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Development of a new empirical relation between RMR and Q rock mass classification systems

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Abstract

Rock mass classification is one of the most important and practical criteria in designing of underground excavations and estimating the related support systems. RMR and Q classifications are the most utilized rock mass classification systems in which different geological surveys and rock mechanics studies have been required for precise determination of their numeric values. Considering the significance of these two classification systems, costly and time-consuming process of data collection in order to determine the required parameters to calculate these systems, development of valid relations between the above classification systems is essential. In this research, different empirical relations in the forms of linear, polynomial, exponential, logarithmic and power equations between the RMR and Q classification systems are firstly developed based on the measured data in the several parts of the Marivan Azad dam tailrace. Then, the logarithmic relation is proposed as the most precision and reliable empirical relation between the above classification systems based on the determination coefficient criterion, significance level and F-test in the ANOVA. Proposed relation is similar to the Bieniawski equation but some modifications have been made in its coefficients for localization and obtaining the better results. Finally, results verification using the evaluation performance indices showed that estimation accuracy of the proposed relation and its conformity with the measured values are better than those of the previous relations and has the higher conformity with the measured data.

Keywords: *Azad dam, Rock mass classification, Statistical analysis, Empirical relation*

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Extended Abstract:

1. Introduction

The main classification systems for designing of underground excavations and rock support estimation are the Q and RMR systems in which the most important ground features or parameters that influence the rock stability are used as inputs (Bieniawski, 1989; Barton et al., 1974; Barton, 2002). The aim of these classifications is to define useful information that can be applied for designing purposes. Because of the significance of these two systems, researchers have developed some empirical equations between them in order to estimate one of them according to another when necessary (Rutledge and Perston, 1978; Moreno Tallon, 1980; Cameron-Clarke and Budavari, 1981; Abad et al., 1984; Bieniawski, 1989; Castro-Fresno et al., 2010; Laderian and Abaspoor, 2012; Sayeed and Knhana, 2015; Soufi et al., 2018). Accordingly, an attempt was made in this paper to develop a new relation between RMR and Q based on the empirical data. This helps to optimize the relation between these systems in order to localize its application.

Considering the significance of the relation between RMR and Q systems, development of an empirical relation between these two classification systems is the main goal of the current study in order to utilize in the local conditions and similar geological properties. For this purpose, required data was firstly measured in the trace tunnel of the Azad dam site and the suitable database was prepared. Then, a best relation between RMR and Q systems with high accuracy was proposed. The main advantage of this relation is that one of the above-mentioned classifications can be determined based on the other which saves cost and time.

2. Materials and methods

In this research, statistical analysis was conducted to develop several empirical relations including linear, logarithmic, polynomial, exponential and power relations between the RMR and Q systems based on the gathered data from the Azad dam site. The determination coefficient (R^2) criterion, significance level and F-test in the ANOVA were used to evaluate the developed equations. According to these criteria, the equation with high R^2 and F with acceptable level of significance was suggested as the best relation and proposed in the current study. Finally, the obtained correlation coefficient (R), root mean square error (RMSE) and mean absolute error (MAE) values from the proposed relation were compared with those of the similar previous relations for verification objects.

3. Tests results

In this research, five equations i.e., linear, logarithmic, polynomial, exponential and power relations were developed between the RMR and Q systems. The results of ANOVA for these equations were demonstrated in Table 1. As shown in this Table, the logarithmic equation was selected as the best relation between RMR and Q systems based on the maximum determination coefficient. Accordingly, Eq. (1) is proposed as an optimum equation between RMR and Q systems. Comparison results based on the R, RMSE and MAE indices showed in Table 2. Moreover, comparison of the proposed equation results with the previous equations and the measured data are demonstrated in Fig. 1. These comparisons proved that the proposed empirical relation has the lower error and higher determination coefficient compared to the previous relations. Also, the obtained results from the new equation are in good agreement with the measure values.

$$RMR = 8.8832 LnQ + 43.26 \quad (1)$$

Table 1. The ANOVA results for selecting the best fitted statistical model on the gathered data

Model Type	Parameter	Sum of squares	Degree of freedom	Mean square	F	Sig.
Linear	Regression	4349.778	1	4349.778	522.194	0.000
	Residual	1441.057	173	8.330		
	Total	5790.834	174			
Polynomial	Regression	5084.786	2	2542.339	619.350	0.000
	Residual	706.049	172	4.105		
	Total	5790.834	174			
Exponential	Regression	2.111	1	2.111	379.874	0.000
	Residual	0.961	173	0.006		
	Total	3.073	174			
Logarithmic	Regression	5233.554	1	5233.554	1624.685	0.000
	Residual	557.280	173	3.221		
	Total	5790.834	174			
Power	Regression	2.776	1	2.776	1619.937	0.000
	Residual	0.296	173	0.002		
	Total	3.073	174			

Table 2. Comparison the results of the proposed equation with the previous ones

Equation/Relation	R	RMSE	MAE
(Rutledge and Perston, 1978)	0.838	3.21	1.94
(Moreno Tallon, 1980)	0.30	10.35	9.47
(Cameron and Budavari, 1981)	0.186	15.63	15.34
(Abad et al., 1984)	0.947	2.11	0.54
(Bieniawski, 1984)	0.940	1.95	0.80
(Castro-Fresno et al., 2010)	0.82	2.76	1.87
(Laderian and Abbaspoor, 2012)	0.92	1.90	0.51
(Sayeed and Knhana, 2015)	0.48	7.23	6.68
(Soufi et al., 2018)	0.63	5.12	3.65
Proposed in the current study	0.95	1.78	0.002

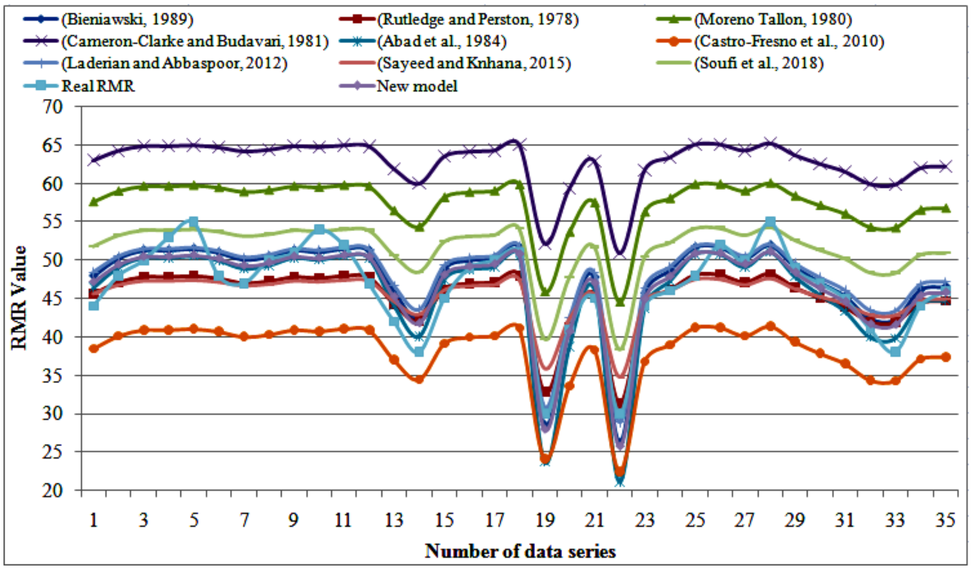

Fig. 1. Comparison the results of proposed equation and previous ones with the measured data

4. Conclusion

The main conclusions of this study have been extracted as follows:

1- A new empirical equation was proposed to predict the relation between RMR and Q rock mass classification systems based on the statistical analysis.
2- The proposed equation has the higher accuracy than the previous ones and its results are in a good agreement with the measured ones.
3- The suggested equation is a new version of Bieniawski equation in which their constant coefficients have been modified for local applications and similar geological conditions.
4- The key advantage of the suggested relation is that one of the Q or RMR classifications can be determined based on the other which saves the cost and time.

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