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The Performance Of Various Rock Bolts On The Stability Of Slopes

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***Abstract*— In this paper, the performance of various rock bolts on the displacement 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. In order to stabilizing the slopes, the various rock bolts (End-anchored, Fully bonded, Plain strand cable, Swellex and Tie back) were installed on the slopes. The results show that for all slopes, the Swellex and Tie back bolts have the highest performance in the stability of slopes. Furthermore, for whole rock bolts by increasing dip of slopes, the displacement on the slopes has been increased. The values of displacement on the slopes depend on the angle of joints with slopes.**

Keywords—Rock slopes; Rock bolts; Displacement; Joints

1. INTRODUCTION

Rock bolts have been used for many years for the support of underground excavations and rock cuts. Rock bolts often consist of plain steel rods with a mechanical or chemical anchor at one end and a face plate and nut at the other and they are always pre-tensioned after installation. For short term applications the bolts are commonly left ungrouted and for long term applications, the space between the bolt and the rock can be filled with cement or resin grout [1].

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 [2, 3] 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 [4].

The slope stability analysis has many applications in the design of rock slopes, roads and open pits structures. A number of methods have been suggested by researchers [5, 6, 7, 8] to evaluate the stability issues of slopes. These methods consider a different set of geotechnical parameters such as weathering, discontinuity spacing and groundwater.

In this research in order to study the performance of various rock bolts on the displacement of rock slopes, the slopes with different dips composed of schist rocks were modeled and various rock bolts 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 [9]. These parameters are obtained based on The Hoek-Brown failure criterion and it is presented in Fig. 1.

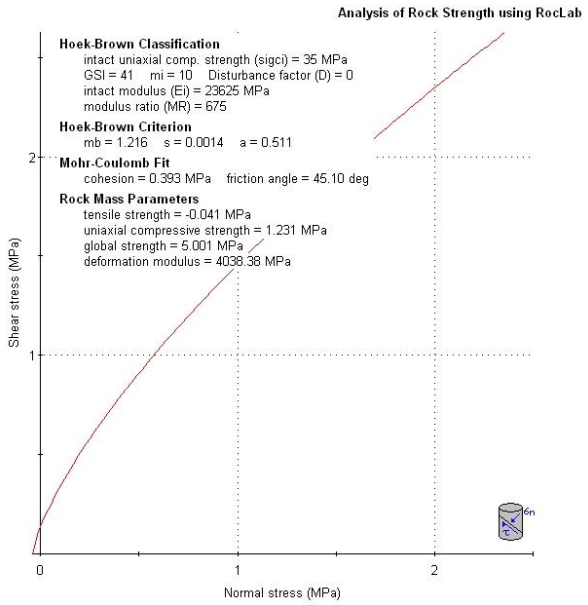

Fig.1. Geomechanical parameters of the schist rocks

3. MODELING OF ROCK SLOPES

To study the performance of various rock bolts on the displacement of rock slopes, the slopes in different dips such as 15, 30, 45, 60, and 75 were modeled by Phase2 software [1] (for example, as Fig. 2). 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 9 meters and the spacing of rock bolts was considered equal to 5 meters. In addition, the angles of joints with slopes differ from 0 to 90 degrees. The rock bolts that were selected for modeling are as follows: End-anchored, Fully bonded, Plain strand cable, Swellex and Tie back.

Each end-anchored bolt behaves as a single element and interaction with the finite element mesh is through the endpoints of the bolt only. Fully Bonded bolts act independently of each other and these bolts do not influence each other directly, but only indirectly through their effect on the rock mass. Plain Strand Cable bolt behaves as a single element and the behaviour of each segment of the bolt has a direct effect on adjacent segments, therefore the bolt can be considered a single element. The Swellex bolt also behaves as a single element and the behaviour of each segment of the bolt has a direct effect on adjacent segments. The Tieback bolt may be pre tensioned and grouted with a user defined bonded length and a Tie back bolt uses the same formulation as the Swellex bolt model [1].

By run the made models, the total displacement of slopes was obtained (for example, as Figs. 3 and 4).

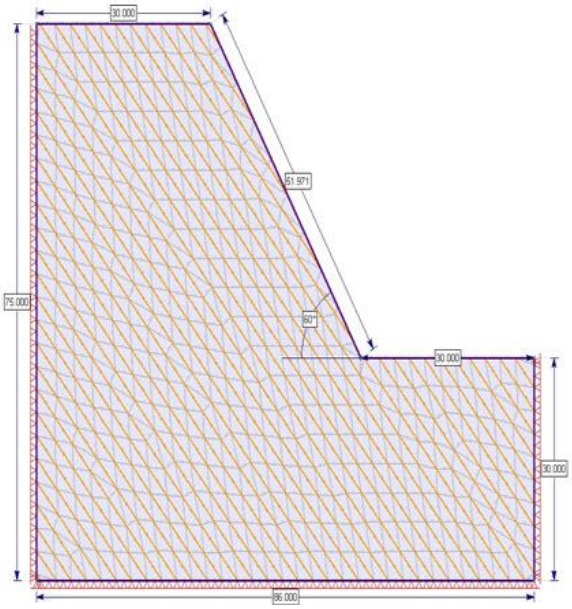

Fig. 2. The slope of 60 degrees with parallel deterministic joints with spacing of 2 meters

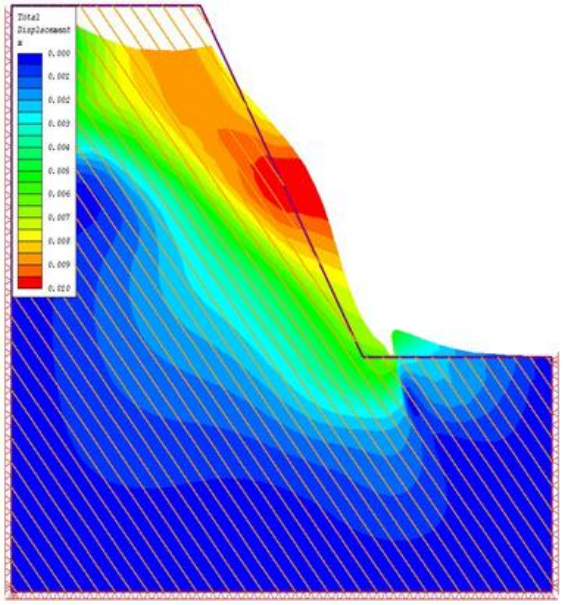

Fig. 3. Total displacement in the slope of 60 degrees with parallel deterministic joints that was not reinforced with rock bolts

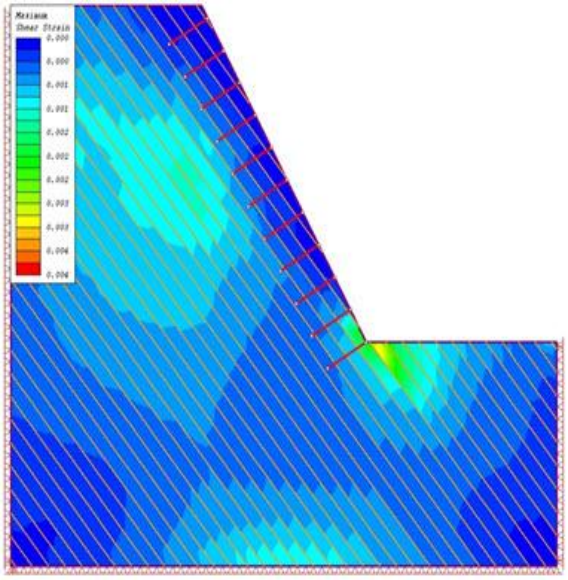

Fig. 4. The maximum shear strain in the slope of 60 degrees with parallel deterministic joints that was reinforced with rock bolts

Similarly, the values of total displacement for other slopes and for whole angle of joints with slope are obtained and presented in Figs. 5 to 9.

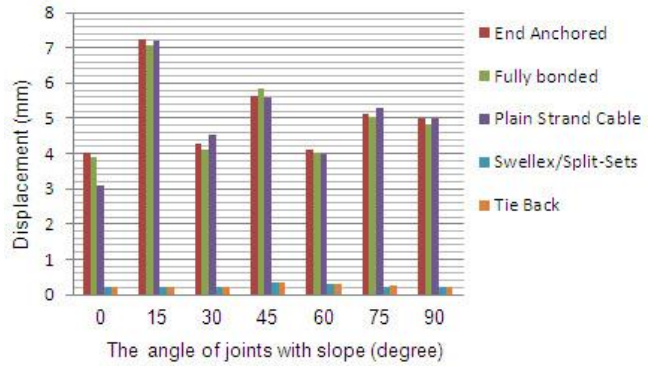

Fig. 5. The diagram shows the values of displacement in the slope of 15 degrees that reinforced with different rock bolts (the angle of joints with slope was modeled from 0 to 90)

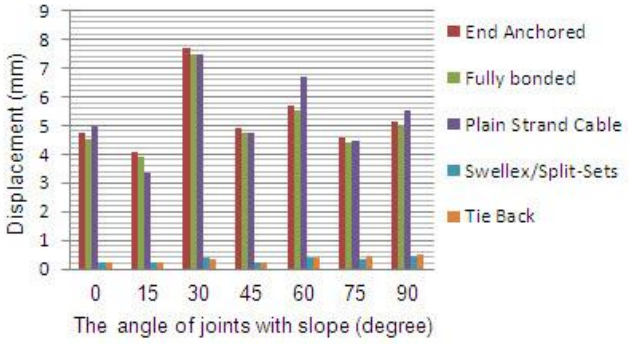

Fig. 6. The diagram shows the values of displacement in the slope of 30 degrees that reinforced with different rock bolts (the angle of joints with slope was modeled from 0 to 90)

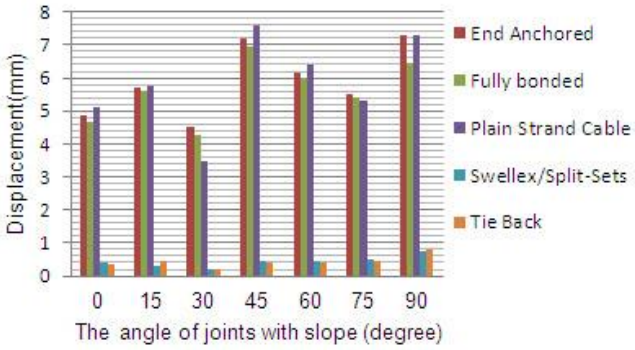

Fig. 7. The diagram shows the values of displacement in the slope of 45 degrees that reinforced with different rock bolts (the angle of joints with slope was modeled from 0 to 90)

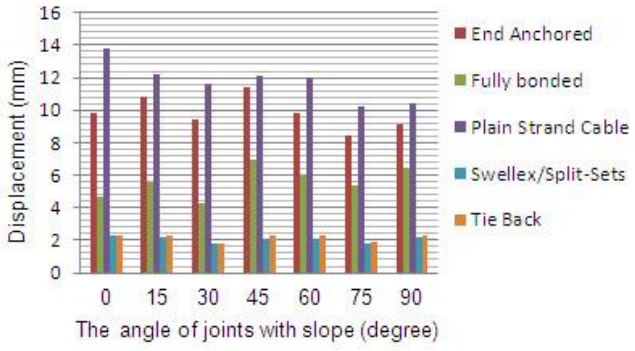

Fig. 8. The diagram shows the values of displacement in the slope of 60 degrees that reinforced with different rock bolts (the angle of joints with slope was modeled from 0 to 90)

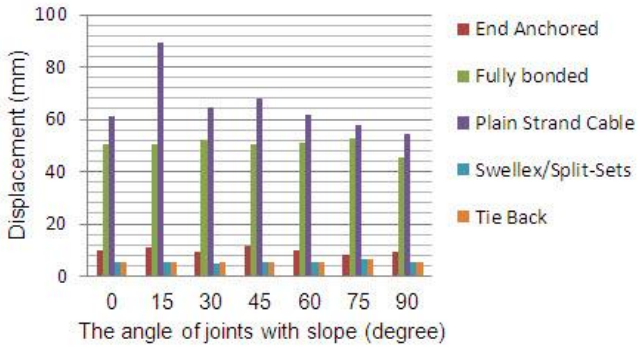

Fig. 9. The diagram shows the values of displacement in the slope of 75 degrees that reinforced with different rock bolts (the angle of joints with slope was modeled from 0 to 90)

The diagrams in Figs. 5 to 9 show that for whole rock bolts by increasing dip of slopes, the displacement on the slopes has been increased. This issue shows the gravitational instability of slopes when dip of slopes increase.

Moreover, the diagrams show that for all slopes, the Swellex and Tie back bolts have the highest performance in the stability of slopes. The End-anchored bolts have been effective only for slopes of 75 degrees and the Fully bonded bolts show better performance in slopes of 60 degrees. Furthermore, the values of displacement on the slopes depend on the angle of joints with slopes. The maximum displacement in the slopes of 15, 30 and 45 degrees is obtained when angle of joints with slopes is 15, 30 and 45 degrees.

4. CONCLUSION

In this research that with aim to analysis the performance of various rock bolts on the displacement of rock slopes is done the following results are obtained:

- For all slopes, the Swellex and Tie back bolts have the highest performance in the stability of slopes.
- By increasing dip of slopes, the displacement on the slopes has been increased.
- The values of displacement on the slopes depend on the angle of joints with slopes.

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