

A Study on Importance of Bacterial Cement Composites

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Abstract

In most structures the steel reinforcements are embedded into the concrete in an order to take over the tensile stresses, as the formation of cracks in concrete is a very common phenomenon which is directly related to the durability of the structure. Percolation of such cracks also leads to a number of issues such as the movement of moisture as well as the deleterious substances into the structure causing deterioration of the cement concrete mixture also causes corrosion in the reinforcement. To maintain a structure in terms of durability, entry of such deleterious materials into the structure must be prevented. In past years, a solution for such problems in the form of bacterial concrete is being developed which due to its self-healing properties not only repairs itself but also improves the service life of structure. The making of bacterial concrete generally involves the addition of bacteria into the cement concrete mixtures with their nutrient broth for the survival of bacteria up to decades serving its purpose. Generally, *Bacillus Subtilis* is used which is a typical soil bacterium which instigates the precipitation of calcite (Kadian A. , 2018) whereas, due to its level 01 according to the bio-safety standards uses of such bacteria's are completely safe, on the other hand epoxy resins and fibers instead of bacteria's are also used to heal cracks in concrete but bacteria's being the most effective are widely used healing agent because of its ability to precipitate calcium carbonate leading to the formation of crack sealing calcium carbonate crystals.

Keywords: *Bacterial Concrete, Fibers, Epoxy Resins, Calcium-Carbonate Crystals.*

Introduction

In most structures the steel reinforcements are embedded into the concrete in an order to take over the tensile stresses, as the formation of cracks in concrete is a very common phenomenon which is directly related to the durability of the structure. Percolation of such cracks also leads to a number of issues such as the movement of moisture as well as the deleterious substances into the structure causing deterioration of the cement concrete mixture also causes corrosion in the reinforcement,

to overcome such problems (H.M.JONKERS, 2011) invented a self-healing agent with 2 components which is to be added to the concrete mixture containing bacteria's with a mineral precursor compound, which gets activated every time whenever cracks appear on the surface of concrete causing ingress of moisture due to which bacteria converts the mineral precursor compound into the calcium carbonate crystals. The precipitated calcium carbonate crystals are responsible for the healing process by sealing the cracks and making the cement concrete matrix less accessible for the deleterious substances to enter and deteriorate the structure. The process of MICP (Microbiologically Induced Calcite Precipitation) is the most important factor, generally it is a series of complex biochemical reactions which includes concomitant precipitation of bacteria, urease and high pH. In MICP, the alcho-philic soil microorganisms or bacteria's play a key role by producing urease which hydrolyze urea to ammonia and carbon dioxide, The ammonia increases the pH in the surroundings, which in turn induces precipitation of CaCO_3 mainly in the form of calcite (Kadian M. , 2018).

The main objective of the study is to prepare a sustainable self-healing concrete using sustainable bacteria's and it was also observed that the biological deposition overall increases the durability of concrete, as the deposition of calcium carbonate reduces the ingress of water considerably. (Kadian & Pannu, A Study of Durability Properties of Bacterial Concrete, 2018) in his study states that the bacterial concrete refers to a new generation of concrete in which selective cementation by microbiologically-induced CaCO_3 precipitation has been introduced for remediation of micro cracks. One possible mechanism is currently being investigated and developed in several laboratories. A technique based on the applications of mineral-producing bacteria.

Efficient sealing of surface cracks by mineral precipitation was observed when bacteria-based mixtures were sprayed or applied onto damaged surfaces or manually inserted into cracks. As in those studies bacteria were manually and externally applied to existing structures. In several methods the possibility to using viable bacteria as a sustainable and concrete-embedded self-healing agent was explored. (Srinivasna Reddy.V et al, 2012) reported that the bacterial or self-healing concrete biologically produces limestone for the healing purpose of the cracks appeared on the surface of concrete structure, special bacteria's such as bacillus genus with its nutrients such as calcium lactate, nitrogen and phosphorus are added to the ingredients of the cement concrete mix, these bacteria's or self-healing agents lies in the dormant within the concrete for decades and even up to 200 years. (kadian, 2018) said MICP (Microbiologically Induced Calcite Precipitation)system is considered for the study by utilizing Bacillus Subtilis and its nutrients which later acts as the food for the microorganisms or bacteria's such as Sodium Bi-Carbonate (NaHCO_3), Ammonium Carbonate (NH_4CL), Calcium Chloride Dehydrate (CaCl_2). Generally, they are mixed in a proportion of 1:2.5:5, Liquid form of Bacillus Subtilis is also added to the proportion (35 ml approx.) with the cell concentration of approximately 100cells/ml. The tests are performed on a cubical concrete section of 150mmx150mmx150mm for calculating and testing the compressive and tensile strength. As a result, it is found that there is a considerable increase in the strength and quality of concrete with added bacteria's/ Bacillus Subtilis.

(Kaur.S., 2015) stated that using bacteria for the self-healing in concrete is unconventional approach in the present concrete studies, it is basically a new approach for an old technique of deposition of microbial mineral which constantly occurs in the natural environment. (Kadian A. , Bending Concrete: Balanced, Under-Reinforced and Over-Reinforced Beam Sections, 2018) in his paper stated while working in laboratory performing tests regarding the strength of concrete at different loads and other factors if satisfactory results are not obtained or the quality example fails to give appropriate results additional testing of concrete setup is required and said when studied deeply at microscopic level, various changes in concrete properties are observed such as electrical and acoustical properties even leading to the complete failure of the structure (Singh & Kadian, 2018).

Therefore, Microbiologically Induced Calcium Carbonate Precipitation is proposed as an effective, environmental friendly crack repair technique (Maheswaran S.et al, 2014)

Steps to Prepare Bacterial Concrete are as follows

- Selection and Development of Bacteria
- Making of Test Specimen
- Testing of various Bacterial Characteristics
- Testing of Strength

Various Types of Bacteria's Used are:

- Bacillus Subtilis.
- Bacillus Sphaericus.
- Basillus Pasteurii.
- Bacillus Cereus.
- Escherichia Coli.

Before adding the above mentioned bacteria's into the cement concrete mix, the concentration of the bacteria's to be used should be measured by Haemocytometer and the optical density should be evaluated by using the Spectrophotometer analysis, whereas to know the morphology of bacterial strains, Gram-Strain method should be considered. According to (Jonkers.H, 2012) , before addition of bacteria's to the cement concrete mix for the precipitation of test specimen, the bacteria's should be cleaned from their culture residues by the process of centrifugation and re-suspension. Currently at most places synthetic polymers such as epoxy treatments are used for repairing the concrete but on the other hand such epoxy treatments are very harmful to the environment as well as to human health, that's why the use of bacterial concrete is focused (Kadian A. , Bio-Concrete: The Future of Concrete Science, 2018). To prepare the test specimen, the bacterial concrete should be prepared by using ordinary Portland cement mixed with the bacterial concentration ranging from 100 to 106 cells/ml of water, the test specimen should also be cured regularly with the tap water at room temperature and should be tested at 7th and 28th day.

An effect of Bacteria's on the specimen strength

In previous studies also it is observed that the specimen prepared with the controlled number of bacteria's shows an excellent improvement in terms of strength as compared to the specimen prepared without using bacteria's. An Increase in compressive strength of 24% to 30% is noted whereas an average increase of 16.25% was also observed in terms of the flexural strength but with these positive effects of bacterial addition there are some negative effects as well, the test specimen with high number of added bacteria's shows a negative impact on the compressive strength development. The test specimen is observed to have 10% less compressive strength than the controlled specimen. As, the concrete is highly alkaline in nature so, the bacteria to be added in the concrete at initial stages must follow certain criteria, such as the survival rate of used bacteria in high alkaline environment for longer period with the ability of forming spores. A bacteria used for such purposes must also have the potential to withstand the mechanical as well as environmental forces (Kadian A. , Effects of MICP in Self-Healing of Bacterial Concrete , 2019). The spores appeared can be easily visualized by the ESEM technique within the size range of 0.8-1.0 μ m.

The major problem related to the crack formation is that the whole process leads to a drastic increase in the material permeability of the specimen resulting in the high increase in the risk of degradation due to the ingress of water and other aggressive chemicals. As the bacteria functions as the catalyst, an addition of suitable mineral precursor compound is needed to be mixed with the material matrix. The maximum allowable amount of the mineral precursor should be limited and controlled as per the limits, as larger quantities of them may negatively affect other properties of the cement concrete in terms of strength and setting time.

Conclusion

In this study, we have investigated the bio-mineral production capacity of the cement in which bacteria's were added as healing agents. The added bacteria's are associated with the alkali-resistant spore forming species of Bacillus Genus. In conclusion we can say that the used alkali-resistant spore forming bacteria related to the Bacillus Genus promises its application in the bacterial concrete as self-healing agents.

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