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Influence of Bacteria on Mechanical Properties of Concrete

T.A. Swathi[1], Chittaiah G[2], Kiran kumar M[2], Jyoshna M[2], Lalitha M[2], Prashanth Y[2], Narendra M[2]

[1] *Assistant professor, Civil Engineering, Srinivasa Ramanujan Institute of Technology, Ananthapuramu -515701*
[2] *Student, Civil Engineering, Srinivasa Ramanujan Institute of Technology, Ananthapuramu- 515701*

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Abstract - An intriguing new technique that can assist in self-repairing concrete cracks is bacteria-based self-healing concrete. Special bacteria in this concrete produce a substance that fills and plugs holes when they get pushed by nutrients and water. strengthening and extending the concrete's lifespan. Concrete is infused with certain types of bacteria, such as Bacillus subtilis, and how they are maintained to remain active throughout time. According to the results, this bacteria- based polymer can strengthen, prevent water damage, and slow the spread of cracks. This technique offers the building sector an environmentally friendly alternative by increasing the durability of concrete structures and reducing maintenance expenses. The development of a bio-concrete with far better self-healing qualities could lead to the creation of a new kind of long-lasting, recycled concrete with a variety of possible uses.

***Key Words*:** Cement, Concrete, Bacteria, Self-healing, Bacilus

1.INTRODUCTION

When constructing buildings, bridges, highways, and other constructions, concrete is a sturdy and often utilized material. Concrete may, however, eventually crack as a result of things like high traffic, temperature fluctuations, or normal wear and tear. The structure may become weakened by these flaws, necessitating costly and time-consuming repairs. concrete that repairs itself using microorganisms. In this kind of concrete, there are unique bacteria that have the ability to "heal" cracks by creating a natural material, such as calcium carbonate ($CaCO_3$), which addresses the cracks as they form. The bacteria are dormant as long as they come to contact with nutrients and water, which causes them to proliferate and fix the damage. The material's permeability is lowered and the risk is much decreased when surface cracks, in particular, continue to mend. Concrete constructions with a high capability for crack healing are advantageous since they strengthen and, more importantly, prolong the material's lifespan.

$CaO + H_20 \rightarrow Ca(OH)_2$

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

The newest approaches to self-healing design are biological approaches. concrete that heals itself using biological techniques based on calcium carbonate precipitation. The process of strengthening sand by utilizing calcium carbonate production and Bacillus subtillis bacteria. Though CaCO3 is the most appropriate concrete filler, some issues have been noticed in bacteria induced concrete in detrimental environment such as high pH values, small pores, severe moisture deficiency, fluctuating temperatures, and low availability of nutrients. Concrete

may crack as a result of weathering, steel corrosion, settling, drying shrinkage, plastic shrinkage, thermal stresses, or load application. Bacterial species like Bacillus subtilis directly act on calcium compounds like calcium lactate to precipitate calcium carbonate in fissures, a process known as bacterial self-healing.

2. Materials

Self-healing concrete is only useful for predicting when damage is only starting and can be readily repaired. It starts displaying the healing process right away. The application of such novel techniques facilitates the healing of comparatively smaller fissures. When bacteria are injected into concrete, a calcium carbonate layer forms, which helps the concrete recover. Bacteria bond sand with gravel and produce calcium carbonate precipitation, which fills concrete cracks. Many strategies have been used to guarantee the longevity and effectiveness of injected bacteria in concrete. One of these strategies is the use of sporous dormant bacterial cells rather than vegetative bacteria. These encapsulated bacterial cells exhibit a strong propensity to produce blocking material that can stop larger concrete fissures. Calcium Carbonate Precipitation Caused by Microbes (MICP). The fundamental idea behind microbiological concrete is that microorganisms produce a calcium carbonate precipitate that serves as a strengthening and blocking substance. Bacteria with the ability to produce urease are typically employed.

Fig-1. Bacillus subtillis bacteria

The Bacillus Subtillis bacteria, which has the ability to autonomously mend cracks, was employed in this experimental investigation. By causing calcite precipitation to develop, it repairs the fissures. Table-1 below lists the characteristics of the Bacillus subtillis bacteria.

Table-1: Physical Characteristics

Name	Bacillus Subtilis
Temperature	30-50°C
Growth Medium	3
Incubation Time	48hrs
PH	6-8

A common option for any kind of building is ordinary Portland cement. OPC 53grade cement is utilized in this investigation as a binding agent for making concrete. Cement's physical qualities were determined through tests, and the results are listed in Table-2 Concrete is prepared using two types of aggregate: nominal tiny particles and coarse aggregate. NCA (20 mm in size) and NFA (zone-II) were used in this investigation.

Fig-2. Ordinary Portland Cement

Fig-3. Fine Aggregate

Fig-4. Coarse Aggregate

Table-2: Physical properties of cement

Characteristics	Result
Fineness	6%
Normal consistency	34%
Setting time	Minutes
Initial Setting Time	35
Final Setting Time	620

NFA and NCA undergo testing to determine their physical characteristics and are displayed Table-3.

Table-3: Characteristics of Fine Aggregate

Characteristics	Test value	
	FA	CA
Fineness modulus	2.7	4.23
Specific gravity	2.49	2.8

3. Methodology

To attain uniformity, concrete, FA, & CA were collected, weighed, and mixed in a dry setting. Then, measurements of bacteria and drinkable water in various ratios were added. To determine the workability of freshly mixed concrete, a slum test was conducted after mixing. After a day, the specimens were processed and demolded. The samples were then allowed to rest in water for 7, 14, and 28 days, depending on the amount of time.

For this investigation, M20 grade cement was taken into consideration. In this experiment, a mix ratio of 1:1.85:3.5 was employed. Nominal concrete microorganisms and four different bacterial concentration levels (102–105 cells/ml) were added to five different kinds of concrete mixtures.

Weigh the necessary amounts of elements such as OPC, FA, and CA, then combine the dry ingredients to create a uniform mixture. Next, determine how much water and bacteria are needed for each mixture. Make the concrete mix and assess its workability right away using the compaction factor and slump tests. The specimen was cast with various concentrations and demolded after a day. The specimens were let to cure in drinkable water for 7, 14, and 28 days at varying ages.

4. Results

After the specimens were cured for seven, fourteen, and twenty-eight days, their compressive strength was assessed using a compressive testing equipment. In Fig. 3.1, the test results are displayed. According to the graph, the percentage increase in concrete's strength with 105 cells/ml after 7, 14, and 28 days is 27.27%, 29.59%, and 32%, respectively.

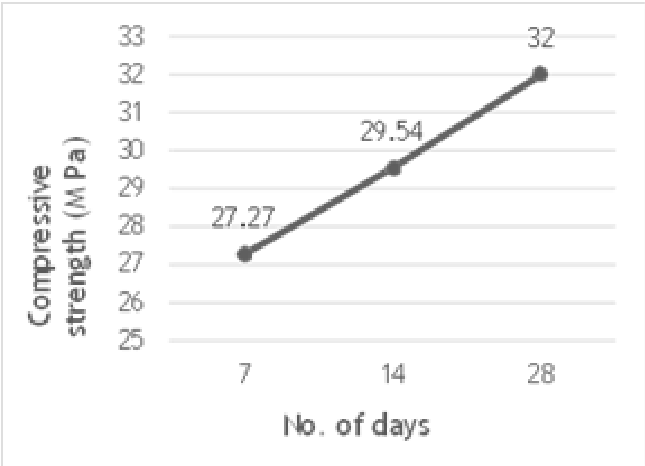

Fig -5. Compressive Strength Results

After seven, fourteen, twenty-eight, and fifty-six days, tests are performed to measure the compressive strength of concrete specimens. After seven, the concrete strength percentile improvement with 105 cells/ml fourteen, and twenty-eight days is 27.27%, 29.59%, and 32%.

In contrast, the strength drops after 7, 14, and 28 days to 15.94%, 21.66%, and 21.84% when there is 106 cells/ml of concentration.

4. Conclusion

1. Bacteria are added to increase the structure's strength up to a specific cell concentration, after which the structure's strength declines.
2. Because Bacillus subtilis may produce calcite precipitate, adding this bacterium species strengthens concrete. Calcium carbonate precipitate clogs the pores of concrete and seals its fissures, making it stronger.
3. In contrast to autogenous healing of unaltered pastes, self-healing with the help of integrated bacteria may therefore produce superior healing (closing of wider fissures). symbolized by the bioconversion of calcium carbonate using the paste's Portland.

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BIOGRAPHIES

Mrs. T A Swathi
Assistant Professor
Department of Civil Engineering
Srinivasa Ramanujan Institute of Technology (Ananthapuramu)

Mr Chittaiah G
UG Student
Department of Civil Engineering
Srinivasa Ramanujan Institute of Technology (Ananthapuramu)

Mr.Kiran Kumar M
UG Student
Department of Civil Engineering
Srinivasa Ramanujan Institute of Technology (Ananthapuramu)

Ms. Jyoshna M
UG Student
Department of Civil Engineering
Srinivasa Ramanujan Institute of Technology (Ananthapuramu)

Ms. Lalitha M
UG Student
Department of Civil Engineering
Srinivasa Ramanujan Institute of Technology (Ananthapuramu)

Mr. Prashanth Y
UG Student
Department of Civil Engineering
Srinivasa Ramanujan Institute of Technology (Ananthapuramu)

Mr. Narendra M
UG Student
Department of Civil Engineering
Srinivasa Ramanujan Institute of Technology (Ananthapuramu)