Experimental Investigation on Mechanical Properties of Self-healing Concrete by using Bacillus Pseudofirmus

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ABSTRACT- *The purpose of this research is to investigate the nature of microorganism Bacillus Pseudofirmus for enhancement of self-healing property and strength in concrete. Cracks in concrete are integral and are one of the implicit weaknesses of concrete. Water and other salts percolate through these cracks, corrosion introduce, and thus reduces the life of concrete. So there was a need to develop an inherent self-healing material which can remediate the cracks in concrete. The concrete structures have various durability issues due to the different conditions and it results to irretrievable damage to the structure and eventually reduction in the strength of concrete structure. Therefore, for improve the mechanical properties of concrete structures cement is replaced by Bacillus Pseudofirmus. For this purpose Bacillus Pseudofirmus is replaced by 0%, 2.5%, 5% by the weight of cement. Numerous tests were conducted like compressive strength, flexural strength, split tensile strength and stress-strain curve at the different percentage of Bacillus Pseudofirmus 2.5%, 5% for the time period of 7, 14, and 28 days curing and relate with conventional concrete.*

Key Words: Bacillus Pseudofirmus, Application, Mechanical Properties, Bacterial Concrete, Crack healing.

I. INTRODUCTION

Bacterial concrete is a superior type of concrete it has the ability to repair itself separately. One another advantage of bacterial concrete is that the introduction of bacteria in concrete also helps in enhancing the mechanical as well as durability properties of concrete in both natural and laboratory conditions. Concrete which forms most important component in the Construction Industry as it is economic, easily accessible and convenient to cast. But drawback of these materials is it is weak in tension so, it cracks under sustained loading and due to aggressive environmental agents which ultimately reduce the life of the structure which are built using these materials. This method of damage take place in the early life of the structure and also during its life time. Bacteria made Calcium Carbonate (Calcite) precipitation has been anticipated as an alternative and environment friendly crack remediation and hence improvement of strength of building materials. Self-healing concrete could solve the problem of concrete structures failing well before the end of their service life. Concrete is one of the key materials used in the construction, from the foundation of buildings to the structure of bridges and underground structures. Conventional concrete has a flaw, it tends to crack when subjected to tension. Because the other pre-defined materials for enhancement in strength were not good for atmosphere and also more expensive than bacterial concrete and they also require regular maintenance. This study is to understand the significance of different micro-organisms in concrete.

II. MATERIALS

Materials utilized in this study to produce self-healing concrete are as follow*:*

1) Cement- The cement used in this experimental project was 43 Grade ordinary Portland cement (OPC) conforming to IS 8112-1989 for casting the specimens of all concrete mixes. Physical properties of cement were calculated and tabulated as given below,

Sr. No.	Properties	Test Result
1.	Consistency	34%
2.	Initial Setting Time	38min.
3.	Final Setting Time	8hrs.
4.	Specific Gravity	3.10

2) Fine aggregate- The fine aggregate used for study belongs to the zone I, was procured from the local fine aggregate suppliers and conform all requirements as per IS: 383-1970. The specific gravity test was performed in the laboratory and value achieved is 2.74.

3) Coarse aggregates- Coarse aggregate of 10 mm and 20 mm sizes were used in this study and they conform all requirements as per IS: 383-1970. It was free from dust particles, vegetation, organic matters, and clay. The specific gravity test was performed in the laboratory and value achieved is 2.74.

4) Water- Ordinary water available in the laboratory was used in this investigation both for mixing and curing the concrete specimen as per IS: 456-2000 and as per IS: 3025 – 1964 part 22 throughout the investigation.

5) Concrete mix proportion designed as per IS: 10262-2009 and as per IS: 456-2000

6) Bacillus Pseudofirmus- The pure culture of Bacillus Pseudofirmus was obtained from Fertilizer Industry, Rau (M.P.).

III. METHODOLOGY

The methodology adopted to accomplish the objective of the experimental investigation and execution of work was done in step by step as follow:

1) Mix design- Mix design was done for M20 grade of concrete as per the guidelines given in IS: 10262 (2009) and IS: 456 (2000). The mixes were designed after considering many trail mixes. The design mix of 1:1.605:2.73 is adopted for casting specimens. Bacillus Pseudofirmus added by 0%, 2.5% and 5% by weight of cement. The water to cement material ratio (w/c) was maintained at 0.45.

2) Weighing- The quantity of all ingredients of the concrete i.e. cement, bacillus pseudofirmus, fine aggregate, coarse aggregate and water for each batch was determined as per the mix design ratio and weighed using weighing machine available in laboratory.

3) Mixing- Process of mixing of various ingredients adopted was as per IS: 516-1959 and hand mixing process was adopted for mixing the concrete.

4) Preparation of moulds- Before casting the specimens, all cube, beam and cylinder moulds were cleaned, screwed tightly and oil was applied to all surfaces to prevent adhesion of concrete during casting.

5) Compaction- Placing of concrete in oiled moulds was done in three layers and each layer tamped 25 times with the tamping rod. After tamping the moulds, they were compacted using vibratory machine.

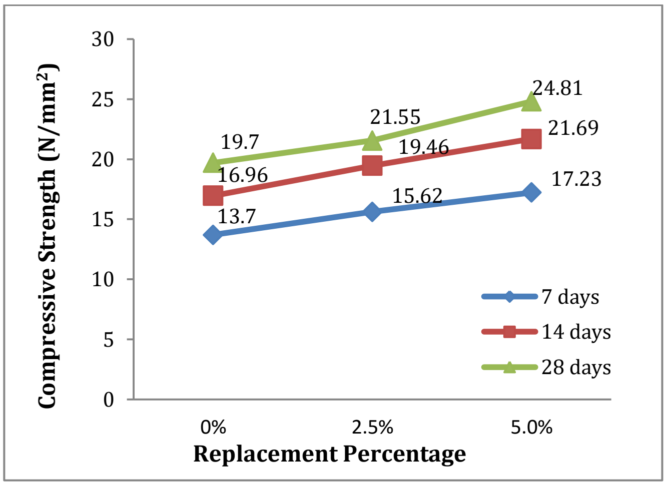
6) Curing- After 24 hours, all the casted specimens were demoulded from the moulds and marked (to identify the casting batch) and immediately put into the curing tank for a period of 7, 14 and 28 days. The specimens were not allowed to become dry during the curing period.

7) Testing- Specimens were taken out from the curing tank after 7, 14 and 28 days to perform various tests. Three numbers of specimens in each sample were tested and the average value was calculated. Fresh concrete property like workability was examined during casting by slump cone test. Hardened properties were found out by carrying out the experimental work on cubes, beams and cylinders which were casted in laboratory and their behaviour under test were observed at 7, 14 & 28 days for compressive strength, flexural strength and split tensile strength and 7 & 28 days for stress strain curve.

IV. RESULTS AND DISCUSSION

As work is carried out in single stages, result of all stage is presented in graphical form. Tests are performed on cubes, beams & cylinders and their 7 days, 14 days & 28 days strengths have been determined. A comparison based on strength of different mix proportions is carried out. A comparison of strengths for 7 days, 14 days and 28 days are also formulated.

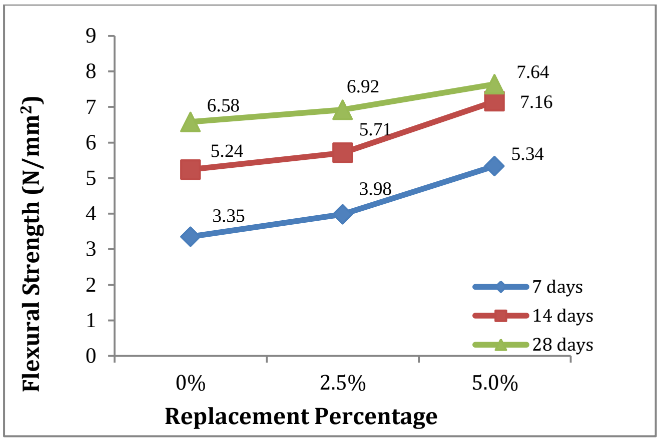
1. Compressive Strength- Compressive strength test is performed on 3 cubes of each batch mix for 7 days, 14 days & 28 days. There are 3 batch mixes and each one having 9 cubes. Of these 9 cubes, 3 cubes are tested for 7 days, 14 days & 28 days each. An average of 3 values as tabulated in subhead results, are considered for discussions.



Graph-1 Compressive Strength in N/mm² at various age (Days)

As shown in the graph: 7 days strength is analysed, 2.5% and 5% replacement by BP, compressive strength is increased by 14.01% and 25.76% respectively. 14 days strength is analysed, 2.5% and 5% replacement by BP, compressive strength is increased by 14.71% and 27.89% respectively. 28 days strength is analysed 2.5% and 5% replacement by BP, compressive strength is increased by 9.39% and 25.93% respectively as compare to conventional concrete mix.

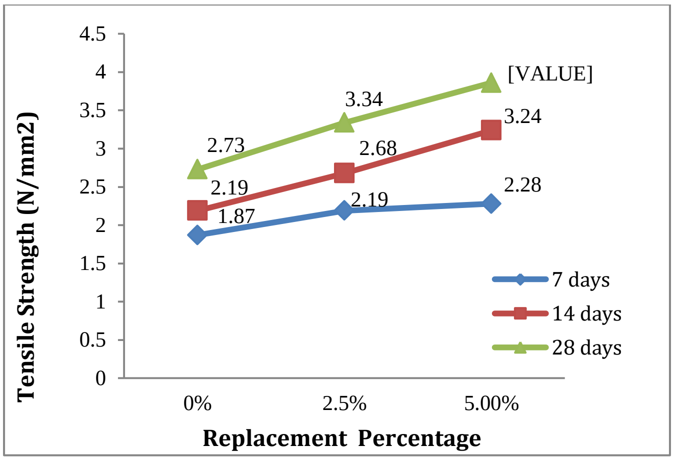
2. Flexural Strength- Flexural strength test is performed on 3 beams of each batch mix for 7 days, 14 days & 28 days. There are 3 batch mixes and each one having 9 beams. Of these 9 beams, 3 beams are tested for 7 days, 14 days & 28 days each. An average of 3 values as tabulated in subhead results, are considered for discussions.



Graph-2 Flexural Strength in N/mm² at various age (Days)

As shown in the graph: 7 days strength is analysed, 2.5% and 5% replacement by BP, flexural strength is increased by 18.8% and 49.4% respectively. 14 days strength is analysed, 2.5% and 5% replacement by BP, flexural strength is increased by 8.97% and 36.6% respectively. 28 days strength is analysed 2.5% and 5% replacement by BP, flexural strength is increased by 5.17% and 16.11% respectively as compare to conventional concrete mix.

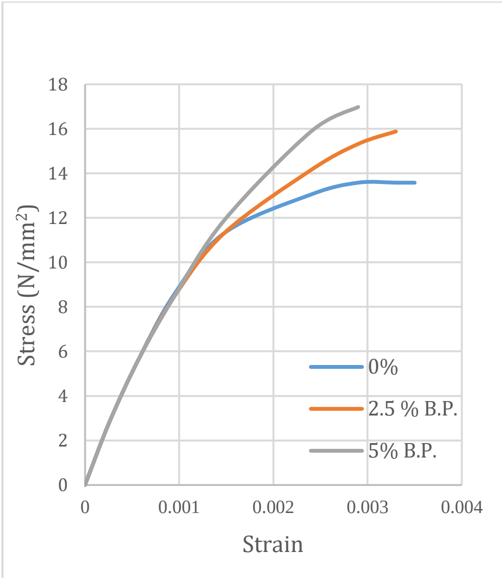
3. Split Tensile Strength- Split Tensile Strength is performed on 3 cylinders of each batch mix for 7 days, 14 days & 28 days. There are 3 batch mixes and each one having 3 cylinders. Of these 9 cylinders, 3 cylinders are tested for 7 days, 14 days & 28 days each. An average of 3 values as tabulated in subhead results, are considered for discussions.



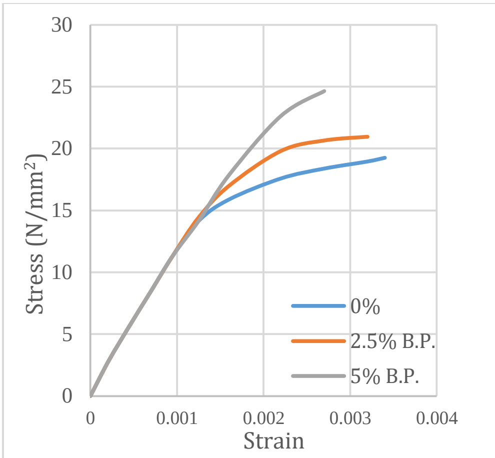
Graph-3 Split Tensile Strength in N/mm² at various age (Days)

As shown in the graph: 7 days strength is analysed, 2.5% and 5% replacement by BP, split tensile strength is increased by 17.11% and 21.92% respectively. 14 days strength is analysed, 2.5% and 5% replacement by BP, split tensile strength is increased by 22.37% and 47.94% respectively. 28 days strength is analysed 2.5% and 5% replacement by BP, split tensile strength is increased by 23.01% and 41.39% respectively as compare to conventional concrete mix.

4. Stress Strain Curve- Stress Strain curve is performed on 1 cylinder of each batch mix for 7 days & 28 days. There are 3 batch mixes and each one having 1 cylinder. Of these 6 cylinders, 3 cylinders are tested for 7 days & 28 days each. Combined the stress strain curve for normal concrete, 2.5% bacillus pseudofirmus and 5% bacillus pseudofirmus for 7 days and same for 28 days and compare the compressive strain and compressive stress of the curves.



Graph-4 Combined Stress Strain Curve (7 days)



Graph-5 Combined Stress Strain Curve (28 days)

As shown in the graph: 7 days compressive strain is analysed for 2.5% and 5% replacement by bacillus pseudofirmus, compressive strain in outermost fibre is reduced to 20.68% and 5.71% respectively as compare to conventional concrete. 28 days compressive strain is analysed for 2.5% and 5% replacement by bacillus pseudofirmus, compressive strain in outermost fibre is reduced to 25.92% and 6.25% respectively as compare to conventional concrete. 7 days compressive strain is analysed for 2.5% and 5% replacement by bacillus pseudofirmus, compressive strain in outermost fibre is increased by 16.93% and 25.03% respectively as compare to conventional concrete. 28 days compressive strain is analysed for 2.5% and 5% replacement by bacillus pseudofirmus, compressive strain in outermost fibre is increased by 8.83% and 28% respectively as compare to conventional concrete.

5. Self-healing of concrete- Self-healing property of bacillus pseudofirmus is performed on 3 cubes of each batch mix for 7 days. Cubes are tested on compressive testing machine after 7days of curing. Load is removed when initial crack was appeared. For easily visible of initial crack painted white lime paste on the surface of the cubes. After that cubes are placed under the exposure condition for easily reaction of bacillus pseudofirmus with atmospheric condition for 14 days.

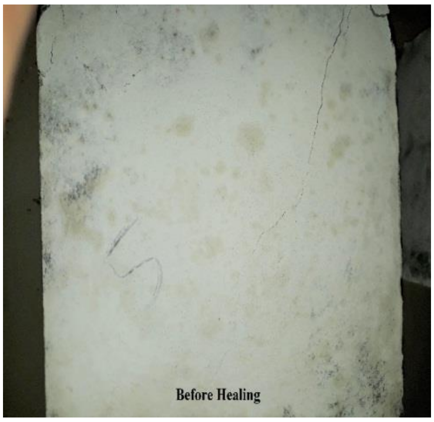


Fig.1- Cracked Specimen

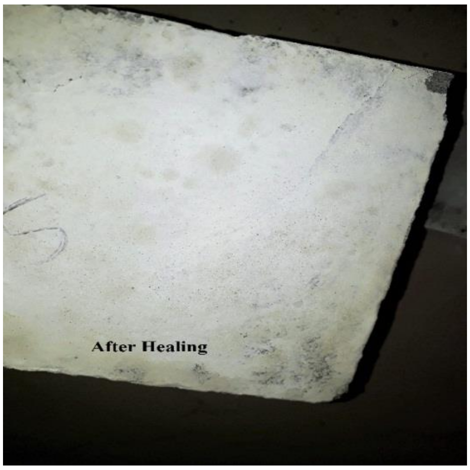


Fig.2- Self-healed Specimen

V. CONCLUSION

The following conclusions are made from the detailed experimental investigations conducted on the behaviour of normal grade conventional concrete.

- Bacteria Bacillus Pseudofirmus plays a significant role in increasing the compressive strength of normal concrete by up to 9.39% and 25.93% respectively for 2.5% and 5% as partial replacement of cement respectively as compared to conventional concrete at 28 days.
- The experiment on concrete beams shows that improvement in flexural strength. Flexural strength is increased by 5.17% and 16.11% respectively as compare to conventional concrete mix at 28 days.
- Maximum compressive strain is reduced 0.0029 from 0.0035 at 7days and 0.0027 from 0.0034 at 28days as compare to conventional concrete. Compressive stress increase up to 16.93% and 25.03% at 7days and 25.01% and 28% at 28 days respectively as compare to conventional concrete.
- Cracked concrete self-healed in 14days.

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