EXPERIMENTAL INVESTIGATION ON BACTERIA ENRICHED FIBRE REINFORCED SELF COMPACTING CONCRETE

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Abstract— *Concrete is one of the prime important material in construction industry. Improvements to the concrete is essential in order to increase the performance and sustainability. Good quality concrete mixes require adequate compaction during casting by skilled labors, which have some disadvantages. Self-compacting concrete (SCC) has the ability to self-level, and compact under its own weight without internal or external compaction. The major drawback of SCC is its low tensile strength which makes it susceptible to progression in micro-cracks resulting in low strength and durability. Steel fiber reinforced self-compacting concrete (SFRSCC) is an advancement to normal SCC. Steel fiber bridges the gap between the cracks, thus minimizing propagation of cracks. The calcite precipitating bacteria are introduced into the concrete during casting and when the cracks occurs in the presence of moisture, bacteria precipitates and heal the cracks.*

Keywords— sustainability, adequate compaction, Self-compacting concrete

1. INTRODUCTION

Concrete, a composite material composed of cement, aggregates, and water, which is mostly used as building material in the construction industry. As the need for sustainable materials is increasing all over the world, innovative technique for making the concrete more durable have significant importance.

[1] In order to increase the performance and sustainability of concrete, improving the properties of concrete is essential. Good quality concrete requires adequate compaction during casting by skilled labors, which have numerous disadvantages. Self- compacting concrete (SCC), concrete that is able to flow and compacted under its own weight without any internal or external compaction. So, SCC can be applicable for placing in areas with congested reinforcement. SCC has an ultimate load bearing capacity under compression but the material is weak in tension. Hence to carry tensile loads steels bars are embedded in concrete. This project studies the effect of Bacteria (Bacillus subtilis) in SCC and SFRSCC. There are no relevant studies regarding the bacteria incorporated self-healing property in SCC. The SCC is made with partial replacement of cement with Micro silica. Besides that, silica fume consists of ultrafine particles and increases the bond strength between cement paste and aggregate by making the interfacial zone denser. Bacteria enriched SFRSCC possess great application than normal self-compacting concrete, which possesses low tensile strength, limited ductility and low resistance to cracking. The microstructure of concrete was visualized by SEM with the addition of bacteria. Hence by the results, the bacteria enriched SCC and SFRSCC is a practical and sustainable concept.

2. EXPERIMENTAL STUDY DESCRIPTION OF MATERIALS.

(1). Bacillus subtilis:

The bacteria Bacillus Subtilis strain no. JC3 is used in this study. The pure culture of Bacillus Subtilis was collected from the Department of Agricultural Microbiology, College of Horticulture, Vellanikkara, and Thrissur. Colonies of strain JC3 were round, convex, smooth and translucent. The size of the colony may reach up to 2-3 mm diameter after 24hrs of incubation in dark aerobic conditions at 37 oC. Bacillus subtilis is an ureolytic bacteria. Ureolytic bacteria can precipitate calcite in the high alkaline environment by converting urea into ammonia and carbonate.

(2). Calcium lactate

Calcium lactate is a black or white crystalline salt made by the action of lactic acid on calcium carbonate. Healing is a result of the bacterial conversion of calcium lactate into calcium carbonate. In this experimental study, the amount of calcium lactate is 3% of binder content. As the binder content is kept constant, the calcium lactate content also remains constant.

(3). STEEL FIBERS

Loose hook ended steel fibre is used. It has greater flexibility with all Portland cement and admixtures, it also provides even distribution in the mix. It improves mechanical anchorage and improves micro crack mechanism, impact resistance, flexural strength and fatigue strength of concrete. In this experiment, steel fibre content varies from 0.5 to 1.5% of total volume. Through their experiences, the Japanese construction companies have found that robotics technology has improved productivity, quality, safety, work conditions, environment, and reduced construction time, labor, hard work and costs.

Productivity and quality in single-tasks robots has successfully being achieved when a specific work is repetitive. However, due to limitations of robots and the complex environment where construction industry is developed, additional work force is still necessary reducing productivity.

3. RESULTS AND DISCUSSIONS

MICRO SILICA BASED SELF COMPACTING CONCRETE

Workability:

The workability is determined using standard tests like flow table test and J- Ring test. The results are shown in table a. strength and fatigue strength of concrete. In this experiment, steel fibre content varies from 0.5 to 1.5% of total volume. Through their experiences, the Japanese construction companies have found that robotics technology has improved productivity, quality, safety, work conditions, environment, and reduced construction time, labor, hard work and costs.

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Mixes	Slump Flow	J-Ring	J-Ring(mm)
MSCC-1	685	673	12
MSCC-2	690	680	10
MSCC-3	680	671	9
MSCC-4	686	677	9
MSCC-5	695	687	8
MSCC-6	700	691	9
MSCC-7	712	701	11

Table a) Workability of Micro silica-based SCC

Compressive strength

Compressive strength test was conducted on concrete specimen, cube of Mix40 SCC with Micro silica as a partial replacement of cement. The obtained results are shown in table b.

Mix	7-day Compressive strength(N/mm^2)	28 days Compressive strength(N/mm^2)
MSCC-1	25.29	41.47
MSCC-2	26.11	42.12
MSCC-3	27.25	43.26
MSCC-4	29.81	45.86
MSCC-5	30.46	47.17
MSCC-6	27.88	44.96
MSCC-7	26.35	41.81

Table b) Compressive strength of Micro silica-based SCC

Split tensile strength

Result shows, there is no significant reduction in strength with increase in the micro-silica content up to MSCC-5, 20% addition of micro silica, beyond 20% there is a decrease in split tensile strength. From the test results of compressive strength, split tensile strength and workability shows that the optimum micro silica content is observed to be 20% i.e. MSCC-5.

4. BACTERIA ENRICHED SCC

Workability

Acceptance criteria of self-compacting abilities in the slump flow test are that a minimum of 650 mm and a maximum of 800mm diameter. Flow table test and J- Ring test shows no significant changes compared to the MSCC-5. flow table test of bacteria enriched scc shows average slump flow diameter as 697mma

Compressive strength

Results show that by the addition of Bacillus subtilis bacteria in MSCC-5 shows about 3.5% increase in compressive strength. Direct incorporation of bacteria also showed an increase in compressive strength of concrete. The increase in compressive strength is due to the reduction in micropores of SCC by the calcite deposition of bacteria, which makes the concrete matrix more compact.

Split Tensile Strength

From the tests conducted there is only a very slight increase in the tensile strength with MSCC-5. So, in general, it can be concluded that there is no significant variation of tensile strength from the parenting mix, MSCC-5. So the results suggest the Bacillus subtilis has no effect on improving.

Flexural Strength

During the testing, the first crack loads were noted. In visual observation it was the crack width is wider, which are greater than 2 mm. The presence of multiple cracks is less. MSCC-5 B1 mixes possess good flexural strength and average ultimate strength was 20.92N/mm2.

5. BACTERIA ENRICHED SFRSCC

Workability

The J-Ring test results on Bacteria enriched SFRSCC shows that the MSCC-5 C1 and MSCC-5 C2 mixes have no visible blocking as it is in between the range

of 0-25mm. But MSCC-5 C3 mix shows minimal to noticeable blocking as it is above 25mm

Compressive strength
Due to metabolic activity of bacteria, Bacillus subtilis converts calcium lactate into calcium carbonates, the fine calcite also fills up the pores and densifies the SFRSCC, which in turn increase the compressive strength. From the result obtained shows it is to be noted that the compressive strength values decline beyond MSCC-5 C2 (1% of steel fibre), show that further increase in steel content will decrease the compressive strength.

Split tensile strength
The addition of steel fibre had resulted in an increase in split tensile strength. Because of the bridging action of steel fibres, the increase in fibre content in the reinforced Self-compacting concrete mixtures had showed improved results in the split tensile strength values.

Flexural strength
Bacteria enriched steel fibre reinforced self- compacting concrete has an enhancement in flexural strength with increased percentage of steel fibre volume by total volume. However, increasing the fibre content decreases the flexural stiffness, while the ultimate load carrying capacity and its corresponding deflection increased. The maximum flexural strength was 29.45N/mm2 (142 KN) for 1.5% of steel fibre (MSCC-5 C3) which is 40% increase compared to the MSCC-5 B1 mix. On comparing the results with Bacteria enriched self- compacting concrete (MSCC-5 B1), it is seen that the improvement in flexural behavior is due to the presence to steel fibre.

6. HEALING BEHAVIOUR OF SCC

To study the healing behavior of SFRSCC the beam specimens were subjected to first crack load along with an incremental load of 10% and 20%. The width of visible crack was marked and measured.

Visual observation and discussion

By taking a close observation to the beams after 28 days the cracks marked less than 0.5 mm width shows proper symptoms of effective healing. Beyond the 0.5mm cracks, the healing of concrete was not that much effective, however white precipitate are seen on the inner surfaces.

Scanning Electron Microscopy and EDS

Scanning electron microscope is used to identify the morphology of the deposited materials within the cracks. Calcium presence is an indication of calcite compounds. The quantification of chemical compounds in the sample using EDS shows the presence of calcite is about 61.89%. The silicate compound contained in the specimen is about 23.97%.

7. CONCLUSION

SCC with partial replacement material of cement has a slump in the range of 650- 800mm. The quantity of micro silica added in SCC varied from 5 to 30% of weight. All the 7 mixes showed good workability and was within the permissible range. The compressive strength of all mixes is above 41N/mm2. SCC with 20% replacement of cement with Micro silica showed better workability and strength. So, the MSCC-5 mix is taken as the optimum mix were 20% replacement of cement is replaced with Micro silica. There is 3.6% increase in compressive strength of bacteria enriched SCC than MSCC-5. The Bacteria enriched SFRSCC mixes fulfilled the requirements of self-compacting concrete, shows good workabilitythroughout. But the increase in steel fibre content cause decrease in the workability. This shows that passing ability of bacteria enriched SFRSCC will be affected by 1.5% addition of steel fibre when passing through reinforcement bars. As the steel fibre content increased in bacteria enriched SFRSCC, theporosity increases. Flexural strength increases with the increase of steel fibre content. Themaximum value of 29.45N/mm2 was recorded for 1.5% steel fibre content, which is 40% more than MSCC-5 B1.

Flexural strength depends on the fibre content and the aspect ratio of fibre. The UPV results show an increase in the time value for the crackedSFRSCC, are due to the increase in the gap and the reflection effect by steel fibre. It shows Calcium and Silicon ions presence, which in turn shows the presence of calcite and Micro silica. The bacteria enriched SCC and steel fibre reinforced SCC are practical in its concepts with good strength and workability compared to normal SCC. The bacteria enriched SFRSCC possess more strength and healing characteristics than bacteria enriched SCC.

REFERENCES

[1] Workability and Compressive Strength Of Bacteria Enriched Steel Fibre Reinforced Selfcompactingconcrete - Nijo Baven

[2] Eduardo N, B. Pereira, Joaquim A, O. Barros, And Aires Camões (2008), Steel Fiber-Reinforced Self-Compacting Concrete: Experimental Research and Numerical Simulation, Journal of structural engineering.

[3] El-Dieb A, Mechanical, durability and microstructural characteristics of ultrahigh strength self-compacting concrete incorporating steel fibres, J. Mater. Des.

[4] F. Altun, B. Aktas_, Investigation of reinforced concrete beams behavior of steel fiber added lightweight concrete, Journal Construction Building Materials.

[5] F. Aslani, S. Nejadi, Self-compacting concrete incorporating steel and polypropylene fibres: compressive and tensile strengths, moduli of elasticity and rupture, compressive stress–strain curve, and energy dissipated under compression, Journal of Composite Building and Engineering.