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The effect of dip of joints on the axial force of rock bolts

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ABSTRACT: In this paper, the effect of dip of joints in rock slopes on the axial force of rock bolts is investigated. For this purpose, the rock slopes with dip of 45 degrees in jointed schist rocks are modeled using the Phase2 software. The joint pattern is parallel deterministic and dips of joints is considered equal to 15, 30, 45, 60 and 75 degrees. In order to stabilizing slopes, the rock bolts with length of 7 meters and spacing of 25 meters are installed on the slopes. For each of joint dip, the axial force of rock bolts for different values of JRC and JCS is measured and the obtained data are analyzed. The results show that dip of joints has a significant effect on axial force of rock bolts. In low values of JRC, the axial force of rock bolts has decreased by increasing dip of joints and when dip of joints with dip of slope is the same, the minimum axial force of rock bolts is obtained for all values of JRC and JCS.

***Keywords*:** Axial force, Rock bolt, Dip of Joint, Joint roughness Coefficient (JRC), Joint Compressive Strength (JCS).

INTRODUCTION

Since rock slopes there are in the jointed and fractured rock masses, 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.

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 joints are very important. 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 (Han and Tang, 2010). They have investigated the numerical simulation for anisotropy of compressive strength of rock mass with multiple natural joints. Panthi and Nilsen (2007) in their research have studied the uncertainty analysis in the physical parameters weak rocks such as shale, phyllite and schist in Himalaya zone before and after excavation. Nakagawa (2004) emphasized to the appropriate modeling of mechanical behaviour of discontinuity and its material properties so as to evaluate the stability and deformational behavior of structures in the discontinuous rock masses.

One of the ways to stabilizing of rock slopes is application of rock bolts. 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 dip of joints on the axial force of rock bolts, the slopes with different dip of joints 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.

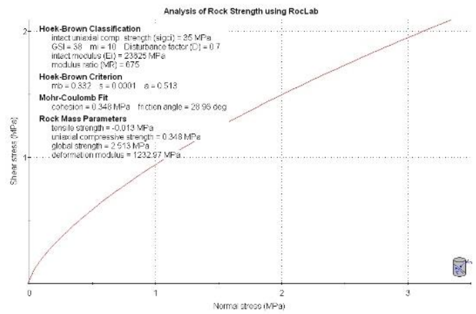

Figure 1. The geomechanical parameters of schist rocks

Modeling of rock slopes

To study the effect of dip of joints in rock slopes on the axial force of rock bolts, the slope of 45 degrees and with different dip of joints (15, 30, 45, 60 and 75 degrees) is modeled 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 Figs. 2 to 6).

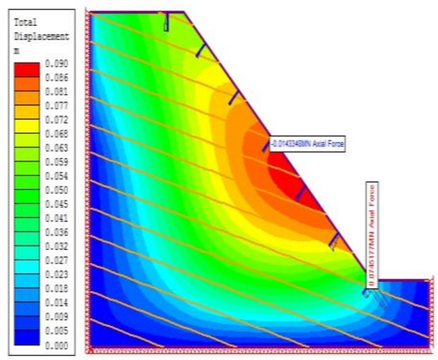

Figure 2. The axial force of rock bolts in the slope of 45 degrees that contains joints with dip of 15 degrees

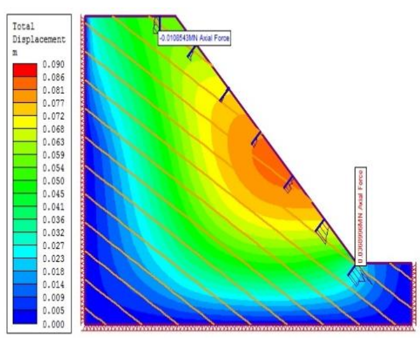

Figure 3. The axial force of rock bolts in the slope of 45 degrees that contains joints with dip of 30 degrees

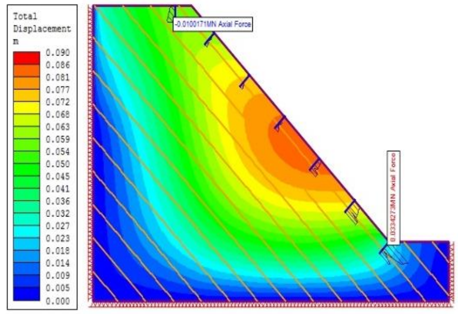

Figure 4. The axial force of rock bolts in the slope of 45 degrees that contains joints with dip of 45 degrees

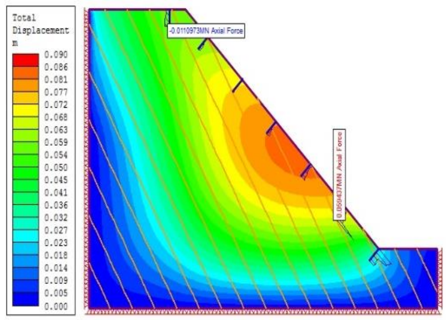

Figure 5. The axial force of rock bolts in the slope of 45 degrees that contains joints with dip of 60 degrees

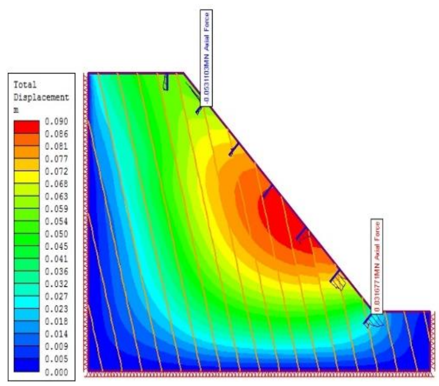

Figure 6. The axial force of rock bolts in the slope of 45 degrees that contains joints with dip of 75 degrees

Similarly, the axial force of rock bolts for all values of JRC and JCS are obtained and presented in Figs. 7 to 11.

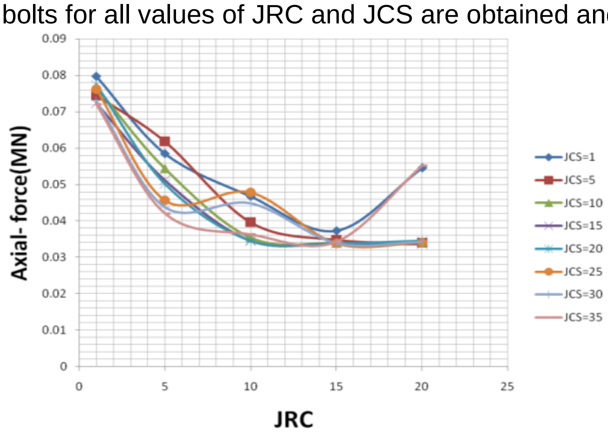

Figure 7. The diagram shows the axial force of rock bolts for the slope with dip of 45 degrees that contains joints with dip of 15 degrees

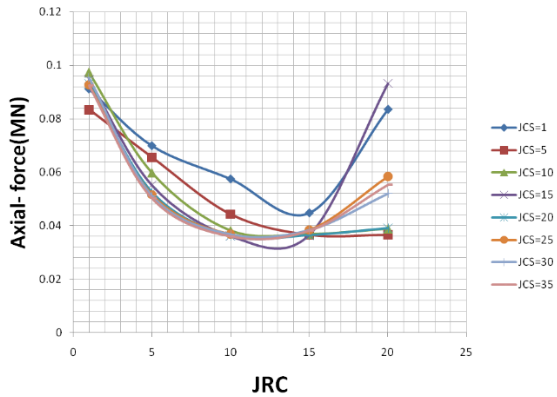

Figure 8. The diagram shows the axial force of rock bolts for the slope with dip of 45 degrees that contains joints with dip of 30 degrees

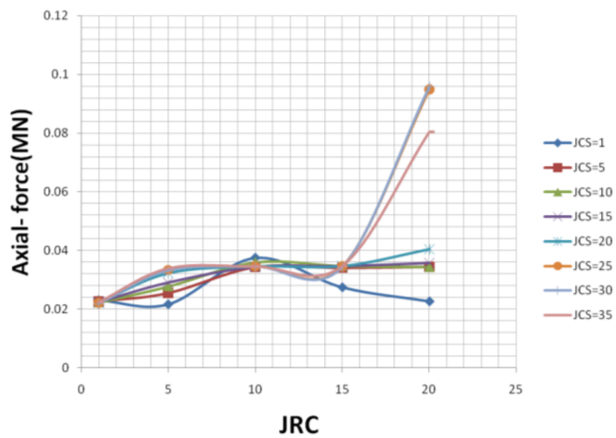

Figure 9. The diagram shows the axial force of rock bolts for the slope with dip of 45 degrees that contains joints with dip of 45 degrees

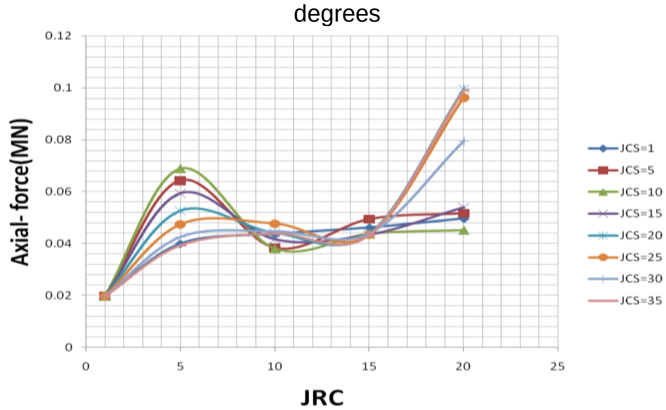

Figure 10. The diagram shows the axial force of rock bolts for the slope with dip of 45 degrees that contains joints with dip of 60 degrees

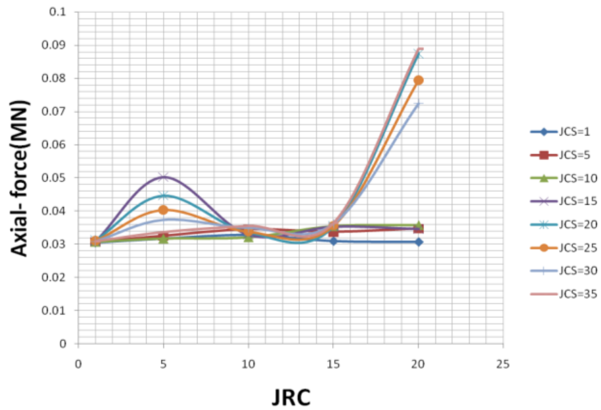

Figure 11. The diagram shows the axial force of rock bolts for the slope with dip of 45 degrees that contains joints with dip of 75 degrees

The diagrams in Figs. 7 to 11 show that in low values of JRC, the axial force of rock bolts has decreased by increasing dip of joints and when dip of joints with dip of slope is the same, the minimum axial force of rock bolts is obtained for all values of JRC and JCS. Moreover, the minimum axial force of rock bolts for all dip of joints is obtained in JRC of 10 to15. In the JRC of 15 to 20, trend of the axial force is mainly ascending and the axial force of rock bolts in the most dip of joints has increased especially in high value of JCS. 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 higher roughness coefficient, the compressive strength has greater role in the dilation of joint surfaces and the axial force of rock bolts has increased. In order to create a necessary condition on the joint surface for generating dilation sliding, we should know that sliding occurs at low normal stresses and sow–tooth surfaces of joints crack and the dilation doesn't occur (Fig. 12). But if existing shear stress is higher than existing stress on the planar surfaces, the compressive strength continuously increases and the rock dilates. So in higher joint roughness coefficients, the saw tooth surfaces become larger and rougher and with increasing the compressive strength, the saw–tooth stay intact and the only alternative for jointed rock mass is that acts as dilation (Fig. 13). That is reason the axial force of rock bolts has increased in higher roughness coefficient.

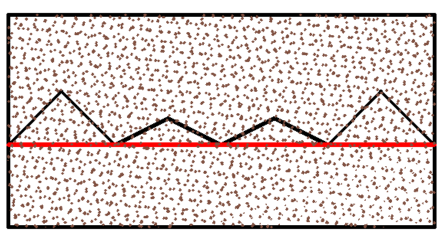

Figure 12. Cracking sow–tooth surfaces of joints in low compressive strength

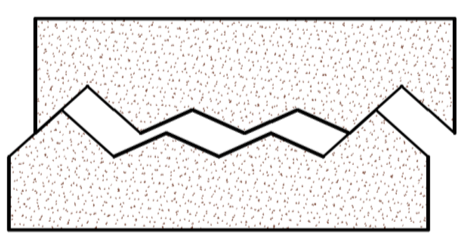

Figure 13. Dilation and sliding of joints on each other in high compressive strength

CONCLUSION

In this research that with aim to analysis the effect of dip of joints in rock slopes on the axial force of rock bolts is done the following results are obtained:

- Dip of joints has a significant effect on axial force of rock bolts.
- In low values of JRC, the axial force of rock bolts has decreased by increasing dip of joints.
- The minimum axial force of rock bolts is obtained when dip of joints with dip of slope is the same.
- The minimum axial force of rock bolts for all dip of joints is obtained in JRC of 10 to15.

In all dip of joints, the maximum effect of JCS on the axial force of rock bolts is obtained for high value of JRC.

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