Chapter 1

Intelligent Models Applied to Elastic Modulus of Jointed Rock Mass

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ABSTRACT

Elastic Modulus ($E_j$) of jointed rock mass is a key parameter for deformation analysis of rock mass. This chapter adopts three intelligent models (Extreme Learning Machine (ELM), Minimax Probability Machine Regression (MPMR) and Generalized Regression Neural Network (GRNN)) for determination of $E_j$ of jointed rock mass. MPMR is derived in a probability framework. ELM is the modified version of Single Hidden Layer Feed forward network. GRNN approximates any arbitrary function between the input and output variables. Joint frequency ($J_n$), joint inclination parameter ($n$), joint roughness parameter ($r$), confining pressure ($\sigma_3$) (MPa), and elastic modulus ($E_i$) (GPa) of intact rock have been taken as inputs of the ELM, GRNN and MPMR models. The output of ELM, GRNN and MPMR is $E_j$ of jointed rock mass. In this study, ELM, GRNN and MPMR have been used as regression techniques. The developed GRNN, ELM and MPMR have been compared with the Artificial Neural Network (ANN) models.

INTRODUCTION

The elastic modulus is a number that defines the object’s resistance to being deformed elastically but not permanently, when a force is applied to it. It is also defined as the slope of its stress-strain curve in the elastic deformation region. It is also known as modulus of elasticity, tensile modulus or Young’s modulus. Modulus of elasticity of rocks depend upon several factors, such as,

- Surface texture
- Type of rock

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• Confining pressure
• Porosity

Usually, joints generate the decisive effects to the failure properties of rocks. Joint frequency can be defined as the number of joints per meter length. Tang (2015) considered the specific property, joint inclination of rock with many number of tests and found that the location and direction of main crack on rock masses without joint were uncertain and random, the peak strength was highest. The main cracks of jointed rock masses were affected obviously with joints, expected the joint inclined angle was 90°. The peak strength was raised with the inclined angles bigger and bigger, even the peak strength was close to the rock masses without joint which the joints inclined angles were 90°. Clearly, the joint inclined angle and its frequency affects obviously the strength and failure properties of rock masses. Joint surface roughness is a measure of the inherent surface unevenness and waviness of the discontinuity relative to its mean plane. The roughness is characterized by large scale waviness and small scale unevenness of a discontinuity. It is the principal governing factor the direction of shear displacement and shear strength, and in turn, the stability of potentially sliding blocks. Ebadi et al., (2011) utilized the resultant displacement of rock mass and joints for forecasting the deformation modulus of rock mass. They also concluded that confining pressure affects the rock mass deformation modulus linearly.

In order to determine the value of elastic modulus for the rocks, the static and dynamic methods are available. The static methods comprised of tension or compression test, bending test and natural frequency vibration test. The quality of rock can be accessed by the elastic modulus value. Greater value of modulus of elasticity represents the high quality of rocks with better configuration.

The elastic moduli and Poisson’s ratio adopts various applications that include:

• Predictions of formation strength
• Well stimulation (fracture pressure and fracture height)
• Borehole and perforation stability
• Sand production and drawdown limits in unconsolidated formations
• Coal evaluation
• Determining the roof-rock-strength index for underground mining operations

The above mentioned in-situ tests may be applied, however those methods are very expensive and time-consuming.

BACKGROUND

Elastic Modulus is the paramount parameter for the mining and civil engineering projects. It is also the eminent criterion for pre-failure mechanical behavior of rock mass. Goodman Jack Test, Cable Jacking test, Plate load test, etc., was used to determine the elastic modulus of rock mass. The available field tests for determination of elastic modulus are very expensive and time consuming (Bieniawski, 1978; Hoek & Diederichs, 2006). In order to overcome this difficulty, the researchers projected some empirical relationships to figure out the elastic modulus of rock mass (Bieniawski, 1973, 1978; Barton et.al., 1974; Hoek and Brown, 1997).
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