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RESEARCH PAPER

Artificial intelligence-optimized design for dynamic compaction in granular soils

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Abstract

This study presents a novel procedure and mathematical model employing four artificial intelligence AI algorithms to predict the cumulative degree of soil compaction CDSC during dynamic compaction DC. The four AI algorithms used in this study involve artificial neural network ANN, support vector regression SVR, gradient boosting machine GBM, and random forest RF. Input variables involve the average SPT N value N_{ini} before dynamic compaction, cumulative applied energy normalized with a cross-sectional area of tamper E_a, and the number of the tamper drops N_{drops}. Apart from cross-validation with a testing set, additional in situ test data gathered from a different section within the study site are used to assess the generalization capacity of the AI models. In addition, out-of-distribution analyses for the four AI algorithms are conducted in the context of parametric studies. The CDSC prediction performance for the four AI models leads to high prediction metrics of accuracy with the r^2 greater than 0.9 for the testing scenario while the r^2 of the other AI models is greater than 0.9 when out-of-sample data are considered except for the GBM. The ANN appears to be the best model as the parametric study takes into account out-of-distribution data and suggests a robust relationship between input variables and CDSC that is more coherent with engineering principles for DC. Finally, the ANN model is utilized to develop a new mathematical model for CDSC prediction.

Keywords Artificial intelligence · Cumulative degree of soil compaction · Dynamic compaction · Machine learning · Standard penetration test

1 Introduction

Dynamic compaction (DC) is one of the primordial ground improvement techniques, it is on record that before 100 AD the Romans implemented this technique, followed by the Chinese who also used it at about 1000 AD, and in the 1800s the Americans [21, 45, 49]. DC is the densification of loose soils by heavy tamping and is achieved by repeatedly dropping a heavy pounder (10–40 tons) from a height of approximately 15–30 m onto the ground at uniform intervals. This causes waves to develop, which induce vibrations in the soil particles, causing the soil skeleton to reorganize and deform, resulting in the densification of the ground with depths [10]. DC is appropriate for the densification of loose sand deposits typically of alluvial, coastal, and sedimentary, including reclamation or hydraulically placed, fills [24, 52].

Design and assessments of dynamic compaction are carried out using empirical correlations and charts. The most widely used empirical correlation estimates the depth of improvement which makes use of applied energy and soil type [29]. A previous study also proposed a chart to estimate the change in average penetration resistance within the depth of improvement [24]. Other charts capture the crater depths (CD) which is a key indicator to select the number of tamper drops per DC phase [33]. Parameters like the cross-sectional area of the tamper, as well as greater

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