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Experimental Study on Strength of Self-Healing Concrete

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Abstract: *Crack formation is very common phenomenon in concrete structure which allows the water and different type of chemical into the concrete through the cracks and decreases their durability, strength and which also affect the reinforcement when it comesin contact with water, CO2 and other chemicals. For repairing the cracks developed in the concrete, it requires regular maintenance and special type of treatment which will be veryexpansive. So, to overcome from this problem autonomous self-healing mechanism is introduced in the concrete which helps to repair the cracks by producing calcium carbonate crystals which block the micro cracks and pores in the concrete. The selection of the bacteria was according to their survival in the alkaline environment such as B.subtilis, Bacillus subtilis and B. subtilis which are mainly used for the experiments by different researchers for their study. The condition of growth is different for different types of bacteria. For the growth, bacteria were put in a medium containing different chemical at aparticular temperature and for a particular time period. Bactria improves the structural properties such as tensile strength, water permeability, durability and compressive strengthof the normal concrete which was found by the performing different type of experiment on too many specimens had varying sizes used by different researchers for their study of bacterial concrete in comparison with the conventional concrete and from the experiment it was also found that use of light weight aggregate along with bacteria helps in self healing property of concrete. For gaining the best result a mathematical model was also introduced to study the stress-strain behavior of bacteria which was used to improve the strength of concrete.*

Key Word : *Bacteria, Bacillus subtilis, Concrete, Bacillus, cracks treatment*

I.INTRODUCTION

Reinforced concrete structures are the most used system in buildings and infrastructure constructions. Concrete is anaffordable material, easy to produce, which allows variable consistency for application (from dry to self-compacting) andcan take different forms and strengths.

In many reinforced concrete structures, cracks are frequent, and they can be acceptable in the structural design as a result of actions considered in the design. In general, concrete elements will suffer combined axial, shear, and bending stresses. These elements will be designed in a way that the compression stresses will be endured by the concrete matrix and the tensile stresses by the reinforcement (Figure 1). The size of acceptable cracks is generally controlled through the material properties, cover, and section design, but mostly through the reinforcement content.

In concrete codes, allowed crack width will depend on the exposure classes, which are chosen depending on the aggressivity of the environment in terms of the risks of corrosion, carbonation, freeze-thaw, erosion, or chemical attacks. In the case of reinforced concrete, values of 0.3 mm of allowed crack width are frequent. In the case of prestressed concrete, cracks of 0.2 mm can be accepted in less aggressive environments. In contrast, no-decompression (and thus, no cracks) is the requirement for the elements under more aggressive conditions. These limits are considered to guaranty that, in the expected service conditions, the structure can maintain its service requirements.

However, it is true that even if the structural conditions are not significantly affected by the crack opening limits allowed for each aggressive class, the durability of concrete and reinforcement can be affected by the mobility of fluids through the open surface cracks. Gaseous materials such as CO_2, water, and acid vapors can be transported even in cracks of up to a few tenths of micro detritus, liquids and gasses with aggressive substances can lead to partial deterioration of concrete an orrosion of the reinforcement, affecting the durability and service life of the structure(Figure 1). If cracking overpasses certain limits, either because the design evaluation was wrong or because the expected service conditions were exceeded, deterioration in specific structures could imply excessive costs for inspection, monitoring, maintenance, and repair.

Self-healing of concrete can be defined as the process in which the material regenerates itself repairing its own cracks,similarly to what happens in some natural materials, such as bones or trees. Increasing the self-healing properties of the concrete can lead to mitigate the potential decrease in durability produced by cracking. The immediate objective of self- healing concrete is promoting a partial or total recoveryof their physical, mechanical and/or durability properties. Its final objectives are toincrease service life or to be able to design more competitive structures. With that purpose, the extent of the propertiesrecovered needs to be quantified accurately as wellas the implications in their long-term performance and service life.

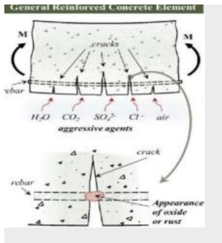

FIGURE 1. General diagram of a reinforcedconcrete element under bending stresses andsome aggressive agents.

Every year, new advances are being researched in order to obtain new ways of producing self-healing in concrete, aswell as new methodologies to quantify those improvements produced, in which properties, and under which conditions. Up to now,hundreds of articles have been published related to the self-healing capacity of several types of cement-based materials, including several reviews. Despite this high number of works published, most of the publications follow a descriptive approach of the results achieved in the different papers, not putting the focus on the questions that still need to be discussed.

II.LITERATURE REVIEW

Kusuma Ketal (2018) In this paper the most important aspects of self-healing concrete were discussed. The bacteria used for the experiment was Bacillus Magneterium. The bacteria was isolated and the bio-concrete mechanism were explained in detail. All the basic tests for cement, fine aggregate and coarse aggregate was conducted and the results were tabulated. The study on the self healing concrete showed that there was an enhancement of compressive strength of concrete. It also showed that the water absorption and the water permeability of the concrete had a positive effect. The paper concluded that the use of bio concrete can be a competent alternative and high quality concrete sealant which is an eco-friendly and a cost -effective waywhen compared to conventional concrete.

Ms. T. Viduthalai et al (2018) In this paper the self healing properties of a concrete for the M25 mix is been elaborately discussed. All the necessary tests were carried out and explained on the materials used. The major tests done for the bacterial concrete were compressive strength test ,split tensile test, water absorption test. The compressive test results showed that therewas a drastic increase in the 7th day, 14th day and the 28th day tests. From the split tensile test results it was observed that theconcrete specimens prepared by incorporating the micro-organisms yielded higher tensile strength as compared to conventionalconcrete. From the water absorption test conducted it was found that at the age of 28 days the percentage of water absorption in conventional concrete is more than that of the self-healing concrete. The self healing assessment was also carried out and reviewed in the paper.

Gaurav Agarwal et al (2017) In this paper the author explained about the mechanism and working of self-healing concrete. Different types of bacteria are used for the study in this paper. The crack of size 0.2 mm are healed autogenously with the helpof bacteria. The characteristics of the bacteria that is to be used is also explained briefly in the paper. The tests that are carriedout are compressive strength of concrete, flexural strength of concrete and split tensile test on concrete. The sustainability testsare done using the Scanning Electron Microscope. It is also found that the bacteria can live in concrete for more than 100 yearsin the form of pores.

Jashira Bashir et al (2016) In this paper the author reviewed on the living concrete. The types of bacteria are explained in this journal. The method of using self-healing bacteria is also carried out. Most importantly the SEM/EDX and XRD Analysis is carried out on the self-healing bacteria. The compressive, split tensile and flexural strength of M20 bipconcrete is found to be higher than that of M20 conventional concrete. It is also found that it can reduce the chance of various defects that can take place in a structure like corrosion reinforcement and its crack. It is also said that the bacteria can be well used in the mortar andthe bricks to. It is concluded that the use of bio-concrete is better than epoxy treatment

Procedure Methodology

Problems Faced by Conventional Concrete

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Modern Solution to Conventional Concrete

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Self-Healing Concrete

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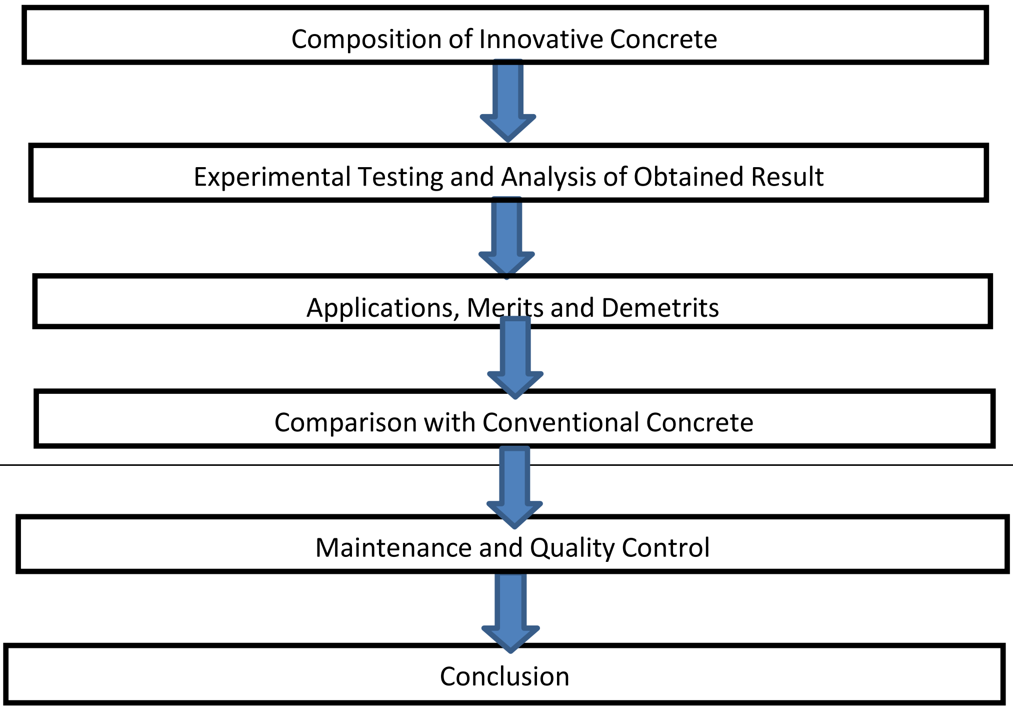


III.RESULT

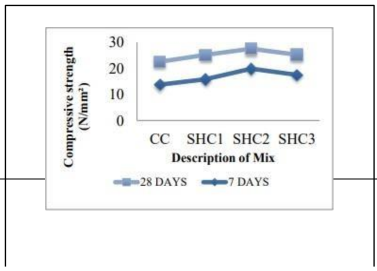
The test results showed that there was increase in strength of bacterial concrete specimens compared to conventional concrete specimens. The main aim of this project is to heal the cracks by itself and the results shows the healing of cracks. The test results, figures and graphs are given below

Mixes	Compressive Strength (N/mm^2)				
	1	2	3	Average	% Increase in strength
CC	13.6	13.9	13.7	13.73	-
SHC1	17.3	15.9	17.6	16.94	23.37
SHC2	20.8	19.4	19.35	19.85	44.57
SHC3	18.5	16.42	17.6	17.5	27.45

Table01 Compressive strength of concrete cubes at 7 Days

Mixes	Compressive Strength (N/mm^2)				
	1	2	3	Average	% Increase in strength
CC	21.9	23.5	22.16	22.52	-
SHC1	24.6	25.3	25.5	25.13	11.58
SHC2	27.5	25.41	29.5	27.47	21.98
SHC3	26.8	24.6	24.1	25.2	11.90

Table 02.Compressive strength of concrete cubes at 28 Days

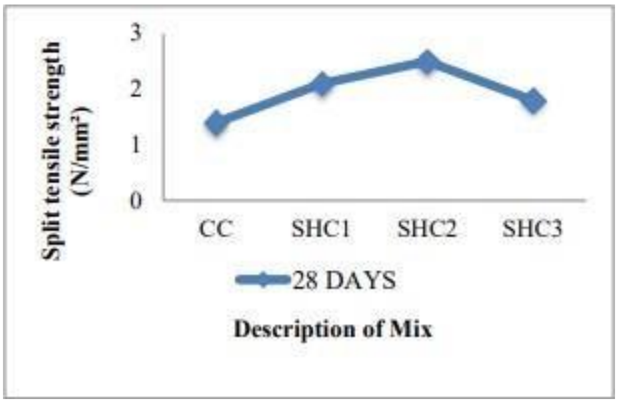


Graph 01..Variation of compressive strength of concrete

Graph.02 ,below shows the variation of **split tensile strength** of concrete. The results showed that the tensile strength of Self-healing concrete.

Mixes	Split Tensile Strength (N/mm^2)				
	1	**2**	**3**	**Average**	**% Increase in strength**
CC	1.5	1.3	1.4	1.4	-
SHC1	2.4	1.8	2.1	2.1	50
SHC2	2.7	2.5	2.3	2.5	78.57
SHC3	1.9	1.8	1.7	1.8	28.57

Table 03. Split tensile strength of cylinders for 28 days.



Graph02. Variation of Split tensile Strength of concrete

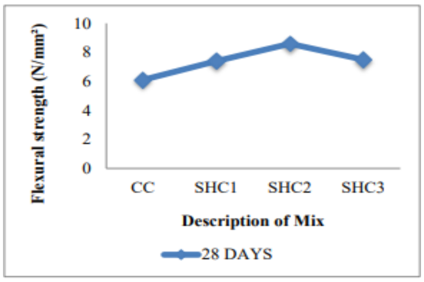
Flexural Strength

Graph.4. shows the variation of flexural strength of concrete. The percentage of increment in strength compared to control specimen is 40%. It is increased with the addition of bacterial cell. This was due to the reason that bacillus subtilis has more calcium precipitation to heal crack in concrete. The results showed that the flexural strength of Self-healing concrete of SHC1, SHC2 and SHC3 are increased than the control.

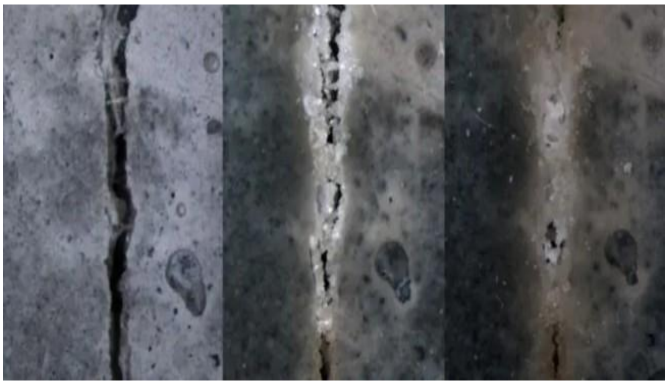
The beam was exposed to two points loading to expose the behavior of the RCC beam. As the load increases the crackwidth is also improved and prolonged towards the top of the beam. The mode of failure of RCC beam was flexure which is due to yielding of steel in tension zone. The concrete was crushed and spalling down.

CC	5.8	6.2	6.3	6.1	-
SHC1	7.6	7.1	7.5	7.4	21.31
SHC2	8.7	8.4	8.7	8.6	40.98
SHC3	7.4	7.4	7.7	7.5	22.95

Table04. Flexural strength



Cracks Healed:



Cracks less than 0.3 mm in width can be healed completely. Cracks which are wider than 0.5 mm may not be healed 10days. Moreover, 0. Cracks ranging in width from 0.15 to 0.3 mm significantly decrease in 7 days and are completely healed in 35 days in our experiment. Cracks of width 0.1 mm are completely healed after around 9-2- and 0.3-mm width cracks are mostlyhealed within 30 days.

IV.DISCUSSION

According to our project result and testing we found out some advantages and disadvantages of self healing concrete are asbelow:

Advantages:

- Redressing of cracks can be done efficiently.
- It offers great resistance against freeze and thaw attacks.
- It has lower permeability when compared to conventional concrete.
- The use of self-healing concrete significantly enhances the strength of concrete.
- The chances of corrosion of reinforcement are reduced to negligible.
- Overall maintenance cost of this concrete is low.

Disadvantages:

- The investigations involved to observe calcite precipitation are costly.
- Cost of this concrete is comparatively higher than conventional concrete; it's about 10-30% more than conventional concrete.
- There is no design of bacterial concrete is mentioned in IS codes or any other codes.
- Bacteria that are used in concrete are not good for human health; hence its usage should be limited to thestructure.

V.CONCLUSION

Based on the present experimental investigations, the following conclusions are drawn

- The addition of Bacillus subtilis bacteria improves the hydrated structure of cement in concrete for a cell concentration of cells per ml of mixing water. So, bacteria of optimum cell concentration of cells per ml of mixingwater was used in the investigation.
- The addition of Bacillus subtilis bacteria increases the compressive strength of concrete. The compressive strength is increased nearly 23% at 28 days for ordinary, standard, and high grades of concrete when compared to controlled concrete.
- From the above proof of principle, it can be concluded that Bacillus subtiliscan be safely used in crack remediation of concrete structure. Bacillus subtilis. which is available in soil can be produced from laboratory, which is proved to be a safe, nonpathogenic, and cost effective.
- Bacterial concrete is a smart concrete exhibiting human-like self-healing characteristics enhancing the strength of the structures, especially under tension.
- The overall service life of the structure is found to be increasing.
- Self-healing concrete is better than the traditional concrete because of its eco-friendly nature.
- This concrete can be used to prevent cracks and hence saving the structure from corrosion of steel. Effective crack remediation with maximum moisture impermeability is one of the striking assets of the self-healing concrete.
- Bacterial concrete has lower heat of hydration and less thermal cracks. There was not much improvement in the tensile strength. As the bacterial solution is added there was increase in compressive and tensile strength and less water absorption for Bacterial concrete

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