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# A Study on Self Healing Bacterial Concrete

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**Abstract:** *Concrete is the foremost building material broadly used in building construction, but cracks formed in concrete are inescapable and one of the major reasons for the weakness of concrete. The major downside of concrete is its low tensile strength due to which micro crack occurs when the load applied is more than its limit and this paves way for the seepage of water and other salts. This initiates corrosion and makes the whole structure vulnerable and leads to the failure of structure. To remediate this type of failure due to cracks and fissures, an approach of using bio mineralisation in concrete has evolved in recent years. In this method, of enhancing the performance of concrete, the calcite precipitating spore forming bacteria is introduced into concrete. When water enters through the cracks, it reacts with bacteria and forms precipitates of calcium carbonate, as a by-product, which fills the cracks and makes crack free concrete. This type of concrete prepared with bacteria is called as bacterial concrete. Various researches have shown positive results by adding calcite precipitating bacteria in concrete. Here in this project, we are going to study the mechanical properties of self-healing bacterial concrete with varying quantities of Bacteria and Calcium lactate. Many researches shown that optimum result of Self-Healing bacterial concrete was obtained at 0.5% and 2.5% Calcium lactate along with 10 and 15ml bacteria. Here we have decided to conduct an experimental study on Self-Healing Bacterial concrete with addition of 10ml bacteria to 0.5% and 2.5% calcium lactate and 15ml bacteria to 0.5% and 2.5% calcium lactate. Here in this study, mechanical properties of SHBC were observed and compared with conventional concrete and also observed that healing of cracks are done.*

**Keywords:** Cracks, Self-Healing Bacterial Concrete, Bacteria, Calcium Carbonate.

## I. INTRODUCTION

### 1.1 Self-Healing Concrete

Self-Healing Concrete is a concrete which heals when it comes in contact with air and water, it produces lime on outer layer of concrete.In most of the traditional concrete mixtures 20-30% of the cement is left un-hydrated.If cracking of the concrete occurs, unreacted cement grains may become exposed to moisture penetrating the crack.In that case the hydration process may start again and hydration process may fill up and heal the crack.

The mechanism of healing cracks is to produce calcium carbonate and then cracks can be filled with calcium carbonate. There are two methods to generate calcium carbonate during self-healing procedures. The first is unreacted cement particles are used to start hydration to form $CaCO_3$. The second is that $CaCO_3$ is formed after dissolution of $Ca(OH)_2$.

Many factors which may influence self-healing abilities have been concluded by previous researchers. There are five main factors as follows:

a) **Moisture content:** Pilot specimens stored in water can heal by themselves more effectively.
b) **Crack width:** Cracks less than 0.3 mm in width can be healed completely. Cracks which are wider than 0.3 mm may not be healed. Moreover, 0.2 and 0.3 mm width cracks are mostly healed within 30 days.
c) **Time for hydration:** Hydration for a longer time can yield a better self-healing performance.
d) **Pressure loaded on cracks:** Loading proper pressure on cracks can stimulate better self-healing ability.
e) **Water–cement ratio:** A higher water–cement ratio includes more unreacted cement particles that can be used for further hydration to boost the generation of calcium carbonate.

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### 1.2 Bacterial Concrete

In early 1980 some articles are available about biological self-healing concrete and after1990 the self-healing concrete development in suspension condition can be added the bacteria with concrete.Bacterial concrete fills up the cracks developed in structures by the help of bacterial reaction in the concrete after hardening.The mechanism of this healing is, the width of range 0.05-0.1mm act as capillary and the water particles seep through the cracks.These water particles hydrate the non or partial reacted cement and the cement expands, which in turn fills the crack. But when the cracks are of greater width, need of other remedial work is required.The bacteria used for self-healing of cracks are acid producing bacteria.

## II. OBJECTIVE

The main objective of this Project:

- To check whether the Bacterial Concrete is working under normal atmospheric conditions or not.
- To determine the strength of Self-healing Bacterial concrete under normal atmospheric conditions after completion of healing process.
- To compare the mechanical properties of Self-healing Bacterial concrete with nominal concrete.

## III. MATERIALS AND METHODOLOGY

### 3.1 Materials

- **Cement:** In this study, Ordinary Portland Cement, 53 grade of cement was used. The Initial setting time of cement used in concrete preparation was 32 minutes, Final setting time was 560 minutes, soundness of cement was 8mm and Normal consistency of cement was 32%.
- **Aggregate:** The Fine Aggregate used in this project is river sand with a specific gravity of 2.59 and the coarse aggregate i.e., Gravel with Specific Gravity 2.6.
- **Bacteria:** The type of bacteria used in this project is Bacillus Subtilis. Bacillus subtilis is a gram-positive, rod-shaped bacterium that are naturally found in soil and vegetation.


**Fig 1: Bacillus Subtilis**

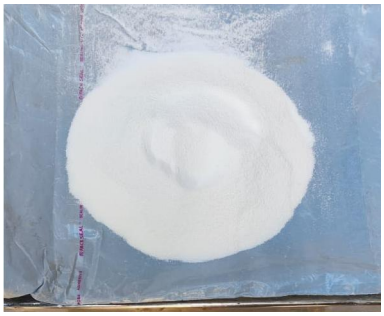

**Fig 2: Calcium Lactate**

- **Calcium Lactate:** Calcium lactate is a white or cream, almost odorless food additive derived from lactic acid. Calcium lactate as a nutrient source was used to support the bacterial growth since concrete does not contain an organic compound like glucose which is necessary for the bacterial growth.The production of calcium carbonate in bacterial concrete is limited to the calcium content in cement.

### 3.2 Methodology

The methodology involved in Bacterial Concrete preparation and testing is clearly illustrated in the flow chart given below.

- Weigh batching was considered.
- Hand mixing and compaction with tamping rod were preferred.
- The Bacillus Subtilis and Calcium Lactate were added to the concrete mix while preparing the concrete.
- Immersion type of curing was adopted in this project.

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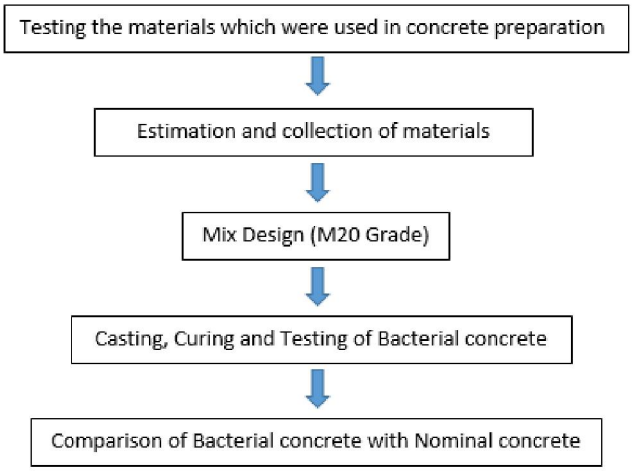


**Fig. 3.** Flow chart of Bacterial Concrete preparation and testing

**Fig 4:** Preparation of Concrete

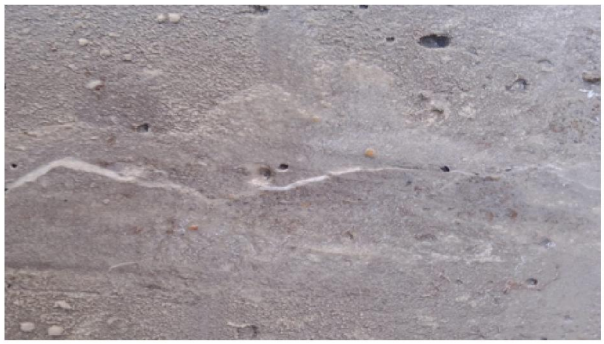

**Fig 5:** Healing of cracks on concrete surface

## IV. RESULTS AND DISCUSSIONS

### 4.1 Compressive Strength Results

The compressive strength tests were conducted on 150x150x150mm specimens and results are tabulated below.

**Table I:** Compressive Strength of Specimens 7, 14 days & 28 days

| **Tests conducted** | | **Compression strength (N/mm$^2$)** | | |
|---|---|---|---|---|
| | | 7 days | 14 days | 28 days |
| Conventional Concrete | | 14.02 | 18.75 | 20.58 |
| Bacterial | 10ml BS and 2.5% CL | Failed | | |
| | 15ml BS and 2.5% CL | 23.3 | 33.01 | 36.66 |

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| | | | | |
|---|---|---|---|---|
| Concrete | 10ml BS and 0.5% CL | 18.19 | 24.88 | 34.66 |
| | 15ml BS and 0.5% CL | 20.73 | 28.59 | 31.84 |

### 4.2 Split Tensile Strength Results

The tensile strength tests were conducted on 150x300mm cylinder specimens and results are tabulated below.

**Table 2:** Split tensile Strength results of Specimens for 7, 14 days & 28 days

| **Tests conducted** | | **Tensile strength (N/mm$^2$)** | | |
|---|---|---|---|---|
| | | 7 days | 14 days | 28 days |
| Conventional Concrete | | 2.72 | 3.05 | 3.20 |
| Bacterial Concrete | 10ml BS and 2.5% CL | Failed | | |
| | 15ml BS and 2.5% CL | 1.76 | 2.35 | 2.615 |
| | 10ml BS and 0.5% CL | 1.48 | 2.05 | 2.26 |
| | 15ml BS and 0.5% CL | 2.05 | 2.82 | 3.11 |

BS – Bacillus Subtilis CL – Calcium Lactate

The results for Compressive and Tensile strength are tabulated above. From table 1, under normal atmospheric conditions the compressive strength for Self-Healing Bacterial Concrete shows greater results when 15ml Bacillus Subtilis and 2.5% Calcium Lactate were added to nominal concrete.

From table 2, the maximum tensile strength for Self-Healing Bacterial Concrete was obtained with the addition 15ml Bacillus Subtilis and 0.5% Calcium Lactate to nominal concrete mix.

## V. CONCLUSION

From Experimental study on Self-Healing Bacterial Concrete (SHBC), the following conclusions are drawn:

The workability increased after addition of Bacteria and Calcium lactate to the concrete mix. We observed that, with the increase in Calcium Lactate percentage, the Setting time also increased. Under normal atmospheric conditions, healing of cracks were done very effectively. The hairline cracks were completely healed, but the cracks having greater width were not healed completely after 28 days of curing.From our Experimental study we suggest that SHBC is preferred where the concrete structures are prone to hairline cracks. Further studies are needed to investigate the strength of SHBC where the cracks are formed with greater width (i.e., other than hairline cracks)

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