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# A Study on Strength, Workability and Fire resistance properties of Bacteria Induced concrete

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***Abstract***
*Concrete is a widely used material in construction that can withstand the compressive load. Because of its brittle nature, it is susceptible to cracks. These minor cracks in the structure lead to the ingress of fluids or substances into the concrete's lower layer. To avoid and overcome these cracks, need for an increase in the strength and durability of concrete. The introduction of bacteria into the concrete mixture works by precipitation of calcium carbonate to fill up the concrete cracks.*

*In this research, extensive laboratory investigations have been carried out to study the effect of introducing Bacillus Subtilis Bacteria on concrete's mechanical properties. In addition to this Fire resisting properties of bacteria-induced concrete are studied. For the study, the microstructure of concrete SEM analysis is carried out on all mixes*

*In this paper, Bacterial Induced Concrete and plain concrete's experimental results are discussed for M40 Grade of concrete for two types of cement. The results show that bacterial induced concrete for OPC mix is 18% increase in compressive strength, 13.84 % increase in flexural strength and 11.32% increase in Split tensile strength compared with normal concrete.*

**Keywords —** *Concrete, Bio-Concrete, Bacillus Subtilis, Fatigue characteristics*

## I. INTRODUCTION

Cement act as a binding material in all concrete structures. Concrete is the most widely used structural material due to its capacity to get casted in any form and shape. Due to the brittle nature of concrete, it is susceptible to cracks. There are many reasons for developing these minor cracks: overloading, improper design, unskilled labors, quality of materials, etc. Presence of cracks promotes the ingress of aggressive and potentially harmful fluids or substances such as sulfate, chlorides, and carbonates. These aggressive fluids permeate inside the concrete, affecting the reinforcement by corrosion, thereby reducing the concrete structure's durability. Cracks may not be considered a failure of the concrete, but the introduction of harmful substances weakens the structure, so it needs to close these cracks by repairing the structure [1]. The rising costs associated with repairs have led researchers to consider crack sealing alternatives with growing interests in crack healing. The introduction of bacteria into the concrete mixture is one such organic method and works by precipitation of calcium carbonate [2] to fill up cracks in concrete.

The current study has drawn that biotechnology can be a supportive device to reduce micro-cracks in concrete structures using Bacillus species of bacterial in concrete. This is the latest advancement of concrete, shows a powerful technique to improve service-life, which considerably reduces maintenance costs and lowers carbon emissions. Bacillus, a common soil bacterium, can continuously precipitate calcium carbonate (calcite) under favorable conditions. The technique can improve the compressive strength and stiffness of cracked concrete specimens [3].

## II. MATERIALS AND METHODS

### A. Cement

Ordinary Portland cement of 53 grade and Portland Pozzolana cement with specific Gravity 3.15 and 2.9 respectively have been used.

### B. Fine aggregate

M sand of specific gravity 2.65 and conforming to IS-383-2016 Zone 2 was used

### C. Coarse aggregate

20mm down 2.70 specific gravity coarse aggregate was used

### D. Chemical Admixture

Conplast SP430 with specific gravity 1.12 for concrete mix

### E. Bacteria

Bacillus subtilis of concentration of $10^5$ cells per liter of water was used. Bacteria were cultured by Bacillus Subtilis pure culture.

### F. Mix Proportion

Mix design for M40 grade concrete is derived as per IS 10262-2009.

**Table 1**
**Mix proportion for OPC mix**

| Contents | Values (Kg/m$^3$) |
|---|---|
| Cement | 383 |
| Water | 153 |
| Fine aggregate | 678 |
| Coarse aggregate | 1250 |
| Super plasticizer | 1.92 |
| Water cement ratio | 0.40 |

**Table 2**
**Mix Proportion for PPC mix**

| Contents | Values (Kg/m$^3$) |
|---|---|
| Cement | 383 |
| Water | 153 |
| Fine aggregate | 653 |
| Coarse aggregate | 1207 |
| Super plasticizer | 1.92 |
| Water cement ratio | 0.40 |

## III. RESULTS AND DISCUSSION

### *A. Selection of Bacterial concentration*

To select the optimum dosage of bacterial concentration, standard mortar cubes were cast with different concentrations. The compressive strength for mortar cubes was tested at 3 7 and 28 days for different cell concertations, as shown in table 3.

**Table 3**
**Bacterial concentration**

| SL. NO | Cell concentration /ml of water | Average compressive strength of cement mortar in N/mm$^2$ | | |
|---|---|---|---|---|
| | | 3days | 7days | 28days |
| 1 | Nil | 26.34 | 38.76 | 51.43 |
| 2 | $10^4$ | 27.98 | 39.97 | 57.61 |
| 3 | $10^5$ | 29.42 | 43.76 | 61.37 |
| 4 | $10^6$ | 28.12 | 41.24 | 57.21 |

### *B. Workability test*

**Table 4**
**Compaction factor test results**

| Type of cement | Compaction factor value | Recommended value |
|---|---|---|
| OPC (M1) | 0.82 | 0.7 to 0.95 |
| OPC+ Bacteria(M2) | 0.86 | |
| PPC (M3) | 0.85 | 0.7 to 0.95 |
| PPC+ Bacteria (M4) | 0.91 | |

Table 4 shows that for bacteria-induced concrete, good work can be produced compared with conventional concrete.

### *C. Compressive strength Test*

A total of 36 cubes of 100x100x100 mm dimensions are cast and tested to determine compressive strength as per IS516-1959. The average compressive strength for 7, 14, and 28 days is shown (Fig 1 and 2). The compressive strength for conventional OPC concrete and bacteria-induced OPC concrete at 28 days was 51.24 MPa and 60.46 MPa. Similarly, for PPC concrete compressive strength is 41.75MPa for conventional concrete and 48.46 MPa for bacteria-induced concrete.

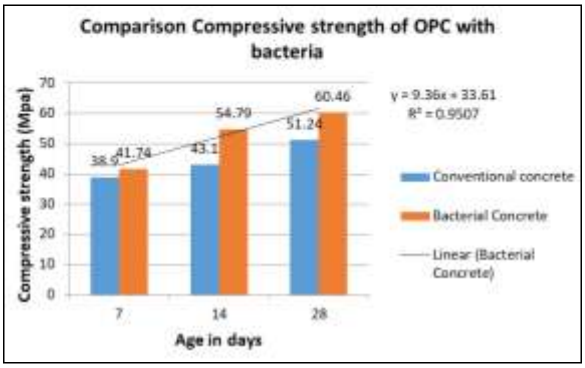


**Fig 1: Comparison of OPC compressive strength**

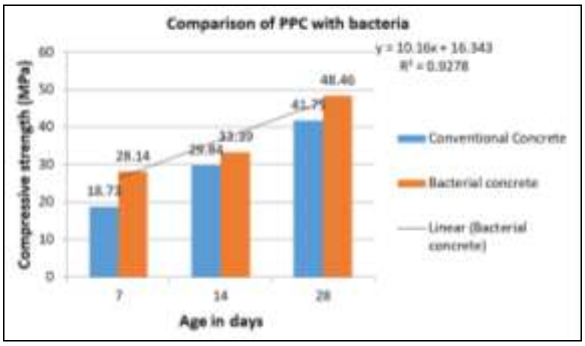


**Fig 2: Comparison of PPC compressive strength**

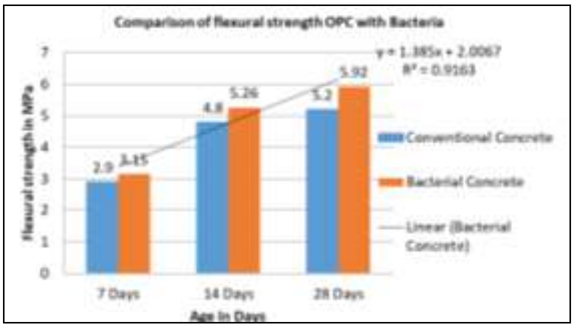


**Fig 3: Comparison of OPC Flexural strength**

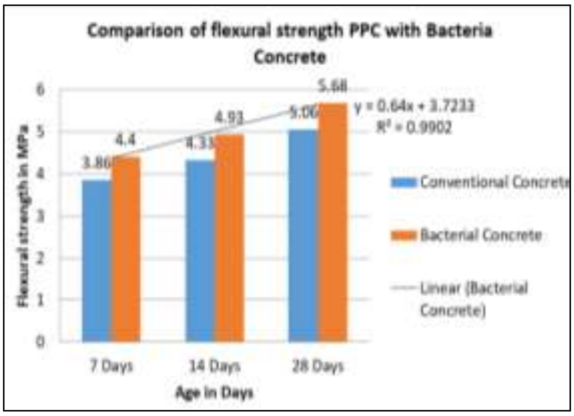


**Fig 4: Comparison of PPC Flexural strength**

### *E. Split tensile strength*

Cylinders of 200mm long and 100 mm diameter were casted and tested for split tensile strength.

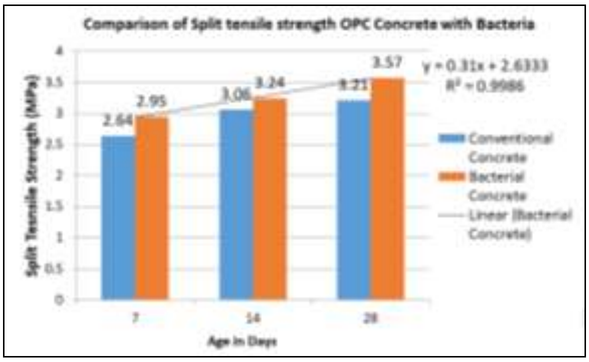


**Fig 5: Comparison of OPC Split tensile strength**

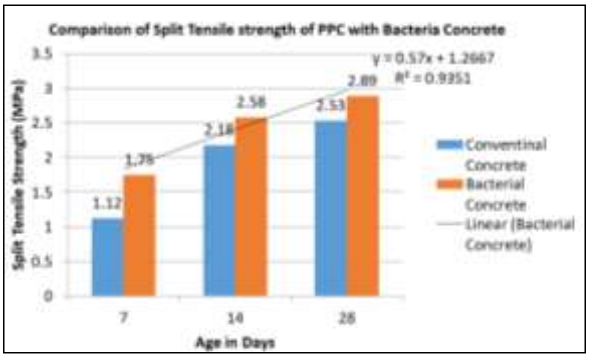


**Fig 6: Comparison of PPC Split tensile strength**

### *F. Fire Test*

Concrete cubes of 100x100x100mm size are casted and cured for 28 days. It is kept in the gas furnace, and cubes are fired for 5, 10, and 15 minutes of Fire. Each cube's surface temperature for 5, 10, and 15 cubes is measured using an infrared gun. Once the cubes are cooled to room temperature after one day, the test is made. But the compressive strength conducted on the theses shows very low strength. The compressive strength results are not included in this paper. The surface temperature of cubes for different times of Fire is as shown in Fig:7.

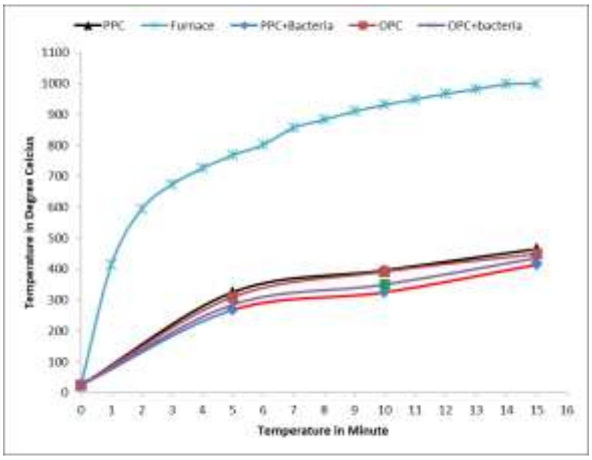


**Fig 7 Surface temperature of all concrete cubes.**


**Fig :8** **Fig :9**

We can observe that normal concrete without bacteria has more cracks than that concrete with bacteria concrete from the observation. So hence can be concluded that bacteria-induced concrete is less prone to cracks during high temperature.

### *G. SEM Analysis of Bacterial Concrete*

To study the microstructure of bacterial-induced concrete, all four mixes are subjected to Scanning electron microscopy analysis. For comparison of the self-healing process of SEM analysis was conducted at 28days of healing.

Production of calcium carbonate-based crystals was the main focus of this as it expresses the respective mix's crack healing efficiency. Calcium carbonate crystals are developed in three different forms: calcite, aragonite, and vaterite. Since the B.Subtilis is a calcite forming bacteria[4]

Out of three, calcite is the most stable form of calcium carbonate. SEM analysis of four mixes is shown below Figures. From SEM analysis, it is proven that the self-healing product CaCo3 is formed in bacteria-induced concrete for both types of cement used in the present experiment.

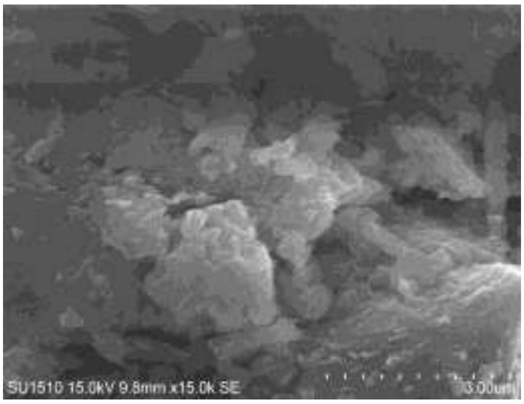


**Fig 10: OPC concrete**

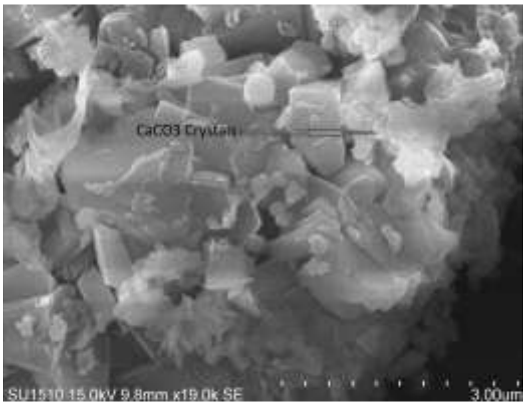


**Fig 11: OPC with Bacteria**

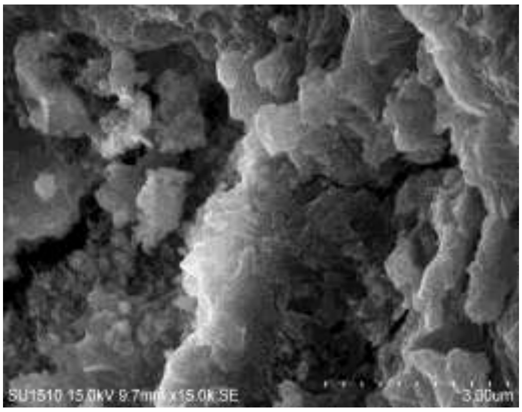


**Fig 12: OPC with Bacteria**

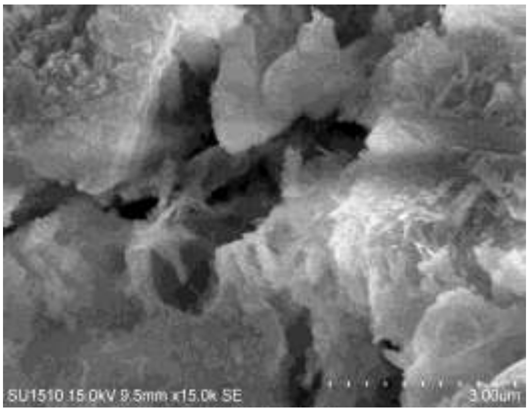


**Fig 13: OPC with Bacteria**

## IV. CONCLUSIONS

Based on the results achieved from the experiment following conclusion are drawn:

1. It is observed from studies that the addition of bacteria increases the workability of concrete in the compaction factor test.
2. $10^5$Cells concentration/ml of water of Bacillus subtilis is an optimum dosage that increases concrete's compressive strength.
3. The addition of Bacillus Subtilis increases 17.99%, 13.84%, and11.32% in compressive strength, Flexural, and split tensile strength of OPC concrete with bacteria compared to conventional concrete.
4. The addition of bacteria increases concrete density, so Bacteria induced concrete can be less permeable concrete.

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