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Engineering and Durability Property of Bacterial Self-Healing Concrete" – A Review

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Abstract: A construction industries are fast growing sector around the globe and Concrete is a key material for construction worldwide due to the strength and durability properties. Along with the positive, there are some lacks in the concrete that is in terms of cracking in concrete, every year millions of resource in terms of money and technology consumes. The bacterial self-healing is novel approach towards the producing durable and crack free concrete by using the Industrial waste which leads to reduce the cost of repairing the cracks by conventional methods and reduce the chances to again development of crack in concrete. For this process bacteria's such as B. subtitles, B. spheres and B. pasteurii etc. are used for self-healing the concrete cracks now days the industrial wastes are rapidly increasing more. So utilize such material and reduce such type of waste in environment, therefore some percentage of cement will replaced by the industrial waste.
Keywords: Bacterial Self-healing, Concrete, Industrial waste.

I. INTRODUCTION

Concrete which forms major components in the construction industry as it is cheap, easily available, and convenient to cast. But drawback of these material is it is weak in tension, which creates cracks in the concrete. Cracks occur due to various mechanisms such as shrinkage, freeze-thaw reaction and mechanical compressive and tensile forces. Cracks in concrete may also enhance the deterioration of embedded steel bars. Without immediate and proper treatment, cracks tend to expand further and eventually required costly repair. Synthetic materials like epoxies are used for remediation, but they are not compatible, costly, reduce aesthetic appearance and need constant maintenance. By introduce the bacteria in concrete it producing calcium carbonate crystals which block the micro cracks are always avoided but to some extents they are responsible to their failure in strength. The selection of the bacteria is depends on the survive capability of bacteria in the alkaline environment. Most of the microorganisms die in an environment with pH value of 10 or above. Bacteria Bacillus will be found to succeed in high alkaline environment. The bacteria survive in the high alkaline environment that formed spores. The pH of the highly alkaline concrete lower to the value in the range 10 to 11.5 where the bacterial spores becomes activated. There are many other bacteria which are survive in the alkaline environment shown in the table 1.

Table1. Bacteria other than Bacillus which are survives in the alkaline environment.

Sr. No.	Application	Types of Bacteria
1	As a crack healer	• B.pasteurii • Deleya Halophila • B. megaterium
2	For surface treatment	• B. sphaericus
3	B.spharicus	• Bacillussubitilis • B. sphaericus • Thiobacillus

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II. LITERATURE REVIEW

A. Pipat Termkhajornkit [1]

in this paper author, has investigated self-healing ability of fly ash – cement system considering compressive strength, porosity, chloride diffusion coefficient, hydration reaction and hydrated products. Research focused on behaviour after shrinkage cracking occurs after 28 days. The amount of cracks was not measured directly but was implied by the amount of total porosity. The results shows that the increases of compressive strength after 28 days of sample containing fly ash was higher than those of ordinary cement paste. As for the porosity, the reductions of total capillary pores after 28 days in fly ash cement paste were higher than those in cement paste. As for chloride diffusion the effective chloride diffusion coefficient of sample with 25% fly ash at 91 days was significantly lower than those of cement paste. From the view point of hydration the amount of cementations material hydrated after 28 days increased when the replacement ratio of fly ash cement system has the self-healing ability for micro cracks that occur form shrinkage. [1]

B. Henk M Jonkers [3]

in this experimental study, shows that the applied two- components bio- chemical self-healing agents, consisting of mixture of bacterial spores and calcium lactate, can be successfully applied to promote and enhance the self-healing capacity of concrete as the maximum healable crack width more than doubled. Oxygen measurement provided evidence that concrete incorporating bacterial spores embedded in expanded clay particles and derived active bacteria remain viable and functional several month after concrete casting. As the metabolically active bacteria consume oxygen, the healing agents may act as an oxygen diffusion barrier protecting the steel reinforcement against corrosion. Advantages of this bacteria based concrete are to presumably primarily in reduction of maintenance and repair costs and extension of the service life of concrete construction.

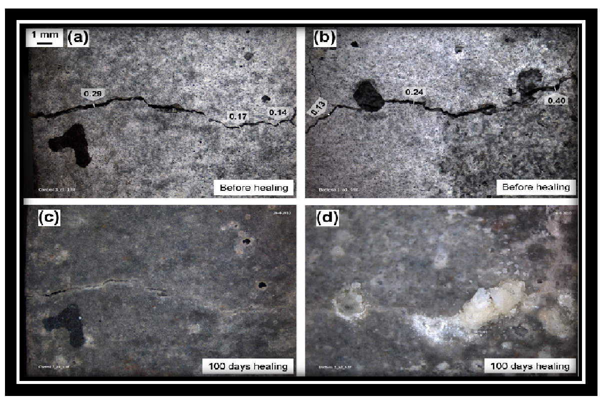

Figure. 1. Stereomicroscopic images of crack-healing process in control mortar specimen before (a) and after 100 days healing (c), in bio-chemical agent-based specimen before (b) and after 100 days healing (d).

C. Luciana Restuccia [13]

in this research study, shows that the production of self-healing concrete was proposed: glass small spheres and pharmaceutical capsules were filled with sodium silicate as a healing agents. The preliminary results of three point bending test seen to indicate that sodium silicate was efficiently released by the capsules when the facture intercepted them. However a limited amount of solution was able to diffuse into the mortar cementations matrix, and a limited strength recovery was evidenced. Based on these experimental results, it is possible to consider the encapsulation technique presented in this paper as a promising technique for self-healing of cracks.

D. Navneet Chahal [6]

in this research author, shows that the *Bacteria S.pasteurii* plays a significant role in increasing the compressive strength of fly ash concrete by up to 22% at the age of 28days. The increase in compressive strength is mainly due to consolidation of the pores inside the fly ash concrete cubes with bacterial induced calcium carbonate precipitation. S.pasteurii cause four times reduction in water absorption which could in turn increase durability of concrete structure. Bacterial calcite deposition observed nearly eight times reduction in chloride permeability, hence the life of the concrete structure can be increased.

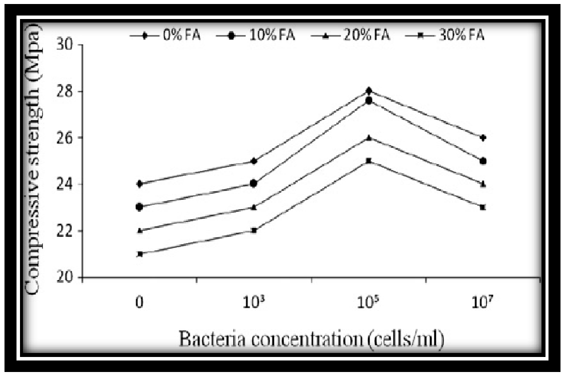

Figure. 2. Effect of bacteria (Sporoscarcina pasteurii) on compressive strength of fly ash concrete at 28 days.

E. Mayur Shantilal Vekariya[7]

in this review paper author, shows that the use of microbial concrete is better than many conventional technologies because of its eco-friendly nature, self-healing abilities and increases in durability of various building materials.[6] It enhance the compressive strength, reduced the permeability, water absorption. This method is very easy and convenient for usage. This will provide high quality structure at an effective cost, least maintenance, environmentally safe. But more work is required to improve the feasibility of this technology form both an economical and practical point of view.

F. Harshali J. [11]

in this research article author, shows that the use of bacteria in concrete it improves the compressive strength and flexural strength of bio concrete cubes compared to conventional cubes. It also reduce water absorption and sorptivity, and enhance the strength of the concrete. It improve the compressive strength of the concrete by filling the pores by calcite formation in fresh concrete. The impermeably of concrete will be increased than the conventional concrete. Bacteria repairs the cracks in the concrete by producing the calcium carbonates crystals which blocks the cracks and repair it.

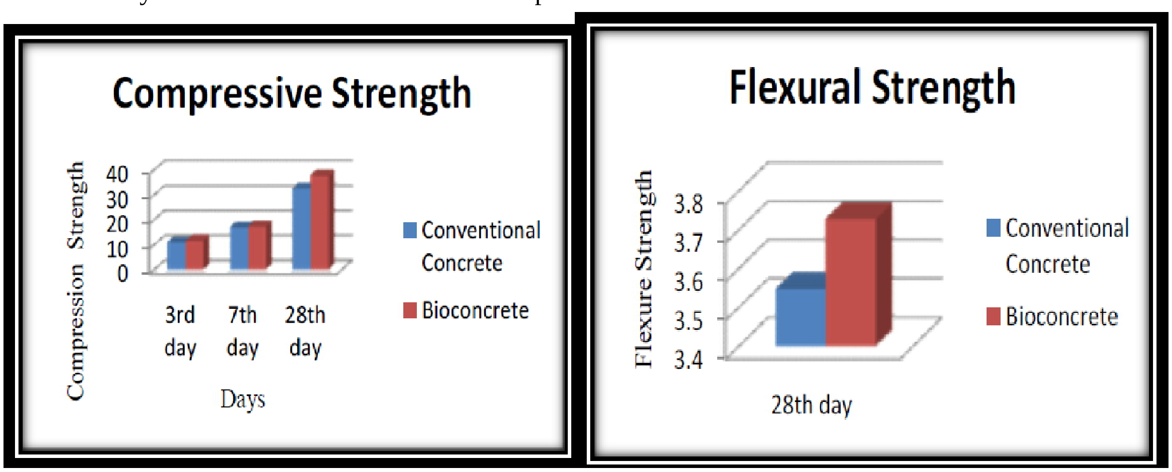

Figure.3. Results of Compressive strength and flexural strength

G. *Dilja Rose Joseph* [12]

in this research author, shows that the work optimizes the percentage of fly ash as cement replacement in *Bacillus Subtilis* microbial concrete. Strength properties like compressive strength, split tensile strength and flexural strength properties were evaluated.[10]In case of microbial concrete, 28^{th} day compressive strength is 26.64% higher than ordinary M30 concrete. After 56^{th} day curing, the strength reaches maximum strength compared to other mixes. As compressive strength, split tensile strength, also follows the same variation. 10% fly ash shows maximum tensile strength. [10] The percentage replacement of fly ash was increased, the split tensile strength of fly ash concrete was also found to be increasing slowly, up to nearly 10% replacement and then it decreased. The increase in strength of microbial concrete is mainly due to filling of the pores and voids with microbiologically induced calcium carbonate precipitation. From the experimental investigation it was found that optimum replacement of fly ash in microbial concrete was near to 10% in terms of strength properties.

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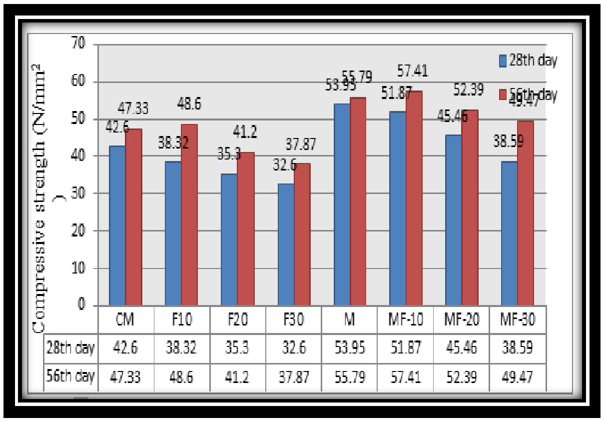

Figure.4. 28th day and 56th day Compressive strength

H. Sunil Pratap Reddy [2]

in this research author, shows that the addition of bacillus subtitles bacteria improves the hydrated structure of cement mortar. The compressive strength of cement mortar is maximum with the addition of bacillus subtilis bacteria for a cell concentration of 10^5 cells per ml of mixing water. So, bacteria with a cell concentration of 10^5 cells per ml of mixing water were used in the investigation. In standard grade concrete the compressive strength is increased upto 14.92% at 28 days by addition of bacillus subtilis bacteria when compared to conventional concrete. The addition of bacillus subtilis bacteria showed significant improvement in the split tensile strength than the conventional concrete. From the durability studies the percentage weight loss and percentage strength loss with 5% H_2SO_4revealed that bacterial concrete has less weight and strength losses than the conventional concrete. In the investigation through acid attack test with 5% H_2SO_4 revealed that bacterial concrete is more durable in terms of “Acid Durability Factor” than conventional concrete and bacterial concrete is less attacked.

III. CRITICAL REMARKS

A. Bacterial calcite deposition observed nearly eight times reduction in chloride permeability.
B. It is possible to consider that the glass small spheres and pharmaceutical capsules were filled with sodium silicate as a healing agents.
C. It enhance the compressive strength, reduced the permeability, water absorption.
D. As fly ash content increased by 10% split tensile value had been increased. And at 22% at 10^5cells/ml concentration of bacteria compressive strength is maximum.
E. Advantages of this bacteria based concrete are to presumably primarily in reduction of maintenance and repair costs and extension of the service life of concrete construction.

IV. CONCLUSION

A. Based on study we conclude that,
1) Bacteria are able to healing the cracks at early stage with small to medium cracks.
2) Regular inspection of concrete will be less due to use of self-healing material used in the concrete.
3) Bacterial repairs the cracks in concrete by producing the calcium carbonate crystal which block the cracks and repair it.
4) It reduce the overall maintenance cost of the structure, and enhance it durability.

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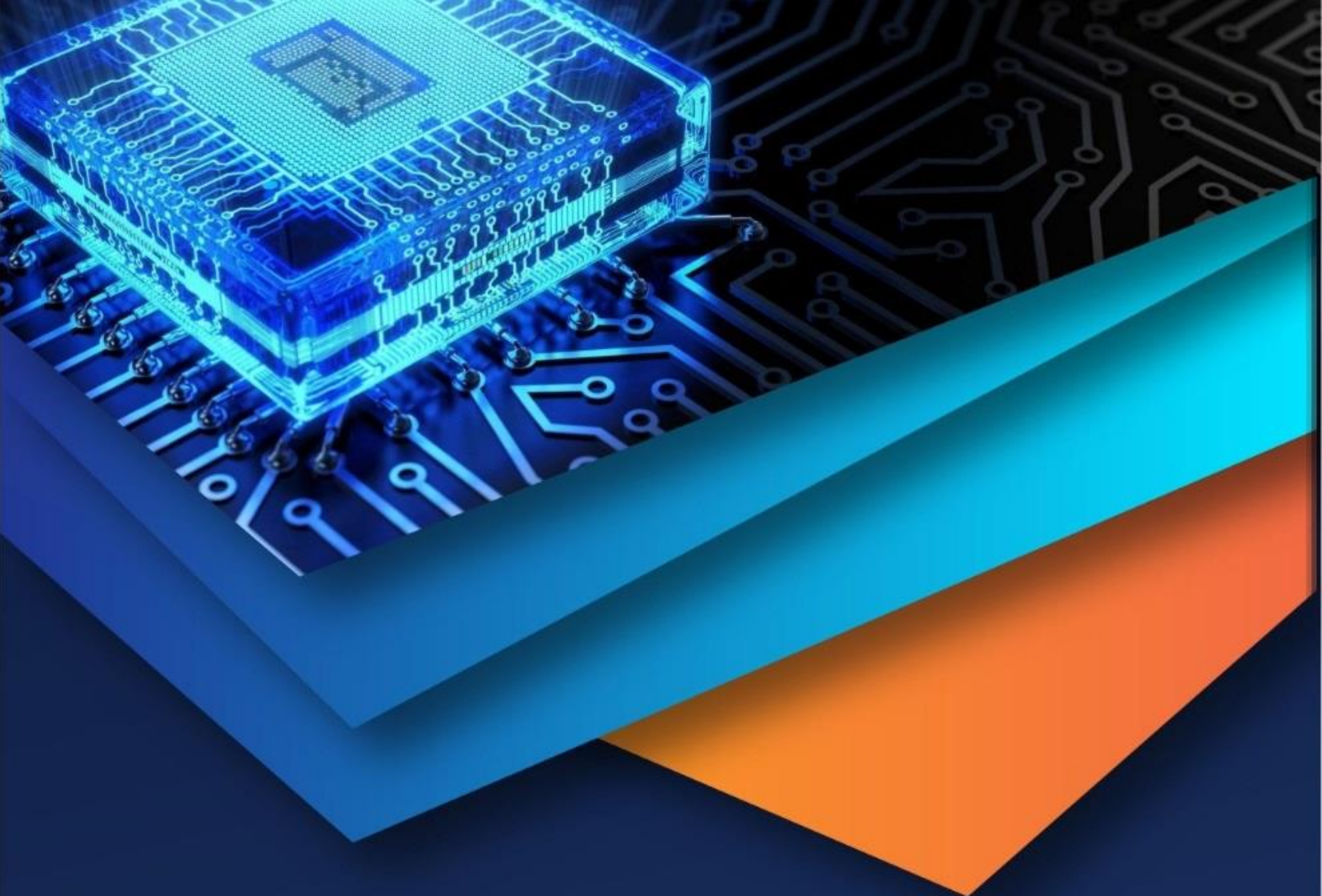

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