Journal of Innovative Science

ISSN(Online): 3082- 4435

Volume- 01| Issue- 02| 2025

Review Article **Received:** 20-09-2025 | **Accepted:** 15-10-2025 | **Published:** 31-10-2025

Smart Materials for Disaster Resilience in Construction: A Review

Ernest Afful Nkansah[1], Richard Darko[2], Christian Kojo Corchil[3], Macleana Oteng Mensah[4] and Japheth Ankamah Brefo[5]

[1] *Department of Materials Engineering, Kwame Nkrumah University of Science and Technology, Ghana*
[2] *Department of Materials Engineering, Kwame Nkrumah University of Science and Technology, Ghana*
[3] *Department of Geological Engineering, Kwame Nkrumah University of Science and Technology, Ghana*
[4] *Department of Materials Engineering, Kwame Nkrumah University of Science and Technology, Ghana*
[5] *Department of Civil and Urban Engineering, New York University, U.S.A.*

Abstract: Smart materials undergo reversible property changes in response to external stimuli, making them ideal for adaptive, durable, and self-recovering infrastructure. Through examination of laboratory research, field implementations, and performance, the review demonstrates substantial benefits, including autonomous damage repair, enhanced seismic energy dissipation, and reduced maintenance requirements. Key findings reveal that shape memory alloy systems achieve reductions in seismic inter-story drifts, fiber-reinforced polymer retrofits reduce collapse probability, and self-healing concrete decreases maintenance frequency. Despite these benefits, adoption faces barriers including incomplete long-term durability understanding, higher initial costs, construction industry cultural resistance, and the absence of comprehensive standards. Integration with Internet of Things connectivity and artificial intelligence analytics creates opportunities for enhanced functionality.

Keywords: Smart materials, Disaster resilience, Self-healing concrete, Shape memory alloys, Fiber-reinforced polymers, Seismic resistance.

INTRODUCTION

Smart materials are engineered substances that exhibit the ability to change their properties in response to external stimuli such as temperature, stress, electric fields, magnetic fields, moisture, or chemical environments (Sobczyk, *et al.*, 2022). These materials possess fundamental characteristics that distinguish them from conventional construction materials: sensitivity to detect changes in their environment, adaptability to alter their properties in response to external stimuli, and, in some cases, the ability to return to their original state when the stimulus is removed.

The increasing frequency and severity of natural disasters driven by climate change present significant challenges to the built environment. Traditional construction materials and methods demonstrate significant limitations when subjected to extreme environmental conditions. Masonry buildings in seismically active regions often exhibit poor performance during earthquakes due to inadequate mortar continuity, a lack of through-stones between wall leaves, and insufficient interconnection between roofs and walls (Langenbach, 2010). Reinforced concrete structures, despite their widespread adoption, can experience dramatic failures from soft story mechanisms and inadequate structural integrity during major seismic events (Langenbach, 2010).

The integration of smart materials into construction applications has gained considerable attention in recent years. Shape memory alloys demonstrate the ability to undergo large strains and recover their original shape through heating or unloading mechanisms, making them suitable for seismic energy dissipation and structural re-centering applications (Hilscher, *et al.*, 2025). Self-healing polymers and concrete systems can autonomously repair cracks and damage through various mechanisms, potentially reducing maintenance costs and extending service life (Amran *et al.*, 2022; Ibrahim *et al.*, 2025). The scope of this review encompasses the comprehensive examination of smart materials specifically designed and applied for disaster resilience in construction.

CATEGORIES RELEVANT TO DISASTER RESILIENCE

Fiber-Reinforced Polymers

Fiber-reinforced polymers (FRP) consist of high-strength fibers embedded in a polymer matrix, offering superior strength-to-weight ratios, corrosion resistance, and durability compared to traditional steel reinforcement. These characteristics make FRP composites suitable for disaster-resilient construction in aggressive environments. FRP composites exhibit excellent resistance to chloride ions and chemical attack, with tensile strength greater than that of conventional steel reinforcement (Albuja-Sánchez *et al.*, 2024; Karbhari, & Zhang, 2022). The lightweight and flexible nature of FRP composites facilitates ease of application for retrofit

***Corresponding Author:** Japheth Ankamah Brefo

DOI- https://doi.org/10.5281/zenodo.17492367

applications, while their elastic response to seismic activity provides enhanced structural resilience (Albuja-Sánchez, *et al.*, 2024). FRP systems have demonstrated effectiveness in improving the seismic resistance of concrete structures. Del Vecchio, *et al.*, (2021) evaluated the cost and effectiveness of fiber-reinforced polymer solutions for large-scale mitigation of seismic risk in reinforced concrete buildings, demonstrating their viability for widespread application in seismic retrofit programs.

Energy-Dissipative Alloys

Energy-dissipative alloys are specialized materials designed to absorb and dissipate mechanical energy through controlled deformation mechanisms, making them valuable for protecting structures from dynamic loading conditions such as earthquakes, wind, and blast events.

Recent developments in high-entropy alloys (HEAs) have produced materials with superior high-temperature damping capabilities. Lei, *et al.*, (2020) demonstrated that $Ta_{0.5}Nb_{0.5}HfZrTi$ HEAs blended with oxygen or nitrogen exhibit peak damping capacity as high as 0.030 at temperatures near 800 K, combined with excellent mechanical properties, including tensile yield strength of approximately 1400 MPa and elongation of 20%. These materials operate at much higher temperatures and wider operating temperature ranges than conventional damping alloys, making them suitable for extreme environmental conditions.

Energy dissipation in these alloys occurs through Snoek-type relaxation mechanisms, where interstitial atoms in severely distorted crystal matrices with complex chemical short-range orders provide both strengthening and damping effects (Lei *et al.*, 2020). The damping capacity corresponds to an energy dissipation of approximately 18.8% in each vibrational load cycle, significantly higher than that of traditional damping materials.

Self-Healing Concrete

Self-healing concrete incorporates various mechanisms to repair cracks that develop during service life. The most widely studied approach involves bacteria-based healing systems, where dormant bacterial spores embedded within the concrete matrix activate when exposed to water and oxygen, producing calcium carbonate precipitates that seal cracks (Amran *et al.*, 2022; Ibrahim *et al.*, 2025). The bacteria Bacillus species are commonly used due to their ability to survive in the alkaline environment of concrete and produce limestone through metabolic processes (Amran *et al.*, 2022). Alternative approaches include microcapsule-based systems containing polymer resins or cementitious materials that rupture upon crack formation, releasing healing agents that polymerize and seal the damage (Ibrahim, *et al.*, 2025).

Shape Memory Alloys

Shape memory alloys (SMAs) are metallic materials that can undergo large deformations and subsequently recover their original shape through thermal activation (shape memory effect) or stress removal (superelastic effect). These unique properties make SMAs good for seismic energy dissipation and structural re-centering applications in disaster-resilient construction. Iron-based SMAs (Fe-SMAs) have emerged as cost-effective alternatives for civil engineering applications, offering thermomechanical properties suitable for prestressing, strengthening, and retrofitting structural components (Hilscher *et al.*, 2025). These materials can be applied through active prestressing with mechanical anchoring or prestressing by thermal activation, making them suitable for strengthening existing structures (Hilscher *et al.*, 2025). SMAs demonstrate significant energy dissipation capabilities, making them effective for seismic applications. SMAs are utilized in various structural applications, including base isolation systems, bracing systems, and post-tensioning applications. Liu *et al.*, (2024) demonstrated the effectiveness of SMA cable-restrained bearings in prefabricated industrial buildings for seismic resilience, showing improved structural performance under seismic loading conditions

MECHANISM OF DISASTER MITIGATION

Use of Shape Memory Alloys for Energy Dissipation

Shape memory alloys provide exceptional capabilities for seismic protection through a combination of energy dissipation, deformation capacity, and re-centering behavior. Liu *et al.*, (2024) demonstrate these capabilities through comprehensive testing and analysis of SMA cable-restrained bearing systems in prefabricated industrial buildings.

The seismic protection mechanism operates through several integrated effects. During earthquake shaking, the building supported on

Publisher: SARC Publisher

sliding isolation bearings moves laterally, isolating the superstructure from ground motions. This base isolation reduces floor accelerations and inter-story drifts, protecting building contents and structural elements. The SMA cable restrainers limit maximum displacement of the isolated building, preventing excessive movement that could damage utility connections or cause pounding against adjacent structures. As the SMA cables deform during large earthquakes, their superelastic behavior provides energy dissipation through hysteretic stress-strain response, converting kinetic energy to heat. Upon cessation of ground shaking, the shape memory effect causes the SMA cables to return to their original length, pulling the building back to its original position and minimizing residual displacement.

Liu, *et al.,* (2024) quantify these benefits through shake table testing. Under moderate earthquake ground motions (peak ground acceleration 0.2-0.4g), the SMA cable-restrained system reduced maximum inter-story drifts by 30-35% compared to fixed-base construction, while limiting peak bearing displacement to 80-100 mm. Under strong earthquake motions (peak ground acceleration 0.6-0.8g), inter-story drift reductions of 40-45% were achieved, with bearing displacements limited to 120-150 mm. Residual displacements after earthquakes were less than 5 mm in all cases, demonstrating effective re-centering.

The parametric analysis conducted by Liu, *et al.,* (2024) provides design insights for optimizing SMA cable-restrained bearing systems. Pre-strain level significantly affects system performance, with an optimal pre-strain of 3-4% providing a balance between initial restraint and available deformation capacity. Too little pre-strain results in excessive displacement before the cables engage, while excessive pre-strain limits the available deformation capacity and increases the forces transmitted to the superstructure. Cable stiffness must be selected to provide adequate restraint without creating excessively high forces. The study found that optimal cable stiffness produces restraining forces of 5-10% of seismic base shear, sufficient to control displacement without negating isolation benefits.

Design recommendations from Liu, *et al.,* (2024) include procedures for determining required cable cross-sectional area based on building mass and seismic hazard, guidelines for cable pre-strain levels, specifications for bearing friction characteristics, and detailing requirements for cable anchorages. The research demonstrates that SMA cable-restrained bearing systems provide a practical and effective solution for seismic protection of prefabricated structures, with potential application to conventional construction as well.

Reinforcement with Fiber-Reinforced Composites

Fiber-reinforced polymers have established themselves as effective seismic retrofit materials for existing concrete structures. Del Vecchio *et al.,* (2021) analyzed 130 reinforced concrete buildings strengthened using FRP systems, finding that the lightweight nature of FRP composites, combined with their ease of installation and reduced disruption during implementation, made them economically viable for large-scale seismic mitigation programs. FRP jackets provide significant improvements in deformation capacity while imparting minimal additional stiffness to structural elements. FRP-strengthened buildings demonstrated increased lateral strength of 40-70%, increased displacement capacity of 60-120%, and reduced vulnerability to collapse by 50-75%, depending on initial building characteristics and strengthening strategy employed. These performance improvements translated to reduced expected annual losses from earthquakes of 30-60%, demonstrating significant risk reduction.

The durability of fiber-reinforced composites in civil infrastructure presents both opportunities and challenges. Karbhari and Zhang (2022) examined durability issues, results, and implications for FRP applications in civil infrastructure, noting that while these materials offer excellent initial performance, long-term environmental exposure requires careful consideration of degradation mechanisms.

FLOOD AND MOISTURE RESISTANCE

Self-Healing Concrete for Water Barrier Applications

Self-healing concrete offers autonomous crack sealing, making it valuable for flood protection and moisture resistance applications. Amran *et al.,* (2022) detailed mechanisms by which self-healing concrete maintains water-tightness despite cracking that would compromise conventional concrete.

Water infiltration through cracks in concrete structures creates multiple problems, including accelerated corrosion of reinforcing steel, freeze-

Publisher: SARC Publisher

thaw damage in cold climates, chemical attack from aggressive environments, and structural deterioration due to erosion. Conventional concrete requires manual inspection and repair to maintain water tightness, with repair costs and disruptions being substantial over the structure's lifetime. Self-healing concrete addresses these issues by sealing cracks autonomously when water enters.

Bacteria-based healing systems operate through a series of biological and chemical processes. When cracks form, water and oxygen enter, activating dormant Bacillus spores embedded in the concrete. These bacteria consume organic nutrients (typically calcium lactate or yeast extract) also embedded in the concrete, producing calcium carbonate through metabolic processes. The calcium carbonate precipitates on crack surfaces, gradually filling the crack. Amran, *et al.*, (2022) report that complete sealing of cracks up to 0.4 mm wide can occur within 7-14 days under favorable conditions (temperature 20-30°C, adequate moisture), with partial healing of larger cracks up to 0.8 mm occurring over 3-4 weeks.

The effectiveness of bacterial healing depends on several factors. Crack width is critical, with complete healing of cracks wider than 0.8 mm being difficult to achieve. Temperature affects bacterial metabolism, with optimal healing occurring at temperatures between 20-37°C, and significantly reduced healing rates below 10°C or above 45°C. Moisture availability is essential, as bacteria require water for activation and metabolism. Multiple healing cycles are possible, though healing efficiency decreases with repeated cracking due to depletion of bacterial nutrients. Amran, *et al.*, (2022) report that properly designed systems can achieve 3-5 healing cycles before nutrient depletion limits effectiveness.

Ibrahim, *et al.*, (2025) emphasize the longevity and resilience benefits of self-healing concrete for infrastructure applications. They discuss how bacterial spores demonstrate remarkable durability, remaining viable for decades within concrete. This long-term viability ensures healing capability throughout the structure's service life, providing "insurance" against cracking from various causes, including settlement, thermal effects, shrinkage, and mechanical overload. For flood protection structures, such as levees, seawalls, and stormwater systems, self-healing concrete offers advantages by autonomously maintaining watertightness despite cracking due to ground movement, vegetation root intrusion, or hydraulic forces.

Ibrahim, *et al.*, (2025) also examined the economic benefits of self-healing concrete. While material costs increase by 10-30% compared to conventional concrete due to the incorporation of bacteria and nutrients, a lifecycle cost analysis shows positive returns. Reduced inspection requirements, eliminated or delayed repair costs, and extended service life combine to provide net economic benefits. For infrastructure in remote or difficult-to-access locations, the benefits are significant as inspection and repair costs are reduced.

Protective Coatings

Mistri *et al.*, (2025) conducted a systematic evaluation of coating and sealer materials for protecting bridge substructure concrete against moisture and chloride ingress. Their research identified effective protective systems that prevent moisture-related deterioration, including freeze-thaw damage, chloride ingress, and reinforcing steel corrosion while reducing maintenance requirements. According to the research, penetrating sealers based on silane/siloxane chemistry provided excellent moisture and chloride resistance while maintaining concrete breathability (important for allowing moisture to escape from within concrete). These systems reduced chloride penetration by 60-80% compared to unprotected concrete and demonstrated good durability over 10+ years of field exposure. However, they provided limited protection against abrasion and required reapplication every 5-10 years, depending on the severity of exposure.

EXTREME WEATHER PROTECTION

Heat and Cold Adaptive Materials

Phase-change materials provide thermal regulation through latent heat storage and release mechanisms. Zhou and Duan (2024) developed leak-proof reversible thermochromic microcapsule phase change materials with high latent thermal storage for thermal management applications. These materials demonstrate the ability to control equilibrium temperatures and provide reversible performance across multiple thermal cycles. Phase change materials store and release large amounts of thermal energy through latent heat of fusion during phase transitions, typically melting and solidification. This capability enables buildings to absorb excess heat during warm periods and release stored heat during cool periods, reducing heating and cooling energy requirements. Zhou

Publisher: SARC Publisher

and Duan (2024) note that organic phase change materials, such as paraffins and fatty acids, offer several advantages, including a large latent heat capacity (150-250 J/g), suitable melting temperatures for building applications (18-28°C, within the human comfort range), chemical stability, and non-corrosive properties.

The primary challenge addressed by Zhou and Duan (2024) is leakage during phase transitions. When organic phase change materials melt, they transition from a solid to a liquid state, potentially leaking from containment structures and losing their functionality. Microencapsulation addresses this challenge by encapsulating phase change material droplets within polymer shells, which contain the liquid phase while allowing for heat transfer. Zhou and Duan (2024) developed a microencapsulation process that produces capsules 1-10 μm in diameter, with shell material that provides excellent containment.

Advanced Sensor Technologies for Environmental Monitoring

Maity and Rajendra Kumar (2024) developed an ultrafast, flexible, and selective water sensor based on multiwalled carbon nanotubes and polyvinylidene fluoride composites screen-printed on cotton fabric. Their research addresses the need for rapid and reliable water detection in building systems for leak detection and flood warning purposes.

The sensor operates by measuring a change in electrical resistance when water comes into contact with the composite material. Multi-walled carbon nanotubes provide electrical conductivity pathways, while the polyvinylidene fluoride polymer matrix provides structural support and a selective response to water. When water contacts the sensor, it disrupts the carbon nanotube networks, causing polymer swelling and an increase in electrical resistance. Maity and Rajendra Kumar (2024) report that resistance increases by 1000-10,000 times the baseline resistance, depending on water quantity and contact area.

Performance characteristics demonstrate remarkable capabilities. Response time (the time from water contact to a detectable resistance change) is 0.6 ± 0.2 seconds, enabling near-instantaneous leak detection. Recovery time (the time it takes for the sensor to return to baseline after water removal and drying) is 0.8 ± 0.2 seconds, allowing for rapid, repeated measurements. Selectivity testing demonstrated that the sensor responds specifically to water, with minimal interference from organic solvents, oils, or atmospheric humidity below condensation levels. Reproducibility testing over 28 measurement cycles showed a standard deviation of only 6%, indicating excellent reliability.

The flexible textile substrate enables integration into building materials and furnishings. Maity and Kumar, R. (2024) demonstrate the fabrication of sensors on cotton fabric through a screen printing process compatible with large-scale manufacturing. The fabric-based sensor can be incorporated into carpets, wall coverings, or ceiling tiles, providing distributed water detection throughout buildings. Integration with wireless communication enables real-time monitoring and automated alerts when water is detected.

Applications in disaster resilience include early leak detection in roofing and plumbing systems before significant damage occurs, flood sensors for basements and ground-level spaces at risk of inundation, moisture monitoring in building envelopes to detect water intrusion from storms, and humidity sensing for mold prevention. The ultrafast response time is crucial for flood warning, as detection within seconds of water arrival enables the automated shutdown of electrical systems or the activation of pumps before damage occurs.

Javaid, *et al.*, (2023) reviewed the broader landscape of self-powered sensors for structural and environmental monitoring, identifying energy-harvesting approaches that enable sensor operation without the need for batteries or external power. Self-powered sensors harvest energy from ambient sources, including vibration (piezoelectric generation), temperature gradients (thermoelectric generation), light (photovoltaic generation), and radio frequency radiation. This energy independence is valuable for disaster resilience applications where power infrastructure may be disrupted.

Javaid, *et al.*, (2023) identify key challenges for self-powered sensor deployment, including limited power availability that constrains sampling rates and data transmission, the need for ultra-low-power electronics and efficient energy storage, the development of reliable energy harvesting under variable environmental conditions, and the integration of multiple energy harvesting mechanisms for continuous operation. They

Publisher: SARC Publisher

present solutions that include hybrid energy harvesting, combining multiple sources, advanced energy storage using supercapacitors or thin-film batteries, intelligent power management circuits that optimize energy use, and event-driven operation, where sensors activate only when changes are detected.

Application scenarios discussed by Javaid, *et al.*, (2023) demonstrate value for disaster resilience. Vibration-powered sensors on bridges can continuously monitor structural health without requiring battery replacement, utilizing earthquake or high wind events to provide energy for increased sampling rates during critical periods. Temperature gradient sensors in building envelopes harvest energy from indoor-outdoor temperature differences, enabling continuous moisture monitoring for leak detection. Hybrid sensors combining photovoltaic and vibration harvesting provide reliable operation across varying conditions.

CHALLENGES AND FUTURE DIRECTIONS

Technical Limitations and Long-Term Durability Concerns

Despite their promising applications, smart materials face significant technical limitations that hinder their widespread adoption. Karbhari and Zhang (2022) identified durability concerns as critical challenges, noting that while laboratory tests demonstrate promising results, real-world applications over decades are needed to determine whether these materials can consistently perform under varying environmental conditions.

Sobczyk, *et al.*, (2022) reviewed smart materials in architecture for actuator and sensor applications, identifying integration challenges in retrofitting projects where compatibility issues with legacy systems must be addressed. Ensuring interoperability between different smart material components and building management systems remains essential for seamless operation.

Barriers to Large-Scale Adoption

Regional adoption of smart materials faces diverse barriers. Yap *et al.*, (2022) examined barriers to the adoption of new safety technologies in construction within developing country contexts, identifying costly investment, organizational culture, and differing client requirements as primary obstacles. Their research revealed six major dimensions: a lack of regulations and legislation, technological limitations, a lack of genuine organizational commitment, prohibitive costs, a poor safety culture, and concerns regarding privacy and data security.

Baharetha, *et al.*, (2024) assessed the challenges influencing the adoption of smart building technology more broadly, finding that technical complexity, economic constraints, and regulatory gaps create significant barriers across different regions and market segments.

Emerging Trends

The future of smart materials in construction is shaped by advances in additive manufacturing, Internet of Things integration, and adaptive material technologies. Skibniewski (2024) examined the present and future of smart construction technologies, identifying the convergence of materials science, digital technologies, and data analytics as key drivers of future development.

Iqbal, *et al.*, (2023) explored the integration of BIM-IoT and autonomous mobile robots for construction, demonstrating how smart materials must be considered within broader technological ecosystems. Javaid, *et al.*, (2023) reviewed self-powered sensor applications, challenges, and solutions, showing how energy harvesting technologies can support smart material systems in construction applications.

Advanced sensing capabilities will play increasingly important roles. Maity, & Kumar, R. (2024) developed ultrafast, flexible water sensors based on multiwalled carbon nanotubes and polyvinylidene fluoride, demonstrating potential for rapid leak detection and flood monitoring applications in buildings.

The development of specialized materials continues to advance on multiple fronts. Brefo, & Yakin, (2025) examined high-performance composite materials for earthquake-resistant structures and analyzed the role of fiber-reinforced and self-healing concrete in enhancing infrastructure durability. Brefo *et al.*, examined sustainable low-carbon cement technologies for reducing construction carbon emissions, showing how material innovations can simultaneously address resilience and sustainability objectives.

Sahu, *et al.*, (2025) proposed a smart bridge infrastructure with automatic height adjustment for flood resilience and intelligent monitoring, illustrating how smart materials can be integrated into adaptive structural systems. Such innovations

Publisher: SARC Publisher

require continued research, standardization efforts, and development of supportive regulatory frameworks.

CONCLUSION

Smart materials have demonstrated substantial value in enhancing disaster resilience across various infrastructure sectors by providing adaptive responses to seismic events, flood conditions, and extreme weather events. Shape memory alloys offer energy dissipation and self-centering capabilities for seismic applications (Hilscher, *et al.*, 2025; Liu *et al.*, 2024). Self-healing concrete systems offer autonomous crack repair, extending service life and reducing maintenance (Amran, *et al.*, 2022; Ibrahim, *et al.*, 2025). Fiber-reinforced polymers enable cost-effective seismic strengthening of existing structures (Del, Vecchio. *et al.*, 2021). Advanced alloys provide superior energy dissipation at elevated temperatures (Lei, *et al.*, 2020).

Moving forward, research should prioritize long-term field performance studies and standardized testing protocols to address durability uncertainties (Karbhari, & Zhang, 2022). Policy development must focus on incorporating smart material guidelines into building codes and providing incentives for the adoption of innovation (Yap, *et al.*, 2022; Baharetha, *et al.*, 2024). Interdisciplinary collaboration among materials scientists, structural engineers, and digital technology specialists will be essential to ensure seamless integration of smart materials into building management systems (Skibniewski, 2024).

Emerging trends in additive manufacturing, Internet of Things connectivity, sensor technologies, and multifunctional adaptive materials are poised to further enhance the resilience, sustainability, and efficiency of the built environment (Iqbal *et al.*, 2023; Javaid *et al.*, 2023; Ligarda-Samanez *et al.*, 2025). Addressing technical limitations, economic barriers, and regulatory gaps will be critical to realizing the full potential of smart materials for disaster-resilient construction.

REFERENCES

1. Albuja-Sánchez, J., Damián-Chalán, A., and D. Escobar. "Experimental Studies and Application of Fiber-Reinforced Polymers (FRPs) in Civil Infrastructure Systems: A State-of-the-Art Review." *Polymers* 16.2 (2024): 250.
2. Amran, M., Onaizi, A. M., Fediuk, R., Vatin, N. I., Muhammad Rashid, R. S., Abdelgader, H., and T. Ozbakkaloglu. "Self-Healing Concrete as a Prospective Construction Material: A Review." *Materials* 15.9 (2022): 3214.
3. Brefo, J. A., and Z. Yakin. "High-Performance Composite Materials for Earthquake-Resistant Structures in the US." 2025.
4. Brefo, J. A., and Z. Yakin. "The Role of Fiber-Reinforced and Self-Healing Concrete in Enhancing US Infrastructure Durability." 2025.
5. Brefo, J. A., Osei, A. K., and J. A. Opoku. "Sustainable Low-Carbon Cement Technologies for Reducing US Construction Carbon Emissions." 2025.
6. Del Vecchio, C., Di Ludovico, M., and A. Prota. "Cost and Effectiveness of Fiber-Reinforced Polymer Solutions for the Large-Scale Mitigation of Seismic Risk in Reinforced Concrete Buildings." *Polymers* 13.17 (2021): 2962.
7. Hilscher, M., Jübner, P., and E. Ghafoori. "Iron-Based Shape Memory Alloys in Construction: A Review of Research, Applications, and Challenges." *Shape Memory and Superelasticity* (2025): 1–15.
8. Ibrahim, S. A., Rizal, M. S. K. M., Aman, N. F. F. M., and A. A. A. Othman. "Revolutionizing Infrastructure: A Review of Self-Healing Concrete for Longevity and Resilience." *Emerging Advances in Integrated Technology* 6.1 (2025): 48–54.
9. Iqbal, F., Ahmed, S., Amin, F., Qayyum, S., and F. Ullah. "Integrating BIM–IoT and Autonomous Mobile Robots for Construction Site Layout Printing." *Buildings* 13.9 (2023): 2212.
10. Javaid, S., Fahim, H., Zeadally, S., and B. He. "Self-Powered Sensors: Applications, Challenges, and Solutions." *IEEE Sensors Journal* 23.18 (2023): 20483–20509.
11. Karbhari, V. M., and S. Zhang. "Durability of Fiber Reinforced Composites in Civil Infrastructure: Issues, Results and Implications." In *Recent Developments in Durability Analysis of Composite Systems*, 267–278. CRC Press, 2022.
12. Langenbach, R. "Traditional Masonry as Earthquake-Resistant Construction." *8th International Conference on Masonry* (2010): 1–26.
13. Lei, Z., Wu, Y., He, J., Liu, X., Wang, H., Jiang, S., et al. "Snoek-Type Damping

Publisher: SARC Publisher

Performance in Strong and Ductile High-Entropy Alloys." *Science Advances* 6.25 (2020): eaba7802.
14. Ligarda-Samanez, C. A., Huamán-Carrión, M. L., Cabel-Moscoso, D. J., Muñoz Sáenz, D. M., Martinez Hernandez, J. A., Garcia-Espinoza, A. J., et al. "Technological Innovations in Sustainable Civil Engineering: Advanced Materials, Resilient Design, and Digital Tools." *Sustainability* 17.19 (2025): 8741.
15. Liu, X., Wang, W., Hu, D., Qu, J., and C. Cao. "Test, Design, and Parametric Analysis of a Prefabricated Industrial Building with Shape Memory Alloy (SMA) Cable-Restrained Bearings for Seismic Resilience." *Engineering Structures* 313 (2024): 118288.
16. Maity, D., and R. T. Rajendra Kumar. "Ultrafast, Flexible, and Selective Water Sensor Based on Multiwalled Carbon Nanotubes/Poly (Vinylidene Fluoride) Screen-Printed on Cotton Fabric." *ACS Applied Engineering Materials* 2.2 (2024): 313–323.
17. Mengesha, G. "Revolutionizing Bridge Engineering: A Comprehensive Review of Smart Materials, AI-Driven Structural Optimization, and Resilient Design Innovations." *AI-Driven Structural Optimization and Resilient Design Innovations* (2025).
18. Mistri, A., Saraswatula, P., and A. K. Mukhopadhyay. "Systematic Evaluation of the Effectiveness of Coating and Sealer Materials for Protecting Bridge Substructure Concrete Against Moisture and Chloride Ingress." *Transportation Research Record* (2025): 03611981251345764.
19. Ogunnaike, A. O., Anyanechi, H., and Z. Alabor. "Harnessing the Potential of Nano-Smart Materials in Building Design: A Systematic Review on User Well-Being." *African Journal of Environmental Sciences and Renewable Energy* 19.1 (2025): 336–347.
20. Sahu, K., Dhruw, S., Khapre, R., Yadav, P., Yadav, U., and D. Hazari. "Smart Bridge Infrastructure: Automatic Height Adjustment for Flood Resilience and Intelligent Monitoring." *International Journal of Scientific Research and Technology* (2025).
21. Skibniewski, M. J. "The Present and Future of Smart Construction Technologies." *Engineering* (2024).
22. Sobczyk, M., Wiesenhütter, S., Noennig, J. R., and T. Wallmersperger. "Smart Materials in Architecture for Actuator and Sensor Applications: A Review." *Journal of Intelligent Material Systems and Structures* 33.3 (2022): 379–399.
23. Tadge, T., Garje, S., Saxena, V., and A. M. Raichur. "Application of Shape Memory and Self-Healable Polymers/Composites in the Biomedical Field: A Review." *ACS Omega* 8.36 (2023): 32294–32310.
24. Yap, J. B. H., Lam, C. G. Y., Skitmore, M., and N. Talebian. "Barriers to the Adoption of New Safety Technologies in Construction: A Developing Country Context." *Journal of Civil Engineering and Management* 28.2 (2022): 120–133.
25. Zhou, Y., and R. Duan. "Leak-Proof Reversible Thermochromic Microcapsule Phase Change Materials with High Latent Thermal Storage for Thermal Management." *ACS Applied Energy Materials* 7.14 (2024): 5944–5956.

Source of support: Nil; **Conflict of interest:** Nil.

Cite this article as:
Nkansah, E. A., Darko, R., Corchil, C. K., Mensah, M. O. and Brefo, J. A. "Smart Materials for Disaster Resilience in Construction: A Review " *Jr. Inn. Sci.* 1.2 (2025): pp 22-29.

Publisher: SARC Publisher