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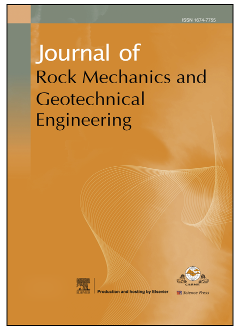

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Geomechanical characterization of volcanic rocks using empirical systems and data mining techniques

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Abstract: This paper tries to characterize volcanic rocks through the development and application of an empirical geomechanical system. Geotechnical information was collected from the samples from several Atlantic Ocean islands including Madeira, Azores and Canarias archipelagos. An empirical rock classification system termed as the volcanic rock system (VRS) is developed and presented in detail. Results using the VRS are compared with those obtained using the traditional rock mass rating (RMR) system. Data mining (DM) techniques are applied to a database of volcanic rock geomechanical information from the islands. Different algorithms were developed and consequently approaches were followed for predicting rock mass classes using the VRS and RMR classification systems. Finally, some conclusions are drawn with emphasis on the fact that a better performance was achieved using attributes from VRS.

Keywords: volcanic rocks; geomechanical characterization; volcanic rock system (VRS); data mining (DM)

1. Introduction

Preliminary calculation of the geomechanical parameters of rock masses can be carried out using the empirical classification systems. These systems consider, between others, the properties like the strength of the rock, density, condition and orientation of discontinuities, groundwater conditions and the stress state. To evaluate these properties, a numerical measure is given and, subsequently, a final geomechanical index is obtained by applying a numerical expression associated with the system. The result allows classifying the rock mass in a certain class associated with important information for the design like in some cases construction sequences, support needs and geomechanical parameters.

The most widely used systems are the rock mass rating (RMR), Q and geological strength index (GSI) (Bieniawski, 1989; Barton, 2000; Hoek et al., 2002). For the deformability evaluation, there are several analytical solutions relating the deformability modulus with geomechanical coefficients. These expressions should always be used considering their application limits. New subsystems were also been developed like the Q_{TBM} system (Barton, 2000). This subsystem, starting from the Q system, allows the prediction of several parameters related to the excavation in TBM (tunnel boring machine) tunnels, and also constitutes an important development for the characterization of geomechanical parameters. Some countries developed their own empirical/classification systems like the Chinese BQ classification system (Feng and Hudson, 2011), and also the MR system in Portugal and applied in Brazil (Rocha, 1976; Miranda, 2003). The Chinese BQ system was developed to aid in the stability evaluation of engineering structures in rock masses providing rock mass characterization in design and construction.

The diversity and variability of rock masses imply the adoption of distinct methodologies for their characterization. Characterization passes, most of the time, to the application of empirical systems without ever leaving part of the realization of in situ and laboratory characterization tests. These empirical systems have been experiencing constant modifications arising from the expansion of knowledge and experience that have been acquired over time. Innovative work was carried out by using data mining (DM) processes in geotechnical engineering to uncover new and useful predictive models in databases of geotechnical data through knowledge discovery in databases (KDD) processes (Miranda and Sousa, 2012; Sousa et al., 2012; Miranda et al., 2013). These processes define the main procedures for transforming raw data into useful knowledge. Thus, refining existing classification systems and/or developing new empirical systems are the normal thing to follow with more experience and knowledge.

Several models were developed using different sets of input information, which allow their use in different conditions of knowledge about the rock mass and can be helpful in the decision-making process. Some of the estimated models use less information than the original formulations while maintaining a high accuracy level. The relevance of the Q index for determining rock mass strength parameters was known since the relation $\tan(J_r/J_a)$ is used to approximate the inter-block shear strength, where J_r and J_a are the parameters from Q system related to the discontinuity characteristics. This assumption was later confirmed by Barton (2013), which means that Q index can also be used to compute strength parameters of jointed rock masses assumed as a continuum medium, corroborating the idea that this index is a very complete and useful parameter. The results of some expressions concerning the calculation of the deformability modulus were compared. A methodology to define a single final value for this parameter was established and validated with the results of reliable in situ tests. It was verified that some expressions may not be adequate for their application in specific rock masses (Miranda and Sousa, 2012).

For volcanic rocks, a new empiric system was developed from the adaptation of the RMR system and by using a classification developed at São Paulo, for the design of several tunnels in basaltic formations (Ojima, 1981; Menezes et al., 2005; Moura and Sousa, 2007). This followed the experience acquired in Brazil during the construction of a wide number of large dams in volcanic foundations, in particular the dam of Itaipú, at time the largest hydroelectric undertaking worldwide, the dam of Água Vermelha and the dams of Jupiá, Ilha Solteira, and Três Irmãos, among others (Pedro et al., 1975; Cabrera, 1988; Herrera, 2005; Silveira, 2009; Sadowski, 2012).

Later, another adaptation of the empirical system developed in Brazil was applied to volcanic road tunnels at Madeira Island (Menezes et al., 2005; Moura and Sousa, 2007). New tools of computer sciences, namely those based on artificial intelligence (AI), can play an important role in the generation of calculation means that make possible the inclusion of that experience and knowledge (Russell and Norvig, 2003). The application of DM techniques to well-organized data gathered from large geotechnical works can provide the basis for the development of models

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