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Editorial: Nano science and technology in concrete composites

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Editorial on the Research Topic
Nano Science and Technology in Concrete Composites

Concrete, the cornerstone of modern infrastructure, faces pressing challenges in sustainability, durability, and environmental impact. The integration of nano science and technology into concrete composites has emerged as a transformative approach to address these challenges. This Research Topic compiles pioneering research that leverages nanotechnology to reimagine traditional concrete systems, offering novel solutions for enhanced performance, resource efficiency, and circularity.

A key theme in this topic is the development of eco-friendly binders that reduce reliance on carbon-intensive cement. The work by Huang et al. demonstrated the successful incorporation of emulsified waste cooking oil (EWCO) into alkali-activated slag concrete (AASC). By replacing conventional binders with industrial byproducts like slag and repurposing waste oil, this study achieves a dual environmental benefit: reducing landfill waste and lowering the carbon footprint of concrete production. The addition of EWCO not only mitigates shrinkage but also enhances resistance to carbonation and sulfuric acid attack. Similarly, Deng et al. explored the use of ultrafine tailings as sustainable backfill materials. By optimizing particle gradation and binder content, their work illustrates how nanoscale adjustments to material composition can improve mechanical strength and reduce reliance on virgin resources. These findings emphasize the potential of nanotechnology to unlock the value of industrial byproducts in construction.

The quest for resilient infrastructure drives research into self-healing concrete. Buegger et al. investigated polyvinyl alcohol (PVA) fiber-reinforced composites, evaluating their capacity to recover stiffness and resist chloride penetration after cracking. Their results reveal that 14–28 days of self-healing reduce chloride ingress by 81%–99%, with hydration products filling microcracks at the nanoscale. This work bridges macroscopic durability metrics (e.g., permeability) with nanoscale healing mechanisms, offering a blueprint for designing concrete that autonomously repairs damage—a critical advancement for extending service life in aggressive environments.

The integration of phase change materials (PCMs) into concrete for energy-efficient buildings is another Frontier explored in this Research Topic. Przybek et al. characterized diatomite as a carrier for paraffin-based PCMs, emphasizing its nanoporous structure for high thermal energy storage. Diatomite's low density, high porosity, and chemical inertness enable efficient encapsulation of PCMs, while its natural origin aligns with sustainability goals. This study exemplifies how nanotechnology can optimize thermal performance in building materials, reducing energy consumption through passive temperature regulation.

At the molecular level, Fang et al. investigated EPEG-based polycarboxylate superplasticizers (PCEs), demonstrating how side-chain density, polymerization degree, and molecular conformation influence cement hydration and rheology. By tailoring PCEs to enhance adsorption kinetics and reduce viscosity, their work reveals how nanoscale polymer design can optimize fresh and hardened concrete properties. Such advancements are critical for achieving high-performance concrete with reduced water and cement content.

The contributions herein span diverse domains—from waste valorization and self-healing mechanisms to nanoscale material design—and collectively highlight the potential of nanotechnology to revolutionize concrete engineering. By bridging fundamental research with practical applications, these contributions pave the way for a new era of nano-engineered concrete—one that harmonizes performance, planetary health, and circular economy principles.

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