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EXPERIMENTAL STUDY ON SELF-HEALING CHARACTERISTICS OF BACTERIAL CONCRETE

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Abstract: *Concrete is a major part of construction material in the world. The major drawback of the material easily cracks due to low tensile strength. Concrete is a combination of cement, fine aggregate, coarse aggregate and water considered as a homogenous material. New technologies have helped to develop new type of construction material in concrete. In this project experimental investigation were carried out to evaluate the influence of bacillus subtilis on compressive strength, split tensile strength, water absorption and self-healing properties. And it is made to heal the crack by the addition of the bacteria in the concrete also increase the strength. Three different concentration were added. Test were performed at the ages of 7, 14 & 28 days. Since the crack formation is major threat for the concrete structures this will study will help to overcome those catastrophic situations. Hence by using this innovative technique of cracking healing in the concrete structures the strength and durability will be increased compared to the conventional concrete. An MICCP (Microbiologically Induced Calcium Carbonate Precipitation) it is an eco-friendly method to enhance the concrete. Investigation on the strength assessment of the bacteria based self-healing concrete by find out optimum dosage of bacteria content to be added maximum strength and also reduce the crack width in concrete structures.*

Keywords: **Bacillus Subtilis, MICCP, Spherification, Self-Healing, Crack.**

1. INTRODUCTION

Concrete is a most commonly used binding material. Cracks in the concrete due to various mechanisms activity such as shrinkage and tensile forces. New developments backed by years of research have provided today's concrete unique, attractive and practical product. Self-healing concrete is a product to induce the limestone biologically to heal the cracks in the concrete surface, specially selected type of bacteria bacillus subtilis is added to the ingredients of the concrete. Bacterial concrete or self-healing concrete to improves the tensile, compressive and flexural strength. In this study of manufacturing of concrete structures by using bacillus subtilis bacteria. The bacterial concrete made by embedding bacteria in the concrete that able to constantly precipitation calcite. Bacillus subtilis bacterial control the cracks in the concrete structures. Cracking of concrete is a common phenomenon. Bacteria used for crack remediating in concrete. This phenomenon is called MICCP (Microbiologically Induced Calcium Carbonate Precipitation). The basic advantage of MICCP by the bacteria in the concrete are increase the strength properties, low maintenance ,high carbonation which can help in decreasing porosity and permeability. MICCP technique helps to bind the sand particles together and make then act like cement. Bacillus subtilis is a common soil bacterium can continuously precipitate a new highly impermeable calcite layer over the surface of an existing concrete layer. The current study focus on cracks controlling in the concrete. Also to calculate the crack width of concrete. Bacillus subtilis bacteria used to make the concrete cubes and cylinders to remediate cracks and increase the overall strength of concrete and increase the life span of concrete.

2. MATERIALS USED

2.1 Cement

Cement is most commonly used binding material, in this project Ordinary Portland Cement (OPC) of 53 grade was used. Cement properties which make the able to join the material together.it consist of grinding the raw materials. Chemical and physical properties of cement are as per IS 12269-1987.

2.2 Fine Aggregate

The materials passing the sieve 4.75 smaller than is called fine aggregate. Commonly natural sand is used as fine aggregate. In this project work manufacturing sand is produced from hard granite stone by crushing. The crushed manufactured sand is called M-sand. Specification for M-sand guidelines IS 383-1970.

2.3Coarse Aggregate

Crushed stone of maximum size 20mm and retained 4.75 mm sieves. The coarse aggregate is angular shape and rough surface texture is used. Specification for coarse aggregate IS 383-1970.

2.4 Admixture

CONPLAST SP 430 is a high range chloride free super Plasticizer.

2.5 Bacteria

In this examination bacillus subtilis microorganisms is utilized. Bacillus subtilis can produce the maximum amount of calcium carbonate precipitation.

2.6 Water

Portable water is generally considered for mixing concrete. Standards specified in IS 456-2000 is used.

3. METHODOLOGY

3.1 Culturing of Bacteria

The Cultured bacterium was collected from Periyar University. Bacteria suspension with a concentration of 10^9 cells/ml were collected. The viability of bacteria was checked in the Microbiology department.

3.2 Dilution of Bacteria

The bacillus subtilis bacteria obtained were serially diluted with water to the concentration of10^5, 10^6 and10^7 cells/ml, under the guidance of Microbiology department.

3.3 Casting

M20 grade concrete mix design were used. In this experiment totally 4 set of mix proportion were casted. Normal concrete and three different concentration of bacterial concrete .cubes and cylinders of each mix consist of 6 cubes and 4 cylinders. The total number of cubes 24 and cylinder 16.

3.4 Curing

Locally available portable water was used to curing at the ages of 7, 14 and 28 days.

3.5 Testing

Compressive test was conducted at concrete cubes size of 150*150*150mm was done at the ages of 7, 14 and28 days. Split tensile strength test was conducted at concrete cylinders size Height 300mm, Diameter 150mm was done at the ages of 14 and 28 days.

4. METHODS USED

4.1 Spherification Process

Spherification is a culinary process employs sodium alginate or calcium lactate. When these chemicals come in contact it shapes a liquid into squashy spheres, which visually and texturally resemble roe. In our study to incorporate the bacteria into the concrete specimens the Spherification process has been involved. Initially the chemicals sodium alginate and calcium lactate are prepared. The bacteria Bacillus Subtilis are added separately to the calcium lactate solution. Since the bacteria is activated it starts to feed on the calcium lactate. Now, into this bacteria incorporates calcium lactate solution the sodium alginate is an added as drops which forms a squeshy sphere layer which acts as a protective cover for the bacteria. This layer of solution is added to the concrete matrix to generate the self-healing property.

4.2 Self-Healing Mechanism

The rate of self-healing will be depending upon the growth of Bacillus bacteria. When the cracks occur the protective sodium alginate cover of the bacteria gets cracked and the bacteria comes into contact with the external environmental pressure. When the moisture enters into the crack, the calcium lactate and the bacteria composites undergoes ureolytic process.

$$Ca\,(NH_2)_2 + 2H_2O \longrightarrow CO_3^{2-} + 2NH_4^+$$

When the oxygen enters into the crack by environmental pressure the bacteria induce Calcium carbonate.

$$Ca(C_3H_5O_3)_2+CO_2+\text{Alkaliphilicbacillus} \longrightarrow CaCO_3 + 5CO_2 + 5H_2O$$

The excess carbonate ions obtained from ureolytic process react with calcium ions and get more quantity of Calcium carbonate.

5. EXPERIMENTAL TEST ON BACTERIAL CONCRETE

Various tests was performed on bacterial concrete to get the good results in various forms of experimental methods summarized below.

5.1 Slump Cone Test

The concrete slump test is an empirical test that measure the workability of concrete. The slump cone test indicate the behavior of fresh concrete cone under the action of gravity forces. The test was carried out with moulds. The mould is placed on a smooth, horizontal surface. The mould is filled with 4 equal parts of concrete. Each layer is tamped 25 times of tamping rod. The types of slumps shows the fig.1

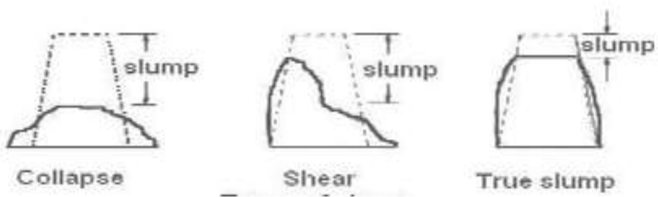

Fig-1: Type of Slump

After tamping the mould is removed by lifting it slowly in a vertical direction. The decrease height of concrete in a mould is noted with scale which found to be 165mm for reference concrete and 60mm for bacterial concrete. The performance of slump cone test shows the fig.2

Fig-2: Slump Cone Test

5.2 Flow Table Test

Flow table test is method to determine the consistence of fresh concrete. This test giving the ability of concrete to flow under the gravitational forces. The cone was placed on the flow table filled concrete with two layers. Each layer is tamped at 25 times. The performance of flow test on concrete shows the fig.3

Fig-3: Flow Table Test

The cone is lifted to measure the concrete flow. Flow percentage which is found to be 60% for bacterial concrete and 62% for bacterial concrete.

5.3 Compressive Strength Test

Compressive strength is the capacity of a material to withstand the axially directed pushing forces. When the limit of compressive strength is reached the brittle materials are crushed. The compressive test is used to determine the hardness of concrete. The compressive test of concrete specimen depends upon the cement, aggregate w/c ration, curing temperature and size of specimen. Performance of compressive strength shows the fig.4

Fig-4: Compressive Test on Cube

The cube specimen of the size 15�5�5cm. the maximum load recorded and the type of failure noted down. Reference concrete, bacteria concentration of10^5, 10^6 and10^7 cells/ml were taken each time after curing interval of 7 days, 14 days and 28 days.

Compressive strength = P/A N/mm^2

P= ultimate load

A= cross sectional area

5.4 Split Tensile Test

Split tensile strength is one of the basic and important property of concrete. It is used to measure the tensile strength of concrete. Cylinder specimen of the size height 30cm, diameter 15cm. the maximum load recorded and the type of failure note down. The performance of split tensile test shows fig.5

Fig-5: Split Tensile Test on Cylinder

Split tensile strength= $2P\backslash\pi DL$

P= maximum applied load

D=diameter

L=length

6. RESULTS

Test Performed:

- Compressive test
- Split tensile test

6.1 Compressive Strength Test

Concrete cubes of the size 15×15×15 cm were tested for crushing strength. The cubes are tested by compression testing machine after 7days, 14 days and 28 days curing. Generally the sample is placed central on the base plate machine and the load have be apply to gradually.

Table-1: Compressive Test Result

Concrete type	7 Days strength (N/mm^2)	14 Days strength (N/mm^2)	28 Days strength (N/mm^2)
Reference Concrete	16.56	18.31	23.34
10^5concentration	18.21	21.36	24.46
10^6concentration	19.14	25.7	27.16
10^7concentration	16.98	22.9	24.5

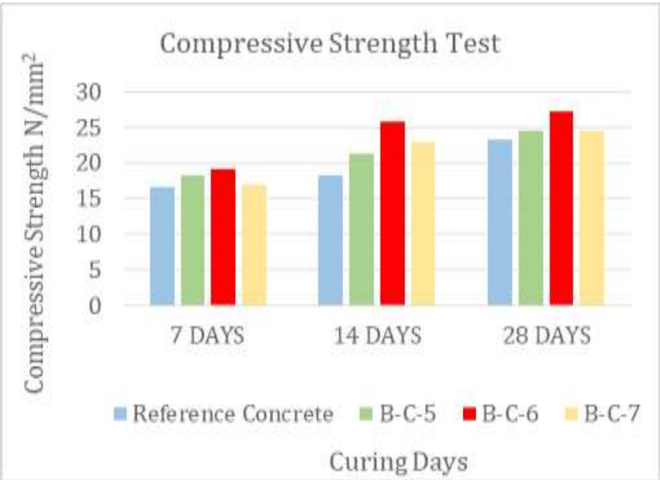

Fig-6: Comparison of Compressive strength between Reference concrete and Bacterial Concrete

6.2 Split Tensile Strength

Concrete cylinder of size height 30cm, diameter 15cm. the cylinders are tested by the compression testing machine after 14 days, 28 days curing.

Load is applied uniaxial tension to concrete specimen. The test was used to measure a tensile strength of concrete. In this method tensile strength of concrete a cylindrical specimen splits vertical diameter. The tensile strength of concrete is found to be lower than that of the compressive strength of concrete. Splitting test is commonly used to measure the tensile strength.

Table-2: Split Tensile Test Result

Concrete type	14 Days strength (N/mm^2)	28 Days strength (N/mm^2)
Reference concrete	1.75	2.4
10^5concentration	1.80	2.369
10^6concentration	2.05	2.998
10^7concentration	1.88	2.086

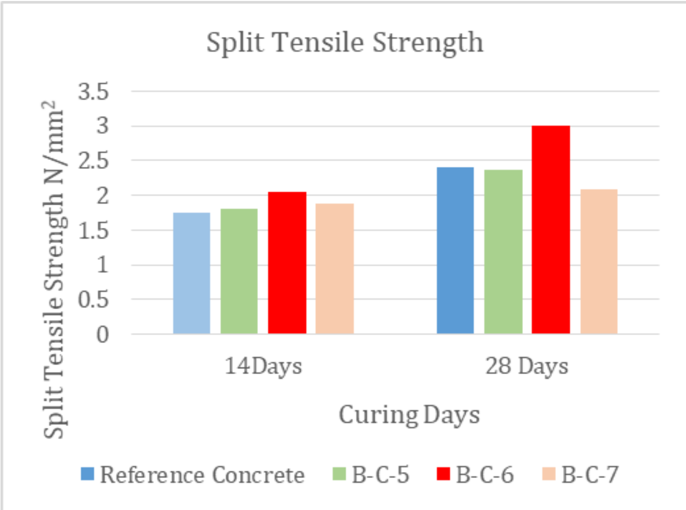

Fig-7: Comparison of Split Tensile Strength between Reference concrete and Bacterial Concrete

7. CONCLUSION

Introducing the bacteria in the concrete makes it beneficial improvement the properties of the concrete more than conventional concrete. Bacillus bacteria repair the cracks by introducing the calcium carbonate precipitation which block the cracks. Bacteria improve the property of concrete and also increase the strength of concrete. The 7days, 14days and 28days strength of bacterial concrete is more than Reference concrete. The optimum concentration of cells found to be 10^6 cells/ml from the experiment results.

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