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An Experimental Study on Strength and Self-Healing Characteristics of Bacterial Concrete

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ABSTRACT- In modern era, concrete is widely used in building material. Concrete is durable, strong and locally available. It has a property of resisting the compressive load to a limit but if the load applied goes beyond the limit, the strength of concrete is reduced because of the development of the cracks in the concrete.

Thus the treatment for these cracks becomes very expensive. The development of cracks in concrete affects the serviceability limit of concrete. The influx of water and harmful chemicals into the concrete may decrease both the strength and life. Structural failure may be caused by micro-cracks. One way to avoid costly manual maintenance and repair is to include an autonomies self-healing mechanism in concrete. One such an alternative mechanism is correctly being studied i.e. a novel technique based on the application of bio-mineralization 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 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 now a days used for repair of concrete are harmful to the environment, hence the biological repair technique is focused.

Recently, it has been found that microbial carbonate Precipitation resulting from the metabolic activities of micro-organisms in concrete modified the overall behavior of concrete. Hence, in this paper, we explain the bacterial concrete, its classification and types of bacteria, chemical processes to fix the micro cracks, advantages ,disadvantages and the possibilities on application of micro-organisms in the concrete. The different strengths of normal concrete and concrete with bacillus were analyzed and the tests were conducted and compared.

KEYWORDS- Bacteria Bacillus Subtillus, Concrete, Aggregates, Cement, Strength

I. INTRODUCTION

The foremost and the most important material which is going to be used in the construction industry is concrete. The availability of concrete is mostly everywhere it has great strength and durability. Concrete have very good resisting power against compressive loads. In certain cases over loading to the concrete may develop cracks with in it , which may cause weakness to concrete and requires amount for its treatment . The use of impure water which contains the harmful chemicals lowers the strength and durability of the concrete , chemicals with affects the durability of the concrete are sulphates and chlorides . Self feeling technology is the introduction of new revolution in concrete to prevent cracking in concrete. This technology has very good potential to heal the cracks and improve the life and serviceability of concrete. This technology have a very low maintenance cast. The most used material in this technology are epoxy resin, fiber, bacteria etc. which can heal the cracks developed in the concrete[11][12]. From all these things the important one is bacteria, which is mixed with concrete and the formation of calcium carbonate precipitates takes place and this precipitates gets filled in these cracks and in this way self feeling of the concrete takes place The self-healing concrete is a concrete in which the cracks are filled by itself by the lime stone which is biologically produced by the bacteria called genus bacillus . In this type of concrete some other nutrients are used for self-healing which are calcium lactate, nitrogen and phosphors. This bacteria can live in the concrete for about 200 years. During the damaging of the concrete the water starts penetrating through these gapes and the bacteria takes the calcium lactate with oxygen and then converts the same into insoluble limestone[13][14]. The lime stone starts filling the gapes and seals the cracks of the concrete. The oxygen which is responsible for rusting the iron is used here for filling the cracks by bacterial conversion. This formation takes place either outside or inside of the cell and sometimes from a distance away with in the concrete. The utilization of the Bio mineralogy in the concrete give birth to bacterial concrete This the new concept induced of $CaCo_3$ precipitation for remediation of micro-cracks.

II. OBJECTIVE

The main objective of current work is:

- To determine the compressive strength of the bacterial concrete.
- To determine the flexural strength of bacterial concrete.

- To determine the split tensile strength of bacterial concrete.
- To compare the strengths with the normal concrete.

III. LITERATURE REVIEW

A. Sakina Najmud din Saife et.a1 [1]

Worked on critical appraisal on bacterial concrete. In the publication they discussed about the some types of bacteria and their processes. The bacterial concrete is important for the continuity of cementious materials, form limestone monuments, sealing on cracks to largely durable cracks etc. It is beneficial for high strength structures with further bearing capacity, erosion prevention of beach sands and low budgeted durable houses. They also found the bacterial concrete as a material for repairing of cracks. It has been noticed that metabolic processes of microorganisms occur within the concrete shows modification to the whole concrete properties especially the compressive strength.

B. Meera C M and Dr Subha V [2]

Have presented paper on the properties of bacterial concrete especially Strength and Durability of Bacteria Based Self-Healing Concrete. In this publication they have explained about the effect on adding Bacillus JC3 on the strength of concrete. They used cylinders of height 20cm and diameter of 10cm and cubes with sizes of 15cm x 15cm x 15cm with mixing and without mixing of bacteria, in M20 concrete. For strength measurement, cylinders were checked for split tensile strength for 28 days and cubes were examined for different bacterial concentrations at the age of 7 days and 28 days .It has been noticed that with the addition of bacteria there is a immense improvement in the tensile strength by 56% for a bacteria concentration of 105units/ml at 28 days and the compressive strength of concrete resulted in abrupt increase by 44% for cell concentration of 105 of mixing water. For durability assessment, water absorption test, chloride test and acid durability tests were performed and from the outcome It can be concluded that with the mixing of bacteria it prevents the weight loss intern of acid exposure conditions to some certain limit, resulting the bacterial concrete have higher factor of Acid Attack .The Water Absorption Test, resulted a little bit increase in the weight of bacterial concrete sample than traditional concrete, therefore the concrete will show less pores due to the creation of Calcium Carbonate precipitate, which results in lesser moisture absorption rate.

C. *Ravindranatha, N. Kannan, Likhit M. L [3]*

Have presented a paper on Bacterial Concrete. In this publication, they made a comparative study in presence and absence of bacterium Bacillus pasteurii. Then the concrete beams and cubes were prepared, casted and were examined at the age of 7 and 28 days for flexural and compressive strengths. It has been noticed that there was a quick improvement in the crack healing and strength when load was subjected to the concrete beams and cubes. It was proved that the microbe had modified the performance of concrete by attaining a substantial increase in strength. The precipitate of calcium carbonate formed by bacteria has occupied some voids and has made the structure compact and seepage resistive.

D. A. T. Manikandan1, A. Padmavathi [4]

Have presented a paper on An Experimental Investigation on Improvement of Concrete Serviceability by using Bacterial powder. Samples were made in three sets for a w/c ratio of 0.5 by weight for conventional concrete, and bacterial culture of 0.25 for bacterial concrete and water cement ratio of 0.25 by weight. The cubes were tested by compression testing machine and Non-Destructive Testing and on the 3rd, 7th and 28th days after casting. There was an increase in the compressive strength by B. subtilus due to accumulation of carbonate (CaCO3) precipitate in cement-sand matrix of bacterial concrete that generated the porous structure in the mortar. The temperature sustainability test of Bacillus subtilis in modified bacterial concrete was done out at different degrees of temperature and was seen that the bacteria even lived from minus 30C to 700C temperatures. There is an increment in the compressive strength of bacterial concrete with microbial carbonate precipitate. The sample displayed the calcite granules grown around the surface of the fracture and also the presence of bacilli bacteria is the proof that suggested the microbial modification on the performance of bacterial concrete.

E. Jagadeesha Kumar BG, R Prabhakara and Pushpa H [5]

Presented a paper on Effect of Bacterial calcium Carbonate Precipitate on Characteristic Strength of cement mortar Cubes. This publication explained the experimental investigations done on the above cubes which were faced with the carbonate precipitation by various bacterial stains and the effect of bacterial carbonate precipitation on the strength i.e compressive strength of cement mortar cube on 7 days, 14 days and 28 days of bacterial treatment. Three bacteria's Bacillus sphaericus, Bacillus flexus and Bacillus pasturii were used. Out of these, Bacillus flexus was taken out from the concrete environment while Bacillus sphaericus and Bacillus pasturii were used. The cement mortar cubes were dipped in water for curing. The result depicted that there was an increase in the early compressive strength of cubes which got decreased with the time. From the above three strains of bacteria, Cubes mixed to Bacillus flexus, showed peak compressive strength as compared to other two bacterial stains. It was enhanced that there is an abrupt increase in the compressive strength due to the compactness of pores inside the cubes containing cement mortar material with the mixing of microbiologically Calcium Carbonate precipitation.

F. RA. B. Depaa and T. Felix Kala [6]

Have presented a paper on Experimental Investigation of Self-Healing Behaviour of Concrete using GGBFS and Silica Fume as Mineral Admixture. In this publication, cubes were formed by mixing silica fume in percentage of 2.5, 5,7.5, 10, 12.5 as a matrix and also some cement content was mixed to the concrete and also the cement content was replaced by GGBFS from 35% to 55%. A conventional normal mixture of concrete cube was prepared without admixture for comparing the various properties of concrete including durability and strength with GGBFS and silica fume admixture. The moulds were firstly tested for characteristic compressive strength after 28 days, and then 70% and 90% of the characteristic compressive load was induced to other set of cubes to form very small cracks for examining the durability of the moulds. The previously loaded concrete cubes were tested for characteristic compressive strength at the age of 7 and 28days. The concrete design mix possessing cement was partially replaced with 35% of GGBFS and has given peak characteristic compressive strength value. The design mix had given peak strength when 12.5% silica fume was added.

IV. MATERIAL USED

A) Water

Water is an important parameter for the hydration of cement. It helps in strengthening the cement gel, the quality and quantity of water is to be looked very carefully. Water should be free from impurities, acids, oils, vegetables, alkalis etc. Water having any kind of carbonates and bicarbonates reduces the overall strength of concrete. Water in concrete has two functions. First it reacts with cement to form a gel in which the aggregates are held in suspension[7]. Next it is used as a lubricant or vehicle in the mixture of cement and aggregate. Water used should be portable. In this investigation portable tap water was used for mixing and also for curing.

B) Cement

Cement is a gray fine powder. when mixed with materials such as fine aggregate and course aggregate and water to make concrete .The water and cement make a paste that binds the fine aggregate and course aggregate together as to harden to concrete . The ordinary cement mainly contains two ingredients such as calcareous and argillaceous[7]. In this work, 53 grade ACC cement was used for preparing concrete mixes and cubes. The cement was of uniform colour that is grey with a light greenish shade and was free from lumps and fulfilled all the requirements as per IS 12269-1987.

The common ingredients of ordinary portland cement are:

- Calcium
- Silica
- Alumina
- Iron

Calcium is obtained from lime stones, chalk, while alumina, iron and silica is obtain from clay, ironore and sand .

C) Fine Aggregate

In this experimental work the sand used was locally procured and conformed to great zone II. Sieve analysis for fine aggregate was carried out in the laboratory as per IS 383-1970[8].

D) Coarse Aggregate

Coarse aggregate used was crushed basalt stones obtain from local quarries. The maximum size of coarse aggregate used was 20mm. The tests for coarse aggregate was as per IS: 2386(part-III) to determine the properties of coarse aggregate[9].

E) Bacillus Subtilis Bacteria

Bacillus Subtilis was brought up in its log phase at concreting site in liquid state. This stage is having bacteria concentration 2*108 cells/ml. This full grown stage is aimed to last for 3 hours at room temperature [10]. These bacteria should be immersed in concrete in its full grown stage. To study the multiplication of bacterial chromosome and cell differentiation, Bacillus Subtilis is considered to be the best studied gram positive bacterium.

V. RESULTS AND DISCUSSION

A. Compressive Strength Test

It was noted with the addition of concentration of bacteria, there was overall improvement in compressive strength over normal concrete as can be seen in table 1.

Table 1: Compressive strength test

Compressive strength (mpa)	Time In (DAYS)			
	7	14	28	90
Normal	28.05	29.09	33.20	35.05
Concentration 1 (30ml/litre of water)	34.29	37.31	39.96	42.85
Concentration ii (45ml/litre of water)	34.70	38.29	42.08	43.54
Concentration iii (60ml/litre of water)	37.42	38.93	44.08	45.87

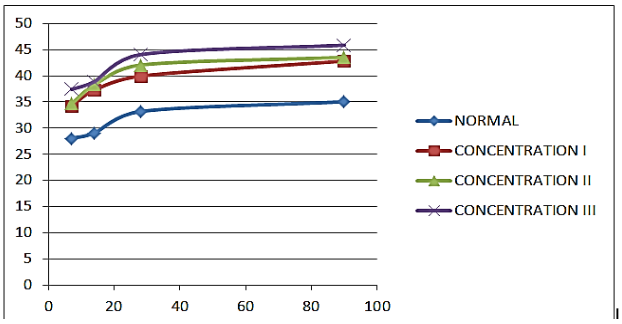

Figure 1: Compressive strength with various concentration of bacteria

In the above figure 1, it shows that the variation in the compressive strength of bacterial concrete in relation to the various concentration of bacteria. Table 2: Flexural strength test

B. Flexural Strength Test

It was determined that the flexural strength was increased as compared to normal concrete .it can be seen in table 2.

Table 2: Flexural strength test

Flexural strength n /mm^2	Time In (Days)			
	7	14	28	90
Normal	7.95	8.00	8.02	8.40
Concentration 1 (30ml/litre of water)	8.07	8.33	8.48	8.54
Concentration ii (45ml/litre of water)	9.20	9.31	9.54	9.75
Concentration iii (60ml/litre of water)	10.28	10.52	10.56	10.84

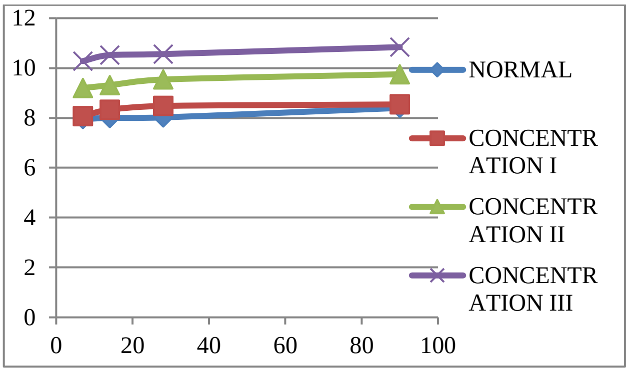

Figure 2: Flexural strength with various concentration of bacteria

In figure 2, it shows the variation in the flexural strength of bacterial concrete in relation to various concentration of bacteria.

B. Split Tensile Strength Test

It was determined that the split tensile strength was increased as compared to normal concrete .it can be seen in table 3.

Table 3: Split tensile strength test

Flexural strength n /mm^2	Time in (days)			
	7	14	28	90
Normal	7.95	8.00	8.02	8.40
Concentration 1 (30ml/litre of water)	8.07	8.33	8.48	8.54
Concentration ii (45ml/litre of water)	9.20	9.31	9.54	9.75
Concentration iii (60ml/litre of water)	10.28	10.52	10.56	10.84

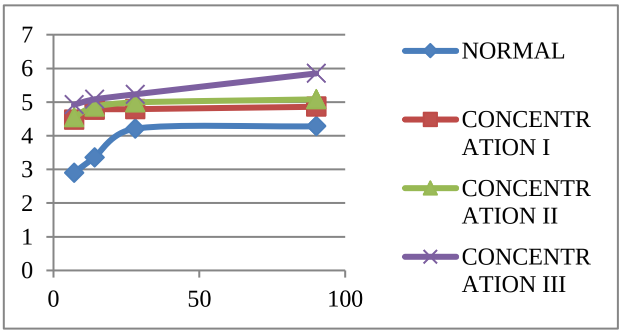

Figure 3: Split tensile strength with various concentration of bacteria

Figure 3 is showing the variation in the split tensile strength of bacterial concrete in relation to various concentration of bacteria

VI. CONCLUSION

The main and the foremost aim of this experimental work is to study the strength of the bacterial concrete and its self – healing properties. From the different experiments during this experimental, the results are summarized below:

- In this study it is found that the micro-organism i.e bacillus Subtilis was more suitable bacteria for self feeling concrete .
- The compressive strength of the concrete having concentration of 60ml per litre of water increased by 33.8% at 14 days as compared to normal concrete and the strength increased 32.77% at 28 days, however the strength increased 30.87% at the 90th day as compared to normal concrete.
- The flexural strength of the concrete having concentration of 60ml per litre of water increased by 31.50% at 14 days as compared to normal concrete and the strength increased 31.6% at 28 days, however the strength increased 29.4% at the 90th day as compared to normal concrete.
- The tensile strength of the concrete having concentration of 60ml per litre of water increased by 51.6% at 14 days as compared to normal concrete and the strength increased 24.22% at 28 days , however the strength increased 36.8% at the 90th day as compared to normal concrete .
- As there in any extreme weather conditions, there is no change in compressive strength. Because Bacteria is alive, when concrete is exposed in any harsh weather conditions.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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