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Managing and mitigating crack in concrete structure using bacteria

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ABSTRACT

In the past decade, the volume of research in the area of both bacterial concrete and self-compacting concrete have been steadily increasing and have been spreading throughout the world. Based on literature surveys on various bacterial concrete, no research has been found in self-compacting concrete incorporating bacteria. The aim is to improve the capacity for crack-repair in concrete by developing a new environment-friendly technique. The overall objective of this paper is to compare various journals of bacterial concrete and to support the usage of bacteria in self-compacting concrete.

Keywords: *Bacterial concrete, Self compacting bacterial concrete*

1. INTRODUCTION

A distinctive feature of the short history of self compacting concrete has been a wide range of applications which have closely followed research and development studies.

It is clear from the proliferation of publications both in journals and in major international conferences in the past decade that the volume of research in bacterial concrete has been steadily increasing and has been spreading throughout the world. Publications on research have been complemented by a substantial number of papers describing applications, i.e. case studies.

Many of the case studies include detailed information on the choice of component materials, the mixture proportions and the resulting concrete properties. There are now a sufficient number of case studies for a systematic evaluation of the spectrum of mix parameters and properties in statistical terms to be both valid and useful. In particular this will include:

- Give potential users and formulators an idea of what can be expected with SCC.
- Give practitioners a context in which to place and evaluate their own experiences.
- Assist researchers who wish to inform their research in the field of bacterial self-compacting concrete.

Publication of case studies depended on the willingness of the authors to make detailed information available.

2. CASE STUDIES

For analysis, five case studies were selected on the basis of concrete that is incorporated with various bacteria. Most of the papers have sufficient information regarding the bacteria being selected, used, and its optimum quantity in concrete.

3. INITIAL OBSERVATIONS

The most significant part of the analysis in this paper are those of the properties, component materials, mix proportions and the type and quantity of bacteria being used. As mentioned earlier, the function of this paper is to discuss the suitability of using bacteria in SCC.
Almost in all cases, it was concluded that bacterial concrete could increase durability, and maintained required compressive strength.

3.1 Fresh properties

It is required to consider the fresh properties of SCC. The slump flow test, which measures the flow capacity, has been universally used to determine the values of slump flow spread. Flow rate values, expressed as T_{500}, L box, U box, and J ring test can also be conducted in SCC. Bacterial SCC satisfied all the fresh properties of normal SCC.

3.2 Hardened properties

Both durability and mechanical properties of bacterial concrete are to be studied. Compressive test, and split tensile test were carried out.

4. TYPE OF BACTERIA USED IN CONCRETE

There are various types of bacteria that can be used in concrete.

- Bacillus pasteurii
- Bacillus spaericus
- Escherichia coli
- Bacillus subtilis
- Bacillus cereus
- Bacillus flexus
- Bacillus pseudoforms

In this work, Bacillus subtilis is being incorporated in self compacting concrete.

4.1 Working of bio-concrete

Self-healing concrete is a product that will biologically produce limestone to heal cracks that appear on the surface of concrete structures. Specially selected types of the bacteria genus Bacillus, along with a calcium-based nutrient known as calcium lactate, and nitrogen and phosphorus, are added to the ingredients of the concrete when it is being mixed. These self-healing agents can lie dormant within the concrete for up to 200 years.

However, when a concrete structure is damaged and water starts to seep through the cracks that appear in the concrete, the spores of the bacteria germinate on contact with the water and nutrients. Having been activated, the bacteria start to feed on the calcium lactate. As the bacteria feeds oxygen is consumed and the soluble calcium lactate is converted to insoluble limestone. The limestone solidifies on the cracked surface, thereby sealing it up. It mimics the process by which bone fractures in the human body are naturally healed by osteoblast cells that mineralize to re-form the bone.

The consumption of oxygen during the bacterial conversion of calcium lactate to limestone has an additional advantage. Oxygen is an essential element in the process of corrosion of steel and when the bacterial activity has consumed it all it increases the durability of steel reinforced concrete constructions.

The two self-healing agent parts (the bacterial spores and the calcium lactate-based nutrients) are introduced to the concrete within separate expanded clay pellets 2-4 mm wide, which ensure that the agents will not be activated during the cement-mixing process. Only when cracks open up the pellets and incoming water brings the calcium lactate into contact with the bacteria these become activated. Testing has shown that when water seeps into the concrete, the bacteria germinate and multiply quickly. They convert the nutrients into limestone within seven days in the laboratory. Outside, in lower temperatures, the process takes several weeks.

5. METHODOLOGY

5.1 Compressive strength

M30 concrete design mix was made. Cubes of size 150mm x 150mm x 150mm were casted with and without adding bacteria by adding various amounts of egg shell powder which serve the bacteria to precipitate $CaCO_3$. Dosage of 10^3 cells/ml bacteria were added. Cubes then tested for compressive strength at 7 and 28 days. The dosage at which high compressive test was achieved considered as optimum dosage.

5.2 Split tensile test

Cylinder of size 300mm x 150mm were casted using with and without bacteria by adding various amounts of egg shell powder which serve the bacteria to precipitate $CaCO_3$. Cylinder were tested for split tensile test at 14 days as per ASTM C496/C4956M.

6. RESULT

6.1 COMPRESSIVE STRENGTH

The compressive strength results for 7 and 28 days are in Mpa for controlled mix and Bacterial mix is shown in graph 1.

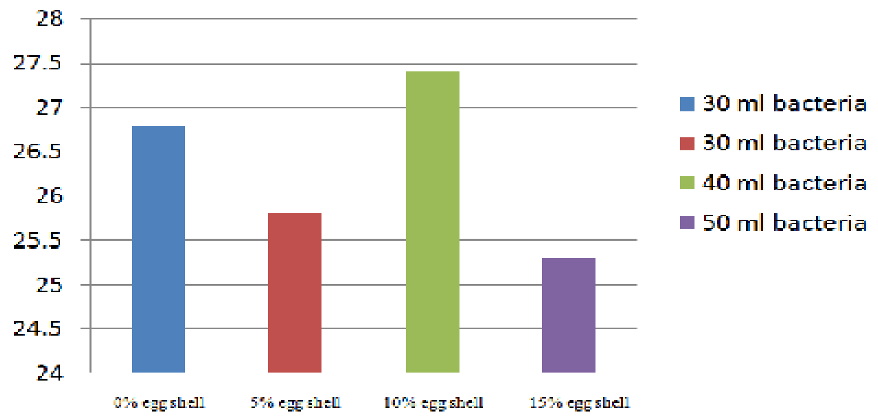

Fig. 1: Comparative test results

6.2 Split tensile strength

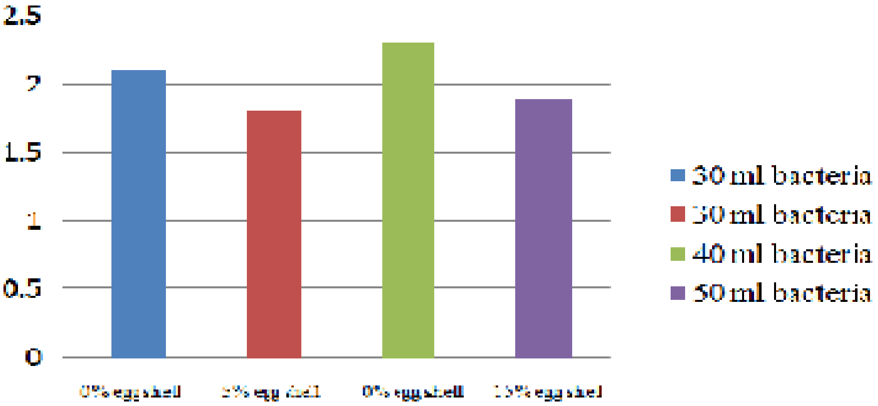

Fig. 2: Tensile strength results for 14 days

7. APPLICATION OF BACTERIA IN CONSTRUCTION AREA

The use of microbial concrete in Bio Geo Civil Engineering has become increasingly popular. From enhancement in durability of cementitious materials to improvement in sand properties, from repair of limestone monuments, sealing of concrete cracks to highly durable bricks, microbial concrete has been successful in one and all.

This new technology can provide ways for low cost and durable roads, high strength buildings with more bearing capacity, long lasting river banks, erosion prevention of loose sands and low cost durable housing. The next section will illustrate detailed analysis of role of microbial concrete in affecting the durability of building structures.

Another issue related with conventional building materials is the high production of greenhouse gases and high energy consumed during production of these materials. The emission of greenhouse gases during manufacturing processes of building materials is contributing a detrimental amount to global warming. Along with this, high construction cost of building materials is another issue that needs to be dealt with.

The above mentioned drawbacks of conventional treatments have invited the usage of novel, eco- friendly, self-healing and energy efficient technology where microbes are used for remediation of building materials and enhancement in the durability characteristics. This technology may bring new approaches in the construction industry.

8. CONCLUSION

1. The concentration of bacteria also plays a major role in it effectiveness.
2. Bacterial concrete prepared with addictives like egg shell powder also gives better strength and durability rather than serving the bacteria.
3. Bacterial concrete shows better resistance to drying shrinkage, resistance to acid attack, better sulphate resistance.
4. Bacillus species give better adaptability to the high alkaline concrete environment.
5. Even surface treatment with bacterial cement paste can enhance durability.
6. Self-compacting concrete is an area where the research has not yet been done. So there is a wide scope to use bacteria in SCC.

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