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An experimental study on strength and self-healing characteristics of bacterial concrete

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ABSTRACT

Concrete is the most commonly used building material that is recyclable. It is strong, durable, locally available and versatile. It is capable to resist the compressive load to a limit but if the load applied on the concrete is more than their limit but if the load applied on the concrete is more than their limit of resisting load, it causes the strength reduction of concrete by producing the cracks in concrete and the treatment of cracks is very expensive. Cracks in concrete affects the serviceability limit of concrete. The ingress of moisture and other harmful chemicals into the concrete may result in decrement of strength and life. Micro-cracks are the main cause to structural failure. One way to circumvent costly manual maintenance and repair is to incorporate an autonomous self -healing mechanism in concrete. One such an alternative repair mechanism is currently being studied, i.e. a novel technique based on the application of biomineralization of bacteria in concrete. The applicability of specifically calcite mineral precipitating bacteria for concrete repair and plugging of pores and cracks in concrete has been recently investigated and studies on the possibility of using specific bacteria as a sustainable and concrete-embedded self-healing agent was studied and results from ongoing studies are discussed. Synthetic polymers such as epoxy treatment etc. are currently being used for repair of concrete are harmful to the environment, hence the use of a biological repair technique in concrete is focused. Recently, it is found that microbial mineral precipitation resulting from metabolic activities of favourable microorganisms in concrete improved the overall behaviour of concrete. Hence in this paper define the bacterial concrete, its classification and types of bacteria, chemical process to fix the crack by bacteria, advantages and dis- advantages and possibilities of application of MICP (Microorganism used for Calcium Carbonate Precipitation in Concrete).The different strengths of Normal concrete and concrete with different concentrations of Bacteria Bacillus spp were used and tests were conducted and compared.

***Keywords**: Bacterial concrete materials, material tests, mix design, compressive strength tests, flexure strength test, split tensile strength test.*

1. INTRODUCTION

Self-healing concrete is a product, which biologically produces limestone by which cracks on the surface of concrete surface heal. Selected types of the bacteria genus Bacillus, along with calcium-based nutrient known as calcium lactate, and nitrogen and phosphorous are added to the concrete when it is being mixed. The self-healing agents can lie dormant within the concrete for up to two hundred years. When a concrete structure damages and water starts to penetrate in the cracks present in it , the bacteria starts to damages and water starts to penetrate in the cracks present in it, the bacteria starts to feed on the calcium lactate consuming oxygen and converts the soluble calcium lactate into insoluble limestone. The limestone formed thus seals the cracks present. It is similar to the process of how a fractured bone gets naturally healed by osteoblast cells that mineralize to reform bone. Consumption of oxygen in the bacterial conversion has an additional advantage. Oxygen, which becomes an essential element for the corrosion of steel to take place is being used in the bacterial conversion. Hence the durability of steel in construction becomes higher. The process of bacterial conversion takes place either in the interior or exterior of the microbial cell or even some distance away within the concrete. Often the bacterial activities trigger a change in the chemical process that leads to over saturation and mineral precipitation. Utilization of concepts of bio mineralogy in concrete lead to invention of a new material termed as Bacterial Concrete. Bacterial concrete refers to a new generation concrete in which selective cementation by microbiologically induced CaCO3 precipitation has been introduced for remediation of micro-cracks.

2. MATERIALS

2.1 Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Water should be free from acids, oils, alkalis, vegetables or other organic impurities. Soft water also produces weaker concrete. Water has two functions in a concrete mix. First, it reacts chemically with cement to form a cement paste in which the inert aggregates are held in suspension until the cement paste has hardened. Next, it serves as a vehicle or lubricant in the mixture of fine aggregate and cement. Potable water is generally considered satisfactory. In the present investigation, potable tap water was used for both mixing and curing purposes.

2.2 Cement

Cement is a fine, grey powder. It is mixed with water and materials such as sand, gravel, and crushed stone to make concrete. The cement and water form a paste that binds the other materials together as the concrete hardens. The ordinary cement contains two basic ingredients namely argillaceous and calcareous. In the present work 53 grade ACC cement was used for casting cubes and beams for all concrete mixes. The cement was of uniform colour i.e. grey with a light greenish shade and was free from any hard lumps and fulfilling the requirements as per IS 12269 -1987.

2.3 Fine Aggregate

The sand used for the experimental works was locally procured and conformed to grading zone II. Sieve Analysis of the Fine Aggregate was carried out in the laboratory as per IS383-1970.

2.4 Coarse Aggregate

Crushed basalt stones obtained from local quarries were used as coarse aggregate. The maximum size of coarse aggregate used was 20 mm. The properties of coarse aggregate were determined by conducting tests as per IS: 2386 (Part – III).

2.5 Bacillus Subtilis Bacteria

Bacillus subtilis will be brought up in its log phase in concreting site in liquid or aqueous state. This stage is having bacterial concentration 2 x 10^8 cells/ml. This full-grown stage is aimed to lasts for 2 to 3 hours at room temperature. These bacteria should be impregnated in concrete in its full-grown stage. Bacillus subtilis is considered the best studied Gram positive bacterium and a model organism to study bacterial chromosome replication and cell differentiation.

Fig. 1: Bacillus Subtilis Liquid

3. HOW DOES BACTERIAL CONCRETE WORKS?

- Self-healing concrete is a product that will biologically produce lime stone to heal cracks that appear on the surface of concrete structure.
- Specially selected types of bacteria genus Bacillus, along with calcium-based nutrients known as calcium lactate & nitrogen phosphorus are added to the ingredients of the concrete when it is being mixed these self-healing agents can lie dormant within the concrete forup to 200 hundred years.
- When a concrete structure is damaged water starts to seep through the cracks that appear in the concrete, the spores of the bacteria germinate on contact with the water and nutrients.
- Having been activated, the bacteria start to feeds oxygen is consumed and the soluble calcium lactate is converted to insoluble limestone. The limestone solidifies on the crack surface, thereby sealing it up.
- The consumption of oxygen during the bacteria conversion of calcium lactate to limestone has an additional advantage. Oxygen is an essential element in the process of corrosion of steel and when bacterial activity has consumed it all and increases the durability of steel reinforced concrete construction.

4. CHEMICAL PROCESS OF BACTERIAL CONCRETE

When the water comes in contact with the un-hydrated calcium in the concrete, calcium hydroxide is produced by the help of bacteria, which acts as a catalyst, this calcium hydroxide reacts with atmospheric carbon dioxide and forms limestone and water. This extra water molecule keeps the reaction going.

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

The limestone then hardens itself and seals the cracks in the concrete.

5. MATERIALS TESTS

CEMENT

Setting time of cement

a) **Initial setting time = 43 minutes**
b) Final setting time = **599 minutes**

Specific Gravity

Specific gravity of cement = **3.16**

Normal Consistency

Normal consistency of cement = **28%**

Physical Examination

(a) Color was uniform grey
(b) No lumps
(c) No adulteration
(d) No over dated

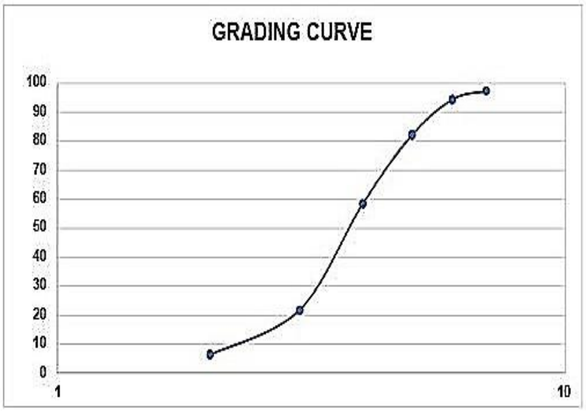

Fig. 2: Collection of coarse aggregates

Crushing value test

The crushing value of given sample = **28.14%**

Los Angeles Abrasion Test

The los Angeles Abrasion Value =**16.2%**

Impact Value Test

Aggregate Impact Value = **18.58%**

Shape Test
(a) The flakiness index = **18.24%**
(b) Elongation index = **14.51%**

Fig. 3: Sieve Analysis gradation curve

Specific Gravity
The specific gravity of coarse aggregates = **2.67**

Table 1: Sieve analysis

Observations and Results:

IS SIEVE SIZE	WEIGHT RETAINED (Kg)	CUMMULATIVE WEIGHT RETAINED (Kg)	% WEIGHT RETAINED	% CUMULATIVE WEIGHT	% FINER
4.75mm	0.0265	0.0265	2.65	2.65	97.35
2.36mm	0.0305	0.057	3.05	5.7	94.30
1.18mm	0.121	0.178	12.1	17.8	82.20
600 microns	0.238	0.416	23.8	41.6	58.40
300 microns	0.367	0.783	36.7	78.35	21.65
150 microns	0.153	0.936	15.3	93.65	6.35
Pan	0.0165	0.950	1.65	95.3	4.7

Specific Gravity
The specific gravity of coarse aggregates = **2.67**

Sieve Analysis
Fineness Modulus = **2.39**

Tests on Bacteria (Bacillus Subtilis)
pH Value
The pH value of bacteria is**= 6.8- 7.2**
Bacteria count /ml= **2 x 10^8/ml**
Specific Gravity of Bacteria =**1.08**

6. DESIGN MIX FOR M_{25}

The concrete of grade of M_{25} Concrete was designed as per IS Code
Step 1: Target Strength for Mix Proportion
fck = fck+1.65*S =25+(1.65*4) =**31.6 N/mm^2**
Step 2: Selection of Water Content **=0.45**
Step 3: Water Required for 1m^3 =197 lit
Step 4: Calculation of Cement Content (197/.45) =438 kg/m^3
Step 5: Proportioning of Volume of Course Aggregate (CA) and Fine Aggregate (FA)
For 0 .45=.61
Volume of CA=0.61 Volume of FA=1-.61=.39
Step 6: Mix Calculations
(a) Volume of Concrete= 1m^3
(b) Volume of Cement = (Mass of Cement/Specific gravity of Cement)*(1/1000) (438/3.16)*(1000^{-1}) =.138m^3
(c) Volume of Water = (Mass of Water/Sg of water)*(1/1000) =197/1000 =.197m^3
(d) Volume of all aggregates =(a-(b+c) =(1-(.138+.197)) =.665m^3
(e) Mass of CA =e*Vol of CA*Sg of CA*1000 = (0.665*0.61*2.67*1000) =1083.086 kg
(f) Mass of FA= e*Vol of FA*Sg of FA*1000 =(0.665*0.39*2.7*1000)
(g) Ratio = Cement**:** Fine Aggregate**:** Coarse Aggregate = 438: 700.245: 1083.086 **=1:1.6:2.47**

7. COMPRESSIVE STRENGTH

Test result for 7,14,18 and 90 days for Bacterial Concrete the cube moulds of size 150mm x 150mm x 150mm were cleaned and checked against the joint movement. A coat of oil was applied on the inner surface of the moulds and unbroken prepared for the concreting operation. Meantime the specified quantities of cement, fine mixture and coarse mixture (passing through IS sieve of 20mm size and maintained on 4.75 mm) for the actual combine wereweighed accurately for concreting. Fine mixture and cement were mixed completely in an exceedingly hand mixer specified the colour of the mixture is uniform. Then, weighed amount of coarse mixture were further mixed until uniform dry mixture is obtained. Then, calculated amount of microorganism and water were further added and compounding were continuing for three to five minutes to obtain a regular combine. The wet concrete was poured into the moulds in a pair of three layers and compacted manually. Once concreting operations, the upper surface was levelled and finished with a mason's trowel. The corresponding identification marks were labelled over the finished surface and that they were be tested for 7,14,28 days and 90-day strengths in an exceedingly compressive strength testing machine.

Table 2: Compressive strength

OBSERVATION TABLE

PEAK STRESS(MPA)	7 DAYS	14 DAYS	28 DAYS	90 DAYS
CODE	AVG	AVG	AVG	AVG
NORMAL	28.05	29.09	33.2	35.05
CONCENTRATION I (30ML/Litre of Water)	34.3	37.3	39.95	42.83
CONCENTRATION II (45ML/Litre of Water)	34.8	38.3	42.0	43.53
CONCENTRATION III (60ML/Litre of Water)	37.4	38.91	44.06	45.85

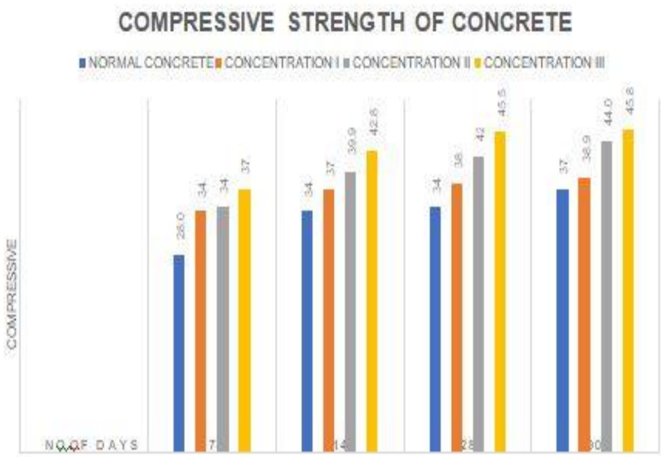

Fig. 4: Bar chart of compressive strength

Fig. 5: Compression test of cube

8. FLEXURAL STRENGTH

Moulds of 10cm x 10cm x 50cm were employed and therefore the Moulds were cleaned and therefore the joints between the sections of Moulds shall be thinly coated with oil and the same coating of oil shall be applied between the contact surfaces of all sides of the Moulds and the base plate so as to confirm that no water escapes throughout the filling. the inside faces of the assembled Moulds shall be thinly coated with Moulds oil to stop adhesion of the concrete. Meantime the desired quantities of cement, fine combination and corresponding coarse combination for the actual combine were weighed accurately for concreting. Fine combination and cement were mixed totally in a hand mixer such that the colour of the mixture was uniform. Then, weighed amount of coarse combination were added to the mixer so it turns into a uniform dry mixture. Then, calculated amount of water and microorganism were added and intermixture was continuing for concerning three to five minutes to urge a consistent combine. The wet concrete was poured into the Moulds in two to three layers and compacted manually. once concreting operations is over, the upper surface was levelled and finished with a mason’s trowel. The corresponding identification marks were labelled over the finished surface and therefore the beams were tested for 7,14,28 and 90 days’ strengths.

Table 3: Flexure Strength

Observation Table

FLEXURAL STRENGTH N/mm²	7 DAYS	14 DAYS	28 DAYS	90 DAYS
NORMAL	7.95	8.00	8.02	8.4
CONCENTRATION I (30ML/Litre of Water)	8.06	8.31	8.50	8.55
CONCENTRATION II (45ML/Litre of Water)	9.1	9.33	9.52	9.77
CONCENTRATION III (60ML/Litre of Water)	10.30	10.50	10.55	10.82

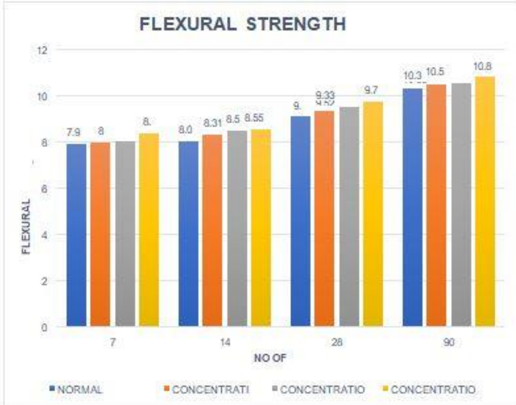

Fig. 6: Bar chart of flexure strength

9. SPLIT TENSLIE STRENGTH

Splitting tensile strength test in concrete cylinder (height 300mm, dia- 150mm) is a method to determine the tensile strength of concrete, which is one of its basic and important properties. Concrete due to its brittle nature is not expected to resist the direct tension and hence develop cracks when subjected to tensile forces. Thus, this test directly indicates the load at which concrete members tend to crack.

Table 4: Split tensile strength

SPLIT TENSILE STRENGTH(Mpa)	7 DAYS	14 DAYS	28 DAYS	90 DAYS
NORMAL	2.90	3.35	4.21	4.28
CONCENTRATION I (30ML/Litre of Water)	4.48	4.76	4.80	4.87
CONCENTRATION II (45ML/Litre of Water)	4.56	4.88	4.98	5.02
CONCENTRATION III (60ML/Litre of Water)	4.90	5.10	5.21	5.86

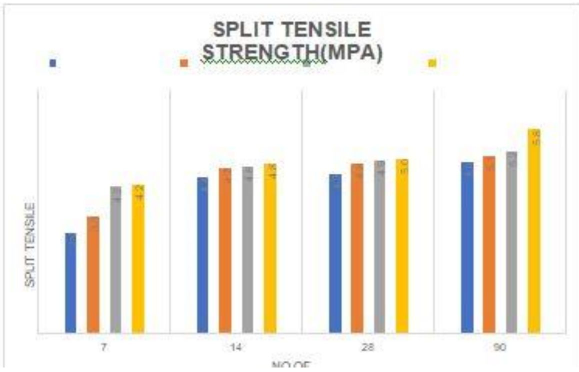

Fig. 8: Bar chart of split tensile strength

Fig. 9: Casting of Cylinder

Fig. 10: Mixing of Concrete

Fig. 11: Compression Test of Cubes

Fig. 12: Testing of Beam

10. CONCLUSION

The aim of the project was the experimental study of the bacterial concrete and its self-healing capabilities. From the different experiments conducted during the course of this project the results are summarized below.

- In this study it is found that bacillus subtilis was more suitable bacteria for self-healing concrete.
- The Compressive Strength of the Concrete having concentration of (60 ml/litre of water) increased by 32.71% at 28 days as compared to normal concrete, however over all strength at 90thday was found to be increased by 31%.
- The flexural strength of the concrete increased for by 31.54%as compared to normal concrete at 28 days and at 90 days it was found to be increased 28.80% at 90th day of testing.
- The Change in tensile strength was also found to be on increasing in the study, the tensile strength increased by 23.75% at 28 days for concentration and at 90th day was found to have increased from 23.75% to 36.91% as compared to normal concrete.
- As there in no change in compressive strength when concrete used to harsh weather conditions bacteria is alive in any extreme weatherconditions.

Fig. 13: Casting of Cylinders

Fig. 14: Testing of Cylinders

Fig. 15: Curing of Specimens

Fig. 16: De-moulding of Cubes

11. REFERENCES

[1] Mayur Vekariya, Prof. Jayeshkumar Pitrode, "Bacterial Concrete: New Era for Construction Industry" Sep 2013, Volume- 4,Issue- 9.

[2] Mostafa Seifan, Ali Khajesh Samani, Aydin Berenjain, "Bio Concrete: Next generation of self-healing concrete".29 Jan 2016.

[3] Koustubh A. Joshi,,Madhav B. Kumthekar, Vishal P Ghodake," Study of Self healing Mechanism and its Impact on Bacillus Bacteria Impregnated Concrete",
[4] June 2016,Volume -3,Issue -6.
[5] Kusuma K,Amit Kumar Rai,Prashant Kumar,Harini K,Harshita M.N,"Self – healing concrete",May 2018,Volume -05,Issue -05,IRJET.
[6] Abhishek Thakur, Akshay Phogat,Khushpreet Singh," Bacterial Concrete and effect of different bacteria on the Strength and water absorption characteristics of concrete: A Review ",Sep-oct 2016,Volume-07,Issue-05.
[7] S. Soundharya, Dr. K Nirmalkumar, "Study on effect of Calcite-Precipitating Bacteria on Self-healing Mechanism of Concrete," July-2014,Vol -01,Issue -04.
[8] Pawar Bhagyashri, Magdum Archana, Bhosale Megh, Pol Sayali,"Bacterial Concrete', Oct-2007,volume-04, Issue -02.

