International Journal of
Science and Engineering Investigations vol. 4, issue 42, July 2015
ISSN: 2251-8843

The Effect of Length of Rock Bolts on the Stability of Rock Slopes

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Abstract- In this paper, the effect of length of rock bolts on the stability of rock slopes was investigated. For this purpose, the rock slopes with different dips in jointed schist rocks were modeled using the Phase2 software and their stability were determined using the critical strength reduction factor (SRF) of slopes. In order to stabilizing slopes, the rock bolts with different length were installed on the slopes. The results show that by increasing length of rock bolts, the strength reduction factor (SRF) has been increased and the maximum of SRF in each slope is obtained for the rock bolts perpendicular to the slopes. Furthermore, by increasing dip of slopes, the effect of length of rock bolts in the strength reduction factor (SRF) is irregular.

Keywords- *Rock slopes; Rock bolts; Strength Reduction Factor (SRF)*

I. INTRODUCTION

The stability of slopes is of great concern in the geo-technic engineering. The slope stability is concerned with many projects, such as foundations of structures, transportation routes and underground storages and basements. The loading conditions and physical nature of rock mass and the geometry of excavations and topography are the factors affecting in the stability of rock slopes. The stability of rock slopes is controlled by the joint sets, characteristics of joint surface, and depth and steepness of the excavated slope face and its orientation with respect to the joint sets. Slope design is concerned with the stability of unstable blocks of rock formed by joint sets. There are several types of slope failures such as plane failure, wedge failure, circular failure, toppling failure and buckling failure.

Rock bolts have been used for years to reinforce the surface and near surface rock of excavated or natural slopes. They are used to improve the stability and load bearing characteristics of a rock mass. When rock bolts are used to reinforce a fractured rock mass, the rock bolts will be subjected to tension, shear and compressive forces. The studies have been done by researchers (Kliche, 1999; Ramamurthy, 2007) to reinforce the slopes with rock anchoring. A general rule for rock bolts is that the distance between rock bolts should be approximately equal to three times the average spacing of the planes of weakness in the rock mass, and the bolt length should be twice the bolt spacing (Hoek and Wood, 1988). In this research in order to study the effect of length of rock bolts on the stability of rock slopes, the slopes with different dips composed of schist rocks were modeled.

II. GEOMECHANICAL PRAMETERS OF SCHIST ROCKS

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

In Rock-Lab program, both the rock mass strength and deformation modulus are calculated using equations of Hoek et al., 2002, and the rock mass constants are estimated using equations of Geological Strength Index (GSI) (Hoek et al., 2002) together with the value of the schist material constant, mi. Finally, the shear strength parameters of the rock mass (C and φ) for the rock masses are obtained using the relationship between the Hoek–Brown and Mohr–Coulomb criteria (Hoek and Brown, 1997).

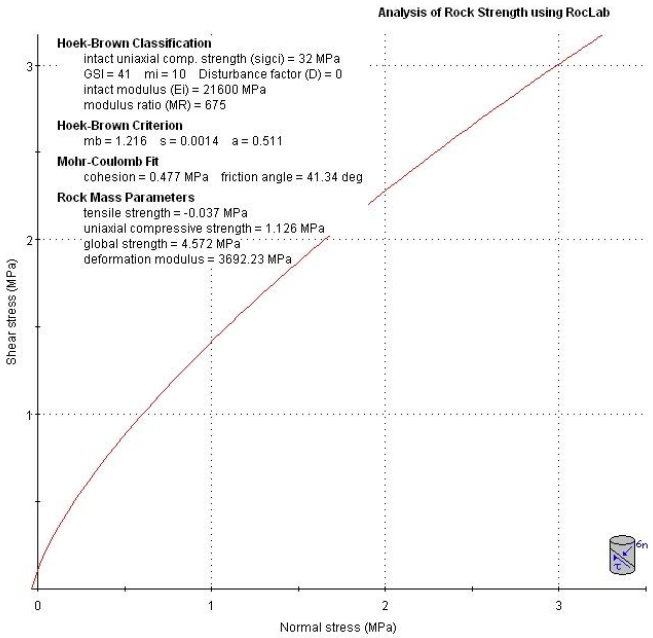

Figure 1. The geomechanical parameters of schist rock masses

III. MODELING OF ROCK SLOPES

To study the effect of length 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 were selected equal to 3, 5, 7 and 9 meters and the spacing of rock bolts was considered equal to 5 meters. In addition, the installation angles of rock bolts 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).

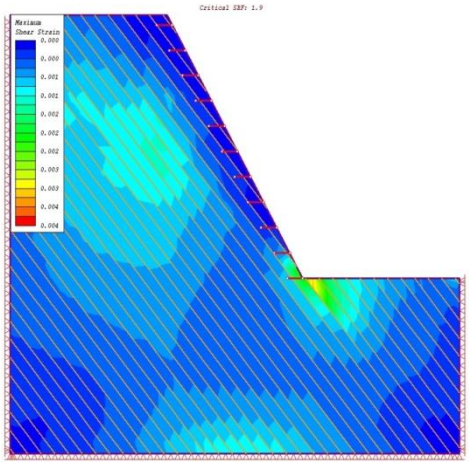

Figure 2. The slope of 60 degrees with parallel deterministic joints reinforced with rock bolts (length of 3 meters) that were installed at angle of -180 degrees (the critical SRF is equal to 1.90)

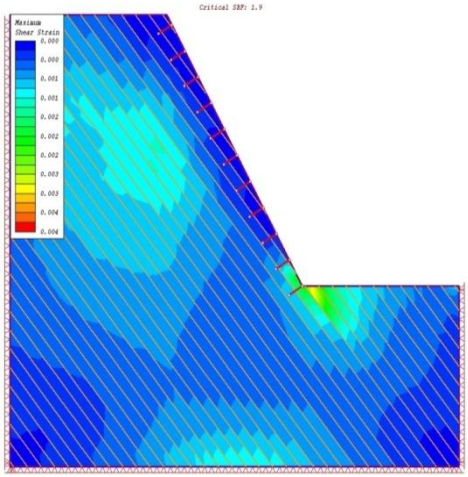

Figure 3. The slope of 60 degrees with parallel deterministic joints reinforced with rock bolts (length of 3 meters) that were installed at angle of -150 degrees (the critical SRF is equal to 1.90)

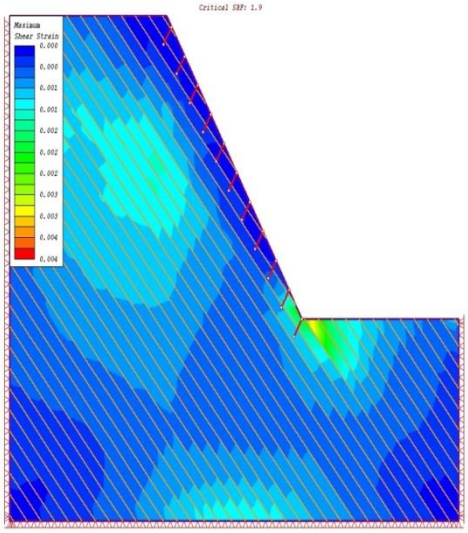

Figure 4. The slope of 60 degrees with parallel deterministic joints reinforced with rock bolts (length of 3 meters) that were installed at angle of -120 degrees (the critical SRF is equal to 1.90)

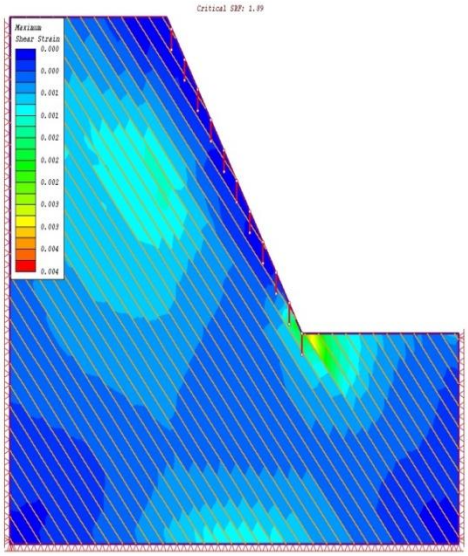

Figure 5. The slope of 60 degrees with parallel deterministic joints reinforced with rock bolts (length of 3 meters) that were installed at angle of -90 degrees (the critical SRF is equal to 1.89)

Similarly, the values of SRF for other slopes and other lengths of rock bolts (5, 7 and 9 meters) are obtained and presented in Figs. 6 to 9.

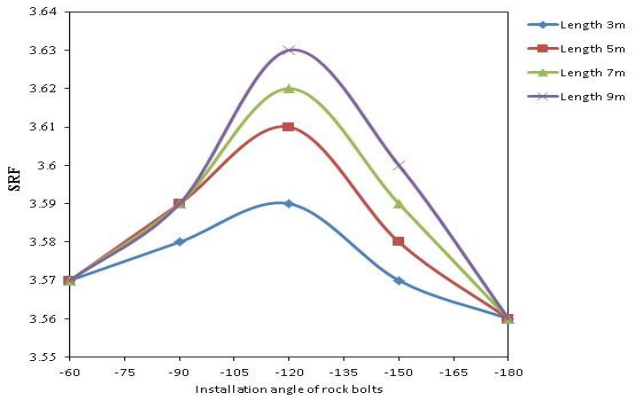

Figure 6. The diagram shows the values of SRF for the slope with dip of 30 degrees and different lengths of rock bolts that were installed at different angles

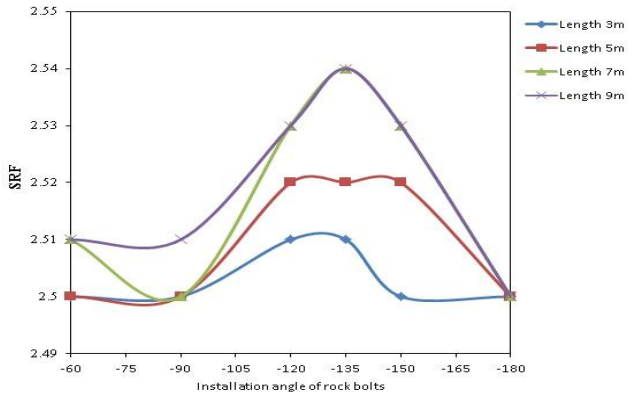

Figure 7. The diagram shows the values of SRF for the slope with dip of 45 degrees and different lengths of rock bolts that were installed at different angles

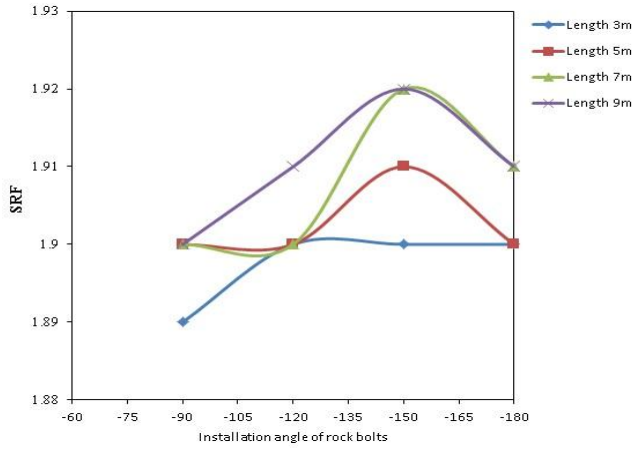

Figure 8. The diagram shows the values of SRF for the slope with dip of 60 degrees and different lengths of rock bolts that were installed at different angles

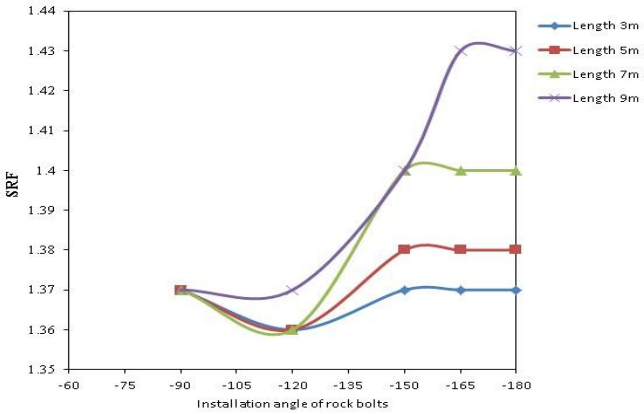

Figure 9. The diagram shows the values of SRF for the slope with dip of 75 degrees and different lengths of rock bolts that were installed at different angles

The diagrams in Figs. 6 to 9 show that by increasing length of rock bolts, the strength reduction factor (SRF) has increased. This issue will result in more sewed joints in slopes and increasing in their shear strength.

Moreover, the diagrams show that by increasing dip of slopes, the effect of length of rock bolt in decrease or increase of SRF is irregular and the maximum SRF in each slope is obtained for the rock bolts perpendicular to the slopes.

The obtained results is consistent with that if bolts installed at an angle steeper than the normal to the sliding plane increases shear resistance negligibly (Haas, 1981), even can be detrimental to stability sometimes (Wyllie and Mah, 2004) because shear component of the tension, acting down the plane, increases the magnitude of the displacing force.

IV. CONCLUSIONS

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

- By increasing the length of rock bolts, the strength reduction factor (SRF) has been increased.

- By increasing dip of slopes, the effect of length of rock bolts in the strength reduction factor (SRF) is irregular.

- For all the distance of rock bolts, the maximum SRF is obtained for the rock bolts perpendicular to the slopes.

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