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Self-Healing Concrete: A Review

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ABSTRACT: Concrete is a brittle material which is magnificent strength in compression and week in tensile strength. When the loading on the concrete member is greater than its limit then cracks are formed. These cracks are micro cracks which are formed due to low tensile strength in concrete.
In concrete member steel produces iron oxides and hydroxides, these are accumulated on the steel works surface and the volume increases. This increase in volume cause cracking by concrete fails under tensile stresses. This paper describes the bacterial concrete it is also called as self healing concrete. The self healing concrete invented by HenkJonkers in 2006. He found the perfect healing agent which survives the harsh environment of concrete that is bacillus. The bacterial concrete used to achieve greater strength than conventional concrete. This paper present an detail overview on self healing concrete review methodologies, advantages and disadvantages

I. INTRODUCTION

Concrete member made up of sand, cement, aggregate and reinforcement. Concrete shrinks and expand due to moisture and temperature changes. The main changes of shrinkage cause reducing in water content in member and thus cracks are formed. To repair and maintenance of member types of Sealant Repairs are used, they are control joint sealant, recurrent movement and stop water leak etc they sealed the cracks against water, debris and frost. This sealant are designed to control the cracks appear in concrete placed at vertically as well as horizontally. They also handle recurrent movement using a flexible type of sealant. But by using sealant it can be increase the difficulty of maintenance and diagnosis of cracks. After applying sealant in case of dyeing, the dry paint peel out. The main disadvantages of sealant, when applying one layer of sealant after drying both the layer new one and old layer are delaminated. It is most commonly used building material, there is wear and tear will no worry for the concrete member in concrete building. We need to bacteria which can survive the environment of concrete (Harden state). Bacillus is perfect match for the bacterial that can survive in concrete. Bacillus bacteria produce spores which is helps to live up bacteria maximum four years without any food or oxygen. The Jonkers made the mixture in order by adding calcium lactate to limestone concrete to feed the bacillus so that the bacteria produce limestone to repair cracks in concrete member.

- Bacteria **are used in self healing concrete are** Bacillus pasteurizing
- Bacillus sphaericus
- Escherichia coli
- Bacillus subtilis
- Bacillus cohnii
- Bacillus balodurans
- Bacillus pseudofirmus

Mechanism Behind bacteria used in self healing concrete

As above mention the bacteria added in concrete is non reacted with limestone and calcium. The limestone and calcium helps the bacteria as a nutrient and heal the cracks developed on the concrete member. These bacteria can be in sleeping stage for around 200 years. For preparation of concrete mix, bacteria added in wet concrete then the mixing id done. The calcium lactate is the food for the bacteria, when we add the bacteria in concrete bacteria survive on the calcium lactate and consume oxygen. The calcium lactate is converted in to insoluble limestone, and it stars to get harden . This, the cracks are fill by self healing concrete without any external agencies. Also the bacteria convert calcium into limestone. This will helps to prevent corrosion of steel due to cracks. This improves the durability of reinforced steel in concrete member.

II. LITERATURE REVIEW

AbhishekPandit , Sahila Shaikh , PranjaliMangalwedhekar , SakshiJagtap ,

Swapnil Gorade Published A Review Paper on Bacterial Concrete Volume 5, Issue 5, 2018, Published bacteria for repaired the cracks in concrete. Conclude that the bacterial concrete inproves strength 15% in 7 days and 18-20 % in 28 days. The regular inspection and maintenance for the concrete structure will be less need due to use of self healing material used in the concrete. The cost of bacterial concrete is initially looks more but it is profitable when we go for bulk quantity and compensated due to reduction in the rehabilitation cost.

D. Gardner et.al published a paper on a survey on problems encountered in current concrete construction &Self healing mechanism. The market research survey was done in the UK and it was found that the annual costs for repair, maintenance and replacement of civil infrastructure projects involve significant expenditure. The market research results verified that self-healing concrete may tackle some of the main concerns facing civil engineering infrastructure. Self healing concrete reduced cost of repair and maintenance over whole life and better durability.

Erik Schlangen and SenotSangadji, published a paper on infrastructure durability and sustainability by self healing mechanisms. An overview is given of new developments obtained in self healing concrete. Three projects discussed of Delft University running to study self healing mechanisms. In first, bacteria added in concrete that can precipitate calcite in a crack and with that make concrete structures water tight and enhance durability. In a second project hybrid fibre reinforced cementations materials SAP are studied that can mechanically repair cracks when they occur. The last project discussed on porous asphalt concrete and how to heal its damage by incorporating embedded microcapsules self healing capacity is enlarged by using encapsulated oil and micro-steel fibres.

Lakshmi.L. et.al.Published a paper on durability and self- healing behaviour of bacterial impregnated concrete. This paper shows the results that bacterial impregnated concrete is crack free & corrosion free by pre- adding the bacteria Bacillus subtilis JC3 into the concrete. Bacteria Bacillus subtilis have the ability to withstand against hostile environment of concrete. B. subtilis have a thick wall membrane which helps to offer resistance against high pH. Hence these bacteria remain hibernated within the concrete for 200 years until gets the suitable environment. Results shows that on durability test of 100 days, 0.1 mm crack width was healed completely, concluding that bacterial concrete is denser & durable.

Mayur Shantilal Vekariyaet. al. explained about bacterial classification & types of bacteria, chemical process to fix the crack by bacteria. They also explained advantages of bacteria in concrete for crack remediation, strength improvement by reducing permeability, corrosion and better resistance to concrete freezing & thawing action. But disadvantages of Bacterial concrete are that its cost is double than conventional concrete. Also growth of bacteria is not good in any atmosphere & media. Design mix of concrete with bacteria is not available in IS code or any other code. Investigation of calcite precipitation is costly to study.

NijoBavenet. al. discuss workability and compressive strength of bacteria enriched steel fibre reinforced self compacting concrete. Steel fibers has no blocking in J- ring test when it is in between the range of 0-25 mm. SCC with 20 % replacement of cement with micro silica has better compressive strength. The bacteria enriched steel fiber reinforced concrete is a practical concept with good compressive strength and flow ability.

S. Sunil Pratap Reddy et.al, studied the performance of the standard grade bacterial (Bacillus subtilis) concrete. Its main focus was on how the right conditions can be created for the bacteria not only to survive in the concrete but to produce proper calcite to repair cracks. Cement mortar cubes with four different cell concentrations and control specimen were casted. Results shows that compressive strength of concrete increased significantly by 14.92% at 28 days due to the addition of bacteria for a cell concentration of 105 cells per ml of water. Addition of bacteria improves the hydrated structure of cement mortar. From SEM analysis, it was noted that pores were partially filled up by material growth with the addition of the bacteria. Bacillus subtilis bacteria showed significant improvement in the split tensile strength than the conventional concrete. From the durability studies, Bacterial concrete has less weight and strength losses than conventional concrete.

Jianyun Wang et.al, investigated use of silica gel or polyurethane immobilized bacteria for self-healing concrete. Bacterial activity decreases a lot in the high pH environment. Hence in this work the possibility to use silica gel or polyurethane as the carrier for protecting the bacteria was investigated. Experimental results show that silica gel immobilized bacteria exhibited a higher activity than polyurethane immobilized bacteria, and hence, more CaCO3 precipitated in silica gel (25% by mass) than in polyurethane (11% by mass) based on thermo gravimetric analysis. However, cracked

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mortar specimens healed by polyurethane immobilized bacteria had a higher strength regain and lower water permeability coefficient compared with specimens healed by silica gel immobilized bacteria.

Process behind Self healing concrete

The bacteria are added in wet concrete, the calcium carbonate is formed as a result of reaction. When water comes in contact with the calcium in concrete, calcium hydroxide is produce with the help of self healing bacteria. This bacteria acts as catalyst, reacts with atmospheric carbon dioxide and formed limestone.

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

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

According to above chemical reaction it will be observed that the limestone hardens itself and seals the cracks in concrete member. The $Ca(OH)_2$ is a soluble mineral it dissolved in water and glint out of the crack in the form of leaching. Bacillus bacteria produce spores which is helps to live up bacteria maximum four years without any food or oxygen. The Jonkers made the mixture in order by adding calcium lactate to limestone concrete to feed the bacillus so that the bacteria produce limestone to repair cracks in concrete member. The calcium carbonate id produce directly due to metabolic process and this process results in efficient bacteria for sealing mechanism. The sample preparation of self healing concrete, the material were mix to prepared concrete of ratio 1:1.5:3. The water cement ratio kept 0.4 ml and add bacteria 15 ml, 20ml, 30ml in different tubes. For the preparation of mould take standard mould size that is 150mm X 150mm X 150 mm. Prepared concrete mix with including bacterial solution. The testing of cube after 7 and 28 days for flexural strength and compressive strength have following observations According to the results the bacterial concrete improve compressive strength of conventional concrete 21% in 7 days and 27% in 28 days approximately. Also the flexural strength improves 4% in 7 days and 9% in 28 days approximately. The calcium carbonate fills the voids and decrease water permeability. The self healing concrete improves resistant to corrosion, shrinkage, attacks of acid and sulphate. It is also improve the durability and workability of concrete.

Advantages of Bacterial Concrete

- Self-repairing of cracks without applying any external agency
- Bacterial concrete increase in compressive strength and flexural strength when compared to normal concrete.
- Resistance towards corrosion and acid, sulphate attacks.
- Reduction inwater permeability of concrete member.
- Reduces the corrosion of steel and improves the durability of reinforced steel concrete.
- By using Bacillus bacteria in concrete mix there is no side effect to human life and hence it can be used effectively.

Disadvantages of Bacterial Concrete

- The cost of bacterial concrete is greater than conventional concrete
- Growth of bacteria is not good in any atmosphere and media.
- IS Code is not available for the design of concrete mix by using bacterial concrete.
- The precipitate used in bacterial concrete is costly

III. CONCLUSION

In this paper we conclude that the bacteria used in concrete mix to improve the resistant to corrosion, shrinkage, attacks of acid and sulphate. It is also improve the durability and workability of concrete. According to the comparison of strength, if we only concentrate on strength then this bacterial concrete is better than conventional concrete. If according to the economy conventional concrete is cheaper than bacterial concrete. The bacteria used in concrete, when we add the bacteria in concrete bacteria survive on the calcium lactate and consume oxygen. The calcium lactate is converted in to insoluble limestone, and it stars to get harden. The bacterial concrete will play major role in modern building material used for repaire and maintenance. However, bacterial concrete is being perfected for repaire and maintenance It may be concluded that this is one of the most commonly used building materials is once again revolutionizing how we build and design our infrastructures. With bacterial concrete, wear and tear will no longer be a worry for concrete buildings..

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