Iranian Journal of Engineering Geology
Summer 2022, Vol.15, No.2

Application of Group Method of Data Handling (GMDH) technique in predicting UCS of limestones

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Abstract

This study aims to propose a practical intelligence system, namely the group method of data handling (GMDH) for indirect predicting the uniaxial compressive strength of limestones. Direct measurement of uniaxial compressive strength of rock in laboratory is time consuming, difficult and costly. In the current study, several rock index tests were conducted, together with unconfined compressive strength tests, on collected limestone block samples. In this study, in accordance to the first set objective, four empirical equations were proposed based on predictors, including dry density, P-wave velocity, slake durability and point load strength index, aiming to predict rock UCS. The results of these analyses confirmed that there is a need to develop new multiple-input models in predicting the UCS. To this end, a GMDH model was designed to forecast rock strength. Aiming to obtain a fair comparison, a pre-developed artificial neural network (ANN), as a benchmark model of intelligence systems, as well as a support vector regression-based model were developed to predict the UCS. Then, through the use of some well-known performance indices, the GMDH and pre-developed ANN and SVR models were assessed and their results were compared to select the best predictive model amongst them. Results confirmed that the GMDH with correlation coefficient of 0.966 and system error of 0.11 for testing data, respectively, is a feasible technique for UCS prediction.

Keywords: *UCS; GMDH; ANN; SVR; Limestone; Hamedan*

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Extended Abstract:

1. Introduction

Uniaxial compressive strength (UCS) and elastic modulus (E) of rocks are two important and basic geotechnical factors for engineering applications such as dam design, tunnels and underground excavations. The direct method for determining the uniaxial compressive strength and elastic modulus in the laboratory is costly and time consuming. In addition, accurate determination of these parameters requires the preparation of high quality core samples, which is especially difficult in the case of weak, layered, foliated and porous rocks. The UCS test is standardized by the ISRM suggested method (Ulusay and Hudson 2007). In recent years, many studies have shown that UCS and E can be predicated indirectly. The interest of the international scientific community in investigating methods which can estimate UCS through indirect measurements, is due to the fact that performing direct UCS test is costly and time consuming; therefore, in practice, indirect tests like point load or p-wave velocity are performed for UCS estimation. Such tests, also known as rock index tests, are relatively easy to perform and quick (Zhou and Yang 2007; Momeni et al. 2015c; Liang et al. 2016; Yang et al. 2018; Fang et al. 2019). Hence, numerous efforts have been made to relate index tests to UCS or E (Kahraman et al. 2005; Diamantis et al. 2009; Khandelwal and Singh 2009; Moradian and Behnia 2009; Yilmaz and Yuksek 2009).

In the present paper, a new model in the field of rock deformation prediction, namely the group method of data handling (GMDH) is introduced. Literature shows that the models that work on the basis of self-organizing networks, containing active neurons (GMDH), are of a higher effectiveness in terms of making more accurate and less labour-intensive predictions. In addition, the paper evaluates the precision of another predictive technique i.e., ANN and SVR in predicting UCS and E. Then, after evaluating the performance predictions of the aforementioned models, the best one amongst them is selected and introduced to solve the problem. Finally, the proposed models are evaluated through the use of well-known performance indices and the best predictive model amongst them will be introduced for the estimation of UCS and E.

2. Materials and methods

For this study, 5 blocks of limestone with dimensions of approximately 20 * 30 * 30 cm were collected from different parts of Hamadan province and transferred to the laboratory. In the laboratory, 60 cylindrical core samples were drilled with a 54.1mm diameter and a length to diameter ratio of 2.5 in accordance with ISRM. For all collected samples, physical properties, namely dry density (γd), wave velocity (Vp) and slake durability (Id2) were determined. In addition, the point load test was used to measure the value of the point load index (Is50) for all samples. Also, uniaxial compressive strength test was performed to determine the unconfined compressive strength of all samples in accordance with ISRM (1981). In total, a database of 60 datasets has been used to model the forecasting techniques, SVR ANN and GMDH. Based on the results of physical and mechanical tests, the values of dry density, wave velocity, durability, point load and unconfined compressive strength are between 2.59 - 2.77 g/cm^3, respectively, 3478 - 6697 m/sec, 97.64 - 99.71 %, 46.5 - 1.19 MPa and 43.39 - 103.99 MPa.

3. Results

In order to evaluate and compare the performance of the models developed in this study, two performance evaluation indices, namely correlation coefficient (R) and RMSE, have been used. Based on the results, it is obvious that all three models GMDH, ANN and SVR have more successful performance compared to the MLR model. Comparison of the results shows that the GMDH model is able to provide a predictive method that can properly evaluate the unconfined compressive strength of limestone without the need for a UCS test. It should be noted that the values of R, RMSE for the test stage of the best GMDH, ANN and SVR models are (0.966, 0.11), (0.955, 0.10) and (0.959, 0.16), respectively. Based on the results, it can be found that the UCS values predicted by GMDH, ANN and SVR are relatively close to the measured values and all three models have almost similar performance.

4. Conclusion

The purpose of this study is to develop a model based on artificial intelligence, GMDH, to predict the uniaxial compressive strength of limestone. After GMDH, ANN and SVR modeling process, the mean correlation coefficient (R) values for the test step of GMDH, ANN and SVR are 0.945, 0.903 and 0.940, respectively. Although all three artificial intelligence methods studied in this study can be used as a practical tool in predicting UCS rocks, the results of the study show that on the database considered in this study, the model GMDH and SVR are far better than the ANN model (as a well-known comparative model) in predicting the UCS of the studied rocks. The GMDH modeling process discussed in this paper can be used by designers and researchers to solve similar problems, but with caution.

References:

Diamantis, K., Gartzos, E., Migiros, G., 2009. Study on uniaxial compressive strength, point load strength index, dynamic and physical properties of serpentinites from Central Greece: test results and empirical relations. Engineering Geology, 108:199–207.

Fang, Q., Bejarbaneh, B.Y., Vatandoust, M., et al. 2019. Strength evaluation of granite block samples with different predictive models. Engineering with Computer, https://doi.org/10.1007/s00366-019-00872.

ISRM (1981) Rock characterization, testing and monitoring, ISRM suggested methods. Int Soc for Rock Mech 211pp

Kahraman, S., Gunaydin, O., Fener, M., 2005. The effect of porosity on the relation between uniaxial compressive strength and point load index. International Journal of Rock Mechanics and Mining Sciences, 42:584–589.

Khandelwal, M., Singh, T.N., 2009. Correlating static properties of coal measures rocks with P-wave velocity. International Journal of Coal Geology, 79:55–60.

Liang M, Mohamad ET, Faradonbeh RS, et al (2016) Rock strength assessment based on regression tree technique. Eng Comput 32:343–354. doi: 10.1007/s00366-015-0429-7

Momeni, E., Nazir, R., Armaghani, D.J., Mohamad, E.T., 2015c. Prediction of unconfined compressive strength of rocks: a review paper. Jurnal Teknologi 77(11): 11-2015.

Moradian, Z.A., Behnia, M., 2009. Predicting the uniaxial compressive strength and static Young's modulus of intact sedimentary rocks using the ultrasonic test. International Journal of Geomechanics, 9:14–19.

Ulusay R, Hudson JA ISRM (2007) The complete ISRM suggested methods for rock characterization, testing and monitoring: 1974–2006. Comm Test methods Int Soc Rock Mech Compil arranged by ISRM Turkish Natl Group, Ankara, Turkey 628:

Yang, H., Liu, J., Liu, B., 2018. Investigation on the cracking character of jointed rock mass beneath TBM disc cutter. Rock Mechanics and Rock Engineering, 51:1263–1277.

Yilmaz, I., Yuksek, G., 2009. Prediction of the strength and elasticity modulus of gypsum using multiple regression, ANN, and ANFIS models. International Journal of Rock Mechanics and Mining Sciences, 46:803–810.

Zhou, J., Li, E., Yang, S., et al. 2019b. Slope stability prediction for circular mode failure using gradient boosting machine approach based on an updated database of case histories. Safety Science, 118:505–518.