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Predictive modelling of strength characteristics of stabilized medium expansive soils

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Abstract

This research explores the use of Artificial Neural Network (ANN) modeling to predict the Unconfined Compression Strength (UCS) of stabilized medium expansive soil, aiming to optimize the parameters influencing soil stabilization. A database comprising 240 data points was compiled from laboratory tests involving seven input parameters: Stabilizers content (SCBA & WMD), Curing Period (CP), Liquid Limit (L.L), Plasticity Index (PI), Specific Gravity (Gs), and Free Swell (FS). ANN modeling, employing Levenberg-Marquardt algorithms, demonstrated successful UCS prediction. Increasing the number of neurons improved model accuracy, with optimum results achieved with 14 neurons. With 14 neurons for LMA, the R and R^2 value reaches 0.99, 0.98 Moreover, plots between experimental and predicted values shows strong correlation as majority of predicted UCS is closed to line of fit. Also error shows large count of data points closed to line of zero error.

Sensitivity analysis highlighted SCBA, WMD, CP, L.L, and P.I as significant contributors to UCS prediction, emphasizing their importance in soil stabilization. The study underscores the effectiveness of ANN modeling in predicting soil strength and recommends 4% SCBA and 20% WMD for optimal stabilization. Overall, this research presents a comprehensive approach to predicting UCS in stabilized expansive soil, offering insights into parameter optimization and model enhancement for future geotechnical applications.

Keywords: ANN Model; Sugarcane Bagasse Ash; Waste Marble Dust; Unconfined Compression Strength; Artificial Intelligence

1. Introduction

Illite, kaolinite, Na^+, and Ca^+, montmorillonite, which belong to the "phyllosilicates" family of clay minerals, make up the moisture-sensitive expansive soils. There is little to no organic matter present. When moistened, these soils have a propensity to expand and contract in opposite directions. As a result, they are also referred to as "vertisols," "expansive," "swell-shrink," "swelling," "black cotton," and "calamitous" soils [1-8] and occasionally as "engineering cancer" [9]. The term "expansive" refers to soil's propensity to expand and contract in volume in response to seasonal moisture fluctuations, endangering the usefulness of pavement infrastructure [10]. Smectite, bentonite, beidellite, vermiculite, attapulgite, nontronite, chlorite, and pedialyte are a few examples of the expansive soils. In 1938, the United States Bureau of Reclamation began investigating issues related to expanding soil. These hazardous soils are additionally referred to as "hidden disasters" due to their swelling and shrinking characteristics. The hydration of the pore spaces between the clay particles is what gives such soils their expansivity. Additionally, the water content at the surface, the kind of clay, and the quantity of pore spaces mostly control the swelling severity, which typically lasts 5 to 8 years or longer [11]. Many soft clays with expansive structures exhibit perplexing behaviors, which are modeled using soft computing techniques, which are becoming more and more popular. Compared to traditional approaches, these strategies have outstanding predictive capabilities [12].

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Volume and strength changes brought on by the entry and exit of water, the water-sensitive expanding soils are challenging. Because of this, the stability of resting constructions may be threatened by cracking, heaving, and failure. They are considered environmentally susceptible and precarious because of the resulting damages. These soils experience volumetric strains of more than 10%, and these significant volume changes result in differential motions that stress infrastructures, particularly light ones like highways and single-story homes, by causing surface cracking. As a result, geotechnical researchers are compelled to develop sustainability guidelines for achieving economy in infrastructures, which necessitates an investigation of the prominent characteristics of swelling soils, such as compaction.

Many soft clays with expansive structures exhibit perplexing behaviors, which are modeled using soft computing techniques, which are becoming more and more popular. Compared to traditional approaches, these strategies have outstanding predictive capabilities [12]. The development of swelling soils' swell-strength (i.e., Ps and unconfined compression strength UCS) as well as the effects of particle gradation, plasticity, compaction, and other factors have all been extensively studied in the past ten years with regard to compacted hydrophilic clays [13–15]. For the preceding design of pavements, residential areas, bridge constructions, water lines, canals, and a variety of lightly loaded infrastructure, a correct estimation of d_{max}, W_{opt}, Ps, and the UCS of hydrophilic clays is crucial [16–19]. Using an oedometer instrument and well acknowledged ASTM standards, the Ps is measured in a lab setting. Due to slower saturation, the test takes a long time, however numerous empirical equations have already been constructed for reliable Ps prediction [20]. The conventional 1-d oedometer test often takes close to two weeks to complete [21]. Instead, the UCS is carried out in a lab setting particularly for saturated, fine-grained soils that have been taken from thin-walled sampling tubes in accordance with ASTM requirements. Various regression analysis techniques were used in the past to produce a wide range of correlations for calculating the UCS of expansive soils [13, 22, and 23].

So in this study, artificial intelligence technique ANN (Artificial Neural Network) was used to predict unconfined compression strength of stabilized medium expansive soil using 7 seven input parameter which includes Stabilizers content (SCBA & WMD), Curing Period (CP), Liquid Limit (L.L), Plasticity Index (PI), Specific Gravity (Gs), and Free Swell (FS) on a 240 points dataset. Levenberg-Marquardt algorithm was used for neural network modeling.

2. Material and Methods

Artificial neural network modeling using Levenberg-Marquardt algorithm was performed in Matlab 2019. A detail trial was performed changing number of neurons and varying percentage data combination of training, validation and testing dataset. It should be noted that a dataset of 240 points was used for training ANN model. A sensitivity study was also performed in which contributions of individual input parameter to output was studied.

3. Result and Discussion

After performing various trials, the following results was performed at 14 no. of neurons and when 70%, 15% and 15% data was used for training, validation and testing respectively. The efficiency of model was investigated based on various statistical parameters.

3.1. Experimental and Predicted Data Comparison

The variation in experimental and predictive values is illustrated using plots shown below in figure 1. It is evident that the predictive models accurately captured the influence of every input parameter (Stabilizer content, curing period, L.L, P.I, G, and free swell) to estimate stabilized soil UCS with lower statistical errors. Figure 1 clearly shows majority of points are closed to line of best fit. Figure 2 shows regression model for training, validation, testing and complete model. R value is closed to 1 which shows strength of linear relationship between input and output variables.

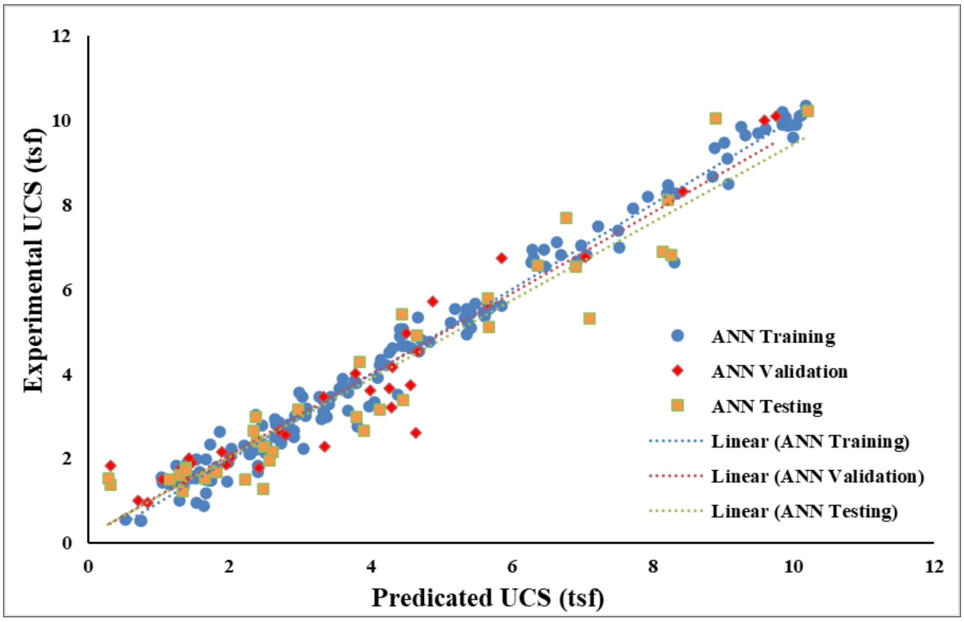

Figure 1 Experimental VS Predicted Values Comparison

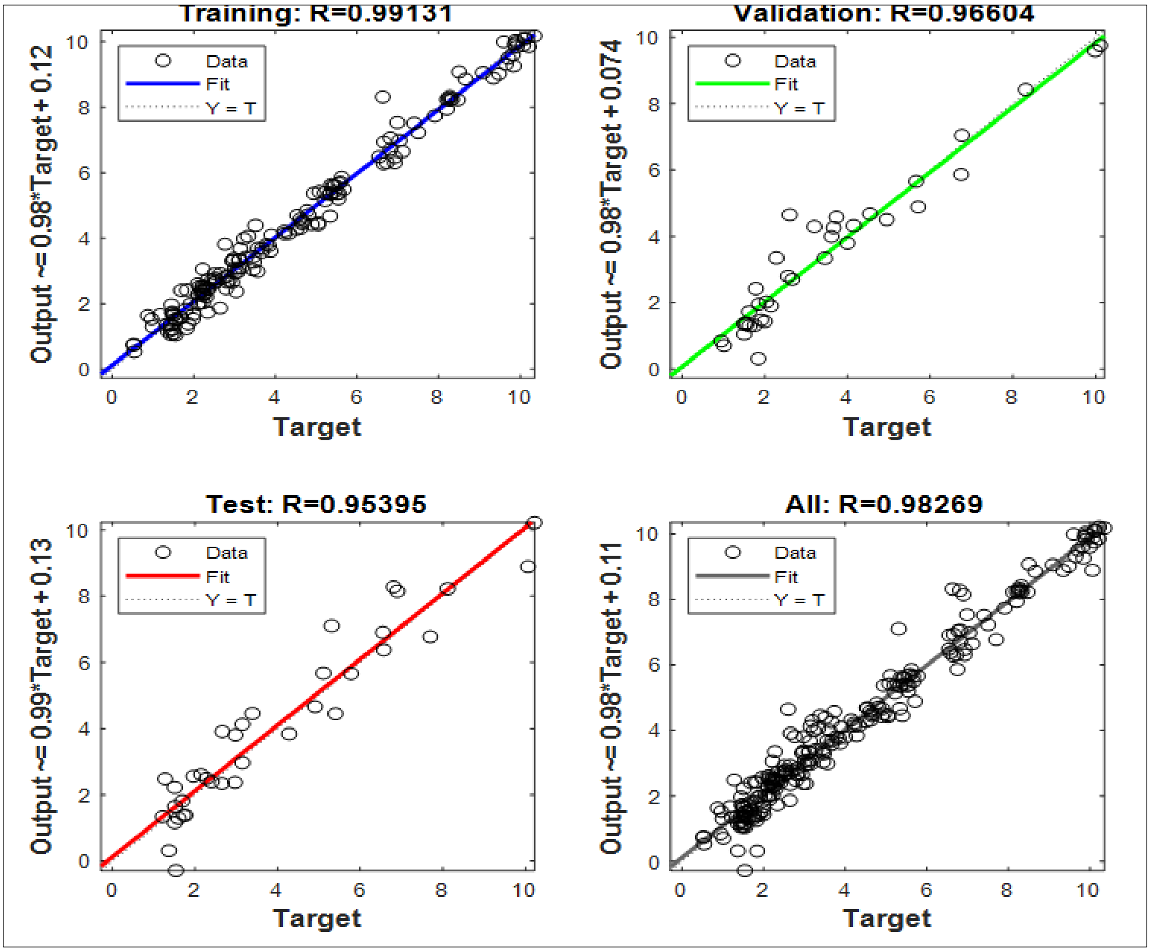

Figure 2 Regression Model

3.2. Sensitivity Analysis

Sensitivity analysis is the study of contribution of individual parameters to outcome (UCS). In both above-mentioned criteria's it was found that SCBA, WMD, CP, L.L and P.I have significant contribution to output as compared to Gs and FS as shown in figure 3.

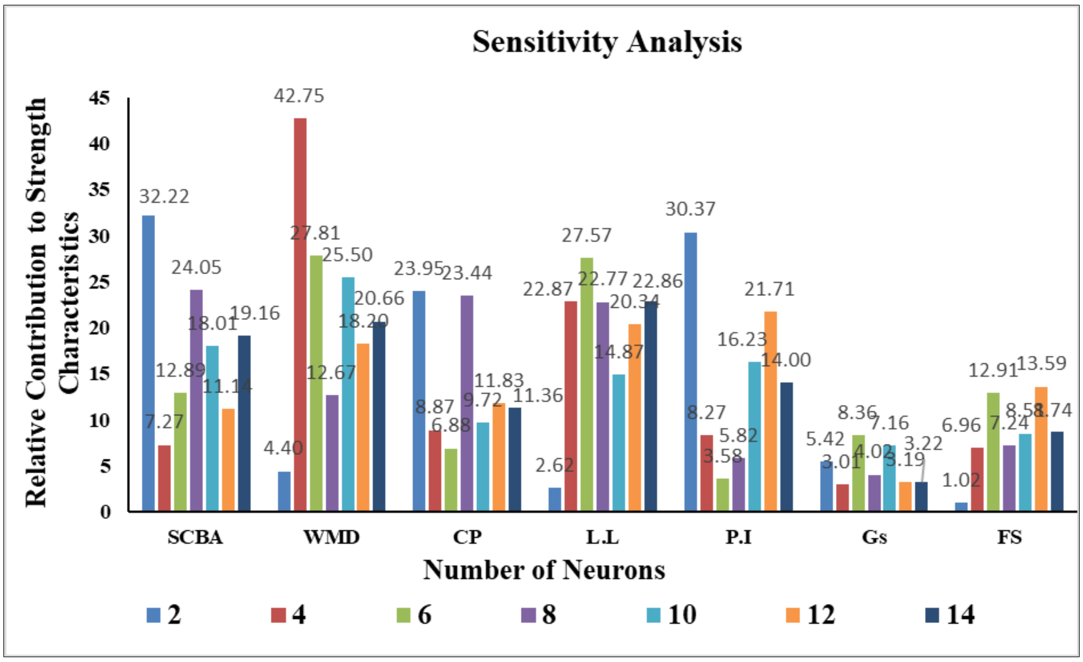

Figure 3 Sensitivity Analysis

4. Conclusions

ANN model successfully predict unconfined compression strength of stabilized medium expansive soil as indicated by correlation coefficient R and regression model. Moreover, majority of points are closed to the best trend line which shows many of the points of experimental and predicted model are closed. Sensitivity study shows more contribution of stabilizers, curing period and plasticity properties to UCS of soil then free swell and specific gravity. So this model can be successfully used to predict UCS of medium expansive soil if we have information about its plasticity properties, specific gravity, free swell and stabilizer content.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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