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Evaluation of Bacillus Subtilis Bacterial Concrete with Normal Concrete

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Abstract: *Concrete is a most commonly used material in the field of construction with high compressive strength but with low tensile strength. The advantage of concrete is that it is easily available, less costly and convenient to cast. Concrete structures are very susceptible to cracking which causes chemicals and water to penetrate in the concrete that degrades the concrete strength, thereby, decreasing the performance of the structure. To solve this problem, eco-friendly concrete is developed. This concrete is formed by inserting bacteria into normal concrete. The grown bacteria are added to the M-25 concrete. The main motive of this research work is to measure the performance of the concrete by the microbiologically induced unique growth or filler. One such contemplation has lead to the improvement of a very unique concrete known as Bacterial Concrete where bacteria is induced in the cement and concrete to heal up the cracks. In this research, numbers of tests are performed on normal concrete and bacterial concrete for 7, 14, and 28 days. To determine the accuracy of the bacterial concrete, parameters such as water absorption, compressive strength, Ultrasonic pulse velocity test (UPVT), Flexural test and slump test are measured.*

Keywords: *M-25 concrete, bacterial concrete, UPVT, compressive strength, water absorption, Flexural strength.*

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I. Introduction

Cement concrete is the most commonly used construction material in the field of civil engineering. The cement concrete is used due to its various advantages such as low cost of material along with low cost of maintenance. Despite its advantages, concrete has some disadvantages such as weak tensile strength that results in cracks found in the building structure [1]. The crack appears during the concrete process that decreases the strength of the buildings. Based on continuous research conducted on a global scale, various modifications are made from time to time to overcome the defects of cement concrete [2]. The ongoing research in the field of concrete technology has led to the development of special concrete, taking into account the speed of construction, strength of concrete, durability of concrete as well as industrial materials such as fly ash, blast furnace slag and silica fume, recently discovered to be beneficial in concrete[3]. The microbial mineral produced by the metabolic activity of microorganisms improves the overall behaviour of the concrete. This process can take place inside or outside the microbial cells or even at a certain distance inside the concrete [4]. Bacterial activity usually initiates chemical changes in the solution, leading to super-saturation and mineral precipitation. The use of these bio-mineral concepts in concrete leads to possible creation of new materials known as “bacterial concrete” [5].

1.1 Bacteria concrete

Bacteria is used as a curing agent in concrete which is suitable for this research work, i.e. they should be capable of long-term effective fracture sealing, preferably throughout the life of the building. The main mechanism for the healing of bacterial cracks is that the bacteria itself acts primarily as a catalyst and converts the precursor compounds into suitable filler materials [6]. The latterly generated compounds like calcium carbonate-based mineral deposits should act as a kind of bio-cement to effectively seal latterly created cracks. Therefore, for effective self-repair, bacterial and bio-cement forerunner compounds should be combined into the material matrix [7].

1.1.1 Bacteria classification

The bacteria are usually classified into three groups; depending on Shape, Gram Stain and on Oxygen demand as shown in figure 1.

i. Allocation on the basis of shape

Depending on the shape, the bacteria are sorted into Bacillli (road shaped bacteria), Cocci (Sphere shaped) and the Spirilla (spiral -shaped bacteria) [8]. In this research, Bacilli are used for bacteria generation.

ii. Allocation on the basis of Gram strain

On the basis of gram strain, the bacteria can be classified into positive and negative Gram. In this method, the operator is employed to join to the bacteria's cell wall.

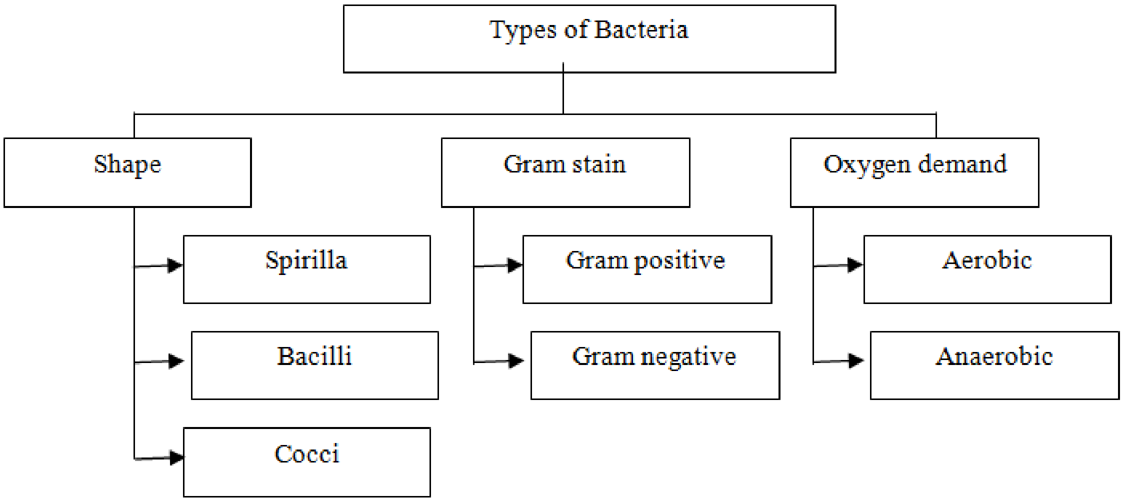

Fig.1: Classification of Bacteria

iii. Allocation on the basis of oxygen demand

The allocation depends upon the constraints of oxygen for the bacterium survival. Oxygen demand can be classified into two types; Aerobic and Anaerobic. Aerobic uses molecular oxygen as incurable electron acceptor whereas anaerobic bacteria molecular oxygen does not be used as a terminal electron adherent.

In this research work, 10ml and 15 ml/m3 bacteria are added to the concrete that forms "calcium Nutrient" and known as "Calcium Lactate". The experiment is carried out in "Bacterial concrete in Spectro testing lab"[9].

1.1.2 Chemical Process of Self-Healing or Bacterial Concrete

When water is added to the un-hydrated calcium in concrete, the bacteria forms calcium hydroxide that behaves as a catalyst [10]. The produced calcium hydroxide comes into contact with the environment CO_2 (Carbon dioxide) that results in the formation of limestone and water [11]. This additional water generated by the equation continues the chemical reaction [12].

$$CaO + H_2O \rightarrow Ca(OH)_2 \quad (1)$$

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O \quad (2)$$

The limestone then solidifies itself and blocks the cracks in the concrete [13].

Fig.2: (a) Formation of Bacteria on agar plate (b) Bacteria before mixing to the concrete

In the proposed work, the bacteria have been formed on agar plate in the natural environment. 100 ml flask has been taken in which 50 ml of basic solution (Alkaline) is added. The solution is kept in temperature ranges from 25<temperature<37 degree Celsius. The mix of M-25 was prepared with cement, fine aggregate and course aggregate in the ratio of 1:1:2 respectively.

II. Methodology

The procedure undertaken to simulate the work is described in this section. Initially, the existing work of the bacterial concrete is performed by various researches being studied. The bacteria are prepared in agar plate under natural environment. In 100ml of the flask, 50 ml basic solution of Alkaline is added and the grown condition is maintained between 25 degrees Celsius and 37 degree Celsius. The generated bacteria are mixed into the water. Then, different load of 386.2 KN, 456.1 KN and 610 KN is applied on different cubes. At last, the parameters are measured to observe the efficiency of the bio-concrete material.

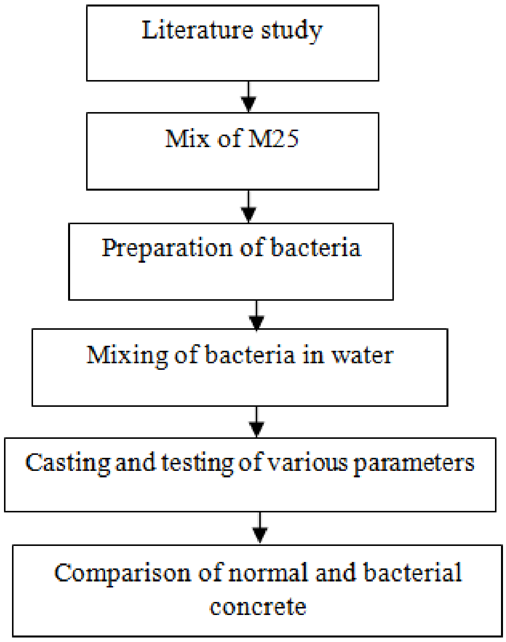

Fig.3: Flow of work

III. Experiment and analysis

In this section, the results obtained for measuring the compressive strength (N/mm2), flexible strength test with varied load, for normal and bacterial concrete are discussed. The test is conducted for 14 to 28 days. The test has been conducted on normal as well as on bacterial concrete. The comparison between the performance of normal and bacterial concrete have been drawn to analyze the effectiveness of the concrete.

Initially, Slump test has been performed for both normal and bacterial concrete M-25. This test is performed to determine the workability of the concrete that represents the strength of the material. Workability is the characteristic of concrete that describes the ease with which the concrete can be mixed which again depends upon the amount of water, aggregate grade. In this research work, the slump test value ranges from 55 to 78 mm.

Table 2: Water absorption test

Types of concrete	Observed value (%)
Normal concrete	3.61
Bacterial concrete	3.54

Water absorption experiment has been performed at a temperature of almost less than 37 degree Celsius and more than 25 degree Celsius for 7, 14 and 28 days. The observed value of water absorption measured in percentage (%) for both tests are shown in table 2.

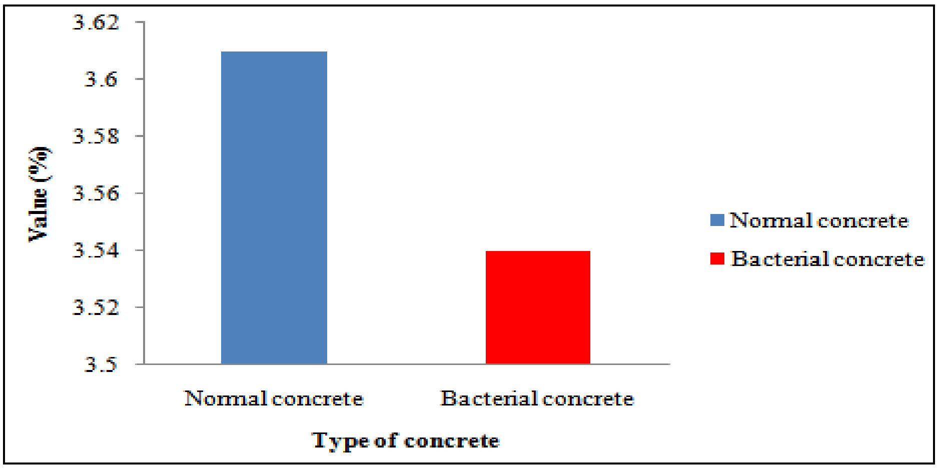

Fig.4: Comparison of water absorption values

The above graph displayed in figure 4 represents the Water absorption values measured for normal concrete and for the Bacterial concrete. The test has been performed in ASTM-C-1585. From the above graph, it has been observed that when Bacteria are added to the concrete, the water absorbing capability increases. In this test, the water absorbing capability of the bacterial concrete has been decreased by 1.93 %.

Table 3: Concrete cubes test (M-25) Mix compressive strength test

Number of days	Normal concrete	Bacterial concrete
	Compressive strength (N/mm^2)	
7	17.1	17.9
14	22.6	25.2
28	25.8	27.9

The above table represents the M-25 concrete cubes test for determining the compressive strength of the concrete. The test has been performed for 7, 14 and 28 days. Three cubes with varying weight (7.875 Kg, 7.975 Kg and 7.742 Kg) have been considered. The three cubes are construed on the same date, 15 March, 2018 but tested at different dates. Different loads 386.2 KiloNewtons (KN), 456.1KN, 610 KN for three cubes. From the above table, it is concluded that in case of bacterial concrete, the load on cube is directly proportional the compressive strength.

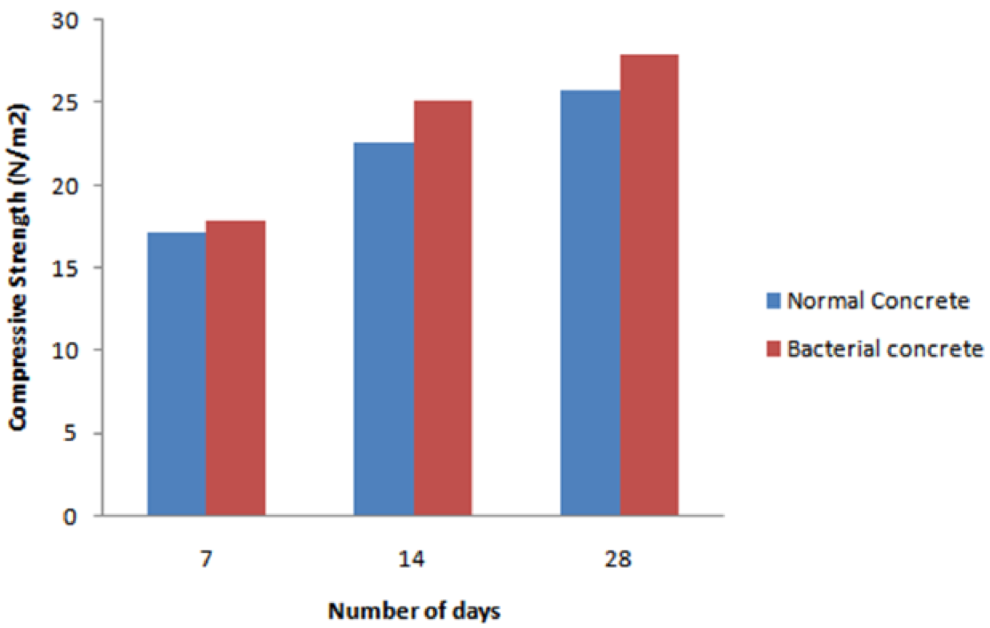

Fig.5: Compressive strength of the bacterial and normal concrete

The above graph represents the compressive strength measured for the different duration for normal M-25 cube and Bacterial concrete M-22. X-axis defines the number of days and Y- axis represents the compressive strength values observed for both normal and bacterial concrete. The blue line defines the compressive strength of Normal concrete and red bar represents the compressive strength values for bacterial concrete. The average value of compressive strength measured for normal concrete and bacterial concrete are 22.8 and 23.6 respectively. Thus, when bacteria added to the normal concrete, it heals date to date and reduces the lime stone that increases the compressive strength. In this research work, the compressive strength of the bacterial concrete has been increased by 3.51%.

Table 4: Ultrasonic pulse velocity test (UPVT)

Equipment make	Proceq concrete-UPVT	Test Frequency	54 KHz
Location	-	Ref, Calibration	Block 25.4 μs
Level	----	Transducer type & size	T/R 2"Ø
Material	Concrete cube	Surface condition	Smooth
Ref.code	IS-13311 (Part-1)	Couplant used	grease

Table 5: Observations of Ultrasonic pulse velocity test

Number of experiment	**Test location**	**Method**	**Ultrasonic pulse velocity (Km/sec)**	**Inference-IS 13311 (P-1) table-2 concrete quality grading**
1	Concrete Cube	Direct	4.4	Good

Table 6: Flexural strength test

Type of concrete	**Date of casting**	**Date of testing**	**Flexural strength test** (Mpa)
Normal	15.03.2018	13.04.2018	3.69
Bacteria	15.03.2018	13.04.2018	3.79

The above table defines the values of flexural strength measured for normal as well as bacterial concrete. The Flexural strength has been measured by Modulus of Rupture (MR) in psi (MPa). It measures the tensile strength of the concrete or slab to oppose failure in bending. The values observed for Flexrual strength are listed in table 5.

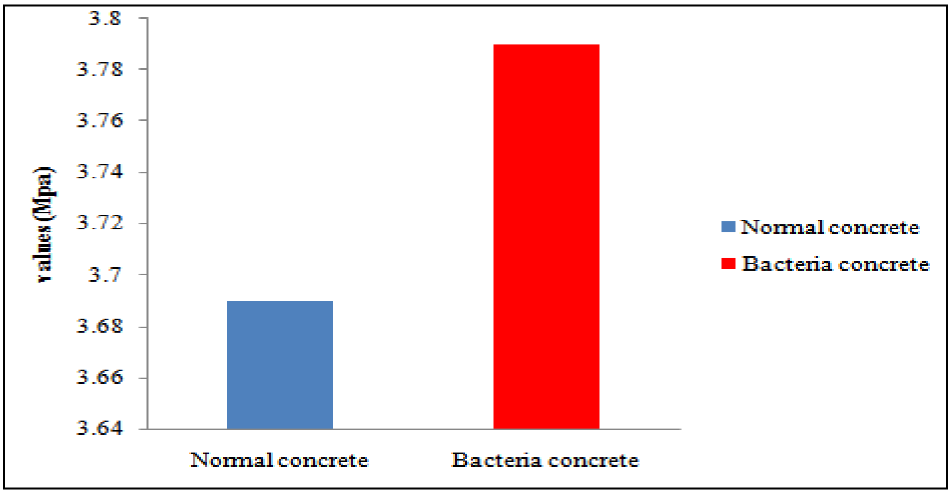

Fig.6: Flexural strength of Normal and bacterial concrete

The above graph defines the flexural strength measured after 28 days in the presence of 180 Kg/m load for both the concrete. The values measured for normal and bacterial concrete are represented by blue and red bar line. The percentage increase in the flexural strength from the normal concrete to the bacterial concrete is 2.71%.

IV. Conclusion

The test has been conducted for 7, 14, and 28 days for measuring various parameters such as water absorption, compressive strength test, UPVT, flexural strength test and slum test. Based on the experiments the following points are drawn:

i. The water absorbing capability of the bacterial concrete has been decreased by 1.93 % from normal concrete which is better for the construction, as the concrete absorbs less water, the probability of steel corrosion and the crack damage decreases and hence, the strength of the concrete increases.
ii. The compressive strength of the bacterial concrete has been increased from normal concrete by 3.51%.
iii. The percentage increase in the flexural strength from the normal concrete to the bacterial concrete is 2.71%. Thus, if we are using self-healing concrete, the failure in bending can be reduced and the tensile strength can be increased.
iv. The cracks with a size of 0.04mm to 0.09 mm are healing up easily.
v. No extra cost have been taken for preparing the concrete
vi. The design concrete is very beneficial when used in the temperature zone of 10 to 50 degree Celsius.

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