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Probabilistic Stability Analysis of Tunnel No.2 of Kurdistan, NW Iran

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Abstract- Stability analysis of tunnels is a geotechnical engineering problem characterized by many sources of uncertainty. Therefore, rock characteristics could not be defined by deterministic values and probabilistic methods would be as a suitable alternative. The tunnel No.2 of Kurdistan in NW Iran is a road tunnel and a part of tunnel is composed of shale rocks. To use probabilistic analysis, the best fitted distributions to rock mass characteristics were first obtained. Using point estimate method (PEM) method we combine probabilistic input variables such as deformation modulus and intact uniaxial compressive strength, and evaluate the distribution of the output variables such as total displacement. The obtain results show that probabilistic approach, when it is possible to have sufficient data on the quality of the rock mass, leads to a better understanding of the project risks.

Keywords- *Probabilistic analysis; Tunnel No.2 of Kurdistan; Shale*

I. INTRODUCTION

In the analysis of tunnel stability, there are uncertainties that caused by different sources. Often the parameters required for stability analysis of tunnels are not well known. In these cases it is favorable to perform a parametric study where model behavior 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 study area is located in in Sanandaj - Sirjan structural zone (Aghanabati, 2004) which has been affected regional convergence in the NE-SW direction. In the regional tectonic, Sanandaj – Sirjan zone is located in the Turkish-Iranian plateau (Allen et al., 2004). It extends from eastern Anatolia to eastern Iran, and typically has elevations of 1.5–2 km.

This paper attempts to present probabilistic analysis of the shale rocks and evaluating their behaviors in the tunnel No.2 of Kurdistan in the northwest of Iran. This tunnel, with span of 12.5 meters will be excavated in the shale rocks in this area is considered as case study.

II. THE PHYSICAL AND MECHANICAL CHARACTERISTICS OF THE SHALE ROCKS

The physical and mechanical properties of the shale rocks are determined from cores obtained of boreholes in a tunnel. The specific gravity of these rocks is equal to 2.65 and the minimum and maximum of UCS varies from 18 to 22 MPa, respectively, and the average value is equal to 20 MPa.

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) were calculated by the RocLab 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 RocLab program, both the rock mass strength and deformation modulus were calculated using equations of (Hoek et al., 2002). In addition, the rock mass constants were estimated using equations of Geological Strength Index (GSI) (Hoek et al., 2002) together with the value of the shale material constant (mi). Also, the value of disturbance factor (D) that depends on the amount of disturbance in the rock mass associated with the excavation method was considered zero for the shale rocks in Fig. 1.

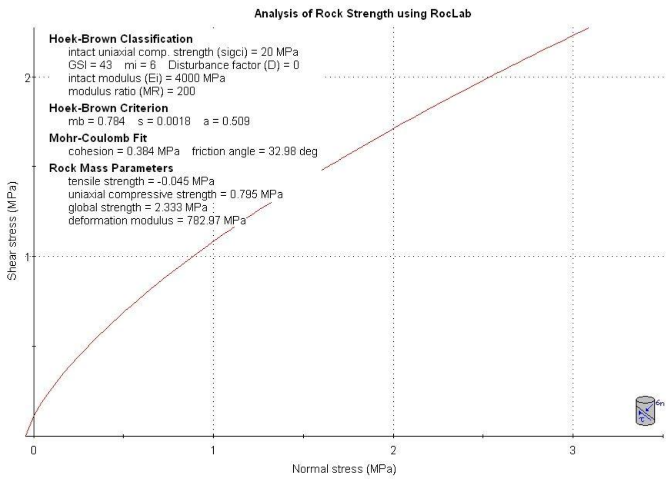
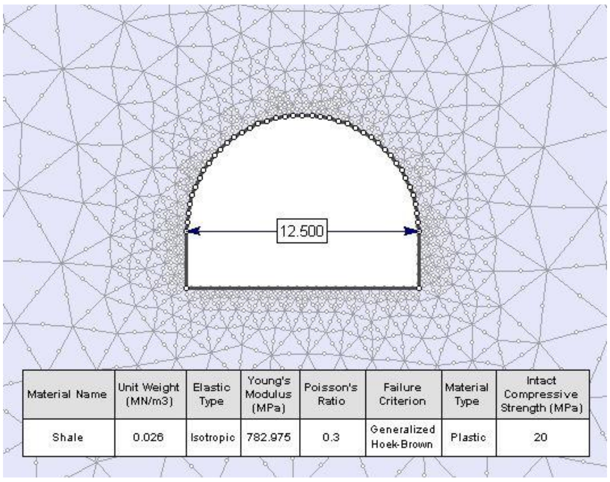


Figure 1. The geomechanical parameters of shale rock masses

III. PROBABILISTIC STABILITY ANALYSIS OF THE TUNNEL

Probabilistic stability analysis of tunnel deformations in the shale rock masses were accomplished using a two-dimensional hybrid element model, called Phase2 Finite Element Program (Rocscience, 1999). This software is used to simulate the three-dimensional excavation of a tunnel. In three dimensions, the tunnel face provides support. As the tunnel face proceeds away from the area of interest, the support decreases until the stresses can be properly simulated with a two-dimensional plane strain assumption. In this finite element simulation, based on the elasto-plastic analysis, deformations and stresses were computed. These analyses used for evaluations of the tunnel stability in the shale rock masses. The geomechanical properties for these analyses were extracted from Fig. 1.

To simulate the excavation of tunnel in the shale rock masses, a finite element models was generated with horseshoe section and 12.5 m span. The outer model boundary was set at a distance of 5 times the tunnel radius and six-nodded triangular elements were used in the finite element mesh (Fig. 2).



Material Name	Unit Weight (MN/m3)	Elastic Type	Young's Modulus (MPa)	Poisson's Ratio	Failure Criterion	Material Type	Intact Compressive Strength (MPa)
Shale	0.026	Isotropic	782.975	0.3	Generalized Hoek-Brown	Plastic	20

Figure 2. Numerical modeling of the tunnel No.2 of Kurdistan

Probabilistic stability analysis of the tunnel includes analysis on the state of displacement in the roof of tunnel. 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. The first, numerical model of the tunnel is run on the state of deterministic analysis and displacement values in the tunnel roof are shown in Fig. 3. As can be seen, displacement values away from the tunnel roof are decreased.

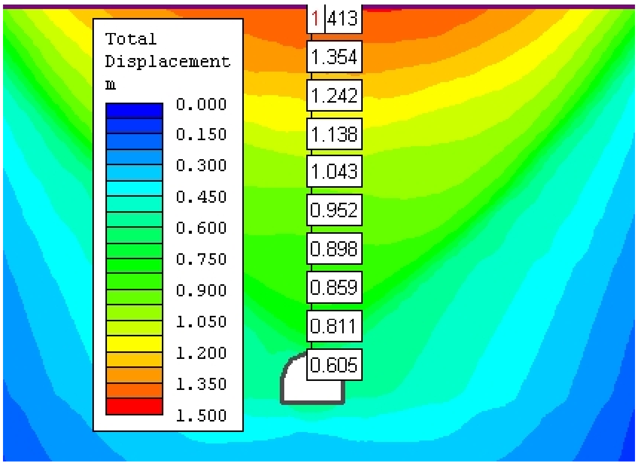


Figure 3. Displacements in the tunnel roof in deterministic analysis

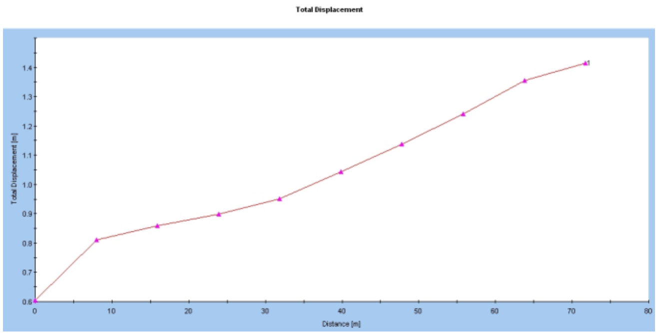


Figure 4. Displacement status away from the tunnel roof in deterministic analysis

The plot in Fig.4 indicates the displacement values in terms of distance away from the tunnel roof. This diagram is composed of three parts that are jointed as distinctive.

In the second stage, probabilistic stability analysis is started by selecting the standard deviation to 3 for deformation modulus. The displacement values in the tunnel roof are shown in Fig.5. As can be seen, the displacement values compared to deterministic analysis have decreased.

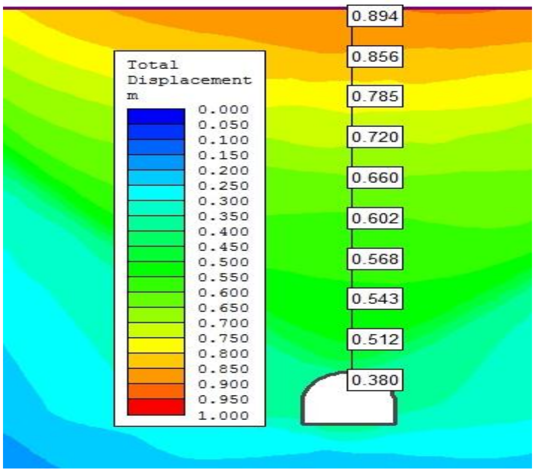


Figure 5. Displacements in the tunnel roof in probabilistic stability analysis (the standard deviation to 3 for deformation modulus)

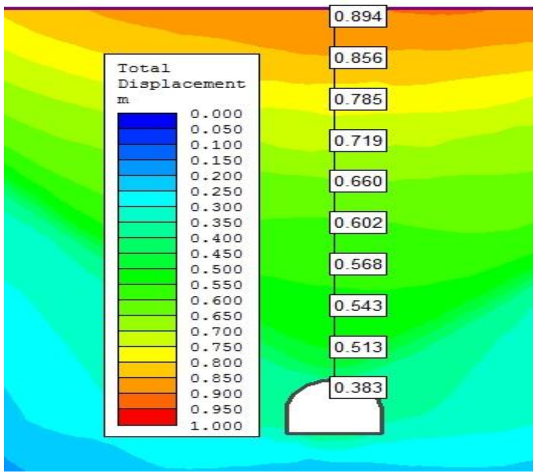


Figure 7. Displacements in the tunnel roof in probabilistic stability analysis (the standard deviation to 3 for intact uniaxial compressive strength)

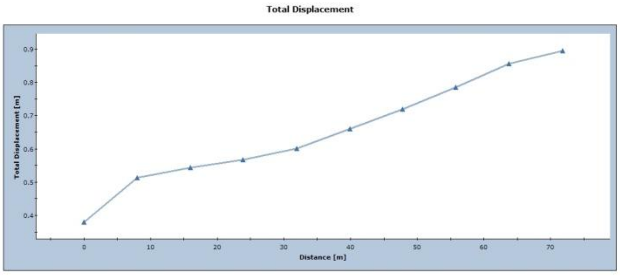


Figure 6. Displacement status away from the tunnel roof in probabilistic stability analysis (the standard deviation to 3 for deformation modulus)

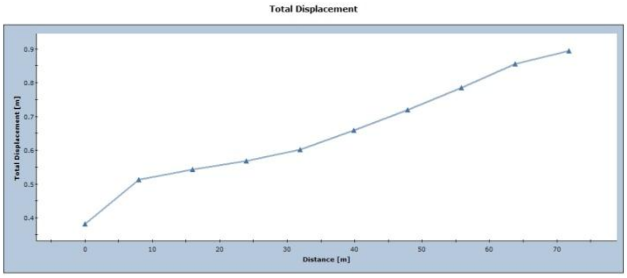


Figure 8. Displacement status away from the tunnel roof in probabilistic stability analysis (the standard deviation to 3 for intact uniaxial compressive strength)

The error plot in Fig.6 indicates the range of possible roof displacements that can be expected for the standard deviation to 3 for deformation modulus.

In the third stage, probabilistic stability analysis is accomplished by selecting the standard deviation to 3 for intact uniaxial compressive strength. The displacement values in the tunnel roof are shown in Fig. 7. As can be seen, the displacement values this time is decreased uniformly across the tunnel roof and the displacement compared to earlier stage is slightly increased.

The error plot in Fig.8 indicates the range of possible roof displacements that can be expected for the standard deviation to 3 for intact uniaxial compressive strength. This diagram shows that the range of possible displacements is much larger than previous case.

The results of this analysis clearly show advantages probabilistic stability analysis to definite analysis and indicate that the deterministic description of tunnel stability with a safety factor is frequently insufficient and the probabilistic analysis will lead to a better understanding of tunnel stability and provide more complete information. A probabilistic approach, when it is possible to have sufficient data on the quality of the rock mass, leads to a better understanding of the project risks.

IV. CONCLUSIONS

This study provides an estimation of the shale rock masses properties that could be used as input data for stability analysis for the tunnel No.2 of Kurdistan. Due to uncertainty in rock masses properties specially, deformation modulus and intact uniaxial compressive strength, a probabilistic analysis using

PEM method is accomplished for determination of displacement values around the tunnel.

Numerical solutions show that the shale rock masses indicate instability due to their lower strength. The displacement values in the tunnel roof in the probabilistic analysis are lower and more uniform than deterministic approach. The results of this study indicated that the deterministic approach of stability analysis should be used associated with probabilistic method to analyze the tunneling projects stability condition.

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