BACTERIAL CONCRETE

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Abstract – *Concrete is considered as the most important construction material. Cracks are the major problem found in this widely used construction material. Formation of cracks is unavoidable. But, it can be healed using various techniques like application of chemicals and polymers. In order to increase the service life of concrete and to reduce replacement costs, long lasting and environmentally friendly treatment methods are preferred.*

Microbial crack remediation is the method used currently by adopting the self- healing approach in concrete structures. It is an environmentally friendly method. This method is attractive due to its rapid and active crack repairing potential and long lasting nature. It is also having good capability and efficient bonding capacity with concrete mixes. For the purpose of healing cracks in concrete structures, it is found that some specific bacterial species isolated from soil can be more effective. They are tolerant to harsh and challenging alkaline environment in concrete. It makes use of the calcite mineral precipitation to heal the cracks in concrete.

Key Words- *Self –healing approach, compatibility, bonding capacity, calcite mineral, microbial crack remediation.*

1. INTRODUCTION

The basic components of any concrete structure are concrete and reinforcement bars. The reinforcement bars are designed to take tensile stresses while the concrete is designed to take compressive stresses. Due to this, the probability of occurrence of cracks in concrete is high. These cracks are having direct relation in the durability property of the structure. Crack formation leads to the corrosion of reinforcement by allowing passage of water and other substances through it. Hence, it is essential to take proper actions to prevent these ingressions to increase the life of the structure. Self healing is the approach characterized to regain the performance of a structure after the defects has occurred. In order to prevent leakage problems and to increase the life of the structure, the technique called Microbiologically Enhanced Crack Remediation (MECR) is used. This is based on the development of calcite precipitation with the aid of some microbial metabolic activities. Hence, it is called as bacterial concrete. Here, microbial urease hydrolyzes the urea to produce ammonia and carbon dioxide. Insoluble calcium carbonate gets accumulated since the presence of ammonia leads to increase in pH. During crack formation, the bacterial spores get activated due to the presence of water. Hence, calcium carbonate gets precipitated. This will leads to the sealing of crack and thus prevents the further ingression of water and chemical substances. It also increases the strength of the concrete structure.

2. BACILLUS SPHAERICUS

Bacillus sphaericus is the bacterium found in soil. This naturally occurring bacterium has the ability to survive in organically rich water medium. VectoLex is the commercial name for a mosquito larvacide sold under Abbot Laboratories by the use of B. sphaericus. Now a day, it is used to fight against West Nile Virus. B. sphaericus has no any ill- effects on humans or animals. However its heavy or continuous exposure may sometimes cause skin rashes, based on the reports from similar Bacillus. Since it has no any harmful effects on human beings, it is considered as probiotic ingredient. It composes enzymes, amino acids, anti inflammatory compounds and colostrums. They are also part of bacteria found in human digestive tract. Health department suggests soap and water washing for the cleaning purposes in case of heavy exposure of this bacterium.

Fig 1- Bacillus sphaericus bacterium

3. BACTERIA- CONCRETE INTERACTIONS

3.1 CHEMISTRY OF THE PROCESS

One of the important biological byproduct calcium carbonate is used in the Microbiologically Enhanced Crack Remediation (MECR). It is a good sealant and hence used in structural formations for remediation of surface cracks and fissures, surface soil consolidation, in base and sub base stabilization etc.

A series of complex biochemical reactions were takes place in Microbiologically Induced Calcium Carbonate Precipitation (MICCP). It includes concomitant involvements of Bascillus Pasteurii, urease and high pH. B. pasteurii, considered as an alkalopilic soil microorganism helps in the production of urease. This in turn hydrolyses urea to forms carbon dioxide and ammonia. Due to the presence of ammonia, pH in the surrounding region gets increased and thus causes the precipitation of calcium carbonate. Overall equilibrium reaction for the precipitation of calcite in aqueous environment is:

$[Ca^{2+}] + [CO_3{}^{2-}] \rightarrow CaCO_3 \downarrow$

The reaction to precipitate calcium carbonate at the cell surface is:

$[Ca^{2+}] + Cell \rightarrow Cell\text{-}[Ca^{2+}]$

$Cl + HCO3 + NH3 \rightarrow NH_4Cl + [CO_3]^{2-}$

$Cell\text{-}[Ca^{2+}] + CO32^{-} \rightarrow Cell\text{-}CaCO_3 \downarrow$

3.2 EMBEDMENT OF MICROORGANISM IN CONCRETE MATRIX

The healing agent (bacteria and nutrients) can be incorporated in the concrete with the aid of three self healing systems. They are vascular, nutrient mixing with other ingredients and encapsulation.

- **Vascular**

It is the method inspired from the structure of human bone. During concrete preparation, the distributed vascular networks were embedded in concrete matrix. The healing agents were supplied from outside through this network. Due to crack formation, a pressure gradient is created between the agent source and position of crack. As a result, the healing agent flows to the destination point.

- **Mixing with other ingredients**

In this method, bacteria and nutrients were directly embedded into the concrete during its mixing stage. Healing agent is mixed with the water used in the preparation of concrete. Bacillus species are alkaliphilic and thus they can tolerate extreme environment in concrete. Spore forming bacterium having thick membrane can survive hundreds of years without nutrients.

- **Encapsulation**

In order to increase the viability of bacteria, healing agent is encapsulated into tubular or ball shaped capsules. During the mixing stage of concrete, this encapsulation protects the bacteria from external forces. These capsules burst at the location of crack formation and hence bacteria can become active for the crack healing.

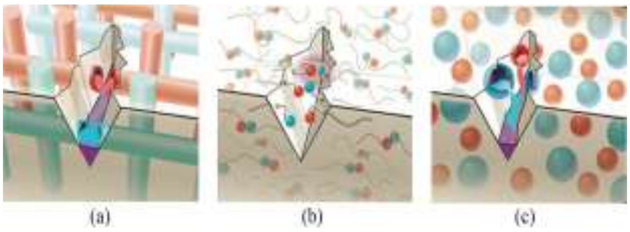

Fig 2- Self-healing types: **a)** vascular, **b)** mixing with other ingredients **c)** encapsulation

4. MATERIALS USED

Various materials used for the preparation of bacterial concrete are:

- **Aggregates**

Crushed aggregate of granite or igneous rocks, with specific gravity of 2.7 and 20 mm nominal size can be used.

- **Sand**

River sand or M sand passing through 4.75 mm sieve and included in well graded category is preferred.

- **Cement**

Cement tested for various properties as per IS: 4031-1988 and IS: 12269-1987 is used. Locally available Portland cement of 43 grades is preferred.

- **Water**

Water confirming to IS 456 for concrete mixing is used.

- **Bacterial strains**

A bacterium cultured in nutrient agar slants and preserved under refrigeration is used.

5. EXPERIMENTAL INVESTIGATION

5.1 PREPARATION OF BACTERIAL SOLUTION

Take distilled water into a 500 ml conical flask. Add 12.5 g of nutrient broth into it. The solution is then made air tight using cotton plug, paper and rubber band. The solution is made free from any contaminants by sterilizing it using a cooker for about 10-20 minutes. Into the orange colored clear solution, about 1 ml of the bacterium is added. It is kept on a shaker at 150-200 rpm speed. A whitish yellow turbid solution is formed after 24 hours of keeping the solution.

Fig 3 - Solution without bacteria

Fig 4 - Solution with bacteria

5.2 COMPRESSIVE STRENGTH TEST

Compressive strength of concrete cubes of size 150 mm x 150 mm x 150 mm were done using compression testing machine.7 and 28 day strengths were tested for the concrete cubes made up of water representing bacterial solution.

Fig 5- Concrete cube subjected to compression

5.3 FLEXURAL STRENGTH TEST

Flexural strength test is made on concrete specimen having size 10 cm x 10 cm x 50 cm. Here also, 7 and 28 day strengths were tested.

6. RESULTS AND DISCUSSIONS

By conducting compressive and flexural strength tests on the concrete specimen, the results obtained are:

Table 1- Compressive strength test results for 7 and 28 days

SI.NO	Days	Normal concrete (N/mm^2)	Bacterial concrete (N/mm^2)
1	7	20.84	27.09
2	28	29.99	38.98

Table -2 Flexural strength test results for 7 and 28 days

SI.NO	Days	Normal concrete (N/mm^2)	Bacterial concrete (N/mm^2)
1	7	3.92	4.6
2	28	7.06	7.85

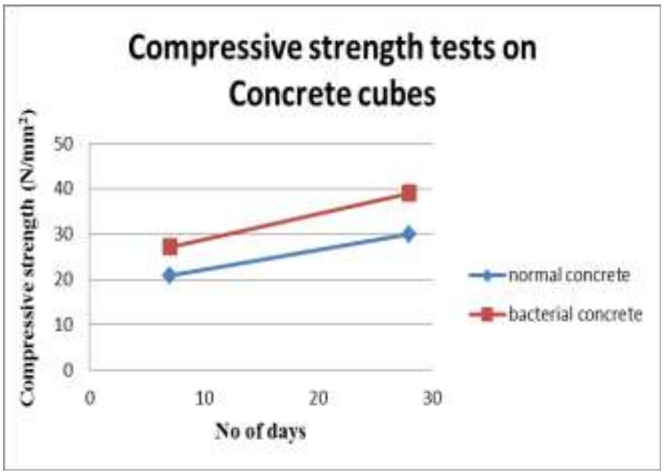

Fig 6 - Compressive strength test results -comparison

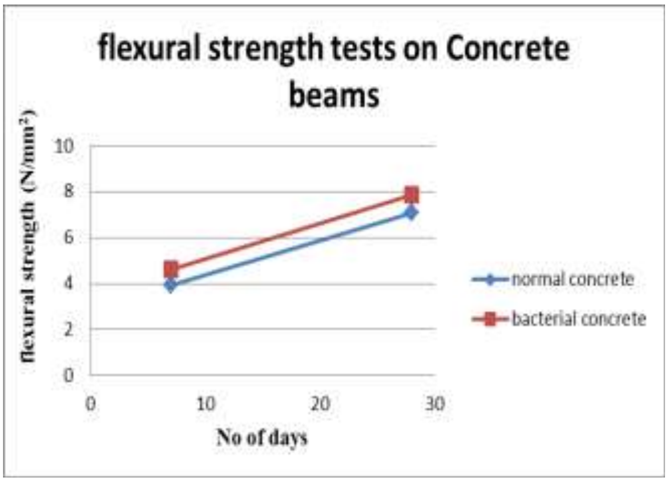

Fig 7- Flexural strength test results –comparison

Thus, through the analysis, it is clear that the 7 and 28 day compressive strength of bacterial concrete (27.09 N/mm^2, 38.98 N/mm^2) is found to be greater than that of the corresponding compressive strength of normal concrete (20.84 N/mm^2, 29.99 N/mm^2). Similarly, the 7 and 28 day flexural strength of bacterial concrete (4.6 N/mm^2, 7.85 N/mm^2) is higher as comparing to that of the normal concrete (3.92 N/mm^2, 7.06 N/mm^2).

7. CONCLUSION

The self healing approach of bacterial concrete prevails over all other methods for crack remediation due to its special features like efficient bonding capacity, sustainability and compatibility with concrete compositions. This method not only heals the crack but also prevents future crack formation. Other advantages of this method include rendering the concrete water tight, reduction in porosity of structure, favorable thermal expansion etc. As compared to the conventional treatment approaches, this method of mixing the healing agent with concrete ensures long standing and economical construction. However, investigations are still going onto study the feasibility of bacterium during concrete mixing and also on their long time effects in hardened concrete. Some associated costs like bacterium, nutrients and labour need to be considered. Thus by adopting strategies to reduce the cost and to increase the self healing efficiency, its applications in future construction projects can be ensured.

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