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Research article

Considering Uncertainty for Estimating Shear Strength Parameters of Intact Rock Using Statistical Methods

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Keywords

Shear Strength Parameters
Mohr-Coulomb Failure Criterion
Hoek Brown Failure Criterion
Uncertainty
t Distribution

English Extended Abstract

Summary

One of the most critical steps in the design process of a rock structure by the limit equilibrium method is to determine the shear strength parameters. Because the prediction of these parameters is always accompanied by uncertainty. In such cases, if the range in which the actual shear strength parameters are located is obtained, the results are more reliable. Hence, in this paper, an applied technique based on probabilistic methods is developed. In the first step, by developing an innovative method for two widely used failure criteria, consist of Mohr-Coulomb and Hoek Brown, statistical samples of shear strength parameters are generated and latter, using the t distribution in which the shear strength parameters are located with confidence 95% are determined separately for the two failure criteria. The available data from the previous research are used for the case study. The results of the case study indicate that the prediction of shear strength parameters with the presented method is more accurate than the conventional methods.

Introduction

Stability analysis of rock structures in mining and civil structures, such as surface mine walls, dams, or rock slopes, is very necessary and important. Because the instability of each of them will cause damage and costs. Shear strength parameters are required for stability analysis. Estimation of shear strength parameters is a critical and vital step in the design and analysis of rock structures. Because the prediction of these parameters is always accompanied by uncertainty. In practice, for determining the shear strength parameters, two failure criteria consist of Mohr-Coulomb and Hoek-Brown, are widely used. The two criteria results are crisp values. Studies show that these results are affected by the uncertainties due to the heterogeneity of the rock or the mathematical relationship of the failure criterion. On the other hand, to estimate the shear strength parameters, at least the results of 5 triaxial stress tests are needed for determining these parameters based on regression. If the number of samples (number of tests) changes or the ultimate strength of one of the samples changes due to the influence of lateral stress in the experiments, the shear strength parameters vary by the regression of the results.

In the past decades, some studies reported the determination of the equivalent parameters of shear strength based on the Hoek- Brown criterion [1-5]. According to Brown, the determination of exact equivalent shear strength parameters is a challenging point due to the inherent uncertainty of rock as well as the failure criterion [6]. In such cases, if the range in which the actual shear strength parameters are located is obtained, the results are more reliable [7-10]. Hence, in this paper, an applied technique based on probabilistic methods is developed. In the first step, by developing an innovative method for two widely used failure criteria, consisting of Mohr-Coulomb and Hoek-Brown, statistical samples of shear strength parameters are

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generated, and later, using the t distribution in which the shear strength parameters are located with confidence 95% are determined separately for the two failure criteria. The available data from the previous research are used for a case study (Table 1) [11].

Table 1. The data used in this research [11]

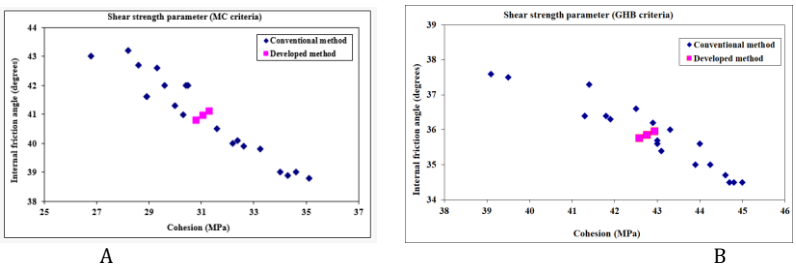
The Pingdingshan sandstone		The Pingdingshan sandstone	
$\sigma_3(MPa)$	$\sigma_1(MPa)$	$\sigma_3(MPa)$	$\sigma_1(MPa)$
0	102.9	5	157.7
0	103.4	10.1	197.1
0	103.6	15.1	224.3
0	122.4	20.1	238
0	128.7	25	258
0	129.4	30	283.5
		30	284.1
		40	305.7

Methodology and Approaches

The conventional method for determining the shear strength parameters is based on the regression of the results of at least 5 groups of data obtained from samples subjected to triaxial stress, according to the Mohr-Coulomb or Hoek-Brown criteria. But in practice, if there are two different groups of triaxial test results of the same type of rock, in the regression of the test results, the shear strength parameters are also changed, and the results are not reliable. Hence, in the first step, using an innovative method, groups of different triaxial test data are generated for the desired rock, and then the cohesion and internal friction angle are determined for each group, and finally, statistical samples of the shear strength parameters are predicted. By generating statistical samples (from shear strength parameters), the range in which the real shear strength parameters are located is determined using the t distribution. Therefore, the obtained result has the highest level of certainty, and the uncertainty is reduced.

Results

Figure 1 shows the shear strength parameters based on the developed method and the conventional method. According to the figure, the developed method is superior concerning the conventional method. This is because of the statistical samples that were produced to determine the range in which the real parameters are located are taken from the conventional method. In other words, if the conventional method is used, the results in Figure 1 may be used in the analysis. But by utilizing the developed method, shear strength parameters are determined with higher certainty and in a more realistic range.



A B

Fig. 1: Comparison of shear strength parameters based on the conventional method and the developed method. A: the Mohr-Coulomb criterion, B: the Hoek-Brown criterion

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Conclusions

In this study, to reduce the inherent uncertainty of the rock and increase the reliability of estimated shear strength parameters of intact rock, a statistical method is developed using statistical approaches. Reviewing the results of the case study indicates that the prediction of shear strength parameters with the developed method is more accurate than the conventional methods.

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