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Editorial: Multi-Scale Investigation on Fiber-Reinforced Composite Materials: From Structural Design, Property Characterization to Engineering Applications

Lik-ho Tam[1], *Chao Wu*[1], *Libo Yan*[2,3] and *Denvid Lau*[4]*

[1]*School of Transportation Science and Engineering, Beihang University, Beijing, China,* [2]*Department of Organic and Wood-Based Construction Materials, Technische Universität Braunschweig, Braunschweig, Germany,* [3]*Centre for Light and Environmentally-Friendly Structures, Fraunhofer Wilhelm-Klauditz-Institut WKI, Braunschweig, Germany,* [4]*Department of Architecture and Civil Engineering, City University of Hong Kong, Hong Kong SAR, China*

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Editorial on the Research Topic

Multi-Scale Investigation on Fiber-Reinforced Composite Materials: From Structural Design, Property Characterization to Engineering Applications

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John L. Provis,
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***Correspondence:**
Denvid Lau
denvid.lau@cityu.edu.hk

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With rapid development of society and economics, frequent population flow and transportation activities have increased the demand for improving load capacity and resilience of building construction and civil infrastructures. Compared with traditional building materials, fiber-reinforced composite (FRC) materials possess outstanding properties including light weight, high stiffness and strength, and excellent fatigue resistance. Consequently, FRC materials, such as fiber-reinforced polymer (FRP) and ultra-high performance concrete (UHPC), have emerged as viable candidates for load-bearing components of new constructions and strengthening components of existing structures (as shown in **Figure 1**). The FRCs with outstanding properties are largely due to multi-scale structures that range from macroscopic constituents including fiber, matrix, and fiber/matrix interface, to their molecular structures. Using the integration of disparate techniques that include experimental tests, theoretical calculations, and molecular simulations, it enables multi-scale investigation on FRC materials. The revealed relationship between structures and properties of FRCs at different length scales could advance the optimal design of FRCs and facilitate engineering applications. The Research Topic is recently organized to collect scientific advances in multi-scale structural design, property characterization, and engineering applications of FRC materials, which includes eight articles.

For FRCs in structural applications, pultruded glass FRP (GFRP) profiles have been increasingly used. Using combined approaches of macroscopic test, microstructure analysis, and numerical simulation, Gribniak et al. showed that GFRP profiles possessed increasing flexural stiffness and ultimate load with higher contents of glass fiber with reduced diameter, as such glass fiber had smaller number of interactional defects in contact zones between fiber and matrix, which ensured the bond performance of fiber/matrix interface, and optimized the reinforcement efficiency of glass fiber. Meanwhile, FRP composites have been widely used for strengthening building structures. Liu et al. reported that for concrete-filled GFRP tubes, the strength of ultra-early strength concrete with zero curing time increased rapidly in a short period, and both GFRP tube and core concrete were compressed efficiently during loading process, which possessed higher compressive bearing capacity

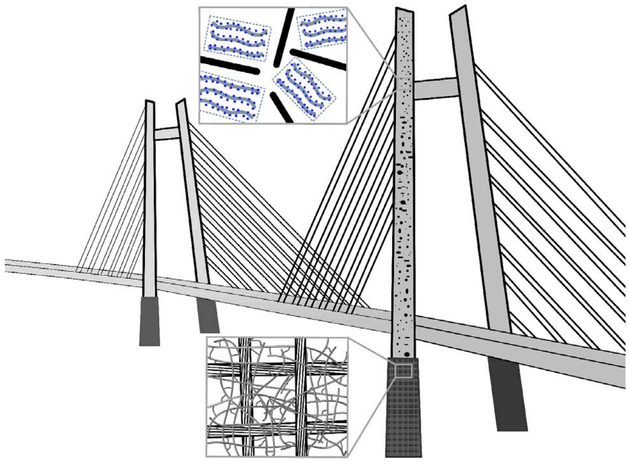

FIGURE 1 | Applications of fiber-reinforced composite materials in bridge.

compared with specimens consisting of normal concrete after 5-h curing. In another investigation on carbon FRP (CFRP)-reinforced glued-laminated beams, He et al. showed that reinforced beams possessed enhanced maximum deflection and bending-resisting capacity by using CFRP sheets with high strengthening ratio and stiffness, as such CFRP sheets mitigated brittle damage of preliminary crack, which changed failure mode from brittle tensile failure of unreinforced beams to ductile compressive failure, and by arranging CFRP sheets close to beam bottom, where CFRP sheets deformed obviously under loading.

Apart from FRP composites, UHPC has been increasingly used in structures with requirements of good mechanical properties and durability. Wang et al. showed that in first 30 days of rehydration of unhydrated cementitious components, there was sufficient space in UHPC to accommodate newly-rehydrated products, which increased splitting tensile strength by filling UHPC with denser structure. In subsequent rehydration up to 90 days, there was insufficient space due to expanding volume of rehydration products, which generated expansion stress and degraded the UHPC strength. Using a mesoscopic FE approach, Yu et al. determined that by distributing more fibers with length direction distributed close to the tensile direction or with inclination angle in range of 15°–30°, fibers could bear more stress under loading, which significantly improved tensile strength of UHPC. Apart from the fiber, the aggregate also affects properties of cementitious composites. Ma and Gao showed that the crushing rate increased and then decreased with increasing moisture content, which continuously decreased with increasing aggregate ratio and dry-wet cycles. Meanwhile, an exceeded leaching amount of Cr was observed in aggregates obtained from railway, which suggested that the source of recycled aggregates should be carefully investigated before using in cementitious composites.

With increasing applications of FRCs, there is an increasing awareness of composite degradation related to debonding between fiber and matrix. Carbon nanotube (CNT) is regarded as a promising reinforcing filler that could improve the adhesion between fiber and matrix. Using molecular simulation, Song et al. vertically aligned SWCNTs on silica surface representing glass fiber outer-layer, and found that the structural failure transited from epoxy/silica interface in uncoated system to silica/SWCNT interface, as SWCNTs led to improved pulling displacement between silica and epoxy, and provided bridging between silica and epoxy. Meanwhile, CNT is also applied to improve properties of fiber/matrix interface in cementitious composite. Cui et al. reviewed recent advances of CNTs' applications in cementitious composites, including preparation and characterization, functionalization applications, and dispersion technology of CNTs used in cementitious composites. It is reviewed that the added CNTs bridge and fill the constituents in cement matrix, which leads to nucleation, optimized pore of matrix with denser structure, and improved nano-cracks bridging, contributing to improved properties of cementitious composites. However, by adding a large amount of CNTs, it results in CNT agglomeration and poor CNT dispersion in cement matrix, which increases structural porosity and degrades the composite mechanical properties.

The contributions in this Research Topic provide a comprehensive reference for multi-scale structural design, property characterization, and engineering applications, which could inspire the development of advanced and durable FRCs in building construction and civil infrastructures. Our editorial team members are grateful to all the authors for their efforts in this Research Topic and also to the reviewers for their rigorous and professional support of this Research Topic.

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