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The effect of joint models on the stability of rock slopes

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Abstract: ***This study presents the effect of joint patterns on the stability rock slopes. For this purpose, the rock slopes with different dips namely 30, 45, 60, and 75 degrees were modeled using the Phase2 software and their stability were determined using the critical strength reduction factor (SRF) of slopes. The joint models are Parallel deterministic, Parallel statistical, Cross jointed, Baecher, Veneziano and Voronoi. The obtain results show that in all slopes, the maximum SRF is related to the Parallel deterministic joints and the minimum SRF is related to the Voronoi joints. Furthermore, the Veneziano joints have created sustainable stability in the all slopes.***

Keywords: Rock slopes; Joint Models; Strength Reduction Factor.

1. Introduction

The slope stability of rocks is an important problem in geotechnical engineering. The joints in the rock masses have a significant role in the stability of rock slopes. A number of joint models are being used by researchers, the models such as Parallel deterministic, Parallel statistical, Cross jointed, Baecher, Veneziano and Voronoi (Rocscience. 1999).

The Parallel deterministic joint model allows that to define a network of parallel joints with a invariant spacing and orientation and allow randomness of the joint location. In this case the spacing, length and persistence of the joints are assumed to be constant (Fig. 1).

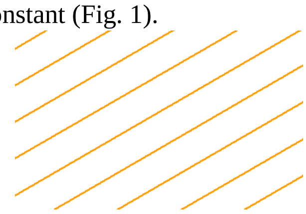

Fig. 1. The parallel deterministic joint model

The Parallel statistical joint network model allows that to define a network of parallel joints with user-defined statistical distributions for the joint spacing, length and persistence (Fig. 2).

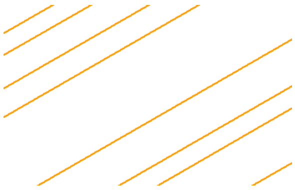

Fig. 2. The parallel statistical joint model

The Cross jointed joint network model allows that to define a network which consists of two sets of parallel joints (e.g. bedding planes with cross joints) which intersect to form rectangular or trapezoidal blocks (Fig. 3).

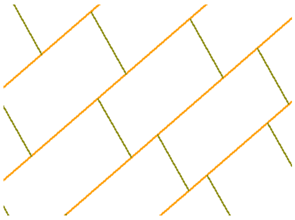

Fig. 3. The cross jointed joint model

The Baecher joint network model (Baecher et al., 1978) can generate intricate joint networks. In this model, joints have finite trace lengths, which follow some statistical distribution. The orientations of joints in a Baecher network vary according to an orientation distribution or it be fixed. The number of joints generated in a Baecher network depends on a joint intensity measure (Fig. 4).

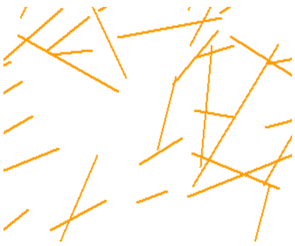

Fig. 4. The Baecher joint model

The Veneziano joint network model is based on a Poisson line process. It however adjusts the Poisson process to generate joints of finite length (Dershowitz, 1985). In this model, each of infinite joint lines which pass through a point is located according to a Poisson point process. The orientations of the lines may be fixed or vary according to some orientation distribution. Furthermore, in this model, each joint line divides into segments of random lengths. These lengths correspond to a specified statistical distribution. A portion of these segments are classified as joints and the remainder as intact rock bridges (Fig. 5).

Fig. 5. The Veneziano joint model

A Voronoi joint model consists of joints that are defined by the bounding segments of these polygons (Dershowitz, 1985). Voronoi pattern starts with a Poisson point process, which defines seeds. The Voronoi cell is the planar region closer to the seed than to any other seed. The bounding segments of this region are lines that have equal distances to the seed and adjacent generator (Fig. 6).

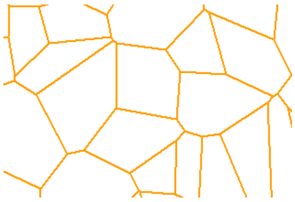

Fig. 6. The Voronoi joint model

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 et al., 1999; Griffiths and Lane, 1999).
In this Research in order to study the effect of joints pattern on the stability of rock slopes, slopes with different dips composed of limestone were modeled.

2.Geomechanical parameters of limestone

In this study, the geomechanical parameters of the jointed limestone 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. 7.

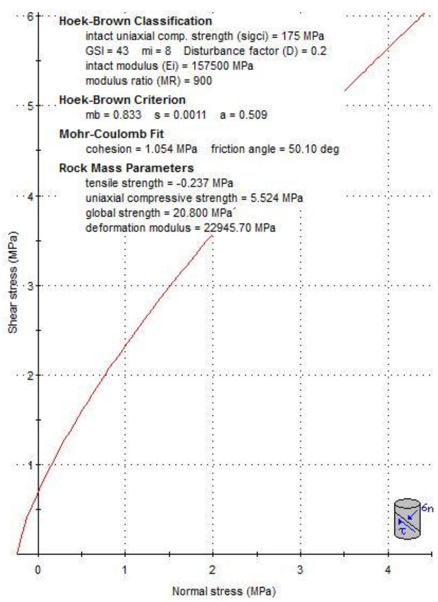

Fig.7. The geomechanical parameters of limestone

3. Modeling of rock slopes

To study the effect of joints pattern on the strength reduction factor (SRF), slopes with dips of 30, 45, 60, and 75 degrees and with joints pattern of Parallel deterministic, Parallel statistical, Cross jointed, Baecher, Veneziano and Voronoi were modeled with the same orientation, spacing and density. By run the made models, the critical strength reduction factor (SRF) of slopes was obtained (for example, as Figs. 8 to 13).

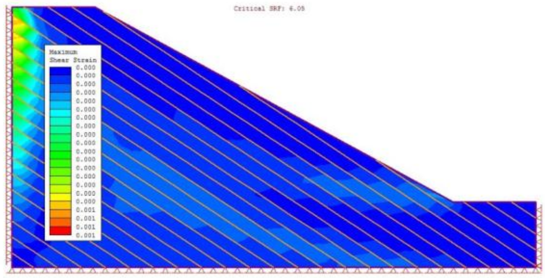

Fig. 8. The slope of 30 degree with Parallel deterministic joints (the critical SRF is equal to 6.05)

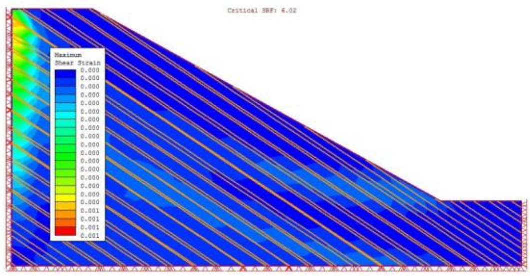

Fig. 9. The slope of 30 degree with Parallel statistical joints (the critical SRF is equal to 6.02)

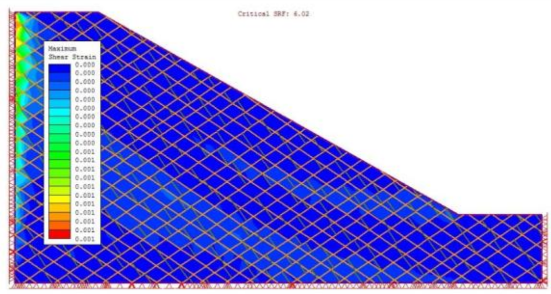

Fig. 10. The slope of 30 degree with Cross jointed joints (the critical SRF is equal to 6.02)

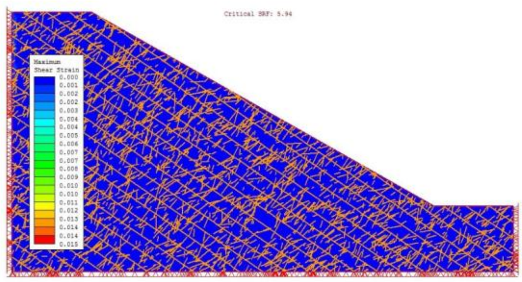

Fig. 11. The slope of 30 degree with Baecher joints (the critical SRF is equal to 5.94)

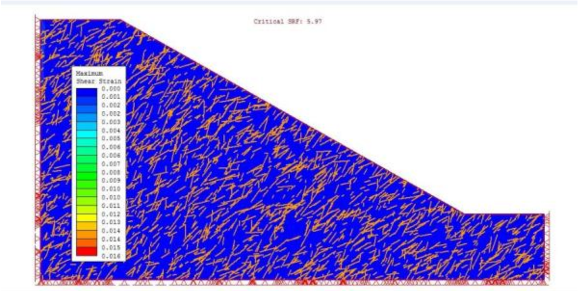

Fig. 12. The slope of 30 degree with Veneziano joints (the critical SRF is equal to 5.97)

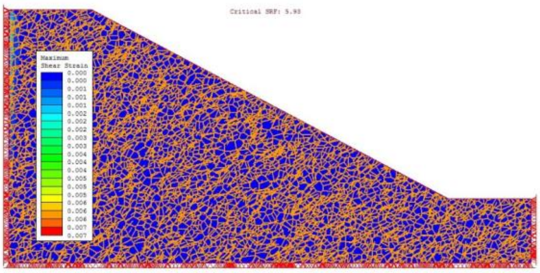

Fig. 13. The slope of 30 degree with Voronoi joints (the critical SRF is equal to 5.93)

Similarly, the values of SRF for other slopes are obtained and presented in diagrams in Figs. 14 to 17.

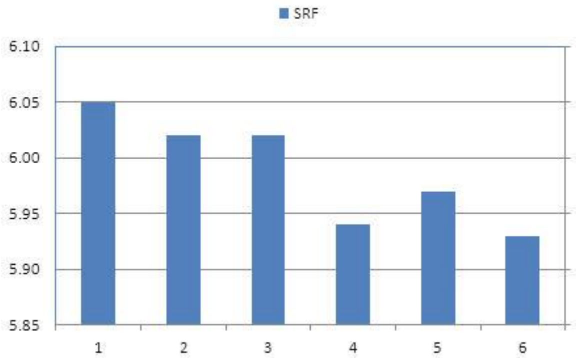

Fig. 14. The diagram shows the values of SRF for six models of joint on the slope with dip of 30 degrees (1-Parallel deterministic, 2-Parallel statistical, 3-Cross jointed, 4-Baecher, 5-Veneziano, 6-Voronoi)

Fig. 15. The diagram shows the values of SRF for six models of joint on the slope with dip of 45 degrees (1-Parallel deterministic, 2-Parallel statistical, 3-Cross jointed, 4-Baecher, 5-Veneziano, 6-Voronoi)

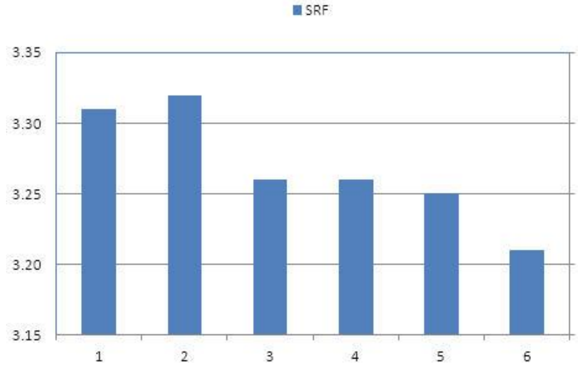

Fig. 16. The diagram shows the values of SRF for six models of joint on the slope with dip of 60 degrees (1-Parallel deterministic, 2-Parallel statistical, 3-Cross jointed, 4-Baecher, 5-Veneziano, 6-Voronoi)

Fig. 17. The diagram shows the values of SRF for six models of joint on the slope with dip of 75 degrees (1-Parallel deterministic, 2-Parallel statistical, 3-Cross jointed, 4-Baecher, 5-Veneziano, 6-Voronoi)

The diagrams in Figs. 14 to 17 show that in all slopes the maximum SRF is related to the parallel joints specially is owned by Parallel deterministic joints. This implies that the lack of connection in the parallel joints is the main cause increasing the shear strength of rock masses. Furthermore, the Voronoi joints have created the minimum SRF in all slopes. Mosaic connection of joints in Voronoi model, has decreased the shear strength of limestone and therefore the stability of slopes has reduced. In all slopes, the Veneziano joints have created mediocrity of the stability and it seems to be the optimal pattern of joints for numerical modeling. Moreover, the diagrams show that by increasing dip of slopes, the SRF has decreased for all joint patterns.

4. Conclusion

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

- By increasing dip of slopes, the strength reduction factor (SRF) has been decreased for all joint patterns.
- The maximum SRF is related to the Parallel deterministic joints.
- The minimum SRF in all slopes is related to the Voronoi

joints.
- The Veneziano joints have created mediocrity of stability in the slopes.

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