Study on Strength of Self Healing Concrete

P. Bala Gopi Krishna, Nayeem Mujeeb, K. Naga Chaitanya

Abstract---Concrete is fundamental material in construction and cracking is a common phenomenon developed due to its relatively low tensile strength. The repairing of the concrete is immediately required to attain its serviceability and also to avoid corrosion of reinforcement so that the cracks don't further expand. For repairing of cracks there will be higher cost expenditure which is uneconomical in many cases and is disadvantageous as there can be unexpected thermal expansions and other health hazards due to chemicals used in the repairing purpose. So in-order to avoid these health hazards and the high cost expenditure an environmental-friendly repair technique is developed using bacteria in this paper.

Index Terms: Bacteria, Concrete, Cracking, Environmental friendly, Low tensile strength, Low cost, Repairing,, Repairing techniques,

I. INTRODUCTION

Concrete is a strong, versatile, durable and locally available material. At early ages of life before the invention of cement, lime was used as a binding material in construction of structures. The modern civilization of construction uses concrete for almost all structures.If concrete cannot withstand loads which are higher than its design loads then there are chances of cracking and structure failure.And hence arises their problems like cracking, bending, wear & tear and the structure may even collapse. Commonly, the concrete fails due to either extreme unexpected loading conditions or due to unexpected rapid weathering.A set of skilled labour is required for repairing various cracks and other structure failure which is uneconomical.Hence there is a true need of self-healing technique of the concrete.This self-healing technique will neither require skilled labour for repairing purposes nor require periodic observation of the structure for cracks. The bacteria "Bacillus pseudofirmus" tends to be dormant in concrete for over 200 years and helps breakdown calcium lactate to form limestone and thereby healing the crack and regaining partial strength overtime.

The real need for self- healing concrete arises because many structures which are inaccessible for repair purpose causes trouble if there arises some problem like cracks or deflection, let us take an example of a simple long span bridge, as time passes and due to wear and tear there is a chance that cracks may appear which is mandatory to be repaired, so for the repairing purposes a set of skilled labour is required and a lot of time and energy expenditure may occur in order to bring back the structural integrity by repairing the structure.

II. METHODOLOGY

A. Preliminary test

Table I: Material and its Properties

S.No	Material properties	Values
1	Fineness modulus of fine aggregate	Zone 2
2	Specific gravity of fine aggregate	2.47
3	Specific gravity of coarse aggregate	2.82
4	Specific gravity of cement	3.16
5	Standard consistency of cement	5 mm (31% water)

By using the above preliminary test values, the obtained Mix ratio for M25 grade concrete is 1:1.75:3.27 and W/C is 0.50, as per IS 10262:2009 and IS 456:2000 guidelines.

B. Casting of specimens

For the comparison of strength of specimens by bacterial healing with cement mortar healing method, different specimens were casted. Total four cubes of standard 150x150x150mm dimensions are casted, one is plain and the remaining 3 are with a crack (notch), compressive strength is to be compared among these four. Similarly four beams and four cylinders were casted to test out flexural strength and split tensile strength respectively.

III. DEVELOPMENT OF BACTERIAL CULTURE

Our selected bacteria are Bacillus Pseudofirmus. Since, it is an anaerobic culture we need to prepare an alkaline media for the growth of the bacteria, for this purpose we referred to the catalogue number MCC-2820 from NCMR Pune. Fig. 1shows Bacillus Pseudofirmus.

Fig. 1: Bacillus Pseudofirmus

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The protocol is as follows:

$NaHCO_3$	4.2 g
Na_2CO_3anhydrous	5.3 g
Distilled water	100 ml

For the above media LB broth should be added as food at the rate of 25 grams per 1000ml. The medium is prepared and it is autoclaved to avoid contamination. A Laminar air flow machine is used for the inoculation process. A loop full of mother sample is added to the prepared medium and then placed the culture in incubator for 24 hours at 35° to 40°Celsius. After which the media showed bacterial growth. Turbidity was checked and confirmed the bacterial growth. Fig. 2 shows Inoculation of Medium.

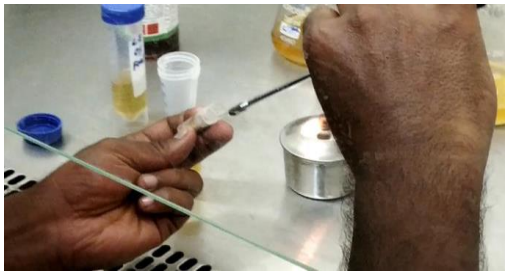

Fig. 2: Inoculation of Medium

For the growth confirmation streaking plates shall be prepared as per the following:

1. Calcium hydrogen carbonate 4.2g
2. Sodium carbonate 5.3g
3. Nutrient agar 2.8g
4. Agar Agar (for solidification,) 1 spatula
5. 100 ml distilled water

Fig. 3 shows Streaking bacteria on petri plates of Agar gel

Fig. 3: Streaking bacteria on petri plates of Agar gel

After streaking the petri plates of Agar gel, were kept in incubator for 24 hours for the growth of bacterial colonies. On the next day, the bacteria shows a eye visible growth of the bacterial colonies on the agar gel. Fig. 4 shows Visibility of bacterial colonies

Fig. 4: Visibility of bacterial colonies

A. Injecting Developed Culture into the Notch

The notch which was created manually of dimensions L=5cm, D= 4cm, T= 1cm. In this notch, prepared culture should be injected along with Calcium lactate (Ca(C3H5O2)2). This procedure is followed by the chemical equation

$$Ca(C_3H_5O_2)_2 + 7O_2 \rightarrow CaCO_3 + 5CO_2 + 5H_2O$$

Here the bacteria acts as an enzyme which formulates the calcium carbonate precipitate in the notch.

Hence here $CaCO_3$ which is lime, formulates a partial strong bond to regain the structural integrity of the specimen. **Fig. 5 shows** Injecting Bacterial Culture

Fig. 5: Injecting Bacterial Culture

After three weeks the healed specimens were observed which are depicted in the below Fig. 6.

Fig. 6: Observation after healing (3rd week)

B. Healing the notch using cement mortar

Now the notches of other specimens are healed with cement mortar for the strength comparison with bacterial healed specimens. The cracks are healed manually using cement mortar of ratio 1:3 as depicted in the Fig. 12 below:

Fig. 12: Specimens healed Using cement mortar

All the above specimens are tested for Characteristic compressive strength, Split tensile strength, and Flexural strength and results were as follows.

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IV. RESULTS

The below Table II shows the Strength Values.

Table II: Strength Values (N/mm²)

Specimen	Plain (with out notch)	Cement mortar healed	Bacterial healed	Empty notch
Cube	32.8	24.8	20.88	18.22
Beam	9.81	9.07	8.829	7.35
Cylinder	4.24	3.112	1.415	0.70

Comparing graphs, for the above respective strengths are as follows and represented in Fig. 13, 14, 15.

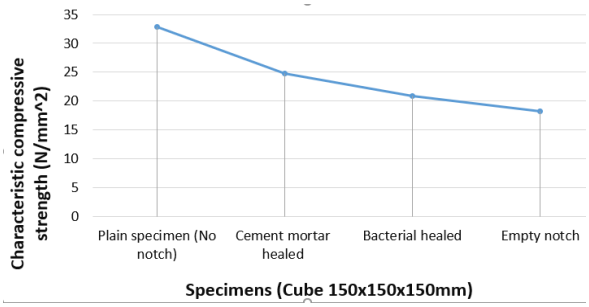

Fig. 13: Compressive strength comparison of all cube specimens

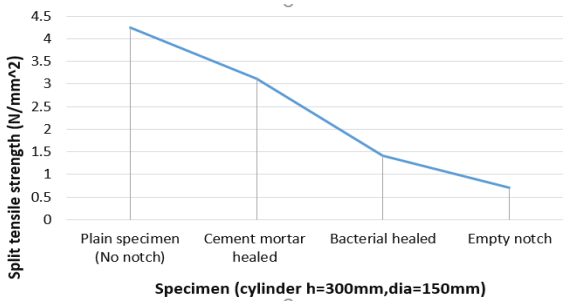

Fig. 14: Split tensile strength comparison of all cylinder specimens

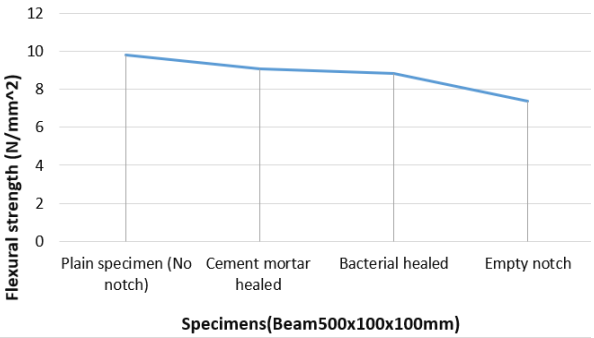

Fig. 15: Flexural strength comparison of all beam specimens

V. COST ANALYSIS

Notch dimensions are 5x3x1cm. An equivalent quantity in volume of bacterial repair culture is required for the repairing purpose.

This equivalent volume is 15ml. For the preparation of culture we require $NaHCO_3$, Na_2CO_3anhydrous, distilled water. Tables II and III Quantity and Cost of Material/equipment.

Table II: Quantity and Cost of Material/equipment

Material/equipment	Quantity	Cost
Distilled water	15ml	Rs 2.83
$NaHCO_3$	0.795g	Rs 7.69
Na_2CO_3anhydrous	0.63g	Rs 1.89
LB Broth	0.375g	Rs 1.44
Inoculate (mother sample)	5% of 2ml=0.1ml	Rs 75
Others (LAF, pipettes, incubator etc)	-	Rs 20

To heal 15cc volume of crack we require Rs 109

For the same size of notch i.e., 15cc cement mortar is used for repairing whose cost analysis is done as follow:

Table III: Material /equipment quantity and cost

Material/equipment	Quantity	Cost
Cement	0.937g	Rs 4.87
Fine aggregate	2.81g	Rs 0.51
Others(Moulds, Trowel, tamping rod etc)	-	Rs 15

To heal 15cc volume of crack we require Rs 20

VI. CONCLUSIONS

- By the observation of bacterial healed specimens as of fig.6 it was concluded that there was precipitation of calcium carbonate ($CaCO_3$) which helps the specimen to partially regain strength.
- The costs for bacterial healing are much greater than cement mortar repairing mix by Rs 89.
- Even though the bacterial healing is uneconomical it has its benefits such as self healing even after further cracking, good aesthetics, environmental friendly
- Bacterial healing is uneconomical as mother culture is costly and as it is included in cost analysis it becomes uneconomical in overall view. But when the mother sample sub-cultured (increased in quantity) it becomes economical.
- So when bacterial healing is used in crack repairing, the bacteria lie dormant for 200 years and can further repair the crack when it comes in contact with water. Hence by this repairing of the structure, it can prevent the reinforcement from exposure to environment and corrosion.

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