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RESEARCH

A mathematical model to predict the porosity and compressive strength of pervious concrete based on the aggregate size, aggregate-to-cement ratio and compaction effort

Sathushka Heshan Wijekoon[1] · Thirugnasivam Shajeefpiranath[1] · Daniel Niruban Subramaniam[1] · Navaratnarajah Sathiparan[1]

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Abstract
The purpose of this study is to explore how characteristics of pervious concrete, such as porosity and compressive strength, are affected by three factors: aggregate size, aggregate-to-cement ratio and compaction effort. The study used three aggregate sizes (5–12 mm, 12–18 mm and 18–25 mm), five different aggregate-to-cement ratios (3.0, 3.5, 4.0, 4.5 and 5.0) and seven different levels of compaction effort (0, 15, 30, 45, 60, 75 and 90 blows). A total of 15 mix designs were used to cast 630 pervious concrete cubes, which were then tested for porosity and compressive strength. The test data were analysed to establish mathematical relationships between the three factors and the two characteristics of pervious concrete. The models accurately predicted the porosity and compressive strength based on the aggregate size, aggregate-to-cement ratio and compaction effort. These models can be useful for practitioners and researchers in optimizing pervious concrete mix designs for various applications.

Keywords Pervious concrete · Compaction · Aggregate size · Porosity · Compressive strength

Introduction

Pervious concrete is a mixture of cement, coarse aggregate and water with high permeability and environmental benefits. It is widely used in the last 40 years around the world, predominantly for pervious paving (Aamer Rafique Bhutta et al., 2013). Pervious concrete allows water to drain and infiltrate through its pores, which reduces surface runoff and flash floods and enhances the ecological performance of the catchment. For example, it can be used in parking lots to increase base flow, preserve water quality and efficiently manage parking space. It also prevents surface glare and reflection at night, which improves driver comfort and safety and creates a quiet environment. In addition, the gaps in pervious concrete may retain heat, which alters the earth's surface temperature and humidity (Yang & Jiang, 2003).

The porosity and compressive strength of pervious concrete are the two key determinants of its suitability for various applications. Porosity is the measure of voids or hollow spaces in the concrete matrix that formed by the gaps between the cement paste-coated aggregates. It is quantified as a percentage of the volume of voids of the total volume of the mixture. The porosity of pervious concrete was observed to vary between 15 and 35%, making it permeable (Chandrappa & Biligiri, 2016; Li et al., 2017; Xu et al., 2018). By adjusting the mix proportion, it can be designed as an appropriate construction material for pavements, railroads and boundary walls. Its compressive strength ranges from 3 to 30 MPa (Alemu et al., 2021). The characteristics of pervious concrete depend on the components, such as cement and aggregates, and the related variables, such as aggregate-to-cement (A/C) ratio, aggregate size, water-to-cement (W/C) ratio and compaction energy (Anburuvel & Subramaniam, 2022).

The aggregate-to-cement ratio is a key parameter that influences the properties of pervious concrete, specifically in the binder coating thickness of aggregates. Many studies have reported that a higher A/C ratio leads to higher porosity, but lower compressive strength. This is because

✉ Navaratnarajah Sathiparan
sakthi@eng.jfn.ac.lk

[1] Department of Civil Engineering, Faculty of Engineering, University of Jaffna, Ariviyal Nager, Kilinochchi, Sri Lanka

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