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A Review on Experimental Study of Bacterial based Self-Healing Concrete

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Abstract: The objective of the present investigation is to obtain the performance of the concrete by the microbiologically induced special growth. One such through has lead to the development of very special concrete known as Bacterial Concrete where bacteria is induced in the mortars and concrete to heal up the faults. In this experimental investigation carried out the evaluate the influence of Bacillus Pasturii bacteria on the compressive strength, resistance against acid attack and chloride penetration of concrete made with and without FLY ASH & GGBS. Cement was replaced with three percentages 30, 40 and 50 with GGBS by weight, and FLY ASH 20 percentages, with a cells concentration of 10 cells/ml of bacteria were used in making the concrete mixes. The tests were performed at the age of 7, 28 and 91 day.
Keywords: Bacillus Pasturii, Bacterial Concrete, FLY ASH, GGBS, Cells Concentration Concrete

I. INTRODUCTION

Concrete is composite material composed of aggregate sand and water bonded by the cement which becomes hard in some time. Concrete is the most widely used conventional construction material which is widely used everywhere in industry such as roads, sidewalk, house, bridge, pipes, dams, canals, silos, and nuclear waste containment. The concrete cost is small and easily available in the market without problem. Approximately 60% of our concrete highway need repair and 40% of our concrete highway bridge are structurally deficient or functionally obsolete. Crack size more than 0.8mm is more difficult to be repaired however with the use of bacteria cracks can heal with the calcite precipitation [5]. Lightweight aggregates added in the place of fine aggregate leads reduction of strength of bacteria based mortar. The strength of bacterial lightweight mortar was more than normal lightweight mortar. This can be used where light weight structures are required. These light weight aggregates are good carrier for bacteria, which increases the healing efficiency and structural durability [8]. The addition of bacteria in Rice husk ash concrete can increase strength properties of concrete due to calcite precipitation at all ages of concrete [10]. Maximum of 24% can be increased in the M50 grade concrete, with maximum calcium carbonate precipitation [12]. The strength of fly ash concrete can be increased by adding Sporoscarcina Pasteurii bacteria which also reduces the porosity and permeability. This results in an increase of compressive strength by a maximum of 22% and reduction in water absorption by four times of normal concrete [16].

A. Self Healing Technique

In this research the bacillus pasteurii bacteria is used .Sporosarcina pasteurii formerly known as Bacillus pasteurii from ol dertaxonomies is a bacterium with the ability to precipitate calcite and solidify sand given a calcium source and urea, through the process of microbiologically induced calcite precipitation or biological cementation. Self-healing techniques are good approaches for rehabilitation of micro-cracks in concrete. Bacillus pasteurii has been proposed to be used as an ecologically sound biological construction material. A perfect self-healing system should sense the damage or cracks which can set of the release of the healing agent.. The autogenously healing techniques show good results in healing of micro-cracks on the surface of the concrete. The addition of bacteria will form a pervious layer on the cracks of concrete, which conforms the precipitation of calcium carbonate [23,25]. 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. the self-healing approaches have been exhibiting promising results in remediating the cracks in the earlier stages of formation of cracks [27]. On the other hand precipitation of calcite in the concrete specimens by hydro gel encapsulation, capsules, and vascular systems seem to be proficiently adept at self-healing in the construction activities and researches.

II. LITERATURE REVIEW

From the relative paper reviewed, few papers selected based on the importance of the study context. Analysis of this paper is presented here.

1) Mian Luo, Chun-xiang Qian, Rui-yang Li "Factors affecting crack repairing capacity of bacteria-based self-healing Concrete "In this research paper authors shows that bacteria-based self-healing concrete was developed by adding the microbial self-healing agent which has the potential to improve self-healing capacity mainly by bacteria induced mineral precipitations. The results showed that the microbial self-healing agent could be used to achieve the goal of concrete crack self-healing. The crack was more and more difficult to be repaired with the increase of average crack width and the repair ability of microbial repair agent was limited for specimens with crack width up to 0.8 mm. Water curing was shown to be the best way for bacteria-based self-healing concrete. In addition, the crack healing ratio of specimens dropped significantly along with the extension of cracking age. When the cracking age was more than 60 days, the crack healing ratio was very small. The results above suggested that the optimal conditions were needed for the practical application of microbial self-healing agent.

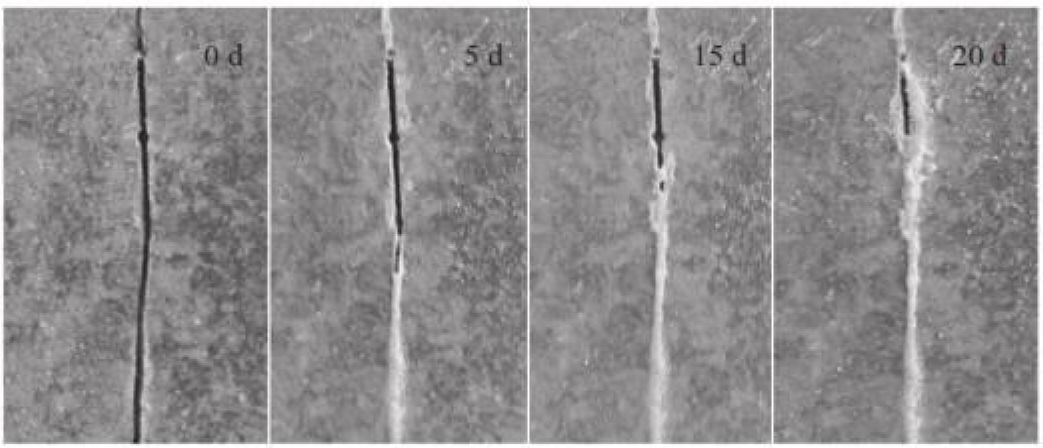

Figure 2.1 Surface images of specimen with a average crack width of 0.3 mm

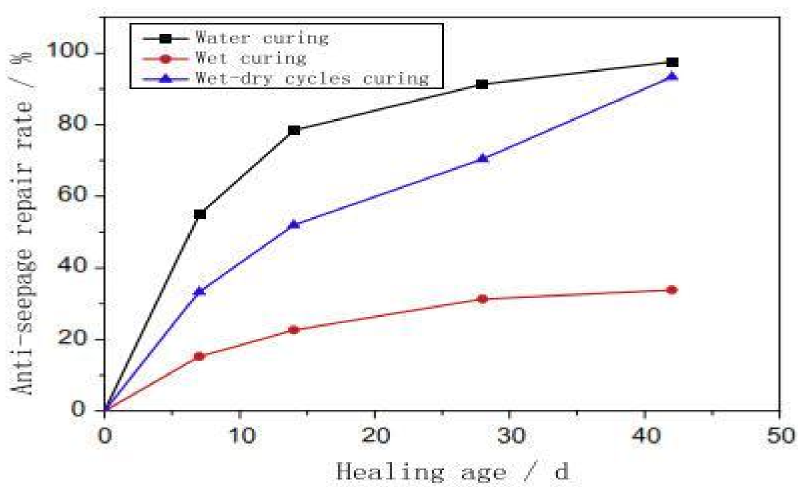

Figure 2.2 Crack healing ratio under different curing ways.

2) Navneet Chahal 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 obs erved nearly eight times reduction in chloride permeability, hence the life of the concrete structure can be increased.

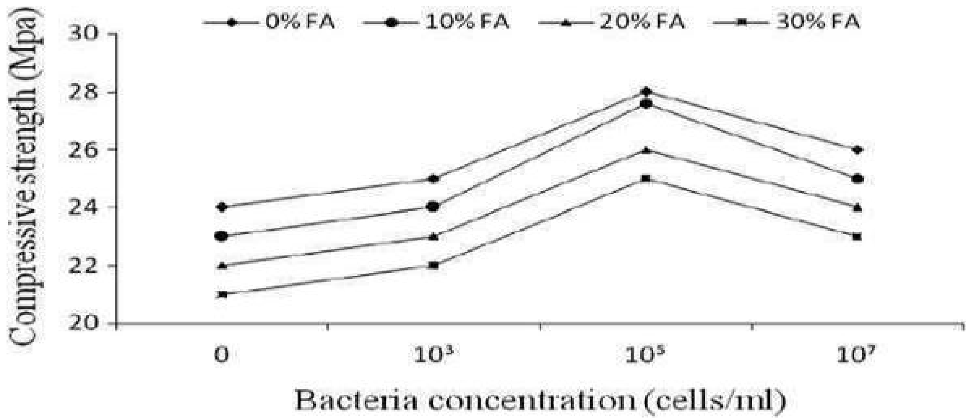

Figure 2.3 Effect of bacteria (Sporoscarcina pasteurii) on compressive strength of flyash concrete at 28 days.

3) V.WIKTOR.H.M.JONKERS "Field performance of bacteria-based repair system: Pilot study In a parking garage in this research work authors says that This liquid-based repair system aims at the Sealing of cracks and decrease of the porosity due to the production of a calcium-based biomineral. The system combines advantages of both a traditional repair system for Concrete (fast reacting and short term efficiency), and bio-based methods (more sustainable, slow process, and long-term efficiency). The bacteria-based repair system has been sprayed onto the surface of cracks and on concrete pavement. The crack-sealing efficiency and improvement of frost salt scaling were assessed by water permeability and freeze/thaw resistance tests respectively. The results were very promising as only cracks that had not been treated with the bacteria based repair system were still heavily leaking. In addition, the freeze/tha w resistance of concrete that was treated with the bio-based repair system was higher than the untreated concrete This paper presents the field performance of the recently developed bacteria-based repair system for concrete. The system combines advantages of both a traditional repair system for concrete (fast reacting and short term efficiency), and bio- based methods (more sustainable, slow process, and long-term efficiency).

Figure 2.4 Test location for the application of the bacteria-based repair system.

4) Kunamineni Vijay, Meena murmur,shirish V. Devo. "Bacteria based self healing concrete" This paper gives a brief description of the various properties of concrete which vary with the addition of bacteria. Micro-cracks are inherently present in concrete. This causes degradation of concrete leading to ingress of deleterious substances into concrete, resulting in deterioration of structures. Due to this concrete needs to be rehabilitated. To surmount these situations self-healing techniques are adopted. By the addition of urease engendering bacteria along with calcium source results in calcite precipitation in concrete. Bio-mineralization techniques give promising results in sealing the micro cracks The ureolytic bacteria which include Bacillus Pasteurii, Bacillus Subtilis which can engenderurea are integrated along with the calcium source to seal the freshly composed micro cracks by CaCO precipitation. For the amelioration of pore structure in concrete, the bacterial concentrations were optimized for better results. The literature shows that Encapsulation method will give better results than direct application method and also shows that the use of bacteria can increase the strength and durability properties of concrete in concrete. The importance of this work is to understand, the use of ureasepr oducing bacteria isolates, such as Bacillus subtilis, bacillus pasteurii species in healing of cracks in concrete. The study has reviewed different types of bacteria that can be used for healing cracks. This study has also identified that bacteria has a positive effect on the compressive strength of Portland cement mortar cubes and concrete. The advantage of using bacteria decreases water penetration and chloride ion permeability. The present study results recommends that using the ''microbial concrete" can be an alternative and high quality concrete sealant which is costeffective, environmental friendly, and eventually leads to improvement in the durability of building materials.

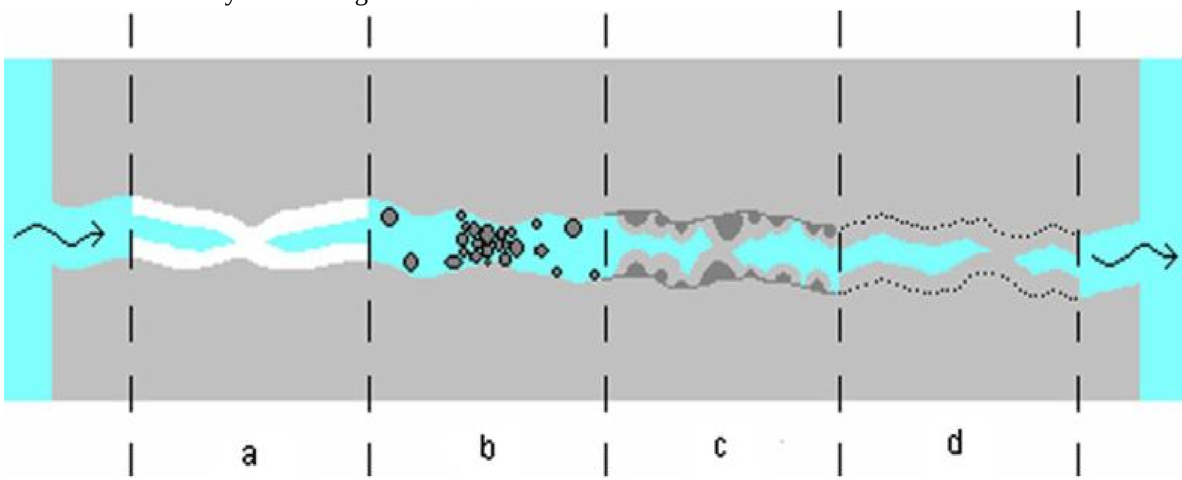

Figure 2.5 Possible self-healing mechanisms for cementitious materials.

5) V.WIKTOR.H.M.JONKERS "Quantification of crack-healing in novel bacteria-based self-healing concrete" In this research paper authors discussed about micro crack formation hardly affects structural properties of constructions, increased permeab ility due to micro crack networking may substantially reduce the durability of concrete structures due to risk of ingress of aggressive su bstances particularly in moist environments. In order to increase the often observed autogenous crack-healing potential of concrete, specific healing agents can be incorporated in the concrete matrix. The aim of this study was to quantify the crack-healing potential of a specific and novel two-component bio-chemical self-healing agent embedded in porous expanded clay particles, which act as reservoir particles this study show that the applied two-component bio-chemical self-healing agent, consisting of a 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. Moreover, oxygen measurements provided evidence that concrete incorporating bacterial spores embedded in expanded clay particles and derived active bacteria remain viable and functional several months after concrete casting. and replace part of regular concrete aggregates. Upon crack formation the two -component biochemical agent consisting of bacterial spores and calcium lactate are released from the particle by crack ingress water. Subsequent bacterially mediated calcium carbonate formation results in physical closure of micro cracks. Experimental results showed crack-healing of up to 0.46 mm-wide cracks in bacterial concrete but only up to 0.18 mm-wide cracks in control specimens after 100 days submersion in water.

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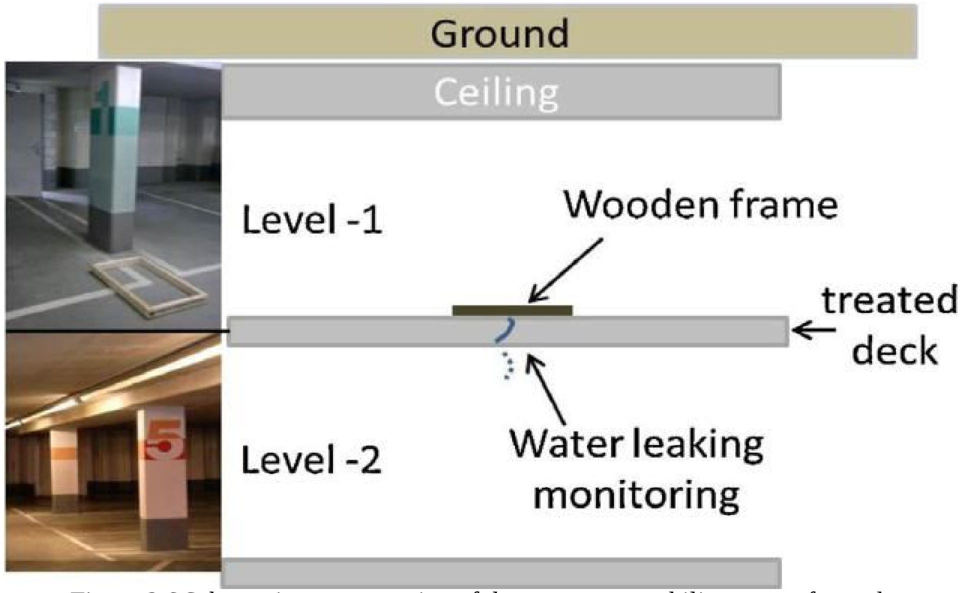

Figure 2.6 Schematic representation of the water permeability test performed.

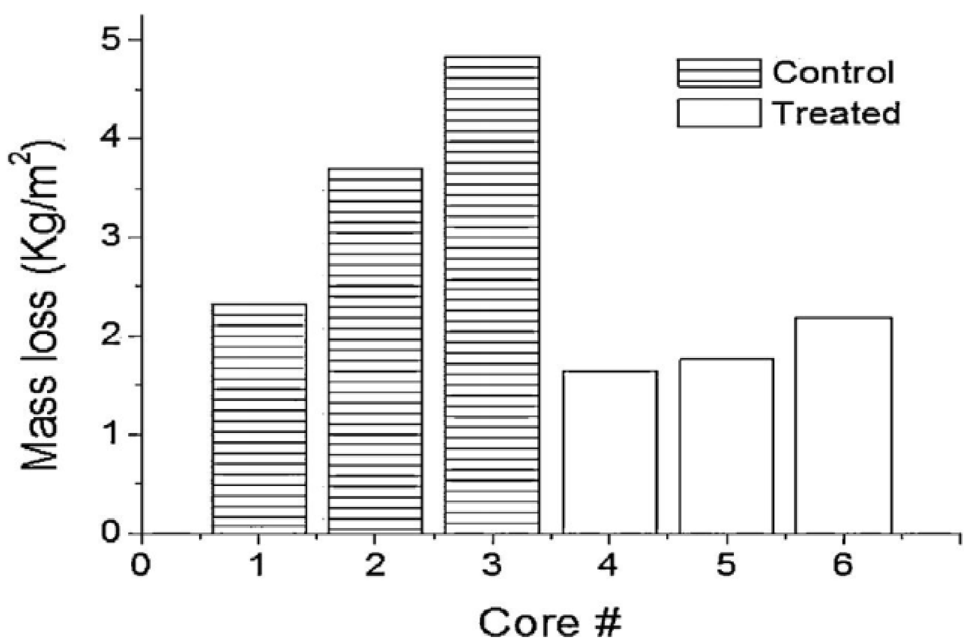

Figure 2.6 Scaling after 7 freeze/thaw cycles.

6) Dilja Rose Joseph in this research author, shows that the work optimizes the percentage of fly ash as cement replacement in Ba cillus Subtilis microbial concrete. Strength properties like compressive strength, split tensile strength and flexural strength properties were evaluated.[10] In case of microbial concrete, 28th day compressive strength is 26.64% higher than ordinary M30 concrete. After 56th 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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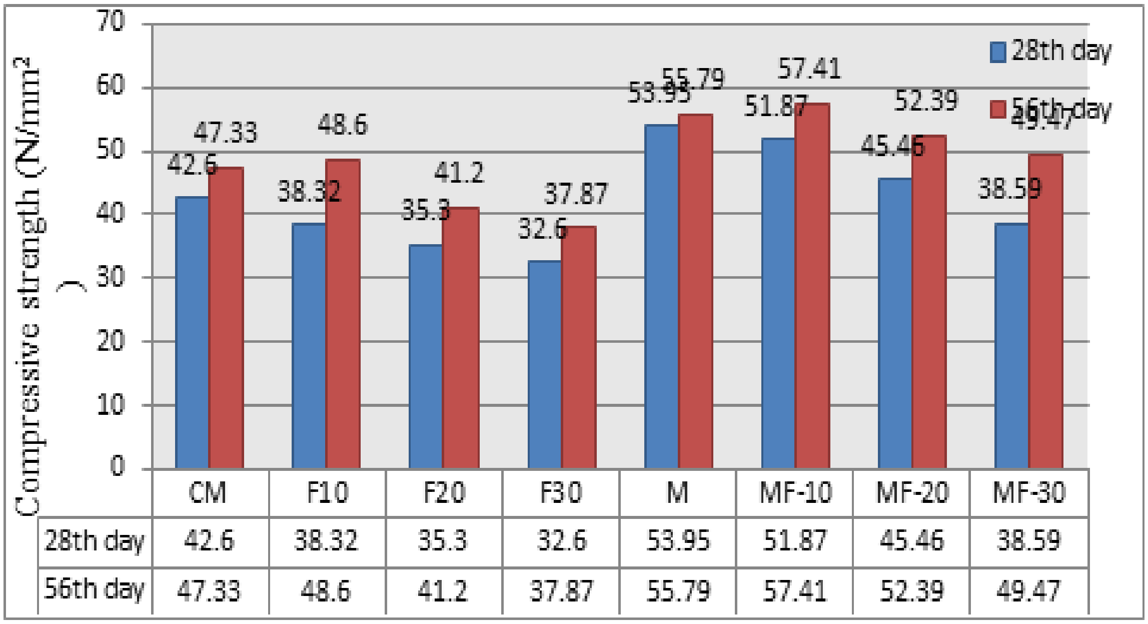

Figure 2.7 28th day and 56th day compressive strength

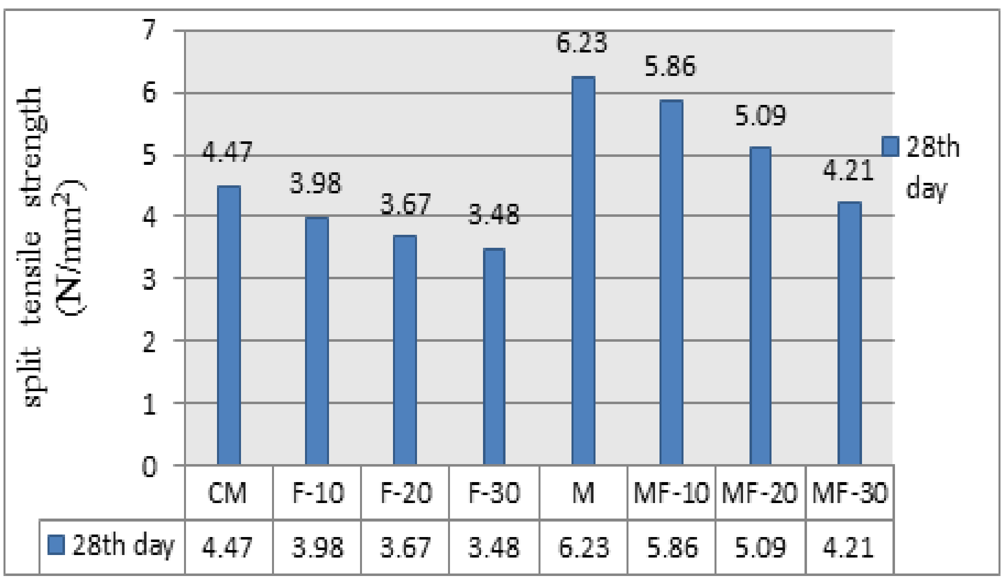

Figure 2.8 28th day split tensile strength

7) Jiaguang Zhang , Yuanzhen Liu, Tao Feng "Immobilizing bacteria in expanded perlite for the crack self-healing in concrete" In this paper authors have discussed about an efficient approach for bacteria-based self-healing concrete to maintain the high-efficiency mineral-forming capacity of incorporated bacteria over a period of time. However, the relatively high-cost, local unavailability, and low adsorption capacity of the current bacteria carriers make them impractical for potential implementation in large-scale concrete structures. In this study, the feasibility of expanded perlite (EP) as a novel bacteria carrier on quantifying cracks-healing in concrete via immobilization of Bacillus cohnii was demonstrated. The effects of two other selfhealing techniques, i.e., direct introdu ction of bacteria and expanded clay (EC) immobilized bacteria, on the efficiency of crack-healing were also investigated. Experimental results showed that specimens incorporated with EP-immobilized bacteria exhibited the most efficient crack-healing after each healing time. The values of completely healed crack widths were up to 0.79 mm after 28 days of healing, which is larger than the value of 0.45 mm for specimens incorporated with EC-immobilized bacteria. Main conclusions can be drawn as follows:

a) EP particles were found to exert a positive effect on the healing capacity of concrete cracks. Specimens incorporated with EP particles for B. cohnii exhibited maximum completely healed crack widths in all samples after each healing time. The values of completely healed crack widths after 28 days of healing were up to 0.79 mm, which is larger than the value of 0.45 mm for specimens incorporated with EC particles.

b) Microstructure analysis confirmed that the mineral precipitations on the crack surface were calcite crystals. The crystal morphology was similar to deformed lamellar rhombohedra.

c) Large amounts of cavities with up to 100 mm in size were observed in the EP particles. These cavities could not only prov ide sufficient cover and oxygen to the immobilized bacteria in concrete, but also allow bacteria to contact with sufficient water, once cracks appear in the concrete matrix

d) The characteristics of higher bacteria content, lower incorporated amount and cost-effectiveness make EP particles more available than EC particles as a promising bacteriacarrier material for large-scale concrete structures.

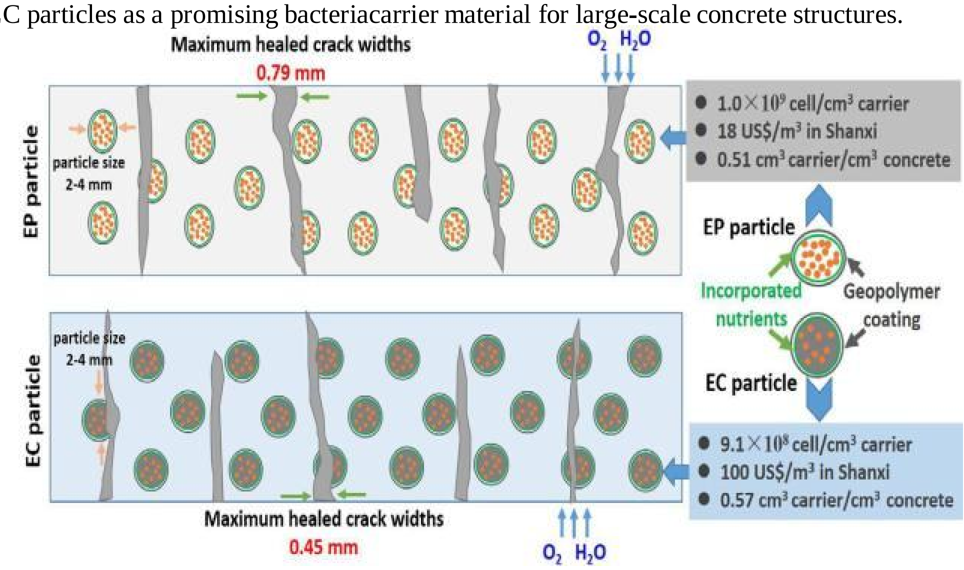

Figure 2.8 Pictorial view of maximum healed crack widths

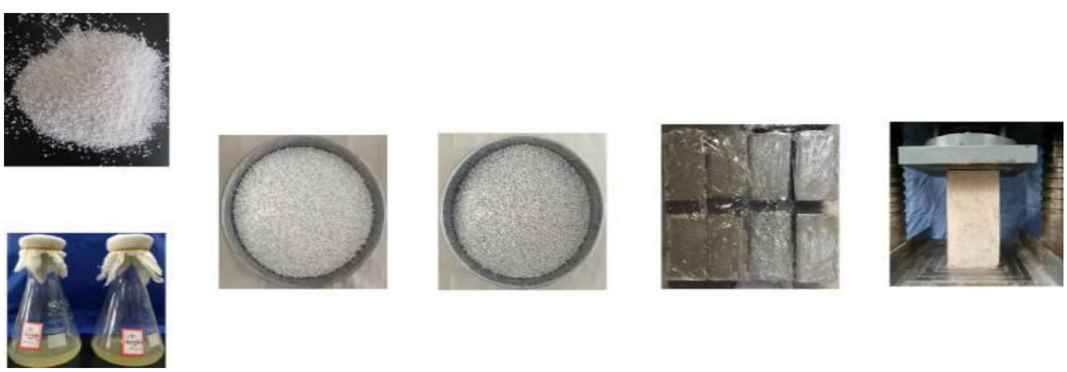

Figure 2.9 Preparation of self-healing concrete specimens via immobilization of B. cohnii spores in EP particles and experimental setup.

III. CONLUSION

A. The compressive strength of the bacterial concrete increased when the addition of the bacillus pasteurii, fly ash, and GGBS.

B. There is decrease in permeability, water absorption.

C. Self-healing technology by using bacteria has proved to be better than many old technologies because this technology has eco-friendly in nature.

D. At 20% replacement of fly ash with cement maximum compressive strength were obtained, while on further increment in reduce.

E. Addition of flyash and GGBS with bacterial concrete has given almost same compressive strength of conventional concrete.

F. Bacillus pasteruii can be produced from laboratory which is proved to be a safe and cost effective.

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