A Review on Properties of Bacterial Silica Flume Concrete

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***Abstract*- — This Ingress of harmful chemicals such as Chloride and sulfate may severely damage the structural properties of concrete as well as corrosion of embedded steel which results in failure of concrete structures. The microstructure of concrete has a direct influence on its durability and strength. The durability and strength of concrete can be improved by using a technique which involves bacterial induced calcite precipitation. Bacteria are capable of precipitating calcium carbonate crystals which enhances the microstructural properties of concrete thereby reduction in permeability of concrete**

***Index Terms*- Bacterial properties, Silica Flume, Concrete.**

INTRODUCTION

Concrete is a composite material which contains cement, fine aggregate, coarse aggregate and water. Its success lies in its versatility as can be designed to withstand harshest environments while taking on the most inspirational forms. Engineers and scientists are further trying to increase its limits with the help of innovative chemical admixtures and various supplementary cementations materials (SCMs). Along with the strength, durability of concrete is also an important parameter which affects the type of concrete that is to be used in certain environments. With the use of SCMs the durability of concrete is considerably enhanced, and after the arrival of novel bacterial carbonate precipitation technique we are able to increase the durability of concrete. In context of durability as with the use of calcite precipitation, the permeability of concrete can be reduced up to a great extent than normal conventional concrete. It is found that bacterial mineral precipitation resulting from metabolic activities of favorable microorganisms in concrete improved the overall behavior of concrete. The process can occur inside or outside the microbial cell. Bacterial activities simply trigger a change in chemistry and pore structure that leads to over saturation and mineral precipitation. Use of these bio mineralogy concepts in concrete leads to potential invention of new material called bacterial concrete.

Supplementary Cementations Material

These materials are generally byproducts from refinery processes or natural materials. The use of SCMs in concrete constructions not only prevents these materials to check the pollution but also to enhance the properties of concrete in fresh and hydrated states. The SCMs can be divided in two categories based on their type of reaction, hydraulic and pozzolanic. Hydraulic materials react directly with water to form cementitious compound like ground granulated blast furnace slag (GGBS). Pozzolanic materials do not have any cementitious property but when used with cement or lime react with calcium hydroxide to form products possessing cementitious properties. Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolana. Concrete containing silica fume can have very high strength and can be very durable (Silica Fume Association, 1987). Silica fume is available as a densified powder or in a water slurry form. Silica fume is also known as micro silica, condensed silica fume, volatilized silica or silica dust. The American concrete institute (ACI) defines silica fume as very fine non crystalline silica produced in electric arc furnaces as a byproduct of production of elemental silicon or alloys containing silicon.

LITERATURE REVIEW

Ramakrishnan et al. (2001) proposed a novel technique in remediating cracks and fissures in concrete by microbiologically inducing calcite precipitation (MICP). *B. pasteurii*, a common soil bacterium can induce the precipitates of calcite. As a microbial sealant, Calcite exhibited its positive potential in selectively consolidating simulated fractures and surface fissures in granites and in the consolidation of sand. MICP is highly desirable chemical reaction because the calcite precipitation induced is a result of microbial activities. The technique can be used to improve the compressive strength and stiffness of cracked or uncracked concrete specimens A durability study on concrete beams treated with bacteria, exposed to alkaline, sulfate and freeze-thaw environments was studied by Ramakrishnan et al. (2001).

The effect of different concentrations of bacteria on the durability of concrete was also studied. It was found that all the beams with bacteria performed better than the control beams (without bacteria). The durability performance increased with increase in the concentration of bacteria. Microbial calcite precipitation was quantified by powder X-ray diffraction (XRD) analysis and visualized by scanning electron microscopy (SEM). The unique imaging and microanalysis capabilities of SEM established the presence of calcite precipitation inside cracks, rod shaped bacterial impressions and a new calcite layer on the surface of concrete. This calcite layer improves the impermeability of the specimen, thus increasing its resistance to alkaline, sulfate and freeze-thaw attack.

A cost effective substrate under submerged fermentation by Alkaliphilic bacteria named *B. subtilis* has been reported by Sanghi et al. (2009) and concluded that high level production of a cellulose free xylanase can be recovered using wheat bran. Later, Sanghi et al. (2010) reported a 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	-

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.

REFERENCES

[1] ACI committee 211.1.81 (1984). Standard practice for selecting proportions for normal heavy weight and mass concrete. ACI Manual of Concrete Practice.

[2] ACI committee (1995). Guidelines for the use of silica fume in concrete (ACI 234R).

[3] ACI Materials Journal, 92, 437–440.

[4] Almusallam, A. A., Beshr, H., Maslehuddin, M., Al-Amoudi, O. S. (2004). Effect of silica fume on the mechanical properties of low quality coarse aggregate concrete. Cement and Concrete Composites, 26, 891-900.
[5] Alexander, M. G., Magee, B. J. (1999). Durability performance of concrete containing condensed silica fume. Cement and Concrete Research, 29, 917-922.
[6] ASTM C 642 (2013). Standard Test Method for density, absorption, and voids in hardened concrete. ASTM International.
[7] ASTM C 1202 (2012). Standard test method for electrical indication of concrete's ability to resist chloride ion penetration. ASTM International.
[8] Holland, T. C. (2005). Silica Fume User's Manual. Silica Fume Association and United States Department of Transportation Federal Highway Administration Technical Report FHWA-IF-05-016.
[9] Igarashi, S. I., Watanabe, A., Kawamura, M. (2005). Evaluation of capillary pore size characteristics in high-strength concrete at early ages. Cement and Concrete Research, 35, 513-519.
[10] IS: 383 (1970). Specifications for coarse and fine aggregates from natural sources for concrete. Bureau of Indian Standards, New Delhi, India.
[11] IS: 10262 (1982) Recommended guidelines for concrete mix design. Bureau of Indian standards, New Delhi, India.
[12] IS: 516 (1959). Indian standard code of practice methods of test for strength of concrete.
[13] Bureau of Indian standards, New Delhi, India.
[14] Kelham, M. (1988). A water absorption test for concrete. Magazine of Concrete Research, 40, 143 – 148.
[15] Khan, M. I. (2003). Isoresponses for strength, permeability and porosity of high performance mortar. Building and Environment, 38, 1051-1056.