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RESEARCH

Effect of aggregate size, aggregate to cement ratio and compaction energy on ultrasonic pulse velocity of pervious concrete: prediction by an analytical model and machine learning techniques

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Abstract
The purpose of present study is to examine how the UPV of pervious concrete changes with three parameters: compaction energy, aggregate size and aggregate-to-cement ratio. The pervious concrete specimens were casted using five levels of compaction energy (0, 15, 30, 45, and 60 blows) and five A/C ratios (3.5, 4.0, 4.5, and 5.0) to test the effects of these factors on UPV. The aggregate sizes were 5–12 mm, 12–18 mm, and 18–25 mm. The study produced 225 pervious concrete cubes with 15 different mix designs and measured their UPV. The study analyzed the test data and developed a mathematical model using machine learning (ML) techniques to establish the associations between the three parameters and the UPV. The study proposed six ML models, such as boosted tree regression (BTR), random forest regression (RFR), and XG boost (XG), to predict the UPV based on compaction energy, aggregate size, aggregate-to-cement ratio. Researchers and professionals may use these models to improve mix design for pervious concrete for a variety of applications.

Keywords Pervious concrete · UPV · Machine learning · SHAP · Compaction energy

Abbreviations

A/C ratio	Aggregate to cement ratio
ANN	Artificial neural network
BTR	Boosted tree regression
LR	Linear regression
KNN	K nearest neighbors
MAE	Mean absolute error
ML	Machine learning
NDT	Non-destructive testing
RFR	Random forest regression
RMSE	Root mean squared error
R^2	Coefficient of determination
SHAP	SHapley additive explanations
SVR	Support vector regression
UPV	Ultrasonic pulse velocity
XG boost	EXtreme gradient boosting

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Introduction

Pervious concrete is a kind of concrete that has a high porosity and permits fluids to flow through it. This form of concrete has several benefits for engineering and environmental purposes (Elango et al., 2021). There are several features such as aggregate type, aggregate size, cement-to-aggregate ratio, water-cement ratio, compaction energy, etc. affect its mechanical and physical properties, such as porosity, strength, durability and permeability (Huang et al., 2020; Subramaniam & Sathiparan, 2022). Therefore, it is important to measure these properties of pervious concrete accurately and reliably (Anburuvel & Subramaniam, 2022). Although destructive lab testing is recommended for measuring these values, due to cost and time, recent time non-destructive test (NDT) measurements used to predict the mechanical characteristics of previous concrete.

Ultrasonic pulse velocity measurement is an NDT method, that can be utilized to assess the characteristics of pervious concrete (Singh et al., 2022). Ultrasonic pulse velocity measurement can estimate the porosity

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