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John L. Provis,
Paul Scherrer Institut (PSI), Switzerland

*CORRESPONDENCE
Ling-Yu Xu,
ling-yu.xu@connect.polyu.hk

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Editorial: High-performance and sustainable concrete materials and structures

Bo-Tao Huang[1,2], Zhi-Liang Zhang[1], Behzad Nematollahi[3], Jing Yu[4], Jian-Guo Dai[5] and Ling-Yu Xu[1,2]*

[1]Institute of Advanced Engineering Structures, Zhejiang University, Hangzhou, China, [2]Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Kowloon, Hong Kong SAR, China, [3]School of Mechanical, Aerospace and Civil Engineering, The University of Sheffield, Sheffield, United Kingdom, [4]Department of Civil Engineering, The University of Hong Kong, Pokfulam, Hong Kong SAR, China, [5]Department of Architecture and Civil Engineering, City University of Hong Kong, Kowloon, Hong Kong SAR, China

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Editorial on the Research Topic
High-performance and sustainable concrete materials and structures

In recent years, the research field of concrete technology has witnessed remarkable strides, characterized by two primary vectors of evolution: the relentless pursuit of superior mechanical performances and the burgeoning emphasis on sustainability (Li, 2019). The quest for enhanced mechanical properties of concrete is paramount for bolstering the structural integrity and safety profiles of modern constructions, amidst the backdrop of evolving engineering paradigms and the burgeoning demand for resilient infrastructures capable of withstanding extreme environmental and loading conditions (Gong et al., 2023; Yu et al., 2024).

Concurrently, the relentless march of industrialization has resulted in a considerable trail of waste and by-products, often destined for landfills, thereby exacerbating air pollution and augmenting carbon emissions. Therefore, the development of sustainable concrete materials and structures has emerged as a pivotal solution to mitigate environmental burdens and advance towards carbon neutrality. This paradigm shift not only aligns with the global imperative to counteract climate change but also opens up promising avenues for the innovative value-added utilization of waste materials.

Nevertheless, the path towards high-performance concrete materials is often fraught with challenges, notably the elevated material costs and carbon emissions associated with their production, which pose barriers to their widespread application in structural engineering. To surmount these hurdles, researchers have focused on the research field of industrial, urban, and agricultural residuals or by-products, exploring their potential as partial substitutes for key concrete components, including cementitious binders, aggregates, and fiber reinforcements (Xiang et al., 2023; Merli et al., 2020). By integrating wastes, it is conceivable to trim both the cost and carbon footprint of high-performance concrete, while fostering the principles of a circular economy.

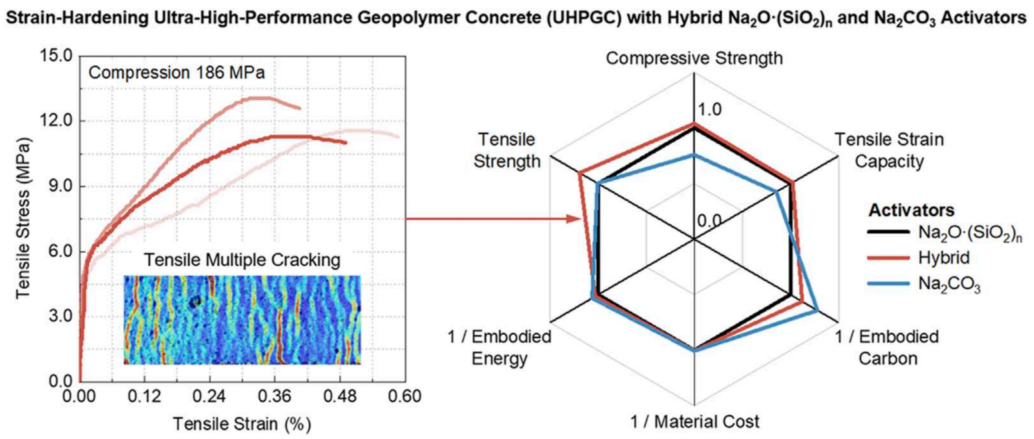

FIGURE 1
Low-carbon strain-hardening Ultra-High-Performance Geopolymer Concrete (UHPGC) using hybrid alkaline activators showed better overall performance compared to the counterparts using sodium carbonate or sodium silicate activators.

However, despite these promising avenues, numerous studies have flagged the potential compromise in mechanical and durability properties of waste-based concretes (Guo et al., 2018; Paul et al., 2018; Xiao et al., 2012), attributed to the inferior mechanical traits or chemical reactivity of the incorporated waste materials. To bridge this gap, ongoing research endeavors are focusing on the design and formulation of high-performance, eco-friendly concrete materials that harmonize advanced mechanical properties with environmental sustainability. This endeavor entails a multi-disciplinary symphony of materials science, engineering, and environmental science, collectively orchestrating innovative solutions for resilient and sustainable infrastructures.

This editorial summarizes the contributions to the Research Topic "*High-Performance and Sustainable Concrete Materials and Structures*", where a total of six articles were published in this Research Topic.

The first article was published by Sun et al., where the structural damage of the steel-Engineered Cementitious Composite (ECC) deck was identified by piezoelectric lead-zirconate-titanate transducers using both experimental tests and numerical simulation. The feasibility of the proposed the impedance-based technology was proved to be effective in structural damage monitoring, which is believed to be meaningful in the research field of structural health monitoring of concrete structures.

Nagaraju et al. produced sustainable geopolymer concrete using rice husk ash, ground granulated blast furnace slag, and silica fume. Artificial neural networks, multi-linear regression analysis, and swarm-assisted linear regression were adopted for the establishment of compressive strength models, on the basis of datasets with different precursors, alkali-activator percentages, Si/Al ratios, and Na/Al ratios. The machine learning method was found effective in designing and assessing the strength characteristics, material costs and sustainability of geopolymer concrete made from agricultural biomass.

Lao et al. successfully developed a low-carbon Ultra-High-Performance Geopolymer Concrete (UHPGC) with a compressive strength over 180 MPa together with a strain-hardening ability using hybrid sodium carbonate and sodium silicate as alkaline activators (see Figure 1). This contribution demonstrated the feasibility of maintaining the balance between mechanical performances and material greenness of UHPGC through the proper mix proportion design, which could facilitate the future promotion of UHPGC materials with combined excellent mechanical performances and material greenness.

Wang et al. investigated the cyclic axial compressive behavior of Fiber-Reinforced Polymers (FRP)-concrete-steel hybrid double-skin tubular columns. The loading scheme insensitivity of the axial stress-strain envelope curve was demonstrated, and the ultimate states of the square columns were similar under cyclic and monotonic axial compression. The diameter-thickness ratio of the inner steel tube was further found to have distinguished impact on the peak load of the columns under cyclic axial compression.

Feng et al. conducted a comprehensive review on the multi-scale grading utilization of recycled aggregates (RA) [i.e., fine powder aggregates, fine aggregates, and coarse aggregates]. The review work stressed the importance of adhesive mortar contents on the performances of recycled aggregate concrete (RAC). The strengthening treatment methods of RA with different particle sizes were further summarized, and the most suitable strengthening treatment was highlighted.

Zhang et al. adopted Ultra-High-Performance Concrete (UHPC) to strengthen masonry structures, with the mechanical performances under axial and eccentric loading comprehensively investigated. In their study, UHPC jacketing was found highly effective for masonry columns strengthening, with the load-carrying capacity and transverse deformability of eccentrically compressed masonry columns improved by up to 103.64% and 71.43%, respectively. The research work is helpful for promoting the future practical application of masonry structures strengthened with UHPC.

Overall, this Research Topic collected articles from sustainable material design to advanced structural applications. The future work in high-performance and sustainable concrete materials and structures could focus on the following aspects: 1) Pushing the performance envelope of high/ultra-high-performance concrete materials towards extreme mechanical and durability performance

(Lao et al., 2023); 2) Designing sustainable concrete materials to achieve excellent mechanical performance, sustainability, and cost efficiency simultaneously (Xu et al., 2023); 3) Recycling and upcycling industrial/urban/agricultural wastes/by-products and alternative natural resources in concrete materials and structures (Li et al., 2024); 4) Developing functional concrete materials and structures for different application requirements (Ran et al., 2024; Jiang et al., 2024); 5) Advancing innovative construction technologies for modern concrete structures (e.g., additive manufacturing and prefabricated/modular-integrated construction) (Buswell et al., 2018); and 6) Exploring effective structural application strategies for high-performance, sustainable, and functional concrete materials (Shen et al., 2024; Senatore and Wang, 2024). All these efforts will contribute to building more resilient, sustainable, and smarter civil infrastructure systems to address the significant challenges of climate change and natural disasters in the future.

Author contributions

B-TH: Writing–review and editing, Funding acquisition, Conceptualization. Z-LZ: Writing–original draft. BN: Writing–review and editing. JY: Writing–review and editing. J-GD: Writing–review and editing, Supervision, Funding acquisition. L-YX: Writing–review and editing, Methodology, Conceptualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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