International Journal of Scientific Research in Civil Engineering
© 2020 IJSRCE | Volume 4 | Issue 5 | ISSN : 2456-6667

Self-Healing Concrete by Using Microbiological Process

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Article Info
Volume 4, Issue 5
Page Number: 01-05
Publication Issue :
July-August-2020

ABSTRACT

It is a well known fact that concrete structures are very susceptible to cracking which allows chemicals and water to enter and degrade the concrete, reducing the performance of the structure and also requires expensive maintenance in the form of repairs. Cracking in the surface layer of concrete mainly reduces its durability, since cracks are responsible for the transport of liquids and gasses that could potentially contain deleterious substances. When microcracks growth reaches the reinforcement, not only the concrete itself may be damaged, but also corrosion occurs in the reinforcement due to exposure to water and oxygen, and possibly CO2 and chlorides too. Micro-cracks are therefore the main cause to structural failure. One way to circumvent costly manual maintenance and repair is to incorporate an autonomous self -healing mechanism in concrete. One such an alternative repair mechanism is currently being studied, i.e. a novel technique based on the application of biominerilization of bacteria in concrete. The applicability of specifically calcite mineral precipitating bacteria for concrete repair and plugging of pores and cracks in concrete has been recently investigated and studies on the possibility of using specific bacteria as a sustainable and concrete embedded self healing agent was studied and results from ongoing studies are discussed. Synthetic polymers such as epoxy treatment etc are currently being used for repair of concrete are harmful to the environment, hence the use of a biological repair technique in concrete is focused. In the present paper, an attempt is made to incorporate dormant but viable bacteria in the concrete matrix which will contribute to the strength and durability of the concrete. Water which enters the concrete will activate the dormant bacteria which in turn will give strength to the concrete through the process of metabolically mediated calcium carbonate precipitation. Concrete, due to its high internal pH, relative dryness and lack of nutrients needed for growth, is a rather hostile environment for common bacteria, but there are some extremophilic spore forming bacteria may be able to survive in this environment and increase the strength and durability of cement concrete. Overview of development of bioengineered concrete using bacterial strain Bacillus Sphericus and its enhanced mechanical and durability characteristics will be briefly described in this paper.

Article History
Accepted : 20 Aug 2020
Published : 01 Sep 2020

Keywords : Bacterial Concrete, Bacillus Sphericus, Self-Healing, Biominerlization.

I. INTRODUCTION

Self-healing concrete is mostly defined as the ability of concrete to repair its small cracks autonomously. The idea of self-healing concrete was inspired from the natural phenomenon by organisms such as trees or animals. Damaged skin of trees and animals can be repaired autonomously. Remediating cracks in concrete structure is important for its service durability and structural safety.The main keyword of this article is self-healing concrete. However, other similar keywords in this area are self-healing, self-repair, autonomous healing, automatic healing, auto-treatment, self-treatment, bioconcrete, bio-inspired, biological concrete, calcite biomineralization, and calcite precipitation. Recently, developing self-healing concrete technology has become an important objective for researchers in biotechnology and civil engineering sciences . During the 1980s, only very few articles can be found related to self-healing concrete, more over serious studies in this area were not established until late 1990's. Among the self-healing designing methods, biological methods are the latest ones.Several processes are proposed for the design of selfhealing concrete. This paper reviewed all processes of self-healing concrete technologies containing (1) natural (2) chemical and (3) biological processes.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 all most everywhere such as soil, water and oil reservoir, acidic hot springs and industrial wastewater. The use of microorganisms to design self-healing concrete has been suggested by several researchers .Gollapudi et al. introduced biological self-healing concrete as environment friendly process . 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 & activate bacteria are the most important for designing the biological self-healing concretes.

II. PROBLEM STATEMENT

Concrete encompasses certain types of cracks in prehardening as well as post hardening stage in the life of a structure. Even with our extreme care and prevention we acquire certain cracks. when concrete become older and harder and cracks occur on the surface, such cracks becomes source of the leakage and seepage and give a passage to the moisture, oxygen, chlorides, carbon dioxide etc. and other chemicals and gases which may cause serious damage to the structure which may cause corrosion to steel and damage to concrete and ultimately structural failure of the member. Cracks that occur before hardening, primarily due to settlement, construction movements, and excessive evaporation of water, are called plastic cracks. Plastic cracking that can be predominantly eliminated through close attention to the mixture design, material placement, and curing. Cracks that occur after the concrete has hardened may be due to variety of reasons. These may be due to mechanical loading, thermal gradients, moisture and incompatibility due to chemicals reactions.

Repair of cracks in concrete structures usually involves applying a concrete mortar which is bonded to the damaged surface. Sometimes, the mortar needs to be keyed into the existing structure with metal pins to ensure that it does not fall away. Repairs can be particularly be time consuming and expensive because it is often very difficult to gain access to the structure to make repairs, especially if they are underground or at a great height. For crack repair, a variety of techniques is available but traditional repair systems have a number of disadvantageous aspects such as different thermal expansion coefficient

compared to concrete and also have impact on environment and health.

III. MATERIAL

1 .BACILLUS SPHAERICUS(Bacteria)

In every 500ml of water while mixing concrete, 10 ML of bacteria was used.

2. CALCIUM LACTATE POWDER

Calcium lactate is a black or white crystalline salt made by the action of lactic acid on calcium carbonate. It is used in foods (as an ingredient in baking powder) and given medicinally.It is created by the reaction of lactic acid with calcium carbonate or calcium hydroxide. Cheese crystals usually consist of calcium lactate, especially those found on the outside, on younger cheese, and on Cheddar cheese. In medicine, calcium lactate is most commonly used as an antacid and also to treat calcium deficiencies.

For 1000ml of distilled water 25 gm. of nutrient in to it.

3.SILICA FUME

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolana. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and, when specified, is simply added during concrete production. Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor.

CHEMICAL PROCESS OF SELF-HEALING OR BACTERIAL CONCRETE

When the water comes in contact with the unhydrated calcium in the concrete, calcium hydroxide is

produced by the help of bacteria, which acts as a catalyst. This calcium hydroxide reacts with atmospheric carbon dioxide and forms limestone and water. This extra water molecule keeps the reaction going.

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

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

The limestone then hardens itself and seals the cracks in the concrete.

IV. RESULTS AND DISCUSSION

I. EXPERIMENTAL TEST

TABLE 1 : COMPARISON BETWEEN COMPRESSIVE STRENGTH OF CONVENTIONAL CONCRETE BACTERIAL CONCRETE .

S.NO Bacterial Normal c

COMPRESSIVE STRENTH (N/*mm*2)

SR NO.	CONVENTIONAL CONCRETE		BACTERIAL CONCRETE	
	7 DAYS	28 DAYS	7 DAYS	28 DAYS
1	19.35	28.55	22.35	33.94
2	18.55	29.45	22.10	31.95
3	19.40	29.85	21.45	32.50

TABLE 2: COMPARISON BETWEEN SPLIT TENSILE STRENGTH OF CONVENTIONAL CONCRETE BACTERIAL CONCRETE

SR NO.	CONVENTIONAL CONCRETE		BACTERIAL CONCRETE	
	Split tensile (N/*mm*2)		Split tensile (N/*mm*2)	
	7 DAYS	28 DAYS	7 DAYS	28 DAYS
1	1.75	3.04	2.74	3.81

ADVANTAGES OF BACTERIAL CONCRETE

- Self-repairing of cracks without any external aide.
- Significant increase in compressive strength and flexural strength when compared to normal concrete.
- Resistance towards freeze-thaw attacks.
- Reduction in permeability of concrete.
- Reduces the corrosion of steel due to the cracks formation and improves the durability of steel reinforced
- concrete.
- Bacillus bacteria are harmless to human life and hence it can be used effectively.

V. SUMMARY

The goal of this paper is to introduce bacteria-based self-healing concrete, currently being developed in our laboratory. On the lab-scale a fully functional system exists. To the concrete mixture a healing agent is added, consisting of two components immobilized in expanded clay particles. Due to bacterial activity a calcium carbonate layer is deposited on the crack surface, sealing and blocking entrance to deteriorating substances. Further research and development is needed in order to make the material ready for application in practice. Since potential advantages are mainly anticipated in reduction of costs for maintenance and repair and service life extension of concrete structures, the self-healing material needs to be cost efficient and durable.

VI. CONCLUSION

This paper reviews intensively about the great potential of biological method, using the bacteria capable of precipitating calcite, as providing the way forward for developing biological self-healing concrete. The precipitation of calcite will form calcium carbonate that would help in healing concrete cracks. The taxonomy proposed in this paper contributes significantly for researchers in the field of biological to embark on the research work of self-healing concrete. The examination achieved utilization of microscopic organisms in cement enhances its strength and durability hence using this type of bacteria for self-healing mechanism in concrete can produce cost effective strong or durable structures.

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Cite this article as :

Shekhar Raut, Nikhil Nitnaware, Prashant Darekar, Prakash Chakor , Prof. Pravin Gunaware, "Self-Healing Concrete by Using Microbiological Process ", International Journal of Scientific Research in Civil Engineering (IJSRCE), ISSN : 2456-6667, Volume 4 Issue 5, pp. 01-05, September-October 2020. URL : http://ijsrce.com/IJSRCE20453