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Editorial

Special Issue on Advanced Fiber-Reinforced Cementitious Composites

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1. Introduction

Fiber-reinforced cementitious composites (FRCC) have emerged as a promising alternative to traditional cementitious materials due to their enhanced mechanical properties and durability. FRCCs are composite materials that combine a cementitious matrix with discrete fibers, which act as a reinforcement, thus improving the overall performance of the material. These fibers can be made of various materials, such as carbon, glass, or natural fibers, each with unique characteristics and advantages. The addition of fibers to the cementitious matrix helps to distribute and dissipate stresses more effectively, reducing the likelihood of cracking, and enhancing the material's tensile strength, toughness, and resistance to deformation. This results in improved overall durability and structural performance, making FRCCs particularly suitable for applications that require high strength and long-term durability, such as in construction and infrastructure projects.

The use of advanced fibers, such as carbon or glass fibers, in FRCCs has been of particular interest due to their exceptional mechanical properties. Carbon fibers provide high tensile strength and stiffness, while glass fibers offer good resistance to chemical degradation. Natural fibers, on the other hand, are often chosen for their low environmental impact and renewable nature.

This Special Issue aims to provide a comprehensive overview of the current research trends in FRCC. This includes topics such as the development of new fiber types, the optimization of fiber-matrix interaction, the characterization of mechanical and durability properties, and innovative manufacturing techniques, and applications of FRCC in various industries. By shedding light on these research trends and discussing the future directions of FRCC, we aim to contribute to the knowledge base of this rapidly evolving field. This will not only enhance our understanding of FRCCs but also stimulate further research and development in the pursuit of more sustainable and high-performance cementitious composites.

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2. Enhancing Mechanical Performance through Fiber Reinforcement

The first trend in cementitious composites research which is featured in this Special Issue is centered on enhancing their mechanical properties through fiber reinforcement. Recent studies, such as the work of Son et al. has explored the use of advanced fibers and found that macro-synthetic, fiber-reinforced concrete (MFRC) improves the flexural performance of structural deck plates, leading to increased compressive strength and modulus of elasticity, and greater flexural stiffness until yielding, as well as a proposed flexural strength model for steel deck plates containing MFRC [1]. Zainal et al. reported that hybrid fiber-reinforced cement composites (HyFRC) with micro and macro fibers exhibit improved tensile and compressive strengths compared to standard cement composites. In addition, slabs made of HyFRC have shown significant improvements with respect to ultimate load capacity, corresponding mid-span deflection, steel reinforcement strain output, and cracking behavior compared to conventional RC slabs [2]. Lu et al. fabricated fiber-reinforced cement composites (FRCC), incorporating carbon fibers modified with nano-SiO_2 to improve the problems of conventional carbon fiber surfaces. The results showed that the flexural and tensile strengths were improved compared to FRCC with an unmodified surface. They also proposed the internal mechanism for the improvement of interface strength after fiber modification was revealed [3].

Moving forward, future research endeavors in this field aim to refine the fiber-matrix interface and develop innovative fiber architectures to maximize the efficacy of load transfer mechanisms.

The overall quality of the research presented is commendable. The studies conducted by various researchers have made valuable contributions to the understanding and advancement of AFRCC. These investigations have provided salient insights into the use of advanced fibers, such as macro-synthetic, fiber-reinforced concrete and hybrid fiber-reinforced cement composites, in improving the mechanical properties of cement-based materials. Moreover, the studies have proposed models and mechanisms to explain the observed improvements. However, a more comprehensive assessment would require evaluating the methodology, experimental procedures, and statistical analyses employed in each study.

Future research in this area aims to refine the fiber-matrix interface and develop innovative fiber architectures to maximize the efficiency of load transfer mechanisms.

3. Investigation of the Influence on Tensile and Electrical Properties by Steel Fibers

The study conducted by Kim et al. focuses on the development of multifunctional cement composites, specifically self-sensing cement composites. The incorporation of functional fillers, including steel fibers, nickel, and carbon, imparts conductive properties to the cement matrix. Carbon conductive fillers are reported to exhibit superior durability and conductivity. The research investigates the impact of carbon-based nanomaterials, such as graphite nanofibers, multi-walled carbon nanotubes (MWC-NTs), and graphene, on the electrical properties of cement paste [4]. Nguyen et al. examine the electromechanical damage detection behavior of strain-hardened steel-fiber-reinforced cement composites (SH-SFRC) with six types of steel fibers. The electrical resistance of SH-SFRCs decreases with increasing tensile strain, indicating micro-crack formation. The investigated SH-SFRCs demonstrate higher gauge factors (50–140) compared to typical metals (around 2), indicating superior damage detection ability. T30/0.3 and T20/0.2 fibers exhibit the highest gauge factors, while S13/0.2 shows the highest electrical conductivity. These findings have significant implications for the development of multifunctional SH-SFRC for civil infrastructure [5]. Jang et al. explore the feasibility of using hybrid polyethylene (PE) and steel fiber-reinforced-cement-composites (HY-FRCC) containing multi-walled carbon nanotubes (MWCNTs) as strain sensors. The proposed smart building material represents a novel multifunctional cement composite with structural and magnetic sensing capabilities. The results indicate the promising potential of cement-based sensors for structural health monitoring in civil infrastructure [6].

Overall, the research presented here demonstrates valuable contributions to the field of multifunctional cement composites and the utilization of various materials and fillers to enhance their properties. The studies provide detailed investigations into the electromechanical behavior and damage detection capabilities of different composites, shedding light on factors such as fiber type, electrical resistance, and gauge factors. The inclusion of carbon-based nanomaterials and the exploration of strain sensing in hybrid composites showcase the innovative nature of the research. However, a comprehensive assessment requires further analysis of experimental methodologies, statistical analyses, and potential limitations.

4. Influence of Fiber Volume Fraction on Ultimate Strength and Failure Modes in UHPFRC Flexural Members

Bae et al. evaluate the ultimate strength of ultra-high-performance fiber-reinforced concrete (UHPFRC) flexural members. The study conducted an experimental program with fiber volume fraction, shear span to depth ratio, and compressive strength of matrix as the main variables. The inclusion of 2% volume fraction steel fiber increases the shear and flexural strength of UHPFRC beams significantly. The ultimate flexural strength and shear strength of UHPFRC members were evaluated using the current design code and UHPC guidelines. The ultra-high strength concrete without steel fiber showed a shear failure. However, in specimens reinforced with steel fiber, the appearance and spread of diagonal cracks were observed. The applicability of two design recommendations was evaluated [7].

The tensile behavior of UHPFRC differs depending on the degree and direction of dispersion of steel fibers in the internal concrete matrix. In this study by Yang et al.-the tensile behavior of the UHPFRC beam was investigated by comparing the analytical results of the moment-curvature curve with the experimental results. Three types of specimens were fabricated based on the design recommendations by incorporating two types of steel fibers at a volume ratio of 1.0% and 1.5%, respectively. The strength of the beams increased as the steel fiber content increased. The bending strengths obtained from the cross-sectional analysis using the material test results were compared with the test results of the beams. Overall, the beams with 1.0% inclusions produced lower estimates of tensile strength, while the beams with 1.5% inclusions produced higher estimates of tensile strength. When the tensile strength of UHPFRC beams was estimated by comparing the analysis results of the moment-curvature curve with the test results of the beams, the estimated tensile strength of UHPFRC increased as the compressive strength increased [8].

Pourbaba et al. experimentally investigated the bending and shearing behavior of UHPFRC type 5 by performing a four-point load test on it. The purpose of this study is to evaluate the flexural and shearing behavior of ultra-high performance fiber beams and compare it with the behavior of ordinary-strength beams and the equations available in the literature. Experiments were conducted with cross-sectional size and fiber reinforcement ratios as variables. It was found that the UHPFRC beams failed primarily in bending, while the normal strength beams failed primarily in shearing. The bending and shearing capacities of the UHPFRC specimens were up to 3.5 times greater than those of the conventional-strength specimens; on average, the bending and shearing loads of the UHPFRC specimens were 1.50 and 6.40 times higher than those of the normal strength specimens for the smaller sections, and 2.46 and 2.42 times higher for the larger sections, respectively [9].

The research presented here offers valuable insights into the ultimate strength, tensile behavior, and flexural/shearing behavior of UHPFRC beams. The studies have employed rigorous experimental programs, investigating variables like fiber content, design recommendations, and cross-sectional size. The results demonstrate significant improvements in strength and performance due to the incorporation of steel fibers in UHPFRC. However, a comprehensive assessment should consider additional factors, including sample size, statistical analyses, and potential experimental limitations.

5. Conclusions

The research trends discussed above demonstrate the current and future directions of research on advanced fiber-reinforced cementitious composites (AFRCC). The field is witnessing a growing emphasis on enhancing mechanical performance through fiber reinforcement, with a focus on advanced fibers and optimizing their incorporation within the cementitious matrix. Durability enhancement and sustainability are also prominent considerations, with efforts being made to incorporate recycled fibers and supplementary cementitious materials, as well as exploring long-term performance and environmental resistance.

In conclusion, the future of advanced fiber-reinforced cementitious composites research lies in the continued exploration and optimization of fiber reinforcement techniques, as well as the integration of sustainable materials and durability enhancement strategies. The development of novel manufacturing techniques and the expansion of structural applications will enable the practical utilization of AFRCC in various industries. Furthermore, advancements in multi-scale modeling and computational simulations will play a crucial role in accelerating the design and development of AFRCC with tailored properties and improved performance. By addressing these research trends, the field of AFRCC holds immense promise for revolutionizing the construction industry with sustainable, high-performance materials.

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