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ENHANCEMENT OF DURABILITY PROPERTIES OF BIOCONCRETE INCORPORATED WITH NANO SILICA

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ABSTRACT

Bacterial concrete, the so called Smart bio material is an eco-friendly concrete in which selective cementation takes place by microbiologically induced $CaCO_3$ .This method is introduced to remediate even micro cracks, voids and pores. Based on experimental investigation carried out the paper presents the results to enhance the mechanical and durability properties by means of introducing Enterobacter sp. in the concrete. The bacterium used in this study has the ability to precipitate calcite is the calcite precipitating bacteria which is readily mixed in the concrete. The precipitated calcite contains crystalline structure that has the ability to readily adhere to the concrete and completely arrests the rise of micro cracks and pores. In addition it has the ability to continuously grow upon itself when it comes in contact with any medium which is highly insoluble in water. The presence of nano-silica in the concrete enhances the C-S-H formation. The strength contribution in the specimen is due to the presence of organic substances. It is available as microbial biomass that is required for the biomineral precipitation. The Organic source adopted here is the yeast extract. A successful attempt has been made on the biomineralization process to enhance the compressive strength, split tensile strength and durability properties of concrete by using the Enterobacter sp. This biological treatment shows promising prospect in increasing strength aspects of the concrete.

Keywords: Bacterial concrete, nano silica, N_2 source, $CaCO_3$ precipitation, Mechanical & Durability studies.

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1. INTRODUCTION

Researches all over the world are attempting to develop high performance concrete by using silica fume and other admixtures in concrete. The inclusion of supplementary cementing material like fly ash has great impact to refine the pore structure and the degree of hydration of the concrete. Conventionally, different variety of sealing agent's namely latex emulsions and epoxies aids in enhancing the durability of the concrete structures.

Materials with self-recuperating ability are been made adequately use to beat the deficiencies of ordinary fixing specialists. Use of urease producing bacteria like Enterobacter sp. effectively addresses these problems, as it has an ability to survive and develop inside of the solid structure. This action significantly helps in mineralization of $CaCo_3$, by hydrolyzing urea present in the earth. It discharges CO_2 from urea that consolidates with Ca+ particles that out comes in testimony of $CaCo_3$ as calcite.

Bacterial cell on discharging the disintegrated inorganic carbon and the ammonium shaped to the microenvironment around the bacterial cell. This aids in fascination of the calcium particles close to the bacterial cell divider with its negative charge. This process has great impact when added to the concrete components. In this the bacterial cell divider goes about as the heterogeneous nucleation site for both the calcium and carbonate particles. This responds and shapes CaCo3 and forms into calcite crystals encompassing the cell because of the progressive stratification. As a result the growth projects out wards to heal the cracks. This makes the calcite crystals at times to surround the whole bacterium and convert them to crystalline phase. Use of these mineralogy ideas in the solid examples prompts the potential creation of new savvy material called Bacterial Concrete.

The use of microbes for $CaCo_3$ deposition or microbial concrete is named as microbially induced $CaCo_3$ precipitation (MICCP). This method is used for solving various durability issues. It is also called 'smart bio material' due to natural capability of precipitating calcite continuously. It was reported that the effect of bio-deposition improves the durability of concrete specimens.

2. MATERIALS

A. Cement

Cement is generally graded according to few set of specifications defined. In this experiment 53 grade ordinary Portland cement (OPC) confirming to IS 12269 (1987) [3] is used for all concrete mixes. The cement is used in a fresh state and without any lumps. The specific gravity of cement is 3.15.

B. Silica fume

Silica fume confirming to IS 15388 (2003) [4] is used. It is a very effective pozzolanic. In the vicinity of dampness it promptly [chemically] responds with Ca(OH)2 at normal temperatures to produce compounds having cementitious properties. The specific gravity of silica fume utilized is 2.2.

C. Fly ash

Class F fly ash is produced from the burning of bituminous coal. Class F Fly ash which confines IS 3812 (2000) [5] is used. This fly ash is pozzolanic in nature and contains less than 10% CaO. The specific gravity of fly ash used is 2.2

D. Quartz sand

The Physical properties of the quartz sand used are given in table 1

Table 1 Properties of Quartz Sand

Specific gravity	2.64
Particle size range	400 µm - 800 µm

E. Quartz powder

The physical properties of quartz powder are given in table 2.

Table 2 Properties Of Quartz Powder

Specific gravity	2.61
Particle size range	2.3 µm - 75µm
Percentage of passing	52%

F. Bacteria & N_2 source

The bacterium used in the study is the *Enterobacter* sp., grown in laboratory to attain the concentration of 10^6 colony forming unit per ml and the N_2 source adopted is the yeast extract. The bacterial solution used in the mix is shown in Fig 1.

Figure 1 Bacterial solution

G. Super plasticizer

Polycarboxylate ether based super plasticizer is used. The properties of are given in table 3.

Table 3 Properties Of Super Plasticizer

Appearance	Light yellow colored liquid
pH	6.5
Volumetric mass @ 20°C	g/l

H. Steel fibers

The Physical properties of Steel fiber are given in the table 4.

Table 4 Properties of Steel Fiber

Specific gravity	17.8
Length	13 mm
Diameter	0.18 mm
Yield stress	

I. Nano silica

Nano silica is produced from Sigma Aldrich imports and exports trade co.ltd is used as received. The physical properties of nano silica are given in the table 5.

Table 4 Properties of Steel Fiber

Appearance	**White color powder**
Particle size	10nm - 20nm
Specific surface area	600 m^2
Density	2.2 - 2.6g/cm^3 at 25°C
Purity	92.50%

3. EXPERIMENTAL WORK

3.1 Casting of control specimens

The Mix proportions for the control specimens were casted as per the ratio given in table 5.

Table 5 Mix Proportions

Composition of HSC	
Cement	1
Silica Fume	0.25
Fly Ash	0.25
Quartz Sand	1.1
Quartz Powder	0.4
Water	0.23
SP	3.50%
Steel Fibers	0.25%

3.2. Casting of bacterial specimens

The casting of the bacterial concrete contains nano-silica and the yeast extract in addition to the control mix. The amount of nano-silica used is maintained constant in all the batches. It is taken 1 % weight of the cement and the yeast in the range of 2, 4, 6, 8 & 10g in each batch. Bacterial culture was prepared using sterile Luria Bertani medium. The Culture is then centrifuged to obtain the bacteria as pellets as shown in fig 2. The pellets of the centrifuged culture are mixed with 100ml water and used in the casting immediately as shown in fig, 3. The mix identification is given in table 6. In which B refers to the bacteria and NS refers to nano silica.

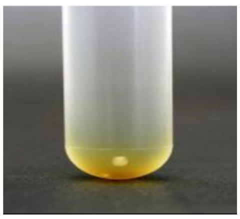

Figure 2 Pellets

3.3. Curing of specimens

After 24 hours the specimens are de-moulded and left for curing. Two types of curing regimes are adopted, oven curing and water curing. The Silica fume is very reactive at high temperature. Thus the pozzolanic reactivity of silica fume is enhanced at elevated temperature. Therefore one day of oven curing at 200°C and one day of water curing is followed which is counted as 28 days.

4. RESULTS & DISCUSSION

4.1. Durability studies

The efficiency of Enterobacter *species* in the presence of nano silica and N_2 source is prominent in 4 g/l yeast. Therefore this quantity of N_2 source is optimized and further carried out for the durability studies namely Rapid Chloride Penetration Test (RCPT), Water absorption test and Sorptivity test.

4.2. Rapid chloride penetration test

The RCPT test is carried out as per AASHTO T277, (ASTM C1202) [8] in the specimen of size 50 mm thickness and 100 mm diameter. The specimen undergoes a DC of 60 V for 6 hours as shown in Fig 6. Two reservoirs are present on either side of the specimen in which one reservoir contains a 3.0 % NaCl solution and 0.3 M NaOH solution. The total charge passed is attained and used to rate the quality of concrete. Measure of the electrical conductance of the concrete is given by the total charge passed at the time of testing.

$$Q = 900 \times (I_0+2I_{30}+2I_{60}+....+2I_{300}+2I_{330}+I_{360})$$

Where,

Q = Charge Passed (Coulombs),

I_0 = Current immediately after voltage is applied (amperes)

I_t = Current at t min after voltage is applied (amperes)

Table 8 Chloride Ion Penetrability

Charge passed (Coulombs)	Chloride ion penetrability
> 4000	High
2000 - 4000	Moderate
1000 - 2000	Low
100 - 1000	Very low
<100	Negligible

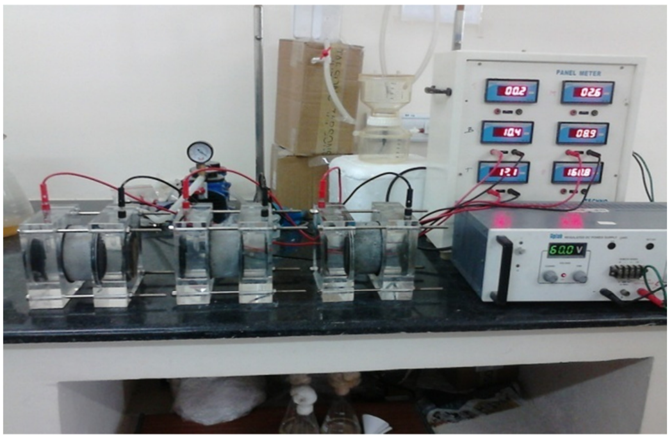

Figure 6 RCPT Test setup

Test results indicate the improvement in resistance to chloride penetration in the bacterial concrete.

4.3. Water absorption test

Water absorption test is carried out as per ASTM C 642-11[9] in the specimen of size 50 mm thick and 100 mm diameter. The cured specimens are dried in an oven at 100^{o}- 110 ^{o}C which is not less than 24 hours. It is allowed to cool after removing from the oven, and mass is determined (A). Then immersed in water for about 48 hours and removed. It is surface dried and weighed again (B) and taken as a second weight. Again the specimen is then placed in an autoclave and boiled upto 5 hours and then left to lose heat and maintain temperature for about 14 – 16 hours. The specimens are again surface dried and weighed (C). Finally completely immersed weight of the specimen in water is measured (D) as shown in Fig 7.

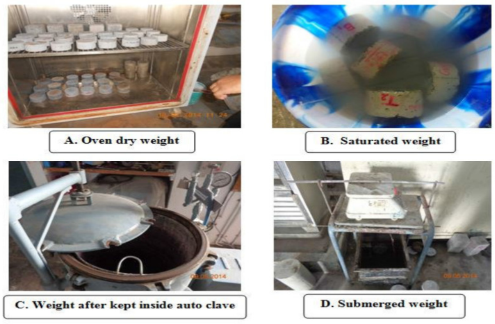

Figure 7 Water absorption Test

4.4. Test on Sorptivity

In accordance with ASTM C 1585-11 Sorptivity test was performed [10] in the specimen of size 50 mm thick and 100 mm diameter. The purpose of this test is to determine the rate of absorption of water in the unsaturated concrete. The function of the increased mass of the specimen resulting from the absorption of water relates to the time wherein one side of the specimen is subjected to water exposure. When the water enters into the pores of concrete by capillary action the rate of penetration is measured.

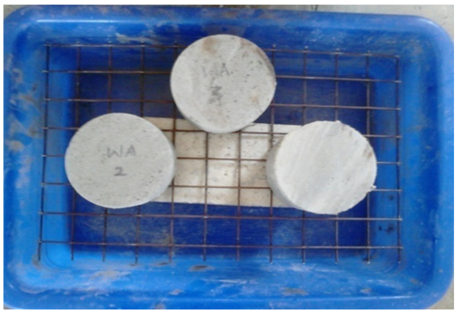

Figure 8 Sorptivity Test setup

5. CONCLUSION

1. From the results of Rapid chloride penetration tests, it is clear that the penetration of chloride ions is reduced for bio specimens compared to control.
2. From the results of water absorption test it is concluded that, the absorption of water is quite higher in control specimens than the bio specimen containing nano silica. The water absorption is reduced up to 50% in HSC containing *Enterobacter sp.* and nano silica.
3. The test results of sorptivity conclude that the bio specimens absorb less water in comparison with the control specimens.

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