Editorial

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Hybrid fiber and ultrahigh performance cementitious composites

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Since the 19th century, composites of cement-based materials have been extensively used as building and construction materials. An understanding of the mechanics of materials and related technologies has facilitated the mitigation of cementitious composite limitations, which increases the demand for cementitious composite. Advanced research showed that many inherent weaknesses of cementitious composite have been overcome and the applicability of cementitious composite has expanded. The use of randomly oriented discontinuous fibers as cementitious composite reinforcement has been innovated to mitigate the cracking due to its low tensile strength. The invention of fiber-reinforced cementitious composite constitutes a significant breakthrough in modern cementitious composite technology. The efficiency of this technology is to enhance the characteristics of cementitious composite, such as the tensile strength, dimensional stability, durability and ductility.

The development of construction materials and related tools has facilitated the innovation of hybrid cementitious materials with ultra-high strength and durability. The ultra-high performance cementitious composite (UHPCC) is a combination of high performance cementitious composite (HPCC) and fibers. These materials are associated with very low water-to-binder ratios and high concentrations of very fine powders, fibers and relevant admixtures. The development of these materials involves optimum packing density and the omission of larger particles. The particle packing density involves mixing materials with similar volumes, which improves the permeation properties of the cementitious composite. The development of microstructure enhancement and particle-packing techniques has facilitated the development of these composites. However, the cost of these materials is high; can sustain more loads with minimum maintenance and rehabilitation costs. The brittleness of cementitious composite increases with an increase in compressive strength, therefore, the use of fiber is vital in UHPCC. UHPCC exhibits superior strength and durability characteristics. To optimize the fresh and hardened properties and the cost of fiber-reinforced cementitious composites, the use of a hybrid system of fibers has become an effective practice. The primary objective of hybridization is to create synergy between fibers, which can maximize the benefits as compared to mono-fiber system.

The incorporation of fibers in a mono or hybrid state in the high and ultra-high performance cementitious matrix has many benefits. Fibers tie the cementitious matrix in such a manner that they form bridges over which the internal strains/stresses are transmitted along the cementitious systems. Thus, the presence of fibers prevents the localization of stresses and prevents the formation of major cracks. Multi-crack formation and high ductility become the dominant features of this type of cementitious composite. Fiber hybridization, in which various types of fiber of different sizes, geometries and elastic moduli were proposed to synergistically combined with an optimized cementitious HPCC matrix to produce a super-hybrid composite of HPCC. Existing studies demonstrate the efficiency of using hybrid fibers of different engineering properties and different unconventional supplementary cementitious materials in super-hybrid composite. Multiple mechanisms introduce the benefits of fiber, such as altering the chemistry and microstructure of hydrated cement, bridging cracks and absorbing fracture energy are proposed.

Fiber hybridization is a modern technique in which two or more fibers are combined in a cementitious matrix. The integration of two fibers can mitigate the drawbacks while retaining the advantages of the fibers. To assess the fiber-reinforced cementitious composite, researchers use two methods, namely, the flexural toughness method or the post-crack strength method. The latter method is considered to be more appropriate for hybrid fiber-reinforced cementitious composite. Fibers are characterized into macro or micro-fibers based on the dimensions or the specific surface area (SSA) of the fibers. The SSA is defined as the surface per mass of the fiber material.

Compared with single fiber composites, fiber hybrid composites are associated with high compressive strength, high splitting tensile strength, high tensile strain capacity, multiple cracking behavior, high flexural strength and high flexural toughness. These improvements are attributed to the finding that the inclusion of fibers enhances the pre- and post-break regions of load-deflection of hybrid fiber cementitious composites (HyFCC) elements. Many researchers exhibited the preferential use of hybrid fibers with respect to mono-fibers that is primarily for the synergetic interactions between hybrid fibers. Recently, thousands of cubic meters per year of fibrous cementitious composites have been used in slabs on grade, concrete, and precast members. The potential use of mono and hybrid fibrous cementations composites include: blast/impact resistant panels, rehabilitation of reinforced concrete structural members, and structural members exposed to explosive and harsh environmental conditions.

Most of the studies available on hybrid fiber UHPCC have been investigating the flexural behavior. However, very limited information on the behavior of hybrid fiber UHPCC members subjected to direct shear are available. In addition, there are very few studies investigating the effects of matrix strength, surface roughness (smooth and rough) of synthetic fibers on the global performance of fresh and hardened cementitious composite of HyFCC. Additionally, very limited studies are available on the response of reinforcement bars embedded in HyFCC, when subjected to slip interfacial stresses. Although, the superior mechanical of performance of hybrid fiber

UHPCC are associated with porous transition zone. Investigations are needed to overcome the problems associated with porous transition zones associated with porous transition zone of hybrid fiber UHPCC. Few researchers have investigated the influence of hybrid multi-scale fibers on UHPCC. Even there is no general agreement between researchers on the optimum contents of various ingredients to be used in these materials. An optimization practice is compulsory to account for the variance in the properties of the constituent materials and ambient conditions.

In general, at present a systematic approach for the assessment and comprehensive guidelines for these materials are not available, which is pertinent to its practical. To facilitate the formulation of standard specifications, greater efforts are needed to transfer such technology so that rapid implementation can occur.

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Conflict of interest

The author declares no conflict of interest.