Materials Science

AIMS Materials Science, 12(5): 1065–1068.
DOI: 10.3934/matersci.2025049
Received: 31 October 2025
Revised: 02 November 2025
Accepted: 03 November 2025
Published: 04 November 2025

https://www.aimspress.com/journal/Materials

Editorial

Special issue: Smart materials in civil structures

Maged A. Youssef

Civil and Environmental Engineering, Western University, London, Ontario, Canada

* **Correspondence:** Email: youssef@uwo.ca.

1. Introduction and scope

The pursuit of resilient, durable, and sustainable infrastructure has placed civil engineering at the forefront of material innovation. Over the past two decades, smart materials have transitioned from theoretical constructs to practical solutions capable of sensing, responding, and adapting to changing environmental or loading conditions. These advances have redefined how civil structures are conceived, monitored, and maintained—leading to safer, more efficient, and longer-lasting infrastructure systems.

The special issue on Smart Materials in Civil Structures was created to highlight the latest developments in the design, characterization, and application of smart materials in civil engineering. The issue emphasizes integrating sensing and actuation technologies into traditional materials, using adaptive and self-healing systems, and coupling smart materials with digital and data-driven frameworks for structural health monitoring and performance optimization.

2. Overview of the special issue

This special issue presents 10 research and review papers from scientists and engineers across diverse academic and industrial backgrounds. Together, these works demonstrate the breadth of smart material research, spanning cementitious composites, metallic reinforcements, advanced geopolymers, and intelligent monitoring systems.

Liu et al. (2025) [1] explored calcium sulphoaluminate foam concrete incorporating fly ash and ground granulated blast-furnace slag, achieving a tailored balance between mechanical and functional performance. Similarly, Hu et al. (2025) [2] examined the durability of fly ash–based concrete under high-salt conditions, providing valuable insights into material behavior in aggressive environments. These studies highlight how material design strategies can advance both sustainability and resilience.

Youssef et al. (2025) [3] investigated the flexural behavior of stainless steel–reinforced concrete elements, demonstrating the potential of corrosion-resistant alloys in structural applications where durability and ductility are essential. Complementing this, Askouni (2025) [4] presented a review on textile-reinforced mortars as frost-resistant strengthening solutions for deteriorated members—an area of growing relevance in cold-climate regions.

Liu et al. (2025) [5] applied molecular dynamics simulations to study the thermal conductivity of hydrated aluminosilicate gels, revealing the nano-scale mechanisms that govern heat transfer in cementitious materials. Torres-Acosta et al. (2025) [6] evaluated the performance of limestone-filled Portland cement pastes, furthering the understanding of binder modifications for sustainability and durability.

Rauf et al. (2024) [7] and Chairunnisa et al. (2024) [8] examined alternative materials through the lens of environmental performance—nickel slag-stabilized soils and fiber-reinforced geopolymers, respectively. Zhang et al. (2025) [9] provided complementary findings on the microstructural evolution of cement-stabilized soils under freeze–thaw cycles, demonstrating how tailored additives enhance shear strength and freeze–thaw resilience.

Cheng et al. (2025) [10] presented a review of ultra-high-performance concrete (UHPC) applications in flat components, focusing on the associated fire-induced spalling risk. The paper synthesizes findings on the relationship between pore structure, moisture content, and explosive spalling, an issue central to the safe adoption of UHPC in high-performance infrastructure.

Collectively, these papers represent a comprehensive cross-section of the field, linking experimental innovation with computational modeling and performance-based evaluation.

3. Emerging trends and future directions

The integration of smart materials into civil structures is moving beyond isolated applications toward system-level adaptation. Modern structures are increasingly envisioned as intelligent systems, capable of self-diagnosis, damage mitigation, and energy self-sufficiency. Several themes emerge from the collective works presented in this issue:

- Multifunctionality: Smart materials are increasingly designed to serve multiple roles—structural, sensing, and energy-harvesting—within a single composite system.
- Digital integration: Coupling material intelligence with digital twins and data-driven analytics offers new pathways for real-time structural assessment and predictive maintenance.
- Sustainability and circularity: The use of industrial by-products and low-carbon constituents aligns smart materials research with global carbon reduction goals.
- Standardization needs: Despite rapid advancement, the field continues to face challenges in developing standardized testing protocols and design codes that capture the unique behavior of adaptive materials.

Continued collaboration among materials scientists, structural engineers, and computational modelers will be crucial to advancing these goals. The synergy between material design, system intelligence, and sustainability is expected to shape the next generation of civil infrastructure.

4. Concluding remarks

This special issue reflects the dedication of researchers worldwide to advancing the science and practice of smart materials for civil infrastructure. The guest-editor extends sincere appreciation to all contributing authors for their high-quality submissions, and to the reviewers and editorial team of AIMS Materials Science for their careful evaluations and continued support.

The research compiled herein demonstrates that the future of civil engineering lies not only in stronger materials but in smarter systems—structures that can sense, adapt, and evolve in response to their environment. It is hoped that this collection will inspire continued innovation and collaboration in this dynamic and rapidly expanding field.

Use of AI tools declaration

The author declares that no artificial intelligence (AI) tools were used in the creation of this article.

Conflict of interest

Maged A. Youssef is on a special issue editorial board for *AIMS Materials Science* and was not involved in the editorial review or the decision to publish this article. The author declares no conflict of interest.

Reference

1. Liu YL, Xiao XZ, Zhou XY, et al. (2025) Tailoring mechanical and functional properties of calcium sulphoaluminate cement (CSA) foam concrete with FA and GGBS replacements. *AIMS Mater Sci* 12: 1025–1040. https://doi.org/10.3934/matersci.2025047
2. Hu FZ, Zhang SJ, Liu J, et al. (2025) Performance test of road fly ash concrete under temperate climate and high salt environment in Asia. *AIMS Mater Sci* 12: 928–943. https://doi.org/10.3934/matersci.2025041
3. Khalifa M, Youssef MA, Ajjan Alhadid MM (2025) Flexural capacity of stainless-steel reinforced-concrete elements. *AIMS Mater Sci* 12: 703–727. https://doi.org/10.3934/matersci.2025030
4. Askouni PD (2025) Textile-reinforced mortar as a potential for enhancing the frost resistance of strengthened structural members. *AIMS Mater Sci* 12: 423–452. https://doi.org/10.3934/matersci.2025022
5. Liu YL, Ren SY, Wang DH, et al. (2025) Molecular structure and thermal conductivity of hydrated sodium aluminosilicate (N-A-S-H) gel under different Si/Al ratios and temperatures: A molecular dynamics analysis. *AIMS Mater Sci* 12: 258–277. https://doi.org/10.3934/matersci.2025014
6. Torres-Acosta AA, Méndez-Páramo RA, Arista-Perrusquía C, et al. (2025) Portland cement paste performance when inert limestone filler is added as clinker replacement. *AIMS Mater Sci* 12: 224–244. https://doi.org/10.3934/matersci.2025012

7. Rauf I, Saputra MTY, Heryanto H, et al. (2024) Laboratory investigation of the influence of aluminum hydroxide on the compressive strength of nickel slag-stabilized soft soils. *AIMS Mater Sci* 11: 1220–1231. https://doi.org/10.3934/matersci.2024060
8. Chairunnisa N, Haryanti NH, Nurwidayati R, et al. (2024) Characteristics of metakaolin-based geopolymers using bemban fiber additives. *AIMS Mater Sci* 11: 815–832. https://doi.org/10.3934/matersci.2024040
9. Zhang CY, Chen F, Wang XD (2025) Microstructural evolution and direct shear strength of cement-stabilized soil under freeze-thaw cycles. *AIMS Mater Sci* 12: 28–47. https://doi.org/10.3934/matersci.2025003
10. Cheng XD, Xia J, Krevaikas T, et al. (2025) A review of the applications of ultra-high performance concrete in flat components and the associated fire-induced spalling risk. *AIMS Mater Sci* 12: 165–202. https://doi.org/10.3934/matersci.2025010