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EXPERIMENTAL INVESTIGATION ON DIFFERENT TYPES OF BACTERIAL CONCRETE(SELF HEALING CONCRETE)

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Abstract - Concrete are the most important materials used in construction industries where the external forces more than the design loads mainly the lateral forces which leads to the deformation and produce cracks in the joints of the structural member. The usage of cement has been increased more over the world results in the air pollution which leads to the ozone depletion. To overcome these type of problem like crack formation and usage of cement content used for repair works can be reduced by using the self healing bacterial concrete. These are materials which heals the crack automatically when the cracks are formed. These self healing is achieved by means of using the Biological healing aspect by using the bacterial concrete. Bacteria are used during the mixing of concrete will cure the cracks the automatically by means of it screeds known as calcium carbonate precipitate. In these study forces are applied to the concrete by means losd is applied in which the cracks are formed in the concrete. The Cracks leads to the penetration of oxygen inside the reinforcement area will forms the Corrosion. To avoid the formation of corrosion the cracks bacterial concrete along with cement are used which results in self healing process. These self healing which cure and arrest the cracks in the structure which gives the environment free pollution and sustainable structure. Two different types of bacteria are used in the concrete and then compare the results.

Key Words: Bacterial concrete, Calcium carbonate, self healing cracks, Bacillus family, calcite.

1. INTRODUCTION

1.1. General

formed due to overloading, improper design, unskilled labours, quality of materials etc. The cracks that formed that allow unwanted pollutants to penetrate inside the concrete structure which leads to steel corrosion and also the production of cement emits equal tonnage of carbon-di-oxide (co2) into the atmosphere and leads to ozone depletion. In this study, we are going to reduce the production of cement which used for repair &maintenance work. Here we are going to introduce biological techniques moreover cement for the preparation of concrete which have some healing ability. Therefore the cement &bacteria will act as a healing agent in these biological concrete. In framed structure the cracks are formed at the Beam-Column joints, if there is an seismic force. Since the concrete is brittle and N no of cracks are formed at the structural element. The Cracks formed allow the oxygen to penetrate inside and starts the Multiplication of bacteria to heal the minor cracks .In these present study we are going to replace conventional concrete with biological concrete for casting of concrete. Then two different types of bacteria used in concrete. After healing the same test is repeated for the healed concrete.

1.2. OBJECTIVES

- The main objective of this study is to determine the use of bacteria in concrete proves to be more effective and it also proves self healing property.
- To determine the self healing capacity of the bacterial concrete.

1.3. SCOPE

- To determine the properties of the materials.
- To examine the mechanical properties of hardened concrete such as compressive strength, flextural strength, split tensile strength.

2. LITERATURE REVIEW

Darshak B. Raijwala, Prashant s. Hinge &Vijay K. Bathor (2009) [1] It has discussed Concrete crack can be reduced by using micro bioloigalcally induced Calcite precipitation (CACO3).CACO3 is induced by means of the common soil bacterium known as the Bacterium known as the "BACILLUS PASTERII". Microbiologically entranced crack Remediation (MECR) was evaluated by comparing the compressive strength of treated mortar cubes with these of control specimens. Energy-Dispersive x-ray diffraction (XRD) analysis was used to qualify distribution in the regions of treated cubes. Compressive strength observed is increased by 12-13% and has the remarkable potential as a sealant for concrete cracks. Modern crack repair methods are epoxy resins, epoxy mortar and other synthetic mixtures. Environmentally friendly biological process that are continuously self remediating. Bacterial concrete is a concrete which can be made by embedding bacteria in the concrete that are able to be constantly precipitate

"CALCITE". This sealant not only a environmentally innocuous but also persist in environments for a prolonged period(Bang el at 2001). Basicellus pasteuri plays a key role by producing urease that hydrolyse UREA to AMMONIA & CARBON-DI-OXIDE. The ammonia increases the PH in the surrounding which in turn induces precipitation of CACO3 mainly to form calcite. To protect the cells from the high PH concrete and high metabolic activity of the bacterium, the micro organisms are immobilized in the polymer, lime, silica fume & fly ash. Basillus pasterui is main in solid medium containing 70g trypcase;5g . Basillus pasteuri confirms that the bacteria serve as the nucleation site for calcite crystals for precipitation. Concentrations of $9.0*10^8$ with different depth of cut like 10.0,20.0,25mm an increase in compressive strength of 15.0%,8.0%, Bacteria near the surface of the mortar cubes are more active than bacteria away from the surface.

Jacobsen. S, Sellevoid. E., (1996) [2] It has discussed the freeze and tha wingon concrete has been self healed by curing in water for2-3 months. Compressive strength, resonance frequency, weight, volume has been noted during the two phases i)Deterioration ii)self healing. 50% of the dynamic modulus loss during the deterioration is completely when it was cured in water for 2-3 months Reduction in compressive strength of 22.9% on deterioration & 4.5% only self healing. Deterioration is governed by the ability to taken up water. The more water leaked through the plastic foil during the freeze and thawing the larger the deterioration. Specimens are kept frozen due to problems with the equipment regained some loss of resonance frequency. Pointing out the positive auto geneous self healing on frost deteriorated concrete. They conduct a large test on the self healing concrete of the compressive strength. Four different types of cement are used they are (1,7,14,28) and self healed at different conditions. They are i)Dry ii)Humid iii)submerged.

Fresh concrete=Quick self healing

Hardened concrete=Less self healing

Healing conditions are more important than the curing conditions.

High humidity=More healing then the submersion.

Fagerlund discussed the effect of continued hydration on degree of saturation. Hydration also the one type of self healing which reduces the water content. It is seen that the all concretes were more or less deteriorated due to internal cracking with durability factors in the range of 9-79%."Self healing of high strength concrete after deterioration by freezing and thawing" CEMENT ANDCONCRETE RESEARCH VOL 26.ISSUE NO 1,1996,PP 55-62.

Klaas van Breugel (2012) [3] The rapidly growing world population and booming economies are two of the major reasons for an increasing demand for buildings and infrastructure. In order to meet these needs large amounts of energy and raw materials are required. In most cases concrete is the main building material for these structures. The question today is how these needs can be accomplished without compromising the ability of future generations to meet their needs (Brundlandt). In this paper first the urgency of this question is explained from the perspective of the building industry. Emphasis is put on the consequences of the lack of quality and related failure costs. This lack of quality results in premature maintenance and repair or even decommissioning and demolishing of structures

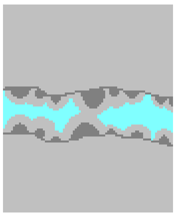

Fig No : 1. Multiplication of bacteria

Mohini P. Samudre, M. N. Mangulkar, S. D. Saptarshi (2014) [4] Concrete is an absolutely essential component of construction materials used in infrastructure and most buildings. Despite its versatility in construction, it is known to have several limitations. It is weak in tension, has limitedductility and little resistance to cracking. Based on the continuous research carried out around the globe, various modifications have been made from time to time to overcome the deficiencies of cement concrete. However, concrete is sometimes exposed to substances that can attack it and cause deterioration. The corrosion of the concrete is caused by the interaction between biological and chemical processes. When the corrosion is sufficiently occurred, it can lead to structural failures with potentially serious long term operational consequences. Due to microbial activities of the bacteria, microbiologically induced calcite precipitation (MICP), a highly impermeable calcite layer is formed which contributes to increase the performance of concrete structure and also has excellent resistance to corrosion. Recent research has shown that specific species of bacteria can be useful to enhance the durability and strength of concrete structures. This microbial concrete presents a potentially enormous lengthening in service-life of infrastructure, substantially reduces the maintenance costs and also considerably increases the safety of structures. This paper outlines the basic mechanism involved in microbial concrete on which studies were carried out to investigate the causes involved in enhancing the strength and durability of concrete.

Keywords: Concrete corrosion, Microbial concrete, Biological processes, Bacteria, MICP.

Ruoting Pei,Jun Liu,Shuangshuang Wang,Mijia Yang.[5] Microbially induced carbonate precipitation (MICP) is a natural process that has shaped the earth from ancient time. In this process, calcium carbonate minerals are formed from calcium carbonate minerals are formed from calcium and carbonate ions. Because calcium carbonate minerals are homogeneous material compatible with concrete and stone and is environmentally friendly. The technology based on Bacillus Cereus induced $CaCO_3$ formation has been commercialized for repairing cracked surface of ornamental stones. Also by incorporating live bacteria in concrete, MICP has been shown to improve mechanical properties and self healing of concrete. Cell walls, dead, or live cells of B.Subtilus were added to cement mortar specimens and the effects were compared with control specimens. At 28 days of curing, cell walls of B.subtilus amended at 3.3 mg/ml (10x) and 0.33 mg/ml (1x) concentration caused significant increase of compressive strength by 15.6% and 14.8%.The effect of bacterial cell walls on physicochemical properties of concrete ,our results showed that bacterial cell walls of B.Subtilus significantly increased compressive strength and decreased porosity. In contrast, live and dead cells of B.Subtilus and components of the urea-$CaCl_2$ media did not increase compressive strength.

3. METHODOLOGY

The constituent materials used were obtained locally and were Ordinary Portland Cement 43 grade (O.P.C), M-sand as fine aggregate and crushed granite as coarse aggregate. Potable water was used for mixing and curing. The tests were carried out as per IS Standards.

4. MATERIALS TO BE USED

4.1. CEMENT

PPC of 53 grades in one lot was procured and stored in air tight container. The cement used was fresh i.e. used within three months of manufacture. It should satisfy the requirement of IS12262. The properties of cement are determined as per IS4031:1968 & results are tabulated.

S. No	PROPERTIES	VALUES
1	Fineness	10%
2	Initial setting time	28min
3	Final setting time	2-3hours
4	Standard consistency	29%
5	Specific gravity	3.15

Table 1: Common properties of cement

4.2. AGGREGATES

A fine aggregate obtained from the river is used for experimental purpose. The less amount of clay and silt (<3% by weight). The hire from silt, clay, salt and organic material and it was clean and dry. It is of size retained in 1.19 micron sieve. The coarse aggregate is strongest and porous component of concrete. Presence of coarse aggregate reduces the drying shrinkage and other dimensional changes occurring on account of movement of moisture. The coarse aggregate used passes in 19 mm and retained in 11.4mm sieve. It is well graded (should of different particle size and maximum dry packing density and minimum voids) and cubical in shape.

Table 2 : common properties of aggregate

Natural Coarse Aggregate (Physical Properties)		Natural Fine Aggregate (Physical Properties)	
Specific Gravity	2.85	Specific Gravity	2.65
Water Absorption	0.55%	Water Absorption	0.65%
Fineness modulus	4.16	Fineness modulus	2.64
Abrasion Value%	22	Abrasion Value%	-
Impact Value%	16	Impact Value%	-
Crushing Value %	23	Crushing Value %	-

4.3. WATER

The ordinary water consist of many micro-organisms which will leads to the change in pH value which does not effect the construction activity. pH of the tap water has been checked in our laboratory. The pH of the tap water tested is about **7.5.**

4.4. DIFFERENT TYPE OF CONCRETE BACTERIAS

Different types of bacteria are used in concrete.They are

- Bacillus pasteurii.
- Bacillus Pseudifirmus
- Bacillus.
- Lysinbacillus Sphaericus.
- Bacillus Megaterium.

Used bacteria

- Bacillus pasteurii
- Bacillus magaterium

The bacillus bacterium is cultured and grown at NASC (Nandha Arts and Science College,Erode)

Fig No. 2 : Broth Culture

5. CULTURE OF BACILLUS BACTERIA

5.1. PREPARATION OF BROTH

The broth is the nutrient medium normally known as the Nutrient Broth containing Peptic digest of animal tissues, Beef extract, Yeast extract and Sodium chloride. Initially, the nutrient broth of 13.00 grams are suspended in the water of 1000ml and can be heated if need to mix thoroughly.

5.2. STERILIZATION OF THE MEDIUM

Sterilization is simply the process through which the microbes are removed or killed. Usually this is done by autoclaving or the pressure heating equipments. The prepared Broth is completely covered and heated at 15 lbs pressure for 15 minutes at a temperature of nearly 121^{o} C.

Fig No. 3 : Sterilization of he medium

5.3. SERIAL DILUTION

The bacteria of total cell concentration of range 10^5 cells per ml concentration need to be taken. This concentration can be achieved by the process of serial dilution. Initially the test tube with sterilized medium of 10 ml Broth is taken and it is inoculated with the hoop of Bacillus bacteria. Then it is thoroughly mixed by shaking the test tube. Now 9 ml of the mixed medium is transferred to the other test tube and it is repeated still 5ml to obtain a 5ml cell concentration.

5.4. INOCULATION OF THE BACTERIA

The bacteria of prepared cell concentration are then inoculated in the prepared broth medium keeping it inside the Laminar Air flow chamber. The Air flow chamber before initial use need to be cleaned thoroughly with the methylated spirit and with the UV radiation to kill the microbes inside if any. The culture was streaked on nutrient broth with an inoculating loop and the slants were incubated at 37^{0}C.

This ensures the quality of cultured species. Inside the Air flow chamber total backflow of atmospheric air is stopped in which the entry of harm full microbes can be stopped. Keen care must be taken throughout the process to ensure the quality by cleanliness. This can be achieved by using the methylated spirit as sanitizer in hands. The face mask should be used to ensure quality of cultured bacteria by avoiding the flow of microbes (if present) into the culture.

5.5. INCUBATION

The bacteria in inoculated broth medium are now incubated in the incubator at the temperature of about 34^{o}C for the period of 20 to 24 hours. This is normally done for the growth of bacteria, since the growth can only be enhanced at this temperature level.

Fig No. 4 : Incubation

5.6. STORAGE OF STOCK CULTURE

Now the inoculated broth medium is kept inside the incubator to at least 12 to 14 hours at normal room temperature to attain the cell growth of the bacteria.

5.7. MAINTENANCE OF STOCK CULTURES

Cultures of Bacillus bacteria are maintained on nutrient broth culture. After 20 to 24 hours of growth, slant cultures were preserved under refrigeration (12^0C) until further use. Sub-culturing was carried out for every 15 hours. Contamination from other bacteria was checked periodically by streaking on nutrient broth plates.

6. CONCRETE MIX DESIGN AND MIX PROPORTION

MIX PROPORTIONS:

M25 grade concrete was designed as per IS 10262- 2019. Quantity of materials per cubic meter of concrete and dosages of carbon fibers used are listed in Table. 3 constant water cement ratio of 0.45 was used.

TABLE 3 : QUANTITY OF MATERIALS USED PER CUBIC METER OF CONCRETE

Material	Cement	Fine Agg	Coarse Agg	Water
Weight (kg/m^3)	438	651	1150	197.16
Ratio	1	1.4	2.6	0.45

7. DISCUSSION ON EXPERIMENTAL STUDIES CONDUCTED

7.1. TEST CONDUCTED ON HARDENED CONCRETE

The results obtained from experimental tests conducted on hardened concrete for conventional
and carbon fiber reinforced concrete with varying fiber dosages of 0%, 0.5%, 0.75% and 1%
are tabulated in Tables 4 Test details and results are discussed in sections 5.2.1

7.1.1. COMPRESSIVE TEST

`Cube specimens of size 150mm x 150mm x 150mm were casted for different proportion in two types of bacteria in 25 ml and 50 ml.

TABLE 4: COMPRESSIVE STRENGTH RESULTS

S.NO	PROPORTION		7 DAYS	28 DAYS
1	Conventional		17.11	22.5
2	Bacillus pasteurii	25ml	11.11	23.2
		50ml	13.7	25.8
3	Bacillus magaterium	25ml	11.85	24.1
		50ml	13.2	24.4

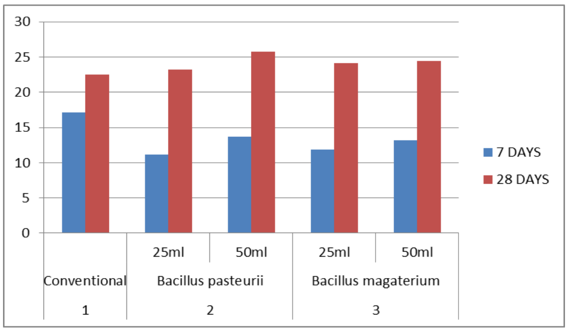

Fig No. 5 :Compressive strength results

7.1.2. COMPRESSIVE STRENGTH OF HEALD SPECIMEN

TABLE 5 : COMPRESSIVE STRENGTH OF HEALD SPECIMEN RESULTS

S.No	PROPORTION		Stress @ 28 days	Load at crack formation of healed Specimen	Stress of Healed Specimen (N/mm^2)
1	Bacillus pasteurii	25 ml	18.62	550	24.4
		50 ml	20.2	580	25.8
2	Bacillus magaterium	25 ml	17.85	530	23.55
		50 ml	19.1	560	24.9

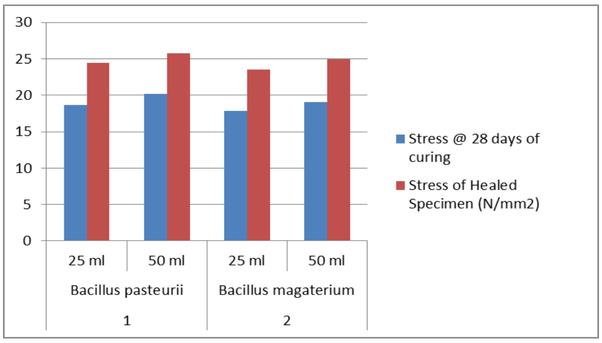

Fig No. 6 : Compressive strength of healed specimen results

8. CONCLUSIONS

- ✓ The use of bacteria in concrete proves to be more effective with increase in strength. It also proves that healing property is more and effective.
- ✓ The use of bacteria is more efficient since the calcite precipitate formed increases the risk of failure.
- ✓ The cracks which are formed in the beams are healed by means of formation of calcite precipitation due to bacterial residue.
- ✓ By comparing the two types of bacterial concrete such as Bacillus pasteurii and Bacillus magaterium in different proportion (25ml & 50ml). The Bacillus pasteurii gives more strength. We recommended the bacillus pasteurii in proportion of 50 ml for construction purpose.

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