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Design of Rigid Pavement Using Bacterial Concrete

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Abstract — Because of its poor stiffness, concrete is a brittle substance that is prone to shattering. Crack repairs are not only costly and time demanding, but they also harm the environment. Designing a new concrete substance that self-repairs cracks might improve its long-term viability. The cultivation of bacteria is the initial step in the inquiry. The strength parameters of bacterial concrete are studied in the second part of the inquiry. The researchers are also looking into the strength characteristics of cement mortar as a result of bacterial induction, as well as the compressive and split tensile strengths of concrete.

Keywords— Bacterial Concrete, Durability, Compressive Strength.

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I. INTRODUCTION

Concrete is the most commonly utilized building material. Despite its structural adaptability, it is known to have several drawbacks. It is brittle in tension, has low ductility, and is susceptible to cracking. Various adjustments have been made from time to time to alleviate the shortcomings of cement concrete based on ongoing research conducted around the world. With industrial materials such as fly ash, blast furnace slag, silica fume, and metakaolin, ongoing research in the field of concrete technology has led to the development of special concrete that considers the speed of construction, the strength of concrete, the durability of concrete, and the environmental friendliness of concrete.

Microbial mineral precipitation arising from metabolic activities of beneficial bacteria in concrete has recently been discovered to improve the overall behavior of concrete. The process might take place inside or outside the microbial cell, or even within the concrete itself. Bacterial activities frequently cause a change in solution chemistry, resulting in oversaturation and mineral precipitation. The application of these Biological concepts to concrete could lead to the development of a novel material known as Bacterial Concrete.

II. OBJECTIVES

This research focused on the autogenous self-healing of cementitious materials. Due to a lack of confirmed, indisputable, fully understood governing mechanism, the efficiency of the autogenous self-healing process still brings concerns and does not ensure successful full-scale applications. Therefore, the objectives of this study were as follows:

1. To understand the mechanisms behind the autogenous self-healing of concrete,

2. To use that knowledge to fully control it

3. To develop/design a cementitious material (or a group of materials) with a specified chemical composition that may self-repair both internally and externally under certain environmental circumstances.

III. LIMITATIONS

The following limitations of the current study can be listed:

The study was designed to be a preliminary investigation of numerous elements impacting self-healing to achieve effective self-healing. As a result, each experiment's number of specimens representing distinct mixes is limited. The analyses' findings are intended to be interpreted qualitatively rather than quantitatively at this time.

To thoroughly confirm the chemical composition of the precipitated self-healing phases, an examination of the mineralogical composition, such as X-ray powder diffraction, should be done in addition to the elemental analysis (XRD). Larger specimens should be tested, resulting in a greater number of studied phases.

IV. EXPERIMENTAL SETUP

The present work is divided into two phases, they are

- PHASE – I: Culture of Bacteria
- PHASE – II: To study the strength behavior of concrete
- PHASE – I: Culture of Bacteria

Culture media

Bacteria were maintained on nutrient agar slants constantly. It forms dry white colonies on nutrient agar. At the time of casting a single colony of the culture is inoculated into the nutrient broth of 25 ml in a 100ml conical flask. Growth conditions are maintained at 37degree Celsius temperature and placed in a 125 rpm orbital shaker

The medium composition required for growth of culture is peptone: 5g/lit, NaCl: 5g/lit, yeast extract: 3g/lit

- PHASE – II:
- To Study the Strength of Cement Mortar

The investigation is carried out to study the strength of cement mortar. A total of 12 sets of cubes are cast and tested to study the compressive strength under axial compression with bacteria of different concentrations and without bacteria. Tests are conducted for compressive strength on cement mortar specimens on completion of 3 days, 7 days, and 28days.

To study the compressive strength and split tensile strength of concrete

The investigation is carried out to study the compressive strength and split tensile strength of concrete of ordinary grade concrete (M20) A total of 12 sets of cubes are cast with the optimized concentration of bacteria and without bacteria and tested to study the compressive strength under axial compression. Concrete cubes of 150 mm x 150 mm x 150 mm are cast. Tests are conducted on concrete specimens for compressive strength on completion of 7 days, 14 days, 28days, a total of 9 sets of cylinders are cast and tested to study the split tensile strength. Tests are conducted for split tensile strength on completion of 28days.

- Materials Used and Their Properties
- Cement

Ordinary Portland cement of 53 grades, available in the local market is used in the investigation. The cement used for all tests is from the same batch. The cement used has been tested for various properties as per IS: 4031-1988 and found to be conforming to various specifications of IS: 12269-1987.

- Ennore Sand
- Ennore sand as per BIS specifications is used to find the compressive strength of cement mortar cubes.
- Coarse Aggregate

Crushed angular granite from the local quarry is used as coarse aggregate. The cleaned coarse aggregate is chosen and tested for various properties such as specific gravity, fineness modulus, bulk modulus, etc. The physical characteristics are tested following IS: 2386 – 1963 and IS 383:2016

- Fine Aggregate

The locally available river sand is used as fine aggregate in the present investigation. The cleaned fine aggregate is chosen and tested for various properties such as specific gravity, fineness modulus, bulk modulus, etc. following IS: 2386-1963 and IS 383:2016

- Water

Water used for mixing and curing is fresh potable water, conforming to IS 3025 – 1964 part 22, part 23, and IS 456 – 2000.

- Bacteria

Bacillus subtilis, a laboratory cultured bacterium is used.

- Mix Design

Mix design can be defined as the process of selecting suitable ingredients of concrete such as cement, aggregates, water and determining their relative proportions with the object of producing concrete of required minimum strength, workability, and durability as economically as possible. The purpose of designing can be seen from the above definitions, as two-fold. The first objective is to achieve the stipulated minimum strength and durability. The second objective is to make the concrete most economically. In this Project M20 grade of Concrete is used with proportion 1:1.18:3.5

- Creation of cracks and treatment process

The creation of cracks was done by a compressive testing machine (CTM). The samples failed by CTM were further used to study the self-healing process. Before doing any treatment crack width was measured (range of 0.2- 1.2mm). treatment of these blocks was done under three different exposure conditions, the cracked cubes were placed under three exposures a)urea (CH_4 N_2 O) (20gm/L) + calcium chloride ($CaCl_2$) (49gm/L) solution b) water and c) air

V. TEST RESULTS

The investigation is carried out to study the strength of cement mortar cubes. The results of the cement mortar strengths at 3 days, 7 days, and 28 days at various cell concentrations were tabulated in table no 1

Table 1. Effect of the Bacillus subtilis Bacteria addition on cement mortar strength.

Cell concentration /ml of mixing water	avg. compressive strength of mortar in MPA					
	3 days	% increase	7 days	% increase	28 days	% increase
Nil (control)	22.20	-	36.54	-	53.50	-
10^4	22.71	2.29	40.14	9.85	57.02	6.57
10^5	24.77	11.57	42.51	16	60.59	13.25
10^6	23.40	5.40	39.04	6.84	56.11	4.87
10^7	22.50	1.35	37.06	1.42	54.16	1.23

To study the compressive strength and split tensile strength of concrete.

The investigation is carried out to study the compressive strength and split tensile strength of concrete. The results of the compressive strength at 7 days, 14 days, 28 days for ordinary grade concrete are tabulated in table no 2

Table 2. Effect of the Bacillus subtilis, Bacteria addition on ordinary (M20) grade concrete

Age (No. of days)	Compressive Strength	
	Conventional Concrete, MPa	Bacterial Concrete, MPa
7	16.36	17.05
14	18.11	23.70
28	25.10	28.50

The investigation is carried out to study the split tensile strength of concrete. The results of the split tensile strength of concrete at 28 days for ordinary grade concrete are tabulated in table no 3.

Table no 3. Effect of the Bacillus subtilis Bacteria addition on Split Tensile Strength on ordinary grade concrete

Age (No. of days)	split tensile Strength	
	Conventional Concrete, MPa	Bacterial Concrete, MPa
28	3.40	3.75

VI. DISCUSSION OF TEST RESULTS

The results of the experimental investigations on conventional and bacterial concrete are discussed in the following sections.

To Study the Strength of Cement Mortar

The compressive strength at 3 days, 7 days, and 28 days for different cell concentrations are given in Table 1. It is observed that the compressive strength of cement mortar showed a significant increase by 13.25% for cell concentrations of 10^5 cells per ml of mixing water. So, for further investigation bacteria with a cell concentration of 10^5 cells per ml of mixing water is used. It is noted that pores are partially filled up by material growth with the addition of bacteria. Reduction in pore due to such material growth will increase the material strength.

To Study the Compressive Strength and Split Tensile Strength of Concrete

In ordinary grade concrete, the compressive strength of concrete at 7 days, 14 days; 28 days are given in table 2. It is observed that with the addition of bacteria the compressive strength of concrete showed a significant increase by 04.21% at 28 days. The percentage of compressive strength improvement is in the order of 04.21% to 13.54% as the age of concrete varies.

In ordinary grade concrete, the Split Tensile Strength on standard cylindrical specimens at 28 days is given in table 3. It is observed that with the addition of bacteria there is a significant increase in the tensile strength by 10.29% at 28 days.

VII. CONCLUSIONS

The following conclusions are drawn from the detailed experimental investigations conducted on the behavior of ordinary grade conventional and bacterial concrete.

1. Bacillus subtilis can be produced in the laboratory which is proved to be safe and cost-effective.

2. The addition of Bacillus subtilis bacteria improves the compressive strength of cement mortar.

3. At a particular cell concentration i.e. at 105cells/ml of mixing water the compressive strength of cement mortar is maximum.

4. The addition of Bacillus subtilis bacteria improves the hydrated structure of cement mortar.

5. In ordinary grade concrete, the compressive strength is increased by 13.93% at 28 days

by the addition of Bacillus subtilis bacteria when compared to conventional concrete.

6. In ordinary grade concrete, the split tensile strength is increased up to 12.60% at 28 days by the addition of Bacillus subtilis bacteria when compared to conventional concrete.

The self-healing process is successfully done through bacterial concrete. Bio concrete technology has been proved to be better than any other conventional technique, as it is eco-friendly and easily available in laboratories. The concrete technology will soon be using bacterial concrete as an alternative to conventional concrete. Bacterial concrete will make a new revolution in the construction industry in the upcoming years. Using this type of bacterial concrete may increase the durability of structures. Also during this process consumption of carbon dioxide (Co2) reduces the level of greenhouse gas emission in the atmosphere.

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