WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Analysis of Self-Healing Mechanisms in Concrete with FRP Reinforcement

Pavan Dattatray Gaikwad[1], Omkar Ajit Ahiwale[2], Prashant Ramesh Devkate[3]

[*1,2,3]Student, Department Of Civil Engineering , RMDSSOE,SPPU University, Pune

ABSTRACT:

Through the development of a strong internal matrix and the encouragement of self-healing qualities for crack mitigation, this study investigates the use of Bacillus subtilis bacteria to increase the durability of concrete. Using the ratio 1:1.5:3.3:2.75:0.50:45, a liquid culture of Bacillus subtilis (24 ml) with a cell concentration of 10^5 cells/ml was added to a concrete mix. Compressive and flexural strength testing were performed on 150 mm × 150 mm cube specimens. The specimens were purposefully cracked in order to assess the self-healing capabilities. The potential of bacterial concrete to prolong the service life of concrete infrastructure is confirmed by experimental results showing that it greatly improves structural performance and consistency when compared to conventional concrete.

Keywords: Self heling concrete, bacillus subtilis, Analysis strength

Introduction:

Although concrete is generally thought of as a homogeneous material, it naturally develops microcracks that let salts and water seep in, speeding up deterioration and drastically lowering the lifespan of the structure. These substances' intrusion may also cause steel reinforcement to corrode, weakening the concrete and endangering public safety. This study explores the use of Bacillus subtilis bacteria to produce a self-healing concrete matrix as a way to increase the service life and structural integrity of concrete. When given the right environment and a calcium source, these microorganisms produce calcium carbonate through metabolic activity, which effectively seals cracks and increases compressive strength and durability. Fiber-reinforced polymer (FRP) concrete performed better in terms of crack healing and structural strength when Bacillus subtilis was added.

What is the self- heling concrete ?

An innovative material called self-healing concrete is made to fix cracks on its own that form over time as a result of mechanical stress, shrinkage, or exposure to the environment. By improving durability and lowering the need for manual maintenance, this cutting-edge concrete type seeks to increase the service life of structures. Concrete cracking is an unavoidable problem that frequently allows water, chlorides, and other dangerous substances to enter, hastening the corrosion and degradation of reinforcement. Autogenous and autonomous healing are the two basic categories into which self-healing mechanisms in concrete can be generally divided. Autogenous healing is based on cementitious materials' inherent capacity to repair minor cracks by carbonating and continuously hydrating unreacted cement particles. But this technique can only be used on extremely small cracks, usually smaller than 0.2

Methodology:

Bacillus subtilis, commonly referred to as hay or grass bacillus, is a rod-shaped, Gram-positive bacterium widely found in soil and vegetation. It is a well-characterized species known for its ability to form resilient endospores, which allow it to withstand extreme environmental conditions such as heat, desiccation, and nutrient limitation. This spore-forming capability is one of its key survival mechanisms, especially under stress-inducing mesophilic conditions, typically ranging from 25°C to 35°C.

As an obligate aerobe, *Bacillus subtilis* requires oxygen for growth and does not undergo fermentation. It is considered non-pathogenic and generally safe for use in various biotechnological and environmental applications. While it may occasionally contaminate food products, it rarely leads to foodborne illness. Due to its robustness, genetic tractability, and safety profile, *Bacillus subtilis* is a subject of extensive scientific research, particularly in the fields of microbiology, biotechnology, and sustainable construction, including its application in self-healing concrete systems.

The self-healing process in concrete is enhanced by the presence of microorganisms, which facilitate the formation of calcium carbonate, a key component in crack sealing. In traditional autogenous healing, calcium hydroxide ($Ca(OH)_2$), a soluble mineral, dissolves in water and leaches out of the cracks, reacting with carbon dioxide to form calcium carbonate ($CaCO_3$), as shown by the following reaction:

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

In bacterial concrete, this process is amplified by the metabolic activity of bacteria that convert calcium-based nutrients into calcium carbonate more efficiently. For instance, when calcium lactate ($Ca(C_3H_5O_2)_2$) is used as a nutrient source, the bacteria metabolize it in the presence of oxygen, resulting in the following reaction:

$$Ca(C_3H_5O_2)_2 + 7O_2 \rightarrow CaCO_3 + 5CO_2 + 5H_2O$$

Both microbial metabolic processes and natural autogenous healing contribute to the formation of calcium carbonate, which seals the cracks. This combination of biological and chemical processes creates a robust, bacteria-driven crack-sealing mechanism that improves the overall durability and self-healing capability of concrete.

Mix design:

The process of selecting components for cement, such as bonding agents, aggregates, and water, and determining their optimal proportions to produce a mixture that offers the best balance of consistency, workability, and durability at the lowest cost is known as mix design. This process involves careful planning and analysis, focusing on achieving the necessary quality and strength requirements while minimizing material costs. The primary objective is to meet the minimum performance standards for the desired application.

Mix design for plain concrete

Material	**1:1.5:3:0.50**
Cement(kg/m)	8.75
Sand(kg/m)	14.56
Aggregate(kg/m)	28.24
Water(L)	4.50

Mix design for bacterial concrete

Material	**1:1.5:3:0.50**
Cement (kg/m)	9.72
Sand (kg/m)	20.16
Aggregate(kg/m)	38.88
Water(L)	4.37

Mix design for bacterial concrete with FRP

Material	**1:1.5:3:0.50**
Cement (kg/m)	9.66
Sand (kg/m)	8.33
Aggregate(kg/m)	18.88
Water(L)	4.83
Glass fiber (GRM)	0.380

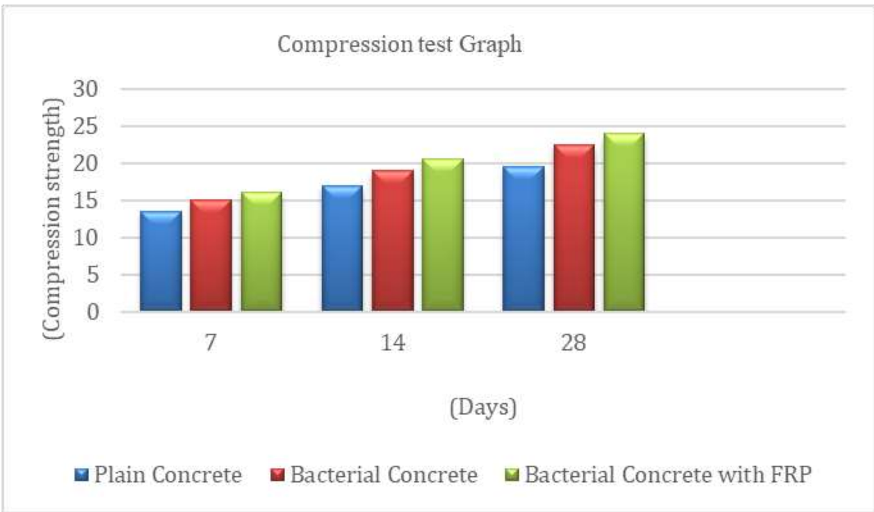
Results:

Compression Test

The compression test for both plain concrete and bacterial concrete cubes was conducted using a Universal Testing Machine (UTM). The concrete blocks, measuring 150 mm x 150 mm x 150 mm, were prepared and placed in a curing for curing 7,14 and 28 days. The compression tests for both plain and bacterial concrete were performed at 7 days. The results indicated that the compressive strength of the self-healing concrete was higher than that of the plain concrete

Compressive strength Value

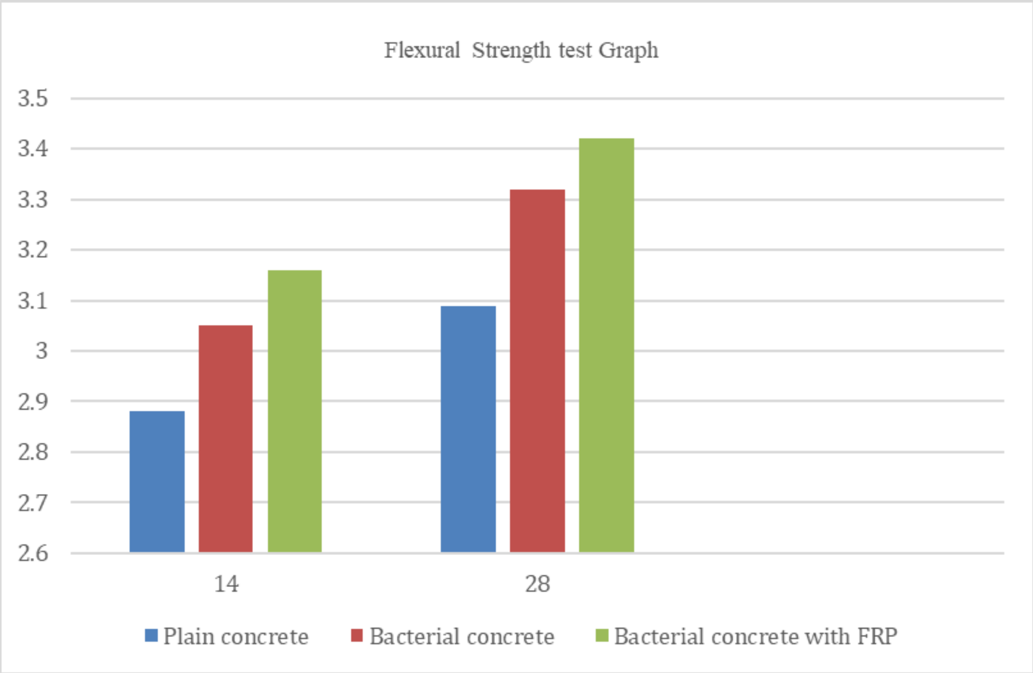
Days	Plain concrete (N/mm2)	Bacterial concrete (N/mm2)	Bacterial concrete with FRP (N/mm2)
7	13.5	15.0	16.0
14	17.0	19.0	20.5
28	19.55	22.5	24.0



Flexural Strength Test

The flexural strength test was conducted to find out tensile strength of both plain and bacterial concrete and bacterial concrete with FRP under bending. This test used to determine the ability of concrete to resist failure due to flexural stresses.

Days	Flexural strength of normal concrete (Mpa)	Flexural strength of bacteria concrete (Mpa)	Flexural strength of bacteria concrete with FRP (Mpa)
14	2.88	3.05	3.16
28	3.09	3.32	3.42



Conclusion

As a results self-heling concrete provide more strength than the normal plain concrete. In this project the strength of bacterial concrete with FRP got more strength than the normal and bacterial concrete. But the cost of the bacterial concrete with FRP is more and it make the project more costly. Advantage of using bacterial concrete is that give more strength and life to the construction work and avoid maintenance cost. In future it will be used in road construction.

References:

List all the material used from various sources for making this project proposal

Research Papers:

1. An Experimental Study on Development of Eco-friendly Self-Healing Concrete: A Green Building Concept – 2021
2. Study of Compressive Strength of Concrete with Different Mix Ratios – 2019
3. Self-Healing Bio-Concrete Using *Bacillus subtilis* Encapsulated in Iron Oxide Nanoparticles – 2022
4. Compressive Strength of Concrete – A Review – 2017
5. Enhancing Compressive Strength of Cement by Indigenous Individual and Co-Culture *Bacillus* Bacteria – 2024
6. Bacterial Self-Healing of Concrete and Durability Assessment – 2020
7. The Utilization of *Bacillus Subtilis* Bacteria to Improve the Mechanical Properties of Concrete – 2021
8. Experimental Study on Self-Healing of Micro-Cracks in Concrete with Environmentally Friendly Bacteria – 2023
9. An Experimental Investigation on Mechanical Properties of Bacterial Concrete Using *Bacillus Subtilis* – 2022