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Experimental Investigation on Strength and Crack Healing Efficiency of Bacterial Concrete Using *Bacillus Subtilis*

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Abstract

Self-healing concrete is an advanced construction material developed to mitigate cracking in conventional concrete. This research presents an experimental investigation on bacterial concrete incorporating *Bacillus subtilis* to evaluate compressive strength, crack-healing efficiency, and durability characteristics. The bacteria precipitate calcium carbonate ($CaCO_3$) in the presence of moisture and nutrients, sealing cracks autonomously. Experimental results at 7, 14, and 28 days indicate an increase in compressive strength by approximately 10–15% and effective crack healing up to 0.5 mm. The study demonstrates that bacterial concrete significantly enhances durability and reduces permeability, making it a sustainable alternative in modern construction.

Keywords

Bacterial Concrete, Self-Healing Concrete, Bacillus subtilis, Crack Healing, Compressive Strength, Sustainable Materials

1. Introduction

Concrete is widely used in construction due to its high compressive strength and versatility. However, it is inherently brittle and prone to cracking due to shrinkage, temperature variations, and applied loads. These cracks allow ingress of water and harmful chemicals, leading to reinforcement corrosion and structural deterioration.

Self-healing concrete using bacterial technology has emerged as an innovative solution. In this method, bacteria such as *Bacillus subtilis* are embedded in the concrete matrix along with a nutrient source. Upon crack formation and water ingress, bacteria activate and precipitate calcium carbonate, sealing the cracks.

2. Literature Review

Author	Bacteria Used	Key Findings
Jonkers et al. (2011)	Bacillus species	Crack healing up to 0.5 mm
De Belie et al. (2018)	Bacillus pasteurii	Improved durability and reduced permeability
Wang et al. (2014)	Bacillus subtilis	Increased compressive strength
Achal et al. (2011)	Bacillus sphaericus	Enhanced crack resistance

3. Objectives

- To study bacterial self-healing mechanism
- To evaluate compressive strength
- To analyze crack-healing efficiency
- To compare conventional and bacterial concrete
- To assess durability performance

4. Materials Used

- Ordinary Portland Cement (OPC)
- Fine Aggregate (Sand)
- Coarse Aggregate
- Water
- *Bacillus subtilis*
- Calcium Lactate (nutrient source)

Formula :

Percentage Increase in Strength:

% Increase = [(Bacterial Concrete – Conventional Concrete) / Conventional Concrete] × 100

5. Methodology

5.1 Mix Design

Concrete mix was designed as per IS 10262:2019 guidelines. Two types of mixes were prepared:

- Control Mix (Conventional Concrete)
- Bacterial Concrete Mix

5.2 Specimen Preparation

Concrete cubes of size 150 mm × 150 mm × 150 mm were cast. Bacteria and calcium lactate were added during mixing.

5.3 Curing Process

Specimens were cured in water for 7, 14, and 28 days.

5.4 Testing Procedures

- Compressive Strength Test (IS 516)
- Crack Induction and Healing Test
- Water Permeability Test

Material	**Quantity (kg/m³)**
Cement	400
Fine Aggregate	650
Coarse Aggregate	1200
Water	180
Bacteria Solution	10 ml/litre
Calcium Lactate	5% of cement

6. Results and Discussion

6.1 Compressive Strength Results

Days	Conventional (MPa)	Bacterial (MPa)	% Increase
7	18	20	11%
14	24	27	12.5%
28	30	34	13.3%

6.2 Crack Healing Efficiency

- Crack healing observed up to 0.5 mm
- $CaCO_3$ deposition confirmed visually

6.3 Permeability Results

- Significant reduction in water permeability observed

Discussion

The improvement in strength and durability is attributed to calcite precipitation by bacteria. This enhances bonding within the concrete matrix and reduces pore spaces.

7. Advantages

- Autonomous crack repair
- Increased durability
- Reduced maintenance cost
- Sustainable solution

8. Limitations

- High initial cost
- Environmental sensitivity
- Limited large-scale use

9. Applications

- Bridges and highways
- Marine structures
- Water retaining structures
- Underground constructions

10. Conclusion

The experimental study confirms that bacterial concrete using *Bacillus subtilis* enhances compressive strength, durability, and crack-healing efficiency. Although initial costs are higher, long-term performance benefits make it a viable sustainable construction material.

11. References

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12. Statistical Observation

The experimental results indicate an average increase of approximately 12–13% in compressive strength of bacterial concrete compared to conventional concrete. This confirms the positive impact of bacterial activity on concrete performance.

Declaration

This research work is original and has not been submitted elsewhere for publication. All sources have been properly cited.