Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 115 (2019) 229-241 EISSN 2392-2192

Influence of Natural Fibers on the Fresh and Hardened Properties of Self-Compacting Concrete (SCC)

Vicente Miguel A. Tan, Mon Emilbert F. Yambao, Rodrigo Rafael Bravo, Joanne A. Familara*

Bansud National High School - Regional Science High School for MIMAROPA, Bansud, Oriental Mindoro, 5210, Philippines

*E-mail address: joanne_familara@yahoo.com

ABSTRACT

The main purpose of the study is to explore the effect of the plant fibers having different volume fraction on the fresh properties of the mix design of SCC such as filling ability, passing ability and segregation resistance as well as its influence on the compressive strength of the hardened SCC. The study started by conducting preliminary test on the aggregates needed in the construction of SCC. The aggregates were mixed together until uniform consistency was attained. Different volume fractions of CN and RS fibers were added on the mix design and molded in a cylindrical molder. The concrete were dried for 48 hours then placed in curing tank. Filling ability were tested by means of slump flow and T500 test. Passing ability were tested using J-ring while segregation resistance were tested using V-funnel and T5min. Hardened SCC with plant fibers were tested for its compressive strength. Based from the collected data, the filling ability were significantly affected by decreasing the slump flow of self-compacting concrete while increasing the time of SCC to spread to a diameter of 500 mm (T500). Furthermore, the passing ability and segregation resistance of SCC increases upon adding various volume fractions of CN and RS fibers. Statistical analysis further proves that there is significant difference between the normal SCC and the SCC with different percentages of CN and RS fibers. In addition, most favorable compressive strength were found when 0.05% CN fiber and 0.10% RS fiber were added to SCC after 7 and 28 curing days.

***Keywords*:** Self-Compacting Concrete, Coconut Fiber, Rice Straw Fiber, Passing ability, Filling Ability, Segregation Resistance

(Received 21 November 2018; Accepted 06 December 2018; Date of Publication 07 December 2018)

1. INTRODUCTION

Natural resources have been extensively used and man is constantly looking for ways to further improve and develop these resources. The use of local materials in construction of buildings is one of the potential ways to support sustainable development in both urban and rural areas. In addition, the sustainable world's economic growth and people's life improvement greatly depend on the use of alternative products in the architecture and construction, such as industrial weretes, conventionally called "green materials" (BASIN news, 2001).

Self-compacting concrete (SCC) were first developed in 1988 by Professor Okamura intended to improve the durability properties of concrete structures (Okamura & Ouchi, 2003). The world-wide awareness in the development of self-compacting concrete highlights the importance of this new type of concrete to modern day construction and can be considered as a major evolution in the construction industry.

Self-compacting concrete is a concrete which has little resistance to flow so that it can be placed and compacted under its own weight without any external vibration. It offers many advantages compared to ordinary concrete. The main advantage is in the elimination of mechanical compaction. It also provides an opportunity to the workers and improves the options open to the construction industry. Aside from increasing the quality of concrete structures produced, the use of self-compacting concrete reduces the construction cost through minimizing the compaction effort and reducing the construction time. Since the development of SCC in Japan, many organizations across the world have carried out research on properties of SCC.

Rice straw is the vegetative part of the rice plant (Oryza, n.d.), cut at grain harvest or after. Although some limited uses of rice straw such as animal feed or paper making are maintained, yet burning is still the principal disposal method for most of the rice straw residue. Instead of burning the straw, recycling it with a mixture of cement forms a sustainable low cost building material, which also reduces atmospheric pollution (Allam et al., 2011). This fiber present the following properties: renewable, non-abrasive, cheap, abundant, and handling and processing causes less health and safety concerns (AL-Kadi et al., 2015). This kind of werete has a greater chance of being utilized for different application in construction and building materials.

Coconut fibers obtained from coconut husk, belonging to the family of palm fibers, are agricultural werete products obtained in the processing of coconut oil, and are available in large quantities in the tropical regions of the world, most especially in Africa, Asia and Southern America. Coconut fiber has been used to enhance concrete and mortar, and has proven to improve the toughness of the concrete and mortar (Gram, H.E.,1983; Ramakrishna, G. & Sundara, T., 2005). Sen and Jagannatha (2011) study (as cited in Zakaria et al.,2015) mentioned that coconut fiber has been tested for filler or reinforcement in different composite materials. The addition of coir also yields a lightweight product and it would resolve the environment and energy concern (Zakaria et al., 2015).

Rice straw and coconut fibers came from their specific products after they have been used. As the natural fibers were agricultural werete, using a natural product became an economic and interesting option. However, the methods for disposing of these agricultural weretes-by-products are either burning or baling. As a result, most farmers tend to burn agricultural werete in open fields, boosting air pollution and serious human health problems due to the emission of carbon monoxide. These agricultural werete which are widely available, renewable, and virtually free cannot be thrown away anymore, but can be utilized as an important resource for industrial productive uses, since one-third of our country's agricultural land produces rice and coconut.

This current research focuses on guidelines for the integration of natural fibers like rice straw and coconut fiber as constituent materials to the mixing proportions of SCC. This study investigates the workability of fresh SCC after the addition CN and RS fibers in volume fraction of 0.05%, 0.10%, and 0.15% by volume of the mix compared to plain SCC. In addition, it also evaluates the effect of plant fibers on the compressive strength of the hardened SCC.

With the global campaign to inspire werete reduction, this approach will contribute to produce sustainable and efficient construction materials, thereby, controlling the magnitude of carbon dioxide emissions in compliance with the environmental requirements. Hence, the goal of this study is to recognize the effects of agricultural werete by-products for SCC as an approach to the improvement of new construction material, thereby creating ecological awareness. Such approaches would help to address concerns of sustainability as well as ecological impact and achieve sustainable results.

2. MATERIALS AND METHODS

Preparation of Natural Fibers

Coconut (CN) husks and rice straw (RS) were collected from Bongabong and Roxas, Oriental Mindoro. The collected husks and rice straw were air dried for seven (7) days. After the drying process, the fibers were separated, fibrillated and cut with a length of 19mm to be added to the SCC mixture.

Preliminary Test on Cement and Aggregates

Ordinary Portland Cement (OPC) was used in this investigation. Commercially available coarse and fine aggregates were purchased at San Mariano Trading. The commercially available OPC, CA and FA were pre-examined at Department of Public Works and Highways (DPWH), Southern Mindoro Engineering Office located at Mansalay, Roxas Or. to ensure the material's properties and determine the exact proportions to be used in the construction of the mix design.

Based on the preliminary test, the following properties were attained:

a) Ordinary Portland Cement (OPC) had a specific gravity of 3.15.
b) Fine Aggregates (FA) consisted of river sand with a specific gravity of 2.732, fineness modulus of 3.15 and an absorption value of 0.806%.
c) Coarse Aggregates (CA) or angular granite material of 25 mm maximum size with a specific gravity of 2.736 obtained from local source was used in the mixture.

After the pre-evaluation on the aggregates of the mix design, the corrected weight of each material to be used in making of the mix design was calculated by the qualified engineer at the DPWH-SMEO. The identified weight was used as the proportions of the mix design.

Production of Mix Design

The amount of cement, fine and coarse aggregates were based on the preliminary test conducted by the DPWH-SMEO in each of the materials used in making the cylindrical concrete. Fine aggregates (FA) of 939.29 kg/m^3 and 1060.71 kg/m^3 coarse aggregates (CA) in its dry state were homogenized in a flat metal plate. Half of the mixing water (108.035 kg/m$^{3)}$ were added to the homogenized mixture until it becomes slurry. Ordinary Portland Cement (OPC) Type I of 373.21 kg/m^3 was added to the mixture with constant mixing. The remaining half of the water and 0.010 kg of superplasticizer was added. Superplasticizer was added to reduce the amount of water to be added in the mix design. After mixing the main component of the mix designs, coconut (CN) fiber and rice straw (RS) fiber with different volume fractions (0.05%, 0.10% and 0.15%) were gradually added in the mix design. These fibers were added in small amounts to avoid congestion and to produce uniform material consistency. After the fibers were incorporated to the mix design, full mixing time of SCC was ensured. The freshly mixed concrete was placed in a standard cylindrical concrete cast with a diameter of 6 inches and a height of 12 inches. The casted mix designs were dried for 48 hours. After the cylindrical mix were confirmed dried, it was submerged in clean water at 20 °C and until taken out for testing. Three replications in every percentage of each plant fiber were constructed and were done at DPWH-SMEO. Table below displayed the composition of the mix design using CN and RS fibers.

Table 1. Composition of Mix Design with Different Volume Fractions of Coconut and Rice Straw Fibers.

Mix design	C Kg/m^3	FA Kg/m^3	CA Kg/m^3	W Kg/m^3	SP Kg/m^3	CN % by volume	RS % by volume
M_0	373.21	939.29	1060.71	216.07	1.67	0	0
M_{1c}	373.21	939.29	1060.71	216.07	1.67	0.05	0
M_{2c}	373.21	939.29	1060.71	216.07	1.67	0.10	0
M_{3c}	373.21	939.29	1060.71	216.07	1.67	0.15	0
M_{1RS}	373.21	939.29	1060.71	216.07	1.67	0	0.05
M_{2RS}	373.21	939.29	1060.71	216.07	1.67	0	0.10
M_{3RS}	373.21	939.29	1060.71	216.07	1.67	0	0.15

2. 1. Fresh Properties of SCC

Filling Ability Test

The consistency and workability of SCC were evaluated using the slump flow test. Slump cone and plate were dampened and the plate was placed on a firm, level ground. The slump cone was filled with the mixture and excess concrete on the top were removed. The cone was lifted vertically upward. The time for the concrete mixture to spread to a diameter of 500 mm (T_{500}) were measured and recorded. T_{500} were the second indication of the filling ability. The final slump flow of the two orthogonal directions after the concrete had ceased flowing had also been measured. The diameter of the concrete flowing out of the slump cone was obtained by calculating the average of two perpendicularly measured diameters. Slump flow, T_{500} test were used to test the filling ability of SCC in reference to ASTM C 1611. Each of the constructed mix design with various volume fraction of CN and RS fibers were undertaken. This test was done in three replications. The slump flow spread were calculated using the formula below.

$$\text{Slump flow} = \frac{1}{2} (d1 + d2)$$

Passing Ability Test

J-ring is an excellent test for the passing ability of SCC. An inverted slump cone were placed inside the J-Ring and after the cone were lifted, the diameters of the concrete, in two directions approximately perpendicular to each other, were measured and averaged to obtain the J-Ring flow. The difference between the slump flow and J-Ring flow is an indicator of the passing ability of the concrete. Three replicates were done for this test. Passing ability test were done in accordance to ASTM C 1621.

Segregation Resistance

V-Funnel Flow Time

The SCC was tested by placing a V-funnel on firm ground and positioning the bucket below the opening of the V-funnel. It was filled with concrete and allowed to remain undisturbed for ten seconds. After ten seconds, the gate of the V-funnel was opened to allow the flow of concrete mixture into the bucket. The time from the opening the gate to the point when light first visible through the bottom will be measured and recorded. This test was done in three replications.

Flow time at $T_{5minutes}$

Same procedure with the V-funnel flow time was performed. This time the concrete were allowed to remain undisturbed for 5 minutes after the second fill of the funnel and allow the concrete to flow out under gravity. Simultaneously, start the stopwatch when the trap door is opened, and record the time for the discharge to complete (the flow time at T 5 minutes). This was taken when light is seen from above through the funnel. Three replicates were done for this test.

Hardened Properties of SCC

Compressive Test

To determine the effect of various volume fractions of CN and RS fibers on the hardened properties of SCC, the specimens for that were cured for 7 and 28 days were subjected to compressive strength test within 6 hours which is the permissible time tolerances in accordance with FOP for AASHTO T 22 of WSDOT Materials Manual (2016).

The cylindrical mix design was tested for its compressive strength at DPWH, Southern Mindoro Engineering Office with the supervision of licensed engineer. Test for compressive strength was done in three replications for 0%, 0.05%, 0.10% and 0.15% CN and RS fibers. Average of the three replicates were calculated and tabulated. Compressive strength test were done in accordance to ASTM C 837.

2. 2. Data Analysis

Data were gathered, recorded and interpreted using Randomized Blocks ANOVA to conclude the significant difference between the fresh the SCC with different plant fiber at various volume fraction.

3. RESULTS AND DISCUSSION

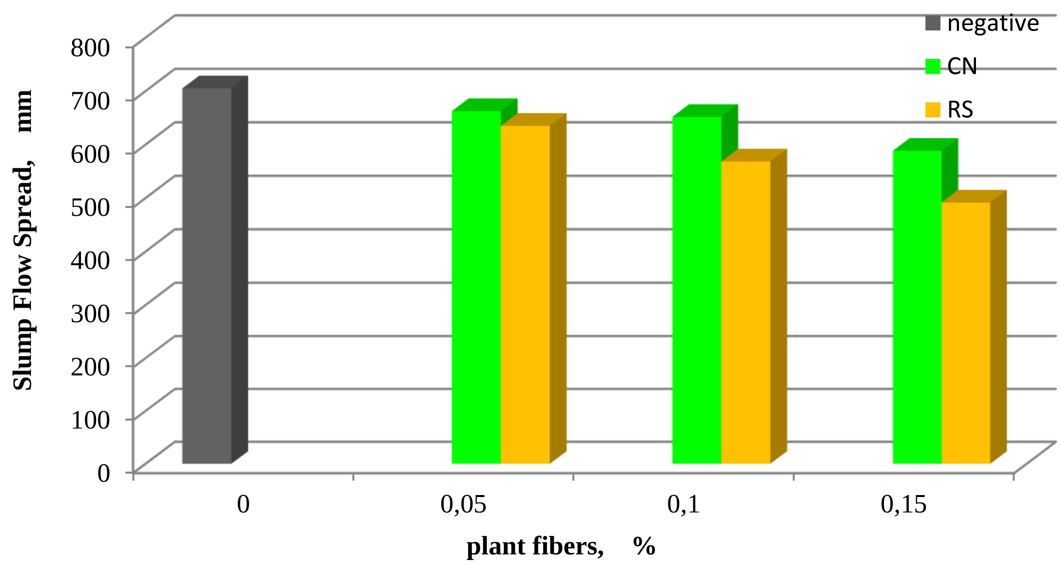


Figure 1. Slump flow spread of SCC with different volume fraction of CN and RS fibers compared to the Negative control

Above figure shows the relationship between plant fibers and slump flow. With an increase in the percentage of plant fibers added in the SCC, there is a decrease in slump flow which is related to the presence of the fiber that can increase the friction between the flowing concrete and the surface of contact in the slump flow test. A similar result can be grasped in the study of Yalley and Kwan (n.d.) showing the decrease in the slump flow spread value as percentage of fiber added to the concrete increased. The result of this study were also supported by the research conducted by Shreeshail, Chougale Pimple and Kulkarni, A. (2014) attested that there were a slump decreased of 30% for 75 AR and 33% for 125AR for 1% fiber content. Similarly, slump value decreased for 2% and 3% fiber content.

To further analyze the slump flow result, Randomized Blocks ANOVA was used. It revealed a p-value of 0.0001 which is lower than the 5% level of significance. Therefore, the null hypothesis was rejected. It implies that there is a significant difference on the slump flow spread of SCC with different volume fraction of CN fibers added. However, slump flow spread of SCC with 0.05% and 0.10% CN fiber were comparable with each other. Meanwhile, a p-value of 7.17×10^{-07} which is also lower than the 5% level of significance were obtained when different volume fraction of RS fiber were added to concrete the mix design, therefore the null hypothesis were rejected. It denotes that there is a significant difference on the slump flow spread of SCC when different volume fractions of RS fibers were added.

According to Nagataki and Fujiwara (1995), a slump flow ranging from 500 to 700 mm is considered as the slump required for a concrete to be self-compacted. More than 700 mm, the concrete might segregate, and at less than 500 mm, the concrete is considered to have insufficient flow to pass through highly congested reinforcement. However, according to EFNARC (2002), a value of at least 650mm is required for SCC and the higher the slump flow (SF) value, the greater its ability to fill formwork under its own weight.

The slump flow results revealed that the SCC with 0.05% and 0.10 % CN fibers meet the standard specification and guidelines set by the EFNARC indicating a remarkable effect in the viscosity of SCC. In addition, when CN and RS fibers were compared depending on the specific percentage of fiber, it affirms that the slump flow result of CN fiber is better than that of the slump flow of RS fiber. On the other hand, 0.15%CN fibers and different volume fraction of RS fiber did not achieve the set standard of slump flow for SCC.

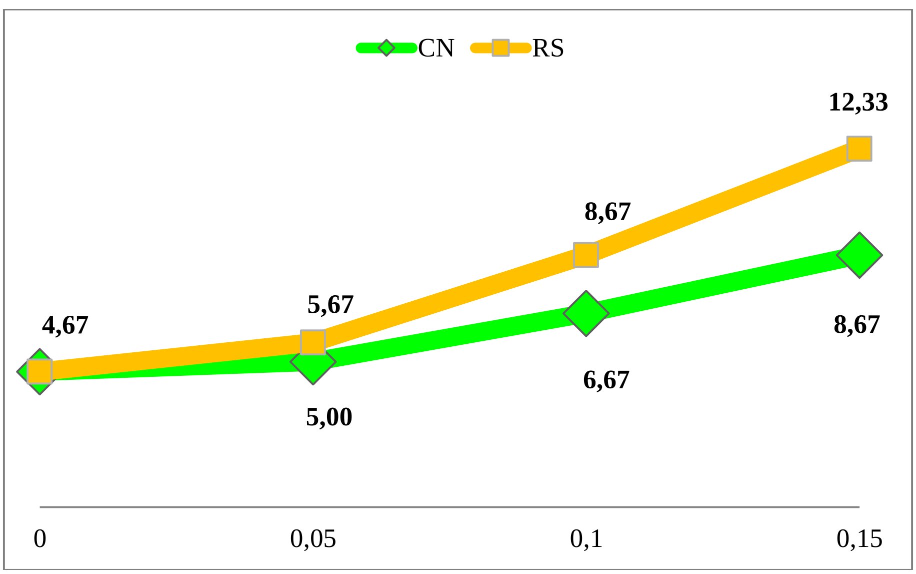


Figure 2. T_{500} Test of SCC with different volume fraction of CN and RS fibers(sec.)

The T_{500} time is a secondary indication of flow. As can be gleaned in Figure 2, as the percentage of plant fiber increases, T_{500} also increases. It indicates that it took longer time for the SCC to spread to a diameter of 500mm as the percentage of fiber increases. A lower time indicates greater flowability. The BriteEuRam research suggested that a time of 3-7 seconds is acceptable for civil engineering applications and 2-5 seconds for housing applications (EFNARC, 2002). SCC with RS fiber of 0.10% and 0.15% as well as 0.15% CN fiber did not meet the specifications set by EFNARC in terms of T_{500} indicating a very high viscosity.

Using Randomized Blocks ANOVA, a p-value of 0.0023 and 2.20×10^{-07} were obtained for T_{500} of SCC with different volume fraction of CN and RS fiber respectively. The p-value attained were lower than the 5% level of significance leading to the rejection of the null hypothesis. Therefore, there is a significant difference on the time taken for the SCC to spread to a diameter of 500mm with respect to different volume fraction (0%, 0.05%,.010%,0.15%) of

CN and RS fibers. It further showed that the addition of 0.05% of CN fiber were comparable to the negative control in terms of T_{500}.

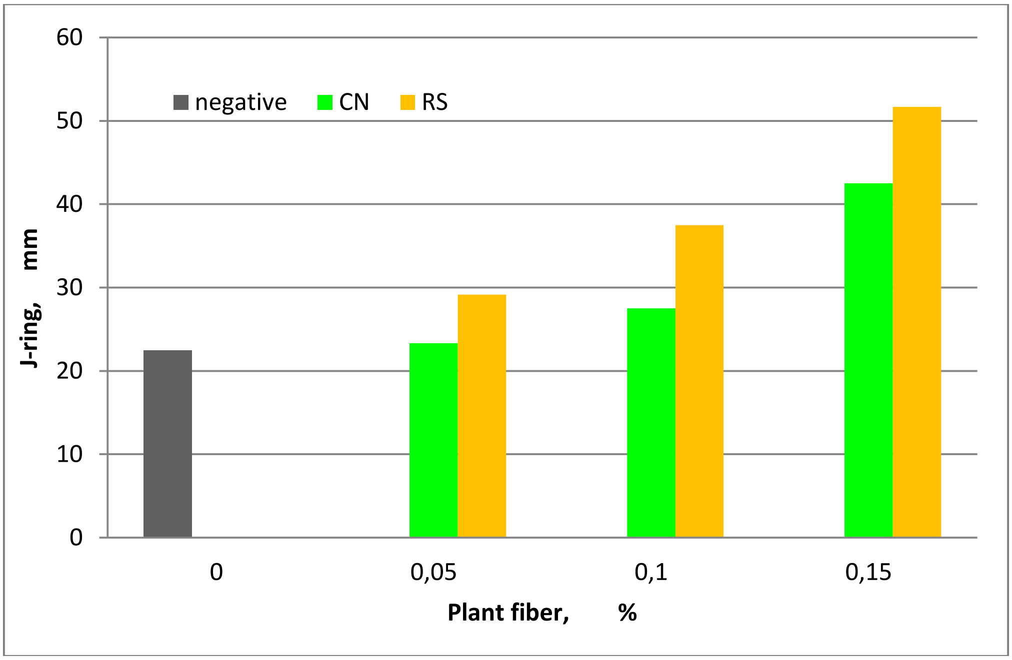


Figure 3. J-Ring test result of SCC with different volume fraction of CN and RS fibers.

This test method provides a procedure to determine the passing ability of self-consolidating concrete mixtures. The difference between the slump flow and J-Ring flow is an indication of the passing ability of the concrete. The negative control acquired a difference of 22.50 mm. SCC with CN fibers of different volume fraction had a difference of 23.33 mm, 27.50mm, and 42.50mm respectively. Meanwhile, the result of J-ring test of SCC with RS fibers obtained a difference of 29.17 mm, 37.50 mm and 51.67 mm. Randomized blocks ANOVA got at p-value of 0.0421 and 0.0005 which is lower than the 5% level of significant. It were concluded that there is a significant differences among SCC with different volume fraction of CN and RS fibers. SCC with CN fibers added and RS with 0.05% and 0.10% had acceptable passing ability.

ASTM C 1621 asserts that a difference less than 25 mm indicates good passing ability and a difference greater than 50 mm indicates poor passing ability. All of the volume fraction of concrete mix design except the SCC with 0.15% RS fiber passed the standards required by ASTM C 1621.

The inverted cone shape restricts flow and prolonged flow times may give some indication of the susceptibility of the mix to blocking. The V-funnel flow time of SCC increases from 6 to 15 seconds with increase in CN fiber content indicating increase in viscosity of concrete. The results of V-funnel test of the negative control and the SCC with 0.05% and 0.10% CN fibers confirms to the standard requirement.

In addition, the graph also displayed that only the SCC with 0.05% RS fibers passed the specification for V-funnel test of SCC. As stated in the EFNARC 2002 (Specification and Guidelines for Self-Compacting Concrete), a V-funnel result of greater than 12 seconds indicates that the viscosity is too high while a result less than 8 seconds signifies a low viscosity. As can be seen in the table, SCC with 0.05% and 0.10% CN and RS fibers met the set standards. However, it was concluded that there is a significant difference on the V-Funnel Test of different volume fraction of CN and RS fibers since the computed p-value 0.0029 and 0.0044 is lower than the 5% level of significance.

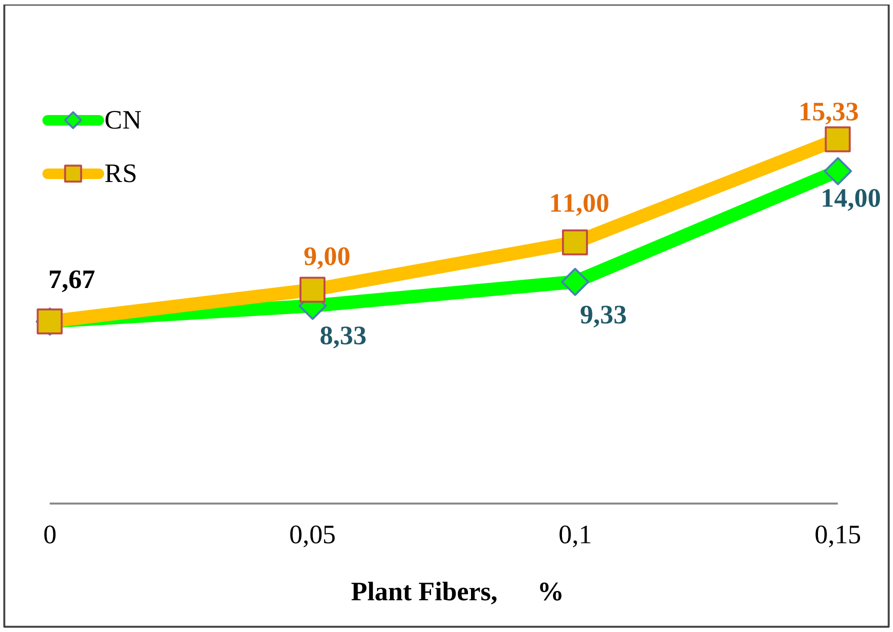


Figure 4. V-Funnel Test of SCC with Different Volume fractions of CN and RS Fibers (sec)

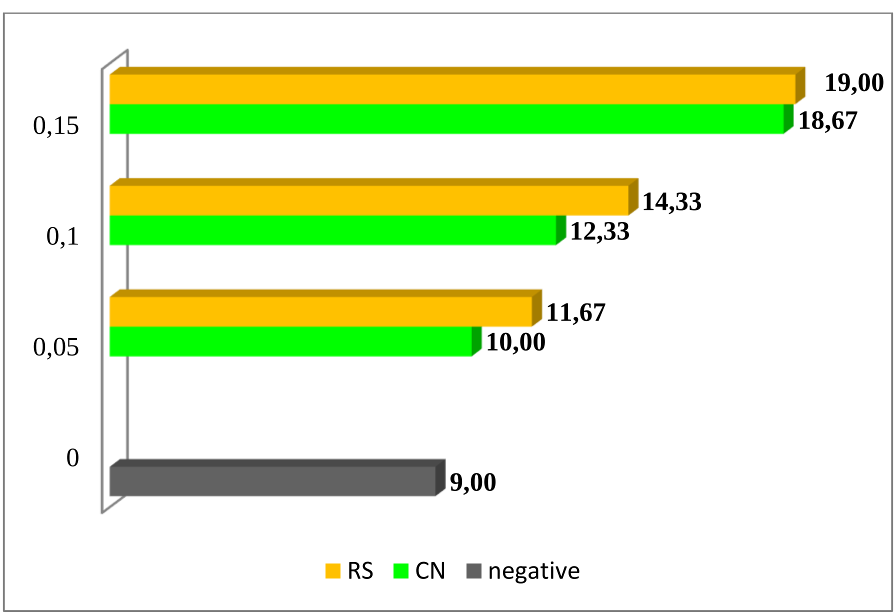


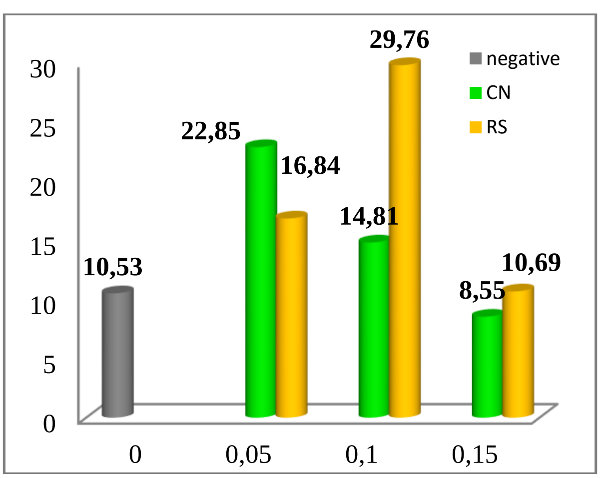
Figure 5. Flow time at T_{5min}. of different volume fractions of CN and RS fibers

Table 2. Difference between the V-Funnel and T5min. test.

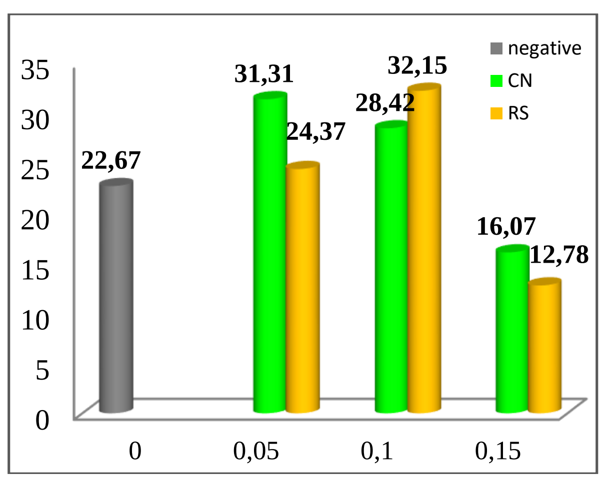
Mix Design	V-Funnel (sec)	T-5minutes (sec)	Difference (sec)
CN-0.05	10.00	8.33	**1.67**
CN-0.10	12.33	9.33	**3.00**
CN-0.15	18.67	14.00	**4.67**
RS-0.05	11.67	9.00	**2.67**
RS-0.10	14.33	11.00	**3.33**
RS-0.15	19.00	15.33	**3.67**

Segregation refers to a separation of the components of fresh concrete, resulting in a non-uniform mix. This can be seen as a separation of coarse aggregate from the cement, caused from either the settling of heavy aggregate to the bottom or the separation of the aggregate from the mix due to improper placement. After 5 minutes of settling, segregation of concrete will show a less continuous flow with an increase in flow time.

Based on graphical representation above, flow time of SCC with CN fiber ranges from 10.00 to 18.67 seconds while SCC with RS fiber ranges from 11.67 to19.00 seconds. The lowest time difference of 1.67 seconds was noted when 0.05% of CN fiber were added to the mix design as presented in Table 2. The acceptable criterion for the difference in time is three (3) seconds as stated in EFNARC 2002, Specification and Guidelines for Self-Compacting Concrete. SCC with 0.05%, 0.10% CN fiber and 0.10% RS fiber satisfied the said criterion. However, concrete with 0.10% and 0.15% RS fiber may be considered acceptable, although the time difference were 3.33 and 3.67 seconds instead of allowable 3 seconds.



(6a) 7 curing days



(6b) 28 curing days

Figure 6. Compressive Strength Result of SCC with varying percentage of CN and RS Fibers After 7(6a) and 28(6b) Curing Days

The figure above shows that compressive strength had a decreasing trend with increasing CN fibre content. As the amount of CN fiber increases, compressive strength decreases. Using randomized block ANOVA, a p-value of 0.0014 were obtained indicating that there is a significant difference on the compressive strength of SCC with different percentage (0, 0.05%, 0.10%, 0.15%) of CN fiber. It implies that 0.05% of CN fibers had the most satisfactory result in terms of compressive strength. The result of the study were supported by Abdullah et al. (2007) testifying that the adding coconut fiber in concrete increases its modulus of rapture and compressive strength of the composites up to certain optimum composition

It can also be seen from the figure that compressive strength of SCC with increasing amount of RS fiber increases then decreases. The result can be supported by the study of Yalley and Kwan which expounds that the addition of natural fibers significantly affects the compressive strength due to difficulties in compaction which therefore led to increase of voids. A p-value of 0.007 were acquired which is lower than the 5% level of significant leading to the rejection of the null hypothesis. Thus, there is a significant difference on the compressive strength of SCC having an increased in percentage of RS fibers. In the fiber reinforced composites, it has been shown that a significant improvement in properties of a concrete can be achieved by adding suitable fibers. In this study, 0.10% RS fiber is recommended to attain a higher compressive strength of SCC.

Changes in compressive strength of SCC with volume fraction of plant fibers can be attributed to the chemical component of natural fiber. The components of natural fibers are cellulose, hemicellulose, lignin, pectin, waxes and water-soluble substances (Bledzki & Gassan, 1999). These are the basic components of natural fibers, governing the physical properties of the fibers. Rice straw is made up of 28-48(%by weight) cellulose (Rowell *et. al*., 2000). Celluloses fibers are flexible and less prone to breakage during processing (Lee, 1991). Sjostrom (1993) reported that the chemical constituents of plant fiber have specialized functions in the cell wall: cellulose forms strong and stiff crystalline regions, cellulose and hemicellulose form semi-crystalline regions which provide necessary flexibility while the amorphous regions of lignin give toughness and cohesion. Chemical composition of natural fiber could be used to strengthen the bond in any construction materials without sacrificing the quality of the materials being produced. Moreover, results of this study found enormous support from the studies mentioned in Zakria, Suleiman and Roslan (2015). It were stated by the previous researchers that in considering the renewable and sustainable environment, natural fiber is growingly being used in composite material especially in building construction. Natural fiber generally offers low production cost, friendly processing, low tool wear and less skin irritation, and good thermal and acoustic insulation properties (Biagiotti, Puglia, & Kenny, 2004). Natural fiber also enhances mechanical and reinforcement for composites includes straw for bricks, mud and poles, plaster and reeds (Hasan, Sobuz, Sayed, & Islam, 2012).

4. CONCLUSIONS

The addition of different volume fraction of CN and RS fibers (0.05%, 0.10% and 0.15%) greatly influence the fresh and hardened properties of self-compacting concrete. Based from the collected data, addition of CN and RS fibers significantly affect the filling ability of the SCC by decreasing the slump flow of self-compacting concrete while increasing the time of SCC to spread to a diameter of 500 mm (T500). Furthermore, the passing ability and segregation resistance of SCC increases upon adding various volume fraction of CN and RS fibers. Statistical analysis further proved that there is significant difference between the normal SCC and the SCC with different volume fraction of CN and RS fibers.

Results also displayed that the addition of CN fiber gave a decreasing trend on the compressive strength of SCC. However, compressive strength were increased for 0.05% and 0.10% addition of RS fibers but significantly decreased at 0.15% RS fiber. Statistical analysis further showed that there is a significant difference on the compressive strength of SCC with varying volume fraction of CN and RS fibers. Optimum compressive strength were established when 0.05% CN fiber and 0.10% RS fiber were added to SCC.

Acknowledgement

The authors are grateful to the Almighty God, to theirs parents and to the Junior High School Department of Bansud National High school-Regional Science High School for MIMAROPA, Philippines.

References

[1] Bahnsawy, A. H., I. Yehia, T. H. Ashour M. H. Khalil M. A. Orabi. (2015). Physico mechanical properties of concrete mixes containing recycled rice straw and blast-furnace slag. *Seventh International Conference on Nano-Technology in Construction.*

[2] Biagotti, J. D., Puglia, D., & Kenny, J. M. (2012). A review on natural fiber-based composite part 1:structure, processing and properties of vegetable fibers. *Journal of Natural Fibers,* 1(2): 37-68.

[3] Ricky Dave T. Mercado, Romnick M. Ureta, Reynan Jay D. Templo, The Potential of Selected Agricultural Wastes Fibers as Acoustic Absorber and Thermal Insulator Based on their Surface Morphology via Scanning Electron Microscopy. *World News of Natural Sciences* 20 (2018) 129-147

[4] Gram, H.E. (2004). Durability of natural fibre in concrete. *Swedish Cement and Concrete Int*. 4177-4188.

[5] Harmathy, T.Z., & Berndt, J.E. (1973). Thermal properties of selected masonry unit concretes. *Journal of the American Concrete Institute,* 70: 132-142.

[6] Hasan, N. M. S., Sobuz, H. R., Sayed, M. S., & Islam, M.S. (2012). The use of coconut fiber in the production of structural lightweight concrete. *Journal of Applied Science,* 12(9): 831-839.

[7] Khedari, J., Suttisonk, B., Pratinthong, N., & Hirunlabh, J. (2001). New lightweight composite construction materials with low thermal conductivity. *Cement & Concrete Composites,* 23: 65-70.

[8] Olafusi, O.S., Adewuyi, A. P., Otunla, A. I., & Babalola, A. O. (2015). Evaluation of fresh and hardened properties of self-compacting concrete. *Open Journal of Civil Engineering,* 5: 1-7.

[9] Ramakrishna, G., & Sundara, T. (2005). Study into the durability of natural fibres and the effect of corroded fibres on the strength of mortar. *Cement and Concrete Composite*, 27, (5): 575-582.

[10] Ravindrarajah, R. S., Farrokhzadi, F., & Lahoud, A. (2003). Properties of flowing concrete and self-compacting concrete with high-performance superplasticizer *Centrefor Built Infrastructure Research*, 1: 1048.

[11] Shreeshail, B.H, Chougale, J. Pimple, D. & Kulkarni, A. (2014). Effects of Coconut Fibers on the Properties of Concrete. *International Journal of Research in Engineering and Technology*, 3(12).

[12] Hosseini, et al. Utilization of coir fiber in multilayer acoustic absorption panel. *Applied Acoustics*, 71 (2010) 241-249.

[13] Khedari, Joseph, Charoenvai, Sarocha, & Hirunlabh, J. New insulating particleboards from durian peel and coconut coir. *Building and Environment*, 38 (2003) 435-441.

[14] Khedari, Joseph et al. New low-cost insulation particleboards from mixture of durian peel and coconut coir. *Building and Environment*, 39 (2004) 59-65.

[15] Koizumi, Tsujiuchi & Adachi. The development of sound absorbing materials using natural bamboo fibers. *WIT Transactions on the Built Environment*, 59 (2002).

[16] Lee & Chen. Acoustic transmission analysis of multilayer absorbers. *Journal of Sound and Vibration*, 248 (4) (2001) 621-634.

[17] Rouquerol et al. Recommendations for the Characterization of Porous Solids. *International Pure and Applied Chemistry*, 66(8) (1994) 739-1754.

[18] Suter, Alice H. Construction noise: Exposure, effectsand the potential for remediation; A review and analysis. *AIHA Journal*, 63 (2002) 768-789.

[19] Wang, Chao-Nan & Torng, Jiunn-Hwan. Experimental study of the absorption characteristic of some porous fibrous materials. *Applied Acoustics*, 62 (4) (2001) 447-459.

[20] Wilson, D.K. Simple, Relaxational Models for the Acoustical Properties of Porous Media. *Applied Acoustics*, 50 (3) (2014) 171-188.