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Editorial

Advances in Sustainable Concrete System

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In recent years, the implementation of a sustainable concrete system has been a great topic of interest in the field of construction engineering worldwide as a result of the large and rapid increase in carbon emissions and environmental problems from traditional concrete production and industry. For example, the uses of supplementary cementitious materials, geopolymer binder, recycled aggregate and industrial/agricultural wastes in concrete are all approaches to building a sustainable concrete system. However, such materials have inherent flaws due to their variety of sources, and exhibit very different properties compared to traditional concrete. Therefore, they require specific modifications in preprocessing, design and evaluation before use in concrete. This Special Issue, entitled "Advances in Sustainable Concrete System", covers a broad range of advanced concrete research in environmentally friendly concretes, cost-effective admixtures and waste recycling, specifically including the design methods, mechanical properties, durability, microstructure, various models, hydration mechanism and practical applications of solid wastes in the concrete system.

A vast amount of research is concentrated on how to effectively use solid wastes. The utilization of recycled moso bamboo sawdust (BS) as a substitute in a new bio-based cementitious material was investigated by Tong et al. [1]. They first focused on the effect of pretreatment methods (cold water, hot water and alkaline solution) on the mechanical properties and microstructure of BS. Since the alkali-treated BS had a more favorable bonding interface in the cementitious matrix, both compressive and flexural strength were higher than those of the other two treatments. However, an increased proportion of BS (1–7%) led to a reduction in workability and strength with a more porous structure, but which still met the minimum strength requirements of masonry construction. The influence of fly ash content on the compressive strength of cemented sand and gravel (CSG) materials was evaluated by Chai et al. [2]. They found that 90 d or 180 d strength should be used as the design strength in the design of CSG dam material. There is an optimal content (50%) of fly ash in CSG materials. The effects of NaOH concentrations on the mechanical properties and microstructure of alkali-activated blast furnace ferronickel slag (BFFS) were assessed by Huang et al. [3]. Less C-A-S-H gel at a low concentration resulted in low compressive strength. A high concentration produced more hydrotalcite than C-A-S-H as intensive reaction at the early stage hindered the growth of C-A-S-H in the later stage, and decreased the Al/Si ratio and polymerization of C-A-S-H, which led to a low strength. Phosphorus slag and limestone composite (PLC) can greatly reduce the adiabatic temperature rise, chloride permeability and drying shrinkage of concrete, but do not affect the long-term strength of concrete [4]. Guan et al. [5] identified the possible problems of coal gangue as a road base via an unconfined compressive strength test, a splitting test, a freeze–thaw test and a drying shrinkage test of cement-stabilized gangue with varying cement amounts. The

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maximum dry density and optimum moisture content of the optimized cement-stabilized gangue and cement-stabilized macadam increased with the increase in cement content. A cement content of 4% is optimal for cement-stabilized coal gangue, which can be used to produce light traffic bases and heavy traffic subbases of class II below highways. The performance of concrete composites comprising waste plastic food trays (WPFTs) as low-cost fibers and palm oil fuel ash (POFA) exposed to acid and sulfate solutions was evaluated in an immersion period of 12 months by Mohammadhosseini et al. [6]. It was discovered that adding WPFT fibers and POFA to the concrete reduced its workability, but increased its long-term compressive strength. As a result of the positive interaction between POFA and WPFT fibers, both the crack formation and spalling of concrete samples exposed to acid and sulfate solutions were reduced. WPFT fibers have a significant protective effect on concrete against chemical attacks. Zhang et al. [7] investigated the influence of ultrafine metakaolin, replacing cement with a cementitious material, on the properties of concrete and mortar. Adding ultrafine metakaolin or silica fume can effectively increase the compressive strength, splitting tensile strength, resistance to chloride ion penetration and freeze–thaw properties of concrete due to the improved pore structure. The sulphate attack resistance of mortar can be improved more obviously by simultaneously adding ultrafine metakaolin and prolonging the initial moisture curing time. Guan et al. [8] investigated the influence of activator, steel slag powder, metakaolin and silica fume on the resulting strength of steel slag cement mortar through orthogonal experiments. The optimal dosages of activator, steel slag powder, metakaolin and silica fume were suggested. Awan et al. [9] evaluated the mechanical performance of untreated and treated (NaOH, lime and common detergent) crumb rubber concrete (CRC). These treatments were performed to enhance the mechanical properties of concrete that are affected by adding CR. The mechanical properties were improved after the treatment of CR. Lime treatment was found to be the best treatment. In two-stage concrete (TSC), Javed et al. [10] placed coarse aggregates in formwork, and then injected grout at a high pressure to fill up the voids between the coarse aggregates. Ten percent and twenty percent bagasse ash were used as a fractional substitution of cement, along with recycled coarse aggregate (RCA). The compressive and tensile strength of the TSC that had RCA was improved by the addition of bagasse ash. Machine learning was used to successfully predict the properties of concrete containing rice husk ash by Iqtidar et al. [11]. Input parameters include age, amount of cement, rice husk ash, super plasticizer, water and aggregates. Artificial neural networks (ANNs), the adaptive neuro-fuzzy inference system (ANFIS), multiple nonlinear regression (NLR) and linear regression were employed to evaluate the properties of concrete containing rice husk ash. The ANN and ANFIS outperformed other methods. Zhou et al. [12] carried out an experimental study of the effects of ground slag powder (GSP) on the hydration, pore structure, compressive strength and chloride ion penetrability resistance of high-strength concrete. Adding 25% GSP increases the adiabatic temperature rise of high-strength concrete, whereas adding 45% GSP decreases the initial temperature rise. Incorporating GSP refines the pore structure to the greatest extent and improves the compressive strength and chloride ion penetrability resistance of high-strength concrete. Increasing curing temperature has a more obvious impact on the pozzolanic reaction of GSP than cement hydration.

Some studies have examined mechanical properties using machine learning, numerical and constitutive models. Shen et al. [13] established machine learning-based models to accurately predict the punching shear strength of fiber-reinforced polymer (FRP)-reinforced concrete slabs. Artificial neural network, support vector machine, decision tree and adaptive boosting were selected to build models. SHapley Additive exPlanation (SHAP) was adopted to provide global and individual interpretations, and feature dependency analysis for each input variable. Nafees et al. [14] provided a new modeling approach using reactive powder concrete (RPC) beam-column joint to predict the behavior and response of structures and to improve the shear strength deformation against different structural loading. RPC in the joint region increased the overall strength by more than 10%, as well as the ductility of the structures. Zhou et al. [15] studied the energy evolution characteristics and damage constitutive relationship of siltstone. The damage constitutive equation of siltstone was developed based on the damage mechanics theory through the principle of minimum energy consumption and by considering the residual strength of rock. Bai et al. [16] investigated the mesoscopic damage mechanism of fiber-reinforced concrete (FRC) under uniaxial tension. The damage constitutive model for FRC under uniaxial tension was established to reflect the potential bearing capacity of materials. The influence of fiber content on the initiation and propagation of micro-cracks and the damage evolution of concrete was evaluated. Zhang et al. [17] examined the behavior of lattice girder composite slabs with monolithic joint under bending using a finite element model and found that lattice girder significantly increased the stiffness of the slab. Additionally, the damage of a reinforced concrete (RC) column with various levels of reinforcement corrosion under axial loads was characterized using the acoustic emission (AE) technique of Chen et al. [18]. Zhou et al. [19] performed a brittleness evaluation of high-strength concrete through a triaxial compression test of C60 and C70 high-strength concrete. With the increase in the confining pressure, the proportion of elastic energy in the whole process of high-strength concrete failure gradually decreased.

Finally, several investigations of durability concrete have been conducted. Wang et al. [20] revealed the effect of crack geometry on chloride diffusion in cracked concrete. The crack depth showed a more significant influence on the chloride penetration depth in cracked concrete than crack geometry did. Compared with rectangular and V-shaped cracks, the chloride diffusion process in cracked concrete with a tortuous crack was slower at the early immersion age, while the crack geometry had a marginal influence on the chloride penetration depth in cracked concrete during long-term immersion. Zhang et al. [21] built a moisture saturation equilibrium relationship of concrete under different temperatures and relative humidity conditions to develop moisture absorption and desorption curves. They concluded that the moisture absorption rate was lower at higher temperatures and largely dependent on the saturation gradient, while the desorption was increased at higher temperatures and mostly affected by the saturation gradient.

The present Special Issue on "Advances in Sustainable Concrete System" collects the current research progress in construction material reforming into a green and sustainable system.

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References

1. Tong, Y.; Seibou, A.-O.; Li, M.; Kaci, A.; Ye, J. Bamboo Sawdust as a Partial Replacement of Cement for the Production of Sustainable Cementitious Materials. *Crystals* **2021**, *11*, 1593. [CrossRef]
2. Chai, Q.; Wan, F.; Xiao, L.; Wu, F. The Influence of Fly Ash Content on the Compressive Strength of Cemented Sand and Gravel Material. *Crystals* **2021**, *11*, 1426. [CrossRef]
3. Huang, Z.; Zhou, Y.; Cui, Y. Effect of Different NaOH Solution Concentrations on Mechanical Properties and Microstructure of Alkali-Activated Blast Furnace Ferronickel Slag. *Crystals* **2021**, *11*, 1301. [CrossRef]
4. Liu, K.; Cui, Y. Effects of Different Content of Phosphorus Slag Composite Concrete: Heat Evolution, Sulphate-Corrosion Resistance and Volume Deformation. *Crystals* **2021**, *11*, 1293. [CrossRef]
5. Guan, J.; Lu, M.; Yao, X.; Wang, Q.; Wang, D.; Yang, B.; Liu, H. An Experimental Study of the Road Performance of Cement Stabilized Coal Gangue. *Crystals* **2021**, *11*, 993. [CrossRef]
6. Mohammadhosseini, H.; Alyousef, R.; Poi Ngian, S.; Tahir, M.M. Performance Evaluation of Sustainable Concrete Comprising Waste Polypropylene Food Tray Fibers and Palm Oil Fuel Ash Exposed to Sulfate and Acid Attacks. *Crystals* **2021**, *11*, 966. [CrossRef]

7. Zhang, S.; Zhou, Y.; Sun, J.; Han, F. Effect of Ultrafine Metakaolin on the Properties of Mortar and Concrete. *Crystals* **2021**, *11*, 665. [CrossRef]
8. Guan, J.; Zhang, Y.; Yao, X.; Li, L.; Zhang, L.; Yi, J. Experimental Study on the Effect of Compound Activator on the Mechanical Properties of Steel Slag Cement Mortar. *Crystals* **2021**, *11*, 658. [CrossRef]
9. Awan, H.H.; Javed, M.F.; Yousaf, A.; Aslam, F.; Alabduljabbar, H.; Mosavi, A. Experimental Evaluation of Untreated and Pretreated Crumb Rubber Used in Concrete. *Crystals* **2021**, *11*, 558. [CrossRef]
10. Javed, M.F.; Durrani, A.A.; Kashif Ur Rehman, S.; Aslam, F.; Alabduljabbar, H.; Mosavi, A. Effect of Recycled Coarse Aggregate and Bagasse Ash on Two-Stage Concrete. *Crystals* **2021**, *11*, 556. [CrossRef]
11. Iqtidar, A.; Bahadur Khan, N.; Kashif-ur-Rehman, S.; Faisal Javed, M.; Aslam, F.; Alyousef, R.; Alabduljabbar, H.; Mosavi, A. Prediction of Compressive Strength of Rice Husk Ash Concrete through Different Machine Learning Processes. *Crystals* **2021**, *11*, 352. [CrossRef]
12. Zhou, Y.; Sun, J.; Zhang, Z. Effects of High-Volume Ground Slag Powder on the Properties of High-Strength Concrete under Different Curing Conditions. *Crystals* **2021**, *11*, 348. [CrossRef]
13. Shen, Y.; Sun, J.; Liang, S. Interpretable Machine Learning Models for Punching Shear Strength Estimation of FRP Reinforced Concrete Slabs. *Crystals* **2022**, *12*, 259. [CrossRef]
14. Nafees, A.; Javed, M.F.; Musarat, M.A.; Ali, M.; Aslam, F.; Vatin, N.I. FE Modelling and Analysis of Beam Column Joint Using Reactive Powder Concrete. *Crystals* **2021**, *11*, 1372. [CrossRef]
15. Zhou, R.; Guo, L.; Hong, R. Study on Energy Evolution and Damage Constitutive Model of Siltstone. *Crystals* **2021**, *11*, 1271. [CrossRef]
16. Bai, W.; Lu, X.; Guan, J.; Huang, S.; Yuan, C.; Xu, C. Stress–Strain Behavior of FRC in Uniaxial Tension Based on Mesoscopic Damage Model. *Crystals* **2021**, *11*, 689. [CrossRef]
17. Zhang, X.; Li, H.; Liang, S.; Zhang, H. Experimental and Numerical Study of Lattice Girder Composite Slabs with Monolithic Joint. *Crystals* **2021**, *11*, 219. [CrossRef]
18. Chen, Y.; Zhu, S.; Ye, S.; Ling, Y.; Wu, D.; Zhang, G.; Du, N.; Jin, X.; Fu, C. Acoustic Emission Study on the Damage Evolution of a Corroded Reinforced Concrete Column under Axial Loads. *Crystals* **2021**, *11*, 67. [CrossRef]
19. Zhou, R.; Cheng, H.; Li, M.; Zhang, L.; Hong, R. Energy Evolution Analysis and Brittleness Evaluation of High-Strength Concrete Considering the Whole Failure Process. *Crystals* **2020**, *10*, 1099. [CrossRef]
20. Wang, Q.; Zhang, G.; Tong, Y.; Gu, C. A Numerical Study on Chloride Diffusion in Cracked Concrete. *Crystals* **2021**, *11*, 742. [CrossRef]
21. Zhang, Q.; Kang, Z.; Ling, Y.; Chen, H.; Li, K. Influence of Temperature on the Moisture Transport in Concrete. *Crystals* **2021**, *11*, 8. [CrossRef]