

## REVIEW ON THE MECHANICAL PROPERTIES OF SELF HEALING CONCRETE

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### ABSTRACT

Concrete has taken hold of the world of infrastructure incredibly quickly. It has become the most commonly used man-made material in construction industry. Cracks are formed in concrete as concrete is weak in tension. These cracks allow moisture and different types of chemicals into concrete and decrease its durability and strength. Nowadays repair, rehabilitation, and maintenance of structures is expensive and time-consuming. So to overcome this problem autonomous self-healing mechanism is introduced in concrete which helps to repair cracks and also improves the strength of the concrete. To prepare self-healing concrete there are two methods- The first is biological method. In this method, *Bacillus Subtilis* bacteria and Calcium lactate was added to the concrete mix. The production of calcium carbonate in bacterial concrete is limited to the calcium content in cement. Hence calcium lactate is externally added to be an additional source of calcium in the concrete. When cracks appear the bacteria will produce limestone and fills the cracks. This bio concrete possesses quality to repair itself and thus increasing the sustainability of concrete. The second method of self-healing concrete is a chemical method. The chemical like Sodium silicate is used to prepare self-healing concrete. In the present study for bacterial concrete *Bacillus Subtilis* bacterium solution of  $2 \times 10^8$  cfu/ml concentration with 2%, 3% and 4% water replacement was mixed to concrete. For the preparation of concrete by chemical method polyethylene glycol and sodium silicate chemicals were added to the water in concrete with varying percentages i.e. 2%, 3% and 4%. The sodium silicate added will react with calcium hydroxide and forms sodium silica hydrate (N-S-H) which is a gel that has the capacity to heal the cracks.

The compressive strength test, split tensile strength test and flexural rigidity test were conducted on the specimens of nominal concrete, bacteria concrete and chemical concrete to understand the mechanical properties and rate of self-healing in concrete. Experimental results reveal bacterial concrete and chemical concrete after 28 days of curing attained better mechanical properties when compared to nominal concrete. To determine the self-healing ability artificial cracks were created on the specimens. These cracked specimens were kept in water for curing and bacterial concrete specimens were healed after 28 days of curing and it took 32 days in the case of concrete used with chemicals. After healing of cracked specimens they are tested and it was found that 4% proportion of bacteria concrete attained maximum strength.

### 1. INTRODUCTION

Concrete has become a basic building element for the present world. The versatility of concrete made the world to use the material like any other. It has good fire resistance, adaptability, high compressive strength and it can take any desirable shape or size. But it is a fragile material as it easily cracks because concrete is weak in tension. Once formation of cracks take place in the concrete it leads to decrease in durability and strength of the concrete structure. This in turn causes deterioration of structure so these micro-cracks are prone to concrete structures. To treat these micro-cracks by traditional methods requires constant maintenance, routine inspections, time and energy. More over to reduce the damage that is caused by cracks require concrete this makes additional production of cement and this leads to release high amount of carbon dioxide in to the environment. To overcome these cons we have to use an alternative repair method where we can decrease usage of concrete and increase the durability and strength for the concrete structure.

Researchers around the world are working on self-healing concrete for crack controlling has become a major hotspot. When crack propagates on the concrete structure the crack will be healed itself without any intervention is called as

self-healing concrete. So by using this moderate repair method we can treat cracks and increase strength of the concrete

Self-healing of concrete to is of various methods to treat cracks. For each method the healing agent which we use will change like capsule based bacteria, vascular healing, shape memory alloy, chemical based and super absorbent polymers. The inspiration for creating SHC is from, when there is a scratch on the human skin the wound will heal itself without any disturbance and there will be internal mechanism to self-heal. In the same way the cracks will heal by using SHC. The healing agents which we use will change the properties of the concrete and they should have some features like crack repairing should be done automatically, there should not be any negative effect on the materials should have long lasting potential of self-healing, should be economical.

Self-healing capability depends on the healing agent we use and environmental conditions like temperature, ph of water, method of mixing. In the present study we are using SHC using bacteria and chemical.

## 2. LITERATURE REVIEW

**Kim Van Tittelboom et al. 2016 [1]** he said that use of synthetic polymers for treating repairs is unfavorable to the environment so in the present investigation he used biological method to repair cracks. For this he used Ureolytic bacteria namely *Bacillus sphaericus* and this bacteria is used to fill the cracks with calcium carbonate and we have to provide calcium lactate as a calcium source. In the present research the amount of crack healing was compared for biological method and traditional method by using water permeability test, visual examination and ultrasonic pulse velocity test. From the experimental results we can say that crack healing by biological method is more effective than traditional methods. Crack healing by using biological method leads to decrease in water permeability than traditional methods. Crack repairing with *B. sphaericus*, which is integrated in silica gel results in improvement of ultrasonic pulse velocity and this indicates that biological method is more useful in crack healing than the traditional method. So we can use biological method as enhanced crack repair technique because this method is not harmful to the atmosphere.

**Henkm.jjonkers et al. 2010 [2]** crack formation is commonly spotted in the concrete structures. The formation of micro-cracks affects the structural properties of the building and decrease the strength of the building. To heal the cracks a novel study was carried out by using the bio-chemical two-component self-healing agent which consists of 6% calcium lactate and bacterial spores concentration of  $1.7 \times 10^5$ . This mixture is inserted in expanded clay particles and these agents will be released from clay particles upon crack formation when water enters into micro cracks. By sequence analysis of 16SrRNA gene of this bacterium reveled that it is *bacillus alkaliniliticus* which is alkali resistant soil bacterium. From the experimental investigations it was found that bacteria-based concrete specimens healed much better than normal concrete specimens after 100 days of immersion of specimens in water. And we can observe doubling of crack healing potential due to precipitation of calcium carbonate by the bacteria and also oxygen was absorbed by the bacterial concrete specimens. Whereas nominal concrete specimens not absorbed oxygen. By the examining the crack healing we can observe there is improvement of the concrete permeability after the damage. So this novel self-healing agent increases durability of concrete structures in wet environments and there is an anticipated potential advantage of this bacterial concrete which helps in reduction of maintenance and repair costs and improves durability of concrete constructions.

**NavneetChahal et al. 2012 [3]** carried out an experimental investigation to assess the influence of *sporoscarcinapasteurii* bacteria on the compressive strength and rapid chloride permeability of concrete made with and without fly ash. This bacterium has the potential to solidify organic nitrogen source through the process of biological cementation. *S. pasteurii* has been proposed to be used as a biological construction material.

**James Gilford et al. 2014 [4]** proposed the technique, encapsulation. By using this method two self-healing agents namely sodium silicate and dicyclopentadiene are encased in a microcapsules and mixed in the concrete. When concrete subjected to cracking the crack reaches the microcapsule and leads to break down of capsules then healing agents which are presented in capsule are released and treat the crack.

**Biqin Dong et al. 2014 [5]** in the present investigation they used a novel microcapsule based self-healing system with a capacity of decreasing of chloride concentration and occurrence of healing activities will be evenly distributed in concrete rather than passive healing mechanisms. The release behavior of the microcapsule was studied by the EDTA (Ethylene Diamine Tetra- acetic Acid) titration method. Based on the experimental results the shell thickness of microcapsules is depends on the controlled dosage of the shell materials.

**SuganyaDevi et al. 2016 [6]** attempted to produce Self-healing concrete by using chemicals like polyethylene glycol and sodium silicate instead of bacteria or polymers. These chemicals are added in to the concrete mix in various percentages by replacing with water and both chemicals used in the present experiment have different properties. The

sodium silicate will be used as a healing agent and also it increases the compressive strength of the concrete and another chemical Polyethylene glycol is used for self-curing of concrete. The sodium silicate which is used in the concrete mix by replacing with water and it reacts with calcium hydroxide in the presence of water and forms sodium silica hydrate gel. This N-S-H gel will be helpful in treating the cracks. From the investigation came to know that mechanical properties of SHC which is cured in water has more strength compare to SHC which is self-cured. And the formed calcium silica hydrate also acts as corrosive inhibitor.

**Giannaros et al. 2016** [7] in the present investigation microencapsulated self-healing mechanism is used to repair cracks. The principle of this method is when crack generates in the cementitious mix the scattered capsule will be ruptured and the material present in the glass tube will be released in to the cracked portion and the crack will be healed. In this experiment sodium silicate is used as healing agent in both liquid and solid form.

**SandipMondala et al. 2017** [8] concrete has become the most widely used construction materials. But one thing we can't avoid is formation of micro cracks and is became an inescapable feature for ordinary concrete and these micro-cracks will slowly increase the permeability of concrete and affects the toughness aspects of the concrete building. In the present investigation they used two types of bacteria namely *Bacillus Cereus* and *Bacillus Subtilis* with three different concentrations ( $10^3$  cells/ml,  $10^5$  cells/ml and  $10^7$  cells/ml) to improve the compressive strength of concrete with respect to conventional concrete.

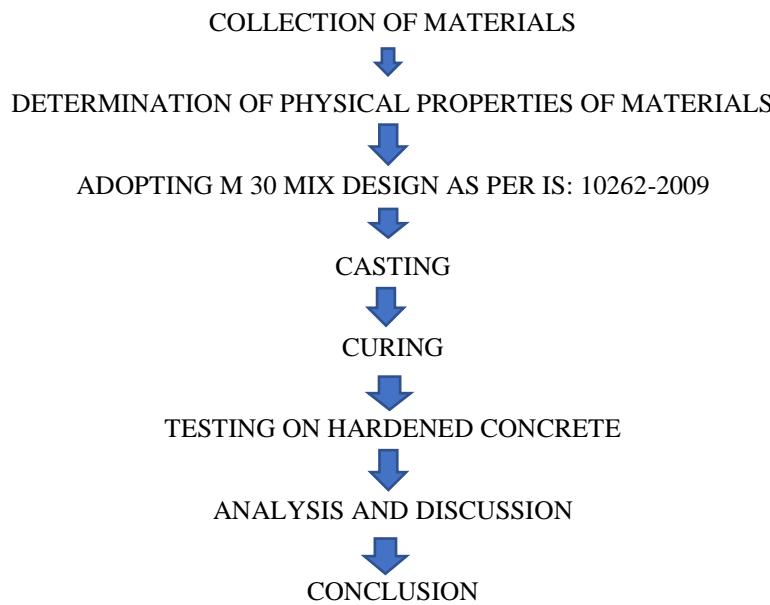
**Kunamineni Vijay et al. 2017** [9] presented extensive studies on self-healing concrete using two ureolytic bacteria. Presence of micro cracks became a major problem in concrete structures and this in turn causes decreasing the strength of the concrete and finally the structure will be failed. To rehabilitate various repair techniques are there but they are time consuming and not economical. To overcome this situation we are using a moderate technique i.e. bacterial concrete is adopted. In the present study they used two healing agents which are *Bacillus* sp. CT-5, *Bacillus Subtilis* bacteria along with calcium source. And this bacterium precipitate calcite in concrete and this  $\text{CaCO}_3$  precipitation is used to treat the freshly formed micro cracks. Experimental studies shows that improvement of 12% in compressive strength as compared to normal concrete specimens due to using *Bacillus subtilis* ( $2.8 \times 10^8$  cells/ml) and Compressive strength is 40% more than the normal concrete by using *Bacillus* sp. CT-5 ( $5 \times 10^7$  cells/mm<sup>3</sup>) so bacteria has a positive effect on the compressive strength of cement mortar cubes and one of the major advantage is it decreases water penetration and ingress of chloride ions.

**Jagannathan et al. 2018** [10] studied the mechanical properties of SHC using bacteria. Concrete is brittle and has low tensile strength still it is used in construction industry for constructing bridges, sleepers, pavements but many concrete structures faces deterioration problems like carbonation, chloride attack. For this we need to repair and retrofit the structures. For crack repairing we are using ureolytic bacteria where it precipitates calcium carbonate crystals and fill the cracks naturally. To have the higher precipitation of calcium carbonate the bacteria which we used should be alkaliphilic, thermophilic. For this study using two *Bacillus* species namely *Bacillus Sphaericus* and *Bacillus Pasteurii* which are resistant to highly alkaline environment of concrete and they are alkaliphilic. So they make the concrete denser and improve compressive strength of concrete. The usage cement is increasing globally and also the emission of carbon dioxide in to the atmosphere has an adverse effect on environment. There are other cementations materials like silica fume, fly ash, ggbs and these materials can be replaced partially to cement. Experimental data shows that the mechanical properties of *Bacillus sphaericus* fly ash concrete has improved than nominal concrete and *Bacillus pasteurii* bacterial concrete. Use of fly ash enriched with *Bacillus sphaericus* to replace cement in concrete is advantages as it is economical and reduces carbon foot print.

### 3. OBJECTIVE

- To evaluate property of material to use and prepare self healing materials.
- To analyze air voids and binding property of Concrete
- Suggest best alternative materials for self healing concrete.

#### 4. METHODOLOGY



##### Collection of Materials :

- Cement : OPC 53
- Fine Aggregate
- Coarse Aggregate : Crushed Stone of size 20mm
- Water : Portable water
- Bacterial Solution : *Bacillus Subtilis* is a laboratory cultured bacterium
- Calcium Lactate
- Sodium Silicate

##### Physical Properties of Materials :

- Tests on Cement :
  - a. Normal consistency of Cement,
  - b. Specific Gravity of Cement
- Test on Aggregate :
  - a. Specific gravity of fine aggregate,
  - b. Fineness Modulus of fine aggregate,
  - c. Specific Gravity of Coarse Aggregate

Mix Design : ADOPTING M 30 MIX DESIGN AS PER IS: 10262-2009

- Casting : Cube specimens of size 150mm×150mm×150mm
- 500mm×100mm×100mm
- Cylindrical specimen of size 150mm dia and length 300mm

Curing : After setting of concrete for 24 hours the moulds are demoulded and concrete specimens are placed in the fresh water. The specimens were tested after 7 and 28 days of curing.

##### Testing of Hardened Concrete :

- Compression Test
- Split tensile test
- Flexural Strength test

#### 5. CONCLUSION

The overall conclusion includes, the two separate moulds are prepared the one where self healing materials are added and another one is conventional concrete block, its mouled and tests are performed and difference in strength between two different blocks are analyzed that self healing blocks have more strength and cracks will be healed.

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