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# A Review on Examination of the Strength Characteristics of Bacterial Self-Healing Concrete for Retrofitting of Rigid Pavement

**Prabhat Pawar** [1]
*PG Scholar, Civil Engineering Department, JIT, Khargone, India.*

**Shashikant B. Dhobale** [2]
*Professor, Civil Engineering Department, JIT Khargone, India.*

***Abstract -***
*Retrofitting rigid pavements involves upgrading existing structures to enhance performance, durability, and service life. This cost-effective and sustainable process addresses issues such as cracks, deterioration, and wear, aiming to optimize load-bearing capacity and resist environmental and traffic-induced stressors. The study explores the potential use of calcium lactate and Bacillus subtilis in retrofitting, providing valuable insights for improving existing concrete structures.*

*The research findings reveal that the controlled addition of bacteria up to 3% results in notable improvements, with a 6.6% increase in compressive strength and a 6.76% enhancement in split tensile strength compared to conventional concrete. However, an increase to 5% bacteria led to reduced strength, emphasizing the need for a balanced approach in retrofitting projects.*

*Additionally, the study indicates that incorporating 5% calcium lactate enhances split tensile strength by 3.03% but reduces compressive strength by 2.02%. Careful consideration is urged when using calcium lactate, especially at higher concentrations, as it can adversely affect different strength parameters.*

*Notably, combining 5% calcium lactate and 3% Bacillus subtilis shows positive synergistic effects, yielding a 4.71% increase in compressive strength and an 18.41% improvement in split tensile strength. This combination presents a promising strategy for optimizing strength criteria in retrofitting applications.*

*One significant finding of the study underscores the potential of bacterial concrete to substantially reduce the need for repairs and maintenance, making it a cost-effective choice for retrofitting rigid pavements. This has critical implications for infrastructure projects, as reduced maintenance requirements translate to long-term cost savings and increased structural durability. This study demonstrates the feasibility of employing calcium lactate with Bacillus subtilis in retrofitting rigid pavements. It emphasizes the importance of optimizing component percentages for specific strength criteria and highlights the cost-effectiveness and long-term benefits of using bacterial concrete in retrofitting applications, contributing to improved performance and durability of rigid pavements.*

***Key Words:*** *Rigid Pavements, Retrofitting, Bacterial Concrete, Bacillus Subtilis, Calcium Lactate, Pavement Durability, Compressive Strength, Self-Healing Concrete.*

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## I. INTRODUCTION

Concrete, being the most commonly used construction material worldwide, plays a significant role in the construction of rigid pavements. However, the repetitive loading experienced by pavements often leads to the development of cracks. These cracks permit the entry of harmful substances, ultimately reducing the concrete's durability. Consequently, this research introduces an environmentally friendly solution to confer self-healing capabilities upon concrete through the use of bacteria as a healing agent.

Retrofitting rigid pavements involves upgrading or enhancing existing concrete pavements or road structures to improve their performance, durability, and service life. It encompasses the repair, reinforcement, or modification of the existing pavement to address issues such as cracks, deterioration, and wear and tear, or to meet modern engineering and safety standards. Retrofitting aims to extend the lifespan of the pavement, optimize its load-bearing capacity, and enhance its resistance to environmental factors, traffic loads, and other stressors. This process is a cost-effective and sustainable approach to maintaining and improving infrastructure while minimizing the need for complete reconstruction or replacement.

Cracks in structural concrete can result from internal factors, such as low concrete strength, and external factors, including structural loads, temperature fluctuations, and aging. These cracks tend to widen due to the absorbent nature of concrete, leading to its deterioration. Timely action is essential to prevent cracks from expanding and compromising structural integrity. Traditional crack repair techniques have limitations, including the environmental impact of the materials used and the temporary nature of the remedies.

To address these issues, a microbiologically induced crack healing mechanism has emerged as a reliable solution. Researchers have discovered that certain types of bacteria, when introduced into cementitious composites, can produce calcium carbonate, which effectively seals these cracks. This process requires a calcium source, with the bacteria acting as mineralization inducers while calcium compounds serve as calcium carbonate precursors and an energy source for the bacteria. To ensure the long-term viability of these bacteria, they need to be in the form of spores. When cracks allow air and water to enter, these spores reactivate, utilize calcium compounds as an energy source, and commence the precipitation of calcium carbonate.

In the case of cement concrete roads, the ultimate strength after 90 days is often considered. This practice is based on the fact that only a limited number of commercial vehicles pass over a specific stretch of road within the initial 90-day period. However, the industry standard typically evaluates concrete strengths after 28 days. To reconcile this, the Indian Road Congress (IRC) provides a multiplying factor to estimate the 90-day strength based on the 28-day strength.

## II. Literature Review

Numerous research and studies have been conducted on bacterial self-healing concrete, focusing on both its workability and strength. Several investigations have been undertaken to explore the properties of concrete using bacteria, also known as self- healing concrete, in order to understand its behaviour and characteristics.

(Abishek Kumar A. A 2020) The study involved the preparation of self-healing concrete, with varying amounts of bacteria added (5ml, 10ml, and 15ml). The findings indicated that the addition of 10ml of bacteria yielded the best results. The inclusion of 10ml of bacteria led to an increase in strength. Compared to conventional concrete, there was a 4.8% increase in 7 days strength, a 12.21% increase in 14 days strength, and a 1.33% increase in 28 days strength. Similarly, split tensile strength was also evaluated, showing a rise of 7%, 4.21%, and 10% for 7 days, 14 days, and 28 days, respectively. Furthermore, water absorption was examined in these specimens, with the 10ml bacterial sample displaying a 9.72% decrease in water absorption.

(Aditya Tadimeti 2020) In this research, various plastics were examined in combination with bacillus subtilis in different aquatic environments. The results demonstrated that bacillus subtilis can degrade polythene in freshwater, albeit with reduced degradation in saline water. Conversely, no degradation was observed for ABS and HIPS plastics, making them suitable for use with bacillus subtilis. The utilization of bacillus subtilis presents a promising approach to reducing polythene waste. However, further literature and research are necessary to understand the behavior of bacillus subtilis in diverse aquatic environments, enabling effective degradation of plastic waste in seas and other settings.

(C. Manvith Kumar Reddy 2020) In this study, bacteria with a concentration of 107 cells/ml were incorporated along with a calcium source, calcium lactate, into the concrete mix. Flexural strength tests were conducted on the concrete, revealing an increase in flexural strength resulting from the addition of bacteria and calcium lactate.

The maximum observed increase was 4%. The research also involved monitoring the healing time and crack length. The results showed that bacterial concrete demonstrated superior healing capabilities compared to conventional concrete, effectively healing cracks up to 100µm in size.

(Mors and Jonker 2019), The paper was written as part of the research program called "Material for Life (M4L)." The study explored four distinct mechanisms for self- healing concrete, which included microcapsules loaded with sodium silicate, porous aggregates loaded with bacteria, shape memory polymers, and mineral healing agents. Over time, the research observed a reduction in crack width and permeability. Crack width variation was assessed using an Ultrasonic Pulse Velocity meter, as well as through optical means employing cameras and microscopy. The findings revealed that capsules based on sodium silicate demonstrated the most significant results among the investigated mechanisms. These capsules proved effective in healing cracks exceeding 100µm in width.

(S.Dinesh 2017) In the study, it was found that the addition of bacteria to concrete enhanced both its compressive and tensile strengths, while also reducing its permeability, water absorption, and the corrosion of reinforcement, as compared to regular concrete. This improvement in structural integrity highlights the positive impact of bacterial concrete on the durability of the structure. Referred to as "Smart Bio material," bacterial concrete has the unique ability to continuously precipitate calcite, making it more environmentally friendly and capable of self-healing compared to traditional concrete. Looking ahead, bacterial concrete shows great promise for constructing long-lasting, cost-effective, and eco-friendly high-quality structures. Its practicality lies in its potential for economical and efficient implementation, despite requiring specialized work. As this technology advances, it is expected to become even more successful from both an economical and practical standpoint.

(Kunamineni Vijay 2017) Understanding the utilization of urease-producing bacterium isolates, including Bacillus subtilis and Bacillus pasteuri species, for concrete crack repair is essential in this endeavor. The study explored multiple bacterial species capable of facilitating crack mending. Furthermore, the research demonstrated that bacteria enhanced the compressive strength of both concrete and Portland cement mortar cubes. Utilizing bacteria presents the added benefit of reducing water infiltration and chloride ion permeability. The study's results propose the adoption of "microbial concrete" as a viable and superior concrete sealer, offering economic and environmentally friendly advantages while enhancing the durability of construction elements.

(N. Ganesh Babu 2016) In this study, bacterial concrete was formulated with calcium lactate as the calcium source. The research program examined the compressive strength of 5% bacterial concrete, which exhibited a 2.63% increase compared to conventional concrete. Different proportions of bacteria (3.5% and 5%) were added, and the most favorable outcomes were obtained when incorporating 10% calcium lactate and 5% bacteria. The results indicated a further 4.35% increase in compressive strength compared to conventional concrete.

(E. Tziviloglou 2016) In this paper, the lightweight mortar containing a self-healing agent based on bacteria demonstrated superior crack sealing performance, particularly when subjected to more realistic healing cycles like wet/dry cycles, as opposed to constant water immersion. Evidence from measurements of oxygen consumption and ESEM observations supports the notion that the improved behavior is a result of bacterial activity. The compressive strength of the bacteria-based mortar is somewhat reduced when heavy sand is replaced with lightweight aggregates. However, this material can still be utilized as an external layer on a heavier construction or in situations where a lightweight structure is required. In conclusion, incorporating this material in buildings would be advantageous, as its enhanced crack sealing capability helps prevent durability issues caused by microcracking.

(Renée M. Mors 2012), The paper offers an introductory overview of self-healing concrete development conducted in the Micro Lab of Tunelet. This marks the initial progress made by "Mr. H. Jonker," the inventor of self-healing concrete, leading towards bacterial concrete. The paper explores different bacteria that can be employed as self-healing agents in concrete. The process involves the use of bacteria along with a calcium source, resulting in the deposition of a calcium carbonate layer on the crack surface. This layer effectively seals and blocks the entrance of stagnant materials. The formation of this layer is explained through specific equations, illustrating that bacteria act merely as catalysts when calcium lactate is added.

$Ca(C3H5O2)2+7O2 \rightarrow CaCO3+H2O$

(Henk M. Jonkers 2008) The research focused on exploring the self-healing properties of concrete and conducting a comparison of compressive strength. Bacterial concrete was prepared using B. Pseudofirmus along with the calcium source, which was Calcium Lactate. The addition of bacteria (B. Pseudofirmus) resulted in a 10% reduction in compressive strength. While the bacteria displayed promising healing properties, they were found to be impractical for real-world applications due to the reduction in compressive strength. The experimental results revealed that adding calcium lactate alone to the concrete led to even lower strength compared to using a combination of bacteria and calcium lactate.

## III. RESEARCH GAP

In all the previously mentioned papers, it is recommended to add bacteria as an additive in approximately 3 to 5%, along with a calcium source. Based on various literature sources, it can be inferred that Calcium Lactate serves as an effective calcium source for bacteria, leading to bacterial concrete with improved compressive and tensile strength compared to conventional concrete. Moreover, properties such as permeability and water absorption are reduced in bacterial concrete.

After conducting in-depth research on various bacterial groups,

## IV. CONCLUSIONS

The literature review underscores the pivotal role of concrete in global construction, particularly for rigid pavements. Repetitive loading and the consequent formation of cracks significantly compromise the durability of concrete structures. Traditional repair methods, while somewhat effective, often offer temporary solutions and have environmental drawbacks, highlighting the need for more innovative and sustainable approaches.

The advent of microbiologically induced self-healing concrete offers a promising solution. Incorporating bacteria such as Bacillus subtilis into concrete can enhance its self-healing properties. These bacteria facilitate the precipitation of calcium carbonate, which effectively seals cracks, thereby improving the concrete's durability. Research indicates that controlled addition of bacteria can enhance compressive and tensile strengths, though optimal concentrations are crucial to avoid potential strength reductions.

Moreover, the combination of calcium lactate with Bacillus subtilis has demonstrated synergistic effects, significantly improving both compressive and tensile strengths. This approach is particularly promising for retrofitting applications, where enhancing existing structures without complete reconstruction is both cost-effective and environmentally sustainable.

The potential for bacterial concrete to reduce the need for maintenance and repairs has profound implications for infrastructure projects. It promises long-term cost savings and increased structural durability. The feasibility of employing this technology in retrofitting rigid pavements is well-supported, emphasizing the importance of optimizing component ratios to achieve desired strength criteria. This aligns with modern engineering and environmental goals, presenting a viable path toward more resilient and sustainable construction practices.

In summary, the literature review establishes a strong foundation for further research and development in self-healing concrete, particularly in retrofitting rigid pavements. Advancements in microbiologically induced healing mechanisms present a viable path to more durable, cost-effective, and environmentally friendly construction practices, potentially revolutionizing infrastructure maintenance and sustainability.

## REFERENCES

[1]. IS:10262 (2019). Concrete Mix Proportioning-Guidelines. New Delhi: Bureau of Indian Standards. https://civiconcepts.com/wp-content/uploads/2020/11/4.IS-10262-2019-New-Mix- design.pdf
[2]. IS:1199 (1959). Methods of Sampling and Analysis of Concrete. New Delhi: Bureau of Indian Standards.
[3]. IS:2386 (1963). Methods of Test For Aggregate For Concrete. New Delhi: Indian Standards Institution. https://law.resource.org/pub/in/bis/S03/is.2386.5.1963.pdf.
[4]. IS:383 (2016). Coarse and Fine Aggregates for Concrete - Specification. BUREAU OF INDIAN STANDARDS. http://skgcgroup.com/wp-content/uploads/2020/02/IS%20383- 2016.pdf.
[5]. IS:516 (1959) Methods of Tests For Strength of Concrete. New Delhi: Bureau of Indian Standards.
[6]. IS:5816 (1999) Splitting Tensile Strength Of Concrete-Method of Test. New Delhi: Bureau Of Indian Standards. https://www.iitk.ac.in/ce/test/IS-codes/is.5816.1999.pdf.
[7]. IS:8112 (2013) Ordinary Portland Cement, 43 Grade — Specification Bureau Of Indian Standards. https://www.iitk.ac.in/ce/test/IS-codes/is.8112.2013.pdf.
[8]. Abishek Kumar A. A, Eveena Stephen, Merin George, Ansaf muhammad, Naveen Charles. 2020. Evaluation of Strength and Durability Properties for Various Amount of Bacillus Subtilis Bacteria in Concrete. International Journal of Engineering Research & Technology (IJERT) 548-551. http://www.ijert.org.
[9]. Aditya Tadimeti, Jeff Sutton. 2020. The Effects of Different Aquatic Environments on the Rate of Polyethylene Biodegradation by Bacillus subtilis.
[10]. Henk M. Jonkers, Erik Schlangen. 2008. "Development of a bacteria-based self-healing concrete." Tailor Made Concrete Structures – Walraven & Stoelhorst 425-430.
[11]. N. Ganesh Babu, Dr. S. Siddiraju. 2016. "An Experimental Study on Strength and Fracture Properties of Self Healing Concrete." International Journal of Civil Engineering and Technology (IJCIET) 7 (3): 398-406. http://www.iaeme.com.
[12]. Paul, sulav indra. 2021. "Identification of marine sponge-associated bacteria of the Saint Martin’s island of the Bay of Bengal emphasizing on the prevention of motile Aeromonas septicemia in Labeo rohita." Aquaculture 1-13. doi:doi:10.1016/j.aquaculture.2021.737156.
[13]. Renée M. Mors, Henk M. Jonkers. 2019. "Bacteria- based self- healing concrete: evaluation of full scale demonstrator projects." RILEM Technical Letters 138-144. doi:http://dx.doi.org/10.21809/rilemtechlett.2019.93.
[14]. Renée M. Mors, Henk M. Jonkers. 2012. "Bacteria-based self-healing concrete-an introduction." 32-39.