Experimental Study on Self Healing Concrete

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Abstract: **- Concrete is strong, durable, locally available building material widely used for construction. If the load applied on the concrete is more than their limit of resisting load, it causes strength reduction of concrete by producing the cracks. The entry of moisture and harmful chemicals into the concrete through cracks can result in decrement of strength and life. The strength and durability of the concrete can be improved by a technique involving bacterial induced calcite precipitation. Micro biologically induced calcite precipitation can heal cracks and improve the performance of the concrete. In this paper an attempt to study bacterial concrete, types and classification of bacteria, mechanism, merits, demerits and applications of bacterial concrete.**

Key words: **- Concrete, bacteria, concrete strength, durability, applications.**

I. INTRODUCTION

Concrete is the major component in the construction industry as it is cheap, easily available and convenient to cast. Concrete is a composite building material composed primarily of cement, aggregate and water. Concrete is is strong in compression but weak in tension. Its drawbacks are low modulus, limited ductility and little resistance to cracking Since it is weak in tension it cracks under sustained loading and due to aggressive environmental agents which ultimately reduce the life of the structure. Micro cracks are the main cause to structural failure. Micro cracks developed in concrete allow liquids and gases through them which eventually lead to damage not only concrete but also the reinforcement gets corroded. There are many techniques available for the treatment of cracks. Besides, by these techniques there are disadvantageous like different thermal expansion coefficient, environment hazard and health hazard. The need for an environment friendly and effective alternate crack remediation technique leads to the development of using the bio mineralization method in concrete known as bacterial concrete, self healing concrete or bio concrete. Bacterially produced Calcite precipitation ($CaCO_3$) is a biological technique called bio- mineralization is used for self healing of cracks. This technique is also used to increase the stiffness of the cracked concrete specimen. Bacillus species are aerobic spore forming gram positive bacteria with specialized thick walled dormant cells, viable for more than 200 years under dry condition. Mixing of calcite precipitating bacteria to concrete so that when it comes in contact with water the bacteria will precipitate calcium carbonate and will heal the cracks. Metabolic activities of bacteria in concrete can improve overall performance of concrete.

II. CLASSIFICATION OF BACTERIA

Bacteria are relatively simple, single celled organisms. Various types of bacteria used in concrete are

- Bacillus pasteurii
- Bacillnesphaericus
- Escherichia colli
- Bacillus Subtilis
- Bacillus cohnii
- Bacillus pseodofirrius
- Bacillus balodurais

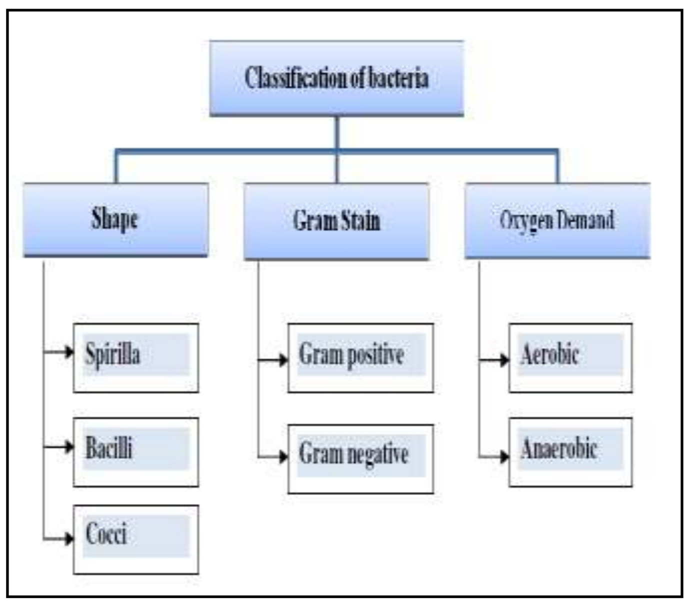

Fig.1. Classification of Bacteria

III. MECHANISM

Different types of bacteria, as well as abiotic factors (salinity and composition of the medium) seem to contribute in a variety of ways to calcium carbonate precipitation in a wide range of different environments. Microorganisms (cell surface charge is negative) draw cations including Ca2+ from the environment to deposit on the cell surface.

The equations given below summarize the role of bacterial cell as a nucleation site

$$Ca^{2+} + Cell \longrightarrow Cell\text{-}Ca^{2+}$$

$$Cell\text{-}Ca^{2+} + CO_3^{2-} \longrightarrow Cell\text{- }CaCO_3 \downarrow$$

The process of microbiologically induced calcium carbonate precipitation is having a complex biochemical reaction. The bacteria can thus act as nucleation site which facilitates for the precipitation of calcite which eventually plug the pores and cracks in concrete.

IV. LITERATURE REVIEW

Dhanya. S et al.,(2016) ***"Strength and Water Absorption of Bacterial Concrete Prepared with M.sand – A Study",*** **[1]** The paper studies Strength and durability (water absorption) of different concentrations (10^4, 10^5 and 10^6cells/ml) of bacterial concrete with bacteria free specimen of M25 grade and to identify the optimum concentration. *Bacillus megaterium* was used for the study. Bacterial concretes shows better durability and compressive strength compared to bacterial free concrete. Percentage increase in compressive strength is of 11.30% and 22.58 for 7 days and 28 days of curing for the identified optimum concentration. Water absorption is less for the bacterial concrete due to microbial induced calcium carbonate precipitation. The concentration 10^5 cells/ml gives optimum result compared to other concentrations.

Etaveni. Madhavi et al.,(2016) ***"Strength Properties of a bacterial concrete when Cement partially replaced with flyash and GGBS",*** **[2]** In this study the cement is replaced by the GGBS and fly ash with bacteria of 10^6 bacillus pasteurii in M40 mix. The GGBS and fly ash was taken in the proportions of 10% by weight of cement. The compressive strength of a bacterial concrete is increased by 10% compare to normal concrete or conventional concrete. Addition of fly ash with bacterial concrete is also increased by 14% compare to normal or conventional concrete. Addition of GGBS with bacterial concrete is also increased by 18% to 20% as compared to normal or conventional concrete.

K. Sriramya et al.,(2017) ***"Bacterial Concrete Using Fly Ash as Partial Replacement",*** **[3]** The concrete is replaced by the GGBS and fly fiery debris with microorganisms of 10^6 bacillus pasteurii in M40 blend. The GGBS and fly slag as taken in the extents of 10% by weight of concrete. This paper shows a survey of various inquires about in the current years on the utilization of bacterial cement/bio-concrete for the upgrade in the solidness, mechanical and permeation parts of cement. It contains thinks about on various bacteria's, their detachment procedure, diverse methodologies for expansion of microscopic organisms in cement, their impacts on compressive quality and water retention properties of cement.

Nafise Hosseini Balam et al.,(2017) ***"Effects of bacterial remediation on compressive strength, water absorption, and chloride permeability of lightweight aggregate concrete",*** **[4]** This paper presents an experimental investigation carried out to evaluate the influence of Sporosarcina pasteurii at cell concentrations of 10^6 cells/ml on water absorption, water permeability, compressive strength, and rapid chloride permeability of Light weight aggregate concrete(LWAC). Leca aggregates were left to soak in a solution of urea-$CaCl_2$ containing bacteria for 6 days to investigate biological improvement of aggregate quality. Four types of LWAC were made under the three treatments of bacterially-treated aggregates, bacteria inoculated in the concrete mix water, and both techniques employed simultaneously and with no bacteria used in either the aggregate or the concrete mix solution as the control. The results revealed an average reduction of about 10% in water absorption, 20% increase in compressive strength, and 20% reduction in chloride penetration in the experimental specimens relative to the same properties in the control ones.

Navneet Chahal et al.,(2013) ***"Permeation properties of concrete made with fly ash and silica fume: Influence of ureolytic bacteria",*** **[5]** The paper presents the permeation properties of concrete made with fly ash and silica fume by adding ureolytic bacteria. The study involves the isolation of urease producing bacteria from alkaline soil. The bacteria were identified by the ability to sustain itself in alkaline environment of cement/concrete. The bacterial isolate was analyzed through DNA sequencing and the bacteria was identified as Sporosarcina pasteurii, which showed maximum urease production when it was grown on urease agar and broth. The bacteria present in the concrete rapidly sealed freshly formed cracks through calcite production. The bacterial concentrations were optimized to 10^3, 10^5 and 10^7 cells/ml. The percentage use of fly ash was 0%, 10%, 20% and 30%, and that silica fume were 0%, 5% and 10%. The experiments were carried out to evaluate the effect of S. pasteurii on the compressive strength, water absorption, water porosity and rapid chloride permeability of concrete made with fly ash and silica fume up to the age 91 days. The test results indicated that inclusion of S. pasteurii enhanced the compressive strength, reduced the porosity and permeability of the concrete with fly ash and silica fume.

RA. B. Depaa et al.,(2015) ***"Experimental Investigation of Self Healing Behavior of Concrete using Silica Fume and GGBFS as Mineral Admixtures",*** **[6]** In this paper the usage of of Silica fume and Ground granulated blast furnace slag (GGBFS), the waste derivatives from coal and steel industries, strength and durability testing of these mixes for achieving the self healing property has been studied. Silica Fuma was added at percentages of 0%, 2.5%, 5%, 7.5%, 10%, 12.5% and cement has been replaced with GGBFS by 35% and 55% respectively. The strength properties of concrete specimens made using silica fume and GGBFS were tested for compressive strength and the durability properties are studied using sorptivity index test. It has been found that the concrete mix containing cement replaced with 35% GGBFS has given maximum compressive strength value. And it has also been found that when silica fume is added as mineral admixture, the mix has given maximum strength at 12.5% addition of silica fume.

V. ADVANTAGES

- Remediates cracks quickly

Concrete specimens gets filled with bacteria, nutrients and sand. Significant increase in compressive strength and stiffness values as compared to those without cells.

- Improvement the strength of Concrete

Compressive strength test results are used to determine that the concrete mixture as delivered meets the requirements of job specification. So effect of microbial concrete on compressive strength and flexural strength of concrete and mortar enhanced by the application of bacteria.

- Better resistance towards Freeze thaw attack

Application of microbial calcite may help in resistance towards freeze thaw reduction due to bacterial chemical process and also it reduces permeability thereby freezing process is decreased.

- Reduction in corrosion of reinforcement

Application of microbial calcite may help in sealing the path of ingress chemicals and improve the life of reinforced concrete structures.

- Reduction in permeability of concrete.
- It increases the durability of concrete.
- Aesthetic appearance are not harmed
- It is pollution free, eco-friendly and natural.
- Decreased production of concrete.
- Lower repair & maintenance cost.
- Applicable to existing buildings in form of spray.
- Curbed carbon dioxide emission from concrete production.

VI. DISADVANTAGES

- Growth of bacteria is not good in any atmosphere and media

Different types of nutrients and metabolic products used for growing calcifying microorganisms, as they influence survival, growth, biofilm and crystal formation. Numerous work should be done on retention of nutrients and metabolic products in the building material.

- The clay pellets holding the self-healing agent comprise 20% of the volume of concrete.
- Cost of bacterial concrete is higher
- Investigation process is of higher cost

Different types of bacteria have different properties to produce an amount calcite precipitation to identify this amount investigation of bacteria is done using "Scanning by Electron Microscopy" and this method is costly and require good skill to carry out this test.

- Non-availability of IS codes

As it is a new research material no code is provided to use it. It is difficult to estimate the doses of bacteria to be used in concrete to get the optimum performance.

VII. APPLICATIONS

The use of bacterial concrete in Civil Engineering has become increasingly popular.

- Enhancement in durability of cementious materials to improvement in sand properties.
- Repair of limestone monuments.
- Sealing of concrete cracks.
- Used in construction of low cost durable housing.
- Used in construction of low cost durable roads.

VIII. CONCLUSION

The paper describes that bacteria based self healing concrete can improve the strength and durability of concrete. With the addition of bacteria in concrete it was found increase in compressive strength, split tensile strength and decrease in permeability, water absorption. Though different types of bacteria can be used to prepare bacterial concrete, spores forming gram positive bacteria gives the most effective results. The spore forming bacteria can remain in concrete for about 200 years. Bacterial concrete is found to be advantageous than conventional concrete due to its self healing capacity and eco friendly nature.

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