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Effect of Modified Waste Rubber Particles on the Properties of 3D-Printed Concrete

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Abstract

To address the high-value utilization challenge of construction waste and waste tires, this study prepared low-carbon 3D-printed recycled fine aggregate (RFA) concrete (3DP-MRRC) by partially replacing RFA with surface-modified rubber aggregates (MRA). The effects of MRA dosage (0–15%) on the rheological properties, setting time, mechanical performance, and mechanical anisotropy of 3DP-MRRC were systematically investigated, with the micro-mechanism revealed via scanning electron microscopy (SEM) and mercury intrusion porosimetry (MIP). Results indicate that the active modified layer on MRA accelerates cement hydration, shortens setting time, and linearly increases static yield stress, satisfying the buildability requirement for 3D printing. With increasing MRA dosage, the compressive strength of 3DP-MRRC decreases continuously, while the flexural strength first increases and then decreases, peaking at 10% MRA dosage. Microscopic analysis confirms that 10% MRA dosage induces needle-like AFt crystals, which split the original macropores of RFA to form a complex ink-bottle pore structure, significantly enhancing crack propagation resistance and flexural toughness. However, MRA agglomeration at 15% dosage shields the modified layer, leading to a sharp increase in median pore diameter and deteriorated mechanical properties. Additionally, the high elasticity of MRA effectively alleviates inter-layer and inter-filament stress concentration, homogenizing flexural anisotropy, while compressive anisotropy increases linearly with MRA dosage. This study provides a feasible strategy for the synergistic resource utilization of construction waste and waste tires in 3D-printed concrete, and recommends 10% MRA as the optimal dosage to balance printability, mechanical performance, and low-carbon benefits.

Keywords

3D-printed Concrete, Modified Rubber Aggregate, Recycled Fine Aggregate, Pore Structure, Mechanical Anisotropy, Low-carbon Building Materials