Design of Sustainable Advanced Fiber Reinforced Concrete using a Multi-Scale Framework

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Abstract

Ultra high performance concrete (UHPC) is an advanced construction material for civil infrastructure development due to its supreme mechanical characteristics and distinct durability properties. There is a notable surge in the application of UHPC, particularly in highway infrastructures in the United States. Due to the multiscale nature of UHPC, various design factors across different length scales must be considered during both the design and construction phases. The first part of the dissertation investigates the influence of fiber orientation and construction processes on the structural performance of UHPC. A comprehensive synthesis of existing literature and the UHPC structural design specifications and recommendations worldwide is conducted to understand how construction processes impact fiber orientation in UHPC elements and how this influence should be addressed in UHPC design. In the second part of the dissertation, sustainable UHPC materials are developed using a multi-scale and probabilistic design approach. A key challenge with UHPC is its high cost and carbon footprint associated with the use of manufactured steel fibers. This study explores the feasibility of using recycled steel fibers (RSF) obtained from waste tires in the UHPC production. The characteristics of RSF are comprehensively characterized, and their influence on the pullout behavior is determined through experimental and analytical methods. A multi-scale probabilistic framework is then employed to facilitate the design of UHPC composites incorporating RSF. In conclusion, the dissertation contributes to the sustainable development of UHPC structures by addressing key issues such as fiber orientation and the use of recycled materials, ultimately enhancing the environmental and economic feasibility of UHPC applications in infrastructure construction.