Performance and Evaluation of Bacterial Concrete

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Abstract— Concrete is a homogenous mixture and cracks in concrete are inevitable so there is a need for repair which affects the economic life of any structure. To overcome this problem an inherent biomaterial is developed, a self-repairing material which can remediate the cracks in concrete. Bacterial concrete is a technique which is highly desirable because the calcium precipitation is induced as a result of microbial activities. This helps in increasing the strength and durability of concrete. Also various other tests carried out on the cube and its results are stated in the paper.. The mechanism of crack healing in bacterial concrete presumably occurs through metabolic conversion of calcium lactate to calcium carbonate what results in crack-sealing. This biochemically mediated process resulted in efficient sealing of sub-millimetre sized (0.15 mm width) cracks. As per the results, it is clearly observed that there is increase in compressive strength, tensile strength and durability in bacterial concrete as compared with normal concrete. This is the main objective of the bacterial concrete for which it was introduced. Various tests which are carried out to study these properties of concrete are compressive strength test, Split tensile test. Scanning Electron Microscope (S.E.M) is used to study the growth of bacteria in the concrete.

Key words: Bacterial Concrete, Cube Tests, Preparation, Mechanism, Crack Healing

I. INTRODUCTION

Concrete structures often suffer from cracking that leads to much earlier deterioration than designed service life. The process of self-healing can be carried out by adding specially selected types of bacteria which are added to the ingredients of the concrete when it is being mixed. These self-healing agents can lie dormant within the concrete for up to 200 years. The "Bacterial Concrete" can be made by embedding bacteria in the concrete that are able to constantly precipitate calcite. Bacillus Sphaericus is a type of soil bacterium which can continuously precipitate a new highly impermeable calcite layer over the surface of an already existing concrete layer. Calcite has a coarse crystalline structure that readily adheres to surfaces in the form of scales. In addition to the ability to continuously grow upon itself it is highly insoluble in water. Due to its inherent ability to precipitate calcite continuously bacterial concrete can be called as a "Smart Bio Material". Cracks in concrete significantly influence the durability characteristics of the structure. The bacterial remediation technique can be used for repairing structures of historical importance to preserve the aesthetics value, as conventional technique, such as epoxy injection cannot be used to remediate cracks in those structures The favourable conditions do not directly exist in a concrete but have to be created. Tests are conducted to study the mechanical properties of the above concrete with various percentages of Bacteria. The tests carried out are Compressive strength test, Split Tensile strength test, Flexural test, two point load test, Soundness Test, Ductility test etc. Some possible mechanisms of a Self-healing concrete are:

1) Formation of material like calcite.
2) Blocking of the path by sedimentation of particles.
3) Continued hydration of cement particles.
4) Swelling of the surrounding cement matrix.

II. MATERIALS

A. Aggregates:

The properties of concrete mainly depend on size and gradation of aggregates used in concrete. We had used concrete mix design confronted to IS 10262 - 2009. The aggregates passing through 20mm IS sieve and retaining on 10mm IS sieve i.e. Metal I aggregates and aggregates passing through 10mm and retaining on 4.75mm IS sieve i.e. Metal II will be used. Fine aggregates passing from 4.75mm IS sieve & retained on 2.36mm IS Sieve. The aggregates which are used are confronted to IS 383 – 1970. The aggregates required will be sieved in the structural lab. The aggregates used should be rounded and angular to improve workability and strength. Use of flaky aggregates should be avoided. The test surface of the aggregates should be dry at the time of mixing. The strength of concrete depends on proper bonding between cement paste and aggregates. The various test which are carried out on aggregates are confronted to IS 2386 – 1963. The test on aggregates include aggregate impact test, crushing value test, los angelos abrasion test. The aggregate impact value shall not exceed 45% by weight for aggregate used for concrete.

B. Cement:

In this project the cement would be Ordinary Portland Cement (OPC) of 53 GRADE Ultratech cement. Cement should be stored in a proper place to avoid formation of floc. The cement used was subjected to various field tests like:

- The cement should not have any floc.
- If there are any flocs they should get crumble between thumb and index finger.
- If thrown into the water it should float for few seconds before sinking.
- If you thrust your hand in cement should give you cool feeling.
- If you hold the cement between your fingers it should not be gritty

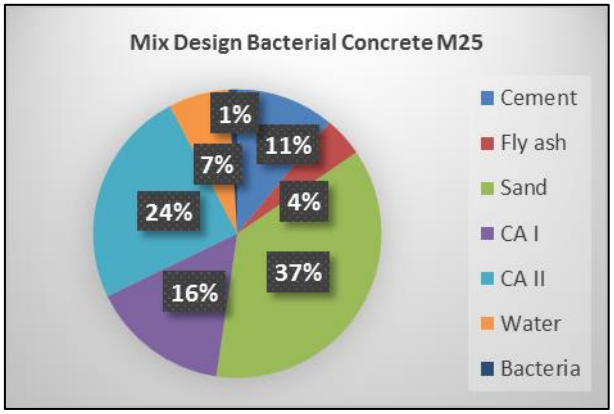
C. Water:

Portable tap water should be used in the casting of self-healing concrete. The temperature of water should be maintained at room temperature. The quantity of water used is critical to obtain a workable and uniform mix. The water used for casting the concrete should have pH 6-8 according to the IS CODE 456-2000

D. Healing agent:

The healing agents which will be used are bacteria‟s named „BACILLUS SUBTILIS‟. The bacterial stain was obtained from Bhavan‟s Biology Laboratory. Before using the stain the bacterial growth was made.

III. MIX DESIGN



IV. INTRODUCTION OF BACTERIA IN CONCRETE:

A. Method 1:

Bacteria will be introduced in the concrete while mixing the concrete. The bacteria will be mixed in the water which is used for mixing the concrete. The proportion of the bacteria is fixed and introduced as per the proportion of water in concrete. The proportions of the bacteria are 105 cells and 106 cells i.e 24ml in 1 litre and 240ml in 1 litre.

Fig. 2: Introduction of bacteria in water
Fig 2 shows introduction of bacteria in water

B. Method 2:

Bacteria are introduced in the concrete at the time of curing. The proportion of the bacteria is fixed and introduced as per the proportion of water in concrete. The proportions of the bacteria are 105 cells and 106 cells i.e. 24ml in 1 litre and 240ml in 1 litre.

C. Method 3:

Bacteria are introduced in the concrete by injecting the bacteria with the help of injection. Care should be taken that the concrete should be in plastic state. The proportion of the bacteria is fixed and introduced as per the cell proportions (105and 106cells)

V. CASTING OF SELF-HEALING CONCRETE:

Casting of 36cubes was done. The standard IS moulds of size 15 × 15 ×15 cm were used for casting. At the time of casting, the aggregates and cement in required quantity were mixed on a clean platform. Then the required amount of water was added to the mix. The mix is thoroughly mixed till uniform colour is obtained. The mixing is done by machine. The surface of block is levelled properly using a trowel. These blocks were kept submerged in water for curing for 28 days after casting. The temperature of water used in curing tank was room temperature

Fig. 3:

A. Curing water:

Portable water should be used for curing. Curing should be done minimum for 1 day for proper hydration of concrete. Various methods for curing are

- Use of gunny bags.
- Water tanks.
- Ponding.
- Use of plastic sheets over ponding.
- Steam curing.

VI. TEST

A. Compressive Strength of Concrete:

The cubes of size 15*15*15 cm are casted for compressive strength. The cubes are casted as per the mix design. The cubes are removed from the moulds after one day of casting.

Procedure:

1) Take certain mix proportion with a certain water cement ratio. Take coarse aggregate, fine aggregate, cement and water as per the proportion. Mix them thoroughly until uniform colour is obtained. This material will be sufficient for casting three cubes of the size 150*150*150mm. In mixing by hand cement and fine aggregate be first mixed dry to uniform colour and then coarse aggregate is added and mixed until coarse aggregate is uniformly distributed throughout the batch. Now the water shall be added and the ingredients are mixed until resulting concrete is uniform in colour. Mix at least for two minutes.
2) Pour concrete in moulds oiled with medium viscosity oil. Fill the cylinder mould in three layers each of approximately 50 mm and ram each layer more than 25 times with evenly distributed strokes.
3) Remove the surplus concrete from the top of the moulds with the help of the trowel.
4) Cover the moulds with wet mats and put the identification mark after about 3 to 4hours.
5) Remove the specimens from the mould after 24 hours and immerse them in water for the final curing. The test is usually conducted at the age of 7-28days. The time age shall be calculated from the time of addition of water to the dry ingredients.

6) Test at least three specimens for each age of test as follows:
7) Apply the load without shock and increase it continuously till the concrete cracks.
8) Note the appearance of concrete and any unusual feature in the type of failure. Total 9
9) cubes are to be tested for 3, 7 and 28 days for compressive test.

B. Split Tensile Test:

Procedure:

1) Take certain mix proportion with a certain water cement ratio. Take coarse aggregate, fine aggregate, cement and water as per the proportion. Mix them thoroughly until uniform colour is obtained. This material will be sufficient for casting three cylinders of the size 150mm diameter X 300 mm length. In mixing by hand cement and fine aggregate be first mixed dry to uniform colour and then coarse aggregate is added and mixed until coarse aggregate is uniformly distributed throughout the batch. Now the
2) Water shall be added and the ingredients are mixed until resulting concrete is uniform in colour. Mix at least for two minutes
3) Pour concrete in moulds oiled with medium viscosity oil. Fill the cylinder mould in four layers each of approximately 75 mm and ram each layer more than 35 times with evenly distributed strokes.
4) Remove the surplus concrete from the top of the moulds with the help of the trowel.
5) Cover the moulds with wet mats and put the identification mark after about 3 to 4 hours.
6) Remove the specimens from the mould after 24 hours and immerse them in water for the final curing. The test is usually conducted at the age of 7-28days. The time age shall be calculated from the time of addition of water to the dry ingredients.
7) Test at least three specimens for each age of test as follows:
   - Draw diametrical lines on two ends of the specimen so that they are in the same axial plane.
   - Determine the diameter of specimen to the nearest 0.2 mm by averaging the diameters of the specimen lying in the plane of premarked lines measured near the ends and the middle of the specimen. The length of specimen also shall be taken be nearest 0.2 mm by averaging the two lengths measured in the plane containing pre marked lines.
   - Centre one of the plywood strips along the centre of the lower platen. Place the specimen on the plywood strip and align it so that the lines marked on the end of the specimen are vertical and centred over the plywood strip.

   The assembly is positioned to ensure that lines marked on the end of specimen are vertical and the projection of the plane passing through these two lines interest the centre of the platen.
8) Apply the load without shock and increase it continuously at the rate to produce a split tensile stress of approximately 1.4 to 2.1 N/mm2/min, until no greater load can be sustained. Record the maximum load applied to specimen.
9) Note the appearance of concrete and any unusual feature in the type of failure.
10) Compute the split tensile strength of the specimen to the nearest 0.25 N/mm2

VII. RESULTS

Comparison of compressive strength between normal concrete and bacterial concrete:-

Days	Normal Concrete	Bacterial Concrete	% Increased
28	2.10	2.48	18.09
56	2.46	3.10	26.06

Table 1:

Days	Normal Concrete	Bacterial Concrete	% Increased
7	20.63	25.55	23.85
28	25.92	30.54	17.82
56	37.94	44.23	16.57

Table 2:

Average Percentage increase in Compressive strength of bacterial concrete in comparison with normal concrete is 19.41%.

Flexural strength test:

Average Percentage increase in Flexural strength of bacterial concrete in comparison with normal concrete is 22.07 %.

VIII. CONCLUSION

1) Bacterial Concrete also known as microbial concrete technology has proved to be better than many conventional technologies because of its eco- friendly nature, self-healing abilities and increase in durability of concrete.
2) The compressive strength of the bacterial concrete was increased by 19.41% as compared to normal concrete.
3) The flexural strength of the bacterial concrete was increased by 22.07% as compared to normal concrete,
4) Due to the production of the calcium precipitate the water permeability of the concrete was decreased.
5) Due to bacterial activity a calcium precipitate layer is deposited on the crack surface, sealing and blocking entrance to deteriorating substance.
6) Bacterial spores and a suitable organic bio chemical precursor compound using porous expanded clay particles as a reservoir is a promising bio-based and thus sustainable alternative to strictly chemical or cement based healing agents.
7) It has been observed that for bacterial proportion 105 cells (24 ml of bacteria in 1000ml) gives optimum results.
8) Bacteria can live in concrete for over 100 years in the form of spores.

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