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Evaluating the Excavation Methods on the Stability of Rock Slopes

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Abstract- Stabilizing slopes is one of the most important geotechnical cases which have an important effect on the road security. In the meantime, excavation methods have an important role in slope stability. These methods effect strength reduction factor (SRF) of slope s due to the force induced on rocks. In this paper four slopes with dips of 30, 45, 60 and 75 degrees were modeled by Phase2 software and in these models, the effect of rock disturbance factor (D) was surveyed on the slope stability. After analyzing the slopes, the diagrams were drawn based on the rocks disturbance factor effect on SRF. The results indicate that the slope stability is affected by the disturbance factor i.e. the excavation method, and in all the slopes because of excavation the SRF amount has reduced in static state. In addition the highest amount of SRF reduction has occurred for the disturbance factor between 0.9 - 1 i.e. the uncontrolled explosion excavation method in huge volume, with this difference that as the dip of slope increases the SRF rate decreases.

Keywords- *Rock Slope, Excavation Method, Disturbance Factor, Strength Reduction Factor (SRF)*

I. INTRODUCTION

Rock slope stability is one of the most important factors in road construction and multiple factors are effective in their stability which evaluating and analyzing these factors can present proper solutions on slope stability. As it is known, slope ruptures are created differently. So identifying the rupture probability risk needs a better slope evaluation which results in better slope improvement methods. Surface excavation can be used for mine excavations, constructing buildings, dam restraints and overflows, factories, power plants, highways and railways. Of these excavations needed for road sections can affect the slope stability near roads.

Excavations for road sections can be conducted with different methods such as explosions, mechanical, digging and etc. each method has a different effect on the slope stability.

The excavation of slopes in rock always leads to stress relief within the rock mass that induces a certain degree of fracturing and disturbance. The level of disturbance can be especially important when the slope is formed using blasting techniques. In order to account for rock mass disturbance during construction, a disturbance factor has been included in the Hoek–Brown failure criterion (Hoek et al., 2002).

Damage and stress relief in the rock masses arise by excavation of slopes and disturbance factor (D) which introduced by Hoek et al. (2002) is related to excavation method. According to Hoek et al. (2002) can be found that D= 0.7 is related to excavation by mechanical methods in some softer rocks can be carried out by ripping and dozing or by small scale blasting in civil engineering slopes that results in modest rock mass damage, especially in the case of exactly controlled blasting, D= 0.8 is related to excavation by modest scale blasting and in the case of partly controlled blasting, D= 0.9 is related to excavation by high scale blasting and D=1 is related to excavation by very poor quality blasting that results in stress relief from overburden removal. The disturbance factor (D) should only be applied to the actual zone of damaged rock (Hoek, 2012).

Stability of slopes and excavation of rocks is one of the important problems in underground structures engineering. A number of methods have been suggested by researchers (Kirsten, 1982; Minty and Kearns, 1983; Caterpillar, 1988; Pettifer and Fookes, 1994) to evaluate the stability issues of slopes. These methods consider a different set of geotechnical parameters such as weathering, discontinuity spacing and groundwater.

This paper mainly focuses on the effect of methods of excavation on the strength reduction factor (SRF) of slopes in the static case.

II. GEOMECHANICAL PROPERTIES OF THE ROCK MASSES

The rock mass properties such as the rock mass strength (σcm), the rock mass deformation modulus (Em) and the rock mass constants (mb, s and a) are calculated by the Rock-Lab program defined by Hoek et al. (2002). This program has been developed to provide a convenient means of solving and plotting the equations presented by Hoek et al. (2002).

The geomechanical parameters of dolomitic rock masses is obtained and presented in Figs. 1.

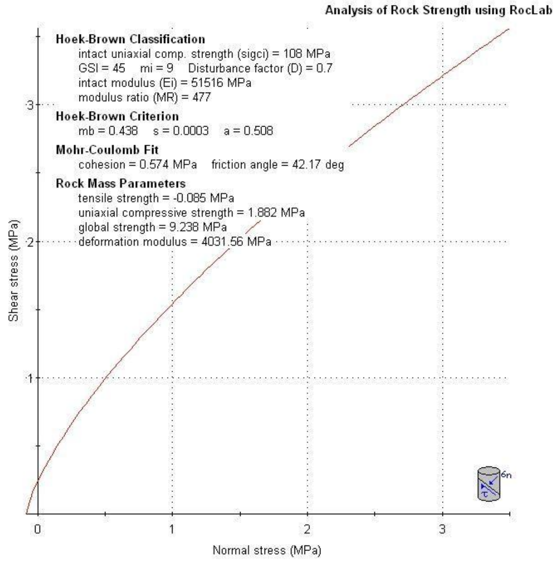

Figure 1. The geomechanical parameters of dolomitic rock masses

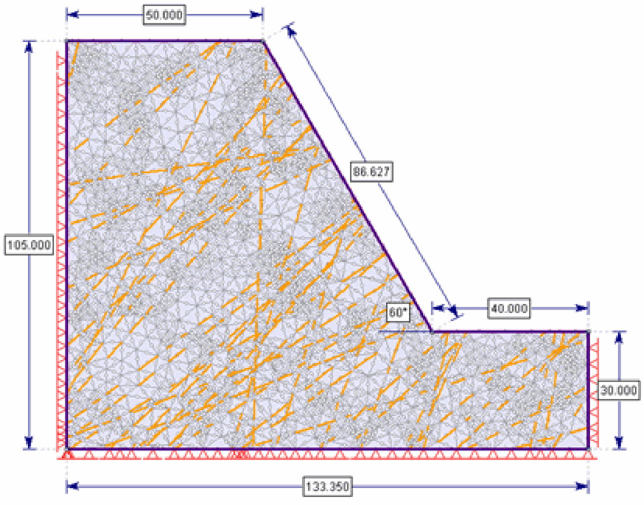

Figure 2. The modeled slope with dip of 60 degree

III. DATA USED IN NUMERICAL MODELING

Numerical analyses are done using a two-dimensional hybrid element model, called Phase2 Finite Element Program (Rocscience, 1999). In this finite element simulation, based on the elasto-plastic analysis, deformations and stresses are computed. These analyses used for evaluations of the stress in the rock masses. The geomechanical properties for these analyses are extracted from Fig. 1. The generalized Hoek and Brown failure criterion is used to identify elements undergoing yielding and the displacements of the side of valleys.

The rock slope stability has been evaluated in a dolomitic rock mass with joints. The slopes have been modeled with dips of 30, 45, 60 and 75 degrees and the joints have a 36 degree dip (for example Fig. 2). It is to be said that all joints have the same specification and condition in all slopes. The disturbance factor for rocks is different in each slope including 0.7, 0.8, 0.9 and 1 which are defined for each excavation method. For showing different joint states, the Veneziano joint model was used.

The rock disturbance factor (D) is considered for different excavation methods as follows:

In mechanical or controlled explosion method in low volumes, the number is 0.7. Explosive excavations with relative controlling in a medium volume, the disturbance factor (D) is 0.8. In high volume explosions the disturbance factor (D) is 0.9. In uncontrolled explosions in high volumes which release great amount of stress due to the rock displacements, the disturbance factor (D) is 1.

For analyzing the slope stability in the static state, in the middle section of the slope, the excavations equal to 6, 13, 20, 26 and 33 percent were performed and in all cases, the four disturbance factors (0.7, 0.8, 0.9 and 1) were put into consideration.

By run the models, the critical SRF was determined (for example Figs. 3, 4, 5, 6) and the obtained results are shown in Figs. 7 to 10.

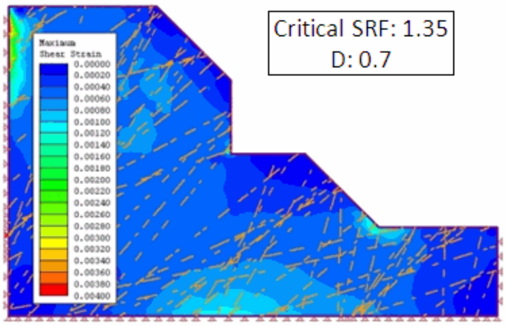

Figure 3. The critical SRF for slope with dip of 45 degree and 33% excavation (D parameter is 0.7)

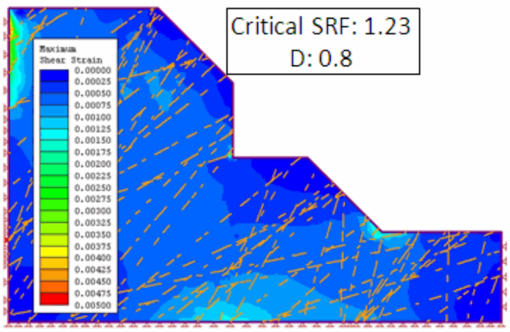

Figure 4. The critical SRF for slope with dip of 45 degree and 33% excavation (D parameter is 0.8)

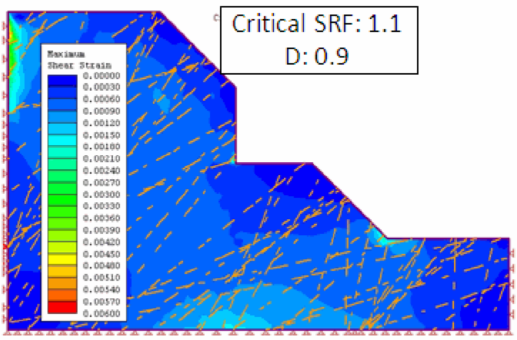

Figure 5. The critical SRF for slope with dip of 45 degree and 33% excavation (D parameter is 0.9)

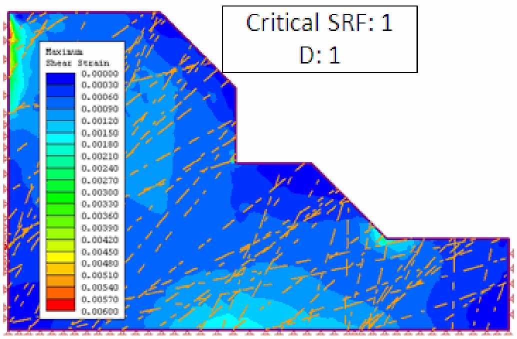

Figure 6. The critical SRF for slope with dip of 45 degree and 33% excavation (D parameter is 1)

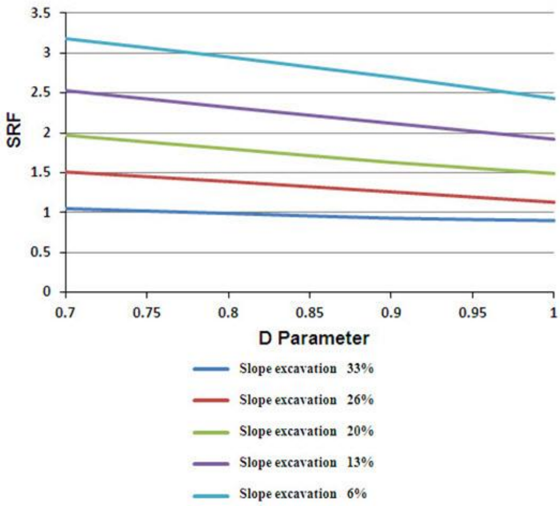

Figure 7. The SRF variations with different excavation percentages according to the D parameter in the slope of 30 degree.

As it can be seen in the above diagrams in all slopes, after the excavation, the critical SRF has reduced which this problem indicates the instability of the slopes due to excavations. The difference is that, by increasing the dip of slope, the SRF rate decreases significantly. This shows that as the dip of slope increases, the excavation effect on the slope instability reduces. Also it can be concluded that as the dip of slope and excavation increase the SRF decreases meaningfully.

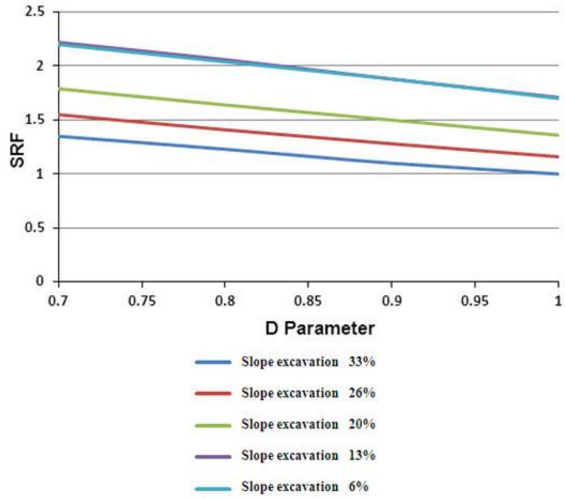

Figure 8. The SRF variations with different excavation percentages according to the D parameter in the slope of 45 degree.

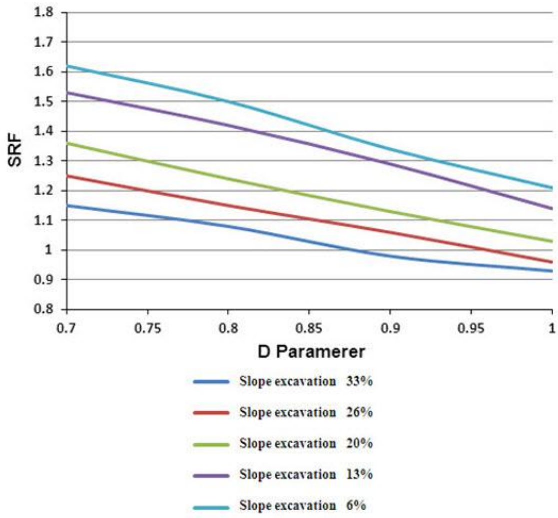

Figure 9. The SRF variations with different excavation percentages according to the D parameter in the slope of 60 degree.

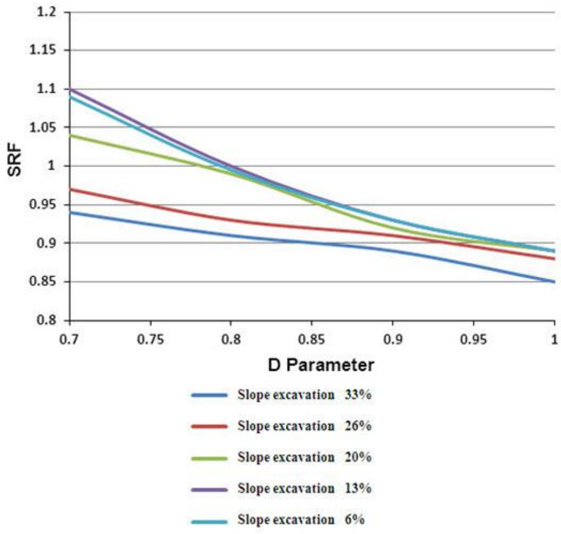

Figure 10. The SRF variations with different excavation percentages according to the D parameter in the slope of 75 degree.

IV. CONCLUSIONS

This study provides an estimation of the effect of disturbance factor on the slop stability. The following conclusions could be noted:

- In all excavations, the critical SRF has reduced which shows their instability due to excavation with this difference that as the dip of slope increases, the SRF rate decreases significantly.
- The stability of all slopes is affected by disturbance factor i.e. the excavation method.
- In all slopes, the highest amount of the SRF is related to the disturbance factor of 0.9 to 1 i.e. the uncontrolled explosion method which causes high stress release due to rock removals.
- In all slopes, the lowest amount of SRF is related to the disturbance factor of 0.7 to 0.8, i.e. the mechanical excavation method or the controlled explosion method in low volumes.
- By increasing the excavation percentage in slopes, the excavation method effect has reduced in the slope stability.
- As the dip of slope increases, the excavation effect rate on the instability of slopes is reduced.

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