

## Application of intelligent and statistical methods in estimating the uniaxial compressive strength of sandstones

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### Abstract

Accurate measurement of uniaxial compressive strength (UCS) is necessary and unavoidable in civil and mining projects. Direct measurement of this parameter is time-consuming, expensive, and difficult despite high accuracy. The purpose of this research is to indirectly determine the uniaxial compressive strength by statistical and intelligent methods. For this purpose, physical properties, point load index, compressional wave velocity, Schmidt hardness, and uniaxial compressive strength of sandstone samples from Siah Bisheh dam site and Damavand city were measured. Then the performance of different models to estimate UCS based on compressional wave velocity, Schmidt hardness, point load index, and density using multivariate linear regression, random forest algorithm (RFA), K-nearest neighbor (KNN), artificial neural network (ANN) and the adaptive neural fuzzy inference system (ANFIS) were investigated. The results showed that among the influencing factors, the point load index has the greatest effect on compressive strength. The results of UCS estimation using intelligent methods showed that RFA provides more accurate results than other investigated methods. The results of this method showed that the value of the model performance index, error (RMSE), and coefficient of determination ( $R^2$ ) are 1.96, 0.02, and 0.99, respectively. The percentage difference between the measured UCS and the predicted average is equal to -0.18%, which shows that the average of the four methods used shows less than one percent difference with the measured average value, and indicates a very high efficiency of these methods for estimating UCS. Finally, the results of the Kruskal-Wallis test showed that there is no significant difference between the measured and predicted UCS values.

**Keywords:** *Physical and mechanical properties, uniaxial compressive strength, prediction, statistical and intelligent methods*

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## Extended Abstract:

### 1. Introduction

Slope stability, prediction of drilling speed, classification of rock masses, modelling, etc. requires knowing the uniaxial compressive strength (UCS) of rocks. Various researchers have predicted the UCS of sandstones using statistical methods and artificial intelligence. In this regard, Hasheminezhad and Sadeghi (2023) estimated the UCS of limestone based on the results of simple and cheap experiments using support vector machine, adaptive neural fuzzy inference system and multilayer perceptron. Their results showed that support vector machine predicts UCS with higher accuracy compared to other studied methods. Afolagboye et al. (2023) conducted a case study for Precambrian rocks from Ado-Ekiti, Nigeria. They developed machine learning models to predict uniaxial compressive strength and highlighted their effectiveness in estimating rock strength. Wang et al. (2023) used advanced techniques based on decision tree based on non-destructive tests and petrography to predict the UCS of rocks. Their study showed the effectiveness of machine learning algorithms in predicting rock resistance using multiple input parameters. Rahman and Sarkar (Rahman and Sarkar 2023) investigated the correlation between uniaxial compressive strength and dynamic properties for six different rock types. Their study highlighted potential relationships between rock uniaxial compressive strength and dynamic elastic properties and provided valuable tips for predicting rock strength using elastic properties. Another research showed that the RFA method performed better than KNN, multivariate regression, and artificial neural network when estimating rock compressive strength (Khan et al., 2022). In another study to predict rock compressive strength by RFA algorithms, artificial neural network, ANFIS, KNN, support vector machine and Gaussian process regression on 68 samples, support vector machine appeared as the most accurate method (Zhang et al., 2023).

The aim of this study is to predict the UCS of sedimentary rocks based on variables such as point load index, density, Schmidt hardness and compressional wave velocity using artificial neural network, multivariate regression, random forest algorithm, K-nearest neighbour (KNN), and ANFIS.

### 2. Materials and methods

The methods proposed by the International Society of Rock Mechanics (ISRM 1981) were used in the preparation of the samples required for this research. The diameter of prepared cylindrical samples is 54mm and their length to diameter ratio is about 2.5. Physical, mechanical and dynamic tests were performed on 58 samples in dry conditions and 18 samples in saturated conditions. Compression wave velocity test ( $V_p$ ) was performed according to ASTM D2845 standard (ASTM D2845 1983). Finally, to evaluate the models from the correlation coefficient, the mean absolute percentage of error (MAPE%), the root mean square error (RMSE), the calculated variance (VAF), and the performance index (PI) was used.

### 3. Results

The results of statistical and intelligent methods in estimating uniaxial compressive strength are presented in Figure 1. As can be seen, RFA shows the best accuracy for predicting UCS. After RFA, ANFIS shows the highest accuracy in predicting UCS. All four intelligent methods presented in this research effectively show the relationships between input parameters and their effects on compressive strength and show strong generalization capabilities for new data.

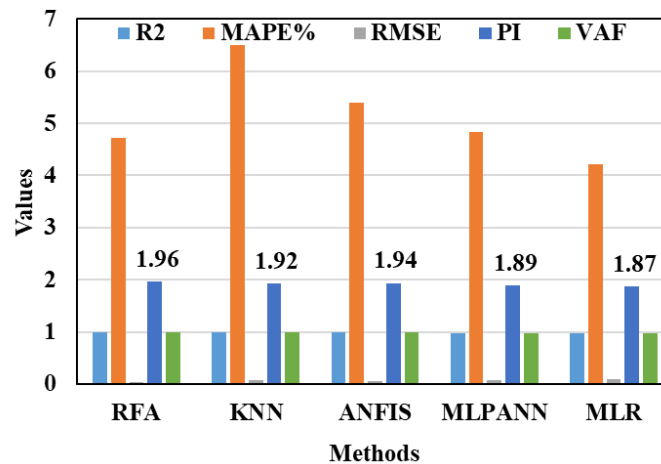


Figure 1 Accuracy of methods for predicting UCS

#### 4. Conclusion

The modeling results showed that artificial intelligence models work with higher accuracy than statistical methods in estimating UCS. Based on various statistical criteria and test data results, among the smart methods, random forest algorithm conservatively estimated UCS with the highest accuracy ( $R^2=0.99$ ,  $RMSE=0.06MPa$ ) among the smart methods used. The Kruskal-Wallis (KW) test for analyzing the difference between predicted and measured UCS values in different methods showed that the predicted UCS values are the same among different methods.

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