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Study on characteristics of bacterial concrete – A Review

Parkavi S
Department of civil engineering
Bannari Amman institute of technology, Erode, Tamilnadu, India

Sneha K S
Department of civil engineering
Bannari Amman institute of technology, Erode, Tamilnadu, India

Rajendran M
Department of civil engineering
Bannari Amman institute of technology, Erode, Tamilnadu, India

Abstract- This paper covers the use of various bacteria in concrete and how the cracks getting self-healed by using the application of bacteria. In all construction process cracking is the major issue to be resolved as it causes a serious problem which reduces the durability of buildings and it leads to many critical concerns. To resolve those problems the structure needs a periodical maintenance which in turn increases the cost of maintenance. Hence microbial concrete emerged as a solution to heal cracks in a reasonable width. In the presence of any carbonate source, a bacterium belongs to Ureolytic family has a potential to precipitate calcium carbonate ($CaCO_3$). The above process comes under the concept of Bio-mineralization. Due to the calcium carbonate ($CaCO_3$) precipitation the cracks get self-healed and checked for its enhancement in compressive strength as well as the durability of structures. Hence this literature shows the significance of various bacteria in self-healing process of concrete.

Keywords –Ureolytic family, calcium carbonate ($CaCO_3$), compressive strength, durability, self-heal.

I. INTRODUCTION

Concrete is one of the most widely used influential materials in construction. Concrete is weak in tension and it is strong in compression. Because of its fragile properties, it is very common to expect cracks in concrete over time. Once the crack is formed in concrete it reduces the durability and strength of the building by causing reinforcement corrosion, plastic shrinkage, sulphate attack and alkali-aggregate reactions [1].Hence self-healing concrete is the solution by rectifying the foible. This increases the lifetime of concrete. Supplementary cementing materials (SCMs) are also added in concrete mixes which results in increasing workability, strength and enhance durability. One of the common means of achieving environment friendly concrete is by using crushed concrete to produce course aggregate [5]. Now a day microbiology induced calcite precipitation has become an alternative repair technique for plugging into micro cracks and pores in concrete. This technique of bacterial remediation prevails other techniques as it is bio based, eco-friendly, cost effective and durable. Urease positive bacteria have been found to influence precipitation of calcium carbonate (calcite) by production of urease enzyme [7]. The most desirable property of concrete is Compressive Strength. Thus by using this methodology we can ensure better compressive strength and durability. Water cement (w/c) ratio plays a vital role in early achieving of strength in concrete. The concrete mix with low w/c ratio gains strength more rapidly when compare to concrete with low w/c ratio [10]. The strength of concrete decides the durability of structures. Durability of concrete cannot be affected if the crack width is less than 0.2 mm [12]. This paper reviews how the cracks in the concrete getting self-healed by using the various kinds of bacteria which has the ability to precipitate calcium carbonate ($CaCO_3$) at various percentages.

II. SELF-HEALING APPROACH OFBACTERIA

With the help of bacterial reaction, the process of self-healing of cracks or self-filling up of cracks in the concrete after hardening is known as Self-Healing Concrete. Once the bacteria is open to the air so that

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they become active and it causes them to toughen and fuse, filling within the crack that has formed, and stick to the limits of the crack to heal the cracks. The process of healing a crack will take as very little [14]. For rehabilitation of micro-cracks in concrete, Self- healing techniques are good approaches. 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 confirms the precipitation of calcium carbonate. Micro biologically induces calcium carbonate precipitation helps to fill the micro cracks and bind the other materials such as sand, gravel in concrete.

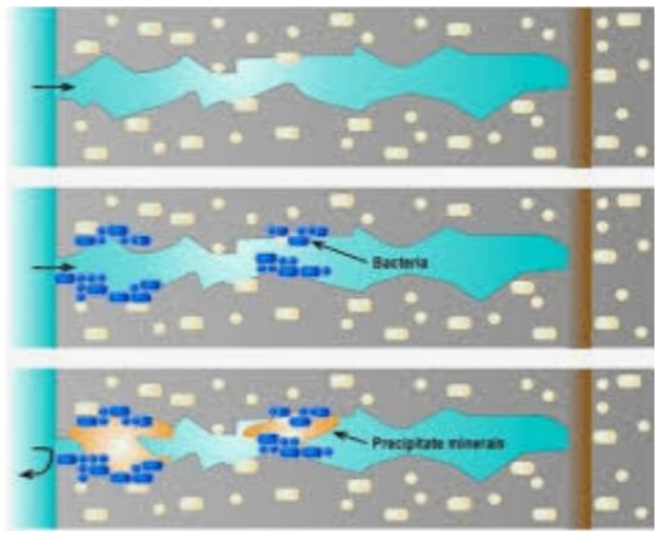

Figure 1. Self healing mechanism in bacterial concrete

Durability of concrete is increased by the involvement of microorganism in calcite precipitation. By converting urea into ammonium and carbonate Bacillus Sphaericus can precipitate CaCO3 in the high alkaline environment Concrete itself can fill the cracks which are less than 0.2mm. But if cracks are greater than 0.2 mm then concrete fail to heal itself which create a passage to deleterious materials. In self-healing concrete, formation of any cracks, leads to activation of bacteria from its stage of hibernation. By the metabolic activities of bacteria, during the process of self- healing, calcium carbonate precipitates into the cracks healing them. Bacteria returns to the stage of hibernation when the cracks are completely filled with calcium carbonate, In future, if any cracks occur, the bacteria get activated and fill the cracks. Bacteria act as a long lasting healing agent and this mechanism of Calcium carbonates formation on bacterial cell wall is called as Microbiologically Induced Calcium Carbonate Precipitation(MICP).

III. INFLUENCE OF BACTERIA IN PROPERTIES OFCONCRETE

A . CompressiveStrength–

Compressive strength is the capacity of a material or structure to withstand axial forces acting on it. The strength of a concrete structures depends on cement, aggregate, bond, water-cement ratio, curing temperature, and age and size of concrete specimen. Concreteisamaterialwithhighcompressivestrength. When the concrete reaches the limit of compressive strength, materials are crushed. Treatment of waste foundry sand with Aspergillus sp. has positive effects on properties of concrete containing waste foundry sand. After 28 days, there is 15.6% increase in compressive strength of concrete having 20% WFS [2]. By using Sulphate Reduction Bacteria in concrete, it was found that there was an increase of compressive strength. The addition of specific bacteria with specific enzyme functions to precipitate calcium carbonate at the pore of the concrete. The process of plugging in the pores at the binder matrix improves compressive strength [8]. The use of Sporosarcinapasteurii bacteria leads to early strength gain and also leads to overall increase in the compressive strength of concrete. The highest gain in compressive strength was obtained when admixture which constitutes of sodium carbonate and calcium chloride was added to the concrete mix [10]. Increase in 26.37% and 19.54% compressive strength of cement mortar having 10% bacterial treated cement kiln dust (CKD) after 28 and 91 days, respectively, was achieved whereas above 10%, decrease in strength was observed thanks to lower cement content, reduced hydration and CSH gel formation [11].Maximum increase in compressive strengths was achieved at 105 cells/ml for all ash concrete; 103 cells/ml shows least compressive strength. With 10%fly ash + 10% silica fume, compressive strength of concrete with103 cells/ml bacterial concentration was 31 and 32 MPa at 28 and91 days respectively [13]. Average compressive strength of concrete-contained bacteria was increased up to 16.2 and 20.8% at the ages of 28 and 270 days, respectively, and 29.3% for sulfate submerged concretes at 270 days. Utilizing bacteria not only produced higher compressive strength but also improved the strength development. Furthermore, relative compressive strength of the sulfate exposed bacteria-containing groups compared to the corresponding water-submerged specimens with an equivalent age was about 12.6% quite that of the control groups at 270 days. Thus, it's concluded that using bacteria in concrete can relatively prevent strength loss of concrete in sulfate exposure. Moreover, compressive strength improvement of concrete by utilizing bacteria was an equivalent (almost equal) in both water and saturated sulfate solution. It may be, thus, concluded that sulfate exposure has no significant effect on bacteria performance [19].

Figure 2. Compressive Strength test

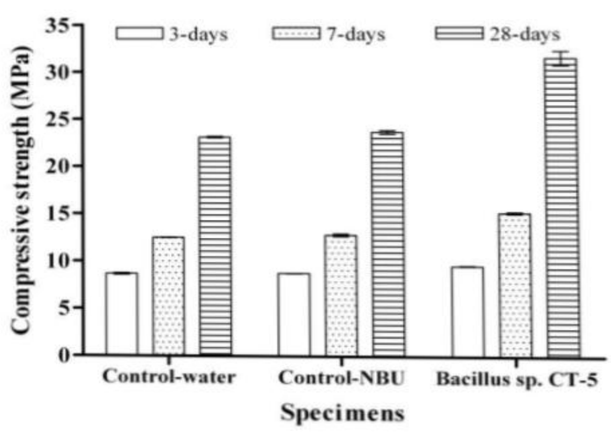

Figure 3. Effect on compressive strength of cement mortar cube at 3 , 7 and 28 days prepared with w/c ratio 0.47.

B. WaterPenetration –

Water absorption and porosity has direct relation with the compressive strength of concrete. Increased water absorption capacity and pore size in concrete results in decrease in compressive strength and the other way around . Control concrete specimen followed an increasing trend of water absorption with increase in CBFD partial replacement percentage for 28 days and 56 days curing. With the addition of bacterial cells, decrease in porosity was observed in concrete specimen at the age of 28 and 56 days. Formation of CaCO3 increases the compressive strength and end in decreased porosity [9]. Bacterial concrete have less percentage of water absorption than bacterial free concrete. The bacterial concrete prepared with 105 cell/ml has less percentage of water absorption after 28 days of curing is 0.576%. Percentage decreases in water absorption of bacterial concrete compared to bacterial free concrete after 28 days of curing are 16.65%,50% and 34.0% respectively for 104, 105, 106 cell concentrations [12]. With the inclusion of bacteria, water absorption ash and silica fume concrete decreased. Bacteria played a big role in decreasing the water absorption of ash concrete which decreased with increase in bacteria cell concentration upto 105 cells/ml, and then, there was reduction within the absorption capacity with 107 cells/ml of bacteria whereas 103 cells/ml was considered as optimum concentration of bacterial dose in decreasing the water absorption [13]. The influence of the surface treatment on the water absorption rate for mortar concrete cubes with a w/c 0.47. Over a period of 168 h, the cubes treated with Bacillus sp. CT-5 has absorbed nearly sixfold less water compare to regulate cubes. The presence of bacteria resulted during a significant decrease of the water uptake compared to untreated specimens. The crack sealing by B. sphaericus resulted during a decrease in water permeability[20].

C . Flexuralstrength–

In M25 grade concrete, with the addition of Bacillus subtilis the share of improvement within the flexural lastingness is within the order of 13.19% to 15.56% at different ages [6]. The cantabro loss i.e abrasion resistance of bacterial concrete mixes is strongly influenced the flexural strength. The flexural strength and cantabro loss are good at 10% of bacteria in bacterial concrete mixes. The flexural strength values are increased and cantabro loss is decreased upto 10% of bacteria in bacterial concrete mixes [14]. The flexural strength of both the traditional and bacterial concrete prepared in two different concentrations. Among the 2 different concentrations of concrete specimen, the upper concentration (150ml) of Bacillus sphaericus (B2) culture proved to extend the strength of prepared bacterial concrete. the many activity of bacterial culture in B1 and B2 concrete specimens, biochemically induced carbonate precipitation between cement sand matrix, which successively increasedthe load resisting capacity [15].

Figure 4. Flexural Strength test

Figure 5. Effect on f strength of cement mortar cube at 3 , 7 and 28 days prepared with w/c ratio 0.47.

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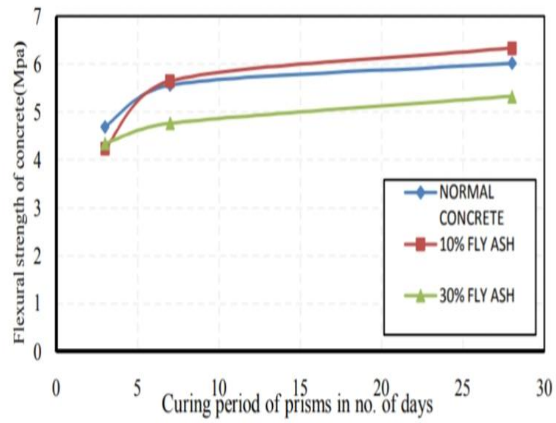

Figure 5. Effect on f strength of cement mortar cube at 3 , 7 and 28 days prepared with w/c ratio 0.47.

D.XRDanalysis–

X-ray diffraction is that the non-destructive technique (NDT) wont to determine the crystalline phases present in any particular substance. X-ray powder diffraction technique is proved to be the foremost prominent technique used for unravelling the structure of the materials in bulk and thin film forms. Concrete samples of every mix (after 28 days curing) were taken and crushed into fine powder by pestle–mortar. The powder samples were analysed during a powder X-ray diffractometer (PANalytical X' Pro). The XRD spectrums were taken from 2h = 10h to 2h = 80h. The peaks within the new positions of the spectrum were marked, compared and identified from the JCPDS file . XRD analysis of concrete samples with or without fungal treated waste foundry sand shows some extra peaks of calcium silicate absorption (68.8%) and porosity (45.9%) of treated concrete. XRD reveals the fungal culture (Aspergillus spp.) is capable to make good C–S–H gel than untreated concrete containing WFS [2]. It suggests that the bacterium is capable of formation new silicate phase within the concrete matrix. The microstructure in homogeneities can cause serious effects on strength and other related mechanical properties because these properties are controlled by the micro structural extremes [13].

E.SEManalysis–

Scanning microscopy (SEM) may be a test process that scans a sample with an beam rather than light to supply a magnified image for analysis. it's also referred to as SEM analysis and SEM microscopy, and is employed effectively in microanalysis and failure analysis of solid inorganic materials. microscopy is performed at high magnifications, generates high-resolution images and precisely measures very small features and objects [4]. The scanning microscope (SEM) analysis of control and bacterial concrete containing 0%, 10%, 20% and 30% CBFD (cement baghouse filter dust). SEM images show the formation of calcium silicate hydrate in concrete specimen. Micro-porous zones within the cement paste, pores or bubbles plugs the pores or voids thereby increasing the strength [9]. SEM was utilized in the emissive mode, which is that the common mode of study . Samples utilized in SEM analysis were gold coated with a sputter coating Emitech K575 before examination. Presence of high amounts of calcium within the samples confirmed the presence of calcite within the sort of carbonate [13]. Distinct crystals embedded in concrete are observed in SEM micrographs of the concrete containing 6×109 cells/mL of S. pasteurii which have completely filled most the pores [19].

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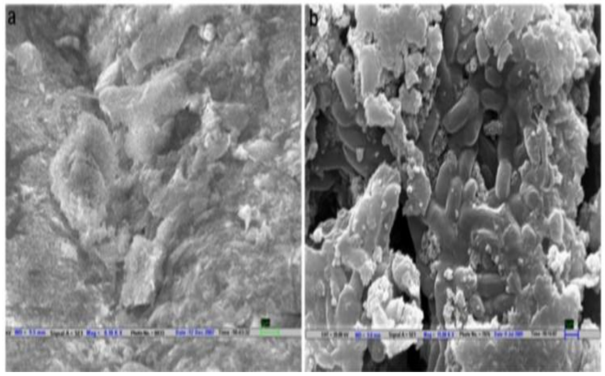

Figure 6. SEM analysis of cement mortar specimen

IV.CONCLUSION

This paper reviews the varied sorts of ureolytic bacterium like Bacillus subtilis , Bacillus plasturii, Bacillus pseudifirmus, Bacillus sphaericus wont to remediate the cracks of structures by its self-healing approach. The advantage of using bacteria decreases water penetration and chloride ion permeability. Bacillus Subtilus are often produced from the lab which is proved to be safe and price economic. It states that the bacterial approach has potential to contribute to self-healing capacity of concrete. The utilization of this biological repair technique is very advantageous because the mineral precipitation induced features a results of microbial activities is pollution free and natural, however further experiments has got to be conducted to look at the sturdiness of this crack technique. This study features a lso identified that bacteria has a positive effect on the compressive strength of hydraulic cement mortar cubes and concrete.

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