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Construction Materials

Editorial: Engineered for sustainability: multi-material strategies in construction

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As environmental pressures intensify and the demand for urban infrastructure accelerates, the construction industry is re-evaluating its material choices. With cities expanding both upward and outward across the globe, the foundational materials of construction must evolve. The challenge is to balance structural performance with sustainability – an imperative that is becoming both a technological and ethical priority.

Construction remains one of the most resource- and emission-intensive sectors, contributing up to 40% of global carbon dioxide emissions (UNEP, 2020). Traditional materials such as cement, asphalt, and steel are integral to modern infrastructure, yet their environmental impacts are now under increasing scrutiny. This has triggered a shift towards more sustainable practices – ones that blend material innovation with environmental responsibility. Central to this transformation is the use of recycled and waste-derived materials. For example, concrete formulations incorporating waste concrete powder or copper slag are proving effective in reducing clinker demand while enhancing strength (Murari *et al.*, 2015; Pushpakumara *et al.*, 2025; Njenga *et al.*, 2025). Similarly, geopolymer concretes – particularly those using ground granulated blast furnace slag – offer a promising low-carbon alternative by repurposing industrial by-products into durable, low-emission binders (Zhang *et al.*, 2025).

One noteworthy advancement is the incorporation of phase change materials into foamed concrete. These composites provide valuable thermal regulation, improving energy efficiency in buildings. At the same time, they align with circular economy principles by repurposing materials that would otherwise be discarded (Tajadod *et al.*, 2025). Such innovations mark a shift from single-function materials to multifunctional composites engineered for durability, energy savings, and longevity.

Mechanical innovation is also driving progress, particularly through the development of ultra-high-performance concrete (UHPC) reinforced with hybrid fibre systems. By integrating steel, basalt, and synthetic fibres, these composites significantly enhance tensile strength, fracture resistance, and overall durability – making them ideal for long-term infrastructure with minimal maintenance needs (Dziomdziora *et al.*, 2025).

In the realm of road construction, the ideal-rutting test is being used to evaluate the rutting and deformation resistance of asphalt mixtures. When paired with environmentally modified binders, these methods can lead to longer-lasting pavements designed to meet measurable performance criteria (Ahmed *et al.*, 2025).

Despite these advances, several hurdles remain. Material compatibility, lack of standardised guidelines, and high implementation costs continue to limit widespread adoption. Many sustainable technologies remain confined to research settings, highlighting the urgent need for stronger collaboration between researchers, industry stakeholders, and policymakers. Regulatory frameworks must also evolve to accommodate new materials while upholding safety, durability, and cost-effectiveness.

The ICE Construction Materials community sits at the intersection of innovation and application. The research featured in this issue – from waste-derived concretes to fibre-reinforced UHPC and resilient asphalt mixtures – demonstrates the transformative potential of integrated material strategies. Together, these contributions point towards a construction future that is not only stronger but also more circular, efficient, and resilient.

Ultimately, engineering for sustainability must become the rule, not the exception. Achieving this goal requires more than developing innovative materials – it demands their integration into planning processes, procurement models, and regulatory policies. As the world faces mounting environmental and societal challenges, the call for responsible innovation grows louder. We urge engineers,

researchers, and planners to continue advancing sustainable materials – not just to build better infrastructure, but to help shape a more sustainable future.

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