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STABILITY ANALYSIS OF ROCK SLOPES (CASE STUDY: ROCK SLOPES IN THE TAHAM ROAD)

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ABSTRACT: This paper presents the stability analysis of rock slopes in the Taham road in NW of Iran. In this study numerical modeling is used for two rock slopes at the route of Taham road. Shear strength reduction analyses is carried out using Phase2 in the basis of Hock–Brown and Mohr–Coulomb criteria. According to results of numerical analysis, Strength Reduction Factor (SRF) of the rock slopes is 1.11 and 1.44 on the basis of Hock–Brown criterion but, 2.13 and 2.41 on the basis of Mohr–Coulomb criterion respectively. The obtained results present that application of Hock–Brown criterion yielded more reliable results in this situation and any rotational failure will not occur. The Hock–Brown criterion allows the non-linear behaviour of the dilation angle with the shear displacement of rock blocks, but the dilation angle in the Mohr–Coulomb criterion is defined to be constant independent on the shear behaviour of rocks.

***Keywords*:** Rock slope, Stability analysis, Taham road, Strength Reduction Factor.

INTRODUCTION

The slope stability of rocks is an important problem in geotechnical engineering. The stability of the slope is always of superior importance during the lifetime of the structures such as highways, railroads and power plants (Aydan etal., 1989). 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 et al., 2003; Bhasin and Kaynia, 2004; Eberhardt et al., 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 et al., 1999; Griffiths and Lane, 1999).

This paper proposes a simple and practical numerical procedure to evaluate the stability of rock slopes in the Taham road. The proposed model is regulated in a united manner to accommodate both the Mohr–Coulomb and generalized Hock–Brown criteria. In this model, all the strength parameters are assumed to be a function of deviatoric plastic strain and to decrease linearly to the residual values.

The study area is located in the Taham road in northwest of Iran. Road cutting has caused several rock slopes in the road, but in here two slopes are investigated. Joints are the most basic structures that have subjected rocks and caused dense fracturing in these rocks.

2. THE ANDESITIC TUFF SLOPE

This slope is composed of andesitic tuffs with a dip of 78 degrees and a height of 25.68 meters.

1.2. Material Characteristics of the andesitic tuffs

The physical and mechanical characteristics of the andesitic tuffs were determined on obtained samples of boreholes and field tests on outcrops. The specific gravity of the andesitic tuffs varies from 2.65 to 2.70. The values of minimum and maximum UCS varies from 81 to 85 MPa respectively, and the average value of 83 MPa.

The average value for the rock material constant mi is determined using Hoek and Brown (1988) failure criterion. The value of mi for the andesitic tuffs is obtained equal to 18.

To acquire the andesitic tuff masses characteristics, site investigations were carried out on the outcrops along the slopes and the core logs of few borehole drillings. The information obtained of these investigations will be used on the rock mass classification as indices.

The most important discontinuities in the site of project are joints and surface beddings. The scan-line surveys, spot measurements, and field observations according to ISRM (1981) were carried out on the rocks along the slope to determine the orientations, spacing, roughness, aperture, persistence, infilling and water condition of the fractures.

2.2. Mechanical properties of the andesitic tuff masses

The rock mass properties such as the rock mass strength (σ_{cm}), 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) (Fig. 1). This program has been developed to provide a convenient means of solving and plotting the equations presented by Hoek et al. (2002).

In Rock-Lab program, both the rock mass strength and deformation modulus are calculated using equations of Hoek et al. (2002). The value of GSI is obtained from the last form of the quantitative GSI chart, which was proposed by Marinos and Hoek (2000).

In addition, the rock mass constants are estimated using equations of Geological Strength Index (GSI) (Hoek et al. 2002) together with the value of the andesitic tuff material constant (mi) (Fig. 1). Also, the value of disturbance factor (D) that depends on the amount of disturbance in the rock mass associated with the method of excavation, is considered equal to 0.7 for the andesitic tuffs, it means these rocks would be disturbed greatly during blasting.

Finally, the shear strength parameters of the rock mass (C and φ) for the andesitic tuff masses are obtained using the relationship between the Hoek-Brown and Mohr-Coulomb criteria (Hoek and Brown 1997) (Fig. 1).

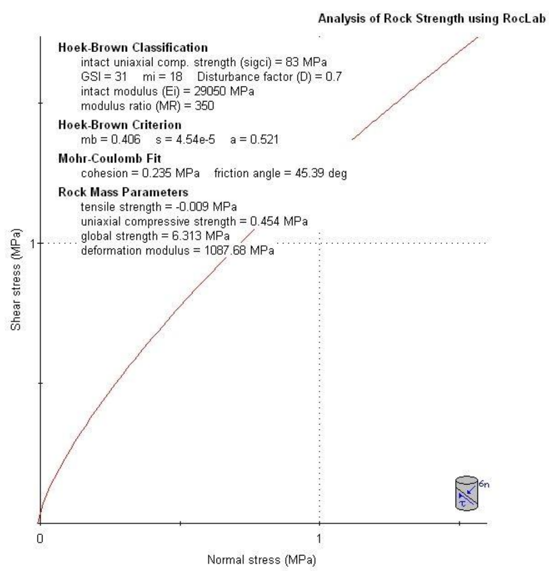


Figure 1. The geomechanical parameters of the andesitic tuff masses

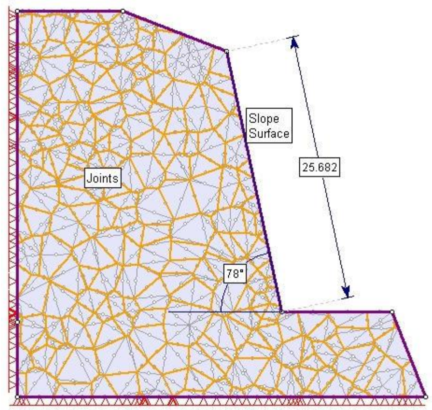
3.2. Stability analysis of the andesitic tuff slope

One of the most important tasks in rock engineering is stability analysis of the rock slopes. The numerical method is employed for stability analysis of the andesitic tuff slope in the Taham road.

Numerical analysis of rock slopes in the study area is accomplished using a two-dimensional hybrid element model, called Phase2 Finite Element Program (Rocscience 1999). The program is based on the finite element method including some geotechnical parameters. These geotechnical parameters are slope height, slope angle, uniaxial compressive strength, Poisson's ratio, unit weight of the rock, Geological strength index (GSI), Hoek–Brown parameters, deformation modulus of rock mass, friction angle, cohesion and situation of the joints and groundwater condition.

The Voronoi joint network model is used for numerical analysis (Fig. 2) and this model is based on a Poisson line process that randomly subdivides a plane into non-overlapping convex polygons. A Voronoi joint network consists of joints that are defined by the bounding segments of these polygons (Dershowitz, 1985).

Shear strength reduction analyses is carried out using Phase2 in the basis of Hock–Brown and Mohr–Coulomb criteria and Strength Reduction Factor (SRF) for this slope is determined. According to results of numerical analysis, Strength Reduction Factor (SRF) of this slope is 1.11 for Hock–Brown criterion and 2.13 for Mohr–Coulomb criterion respectively, and any rotational failure will not occur (Figs. 3 and 4). The obtained results present that application of Hock–Brown criterion yielded more reliable results in this slope.



Material Name	Color	Initial Element Loading	Unit Weight (MN/m3)	Elastic Type	Young's Modulus (MPa)	Poisson's Ratio
Andesitic Tuff		Field Stress and Body Force	0.0267	Isotropic	1087.68	0.3

Fig. 2. The model of slope with Voronoi joint network

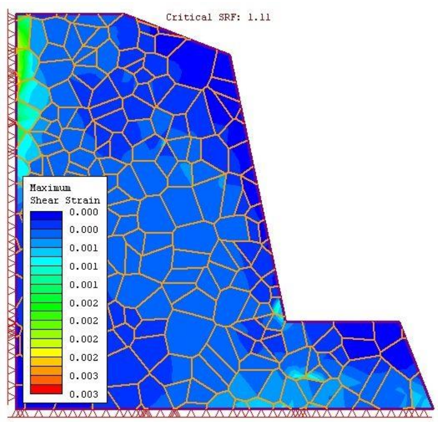


Fig. 3. Shear strength reduction analysis of the andesitic tuff slope on the basis of Hock–Brown criterion(Critical SRF= 1.11)

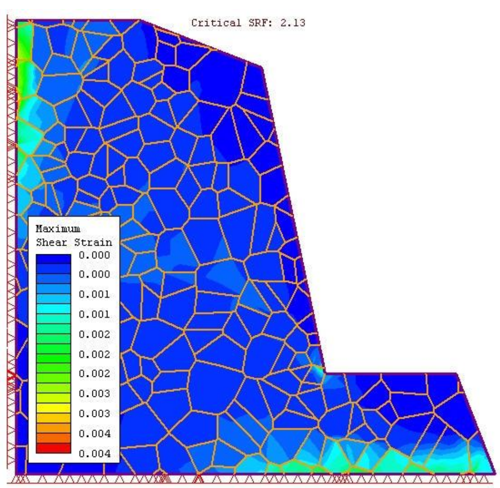


Fig. 4. Shear strength reduction analysis of the andesitic tuff slope on the basis of Mohr–Coulomb criterion (Critical SRF= 2.13)

3. THE PORPHYRITE ROCK SLOPE

This slope is composed of the porphyrite rocks with a dip of 86 degrees and a height of 26.02 meters.

1.3. Material characteristics of the porphyrite rocks

The physical and mechanical characteristics of the porphyrite rocks were determined on obtained samples of boreholes and field tests on outcrops. The specific gravity of the porphyrite rocks varies from 2.67 to 2.70. The values of minimum and maximum UCS varies from 110 to 115 MPa respectively, and the average value of 112 MPa.

The average value for the rock material constant mi is determined using Hoek and Brown (1988) failure criterion. The value of mi for the porphyrite rocks is obtained equal to 20.

2.3. Mechanical properties of the porphyrite rock masses

The rock mass properties such as the rock mass strength (σ_{cm}), the rock mass deformation modulus (Em), the rock mass constants (mb, s and a) and the shear strength parameters of the rock mass (C and φ) are calculated by the Rock-Lab program defined by Hoek et al. (2002) (Fig. 5).

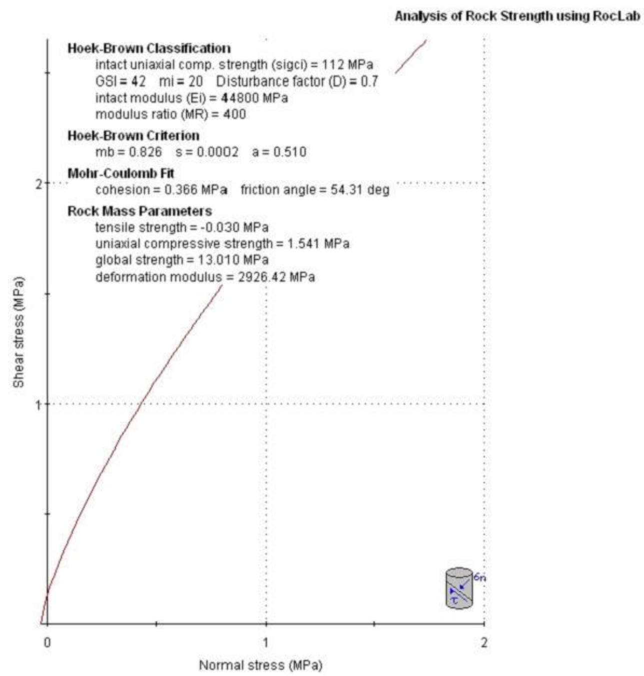


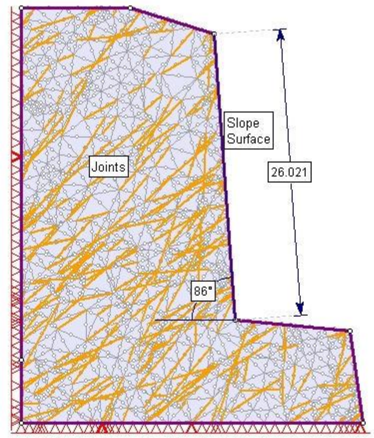
Fig.5. The geomechanical parameters of the porphyrite rock masses

3.3. Stability analysis of the porphyrite rock slope

The numerical method is employed for stability analysis of the porphyrite rock slope in the Taham road.

Numerical analysis of rock slopes in the study area is accomplished using a two-dimensional hybrid element model, called Phase2 Finite Element Program (Rocscience 1999). The Veneziano joint network model is used for numerical analysis (Fig. 6) and this model is based on a Poisson line process. It adapts the Poisson process to generate joints of finite length (Dershowitz, 1985).

Shear strength reduction analyses is carried out using Phase2 in the basis of Hock–Brown and Mohr–Coulomb criteria and Strength Reduction Factor (SRF) for this slope is determined. According to results of numerical analysis, Strength Reduction Factor (SRF) of this slope is 1.44 for Hock–Brown criterion and 2.41 for Mohr–Coulomb criterion respectively, and any rotational failure will not occur (Figs. 7 and 8). The obtained results present that application of Hock–Brown criterion yielded more reliable results in this slope.



Material Name	Color	Initial Element Loading	Unit Weight (MN/m3)	Elastic Type	Young's Modulus (MPa)	Poisson's Ratio
Porphyrite		Field Stress and Body Force	0.0267	Isotropic	2926.42	0.3

Fig. 6. The model of slope with Veneziano joint network

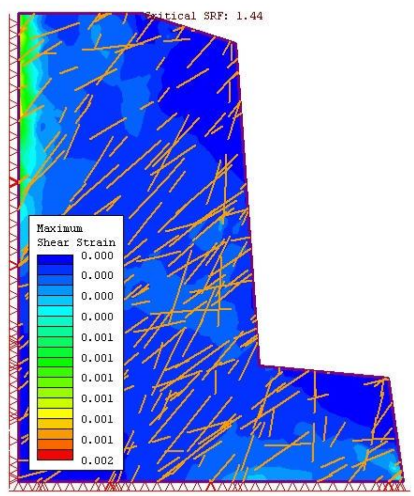


Fig. 7. Shear strength reduction analysis of the porphyrite rock slope on the basis of Hock–Brown criterion (Critical SRF= 1.44)

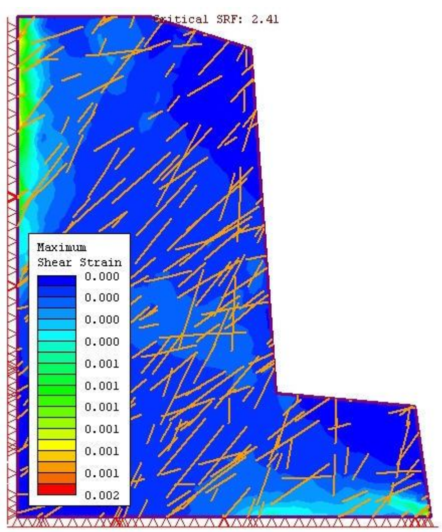


Fig. 8. Shear strength reduction analysis of the porphyrite rock slope on the basis of Mohr–Coulomb criterion (Critical SRF= 2.41)

CONCLUSION

This study is aimed at assessing the stability of the rock slopes in the Taham road in northwest of Iran. Based on the information collected in the field and laboratory, the slope stability is investigated. Shear strength reduction analyses is evaluated using Phase2 and Strength Reduction Factor (SRF) for the rock slopes is determined. The obtained results present that in these slopes any rotational failure will not occur and application of Hock–Brown criterion yielded more reliable results. Therefore, to avoid risk in construction works it is recommended that the Hock–Brown criterion be used.

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