INTERNATIONAL JOURNAL OF PAVEMENT ENGINEERING
2025, VOL. 26, NO. 1, 2477769
https://doi.org/10.1080/10298436.2025.2477769

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Investigation of the compactability of pervious concrete and its impact on porosity and compressive strength

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ABSTRACT

Compressive strength is often predicted from porosity or mix-design parameters. The inability to convert laboratory scale-compaction-energy to industrial-scale limits the application of performance prediction models. This study analyses compactability as a predictor which translates easily across studies and applications. Pervious concrete specimens were cast using eight different aggregate-to-cement ratios (2.5–7.0), compaction-levels (0–75 blows from standard-Proctor rammer) and 2-types of compaction energy distribution (single-layer and three-layer distributions). 672 specimens were tested for wet-density, theoretical-porosity, measured-porosity, compressive-strength and compactability. The Analysis-of-Variance and classification techniques, quadratic discriminant analysis and the Boosted Forest algorithm classified two groups of specimens based on five performance parameters with 94% accuracy. This indicated a significant difference imparted by compaction energy distribution on pervious concrete performance. Gaussian Process Regression predicted measured the porosity and compressive strength of samples with compactability and aggregate-to-cement ratio with 94% accuracy for both groups of specimens separately. The combined sample matrix model yielded high accuracy (86%) but failed on marginal observations significantly.

ARTICLE HISTORY
Received 10 September 2024
Accepted 5 March 2025

KEYWORDS
Pervious concrete; compactability; aggregate-to-cement ratio; compressive strength; machine learning

1. Introduction

Pervious concrete, originally an alternative and environmentally sustainable pavement material, is intended to increase the hydrologic condition of a catchment that undergoes urban development (Lian *et al.* 2011, Aamer Rafique Bhutta *et al.* 2013, Nan *et al.* 2021). Pervious concrete, however, can also harbour other benefits such as heat and sound insulation in addition to environmental benefits such as reduced carbon foot print and generation of wastes (Corinaldesi and Moriconi 2010, Lin *et al.* 2016). Pervious concrete is advised to have zero slump (no workability) and zero compaction, so that the binder would not move during casting and block the passage at the bottom face (Sumanasooriya and Neithalath 2011, Gupta 2014). Zero compaction and zero slump make the binder-coated aggregates assume the initial structure as it is poured, which consequently contrives variation in packing each time it is poured, resulting in varied heterogeneous packing of binder-coated aggregates (Anburuvel and Subramaniam 2022, Sajeevan and Subramaniam 2023). Unique packing of binder-coated aggregates across various pours results in high uncertainty in the mechanical performance parameters of pervious concrete. This restricts potential applications on an industrial scale that require mass production with uniform characteristics (Subramaniam *et al.* 2022, Ahilash *et al.* 2024, Reyad *et al.* 2024, Shobijan *et al.* 2024).

1.1. Compaction of pervious concrete

Several studies have deployed minimal compaction, mostly with tamping rods to attain uniformity across specimens and pours (Akand *et al.* 2016, Chandrappa and Biligiri 2016, Shobijan *et al.* 2024, Subramaniam and Anburuvel 2024, Wijekoon *et al.* 2024a). However, this resulted in high variation in reported mechanical properties across experiments in different laboratories, mostly owing to unregularised compaction (no standard measure of compaction) (Kevern *et al.* 2009, Lim *et al.* 2013, Sajeevan *et al.* 2023, Anburuvel and Subramaniam 2024). Furthermore, few studies have attempted to analyse mechanical properties with different amounts of compaction energies supplied, thereby optimising compaction without compromising on porosity while also making the cast homogeneous in properties (Subramaniam *et al.* 2022, Sathiparan *et al.* 2024, Subramaniam *et al.* 2024, Wijekoon *et al.* 2024a, Wijekoon *et al.* 2024b). The studies have established that 20–30 blows of compaction from a standard Proctor rammer with 2.5 kg weight and 300 mm free fall, compaction supplied in three equal layers, would be required to make the wet mix of pervious concrete uniform in characteristics.

1.2. Performance model of pervious concrete

Contemporary literature focusses more on optimising aggregate-to-cement ratio, water-to-cement ratio, aggregate size

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/10298436.2025.2477769.