An Experimental Analysis Property of Bacterial Silica Flume Concrete

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Abstract

The work is involved with the use of Ureolytic bacteria in concrete which could make it more durable. The bacteria present in the concrete rapidly sealed freshly formed cracks through calcite production. The bacterial concentration was optimized to 105 cfu/ml .In concrete mix, cement was replaced with silica fume in 5%, 10% and 15% by weight of cement. The experiments were carried out to estimate the effect of bacteria on the compressive strength, water absorption, porosity, rapid chloride permeability and sorptivity of concrete made with silica fume up to the age of 28 and 56 days. The test result shows that inclusion of bacteria enhanced the compressive strength by 12%, reduced the porosity, water absorption and sorptivity by upto 55% of the silica fume concrete. The improvement in compressive strength was due to deposition of calcite precipitated by bacteria within the pores which was scanned by electron microscopy and characterized by XRD and revealed calcium carbonate precipitation. This precipitation also reduced the chloride permeability in concrete with silica fume. The bacteria improve the impermeability of concrete by improving its pore structure and thereby enhancing the life of concrete structure.

Keywords— *Bacterial properties, Silica Flume, Concrete.*

I. INTRODUCTION

Because of its extreme fineness and very high amorphous silicon dioxide content, silica fume is a very reactive pozzolanic material. As the Portland cement in concrete begins to react chemically, it releases calcium hydroxide. The silica fume reacts with this calcium hydroxide to form additional binder material called calcium silicate hydrate (CSH) which is very similar to the calcium silicate hydrate formed from hydration of Portland cement (Chahal, 2012). It is an additional binder that gives SF concrete its improved properties. Mechanism of silica fume in concrete can be studied basically under three roles:

(i) Pore-size Refinement and Matrix Packing: The presence of silica fume in the Portland cement concrete mixes causes considerable reduction in the volume of large pores at all ages. It basically acts as filler due to its fineness and because of which it fits into spaces between grains in the same way that sand fills the spaces between particles of coarse aggregates and cement grains fill the spaces between fine aggregates grains.

(ii) Reaction with Free-Lime (from hydration of cement): Calcium hydroxide crystals in Portland cement pastes are a source of weakness because cracks can easily propagate through or within these crystals without any significant resistance affecting the strength, durability and other properties of concrete. Silica fume which contains siliceous material reacts with CH resulting in reduction of CH content in addition to increasing strength contributing cementitious products (CSH) which in other words can be termed as Pozzolanic Reaction.

(iii) Cement Paste–Aggregate Interfacial Improvement: In concrete the characteristics of the transition zone between the aggregate particles and cement paste plays a substantial role in the cement-aggregate bond. Silica fume addition impacts the thickness of transition phase in mortars and the degree of the orientation of the CH crystals in it. The thickness compared with mortar containing only ordinary Portland cement decreases and decline in degree of orientation of CH crystals in conversion phase with the addition of silica fume. Hence mechanical properties and durability is improved because of the enhancement in interfacial and bond strength. Mechanism behind is not only connected to chemical creation of CSH (i.e. pozzolanic reaction) at interface, but also to the microstructure reformation (i.e. CH orientation, porosity and transition zone thickness) as well.

II. MATERIAL AND MTHODOLOGY

Compressive Strength

For each set three standard cubes were cast to determine 28 days and 56 days compressive strength after curing. Cubes were cast and compacted on a vibration machine. After de-molding, all specimens were cured in water at room temperature for compression testing until 28 and 56 days. Cube specimens of size 150 mm were cast for compressive strength as per Indian standard specifications IS: 516 1959.

3.2.4.2 Water Absorption and Porosity

The water absorption and porosity test was conducted as per ASTM C 642 13 in order to determine the increase in resistance towards water penetration in concrete. The cube moulds of 150 mm were prepared both with and without bacteria and silica fume replacement. The concrete specimens were cured for 28 days and 56 days. After curing, the specimens were oven dried at 110°C in oven for 24 hours after removing from oven specimens are allowed to cool in dry air to about 20-25°C and weighed. Then the specimens were immersed in water at approximately 21°C for 48 hours and saturated mass after immersion was calculated. Then the specimens were placed in suitable receptacle, covered with tap water and were boiled for 5 hours, further the saturated mass after boiling was calculated. Apparent mass of boiled specimens are then calculated by suspending it in steel wire basket.

2.4.3 Rapid Chloride Permeability Test

Corrosion is mainly caused by the ingress of chloride ions into concrete disturbing the original passivity present. Rapid chloride permeability test (RCPT) has been developed as a quick test able to measure the rate of transport of chloride ions in concrete. One of the main characteristics influencing the durability of concrete is its permeability to the ingress of chloride. The chloride ion present in the concrete can have harmful affect on concrete as well as on the reinforcement. Swelling of concrete due to chloride ion penetration is 2 to 2.5 times larger than that observed with water penetration. So this test covers the experimental evaluation of electrical conductance of concrete to provide rapid indication of concrete resistance against chloride ion penetration.

Six hour test reading are observed to determine the permeability of the samples. Procedure for conducting test is as follows:

The cylinders (100 × 200 mm) thickness with and without bacterial culture were cast and allowed to cure. Specimens were placed in the vacuum dessicator bowl, the setup of the vacuum pump, dessicator with stopcock, vacuum gauge and valve and the deaerated water container after the water has filled the desiccators. The vacuum was maintained in the desiccators bowl for 3 hours. The deaerated water was allowed to flow into the dessicator, so that it completely covers the specimens and no air was allowed to enter. Again the vacuum was maintained for another one hour. Then the specimens were left to soak in the container water for another 18 hours. The specimens were removed from the dessicator, dried and placed in gasket. The liquids (3% NaCl and 0.3 N NaOH solutions) were filled in the two cells. Power supply was set to 60V, and final current reading was recorded after 6h of testing procedure.

3.2.4.4 Sorptivity Test

This test method is used to determine the rate of absorption (sorptivity) of water by hydraulic cement concrete by measuring the increase in the mass of a specimen resulting from absorption of water as a function of time when only one surface of the specimen is exposed to water. The exposed surface of the specimen is immersed in water and water

ingress of unsaturated concrete dominated by capillary suction during initial contact with water (ASTM C 1585 -13). 100mm diameter and 50 mm thick concrete disk are prepared as according to ASTM C 1585-04 for conducting the test. Following procedural steps are taken to complete the test.

1. The specimen was dried in oven at about 105°C until constant mass was obtained. Specimen was cool down to room temperature for 6hr.
2. The side of the specimen was coated with electrician tape to achieve unidirectional flow.
3. The specimen was exposed to water on one face by placing it on slightly raised seat (about 5mm) on a pan filled with water.

The water on the pan was maintained about 5mm above the base of the specimen during the experiment as shown in the figure below. The weight of the specimen was measured at intervals defined by the above mentioned code. The absorption *I* was calculated from the formula:

Scanning Electron Microscopy

An SEM is essentially a high magnification microscope, which uses a focused scanned electron beam to produce images of the sample, both top-down and, with the necessary sample preparation, cross-sections. The morphology and chemical constituents of the Concrete samples were analyzed with SEM. The Scanning Electron Microscope (SEM) is a powerful instrument which permits the characterization of heterogeneous materials and surfaces. Samples were completely dried at room temperature, then specimens were examined at accelerating voltage range of 20 kV by a SEM (JEOL, JSM 6510 LV).

XRD

X-ray diffraction is a non-destructive technique used to determine the elements present in any particular substance. X-ray powder diffraction technique is the most prominent technique used for unraveling the structure of the materials in bulk and thin film forms. XRD spectra were obtained using an X'Pert PRO (PAN alytical) diffractometer with a Cu anode (40 kV and 30 mA) and scanning from 5° to 60°. Each sample was crushed and ground before mounting onto a glass fiber filter using a tubular aerosol suspension chamber (TASC). The components of the sample were identified by comparing them with standards

established by the International Center for Diffraction Data (ICDD). All experiments were performed in triplicate. X-ray diffraction is based on the fact that, in a mixture, the measured intensity of a diffraction peak is directly proportional to the content of the substance producing it. The samples for X-Ray diffraction analysis ere prepared in powdered form. The concrete sample was taken from the inner core of the matrix. For any mineral to be present, all the strong peaks should be present in the XRD graph, else the mineral is not present.
potentially effective alternative treatment for industrial

Permeation Properties

Permeability may be defined as the measure of the ability of a material to allow fluids to pass through it. Water absorption is defined as the amount of water absorbed by a material when immersed in water for a stipulated period of time. It is calculated as the ratio of the weight of water absorbed by a material, to the weight of the dry materials. In this section we are presenting here the results obtained by various researches on influence of bacteria on Permeation properties of concrete. Bacterial deposition of a layer of calcite on the surface of the specimens resulted in a decrease of capillary water uptake and gas permeability (De Muynck et al., 2008). The effects of bacterial carbonate precipitation on the durability of mortar specimens with different porosity. The surface deposition of calcium carbonate crystals decreased the water absorption with 65 to 90% depending on the porosity of the specimens. As a result, the carbonation rate and chloride migration decreased by about 25–30% and 10–40% respectively. Filling of cracks in the bacterial self-healing concrete proposed by Wiktors and Jonkers (2011) and Wang et al. (2014) became gas and watertight after activation of the bacteria with consumption of the nutrients and crack filling with deposited $CaCO_3$ crystals. Van Tittelboom et al. (2010) noted that the water permeability of damaged specimens containing capsules filled with polymeric healing agent was similar to values obtained for undamaged specimens.

Reinhardt and Joss (2003) studied the permeability of self-healing concrete as a function of temperature and crack width and found that the flow rate rises non- linearly in case of an increase of the crack width. The influence of temperature is also well recognizable. The following table compares the test results and theoretical prediction by normalizing the flow rates to the value of 0.08 mm crack width and 20℃.
Achal et al. (2011) studied the water absoption and sorptivity results proved treated mortar cubes absorbed more than three times less water than control cubes as a result of microbial calcite deposition. Microbial deposition of a layer of calcite on the surface of the concrete specimens resulted in substantial decrease of water uptake and permeability compared to control specimens without bacteria. *B. megaterium* was used to Microbially treat the cube specimens. Muynck et al. (2008) and achal et al. (2010) also studied the effect of bacterial precipitation on Sorptivity of concrete/Mortar specimens found a significant decrease in the permeation properties of concrete.

Silica Fumes:

Silica fume, also known as micro silica, is amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is a pozzolanic material for high performance concrete.

It is sometimes confused with fumed silica. However, the production process, particles characteristics and fields of application of fumed silicon are all different from those of silica fume.

Table No. : Specified properties of silica fume according to IS 15388:2003

Property	Value
Particle size (µm)	< 1
Bulk density (kg/m3)	130-600
Specific Gravity	2.22
SiO2 (percent by mass, min.)	85
Moisture Content (max, %)	3
Loss on ignition (max, %)	4

Chemical Composition

Chemical compositions of silica fume is mainly consists of silicon oxide, calcium oxide and alkali are found in very low amount. Although silica fume and constituent mineral percentage may vary according to the process of alloy refinery and percentage of silica in constituent ferrosilicon alloy from which the silica fume is extracted. Chemical composition of silica fume reported by various authors is followed in Table 1.2.

Table 1.2: Chemical composition of silica fume samples

Oxides	Sandvik and Gjorv -1992	Titherington and Hooton (2004)	Yazici (2008)
SiO2	92.1	96.65	92.26
Al2O3	0.5	0.23	0.89
Fe2O3	1.4	0.07	1.97
CaO	0.5	0.31	0.49
MgO	0.3	0.04	0.96
K2O	0.7	0.56	1.31
Na2O	0.3	0.15	0.42
SO3	-	0.17	0.33
LOI	2.8	2.27	-

III. CONCLUSION

1. Water absorption was assessed for all concrete mixtures. It was found that water absorption was less in mixtures with bacteria addition as compared to the mixtures without bacteria. This indicates that it may be due to the calcite precipitation action of bacteria and addition of silica fume as filler and pozzolanic material
2. Compressive strength in all cases increased with increase in age for all mixtures with or without bacteria. However, the rate of compressive strength increase was higher in case of mixtures with bacteria than mixtures without bacteria.
3. From the above it has been concluded that the improvement in compressive strength was due to deposition of calcite on the bacteria cell surfaces within the pores which was scanned by electron microscopy and confirmed by XRD which revealed calcium carbonate precipitation.
4. Water porosity was assessed for all concrete mixtures. It was found that water porosity was less in mixtures where bacteria were added as compared to the mixtures without bacteria. This indicates that the pores of the concrete may be reduced in number or may have been blocked, which was the result of calcite precipitation by bacteria
5. Chloride permeability resistance was assessed for all concrete mixtures. It was found that chloride permeability resistance was less in mixtures where bacteria was added as compared to the mixtures without bacteria which indicates resistance to the flow through the voids of concrete as a result of reduction in their number or blockage.
6. Sorptivity was assessed for all concrete mixtures. It was found that sorptivity was less in mixtures where bacteria was added as compared to the mixtures without bacteria which indicates resistance to the flow through the voids of concrete as a result of reduction in their pore structure or blockage.

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