A Review Paper on Improving Durability of Self Healing Concrete

Vitthal Ahirkar[1], Prof. Manish Bhatkar[2]

[1]*Dept. of Civil Engineering, JCOET Yavatmal, India*
[2]*Assistant Professor, Dept. of Civil Engineering, JCOET Yavatmal, India*

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Abstract - *On general observation we found that there are cracks in concrete construction after some time of construction and its cost of repair and in some cases impossible. To overcome if we are going to study of self healing concrete. The study was carried out on a bacteria based self healing concrete using Bacillus Subtilis bacteria. A proved very beneficial for construction of durable structures and it also improved the properties of concrete and maintenance cost is reduced, and experimentally about autonomous self healing mechanism with the help of biochemical process. In which metabolic conversion will occurs and crack sealing, will get filled which will be beneficially in environment case. Reconstruction and maintenance cost reduction.*

***Key Words*: Bacillus subtilis, Bacteria, Calcium lactate Durability, self healing concrete**

1. INTRODUCTION

Concrete it is the most widely used material for the construction. Concrete is weak in tension and strong in compression and cracks are inevitable in concrete. Once cracks form in concrete it may reduce the lifespan of the concrete structures. Micro-cracks and pores in concrete are highly undesirable because they provide an open pathway for the ingress of water and deleterious substances which leads to the corrosion of reinforcement and reduces the strength and durability of concrete. Various repair techniques are available to repair the cracks, but they are highly expensive and time consuming process. There are moderate techniques to repair the cracks in concrete by itself called Self-Healing Concrete. This bacterial remediation technique surpasses other techniques as it is bio-based, eco-friendly, cost-effective and durable. Concrete is a highly alkaline material, the bacteria added is capable of withstanding alkali environment. Bacteria with calcium nutrient source are added into the concrete at the time of mixing. If any cracks will be formed in concrete, bacteria precipitate calcium carbonate, this will seal the cracks.

Large cracks may affect the structural integrity while the small cracks reduce the durability of the structure. Cracks also increase the permeability of matrix thereby increasing the chances of corrosion in reinforcement. Therefore, the sole cause of structural failure is cracking. In order to reduce the chances of crack formation a structure requires regular maintenance which can be costly and may further increase the maintenance cost of the structure. One way to reduce such costs and to increase the durability of structure is to use a concrete that has self-healing mechanism. This technique is based on bio mineralization of bacteria in concrete, a biological process commonly seen in few forms of microorganisms. The strength and durability can be increased by using these microorganisms as binders and fillers in concrete. Epoxy treatment is currently used for the repair works which is harmful to the environment and health as toxic fumes and gases evolved may cause serious skin and breathing issues. Hence the use of biological techniques should be focused. The use of biological techniques in concrete lead to the invention of a new building material. This is bio-concrete.

The selection of bacteria is Bacillus Subtilis is important and needs to exhibit high resistance against high pH, temperature, and serious limitation of water. Usually mesospheric microorganisms cannot grow normally in these conditions. Spore forming bacteria from the genus Bacillus subtilis is best suitable for such concrete.

2. MECHANISM OF SELF HEALING

The micro cracks that are developed inside the concrete due to the immoderate tensile forces provides the site for self-healing via bacterial activities. The bacterial spores and calcium lactate that are used as the healing agents, act as the precursors during the process. The spores along with the calcium lactate are embedded and stored into the expanded clay pellets consisting of pores and bubbles. These pellets are then distributed uniformly throughout the concrete during the mixing process. Whenever crevices are formed in such concrete, the pellets rupture thus letting the bacterial spores and chemical precursor out. The moisture and oxygen enters such micro cracks furnishing favorable environment for the multiplication of the bacteria. R. Spinks, in an article for Guardian, comments on the interesting nature of the healing process. It is only with the arrival of concrete nemesis rainwater or atmospheric moisture seeping into cracks. That the bacteria starts to produce the limestone that eventually repair the cracks. In concrete cracks up to 0.2mm wide are healed autogenously. Such micro cracks are acceptable as these do not directly influence the safety and strength of concrete. The in-built bacteria-based self-healing process was found to heal cracks completely up to 0.5mm. Oxygen and water, which were responsible for degrading the quality of concrete, now triggers the process.

Fig. 1 and Fig. 2 shows the before and after healing process

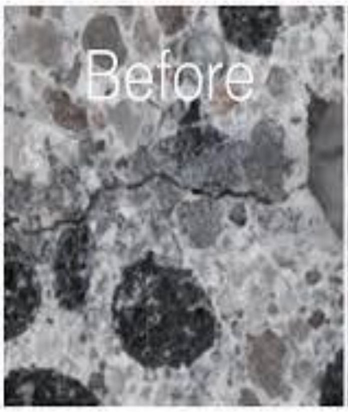

FIG.1

FIG.2

3. PREPARATION OF BACTERIAL CONCRETE

Bacteria are added to concrete mix in suspension state and it must meet certain criteria. Bacteria used as self-healing agent should be able to survive high alkaline environment of concrete for long durations and be able to form spores (highly resistant structures) withstanding mechanical forces during concrete mixing. A bacterial concrete mix prepared using alkali-resistant soil bacteria Bacillus subtilis JC3 along with nutrients from which the bacteria could potentially produce calcite based bio-minerals. The bacteria genus Bacillus has been found to thrive the high-alkaline environment of concrete due to its extremely thick outer cell membrane that enables them to remain viable until a suitable environment is available to grow. They would become active when the cracks form on concrete surface allowing water to enter into the structure. This phenomenon will reduce the pH of the concrete environment where the incorporated bacteria become activated. A peptone based nutrients supplied along with bacteria content in suspension helps in producing calcite crystals.

4. WORKING PRINCIPLE OF SELF HEALING PROCESS

In concrete structures, the micro cracks up to 0.2 mm wide are healed autogenously due to hydration of non-reacted cement particles present in the concrete matrix coming in contact with ingress water. The bacteria based self-healing process has been found to heal cracks completely up to 0.5 mm width. On the surface of control concrete, Calcium Carbonate will be formed due to the reaction of CO_2 present with Calcium Hydroxide present in the concrete matrix according to the following reaction:

$$CO_2 + Ca\,(OH)_2 \rightarrow CaCO_3 + H_2O$$

The Calcium Carbonate production in this case is rationed due to the limited amount of CO_2 present. As $Ca(OH)_2$ is a soluble mineral, it gets dissolved in entering water and diffuse out of the crack in the form of leaching. The self-healing process in bacteria incorporated concrete is much more efficient due to the active metabolic conversion of Calcium nutrients by the bacteria present in concrete:

$$Ca(C_3H_5O_2)_2 + 7O_2 \rightarrow CaCO_3 + 5CO_2 + 5H_2O$$

Here Calcium Carbonate is produced directly due to microbial metabolic process and also indirectly due to autogenously healing. This process results in efficient bacteria-based crack sealing mechanism. Ureolytic bacteria, Bacillus Subtilis JC3 can precipitate $CaCO_3$ in the high alkaline environment by converting urea into Ammonium and Carbonate. The Ammonia degradation of urea increases the pH locally and promotes the microbial deposition of carbonate as calcite crystals in a calcium rich environment sealing the crack and maintains the pH of concrete.

5. LITERATURE REVIEW

V. Ramakrishnan, R.K.Panchalan, and S.S.Bang: has published a paper on Bacterial Concrete a Concrete for the Future which says a common soil bacterium was used to induce calcite precipitation. This technique is highly desirable because the mineral precipitation induced as a result of microbial activities, is pollution free and natural. The effectiveness of this technique was evaluated by comparing the compressive strength and stiffness of cracked specimens remediated with bacteria and those of the control specimens (without bacteria). Experimental investigation was also conducted to determine the strength regaining capacity (modulus of rupture) of cracked beams remediated with different concentrations of bacteria. This paper also presents the results of a durability study on cement mortar beams treated with bacteria, exposed to alkaline, sulphate and freeze-thaw environments. Different concentrations of bacteria were used for the investigation. It was found that the use of bacteria improved the stiffness, compressive strength, modulus of rupture and durability of concrete. Scanning electron microscope (SEM) was used to document the role of microbiologically induced mineral precipitation in improving the strength and durability aspects of concrete.

C. C. Gavimath, B. M. Mali, V. R. Hooli, J. D. Mallpur , A. B. Patil , D.P.Gaddi, C.R.Ternikar : has published a paper on potential application of bacteria to improve the strength of cement concrete in which the potential application of bacterial species i.e. B.subtilis to improve the strength of cement concrete is studied. Here they have made an attempt to incorporate dormant but viable bacteria in the concrete matrix which will contribute to the strength of the concrete. Water which enters the concrete will activate the 5 dormant bacteria which in turn will give strength to the concrete through the process of metabolically mediated calcium carbonate precipitation. Concrete, however, is due to its high internal pH, relative dryness and lack of nutrients needed for growth, a rather hostile environment for common bacteria, but there are some extremophilic spore forming bacteria may be able to survive in this artificial environment and increase the strength and durability of cement concrete. In this study they found that incorporation of spore forming bacteria of the species Bacillus will not negatively affect the compressive and split tensile strength of the cement concrete.

A. Surendran and S. John Vennison: has published a Journal on Occurrence and Distribution of Mosquitocidal Bacillus subtilis in Soil which says Bacillus subtilis is one of the effective biolarvicides to control Culex species and the monitoring of larval susceptibility is essential to avoid resistance development. Mosquito larvicidal activity of B. subtilis was assessed by isolating them from ecologically different soil habitats in and around Devakottai of Tamil Nadu inSouth India. The isolated organisms were confirmed as Bacillus subtilis based on biochemical characterization and microscopic observations.

Thirumalaichettiar : has published a paper on bacterial concrete says a novel technique in remediating cracks and fissures in concrete by utilizing microbiologically induced calcite (CaCo3) precipitation is discussed. Microbiologically induced calcite precipitation (MICP) is a technique that comes under a broader category of science called biomineralization. It is a process by which living organisms form inorganic solids. Bacillus Subtilis, a common soil bacterium can induce the precipitation of calcite.

6. MATERIALS

Cement - Cement is a binder material, Ordinary Portland Cement (OPC) of 53 grade was used. The physical and chemical properties of cement are as per IS:456-2000.

Fine aggregate - River sand passing through 4.75mm IS sieve and confirming to zone-1 of IS:383-1987 was used. The specific gravity was found to be 2.3

Coarse aggregates -It is crushed stones of maximum size 20mm and retained on 4.75mm IS sieves. Test as per IS: 2386-1963 is used.

Water- Potable water has been used for casting concrete specimens. The water is free from oils, acids, and alkalis.

Micro-organism -Bacteria from genus Bacillus species "Bacillus Subtilis" is rod shaped, form a tough protective end spores allowing it to tolerate extreme environmental conditions. When a concrete structure is damaged, water start to seep through the cracks and the spores of the bacteria start to grow on contact with water and nutrients. It can adjust to alkaline condition of concrete for the production of calcium carbonate. It can withstand high pressure and consumes surplus oxygen, thus preventing steel corrosion. The reaction also causes an increase of pH from neutral to alkaline conditions forming bicarbonate and carbonate ions, which precipitate with the Calcium ions in the concrete to form Calcium Carbonate minerals. The further crystallization of the Calcium Carbonate minerals heals the pores and cracks in the concrete.

7. ADVANTAGES AND DISADVANTAGES OF SELF HEALING CONCRETE

ADVANTAGES

1) Improvement in compressive strength.

2) Reduction in permeability.

3) Reduction in corrosion of steel.

4) Increase the service life of structure than expected life.

5) It helps in reduced maintenance and repair cost of structures.

DISADVANTAGES

1) Cost of bacterial concrete is double than conventional concrete.

2) Investigation of calcite precipitation is costly.

8. APPLICATION OF SELF HEALING CONCRETE

1) Construction of underground retainers for hazardous waste material.

2) Construction of building in seismic zone and high rise structures.

3) Water retaining structure

9. CONCLUSIONS

1) Self healing concrete is the best solution for the demand of sustainable concrete. Due to its ability of self repair and durability. In future self healing concrete is going to play the most important role in concrete technology.

2) Self-healing concrete is eco-friendly and Enhance compressive strength and reduce the permeability.

3) Bacterial concrete technology has proved to be better than many conventional technologies.

4) Bio concrete enhance the life time of a structure by more than the expected value.

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REFERENCES

1) Jonkers, H., 'Self healing concrete: a biological approach', in S. van der Zwaag (ed.) 'Self Healing Materials: An alternative approach to 20 centuries of materials science' (Springer, Dordrecht, 2007) 195- 204.

2) Dr. Nele De Belie, Ghent University, Belgium, "Self-Healing of Concrete".

3) DeMuynck W, deBelie N, Verstraete W (2007) Improvement of concrete durability with the aid of bacteria. Proceedings of the First International Conference on Self HealingMaterials 18– 20 April 2007, Noordwijk aan Zee, The Netherlands.Edvardsen C (1999)

4) Soundharya S, Nirmal KK. Strength improvement studies on self healing characteristics of bacterial concrete. International Journal of Engineering Science Invention Research and Development. 2014 Oct; I(IV):162–4.

5) E. Ezhilarasi, G. Geetha, K. Baskaran, "Experimental flexural behaviour of self healing concrete using Bacillus Subtilis bacteria" published in International Journal of Engineering Research and Technology (IJERT); Volume: 05 Issue: 12, December 2016.

6) S. Sunil Pratap Reddy, M. V. Seshagiri Rao, P. Aparna and C. H. Sasikala, Performance of Ordinary Grade Bacterial (Bacillus Subtilis) Concrete, *International Journal of Earth Sciences and Engineering, ISSN 0974- 5904, Vol. 03, No. 01, February 2010, pp. 116-124 .*

7) C.C. Gavimath, B.M.Mali, V.R.Hooli,A.B Patil, Potential application of bacteria to improve the strength of cement concrete, *International Journal of Advanced Biotechnology and Research (2011), pp 541-544*.