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Investigation on Bacterial Cement Composites

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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 horizontal forces are applied to the three storey single bay framed structure by means of using the hydraulic jack in which the cracks are formed in the framed structure mainly the cracks are formed in the Beam-Column Joints. 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 60% of fly ash 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.

Keywords: Bacterial concrete, Calcium carbonate, Epoxy resins, Self healing agent.

1. INTRODUCTION

Cement plays the vital role in construction industry. Cement act as a binding material in all concrete structures. The Major problem in concrete structure is minor cracks. These cracks are formed due to overloading, improper design, unskilled labors, 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 dioxide (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 we are replacing 60% of flyash in cement for the preparation of concrete which have some healing ability. Therefore the flyash &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 nos 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 three respective frame .After healing the same test is repeated for the healed framed structure. This storey is compared with conventional frame which has biological frame

2. METHODOLOGY

The methodology for producing a self-healing concrete involves the following steps.

i. Selection and cultivation of bacteria.

ii. Preparation of test specimens.

iii. Characterization studies

- X-ray diffraction
- Scanning Electron Microscopy (SEM)
- Thermo-Gravimetric Analysis (TGA)
- Compressive Strength and Tensile Strength Testing
- Ultrasonic Pulse Velocity

2.1 Selection of Bacterial Species

Spore forming alkali-resistant bacteria can be isolated from its source. Bacterial strains such as Bacillus pasteurii, Escherichia coli, Bacillus sphaericus, Bacillus subtilis, Bacillus cereus etc., are commonly used for research works. Initially these bacteria are obtained from the source and first cultured in a solid media and then transferred to nutrient broth (liquid media) which is sterile and kept shaking in an incubator.

2.2 Measurement of Bacterial Cells

Concentration of bacterial cells is measured by Haemocytometer and optical density could be found by spectrophotometer analysis before adding bacteria to cement composites. Gram staining method was used to determine the morphology of the bacterial strains and the bacterial cultures are tested for urealytic activity and also calcium carbonate precipitation [7]. Before addition to cement cement mixture for test specimen preparation, bacteria should be cleaned from culture residues by repeated centrifugation and resuspension of obtained cell pellet in a clean tap water. Ureolytic bacteria such as B. sphaericus could precipitate $CaCO_3$ by conversion of urea into ammonium and carbonate. subtilis (CMBS). It is found that there is 28% improvement in compressive strength of CMBS incorporated concrete compared to control concrete with optimum concentration [8]. Matrix capillary water of young concrete is typically characterized by pH values between 11 and 13. Bacteria added to the concrete mixture thus do not only have to resist mechanical stresses due to mixing but should also be able to withstand a high alkalinity for prolonged periods. Most promising bacterial agents for incorporation in the concrete matrix therefore appear to be alkaliphilic (alkali-resistant) spore-forming bacteria. As the concrete matrix is toxic due to ingress oxygen (diffusion through matrix capillaries) incorporated bacteria also need to be oxygen tolerant.

Such aerobic alkaliphilic spore-forming bacteria occur within the genus Bacillus, and several representatives of these were therefore selected to test their applicability as healing agent in concrete [9]. The starting point of the research is to find bacteria capable of surviving in an extreme alkaline environment. Cement and water have a pH value of up to 13 when mixed together, usually a hostile environment for life most organisms die in an environment with a pH value of 10 or above. The search concentrated on microbes that thrive in alkaline environments which can be found in natural environments. Samples of endolithic bacteria (bacteria that can live inside stones) will be collected along with bacteria found in sediments in the lakes. Strains of the bacteria genus Bacillus will be found to thrive in this high-alkaline environment.

2.3 Preparation of Test Specimens

Bacterial concrete casted by using ordinary Portland cement mixed with bacterial concentration 106 cells/ml of water. Conventional concrete samples are also casted in parallel. The specimens are cured under tap water at room temperature and tested at 7, and 28 days .

2.4 Characterization Studies

The formation of calcite by means of bio-mineralization can be analysed by using various characterization techniques or methods. These techniques are specialized or involve all modes of microbial analysis like imaging, diffraction and spectroscopy, including light, X-rays, neutron or electron as primary radiation. To conduct the above studies, samples should be collected from the tested mortar or concrete specimens in the form of powders or broken pieces.

3. MATERIALS

General Material investigation is done to test the various materials that are used in making concrete cubes. According to these test results obtained we designed the mix ratios for the materials and prepared the concrete cubes, beams and cylinders. The information are given below, Cement OPC of 43 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. Fine Aggregate A fine aggregate obtained from the river is used for experimental purpose. The fewer amounts of clay and silt

Constituents	Natural sand(%)	Test method
SiO_2	80.78	IS: 4032-1968
Al_2O_3	10.52	
Fe_2O_3	1.75	
CaO	3.21	
MgO	0.77	
Na_2O	1.37	
K_2O	1.23	
TiO_2	Nil	
Loss of ignition	0.37	

Bulking of Fine Aggregate Table the representative of sample of sand, from the available lot at sight. Fill the graduated jar with sand up to certain weight compacting. Level the sand surface by gentle motion and note down this height. Now pour the water into the graduated jar containing sand till the sample is submerged. Cover the jar with the disk and give some motion. The tamping rod should be moved through out into sample in the jar, so as to ensure to removed of entrapped air completely.

MIX DESIGN

General Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. The main objective is to stipulate the minimum strength and durability. The mix design adopted in our project for the grade of M40. Fly Ash Ordinary Class F fly Ash of Cementitious property collected from the nearer Thermal power plant of specific gravity 2.31 is taken. The quality parameters of flyash for use in concrete confirming to IS 3812(part 1) has been used

4. HEALING AGENT

4.1 Self-healing

Current material design in engineering follows the concept of damage prevention. An alternative design principle is that of self-healing materials, according to the concept of damage management as introduced by Vanderzwaag [2]. Damage formation does not necessarily cause problems, if it is subsequently healed in an autonomous process. Self healing materials have to serve some roles and meet several properties. Damages should be sensed, followed by transportation of healing agent to the damage site, triggering repair of the damage. In the ideal case self-healing materials are cheap and have properties equal or superior to currently used materials, with the ability to heal defects of any size, multiple times, completely and autonomously.

In case of concrete durability performance is mainly considered for damage to be healed, in order to reduce costs of repair and maintenance. An overview of characteristics for selfhealing concrete is given by Jonkers [10]. Target for self-healing concrete is to reduce matrix permeability by sealing or blocking cracks. Healing agent is incorporated in the concrete matrix and acts without human intervention. Preference lies in agents working as a catalyst, enabling multiple healing events. To make the material technically and economically competitive, healing agent should be cheap in relation to the low price of concrete, remain potentially active for long periods of time and be concrete compatible to not negatively affect material characteristics.

4.2 Microbial healing

Concrete already has a built-in healing mechanism due to on-going chemical, physical and mechanical processes. Most significant is precipitation of calcium carbonate [11]. Average limit for which healing can still occur is a crack width of 0.2 mm. Carbonation reaction lies at the base of the calcium carbonate production, where diffused carbon dioxide reacts with the hydration product calcium hydroxide as can be seen in Eq. (1).

$$CO_2 + Ca(OH)_2 \circledcirc CaCO_3 + H_2O \quad (1)$$

The principle of microbial healing also lies in the precipitation of calcium carbonate [4]. Ingress water activates dormant bacteria. Dense layers of calcium carbonate are produced by bacterial conversion of an incorporated mineral precursor compound. In case of calcium lactate the reaction is as given in Eq. (2), where bacteria only act as a catalyst.

$$Ca(C_3H_5O_2)_2 + 7O_2 \rightarrow CaCO_3 + 5CO_2 + 5H_2O \quad (2)$$

From the metabolic conversion of calcium lactate carbon dioxide is produced, which further reacts with the calcium hydroxide from the concrete matrix according to the chemical reaction in Eq. (1), producing additional calcium carbonate.

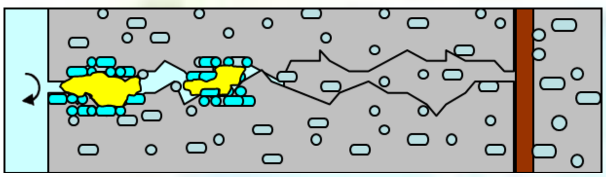

Fig 1: Scenario of crack-healing by concrete-immobilized bacteria

4.3 Direct addition

Healing agent mainly consists of bacteria and a mineral precursor compound. First important consideration was to choose concrete compatible bacteria. Bacteria should survive and remain active in the highly alkaline environment. Since concrete structures are designed to last at least 50 to 100 years, bacteria should remain viable for a long period of time. Therefore a specific group of alkaliphilic spore-forming bacteria was selected. The thick cell walled spores are produced by bacteria when living conditions become less favourable.

The combination of suitable bacteria and calcium lactate as mineral precursor compound calcium lactate indeed resulted in production of calcium carbonate precipitates in concrete cracks. The observed mineral production in time however appeared limited when calcium lactate and bacterial spores were directly added in unprotected form to the concrete mixture, probably due to full integration of the precursor compound in the matrix limiting its access to bacteria [12]. Increased potential for long-term viability and activity may be reached when integrated bacterial spores are immobilized or protected and the precursor compound is kept accessible for bacterial conversion. Calcium lactate[15] however, appeared to be the most suitable compound as its application as main healing agent ingredient resulted in even enhanced concrete compressive strength values . Tests on concrete compatibility showed no significant influence on flexural and compressive strength characteristics for concentrations of added bacteria up to 109 cm.

5. EFFECT OF HEALING AGENT ADDITIONS ON SPECIMEN STRENGTH

As incorporation of healing agents to concrete may have unwanted negative effects on material properties, development of compressive strength of control specimen without additions as well as specimen with bacteria or organic compound additions was investigated. Incorporation of a high number of bacteria appears to have a mildly negative effect on compressive strength development as bacterial test specimen appeared almost 10% weaker then control specimen. Effect of organic compound incorporation on development of strength appeared however strongly dependent on compound identity.

6. BACTERIAL SPORE FORMATION

Addition of manganese to the growth medium stimulated the formation of bacterial spores substantially. Light microscopic analysis of growing cultures. Spores could be easily visualized by ESEM analysis due to their thick cell walls and their diameter appeared to be typically in the size range of 0.8–1 μm.

7. RESULTS AND DISCUSSIONS

One major problem associated with crack formation is that the process results in a drastic increase in material permeability increasing the risk of matrix and embedded reinforcement degradation by ingress water and other aggressive chemicals. Active bacterially mediated mineral precipitation could result in crack-plugging and concomitant decrease in material permeability. As bacteria function as catalyst, a suitable mineral precursor compound needs additionally to be incorporated in the material matrix to provide a truly autonomous repair mechanism. However, the maximal allowable amount of mineral precursor compound introduced to the concrete mixture is likely limited as larger quantities may negatively affect other concrete properties such as setting time and (final) strength. Self-healing concrete should be able to heal or seal, by filler material formation, freshly formed cracks to inhibit ingress of water and other chemicals which could cause preliminary degradation[14] of the material matrix or embedded reinforcement. In this study we investigated the bio-mineral production capacity of cement stone specimen in which bacteria were incorporated as healing agent. The integrated bacteria applied in this study are affiliated to alkali-resistant spore-forming species of the genus Bacillus. In conclusion we can state that alkali-resistant spore-forming bacteria related to the genus Bacillus represent promising candidates for application as self-healing agent in concrete and probably other cement-based materials. It is found that cement stone incorporated bacterial spores are able to convert concomitantly incorporated calcium lactate to calcium carbonate-based minerals upon activation by crack ingress water [13]. Although concrete with a high self-healing (crack healing) potential is wanted, the addition of healing agents such as bacteria and/or (organic) chemical compounds to the paste may result in unwanted decrease of strength properties.

8. CONSIDERATIONS

In order to consider practical application several characteristics have to be determined. Viability and functionality of incorporated bacteria is enhanced until several months after concrete casting. For practice long-term self-healing capacity is needed, ideally for the duration of the service life of the concrete structure. Also multiple healing events should be possible. Cost efficiency is also important. Concrete is a relatively cheap construction material, and adding a self-healing material to the concrete mixture has to be economically feasible. E.g. the return on investment price could come from savings on otherwise needed repair and maintenance costs. In order to minimize the price of the healing agent, its production should be straightforward with large output and little loss, minimizing the use of complex procedures, heating and cooling.

9. CONCLUSION

From the above discussion the bacteria such as Bacillus Pasteuri, Bacillus megaterium, Bacillus subtilis are having some disadvantages and also Pseudomonas aeruginosa are undoubtedly pathogen and cannot be directly applied in building structures like houses and offices because of health concerns.Finally we conclude that the Bacillus Sphaericus and Eschericheria Coli have some advantageous than above bacteria.

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