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Exploratory Research Using Bacteria as a Self-Healing Concrete: Review

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Abstract-This study illustrates that the utilization of microorganisms-Bacillus Subtlis is productive for development of a tough framework and put forth a concentrated effort mending concrete as strategy for break control to upgrade administration life in solid structure. Crack formation is very common occurrence in concrete structure which allows the water and different type of chemical into the concrete through the cracks and reduces their durability, strength and which also affect the reinforcement when it comes in contact with water, carbon-di-oxide and other chemicals. It is expensive to maintain or repair concrete-based structures every now and again. For resolving this issue self-healing concrete mechanism is introduced in the concrete which helps to repair the cracks by producing calcium carbonate crystals which close up the micro cracks and pores in the concrete The investigation illustrates that there is a remarkable increase in the quality of cement added with bacteria or bacterial concrete contrasted with conventional concrete.

Keywords-Concrete, Self-healing, Conventional concrete, Bacterial concrete.

I. INTRODUCTION

Concrete is the most frequently used building material which is recyclable. Concrete in structures is used to resist the compression stresses and reinforcements are used to resist the tensile stresses in concrete. Concrete does not require excess water to achieve maximum strength. But an excess quantity of concrete used in residential work has too much water added to the concrete on the work site. This water is added to make the concrete simple to install. This excess water also minimizes the strength of the concrete. Shrinkage is a main reason of cracking.

As concrete hardens and dries it gets shrink. This is the reason of excess water evaporation. The wetter is the concrete mix, the greater is the shrinkage. While larger cracks can potentially hamper structures integrity and therefore it requires repair action while smaller cracks typically with a crack width smaller than 0.2 mm are generally considered unproblematic.

Bacterial Cement is the new innovative procedure in which the microscopic microorganism is added to blend with cement, fine and coarse aggregates, water and some selected chemicals like Bacillus Subtilis and Bacillus pasteurii which increases the strength and acts as an outstanding self-healing agent.

These bacteria can be used to improve the compressive strength of a concrete. It can lie dormant within the concrete for decades and has the ability to pass the high pH of concrete. When there are cracks on the concrete, water sprayed on it or the moisture in the air triggers the bacteria to germinate and form limestone and seal the cracks.

It is observed that the concrete-healing happen in 3 to 4 weeks and the bacteria can seal up to 0.8mm wide. Bacillus for the production of calcium carbonate minerals. The digestion of this family includes the enzymatic hydrolysis of urea to smelling salts and carbon dioxide.

The response additionally makes an expansion of pH from nonpartisan basic conditions shaping bicarbonate and carbonate particles which hasten with the calcium particles in solid to frame calcium carbonate minerals. The formation of calcium carbonate mends the pores and splits in the solid. Bacterial concrete is an example of connecting nature to construction.

Fig.1 (a) Bacillus Subtilis on a Nutrient Agar.

Fig. 2 (b) Bacillus Subtilis in liquid form

Fig. 3 (c) Bacillus Subtilis
Fig 1.

II. METHODOLOGY

This study aims to analyse and evaluate the effectiveness of bacteria Bacillus Subtilis in compressive, flexural, split tensile, water absorption, also, how effective it is to seal cracks. Preparation of Bacteria (Sub-Culturing) Microbiological culture made by exchanging a few cells from past culture to crisp development medium. Sub-refined is utilized to drag out the life and additionally grow the quantity of cells of microorganisms in a culture.

Fig 2. Ingredients in making culture Medium (Bacteria's Nutrient Broth).

The ingredients are urea, Bacillus Subtilis, sodium bicarbonate (NaHCo3), ammonium carbonate (NH4Cl), calcium chloride dehydrate (CaCl2) and nutrient broth. These are the nutrients needed for the bacteria to survive and it also serves as its food or nutrient. The researchers used autoclave machine, test tubes, Erlenmeyer flasks, inoculating wire and biosafety cabinet.

1. Process of Sub-culturing:

The bacteria are cultured in mass on culture medium. The culture is made using nutrient broth which consists of Urea Broth, Sodium Bicarbonate, Ammonium Chloride and Calcium Chloride Dehydrate. The culture medium is sterilized in autoclave at 121℃ at pressure of 151ps.

- Dilute the 2.10 grams of nutrient broth, 1.50 grams of sodium bicarbonate, 7 grams of ammonium carbonate,7 grams of urea broth and 5 grams of calcium chloridedehydrate in 1 litre of water. Stir well.
- Sterilize the apparatus needed for the inducing of Bacillus Subtilis bacteria to reduce contamination.
- Sterilize the mixed nutrients on the autoclave machine at a pressure of 151 PS (pressurized steam) for 30 minutes.
- Inoculating needle will be used to extract a colony of bacteria placed in agar plates/ test tubes. At the biosafety hood, ready the sterilized nutrient broth and the Bacillus Subtilis bacteria. Use the inoculating wire, be sure that the loop is red-hot.
- Test tube openings are run through the heat to make sure that there are no other contaminants in the tube entrance.
- Close the test tubes tightly with cotton to reduce contamination.
- Put the test tubes and the Erlenmeyer flasks with Bacillus Subtilis bacteria at the incubator for 18 to 24 hours at room temperature for it to grow.

(a) (b)

Fig 3. Inducing of Bacillus Subtilis on the Sterilized Nutrient Broth.

2. Mixing of Conventional Concrete:

The researchers opted to use the concrete mixture 1:2 1/2:5:0.45. Which is 1 cement bag, 2 and a half bags of sand, 5 bags of coarse aggregates and 0.45 for the water-cement ratio.

- Mix the cement, sand and coarse aggregate manuallyon a platform.
- Add water and mix until the desired mixture wasattained.
- Place it in the mould, fill it in three layers.
- Compact each layer with 25 strokes using a tampingrod and smoothen it with a trowel.
- Level the top surface and smoothen it with a trowel.

III. RESULTS

1. Preparation of Specimen:

Standard grade concrete design mix is made withcylinders (6”x12”) and (3”x3”), rectangular molds (21”x6”x 6”) and cubes (6”x6”. These specimens are casted with bacteria and without bacteria. Hardened and demolded after 24 hours.

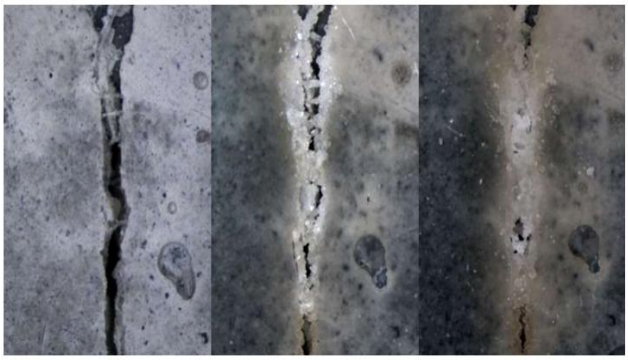

Fig 4. Rectangular molds.

2. Sealing of Cracks due to Calcium Carbonate Precipitation:

Bacillus Subtilis has been used to precipitate calcium carbonate in order to seal cracks. Microbiologically Induced Calcite Precipitation or MICP is a phenomenon concerning the urease enzyme and can be effectively used wherein the bacteria is mixed with nutrient broth to create conditions where they can seal cracks and pores. Calcite deposits were observed to be effective at sealing cracks and consolidating the surface finish of the concrete.

This process can be considered as an organic remediation in healing concrete and that can be used in other industrial applications. Calcite precipitation is able to reduce moisture ingress. Theconditions for the crack to heal is when the concrete or the crack is in contact with moisture that is the time the bacteria will activate or will self-heal.

IV. OBSERVATIONS

Table 1. Compressive Strength Test

28 Days Average Compressive Strength Test Result of Conventional and BacterialSample	
Conventional	12.49
Bacterial	19.26

Table 2. Split Tensile Strength Test

28 Days Average Split Tensile Strength Test Result of Conventional and BacterialSample	
Conventional	6.34
Bacterial	9.36

Table 3.Flexural StrengthTest

28DaysAverageFlexural StrengthTestResultof ConventionalandBacterialSample	
Conventional	8.47
Bacterial	10.33

Table-4Water Absorption Test

28 Days Average Water Absorption Test Result of Conventional and BacterialSample	
ConventionalConcrete	
Sample	WaterAbsorption
1	4.86
2	4.73
3	3.66
Average	4.42
BacterialConcrete	
Sample	WaterAbsorption
1	2.13
2	3.16
3	2.32
Average	2.54

V. DISCUSSION

The researchers conclude that the concrete added with30 ml of liquid form of Bacillus Subtilis can withstandthe compressive, flexural and split tensile strength test.The water absorption of bacterial concrete has lower rate compared on conventional concrete, this is because of the microorganism’s actuated development of calcium carbonate in the voids in concrete, leading to a lesser void and hence a lesser permeability.

Bacillus Subtilis can be produced in the laboratory and it is proven to be safe because its biosafety level isonly 1 and it is a bacterium that can be found in soil.The compressive strength test, the researchers found out that there is increase in strength compared to conventional concrete and its highest percentage increase is 35.15%.

In split tensile strength test, the bacterial concrete withcell concentration of 105 gives the optimum result which is proven by 12.01% in 7 days, 28.71% in 14 days and 32.26% in 28 days of curing.

In flexural strength test, the researchers observed that among the three (3) curing days, the 7 days have an increase of 19.73%, the 28 days have an increase of 18.01%, while the 14 days have an increase of 13.98%. Its average increase is 17.24%.7, 14- and 28-days test results shows that absorption rate in concrete with bacteria lead to the reduction in water absorption compared with conventional concrete.

VI. CONCLUSION

The trial consider demonstrates the expansion of microscopic organisms that the addition of bacterial Solution-Bacillus Subtilis in concrete shows improvements in different properties of concrete as far as compressivequality test, split tensile strength test, water absorption test, and flexural quality test.

As the microbes can deliver in the research centre, it could be ended up being exceptionally protected and doesn't give treat to human health. The examination achieved utilization of microscopic organisms in cement enhances its strength and durability hence using this type of bacteria for self-healing mechanism in concrete can produce cost effective strong or durable structure.

VII. RECOMMENDATION

With the data and computations presented in this study, the researchers analyzed and studied the performance ofbacteria Bacillus Subtilis in concrete and recommend the following for better production of concrete mixtures.

- The use of other method in applying bacteria inconcrete like microencapsulation system.
- The use of different ureolytic endospore-forming bacteria such as E-Colii, SporosarcinaPasteurii, Pseudoformis, and Shewanella Species.
- Considering other brands of cement as it may vary in some properties such as strength and durability.
- For future work, the researchers would also recommend to test other parameters such as porosity, acid resistance and chloride resistance.
- The researchers would also recommend to check if paint can affect the healing.

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