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TECHNICAL PAPER

Exploring the impact of nano-limestone cementitious material on mechanical, infiltration, and microstructure properties of pervious concrete

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Abstract
The impact of nano-limestone (NL) on the properties of pervious concrete (PC) is the focus of this study. The work explores workability, paste drain down, porosity via CT scanning, hardened density, mechanical strength, infiltration, and microstructural properties of PC. Field emission scanning electron microscopy, X-ray diffraction, and Fourier transform infrared spectroscopy facilitated the microstructural analysis. The findings verified that NL served as an inert substance that enhanced the density of the microstructure in PC. Moreover, it expedites cement hydration process by promoting the generation of nuclei at the boundaries. Different replacement rates of NL (1%, 2%, 3%, and 4%) were examined concerning cement. At a 2% NL replacement, the measured compressive strength of PC was 12.12 MPa and 24.29 MPa after 3 and 28 days, respectively. Splitting tensile strength recorded values of 1.62 MPa and 3.12 MPa, while shear strength measured 1.92 MPa and 3.75 MPa for the same periods. Significant enhancements were observed with compressive strength increasing notably by 48.2% after 3 days and 19.2% after 28 days. Similarly, the splitting tensile and shear strengths displayed remarkable increments of 48.6% and 16.4% after 3 days and 58.6% and 26.4% after 28 days, respectively. However, an increased NL percentage resulted in reduced permeability, rendering PC nearly impermeable at 4% replacement. The optimal NL percentage to maintain PC permeability was $\leq 2\%$, preserving an infiltration rate of 2.43 mm s^{-1}.

Keyword Infiltration rate · Mechanical properties · Microstructure · Nano-limestone · Pervious concrete

Introduction

Cement production is likely to increase in future, releasing CO_2 into the atmosphere. Hence, a proper and sustainable practice is necessary to control the excess production of cement and its impact on the environment [1, 2]. The use of nano-materials in normal and pervious concrete as the replacement of basic ingredients like cement or as a blend has shown potential for improvement in both mechanical and durability properties of concrete, thereby helping to decrease cement usage that can indirectly lead to a reduction in cement production [2]. The same is credited to the very high surface area of nano-materials than the macro materials. The nano-materials are reported as highly reactive and thus quickly enhance the mechanical properties of the blends. The basic mechanism for improving properties is based on the nucleation sites for forming nano-calcium silicate hydrate (CSH) gel. CSH gel acts as a nano-material in the concrete by filling nano-pores, thereby acting as nano-reinforcement, enhancing the hydration process and durability [3]. Nanotechnology thus provides wide scope for improvement in the properties of traditional and specially designed porous concrete. Porous concrete, commonly known as pervious concrete, contains cement, coarse aggregates, water, and very little or no fine aggregates. However, unlike normal concrete, it is a composite with a void ratio of 15–25% [4, 5]. The primary goal of pervious concrete (PC) is to create a system of continuous interconnected pore structure, typically accomplished by reducing or fully eliminating the amount of fine aggregates and only cement, coarse aggregates, and water are used. To achieve bonding between adjacent particles, the coarse aggregates must be coated with an optimal

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