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Editorial

FRP for Infrastructure Applications: Research Advances

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Driven by the incentive to break the infrastructure corrosion cycle, fiber reinforced polymers (FRP) composites were introduced as potential materials to produce corrosion-free infrastructure [1]. FRP were also sought to create a new generation of smart infrastructure where performance monitoring can be integrated in structural design and construction [2]. The widespread production of synthetic fibers, including glass fibers, carbon fibers and Kevlar fibers, enabled the creation of FRP composites with much improved mechanical and durability performances for infrastructure applications compared with classical construction [3]. Research and development over the past 40 years has addressed practical challenges for enabling the use of FRP materials in infrastructure applications [4]. In this Special Issue of *Fibers*, nine publications are dedicated to reporting progress in research examining the use of FRP in infrastructure applications. The reported papers can be classified into four categories addressing: innovative structural systems using FRP, improving energy dissipation in infrastructure using FRP, methods for computational simulation of structural elements using FRP and finally new FRP materials synergies for infrastructure applications.

The first group of papers in the Special Issue reported innovative FRP structural systems. Rasheed et al. [5] investigated failure modes and flexural capacity in concrete T and rectangular beams with transverse U-wrapped carbon fiber reinforced polymer (CFRP) anchorage in addition to externally bonded sheets of flexural CFRP. Results showed that this combination shifted the failure mode from the original debonding to flexural failure and, thus, provided higher flexural capacity by delaying delamination and debonding in the flexural CFRP sheets and by providing anchorage through shear friction. Moreover, Al-Rahmani and Rasheed [6] proposed covering rectangular concrete columns with FRP wrap. The authors showed that the pairing of FRP confinement with steel ties confinement required nonlinear analysis for the determination of axial capacities. A parametric study was performed which showed that the dual confinement system increased the axial capacity by 21% and 11% compared to the steel-only and FRP-only columns, respectively.

The second group of articles examined the possible use of FRP to improve energy dissipation in infrastructure application. Dezfuli and Alam [7] studied the response of 1/4-scale carbon fiber reinforced elastomeric isolators (FREIs) exposed to cyclic loading. Results showed that lateral flexibility and damping capacity were both increased by decreasing the cyclic loading rate, while vertical pressure had no effect on the lateral response of the system. The equivalent damping ratio increased from 9.1 to 13.2% when the rubber thickness doubled from 12 mm to 24 mm. By doubling the amount of rubber layers from 8 to 16, a decrease of 60% was observed in the effective horizontal stiffness and an increase of 22% was observed in the equivalent viscous damping at 100% shear-strain amplitude. Furthermore, Kabir et al. [8] investigated the effect of coupling shape memory alloy (SMA) with FRP or steel reinforcement in the plastic hinge region located in beam-column joints on energy dissipation capacity and load-story drift for seismic resistance. The addition of SMA was shown to reduce residual deformation and provide reasonable energy dissipation capacity during extreme loading. SMA also contributed the dual benefits of having high corrosion resistance and allowing the structure to regain its original shape following large deformations.

The third group of articles examined computational simulation using the finite element (FE) method of FRP. Abdelkarim and ElGawady [9] investigated the axial compressive load of concrete-filled fiber tube (CFFT) polymers, wherein the tubes were designed for large rupture strains using recycled materials (resulting in polyethylene naphthalate and polyethylene terephthalate). LS-DYNA was used to perform a parametric study incorporating finite element analysis. The results showed that the CFFT polymers provided high strength and high ultimate strain capacity under axial compressive loading. Finally, Gouda and El-Salakawy [10] simulated the punching shear behavior of interior slab-column connections incorporating glass fiber reinforcement polymer (GFRP) reinforcement bars using finite element (FE) methods. A parametric study was conducted using the FE model and showed that increasing the perimeter-to-depth ratio, reinforcement ratio, and column aspect ratio, decreased reinforcement strain and deflections and increased ultimate capacity. By enlarging the reinforcement ratio from 0.15 to 1.2%, the slab shear strength increased by 93%. By increasing the perimeter-to-depth ratio by 33% and 65%, the punching shear stresses at failure lessened by 25% and 34%, respectively. Additionally, the punching strength was increased by 95% as a result of expanding the column aspect ratio from one to five.

In the fourth group of papers investigating new FRP materials synergies, Alberti et al. [11] studied the ability of polyolefin fiber reinforced concrete (PFRC) to improve residual strength following small deformations through a combined use of long, macro-synthetic polyolefin fibers and short, steel-hooked fibers. This combination maintained high-performance properties and reliable fracture behavior and increased the fracture energy of plain concrete 38 times. Additionally, PFRC displayed an increased tensile strength, toughness, and ductility. From another perspective, Ghazy et al. [12] examined the use of nano-silica particles in nano-modified fiber-reinforced cementitious composites/mortars (NFRM) to improve mechanical and durability properties of cement-bases systems for the repair of concrete structures. Toughness, flexural and compressive strengths, resistance to salt-frost scaling, penetrability, and drying shrinkage were investigated for different fiber types (including polypropylene, basalt, and steel). The results revealed that the use of nano-silica improved the compressive strength of beams, the flexural strength at 14 days, toughness, and the resistance to salt-frost scaling in NFRM. The use of nano-silica showed up to 10% higher flexural strength at 14 days compared with control beams. Furthermore, the addition of 2% nano-silica increased toughness by up to 53% compared with control specimens. On the other hand, Jabr et al. [13] studied the effect of a fiber-/fabric-reinforced cementitious matrix (FRCM), consisting of a fiber mesh or grid encased in a cementitious bonding material, on the flexural strength of steel-reinforced concrete beams. The results showed that FRCM strengthened with polybenzoxazole (PBO) fibers significantly increased the ultimate capacity of the beams compared to glass and carbon FRCM. Increases in ultimate capacity of 33% and 25% were observed for beams with low and moderate steel reinforcement ratios, respectively, when compared to an un-strengthened beam. Post-crack and post-yielding stiffnesses were increased, and the axial stiffness ratio decreased with the use of PBO in FRCM.

In summary, this Special Issue provides significant insight into recent advances on using FRP in infrastructure applications showing the promise of new materials and structural systems and significant improvement in computational methods. The Special Issue also informs the reader about a new class of applications where FRP are used for energy dissipation in infrastructure. This is of great importance for infrastructure subjected to earthquakes. The Special Issue also alludes to the need for research on efficient computational methods that can help to realize the potential benefits of FRP materials in next generation of smart infrastructure.

Conflicts of Interest: The author declares no conflict of interest.

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