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Prediction of Deformation Modulus of Rock Masses in Southwest Iran Using Multivariate Linear Regression

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KEYWORDS

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ABSTRACT

Summary

Knowing geomechanical parameters of soil and rock is among the important items of designing and constructing engineering structures. Deformation modulus may be determined through in-situ tests and indirect methods. For indirect estimating of this module, empirical relations are simple and inexpensive methods, but their uses in other parts of the world were associated with errors due to the variation of rock type and the nature of rock mass. In the present article we attempted to estimate the deformation modulus (E_m) of the rock masses of southwestern Iran by using intact rock elastic modulus (E_i) and Rock Mass Rating (RMR) parameters. To do that, the multivariable linear regression method was used. The database used included 333 data. In order to study the relation performance and to evaluate its accuracy, R^2 coefficient (coefficient of determination) and RMSE (root-mean-square error) were used. For this data R^2 coefficient was 0.811 and RMSE value was 0.1921.

Introduction

One of the indirect methods of estimating deformation modulus is using engineering classification of rocks. These relations are provided for determining deformation modulus of rock mass based on geomechanical parameters and various rock mass classification systems such as Rock Mass rating (RMR), Rock Mass Index (RMi), Geological Strength Index (GSI), Rock Quality Designation (RQD) and Q classification system, and by using in-place tests results done at different places of the world. Some of the empirical relations for estimation of deformation modulus of rock mass are presented in Table 1 along with the year of introduction and the researchers' names.

Table 1. Some of the empirical relations for estimation of deformation modulus of rock mass

Researchers' Names	Empirical Relation
Hoek et al.	$E_d = (1\text{-}D/2)\sqrt{\frac{\sigma ci}{100}}\,10^{(RMR-10)/40}$,0<D<1
Gokceoglu et al.	$E_d = 0.0736\, e^{0.0755RMR}$
Galera et al.	$E_d = 147.28\, e^{(RMR-100)/24} - 0.202RMR$
Sonmez et al.	$E_d = E_i 10^{[\frac{((RMR-100)(100-RMR)]}{4000\exp(\frac{-RMR}{100})}}$
Mohammadi and Rahmannejad	$E_d = 0.0003\, RMR^3 - 0.0193RMR^2 + 0.3157\, RMR + 3.4064$

E_i: deformation modulus of rock mass (GPa), σci: Uniaxial compressive strength of intact rock

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Methodology and Approaches

The data used in this research included 333 samples which were obtained from dilatometer tests done in the projects locating at the southwest of Iran. The dilatometer used in these tests was of IF096 Type. To introduce empirical relation for rock masses of southwestern Iran, the results of dilatometer tests performed in seven dam sites including Bazoft, Bakhtyari, Tang Mashooreh, Khersan 2, Khersan 3, Seymareh and Karoon 1, which were located at southwest of Iran, were used. The numbers of data for each of the dams were 28 data for Bazoft Dam, 74 data for Bakhtyari Dam, 50 data for Tang Mashooreh, 61 data for Khersan 2, 57 data for Khersan 3, 53 data for Seymareh, and 10 data for the development plan of Karoon 1.

In this research, we attempted to do the required analysis on the gathered data and by using multivariable linear regression technic in SPSS Software and finally, to make a logical relation and a new regression equation by studying the relation between input parameters and the deformation modulus of the rock mass.

Results and Conclusions

Equation 1 was achieved for deformation modulus of rock mass based on the statistical analysis.

$$\text{Log } E_m = -0.674 + 0.406 \log RMR + 0.842 \log E_i \quad (1)$$

Where:

Em, Ei and RMR are deformation modulus of rock mass (in GPa), Elastic modulus of intact rock (in GPa) and rock mass rating, respectively.

In multivariable linear regression method, the correlation coefficient indicated that 81.1 percent of the rock mass deformation modulus variations might be justified by variations in RMR and elastic modulus of intact rock. The value of root-mean-square error was calculated for different relations as well as the introduced relation. The value of root-mean-square error for the relation obtained in this article was 0.1921 which showed that the deformation modulus of rock mass could be estimated with less error than by other researchers' relations.