Self-healing Concrete

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Abstract- Crack formation is very common phenomenon in concrete structure which allows water and different types of chemicals into concrete through the cracks and decreases durability, strength & affects the reinforcement. Due to this negative impact of construction processes on environment and a decrease in investment, there is a need for concrete structures to operate longer while maintaining their high performance. Self- healing concrete has the ability to heal itself when it is cracked, thereby protects the interior matrix as well as reinforcement steel, resulting in increased service life. By introducing Bacteria in concrete, it produces calcium carbonate crystals which block the micro cracks and pores in the concrete. After studying research papers, it was observed that bacteria improve the structural properties such as tensile strength, water permeability, durability, compressive strength of the normal concrete which was found by performing different type of experiment on specimen. Compressive strength of the concrete was tested by casting specimens of M-25 concrete grade and performing significant tests on them with sets of specimens having different curing time. Study for ideal percentage of concrete was also done which can give best results for compressive strength of concrete. Self -healing concrete was observed the best solution for the demand of sustainable concrete due to its ability of self-repair and durability. Self -healing efficiency on concrete of M-25 grade was observed satisfying during the experiment. Cracks were sufficiently healed during the observation period after adding the bacterial paste of bacillus subtillis and water

Key Words: **Bacillus subtillis, M-25 Concrete grade,**

1.INTRODUCTION

Concrete which forms major components in the construction industry as it is cheap, easily available 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 process of damage occurs in the early life of the building structure and also during its life time. Synthetic materials like epoxies are used for remediation. But they are not compatible, costly, reducing aesthetic appearance and need constant maintenance. Therefore, bacterial induced calcium carbonate (calcite) precipitation has been proposed as an alternative and environment friendly crack remediation and hence improvement of strength of building materials

1.1 PROBLEM STATEMENT

- Reduced efficiency of a structure due to developed cracks
- High maintenance cost after generation of cracks

1.2 OBJECTIVES

- To study various self-healing methods for concrete structures
- To increase the efficiency of a structure by introducing self-healing mechanism
- To check the efficiency of bacillus subtilis as a self-healing property on M-25 grade of concrete
- To reduce the repairing cost and to increase the life span of the structure

2. REVIEW OF LITERATURE

2.1 Carola Edvardsen, *et, al.* (1999) The experimental studies showed the formation of calcite in the crack to be almost the sole cause for the autogenously healing. The crystal growth rate is dependent on the crack width and water pressure, whereas concrete composition and water hardness have no influence on autogenously healing

2.2 Jashir bashir, et, al. (2016) In this study M 20 Concrete grade was studied for various properties of self healing concrete using 3 bacteria namely Bacillus Subtilis, Bacillus Sphaericus, Bacillus pasteurii and the results were compared.

2.3 Xin wang, et, al. (2017) In this study, a new type of cement-based healing pellets (CHPs) were proposed to accelerate the healing efficiency of concrete, which was mainly based on the introduced Na_2CO_3 on promoting the formation of calcium carbonate ($CaCO_3$) in cracks..

2.4 Roli verma, et, al. (2018) In this study they observed the Self Healing Concrete has comparatively very less permeability, more durability and strain bearing capacity than the conventional concrete. While most healing agents are chemically based, more recently the possible application of bacteria as self-healing agent has also been considered.

2.5 Sneha M Varghese, et, al. (2018)

In this study tests are conducted to find the favorable concentration of Bacillus Subtillis and Fly Ash in self healing concrete. The Concentration of Bacteria was found to be 6x 10 6cells/ml and percentage of cement that can be replaced with Fly Ash to be 25%

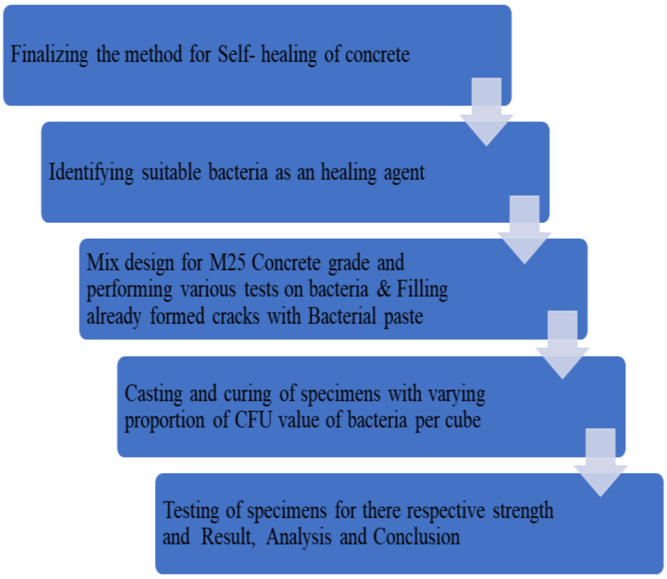
2.6 Ishraq mohammad ali khattab, et, al. (2019) The study reviews various methods and techniques for self-healing concrete design. These methods are chemical, biological, and Natural self-healing processes. This study although focuses mainly on promising biological method especially using bacteria.

2.7 Lagazo, et, al. (2019) In this study researchers produced Bacillus Subtilis in the laboratory and it is proven to be safe because its biosafety level is only 1 and it is a bacterium that can be found in soil.

2.8 P. Bala Gopi Krishna, et, al. (2019) In this study Bacillus Pseudofirmus was used as an healing agent for the self healing concrete. For the comparison of strength of specimens by bacterial healing with cement mortar healing method, different specimens were casted.

3. METHODOLOGY

This project focuses on study of ideal percentage of bacteria in the concrete which can give the best results for the compressive strength for concrete.



This study mainly focuses on effect of bacteria on different grades of concrete. Various strengths of the concrete will be tested by casting specimens of M-25 concrete grade and performing significant tests on them with sets of specimens having different curing time. The test results would be compared with conventional concrete in many perspectives. Analysis will be done and a conclusion would be drawn on the effect of bacteria on concrete.

Various specimens were cast for determining Compressive strength of the concrete. M-25 grade of concrete was finalized for the Concrete specimens. Material testing for Cement & aggregates was done accordingly. Test results of Material testing were used to calculate Mix design for M-25 concrete grade according to IS 456-2000.

Tests conducted

- Spectrophotometry
- Compression Test
- Surface Curing Analysis

4. Result and Analysis

Table-1 Results for spectrophotometry

Sr No.	Cell	Absorption	Concentration
001	Reference	0.0000	0.0000
002	Sample 1	0.0931	0.0000
003	Sample 2	0.1163	0.0000
004	Sample 3	0.0804	0.0000
005	Sample 1	0.2086	0.0000
006	Sample 2	0.1640	0.0000
007	Sample 3	0.2943	0.0000
008	Sample 1	0.2116	0.0000
009	Sample 2	0.1933	0.0000
010	Sample 3	0.2751	0.0000
011	Sample 1	0.2535	0.0000
012	Sample 2	0.3602	0.0000
013	Sample 3	0.0606	0.0000

CELL=S3 625.0mm 0.0607A k=0.000

Table-2 Results for compressive strength of testing for 27 cubes according to curing period

Quantity of bacteria	3 Days	7 Days	28Days
1.5 x 10^{12} CFU	8.3751 kN/mm²	18.7633 kN/mm²	26.769 kN/mm²
3 x 10^{12} CFU	10.5931 kN/mm²	19.9353 kN/mm²	28.922 kN/mm²
4.5 x 10^{12} CFU	12.4489 kN/mm²	24.769 kN/mm²	32.200 kN/mm²

Graphical comparison of conventional and bacterial values:

Chart-1 Results for 1.5 x 10^{12} CFU

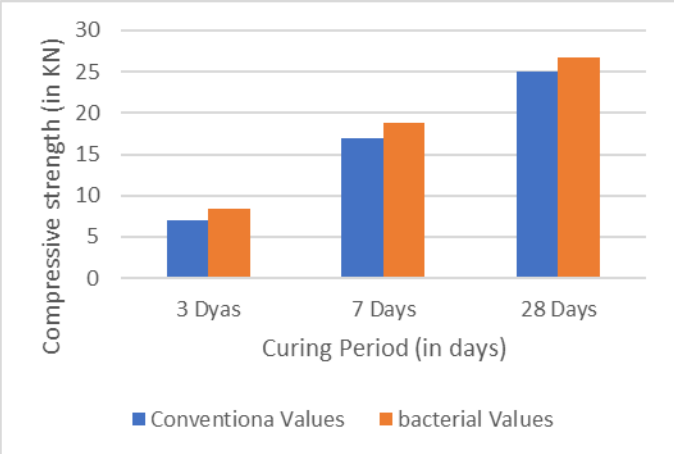


Chart-2 Results for 3 x 10^{12} CFU

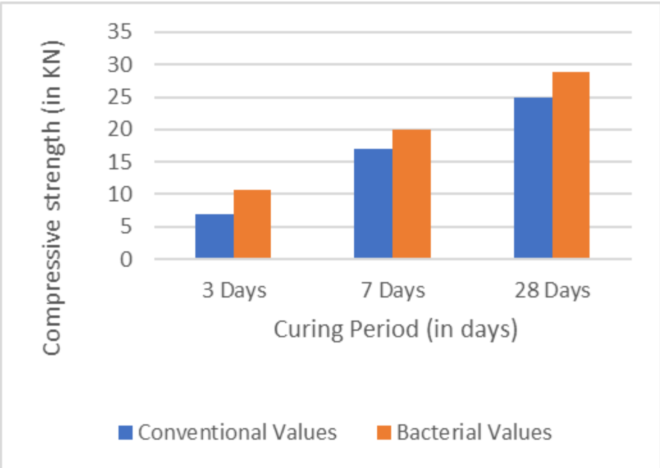
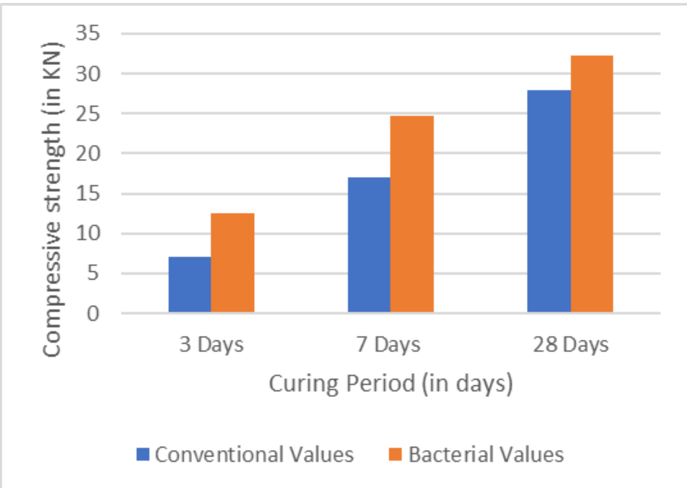


Chart-3 Results for 4.5 x 10^{12} CFU



The experiment with the bacteria on already formed cracks was done. In this part the bacteria was mixed with the water and a thick white paste was formed. While preparing the bacterial paste the water was added with the proportion of (1:20). This paste was then added in the already formed cracks of cubes. The selection of cracks were done based on the width of the cracks, 1-2 mm width of cracks were finalized for the specimens. The cracks were filled by the bacterial paste and were kept for the observation. Daily observations were taken for a month, and a notable difference was observed in the crack width. During the observation period the crack width was reduced and the cracks were healed by the reaction of bacteria.

Fig 1

Specimen No. 1

Day-1 Day- 30

(Cracked) (Healed)

Fig 2

Specimen No. 2

Day-1 Day- 30

(Cracked) (Healed)

5. CONCLUSIONS

1. Cracks were sufficiently healed during the Observation period after adding the Bacterial paste of Bacillus subtilis and water

2. Self-healing efficiency on concrete of M-25 grade was observed to be increased by 25% compared to conventional concrete

3. While adding of bacteria increases the life span of a structure while reducing the repairing and

maintenance cost it makes it an affordable option in construction industry

4. Self-healing concrete is the best solution for the demand of sustainable concrete due to its ability of self-repair and durability. In future, self-healing concrete is going to play the most important role in concrete technology

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