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The effect of installation angle of rock bolts on the stability of rock slopes

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ABSTRACT: In this paper, the effect of installation angle of rock bolts on the stability of rock slopes was investigated. For this purpose, the rock slopes with different dips namely 30, 45, 60, and 75 degrees in jointed schist rocks were modeled using the Phase2 software and their stability were determined using the critical strength reduction factor (SRF) of slopes. The joint pattern is parallel deterministic and in order to stabilizing slopes, the rock bolts with different angles were installed on the slopes. The results show that by increasing dip of slopes, the strength reduction factor (SRF) has been decreased and the maximum of SRF in each slope is obtained for the rock bolts perpendicular to the slopes.

Keywords: Rock slopes; Rock bolts; Strength Reduction Factor (SRF).

INTRODUCTION

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). 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 tunnels or 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, seto they are not fully dependent on their pull-out strength.

Stability by strength reduction is a manner that the factor of safety is determined by weakening the soil or rock in stages in an elastic-plastic finite element analysis until the slope fails. The factor of safety is considered to be the factor by which the soil or rock strength needs to be reduced to reach failure (Dawson ., 1999; Griffiths and Lane, 1999).

In this Research in order to study the effect of installation angle of rock bolts on the stability of rock slopes, 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.

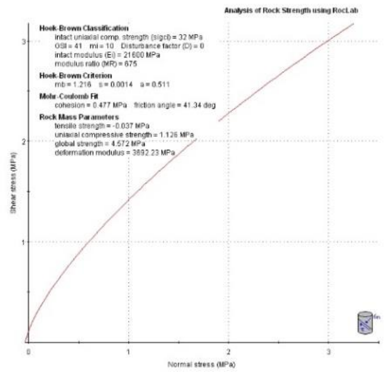

Figure 1. The geomechanical parameters of schist rocks

Modeling of rock slopes

To study the effect of installation angle of rock bolts on the stability of rock slopes, the slopes in different dips such as 30, 45, 60, and 75 were modeled by Phase2 software (Rocscience, 1999). In the models, the pattern of parallel deterministic joints was used in spacing of 2 meters. Also, the joints all over the slopes have the same conditions in the spacing of joints, the roughness of joints' surface, and the resistance of joints' walls. Moreover, the length of rock bolts and the distance of their places were 7 meters and 5 meters respectively. In addition, the installation angles of them on the slopes differ from -60 to -180 degrees from horizontal. By run the made models, the critical strength reduction factor (SRF) of slopes was obtained (for example, as Figs. 2 to 5).

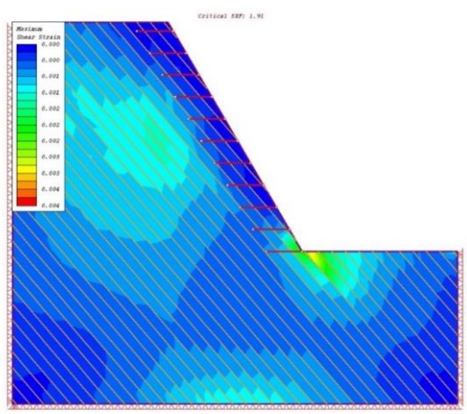

Figure 2. The slope of 60 degrees with parallel deterministic joints reinforced with rock bolts that were installed at angle of -180 degrees (the critical SRF is equal to 1.91)

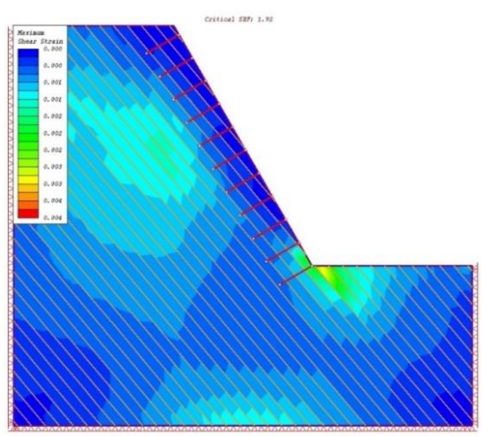

Figure 3. The slope of 60 degrees with parallel deterministic joints reinforced with rock bolts that were installed at angle of -150 degrees (the critical SRF is equal to 1.92)

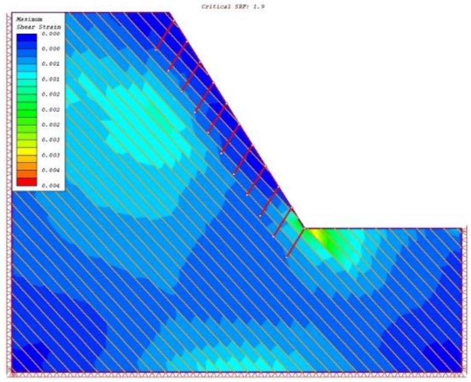

Figure 4. The slope of 60 degrees with parallel deterministic joints reinforced with rock bolts that were installed at angle of -120 degrees (the critical SRF is equal to 1.90)

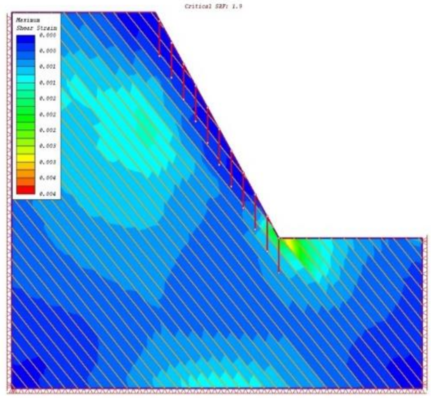

Figure 5. The slope of 60 degrees with parallel deterministic joints reinforced with rock bolts that were installed at angle of -90 degrees (the critical SRF is equal to 1.90)

Similarly, the values of SRF for other slopes are obtained and presented in Figs. 6 to 9.

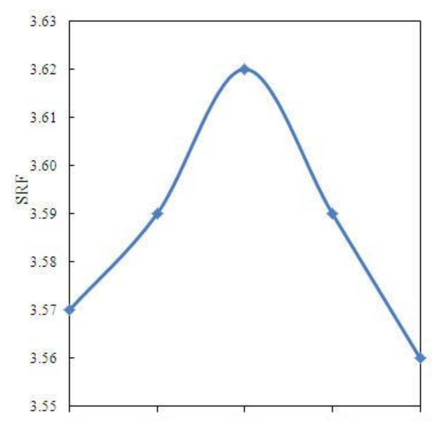

Figure 6. The diagram shows the values of SRF for the slope with dip of 30 degrees and different installation angles of rock Bolts

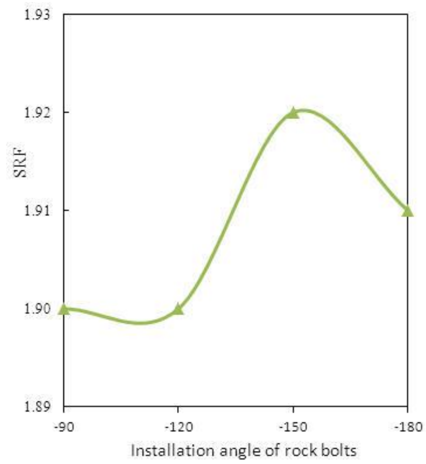

Figure 7. The diagram shows the values of SRF for the slope with dip of 45 degrees and different installation angles of rock bolts

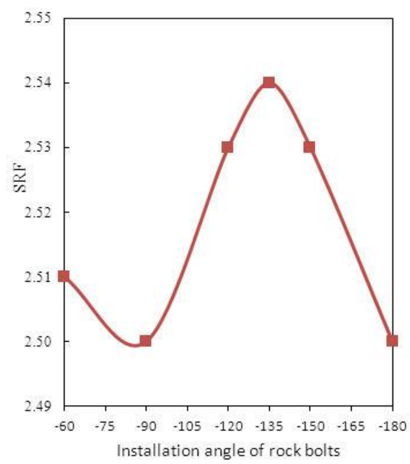

Figure 8. The diagram shows the values of SRF for the slope with dip of 60 degrees and different installation angles of rock bolts

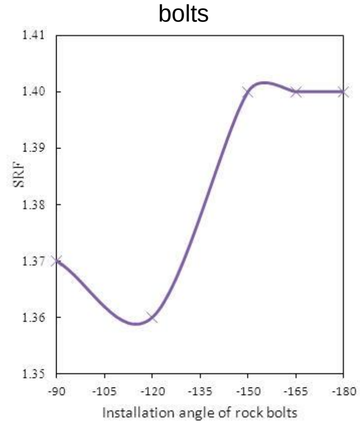

Figure 9. The diagram shows the values of SRF for the slope with dip of 75 degrees and different installation angles of rock bolts

The diagrams in Figs. 6 to 9 show a decrease in strength reduction factor (SRF) by increasing dip of slopes. The reason of decreasing in SRF by an increase in dip of slopes is that by enhancing the dip of slopes, the state of stresses in the slopes is changed and the minimum main stress (σ3) will reduces. This issue is resulted in a larger Mohr circle of stress so it will cause that the shear strength envelope Hoek-Brown to cut the Mohr circle and the decreasing of SRF will emerge. Moreover, the diagrams show that in the slope with dip of 30 degrees, the most appropriate angle for installation the rock bolts is -120 degrees from horizontal. Also, in the slope with dip of 45 degrees, the most appropriate angle for installation the rock bolts is -135 degrees from horizontal. In addition, in the slope with dip of 60 degrees, the most appropriate angle for installation the rock bolts is -150 degrees from horizontal. Furthermore, in the slope with dip of 75 degrees, the most appropriate angle for installation the rock bolts is -165 degrees from horizontal. These results show that the maximum SRF in each slope is obtained for the rock bolts perpendicular to the slopes.

CONCLUSION

In this research that with aim to analysis the effect of installation angle of rock bolts on the stability of rock slopes is done the following results are obtained:

- In all slopes, by increasing dip of slopes, the strength reduction factor (SRF) has been decreased.
- The maximum SRF in each slope is obtained for the rock bolts perpendicular to the slopes.

By installing the rock bolts away from perpendicular to the slopes, the strength reduction factor (SRF) has been decreased.

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