rock bolts as the value of joint roughness coefficient (JRC) and joint compressive strength JCS) increases. In lower roughness coefficient, the compressive strength has greater role in the stability of joints and the axial force of rock bolts has decreased. In higher roughness coefficient, the compressive strength has greater role in the dilation of joint surfaces and the axial force of rock bolts has increased.

CONCLUSION

In this research that with aim to analysis the effect of joint roughness coefficient (JRC) and joint compressive strength (JCS) on the axial force of rock bolts is done the following results are obtained:

- In all slopes, by increasing dip of slopes, the axial force of rock bolts has been increased.
- The maximum axial force of rock bolts in each slope is obtained for JRC of 15 to 20.
- In most slopes, the minimum axial force of rock bolts is related to JRC of 10 to 15.

The maximum effect of JCS on the axial force of rock bolts is obtained for high value of JRC.

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