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The Effect Of Spacing Of Rock Bolts On The Stability Of Rock Slopes

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***Abstract*— In this paper, the effect of spacing of rock bolts on the stability of rock slopes was investigated. For this purpose, the rock slopes with different dips in the 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 the slopes, the rock bolts with different spacing were installed on the slopes. The results show that by increasing spacing of rock bolts, 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. Furthermore, by increasing dip of slopes, the effect of spacing of rock bolts in the strength reduction factor (SRF) is irregular.**

Keywords—Rock slopes; Rock bolts; Spacing; Strength Reduction Factor (SRF)

1. INTRODUCTION

Stability rock slopes has a prominent influence in projects such as transportation routes and open pits. Numerical methods have become very popular in recent years for stability analysis of rock slopes. They are categorized into two groups: continuum-based methods (e.g., the FDM, FEM, BEM, etc.) and discontinuum-based methods (e.g., the distinct element codes such as UDEC, 3DEC, etc.). In these methods, both stress and displacements in a block can be calculated and various constitutive relations (e.g., anisotropic, plastic, etc.) can be employed. Furthermore, in these methods complex slope geometries can be handled and groundwater flow can be coupled.

Stability by strength reduction is a manner that the factor of safety is determined by weakening the 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 rock strength needs to be reduced to reach failure [1, 2].

In the Strength Reduction approach, the rock strength is reduced, and so there is a need to redistribute the stresses. This can be done by the stress redistribution algorithm, and so this option can be indirectly used to do a strength reduction stability analysis.

The strength reduction factor (SRF) is defined as:

$$SRF = \left[\tan\varphi \,/\, \tan\varphi f \right] = \left[c \,/\, cf \right]$$

where φf and cf are the effective stress strength parameters at failure, or the reduced strength.

Rock bolts 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 [3, 4] 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 [5].

In this research in order to study the effect of spacing of rock bolts on the stability of rock slopes, the slopes with different dips composed of schist rocks were modeled and rock bolts with different spacing were used for stabilizing of the slopes.

2. GEOMECHANICAL PARAMETERS OF SCHIST ROCKS

In this study, the geomechanical parameters of the jointed schist rocks were obtained using Roclab software [6]. These parameters are obtained based on The Hoek-Brown failure criterion and it is presented in Fig. 1.

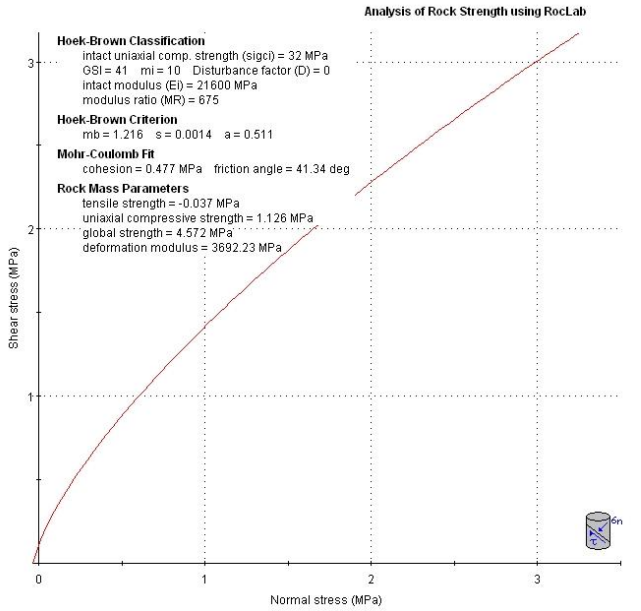

Fig.1. Geomechanical parameters of the schist rocks

3. MODELING OF ROCK SLOPES

To study the effect of spacing 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 [7]. 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 was selected equal to 7 meters and the spacing of rock bolts was considered equal to 3, 4, 5, 6 and 7 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).

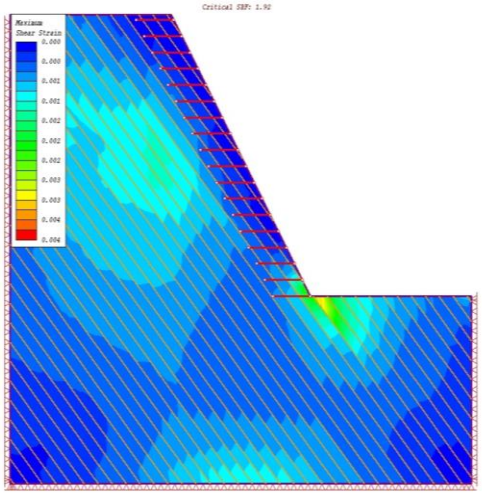

Fig. 2. The slope of 60 degrees with parallel deterministic joints reinforced with rock bolts (spacing of 3 meters) that were installed at angle of -180 degrees (the critical SRF is equal to 1.92)

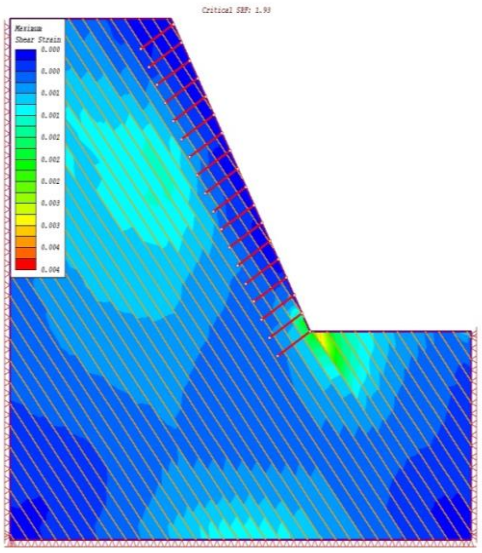

Fig. 3. The slope of 60 degrees with parallel deterministic joints reinforced with rock bolts (spacing of 3 meters) that were installed at angle of -150 degrees (the critical SRF is equal to 1.92)

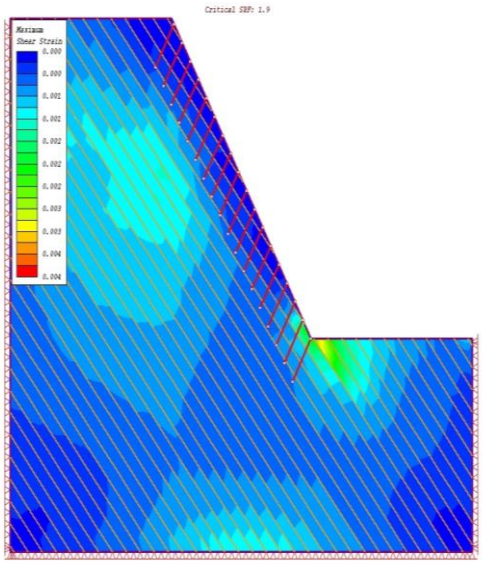

Fig. 4. The slope of 60 degrees with parallel deterministic joints reinforced with rock bolts (spacing of 3 meters) that were installed at angle of -120 degrees and without pre-tensioning (the critical SRF is equal to 1.90)

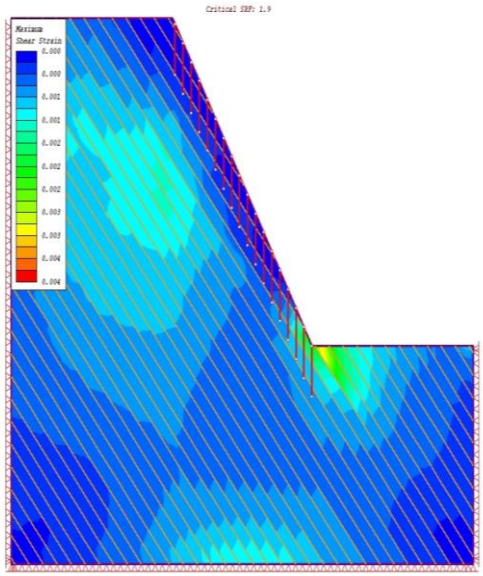

Fig. 5. The slope of 60 degrees with parallel deterministic joints reinforced with rock bolts (spacing of 3 meters) that were installed at angle of -90 degrees (the critical SRF is equal to 1.90)

Similarly, the values of SRF for other slopes and other distance (4, 5, 6 and 7 meters) are obtained and presented in Figs. 6 to 9.

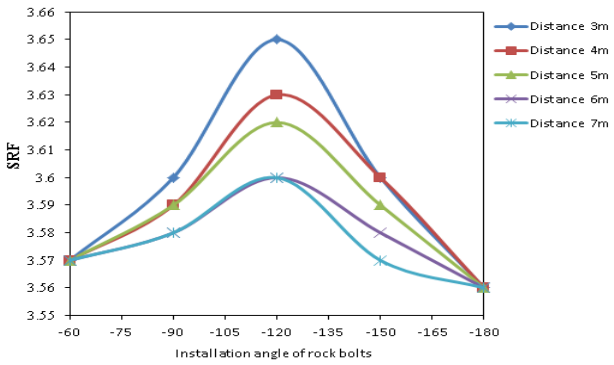

Fig. 6. The diagram shows the values of SRF for the slope with dip of 30 degrees and different spacing of rock bolts that were installed at different angles

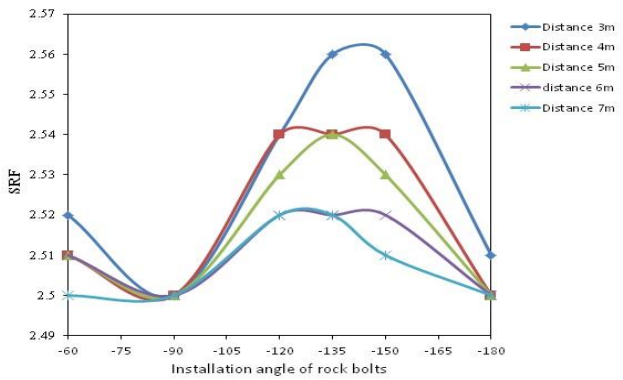

Fig. 7. The diagram shows the values of SRF for the slope with dip of 45 degrees and different spacing of rock bolts that were installed at different angles

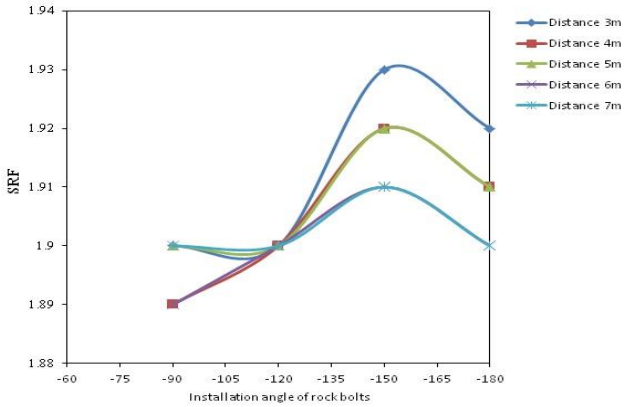

Fig. 8. The diagram shows the values of SRF for the slope with dip of 60 degrees and different spacing of rock bolts that were installed at different angles

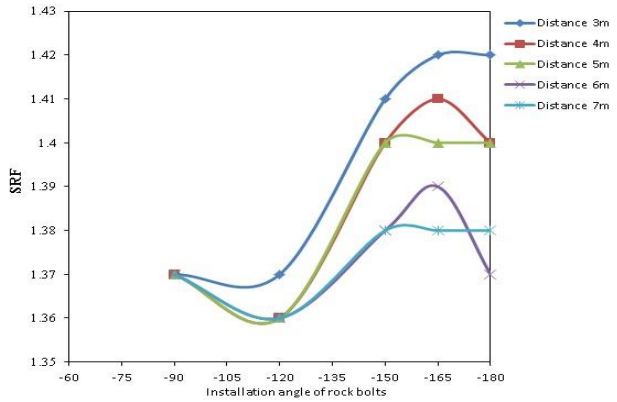

Fig. 9. The diagram shows the values of SRF for the slope with dip of 75 degrees and different spacing of rock bolts that were installed at different angles

The diagrams in Figs. 6 to 9 show that by increasing distance of rock bolts, the strength reduction factor (SRF) has been decreased. This issue is resulted from less sewed joints in per unit of surface which the shear strength of joints won't increase as expected.

Moreover, the diagrams show that by increasing dip of slopes, the effect of distance 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. When the rock bolts are perpendicular to joint as shown in Fig. 10, the rock bolts does not bear significant value of tensile stress due to absence of sizable yielding and bending of the rock bolts when joints are displaced and therefore additional shear resistance from the rock bolts is not possible [8].

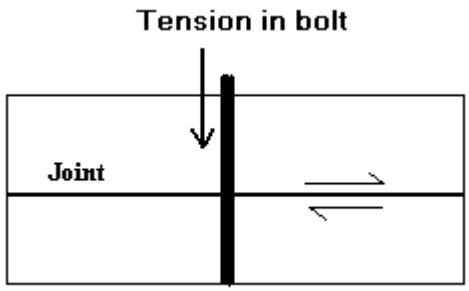

Fig.10. Rock bolt installed perpendicular to joint [9]

4. CONCLUSION

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

- By increasing the distance of rock bolts, the strength reduction factor (SRF) has been decreased.
- By increasing dip of slopes, the effect of spacing of rock bolts in the strength reduction factor (SRF) is irregular.
- For all spacing of rock bolts, the maximum SRF is obtained for the rock bolts perpendicular to the slopes.

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