

Data Mining, Mapping and Modelling of the Strength of Cement-Stabilised Soils

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Abstract

Cement stabilisation has been widely used for improving the engineering properties of soft soils. The unconfined compressive strength (UCS) is the most common strength parameter used for the current design practice of cement-stabilised soil due to its simplicity and cost-effectiveness. However the UCS test does not take into account the effect of confining stress on material strength, and thus it is considered to be conservative, variable and lacking in reliability. The undrained triaxial compression test, although less straightforward to conduct and more costly, is more representative in terms of simulating actual field conditions. In order to improve the cost efficiency and reliability in design and construction of cement-stabilised soils, it is essential to develop a better understanding of where the reliance of the UCS test results lies and to establish appropriate correlations between the UCS and the undrained triaxial strength to guide design.

The first part of this work presents data collection and collation from six research-based projects involving both UCS tests and undrained triaxial tests, performed on the same laboratory-prepared cement-treated soil samples. Results from the UCS tests were compared and correlated to those from the undrained triaxial tests by normalising the data and developing contour plots to illustrate the relationships between the two strengths. Variation in strength correlations was found to be dependent on a number of factors relating to soil properties (i.e. soil type, grain size distribution, soil water content), cement content, mixing conditions (i.e. total water to cement ratio), curing conditions (i.e. curing time and stress) and testing methodology (i.e. backpressure and strain rate). A general trend was concluded based on the mapping of the results that the undrained triaxial strength values could be taken as the same magnitude as the UCS values at $\sim 100\text{kPa}$ confining stress regardless of the values of the cement content, curing time or total water to cement ratio, for all soils studied in this work. At higher confining stress level, the difference between the two strengths increased, and at lower values, the UCS value appeared to be higher than the undrained triaxial strength value. As the correlations between laboratory strength measurements of cement-stabilised soils were considered to be a result of the simultaneous effects of a number of variables, contour maps can only express the effects of two independent variables. Hence, a Bayesian neural network model was developed to provide better estimation of the strength correlations as a function of aforementioned input parameters. Neural networks are models inspired by human brain that are capable of machine learning and pattern recognition. They have been used in recent years in similar modelling works in many areas of geotechnical engineering, such as soil correlations, determining soil liquefaction resistance, settlement prediction, soil behaviour modelling and predicting resistance of drilled shafts. Results from this neural network model were found to emulate the known trends and reasonable estimates of the difference between the two strengths were obtained. The results showed that undrained triaxial compressive strength values could be estimated using the predicted strength correlations given the UCS values.

In order to further explore the applicability of artificial neural network modelling for cement-stabilised soils, the second part of the study extends its application to predicting the UCS and stiffness of stabilised soils. Data on a large number of soil-stabilisation projects worldwide were collated into easy-access databases of strength and influencing variables. Predictions obtained from models developed in this study using these databases were in good agreement with actual measurements, and sensitivity analysis results performed by the models were found to coincide with the known effects of the input variables on the output concluded in literature. It was shown that these neural network data-driven models were able to account for non-linear features that could not be accounted by a linear model, and quantify the uncertainties in the predictions. The correlations between stiffness and strength from both the UCS test and undrained triaxial compression test were also studied as part of the work. Relationships between the UCS and stiffness for laboratory-stabilised soils and field deep mixing were found to be consistent with the findings from existing literature. The overall research highlighted the potential of using artificial intelligence for providing preliminary design parameters of cement-stabilised soils.