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Application of adaptive neuro-fuzzy technique to predict the unconfined compressive strength of PFA-sand-cement mixture

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ABSTRACT

The paper addresses the application of an adaptive neuro-fuzzy (ANFIS) computing technique to predict the unconfined compressive strength of the pulverized fuel ash–cement–sand mixture. A series of unconfined compressive tests were performed on several mixtures of cement, pulverized fuel ash (PFA), and sand for checking and training data for the ANFIS network. Although some mathematical functions were applied to model the unconfined compressive strength of the construction materials, numerous setbacks of the models were observed. The artificial neural network (ANN) can be used as an analytical method for various prediction purposes because it provides the benefit of independency on the knowledge of internal system parameters, compressed compact solution in terms of multi-variable problems and rapid computation. The ANFIS is a particular class of the ANN family with attractive estimation and learning potentials. This provides a suitable platform when the analysis is aimed to counter the uncertainties in a system. The ANFIS RMSE was 0.0617 for prediction of the unconfined compressive strength of the pulverized fuel ash–cement–sand mixture.

1. Introduction

Recently, ground development has experienced tremendous setbacks due to overpopulation, shortage of energy, insufficiency of resources and land scarcity [1]. In conventional construction, huge amount of resources is turned into waste materials, while they should be sustained for future advancements [2]. A possible avenue of research is to find new materials in order to substitute the traditional construction resources. Terashi and Juran [3] explained different techniques of ground improvement that can improve the geotechnical properties of weak soil. Among the methods, the chemical stabilization is regarded as an effective solution for a number of geotechnical problems [4]. The chemical stabilization is categorized based on the construction technique and the nature of chemical reactions [5–7].

The pulverized fly ash (PFA) is a coal combustion byproduct (CCB) formed following the burn of pulverized coal. According to the ASTM C 618 [8], the PFA is categorized under the class-C fly ash. It exhibits both the cementation and pozzolanic behavior owing to the available calcium content (CaO) [9,10]. Based on the X-ray studies [11,12], the PFA is found as a complicated substance with regards to the chemical composition and the crystallography. In general, it contains mullite ($2SiO_2 \cdot 3Al_2O_3$), quartz (SiO2), magnetite (Fe_3O_4), hematite (Fe_2O_3), and other minor minerals including lime (CaO), anhydrite ($CaSO_4$), and gypsum ($CaSO_4 \cdot 2H_2O$) [13].

Jo et al. [14] studied the effects of PFA, cement and lime on the unconfined compressive strength (UCS) of the sand composite materials. They reported that when the lime and cement contents of the mixture are maintained at 20% of the total mixture weight, the UCS increases by 50%, providing that the PFA content increases. Motamedi et al. [9] indicated that the cement content has a major effect on the UCS of the sand–PFA mixtures. For example, they mentioned that when the PFA content was fixed at 30% of the total specimens weight, increased cement content led to raise in the UCS up to 13.22. The authors also reported that if the percentage of PFA in a medium exceeds 20% of the total weight, the final UCS decreases. Openshaw [15] and Snelson et al. [16] reported the same on the reduction of the UCS when the PFA content exceeds an optimum amount. Shervin et al. [9] advised that the fly ash content should not be more than 20% of the total weight of the medium if the strength of mixture is of concern.

There is a growing demand for the application of artificial intelligence techniques to investigate structural elements [17]. Despite the fact that various mathematical functions were used to model the UCS of construction materials, disadvantages such as the long computation time should not be ignored. The computation power of the ANN can

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