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An International Journal of Multidisciplinary Research

Bacteria Based Self-Healing Concrete for Crack Repair

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Abstract:

Concrete is commonly used in construction to handle compression, but it has a low tensile strength which causes cracks to form. These cracks can let in water and chemicals, causing the reinforcement bars to corrode. Fixing these cracks is hard and costly. To prevent them, we can add special bacteria to the concrete that reacts with calcium to create calcium carbonate crystals. This process blocks the cracks in the concrete, and can even seal very small cracks up to 0.15mm. This study provides information on a technique to enhance the strength and durability of present-day concrete by introducing Bacillus pasteurii, a soil bacterium, which, as a byproduct of its metabolic activity, displays bio-calcification. When a carbonate ion is present, the calcium precipitate secreted by the bacterium during the bio-calcification process turns into $CaCO_3$. The concrete's holes are filled with this material., resulting in a more compact texture. As a result, the growth of filler material within the concrete's pores enhances its strength. Concrete cubes and beams that underwent compressive and flexural strength tests with and without the bacterium were compared. The research discovered that after being exposed to loading, the specimens treated with the bacterium showed a notable improvement in strength and crack healing.

Keywords: Bacillus pasteurii, self-healing, bacteria for concrete, concrete.

Introduction:

Bacteria-based self-healing concrete is a type of concrete that has the ability to repair its own cracks. The process involves the use of a specific type of bacteria, called Bacillus bacteria, which is mixed into the concrete during the production process. When a crack occurs in the concrete, water enters and activates the bacteria, causing it to produce limestone that fills the crack and restores the structural integrity of the concrete. This technology has the potential to reduce maintenance costs and increase the lifespan of concrete structures, such as bridges and buildings. However, more research is needed to determine its effectiveness in real-world applications and its long-term durability. The use of bacterial concrete in India is a relatively recent development and its application is still limited. In 2016, researchers at the Indian Institute of Technology (IIT) Delhi developed a bacterial concrete that is capable of self-healing cracks. The researchers used a combination of bacteria and calcium lactate to create the self-healing concrete. Since then, there have been some pilot projects in India that have tested the effectiveness of this technology. For example, in 2019, the Indian Army used bacterial concrete to repair a damaged runway at its airbase in Jaisalmer. This successful project demonstrated the potential benefits of using bacterial concrete in infrastructure projects in India. However, the technology is still in its early stages of adoption in the country and further research and development is needed to fully realize its potential. The process of bacterial healing is initiated when water penetrates a crack in concrete, which may initially be a tiny fissure that serves as a trigger for the bacteria to start working. Self-healing concrete can use a few different types of bacteria, such as Bacillus Pseudofirmus, Bacillus Cohnii, and Bacillus Sphaericus. These bacteria are inserted into the concrete matrix in spores or small round capsules that contain calcium lactate, which serves as a nutrient source for the bacteria when they become active. The bacteria are capable of surviving in the concrete matrix for more than 200 years and can be reactivated if the healed area experiences further cracking. If the concrete cracks, the capsules rupture, and water enter, this activates the bacteria.

Self-healing bacterial concrete is a novel technology that has been developed to enhance the durability and longevity of concrete structures. The application of self- healing bacterial concrete in India can be beneficial in several ways, including:

1. Infrastructure development: India is currently investing heavily in infrastructure development, with a focus on building highways, bridges, and airports. Self-healing concrete can be used to build these structures, making them more durable and reducing maintenance costs over time.
2. Water storage tanks: Self-healing concrete can be used to build water storage tanks that are resistant to cracking and leaks, ensuring the safety and reliability of the water supply.
3. Industrial flooring: Self-healing concrete can be used to build industrial flooring that is resistant to damage caused by heavy machinery and equipment.
4. Heritage conservation: India has a rich cultural heritage, and many historical monuments and buildings are in need of repair and restoration. Self-healing concrete can be used to repair and restore these structures, ensuring their preservation for future generations.

Problem Statement:

Conventional concrete structures are prone to cracking and damage over time, which can lead to costly repairs and reduced durability. These cracks can also compromise the structural integrity of the building, leading to safety concerns. Current repair methods often involve significant time and expense, resulting in lengthy downtimes and inconvenience. The use of self-healing bacterial concrete aims to address these problems by incorporating bacteria that can grow and repair the concrete on its own, reducing the need for costly and time-consuming repairs while increasing the durability and safety of the structure. However, there are still challenges that need to be addressed, such as optimizing the bacterial mixture for different applications, ensuring the long-term effectiveness of the healing process, and addressing any potential safety and environmental concerns related to the use of bacteria in construction materials.

Aim and Objectives:

1. The focus of this investigation was on the autogenously self-healing of cementitious materials. The effectiveness of this process has been a subject of concern due to the lack of a confirmed and fully comprehended governing mechanism. Consequently, the study had three primary goals:
2. To gain an understanding of the mechanisms responsible for the autogenous self-healing of concrete.
3. To develop a cementitious material or a set of materials with a specific chemical composition that can self-repair both internally and externally in specific environmental conditions.
4. To study the effect of bacterial concrete on the strength parameters.

1. **Methodology:**
   - Opening Section
   - Examination of Existing Research
   - Identifying Research Void
   - Work Objectives
   - Bacterial Cultivation for Concrete
   - Evaluation of Concrete Materials
   - Concrete Design Utilizing Various Bacterial Strains
   - Establishing the Optimal Dosage for Self-Healing Bacterial Concrete
   - Analysis and Discussion of Findings
   - Closing Remarks
2. **Materıals used and mix proportions:** The different materials used in this investigation are
3. **Cement:**

   The investigation employs 53-grade Ordinary Portland cement, which can be found in the nearby market. The cement used for all experiments comes from a single batch. The cement has undergone several tests in accordance with IS: 4031-1988 to evaluate its various properties, and it has been determined that it meets the various specifications outlined in IS: 12269-1987.The cement had a specific gravity of 3.15 and a specific surface area of 225 m^2/g, with an initial setting time of 150 minutes and a final setting time of 250 minutes.
4. **Fine aggregate:**

   We use fine aggregate that conforms to Zone-I according to IS: 383-2016.It has a specific gravity of 2.60 and a bulk density of 1.45 g/cc.
5. **Coarse aggregate:**

   In this study, crushed angular aggregates from a nearby quarry are utilized as the coarse aggregate. The coarse aggregate is meticulously cleaned and subjected to several tests, including specific gravity, fineness modulus, bulk modulus, among others, in accordance with the IS: 2386-1963 and IS 383:2016 standards to determine its physical characteristics.

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An International Journal of Multidisciplinary Research

6. **Bacteria:**

Bacteria are uncomplicated unicellular life forms. In this study, Bacillus pasteurii was utilized, which has the unique capacity to induce calcium carbonate precipitation when exposed to any carbonate source. This bacterium was chosen to enhance the strength of concrete test samples, and its utilization resulted in improved specimen durability. The species of bacteria employed in this research belong to the Bacillus genus. Through inorganic crystal precipitation, these microbes promote the self- healing of concrete cracks, enabling it to endure various temperature conditions.

7. **Mix proportions:**

The aim of this study is to assess the impact of incorporating the ideal bacterial concentration on the compressive strength and split tensile strength of standard-grade concrete (M20). A total of twelve sets of concrete cubes measuring 150mm x 150mm x 150mm are prepared, and their compressive strength is examined under axial compression at intervals of 7, 14, and 28 days. Following the 28-day period, an additional nine sets of cylindrical specimens are created and analyzed for their split tensile strength.

8. **Results and Conclusion:**

Concrete specimens were subjected to testing in accordance with IS: 516-1956. To examine the compressive strength and split tensile strength of concrete, an investigation was conducted. Table 1 presents the data for the ordinary grade concrete's compressive strength at 7, 14, and 28 days.

Table 1 shows the impact of adding bacteria to ordinary (M20) grade concrete.

Effect of the Bacteria Addition on Ordinary (M20) Grade Concrete

Age	Compressive Strength	
(No. of days)	Conventional Concrete, MPa	Bacterial Concrete, MPa
7	14.5	16
14	17	19.5
28	25.5	27.6

Table 2 shows how adding bacteria affects the strength of concrete of average grade in terms of splitting tensile.Table

Age (No. of days)	Split Tensile Strength	
	Conventional Concrete, MPa	Bacterial Concrete, MPa
28	4.45	5.75

Conclusion:

The compressive strength of ordinary grade concrete at 7, 14, and 28 days is shown in Table

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An International Journal of Multidisciplinary Research

1. The findings show that the addition of bacteria significantly increased the compressive strength of concrete, especially at day 28, when the improvement was 4.24%. As concrete ages, its compressive strength changes by a range of 7.60% to 4.24%.
The Split Tensile Strength of typical cylindrical specimens of ordinary-grade concrete at 28 days is shown in Table 2. The results show that the addition of bacteria significantly increased the tensile strength, especially at day 28, when the increase was29%.

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