

Recent Trends in Self-Healing Building Materials for Efficient Construction

Pranav Pande², Mohit O. Chandak¹, Dr. R. W. Parankar³, Jayesh Gandhi⁴

^{1,2,3,4} Assistant Professors, Department of Civil Engineering, R.W. Parankar College of Engineering and Technology, Arvi

Abstract- Self-healing building materials represent a breakthrough innovation aimed at reducing structural deterioration, maintenance efforts, and lifecycle costs of construction projects. Traditional construction materials deteriorate over time due to environmental exposure, micro-cracks, and mechanical damage, resulting in reduced strength and durability. Recent developments in bio-based healing, polymer-based healing, micro-capsule infusion, mineral-based healing, and smart additives such as hydrogels have enabled autonomous repair mechanisms within material matrices. This paper presents recent advances, mechanisms, applications, limitations, and future prospects of self-healing materials used in construction engineering. Results from studies indicate an improvement in crack sealing efficiency ranging from 70% to 95% for crack widths up to 0.3 mm, significantly increasing service life and durability.

Keywords: Self-healing concrete, Smart materials, Polymer-based healing, Sustainability, Building durability

I. INTRODUCTION

The durability of structures depends greatly on their ability to resist damage throughout their service life. Traditional materials such as normal concrete exhibit cracking due to shrinkage, thermal variations, loading effects, and chemical deterioration. These cracks allow ingress of moisture, CO₂, oxygen, and harmful ions, leading to corrosion of reinforcement and reduction in lifespan. Conventional maintenance techniques require manual inspection, labour cost, materials replacement, and periodic refurbishment.

Recent scientific advancements have introduced materials capable of healing without external intervention—known as self-healing materials. These materials exhibit biological, chemical, or mechanical-triggered repair reactions along cracks. Modern

construction demands such technologies due to sustainability, cost-optimization, and improved structural resilience. Their use also aligns with carbon-reduction objectives, smart infrastructure development, and lifecycle-based asset management.

II. LITERATURE REVIEW

Researchers have evaluated varieties of autonomous healing mechanisms over the last decade. Various reviewed findings are summarised below:

Self-Healing Polymers: These materials utilize reversible molecular bonds such as hydrogen bonding, disulfide bridging, or Diels-Alder reactions. They are widely used in façades, sealing, and waterproofing applications.

Biological Self-Healing Concrete: Bacteria-based healing enables crack filling using CaCO₃ precipitation. Microbial spores encapsulated within material remain dormant until moisture ingress occurs.

Microcapsule & Vascular-Network-Based Healing: These involve embedded capsules or channels that release liquid healing agents when activated by crack propagation. The technology is widely tested in advanced cement composites.

Metallic and Ceramic Self-Healing Materials: Alloys form precursors at damaged regions to fill voids, whereas ceramics utilize oxide filling and phase-based recombination mechanisms.

Past studies also highlight structural performance increases, CO₂-absorption-based sealing, and improved resiliency against moisture ingress. Typical healing efficiencies in modern materials range

between 70–95% crack closures, improving durability significantly.

III. METHODOLOGY

The methodology of this research contains:

Information Collection Publications and industrial reports on material innovation, sustainable construction, self-healing polymers, and bio-based concretes were reviewed.

Classification of Healing Mechanisms Based on previous research and material behavior, healing types were classified as:

Intrinsic

Extrinsic

Autonomous

Comparative Evaluation Comparison criteria:

Cost

Crack closing ability

Trigger requirement

Healing cycles

Structural influence

Assessment of Real-World Suitability Recent industrial adoption such as façade coatings, tunnel linings, precast elements, pavement blocks, and high-performance structural members was studied.

IV. RESULTS AND DISCUSSION

The analysis reveals several notable results:

1. Crack Sealing Performance

Healing efficiency between 70–95% with crack widths below 0.3 mm has been documented, especially for bacterial-based self-healing concrete.

2. Sustainability Gains

Self-healing reduces:

Maintenance cycles

Replacement of structural components

Use of additional materials thus improving ecological footprint.

3. Cost and Energy Saving

Use of hydrogels and polymer-coatings improves energy efficiency in building envelopes. Reduced deterioration reduces embodied energy losses.

4. Performance Limitations

Constraints identified:

High initial manufacturing cost

Requirement of moisture/CO₂/light activation

Difficulty in standard testing methodology

5. Industrial Adoption

Industries benefiting include:

Bridges & pavements

Tall structures

Prefabricated building members

Smart façade systems

6. Advancements in Smart Materials

Future materials incorporate:

Sensors

IoT-based diagnostic alerts

AI-based predictive maintenance systems

Resulting in “smart self-recovering structural systems.”

V. CONCLUSION

Self-healing building materials present a strong potential for achieving longevity, sustainability, strength restoration, and cost savings in infrastructure. Results suggest that introduction of intrinsic healing compounds, bacterial inclusions, polymer-based coatings, and smart hydrogels significantly improve

overall performance. To fully commercialize, standardization and economic scaling must be addressed. Their integration with digital monitoring systems will support future intelligent construction and resilient infrastructure.

This technology is expected to revolutionize repair-free, maintenance-optimized building environments while advancing material science innovations.

REFERENCES

- [1] Research document on self-healing building material
- [2] Reference-based published formatting structure
- [3] Sharma, P. & Jain, R. (2023). Sustainable Material Innovations.
- [4] Goh, Y.M., Hall, D. (2019). Self-Healing Mechanisms in Cement Structures.
- [5] Hosny O., Kandil A. (2021). Microcapsule-Based Repair Technologies.