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# Feasibility Studies on Microbial Concrete

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**ABSTRACT**

Concrete is absolutely an essential component in construction material used in most of the buildings. It is mostly weak in tension and due to external loading the micro cracks was occur. The cracking allows chemicals and water to enter into the degraded concrete, reducing the performance of the structure and also it requires more expensive maintenance in the form of repairs. The micro cracks grow up to the reinforcement and hence the corrosion may occur due to exposure of water and oxygen, and possibly $CO_2$ and chloride ions. In this paper, the study was made on application of self-healing property in concrete. The mineral precipitating bacteria and additives were investigated based on the strength and durability performances. Hence this paper outlines the types of bacteria, method of application, and medium of curing and pH concentration to overcome the strength and durability requirement.
**Keywords :** Bacterial concrete, self-healing mechanism, strength and durability, micro-cracks.

## I. INTRODUCTION

The bacteria's are recommended for the bacterial concrete by considering the amount of calcite precipitation formed by their self-healing mechanism. The "Microbial concrete" are by adding spore forming bacteria in the concrete that are able to continuously precipitate calcite and this process of production of calcite precipitation is called Microbiologically Induced Calcite Precipitation (MICP). Bacterial Cultures improves the strength of cement sand mortar and crack repair on surfaces of concrete. The basic principle for this process was that the microbial urea's hydrolyzes urea to produce ammonia and carbon dioxide and the ammonia released in surrounding simultaneously increases the pH, leading to accumulation of insoluble calcium carbonate. Calcium carbonate precipitation, a metabolic process can occur in some bacteria, has been investigated and proven the scientific and technological implications.

Spores are dormant but viable bacterial spores immobilized in the concrete matrix will become metabolically active when water entering freshly into the concrete. The presence of nutrients bacteria precipitates the calcite in concrete. The alkaline environment of concrete with pH around 12 is the major hindering factor for the growth of bacteria. Some bacteria have the ability to produce end spores to endure an extreme environment, as observed by the studies. This technique is used to improve the compressive strength and helps in reduction the permeability of concrete. The concrete strength and durability were improved by various types of Bactria which are used for making microbial concrete.

## II. METHODS AND MATERIAL

### Recent Researches

Ramakrishnan *et al* (2001) studied about the improvement of concrete in durability, by microbiologically induced calcite precipitation (MICP) to improve the compressive strength and stiffness of the cracked concrete specimen. *Bacillus Pasteruii* was used to induce the precipitation of calcite. The beams treated with bacteria exposed to alkaline, sulphate and freeze-thaw environment was tested to check the durability nature. It was found that increase in the concentration of bacteria increase the durability performance. Scanning Electron Microscopy analysis was made to found that the calcite precipitation occurred inside the crack. It was finally concluded that the calcite layer improved the impermeability of the specimen.

Parks *et al* (2010) investigated about the effect of autogenous healing which occurs in concrete, when hair line crack in concrete repair themselves through reaction with water and /or constituents in water. It was found that at a pH of 9.5 appreciable healing was occurred. When higher strength healing was occurred, Scanning electron microscopy with energy dispersive spectroscopy (SEM – EDS) identified the presence of magnesium silicate material and also it was found that cracks were sealed by autogenous healing carbonation of internal concrete surface was not detected.

Jonkers *et al* (2010) investigated the development and significance of bacteria based self-healing material with an idea of ensuring the self-repair of concrete. Bacteria added in the concrete produced calcium carbonate based minerals, which induced the sealing and water tightening of cracks. The bacteria belonging to the spore forming alkali-resistant genus showed mineral producing activity when incorporated for long period. The principle mechanism of bacterial crack healing was that the bacteria acted as a catalyst and produced a new compound such as calcium carbonate based mineral precipitate which could be even better if acts a type of bio cement which seals newly formed cracks.

Tittleboon *et al* (2010) studied about the use of bacteria in concrete to repair cracks. The ureolytic bacteria namely bacillus Sphaericus was used for the conversion of urea into ammonium and carbonate in micro environment to precipitate $CaCo_3$. The urea increased the pH and promoted the deposition of carbonate. Permeability test, ultrasonic measurement and visual examination were done in concrete. The bacteria against high pH in concrete were protected by silica gel. Bacillus Sphaericus, immobilized in silica gel gave good result in increasing value of ultrasonic pulse velocity indicated the crack bridging.

Afifudin *et al* (2011) discussed about the formation of calcium silicate gel by microbial participation. The untreated and chemically modified Bacillus Subtilis were prepared and by X-ray diffraction analysis in the presence of C-S-H gel was substantiated. The compressive strength of the concrete was investigated by different concentration of bacillus subtilis and it was found that the silicate absorption was done by Bacillus Subtilis and there was no difference between the two types of bacteria in the process of adsorption of silicate. Thus the increase in compressive strength was obtained because of the use of Bacillus Subtilis for about 20%.

Elmoaty *et al* (2011) examined the self-healing phenomenon of concrete in water which depends upon the presence of unhydrated cement particles. Mechanism of polymer in concrete depends on creating the layer and net off polymer along cement particles which enhances the properties of polymer modified concrete. The self-healing process extended up to 60 days to study the effect of polymer type, polymer dose, cement content, cement type, water cement ratio and age of damage. Based on the polymer type the polymer dose were increased to increase the healing degree at the same healing time and also concluded that the reduction in water-cement ratio reduces its healing degree. The conventional specimen at 20 days immersion in water was enough to achieve most healing whereas polymer concrete required more than that.

Achal *et al* (2011) focused the improvement in strength and durability of fly ash amended concrete by microbial calcite precipitation. The effect of bacillus megaterium was studied in concrete. Microbial cells which prevent ingress of water effectively in different concentration of fly ash amended concrete and the involvement of bacteria was analyzed by SEM analysis. The use of biological technique was highly desirable as it resulted in pollution free and increase the strength and enhanced the water permeability. It was concluded that the 21% of improvement in compressive strength and three times less water absorption.

Wiktor *et al* (2011) examined the crack healing in concrete based on self-healing property. The biochemical agent which consists of bacterial spores and calcium lactate was used to arrest the crack by self-healing mechanism. The micro cracks were arrested by the formation of calcium carbonate. It was found that the maximum healable crack width was doubled by various measurements. The oxygen measurements showed that the concrete incorporates bacterial spores and remain viable. The control specimens were heal the concrete up to 0.18 mm for 100 days submersion in water whereas the bacterial specimen heals the crack width of 0.18 to 0.46 m.

Chalal *et al* (2012) used *Bacillus Sporosarcin,* an ureolytic bacteria to determine its influence on the compressive strength, water absorption and rapid chloride permeability of concrete with silica fume. Due to the deposition of bacterial cells within the pores, there was an improvement in compressive strength. The direct involvement of bacteria was revealed by XRD. The reduction in chloride permeability of concrete was occurred due to calcite deposition in concrete and increased durability of concrete structures.

Huang *et al* (2012) investigated the self-healing efficiency in cementitious material with the effect of capsules. The self-healing of cracks by further hydration of unhydrated cement particles were obtained by the embedded encapsulated water in the cement paste to promote the further hydration. The capsules were broken and the stored water in the capsules were released along the cracking pattern. From the result it can be learned that the increased rate of healing efficiency depends upon the amount of released water and size of the capsules.

Sahamitmongkol *et al* (2012) investigated the use of different additives in mortar to study the self-crack closing ability. The mortar specimen with two reinforcement were impregnated to study the crack width at the age of 3rd and 28th days. Each specimens were cured after testing to improve the performance of the crack closing when plenty of water is supplied. The crystalline admixture showed the best performance of crack heals up to 0 to 0.05 mm width. For larger cracks the mortar with silica fume was more outstanding in their healing property and it is concluded that fly ash was found to be worst additive in their performance.

Pelletier *et al* investigated the self-healing concrete impregnated with micro-capsulated healing agent. The polyurethane microcapsules were stored with sodium silicate solution inside the concrete matrix. Due to the propagation of cracks the microcapsules were ruptured to release the sodium silicate, it reacts with calcium hydroxide in cement to produce C-S-H gel which heals the cracks partially. The samples were retested after one week from the test of incipient failure to allow them for self-healing. The samples containing the microcapsules had 20-26% recovered strength after the damage whereas the conventional had 10-14%.

Schlangen *et al* (2013) focused on infrastructure by self-healing mechanisms. The author made use of bacteria, fibre reinforced cementitious material in concrete were studied. And also the raveling of porous asphalt concrete was discussed and the process of healing the damage was rectified by incorporating embedded microcapsules of steel fibers and the result showed that self-healing was not ease but the materials can be designed for it.

Rao *et al* (2013) focused on the development of bioengineered concrete using bacterial strain. *Bacillus subtilis* was used to investigate the mechanical and durability characteristics of the concrete. The tests were conducted and it was found that there was a greater improvement in the compressive strength and it was due to the growth of filler material in the pores of the matrix. The result obtained from SEM also concluded the presence of microbiologically induced precipitation within the pores of the concrete.

Kumar *et al* (2013) studied about the compressive strength of bacterial cubes when it was subjected to Bacterial Calcite Precipitation. The bacteria's namely *Bacillus Flexus*, *Bacillus Pasteurii and Bacillus Sphaericus* were used in the concrete and it was tested to determine the compressive strength. It was found that the Bacillus Flexus gave good compressive strength of about 18% when compared to that of the control specimen and also the pH of the precipitation media was increased up to 12 to reduce the growth of bacteria which also reduced the precipitation effect.

Vekaraiya *et al* (2013) studied about the synthetic polymer as epoxy resin in a repairing technique for concrete. Microbiologically induced calcite or calcium carbonate precipitation technique was adopted to remediate cracks and fissures in concrete. It was found that the use of MICP was eco-friendly nature and increased the durability of the structure. It also enhanced the improvement in compressive strength, reduction in permeability and water absorption.

Wang *et al* (2013) gave an experimental study on cementitious composites embedded with organic microcapsules. The specimens were prepared with organic microcapsules and a catalyst with cement and sand to determine the flexural and compressive strength. It was found from the result that the increase in the amount of microcapsules increased the strength of the concrete. The results from the chloride ion permeability tests showed that the failure was due to compression but the recovery rate and the healing was due to microcapsules used in the concrete.

Samudure *et al* (2014) summarized their view on Microbiologically Induced Calcite Precipitation (MICP) process. The performance of the concrete structure was increased by the formation of highly impermeable calcite layer and also it gave good resistance to corrosion. The ureolytic bacteria were used in the concrete to precipitate the calcite and it hydrolysis urea to produce ammonia and carbon dioxide which increased the pH of the bacteria.

Ravindranatha *et al* (2014) experimentally studied the healing and durability of concrete. The microorganism namely *Bacillus Pasteurii* was obtained from soil were used as a healing agent. Bacillus pasteurii had the phenomenon of bio calcification as a part of metabolic activity. The comparison study was made with concrete cubes and prism with and without the microorganism. Due to the bio calcification process microorganism secrets $CaCo_3$ which fill the voids in the concrete, which in turns improve the concrete strength and thereby heal the cracks. The crack healing property reduces the permeability of water which tends the concrete more durable.

Wang *et al* (2014) made an investigation on hydrogel encapsulated carbonate precipitating bacteria's for obtaining self-healing in concrete. *Bacillus Sphaericus* was used as a biological agent and various tests were done in order to determine the various effects of bacteria in the concrete. The hydrogel encapsulated in the concrete increased the amount of crack filling and decreased the water permeability which tends to increase in self-healing property. It was concluded that it can heal 0.5mm width crack and decreased water transportation.

Guadalupe *et al* (2014) discussed about the use of two different strain hardening cement based composites. Alkaliphilic spore forming bacteria and calcium lactate was used as a nutrient to the bacteria. The oxygen profile measurement was done to determine the metabolic activity of the bacteria which showed that the oxygen was consumed by the bacteria which helped in the process of self-healing mechanism. Thus it was found that the bio based self-healing process increased the mechanical properties.

Chowdhurya *et al* (2015) studied about the use of urea formaldehyde Microcapsules by extrinsic self-healing concept where the curing epoxy resin system has the healing agent prepared by in-situ polymerization for structural analysis microcapsules were characterized by Fourier transform infrared spectroscopy (FTIR). Two different microcapsules were added and various tests such as low velocity impact test and thermos copy analysis were conducted. It was found that the bleeding of healing agent from the microcapsules filled the damage area and it increased the strength of the concrete.

Achal *et al* (2015) reviewed about the sustainable construction by microbial precipitation. One of the most sustainable ways in microbial precipitation was the precipitation of CaCo3 and it was used by the author in this paper to determine the strength and durability of the construction materials. Bio mineralization, bio cementation and bio deposition were taken in the concrete due to microbial action. The use of MICP in concrete altered the formation of pores by surface deposition and by binding property the strength of lose materials was increased.

Wiktor *et al* (2015) studied the field performance in a parking garage based on repair system of concrete using bacteria based admixtures. In this system 2 solutions namely mix of sodium silicate, sodium gluconate, alkaliphilic bacteria and calcium nitrate, alkaliphilic bacteria were sprayed on the surface of the crack and on the concrete pavement. The water permeability and freeze-thaw resistance proved the crack sealing efficiency and improvement of frost salt scaling. The silica based component ensures an alkaline pH and formation of gel inside the crack which allowed rapid sealing within few hours.

Luo *et al* (2015) investigated the factors affecting crack repairing capacity of bacteria based self-healing concrete. The precipitations were formed on the specimen due to bacteria induced mineral precipitations and it was analyzed with SEM-EDS, XRD. The crack healing was researched by the characterization method of area repair rate anti seepage repair rate. The precipitations found at the crack surface were calcite, which appeared lamellar close packing morphology and it was concluded that the repairing ability was restrained crack width of 0.8 mm and the crack healing ratio was very small when the cracking edge exceeds more than 60 days.

## III. CONCLUSION

From the literature study, the conclusion can be drawn as,

- *Bacillus Subtilis* have the positive effect on concrete compressive strength of 28% compared with conventional specimen.
- The silica gel were used in specimen to protect the *Bacillus Sphaericus* culture against high Ph in concrete.
- The use of autoclaved bacteria instead of active bacteria reduced the water permeability.
- The phosphate medium used for curing bacterial specimen gave better resistance to alkali, sulphate and freeze-thaw attack.
- For bacterial spores and calcium lactate the crack healing was up to 0.46mm wider cracks in bacterial concrete but only up to 0.18mm wider crack in control specimen
- *Bacillus Pasteurii* induce reduction in water absorption which in turns increase durability of concrete and reduction in chloride permeability.
- The microcapsules encapsulated with *Bacillus Sphaericus* had 4 times crack heal efficiency and 10 times lower the water permeability.
- The use of sodium silicate in microcapsules impregnated in concrete had 20-26% recovered strength after the damage whereas the conventional had 10-14%.

## IV. REFERENCES


[1] Abd_Elmoaty M. Abd_Elmoaty (2011),"Self-healing of polymer modified concrete", Alexandria Engineering Journal, Vol.50, pp.171–178.

[2] Afifudin, H., Nadzarah, W, Hamidah M.S and Noor Hana H. (2011),"Microbial Participation in the Formation of Calcium Silicate Hydrated (CSH) from Bacillus subtilis", Procedia Engineering, Vol. 20, pp. 159 – 165.

[3] Dechkhachorn Jaroenratanapirom and Raktipong Sahamitmongkol (2011), "Self-Crack Closing Ability of Mortar with Different Additives", Journal of Metals, Materials and Minerals, Vol.21, pp.9-17.

[4] Erik Schlangen and Senot Sangadji (2013), "Addressing Infrastructure Durability and Sustainability by Self-Healing Mechanisms - Recent Advances in Self-Healing Concrete and Asphalt". Procedia Engineering, Vol.54, pp.39–57.

[5] Guadalupe Sierra Beltran M., Jonkers H.M and Schlangen E (2015), "Characterization of sustainable bio based mortar for concrete repair", Construction and Building Materials, Vol.67, pp.344- 352.

[6] Haoliang Huang and Guang Ye (2012)," the effects of capsules on self-healing efficiency in cementitious materials", Second International Conference on Microstructural-related Durability of Cementitious Composites.

[7] Henk M. Jonkers and Erik Schlangen E (2009). "A two component bacteria-based self-healing concrete", Concrete Repair, Rehabilitation and Retrofitting II, pp. 119–20.

[8] Jagadeesha Kumar B G and R Prabhakara, Pushpa H. (2013),"Effect of Bacterial Calcite Precipitation on Compressive Strength of Mortar Cubes", International Journal of Engineering and Advanced Technology (IJEAT), Vol.2, No. 3, pp. 486-491.

[9] Jeffrey Parks, Marc Edwards, Peter Vikesland, Abhijeet Dudi (2010), "Effects of Bulk Water Chemistry on Autogenous Healing of Concrete", Journals Of Materials In civil engineering, vol.22, pp. 515-524.

[10] Kim Van Tittelboom, Nele De Belie, Willem De Muynck, Willy Verstraete (2010)," Use of bacteria to repair cracks in concrete", Cement and Concrete Research, vol. 40, pp. 157-166.

[11] Mayur Shantilal Vekariya and Prof. Jayeshkumar Pitroda (2013),"Bacterial Concrete: New Era for Construction Industry", International Journal of Engineering Trends and Technology (IJETT), Vol. 4, Issue 9, pp.4128-4137.

[12] Mian Luo, Chun-xiang Qian , Rui-yang Li (2015),"Factors affecting crack repairing capacity of bacteria-based self-healing Concrete" .Construction and Building Materials, Vol. 87, pp.1–7.

[13] Mohini P. Samudure, Mangulkar M.N and Saptarshi S.D (2014),"A Review of Emerging Way to Enhance the Durability and Strength of Concrete Structures- microbial concrete", International Journal of Innovative Research in Science, vol.3,issue 2, pp. 9311-9316.

[14] Navneet Chahal, Rafat Siddique, Anita Rajor (2012),"Influence of bacteria on the compressive strength, water absorption and rapid chloride permeability of concrete incorporating silica fume", Construction and Building Materials Vol. 37. pp. 645-651.

[15] Ramakrishnan V., Ramesh K. Panchalan and Sookie S. Bang (2001),"Improvement of concrete durability by bacterial mineral precipitation", South Dakota school of mines & technology.

[16] Ravindranatha, Kannan N., Likhit M.L (2014), "Self-healing material bacterial concrete", International Journal of Research in Engineering and Technology, Vol. 03,issue 3, pp. 656-659.

[17] Reaz A. Chowdhury, Mahesh V. Hosur, Md. Nuruddin, Alfred Tcherbi-Narteha, Ashok Kumar, Veera Boddu, and Shaik Jeelani (2015),"Self-healing epoxy composites: preparation, characterization and healing performance", Journals of Material Research and Technology, vol.4,pp. 33–43.

[18] Seshagiri Rao M.V., Srinivasa Reddy S., Hafsa M., Veena P and P.Anusha (2013),"Bioengineered concrete- A Sustainable Self-Healing Construction Material", Research Journal of Engineering Sciences, vol.2, pp.45-51.

[19] Siddique R and Chahal N (2011), "Effect of ureolytic bacteria on concrete properties". Construction and Building Materials Vol. 25, pp. 3791-3801.

[20] Varenyam Achal, Abhijit Mukherjee (2015)," A review of microbial precipitation for sustainable construction", Construction and Building Materials.

[21] Varenyam Achal, Xiangliang Pan and Nilufeer Ozyurt (2011),"Improved strength and durability of fly ash-amended concrete by microbial calcite precipitation", Ecological engineering, Vol.37, pp. 554–559.

[22] Virginie Wiktor and Henk M. Jonkers (2011),"Quantification of crack-healing in novel Bacteria-based self-healing concrete", Cement and Concrete Composites, Vol.33, pp. 763–770.

[23] Wang J Y., Snoeck D., Van Vlierberghe S., Verstraete W. and De Belie N (2014),"Application of hydrogel encapsulated carbonate precipitating bacteria for approaching a realistic self-healing in concrete", Construction and Building Materials, Vol. 68, pp. 110-119.

[24] Wang J Y., Soens H., Verstraete W and De Belie N (2014),"Self-healing concrete by use of microencapsulated bacterial spores", Cement and Concrete Research, vol. 56, pp. 139–152.

[25] Wiktor V and Jonkers H.M (2015), "Field performance of bacteria-based repair system: Pilot study in a parking garage", Case Studies in Construction Materials.