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# EXPERIMENTAL STUDY ON BEHAVIOUR OF BACTERIAL CONCRETE

Sandeep T D[1], Nitish Kumar K[2]

[1]*Department of Civil Engineering & New Horizon College of Engineering,*
[1]*Department of Civil Engineering & New Horizon College of Engineering,*

***Abstract*— This experimental study is deals with assessment of behavior of bacterial concrete with three different bacteria's such as Bacillus Subtilis, Bacillus Sereus and E- Coli. M25 grade concrete mix is designed as per IS 10262: 2009. The compressive strength is carried out at 7, 14 and 28 days of curing period, whereas the water permeability test is done at 28 days to determine co-efficient of permeability of concrete. The 7 Days compressive strength results shows that the Bacillus Subtilis, Bacillus Sereus and E- Coli strength increases by 13.07% , 11.11% and 14.36 % respectively as that of normal concrete. The 28 Days compressive strength results show that the Bacillus Subtilis, and E- Coli strength increases by 6.20% and 13.88% respectively. Bacillus Sereus strength decreases by 6.95 % comparing with normal concrete. The co efficient of permeability for Bacillus Subtilis, Bacillus Sereus and E- Coli bacteria decreased by 63.76 %, 51.18 % and 92.90 % as that of normal concrete.***

***Keywords*— Bacillus subtilis, Bacillus sereus, e- coli, Compressive strength, Permeability**

## I. INTRODUCTION

The occurrence of autogenously healing or self-healing of cracks in concrete has been recognized in several recent studies. The capacity for self-healing in concrete appears to be limited to micro cracks of width up to 0.1-0.2mm. The mechanism of the self-healing process may actually differ as it mainly depends on the composition of concrete mixture. For eg: Crack healing in mortar of centuries – old brick buildings in Amsterdam canals has been observed, and here the process was contributed to dissolution and reprecipitation of calcium carbonate within the mainly lime based mortar matrix. Crack penetrating water would not only dissolve calcium calcite particles present in the mortar matrix, but also carbon dioxide reacts with hydrated lime constituents such as calcium oxide and calcium hydroxide. The following reactions take place.

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

The freshly produced products from the above reactions that are precipitated on the surface of cracks resulted in the crack healing due to high energy consumption and carbon dioxide emissions. However concrete with low cement content will not feature significant crack healing capacity as the cement particles have already undergone full hydration during the early stages. To improve the durability of such cheap and eco-friendly sustainable concrete an alternative self-healing mechanism is likely to be incorporated. One such mechanism can be provided with mineral producing bacteria, alkaliphilic bacteria and endolithic bacteria. Particularly, the bacteria of the latter producing groups appear to be more promising for the self-healing properties. This not only heals the cracks but also increases the strength properties of the concrete such as compressive strength, flexural strength etc.

### Mechanism of self healing bacteria

There are various types of bacteria's that can be used in the concrete such as bacillus subtilis, bacilluscohnii, bacilluslichenformis etc. In this project, we have selected bacillus subtilis, bacillus cereus and e-coli due to its ease of availability. These bacteria's are capable of producing protective endospores to tolerate extreme conditions. The nutrients for the bacteria which are able to precipitate calcite are calcium sources phosphorous and nitrogen sources. These bacterial components remain dormant in concrete, when the seepage of water takes place into formed cracks helps in reacting with the nutrient to precipitate calcite.

The main parameter that is considered is the change in pore structure. Though change in pore structure gives better result in preventing ingress of harmful chemicals into concrete that may cause deterioration of structures. Compared to traditional concrete the bio-cement incorporated has shown higher strength from previous research. The urease producing alkaphilic bacteria which is grown in nutrient media, added with the healing agent of calcium source to the concrete mix has showed relatively higher compressive strength when compared to traditional concrete. The formation of calcium carbonate precipitates is due to the hydrolysis of urease which results in the production of ammonia and carbonate. Ammonia release increases the pH of medium which is a favorable condition for the precipitation of calcium carbonate. Carbonate binds calcium ions present in medium resulting in the formation of calcium carbonate crystals which was deposited in agar. All the three bacteria's are capable of precipitating calcite which will heal the micro cracks and pores in concrete. From previous experiments the inclusion of bacteria has increased the compressive strength of the concrete. The improvement in the compressive strength is due to the plugging of micro cracks and pores in concrete with calcite precipitated in the bacteria. This is probably due to the deposition of calcite on the micro-organism cell surfaces and within the pores of cement sand matrix which plug the pores. The durability of the concrete has also been enhanced with this technique. Calcium carbonate precipitation is affected by various factors:

 

A. Calcium concentration
B. Concentration of dissolved inorganic carbon
C. $P^H$
D. Availability of nucleation sites

## II. LITERATURE REVIEW

The main aim of the research was to find the right type of bacteria that has to survive in extreme conditions like alkaline environment. In order to find this a different bacterial combination are used in the research. Based on the following literature we take up further study. Henk M Jonkers et al [1] suggested that in addition of specific organic mineral precursor compounds plus spore-forming alkaliphilic bacteria as self-healing agents produces up to 100-µm sized calcite particles which can potentially seal micro to even larger-sized cracks. Mayur Shantilal vekariya et al [2] suggested that use of microbial concrete technology has proved to be better than many conventional technologies and it enhances compressive strength, reduction in permeability, water absorption and reinforced corrosion. K. Nirmalkumar et al [3] concluded that the treated and untreated tannery effluent can be used for construction purpose after adding suitable admixture in optimized proportion as far as the sulphate attack, chloride attack and chemical attack is concerned. M. V. Seshagiri Rao et al [4] study showed that a 25% increase in 28 day compressive strength of cement mortar was achieved. The strength improvement is due to growth of filler material within the pores of the cement–sand matrix as shown by the scanning electron microscopy. Scanning Electron Microscopy (SEM) also confirmed the role of microbiologically induced precipitation within the mortar matrix. B. G. Jagadeesha Kumar et al [5] concluded that the positive potential of microbial induced Calcite precipitation increases compressive strength mainly due to consolidation of the pores inside the cement mortar cubes with micro biologically induced Calcium Carbonate precipitation. C. M. Meera et al [6] experimental study on the addition of bacteria Bacillus subtilis JC3 in concrete shows improvement of 42% in compressive strength and 63% increase in split tensile strength compared to conventional concrete. Durability test revealed higher acid durability factor and higher acid attack factor from acid test. L.Soundarie [7] concluded that with the addition of Bacillus subtilis compressive strength increases in the order of 12.32%, to 30.05% at different ages, spilt tensile strength is in the order o f 13.80% to 18.45% at different ages and flexural tensile strength is in the order of 13.19% to 15.56% at d different ages. Cost o f the bacterial concrete is 15% increased to that o f conventional concrete. But compare to other type of special concrete it should be very economical.

## III. MATERIALS AND METHODS

### *A. Physical Properties of the Materials*

The ordinary Portland cement of 53 grade cement was used in the study. The physical properties of the cement are given in Table.1The fine aggregate and the coarse aggregate is procured from the local vendor and the properties of the aggregates are given in Table 2 and Table 3 respectively. All the materials are tested as per Indian standards.

TABLE I
PHYSICAL PROPERTIES OF THE CEMENT

| Sl no | Properties | Limits | Results |
|---|---|---|---|
| 1 | Standard consistency | 24%-34% | 30% |
| 2 | Specific gravity | 3-4 | 3.03 |
| 3 | Initial setting time | Not less than 30 min | 55 min |
| 4 | Final setting time | Less than 10 hours | 8 hours |
| 5 | Fineness test | Less than 10% | 5% |
| 6 | Compressive strength (28 days) | 53 | 53 |

TABLE II
PHYSICAL PROPERTIES OF FINE AGGREGATE

| Sl no | Properties | Limits | Results |
|---|---|---|---|
| 1 | Specific gravity | 2.65 | 2.64 |
| 2 | Zone | - | Zone II |
| 3 | Fineness modulus | 2-4 | 2.6 |

TABLE III
PHYSICAL PROPERTIES OF COARS AGGREGATE

| Sl no | Properties | Limits | Results |
|---|---|---|---|
| 1 | Specific gravity | 2.5 – 3 | 2.506 |
| 2 | Water absorption | 1 – 2 % | 2% |
| 3 | Bulk density (gm/cc) | - | 1.55 |

*B. MIX PROPORTION*

The Concrete mix is designed as per IS 10262:2009 by considering the properties of the material. The mix proportion corresponds to 1:1.9:3.15 with w/c ratio of 0.45.In order to achieve a desired slump; a superplastcizer of 2% by the weight of the cement is used.

*1. Compressive strength*:

The compressive strength of concrete was done by considering the dry proportion of ingredients (Cement, Sand & Coarse Aggregate) as per the mix design requirements. The cell concentration of 10, 00,000 cells/ml of mixing water is to be added during the mixing of bacterial concrete. In our research work we adopted direct method of mixing in which bacteria's are directly mixed with water. The cubes should be placed correctly on the machine, carefully align the specimen with the spherically seated plate. The load will be applied to the specimen axially at the rate of 140 kg/cm 2 per minute till the cube collapse. The maximum load at which the specimen breaks is taken as a compressive load. Readings of controlled concrete as well as bacterial concrete is noted down and further comparison is made. Comparison is made with concrete with all the three bacterial concrete for 7 days, 14 days and 28 Days.

*2. Permeability test:*

The rate of flow under laminar flow conditions through a unit cross sectional area of porous medium under unit hydraulic gradient is defined as coefficient of permeability. When concrete is permeable it can cause corrosion in reinforcement in presence of oxygen, moisture, CO2, SO3- and Cl– etc. This formation of rust due to corrosion becomes nearly 6 times the volume of steel oxide layer, due to which cracking develops in reinforced concrete and spalling of concrete starts. To avoid this corrosion we used various bacteria's in concrete and we made an attempt to determine the coefficient of permeability at 28 days for

## IV. RESULT AND DISCUSSION

***1. Compressive strength***

The compressive strength of the concrete mixes with different types of bacteria is tested at 7, 14 and 28 days of curing period. It is depicted in Fig 1, 2 and 3 respectively. The strength at 7 days increases with incorporation of bacteria in the mix.

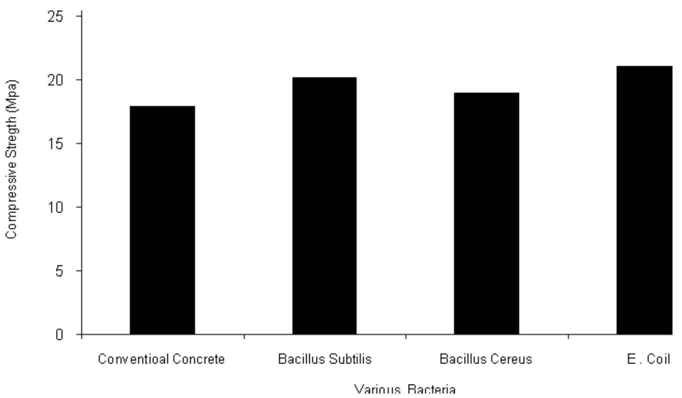


*Figure.1. Seven days strength of the concrete*

The above results shows that increases in the compressive strength in Bacillus Subtilis, Bacillus Sereus and E- Coli by 13.07%, 11.11% and 14.36 % respectively comparing with normal concrete.

 

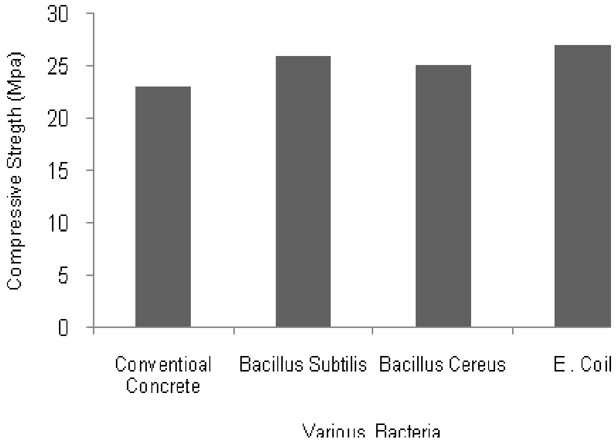


*Figure.2. Fourteen days strength of concrete*

The above results shows that increases in the compressive strength in Bacillus Subtilis, Bacillus Sereus and E- Coli by 13.04%, 8.11% and 21.73 % respectively comparing with normal concrete.

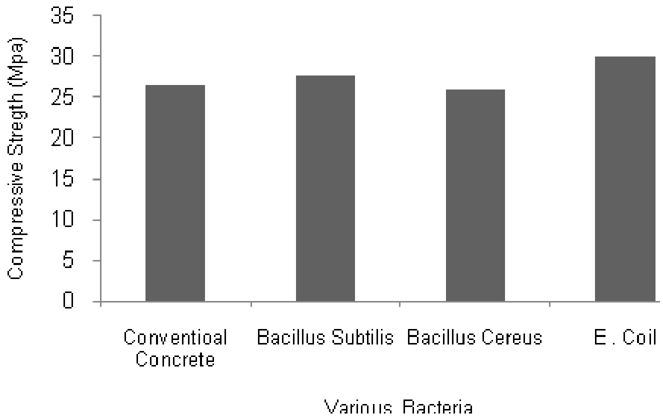


*Figure.3. Twenty eight days strength of the concrete*

The above results show that the Bacillus Subtilis, and E- Coli strength increases by 6.20% and 13.88% respectively. Bacillus Sereus strength decreases by 6.95 % comparing with normal concrete

***2. Permeability***

The coefficient of permeability of the concrete mixes with different types of bacteria is tested at 28 days of curing period. It is depicted in Fig 4. The coefficient of permeability decreases with incorporation of bacteria in the mix.

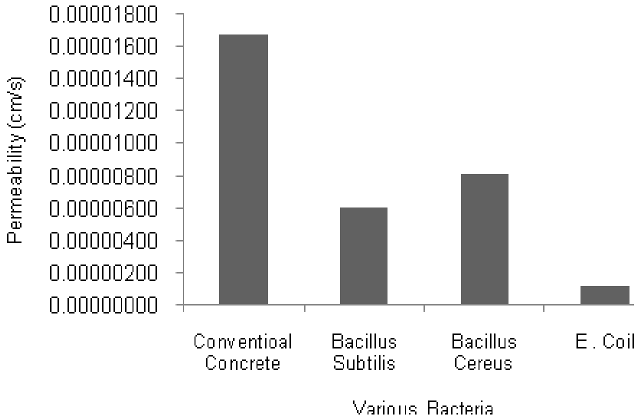


*Figure.4.28 days Permeability comparison with conventional concrete and bacterial concrete*

 

## V. CONCLUSIONS

The present experimental study resulted in following important conclusions. The 7 Days compressive strength results shows that the Bacillus Subtilis, Bacillus Sereus and E- Coli strength increases by 13.07% , 11.11% and 14.36 % respectively comparing with normal concrete. The 28 Days compressive strength results show that the Bacillus Subtilis, and E- Coli strength increases by 6.20% and 13.88% respectively. Bacillus Sereus strength decreases by 6.95 % comparing with normal concrete. Increase in compressive strength is mainly due to the consolidation of the pores inside the cement mortar with microbiologically induced calcite precipitation.

The co-efficient of permeability for Bacillus Subtilis, Bacillus Sereus and E- Coli bacteria result shows that it is decreased by 63.76 %, 51.18 % and 92.90 % as that of normal concrete. A lower permeability due to healing of cracks would result in a decreased ingress rate of water percolation.

As the bacterial concentration increases, $CaCO_3$ precipitation also increases.

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