International Journal of Innovative Research in Engineering & Management (IJIREM)
ISSN: 2350-0557, Volume-3, Special Issue-1, April-2015
Fifth National Conference on Innovative Practice in Construction Waste Management (IPCWM'15) On 8th & 9th April, 2015
Organized by Department of CIVIL Engineering, Sri Ramakrishna Institute of Technology, Coimbatore, India

Effect of Bacteria on Strength and Self Healing Properties of Concrete Using Silica Fume

D.Gowtham
PG Scholar,
Department of Civil Engineering,
Sri Krishna College of Technology,
Coimbatore,India

V.Poornima
Assistant Professor,
Department of Civil Engineering,
Sri Krishna College of Technology,
Coimbatore,India

Dr.R.Venkatasubramani
Professor and Head,
Department of Civil Engineering,
Sri Krishna College of Technology,
Coimbatore,India

ABSTRACT
The aim of the study is to obtain the strength of the concrete by the microbiologically induced special growth or filler. Here Bacillus Subtilis bacteria is induced in the concrete to heal up the cracks. With the rapid industrialization and urbanization, the generation of industrial by-product is also increasing very rapidly. This not only pollutes the environment but also creates disposal problems. Silica fume, an industrial by-product is replaced for cement in different proportions. Cubes, Cylinders and Prisms were casted for different mix proportions of Silica fume with bacteria. This paper gives information about the research carried out on cement with partial replacement of Silica fume with bacteria in the mix giving good results and being highly sustainable and eco-friendly. From the results of the investigation, it has been observed that, the performance of concrete with Silica fume and bacteria is better than that of the conventional concrete. Microbiologically induced calcite precipitation (MICP), a highly impermeable calcite layer formed over the surface of an already existing concrete layer, due to microbial activities of the bacteria Bacillus subtilis seals the cracks in the concrete structure and also has resistance to corrosion.

Keywords
Bacteria, Bacillus Subtilis, Silica fume.

1. INTRODUCTION
Concrete is by far the most widely using building material in the world. Concrete has a large load bearing capacity for compression load, but the material is weak in tension. The steel bars provided in concrete take over the load when the concrete cracks in tension. To increase the durability of the structure either the cracks that are formed are repaired later or in the design phase extra reinforcement is placed in the structure to ensure that the crack width stays within a certain limit. Durability is one reason to prevent cracks or limit crack widths. Other reasons are water tightness of structures, loss of stiffness and aesthetic reasons. Cracks widths in concrete structures should be limited, mainly for durability reasons. If cracks widths are too large, the cracks need to be repaired or extra reinforcement is needed as said already in design. If a method could be developed to automatically repair cracks in concrete this would save an enormous amount of money, both on the costs of injection fluids for cracks and also on the extra steel that is put in structures only to limit crack widths. A reliable self –healing method for concrete would lead to a new way of designing durable concrete structures, which is beneficial for national and global economy. The "Bacterial Concrete" can be made by embedding bacteria in the concrete that are able to constantly precipitate calcite. This phenomenon is called microbiologically induced Calcite precipitation. Calcium carbonate precipitation, a widespread phenomenon among bacteria, has been investigated due to its wide range of scientific and technological implications. Calcite formation by Bacillus Subtilis is a model laboratory bacterium, which can produce calcite precipitates on suitable media supplemented with a calcium source. A common soil bacterium, Bacillus Subtilis was used to induce CaCo3 precipitation. The basic principles for this application are that the microbial urease hydrolyzes urea to produce ammonia and carbon di oxide and ammonia released in the surroundings subsequently increases pH, leading to accumulation of insoluble CaCo3. The favorable conditions do not directly exist in a concrete but have to be created. A main part of the research will focus on this topic.

2. MATERIALS USED
2.1 Cement
Ordinary Portland Cement 53 grade confirming to IS 12269-1987.

2.2 Fine Aggregate
Locally available river sand confined grading zone II of IS: 383-1970.

2.3 Coarse Aggregate

Locally available crushed blue granite stones conforming to graded aggregate of nominal size 20mm as per IS: 383-1970.

2.4 Chemical Admixture

Super plasticizer CONPLAST-SP 430 in the form of sulphonated Naphthalene polymers complies with IS: 9103-1999 and ASTM 494 type F.

2.5 Water

Potable water as per IS: 456-2000.

2.6 Silica Fume

Silica fume used was confirming to ASTM- C (1240-2000) named Micro Silica 920 D.

2.7 Micro-Organism

Bacillus Subtilis, a laboratory cultured soil bacterium.

3. MIX DESIGN

In this study mix design has been prepared for M40 mix by using IS 10262:2009. In this mix the cement is partially replaced with varying Silica fume percentages of 5%, 10% and 15%.

Table 1. Mix Proportion

Water	Cement	Fine aggregate	Coarse aggregate
157.6 Liters	437.77kg	671.47kg	1187.3kg
0.36	1	1.53	2.71

Table 2. Mix Proportions

Mix	OPC (kg/m^3)	Silica Fume (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (litre/m^3)	Chemical Admixture (litre/m^3)	Bacterial Solution (ml/litre of water)
M1	437.77	0	671.47	1187.3	157.6	5.25	5
M2	415.88	21.88	671.47	1187.3	157.6	5.25	5
M3	393.99	43.77	671.47	1187.3	157.6	5.25	5
M4	372.10	65.66	671.47	1187.3	157.6	5.25	5

4. EXPERIMENTAL INVESTIGATION

4.1 Curing

4.1.1 Bacterial Concrete

The concrete with Bacteria is cured in the water which contains calcium chloride and urea for their efficient growth.

Table 3. Ingredients For Curing

Type	Grams per litre of water
Urea	20
Calcium chloride	50

5. STRENGTH STUDIES

5.1 Compression Strength Test

All the cubes were tested under drying condition, after drying the surface of the specimens containing no moisture in it. For each mix proportion three cubes were tested at 7 days, 14 days and 28 days. Using compression testing machine of 2000Kn capacity as per IS: 516-1959. The tests were carried out at a uniform rate stress level with the specimen properly placed and centered in the testing machine. Load was applied gradually with the help of hydraulic pumps until dial gauge reading just get reverses its direction of motion. The reverse of needle indicates the total failure load of specimen. The dial gauge reading is noted at the instant of failure, which is ultimate load of specimen. From that the compressive strength of particular mix cube calculated by dividing the cross sectional area of cube specimen from ultimate load will give the compressive strength at failure load.

5.2 Split Tensile Strength Test

This is an indirect test method to determine the tensile strength of concrete of test specimen of cylinders. Split tensile strength were carried out at the age of 28 days for the cylinder specimen size 100mm diameter and 150mm length, using compression testing machine of 2000Kn capacity as per IS 516-1959. To avoid direct load on the specimen, the cylindrical specimens were kept below the wooden strips. The load was applied gradually till the specimens split and readings are noted. The split tensile strength of specimen were calculated from the following relationship.

5.3 Flexural Strength Test

The prism specimens of size 500 x 100 x 100 mm were used for the determination of the flexural strength. The bearing surface of the supporting and loading rollers were wiped clean and any other loose fine aggregate or other materials removed from the surface of the specimen where they are to make contact with the rollers. The specimen was then placed in the machine and two point load was applied. Load was increased until the specimen failed and the load at failure was recorded and the flexural strength was determined. Flexural strength was taken as the average strength of three specimens.

6. RESULT AND DISCUSSIONS

Table 4. Compression Strength Result

Mix	Percentage replacement of Silica Fume	Average Compressive Strength at 7 days (MPa)	Average Compressive Strength at 14 days (MPa)	Average Compressive Strength at 28 days (MPa)
M1	0	25.33	35.11	39.33
M2	5	32.88	45.77	48.88
M3	10	31.11	45.11	52.44
M4	15	30.66	42.66	50.66

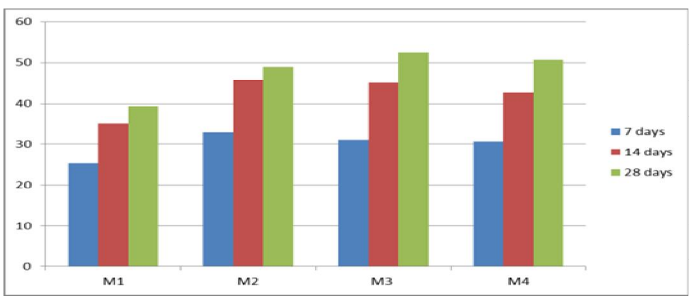

Figure 1. Compression Strength Graph

The compressive strength was found to be 33% more than that of nominal mix when cement is replaced with 10% of silica fume.

Table 5. Split Tensile Strength Result

Mix	Percentage replacement of Silica fume	Average Split Tensile Strength at 7 days (MPa)	Average Split Tensile Strength at 14 days (MPa)	Average Split Tensile Strength at 28 days (MPa)
M1	0	2.05	2.33	3.39
M2	5	2.12	2.68	3.89
M3	10	2.26	2.97	4.10
M4	15	2.47	3.25	4.24

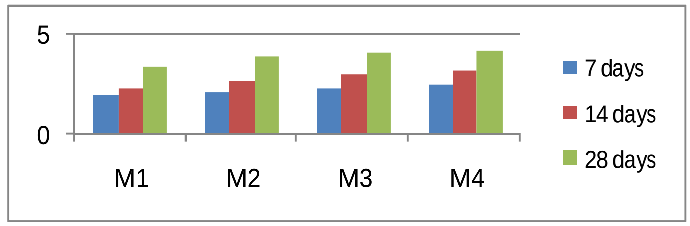

Figure 2. Split Tensile Strength Graph

The split tensile strength was found to be 25% more than that of nominal mix when cement is replaced with 15% of silica fume.

Table 6. Flexural Strength Result

Mix	Percentage replacement of Silica fume	Average Flexural Strength at 7 days (MPa)	Average Flexural Strength at 14 days (MPa)	Average Flexural Strength at 28 days (MPa)
M1	0	4.3	5.58	6.92
M2	5	4.84	6.41	7.12
M3	10	4.97	6.84	7.23
M4	15	3.85	5.12	6.63

The flexural strength was found to be 5% more than that of nominal mix when cement is replaced with 10% of silica fume.

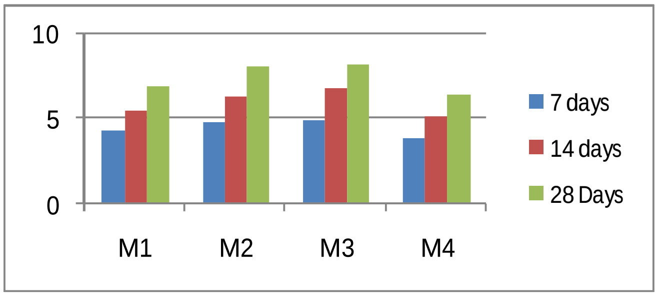

Figure 3. Flexural Strength Graph

7. ANALYSING SELF-HEALING CAPACITY OF BACTERIAL SAMPLES

Figure 4. Crack Due To Manual External Loading

Figure 5. Crack Healing in the Specimen with Bacteria

8. CONCLUSION

- Bacillus Subtilis can be produced from laboratory, which is proved to be a safe and cost effective.
- The addition of Bacillus Subtilis bacteria and Silica fume increases the compressive strength of concrete.
- The compressive strength of concrete cube is maximum with the addition of Bacillus Subtilis bacteria with Silica fume replacement of 5%.
- The compressive strength is increased upto 33% at 28 days by addition of Bacillus Subtilis bacteria and Silica fume when compared to conventional concrete.
- The addition of Bacillus Subtilis bacteria increases the split tensile strength and flexural strength when compared to conventional concrete.
- From the above it can be concluded that Bacillus Subtilis can be easily cultured and safely used in improving the strength characteristics of concrete with Silica fume

9. SUGESSTIONS FOR FUTURE WORK

- The present study deals only with strength and healing properties of various mixes. So that various durability tests can be carried out and it may be compared.
- Due to culture of bacteria, our surrounding eco-system and fertility of soil will be preserved.
- Aesthetical appearance of the building will be maintained and also reduce the cost of rehabilitation works.
- The bacterial concrete widely used in earthquake resistance structure because of precipitation of calcite layer in the concrete offers lateral stability.

REFERENCES

1). ACI 234R – 96: "Guide for the Use of Silica Fume in Concrete".
2). Awolusi T.F.,Akinkurolere O.O., Oke O. L., AdetifaO.A.,"Laboratory Investigation on the Short-Term Compressive Strength of Microbial Laterized Concrete" Civil Engineering and Architecture 1(4): 109-113, 2013.
3). DebabrataPradhan,D. Dutta, " Influence of Silica Fume on Normal Concrete" DebabrataPradhan et al. Int. Journal of Engineering Research and Applications Vol. 3, Issue 5, Sep-Oct 2013, pp.79-82.
4). Des King, "The Effect of Silica Fume on the Properties of Concrete As defined In Concrete Society Report 74, Cementitious Materials", 37th Conference On Our World In Concrete & Structures: 29 - 31 August 2012.
5). IS 10262 – (2009): Concrete mix proportioning – guidelines. Bureau of Indian Standards, New Delhi.
6). IS: 516-1959. Indian Standard Methods of Test for Strength of concrete. Bureau of Indian Standards, New Delhi.
7). Muhammad Isha, I., Afifudin, H., and MohdSaman, H., "Bacillus Subtilis - And ThermusThermophilus – Derived Bioconcrete In Enhancing Concrete Compressive Strength"ISSN No: 2289-3253 Vol.1, No.1, (July 2012).
8). Silica fume Association: "Silica fume user's manual", April 2005.
9). S.SunilPratap Reddy, M.V.SeshagiriRao, P.Aparna and Ch.Sasikala, "Performance of Ordinary Grade Bacterial (Bacillus Subtilis) Concrete"ISSN 0974-5904, Vol. 03, No. 01, February 2010, pp. 116-124.
10). S.SunilPratap Reddy, M.V.SeshagiriRao, P.Aparna and Ch.Sasikala, "Performance of Standard Grade Bacterial (Bacillus Subtilis) Concrete"Asian Journal of Civil Engineering (Building and Housing) Vol. 11, No. 1 (2010).