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A Review on Self Healing Concrete

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Abstract: Self-healing concrete, also known as bacterial concrete, fills in structural flaws caused by bacterial response in the concrete after it has hardened. The manufacture of bacterial concrete and several bacterial types are addressed. The usage of technology has raised construction standards to a new, lofty level in the modern era. To create a concrete structure that is excellent, sustainable, and affordable, several sorts of procedures, methods, and materials are used. However an effective building struggles to last the length of time it is intended to due to human error, improper handling, and unskilled work. After construction, a number of issues, including weathering, cracks, leaks, and bending, etc., appear. Many corrective measures are implemented before and after the construction to address these types of issues.This review paper mainly focuses on biological self healing concrete but the chemical self healing concrete is also mentioned.

Keywords: Self Healing concrete, chemical self-healing process, biological self-healing process

I. INTRODUCTION

There are numerous solutions for the widespread issue of building cracking before and after the crack. Self-Healing or Bacterial Concrete is one of the corrective processes. Self-Healing Concrete is a type of concrete that can repair or fill in gaps on its own after hardening thanks to a bacterial reaction. Little fractures that form in a structure with a width between 0.05 and 0.1mm can be seen to be entirely sealed by repeating dry and wet cycles. The water particles penetrate through the fissures and function as capillaries, which is how this autogenously mending process works. These water droplets hydrate the partially or completely unreacted cement, which expands to cover the crack.

II. LITERATURE REVIEW

According to M.Monishaa, due to its eco-friendliness, self-healing capabilities, and increase in the durability of different building materials, microbial concrete technology has proven to be superior to many conventional technologies. The largest improvement is its capacity to contain105 cells/ml for all age groups. The results showed that the 28-day compressive strength increased by13.2%, the split tensile strength increased by 21.4%, and the flexural strength increased by16.04%.The self-healing effect will be enhanced by increased CaCO3 precipitations. The amount of precipitated CaCO3 will grow with the concentration of bacteria and Ca 2+. Polyethylene fibre can boost the concrete's mechanical qualities.

According to Mr. Sk. Alisha, Mr. P. Rohit, Mr. K.S.N. Sachin, Mr. V.Rajesh Babu,due to its durability and ability to repair itself, self-healing concrete is the best solution for the demand for property concrete. Self-healing concrete will be the most important component of concrete technology in the future. On the microorganism cubes, there is a lot of association heat; As a result, a lot of water is needed to cure. In comparison to conventional concrete, the compressive strength is increased by twenty. The cost of structure upkeep in typical concrete is extremely high. However, the value of maintenance work decreases once the self-healing concrete is constructed. They look like a carbonate precipitation. The generated cracks begin auto-filling once the sucking is complete. After the microorganism was added to the concrete, smart strength was achieved in 28 days. Thirty days is the bare minimum for crack repair. Structures made of self-healing concrete are significantly more durable than conventional concrete.

The outcomes of the experiments carried out by S.S. Lucas proved that replacing aggregates with expanded clay impregnated with bacteria might significantly increase the strength of concrete. It has been established that calcium carbonate, the primary reaction product resulting from the bacterium activity, was in fact what triggered the recovery. Although more research is needed to determine the durability of this concrete and the longevity of the bacteria, the results show that it is feasible.

A comprehensive investigation of bio concrete using bacillus megaterium bacteria was published in a paper by Kusuma K. They have switched from drinking water to bacterial water, which has about105 bacillus water. Bacterial concrete was found to perform megaterium cells per milliliter of better than conventional concrete. It expanded the compressive strength of bacterial cement by 11.96% than traditional cement. The surface of bacterial concrete has been enhanced as a result of the precipitation of calcite on the specimen's surface. It was determined that the decrease in water absorption was 0.45%. Water permeability was reduced as a result of calcite filling the pores. Additionally, it made building materials more durable. It demonstrated that employing such bacteria improves water absorption, permeability, and compressive strength.

Er. Chetan Kumar, Er. Shaitan Singh Rawat, Er. Swati Soni described the methods of designing self healing concrete. The incorporation of bacteria into the concrete is extremely beneficial because it enhances its quality beyond that of conventional concrete. The study looked at various kinds of bacteria that can be used to fix concrete cracks Calcium carbonate crystals, which block and repair concrete cracks, are produced by bacteria to repair them. Numerous researchers have investigated the self-healing properties of concrete and discovered the following: bacteria increase the strength of conventional concrete by 13.75 percent in three days, 14.28 percent in seven days, and 18.35 percent in 28 days.As is common knowledge, self-healing concrete costs less to repair and maintain than conventional concrete. Therefore, in order to enhance concrete structures, we must enhance and utilize these techniques. The self-healing concrete design concepts and strategies are presented in this paper.

III. PROCESS OF SELF HEALING CONCRETE

A. Biological Self-Healing Concrete

Bio concrete is one example of combining construction with nature. The process of mixing bio concrete, also known as living concrete, is identical to that of regular concrete, with the addition of a healing agent. This remains intact throughout mixing and placing, only activating when the concrete cracks and comes into contact with water. In concrete, the healing agents can lie dormant for about 200 years. In order to fill in surface cracks, bio concrete produces limestone ($CaCO_3$) crystals. Water enters the concrete structure when the cracks begin to form. In the wake of interacting with water and oxygen, the dormant microbes become dynamic. While feeding on calcium lactate, they combine calcium with carbonate ions to form limestone or calcite, which seals the cracks, where they multiply and germinate. Bio concrete mimics the mineralization process that osteoblast cells use to naturally heal fractures in humans. Not only does the consumption of oxygen aid in the bacterial transformation of calcium lactate into limestone, but it also aids in the reduction of the oxygen content in concrete, which makes it a favorable environment for corrosion. The oxygen is used up by bacteria during conversion, which makes steel reinforcement more durable.

B. Chemical Self-Healing Concrete

Using this method, chemical components are injected into the fractures in the concrete to repair them. It is additionally known as artificial healing Liquid officials, such as glue, are required to combine with fresh concrete in tiny holders in order to create chemically self-healing materials. The two main methods for treating and repairing concrete that employ glue are described in detail below: The first is enclosed glue, followed by hollow pipettes and vessel networks that hold glue.

IV. BACTERIAS USED IN THE CONCRETE

1) Bacillus sphaericus
2) Bacillus pasteurizing
3) Escherichia coli
4) Bacillus cohnii
5) Bacillus subtilis
6) Bacillus pseudofirmus
7) Bacillus balodurans

V. SELF HEALING

A. Autogenous Healing

Two mechanisms allow for autogenous healing: unreacted cement particles continue to hydrate, and the carbonation of calcium hydroxide precipitated calcium carbonate ($CaCO_2$). CSH formation dominates autogenous healing at early ages as unreacted cement particles on crack faces become hydrated. Calcium carbonate precipitation occurs as a result of insufficient unhydrated cement at a later stage, which results in healing.

Autogenous healing requires three conditions: a limited crack width, cementitious minerals present to participate in the reactions, and a constant supply of water. In the presence of moisture, the width of a healable crack can range from 20 m to 138 m for complete healing and up to 150 m for partial healing. Before the crack can be completely sealed, the cement particles or calcium hydroxide in the concrete surrounding it will be consumed if the crack is too wide. Because reaction products are used up with hydration, the effectiveness of healing decreases with concrete age. Self-healing requires a more practical and robust strategy due to autogenous healing's inherent limitations.

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B. Autonomous Healing

Autonomous self-healing agents are stored in vessels either as discrete microcapsules or as a vascular network. Designated arrival of the epitomized material in harm zones is accomplished through a delivery trigger, for example, container break or change in pH of pore arrangement. Mending specialists respond with substances in the interior cementitious climate, synthetics in the host framework, or with other typified substances, to tie the cracked faces together. A vascular system is made up of a network of thin, brittle tubes that are filled with a healing agent and connected to a reservoir outside the body that keeps the healing agent coming. The mending material is delivered into the substantial when a break breaks a segment of the cylinder. A fragile network of brittle tubes is not practical for industrial use due to the additional precautions required to protect it against breakage during concrete casting , despite this system's extensive healing potential and good repeatability. The discrete encapsulation of healing agents in spherical or tubular microcapsules is a more practical approach. These uniformly dispersed microcapsules break open when concrete cracks healing agent is released into the crack by capillary or gravity forces upon rupture.

VI. MECHANISM OF SELF HEALING CONCRETE

Self-healing concrete is produced by a biological reaction between unreacted limestone and a calcium-based nutrient with the assistance of bacteria to repair construction defects. Together with the calcium supplement calcium lactate, certain microorganisms known as Bacillus are utilised. When mixing is complete during the preparation of concrete, these products are added to the wet concrete. The latent stage of this bacteria can last for almost 200 years. Water pours into the concrete cracks as soon as they develop. The bacteria's spores start to grow and begin to feed on the calcium lactate, which consumes oxygen.

Limestone is created from the soluble calcium lactate. The insoluble limestone starts to become more solid. thereby naturally filling the crack without additional assistance. Another benefit of this process is that by consuming oxygen while converting calcium into limestone, the bacteria prevent steel from corroding because of fissures. This increases the steel-reinforced concrete construction's durability.

VII. BACTERIAL SELF HEALING CONCRETE PREPARATION

A. Bacterial Concrete Can Be Produced In Two Ways

1) Method Of Direct Application

When concrete is mixed in this way, bacterial spores and calcium lactate are directly added to it. Using this bacteria and calcium lactate does not alter the average properties of concrete. The bacteria become exposed as a result of changes in the climate. When water comes into contact with these bacteria, they germinate, feed on calcium lactate, and produce limestone, thereby sealing the cracks.

2) Method Of Encapsulation

The bacteria and their food, like calcium lactate, are put inside treated clay pellets in this method to make concrete. About 6% of the clay pellets are added to make self-healing concrete.

When bacterial concrete is used to construct concrete structures and when construction damage occurs and clay pellets are broken, cracks are sealed. After germinating, the bacteria consume the calcium lactate, producing limestone that hardens and seals cracks. Although more expensive than direct application, this approach is the most widely used.

VIII. CHEMICAL PROCESS

Calcium hydroxide is produced with the help of bacteria which acts as a catalyst when the water comes in contact with the un-hydrated calcium in the concrete. With atmospheric carbon dioxide, this calcium hydroxide reacts, which forms water and limestone.

$CaO+H_2O \rightarrow Ca(OH)2$

$Ca(OH)2+CO_2 \rightarrow CaCO3+ H_2O$

IX. ADVANTAGES & DISADVANTAGES OF BACTERIAL SELF HEALING CONCRETE

A. Advantages of Self-Healing Concrete

1) Crack self-healing without external assistance.
2) When compared to standard concrete, there is a significant increase in both the compressive and flexural strengths
3) Ability to resist freeze-thaw attacks.

4) Reduction in concrete's permeability.
5) Improves the durability of steel-reinforced concrete and reduces steel corrosion caused by cracks.
6) Because Bacillus bacteria do not harm living things, they can be used effectively.

B. Disadvantages Of Self-Healing Concrete

1) The price of bacterial concrete is twice that of standard concrete.
2) Bacteria can't grow well in any environment or medium.
3) The self-healing agent is held in clay pellets that make up 20% of the concrete's volume. The concrete may develop a shear or fault zone as a result of this.
4) There is no IS code or other code for the design of mixed concrete containing bacteria in this location.
5) Calcite precipitate research is expensive.

X. CHALLENGES FOR THE FUTURE

Despite the fact that natural and chemical self-healing processes are well-known for designing self-healing concrete, the biological process is a young and promising technology that has not yet been fully understood. Until now, it has been possible to isolate numerous natural bacteria that can be used to design self-healing concrete. One of the many benefits of using bacteria is that they are simple to culture. 2) Bacterial isolation is not particularly difficult, and 3) numerous methods have been described for adding bacteria to concrete. Conversely, bacteria lack sufficient resistance to concrete's harsh conditions—high pH, low water content, high temperature, etc. As a result, research into other kinds of microorganisms, particularly fungi, is crucial. Even though there aren't many articles on using fungi to make self-healing concrete, the mechanism of how fungi fill in cracks or the best conditions for fungi to grow aren't completely understood, so this could be a good area for future research. Biologically induced mineralization processes based on bacteria have been widely studied over the past ten years, but there are still significant limitations. Due to their exceptional capacity to adapt to the damaging environment of concrete and extraordinary capacity to promote calcium mineralization, fungi are one of the best options to be used as self-healing agents and should no longer be disregarded. There is a pressing need for research into fungi-mediated self-healing concrete.

XI. CONCLUSION

The methods for designing self-healing concrete are described in this paper. The incorporation of bacteria into the concrete is extremely beneficial because it enhances its quality beyond that of conventional concrete. The study looked at various kinds of bacteria that can be used to fix concrete cracks. Calcium carbonate crystals, which block and repair concrete cracks, are produced by bacteria to repair them. Numerous researchers have investigated the self-healing properties of concrete and discovered the following: bacteria increase the strength of conventional concrete by 13.75 percent in three days, 14.28 percent in seven days, and 18.35 percent in 28 days.As is common knowledge, self-healing concrete costs less to repair and maintain than conventional concrete. Therefore, in order to enhance concrete structures, we must enhance and utilize these techniques. The self-healing concrete design concepts and strategies are presented in this paper.

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