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PERFORMANCE AND CHARACTERISTICS OF BACTERIAL CONCRETE

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Abstract - *Bacterial concrete or self healing concrete fills up the cracks developed in structures by the help of bacterial reaction in the concrete after hardening. Types of bacteria, its mechanism and preparation of bacterial concrete is discussed. In modern days, the use of technology has taken the standards of construction to a new high level. Different types of procedures, methods and materials are used to attain a very good, sustainable and economic concrete construction. But due to human mistakes, incorrect handling and unskilled labors. An efficient building is hard to sustain its designed life. Many problems like weathering, cracks, leaks and bending etc., arises after the construction. To overcomes this types of problems, many remedial procedures are undertaken before and after the construction. This project represents study of bacteria concrete.*

Key Words: Bacterterial concrete, self compacting concrete, cracks, Calcium carbonate

1. INTRODUCTION

Concrete which forms major components in the construction Industry as it is cheap, easily available and convenient to cast. But drawback of these materials is it is weak in tension so, it cracks under sustained loading and due to aggressive environmental agents which ultimately reduce the life of the structure which are built using these materials. This process of damage occurs in the early life of the building structure and also during its life time. Synthetic materials like epoxies are used for remediation .But they are not compatible, costly, reduce aesthetic appearance and need constant maintenance .Therefore bacterial induced Calcium Carbonate (calcite) precipitation has been proposed as an alternative and environment friendly crack remediation and hence improvement of strength of building materials

A novel technique is adopted in remediating cracks and fissures in calcium concrete by utilizing Microbiologically Induced Calcite or Carbonate (CaCO3) Precipitation (MICP) is a technique that comes under a broader category of science called biomineralization. MICP is highly desirable because the Calcite precipitation induced as a result of microbial activities is pollution free and natural .The technique can be used to improve the compressive strength and stiffness of cracked concrete specimens. Research leading to microbial Calcium Carbonate precipitation and its ability to heal cracks of construction materials has led to many applications like crack remediation of concrete ,sand consolidation ,restoration of historical monuments and other such applications. So it can be defined as "The process can occur inside or outside the microbial cell or even some distance away within the concrete .Often bacterial activities simply trigger a change in solution chemistry that leads to over saturation and mineral precipitation. Use of these Bio mineralogy concepts in concrete leads to potential invention of new material called –Bacterial Concrete.

2. ADVANTAGES OF USING BACTERIA IN CONCRETE

- Around five per cent of all manmade carbon dioxide emissions are from the production of concrete, making it a significant contributor to global warming .Finding a way of prolonging the lifespan of existing structures means we could reduce this environmental impact and work towards a more sustainable solution.
- This could be particularly useful in earthquake zones where hundreds of buildings have to be flattened because there is currently no easy way of repairing the cracks and make them structurally sound.
- Fills the crack in an efficient period of time so that the life period of a concrete structure can be expected over 200 years
- Prevents the use of cement in future used as a maintenance structure by drilling and grouting process so in this way, less use of cement can be seen
- As we know more of cement content, more will be carbon dioxide gases released causing global warming, effecting the ozone layer. By using this bacteria, the structure does not need to be repaired except for the less cases and so results in less use of cement

3. VARIOUS TYPES OF BACTERIA USED IN CONCRETE

There are various types of bacteria were used in construction area

Bacillus pasteurii

Bacillus sphaericus

Escherichia coli

Bacillus subtilis

Bacillus cohnii

Bacillus balodurans

Bacillus pseudofirmus

4. VIABLE BACTERIA AS SELF HEALING AGENT

The bacteria to be used as self- healing agent in concrete should be fit for the job, i.e. they should be able to perform long-term effective crack sealing, preferably during the total constructions life time. The principle mechanism of bacterial crack healing is that the bacteria themselves act largely as a catalyst, and transform a precursor compound to a suitable filler material. The newly produced compounds such as calcium carbonate-based mineral precipitates should than act as a type of bio-cement what effectively seals newly formed cracks. Thus for effective self –healing, both bacteria and a bio-cement precursor compound should be integrated in the material matrix. However, the presence of the matrix-embedded bacteria and precursor compounds should not negatively affect other wanted concrete characteristics .Bacteria that can resist concrete matrix incorporation exist in nature, and these appear related to a specialized group of alkali-resistant spore-forming bacteria. Interesting feature of these bacteria is that they are able to form spores, which are specialized spherical thick-walled cells somewhat homologous to plant seeds. These spores are viable but dormant cells and can withstand mechanical and chemical stresses and remain in dry state viable for periods over 200 years (FIG 1).

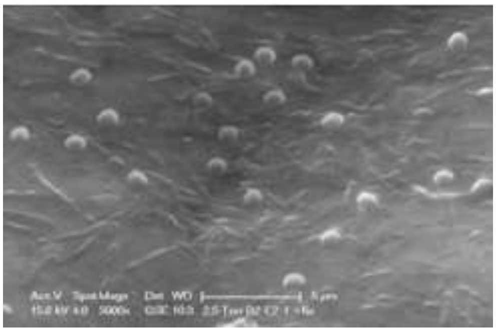

FIG.1: ESEM photomicrograph

However, when bacterial spores were directly added to the concrete mixture, their lifetime appeared to be limited to one-two months. The decrease in life-time of the bacterial spores from several decades when in dry state to only a few months when embedded in the concrete matrix may be due to continuing cement hydration resulting in matrix pore-diameter widths typically much smaller than the 1-μm sized bacterial spores. Another concern is whether direct addition of organic bio-mineral precursor compounds to the concrete mixture will not result in unwanted loss of other concrete properties. In the preceding study it was indeed found that various organic bio-cement precursor compounds such as yeast extract, peptone and calcium acetate resulted in a dramatic decrease of compressive strength. The only exception appeared to be calcium lactate what actually resulted in a 10% increase in compressive strength compared to control specimen.

In order to substantially increase the lifetime and associated functionality of concrete incorporated bacteria, the effect of bacterial spore and simultaneously needed organic bio mineral precursor compound (calcium lactate) immobilization in porous expanded clay particles was tested. It was found that protection of the bacterial spores by immobilization inside porous expanded clay particles before addition to the concrete mixture (FIG. 5.2) indeed substantially prolonged their life-time. Currently running viability experiments show that still after 6 months concrete incorporation no loss of viability is observed, suggesting that their long term viability as observed in dried state when not embedded in concrete is maintained.

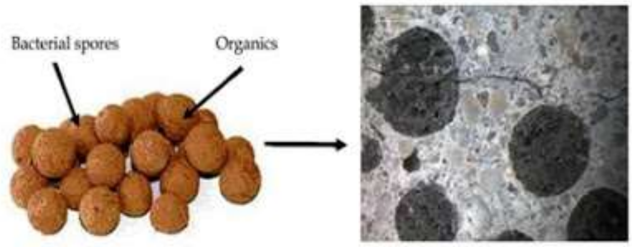

FIG.2 self- healing admixture composed of expanded clay particles(left)loaded with bacterial spores and organic bio mineral precursor compound (calcium lactate)

When embedded in the concrete matrix(right).Sample paragraph, The entire document should be in cambria font. Type 3 fonts must not be used. Other font types may be used if needed for special purposes. The entire document should be in cambria font. Type 3 fonts must not be used. Other font types may be used if needed for special purposes.

5. PREPARATION OF BACTERIAL CONCRETE

Bacterial concrete can be prepared in two ways

- By direct application
- By encapsulation in light weight concrete

By the method of direct application bacterial spores and calcium lactate are added directly while making the concrete and mixed .Here when the crack occurs in the concrete bacterial spores broke and bacteria comes to life comes to life and feed on the calcium lactate and limestone is produced which fill the cracks.

By encapsulation method the bacteria and its food, calcium lactate, are placed inside treated clay pellets and concrete is made. About 6% of the clay pellets are added for making bacterial concrete. When concrete structures are made with bacterial concrete, when the crack occurs in the structure and clay pellets are broken and bacterial treatment occurs and hence the concrete s 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 to human life and hence it can be used effectively.

6. MECHANISM OF BACTERIAL 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.

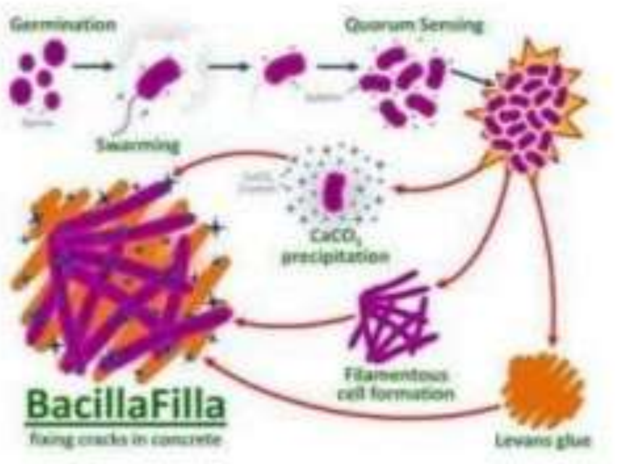

FIG 3 the crack fixing process

In the crack fixing process the anaerobic type bacteria which can be using along with concrete can be fix that crack by step by step. At first germination of germs by spores and swarming themselves and quorum sensing and growing from proper medium in large amount in particular time and from the metabolism process leans glue is produce and making such type of filamentous cell formation and precipitation CaCO3. This both material combine with each other and making cementations material.

7. CHEMICAL PROCESS TO REMEDIATE CRACKS BY BACTERIA

Crack –penetrating water would not only dissolve calcite (CaCO3) particles present in mortar matrix ,but would also react together with atmospheric carbon dioxide with not fully hydrated lime constituents such as calcium oxide and calcium hydroxide according to the following reactions:

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

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

The freshly produced minerals from the above stated reactions and from dissolved and re-crystallized calcite mineral, precipitated on the surface of cracks what resulted in crack-sealing and concomitant reduction in permeability of the mortar. The healing potential of this system was directly related to the amount of nonreacted lime particles within the set mortar. Calcium carbonate precipitation is a straight forward chemical process governed mainly by four key factors.

1. Calcium concentration

2. Concentration of dissolved inorganic carbon(DIC)

3. The pH

4. Availability of nucleation sites

The concentration of calcium carbonate ions is related to the concentration of DIC and the pH of a given aquatic system. The precipitation of Calcium carbonate crystals occurs by heterogeneous nucleation on bacterial cell walls once super saturation is achieved .The fact that hydrolysis of urea is a straight forward microbial process and that a wide variety of microorganisms produce urease enzyme and makes it ideally suited for crack remediation for building material applications. This precipitation forms a highly impermeable layer which can be used as crack remediation for concrete or any other building material. The precipitated calcite has a coarse crystalline structure that readily adheres to the concrete surface in the form of scale. In addition it has the ability to continuously grow upon itself and it is highly insoluble in water.

8. STUDY ON PERMEABILITY OF BACTERIAL CONCRETE

Permeability is the most crucial internal factor in concrete durability .The durability of a concrete is closely related to its permeability. The permeability dictates the rate at which aggressive agents can penetrate to attack the concrete and the steel reinforcement. Water penetrability is defined as the degree to which a material permits the transport gases, liquids or ionic species through it. Water can be harmful for concrete, because of its ability to leach calcium hydroxide from the cement paste, to carry harmful dissolved species such as chlorides or acids into the concrete, to form ice in large pores in the paste, and to cause leaching of compounds from the concrete. Bacterial concrete works on the phenomenon of microbiologically induced calcite precipitation. Calcite crystals formed, due to microbial activities of bacteria Bacillus , seals the cracks and pores in concrete and enhances the strength and durability of concrete by making concrete impermeable to transport different fluids or gases, like water, chlorides, sulfates or oxygen.

9. APPLICATION OF BACTERIA IN CONSTRUCTION AREA

From enhancement in durability of cementations 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 bearing capacity, long lasting river banks, erosion prevention of loose sands and low cost durable housing. Another issue in conventional building materials is the high production of greenhouse gases and high energy consumed during production of these materials and these greenhouse gases leads to global warming. High construction cost of building materials is another drawback in such cases. These drawbacks have lead to use 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.

FIG 4: Application of Bacterial Concrete in Construction Area

10. COST COMPARISON OF CONVENTIONAL AND BACTERIAL CONCRETE

The cost of self-healing concrete is about double that of conventional concrete, which is presently about €80 euros per cubic metre. At around €160 per cubic metre, self-healing concrete would only be a viable product for certain civil engineering structures where the cost of concrete is much higher on account of being much higher quality, for example tunnel linings and marine structures where safety is a big factor – or in structures where there is limited access available for repair and maintenance. In these cases the increase in cost by introducing the self-healing agents should not be too enormous.

Added to this, if produced on an industrial scale it is thought that the self- healing concrete could come down in cost considerably. If the life of the structure can be extended by 30%, the doubling in the cost of the actual concrete would still save a lot of money in the longer term. Research is currently working on the development of an improved and more economic version of the bacteria-based healing agent which is expected to raise concrete costs only by a few euros.

A second self-healing agent that will be much cheaper and also would result in much stronger concrete is being developed. Presently the majority of the extra cost comes from the calcium lactate which is very expensive. The process of embedding the bacteria and nutrients into the pellets is also expensive because it involves a vacuum technique. A sugar-based food nutrient would potentially bring down the cost of the self-healing concrete to €85-90 per cubic metre. But a sugar-based nutrient would not remain intact within expanded clay pellets as calcium lactate does. Much of the sugar would be dissolved and it would delay the setting time of the concrete. The new selfhealing agent being developed would immobilise the sugar-based nutrient during the mixing process. So the team has now developed an alternative self-healing agent with a new shape and form and the way that the bacteria and nutrients would be stored would be totally different. The new healing agent would comprise only 3-5% of the overall volume and the concrete would therefore be much stronger. The new selfhealing agent would be a viable product for most structural concrete applications .If the cost of the self-healing agent can be brought down sufficiently and the concerns over the long-term effects on the concrete performance properly addressed, then the product could have great potential.

11. CONCLUSION

1. Bacterial 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.

2. Work of various researchers has improved our understanding on the possibilities and limitations of biotechnological applications on building materials.

3. Enhancement of compressive strength, reduction in permeability, water absorption, reinforced corrosion have been seen in various cementitious and stone materials.

4. In bacterial concrete interconnectivity of pores is disturbed due to plugging of pores with calcite crystals. Since interconnected pores are significant for permeability, the water permeability is decreased in bacteria treated specimens.

5. Cementation by this method is very easy and convenient for usage. This will soon provide the basis for high quality structures that will be cost effective and environmentally safe but, more work is required to improve the feasibility of this technology from both an economical and practical viewpoints.

6. The application of bacterial concrete to construction may also simplify some of the existing construction processes and revolutionize the ways of new construction processes.

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