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EFFECTS OF BAMBOO FIBERS AND LIMESTONE POWDER ON FRESH PROPERTIES OF SELF-COMPACTING CONCRETE

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Self-compacting concrete (SCC) flows through densely steel reinforced elements and consolidates under self-weight without need for vibration or compaction. This helps in complex and densely reinforced structures. The integration of fibers and fillers in concrete improves its general properties. The addition of fibers in particular can regulate the flow and workability of the concrete; hence, the high workable nature of SCC can be an ideal mix for the incorporation of fibers. This research investigates the effect of bamboo fibers and limestone powder on the fresh properties of self-compacting concrete. Bamboo fibers of an aspect ratio of 50 and varied volumes of 0.25%, 0.5%, 0.75% and 1% were adopted for this research. The workability of the mix was assessed by slump flow test and V- funnel test. For fiber volumes of 0.25%, 0.5%, 0.75%, it was observed that the coarse aggregate was evenly distributed across the spread, indicating good viscosity and stability of the mix. The presence of 10% percent limestone powder improved the workability of the concrete mix. This can be attributed to filler properties of limestone powder, which, affecting the cement particle system, changed the ordinary distance between them and modified the water quantity available for the hydration process. These results proved that the bamboo fiber and limestone powder can be sustainably adopted to regulate the flow-ability of SCC without compromising desired properties.

Keywords: Natural fiber, Workability, Flowability, Congested reinforcement, Slump test, V-funnel test.

1 INTRODUCTION

Concrete is a revolutionized material over the years of human existence and both open to accommodate new inclusions and give rise to new types. Vast use of concrete made up of lime and volcanic ash was verified during the era of Roman Empire (Li 2011). Then came the era of concrete using the blend of Portland cement, fine and coarse aggregates, admixtures and water. Currently, concrete is the primarily material adopted by the construction industry for it the ability to be molded into different shapes and for affordability. In today's sustainability-driven world, guided by the ever-increasing concern for the deteriorating environment, efforts are made to create more ecological concrete with many constituent materials substitution (Olofinnade *et al*. 2016 and 2017, Ede *et al*. 2017 and 2018). The use of concrete worldwide is twice as much as wood, steel, aluminum, and plastics put together, and are only exceeded in the present world by the usage of naturally occurring water (Koehler and Fowler 2007). Self-compacting concrete

(SCC) is an emerging technique of concrete technology, to tackle the problem of concreting through congested reinforcement. The uniqueness of SCC is due to properties, like filling ability, flow ability, pump ability, durability, and the ability to make production of concrete more mechanized**.** Modern concrete made with Portland cement generates about 5% of the total Co_2 emitted today to the environment, while normal SCC requires an increased powder content which leads to a notable upsurge in material cost and other associated negative effects such as increase in thermal stress and shrinkage. This necessitated the need to provide suitable filler materials to assuage such undesirable effects. The fillers materials or supplementary cementitious materials (SCM) can be pozzolanic or hydraulic. Because concrete is a material open to inclusions, the SCMs may consist of locally available materials such as rice husk ash, fly ash, pulverized fuel ash (PFA), silica fume, granulated ground blast furnace slag (GGBS), and lime stone powder (Zhu and John 2005).

The addition of limestone powder in self-compacting concrete significantly enhances the fresh properties due to the increase of the workability derived from the ability of limestone powder to retain water in fresh mix and improve the stability and deformability of fresh SCC mix. The enriched fresh properties can be attributed to the improve particle packing system, better water retention of fresh mix, and arguably possible chemical reaction involving cement and Calcium carbonate ($CaCO_3$) to form carbon-aluminate ($C\text{-}Al_2O_3$) (Surabhi *et al*. 2009). The introduction of fibers as reinforcements in concrete is not new, it was first developed by the Egyptians, where straws and the hair of animals were adopted (Bindu 2016). Resent research and design of fiber reinforced concrete began to increase in the 1970s and various types of fibers have been developed such as steel fiber, glass, Polypropylene, Nylon and Polyester, etc. (ACI Committee 2002). In most of the developing countries, agricultural plants are utilized for development and production of useful composites. Bamboo is one of these natural materials and it is found in abundance in Africa, Asia and Southern part of America, yet not adequately exploited for concrete design technology.

Self-compacting concrete was developed in Japan in the late 1980's by Professor Okamura and his team in a quest for a more durable and sustainable concrete in highly congested reinforcement environment without the need for vibration or compaction (Okamura and Ouchi 1999). Use of admixtures to improve the workability of SCC made with natural fiber and supplementary cementitious material such as limestone, fly ash, silica fume is documented in literature (Li, 2011). Although, the introduction of natural fibers in concrete can be found in literature, the use of bamboo fiber in concrete has not been adequately explored. These problems brought about this research. Self-compacting concrete, containing environmentally friendly bamboo fibers and limestone as a supplementary material is being considered in this research. The aim of this research is to determine the effect of limestone powder and bamboo fibers on the fresh properties of the fiber reinforced self-compacting concrete. This will be done by performing fresh property tests of concrete specimen. The type of concrete to be obtained will be referenced as Bamboo Fiber-Reinforced Self Compacting Concrete (BFR-SCC).

2 METHODOLOGY

2.1 Material Selection

The material selection and methodology implemented affect the results obtained. The materials adopted, their various properties, and the methodologies embraced for analyzing the fresh properties of BFR-SCC are discussed in this section. All tests were carried out at Covenant University. An Ordinary Portland cement brand available in Nigeria (Dangote cement), of grade 42.5N was adopted for this research. The filler material used is locally available, finely grinded and sieved limestone powder. CONPLAST SP430 super-plasticizer, which disperses fine particles in concrete mix and enables water content of the concrete to perform more effectively was used. Sharp sand of maximum particles size of 5 mm and crushed granite of 19 mm were used as aggregates. A water to cement ratio of 0.5 was adopted. Figure 1 shows the limestone powder and the aggregates adopted for the research.


(a) (b) (c)

Figure 1. (a) Limestone powder; (b) Coarse Aggregate; (c) Fine Aggregate

The bamboo fibers used had a maximum length of 50 mm with varying diameters. Bamboo sticks were cut into pieces with the back scrapped off and soaked in water for at least a day. The soaked bamboo was beaten into strips then combed into fibers. These fibers were placed in 2% solution of sodium hydroxide for a day as treatment. Water absorption test is also carried out. Bamboo tree and fiber are shown in Figure 2.

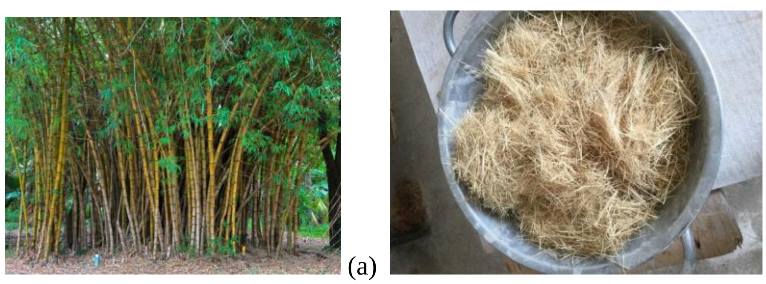

(a) (b)

Figure 2. (a) Bamboo tree; (b) Bamboo fiber.

2.2 Mix Design and Test Methods

For this study, various tests were carried out to determine the fresh properties of the BFR-SCC samples such as the slump test, L-box test, and the V- funnel test. For 0, 0.25, 0.5 and 0.75% of fiber to cement weight with 10% of limestone powders and fiber length (50mm) kept constant, fresh properties and microstructural test of hardened concrete were determined. Different mix design of self-compacting concrete was tried by volume in accordance with EFNARC (2002). Based on test results, adjustments are made, and then the mix is re-batched with further testing until the required properties are achieved. The curing process was done by submerging the specimen in clear fresh water in a curing tank. Prior to this, the samples were stored in the laboratory at room temperature for 24 hours, and then they were marked and removed from the molds.

2.3 Slump Test and V-Funnel Test

The slump test was carried out to assess the flowability of SCC. It gives some indication of the segregation of the sample but doesn't give any indication on the ability of the concrete to pass through dense reinforcements. The V-funnel test was used to measure the flowability of concrete with a maximum aggregate size of 19 mm. The results of this test can be influenced by the properties of the concrete such as volume of aggregate in the mix. Figure 3 shows slump test and the V-funnel test procedures.

(a) (b)

Figure 3. (a) Slump flow test; (b) V funnel test.

2.4 Preparation of Cubes

The molds were cleaned and oiled and then filled with BFR-SCC concrete without compacting and the top surface is leveled and smoothened with trowel. The test sample are stored in moist air under room temperature for 24 hours and after then marked and removed from the mold. The removed cubes are cured in a curing tank prior to the compressive test.

2.5 Microstructural Properties

A scanning electron microscope (SEM) was used to analyze the microstructural properties of selected BFR-SCC mixtures in order to get a more detailed understanding of the fresh properties.

3 RESULTS

3.1 Fresh Property Test Results

3.1.1 *Flow and T_{50}*

EFNARC LIMITS: slump flow – (550- 800) mm; T50- < 12 seconds.

From Figure 4, the SCC mixtures had a slump flow diameter of 490-690 mm, with SCC2 (10% limestone) having the highest slump flow. All SCC mixtures, where within the acceptable limits for SCC design except BFRSCC4 (1% fiber content), which had poor flowing ability due to the high presence of bamboo fibers. SCC1, SCC2 and BFRSCC1 had good deformability and are considered as class 1 slump flow while BFRSCC3 (0.75% fiber content) falls under class 2. It can also be observed from the bar chart that an increase in fiber content causes a decrease in the filling ability of SCC. There is a 25% reduction in slump flow between BFRSCC (0.75% fiber) and plain SCC containing limestone. After the slump flow was carried, it could also be observed that the coarse aggregate got to the edge of the slump flow and did not remain in the center except for the case of BFRSCC4. The presence of uniform distribution of larger particles across the spread indicates good viscosity and stability of the mix.

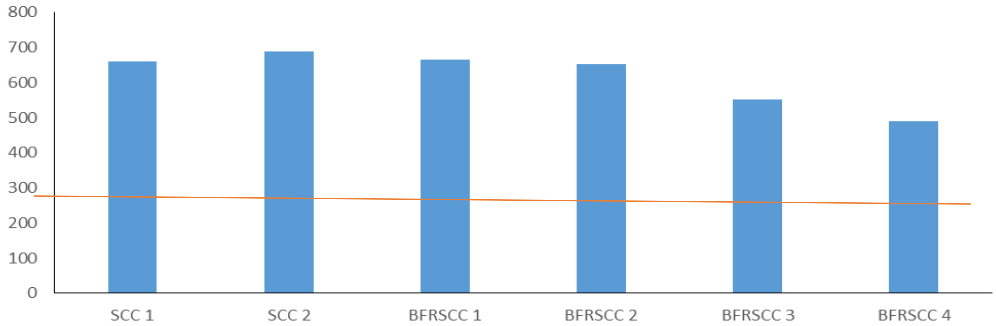


Figure 4. Slump flow for the various samples.

3.1.2 *V- funnel test result*

EFNARC LIMITS: V- funnel – (6 - 12) sec.

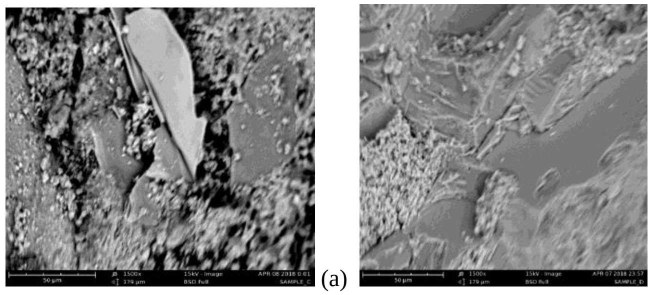
Table 1. V-funnel test results.

MIX	**V-funnel (sec)**
SCC1	8.08
SCC2	7.06
BFRSCC1	9.52
BFRSCC2	11.48
BFRSCC3	18
BFRSCC4	0

From Table 1, the flow times for the various SCC samples were within 8-18 seconds. All samples were within specified limits except BFRSCC3 and BFRSCC4, which is an indication that both mixes have poor passing ability. It could also be seen that SCC 2 containing 10% percent limestone required the least time, indicating that the addition of limestone powder improved the workability of the concrete mix. This could be attributed to filler properties of limestone powder that affected the cement particle system, changed the ordinary distance between them, and modified the water quantity available for the hydration process. The increase in fiber gave rise to a reduction in flowability.

3.1.3 *Microstructural properties*

Figure 5(a) and (b) represent control 1 (plain self-compacting concrete) and 2 (10% limestone powder) after 28 days of curing. From the scan as magnified by the SEM, Figure 5(a) shows a dense interfacial structure. The SEM scan shows the presence of pores on the interface, this is due to the lack of fine particles to fill the pore spacing. Compared to the control 1, sample control 2 shows a tight pore structure. From the SEM, it can be shown that the pores and particle size distribution have a significant effect on the physical strength of the concrete.



(a) (b)

Figure 5. (a) SEM features of control 1 mix; (b) SEM features of control 2 mix.

4 CONCLUSIONS

This research determined the influence of bamboo fibers and limestone powder on the fresh and microstructural properties of self-compacting concrete. It can be seen that an increase in fiber content enhanced the cohesiveness and internal resistance of the fresh mix, thereby reducing the workability of the mix, while the optimal bamboo fiber content that can be used is 0.75%, as it had a slump flow of 552 mm, which is within the required limit.

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