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Investigation of boundary layer impact on pervious concrete

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ABSTRACT

Industrial application of pervious concrete (PC) is limited by uncertainty in assessing performance characteristics in design phase. Compaction increases uniformity of characteristics in mass production. Spatial distribution of porosity indicates existence of boundary layers in laboratory samples, which affect mechanical properties of PC specimens and applications. This study analyses the impact of design parameters on boundary layers and porosity distribution of PC. The effect of boundary layers observed in laboratory scale samples is vital in scaling them up for industrial applications. Approximately 2400 laboratory specimens of $150 \times 150 \times 150$ mm^3 were cast with varying aggregate-to-cement (A/C) ratio (2.5–7.0), aggregate-size-distribution (12–25 mm), compaction energy (15–75 blows from standard proctor rammer) and compaction energy distribution (2 distributions in 3 layers) with 6 replications. Porosity and porosity distributions were analysed using image analysis techniques. The A/C ratio and compaction were observed to impact characteristics of the bottom boundary layer, which varies in thickness up to 25 mm. Optimising design parameters not only enhances the performance of pervious concrete but also optimally reduces the boundary layer effect. The boundary layer of the top face is not significantly affected by design parameters and was observed to be rather constant at 10 mm.

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Pervious concrete; compaction; boundary layer; image analysis; effective porosity

Introduction

The water-sensitive urban design (low impact development) attends to the eleventh goal of the seventeen sustainable development goals (SDGs) of the United Nations which is to build cities and human settlements that are inclusive, safe, resilient and sustainable (Pradhan *et al.*, 2017, Subramaniam *et al.*, 2021). Accordingly, green building concepts were formulated in congruence with the objectives of attaining sustainability in urbanisation (Subramaniam *et al.*, 2014, Zuo and Zhao, 2014).

Pervious concrete as a green building material

Pervious concrete is considered a green material for numerous reasons including the elimination of fine aggregates (sand) and thereby reducing material consumption (Aamer Rafique Bhutta *et al.*, 2013). Porosity reduces the solid content of the material and facilitates fluid flow through connected pores which adds to retaining natural urban catchment hydrological characteristics (Brattebo and Booth, 2003, Brown and Borst, 2015, Rinduja *et al.*, 2021, Subramaniam *et al.*, 2021). This will not only increase water percolation but also traps air in between, effectively reducing the thermal conductivity of pervious concrete (Barnhouse and Srubar III, 2016, AlShareedah and Nassiri, 2021). Pervious concrete in addition, due to its porous structure and cavities, dissipates sound energy upon penetration and reflection, potentially serving as sound-absorbing material (Chandrappa and Biligiri, 2016). Pervious concrete can, therefore, be applicable as sound barriers beside the highways to reduce sound pollution in the environment (Zhang *et al.*, 2020). Pervious concrete in addition prevents skidding of vehicles and reduces accidents. Contemporarily in urban development, pervious concrete is used predominantly for the construction of light-road pavements, parking slots and walkways and not as a material for roads because of limited compressive strength and lack of uniformity in mechanical performance characteristics (Chen *et al.*, 2013, Chandrappa and Biligiri, 2017).

Characteristics of pervious concrete in contemporary research

Pervious concrete is a lightweight concrete that has a density varying between 1500 and 2400 kg/m^3 and depends primarily on aggregate to cement ratio and compaction energy (Aamer Rafique Bhutta *et al.*, 2013, Sajeevan *et al.*, 2021). The absence of fine aggregates contrives the main difference from conventional concrete (Carsana *et al.*, 2013). The absence of fine aggregates and an increased aggregate to cement ratio increases porosity, while compaction on the contrary reduces it (Shen *et al.*, 2013). An increase in porosity, in turn, affects the performance of the resulting concrete, predominantly as a decrease in compressive and flexural strengths (Chindaprasirt *et al.*, 2008, 2009, Lian *et al.*, 2011). In conventional concrete, the porosity is usually less than 1% where the coarse aggregates will be surrounded by a mix of binder and fine aggregates. However, in pervious concrete, the porosity may

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