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Editorial

High-Performance Construction Materials: Latest Advances and Prospects

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1. Introduction

Our civilization has used construction materials extensively, especially for infrastructure projects. The importance of construction materials in enhancing the sustainable performance of structures and buildings goes without saying. Therefore, the continued development of more advanced construction materials with improved performance is of paramount importance.

Many innovations in high-performance construction materials have enabled the design and construction of sustainable and durable infrastructure. For instance, concrete is the most widely used building material in the world. To overcome the brittleness of concrete, fibers are used throughout the world for the development of fiber-reinforced cementitious composites with high ductility. In recent years, low heat Portland cement has been used to lower the cement hydration heat in attempts to reduce the thermal cracking risk. To improve the mechanical properties and microstructure of concrete, nanomaterials, such as silica fume, have been adopted.

This Special Issue "High-Performance Construction Materials: Latest Advances and Prospects", aims to reflect the current state-of-the-art and new developments in all topics relevant to high-performance construction materials. This Special Issue gathers fifteen papers regarding innovative building materials, use of nano additions in buildings, use of waste materials and industrial byproducts in concrete, fiber-reinforced cementitious composites, and durability studies, etc. This Special Issue provides a comprehensive background for material engineers, researchers, and experts in the field. An overview of these papers is given as follows.

2. Overview of This Special Issue

Concrete structure construction with a high strength grade in cold regions is a significant problem. Zhou et al. [1] found that the combination of graphene nanoplatelet (GNP) incorporation and electric thermal (ET) curing could effectively improve performance when preparing high-strength concrete (GNP-HSC) at −20 °C. Mechanical property results indicated that the combination of GNP incorporation and ET curing could effectively stimulate the strength formation of HSC samples to 91.2 MPa at an early age. This work provides new insights into the application of GNP as a nanoscale material to improve the performance of HSC structures at extremely low temperatures.

He et al. [2] studied the mechanical properties and acoustic emission (AE) characteristic changes of concrete with different graphite powder (GP) content. Their results showed that: (1) Poor adhesion and low interlocking of graphite with cement stone weakened the compressive strength. (2) For concrete with a low graphite content, the second sharp rise in ringing counts or energy released during the compressive process can be regarded as a failure alarm. (3) The initial defects caused by GP significantly lowered the initial fracture toughness, but its bridging effect significantly enhanced the unstable fracture toughness of concrete by up to 9.9% at 9% GP content.

Chen et al. [3] investigated the physical performance, mechanical properties, freeze–thaw resistance, impermeability performance, phase composition, and microstructure of waste tires/sand-based autoclaved aerated concrete composite materials. The results demonstrated that the 750-μm-sized waste tire particles on the surface of the sand-based autoclaved aerated concrete (SAAC) composite did not agglomerate. The SAAC composites, with a relatively high compressive strength and low mass-loss rate, were obtained when the contents of waste tire particles ranged from 1.0 to 2.5 wt.%.

In Yuan et al.'s [4] work in this Issue, the toughness of pre-packaged grouts (PPG) was improved by incorporating crumb rubber. The results showed that, firstly, the addition of crumb rubber improved the PPG's toughness, while reduced its mechanical strength. Secondly, the crumb rubber grouts' rheological properties can be fully exploited by increasing the stirring rate and time, which exhibited the characteristics of no bleeding and micro-expansion. Finally, the optimal proportion and mixing technique of crumb rubber grouts were proposed.

The geopolymerization process is an appropriate way of disposing of municipal solid waste incineration fly ash (MSWIFA). In Wang et al.'s [5] study, coal fly ash (FA) and metakaolin (MK) were used to prepare a geopolymer composite, with MK being partially replaced by different proportions of MSWIFA through the alkali-activation method. Their results showed that when the content of MSWIFA reached the maximum of 35%, the porosity and average pore diameter increased by 25% and 16%, respectively, compared with that without MSWIFA. All of the geopolymer composites had a similar internal structure, consisting of O-H, C-O, Si-O-Si, and Si-O-Al.

To investigate the effect of ground granulated blast-furnace slag (GGBS) on the fracture toughness of reactive powder concretes (RPC), Sreenath et al. [6] investigated the effect of the partial replacement of OPC with GGBS in non-fibrous and fibrous RPCs, on its mode I (pure opening), mode III (pure tearing), and mixed-mode I/III fracture behavior. They found that the fibrous mix with 30% OPC, replaced with GGBS, exhibited the highest values of mode I and mode III fracture toughness. This study confirmed the ability of GGBS as an SCM to improve the fracture toughness of RPC mixes.

To increase the amount of granular and powdery solid waste in rock-filled concrete (RFC), Han et al. [7] utilized iron ore tailing (IOT) and phosphogypsum (PG) separately as granular and powdery solid waste. They combined modified PG, ground blast-furnace slag (GBFS), steel slag, and cement clinker together to obtain a parathion gypsum slag cement. The artificial rockfills made of IOT and parathion gypsum slag cement are used to increase the dosage of solid waste, in order to replace the natural rocks in RFC. In their artificial rockfills, the mass fraction of granular solid waste is 83.3%, and the mass fraction of total solid waste is 99.3%.

In a study conducted by Zhang et al. [8], a hydroxypropyl methylcellulose (HPMC) was used as a new additive for porous vegetarian concrete (PVC) to improve its void structure and strength. The results show that the bonding forces between the recycled aggregates and packing layer are elevated by viscosity improvement. The viscosity and flowability are significantly related to the dosage of HPMC from 0 to 0.3‰. The harden time is also delayed while the content of HPMC increases. The segregation phenomenon caused by the recycled aggregate powder in porous concrete could also be relieved by adding HPMC. The durability of PVC in the wetting–drying cyclic test is significantly improved by incorporating HPMC.

Murali et al.'s [9] research examined the modified drop-mass impact performance on functionally graded preplaced aggregate fibrous concrete (FPAFC) against repeated low-velocity impacts. Three-layered FPAFCs were prepared with the outer layers reinforced with steel and polypropylene fibers to evaluate the impact resistance in this study. Their results revealed that the specimens comprising 3.6% steel fibers at the top layer and no fiber at the middle layer exhibited the highest percentage improvements of 633% and 2732% recorded for the cracking and failure impact number, respectively.

In Murali et al.'s other work [10] in this Special Issue, a novel composite comprising geopolymer fibrous concrete (GFC) at the tension zone and geopolymer concrete (GC) at the compression zone was developed. The results indicated that the impact strength of GFC was significantly improved in long steel fiber-based specimens. In addition, two layered specimens comprising different fibers—short polypropylene, long polypropylene, short steel, and long steel—exhibited a positive influence on impact strength. Compared to a single-layer specimen, the inferior impact strength was recorded in the two-layered specimen.

Prasad et al. [11] evaluated the performance of functionally graded preplaced aggregate fibrous concrete (FPAFC) via the low-velocity projectile impact tests. The bioinspiration of the excellent impact strength of turtle shells was used to design an FPAFC comprising a higher amount of steel and polypropylene fibers at the outer layers. Their findings indicated that regardless of fiber type and distribution, the compound bevel projectile needle produced the lowest impact numbers for all single-, double-, and triple-layer specimens compared to the convex edge and hollow edge projectiles.

In Tan et al.'s study [12], silica fume and polyvinyl alcohol fiber was compounded in concrete to improve its mechanical properties and frost resistance. The results showed that with the incorporation of silica fume and polyvinyl alcohol fiber, the compressive and flexural strengths of concrete were improved, and the decrease in mass loss rate and relative dynamic elastic modulus of concrete after freeze–thaw cycles were significantly reduced, which indicated that the compounding of silica fume and polyvinyl alcohol fiber improved the frost resistance of concrete. They also developed two models to validate their results.

In Mao et al.'s study [13], polyether modified silicone (PMS) defoamer and its compound use with mineral admixtures Portland cement and silica fume were investigated on the effectiveness in reducing expansion and improving other properties of magnesium ammonium phosphate cement (MAPC) mortar. The results showed that the compound use of PMS defoamer and Portland cement as a new defoaming formula effectively reduced the volume expansion from 7.92% to 0.91%. The compressive strength and interfacial bonding strength were significantly improved by over 34% and 60%, respectively.

In another experimental work by Mao et al. [14] in this Special Issue, the manufactured limestone sands were investigated as an alternative to quartz sands for the preparation of MAPC mortar. In this work, the limestone fines in manufactured sands were found to be the key factor that influences properties of MAPC mortar by causing bubbling and volume expansion before hardening. As a result, the mechanical strength of MAPC mortar decreased with the increasing content of limestone fines due to increased porosity. The effective defoaming methods for inhibiting bubbling was the key to the utilization of manufactured sands in preparation of MAPC mortar

The effect of sand type on the rheological properties of self-compacting mortar was studied by Yang et al. [15]. Four varieties of sand, namely quartz sand, river sand, and two kinds of manufactured sand, were selected and studied. They pointed out that, based on the particle shape–weight parameters, the rheological properties of mortars can be predicted. Based on the mortar rheological threshold theory, the self-compacting mortar (SCM) zone can be drawn.

3. Conclusions

In this Special Issue, 15 papers were collected about the investigation of durability, preparation, and microstructure of hydraulic concrete. They are state-of-the-art research, aiming at providing contributions on the topic of sustainable high-performance hydraulic concrete.

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