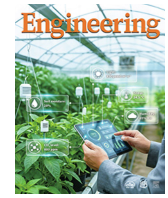
ARTICLE IN PRESS

Engineering xxx (xxxx) xxx

Contents lists available at ScienceDirect

Engineering

journal homepage: www.elsevier.com/locate/eng

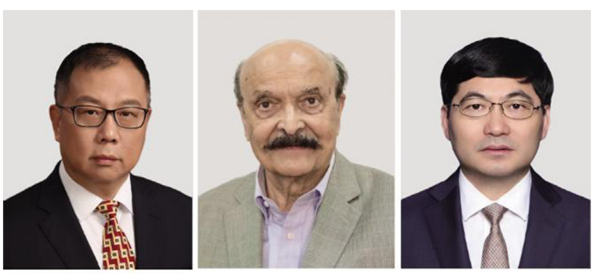


Editorial

Editorial for the Special Issue on Sustainable and High-Performance Structural Materials

Qingrui Yue [a], Surendra P. Shah [b], Jiaping Liu [c]

[a] School of Future Cities, University of Science and Technology Beijing, Beijing 100083, China
[b] McCormick School of Engineering, Northwestern University, IL 60208, USA
[c] School of Materials Science and Engineering, Southeast University, Nanjing 210089, China



Qingrui Yue Surendra P. Shah Jiaping Liu

Cement-based materials and fiber-reinforced polymer (FRP) composites are fundamental material families in modern construction. As structural materials, both occupy important positions in terms of global production volume, economic contribution, and carbon footprint. Cement-based materials are the most widely manufactured materials on Earth, with approximately 40 billion tonnes of cement produced annually, accounting for 7%–8% of global carbon dioxide (CO_2) emissions. On the other hand, owing to unique advantages including high specific strength, excellent corrosion resistance, and design flexibility, FRP composites are garnering widespread attention in civil engineering applications. Both materials are being significantly advanced in terms of sustainability and high performance through cutting-edge studies. The key directions of recent research in this field involve simultaneously reducing embodied carbon, extending structural life, and enabling hybrid systems.

Source reduction, process reduction, and end-use carbon sequestration comprise the core three-tiered strategy for achieving sustainable cement-based materials. Regarding source reduction, the focus is on replacing high-carbon Portland cement clinker with aluminosilicate-rich natural resources and industrial solid wastes. In this special issue, Zunino et al. attempt to improve the early-age strength of limestone calcined clay cements (LC^3), a promising low-carbon binder system, to overcome issues with initial performance. Toward process reduction, the goal is to enhance materials' long-term durability and service life. In this issue, Feng and Zhou present a multiscale fiber strategy that allows the production of ultra-high-performance concrete (UHPC) with both high toughness and deformability. Moreover, Zhao and Cyr incorporate nano-silica aerogel into lightweight insulating concrete. Concerning end-use carbon sequestration, the key is to enable cement-based materials to actively absorb and sequester CO_2. In a study by Choi et al., the researchers not only improve the mechanical performance but also increase the CO_2 uptake capacity of the cement-based material. Multiscale modeling can provide support for understanding the mechanisms of cement-based materials. In this issue, Fame and Ueda establish atomic models to investigate the adsorption behavior of nanofillers on C–S–H and their stability in marine environments, while Zhou and Li employ discrete mesoscale models to simulate the mechanical response of fiber-reinforced composites. Overall, this direction for cement-based materials progresses from macro-performance to micro-mechanisms, from strength to multifunctional synergy, and from ordinary cement-based materials to parallel advances in ultra-high-performance and low-carbon systems.

Research on FRP composites spans pultruded profiles, bars, retrofitted structures, functional applications, and durability modeling, emphasizing both structural performance and smart functionality. At the component level, Dias et al. show that reliability-based code calibration for pultruded glass-fiber-reinforced polymer (GFRP) beams under web-crippling marks a shift from lab-scale experiments to design standards. Attention is also given to FRP bar durability, as Hao et al. predict the moisture uptake in GFRP bars for long-term assessment using a dual-phase model. In the area of FRP–concrete synergy, Zhang and Lin establish a stress–strain model for FRP-confined UHPC. Moreover, J-H Kim and YJ Kim design carbon-fiber-reinforced polymer (CFRP)/UHPC-strengthened beams thermocyclic distress that reveal a performance evolution under coupled actions. In a study by Zhang et al., ductility is imparted via compression-zone confinement to address brittle failure, and a damage-plasticity model is introduced for confined concrete. Zhou and Feng report on their construction of smart steel–FRP bars, which can monitor cracking and self-evaluate their properties. In summary, FRP materials are transitioning

https://doi.org/10.1016/j.eng.2026.05.006
2095-8099/

from passive reinforcement to active smart sensors, being synergized with UHPC, and being integrated into reliability and durability frameworks.

Looking ahead, sustainable cement-based materials and FRP composites will deeply converge toward full-life-cycle low-carbon composites, combining renewable or bio-based matrices with recyclable or biodegradable FRPs. At the structural level, reliability-based design methods will uniformly incorporate the variability of green cement-based materials and the durability degradation of FRP. At the functional level, self-sensing, self-healing, and cathodic protection will be integrated into unified composite systems. Ultimately, sustainability and high performance will no longer be a trade-off but will be reconciled through synergistic cross-structural material design.

This special issue aims to clarify research directions and solution strategies for structural materials, inspiring further advances toward greener, more efficient, and resilient structural materials. We sincerely thank all the authors for contributing their outstanding work to this special issue on sustainable and high-performance structural materials. Our gratitude also goes to the dedicated reviewers and the editorial team for their rigorous and timely efforts.