International Journal of
Concrete Technology

ISSN: 2456-8317
Volume 11, Issue 1, 2025
January–June
DOI (Journal): 10.37628/IJCT

https://journalspub.com/journal/ijct/

Effect of *Bacillus Subtilis* on Corrosion of Steel in Reinforced Cement Concrete

Sneha Gurav[1], Swaraj Shigvan[1], Rohit Chavan[1], Sanjiv Rahate[1], Rajesh Parade[2,*]

Abstract

Concrete is one of the most used building materials due to its cost- effectiveness, ease of availability, and versatility. It is the backbone of modern construction, being widely applied in infrastructure, residential, and commercial projects. However, it is particularly vulnerable to crack formation, which significantly reduces its service life. These cracks compromise structural integrity by allowing water ingress, which leads to the corrosion of reinforcing steel, eventually making the entire structure vulnerable to failure. Additionally, these pathways facilitate the entry of harmful substances, such as chlorides and sulfates, which further deteriorate the concrete matrix and accelerate structural degradation. To address this critical issue, the innovative technique of incorporating bacteria into concrete has been developed. Known as bacterial concrete, this method enhances properties, such as compressive strength, self-healing ability, increased durability, and reduced permeability. The bacteria, typically in liquid or powder form, are specifically selected for their ability to survive in harsh alkaline environments and remain dormant within the concrete matrix. Upon the occurrence of cracks and subsequent water ingress, these bacteria are activated, triggering a biological reaction. The bacteria metabolize nutrients, like calcium lactate and produces calcium carbonate (limestone), which fills the cracks and restores the structure's integrity. This process, known as Microbiologically Induced Calcite Precipitation (MICP), not only prevents harmful substances from penetrating the concrete but also delays the onset of steel corrosion, thereby significantly increasing the longevity of the structure. By consuming oxygen during the metabolic process, the bacteria further inhibit the corrosion of steel reinforcement, ensuring safer and more durable construction. Moreover, bacterial concrete reduces maintenance costs and environmental impact by minimizing the need for frequent repairs, making it an economically and ecologically sustainable option. As a groundbreaking advancement in the construction industry, bacterial concrete offers a promising solution to address the durability challenges associated with traditional concrete materials. Its ability to heal cracks autonomously and enhance structural resilience marks a significant step forward in the development of sustainable and high-performance building materials.

***Author for Correspondence**
Rajesh Parade
E-mail: rajesh.parade@vpmmpcoe.org

[1]Student, Department of Civil Engineering, VPM's Maharshi Parshuram College of Engineering (MPCOE), Velneshwar, Maharashtra, India
[2]Professor, Department of Civil Engineering, VPM's Maharshi Parshuram College of Engineering (MPCOE), Velneshwar, Maharashtra, India

Received Date: January 02, 2025
Accepted Date: January 13, 2025
Published Date: January 22, 2025

Citation: Sneha Gurav, Swaraj Shigvan, Rohit Chavan, Sanjiv Rahate, Rajesh Parade. Effect of *Bacillus Subtilis* on Corrosion of Steel in Reinforced Cement Concrete. International Journal of Concrete Technology. 2025; 11(1): 6–13p.

Keywords: Concrete, MICP, *Bacillus subtilis*, bacterial concrete, corrosion prevention

INTRODUCTION

Concrete is a primary building material widely used in construction due to its affordability, availability, and high compressive strength. Its versatility and ease of application make it a cornerstone of modern infrastructure, being utilized in everything from residential buildings to bridges and dams. However, despite its many advantages, concrete is inherently prone to crack formation, which poses significant challenges to its durability and longevity.

Cracks in concrete are not merely aesthetic concerns; they severely compromise its structural integrity. These cracks act as conduits for water and aggressive chemicals to penetrate the concrete matrix, leading to the corrosion of embedded steel reinforcements. Over time, this corrosion reduces the load-bearing capacity of the structure, increasing the risk of catastrophic failure. Additionally, freeze-thaw cycles, chemical attacks, and other environmental factors exacerbate the damage, further reducing the lifespan of concrete structures [1–4].

To address these critical issues, innovative solutions have been explored, one of which is bacterial concrete. Bacterial concrete represents a breakthrough in sustainable construction technology by leveraging biological processes to enhance concrete performance. This bio-engineered material incorporates specific strains of bacteria, such as *Bacillus subtilis*, into the concrete mix. These bacteria remain dormant during normal conditions but become activated when water enters through cracks [5–9].

Once activated, the bacteria metabolize nutrients, like calcium lactate in the presence of oxygen, producing insoluble calcium carbonate (limestone). This process, known as microbiologically induced calcite precipitation (MICP), fills and seals the cracks, restoring the concrete’s integrity. In addition to healing cracks, bacterial activity consumes oxygen, which is a critical factor in the corrosion of steel reinforcements.

Consequently, bacterial concrete not only repairs itself but also protects the embedded steel, significantly enhancing the durability and service life of the structure.

This innovative approach has the potential to revolutionize the construction industry by offering a sustainable, cost-effective, and efficient method to mitigate the challenges associated with traditional concrete [10–16].

OBJECTIVES

1. To study the impact of *Bacillus subtilis* on fresh and hardened concrete.
2. To analyze and compare the properties of conventional concrete with bacterial concrete.
3. To evaluate the effectiveness of bacterial concrete in preventing steel corrosion [17].

METHODOLOGY

The methodology for this study involves the following steps:

1. *Selection of Materials:* Standard concrete ingredients, including cement, aggregates, and water, along with *Bacillus subtilis* bacteria in either liquid or powder form.
2. *Preparation of Concrete Mix:* Mixing conventional and bacterial concrete with precise proportions.
3. *Testing on Fresh Concrete:* Workability tests, such as slump test and compaction factor test.
4. *Curing and Monitoring:* Curing of concrete samples in both water and calcium lactate solutions to activate bacterial activity.
5. *Mechanical Testing:* Conducting compressive strength, tensile strength, and flexural strength tests to evaluate performance.
6. *Durability Testing:* Assessing permeability, crack healing, and corrosion resistance in reinforced concrete [18].

MECHANISM OF BACTERIAL CONCRETE

Bacterial concrete operates on the principle of MICP. This process involves the following steps:

1. *Activation of Bacteria:* When cracks form in concrete and water penetrate, the dormant bacteria are activated.
2. *Metabolism of Calcium Lactate:* The bacteria utilize calcium lactate as a nutrient and produce carbon dioxide as a by-product.

3. *Formation of Calcium Carbonate:* The carbon dioxide reacts with calcium ions present in the concrete matrix to form insoluble calcium carbonate (limestone).
4. *Crack Sealing:* The calcium carbonate precipitate fills the cracks, sealing them and preventing further loss of water and harmful substances.

ADVANTAGES OF BACTERIAL CONCRETE

1. *Enhanced Durability:* The self-healing property of bacterial concrete extends the lifespan of structures.
2. *Reduction in Permeability:* The formation of calcium carbonate seals pores and capillaries, reducing water penetration.
3. *Corrosion Resistance:* The consumption of oxygen by bacteria delays the onset of steel corrosion, maintaining the structural integrity.
4. *Improved Mechanical Properties:* Increased compressive and tensile strength compared to conventional concrete.
5. *Environmental Benefits:* Reduced need for repairs and maintenance, lowering the carbon footprint of concrete structures.

EXPERIMENTAL INVESTIGATION

Materials and Mix Design

The experiment involves preparing two sets of concrete samples:

1. Conventional Concrete: Standard mix design as per IS codes.
2. Bacterial Concrete: Standard mix infused with *Bacillus subtilis* bacteria and calcium lactate.

Testing Procedures

1. *Workability Tests:* Slump test and compaction factor test to measure the workability of fresh concrete.
2. *Compressive Strength Test:* Evaluation at 7, 14, and 28 days to compare the strength of conventional and bacterial concrete.
3. *Durability Tests:* Water permeability tests and accelerated corrosion tests on reinforced samples.
4. *Crack Healing Observation:* Microscopic analysis of crack healing overtime (Figure 1).

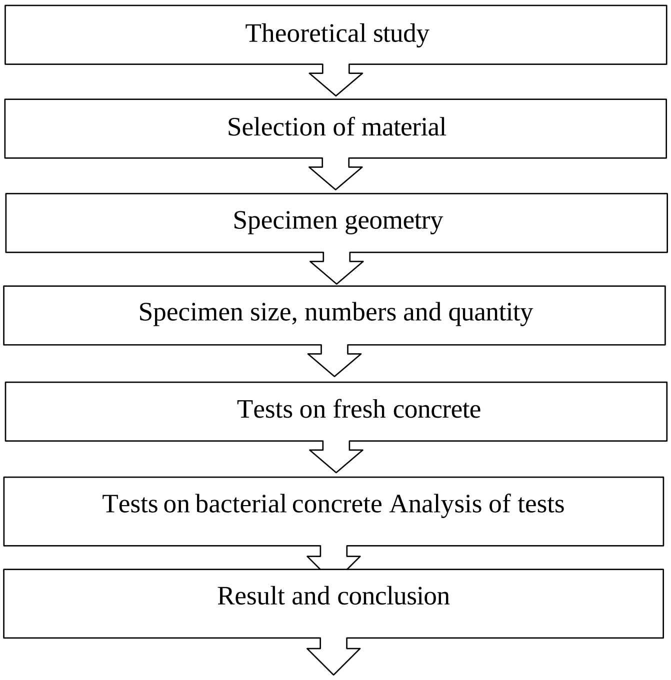

Figure 1. Methodology.

Material

1. Cement
2. Fine Aggregates
3. Coarse Aggregates
4. *Bacillus Subtilis*
5. Reinforcement
6. Water

THEORETICAL ANALYSIS OF MATERIAL

1. *Cement:* It can be defined as material having adhesive and cohesive properties which make it capable of bonding material fragments into a compact mass.
2. *Fine Aggregate:* Aggregate materials help to make concrete mixes more compact. It prevents the development of a crack in the concrete. Natural river sand conforming grading is used as IS: 383-1987.
3. *Coarse Aggregate:* It makes a solid and hard mass of concrete with cement and sand. It provides bulk to the concrete. The coarse aggregate having a diameter of 20 mm size is used.
4. *Bacillus Subtilis: Bacillus subtilis,* also known as the hay bacillus or grass bacillus is a gram-positive bacterium found in soil and the gastrointestinal tract of ruminants and humans. *Bacillus subtilis* is rod-shaped and can form a tough, protective endospore allowing it to tolerate extreme environmental conditions. It is historically classified as an obligatory aerobe though evidence exists that it is a facultative anaerobe *bacillus subtilis* is also considered the best. It is one of the bacterial champions in secreted enzyme production and used on an industrial scale by biotechnology companies. The proportion of the bacteria used is 10^5 cells i.e. 24 ml in 1 liter water (Figure 2).
5. *Reinforcement:* Steel bar used as a tension device in reinforced concrete structure to strengthen and aid the concrete under tension. The steel bar having diameter 12 mm size is used.
6. *Water:* Water is used for the preparation of test samples as well as for the curing of the test specimens.

Figure 2. Bacteria *bacillus subtilis* under the microscope.

Specimen Information (Figure 3 and Tables 1 and 2)

- *Size of Specimen:* 150 x 150 x 150 mm.

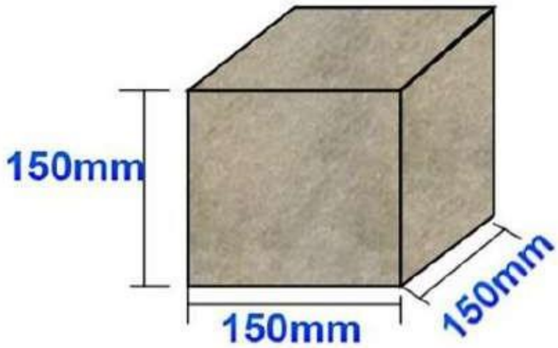

Figure 3. Number of specimen.

Table 1. The total numbers of specimens 6.

S.N.		Specimen
1.	Conventional Concrete	3
2.	Bacterial Concrete	3

Mix Design

- Cement = 8.25 kg
- Fine Aggregate = 22.36 kg
- Coarse Aggregate = 48.71 kg
- Water = 4.125 lit

Table 2. Grade of concrete and its nominal mix ratio.

Grade of Concrete	Ratio of Concrete Mix Design
M20	(1:1.5:3) (Cement: Fine Aggregate: Coarse Aggregate)

TEST ON MATERIALS

1. Specific gravity of fine aggregate = 2.615.
2. Specific gravity of coarse aggregate = 2.4.
3. Water absorption test on coarse aggregate = 2.72%.

Test on Fresh Concrete are shown in Figures 4–9.

Figure 4. Slump cone test.

Figure 5. Compaction factor test.
Compaction Factor Value = 0.95.

Figure 6. Flow test.
Flow Percentage = 60%.

Figure 7. Curing this specimen.

Figure 8. Keep it in sea water.

Figure 9. Break the specimen.

Experimental Work

- Casting 6 no. of reinforced cement concrete cube specimen– 3 Conventional & 3 bacterial cube
- Compare results of corrosion of steel occur in conventional & bacterial concrete.

CONCLUSIONS

Bacterial concrete represents a significant advancement in construction technology, offering a sustainable solution to the persistent problem of cracks in concrete structures. By utilizing the self-healing ability of *Bacillus subtilis*, this innovative material not only enhances durability and strength but also reduces maintenance costs and environmental impact. The integration of bacterial concrete in modern construction practices has the potential to revolutionize the industry, ensuring safer and longer-lasting structures.

This self-healing mechanism makes bacterial concrete a reliable alternative to conventional methods of crack repair, which often involve labor-intensive and costly interventions. The process of MICP not only addresses the visible cracks but also strengthens the internal matrix of the concrete, reducing its permeability and increasing resistance to chemical attacks and freeze-thaw cycles.

Moreover, the bacteria's ability to consume oxygen plays a crucial role in mitigating the corrosion of steel reinforcement, which is a leading cause of structural deterioration.

In addition to its functional benefits, bacterial concrete contributes to environmental sustainability. Traditional concrete repairs often require additional materials and energy, leading to increased carbon emissions. By reducing the frequency and extent of repairs, bacterial concrete helps lower the overall environmental impact of construction projects. Furthermore, the use of naturally occurring bacteria as a key component aligns with eco-friendly construction practices, paving the way for more sustainable infrastructure development.

Future research and development in bacterial concrete can further enhance its efficacy and cost-effectiveness. Exploring different bacterial strains, optimizing nutrient formulations, and scaling up production processes can make this technology more accessible and affordable. Additionally, integrating bacterial concrete with advanced monitoring systems can enable real-time assessment of crack healing, ensuring timely interventions when need.

In conclusion, bacterial concrete is not just an innovative material but a transformative approach to addressing some of the most pressing challenges in construction. Its ability to heal cracks autonomously, enhance durability, and minimize environmental impact positions it as a game-changer in the construction industry. As the demand for resilient and sustainable infrastructure continues to grow, bacterial concrete offers a promising pathway toward building a more durable and sustainable future.

REFERENCES

1. Reddy VS, Krishna PVSSSR, Karthik GS, Shrihari S. Assessment of corrosion inhibiting efficiency of microbes induced concrete. E3S Web Conf. 2020;184:1114. doi: 10.1051/e3sconf/202018401114.
2. Chaitanya JSN, Mounika K. Experimental study on bacterial concrete. 2018. Available at https://www.irjet.net/archives/V4/i12/IRJET-V4I12367.pdf
3. Farzana KS, Althaf KZ, Marshal KK, Aswathy KV. Use of seawater in concrete. KMEA Engineering College. Available at http://www.ijret.org/Volume_6_Issue_4
4. Ganesh M, Bramhanand K, Yuvraj J. A review on bacterial concrete. 2023. Available at https://www.researchgate.net/publication/279889125
5. Aravinthan K, Arshad K, Asa SA. Experimental study on characteristics of bacterial concrete. Int J Adv Res Ideas Innov Technol. 2018;6(4).
6. Ravindranatha, Kannan N, Likhit M. Self-healing material bacterial concrete. Int J Res Eng Technol. 2014;3(Special Issue 3):656.
7. Yogeswaran Y, Juki MI, Alshalif AF, Sabah SA. The effect of bacteria on steel corrosion in concrete: A review. RTCEBE Periodicals. Available at http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
8. Venkatesh RM, Anandan S, Rao GR. Microbial calcite precipitation in reinforced concrete. ACI Mater J. 2012;109(2):157–164.
9. Sharma D, Thakur D, Kumar S. Enhancing properties of concrete using bacteria: A systematic review. J Civil Struct Health Monit. 2021;11:105–120. doi: 10.1007/s13349-020- 00436-7.
10. Patel S, Mehta R. Crack healing in bacterial concrete: A comparative study. Int J Concr Res Appl. 2019;9(3):210–220.
11. Sharma PK, Kaushik V, Yadav D. Durability of bacterial concrete under harsh environmental conditions. Mater Today Proc. 2020;45:1214–1220. doi: 10.1016/j.matpr.2020.02.432.
12. John S, Rao A. Sustainable use of bacterial concrete in modern construction. J Green Constr Eng. 2022;14(1):1–12.
13. Reddy VS, Krishna PVSSSR, Karthik GS, Shrihari S. Corrosion prevention of reinforced concrete with microbial calcite precipitation. Int Conf Materials. 2020;184:1114. doi: 10.1051/e3sconf/202018401114.
14. Marthak S, Khanna T. Bacillus subtilis: A game-changer in self-healing concrete. J Constr Mater Eng. 2021;30(6):455–470. Available at https://journals.sagepub.com/
15. Vinodkumar K, Manikandan R, Sundararaj P. Experimental insights into bacterial concrete properties. Int J Concr Struct Mater. 2019;13(1):75–83.
16. Hossain S, Das D, Ahmed S. Bacterial concrete and its impact on environmental sustainability. Environ Eng J. 2023;5(3):15–22. doi: 10.1016/j.enveng.2023.03.015.
17. Najiya KS, Althaf KZ. Enhancing steel corrosion resistance in bacterial concrete. Int J Eng Res Appl. 2023;11(2):100–107.
18. Kale M, Jadhav Y. Experimental findings on self-healing bacterial concrete. J Struct Eng Technol. 2020;25(4):298–312.