BACTERIA IMPREGNATED CONCRETE – A NEW WAY TO INCREASE THE DURABILITY OF CONCRETE STRUCTURES

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ABSTRACT

In this era of modern world concrete is gaining a lot of importance all over the world .But the main issue with the concrete is the cracks which gets developed in it after some days. And to repair this cracks is not an easy task so in this paper we have explained the process of healing the concrete by using bacteria of bacillus family which has the ability to precipitate calcite. This process of self-healing is often called as microbiologically introduced calcite precipitation (MICP). It has been found that by using the bacteria there is a significant increase in the compressive strength of concrete blocks. Also the cracks up to a width of 0.2-1mm were healed with the exposure of water and chemical solution.

Keywords- bacteria; calcite precipitation; concrete; compressive strength; crack; microbiologically introduced; self-healing.

I.INTRODUCTION

Concrete is one of the most important materials which are weak in tension and strong in compression used all over the world. In this era of urbanization and industrialization concrete is gaining a lot of importance. The increase in the production of cement has created some problems such as carbon dioxide emission in the production of cement which has created environment issues. Also the cracks in the concrete caused due to low tensile strength of the concrete. These cracks create a free passage for water and other substances to seep through the concrete mass which corrodes the reinforcement reducing its service life. Hence the formation of cracks is the major cause for damage in concrete structures. Therefore it is more important to prevent these cracks at the start or it becomes a major crack, and to remediate these major cracks is not economical. So some alteration is needed in the construction material.

The self-repairing may be incurred by different methods, such as secondary hydration of unhydrated cement, encapsulation of polymers, and fiber addition. Among these different methods one which we are working on is the bacteria impregnation into the concrete which produces calcite as precipitate, this method is becoming more and more popular these days it is recognized by different names such as bio-concrete, self-healing concrete, environment friendly concrete, bio-remediation of concrete, etc. It works on the technique of microbiologically introduced calcite precipitation (MICP). This precipitated material is calcite ($CaCo_3$) which is durable strong enough to resist impact from concrete and environment friendly bio-material. In this, bacteria of bacillus family having ability to precipitate calcite are impregnated into the concrete during mixing. This method is widely studied by civil engineers for the crack remediation in concrete.

II.PROCEDURE

2.1 Materials

2.1.1 Bacteria

Calcite producing bacteria "Bacillus Subtilis" was procured from microbiology department of new arts college Ahmednagar. It is also known as the hay bacillus or grass bacillus. Moreover it is a Gram-positive, catalase-positive bacterium which is found in soil and the gastrointestinal tract of ruminants and humans. A member of the genus Bacillus, Bacillus subtilis is a rod-shaped bacteria also it can form a tough, protective endospore which allows it to tolerate extreme environmental conditions.

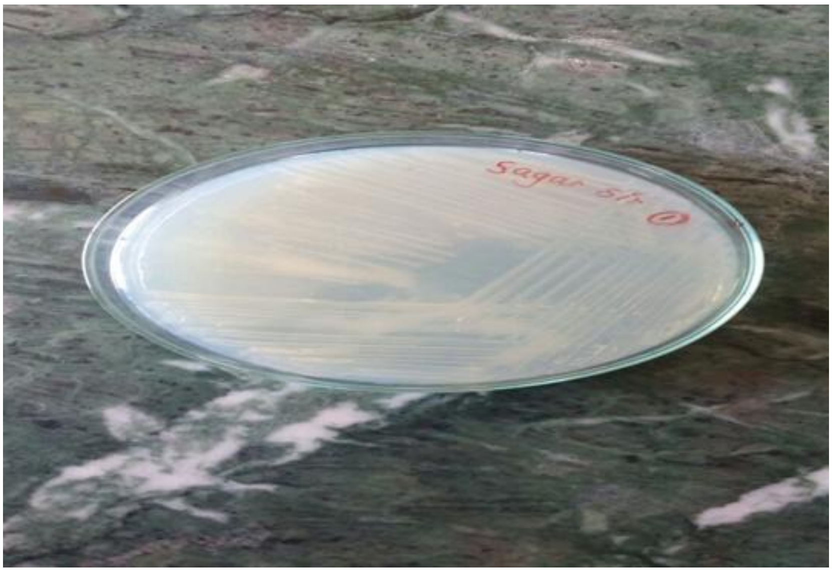

Figure 1-Strained Bacillus Subtilis

2.1.2 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 nutrient broth of 25 ml in 100ml conical flask. Growth conditions are maintained at 37degree celcius temperature and placed in 125 rpm orbital shaker.

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

2.1.3 Cement

Ordinary Portland cement of 43 Grade which was available in local market is used in this investigation. The cement used has been tested for various properties as per IS: 4031-1988 and found to be confirming to various specifications of IS: 12269-1987 having specific gravity of 3.0.

2.1.2 Aggregates

In our investigation we had used locally available natural sand confirming to zone I according to IS- 383. Specific gravity of sand was found out to be 2.60.

The coarse aggregate is strongest and porous component of concrete. Presence of coarse aggregate reduces the drying shrinkage and other dimensional changes occurring on account of movement of moisture. In our investigation we had used the aggregate passing through 20mm IS-Sieve and retaining on 12.5mm sieve. The specific gravity of aggregate was found out to be 2.8.

2.2 Methods

2.2.1 Culture of bacteria

The prepared culture was maintained in a medium of pH around 7. After this the medium was placed into the orbital shaker having speed 125rpm for 4 days at a temperature 37 degree celcius. The concentration of bacteria was maintained constant throughout as 10^5 cells/ml based on earlier research it was found that this concentration gives optimum results. This concentration was achieved by serial dilution method.

Figure 2-Cultured Bacillus Subtilis

2.2.2 Preparation of sample

We have used M30 grade of concrete in our investigation having mix ratio of 1:1.66:2.52 according to IS 10262 (2009). Cubes, beam and cylinders of specified sizes given by IS: 516(1999). For bacterial concrete three different solutions were made of 15ml, 25ml and 35ml having a concentration of 10^5cells/ml. All the samples were demoulded after 24 hours of casting and then cured in water up to 28 days. Nine cubes (three each for 3, 21 and 28 days) for three different conditions (15ml, 25ml and 35 ml). Total 36 numbers of cubes including controlled concrete samples were prepared.

2.2.3 Creation of cracks and treatment process

Creation of cracks was done by 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.

2.2.4 Compressive strength test

Cubes casted are tested for compressive test under compressive testing machine (CTM). The tests were taken after 3, 21 and 28 days. Compressive strength is the capacity of material to withstand axially directed forces. When this concrete achieves its compressive limit it crushes. Therefore compressive strength is the important phenomenon of concrete. Cubes were tested according to IS 516 (1959). The compressive strength of the cubes was tested after 3, 21 and 28 days.

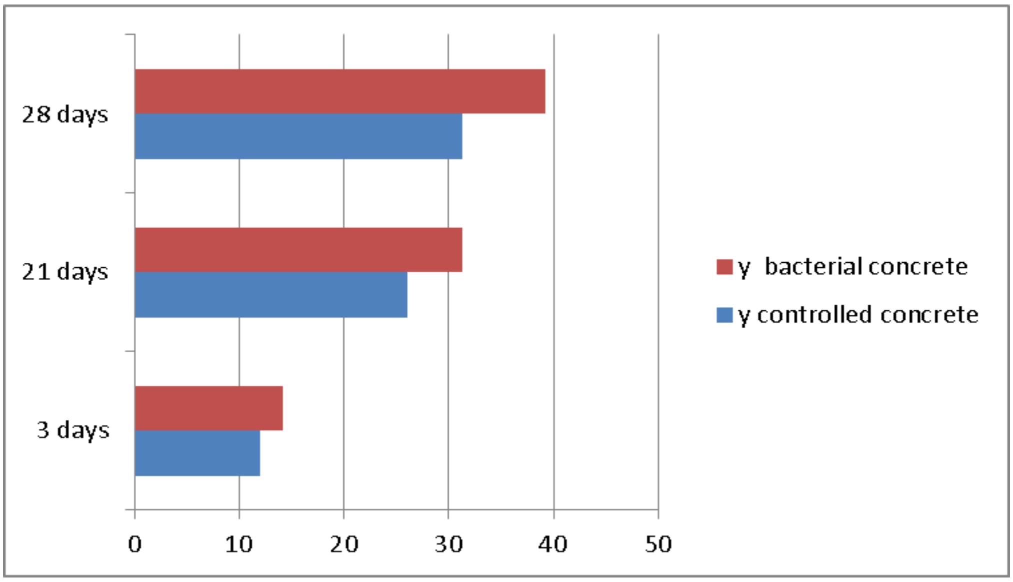

Figure 3-Compressive strength results

2.2.5 Analysis of cracks

Firstly the cracks filled were examined by naked eyes. Further the precipitated material has to be analyzed with Scanning Electron Microscope (SEM) equipped with an Energy Dispersive Spectrometer (EDS), and by X-ray Diffraction (XRD).

III. RESULTS

3.1 Compressive strength test

Figure 3 shows the increase in compressive strength of concrete for the optimum concentration of bacteria. The maximum results obtained are for 35 ml of bacterial solution. With respect to controlled specimens the increase in compressive strength was found out to be 20%, 24%, 28% at 3 days, 21 days and 28 days respectively. This increment in compressive strength may be due to calcite precipitation occurred due to bacteria which healed the micro cracks in the matrix making it denser.

3.2 Examination of cracks

After cracking the specimens placed in three exposure conditions which were a)urea ($CH_4 N_2 O$) (20gm/L) + calcium chloride ($CaCl_2$) (49gm/L) solution b) water and c) air. At the optimum concentration of bacterial specimen placed in urea and calcium chloride solution gave maximum crack filling as compared to other specimens. The specimens kept in air have negligible crack filled. This shows that for self-healing water is must without which crack cannot be filled. Figure 4 shows the crack filled specimen of urea solution for optimum concentration.

Figure 4- Self-Healed Specimen

IV. CONCLUSION

Based on the present investigation the following conclusions may be drawn.

- Bacteria can play an important role in the development of compressive strength of concrete.
- For optimum solution of 35 ml the compressive strength is 39.16 Mpa which is maximum as compared to controlled concrete.

- The self-healing process is successfully done through bacterial concrete.
- Bio concrete technology has been proved to better than any other conventional techniques, as it is eco-friendly and easily available in the laboratories.
- The concrete technology will soon be using bacterial concrete has 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-di-oxide(Co_2) reduces the level of greenhouse gas emission in the atmosphere.

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