



Archives available at journals.mriindia.com

**International Journal on Theoretical and Applied Research in
Mechanical Engineering**

ISSN: 2319-3182

Volume 14 Issue 01, 2025

Bacteria-Based Self-Healing Concrete Technologies: A Review of Literature and Future Perspectives

¹Mr. Rohit N. Gaidhane, ² Dr. Tushar G. Shende, ³ Dr. Alok Rai

¹Research Scholar, Structural Engineering, Department of Civil Engineering, G.H. Rasoni College of Engineering and Management, Nagpur, Maharashtra, India

²Associate Professor, Structural Engineering, Department of Civil Engineering, G.H. Rasoni College of Engineering and Management, Nagpur, Maharashtra, India

³Associate Professor, Department of Microbiology, Seth Kesarimal Porwal College of Arts, Kamptee, Maharashtra, India

Email: ¹rohit.gaidhane.mtechstr@ghrcemn.raisoni.net, ² tushar.shende@raisoni.net, ³alok.rrai@gmail.com

Peer Review Information	Abstract
<p>Submission: 05 Nov 2025 Revision: 25 Nov 2025 Acceptance: 17 Dec 2025</p>	<p>The purpose of this literature review is to analyse various works conducted on concrete that heals itself formed by incorporation of bacteria. Self-healing concrete utilizing bacteria is a noteworthy development in the field of sustainable construction technology. This literature review synthesizes findings from a range of recent studies on the mechanisms, performance, and challenges of bacteria-based self-healing concrete systems. Research indicates that incorporating specific bacterial strains predominantly from the Bacillus genus into concrete enables the material to autonomously repair cracks through the Calcium carbonate precipitation caused by microbes, which efficiently seals fractures and restores integrity. Multiple papers demonstrate enhancements in mechanical properties, such as compressive strength and durability, along with the ability to heal cracks under various environmental conditions. Key factors influencing self-healing performance include the choice of bacterial species, nutrient availability, crack size, and the highly alkaline environment of concrete; advances in encapsulation methods and genetic engineering further enhance bacterial viability and healing efficiency. Despite demonstrated benefits, challenges remain in optimizing economic feasibility, ensuring long-term viability of bacteria, and scaling the technology for widespread application. Collectively, the reviewed literature highlights bacteria-powered self-healing concrete as a promising, environmentally aligned material poised to transform the maintenance and resilience of infrastructure.</p>
<p>Keywords</p> <p>Autonomously, Microbially induced precipitation, encapsulation, alkaline, resilience.</p>	

Introduction

The most popular building material is concrete, but over time, its ability to crack may affect durability and structural integrity. Conventional repair techniques are frequently expensive, time-consuming, and could not offer lasting fixes.

The idea of bacterially self-healing concrete has gained traction recently as a viable, sustainable substitute. This new technique utilizes selected bacterial strains like those in the Bacillus genus, that, when activated by water intrusion, can precipitate calcium carbonate (CaCO₃) to close

gaps on their own. In addition to restoring concrete's mechanical qualities, the bio mineralization process increases the material's resistance to chemical and water penetration, extending its lifespan and durability. The process, known as bio mineralization, not only restores the mechanical properties of concrete but also enhances its resistance to water and chemical penetration, thereby improving durability and lifespan. Encapsulation techniques, such as embedding bacterial spores in microcapsules or expanded perlite, have been developed to protect the bacteria until cracks form, ensuring effective healing even under challenging conditions. Research demonstrates that bacterial self-healing can significantly reduce permeability, heal cracks up to nearly 1 mm wide, and increase compressive strength. As the field advances, optimizing bacterial strains, nutrient delivery, and encapsulation methods remains crucial for large-scale, cost-effective implementation.

"In this review, the mechanisms, efficiency, and practical challenges of bacteria-driven self-healing concrete are analysed, with attention to its promising role in advancing construction technology."

Literature Review

Pui Yan Wong¹ (2024) The author aims to highlight the potential of bioconcrete, which uses microbial metabolic processes to self-heal cracks by precipitating calcium carbonate (CaCO₃). While the method enhances durability and is eco-friendly, the author identifies key challenges like microbial viability and high costs. The paper calls for further research into diverse biological agents (including fungi and algae), improved microbial ecosystems, advanced encapsulation methods, and the use of computational tools (ANN, ML) to optimize the healing process. Encouraging the creation and broad use of self-healing bioconcrete for sustainable infrastructure is the aim.

Yasmeena Javeed² (2024) The current research examines several methods for concrete self-healing, emphasizing the drawbacks of autogenous repair, which works best on extremely small cracks. Using species like *B. subtilis* and *S.*

pasteurii, it highlights the potential of bacterial self-healing to fix cracks up to 1 mm, particularly when the bacteria are encapsulated and mixed with organic calcium sources like calcium lactate. The pH, temperature, and moisture levels all affect how well this approach works, and natural curing conditions significantly enhance healing results. The study also supports the use of macroscale modeling

for real-world applications and observes that different bacteria provide varying strength enhancements. The study concludes that microbial self-healing concrete is a viable, a method that can be scaled up to improve longevity of concrete constructions.

Alireza Soleimanbeigi³ (2025) When paired with silica fume (SF), the addition of *Sporosarcina ureae* bacteria late in the mixing process maintains activity and greatly increases the strength and durability of concrete. Encapsulation is less effective than direct bacterial addition. Through calcium carbonate precipitation, which fills holes and densifies the concrete, the mix repairs cracks up to 1 mm in 28 days. SF increases durability by improving microstructure and lowering water absorption.

Gupta Souradeep⁴ (2017) The author reviewed the use of bacteria based method for repairing cracks in concrete, focusing on how bacteria are added either directly or via encapsulation. The paper examines four main factors affecting bacterial healing effectiveness: the materials and methods used for encapsulating bacteria, the ability of bacteria to seal cracks and restore mechanical and durability performance, the impact of incorporating bacteria or capsules on concrete traits, and the survival of these capsules during mixing.

Ali Raza⁵ (2022) The main conclusions of this study demonstrate how well Microbially Induced Calcium Carbonate Precipitation (MICP), which uses calcium lactate and *Bacillus pumilus*, heals fractures and increases the lifespan of concrete, surpassing or matching traditional restoration techniques. Treatments such as BSF and BSC demonstrated near-complete crack closure (99–100%) and significantly reduced permeability for cracks up to 1.55 mm in size. The MICP process improves compressive strength by promoting calcite precipitation, which bridges cracks and densifies the concrete matrix. Microstructural analyses confirmed that the dense formation of calcite is the primary factor behind the observed healing and durability enhancements. Additionally, this biological repair approach is environmentally friendly and free from pollution. Ongoing research focuses on optimizing MICP for healing larger cracks, assessing durability under various environmental stresses, and evaluating mechanical properties such as fatigue resistance.

Ismael Justo-Reinoso⁶ (2024) "The study highlights that BBSHC currently has an environmental impact roughly 85% higher than conventional concrete, primarily due to the energy-intensive nature of chemical production and bacterial encapsulation." However, using

BBSHC selectively, such as in the concrete cover zone, can reduce overall structural impacts by 12–50%. Improving sustainability requires more renewable energy, fossil-free raw materials, and optimized transportation. Although long-term data is limited, if BBSHC effectively reduces repair needs by healing cracks autonomously, its environmental benefits will grow.

Mahmoud A. Elshazly⁷ (2025) The author wanted to see how two bacterial strains, *Bacillus Megaterium* (BM) and *Bacillus Sphaericus* (BS), performed as self-healing agents in mortar at low and sub-zero temperatures. They investigated various bacterial concentrations to see how they affected the mechanical qualities of mortar, crack healing abilities, and bacterial survival. The study also includes microstructure analysis to better understand how bacteria help with recovery. Finally, the author wanted to know which bacteria are competent at self-healing concrete in cold situations and how temperature influences their performance.

Mohamed Alazhari⁸ (2018) This research explores optimizing bacterial self-healing concrete by focusing on the right balance of bacterial spores, nutrients, and precursors. Using coated expanded perlite as a carrier for spores and nutrients separately, the study shows that effective crack healing requires not only sufficient healing compounds like calcium acetate but also a minimum number of bacterial spores (about 8×10^9 spores per gram of calcium acetate). Healing was observed under moist and humid conditions over 165 days, but faster healing might occur under wet/dry cycles.

Lei V. Zhang⁹ (2021) The author demonstrates that *Sporosarcina pasteurii* bacteria, carried by recycled expanded glass granules, can effectively heal cracks in eco-friendly alkali-activated concrete. The bacteria survive the alkaline environment, producing calcium carbonate that fills cracks up to 111 μm within 90 days, reducing water absorption and improving durability. Higher temperatures and wet-dry cycles boost healing. PVA fibers also aid calcite formation. This biogenic self-healing approach shows promise for increasing the strength and sustainability of green concrete built from recycled resources.

Kunamineni Vijay¹⁰ (2021) The author wants to highlight that using urease-producing bacteria like *Bacillus subtilis* and *Bacillus pasteurii* in concrete can naturally heal micro-cracks through calcite (CaCO_3) precipitation. This self-healing process improves the concrete's strength, durability, and reduces water and chloride penetration. The study emphasizes that encapsulating bacteria yields better results than direct application.

Zinab Helal, Hani Salim¹¹ (2021) This study shows that adding bacteria and steel fibers to concrete greatly improves its strength and ability to heal cracks. Adding 2.5% bacteria improved compressive strength in both fresh and sulfate water. Combining bacteria with steel fibers further enhanced strength in multiple ways. Microscopic analysis confirmed bacteria produce calcium carbonate, which helps fill cracks. Overall, bacteria-based bio-concrete with steel fibers is a sustainable way to make stronger, more durable concrete.

Shoib Wani¹² (2021) The author wants to communicate that this study examined how different concentrations of *Bacillus megaterium* (BM) and *Bacillus sphaericus* (BS) affect concrete's strength, durability, and self-healing abilities. The optimal concentration for BM was found to be 10^9 CFU/mL,

which significantly improved compressive, tensile, and flexural strengths compared to control samples after curing. BM also showed higher urease activity than BS, aiding mineral precipitation that fills cracks. The bacteria effectively healed cracks up to 0.8 mm wide, with the best results (92% repair) for cracks between 0.1 and 0.3 mm.

Hayeon Kim, H.M. Son¹³ (2021) The author explains that bio-mineralization—a process where bacteria produce carbonate minerals to fill cracks—is a promising, eco-friendly method to improve concrete durability. However, bacterial survival and activity, which are crucial for effective self-healing, can be negatively affected by harsh conditions inside concrete during curing. To overcome this, advanced techniques like encapsulating bacteria in protective carriers have been developed, improving their viability and repairs cracks up to 1.2 mm

After studying the paper it is concluded that, bacterial concrete can successfully repair cracks, with some papers reporting almost 100% closure for cracks up to 1.55 mm. This capability doesn't just seal the surface; it restores the material's compressive strength and durability, making it a more robust and long-lasting structure. The research has explored various techniques for adding bacteria, concluding that the method of incorporation is critical. Encapsulating the bacteria in protective carriers, such as expanded perlite or recycled glass, has proven to be the most effective strategy. This protective "house" defends bacteria from the severe alkalinity of the concrete, ensuring they remain dormant and ready to spring into action when a crack appears. Gupta Souradeep et.al the key healing process, according to the article, is Microbial Induced Carbonate Precipitation

(MICP). Bacteria present in concrete produce calcium carbonate (CaCO_3) to seal micro-cracks. This is considered an environmentally friendly and autonomous method. The authors emphasize four critical variables that influence the effectiveness of this bacterial self-healing: encapsulation, bacterial survival, impact on concrete, and healing ability. Ali Raza et al. The paper focuses on Microbially Induced Calcium Carbonate Precipitation (MICP) as the main mechanism. It specifically uses the bacterium *Bacillus pumilus* along with a nutrient source (calcium lactate) to initiate this process. Bacterial activity causes calcium carbonate to form, sealing gaps and densifying the concrete.. Shoib Wani et al. The study found that there is an optimal concentration for each bacterial species to be effective. For *Bacillus megaterium*, the best concentration was 10^9 CFU/mL, while for *Bacillus sphaericus*, it was 10^5 CFU/mL. The self-healing process was effective for narrow cracks, with the best results (up to 92% repair) observed for cracks between 0.1 and 0.3 mm wide. The healing efficiency decreased for cracks wider than 0.8 mm. Mohamed Alazhari et al. The authors' key contribution is their method for implementing the healing agents. They used coated expanded perlite as a carrier, but crucially, they separated the bacterial spores from the nutrients by encapsulating them in two different components. The aim was to prevent the bacteria from germinating and producing healing agents prematurely during the concrete mixing process.

Specimen And Material

Researchers studied, the phenomenon about the sample and cubes were used, firstly the cubes without bacteria and the second one is the cube with bacteria were casted. Taking the cube of size 150x150x150mm, cylinder of size 150 ϕ x 300mm with add mixture of cement, sand and aggregate ration is grade M25. Concrete mix were prepared properly and the concrete cubes and cylinder were casted. After the curing process various test are carried in the cubes and cylinder i.e. compressive strength test, Split tensile strength test, tensile strength test. Other literature paper also explain the about the cracking process that is the minimum crack can heal is 0.3mm and the maximum crack can heal is up to 1mm-1.55mm. The controlled cracking and healing methodology is used to study the concrete's bacterially-induced self-healing capabilities. The method used are 1. Casting of cube specimens with pre-induced cracks. 2. Observation and tracking of crack healing over a set time period. 3. Assessment of healing performance based in reduction in crack width. 4. Measurement of healing efficiency using image analysis techniques and microscopy. 5. Statistical analysis was conducted to evaluate the relationship between healing time and crack size. Crack healing typically began around three weeks after crack formation, with full healing observed within 21 to 30 days.

Author Name	Bacteria Used	Various Tests Conducted	Key Finding and Result
Elshazly et al. (2025)	<i>Bacillus megaterium</i> , <i>Bacillus sphaericus</i>	Compressive & flexural strength, SEM, EDS, XRD	At room and freezing temperatures (24°C and 0°C), <i>Bacillus megaterium</i> and <i>Bacillus sphaericus</i> (at 2.5%) showed complete crack healing (100%) and improved mechanical strength. At sub-zero temperatures (-16°C), only <i>B. megaterium</i> remained active with a healing efficiency of 38.37%, highlighting its suitability for cold climates.
Justo-Reinoso et al. (2023)	Non-ureolytic bacterial endospores	Life Cycle Assessment (LCA)	According to the life cycle evaluation of bacteria-based self-healing concrete (BBSHC), the environmental effect of its manufacture is 85% higher because of the additional materials used, its selective use in reinforced concrete structures can reduce non-structural steel and improve sustainability by up to 50%, leading to CO ₂ savings.
Raza & Khushnood (2022)	<i>Bacillus pumilus</i>	Digital image processing, Permeability, SEM, EDX, XRD	Using <i>Bacillus pumilus</i> with calcium lactate, 99–100% healing was achieved for cracks ranging between 0.29–1.55 mm. The technique, verified through digital image processing and SEM-EDX,

			also resulted in enhanced water tightness, recovered compressive strength, and permeability improvements comparable to traditional methods.
Soleimanbeigi et al. (2025)	Sporosarcina ureae	Compressive strength, Flexural strength, Water absorption, SEM, XRD, FT-IR	The integration of <i>Sporosarcina ureae</i> in concrete—both directly and encapsulated—along with silica fume, led to complete healing of small cracks (≤ 0.3 mm) and significant healing of larger ones (0.3–1.0 mm). Mechanical strength, shrinkage resistance, and water absorption were also improved, with microstructural analysis confirming CaCO_3 deposition.
Javeed et al. (2024)	<i>Bacillus aerius</i> , <i>B. subtilis</i> , <i>B. acetophenoni</i> , <i>B. odysseyi</i> , <i>Sporosarcina pasteurii</i>	Compressive strength, Flexural strength, Splitting tensile strength	Multiple <i>Bacillus</i> strains (<i>B. aerius</i> , <i>B. subtilis</i> , <i>B. acetophenoni</i> , <i>B. odysseyi</i> , <i>S. pasteurii</i>) enhanced compressive, tensile, and flexural strength by up to 42.8%, 35.2%, and 29.1% respectively. Results show that bacterial concentration and environmental conditions like pH and temperature are critical for optimal self-healing outcomes.
Wong et al. (2024)	Multiple strains including fungi	Review of mechanisms, encapsulation, field performance	This review found that combining bacteria and fungi in concrete could yield robust self-healing systems. It emphasized the importance of microbial viability, encapsulation techniques, and environmental conditions. Encapsulation improves delivery but faces challenges in large-scale use. Fungi offer promise due to better durability in extreme environments.
Shaheen et al. (2022, cited by Raza et al.)	<i>Bacillus subtilis</i> , <i>Bacillus pumilus</i>	pH tolerance, CaCO_3 precipitation efficiency, alkaline resistance	Alkaliphilic strains like <i>B. pumilus</i> show effective calcite formation at high pH, indicating strong suitability for concrete applications.

Research Gap

1. One of the most significant materials for construction, concrete is subjected to rapid deterioration and cracking, which may threaten structural integrity and necessitate costly maintenance or repairs. Conventional repair techniques are frequently time-consuming, labour-intensive, and only offer short-term respite. The creation of bacteria-based self-healing concrete has become a novel and environmentally friendly solution in recent years, with the potential for autonomously heal cracks, increase durability, and prolong the life of structures.
2. There is little knowledge about which bacterial strains work best and at what doses to maximize self-healing effectiveness.
3. The influence of external parameters such as humidity, temperature, and pH on bacterial survival and their ability to induce self-healing

in concrete. Healing efficiency is not yet fully established.

4. There is a lack of robust predictive models capable of accurately forecasting the mechanical behaviour and service life extension of concrete that heals spontaneously by utilizing bacteria.
5. Insufficient experimental data are available on bacterial activity's influence on critical mechanical properties, including tensile strength, stiffness, and ductility.
6. Further investigation is required to understand how bacterial-induced mineral precipitation influences concrete's microstructure, long-term durability, and resistance to aggressive environments.
7. Currently, no standardized testing protocols or regulatory

Conclusion

Evaluating concrete's self-healing potential in real-world constructions is crucial to assure safety, resilience, and longer service life. While concrete possesses a natural ability, known as autogenous healing, to seal micro-cracks, this phenomenon is limited to very fine cracks and is highly dependent on external conditions such as humidity and temperature. Research indicates that exposure to water accelerates the healing process, with immersion environments demonstrating greater effectiveness.

The integration of bacteria into concrete presents a breakthrough solution by overcoming the shortcomings of natural healing. Bacteria-based self-healing concrete offers significant advantages, including enhanced durability, longer structural lifespan, reduced maintenance requirements, and improved sustainability. This novel technique has the potential to transform the building industry by providing infrastructure that is not only stronger and more lasting, but also more ecologically friendly.

References

Yan Wong , Joyabrata Mal , Anna Sandak , Lijun Luo, Jianxiong Jian, Nirakar Pradhan, Advances in microbial self-healing concrete: A critical review of mechanisms, developments, and future directions, *Science of The Total Environment*, Volume 947, 15 October 2024, 174553.

Yasmeena Javeed, Yingxin Goh, Kim Hung Mo, Soon Poh Yap, Bey Fen Leo, Microbial self-healing in concrete: A comprehensive exploration of bacterial viability, implementation techniques, and mechanical properties, *Journal of Materials Research and Technology*, Volume 29, March–April 2024, Pages 2376-2395.

Alireza Soleimanbeigi, Parham Hayati, Jafar Sobhani, Parvaneh Saffarian, Synergistic effects of *Sporosarcina ureae* and silica fume on self-healing and plastic shrinkage cracks in bio-green concrete pavement, Synergistic effects of *Sporosarcina ureae* and silica fume on self-healing and plastic shrinkage cracks in bio-green concrete pavement, *Results in Engineering*, Volume 26, June 2025, 105526.

Hesam Doostkami, Javier de Jesús Estacio Cumberbatch, Sidiclei Formagini, Pedro Serna, Marta Roig-Flores, Self-healing capability of conventional, high-performance, and Ultra High-Performance Concrete with commercial bacteria characterized by means of water and chloride penetration, *Construction and Building Materials*, Volume 401, 19 October 2023, 132903.

Ismael Justo-Reinoso, Noemi Arena, Bianca J. Reeksting, Susanne Gebhard, Kevin Paine, Bacteria-based self-healing concrete– A life cycle assessment perspective, *Developments in the Built Environment*, Volume 16, December 2023, 100244.

Muhammad Arslan Ahmad, Jinlong Zhang , Bing Liu , Xie Guohao , Tan Xiaoyi , Gu Haoying, Song Changjie , Luo Runhao , Xie Xiaona, Li Weilin, Rong Huang, Tan Peiwen, Xu Deng, Synergistic effect of composite bacteria on self-healing process of concrete crack, *Case Studies in Construction Materials*, Volume 20, July 2024, e03028.

Mahmoud A. Elshazly , Ahmed A. Elakhras , Ahmed A. Elshami, Seleem S.E. Ahmad, Mohamed A.R. Elmahdy, Investigating the effectiveness of a bacterial self-healing mechanism for repairing cracks in sustainable cement mortar at low temperatures, *Results in Engineering*, Volume 25, March 2025, 103907.

Ricardo Hungria , Marwa M. Hassan , Momen Mousa, Effects of hydrogel-encapsulated bacteria on the healing efficiency and compressive strength of concrete, *Journal of Road Engineering*, Volume 3, Issue 2, June 2023, Pages 156-170.

M. Omar Osta, Faisal Mukhtar , Effect of bacteria on uncracked concrete mechanical properties correlated with damage self-healing efficiency – A critical review, *Developments in the Built Environment*, Volume 17, March 2024, 100301.

Mohamed Alazhari a, Trupti Sharma b, Andrew Heath a, Richard Cooper b, Kevin Paine (Application of expanded perlite encapsulated bacteria and growth media For self-healing concrete) Volume 160, 30 January 2018, Pages 610-619.

Lei V. Zhang , Moncef L. Nehdi , Ahmed R. Suleiman, Malihe Mehdizadeh Allaf , Manguang Gan (Crack self-healing in bio-green concrete) Volume 227, 15 December 2021, 109397.

Manpreet Bagga, Is Kunamineni Vijay , Meena Murmu, Shirish V. Deo (Bacteria based self-healing concrete – A review) Volume 152, 15 October 2017, Pages 1008-1014.

Muhammad Khubaib Akhtar a, Maria Kanwal, Assessment of mechanical attributes and microstructural densification of self-healing recycled coarse aggregate concrete using various bacterial immobilizers. *Journal of*

Building Engineering, volume 69, Page 89, 15 June 2023.

Jirapa Intarasoontron, Wiboonluk Pungrasmi, Evaluation of Microencapsulation Techniques for MICP Bacterial Spores Applied in Self-Healing Concrete. Construction and Building Materials, volume 302, sci, 4 October 2023.

Zinab Helal, Hani Salim, Seleem S.E. Ahmad, Hesham Elemam, Ahmed I.H. Mohamed, Mohamed A.R (Sustainable bacteria-based self-healing steel fiber reinforced concrete) Volume 20, July 2024, e03389.

Rubaiya Rumman, Ahmed Bediwy, M. Shahria Alam Development of self-healing system for concrete with selective heating around crack. Case Studies in construction materials, volume 20, July 2024.

Shan He, Masi Nuri, Henk M. Jonkers, Mladena Luković, Erik Schlangen, Structural behaviour of reinforced concrete beams with self-healing cover zone as lost formwork. Developments in the Built Environment, volume 18, page 100, April 2024.

S. Shivanshi, Gourab Chakraborti, K. Sandesh Upadhyaya, N. Kannan, A study on bacterial self-healing concrete encapsulated in lightweight expanded clay aggregates. Materialstoday; Proceedings, 3 April 2023.

Sailong Hou, Shoib Wani ,Michał Jan Gęca ,Thirumalini Selvaraj ,T. Shanmuga Priya (Assessing the influence of Bacillus megaterium and Bacillus sphaericus in cementitious materials: Promoting sustainability towards strength, durability and crack repair) Volume 15, Issue 6, June 2024, 102748.

Vanessa Giaretton Cappellesso, Tim Van Mullem, Elke Gruyaert, Kim Van Tittelboom, Nele De Belie, Self-healing concrete with a bacteria-based or crystalline admixture as healing agent to prevent chloride ingress and corrosion in a marine environment. Developments in the Built Environment, volume 19, October 2024.

Elke Gruyaert, Kim Van Tittelboom, Nele De Belie, Self-healing capability of concrete with crystalline admixtures in different environments. Oct. 2024.

Iman Abavisani, Omid Rezaifar, Ali Kheyroddin, Efficient approaches to autogenous and autonomous self-healing concrete: a review. Magazine of Concrete Research, volume 75, page 1051-1079, 4 July 2023.

M. Omar Osta, Faisal Mukhta, Effect of bacteria on uncracked concrete mechanical properties correlated with damage self-healing efficiency – A critical review. Developments in the Built Environment, volume 17, march 2024.

M. Omar Osta, Faisal Mukhtar, Effect of bacteria on uncracked concrete mechanical properties correlated with damage self-healing efficiency – A critical review. Developments in the Built Environment, volume 17, March 2024.

Guoqing Wang, Liang Zhang, Chenjia Xu, Shujia Zhang, Analysis of factor affecting the stability of large-span cable-braced timber gridshells. Devolpments in the Built Environment, volume 17, March 2024.

Pui Yan Wong, Joyabrata Mal, Anna Sandak, Self-healing concrete based on different bacteria: a review. Science of The Total Environment, volume 947, 15 October 2024.

Jae-In Lee, Se-Jin Choi, Compressive strength, chloride-ion-penetration resistance, and crack-recovery properties of self-healing cement composites containing cementitious material capsules and blast-furnace-slag aggregates. Journal of CO2 Utilization, volume 86, August 2024.

Sankaran Deeba, Arun Kumar Ammasi, Self-healing of high strength concrete after deterioration by freeze/thaw, Self-healing characterization of engineered cementitious composite materials, Ceramic Processing Research Review on the self-healing concrete-approach and evaluation technique. Case Studies in Construction Materials, volume 20, July 2024.

Sudha Uthaman, Vinita Vishwakarma, Remediation of concrete using microorganisms. Journal of Building Engineering, volume 79, 15 November 2023.

Hayeon Kim, H.M. Son, Joonho Seo, H.K. Lee (Recent advances in microbial viability and self-healing performance in bacterial-based cementitious materials: A review) Volume 274, 8 March 2021, 122094.

J.Y. Wang, D. Snoeck, W. Verstraete, Application of hydrogel encapsulated carbonate precipitating bacteria for approaching a realistic self-healing in concrete. Construction and Building Materials, volume 68, pages 110-119, 15 October 2024.

Yasmina Shields, Davide diSumma, Nicolas Ospitia, Gontran Herrier, Erik Schlangen, Tony Jeffers

on, Kim Van Tittelbom, First large scale application with self-healing concrete in Belgium: analysis of the laboratory control tests.

Journal of Building Engineering, volume 95, page 110, 15 October 2024.