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Effect of Bacillus subtilis on abrasion resistance of Bacterial Concrete

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Abstract:

In the recent past bacterial concrete has been emerged as remedial measure of healing cracks in structures like bridges, RCC Buildings, RCC Pipes, Canal Lining, Pavement etc.Crack formation is incredibly common occurrence in concrete structure that permits the water and completely different sort of chemical into the concrete through the cracks and reduces their strength and that additionally have an effect on the reinforcement once it comes contact with water, carbon dioxide and different chemicals. For repairing the cracks occurred within the concrete, it needs regular maintenance and special sort of treatment which can be terribly expensive. In bacterial concrete, particular types of microorganisms can really be useful to repair cracks in the existing concrete structures. This is a new technique adopted in the formation of concrete by utilizing microbiologically induced calcite ($CaCO_3$) precipitation. In this paper, an experimental investigation done to arresting the cracks in the concrete using Bacillus subtilis bacteria and calcium lactate.In this study Bacillus subtilis bacteria with calcite lactate is used in different percentages such as 5%, 10%and 15% of cement weight for M40 grade concrete.The abrasion resistance was measured in terms of cantabro loss for all mixes at the ages of 3,7,28 days of curing. Investigation results have shown that the cantabro loss decreases as flexural strength increases.

Keywords*:* Bacterial Concrete, Cantabro loss, Flexural strength, Bacillus Subtilis.

INTRODUCTION

Concrete has become an essential building material in the current modern era of infrastructural projects across the world. As this material is prone to crack inferable from its brittle and less resistant to straining demands the uutilization of steel reinforcement or rebar in it. Since its bond with steel bars, concrete becomes most effective in resisting tension than when it does not contain any reinforcement, and the tensile strength of concrete is lesser than compressive strength. [1]. Bacterial concrete normally seeks to repair these flaws, so as to increase the service lifetime of any concrete structure. There's a material inside the realm of self-healing concrete in development, now, which will solve several of the issues usually related to ordinary concrete. Bacillus subtilis bacteria, calcium lactate and nutrient broth mixed with concrete [2]. This paper also will make a case for, in-depth, the method that extent part behind microorganism self-healing in concrete and can describe the various parts that extent part bounded within the process then they work severally and put together. This paper also will turn over into sensible applications of this self-healing technique, and additionally real-world integrations in presently standing structures.

THE BIOLOGICAL SELF-HEALING PROCESS:

Once the bacteria is open to the air and therefore the “food,” the microorganism stand an action that causes them to toughen and fuse, filling within the crack that has formed, and stick to to the limits of the crack to heal the cracks. The method of healing a crack will take as very little [3].

Concrete constructions are presently designed in keeping with set standards that enable cracks to create up to 2mm wide. Such small cracks are usually thought-about acceptable. Whereas remedial of 0.2mm [4, 5] cracks occurred in the conventional samples. The fundamental idea behind our specific version of self-healing concrete is utilizing sure kinds of bacteria (in this case Bacillus subtilis) then they operate to heal small cracks inside the concrete before they grow into bigger and more durable to manage cracks. This bio calcification method involves many parts, to complete these tasks [6-7]. Trendy techniques like X-ray diffraction tests and SEM analysis are used to quantify the stages of spar deposition on the surface and in cracks [8-9].

When the bacteria is mixed with concrete, the bacteria undergo inactive state. When it is exposed towards environment (air), then all their functions are stimulated. Whenever the crack occurred inside the concrete, the bacteria starts biological process and forms calcite at the crack [10]. When the bacillus subtilis interaction with calcium lactate and water, the bacteria spores start germinating. The bacterial starts feed on the calcium lactate. These pores are available in concrete up to 200 years [11]. As the microscopic organisms sustains oxygen, the calcium lactate is change over to limestone, which fills the cracks arisen in concrete [12].

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O \quad (1)$$

$$CaC_6H_{10}O_6 + 6O_2 \rightarrow CaCO_3 + 5CO_2 + 5H_2O \quad (2)$$

MATERIALS AND METHODS

Cement:

Ordinary Portland 53 grade cement used in the experimental investigation.

Table 1. Physical properties of Portland cement (53 grade)

S. No.	Test Property	Result	Requirements as per IS 12269-1987
1	Fineness (a) Sieve test (b) Blaine	 2% 285m^2/kg	 Not more than 10% Min 225 m^2/kg
2	Normal Consistency	31.0%	-
3	Specific Gravity	3.01	-
4	Initial setting time	95minutes	> 30 minutes
5	Final setting time	284minutes	> 600 minutes
6	Compressive strength (a) 3days (b) 7days (c) 28days	28N/mm^2 41 N/mm^2 56N/mm^2	27 N/mm^2(Min) 37 N/mm^2(Min) 53 N/mm^2(Min)
7	Soundness (Le-Chatlier Exp.)	2mm	Not more than 10mm

Fine Aggregate:

Local available river sand used as fine aggregates in this work.

Coarse Aggregate:

Coarse aggregate from nearby crusher was collected. The aggregate sizes are 20, 12 and 6 mm

Water:

Locally available potable drinking water used in the experimental work for all mixes.

Bacteria:

In this research, Bacillus subtilis bacteria used which is cultured at DVS Bio life Pvt Ltd Laboratory, Hyderabad, India.

Calcium lactate:

Calcium lactate ($C_6H_{10}CaO_6$) used for this experimental work along with Bacillus subtilis bacteria as nutrient broth. It is available in powder form having white colour.

Culturing of Bacillus Subtilis:

Primarily preparation of Nutrient Broth (media) was done by adding 2.5 grams of Peptone, 1.5 grams of Beef extract and 2.5 grams of Sodium Chloride (NaCl) to a 500 ml of distilled water in a conical flask. Conical flask was covered with a cotton plug and was enclosed with silver foil.

Figure 1. Making the Solution of Nutrient Broth

This Solution was sterilized using an autoclave for about 20 minutes at a constant temperature of 121°C and pressure of 15 lbs. In autoclave, water should be filled up to level 1. After sterilization, the solution was contaminant free and it was in clear orange colour.

Figure 2. Contaminant Free Solution after the Sterilization Process

Later, the flask will be opened in lamina air flow chamber and a small pinch of the bacteria was added to the solution as shown in fig.

Figure 3. Adding the Bacillus Subtilis to the Nutrient Broth Medium in Aseptic Room Under the Laminar Air Flow Equipment

Then it was incubated in an orbital shaker with a speed of 125 rpm at 37°C.After 24 hours, it was observed that the colour of bacterial solution changed to whitish yellow turbid as shown in fig which indicates the growth of bacillus Subtilis.

Mix Design:

The mix proportions for M40 grade concrete are designed using IS: 10262-2009. Materials required per one m^3 of concrete is shown in Table 2.

Table 2. Concrete mix proportions per one cubic metre

Mixture No	BC00	BC05	BC10	BC15
Cement(kg/m^3)	390	390	390	390
River Sand(kg/^{3})	642	642	642	642
Crushed Rock Sand(kg/m^3)	--	--	--	--
Coarse Aggregate (kg/m^3)	1261	1261	1261	1261
w/c ratio	0.45	0.45	0.45	0.45
Bacterial Cells (cfu/ml)	10^5	10^5	10^5	10^5
Percent of bacterial solution	00	05	10	15

Flexural strength Test:

Flexural strength of concrete test was on 100 mm x 100 mm x 500 mm. all the specimens casting was done according to IS: 516-1959 specifications.

Cantabro Abrasion Test:

This test was conducted with a Los Angeles abrasion testing machine by without placing abrasive charges in the form of steel balls in accordance with ASTM C 1747. The three cylindrical specimens of size 150 mm diameter and 100 mm height were placed in machine shown in Figs. 4. Note the Initial weight of each specimen (w1) before placing into the machine. Then this machine was allowed to rotate at various revolution levels such as 50, 100, 150, 200, 250 and 300 revolutions. At each level of revolution the abraded specimens were cleaned from any loose debris and weighed accurately to measure w2. Finally the percentage loss was calculated using the following equation:

$$\text{Cantabro Loss, \%} = \frac{w1}{w2} \text{x100}$$

where w_1 = Initial weight of the test specimen, w_2 = Final weight of the test specimen.

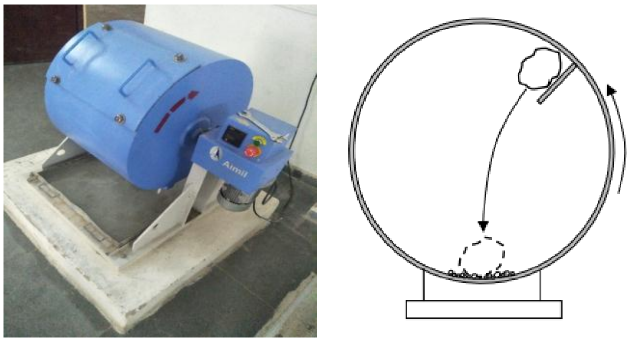

Figure 4. Illustration of cantabro loss test

Figure 5. Preparation of samples for cantabro test

RESULTS AND DISCUSSIONS

Table 3. Average cantabro loss of bacterial concrete

Percentage of bacteria in concrete	Cantabro loss @ 3 days (%)	Cantabro loss @ 7days (%)	Cantabro loss @ 14 days (%)	Cantabro loss @28 days (%)
0	13.24	12.87	12.11	11.36
5	14.92	12.22	11.56	9.86
10	10.11	9.23	8.15	7.45
15	15.23	14.88	12.35	11.58

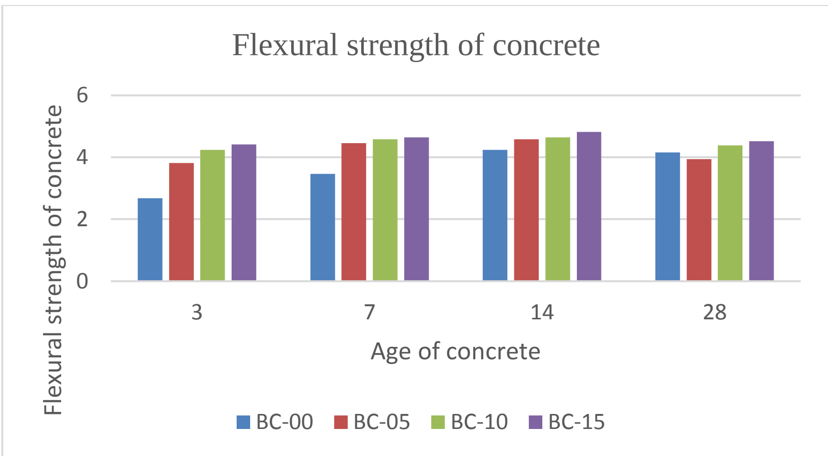

Figure 6. Flexural strength of bacterial concrete

Figure 7. Shape of specimen used in cantabro test at before 50 rev and after 300 rev

CONCLUSION

From the experimental work carried out on bacterial concrete mixes, following conclusions were drawn:

i. The cantbro loss i.e abrasion resistance of bacterial concrete mixes is strongly influenced the flexural strength

ii. The flexural strength and cantabro loss are good at 10% of bacteria in bacterial concrete mixes

iii. The flexural strength values are increased and cantabro loss isa decreased upto 10% of bacteria in bacterial concrete mixes

iv. The addition of bacteria in concrete has significantly omproved the cantabro loss and flexural strength at all ages.

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