A REVIEW PAPER ON SELF HEALING CONCRETE

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ABSTRACT

In recent years, researches concerning the strength, toughness and the durability of cement based concrete structures. The interest on concrete's self-healing process is increasing, due to the rapidly deterioration of that material which tends to crack and thus quickly deteriorate. Crack formation is very common phenomenon in concrete structure which allows the water and different type of chemical into the concrete through the cracks and decreases their durability, strength and which also affect the reinforcement when it comes in contact with water, CO_2 and other chemicals. It is costly to maintain or repair concrete based structures time to time. For resolving this problem self-healing concrete mechanism is introduced in the concrete which helps to repair the cracks by producing calcium carbonate crystals which block the micro cracks and pores in the concrete. Self-healing concrete is classified into two parts: autonomous self-healing concrete and autogenous self-healing concrete.

KEY WORDS: *Concrete, Self-healing, Cracks, Repair, Strength, Bio-concrete.*

1. INTRODUCTION

Concrete is the mostly used material for the construction having high compressive strength and low tensile strength. Cracking of concrete is a common phenomenon. Without immediate and proper treatment, cracks in concrete structures tend to expand further and eventually require costly repairs. Even though it is possible to reduce the extent of cracking by available modern technology, remediation of cracks in concrete has been the subject of research for many years. There are a large number of products available commercially for repairing cracks in concrete: structures epoxy, resins, epoxy mortar and other synthetic mixtures. Cracks and fissures are a common problem in building structures, pavements, and historic monuments. We have introduced a novel technique in fixing cracks with environmentally friendly biological processes that is a continuous self-remediating process. In the study, Bacillus pasteurii that is abundant in soil has been used to induce CaCO3 precipitation. It is therefore vital to understand the fundamentals of microbial participation in crack remediation.

Definition

The "Bacterial Concrete" is a concrete which can be made by embedding bacteria in the concrete that are able to constantly precipitate calcite. This phenomenon is called microbiologically induced calcite precipitation. It has been shown that under favorable conditions for instance Bacillus Pasteruii, a common soil bacterium, can continuously precipitate a new highly impermeable calcite layer over the surface of an already existing concrete layer. The favorable conditions do not directly exist in a concrete but have to be created.

Figure: Self-Healing Concrete

1.2 Classification

1.2.1 Autogenous Self-Healing

The autogenous self-healing depends on most part of advanced hydration of concrete, carbonation of calcium hydroxide as well as another binder while. The autogenous self-healing is a traditional and famous method of concrete that occurred because of:

(1) Blocking cracks by waste
(2) Carbonation of Ca0H,
(3) Expansion of the hydrated concrete matrix in crack flanks and
(4) Ongoing hydration of clinker minerals cracks may heals after a while.

1.2.2 Autonomous Self-Healing Concrete

Autonomous self-healing concrete entirely relied on manual method that operates manually. The autonomous self-healing is been identify through a special terminology such as:

1. The vascular method;
2. Capsule method;
3. The bacterial method;
4. The electrodepositing method;
5. The shape memory alloy method;
6. The microwave method and/or induction energy.

2. Processes of Self-Healing Concrete

There are many processes of self-healing concrete technologies which are given below:

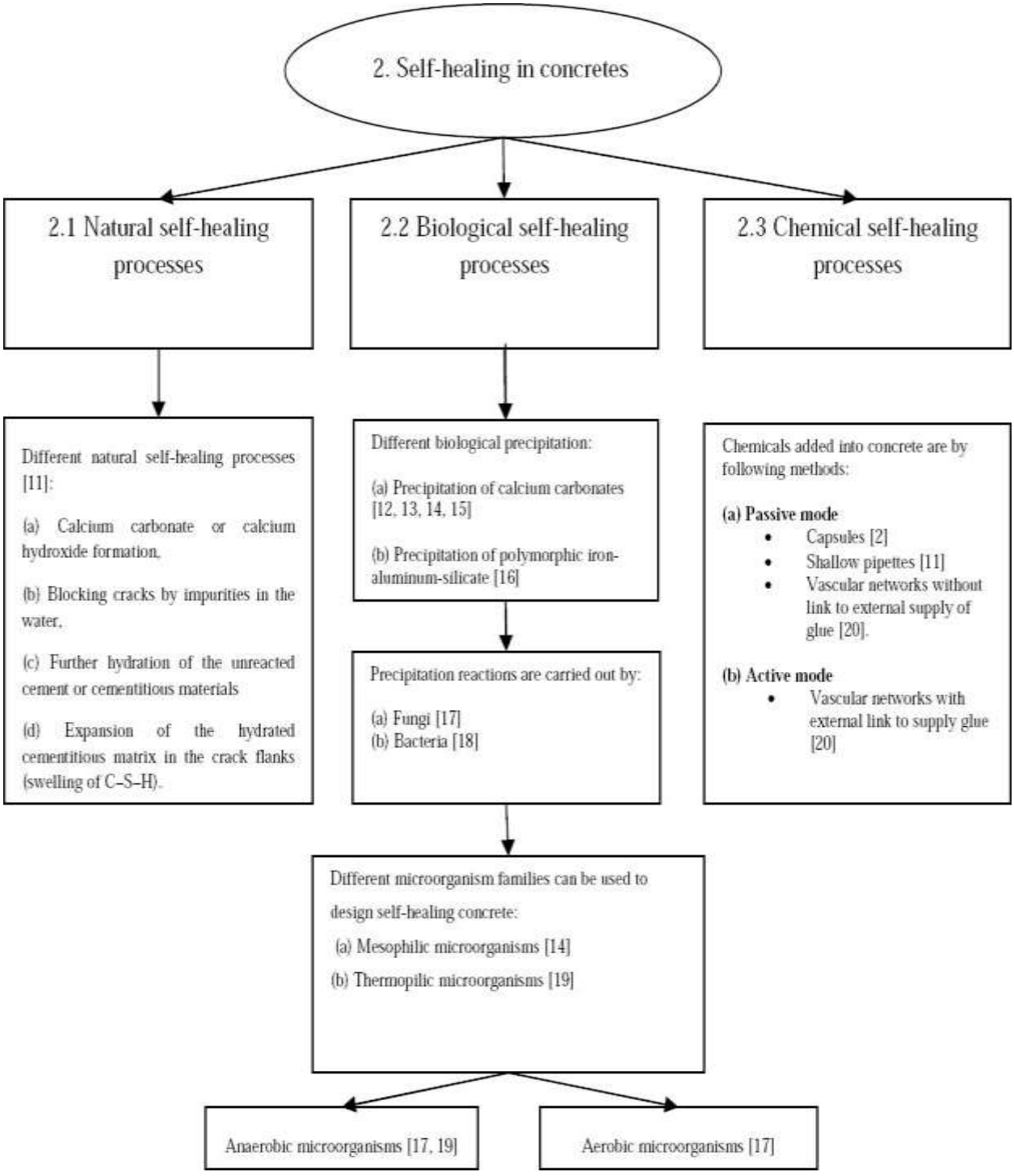
(i) Natural process;
(ii) Chemical process;
(iii) Biological process.

2.1 Natural Self-healing process

Some processes can partly fix concrete fracture in natural methods. Following are the four processes that can block cracks in concretes:

1. The development of CaC03 or Ca0H is another method to prevent crack
2. Crack is obstructed by impurities in the carriage of water
3. Crack is further obstructed by hydration of the unreacted cement

4. Crack is impeded by the enlargement of hydrated *cementitious* pattern in the crack loins (such as the lump of calcium silicate hydrate gel)



2.2 Chemical self-healing process

Chemical healing process mainly refers to the artificial healing by injecting chemical compounds into the crack for healing. Self-healing concrete is designed by mixing chemical liquid regents (i.e. glue) with fresh concrete in small

containers. The two common chemical methods that make use of glue addition to the concrete for healing purposes: (1) Hollow pipettes and vessel networks containing glue
(2) Encapsulated glue.

2.3 Biological self-healing process

The use of microorganisms to design self-healing concrete has been categorized as biological strategy by several researchers. Microorganisms can grow almost everywhere such as soil, water and oil reservoir, acidic hot springs and industrial wastewater. Microorganisms are mostly divided into three important categories: bacteria, fungi, and viruses. Among these microorganisms, special strains of bacteria capable of precipitating certain chemicals are used to design the biological self-healing concrete. Precipitation of polymorphic iron-aluminum-silicate ((Fe_5AI_3) $(SiAl)O_{l0}(OH)_5$) and calcium carbonate ($CaCO_3$) are the most important processes use for designing the biological self-healing concretes. The process of calcite precipitation is influenced by the decomposition of urea by bacteria, with aid of the bacterial urease enzyme. As a result of metabolism of bacteria species give urease, that catalyses' urea to ammonia and carbonate. Further these components hydrolyze to carbonic acid and ammonium chloride that leads to the formation of calcium carbonate (calcite crystal).

$$CO(NH_2)_2 + H_2O \rightarrow NH_2COOH + NH_3 \quad (1)$$

$$NH_2COOH + H_2O \rightarrow NH_3 + H_2CO_3 \quad (2)$$

$$H_2CO_3 \leftrightarrow HCO^-_3 + H^+ \quad (3)$$

$$2NH_3 + 2H_2O \leftrightarrow 2NH_{4+} + 2OH^- \quad (4)$$

$$HCO_{3-} + H_+ + 2NH_{4+} + 2OH^- \leftrightarrow CO_{32-} + 2NH_{4+} + 2H_2O \quad (5)$$

3. Material

Self-healing materials are group of energetic materials that have the structurally combined strength to fix damage created by mechanical way over time. The thought arises from biological methods, which have the capacity to fix after being damage.
(1) Biomimetic Design Approaches
(2) Liquid-Based Healing Agents
(3) Self-Healing of Cementitious Composites

4. Tests on Self-Healing Concrete

4.1 Water Permeability Test

For self-healing nature of concrete water permeability is also an important factor. After the splitting test the concrete specimen was broken completely. During the splitting test some fluid come out of the tube and emigrated into the cracks and then the specimen put in the curing room to wait till the solution become gel and the polyurethane foam formed after this cylinder were immersed into the water for 3 days. Take out cylinder after 3 days and dried it. The dry cylinder was fitted inside the pvc ring. During the water permeability test the vacuum saturation allows to establish a steady flow condition in a specimen which was first vacuumed in the vacuum chamber for 2-3 hours and then de-mineralized water was added into the chamber. The cylinder was kept immersed completely into the water for 24 hours due to the completely immersed specimen the vacuum stopped. Then cylinder was taken out and prepare for the water permeability test.

4.2 Compressive Strength

Compressive strength of the concrete is the capacity of the structure to resist the load acting on them. By the adding of bacteria to the concrete it improves the compressive strength of concrete as compare to conventional concrete. The compressive strength of concrete was improved by 14.92% by adding bacillus subtilisjc3 as compare to the conventional concrete. It was found that b. Sphaericus improved the compressive strength of concrete by 30.76% in 3 days, 46.15% in 7 days and 32.21% in 28 as compared to conventional concrete.

S.No	Bacterial concrete			Conventional concrete	
	Compressive strength (N/mm²)			Compressive strength(N/mm²)	
	Name of bacteria	7 days	28 days	7 days	28 days
1	Bacillus Subtilis	22.18	32.74	20.84	29.99
2	Bacillus sphaericus	34.58	45.72	20.84	29.99
3	Bacillus pasteurii	27.09	38.98	20.84	29.99

4.3 Oxygen Consumption Measurement

Oxygen consumption measured when oxygen consumed by aerobic bacterial metallic conversion of calcium lattice. For the study the optical oxygen micro sensors were used for quantification of water submerged control and bio chemical healing agent containing mortar specimens and it can be calculated by calculating the change in oxygen concentration in the linear part of the gradient in the diffusive boundary layer using fick's first law of diffusion.

$J = -D_{(oxygen)} * dC_{(z)}/dZ$

Where D_{oxygen} is the diffusion coefficient of O_2 in water, and $C_{(z)}$ is the concentration of O_2 at depth Z.

4.4 Gas Permeability

Rilem- cembureau method can be used to find the gas permeability using the principal as the hagen- poiseuille relationship for laminar flow of a compressible fluid through a porous body having small capillaries under steady state. Martin sommer oxygen permeability experiment measures the rate of flow of oxygen.

4.5 Treatment Procedure

For the treatment procedure the specimen is immersed in the 0.3 and 0.6 L of a 1 day old stock culture of *B. sphaericus* prior to submerge in the nutrition solution for 24 days due to this ureolytic activity primarily result from bacteria inside the specimens. Selection of the treatment based on the commercial availability according to their different mechanisms in table

Group	Subgroup	Composition of conventional technique/nutrient solution
Biodeposition treatment	Ureolytic mixed cultures	1. Urea, NBP 2. Urea, calcium acetate 3. Urea, calcium chloride 4. Urea, NBP calcium acetate 5. Urea, NBP calcium chloride
	Bacillus sphaericus	1. Ureas, NBP 2. Urea, calcium acetate 3. Urea, calcium chloride 4. Urea NBP, calcium acetate 5. Ureas NBP, calcium chloride

4.6 Effect on the Strength Test

As amalgamation of healing agent to concrete may have unwanted negative effects on the mechanical properties. The consolidation of a high number of bacteria (5.8 x 108 cm-3 cement stone) will have a negative effect on the compressive strength development as bacterial test specimen appeared almost weaker than control specimen. Tensile strength is the ability of a material to withstand a pulling (tensile) force. Earlier studies have proven that bacterial concrete shows the better tensile strength as compare to the conventional tensile strength as shown below.

S.No.	No. of days	Split tensile strength of conventional concrete cylinders, N/mm^2	Split tensile strength *B. sphaericus* concrete cubes, N/mm^2	% increase in Strength
1.	3	3.78	4.30	13.75
2.	7	4.62	5.28	14.28
3.	28	4.85	5.74	18.35

5. Advantage and disadvantages of Self-Healing Concrete

5.1 Advantages

- Redressing of cracks can be done efficiently.
- It offers great resistance against freeze and thaw attacks.
- It has lower permeability when compared to conventional concrete.
- The use of self-healing concrete significantly enhances the strength of concrete.
- The chances of corrosion of reinforcement are reduced to negligible.
- Overall maintenance cost of this concrete is low.

5.2 Disadvantages

- The investigations involved to observe calcite precipitation are costly.
- Cost of this concrete is comparatively higher than conventional concrete; it's about 10-30% more than conventional concrete.
- There is no design of bacterial concrete is mentioned in IS codes or any other codes.
- Bacteria that are used in concrete are not good for human health; hence its usage should be limited to the structure.

6. Conclusion

This paper gives the methods for designing self-healing concrete. Introducing the bacteria within the concrete performs extremely useful it improves the attribute of the concrete, which is higher than the conventional concrete. The study reviewed about different types of bacteria that can be used for remedying cracks in concrete. Bacteria repair the cracks in concrete by producing the calcium carbonate crystal which block the cracks and repair it. Many researchers done their work on the self-healing nature of concrete and they had found the following result that bacteria improves the property of conventional concrete such as increase in 13.75% strength increased in 3 days, 14.28% in 7 days and 18.35% in 28 days. As we all know that the repairing and maintenance are costly by the conventional methods than the self-healing concrete. So we have to improve and use these methods for the betterment of concrete structures. This paper gives the ideas and methods for designing the self-healing concrete.

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