Doctoral Dissertation Abstract

Enhancing Mechanical Performance of Brittle Materials through Fiber Reinforcement: A Study on FRC and FRI

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This doctoral thesis emerges from the crucial need of enhancing the mechanical performance of brittle materials. This study investigates how the addition of reinforcing fibers into brittle materials can substantially improve their ductility, thereby elevating their overall mechanical performance. A key element of this research is the implementation of a two-step casting process. This casting approach, detailed in subsequent sections, ensures the systematic and controlled integration of reinforcements into brittle matrices.

In the initial phase of this study, our focus was directed towards cementitious materials. This thesis presents the results of experimental research conducted on fiber-reinforced cement-based composites, utilizing polymeric aggregate and recycled steel fibers. A total of 18 concrete prisms were cast using a two-stage procedure. The outcomes of this two-stage casting process revealed multiple cracks and a deflection-hardening behavior in the post-cracking regime, as observed during three-point bending tests. Additionally, both flexural and compressive strength exhibited notable improvements with increasing fiber volume fraction.

In the subsequent phase, the study shifts to the reinforcement of ice as a structural material. In regions characterized by cold climates, construction poses significant challenges and expenses, primarily attributed to the logistical complexities of supply transportation. Consequently, relying on conventional materials becomes impractical, particularly in northern areas. Ice presents itself as a practical, locally sourced, bio-based material with various applications. Ice composites, employed in construction for an extended period, have demonstrated versatility.

However, integrating ice into the construction industry presents notable difficulties. Specifically, utilizing ice in structural applications poses two primary concerns: low strength and brittle failure. Therefore, finding a practical solution to address these issues becomes imperative. This thesis presents the outcomes of an experimental campaign on fiber-reinforced ice composites. These composites were crafted using plain water and fortified with organic fibers. A total of 36 ice prisms were meticulously cast, each with varying fiber content, at temperatures of -24°C, -18°C, and -5°C. Subsequent tension and compression tests revealed that both flexural and compressive strength exhibited enhancement with the addition of fibers. Notably, the Fiber-Reinforced Ice (FRI) composites displayed multiple cracks, indicative of ductile behavior, representing a promising solution to the inherent challenges of utilizing ice as a structural material.

This research highlights the significant potential of fiber-reinforced composites to enhance the mechanical performance of brittle materials. By using Fiber-Reinforced Concrete (FRC) as a methodological reference, the study leverages a well-established framework for evaluating mechanical and elastic indices (MI/EI) in composite materials. Drawing parallels between FRC and Fiber-Reinforced Ice (FRI), this approach facilitates the application of proven concepts to FRI, enhancing the understanding and assessment of its properties. The outcomes of this research have the potential to influence the design and development of materials across various industries, paving the way for creating robust and durable structures capable of withstanding challenging mechanical environments.