AN OVERVIEW OF VIABLE USE OF BACTERIAL CONCRETE FOR CRACK HEALING

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ABSTRACT

It is very common for concrete to develop cracks. There are many causes for crack development in concrete. Some of the major causes are, temperature variations, chemical reactions, weathering, shrinkage, error in design/construction, etc. Cracks in concrete will deteriorate the strength of the structure. Use of bacterial concrete is one of the eco friendly techniques for crack healing. This technique uses the calcium precipitate produced by bacterial metabolic activities to heal cracks. Bacterial concrete shows greater strength and durability than normal concrete. This paper presents a review of recent works done in bacterial concrete and the process involved in crack healing. An exhaustive literature study about the experimental studies on strength and durability properties of bacterial concrete is also presented here. From the existing works it is found that bacterial concentration of 10^5 cells/ml is identified as optimum concentration. Use of wheat bran is found as an alternative substrate to bacterial growth to minimize the cost.

Key words: crack healing, Bacterial concrete, strength, durability, optimum concentration.

INTRODUCTION

Concrete is the mostly used construction material. Many researches have been done over the year to make concrete strong, durable and eco-friendly. Crack in concrete is one of the major issues which affect the strength of the structure. Many traditional methods are in use for crack repair like impregnation of cracks with epoxy based fillers, latex binding agents such as acrylic, polyvinyl acetate, butadiene styrene, etc. But, they are not compatible, costly, reduce aesthetic appearance and need constant maintenance. Thus the need for an eco-friendly remediation leads to the concept of bacterial concrete.

BACTERIAL CONCRETE

Bacteria are small single-celled organisms. Bacteria are found almost everywhere on Earth and are vital to the planet's ecosystems. Some species of bacteria can live under extreme conditions of temperature and pressure. The first patented research on protection of ornamental stone by calcite precipitate of bacteria opens the gate for bacteria in construction material. Following this many researches were done using bacteria in concrete like crack healing, antifungal mortar, alternative surface treatment for concrete, etc.,

Bacterial concrete use the calcium carbonate produced by bacteria to heal cracking. The bacteria’s injected in the concrete are in an inactive condition. When cracks are formed in concrete moisture and air activates the bacteria. The metabolic activity of these active bacteria continuously produces calcium carbonate. This process of calcium carbonate production is called Microbiologically Induced Calcite Precipitation (MICP) technique. This precipitate fill the cracks and voids and improves the strength.

The chemical reaction involving the calcium

$$Ca^{2+} + Cell \rightarrow Cell\text{-}Ca^{2+} \; . \; . \; . \; . \; (1)$$

$$Cell\text{-}Ca^{2+} + CO_3^{2-} \rightarrow Cell\text{-}CaCO_3\downarrow \; . \; . \; . \; (2)$$

In equation (1) the negatively charged bacterial cell wall attracts the positively charged Ca^{2+} to deposit on the cell wall. In equation (2) the Ca^{2+} ion then react with the Co_3^{2-} ion and finally it leads to the precipitation of $CaCO_3$ at the cell surface.

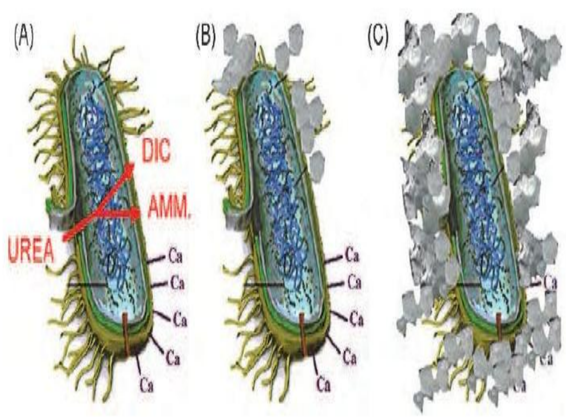


Fig 1: Illustration of calcium Carbonate precipitation mechanism induced by urease enzyme[1] activity in microorganism (A) Ca ions attracted to bacterial cell. Urea is added, dissolved carbon (DIC) and Ammonia (AMM) are released into environment. (B) The whole cell is encapsulated; (C) Calcium Carbonate precipitation ensues.

REVIEW OF LITERATURE

Many researchers carried out works to find the potential use of bacterial concrete as a sustainable solution for crack healing in concrete. An exhaustive survey of the major works had been carried out and

carbonate precipitate is shown below[13]

the major findings of various researchers across the globe is presented herewith.

Ramachandran et al[2, 3, and 4]studied the effectiveness of using *Bacillus pasteurii* and *Escheria coli* for repairing cracks in concrete. Polyurethanes (PU) was used as a vehicle for immobilization of enzymes and whole cells. SEM and XRD analysis proves the presence of calcium carbonate precipitate. The process of calcium carbonate precipitation was also discussed. Studies on the effects of Bacillius pasteurii bacteria on compressive strength of mortar cubes at 7 and 28 days and found to be increased. The shrinkage, resistance to alkalinity and sulphate attack also proves the durability of bacterial concrete

S. Krishnapriya et.al [6] had attempted to make a comparative study on the performance of new 3 indigenous bacterial species with B. megaterium MTCC 1684 as reference. The indigenous species are B. megaterium BSKAU, B. licheniformisBSKNAU and B. flexusBSKNAU. The authors had used the wheat bran as an alternative substrate for bacterial growth to minimize the cost. The concrete specimen of grade M25 with different bacterial species were tested for compressive strength. The bacterial concrete specimen with all the 3 strains of bacteria and the reference bacteria showed a greater compressive strength than control specimen. The study on crack healing using SEM analysis showed that the concrete specimen with B. megaterium BSKAU, B. licheniformis BSKNAU and B. megaterium MTCC 1684 has complete healing while B. flexus BSKNAU showed only partial healing. Thus the species other than B. flexus BSKNAU were preferred.

Table 1: Compressive strength values of concrete mixtures as given by S. krishnapriya et.al [6] [Values are mean ± standard deviation].

Bacteria	Bacterial calls/ml of mixing water	Concrete mixture	Compressive strength at 28days in Mpa
No Bacterial cells	0	M1(control)	33.00 ± 0.33
	10^5	M2	37.00 ± 1.06
	10^5	M3	36.50 ± 0.44
Live Cells	10^5	M4	35.00 ± 0.19
	10^5	M5	38.30 ± 0.53

Navneet Chahal et.al [7] This study shows the performance of Sporoscarcinapasteurii bacteria on fly ash concrete. In this work the cement was partially replaced with 10, 20 and 30 percentage of fly ash. Different concentrations (0, 10^3,10^5,10^7 cells/ml) of bacteria were used in the concrete. The compressive strength test shows 22% increase in compressive strength for 10^5 concentration. Water absorption reduced four times. Chloride permeability reduced nearly eight times. Thus it makes the concrete more durable. Long term properties had to be studied.

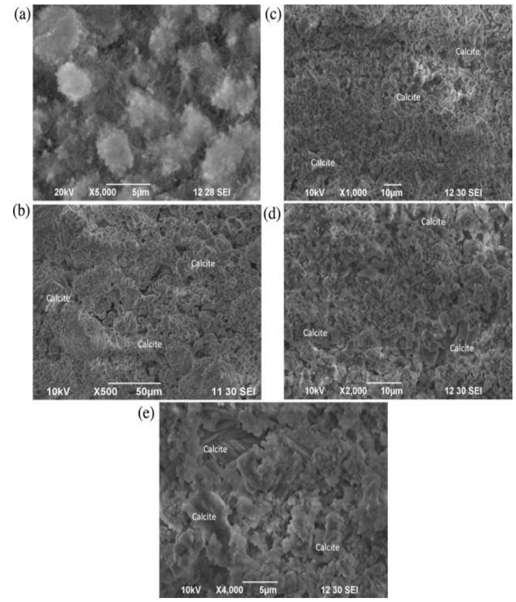


Fig. 2. Scanning electron micrographs of (a) control concrete specimen with no calcite crystals, (b) concrete specimen with *Bacillus megaterium* BSKAU indicating the presence of calcite crystals, (c) concrete specimen with *Bacillus licheniformis* BSKNAU indicating the presence of calcite crystals, (d) concrete specimen with *Bacillus flexus* BSKNAU indicating the presence of calcite crystals and (e) concrete specimen with *Bacillus megaterium* MTCC 1684 indicating the presence of calcite crystals. [6]

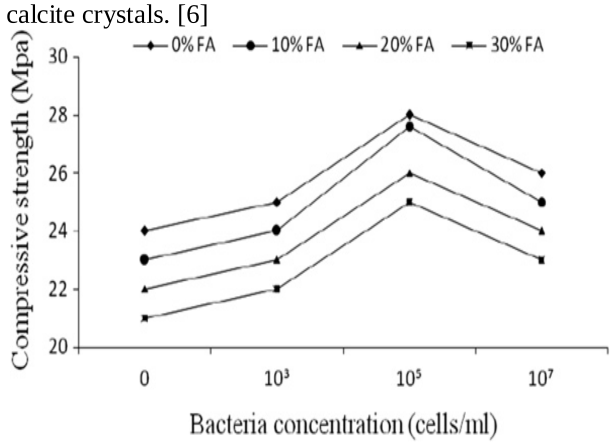
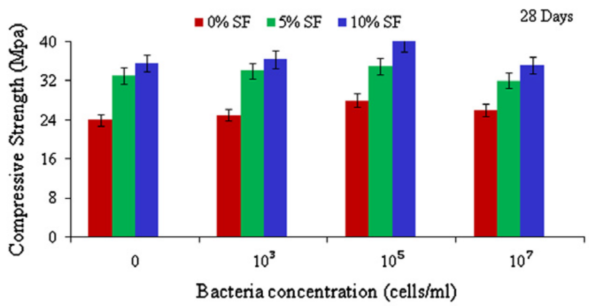
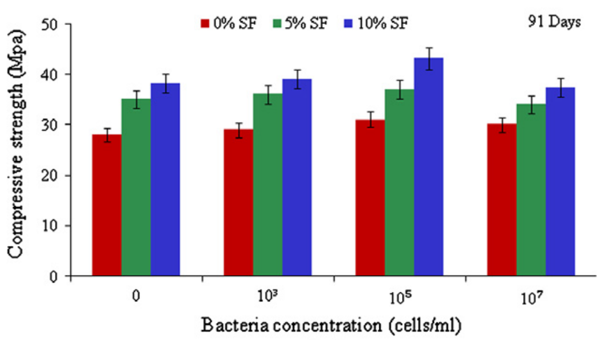


Fig. 3. Effect of bacteria (Sporoscarcinapasteurii) on compressive strength of fly ash concrete at 28 days, as given by Navneet Chahal et.al. [7]

Navneet Chahal et.al [8] In this study Sporoscarcinapasteurii bacteria at various concentration levels (0, 10^3,10^5,10^7 cells/ml) were used in the concrete. In this study cement was replaced with 5% and 10% of silica fume by weight. A study on compressive strength, water absorption and chloride permeability of concrete containing bacteria was performed. The maximum compressive strength was observed for concentration 10^5 with



(a)



(b)

Fig. 4. Effect of bacteria (Sporosarcinapasteurii) on compressive strength of silica
Fume concrete at (a)28 days (b) and 91 days [8]

Table 2: Average compressive strength of concrete at a)7 days b) 28 days [9].

CONCLUSION:

- Bacterial concrete is observed as a better

Sl. No	Cell Concentrations per ml of mixing Water	Average Compressive Strength of Cubes (N/mm^2)	
		7Days	28Days
0	0	17.4	28.3
1	10^3	18.1	29.7

10% silica fume. Compressive strength was 38.2MPa and 44MPa at 28 and 91 days respectively. Water absorption and chloride penetration also reduced more for the concentration 10^5 with 10% silica fume. The calcium carbonate presence was confirmed using SEM, XRD and EXD.

Smitha. M et.al [9] in this paper the compressive strength and durability (water absorption) of different concrete with concentrations (10^4, $10^5$and 10^6cells/ml) of bacterial were compared with control specimen of M25 grade concrete to identify the optimum concentration. The bacteria used was Bacillus megaterium. Here the fine aggregate was fully replaced with M-sand. The optimum concentration of bacteria that gives more strength and durability was found as 10^5cells/ml than other concentrations made in the study. Compressive strength was increased by 11.30% and 22.58% for 7 days and 28 days. Water absorption decreased 50% than control mix after 28 days of curing for optimum mix.

Table 3: Average water absorption of concrete at 28 days [9]

Sl. No	Cell Concentrations (Cells/ml)	Water absorption (%)
1	0	1.153
2	10^4	0.961
3	10^5	0.576
4	10^6	0.76

method for crack repair than conventional method.

2	10^4	21.33	31.5
3	10^5	19.77	30.1

- Presence of bacteria in concrete significantly affects its strength durability. Many researchers have found that bacterial concentration of 10^5 shows as optimum results.
- Further studies are required for improvement of properties of bacterial concrete and to make it more convenient for practice.
- More work has to be carried out on use of bacteria in concrete to make this technique a cost effective one.

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