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The effect of pore pressure on the rock slope stability

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ABSTRACT: Rock slope stability analysis can be applied for transportation systems such as highways and railways. Failure of rock slopes includes a variety of rock falls, landslides and general instability of rock slopes. This article is done in a rock slope which is composed of jointed tuff rocks. In the modeling of slope, the joints with different dips of 0, 30, 45, 60 and 90 degrees using phase2 software were analyzed. The most important factor that investigated in this study is the effect of pore pressure on the joints in such a way that the value of 0 Mpa to 0.5 Mpa has been considered .The results indicate that by increasing pore pressure on the joints, the critical SRF decreased and the highest decrease of SRF is occurred in the pore pressure of 0.1 Mpa.

***Keywords*:** Rock slopes; Joints dip; Pore pressure; Strength Reduction Factor.

INTRODUCTION

Nowadays rock slope stability is one of the most important problems in large construction projects and factors that cause instability of slopes lead to rock fall, soil and debris and finally destroying the balance of mass in slope. A great variety of numerical analyses such as finite element and distinct element methods are performed with development of many kinds of numerical programs on the geotechnical problems. A number of methods are being used for the assessment of slope stability (Crosta, 2003; Bhasin and Kaynia, 2004; Eberhardt, 2004).
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, 1999; Griffiths and Lane, 1999). The rock mass properties such as the rock mass strength, the rock mass deformation modulus and the rock mass constants (mb, s and a) were calculated by the Roclab program defined by Hoek, (2002). This program has been developed to provide a convenient means of solving and plotting the equations presented by Hoek, (2002).
In rock slopes, jointed tuff rock masses are found widely in this paper by using Roclab software, tuff rock mechanical parameters are obtained and then entered Phase 2 software and analyzed.

Rock mass properties

Roclab software is the software for determining the resistance parameters of rock mass that acts according to the generalized Hook-Brown criteria. The identified rock mass properties by Roclab can be used in numerical analysis software such as Phase2 (analysis of stress finite element and designing of supports for excavated constructs) or Slide (analysis limit equations of slope stability).

Table 1. Mechanical properties of jointed tuff rock mass

Roclab program's input and output						
Hoek Brown Classification				Hoek Brown Criterion		
σ_{ci} (Mpa)	GSI	mi	D	mb	s	a
Intact Uniaxial Compressive Strength	Pick GSI Value			Pick mi Value		Disturbance Factor
175	50	13	0.7	0.833	0.0007	0.506
Mohr-Coulomb Fit				Rock Mass Parameters		
C (Mpa)	φ(degree)	σ_t(Mpa)		σ_c(Mpa)	σ_{cm}(Mpa)	Edm(Mpa)
Cohesion	Friction angle	Tensile strength		Uniaxial compressive strength	Global strength	Deformation modulus
0.506	50.36	- 0.15		4.482	20.994	5632.3

Numerical modeling

The required data for software entering data for analysis of slope stability are as the following: shape and dimensions of cross section of slope, dip and the direction of joints, the situation of joints and the existing pore pressure. In this research, slope stability in one jointed rock mass is studied, in such a way that slope angel is 45 degree and joints dip are 0, 30, 45, 60, and 90 degree. After several analyses, for better conclusion of this paper and control of slope stability, we concluded that the existing pore pressure in joints studied during 10 cases that these points are including 0, 0.05, 0.1, 0.125, 0.15, 0.2, 0.25, 0.3, 0.35, 0.5 Mpa.

Numerical analysis for slope deformations in tuff rock masses is conducted by using a two dimensional hybrid element method called Phase2 finite element software (Rocscience, 1999). In this modeling (finite element) that is founded based on the elasto-plastic, deformations and stresses calculated. These analyses are used for evaluating the stability of jointed tuff rock mass. Geo-mechanical properties for these analyses are extracted from Table 1. For identifying submission elements and plastic area around slopes, Hook and Brown fracture criteria is used.

The finite element modeling is shown in Fig.1. In this figure, dip of slope is 60 degree and dip of joints is 45 degree. Because we want the joints group nearly be parallel to rock mass, we considered the Veneziano joint model. The Veneziano joint network model that is used for numerical analysis is based on a Poisson line process. It adapts the Poisson process to generate joints of finite length (Dershowitz, 1985).

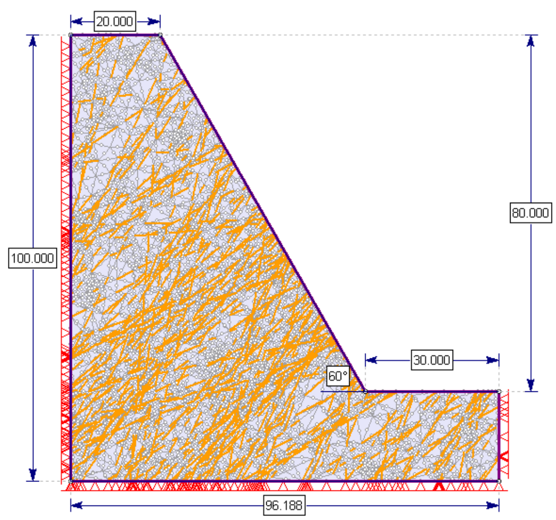

Figure 1. Finite element mesh and the Veneziano joint network

Analysis of resulting output from software

For studying the stability of slope, firstly we should investigate strength reduction factor (SRF) that is representing slope confidence coefficient (Fig. 2). The next stage we investigate that in what parts of rock mass the joints are ruptured (Fig. 3). With applying vertical stresses and increasing the pore pressure, shear strength decreases and finally in the parts of slope that joints are yielded, tension or shear ruptures are created and led to instability of slope.

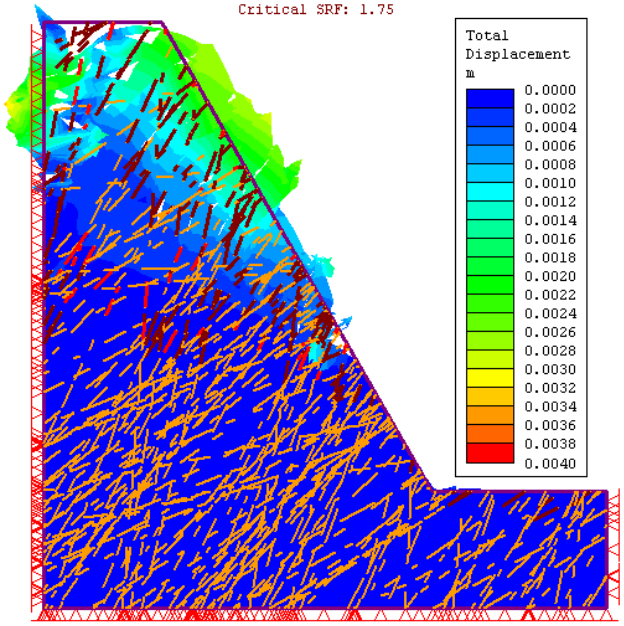

Figure 2. Shear strength reduction analysis of the slope in the basis of Hock–Brown criteria(dip of slope is 60 degree , dip of joints is 45 degree and pore pressure is 0.1 Mpa)

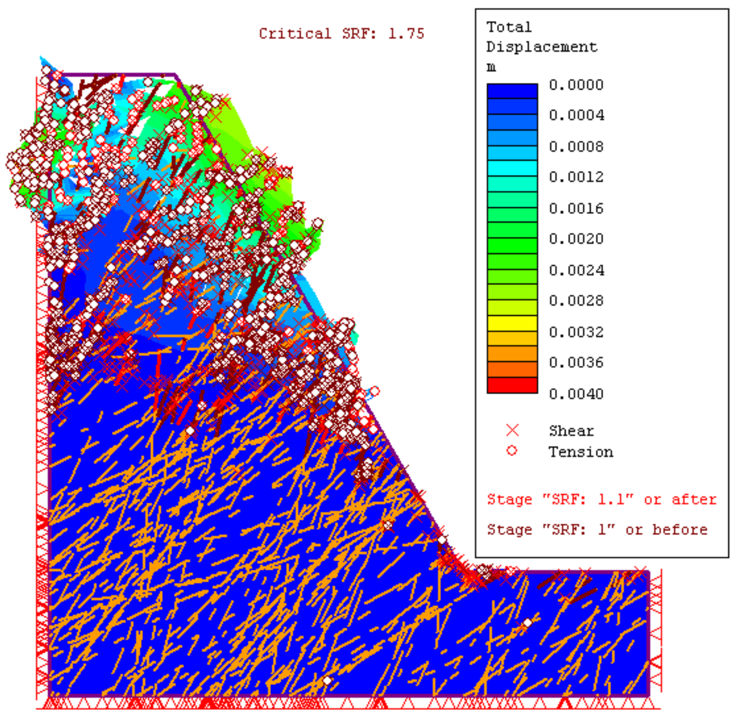

Figure 3. The yielded joints that are affected by shear, tension and increasing of pore pressure

The diagram in Fig. 4 shows that by increasing of pore pressure on the joints, the critical SRF decrease and the greatest decrease occurred in pore pressure of 0.1 Mpa. The diagram in Fig. 5 shows that critical pore pressure that cause instability of slope, in the joint dip of 45 degree has the highest value.

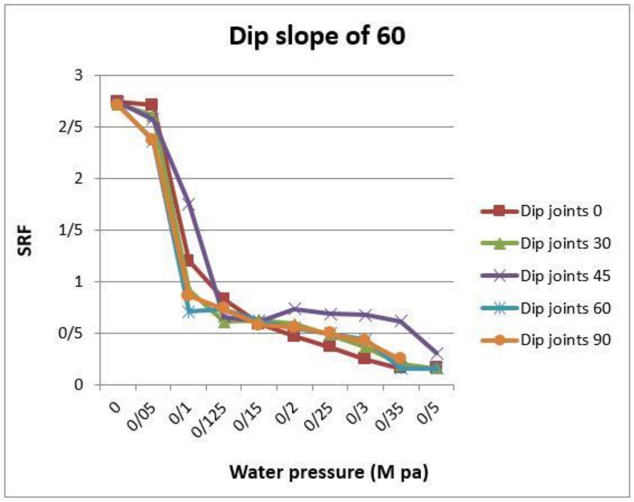

Figure 4. The strength reduction factor regarding to the pore pressure in the different joints dip on the slope of 60 degree

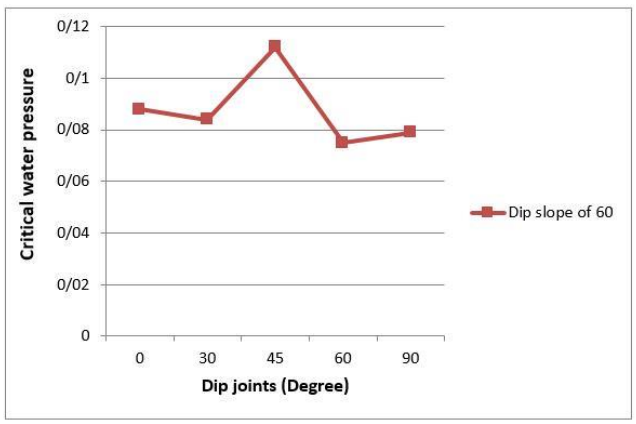

Figure 5. The critical pore pressure in the different joints dip on the slope of 60 degree

CONCULSION

In this paper the effect of pore pressure on the joints in the rock slopes are evaluated. The analyzing results are as the followings:

- By increasing pore pressure on the joints, the critical SRF decreased.
- The highest decrease of SRF is occurred in the pore pressure of 0.1 Mpa and after this value, the critical SRF decreased gradually.
- The critical pore pressure that cause instability of slope, in the joint dip of 45 degree has the highest value.

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