STRENGTH IMPROVEMENT STUDIES ON THE TERNARY BLENDED BACTERIAL SELF COMPACTING CONCRETE (TBBSCC)

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ABSTRACT. Nowadays, use of bacteria in concrete is gaining popularity across the world, due to its ability to repair cracks in concrete but the disadvantage is that spores of the bacteria may get damaged due to the mechanical forces induced on the concrete while producing it. On the other hand, Self Compacting Concrete (SCC) is a highly engineered flowable and non-seggregable concrete which does not require compaction by any mechanical vibrations. Also, SCC differs from that of ordinary concrete, in more fines content, less coarse aggregate and also in the use of high range water reducer admixture and Viscosity Modifying Agent. Further, the use of more fines content in the form of blended cement comprising of flyash, GGBS etc. has both technical as well as environmental advantages i.e., the various pozzolona available can be utilized more effectively thereby reducing the cost in the construction industry. Therefore, in this study, an attempt has been made to study Bacterial Self Compacting Concrete with a Ternary Blend of cement, flyash and GGBS with Bacillus Subtilis, a non-toxic soil bacterium. Aggregate of size 12 mm and river sand were used to improve the workability of the concrete. Water-binder ratio of 0.3 was used. A two-in-one chemical admixture containing both HRWRA and VMA is used for the study. Studies on the fresh properties of SCC as well as studies on the strength properties were carried out. The strength studies shows that there is a notable difference between the strengths of TBBSCC and reference concrete without bacteria.

Keywords: Ternary, blended, SCC, bacteria, concrete

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INTRODUCTION

In recent times, several researches are being carried out on calcite (Calcium carbonate) precipitating bacteria in concrete which seals the microcracks formed in the concrete. This technique is generally called MICP (Microbially Induced Calcium carbonate Precipitation) [1]. The mechanism is that, the spores of ureolytic bacteria which can thrive in high alkaline environment (also called as alkaliphilic bacteria), along with a nutrient / food (to support the bacteria when they become active) are incorporated into the concrete. When water needed for the activation of bacterial spores seeps through the cracks of concrete, it germinates, consumes oxygen, feeds on the nutrient and precipitates calcium carbonate ($CaCO_3$) as a result of metabolism. Thus the cracks are sealed by the $CaCO_3$ produced by the bacteria. Also, when the cracks are formed in the later stage, it is not required to repair the concrete by chemical means, the concrete self-heals by using bacteria. But, the drawback is that the spores of the bacteria may get distorted due to the mechanical forces applied on the concrete while making it.

Self-compacting concrete (SCC) is one such concrete, which is designed to compact under its own weight and does not require any compaction by mechanical vibrations. Since SCC eliminates compaction, the problem of bacterial spores getting damaged by mechanical vibrations can be avoided. In turn, the drawback of SCC like formation of plastic and drying shrinkage cracks can be well taken care by the bacteria.

But, SCC mix should be designed in such a way that it should be flowable enough to fill up the formwork, at the same time, it should neither seggregate nor bleed. In order to make SSC resistance to seggregation, usually mineral admixtures, i.e., blended cements are being used in SCC.

Use of blended cements can reduce the cement consumption, thereby reducing CO_2 emission by 13-22% [2]. Further, use of blended cement is not only an economical and environmental friendly way of using concrete but also has several advantages like it reduces water-cement (w/c) ratio, improves workability, reduces permeability, reduces alkali-aggregate reactions, prevents sulphate attack, thereby enhancing durability of concrete [3].

Thus an attempt has been made to study the combined effect of blended concretes, self healing by bacteria and self compaction properties in concrete, so as to acquire a more efficient, economical and technically sound concrete for the construction industry.

MATERIALS AND METHODS

The details of the materials used in the investigation are as follows:

Cement

Ordinary Portland Cement (OPC) 53 grade of specific gravity 3.15 was used.

Fine Aggregate

Locally available clean, natural river sand of specific gravity 2.68, bulk density of loose aggregate 1520 kg/m^3 conforming to IS 383-1970 was used.

Coarse Aggregate

Rounded aggregate of maximum size 12 mm of specific gravity 2.7, loose bulk density of 1420 kg/m^3 conforming to IS 383-1970 was used.

Flyash

Class F flyash of specific gravity 2.18 was used.

Ground Granulated Blast-furnace Slag (GGBS)

Ground Granulated Blast-furnace Slag (GGBS) of specific gravity of 2.92 was used.

Water

Locally available potable water conforming to IS 456-2000 was used.

Bacterial Culture

Bacillus Subtilis (B. Subtilis), a non-toxic, gram positive and rod - shaped soil bacterium which can grow at pH = 12 and temperature 30ºC was selected for the study. The pure culture of B. Subtilis (MCC 2183) was obtained from the Microbial Culture Collection (MCC), Pune in a freezed dried condition. The pure culture formed irregular dry white colonies on nutrient agar medium (Figure 1).

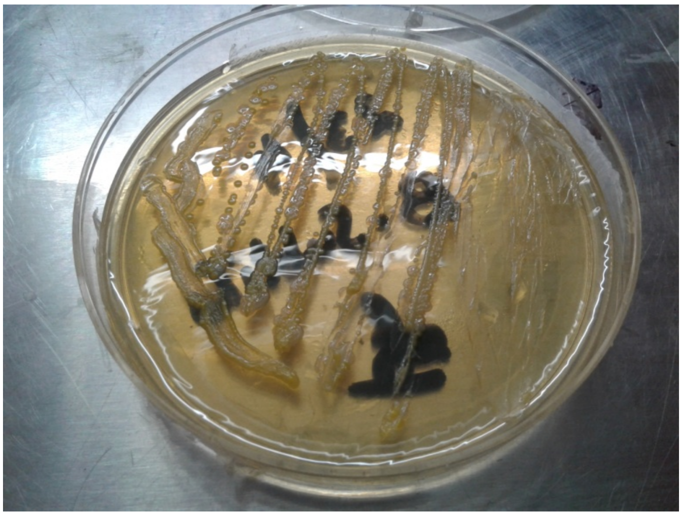

Figure 1 Dry white colonies on nutrient agar medium

The bacterial growth curve using UV visible spectrophotometer at wavelength 600nm showed that the maximum growth of bacteria occurred at 24th hour. The bacteria was preserved on nutrient agar slants (solid medium) for future use.

Whenever required a single colony of the culture is inoculated into an autoclaved nutrient broth (liquid medium) of 100ml in 500ml conical flask and kept in shaking incubator (to ensure uniform growth) at 37ºC for 24 hours to ensure maximum growth (Figure 2). The nutrient agar / nutrient broth medium required for the growth of bacteria contains peptone, NaCl and beef / yeast extract.

Figure 2 Autoclaved nutrient broth medium

Addition of Bacterial Culture in the concrete

B. Subtilis is added in terms of no. of cells/mL of water in the concrete. Haemocytometer was used to count the no. of bacterial cells. Four different concentrations of 10^3, 10^4, 10^5 and 10^6 no. of cells/mL of water were used for the study.

Calcium Lactate (Nutrient for B. Subtilis)

Calcium lactate was used as nutrient for B. Subtilis in concrete since it does not interfere with the setting time of the concrete [4]. A 1% solution of calcium lactate was used as a calcium source (nutrient) for B. Subtilis in the concrete.

Superplasticiser

A two-in-one superplasticiser including Viscosity Modifying Agent (VMA) - Master Glenium Sky 8662 was used for the study.

SCC Mix Design

The SCC mix proportion for M30 grade of concrete was designed using Nan Su method [5]. After several trials with different water-binder ratio (w/b) and the fresh properties of concrete satisfying the requirements of EFNARC 2005, w/b of 0.3 and super-plasticiser (SP) dosage of 0.8% of binder was selected for the final mix. The ratio of SCC materials required for $1m^3$ of M30 concrete is shown in Table 1.

Table 1 Ratio of SCC materials required for $1m^3$ of M30 concrete

CEMENT	SAND	COARSE AGGREGATE	FLYASH	GGBS	SUPER-PLASTICISER
1	4.087	3.81	1.23	0.52	0.8

EXPERIMENTAL INVESTIGATION OF TBBSCC

For the ratio mentioned above and for w/b ratios of 0.3, the fresh properties of TBBSCC like slump flow, T500, V-funnel and L-box were found. TBBSCC cubes of size 150mm*150mm*150mm were casted to find out the compressive strength at 7 and 28 days. The quantity of SCC materials required for $1m^3$ of M30 concrete is shown in Table 2.

Table 2 Quantity of SCC materials required for $1m^3$ of M30 concrete

CEMENT	SAND	COARSE AGGREGATE	FLYASH	GGBS	SUPER-PLASTICISER
218 kg	890 kg	831 kg	268 kg	115 kg	4.8 litres

The w/b ratio was 0.3. Concentration of B. Subtilis culture used were in the order of 10^3, 10^4, 10^5 and 10^6 no. of cells/ml of water. A 1% solution of Calcium lactate was also added for the nutrient requirement of the bacteria. Reference TBBSCC without bacteria was also casted. From the results of compressive strength test, it was found that 10^6 no. of cells/ml of wáter gave the máximum strength. Therefore, 10^6 no. of bacterial cells/ml of wáter was optimized.

Then, TBBSCC cylinders and beams with (10^6 no. of cells/ml of wáter) and without bacteria were casted to find out the Split tensile and Flexural strength at 7 and 28 days. The TBBSCC were cured properly for 7 and 28 days and tested.

RESULTS AND DISCUSSION

Table 3. summarizes the fresh properties TBBSCC. The fresh properties of TBBSCC were found to satisfy the requirements of EFNARC 2005.

Table 3 Fresh Properties of TBBSCC

PROPERTIES	VALUES
Slump-flow	700 mm
T500	2.78 secs
V-Funnel	4.12 secs
L-Box	0.94

Table 4. summarizes the compressive strength test values of TBBSCC at 7 and 28 days containing different concentration of B. Subtilis for w/b 0.3. It is found that the compressive strength was maximum i.e., 37.5 N/mm^2 and 46.4 N/mm^2 at 7 and 28 days respectively, when the addition of bacteria was 10^6 no. of cells/ml of water compared to the reference and other concentrations of bacteria. Thus the bacterial concentration was optimized to 10^6 no. of cells/ml of water.

Table 4 Compressive Strength test results (N/mm^2)of TBBSCC

NO. OF CELLS / ML	AT 7 DAYS	AT 28 DAYS
0	25.39	36.83
10^3	31.03	43.14
10^4	31.65	46.04
10^5	34.62	46.27
10^6	37.5	46.4

Table 5. summarizes the split tensile strength test values of TBBSCC at 7 and 28 days for w/b 0.3. The split tensile strength of TBBSCC with bacterial concentration 10^6 no. of cells/ml of water is found to be more than the reference.

Table 5 Split Tensile test Strength results (N/mm^2)of TBBSCC

NO. OF CELLS / ML	AT 7 DAYS	AT 28 DAYS
0	1.152	2.14
10^6	1.537	2.422

Table 6. summarizes the flexural strength test values of TBBSCC at 7 and 28 days for w/b 0.3. The flexural strength of TBBSCC with bacterial concentration 10^6 no. of cells/ml of water is found to be more than the reference.

Table 6 Flexural Strength test results (N/mm^2) of TBBSCC

NO. OF CELLS / ML	AT 7 DAYS	AT 28 DAYS
0	4	5.18
10^6	4.1	5.28

CONCLUSION

1. The maximum compressive strength of TBBSCC using B. Subtilis (MCC2183) at 7 and 28 days were observed with a bacterial concentration of 10^6 no. of cells/ml of water.
2. The compressive strengths were 47.69% and 25.09% for 7 and 28 days respectively using B. Subtilis when compared to concrete without bacteria.
3. The split tensile strengths were 33.4% and 13.17% for 7 and 28 days respectively using B. Subtilis when compared to concrete without bacteria.
4. The flexural strengths were 2.5% and 1.93% for 7 and 28 days respectively using B. Subtilis when compared to concrete without bacteria.

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