**A Review On Healing Of Concrete Cracks By Bacteria**

**Abstract**

Concrete is the most widely used construction material. Despite its versatility in construction, it is known to have several limitations. It is weak in tension, has limited ductility and little resistance to cracking. Based on the continuous research carried out around the globe, various modifications have been made from time to time to overcome the deficiencies of cement concrete. Micro-cracks are the main cause to structural failure. One way to circumvent costly manual maintenance and repair is to incorporate an autonomous self -healing mechanism in concrete. One such an alternative repair mechanism is currently being studied, i.e. a novel technique based on the application of bio-mineralization of bacteria in concrete. The applicability of specifically calcite mineral precipitating bacteria for concrete repair and plugging of pores and cracks in concrete has been recently investigated and studies on the possibility of using specific bacteria as a sustainable and concrete -embedded self-healing agent was studied and discussed. Synthetic polymers such as epoxy treatment etc. are currently being used for repair of concrete are harmful to the environment, hence the use of a biological repair technique in concrete is focused. Recently, it is found that microbial mineral precipitation resulting from metabolic activities of favourable microorganisms in concrete improved the overall behaviour of concrete.

**Key words**: bacterial concrete, types of bacteria,MICP, construction, chemical process

**Introduction**

The ongoing research in the field of concrete technology has lead to the development of special concrete considering the speed of construction, the strength of concrete, the durability of concrete and the environmental friendliness with industrial material like fly ash, blast furnace slag, silica fume, metakeolin etc. Recently, it is found that microbial mineral precipitation resulting from metabolic activities of favorable microorganisms in concrete improved the overall behavior of concrete. The process can occur inside or outside the microbial cell or even some distance away within the concrete. Often bacterial activities simply trigger a change in solution chemistry that leads to over saturation and mineral precipitation. Use of these Bio mineralogy concepts in concrete leads to potential invention of new material called ―Bacterial Concrete.

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**Fig Magnified image of Rod shaped impressions consistent with the dimensions of B. pasteurii, spread around the calcite crystals. (courtesy: ASM MicrobeLibrary.org)**

**2. REVIEW OF LITERATURE**

**2.1 V. Ramakrishnan et al, (2001)(73)**

He 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 bio-mineralization. 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. This calcite layer improves the impermeability of the specimen, thus increasing its resistance to alkaline, sulphate and freeze-thaw attack.

**2.2 Day J L et al, (2003)(18)**

This paper describes the results of an innovative approach in concrete crack remediation utilizing microbiologically induced calcite. A common soil bacterium, Bacillus pasteurii, was used to induce calcite precipitation. The basic principles for this application are that the microbial urease hydrolyzes urea to produce ammonia and carbon dioxide, and the ammonia released in surroundings subsequently increases pH, leading to accumulation of insoluble calcite. To protect the cells from the high pH of concrete, the microorganisms were immobilized in polyurethane polymer, lime, silica fume, and fly ash, and then applied in concrete crack remediation. Based on observations made in this study, it is concluded that MECR has excellent potential in cementing concrete as well as several other types of structural cracks.

**3. Classification of Bacteria**

**Classification of Bacteria**

**Basis on Shape**

**Basis on Gram Strain**

**Basis on Oxygen Demand**

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**3.1 Classification on the Basis of Shapes**

Bacteria are usually classified on the basis of their shapes. Broadly, they can be divided into Rod-shaped bacteria (Bacilli), Sphere-shaped bacteria (Cocci) and Spiral-shaped bacteria (Spirilla).

**3.2 Classification on the Basis of Gram Strain**

This classification is based on the results of Gram Staining Method, in which an agent is used to bind to the cell wall of the bacteria, they are Gram-positive and Gram-negative.

**3.3 Classification on the Basis of Oxygen Requirement**

This classification is based on the requirement of oxygen for the survival of the bacterium. They are Aerobic (Use molecular oxygen as terminal electron acceptor) and Anaerobic (Do not use molecular oxygen as terminal electron acceptor).

**4. Various bacteria used in the concrete are**

i) Bacillus pasteurii

ii) Bacillue sphaericus

iii) Escherichia coli

iv) Bacillus subtilis (used in the present study)

**4.1 Bacillus subtilis JC3**

Researchers with different bacteria proposed different bacterial concretes. The various bacteria used in the concrete are Bacillus pasteurii, Bacillue sphaericus, E.coli etc. In the present study an attempt was made by using the bacteria Bacillus subtilis strain no. JC3. The main advantage of embedding bacteria in the concrete is that it can constantly precipitate calcite. This phenomenon is called microbiologically induced calcite precipitation (MICP). Calcium carbonate precipitation, a widespread phenomenon among bacteria, has been investigated due to its wide range of scientific and technological implications. Bacillus subtilis JC3 is a laboratory cultured soil bacterium and its effect on the strength and durability is studied here.

**How does Bio-concrete work?**

Process of fixing cracks in concrete by bacteria in such a process can be shown in Fig. In the crack fixing process the anaerobic type bacteria which can be using along with concrete can be fix that crack by step by step. At first germination of germs by spores and swarming themselves and quorum sensing an growing from proper medium in large amount in particular time and from the metabolism process - levans glue is produce and making such type of filamentous cell formation and precipitation CaCO3. This both material combine with each other and making cementations material.

**CHEMICAL PROCESS TO REMEDIATE CRACKS BY BACTERIA**

Micro-organisms (cell surface charge is negative) draw cations including Ca2+ from the environment to deposit on the cell surface. The following equations summarize the role of bacterial cell as a nucleation site.

Ca2+ + Cell Cell-Ca2+

Cell-Ca2+ +CO32-  Cell-CaCO3

The bacteria can thus act as a nucleation site which facilitates in the precipitation of calcite which can eventually plug the pores and cracks in concrete.



**Fig. calcite precipitation by bacterial cell**

Source: “Key roles of pH and calcium metabolism in microbial carbonate precipitation,*-*Hammes, F. &Verstraete,W. (2002)*.* Fig.

**APPLICATION OF BACTERIA IN CONSTRUCTION AREA**

The use of microbial concrete in Bio Geo Civil Engineering has become increasingly popular. From enhancement in durability of cementitious materials to improvement in sand properties, from repair of limestone monuments, sealing of concrete cracks to highly durable bricks, microbial concrete has been successful in one and all. Application of various bacteria in construction area by various authors shown in **Table** and other application of bacteria in construction area shown in **Fig.**

**Table - Application of various bacteria in construction area**

|  |  |  |
| --- | --- | --- |
| **APPLICATION** | **ORGANISM** | **REFERENCE** |
| Cement mortar and Concrete  C:\Users\Sh\Desktop\bacteria3.jpg | Bacillus cereus  Bacillus sp. CT-5  Bacillus  Pasteurii  Shewanella  Sporosarcina pasteurii | Le Metayer – Leverel et al (1999)  Achal et al. 2011b  Ramachandran et al (2001)  Ghosh et al (2005)  Achal et al (2011a) |
| C:\Users\Sh\Desktop\bac2.jpgRemediation of cracks in concrete | Sporosarcina pasteurii  Bacillus Pasteurii  Bacillus sphaericus | Bang et al (2001)  Ramachandran et al (2001)  Ramakrishnan (2007)  De Belie et al (2008)  De Muynck et al (2008a, b) |
| Self – Healing  C:\Users\Sh\Desktop\bacteria.jpg | Bacillus Pseudifirmus  Bacillus Cohnii | Jonkers et al (2007) |

**ADVANTAGES AND DIS ADVANTAGES OF BACTERIAL CONCRETE:**

**ADVANTAGES:**

1. **Material concrete in Crack Remediation:**
2. **Improvement in Compressive Strength of Concrete:** Significant enhancement in the strength of concrete and mortar can be seen upon application of bacteria.
3. **Better Resistance towards Freeze-Thaw Attack Reduction:** Application of microbial calcite may help in resistance towards Freeze-Thaw Reduction due to bacterial chemical process and also it can reduced the permeability than freezing process decreased.
4. **Reduction in permeability of Concrete:** Permeability can be investigated by carbonation tests as it is increasingly apparent that decrease in gas permeability due to surface treatments results in an increased resistance towards carbonation chloride ingress. Carbonation is related to the nature and connectivity of the pores, with larger pores giving rise to higher carbonation depths.
5. **Reduction in Corrosion of Reinforced Concrete:** Application of microbial calcite may help in sealing the paths of ingress and improve the life of reinforced concrete structures and resists the attack of acid.

**DIS-ADVANTAGES:**

1. **Cost of Bacterial Concrete is double than conventional concrete.**
2. **Growth of Bacteria is not good in any Atmosphere and media:** Different types of nutrients and metabolic products used for growing calcifying microorganisms, as they influence survival, growth, biofilm and crystal formation. More work should be done on the retention of nutrients and metabolic products in the building material.
3. **Design of Mix Concrete with Bacteria there is no available any IS-code or other code:** As it is a new research material and not famous to use in construction area hence no code is provided to use it and it is hard to calculate the doses of bacteria use in concrete to get optimum performance.
4. **Investigation of Calcite Precipitation is costly studied.**

**CONCLUSION**

* Microbial concrete technology has proved to be better than many conventional technologies because of its eco- friendly nature, self-healing abilities and increase in durability of various building materials. Work of various researchers has improved our understanding on the possibilities and limitations of biotechnological applications on building materials. Cementation by this method is very easy and convenient for usage. This will soon provide the basis for high quality structures that will be cost effective and environmentally safe but, more work is required to improve the feasibility of this technology from both an economical and practical viewpoints.
* Higher concentrations reduced the regaining strength of the beams.
* It was found that all the specimens with bacteria formed a layer of calcite at the surface, thus improving its impermeability and its resistance to alkaline environment, sulphate attack, deciding chemicals and freeze-thaw.
* It can be concluded that cracks remediated with bacteria can improve the strength and the durability of the structure.

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