Functionalized Carbon Fiber Textile Reinforcements with Fiber-Based Strain Sensing

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Abstract

Textile-reinforced concrete (TRC) has emerged as a high-performance, corrosion-resistant, and sustainable alternative to conventional steel-reinforced concrete. However, the limited interfacial bond between carbon fiber non-crimp fabric (CF-NCF) reinforcements and the concrete matrix restricts efficient load transfer and overall ductility. This study presents a novel approach to enhance the mechanical and functional performance of TRC by integrating geometrically modified carbon fiber tetrahedral-shaped rods (CF-TSR) combined with fiber-based strain sensing.

Five reinforcement configurations were fabricated, ranging from an unmodified reference to four CF-TSR integrations per specimen. The functionalized CF-NCFs were embedded in fine-grained concrete and tested under quasi-static tensile loading Digital image correlation and in-situ electrical resistance measurements of the integrated textile sensors enabled a detailed correlation of mechanical, optical, and electrical data.

The Results showed that a moderate geometric modification - specifically the integration of one CF-TSR per specimen - enhanced the elongation at peak stress (+4.6 %), elongation at break (+7.8 %), and absorbed energy (+7.1 %) compared to the reference, while maintaining comparable tensile strength. Optical and electrical analyses demonstrated strong correlations between crack formation, stress evolution, and sensor signals, demonstrating the capability of the integrated textile sensors for in-situ structural health monitoring (SHM).

The study highlights the potential of combining optimized mechanical reinforcement with integrated sensing to create smart TRC systems that enhance ductility and enable real-time damage detection. The lightweight, corrosion-resistant textile design also offers high potential for retrofitting and strengthening existing concrete structures.

Keywords

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