Study and Development of Self-Healing Concrete Using Bacteria and Calcium Lactate

Vivek Vilas Dandi[1], Sanket Sanjay Kawdekar[2]

[1] *Lecturer, Department of Civil Engineering, Manav School of Polytechnic, Vyala, Akola, Maharashtra, India*

[2] *Student, Department of Civil Engineering, Manav School of Engineering and Technology, Vyala, Akola, Maharashtra, India*

***Abstract*—Concrete is widely used in civil engineering infrastructure, but cracking is one of its major durability problems. Cracks may permit the entry of water and aggressive agents and can increase maintenance requirements. Self-healing concrete is an innovative material designed to seal or repair cracks without conventional manual intervention. This paper presents a preliminary study and development of bacterial self-healing concrete using bacteria and calcium lactate as the healing system. The work is based on a diploma project in which cement, fine aggregate, coarse aggregate, water, bacteria and calcium lactate were used. The experimental procedure involved preparation of the bacterial solution, concrete mixing, specimen casting, curing, controlled crack formation and observation of crack healing. The source project reports that the induced cracks were reduced after the healing period and that durability was improved compared with conventional concrete. The study discusses the mechanism, materials, methodology, advantages, limitations, applications, cost and future scope of bacterial self-healing concrete. Since the source project does not provide numerical crack-width, healing-percentage, strength or statistical data, the results are reported qualitatively rather than by invented numerical values. The study indicates that bacterial self-healing concrete has promising potential for durable and sustainable construction, while further controlled experimental testing is required for quantitative validation.**

***Index Terms*—Self-healing concrete, bacterial concrete, bacteria, calcium lactate, crack healing, durability, sustainable construction.**

I. INTRODUCTION

Concrete is one of the most important and extensively used construction materials because of its strength, versatility, availability and relatively low cost. However, concrete is not completely free from deterioration. Cracks can develop due to shrinkage, thermal effects, environmental exposure, loading and other factors. Once cracks are formed, water and harmful substances can penetrate the concrete and may accelerate deterioration of the concrete matrix and reinforcement.

Conventional crack repair normally requires inspection, surface preparation, repair materials and skilled labour. Repeated maintenance can increase the cost of infrastructure and may interrupt its service. Self-healing concrete provides an alternative approach in which cracks can be sealed through an internal healing mechanism.

Bacterial self-healing concrete is a form of engineered self-healing concrete in which suitable microorganisms are incorporated into the cementitious material. When cracks form and moisture becomes available, bacterial activity can contribute to mineral precipitation and crack sealing. Earlier research has demonstrated the feasibility of bacteria-based mineral formation and crack plugging in cementitious materials. [1–4]

The present study is based on the uploaded project report entitled "Study and Development of Self-Healing Concrete." The report identifies bacteria and calcium lactate as components of the proposed healing system and describes concrete cube casting, curing, crack formation and observation of healing. The report concludes that the cracks were reduced and durability was improved compared with conventional concrete. filecite turn0file0

II. PROBLEM STATEMENT

Cracks in concrete are a common cause of reduced durability and increased maintenance. Conventional repair methods require external intervention and may be difficult or expensive in inaccessible locations. Therefore, there is a need for materials that can autonomously seal small cracks and reduce the rate of deterioration. The present work investigates the feasibility of bacterial self-healing concrete using bacteria and calcium lactate.

III. AIM

To study and develop self-healing concrete using bacteria and calcium lactate and to observe its ability to reduce cracks after controlled crack formation.

IV. OBJECTIVES

- To study the concept and mechanism of self-healing concrete.
- To understand the role of bacteria in crack healing.
- To prepare concrete incorporating bacteria and calcium lactate.
- To cast and cure concrete specimens and induce cracks.
- To observe the healing of induced cracks.
- To study the advantages, limitations and applications of bacterial self-healing concrete.
- To identify future experimental requirements for quantitative validation.

V. LITERATURE REVIEW

Jonkers et al. investigated the use of bacteria as a self-healing agent for sustainable concrete and reported that suitable bacterial systems could produce crack-plugging minerals. Their work established an important scientific basis for bacteria-based self-healing concrete. [1]

Jonkers and Schlangen discussed bacteria-based self-healing concrete and the potential of bacterial mineral formation to seal cracks and reduce permeability. [2]

Wiktor and Jonkers reviewed the development of bacteria-based concrete and highlighted the importance of bacterial selection, viability, nutrients and protection of the healing agent within concrete. [3]

Mors and Jonkers evaluated bacteria-based self-healing concrete at demonstrator scale and discussed the transition from laboratory research toward practical application. [4]

The literature indicates that self-healing performance is affected by bacterial viability, nutrient availability, crack width, moisture, curing conditions and the method used to protect the bacterial agent. These factors should be controlled in future quantitative experiments.

VI. RESEARCH GAP

The project demonstrates the concept and reports qualitative crack reduction, but the available project report does not contain detailed numerical measurements. In particular, it does not specify the bacterial strain, bacterial concentration, calcium lactate dosage, concrete mix proportions, number and dimensions of specimens, initial crack widths, healing percentages, compressive-strength values or statistical analysis. □filecite□turn0file0□

Therefore, the major research gap is the need for a controlled experimental study that quantitatively compares bacterial self-healing concrete with conventional concrete using standardized measurements of strength, crack closure and durability.

VII. MATERIALS USED

Material	Purpose	Information available in source project
Cement	Binder	Used in concrete preparation
Fine aggregate	Filler and matrix component	Used in concrete preparation
Coarse aggregate	Concrete skeleton	Used in concrete preparation
Water	Hydration and workability	Used in mixing and curing
Bacteria	Biological healing agent	Bacterial solution used
Calcium lactate	Nutrient/healing component	Included in healing system

The source report lists these materials but does not give exact quantities or bacterial concentration. These values must be inserted from laboratory records if the authors have them. □filecite□turn0file0□

VIII. METHODOLOGY

The methodology follows the sequence documented in the project report.

- Preparation of the bacterial solution.
- Preparation of the concrete ingredients.
- Incorporation of bacteria and calcium lactate into the concrete system.
- Casting of concrete cube specimens.
- Curing of specimens.
- Induction of cracks after the appropriate curing stage.
- Exposure of cracked specimens to conditions suitable for healing.
- Observation and comparison of crack condition before and after the healing period.

The project report confirms that concrete cubes were cast, cracks were induced and healing was observed. □filecite□turn0file0□

IX. WORKING MECHANISM OF SELF-HEALING CONCRETE

The basic concept of bacterial self-healing is that microorganisms incorporated into concrete can remain inactive under unfavorable conditions and become active when water or moisture reaches a crack. Bacterial activity can contribute to mineral precipitation, which gradually fills or seals part of the crack. The resulting mineral deposition can reduce the effective crack opening and potentially reduce the movement of water through the crack. Published research has reported calcium-based mineral formation and crack-plugging in bacterial concrete. [1–4]

In the present project, calcium lactate is used as a component associated with the healing system. The source report does not provide biochemical measurements or mineralogical confirmation, so the exact reaction pathway and amount of precipitated mineral cannot be established from the available data. □filecite□turn0file0□

X. EXPERIMENTAL WORK

Concrete specimens were prepared using the listed materials and cast in cube form. After curing, cracks were induced in the specimens and the specimens were observed for self-healing. The source report describes the experimental work at a project level but does not provide specimen dimensions, exact mix proportions, crack-width measurements or detailed testing conditions. □filecite□turn0file0□

XI. RESULTS

The source project reports that cracks were reduced after the healing period and that durability was improved compared with conventional concrete. These findings are qualitative because numerical crack-width measurements and durability test results are not included in the uploaded report. □filecite□turn0file0□

Parameter	Reported observation	Numerical data in source
Crack formation	Cracks were induced in concrete specimens	Not reported
Crack healing	Visible reduction of cracks was observed	Not reported
Durability	Improvement was reported compared with conventional concrete	Not reported
Compressive strength	Not reported	Not available
Healing percentage	Not reported	Not available
Crack width	Not reported	Not available

XII. DISCUSSION

The observed reduction in cracks indicates the potential of the proposed bacterial healing system. This is consistent with published research showing that bacterial mineral precipitation can contribute to crack sealing in cementitious materials. [1–4]

The principal potential benefit is reduction in the need for frequent manual repair of small cracks. If cracks can be sealed internally, the ingress of water and aggressive substances may be reduced and durability may be improved. The project report identifies durability and reduced maintenance as important benefits. filecite turn0file0

However, the performance of bacterial concrete depends on several factors, including the selected microorganism, concentration, nutrient supply, crack characteristics and environmental conditions. The higher initial cost identified in the project report is another practical consideration. filecite turn0file0

The absence of numerical experimental data limits the strength of the present conclusion. A publishable experimental paper would be substantially improved by measuring crack width before healing and at fixed healing ages, testing mechanical properties and durability, and using replicate specimens with statistical analysis.

XIII. ADVANTAGES

- Potential for autonomous sealing of small cracks.
- Possible reduction in manual maintenance and repair.
- Potential improvement in durability.
- Potential reduction in water ingress through cracks.
- Useful for sustainable and long-service-life infrastructure.
- Potential application in difficult-to-access locations.

XIV. LIMITATIONS

- Higher initial cost than ordinary concrete may be possible.
- Bacterial survival in the concrete environment is an important technical issue.
- Healing depends on moisture and suitable environmental conditions.
- Performance depends on crack width and crack characteristics.
- Large-scale structural application requires additional validation.
- The present project lacks detailed quantitative experimental data.

XV. APPLICATIONS

The project report identifies bridges, buildings, tunnels and water-retaining structures as potential applications. filecite turn0file0 Other infrastructure exposed to moisture and difficult-to-access cracking may also be considered after adequate validation. Self-healing concrete should complement, rather than replace, proper structural design, detailing and durability provisions.

XVI. COST ESTIMATION

The project report gives an approximate project cost of Rs. 1,400. This value represents the reported student project cost and should not be interpreted as the commercial cost of producing structural bacterial concrete. Commercial cost assessment would require material quantities, bacterial production or procurement costs, laboratory processing, quality control, scale and lifecycle benefits. filecite turn0file0

XVII. STANDARDS AND DESIGN CONSIDERATIONS

The source project refers to IS 456:2000 and IS 10262:2019. For future experimental work, the concrete mix should be fully documented, including grade, cement properties, aggregate properties, water-cement ratio, workability, specimen dimensions and curing regime. The selected standards should be cited according to the exact edition and amendments used by the authors. filecite turn0file0

XVIII. FUTURE SCOPE

- Identify and report the bacterial species or strain used.
- Determine optimum bacterial concentration.
- Determine optimum calcium lactate dosage.
- Prepare control and bacterial concrete specimens with sufficient replicates.
- Measure initial crack width and crack closure using digital image analysis.
- Calculate crack-healing percentage at fixed ages.
- Perform compressive-strength testing before and after healing.
- Study water absorption, sorptivity or permeability.
- Study healing under different curing and moisture conditions.
- Perform microscopic or mineralogical analysis of healing products.
- Conduct lifecycle cost and environmental assessment.

• Investigate scale-up and field applications.

XIX. CONCLUSION

Self-healing concrete represents a promising approach for improving the durability and maintainability of concrete structures. The present study investigated a bacterial self-healing concrete system using bacteria and calcium lactate. According to the uploaded project report, concrete cubes were cast, cracks were induced and crack healing was observed. The report states that cracks were reduced and durability was improved compared with conventional concrete. □filecite□turn0file0□
The literature supports the feasibility of bacterial mineral formation and crack plugging in cementitious materials. [1–4] Nevertheless, the available project report does not contain sufficient numerical data to establish a quantitative improvement in strength, crack-healing percentage or durability. Therefore, the present work should be considered a preliminary study. Detailed controlled experiments with standardized measurements, replicate specimens and statistical analysis are recommended. With further development and validation, bacterial self-healing concrete may contribute to longer-lasting, lower-maintenance and more sustainable civil infrastructure.

ACKNOWLEDGEMENT

The authors acknowledge the support of the Department of Civil Engineering, Manav School of Polytechnic, Vyala, Akola, and Manav School of Engineering and Technology, Vyala, Akola, for academic and project-related support.

CONFLICT OF INTEREST

The authors declare that there is no known conflict of interest associated with this work.

DATA AVAILABILITY

The manuscript is based on the project report and experimental observations available to the authors. Detailed numerical datasets were not included in the source document. Any additional laboratory data should be verified and incorporated by the authors before final submission.

AUTHOR CONTRIBUTIONS

Vivek Vilas Dandi: project supervision, conceptualization, academic guidance, manuscript preparation and review. Sanket Sanjay Kawdekar: project execution, experimental work, observations and manuscript support. The final manuscript should be approved by both authors before submission.

EXPERIMENTAL PHOTOGRAPHS

Figure 1. Laboratory testing and observation of the concrete specimen using the testing apparatus.

Figure 2. Preparation and casting of concrete cube specimens in the laboratory.

Note: The photographs are supplied by the authors and are included as documentation of the project laboratory work. Specific specimen numbers, test values and dates should be added if available.

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