# The Application Of Point Estimate Method (PEM) In The Tunnel No.2 Of Kurdistan, NW Iran

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***Abstract*— This paper presents a new probabilistic method that modifies conventional modeling manners by incorporating inherent variability of geomechanical parameters in finite element numerical models using statistical techniques. Using point estimate method (PEM) we combine probabilistic input variables such as deformation modulus, intact uniaxial compressive strength and Passion's ratio, and evaluate the distribution of the output variables such as total displacement. The geomechanical characteristics of rocks 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. The obtain results show that probabilistic the deformation modulus of shale rock masses have the maximum impact in the total displacement, the maximum and minimum stress in around the tunnel.**

***Keywords*— *Point Estimate Method (PEM); Tunnel No.2 of Kurdistan; Shale***

## 1. INTRODUCTION

In geotechnical engineering, various statistical techniques such as Monte-Carlo, first order second moment, Hasofer-Lind, and point estimate method (PEM) have been used [1, 2]. Among these methods, the point estimate method that proposed by [3] is used due to its simplicity, accuracy, and flexibility. 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 point estimate method 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 [4].

The study area is located in in Sanandaj - Sirjan structural zone [5] 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 [6]. It extends from eastern Anatolia to eastern Iran, and typically has elevations of 1.5–2 km.

The purpose of this paper is to present and demonstrate a new probabilistic methodology that applied for the tunnel No.2 of Kurdistan in the northwest of Iran that considers the inherent variability of geomechanical parameters. This tunnel, with span of 12.5 meters will be excavated in the shale rocks.

## 2. 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 ($\sigma_{cm}$), the rock mass deformation modulus (Em) and the rock mass constants (mb, s and a) were calculated by the RocLab program defined by [7] (Fig. 1). This program has been developed to provide a convenient means of solving and plotting the equations presented by [7].

In RocLab program, both the rock mass strength and deformation modulus were calculated using equations of [7]. In addition, the rock mass constants were estimated using equations of Geological Strength Index (GSI) [7] 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.

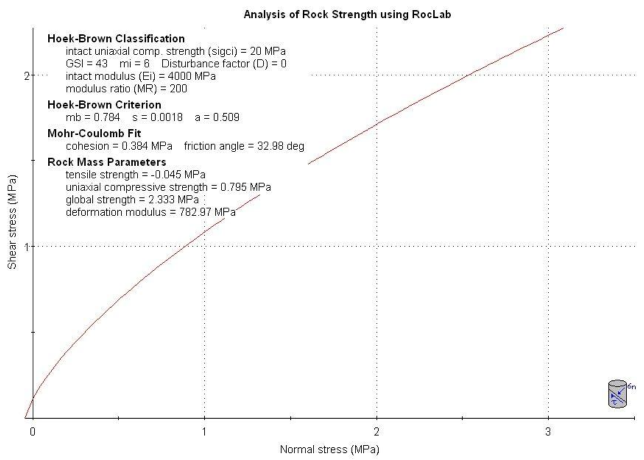
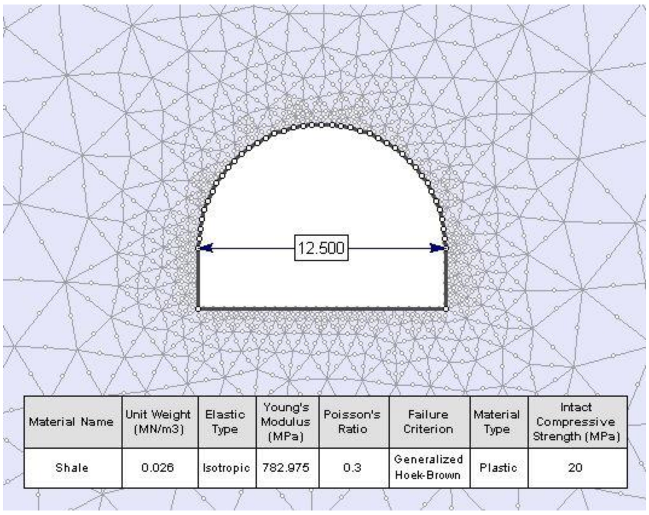



Fig.1. The geomechanical parameters of shale rock masses

3. 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 [8]. 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 |

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

Probabilistic stability analysis of the tunnel includes analysis on the state of total displacement, the maximum and minimum stress 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 the total displacement, the maximum and minimum stress values in the tunnel roof are shown in Figs. 3, 4 and 5.

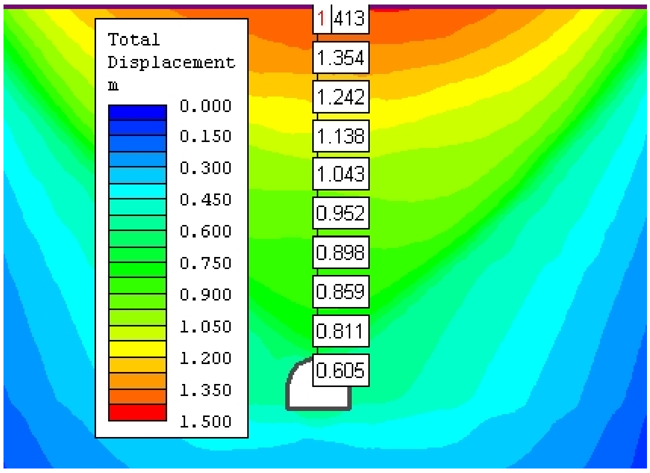



Fig. 3. The total displacements in the tunnel roof in deterministic analysis

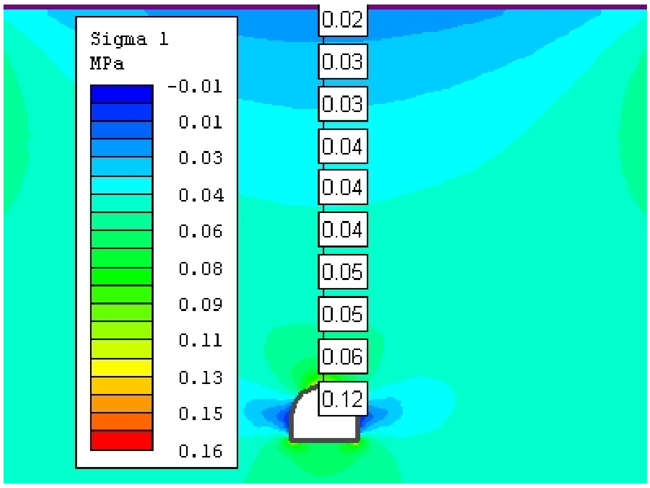



Fig. 4. The maximum stress in the tunnel roof in deterministic analysis

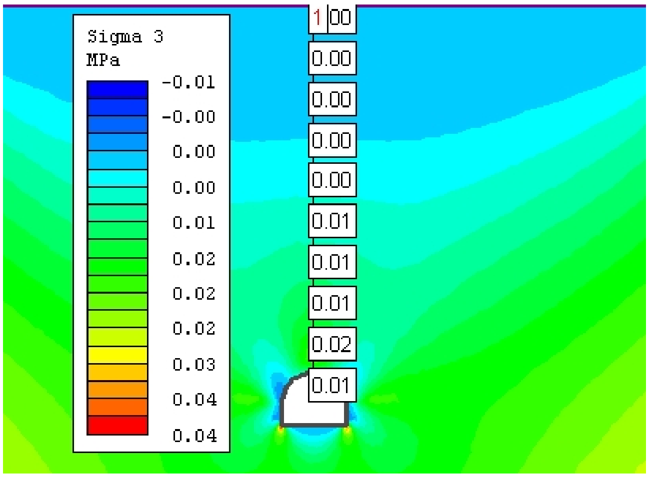



Fig. 5. The minimum stress in the tunnel roof in deterministic analysis

In the second stage, probabilistic stability analysis is started by selecting the standard deviation 1 to 3 for deformation modulus and intact uniaxial compressive strength. The standard deviation for Passion's ratio is considered 0.01 to 0.03. By run the models, the values of total displacement, the maximum and minimum stress in the tunnel roof are determined and percent of their changes is shown in Figs. 6 to 14.

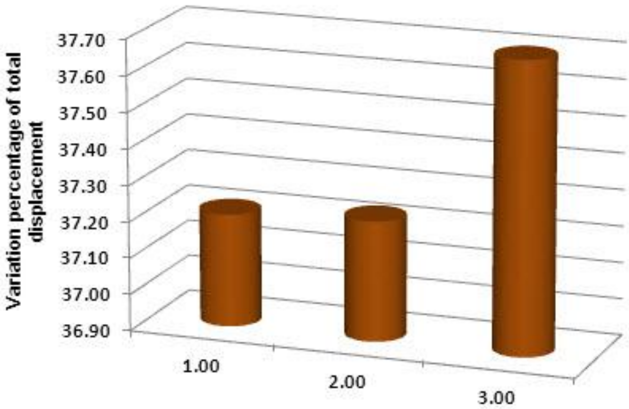



Fig. 6. The variation percentage of total displacements in the tunnel roof to standard deviation 1 to 3 for deformation modulus

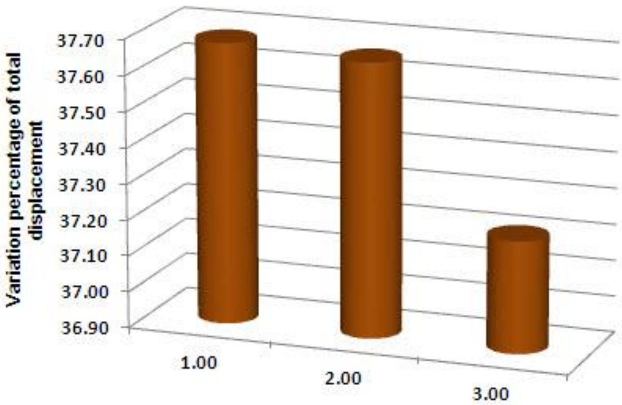



Fig. 7. The variation percentage of total displacements in the tunnel roof to standard deviation 1 to 3 for intact uniaxial compressive strength

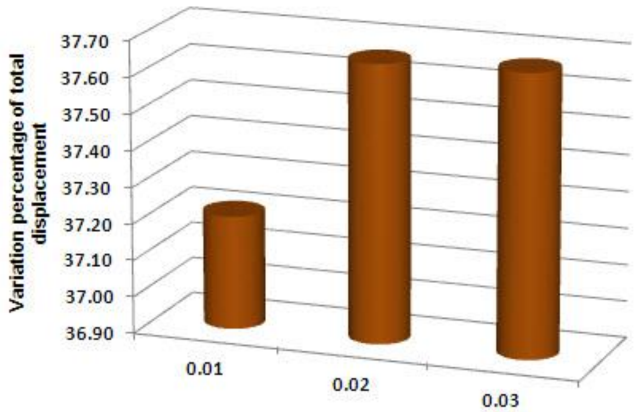



Fig. 8. The variation percentage of total displacements in the tunnel roof to standard deviation 0.01 to 0.03 for Passion's ratio

As the diagrams in Figs. 6, 7 and 8 show, the maximum change of total displacement in the tunnel roof is related to deformation modulus with standard deviation of 3.

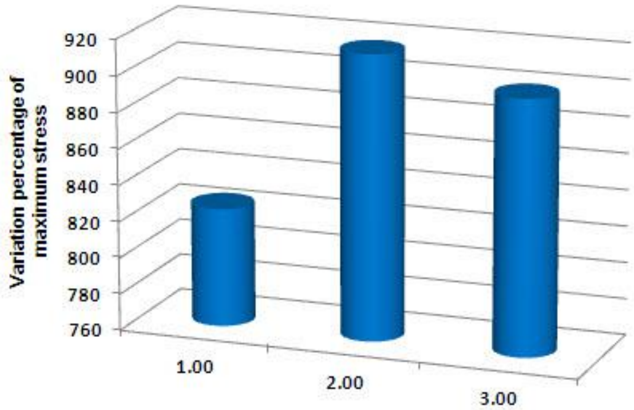



Fig. 9. The variation percentage of maximum stress in the tunnel roof to standard deviation 1 to 3 for deformation modulus

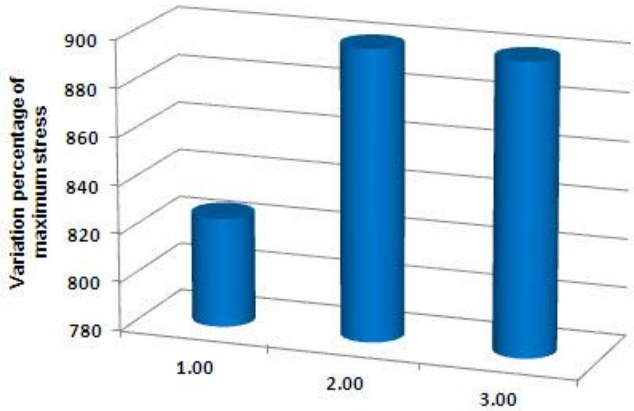



Fig. 10. The variation percentage of maximum stress in the tunnel roof to standard deviation 1 to 3 for intact uniaxial compressive strength

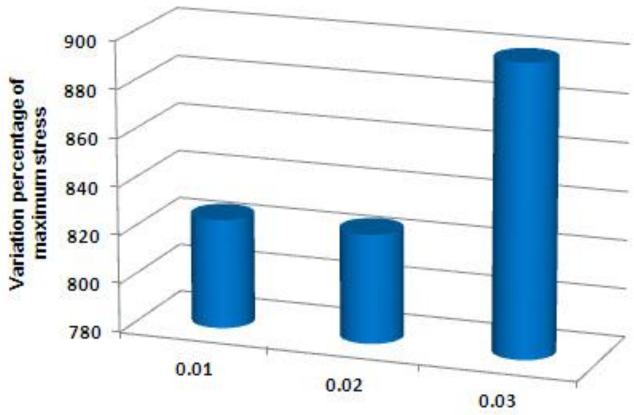



Fig. 11. The variation percentage of maximum stress in the tunnel roof to standard deviation 0.01 to 0.03 for Passion's ratio

As the diagrams in Figs. 9, 10 and 11 show, the most change of maximum stress in the tunnel roof is related to deformation modulus with standard deviation of 2.

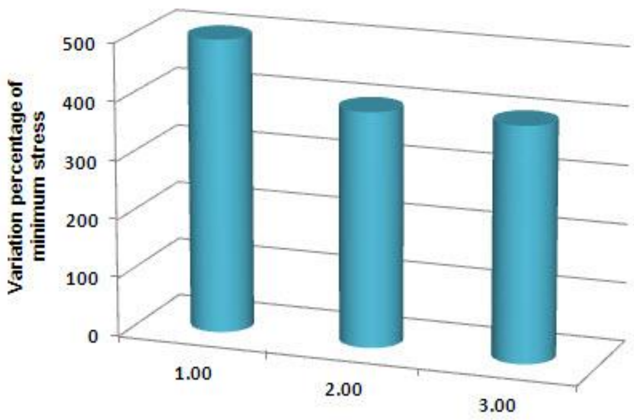



Fig. 12. The variation percentage of minimum stress in the tunnel roof to standard deviation 1 to 3 for deformation modulus

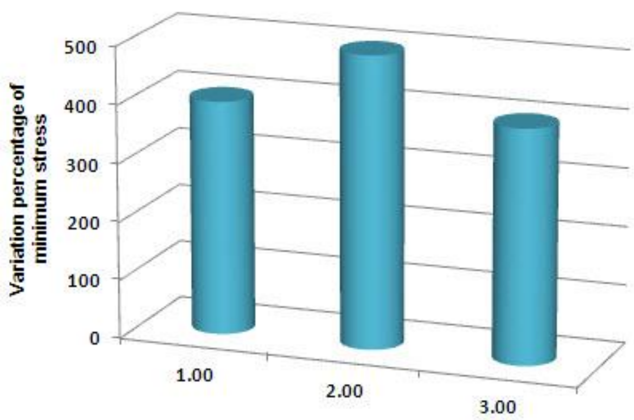



Fig. 13. The variation percentage of minimum stress in the tunnel roof to standard deviation 1 to 3 for intact uniaxial compressive strength

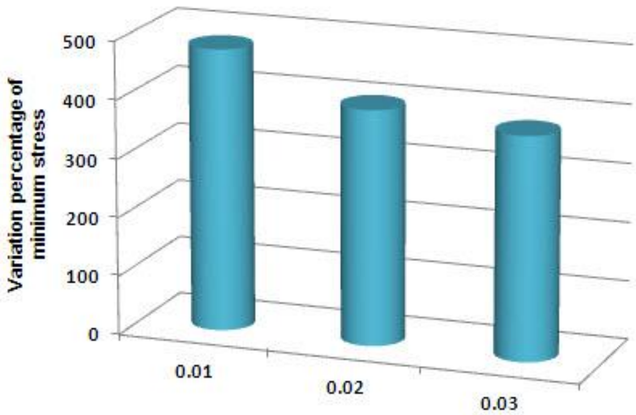



Fig. 14. The variation percentage of minimum stress in the tunnel roof to standard deviation 0.01 to 0.03 for Passion's ratio

As the diagrams in Figs. 12, 13 and 14 show, the most change of minimum stress in the tunnel roof is related to deformation modulus with standard deviation of 1, intact uniaxial compressive strength with standard deviation of 2, and Passion's ratio with standard deviation of 1.

The results of this analysis clearly show advantages probabilistic stability analysis to definite analysis and indicate that the deformation modulus of shale rock masses have the maximum impact in the total displacement, the maximum and minimum stress in the tunnel roof. Therefore, the point estimate method (PEM) will lead to a better understanding of tunnel stability and provide more complete information. 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.

## 4.Conclusions

Due to uncertainty in rock masses properties specially, deformation modulus, intact uniaxial compressive strength and Passion's ratio a probabilistic analysis using PEM method is accomplished for determination of displacement and stress values around the tunnel No.2 of Kurdistan.

The results of the evaluations show that probabilistic the deformation modulus of shale rock masses have the maximum impact in the total displacement, the maximum and minimum stress in the tunnel roof.

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