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Analysis on Self Healing Concrete using Bacteria

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Abstract:
This paper explains about the investigations that are taken up to study the characteristics strength in ordinary grade concrete and standard grade of concrete with and without the addition of bacteria's such as Bacillus subtilis, Bacillus pasteurii, Escherichia coli and Bacillus sphaericus. We have taken a vast study and concluded certain important objectives of Bacterial Concrete. Self healing agents such as epoxy resins, bacteria, fiber are used to heal cracks in concrete. Among these, bacterias which are used in concrete are effective. When the bacteria is mixed with concrete, the calcium carbonate precipitate is formed and this precipitate fills the cracks and makes the crack free concrete which has been proposed as an alternative and environmental friendly crack repair technique. It also shows increased compressive strength, split tensile strength, and flexural strength. When cement is replaced with fly ash, aluminium cans, crushed concrete and fine aggregate with foundry sand proportionally, bacterial concrete shows an increased range of 36.5% in compressive strength and shows more useful properties when compared with normal concrete.

Keywords: Environmental friendly, Bacteria, crack self healing, crack free concrete, high compressive strength, split tensile strength, flexural strength.

I. INTRODUCTION

Concrete is an important and extensively used building material for construction works. It is mainly used in heavy constructions because of its strength and durability. No matter how carefully the concrete is mixed or reinforced. It eventually ends up in cracking at some point. There is a disadvantage that, the cement industry is one of the primary producers of carbon dioxide, a major green house gas. Concrete causes damage to the most fertile layer of the earth, the topsoil. Concrete is used to create hard surfaces which contribute to surface run off that may cause soil erosion, water pollution and flooding. Concrete dust released by building demolition and natural disaster can be a major source of dangerous air pollution. It can cause health concerns due to toxicity and radioactivity. There are also many factors that affect the durability and strength of concrete, one of the most common hindrances is crack formation. Large cracks may affect the structural integrity while the small cracks reduce the durability of the structure. Cracks also increase the permeability of matrix, thereby increasing the chances of corrosion in reinforcement. Therefore, the whole cause of structural failure is cracking. In order to reduce the chances of crack formation, a structure requires regular maintenance which is costly and may further increase the maintenance cost of the structure. One way to reduce such costs and to increase the durability of structure is to use a concrete that has self-healing mechanism. This technique is based on bio mineralization of bacteria in concrete, a biological process commonly seen in few forms of microorganisms. The strength and durability can be increased by using these microorganisms as binders and fillers in concrete. Epoxy treatment is currently used for the repair works which is harmful to the environment and health as toxic fumes and gases evolved may cause serious skin and breathing issues. Hence cement is partially replaced with fly ash in order to reduce it. The fly ash and foundry sand are used in place of cement and fine aggregates increases a range of 36.5% in compressive strength of bacterial concrete than that of normal concrete. Also the use of biological techniques should be focused. The use of biological techniques in concrete lead to the invention of a new building material i.e. bio-concrete.(BACTERIAL CONCRETE)

RESEARCH SIGNIFICANCE:

The main significance of the study is to heal the cracks in structural elements by using the bacteria called Bacillus subtilis. Synthetic polymers can also be used to treat the cracks which are harmful to environment, which needs to develop biological treatment techniques. Biological treatment is a type of technique in which bacteria is mixed with conventional concrete to heal the cracks in structural elements. Another important significance is to reduce the production of cement which contributes to air pollution by releasing CO2. Fly ash, which is a thermal power plant wastage having cementitious properties is used as the substitute to cement and helps in reducing the usage of cement.

BIO-CONCRETE-THE LIVING CONCRETE:

Bio concrete is an example of linking nature with construction. The bio concrete or the living concrete is mixed in the same way as that of regular concrete but the extra ingredient i.e. the healing agent is added. This agent remain intact while mixing and placing, it becomes active only when it comes in contact with water if the concrete cracks. The healing agents can remain dormant in concrete for about 200 years. Bio concrete produces limestone ($CaCO_3$) crystals to fill up the cracks appearing on the surfaces. When the cracks begin to form in the concrete structure water enters the cracks. After coming in contact with water and oxygen, the inactive bacteria become active. They multiply and germinate in the calcium based nutrient (calcium lactate), while feeding on the lactate they combine calcium with carbonate ions to form limestone or calcite which seals the cracks. Bio concrete's principle is similar to the principle involved in healing of bone fractures in humans naturally by mineralization caused by osteoblast cells. The oxygen consumption not only helps in bacterial conversion of

calcium lactate to limestone but also helps in reducing the oxygen content in concrete which creates a medium for corrosion. Due to bacterial conversion, the oxygen gets consumed thereby increasing the durability of steel reinforcement.

BACTERIAS UESD IN CONCRETE:

In suspension state, concrete mix is added with bacteria. Concrete being extremely alkaline in nature, the bacteria added should fit in some special norms. The added bacteria should be able to withstand the harsh environmental conditions of concrete. Concrete is a dry material and the pH value of cement and water when mixed is up to 13 which makes it confrontational as most of the organisms cannot survive in an environment having pH value higher than 10.

TYPES OF BACTERIA:

Bacteria naturally occur in nature in various forms. They are present not only on the surface but also beneath the surface of the earth. The various bacteria that can be used in concrete are:

- **Anaerobic Bacteria:** If anaerobic bacteria like closely related species of shewanella are added to concrete, the compressive strength increases from 25-30%.
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- **Aerobic Bacteria:** The various types of aerobic bacteria that can be used in concrete are:

i. Bacillus pasteurii
ii. Bacillus sphaericus
iii. Escherichia coli
iv. Bacillus subtilis
v. Bacillus cohnii
vi. Bacillus pseudofirmus
vii. Bacillus halodurans
viii. Bacillus massiliensis

Bacillus subtilis:

- ✓ Bacillus subtilis is also called as the grass bacillus.
- ✓ It is a common soil bacterium.
- ✓ Bacillus subtilis is a model laboratory bacterium, which can produce calcite precipitates on suitable media supplemented with a calcium source.
- ✓ Bacillus subtilis is used to induce precipitation of CaCO3 at a faster rate.

Bacillus sphaericus:

- ✓ Bacillus sphaericus is an aerobic bacteria which frames round an endospore.
- ✓ It is a gram positive bacterium, with bar formed cells that shape chains.
- ✓ It is an actually happening bacterium-detached, refined, and marked for mosquito control.

II. HOW IT IS APPLIED

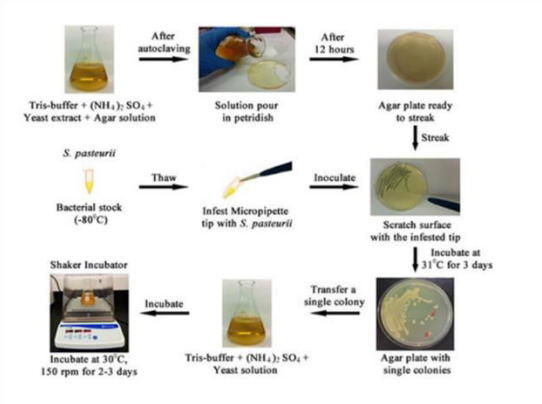
1. BY DIRECT APPLICATION:

The bacteria and the chemical precursor (calcium lactate) are added directly while making the concrete.

2. BY ENCAPSULATION OF LWA:

- ➢ The part of the coarse aggregate is replaced by the light weight aggregate(LWA), which is impregnated with twice the calcium lactate solution and the spores of bacteria.
- ➢ After impregnation the clay particles with 6% healing agents and the concrete is made. When concrete structures are made with bacterial concrete, when the crack occurs in the structure, the clay pellets are broken and bacterial treatment occurs. Hence the concrete is healed. Minor cracks about 0.5mm width can be treated by using bacterial concrete. Among these two methods encapsulation method is commonly used, even though it's costlier than direct application. Bacillus bacteria are harmless human life and hence it can be used effectively.

PREPARATION AND GROWTH OF BACTERIA
THE OUTLINE OF THE ENTIRE CULTURE PROTOCOL REPRESENTED AS AN ALGORITHMIC SCHEMATIC



III. ABILITY OF BACTERIA IN CONCRETE:

- They should be able to perform long term effective crack sealing, preferable during the total constructions life time.
- Both bacteria and a bio-cement precursor compound should be integrated in the material matrix.
- Only specific alkaliphilic bacteria can survive in such hostile environment of concrete.
- It is necessary to immobilize the bacterial cells and to protect them from high pH of 9 in concrete.
- Polyurethane(PU) has been widely used for immobilization of nutrients and bacterial cells even silica gel was used to protect the bacteria against the high pH in concrete.

MECHANISM:

Cracks less than 0.2mm can be auto fill by concrete. But if cracks are more than 0.2mm then concrete itself fail to heal. Thus it creates an opening passage for the chemicals and other cooroding materials. When the concrete is mixed with bacteria(bacteria subtillis), the bacteria goes into a dormant state, a lot like seeds. All the bacteria need is, exposure to the air to activate their functions. In bio-concrete, if water is in the contact with the concrete through the cracks, the bacteria get activated and starts precipitating calcite crystals. The spores of the bacteria germinate on contact with the water and nutrient. Having been activated, the bacteria starts feed on the calcium lactate nutrient. Such spores have extremely thick cell walls that enable them to remain intact for upto 200 years while waiting for a better environment to germinate. As the bacteria feeds oxygen, the soluble calcium lactate is converted into insoluble limestone. The limestone solidifies on the cracked surface, thereby sealing it up. Oxygen is an essential element in the process of corrosion of steel and when the bacterial activity has consumed it all, it increase the durability of steel reinforced concrete construction. Tests show that bacteria embedded

concrete has lower water and chloride permeability and higher strength regain than the surface application of bacteria. Thus the tensile strength, compressible strength and flexural strength is also increased. The last, but not least, key component of the self-healing concrete formula is the bacteria themselves.

CHEMICAL REACTION:

Various bacteria and biotic factors contribute to this in different ways In the process of calcium carbonate precipitation, the key factors governing the process are

- Calcium concentration
- Concentration of dissolved inorganic carbon
- The pH and the availability of nucleation sites

On the surface of control concrete, Calcium Carbonate will be formed due to the reaction of CO2 present, with Calcium Hydroxide present in the concrete mix according to the following reaction.

$$CO2 + Ca(OH)2 \rightarrow CaCO3 + H2O \quad (1)$$

As Ca(OH)2 is a soluble mineral, it gets dissolved in entering water and diffuse out of the crack in the form of leaching. The self-healing process in bacteria incorporated concrete is much more efficient due to the active metabolic conversion of Calcium nutrients by the bacteria present in concrete.

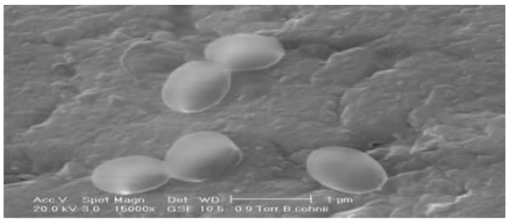
$$Ca(C3H5O2)2 + 7O2 \rightarrow CaCO3 + 5CO2 + 5H2O \quad (2)$$

Here Calcium Carbonate is produced directly dueto microbial metabolic process and also indirectly due to autogenously healing. This process results in efficient bacteria-based crack sealing mechanism.

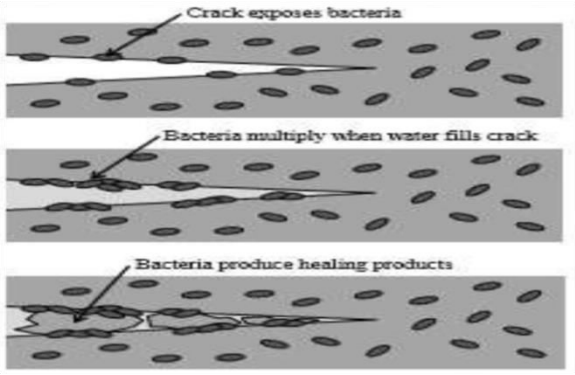
IV. RESULT:

The most promising bacteria to use for self-healing purposes are alkaliphilic (alkali-resistant) spore-forming bacteria. The bacteria, from the genus Bacillus Subtilus is adopted for present study. It is of great concern to the construction industry whether or not these bacteria are "smart" enough to know when their task is complete because of safety concerns. Bacillus subtilus which is a soil bacterium is harmless to humans as it is non-pathogenic micro-organism.

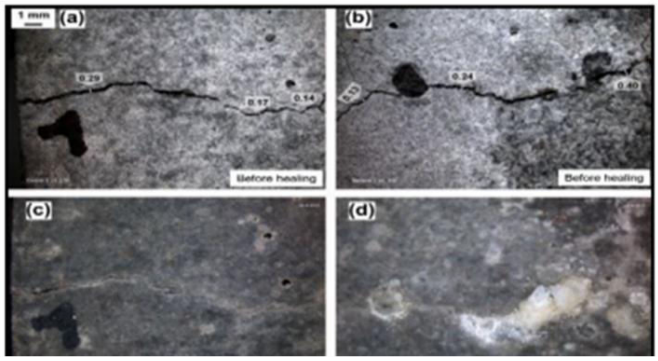
Electron microscope photograph of Bacterial spores



How it works:



SEM IMAGE OF CRACK HEALING PROCESS IN CONCRETE BY USING BACTERIA



ADVANTAGES:

- The use of bio concrete significantly influences the strength of concrete.
- It has increased level in compressive, tensile, and flexural strength when compared with ordinary concrete.
- It has lower permeability than conventional concrete.
- It offers greater resistance to freeze-thaw attacks.
- Eco-friendly and reduces the emission of green house gases.
- Oxygen is an agent that can induce corrosion, as bacteria feeds on oxygen tendency for the corrosion of reinforcement can be reduced.
- Remedying of cracks can be done efficiently.
- It helps in reduced maintenance and a repair cost of this concrete is low.
- Improvement in compressive strength of concrete.
- Formation of cracks will be healed in the initial stage itself thereby increasing the service life of the structure than expected life.

DISADVANTAGES:

- Cost of bacterial concrete is double than conventional concrete.
- Growth of bacteria is not good in any atmosphere and media and it's usage should be limited to the structure.
- Design of bacterial concrete is not mentioned in IS codes or any other codes.
- Cost of this concrete is comparatively higher than conventional concrete i.e. about 7-28% more than conventional concrete.
- The sprouting of bacteria is not suitable in any environment.
- The investigations involved in calcite precipitation are costly.

BENEFITS OF BIO-CONCRETE:

The climate of India is diverse from region to region because of its topography. It observes a wide range of temperature changes from mountains, plains, forests, to beaches. Many cities such as New Delhi, Lucknow, Patna, Varanasi etc. observe drastic temperature changes from very warm climate in April to mid-June to very cold climate between November and February. Extreme climates can deteriorate the concrete surfaces and which may ultimately result in failure of structure. Bio concrete can be used as the best alternative for constructions in extreme climates. As India is a developing country, impressive infrastructure plays an important role so bio concrete can be used in the construction of crack resistant and durable high rise buildings and underground constructions. Apart from this bio concrete can be used for constructing structures meant for irrigation.

APPLICATIONS:

- Self-healing bacterial concrete can be used for sectors such as tunnel-lining, structural basement walls, highway bridges, concrete floors and marine structures.
- It is used to build low cost durable housing.
- It is also used to build high strength buildings with more bearing capacity.
- Erosion prevention of loose sands.
- Used as Crack filling materials, in cement mortar, in precast mortar, in concrete, in brick production, to give cover to previous concrete.
- Used as green roofing.

V. CONCLUSION:

The conclusion can be summarized as:

• The compressive, split tensile and flexural strength of M20 bio-concrete is found to be higher than M20 conventional concrete.

• Bacteria can further be used in mortar and bricks to improve their properties.

• Crack remediation using bio-concrete is better than epoxy treatments.

- Microbial concrete technology has proved to be better than many conventional technologies because of its eco-friendly nature, self-healing abilities and increase in durability of various building materials.
- Enhancement of compressive strength, reduction in permeability, water absorption, reinforced corrosion have been seen in various cementitious and stone materials.
- The application of bacteria as a self-healing agent in concrete appears promising.
- Hence by these techniques the emission of green house gases can be reduced and the environment is also protected.

VI. REFERENCE

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