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# Bacterial Concrete: A Review

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## ABSTRACT

*Major component in the construction industry is concrete as it is cheap, easily available and convenient to cast. Disadvantage being its weak in tension so, it cracks under sustained loading and also due to aggressive environmental agents that reduces the life of the structure which are built using these materials. To counter these problems, a new revolutionized concept has come into limelight which is "Self Healing Concrete or Bio/Bacterial Concrete".*

*The "Bacterial Concrete" is a concrete which can be made by embedding bacteria in the concrete that can constantly precipitate calcite. This phenomenon is called "Microbiologically Induced Calcite Precipitation" (MICP). Bacillus Pasteruii, a common soil bacterium, can continuously precipitate a new highly impermeable calcite layer over the surface of an already existing concrete layer under suitable environmental conditions. Other bacteria species which can be used for the same purpose are Pasteurii, Cohnii and Filla.*

***Keywords: MICP, Bacillus Subtilis, Bacillus Pasteurii, Bio Concrete***

## INTRODUCTION

Concrete can bear up withcompression load, but the materialis weak in tension. Hence, steel reinforcement is provided and the steel bars take over the load when the concrete cracks in tension. However, the development of cracks in the concrete pose a problem. Due to reasons like freeze-thaw reactions, shrinkage, low tensile strength of concrete etc, cracks develop during the process of concrete hardening resulting in weakening of the buildings. Due to lack of permeability, water droplets seeping inside can damage the steel reinforcement present in the concrete member. When this phenomenon occurs, the strength of the concrete decreases causing the decay of structure.Synthetic materials like epoxies are used to remediate, but costly, not compatible and need time to time maintenance. Using chemicals is also causing damage to the environment. The need for an environment friendly and effective alternate crack remediation technique leads to the development of using the bio mineralization technique in concrete. Here we are incorporating calcite precipitating bacteria to concrete in certain concentrations so that the bacteria will precipitate calcium carbonate when it comes in contact with water and this precipitate will heal the cracks. Micro biologically Induced Calcite Precipitation (MICP) is the process behind bio mineralization. The basic principle in the process is that the microbial urease, hydrolyzes urea, to produce ammonia and carbon dioxide and the ammonia released in surroundings subsequently increases the pH, leading toaccumulation of insoluble calcium carbonate. Thus, this self-healing system can help in achieving a massive cost reduction in terms of health monitoring, damage detection and maintenance of concrete structures which assures a safe service life of the structure.

## OBJECTIVES

- Cultivation of bacteria.
- Detection of precipitate i.e. $CaCO_3$ from the bacteria.
- Increasing the characteristic strength of concrete.

## METHODOLOGY

- Literature Survey
- Collection of Required Raw materials
- Testing of materials for project purpose.

- Designing of concrete for Grade mix as per IS 10262-2009
- Culturing of Calcite Depositing Bacteria
- Casting and Curing of controlled concrete cubes.
- Application of Cultured Bacteria for Cracked Surface
- Characterization studies
- X-ray diffraction
- Scanning Electron Microscopy (SEM)
- Conclusions on the results.

## LITERATURE REVIEW

As per Sri Bhavana R. et-al(2017), a biological repair technique was used in which bacteria of $10^5$cells/ml were mixed with concrete to heal the cracks. The effect of Bacillus subtilis on the compressive strength, tensile strength and Flexural test for 3, 7 and 28 days were carried out experimentally. Numerous papers which discussed about the various strains of bacteria.Epoxy resins, bacteria, fiber that serve as Self Healing Agents are used to heal cracks in concrete. Among these, bacteria used in concrete are effective as per Amudhavalli N. et-al(2015). Thakur A. et-al(2016) have studieddifferent bacteria's, their isolation process, different approaches for addition of bacteria in concrete, their effects on compressive strength and water absorption properties of concrete and also the SEM and XRD analysis of concrete containing bacteria.Durability can be enhanced by preventing further ingress of water and other substances. Self healing agents such as epoxy resins, bacteria, fiber are used to heal cracks in concrete. Among these, bacteria used in concrete are effective. When the bacteria is mixed with concrete the calcium carbonate precipitates forms and these precipitates filling the cracks and makes the crack free concrete and has been studied significantly by Hanumanthrao M. and Viswanadh G.(2015). A new biotechnological method based on calcite precipitation to improve the strength of structural concrete has come into scenario. Andalib R.(2015)found that the compressive strength of the higher grade of structural bacterial concrete has improved as compared to lower grade due to more precipitation of calcite. Jonkers H**.**investigated the crackhealing capacity of a specific bio-chemical additive, consisting of a mixture of viable butdormant bacteria and organic compounds packed in porous expanded clay particles. Metabolicconversion of calcium lactate to calcium carbonate what results in crack-sealing. During the mixing of concrete, bacteria produces calcium carbonate precipitate that cure the cracks automatically. Performance of Bacillus Sphaericus and Escherichia Coli in concrete have been studied and also it deals with the comparison of bacterial concrete in strength aspects w.r.t. conventional. The bacterial strains produce calcite precipitation was examined by X-ray diffraction (XRD) analysis and visualized by Scanning Electron Microscope(SEM).Vekariya M. et-al(2013) have definedthe bacterial concrete, its classification and types of bacteria, chemical process to fix the crack by bacteria, advantages and disadvantages and possibilities of application of MICP and advantages by switching it over epoxy resins.Bacterias in M40 grade concrete and to intensify its properties of hardened concrete were studied by Naveen B. and Sivakamasundari S.(2016).They have also studied the strength of structural elements and examining it with partialreplacement of cement by fly ash enriched withbacteria. A paper on Strength And Durability assessment Of Bacteria Based Self-Healing Concrete was done by Meera C M and DrSubha V. In this paper they have discussed about the effect of Bacillus Subtilis JC3 on the strength and durability of concrete. For this, cubes of sizes 150mm x 150mm x 150mm and cylinders having a diameter of 100 mm and a height of 200 mm with and without addition of bacterial species, of M20 grade concrete was put to test. For strength assessments, cubes were tested for different bacterial concentrations at 7 days and 28 days and cylinders were tested for split tensile strength at 28 days.Compressive strength of concrete showed significant increase by 42% for cell concentration of $10^{5}$ of mixing water.Tensile strength of concrete increased by 63% for a bacteria concentration of $10^5$ cells/ml at 28 days. For durability assessment, acid durability test, chloride test and water absorption test were also done. A comparative study was made with concrete cubes and beams subjected to compressive and flexural strength tests with and without the bacterium Bacillus pasteurii by the authors Ravindranatha, N. Kannan and Likhit M. L. The concrete cubes and beams were prepared by adding calculated quantity of bacterial solution and then they were tested for 7 and 28 day compressive and flexural strengths. It was found that there was high increase in strength and healing of cracks subjected to loading on the concrete specimens. The bacteria proved itself in enhancing the properties of the concrete by achieving a very high initial strength increase. The calcium carbonate excreted by the bacteria has filled some percentage of void volume thereby making the texture more compact and resistive to seepage.An experimental study on strength and fracture properties of self healing concrete was done by N. Ganesh Babu and Dr. S. Siddiraju. They have made an attempt is made to seal the cracks in concrete using bacteria and calcium lactate. The percentages of bacteria selected for the study are 3.5% and 5% by weight of cement. In addition, calcium lactate was used at 5% and 10% replacement of cement by weight. Bacteria produces calcium carbonate crystals which blocks the micro cracks and pores in the concrete after reacting with calcium lactate. Bacillus Pasteurii is used for different bacterial concentrations for M40 grade of concrete. Various tests such as elastic modulus, compressive strength and fracture of concrete were significantly analyzed and studied.Jagadeesha Kumar B G, R Prabhakara and Pushpa H, published a paper on effect of Bacterial Calcite Precipitation on Compressive Strength of Mortar Cubes. Experimental investigations carried out on mortar cubes which were subjected to bacterial precipitation by different bacterial strains and influence of bacterial calcite precipitation on the compressive strength of mortar cube on 7, 14 and 28 days of bacterial treatment were analyzed. Three bacterial strains Bacillus flexus, isolated from concrete environment, Bacillus pasturii and Bacillus sphaericus were also used. Amongst the 3 strains of bacteria, cubes treated with Bacillus flexus, which is not reported as bacteria for calcite precipitation has shown maximum compressive strength than the other two bacterial strains and control cubes. It was studied that the increase in compressive strengths is mainly due to consolidation of the pores inside the cement mortar cubes due to MICP (Micro Biologically Induced Calcium Carbonate Precipitation) phenomena.Feasibility Study on Bacterial Concrete as an innovative self crack healing system has been done by V Srinivasa Reddy, M V SeshagiriRao and S Sushma. 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 was significantly analyzed. 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 has been 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. Corn Steep Liquor (CSL) or Lactose Mother Liquor (LML) effluent from starch industry can also be used, so that overall process cost reduces making it more economical and a feasible approach.SakinaNajmuddinSaifee et .al have discussed about the different types of bacteria and their applications in their paper. The bacterial concrete is very much useful in increasing the durability of cementous materials, repair of limestone monuments, sealing of concrete cracks to highly durable cracks etc. Useful for construction of low cost durable roads, high strength buildings with more bearing capacity, erosion prevention of loose sands and low cost durable houses. They have also briefed about the working principle of bacterial concrete as a repair material. It was also observed in the study that the metabolic activities in the microorganisms taking place inside the concrete results into increasing the overall performance of concrete including its compressive strength. This study also explains the chemical process to remediate cracks.

**ADVANTAGES**

- Improvement in compressive strength of concrete
- Better resistant towards freeze thaw attack
- Reduction in permeability of concrete
- Reduction in corrosion of reinforced concrete
- Eco friendly

**CONCLUSION**

- Bacterial concrete is advantageous than conventional concrete due to its self-healing capacityand eco-friendly nature.
- Calcite precipitate of bacteria indirectly increases the strength of concrete by filling the voids.
- The cost of bacterial concrete is more. So, it is profitable when we go for higher RC structures. By using bacterial concrete the rehabilitation cost can be reduced.
- As from the study is predictedthat the life of bacterial concrete is more than conventional concrete. So, the use of biological concretecan create new job opportunities for the experts. The cost of the bacterial concrete, according to theopinions of other researchers can increase up to 30% than the conventional concrete, depending upon thetype and concentration of bacteria. But the maintenance cost can be reduced bythe use of bacterial concrete.
- This method is easy and convenient in the whole process of cementation. This technology will providelong life to the structure due to its good durability properties but more work is required on the followingmentioned issues to improve the feasibility of this technology from practical viewpoints. Issues related toits economical factors and qualities related to bacteria are still to be finding out.

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