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Application of Biochemical in Civil Engineering

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Abstract-*The concrete is widely used construction material in the world. It has very good compressive strength but it is weak in tension. A typical durability-related phenomenon in many concrete constructions is crack formation. While larger cracks hamper structural integrity, also smaller sub-millimeter sized cracks may result in durability problems as particularly connected cracks increase matrix permeability. Ingress water and chemicals can cause premature matrix degradation and corrosion of embedded steel reinforcement. A novel strategy to restore or remediate such structures is bio mineralization of calcium carbonate using microbes. There are millions of bacteria available, and certain of it can be used in the construction industry for enhancement of the overall construction. Recently it is found that microbial mineral precipitation resulting from metabolic activities of favorable microorganisms in concrete improved the overall behavior of concrete. The Application of Specific Calcite Mineral Precipitating Bactria for Concrete Repair & Plugging Of voids And Cracks In Concrete Has Been Recently Investigated. The Possibilities Of Using Specific Bacillus Bacteria As Sustainable And Concrete Embedded Self-healing Agent Was Studied & Results From Current Studies Are Discussed.*

The present study investigated the effects of Bacillus Subtilis Jc3 on compressive strength and water-absorption tests. The results showed a 16% increase in compressive strength of cement concrete with the addition of bacterial cells. Treated cubes absorbed three times less water than control cubes as a result of microbial calcite deposition. Different proportions 10^5,10^6,10^7,10^8 *and* 10^9 *cells/ml concentration can be added but by studying of research paper we adopt optimum concentration* 10^7 *cells/ml in concrete to check the compressive strength and water-absorption tests.*

Keywords: *"Bacterial Concrete", "Calcite Precipitation", "Bacillius Subtilis", "Self Healing Concrete", "Crack Mechanisam"*

I. INTRODUCTION

Concrete is a vital building material that is an absolutely essential component of public infrastructure and most buildings. It is most effective when reinforced by steel rebar, mainly because its tensile strength without reinforcement is considerably low relative to its compressive strength. It is also a very brittle material with low tolerance for strain, so it is commonly expected to crack with time. These cracks, while not compromising structural integrity immediately, do expose the steel reinforcement to the elements, leading to corrosion which heightens maintenance costs and compromises structural integrity over long periods of time. That being said, concrete is a high maintenance material. It cracks and suffers serious wear and tear over the decades of its expected term of service. It is not flexible and cannot handle significant amounts of strain. Self-healing concrete in general seeks to rectify these flaws in order to extend the service life of any given concrete structure.

A. Classification of bacteria

Bacteria is generally classified in three category Basis on Shape, Basis on Gram Stain and Basis on Oxygen Demand which shown in Fig. 2 and sub Types of each category also can be shown in Fig. 3, Fig. 4, and Fig. 5.

A1. Classification Base on the Shape of Bacteria

Bacteria are usually classified on the basis of their shapes. Broadly, they can be divided into road shaped bacteria (bacilli), sphere shaped bacteria (cocci) and spiral shaped bacteria (spirals).

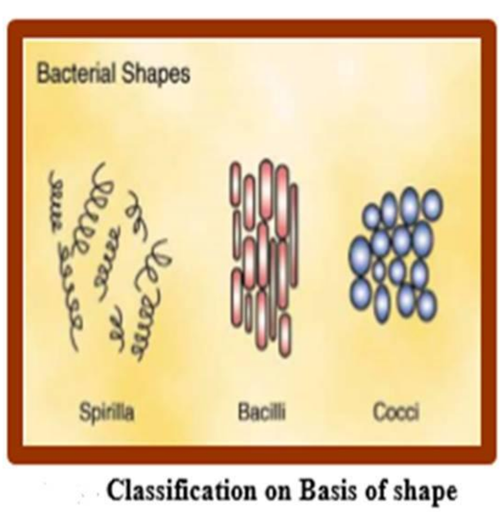

Fig 1 Classification on basis of shape

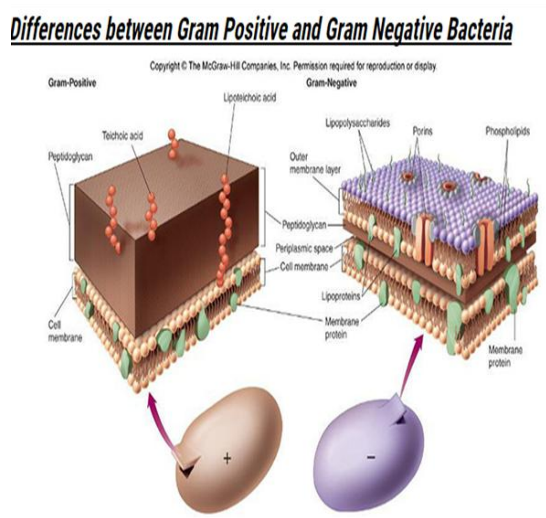

Fig. 2 Differences Between Gram Positive And Gram Negative Bacteria

A2. Classification On The Basis of Gram Strain

This classification is based on the results of gram staining method, in which an agent is used to bind to the cell wall of the bacteria; they are gram positive and gram negative.

A3. Classification On The Besis Of Oxygen Reqiurment

This classification is based on the requirement of oxygen for the survival of the bacterium. They are aerobic and anaerobic.

B. Various Bacteria Used In The Concrete Are

1. Bacillius Pasteurii
2. Bacillius Sphaericus
3. Escherichia Coli
4. Bacillius Subtilis

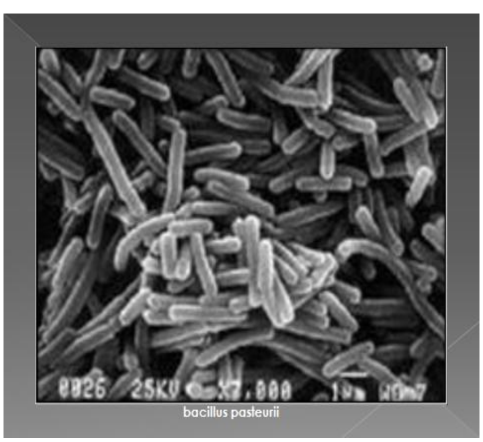

Fig 3. Bacillus pasteurii

Fig 4. Bacillus Sphaericus

Fig 5. E.coil

Fig 6. Bacillus Subtillis

C. Bacillius Subitils Jc3

We can developed bacterial concrete by using different kind of bacteria for an example bacillius pasteurii, bacillius sphaericus, e.coli etc. In the present work an attempt was made by using the bacteria bacillius subtilis strain number jc3. The main advantage of embedding bacteria in the concrete is that it can constantly precipitate calcite. This phenomenon is called microbiologically induced calcite precipitation (MICP). Calcium carbonate precipitation, a widespread phenomenon among bacteria, has been investigated due to its wide range of scientific and technological implications. Bacillus subtilis jc3 is a laboratory cultured soil bacterium and its effects on the strength and durability is studied here.

D. Maintenance Of Stock Culture

Stock culture of bacillus subtilis jc3 are maintained on nutrient agar slants. Culture is streaked on agar slants with and inoculating loop and thus slants are incubated at 37° c, after 2-3 days of growth slants culture are preserved under refrigeration at 4°c temperature until further use. Subculturing can be carried out for every 90 days. Contamination from other bacteria is checked periodically by streaking on nutrient agar plates.

Fig.7 Slant of bacillius subtilis bacteria and nicrome wire

II. Materials & Methodology

A. Microorganisms

Bacteria species which called Bacillius Subtilis strain number jc3, obtained from National Chemical Laboratory, Pune, India, was used in this study. The aerobic organisms is a moderately alkalophilic (growth optimum pH 9.25) and it was shown that sufficient activity for biocementation could be cultivated in non sterile conditions with a minimum of upstream and downstream processing. Bacillius Subtilis, a common bacterium naturally occurring in the subsurface, is such an aerobic microorganism. In addition, cells of Bacillius Subtilis do not aggregate; this ensures a high cell surface to volume ratio, a condition that is essential for efficient cementation initiation.

B. Culture Media

Bacillius Subtilis strain number jc3 was cultivated under aerobic batch conditions in 10 g/l yeast extract, 5 g/l NaCl, 25 mM CaCl2 and 20 g/l urea. Medium pH adjusted before sterilization to 6.5 by 1 N HCl. Urea/$CaCl_2$ was added post autoclaving by 0.22 filter sterilization to prevent chemical decomposition under autoclave condition.

C. Cement and Aggregate

The starting materials used in this investigation are ordinary Portland cement (OPC) which provided by Krishna Builde Space Pvt. Ltd., Government Approved Contractor, Rajkot of Ultratech Cement and aggregate obtained from west zone of Gujarat. Their compositions for normal mix design of concrete grade M25 is given in Table 1.

For the casting of Normal concrete mix of grade M25, follwing proportions of different materils are used.

Material	**Proportion**
Cement	409 Kg/m^3
Sand	658 Kg/m^3
Coarse Aggregate	779 Kg/m^3
Fine Aggregate	419 Kg/m^3
W/C Ratio	0.46

Table-1

D. Preparation Of Microbial Cement Concrete

The Concre cubes were prepared using normal mix design of concrete grade M25 is given in Table 1. Total 12 cubes of 15cmx15cmx15cm were prepared using sand, Cement and Coarse Aggregate and Grit by weight. For each cubic mold casting Sand, Cement and Coarse Aggregate and Grit were thoroughly mixed, adding along with grown culture, at a W/C ratio of 0.46, of Bacillius Subtilis added in mix at rate of 10^7 cells per ml., bacterial cells concentration was measured by spectrophotometer. The fresh concrete mix were cast into the mold and compacted on a vibration machine then cured in humidity chamber with relative humidity 100% for 24 h. After de-molding the control specimens and the specimens with bacteria were cured in curing chamber at room temperature until the times of testing at the intervals of 3, 7, 14 and 28 days.

Steps to be followed to prepare normal concrete and bacterial concrete are mention below. First of all we have prepare normal mix design of concrete of grade M25 using IS codes method. Simultanelusly prepared mix design of grade M25 with IS codes method and add bacterial solution with concentration of cells 107 celss/ml.

Methodology

IS CODE REFERANCE AND USAGE

⇩

MIX DESIGN OF M25

⇩

MIX PROPORTION

⇩

IDENTIFICATION OF BACTERIA

⇩

INTRODUCTION OF BACTERIA

⇩

PREPARATION OF BACTERIA

⇩

MIXING OF BACTERIA IN WATER

⇩

CASTING AND TESTING OF COMPRESSIVE STRENGTH OF CONCRETE

⇩

COMPARISION OF CONVENCTIONAL AND BACTERIAL CONCRETE

Fig. 7 Casting of Normal concrete

E. Water absorption

Water absorption measurements were done by weighing the saturated specimens (W1) and dried specimens in oven at 80 Degree._C for 24 h (W2) at curing times of 3, 7, 14 and 28 days. The water absorption is calculated from the following equation:

Water absorption; % = [(W2 -W1)/W1] x 100:

F. Compressive strength

This test was carried out on four specimens following the procedure described by IS code. Compressive strength measurements were carried out using 30 tones Capacity Compression Testing Machine.

II. Result & Conclusion

A. Comparision Of Compressive Strength Of Normal M 25 Grade Concrete And Biochemical Concrete

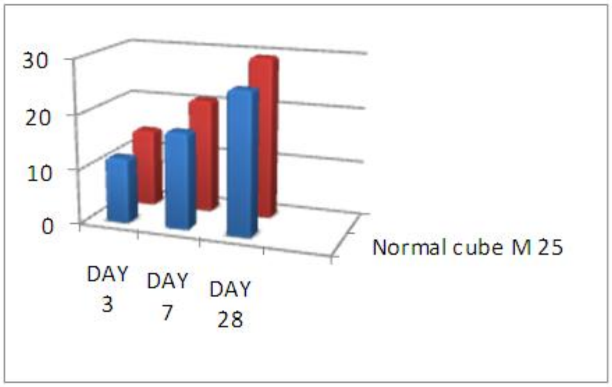

Chart Shows the Comparison of Compressive Strength of Normal Concrete Cube and Concrete Cube prepared using Bacterial Solution

A1. Improvment In Compressive Strength Of Concrete

Specimen were field with bacteria, nutrients and sand. Significant increase in compressive strength and stiffness values as compared to those without cells was demonstrated. Compressive strength test results are used to determine that the concrete mixture as delivered meets the requirement of the job specification. It was observed that significant enhancement in the strength of concrete and mortar can be seen upon application of bacteria.

A2. Decrease in Water Absorbtion of Concrete Cubes

Water absorption of cement concrete specimens and cube mixed with bacterial cell concentrations of 10^7 cells per ml cured under water, at 3, 7, 14 and 28 days. The results show that the water absorption of cement concrete with or without bacterial cells decreases with time of curing up to 28 days; this is due to the continuous hydration and accumulation of hydrated products which fill the open pores of the specimens. Also, the water absorption values of specimens mixed with bacterial cells at 10^7 cells per ml concentrations are lower than those of control specimens.

B. Conclussion

Bacteria from various natural habitats have frequently been reported to be able to precipitate calcium carbonate both in natural and in laboratory conditions (krumbein, 1979; rodriguez et al., 2003). Different types of bacteria, as well as abiotic factors (salinity and composition of the medium) seem to contribute in a variety of ways to calcium carbonate precipitation in a wide range of different environment. Calcium carbonate precipitation is a straight forward chemical process governed mainly by four key factors: 1).The Calcium Concentration, 2).The Concentration Of Dissolved Inorganic Carbon, 3).The pH value And 4). The Availability of Nucleation Sites

Compressive strength of concrete is increase after inclusion of biochemical (bacillus subtillis) in concrete. Compressive strength increase in bacterial content upto 10^7 cells/ml concentration further increase in bacterial content shows decrease in compressive strength.

The compressive strength of Concrete cubes increases due to the bacterial biomass and microbial calcite precipitation within the pores and on the surface of specimen. On the other hand, the water absorption values of cement concrete specimen decrease with increasing bacterial cells concentrations. The biomass and precipitated calcite content increases which fill some of the open pores and therefore, which decreases the extent of water absorption. The water absorption is linearly proportional to the total porosity of the cement concrete cubes.

C. Limitations of Bacterial Concrete

1. Cost Of Bacterial Concrete Is Double Than The Conventional Concrete Said By Dr. Henk Jonkers In 2011 But It Can Be Reduce This Cost By Growth Of The Technique.
2. Different Type Of Nutrients And Metabolic Products Used For Growing Calcifying Microorganism. Type of nuitrients Influence the Survival, Growth, Biofilm And Crystal Formation.
3. It is newely developed construction material and technique in the world, Hence Not Any Standard Code or references are available to develop bacterial concrete.

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