A REVIEW ON SELF HEALING CONCRETE USING MICROBIAL AGENT

Pritam Das*1, Prof. Dr. Biman Mkkherjee*2

*1Post Graduation Student, Department Of Civil Engineering, Narula Institute Of Technology, Kolkata, India.
*2Professor, Department Of Civil Engineering, Narula Institute Of Technology, Kolkata, India.

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ABSTRACT

Concrete is the most important of all our construction materials. It's the most widely used material on earth, after water. It's a material that is widely used in the construction market due to its availability and cost, although it is prone to fracture formation. Therefore, there has been a surge in interest in self-healing materials, particularly self-healing capabilities in green and sustainable concrete materials, with a focus on different techniques offered by dozens of researchers worldwide in the last two decades. 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. So we are trying to seal cracks as they form, by using bacteria which are able to produce limestone and if we can incorporate those into the cracks or around the cracks that will form, the limestone will then plug those gaps. Environment within Concrete is very hostile and the bacteria which fit the bill can survive in this hostile environment of high alkaline pH and produce limestone at the same time it's called Bacterial concrete. These are three bacterial cultures which are working with in the lab and they are perfectly grown in alkaline conditions. So overcome this, an attempt is made in Bacterial concrete with non-pathogenic, spore forming, calcite mineral precipitating bacterium "Bacillus subtilis". M25 grade concrete is prepared with different bacterial cell concentration of \(10^4\), \(10^5\) and \(10^6\) cells per millilitre of water. The overall development of strength and durability of self-healing concrete using Bacillus subtilis has investigated and compared with control concrete.

Keywords: Self-Healing Concrete, Efficiency Of Self-Healing, Bacillus Subtilis, Calcium Carbonate Precipitating, Crack, Compressive Strength And Durability Properties.

I. INTRODUCTION

Concrete concrete is one of the most widely used materials for construction works in the field of civil engineering. This is mainly due to low cost of materials and construction, for concrete structures as well as low cost of maintenance. Concrete has a large load bearing capacity for compression load, but the material is weak in tension. Concrete has brittle nature thus cracks are not preventable. Therefore, cracks pave the way for many robust harmful fluids and substances like carbonates, chlorides, and sulfate. The concrete is being permeated by some aggressive fluids inside, it basically affect the reinforcement thus it reduces the durability of the concrete structure. For the treatment purpose, there are two choices, either by sealing the concrete or healing it. The sealing process cost rising thus we looking for another way which is now healing the concrete. Many studies conducted, the showed promising results which organic and inorganic materials could be used to seal the cracks. Bio- Concrete or Self-Healing Concrete have a new type of concrete developed by researchers called BioConcrete or Self-Healing Concrete, can be used to treat the inanition treatment cracks by adding a special type of bacteria to a concrete mixture that has the ability to produce and precipitate of calcium limestone (calcium carbonate) will have the ability to repair and treatment hair cracks.

When cracks appear in a concrete structure and water starts to seep in through, the pores of the bacteria starts microbial activities on contact with the water and oxygen. In the process of precipitating calcite crystals through nitrogen cycle, the soluble nutrients are converted to insoluble CaCO3. The CaCO3 solidifies on the cracked surface, thereby sealing it up.
Several processes are proposed for the design of self-healing concrete. This paper reviewed all processes of self-healing concrete technologies containing (1) natural (2) chemical and (3) biological processes.

The research idea involves adding different concentrations of the prepared solution bacteria type Bacillus Subtilis (B.S), adding to the concrete mixture, conducting the water absorption tests, compressive strength comparing of the control specimens. Also, concrete specimens at the age of 28 days was applied load 10% of the compressive strength of the specimens examined for the purpose of healing micro-cracks in the concrete specimens to and this return to curing and tested with ages 60 and 90 days to demonstrate the effect of the effectiveness of bacteria in concrete cracks self-healing.

History of Self-healing Concrete

Bio-concrete was first introduced as a way of self-healing concrete. Ferdinard Cohn first introduced the idea of bacteria-mediated concrete in 1877, and he claimed that with the bacteria known as “Genus Bacillus” concrete could be healed. Bacteria of Bacillus species are the most predominant and remarkable important microorganisms which have the capacity to precipitate calcium carbonate continuously under suitable conditions.

II. LITERATURE OF REVIEW

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.

Ramakrishnan et al. (2001) used Bacillus pasteurii to check the compressive strength, durability of concrete with different concentrations of bacteria and found that treated bacterial beams gained better strength than the control beams (without bacteria) and durability of concrete was increased with an increase in the concentration of bacteria.

Meera and Subha (2007) used Bacillus subtilis to study the strength and durability of concrete. They used M20 grade concrete for the preparation of cubes and cylinders with and without the addition of microorganisms and tested for strength analysis, acid attack, chloride penetration, and water absorption. It was observed that 42% of compressive strength increment and the split tensile strength was increased by 63% with the bacteria concentration of $10^5$ cells/ml at 28 days.

Siddique et al. (2014) studied the influence of bacteria on concrete’s strength and permeation characteristics by incorporating silica fume. Concrete cubes were prepared with silica fume by partial replacement of cement (5, 10, and 15%) with different concentrations of bacterial culture and tested for their strength. Compared to control, the bacterial compressive strength was increased by 10–12%, water absorption and porosity are reduced in the range of 42–48%, 52–56%, and 54–78%, on the 28th day.

Srinivasa Reddy et al. (2015) used Bacillus subtilis to study the feasibility and cost analysis of bacterial concrete. Different bacterial cell concentrations were incorporated in cement mortar cubes of different grades to check the compressive strength with 105 /ml cell concentration. The cost analysis was increased 2.3 to 3.9 times with the decrease in grade, in treated concrete compared to control.

Chithra Bai and Varghese (2016) used Bacillus Subtilis to study the strength properties of fly ash-based bacterial concrete. Concrete bricks were prepared by replacing cement with fly ash (10%, 20%, and 30%) with different cell concentrations of $10^3$, $10^4$, and $10^5$ cells/ml and tested for their strength and found that maximum flexural strength, compressive strength, and split tensile strength values were obtained at $10^5$ cells/ml.

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.
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 Na2CO3 on promoting the formation of calcium carbonate (CaCO3) in cracks.

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.

Sneha M Varghese, et al. (2018) In this study tests are conducted to find the favorable concentration of Bacillus Subtilis and Fly Ash in self healing concrete. The Concentration of Bacteria was found to be 6x10^6cells/ml and percentage of cement that can be replaced with Fly Ash to be 25%.

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

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.

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.

III. PROBLEM IDENTIFICATION

The Literature review has noticed that the performance of bacteria has not been investigated microbially before addition to concrete. Based on the literature review, the research gaps are identified as follows.

1. There is no properly available data found to investigate bacterial growth performance under different temperature and environmental conditions.

2. The Performance of bio concrete under different curing conditions is to be investigated.

3. The exclusive studies are yet to be done in terms of strength and durability characteristics of self healing concrete.

4. The concretes microstructure behavior has to be evaluated to identify the elements formed during the healing process.

IV. PREPARATION OF BACTERIAL CONCRETE

1. Selection of Bacteria:

A significant number of bacterial species have been identified as producers of calcium carbonate, a crucial component in the creation of self-healing concrete (Tittelboom et al., 2010; Chen et al., 2012; Lui et al., 2013). The initial focus of the investigation was to identify bacteria capable of thriving in highly alkaline environments. The combination of cement and water results in a pH value of up to 13, typically considered an inhospitable setting for life. The majority of organisms cannot survive in an environment with a pH value of 10 or higher. Consequently, it is essential to introduce bacteria with strong resistance to elevated pH levels, high temperatures, and limited water availability.

It was observed that the sole group of bacteria able to endure an alkaline environment produces spores, enabling them to withstand adverse conditions such as radiation, desiccation, disinfectants, and heat. When these bacteria are incorporated into concrete, their spores remain dormant until the concrete develops cracks. As water infiltrates the structure, the pH of the highly alkaline concrete decreases from pH 13 to a range of pH 10-11.5. In many studies, spores from alkali-resistant bacteria belonging to the Bacillus genus are utilized instead of directly introducing bacteria into the concrete. These spores act as a self-healing agent within the concrete (Muynck et al., 2008; Jonkers et al., 2010).

2. Application of Bacteria in Concrete:

In biological self-healing concrete microorganisms can be added to the concrete structures through various methods, which include the addition of microbial broth directly into the fresh concrete, addition in the form of spores, by encapsulation form using vascular networks (Toohey et al., 2007; Wu et al., 2012; Wang et al., 2012).
Microencapsulation has been used since the 1950s in numerous construction materials and also in many industries such as food, pharmaceutical, textile, and chemical (Boh and Sumiga, 2008).

Bacterial concrete can be prepared in two ways

1. **By Direct Application** –
   Through this direct application, bacterial spores and calcium lactate are introduced into the concrete mixture. In the event of a crack formation in the concrete, the bacterial spores rupture, consume the calcium lactate, and generate limestone to fill the cracks.

2. **By Encapsulation** –
   The bacteria and calcium lactate are enclosed within specially treated clay pellets, which are then incorporated into the concrete mixture. Approximately 6% of the clay pellets are utilized in the production of bacterial concrete. In the event of cracks forming in structures constructed with encapsulated materials, the clay pellets break, initiating bacterial treatment, and consequently, the concrete undergoes healing. Bacterial concrete is effective in mending minor cracks, typically around 0.5 mm in width.

Among these two methods, the encapsulation method is costlier than the direct application.

**V. MATERIALS AND EXPERIMENTAL METHOD**

This project centers around investigating the optimal bacterial percentage in concrete that yields the most favorable outcomes in terms of compressive strength.

1. Finalizing the method for self-healing of concrete
2. Identifying suitable bacteria as an healing agent
3. Mix design for M25 concrete grade and performing various tests on Bacteria & filling already formed cracks with Bacterial paste.
4. Casting and curing of specimens with varying proportion of CFU value of bacteria per cube
5. Testing of specimen for their respective strength and result analysis and Conclusion.

The primary emphasis of this research lies in examining the impact of bacteria on diverse grades of concrete. Different strengths of concrete will be assessed through the casting of M-25 grade concrete specimens, subjecting them to significant tests at various curing times. The obtained test results will be compared with those of traditional concrete from various 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.

**VI. ADVANTAGES OF MICROBIAL CONCRETE**

- The use of bio concrete significantly increases the strength of concrete.
- It has lower permeability than conventional concrete.
- It shows great resistance to freeze-thaw attacks.
- It shows the reduction in corrosion of reinforcement concrete.
- Remediating of cracks can be done efficiently.
- The maintenance cost of this concrete is low.
- Eco friendly.
- More resistible to the crack as compared to the ordinary concrete.
- Acts as an impervious material.
- It acts as anti-corrosive concrete.

**VII. CONCLUSION**

This review highlights the superiority of bacterial concrete over conventional technology, attributing its advantages to self-healing properties, eco-friendliness, and enhanced durability. It is very effective in increasing the strength and durability of concrete. It also shows better resistance to drying shrinkage, resistance to acid attack, better sulphate resistance. Bacterial concrete prepared with admixtures like silica fume, fly ash etc, also gives better strength and durability. This review improved our understanding on bacterial concrete. The
insights from this review have advanced our comprehension of bacterial concrete, showcasing its ability to increase compressive and flexural strength while reducing permeability, water absorption, and corrosion of reinforcement compared to conventional concrete. Therefore, bacterial concrete can significantly contribute to contemporary construction, demanding precise technologies to produce cost-effective and environmentally safe high-quality structures.

VIII. REFERENCES


Shital Wani, Shubham Ghuge, Sayali Kadam, Snehal Gulve, Self-healing Concrete Volume: 09 Issue: 06 | Jun 2022 IRJET