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MECHANICAL PERFORMANCE OF NANO-SILICA MODIFIED PERVIOUS CONCRETE: EXPERIMENTAL TESTS AND LDEM SIMULATIONS

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Abstract

This study investigates the mechanical behavior of nano-silica modified pervious concrete (PCNS) through a combined experimental and numerical approach, aiming to clarify the potential benefits of nano-silica additions and validate advanced modeling strategies. The experimental program compares plain pervious concrete (PPC) and PCNS (3% nano-silica by cement weight) by measuring infiltration rate, density, porosity, and mechanical performance under compression, splitting tensile, and four-point bending. Results indicate that nano-silica markedly reduces the infiltration rate due to the filling effect and the formation of a denser surface layer. However, density and porosity remain statistically unchanged, and no significant improvements are observed in compressive, tensile, or flexural strengths. Moreover, the higher compaction effort required for PCNS induces a vertical density gradient, which negatively affects mechanical response.

To complement these findings, numerical simulations are performed using the Lattice Discrete Element Method (LDEM). In this framework, pervious concrete is represented as a three-dimensional lattice of truss elements governed by a trilinear constitutive law, applied here for the first time to simulate quasi-brittle materials. Material heterogeneity is introduced through a Weibull-distributed random field for fracture energy. The model is calibrated using four-point bending data from PPC and validated against compressive and tensile tests. Predictions show close agreement with experiments, with strength errors below 6% and simulated crack paths consistent with observations.

Overall, the study demonstrates that the LDEM is a robust and reliable tool for simulating the mechanical response of pervious concrete. The model accurately captures experimental behavior under different loading conditions, reproduces crack development, and provides valuable insights for the design and optimisation of heterogeneous cement-based composites.

Keywords
Cement-based composite; Lattice Discrete Element Method; nano-silica; pervious concrete

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