Analysis of Pile Capacity Parameters using Functional Networks and Multivariate Adaptive Regression Splines: An Assessment

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Abstract- The soil is found to vary spatially everywhere in nature. As such, it's generally a difficult task to predict the nature of soil for any particular application with traditional methods like experimental, empirical, finite element or finite difference analysis. Analysis with traditional methods taking into factor all the varying inputs makes it a complex problem, which is difficult to solve and comprehend. This necessitates the use of statistical modelling tool for the solution to problems concerning soil. Pile foundations are widely used in civil engineering construction. However, owing to the variable behavior of soil and the dependence of vertical pile load capacity on numerous factors, there does not exist a definite equation which can estimate the pile load accurately and include all the factors comprehensively. Artificial intelligence techniques are known to successfully develop accurate prediction models with the obtained input and output data form laboratory experiments or field data. Therefore, the present study deals with development of prediction models for pile capacity parameters based on field and laboratory database available in literature using two recently developed artificial intelligence techniques, functional networks (FN) and multivariate adaptive regression splines (MARS). In the present study, FN and MARS were used to develop prediction models for the lateral load capacity of piles, vertical capacity of driven piles in cohesion less soil, friction capacity of piles in clay, axial capacity of piles and pullout capacity of ground anchors. In all the cases, prediction equations were provided for the developed models which were found to be simple and can be easily used by practicing geotechnical engineers.
Keywords: FN, AI, AAE, MAE, RMSE

I. INTRODUCTION

Soil is a result of continuous weathering and decaying process in nature. The final nature of any soil is greatly affected by the way soil has been transported, the temperature it has been subjected to and many other factors. This leads to change in the properties of soil to vary from place to place. Conventionally, most of the time, the problems in soil mechanics are analyzed using a lot of assumptions so that the problem at hand can be simplified and a solution can be reached at. The solutions reached at this way may not give the right solution for a practical situation and evidently, we require more assumptions and adequate factor of safety when applying these solutions. This problem mainly arises due to the incomplete and inadequate understanding of the involved phenomena and the factors affecting the output. The availability of data is also, most of the time, limited and inexact. Thus, the general practice is to use empirical solutions which may be presented in the form of equations, design charts or tables. Piles as deep foundations are widely used in civil engineering in various structures to transfer load either to higher depths when sufficient support is not available at shallow depths or the load is high.

II. PREVIOUS WORK

Hansen and Broms [2020] based on earth pressure theories were the earliest attempts at prediction of laterally loaded piles. Also proposed dynamic equations which were based on Winkler's soil model. The design of laterally loaded piles is a complex problem and needs solution to non-linear differential equations.

Poulos and Davis [2019] Therefore Non-linear p-y curves were proposed to predict the lateral load capacity of pile. Used nonlinear p-y curves and finite element method to predict the capacity of laterally loaded piles. However, all the methods stated above were found to predict the pile capacity of laterally loaded piles uncertainly due to the variations in soil properties. Hence, empirical methods.

Hansen & Broms [2018] are still predominantly in use. Inspite of numerous investigations, both theoretical and experimental, conducted over the years to predict the behavior and the load capacity of piles, the mechanisms governing the piles are not yet clear.

Poulos and Davis [2016] Correlations were developed later, with in-situ tests in attempt to solve the problems associated with earlier empirical equations. These correlations were able to reflect the natural conditions of soil to some extent, but still they had several 18 limitations. Based upon the results from load tests, many empirical equations developed to calculate the pile capacity of both the end bearing and friction piles based upon the soil parameters expecting to predict quick and fairly accurate estimates of the pile capacity.

Das and Basudhar [2015] Back propagation neural networks (BPNN) was used to predict the skin friction in piles used ANN to predict the ultimate load capacity of piles and found ANN to perform better than Engineering News formula, Hiley formula and Janbu formula. Many other future attempts were made to predict the pile load capacity in both cohesion less soil and clayey soil using ANN and it was inferred that ANN has a better prediction capability for pile load capacity as compared to traditional empirical methods.

Das and Basudhar [2012] found ANN to be better than used another AI technique, support vector machine (SVM) and found it to have a better prediction capability than ANN. developed Gaussian process regression (GPR) and SVM models on data set of and found GPR to be better than SVM.

Momeni et al. [2009] used a hybrid genetic algorithm (GA)- based ANN to predict the bearing capacity of piles and found GA-based ANN to be better than the conventional ANN. used MARS and BPNN to develop drivability prediction models for a database containing 4072 pile data sets with a total of seventeen variables and found MARS and BPNN to be equally efficient in terms of statistical parameters but MARS was computationally more efficient and gave a more comprehensive mathematical model.

III. METHODOLOGY

Functional Networks are a recently introduced extension of neural networks. A FN is considered as a novel generalization of neural networks as it can to take into account both data and the domain knowledge to estimate the unknown neuron functions. The initial topology of the FN can be condensed to a much simpler topology. FNs thus, eliminate the problem of neural networks being 'black boxes' by using both the domain knowledge, i.e., associative, commutative, distributive etc. and the data knowledge to derive the topology of the problem. FNs use domain knowledge to determine the structure of the network and data to estimate the unknown neuron functions. In FN, arbitrary neural functions are allowed and they are initially assumed to be multiargument and vector valued functions.

IV. CONCLUSIONS

The present study was an attempt to develop prediction models for the pile capacity parameters using two recently developed AI techniques, FN and MARS. Prediction models were developed to calculate the lateral load capacity of piles, vertical capacity of driven piles in cohesion less soil, friction capacity of piles in clay, axial capacity of piles and pullout capacity of ground anchors.

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