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A Review Paper on Application of Bacillus Subtilis Bacteria for Improving Properties and Healing of Cracks in Concrete

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Abstract - *Self healing concrete is a bacterial concrete which heals itself automatically without any maintenance. When the cracks formed in concrete it comes in contact with air, water and moisture, bacteria gets activated and forms lime as a result cracks heals itself. Building requires less maintenance as well as more durability, corrosive resistance and it is fulfill by the bacterial concrete. Now a days, Bacterial concrete has been accepted in the construction industry as a challenging composition for self repairing and incrementing the compressive strength of the concrete.*

***Key Words*: Bacterial concrete, Bacillus subtilis, Calcium lactate**

1.INTRODUCTION:

Cracks in concrete is a phenomenon that can hardly be complete avoided due to shrinkage reactions of setting concrete and tensile stresses occurring in set structures. Durability of concrete is impaired by these cracks since they provide an easy path for the transportation of liquids and gasses that potentially contain harmful substances. If micro-cracks grow and reach the reinforcement, not only the concrete itself may be attacked, but also the reinforcement will be corroded.

Adopting bacteria induced carbonate precipitation to fill the cracks is very innovative. The microbial precipitation depends on several factors including the concentration of dissolved inorganic carbon, the PH, and the concentration of calcium ions and the presence of nucleation sites. Also, when Bacteria are used to work for the healing of cracks in concrete, the major hindering factor is the high alkaline environment of concrete, restricting the growth of the bacteria. Therefore, necessary measures need to be taken to protect bacteria in concrete.

When the cracks formed in concrete it comes in contact with air, water and moisture. Due the interaction of moisture or water with bacteria, the bacteria gets activated and forms lime as a result cracks heals itself. Similarly, Bacterial concrete provides more compressive strength. Bacillus Subtilis has the great potential to heal the cracks in concrete surface and thereby enhancing th durability of a concrete structure or an element.

By the use of Bacterial concrete buildings requires less maintenance as well as more durability, corrosive resistance and it is fulfill by the bacterial concrete. Now a days, Bacterial concrete has been accepted in the construction industry as a challenging composition for self repairing and incrementing the compressive strength of the concrete. Bacterial concrete also plays the helping role in a seismic zone at a primary stage.

2. THE BACTERIA-BACILLUS SUBTILIS:

Firstly bacillus subtilis is known as *Vibrio subtilis*, this bacteria was discovered by Christian Gottfried Ehrenberg in 1835. It was renamed in 1872 by Ferdinand Cohn. *Bacillus subtilis* (*B. subtilis*) is a Gram-positive, aerobic bacteria. It is rod-shaped.

- Bacillus Subtilis is a non-pathogenic and non-toxicogenic bacteria.
- Self healing property of a concrete is achieved by introducing the Bacillus Subtilis bacteria into a concrete matrix during mixing.

- When a crack formed in the concrete surface, the ingress water reacts with the bacteria and which in turn produce Calcium carbonate (caco3) which is a main composition of lime.
- Since, the bacteria need a food to survive so we chose Calcium lactate as a chemical precursor to do the work.

3. LITERATURE REVIEW:

S. Sanjay, S. Neha, and R. Jasvir (2016),This paper was presented the experimental investigation on bacterial concrete to increase the strength of bio concrete and to inform the process involved in the bacterial concrete. To know the calcite crystals formed in bacterial concrete analysis of microstructure has been done that is used for the potential to recovery the cracks in bacterial concrete and

also to inform the biological reaction in concrete. As a result, has been got because of good adaptability of nutrient broth medium of bio concrete at 28 days attained better strength when compared to urea medium [1].

A. Thakur, A. Phogat, K. Singh (2016), This paper has presented the overview of several paper in the current years on the use of bio concrete for improving in the mechanical properties, durability and permeation features of normal concrete. They have been studies the analysis on bio concrete by XRD and SEM tests and also several types of bacteria's, their isolation process, several methods used in the adding of bacterial species in concrete and their belongings on water absorption and compressive strength. Finally, they concluded the bacterial type such as B. cereus and S. pasteurii extreme rise in the compressive strength and the maximum reduce in water absorption for 28 days curing period of specimen respectively. The bacterial like bacillus sphaericus, B. pasteurii, and Bacillus flexus are not harm the human body and also, they have the potential to precipitate calcite but some other bacterial species is dangerous for human health [2].

N. Amudhavalli, K. Keerthana and A. Ranjani (2015), this paper has presented the overview of bacterial concrete, bacteria the state of art results in all projects show that material designed as self-healing agents. Some of the bacteria is drawbacks not directly functional in construction structure like houses and offices because of health concerns this bacteria like B. Pasteuri, B. megaterium, B. subtilis. Lastly, they achieve that bacterium that have used in concrete in better way because of their advantages than other bacteria that are B. Sphaericus and Eschericheria Coli [3].

N. Chahal and R.Siddique (2008) this study has been presented that with use of Sporosarcina pasteurii which would make it, self-healing. They observed that newly formed cracks healed by the presence of bacteria. In the concrete mix 10%, 20% and 30% and also 5% and 10% dosage of fly ash and silica fume respectively replacing cement in the bacterial solution of 103, 105 and 107 cells/ml. They did tests on the water absorption and porosity, chloride permeability and compressive strength by using up to age 91 days. They concluded that by the presence of S. pasteruii increase compressive strength, cut downs the permeability and porosity of silica fume and fly ash concrete [4].

V Srinivasa Reddy, M V SeshagiriRaoand S Sushma8, have published a paper on Feasibility Study on Bacterial Concrete as an innovative self crack healing system. This paper describes about the effect of bacterial cell concentration of Bacillus subtilis JC3, on the strength, by determining the compressive strength of standard cement mortar cubes of different grades, incorporated with various bacterial cell concentrations. This shows that the Improvement in compressive strength reaches a maximum at about 105/ml cell concentration. The cost of using microbial concrete compared to conventional concrete which is critical in determining the economic feasibility of the technology, is also studied. The cost analysis showed an increase in cost of 2.3 to 3.9 times between microbial concrete and conventional concrete with decrease of grade. And nutrients such as inexpensive, high protein- containing industrial wastes such as corn steep liquor (CSL) or lactose mother liquor (LML) effluent from starch industry can also be used, so that overall process cost reduces dramatically. Precipitation of these crystals inside the gel matrix also enhances the durability of concrete significantly. Furthermore, this analysis has shown an increase in the cost of production and a significant decrease in carbon footprint compared to conventional concrete[5].

Ramakrishnan et al, (2001) proposed a novel technique in remediating cracks and fissures in concrete by microbiologically inducing calcite precipitation. Microbiologically induced calcite precipitation is a technique that comes under a broader category of science called biomineralization. Bacillus pasteurii, a common soil bacterium can induce the precipitates of calcite. As a microbial sealant, Calcite exhibited its positive potential in selectively consolidating simulated fractures and surface fissures in granites and in the consolidation of sand. MICP is highly desirable chemical reaction because the calcite precipitation induced is a result of microbial activities. The technique can be used to improve the compressive strength and stiffness of cracked concrete specimens. A durability study on concrete beams treated with bacteria, exposed to alkaline, sulfate and freeze-thaw environments was studied by him. The effect of different concentrations of bacteria on the durability of concrete was also studied by him. It was found that all the beams with bacteria performed better than the control beams (without bacteria). The durability performance increased with increase in the concentration of bacteria. Microbial calcite precipitation was quantified by X-ray diffraction (XRD) analysis and visualized by SEM. The unique imaging and microanalysis capabilities of SEM established the presence of calcite precipitation inside cracks, rod shaped bacterial impressions and a new calcite layer on the surface of concrete. This calcite layer improves the impermeability of the specimen, thus increasing its resistance to alkaline, sulfate and freeze-thaw attack [6].

4. SCOPE AND OBJECTIVES OF WORK:

FROM DETAILED LITERATURE REVIEW THE FOLLOWING POINTS ARE EVIDENCE:

- Develop bacterial concrete by introducing the bacteria's of bacillus family.
- To find optimum dosage of bacteria required for bacterial concrete.
- To increase compressive strength of concrete.
- To remediate the cracks developed in concrete.

- To study the durability of concrete under various weathering conditions. To check the performance of bacillus subtilis by durability test.

- To verify the performance of bacillus subtilis with 1mm and 2mm crack width and 15mm, 20mm, 25mm, and 30mm crack depth.

CRACK COMPARISON BETWEEN BACTERIAL CONCRETE AND CONVENTIONL CONCRETE

5. IMPORTANCE:

- **It gets automatically activated and heals the crack :-**

  When the cracks formed in concrete comes in the contact with air, water and moisture, bacteria gets activated and forms lime as a result cracks heals itself. The bacteria grows in the sufficient atmosphere.

- **Reduces the corrosion :-**

  Bacterial concrete does not allow the corrosive agent to reach the reinforcement, before that it heals itself and avoid or reduce the corrosion.

- **Reduces the maintenance :-**

  Whenever the cracks gets form the Bacterial concrete heals the cracks automatically and reduce the maintenance and cost.

6. WORKING PROCESS:

- **Culture of Bacteria:**

  Firstly bacillus subtilis is known as *Vibrio subtilis*, this bacteria was discovered by Christian Gottfried Ehrenberg in 1835. It was renamed in 1872 by Ferdinand Cohn. *Bacillus subtilis* (*B. subtilis*) is a Gram-positive, aerobic bacteria. It is rod-shaped.

- **Mix design:**

  selecting suitable ingredients of concrete(M25) such as cement, aggregates, water and determining their relative proportions with the object of producing concrete of required minimum strength, workability and durability as economically as possible.

- **Mixing, Casting and Curing:**

  Mixing:

  Mixing is done with the cement, sand and aggregate in the proportion of 1:2:2 (M25 Grade) with respective proportion of bacteria.

  Casting:

  A total 18 cubes and 18 cylinders were casting for performing the Compressive strength and Tensile strength including both with and without bacteria concrete.

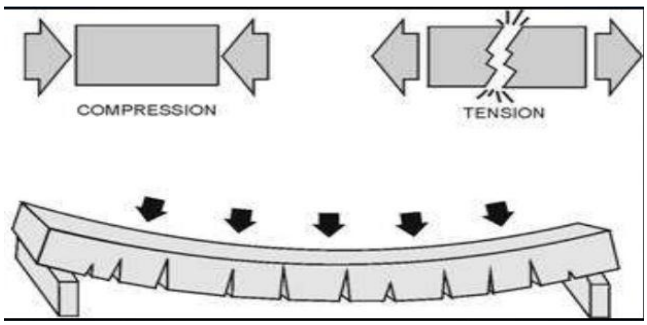
  Curing:

  The cubes and cylinders are kept immersed in water for curing at the intervals of 7 days, 14 days and 28 days.

Preliminary test of the concrete using Bacteria:

Compression test: - A total 18 cubes were tested for Compressive Strength including both with and without bacteria concrete. Compression strength test will be carried out on 7 days, 14 days and 28 days.

Tension test :- A total 18 Cylinders were tested for split tensile strength including both the specimens of with and without bacteria. Tension test will be carried out on 7 days, 14 days and 28 days.



COMPRESSION AND TENSION TEST

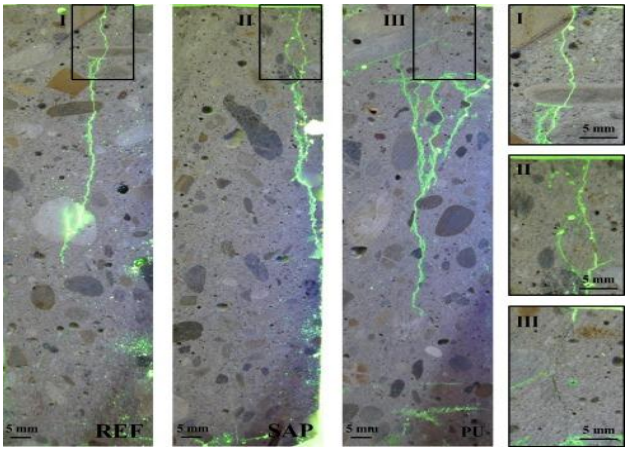
7. APPLICATIONS:

- Construction of building to achieve more durability.
- Construction of building in earthquake zone.
- Construction of building with less maintenance.

8. ADVANTAGES:

- Self repairing of cracks without any external aide.
- Significant increase in compression strength and flexural strength.

- Reduce the corrosion of steel.
- Harmless to human life and hence it can be use effectively.



9. DISADVANTAGES:

- Cost of the Bacteria is more.
- Bacteria needs proper atmosphere for growth.

10. CONCLUSIONS

1) Bacteria improves the property of conventional concrete such as increase in 13.75% strength increased in 3 days, 14.28% in 7 days and 18.35% in 28 days.
2) Self healing concrete is eco-friendly.
3) Enhance compressive strength and reduce the permeability.
4) Reduce the corrosion of steel.
5) Bacterial concrete technology has proved to be better than many conventional technologies.
6) Bio concrete enhance the life time of a structure by more than the expected value.

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