Journal of Novel Applied Sciences
Available online at www.jnasci.org
©2014 JNAS Journal-2014-3-S1/1520-1523
ISSN 2322-5149 ©2014 JNAS

Probabilistic stability analysis of andesitic tuff slope in the Taham road

Vahid Hosseinitoudeshki* and Fardin Roomi

Department of Civil Engineering, Zanjan Branch, Islamic Azad University, Zanjan, Iran

***Corresponding author*:** Vahid Hosseinitoudeshki

ABSTRACT: This paper presents the probabilistic stability analysis of andesitic tuff slope in the Taham road in NW of Iran. To use probabilistic analysis, the best fitted distributions to rock mass characteristics were first obtained. Using point estimate method (PEM) we combine probabilistic input variables such as the material constant for intact rock (mi), the geological strength index (GSI), deformation modulus (E), intact uniaxial compressive strength (σ_{ci}), and evaluate the distribution of the output variables such as strength reduction factor (SRF). Shear strength reduction analyses is carried out using Phase2 in the basis of Hock–Brown criterion. The obtain results show that the stability of the andesitic tuff slope is more sensitive to the parameters related to lithology of slope than mechanical parameters.

***Keywords*:** Probabilistic analysis; Andesitic tuff slope; Taham road; Strength Reduction Factor.

INTRODUCTION

In the analysis of slope stability, there are uncertainties that caused by different sources. Often the parameters required for stability analysis of slopes are not well known. In these cases it is favorable to perform a parametric study where model behaviour is examined for a range of possible inputs. Therefore, probabilistic methods are used in these cases and here the point estimate method (PEM) has been applied. The purpose of the method is to be able to combine probabilistic input variables and to evaluate the distribution of the output variables. The rule of PEM is to compute solutions at various estimation points and to combine them with appropriate weighting in order to get an estimation of the distribution of the output variables (Rocsceince, 2012).

The slope stability of rocks is an important problem in geotechnical engineering. 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).

This paper attempts to present probabilistic analysis of the andesitic tuff slope in the Taham road. 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 the andesitic tuff slope is 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 . (2002) (Fig. 1). This program has been developed to provide a convenient means of solving and plotting the equations presented by Hoek . (2002).

In Rock-Lab program, both the rock mass strength and deformation modulus are calculated using equations of Hoek . (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 . 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).

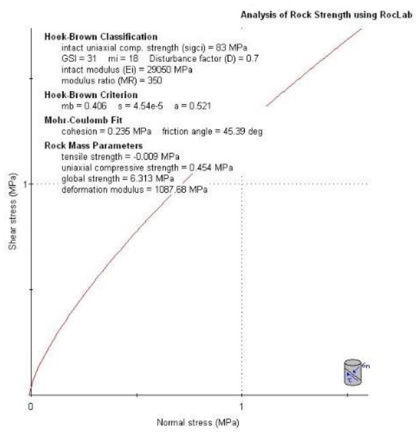


Figure 1. The geomechanical parameters of the andesitic tuff masses

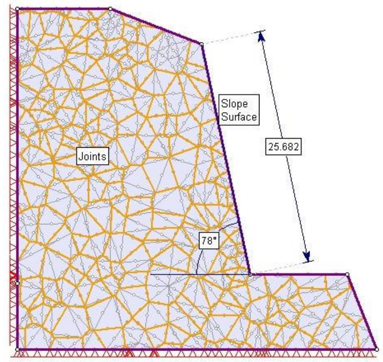
3.2. Stability analysis of the andesitic tuff slope

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 criterion and the strength reduction factor (SRF) for this slope is determined. According to results of numerical analysis, the strength reduction factor (SRF) of this slope is 1.11 for Hock–Brown criterion, and any rotational failure will not occur (Figs. 3).



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

Figure 2. The model of slope with Voronoi joint network

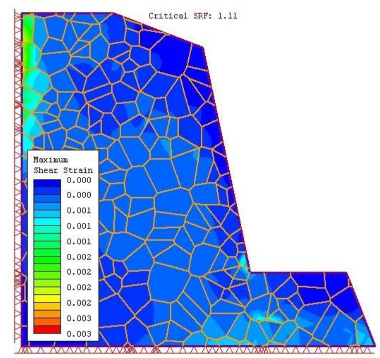


Figure 3. Shear strength reduction analysis of the andesitic tuff slope in deterministic analysis (Critical SRF= 1.11)

PROBABILISTIC STABILITY ANALYSIS OF THE ANDESITIC TUFF SLOPE

Probabilistic stability analysis of the andesitic tuff slope includes analysis of shear strength reduction factor. The best guess for the Hoek and Brown parameters enter and run the analysis. However, the properties of these parameters are not well known, so we will run a statistical analysis by varying the parameters in a systematic way to see the range of possible behaviours.

Probabilistic stability analysis is done by selecting the standard deviation to 1, 2 and 3 for the material constant for intact rock (mi), the geological strength index (GSI), deformation modulus (E), and intact uniaxial compressive strength (σ_{ci}). For each the above, the strength reduction factors (SRF) of the andesitic tuff slope is obtained and its changes in percent is shown in Fig. 4.

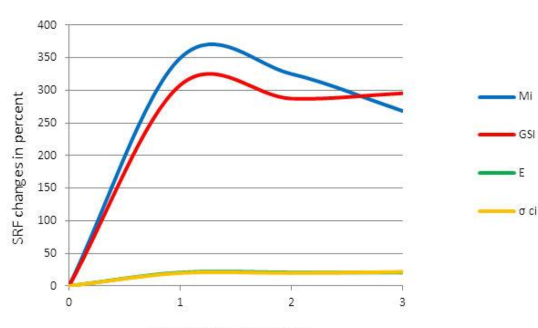


Figure 4. Diagram of changes the SRF for geomechanical parameters with different values of standard deviation

The diagram in Fig. 4 shows that by applying the uncertainty in geomechanical parameters of andesitic tuffs, the amount of strength reduction factor (SRF) of the slope is increased. As can be seen, the greatest change in the amount of strength reduction factor (SRF) is related to the uncertainty in the parameters of mi and GSI with a standard deviation to 1. Furthermore, the parameters of E and σ_{ci} have the least impact on the strength reduction factor of the andesitic tuff slope. This suggests that the stability of the andesitic tuff slope is more sensitive to the parameters related to lithology of slope than mechanical parameters.

CONCLUSION

This study is aimed to present probabilistic analysis of the andesitic tuff slope 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 the strength reduction factor (SRF) for the rock slopes is determined. The obtained results present that in this slope any rotational failure will not occur and the greatest change in the amount of strength reduction factor (SRF) is related to the uncertainty in the parameters of mi and GSI namely, parameters related to the lithology of slope.

REFERENCES

Dawson EM, Roth WH and Drescher A. 1999. Slope Stability Analysis by Strength Reduction, Geotechnique, 49(6): 835-840

Dershowitz W. 1985. Rock Joint Systems., Ph.D. Thesis, Massachusetts Institute of Technology, Cambridge, MA

Griffiths DV and Lane PA. 1999. Slope Stability Analysis by Finite Elements, Geotechnique, 49(3): 387-403

Hoek E and Brown T. 1997. Practical estimates of rock mass strength, Int. J. Rock Mech. Min. Sci., 34 (8): 1165–1186

Hoek E and Brown T. 1988. The Hoek–Brown failure criteria—a 1988 update, In: Proc. 15th Canadian Rock Mech. Symp, 31–38 pp

Hoek E, Carranza-Torres C and Corkum B. 2002. Hoek–Brown Failure Criterion-2002 Edition, Rocscience

ISRM. 1981. In: Brown, E.T. (Ed.), Rock Characterization, Testing and Monitoring, ISRM Suggested Methods, Pergamon Press, Oxford

Marinos P and Hoek E. 2000. GSI: a geologically friendly tool for rock mass strength estimation, Proceedings of the GeoEng2000 at the Int Conference on Geotechnical and Geological Engineering, Melbourne. Technomic publishers, Lancaster, 1422–1446 pp

Rocscience. 1999. A 2D finite element program for calculating stresses and estimating support around the underground excavations. Geomechanics Software and Research. Rocscience Inc., Toronto, Ontario, Canada

Rocscience.2012. Phase2, 5. Rocscience Inc., Toronto, www.rocscience. com.