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EXTENDED ABSTRACT

Modeling of Unconfined Compressive Strength (UCS) of Full-Depth Reclaimed Base Materials Stabilized with Portland Cement Using Evolutionary Polynomial Regression

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1. Introduction

In the present study, Evolutionary Polynomial Regression (EPR) technique is employed to develop a mathematical model to estimate the USC of Full Depth reclaimed (FDR) materials stabilized with Portland cement. To this end, a dataset containing 62 records from experimental studies related to unconfined compressive strength of full-depth reclaimed (FDR) base stabilized with Portland cement were used. Percentage of cement, percentage of RAP, percent passing of #200 sieve, optimum moisture content, and curing time were considered as independent variables. The results show that EPR has a great capability for prediction of the UCS in case of FDR base stabilized with Portland cement.

2. Methodology

2.1. Experimental study

In order to create a dataset for modeling using EPR, two different soil types were blended with different percentages of Reclaimed Asphalt Pavement (RAP) of 0, 20, 40, and 60% and then these blends were stabilized by adding 3, 4, 5 and 6% of Portland cement. In the first step, using the modified Proctor test (ASTM D-180 method), both maximum dry density and optimum moisture content of each mixture were determined and after while the UCS test was performed on 7 days and 28 days cured samples, according to the ASTM D1633 (method A).

2.2. EPR modeling

EPR is a hybrid regression method based on evolutionary calculations developed by Giustolisi and Savic (Giustolisi and Savic, 2006). The EPR can be expressed as Equation 1:

$$y=\sum_{j=1}^{m}F\left(X\ ,f\left(X\right),a_j\right)+a_o \tag{1}$$

Where y denoted the predicted vector of the output, a_0 and a are parameters, F is an assumed function, X is independent variables, F is a given function, and m is the number of terms. This equation can be transformed to this form Equation 2:

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$$Y_{N\times 1}(\theta, Z) = \left[I_{N\times 1} \quad Z^{j}_{N\times m}\right] \times \left[a_0 \quad a_1 \quad \dots \quad a_m\right]^T = Z_{N\times d} \times \theta^T_{d\times 1} \tag{2}$$

where $Y_{N\times 1}$ (θ, Z) is the least-squares vector, $\theta_{d\times 1}$ is the vector of d, and $Z_{N\times d}$ is a matrix formed by I, unitary column vector for bias a 0, and m vectors of variables Z^j that for a fixed j are a product of the independent predictor vectors of variables/inputs, $X=<X_1, X_2, \dots, X_k>$.

3. Results and discussion

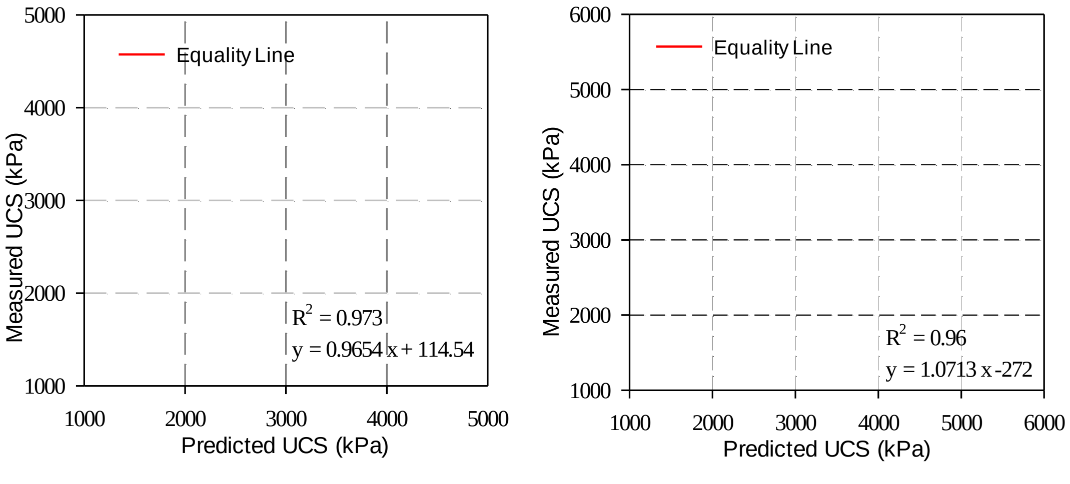
3.1. Modeling of UCS using EPR

In this research, EPR MOGA-XL vr.1 was used to predict UCS using ERP (Laucelli et al., 2012). In order to model UCS using the EPR method, 70% of the data were considered as training set and 30% of the data were considered as testing set. Also, three logarithmic, hyperbolic tangent and hyperbolic secant functions were used for modeling. The model based on hyperbolic secant function (Equation 3) had the highest coefficient of determination (R^2=0.966) and the lowest mean absolute percentage error (MAPE=0.036). This model is as follows:

$$\begin{aligned} UCS = {} & 609785069 \cdot \frac{1}{P_{200}^{\;1.5}} \cdot Sech\left(RAP^{0.5} \cdot C^{0.5}\right) + 167242603 \cdot \frac{OMC^{1.5}}{RAP^{1.5}} \cdot Sech\left(\frac{P_{200}^{\;2}}{RAP^{1.5}}\right) + 566.7498 \cdot C^{1.5} \cdot Sech\left(OMC^{0.5}\right) + \\ & 64.6657 \cdot CT^2 \cdot OMC^{0.5} \cdot Sech\left(OMC\right) + 87.1141 \cdot \frac{P_{200} \cdot C^{1.5}}{OMC^{0.5}} \cdot Sech\left(C^{0.5}\right) \end{aligned} \tag{3}$$

Where *UCS* represents the unconfined compressive strength (kPa), *RAP* is the content of reclaimed asphalt pavement (%); *C* is the cement content (%); *CT* is the curing time (day); *P*200 is the percentage passing through the No. 200 (75 μm) sieve; and *OMC* is the optimum moisture content (%).

Results of this study indicate that the developed model is able to predict UCS with error less than 10% in most cases. Also the values of R^2 based on training and testing sets is 0.9667 and 0.9521, respectively (Fig. 1).



(a) (b)

Fig. 1. Performance of EPR model: a) training set, b) testing set

3.2. Sensitivity analysis using Gamma test

Gamma testing was used to determine the degree of the importance of input parameters based on the UCS values. To this end, firstly, all parameters were considered for modeling and the value of V_{ratio} was calculated. In the next steps, each of the input parameters was removed from the input parameters and the value of V_{ratio} was calculated again. V_{ratio} is a dimensionless parameter that has values between 0 and 1. The value of V_{ratio} after removing different parameters is represented in Fig. 2. As can be seen, by removing the cement content (c), V_{ratio} gets the highest value, which indicates that the cement content is the most influential parameter on predicting the UCS.

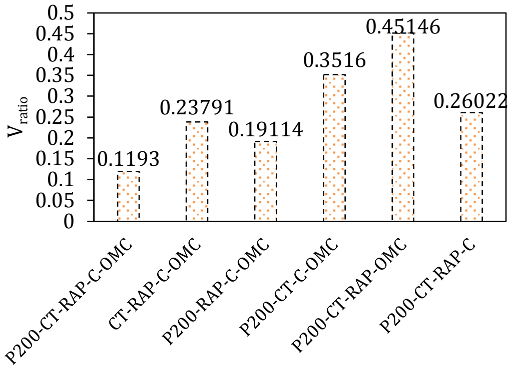


Fig. 2. Effect of removing different parameters on V_{ratio}

4. Conclusions

This study indicates that the developed model based on the EPR method has the ability to predict UCS of base stabilized with Portland cement, accurately. Results of this study confirms that the EPR model has superior capability to predict UCS with error less than 10% in most cases and coefficient of determination (R^2) is 0.9667 and 0.9521 for training and testing sets, respectively. Also, sensitivity analysis by Gamma test shows that the cement content is the most influential parameter on predicting the UCS.

5. References

Giustolisi O, Savic DA, "A symbolic data driven technique based on Evolutionary Polynomial Regression", Journal of Hydroinformatics, 2006, 8 (3), 207-222.

Laucelli D, Berardi L, Doglioni A, Giustolisi O, "EPR-MOGA-XL: an Excel based paradigm to enhance transfer of research achievements on data-driven modelling", Proceedings of 10th international conference on hydroinformatics HIC, 2012, 122, 14-18.