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# Self-Healing Concrete

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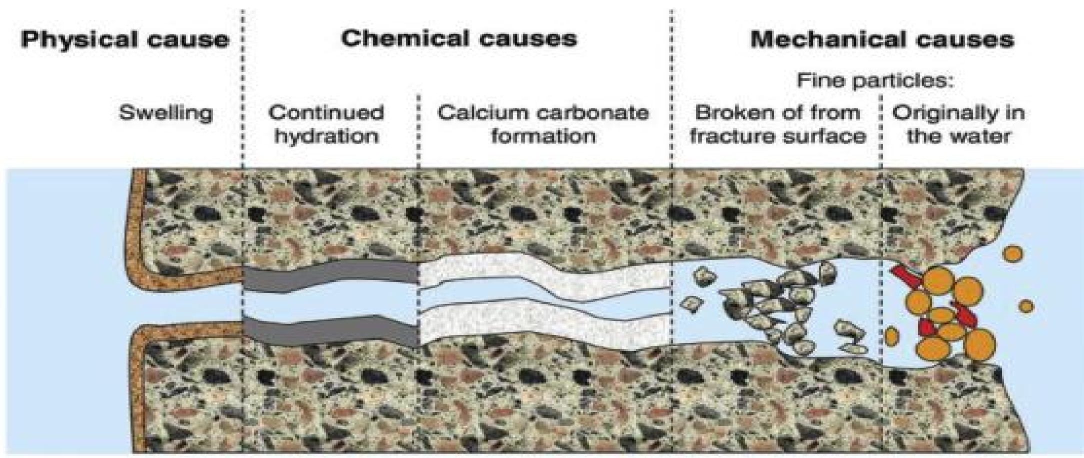
**Abstract:** *Many concrete elements crack without there being any concern; some are even designed to crack. But for some elements, the avoidance, repair, or self-healing of cracks is of benefit. This is particularly true when steel reinforcement is present, such as in much large-scale infrastructure. In such concrete, the presence of unplanned cracks may raise the risk of corrosion of the reinforcement and subsequent deterioration of the concrete. Traditional concrete, if in contact with water, has a mechanism for self-healing called autogenous healing. It has this capacity because un-hydrated cement remains present in the matrix. When water contacts the un-hydrated cement, further hydration occurs and 'heals' the crack. Self-healing concretes reduce the need to detect and repair cracks and are one strategy to address corrosion risk. This has social, economic, and environmental benefits, as overcoming/reducing the need for maintenance and/or increasing longevity reduces disruption, as well as the cost and use of materials.*

**Keywords:** self-healing, concrete, autogenous, autonomous

## I. INTRODUCTION




Self-healing concrete, also known as self-repairing concrete, is a type of concrete that can fix cracks on its own. It can seal cracks and partially or fully restore the mechanical properties of structural elements.Self-healing concrete is mostly defined as the ability of concrete to repair its cracks autogenously or autonomously. It is also called self-repairing concrete. Cracks in concrete are a common phenomenon due to its relatively low tensile strength. Durability of concrete is impaired by these cracks since they provide an easy path for the transportation of liquids and gases that potentially contain harmful substances. If microcracks grow and reach the reinforcement, not only the concrete itself may be attacked, but also the reinforcement steel bars will be corroded. Therefore, it is important to control the crack width and to heal the cracks as soon as possible. Self-healing of cracks in concrete would contribute to a longer service life of concrete structures and would make the material not only more durable but also more sustainable. Self-healing is actually an old and well-known phenomenon for concrete as it possesses some natural autogenous healing properties.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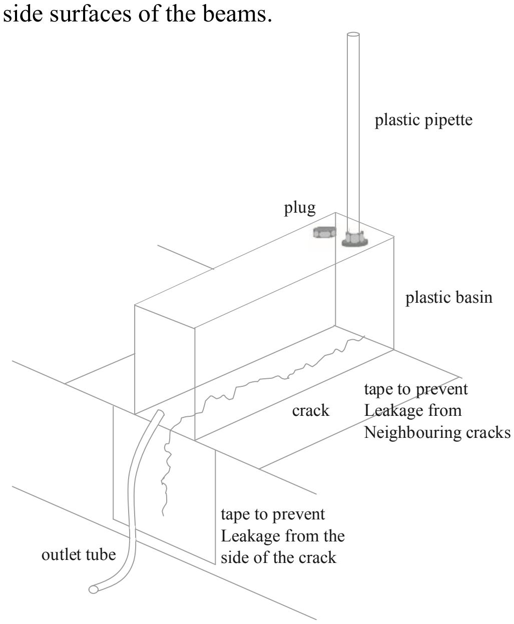
Due to ongoing hydration of clinker minerals or carbonation of calcium hydroxide ($Ca(OH)_2$), cracks may heal after some time. However, autogenous healing is limited to small cracks and is only effective when water is available, thus making it difficult to control. Nonetheless, concrete may be modified to build in autonomous crack healing. Several researchers started to investigate this topic. Many self-healing approaches are proposed. They mainly include autogenous self-healing method, capsule-based self-healing method, vascular self-healing method, electrode position self-healing method, microbial self-healing method, and self-healing method through embedding shape memory alloys (SMAs).

## II. METHODOLOGY

**(Improved) autogenous and autonomous crack repair**

For the beam with encapsulated polyurethane, crack creation triggered breakage of the capsules, release of the healing agent and subsequent crack repair. For the other self-healing approach under investigation, contact of the cracked concrete beam with water is needed in order to activate the healing mechanism. As contact with water also promotes autogenous healing, the natural mechanism of crack healing which is inherent to concrete, it was decided to bring all beams (REF, PU and SAP) in the same way in contact with water. In this way all beams would exhibit autogenous crack healing to some extent and this effect is filtered out when results are compared mutually. Bringing the beams in contact with water to obtain autogenous healing and to activate the approach with SAP, was done by spraying the beams with water four times a day during 1 min for a time span of 6 weeks (last 6 weeks within the 7 weeks healing period). Therefore, a plastic tube containing holes divided over the complete length of the tube was positioned in the middle above each of the beams. At certaintimes, water was pumped through the tubes so it was sprayed on the top and subsequently flowing along the side surfaces of the beams.




**Detection of healing activation by using acoustic emission hit activity**

As previously done on small-scale test samples, activation of the self-healing approach based on encapsulated polyurethane was confirmed by means of acoustic emission analysis. Based on an energy-analysis, a discrimination could be made between hits obtained due to crack formation and capsule breakage. Every time a capsule breaks or a crack forms, each of the AE transducers captures a waveform, represented by a set of descriptors which were analyzed in this study. Thereby, the AE hit's energy, derived from the area under the waveform shape, is indicative to the released fracture energy and its magnitude and general characteristics are indicators of the damage mode. High energy hits corresponded to discrete events of capsule breakage and were well differentiated from the rest of the AE events.

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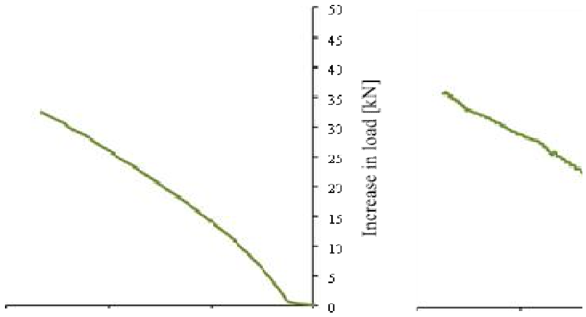
Only in the case of capsule breakage, the energy received by all the eight transducers placed at the surface of the beam exhibited values ranging from 2000 to 12,000 depending on the receiver's test. It appears that the healing activation protocol based on AE energy analysis can also be applied on real-scale concrete structures.



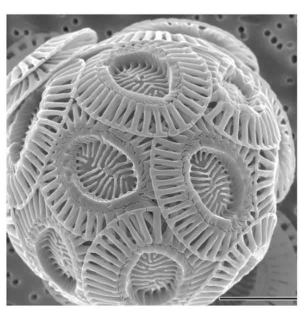

Deflection [mm] Deflection [mm] Deflection [mm]

### III. LITERATURE REVIEW

The drive towards sustainability in the construction industry has led to innovative approaches that not only enhance the durability of concrete but also aim to reduce carbon emissions. Several self-healing concrete technologies specifically target both these aspects of self-repair and carbon reduction [5]. A few notable examples and case studies were analyzed, starting with current self-healing mechanisms. "Microbially induced calcium carbonate precipitation (MICP) is one of the low-toxic crack repair methods. The biomediated calcium carbonate (CaCO3) is produced due to the reaction between urease producing bacteria with nutrients and urea. The ureolytic bacteria combines with the urea during the reaction process, converting the urea into the ammonium and carbonate ions, and the precipitation of CaCO3 is associated with calcium salt addition [6]". MICP is an innovative approach for continuously repairing micro-cracks in concrete, improving its durability, and thus reducing maintenance costs [7]. The study Nasser and team carried out examined the impact of bacterial addition over 3–120 days. The results showed that, at all ages tested, the volume of permeable voids decreased in all treated samples compared to the control group. As a result, the compressive strength increased due to decreased porosity and permeability [7]

Another technology reviewed was the use of biogenic limestone. Biogenic limestone employs photosynthetic bacteria to produce limestone within the concrete matrix. Like MICP, the bacteria can capture and convert $CO_2$ into calcium carbonate, a process that naturally heals cracks and strengthens the concrete.

As stated previously, to make Portland cement, limestone is typically extracted from quarries and then burned at high temperatures. This process releases a significant amount of carbon dioxide into the atmosphere. However, a recent research study has found that using biologically grown limestone, created through photosynthesis by certain species of calcareous microalgae, similar to growing coral reefs, can replace the need for quarried limestone. This biologically grown limestone, through cultivation by coccolithophores, is a net carbon-neutral alternative to traditional limestone. In other words, the amount of carbon dioxide released during manufacturing is equal to the amount captured by the microalgae during photosynthesis

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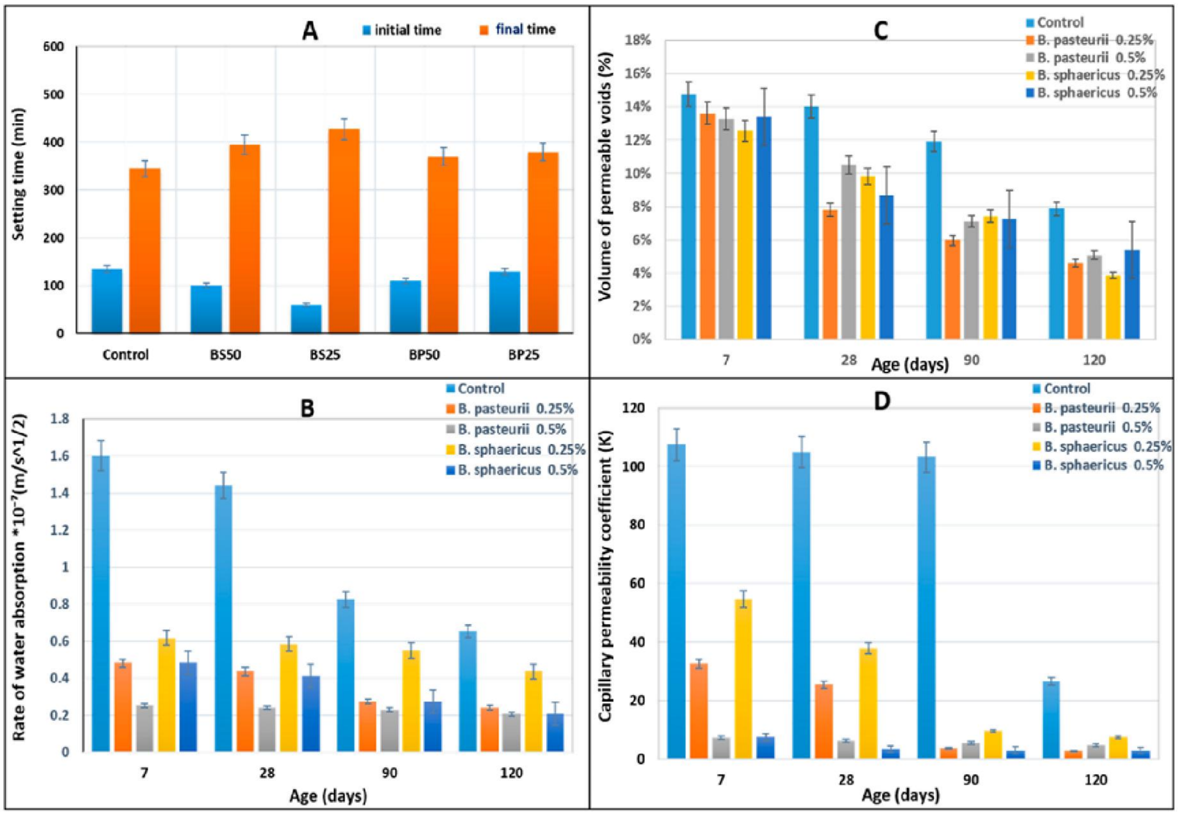
## IV. RESULTS AND DISCUSSION

Here, we took 2 different bacteria along with 2 different ratios of the bacteria used in the concrete, B. pasteurii 0.25%, B. pasteurii 0.5%, B.sphaericus 0.25% and B.shaericus 0.5%

Results are as follows;




**(A) Initial and final setting times; (B) rates of water absorption; (C) volumes of permeable voids (%); (D) capillary permeabilities for bacterial and control mortar samples using 0.25% and 0.50% concentrations of cement weight.**

The study that our team carried out examined the impact of bacterial addition over 3–120 days. The results showed that, at all ages tested, the volume of permeable voids decreased in all treated samples compared to the control group. As a result, the compressive strength increased due to decreased porosity and permeability.

Regarding carbon reduction, MICP uses bacteria that precipitate calcite naturally when activated by water ingress in cracks. The calcite precipitation not only heals the cracks but can also sequester carbon dioxide during the formation of calcium carbonate. This biological process turns concrete into a carbon vessel, offsetting some carbon emissions associated with cement production. Additionally, the concrete's durability is enhanced, and its service life is extended, reducing the environmental impact of frequent repairs and replacements. Critically speaking, "this pathway hasa few drawbacks, such as the emission of nitrogen oxide in the atmosphere and an increased risk of salt damage by conversion to nitric acid in concrete due to the production of an excessive amount of ammonia in the matrix. To deal with this drawback of excessive ammonium ion production, few researchers have proposed the idea of metabolic conversion of organic compound (organic acid salt) to calcium carbonate. When organic acids (such as calcium lactate) are aerobically oxidized, carbon dioxide is generated in an alkaline atmosphere, which is converted to $CaCO_3$ in the presence of $Ca^{2+}$. Compared to the ureolysis pathway, this metabolic conversion is more suitable, with respect to

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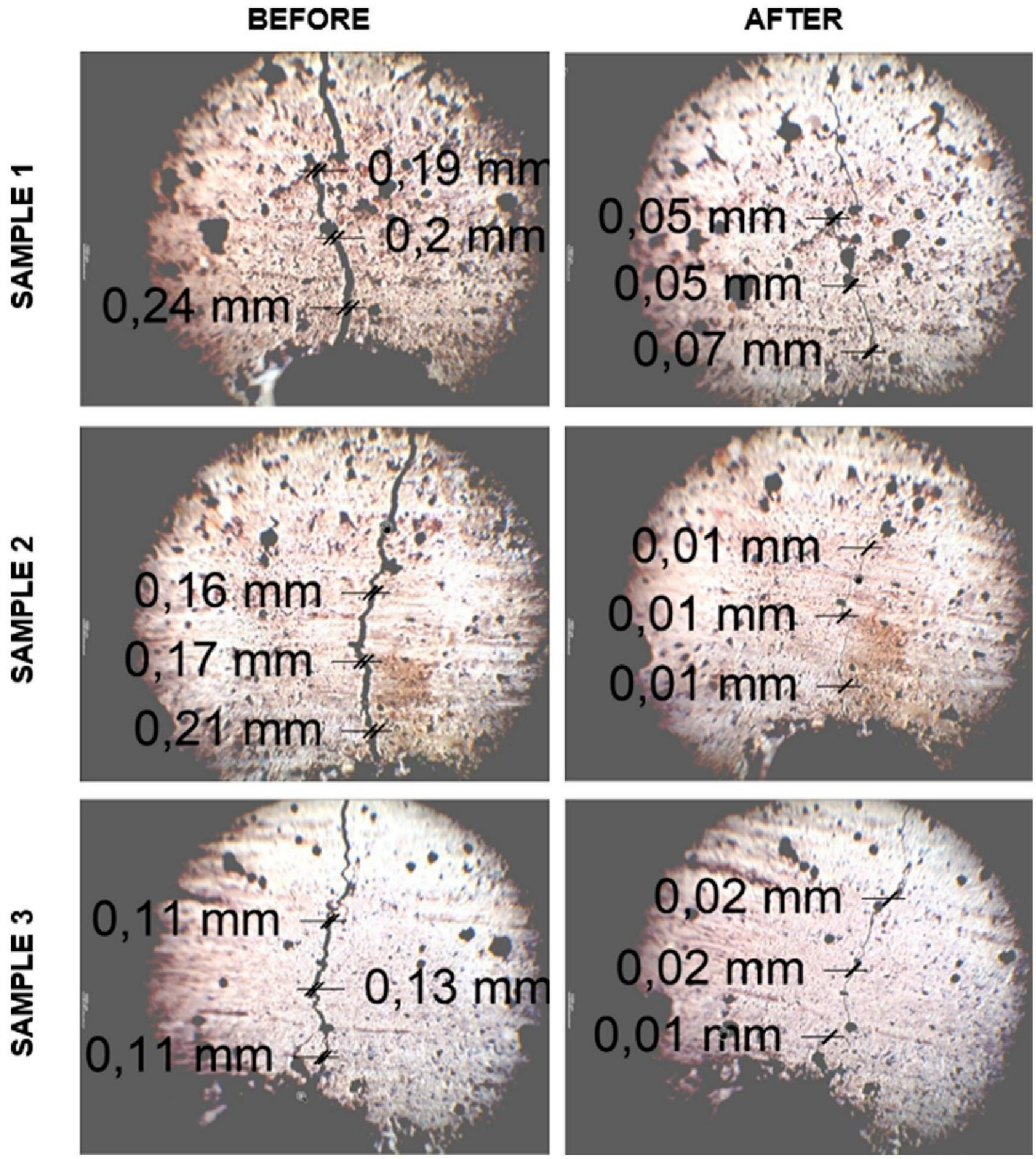
compatibility with concrete matrix composition, protection of reinforcement bars, and most importantly high production of $CaCO_3$ but no ammonium




## V. CONCLUSION

In conclusion, current research and innovation in self-healing concrete have shown that it increases the life span and durability of structures and infrastructure in our built environment. Advancements in material science and engineering have impacted the cement manufacturing process and how we process industrial waste by-products, incorporating materials like copper slag to replace natural river sand and using bacteria to proliferate calcium carbonate to mend cracks and increase strength.

Innovations in self-healing concrete formulation and application have advanced with the research of bio-based agents like bacteria and fungi, microencapsulation techniques, and novel materials such as shape-memory polymers. These developments not only enhance the structural integrity and longevity of concrete structures but also contribute to reducing the maintenance costs and environmental impacts associated with traditional concrete repair methods. Several challenges must be addressed to facilitate the broader application and commercialization of self-healing concrete technologies. These include optimizing the efficiency and reliability of the self-healing mechanisms under various environmental conditions, scaling up production processes while maintaining cost-effectiveness, and gaining regulatory approval and market acceptance. Future research should continue to focus on these areas, aiming to refine the performance characteristics of self-healing concrete and expand its applicability across different climates and construction types.

As the construction industry moves towards more eco-friendly and resilient materials, self-healing concrete is critical to future development. Embracing this innovative material can lead to more sustainable urban environments, demonstrating a commitment to advancing construction technology while addressing the pressing needs of our infrastructure and the environment.

## VI. ACKNOWLEDGEMENTS

It gives me immense pleasure to present my Project Report on “Self-healing/Immortal concrete” and to express my deep regards towards those who have offered their valuable time and guidance in my hour of need.

I would like to express my sincere and whole-hearted thanks to my project guide Mr. Vipul Ranjane and Head of Department Mrs. Deepa Nair for contributing their valuable time, knowledge, experience and guidance in making this project successfully done.

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This report helped me to learn new techniques, developments taking place in Civil Engineering and to revise some previous concepts. Indeed, I perceive this opportunity as a milestone in my career development.

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## REFERENCES

[1] Rama Mohan Rao P. “Properties of Bacterial -based Self-Healing Concrete”. Volume :9 Issue:2016.

[2] Suyug S. Pawar “Bacteria based Self-Healing Concrete”. Volume: 5 Issue: 3 March 2003

[3] S.R. White, N.R. Sottos, P.H. Geubelle, J.S. Moore, M.R. Kessler, S.R. Sriram, E.N. Brown, S. Viswanathan, Autonomic healing of polymer composites, Nature 409 (2001) 794–797.

[4] C. Edvardsen, Water permeability and autogenous healing of cracks in concrete, ACI Mater. J. 96 (4) (1999) 448–454.

[4] H.-W. Reinhardt, M. Jooss, Permeability and self-healing of cracked concrete as a function of temperature and crack width, Cem. Concr. Res. 33 (7) (2003) 981– 985.

[5] V. Li, E.H. Yang, Self healing in concrete materials, in: S. Van der Zwaag (Ed.), Self Healing Materials: An Alternative Approach to 20 Centuries of Materials Science, Springer Science, Dordrecht, The Netherlands, 2007, p. 388.

[6] A. Jefferson, C. Joseph, R. Lark, B. Isaacs, S. Dunn, B. Weager, A new system for crack closure of cementitious materials using shrinkable polymers, Cem. Concr. Res. 40 (5) (2010) 795–801.

[7] H.X. Dennis Lee, H.S. Wong, N. Buenfeld, Self-sealing cement-based materials using superabsorbent polymers, in: O.M. Jensen, M.T. Hasholt, S. Laustsen (Eds.), International RILEM Conference on Use of Superabsorbent Polymers and Other New Additives in Concrete, RILEM Publications s.a.r.l, Lyngby, Denmark, 2010, pp 171–178..