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EFFECT OF BACILLUS TYPE OF BACTERIA MIXED WITH ENNORE SAND ON STRENGTHENING OF CRACKED CONCRETE

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Abstract: Cracks are the common type of failure in concrete which are irreversible in process [1, 2] Bacillus Pasteruii, Bacillus Cohni, Bacillus Sphearicus are common soil bacterium induce the precipitation of calcite exhibited its positive potential in selectively consolidating simulated fractures in the consolidation of sand.[1, 3, 4, 5] In this study cracks of concrete were filled with different types of Bacillus bacteria mixed with Ennore Sand to repair cracks. A compression, flexural and durability tested on mortar cubes and concrete beams treated with bacteria were studied. The effect of different depth of crack on the compression, flexural and durability of concrete was studied. It was found that all the increase in depth of crack reduce the strength of cubes and beams.

Keywords: Bacterial Concrete, Self-Healing, Cracks, Concrete, Repair, Ennore Sand

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INTRODUCTION

In concrete, cracking is a regular observable fact due to the comparatively low tensile strength. Many factors are affecting the durability and strength of concrete. High tensile stresses can result from external loads which lead to failure of concrete. Many methods and material are available in market to repair concrete cracks. But most of materials are not eco-friendly and cause environment pollution and due to these many are banned in many countries. Bacterial induced calcium precipitation type repairing technique is eco-friendly and has been proposed as an alternative and environmental friendly crack repair technique. B. pasteurii produces urease, which catalyzes urea to produce CO_2 and ammonia, resulting in an increase of pH in the surroundings where ions Ca_2^+ and CO_3^{2-} precipitate as $CaCO_3$. Possible biochemical reactions in medium to precipitate $CaCO_3$ at the cell surface that provides a nucleation site. The microbial urease catalyzes the hydrolysis of urea into ammonium and carbonate.[9] One mole of urea is hydrolyzed intracellularly to 1 mol of ammonia and 1 mole of Carbamic acid (1), which spontaneously hydrolyzes to form an additional 1 mole of ammonia and carbonic acid (2).[3, 4, 5, 6, 7, 8, 9, 10]

$$CO(NH_2)^2 + H_2O \text{ ---> } NH_2COOH + NH_3 \quad (1)$$

$$NH_2COOH + H_2O \text{ ---> } NH_3 + H_2CO_3 \quad (2)$$

Ammonium and carbonic acid form bicarbonate and 2 moles of ammonium and hydroxide ions in water (3 &4).

$$2NH_3 + 2H_2O \text{ <---> } 2NH^{+4} + 2OH^- \quad (3)$$

$$H_2CO_3 \text{ <---> } HCO^{-3} + H^+ \quad (4)$$

The production of hydroxide ions results in the increase of pH, which in turn can shift the bicarbonate equilibrium, resulting in the formation of carbonate ions (5)

$$HCO^{-3} + H^+ + 2NH^{+4} + 2OH^- \text{ <---> } CO_3^{-2} + 2NH^{+4} + 2H_2O \quad (5)$$

The produced carbonate ions precipitate in the presence of calcium ions as calcium carbonate crystals (6).

$$Ca^{+2} + CO_3^{-2} \text{ <---> } CaCO_3 \quad (6)$$

The formation of a monolayer of calcite further increases the affinity of the bacteria to the soil surface, resulting in the production of multiple layers of calcite.

Bacteria such as Bacillus pasteurii, Bacillus pseudofirmus, Bacillus cohnii, Sporosarcina pasteuri, and Arthrobacter crystallopoietes increase the compression strength of concrete through their biomass. Not all bacteria increase the strength of concrete significantly with their biomass[11].

Bacillus sp. CT-5. can reduce corrosion of reinforcement in reinforced concrete by up to four times. Sporosarcina pasteurii reduces water and chloride permeability. B. pasteurii increases resistance to acid [11].146 Bacillus pasteurii and B. sphaericuscan induce calcium carbonate precipitation in the surface of cracks, adding compression strength.[11]

MATERIALS AND EXPERIMENTAL PROGRAM

For casting of Mortar and Concrete beams for test OPC cement grade 53, Potable water, Ennore Sand, Coarse aggregates and Bacillus type of Bacteria (Bacillus Pastuerii, Bacillus Cohni and Bacillus Sphearicus) were used. Following test was conducted with procedure to measure the effect of Bacteria on strengthening of concrete cracks repairing.

Fig. 1(a) Insertion of Bacterial paste into crack (b) Feeding Bacteria with Urathine-P

A. Compression Test

Mortar cubes were made by using ordinary Portland cement 53 Grade. Cement and Ennore Sand ratio is used as 1:3 (by weight). Moulds with dimensions of 70.6 mm× 70.6 mm× 70.6 mm. After casting, all moulds were placed in a normal temperature of room with a relative humidity of more than 90% for a period of 24h. After de-moulding, the specimens were placed for the curing for 28 days. After that for 28 days different bacteria inserted in crack mixed with standard sand and after that bacteria's were feed at every 6 hours interval. And After it Compression test carried out at 7th, 28th and 56th day.

B. Flexural strength study

Concrete Beams grade M20 were made by using ordinary Portland cement. Moulds with dimensions of 500 mm× 100 mm× 100 mm. After casting, all moulds were placed in a normal temperature of room with a relative humidity of more than 90% for a period of 24h. After de-moulding, the specimens were placed for the curing for 28 days. After that for 28 days different bacteria inserted in crack mixed with standard sand and after that bacteria's were feed at every 6 hours interval. And After it Flexural test carried out at 28th and 56th day.

Figure -2 Flexural Test setup

Test result and Discussion

The effects of the following parameters on the compression, flexural and durability of concrete were investigated:

- Depth of crack
- Number of days from healing of crack

Result of Compression and Flexural tests are shown in table – 1 & 2 respectively.

Table – 1 Average Compressive strength after 28 days of filling bacteria

Crack Depth	Normal Cube(Without Crack & Bacteria) (N/mm^2)	Cracked Cube (N/mm^2)	Cracked cube repair with Bacillus Pastuerii (N/mm^2)	Cracked cube repair with Bacillus Sphearicus (N/mm^2)	Cracked cube repair with Bacillus Cohni (N/mm^2)
5 mm	27.33	25.48	26.37	25.90	26.52
10 mm		23.68	25.72	25.68	25.70
15 mm		22.86	25.34	25.23	25.32
20 mm		21.09	23.83	23.62	21.84
25 mm		19.69	22.70	21.89	21.85

Table – 2 Average Flexural Strength after 28 days of filling Bacteria

Crack Depth	Normal Cube(Without Crack & Bacteria) (N/mm^2)	Cracked Cube (N/mm^2)	Cracked cube repair with Bacillus Pastuerii (N/mm^2)	Cracked cube repair with Bacillus Sphearicus (N/mm^2)	Cracked cube repair with Bacillus Cohni (N/mm^2)
5 mm	6.79	6.28	6.59	6.56	6.54
10 mm		6.13	6.51	6.46	6.39
15 mm		5.94	6.45	6.40	6.37
20 mm		5.77	6.37	6.32	6.28
25 mm		5.58	6.46	6.23	6.22

All the test results were compared with that of the uncracked and cracked concrete and mortar. It was found that all the specimens effectively healed which had less depth of crack.

CONCLUSIONS

• From the test results of Compression test and Flexural test, we can conclude that repaired cracked concrete with Bacillus type bacteria can be re-strengthen up to almost its original strength in case of smaller depth cracks. But in case of larger depth than 15 mm improvement in compressive strength reduces as the depth of crack increases. Because for calcite precipitation process Bacillus type bacteria needs more oxygen. Due to larger depth Bacteria didn't get enough amount of Oxygen from atmosphere.

• The use of this biological repair technique is highly desirable because the mineral precipitation induced as a result of microbial activities is pollution free and natural.

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