

## Editorial

# Fiber-Reinforced Concrete with Application in Civil Engineering

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With the development of science and technology of materials in civil engineering, concrete material has been the most widely used building material all over the world. The most famous advantage of concrete is its high compressive strength. However, there are many defects for concrete materials, such as low anticracking performance, bad toughness, low tensile strength, and so on. During the failure of the concrete structure under the action of load, the energy consumed is very limited, and many cracks with different size scale will come into being. The concrete with higher strength has larger brittleness. The existing of a large number of cracks has great adverse influence on the mechanical properties and durability of concrete structures, which will result in shortening of the service life of the structures. The defects of common concrete restrict the application under severe conditions to a large extent.

In order to overcome the defects of concrete material, many researchers have conducted a lot of investigation to improve the properties of concrete, especially the toughness of concrete. It has been proved that the using of fibers can improve the mechanical properties and durability of concrete. A large number of studies have been conducted to study the performance and advantages of fiber-reinforced concrete in the last several decades. The fibers often used in concrete materials include steel fiber [1], glass fiber [2], polyethylene fiber [3], polypropylene fiber [4], polyvinyl alcohol fiber [5], polyester fiber [6], basalt fiber [7], and natural fiber [8]. There are three kinds of actions of fibers on concrete, which include anticracking, reinforcing, and toughening. The anticracking action refers to the ability to restrict and reduce the generation and development of

shrinkage cracks in the concrete. The reinforcing action can be defined as that the addition of fibers decreases the adverse effect of the defects inside the concrete on the strength of the concrete and improves the mechanical properties of the concrete. The toughening action refers to the bridge effect of the fibers across the cracks inside the concrete, which improves the toughness of the concrete after cracking.

This special issue aims at bring investigators from industry and academia together to report and explore the new investigation techniques, new preparation methods and basic material properties, testing methods and standardization in civil engineering, fresh properties and constructability, shrinkage and creep, structural performance and modeling, functional coatings for buildings, durability and sustainability, and field applications in fiber-reinforced concrete materials and review the latest progress in this field. Out of about fifty-two submitted manuscripts, twenty-three research manuscripts have been selected and published in this special issue because of their good quality and relevance to the theme of this special issue. The selected articles address various aspects, including the mechanical properties and durability of steel fiber-reinforced concrete, materials and structural performance of fiber-reinforced ultrahigh-performance concrete, tensile mechanical properties and failure modes of basalt fiber concrete, the effect of various waste powder and mineral admixtures on the durability and mechanical performance of concrete, and the numerical modeling of properties of fiber-reinforced concrete.

Among various fibers, steel fiber is the most famous fiber used in concrete materials. The paper titled “Effects of Single and Hybrid Steel Fiber Lengths and Fiber Contents on the

Mechanical Properties of High-Strength Fiber-Reinforced Concrete” is authored by K.-C. Kim et al. They conducted an experimental study on the mechanical properties of high-strength fiber-reinforced concrete (HSFRC). In this study, they used three steel fiber contents and three steel fiber lengths. The results indicate that the compressive strength, elastic modulus, and tensile strength of the HSFRC mixture with hybrid steel fibers were similar to those of the mixtures with a single length of steel fiber. Y. Zheng et al. compared the mechanical properties of steel fiber-reinforced concrete with different strengths prepared by traditional mixing and vibratory mixing methods. Their results indicate that vibratory mixing can effectively improve the distribution of steel fibers in concrete and can increase the density of steel fiber concrete, and therefore, it effectively improves the mechanical properties of steel fiber-reinforced concrete when compared to the traditional mixing method. H. Feng et al. investigated the mechanical performance of magnesium phosphate cement mortar-reinforced microsteel fibers. The results showed that the addition of microsteel fibers from 0% to 1.6% by volume significantly improved the compressive strength of the mortar, and the addition of microsteel fibers changed the flexural failure mode of magnesium phosphate cement mortar from brittleness to ductility. The paper titled “Mechanical Properties of Steel Fibers and Nanosilica Modified Crumb Rubber Concrete” is authored by Y. Wang et al. Through a series of experiments, the mechanical properties of crumb rubber concrete reinforced with nanosilica and steel fibers were investigated. According to their results, the brittle failure of the crumb rubber concrete can be improved, and the mechanical properties can be enhanced by the addition of steel fibers and nanosilica. Besides, the improvement of steel fibers on the splitting tensile strength of modified crumb rubber concrete is more obvious, while the nanosilica plays an important role on the enhancement of compressive performance. The chloride diffusion coefficient has been regarded as the most important parameter to predict the chloride ingress of concrete. Based on a series of chloride bulk diffusion tests, Q. Wang et al. presented a proper model to calculate the chloride diffusion coefficient of concrete reinforced with steel fibers. Their results showed that the unstressed specimens of steel fiber-reinforced concrete exhibited better chloride resistance, and the chloride diffusion coefficient of steel fiber-reinforced concrete was reduced by the compressive stress, while that of the plain concrete had no obvious changes. The addition of steel fibers has great improvement on the chloride resistance of concrete. The proposed model can provide a simple method to calculate the chloride diffusion coefficient of the specimens of steel fiber-reinforced concrete under bending load. The paper titled “Stress-Strain Behavior of Steel Fiber-Reinforced Concrete Cylinders Spirally Confined with Steel Bars” is authored by B. Sabariman et al. They investigated the effect of the application of hooked-end steel fibers in spirally confined concrete with various pitches. In their testing, the standard concrete cylinders were spirally confined with steel bars and with/without hooked-end steel fibers. Their results indicated that the using of hooked-end steel fibers had great

contribution on improving both compressive strength and ductility of concrete, and the compressive strength and ductility of steel fiber-reinforced concrete also increased with the decrease of the spiral’s pitch.

Some short fibers can be added into cementitious composites to produce a kind of high-performance construction materials, which is often called engineered cementitious composite (ECC). O. Holcapek et al. prepared a new kind of cementitious composite using ceramic fibers and carried out some experiments to evaluate the resistance to elevated temperatures of the composite. Their results indicated that hydrothermal curing had positive effect for the purpose of refractory cement composites reinforced by ceramic fibers, and the flexural strength, both before and after being subjected to elevated temperatures, achieved an especially excellent level. L. Liu et al. presented an experimental study on the flexural properties of ECC. It can be observed that the number of cracks increased with the increment of stress levels, and most of the cracks were formed during the earlier stage of the dynamic test. The paper titled “Effects of Shrinkage-Compensation on Mechanical Properties and Repair Performance of Strain-Hardening Cement Composite Materials” is authored by S.-J. Jang et al. They studied the influence of expansive admixture on the mechanical properties of strain-hardening cement-based composites and investigated the structural performance of reinforced concrete (RC) beam specimens repaired with strain-hardening cement composite materials. Y. Guan et al. studied the flexural properties of ECC-concrete composite beam and revealed the impacts of bonding at the interface and fiber mesh reinforcement on the flexural properties and cracking pattern. It can be concluded that the fiber mesh reinforcement could further improve the flexural properties regardless of the bonding condition. Based on a lot of tests, Y. Liu et al. discussed the effect of silica fume (SF) and ground-granulated blast-furnace slag (GGBS) on the frost resistance of ECC with high volume of fly ash. Their result shows that the relative dynamic elastic modulus and mass loss of ECC in sodium chloride solution by freeze-thaw cycles are larger than those in tap water by freeze-thaw cycles, and the relative dynamic elastic modulus and mass loss of ECC by freeze-thaw cycles increase with increasing fly ash content.

With the development of concrete technology, ultrahigh-performance concrete has been manufactured to meet higher and higher requirement on concrete structures. Various waste mineral admixtures are used to prepare ultrahigh-performance concrete (UHPC). J. Liu and R. Guo prepared ultrahigh-performance concrete by applying steel slag powder and steel slag aggregate. They determined the fluidity, non-evaporable water content, and pore structure of the paste and the compressive strength of UHPC and observed the morphologies of the hardened paste and the concrete fracture surface. The paper titled “Exploitation of Ultrahigh-Performance Fiber-Reinforced Concrete for the Strengthening of Concrete Structural Members” is authored by M.A. Al-Osta. He reviewed, analyzed, and discussed the recent issues and findings regarding the use of fiber-reinforced UHPC as a repair or strengthening material for concrete structural members and recommended the concerning areas where future attention and research on the use of fiber-reinforced

UHPC as a strengthening material needs to be focused if the material is to be applied in practice. P. Zhang et al. studied the influencing factors on the performance of fiber-reinforced UHPC under the condition of room temperature. It can be concluded that the water/binder ratio, the ratio of cement replaced by ground-granulated blast-furnace slag, the dosage of fly ash, and the particle size of sintered bauxite have great effect on the properties of fiber-reinforced UHPC. S. Han et al. conducted the experiment study of modeling for the early-age shrinkage of fiber-reinforced UHPC under different curing conditions. The calculation model of early-age shrinkage was established based on the theory of shrinkage of cementitious materials, which can provide theoretical support for the structural design and engineering application of fiber-reinforced UHPC. The paper titled "Simulation of the Flexural Response of Ultrahigh Performance Fiber-Reinforced Concrete with Lattice Fracture Model" is authored by C. Gu et al. They simulated the flexural response of fiber-reinforced UHPC based on the lattice fracture model, which has the potential to help with the materials design of fiber-reinforced UHPC. The effects of fiber orientation and fiber content were studied with the lattice fracture model.

The paper titled "Mechanical Properties and Service Life Prediction of Modified Concrete Attacked by Sulfate Corrosion" is authored by M. Zhang et al. They studied the mechanical properties and service life prediction of polypropylene fiber-reinforced concrete attacked by sulfate corrosion. Their results indicated that the strength of concrete increased in the early stages of corrosion and decreases gradually later, and the admixture significantly improved the resistance to sulfate erosion of the modified concrete, while polypropylene fiber played a less important role on anti-corrosion properties. J. He et al. conducted the uniaxial tensile tests of basalt fiber/epoxy (BF/EP) composite material with four different fiber orientations under four different fiber volume fractions and analyzed the variations of BF/EP composite material failure modes and tensile mechanical properties. Their results show that the tensile strength, elastic modulus, and limiting strain of BF/EP composite material all decrease with increasing fiber orientation angle when the fiber volume fraction is constant, and the tensile strength, elastic modulus, and limiting strain of BF/EP composite material all increase with increasing fiber volume fraction when the fiber orientation angle is constant. S. Rico et al. presented a state-of-the-art report on fiber-reinforced lightweight aggregate concrete masonry. In order to solve the issues of the brittleness of the unit for masonry concrete, they proposed a reliable solution, which consists of introducing steel fibers to the lightweight aggregate concrete masonry mix. The solution can provide invaluable data for the production of a ductile masonry unit capable of withstanding seismic loads for prolonged periods.

Besides the properties of fiber-reinforced concrete, the structural performance of the structures made of fiber-reinforced concrete was investigated and discussed in this special issue. C. Boonmee et al. studied the gravity load collapse behavior of extremely poor quality-reinforced concrete columns under cyclic loading. The results showed that the use of deformed bars (associated with larger amount of

longitudinal reinforcement) caused the damage to severely dissipate all over the height of the columns, and such damage caused columns to collapse at a lower drift compared to those using round bars. G. Zhao et al. numerically simulated the static load carrying capacity of a non-corroded reinforced concrete (RC) simply supported beam using Abaqus software and verified the reliability of the finite element model by comparing with the test results. Moreover, they calculated the macroscopic mechanical properties of the beam under different degrees of corrosion based on the established model. Their results indicate that the macroscopic mechanical properties of the corroded beam are affected by the coupling effect of bond-slip degradation and the mechanical property degradation of the rebar and that the bearing capacity and ductility of the beam are decreased and its brittleness is increased with the increase in the corrosion rate. W. Zheng et al. carried out a series of experiments to investigate the seismic performance and shear strength of reactive powder concrete interior beam-column joints subjected to reverse cyclic loads. The results show that reactive powder concrete beam-column joints have a higher shear-cracking strength and shear carrying capacity and strength degradation and rigidity degradation are not notable and that the use of reactive powder concrete for beam-column joints can reduce the congestion of stirrups in joints' core. The paper titled "Seismic Performance of a Corroded Reinforce Concrete Frame Structure Using Pushover Method" is authored by M. Zhang et al. They built a finite element model of a six-storey-three-span reinforced concrete (RC) frame structure using SAP2000 software. Their results showed that the seismic performance of the RC frame decreased significantly due to corrosion of the longitudinal rebars and that the interstory drift ratios increase dramatically with the increasing of the corrosion rate. Besides, the formation and development of plastic hinges (beam hinges or column hinges) will accelerate, which leads to a more aggravated deformation of the structure under rare earthquake action, resulting in a negative effect to the seismic bearing capacity of the structure.

## Conflicts of Interest

The editors declare that they have no conflicts of interest.

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