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THE EFFECT OF NATURAL FIBER (BANANA FIBER) ON THE MECHANICAL PROPERTIES OF SELF-COMPACTING CONCRETE

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Self-compacting concrete is an innovative concrete technology with higher flowability properties by adding the mineral admixtures such as superplasticizers and not necessary to vibrate concrete. The banana fibers were used in this investigation because banana fiber is an environmentally friendly material with good properties compared to synthetic fiber. The experimental test consisted of two phases of research, i.e., preliminary research, which had the aim to investigate the appropriate percentage of superplasticizer in the mixed composition of self-compacting concrete. The percentages of superplasticizers were 0.7%, 1%, and 1.4%. The second phase of research on the effect of additional banana fiber on self-compacting concrete was carried out, examining workability, compressive strength, and the splitting tensile strength of concrete. In this research, the percentages of fiber were 0.12%, 0.3%, and 0.5% of the cement weight, and evaluated the effect of fiber treatment. The treated fibers mean that the fiber is immersed in NaOH solution or named as a delignification process. The hardened concrete specimen was used for determining the mechanical strengths, such as the compressive strength and split tensile strength tests. The test results found that the optimum value for superplasticizer dosage was 0.7% of cement weight, which can fulfill the whole criteria of fresh concrete and hardened SCC concrete. Furthermore, the specimen with the adding banana fiber of 0.12% by cement weight and treated fiber indicated a decrease in workability. Compared to the control concrete, it inversely increased compressive strength up to 44.36% and tensile strength up to 17.78%.

Key words: self-compacting concrete, banana fiber, mechanical properties, delignification process

INTRODUCTION

Self Compacting Concrete

The innovative concrete technology, which improved flow easily and homogeneity without compacting or vibrating concrete to fulfill the formwork by adding the mineral admixtures, can be implemented for self-compacting concrete, SCC [1-5] dan two-stage concrete [6-13]. According to Dehn et al. [14], the basic principle concept on self-compacting concrete mix design is the relation between superplasticizer (SP) and fresh concrete characteristics, as shown in Figure 1. Usually, the superplasticizer on SCC is required for dispersing cement particles and separating them into fine particles. Moreover, the percentages of superplasticizer (SP) and aggregates types play an important role in the mix design of SCC [15]. According to Persoon [16], the flowability of fresh concrete would be increased with the greater proportion of fine aggregate if compared to the coarse aggregate, the more in the mix design of SCC. However, if the percentage of fly ash is too much in mix composition, the compressive strength of concrete would be decreased. If too much coarse aggregate in the mix design, the segregation risk concrete would be increased too. So the requirement of adding mineral admixtures to avoid bleeding and segregation, such as fly ash, limestone powder, silica fume, or other admixture, can solve this problem. The coarse aggregate composition in conventional con-

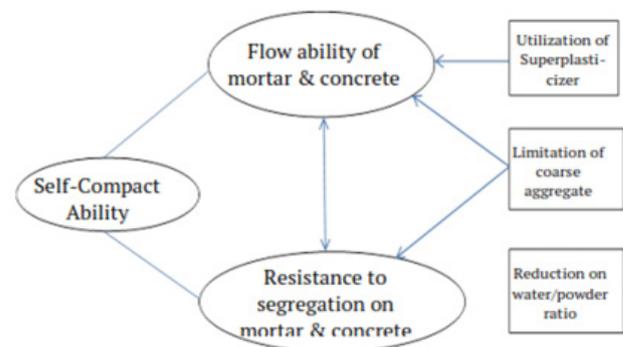


Figure 1: Basic principle concept on self-compacting concrete production (Dehn, et al., 2000)

crete is approximately 70-75% of total concrete volume. Whereas for SCC producing, the amount of coarse aggregate is being limited to less than 50% of total concrete volume [17].

Natural fibre

Applying natural fiber such as rice husk, coconut fiber, or an artificial natural fiber such as steel ash as an admixture in conventional concrete is a well-known concept in construction technology. The main intention of utilizing natural fibers is to alleviate the environmental effect produced by non-biodegradables of synthetic fibers. Natural fibers are used as an additive in concrete mixing due to

their non-abrasive, non-toxic, lightweight, biodegradable properties, environmentally friendly materials, and good properties compared to synthetic fiber [18-19]. Banana fiber is one of the agricultural waste materials from banana cultivation. Banana fiber belongs to the alternatives natural fibers that produce good mechanical properties. Several studies have shown that adding natural or non-natural waste to concrete mixtures can have several advantages, such as reducing the volume of conventional concrete raw materials and increasing the mechanical properties of concrete. One of the natural additives that can be used is banana fiber. Previous studies show that the addition of banana stem fibers to the concrete can increase the mechanical strength of the concrete [20-21]. Previous research by Chandak et al. [22] investigated that the addition of banana fiber by 0.5% for SCC increased the compressive strength of concrete by 14% compared to normal concrete. This result also decreased the slump value of the fibrous SCC concrete, thereby reducing the workability value. Furthermore, the addition of fiber of 0.3%, 0.5%, 0.7%, and 1% with the respective resulted for compressive strength of 30.8 MPa, 38.7 MPa, 35 MPa, and 33 MPa. Moreover, for tensile strength, the results were 2.4 MPa, 2.54 MPa, 2.72 MPa, and 2.9 MPa, respectively. The results obtained that compressive strength continues to increase with the fiber content of banana stalks, and the optimum variation is the addition of 0.5% banana stalk fiber [23]. In the current study, the experimental test was conducted to evaluate the appropriate percentages of superplasticizer in CSS composition, the optimum percentage of banana fiber in the SCC mix design, and the treatment effect on banana fiber using alkali. The hypothesis stated that banana fiber subjected to alkaline treatment had higher mechanical strength than can be used for self-compacting concrete.

MATERIAL AND METHOD

Test of Agregate

Physical characteristics of fine and coarse aggregates are determined first in Table 1 and Table 2. The particle size distribution of fine and coarse aggregates is plotted in Fig.2. Moreover, the characteristic of cement can be tabulated as Table 3.

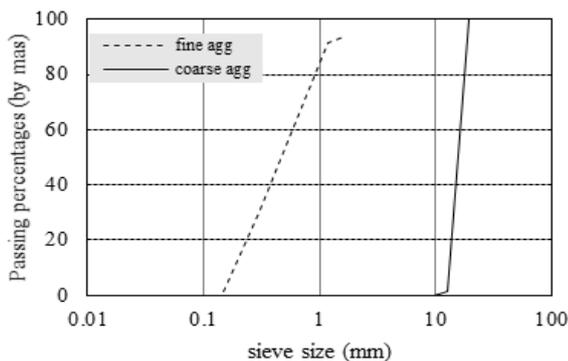


Figure 2: Sieve analysis of fine and coarse aggregate

Table 1: Characteristic of fine aggregates

| Characteristic | Observed value | Code |
|------------------|-------------------------|---------------|
| Name | Barito sand | - |
| Type | Mild sand | - |
| Grade Zone | III | - |
| Specific gravity | 2.63 gr/cm ³ | SNI 1970:2016 |
| Water absorption | 2.98% | SNI 1970:2016 |
| Fineness modulus | 3.20 | |

Table 2: Characteristic of coarse aggregates

| Characteristic | Observed value | Code |
|------------------|-------------------------|---------------|
| Name | Lok Bangkal | |
| Water absorption | 1.13% | SNI 1969:2016 |
| Specific gravity | 2.59 gr/cm ³ | SNI 1969:2016 |
| Abrasion value | 36% | SNI 2417:2018 |
| Fineness modulus | 6.98 | |

Table 3: Characteristic of cement

| Characteristic | Observed value | Code |
|-----------------------|-------------------------|------------------|
| Type | PCC | |
| Specific gravity | 3.37 gr/cm ³ | SNI 2531:2015 |
| Normal consistency | 26.6% | SNI 03-6826-2002 |
| Innitial setting time | 83.3 minutes | ASTM C403 |
| Final setting time | 150 minutes | ASTM C403 |

Mix Design of SCC

There is no standard method for SCC mix design. According to EFNARC 2005 [24], academic institutions and companies have developed their mixed proportioning methods. Due to the lack of standardization for self-compacting concrete mix designs in Indonesia, this study carried out a mix design based on the Indonesian Standard of SNI 03-2834-2000 and SNI 7656:2012, which satisfied the requirements of EFNARC 2005 guidelines. The concrete test was carried out by using EFNARC 2005 for investigating fresh concrete of SCC that consists of filling ability, viscosity, and passing ability test. ASTM - C 39 was applied for identifying the compressive strength of hardened cylindrical concrete specimens. The splitting tensile strength is determined by following ASTM - C 293. The compressive strength and splitting tensile strength tests were conducted 28 days after curing. There were two stages of the research, i.e., preliminary research for discovering the optimum percentage of superplasticizer in the mixture of SCC based on composition constituent materials, described in Table 4. This research aims to investigate the adding of natural fiber (banana fiber) with

various percentages of fiber for SCC. The mix composition of SCC will be developed based on the optimum result from preliminary research in terms of specimen behavior in fresh concrete based on EFNARC [24] and hardened concrete of SCC.

Table 4: Self-compacting concrete mix composition for preliminary research

| Materials | Composition |
|-----------------------|----------------------------------|
| water | 244 ltr |
| Cement | 518 kg |
| Fine aggregate (FA) | 882 kg |
| Coarse aggregate (CA) | 752 kg |
| Viscocrete 1003 (Sp) | SCCSP0.7 = 0.7% of cement weight |
| | SCCSP1.0 = 1.0% of cement weight |
| | SCCSP1.4 = 1.4% of cement weight |

Delignification treatment of Banana Fiber

In order to remove lignin and hemicellulose that have responsibility for the instability of fibers, alkali treatment or delignification of banana fibers has been used by using NaOH solutions to improve the performance of banana fibers. Processing of delignification treatment of fibers can be depicted in Figure 3.

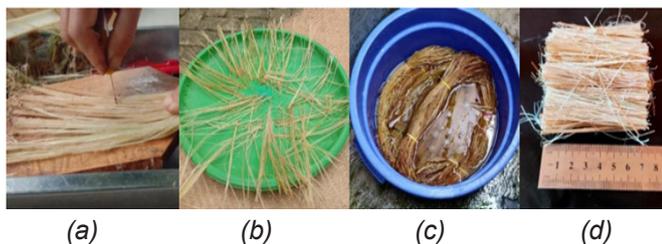


Figure 3: natural fiber (a) banana stem plants, (b) natural drying of banana fibers, (c) delignification treatment, (d) cutting 7 cm of banana fibers

From Fig 3, the banana fibers were drawn from the banana stem plants. Firstly, banana fibers were extracted using a needle or pin. The banana fibers were dried under the sunlight for 3 x 24 hours (natural drying), and in this experiment, the banana fibers could be cutting for 7 cm [25] for untreated specimens. For delignification treatment of fiber, banana fibers were immersed in 5% NaOH solution for 24 hours. After that, the treated banana fibers were washed and soaked with distilled water for 24 hours to remove the excess of NaOH at the surface of banana fibers. Afterward, the banana fibers would be dried under sunlight for 24 hours or dried oven at 110oC. Similarly, with the untreated specimen, the banana fibers could be cutting for 7 cm.

RESULT AND DISCUSSION

Fresh concrete

For ensuring the workability and homogeneity of SCC, the slump-flow test was conducted. The target of slump flow should be between 520 mm until 900 mm [24]. The slump flow of SCC specimens was measured as 565mm, 600 mm, and 630 mm for 0.7%, 1.0%, and 1.4% of SP, respectively, as shown in Table 5. Moreover, as per EFNARC (2005), SCC can be classified on the criteria of slump-flow as a filling ability/flowability test. The process of the fresh concrete test can be shown in Figure 4.

Table 5: Slump flow specimens and superplasticizer dosages

| Specimen Code | Dosage of sp (%) | Slump flow (mm) |
|---------------|------------------|-----------------|
| SCCSP0.7 | 0.7 | 565 |
| SCCSP1.0 | 1.0 | 600 |
| SCCSP1.4 | 1.4 | 630 |

The fresh properties of mixes for all specimens were tabulated in Table 6 and Figure 5

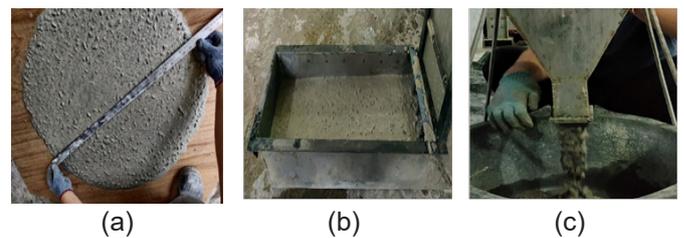


Figure 4: fresh concrete tests carried out on specimen (a) Slump flow test (b) L-box test. (c) V-funnel test

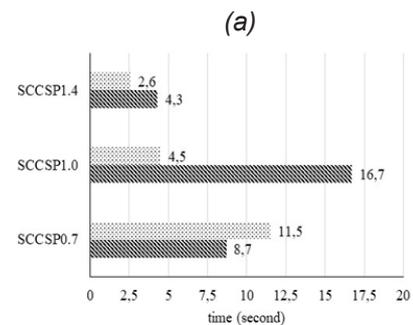
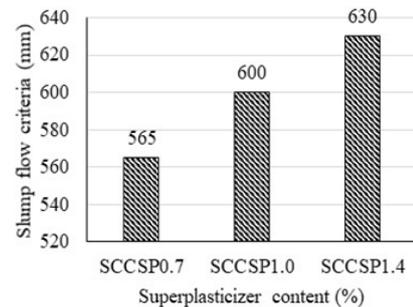


Figure 5: (a) The value of slump flow test, (b). The value of V funnel and T-500 test

Table 6: The Result of test properties and methods for evaluating of SCC Specimens

| Mix ID | Superplasticizer dosages (%) | Filling ability/flowability class | Viscosity Class | | Passing ability class |
|----------|------------------------------|-----------------------------------|-------------------|----------------|-----------------------|
| | | Slump flow (mm) | V-Funnel (second) | T-500 (second) | Lbox Test |
| SCCSP0.7 | 0.7 | 565 | 8.7 | 11.5 | 1,0 |
| SCCSP1.0 | 1.0 | 600 | 16.7 | 4.5 | 0,2 |
| SCCSP1.4 | 1.4 | 630 | 4.3 | 2.6 | 0,4 |

From the conducted tests, which are shown in Table 6 and Figure 5, the addition of a superplasticizer affected the fresh properties characteristic of SCC. The higher the superplasticizer content, the slump flow would be increased significantly. The fresh concrete test result showed that the highest diameter slump flow value was 630 mm on mix design with content Sp of 1.4 %. However, the superplasticizer content of 0.7% of cement weight as SCCSP0.7 specimens would then be applied for self-compacting concrete designing or as control specimens for further research because it can fulfill all SCC criteria in terms of passing ability, viscosity, and filling ability.

Mix Design of Banana Fibre of SCC

The mix design was developed based on the mix proportion of SCCSP0.7 specimens from preliminary research. The mix compositions of utilizing an addition of natural fibre such as banana fiber in various percentages of 0.12%, 0.3%, and 0.5% of cement weight in the composition of SCC mix design as main research can be tabulated in Table 7.

Table 7: The Mix Proportioning of Banana Fibre SCC

| Mix ID | constituents Materials (kg/m ³) | | | | SP % | Banana Fiber | | Treatment of Banana Fibre |
|------------|---|-----|-----|-------|------|--------------|-------------------|---------------------------|
| | cement | CA | FA | Water | | % | gr/m ³ | |
| SCCSP0.7 | 518 | 752 | 882 | 244 | 0.7 | 0 | 0 | - |
| SCCSP0.7_A | 518 | 752 | 882 | 244 | 0.7 | 0.12 | 15.54 | Normal |
| SCCSP0.7_B | 518 | 752 | 882 | 244 | 0.7 | 0.3 | 38.86 | Normal |
| SCCSP0.7_C | 518 | 752 | 882 | 244 | 0.7 | 0.5 | 64.77 | Normal |
| SCCSP0.7_D | 518 | 752 | 882 | 244 | 0.7 | 0.12 | 15.54 | delignification |
| SCCSP0.7_E | 518 | 752 | 882 | 244 | 0.7 | 0.3 | 38.86 | delignification |
| SCCSP0.7_F | 518 | 752 | 882 | 244 | 0.7 | 0.5 | 64.77 | delignification |

Natural Fibre of SCC Result

Fresh Concrete of Banana Fiber SCC

The characteristic of SCC Based on the fresh concrete with adding the percentage of banana fibers was shown in this research. As per EFNARC [24], SCC can be classified on slump-flow were tabulated in Table 8 and Figure 6. Based on the results of the tests carried out, it can be seen that the variation added to banana stem fiber has decreased in its overall workability. (Only SCCSP0.7 and SCCSP0.7_A fulfill EFNARC 2005 code for slump flow criteria) It can be concluded that the addition of natural fiber can reduce the workability of the specimen with and without the delignification process. The effect of the delignification of fiber through the workability of all specimens can be shown in Fig.6(a).

Hardened concrete of SCC

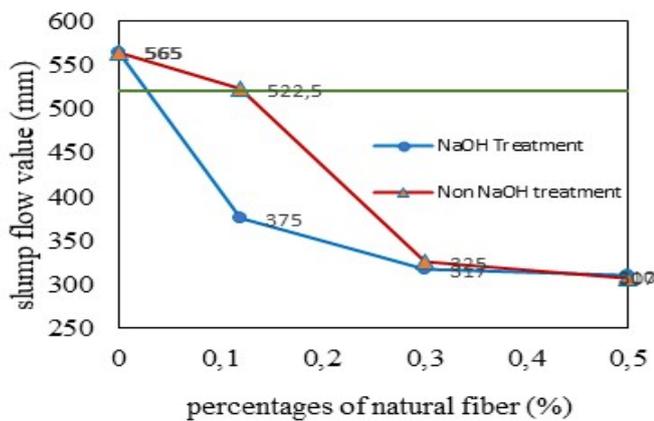
The compressive strength of SCC after the curing period of 7, 14, and 28 days are the average compressive strength of SCCSP0.7 and SCCSP1.4 These are shown in Figs. 7. The results exhibited that a gradual increase in strength with the age of curing days. The compressive strength of the SCCSP0.7 specimen with 0.7% and 1.4% of superplasticizer were determined as 32.67MPa and 35.14MPa. The result indicated that the percentage change in compressive strength performance for the SCCSP1.4 specimen is 7.56% higher than the SCCSP0.7 specimen with a lower dosage of admixtures, as shown in Fig.5(b). A total of 60 cylinder samples were used, consisting of 45 cylinder samples for the compression test and 15 cylinders samples for the splitting test. The hardened concrete test for compression test was

Table 8: The Result of Fresh Concrete of SCC Specimens

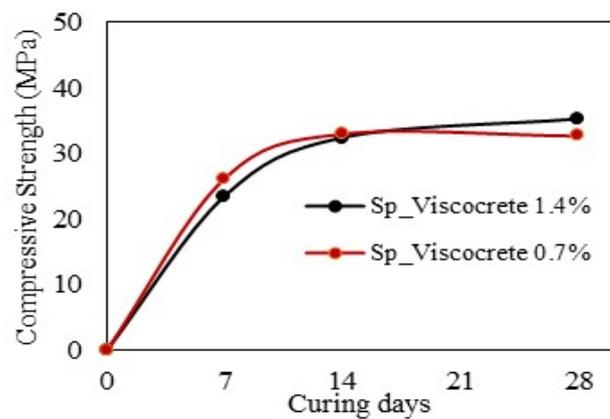
| Mix ID | Banana fiber (%) | Treatment | Slump flow test (mm) |
|------------|------------------|-----------------|----------------------|
| SCCSP0.7 | 0 | - | 565 |
| SCCSP0.7_A | 0.12 | Normal | 522.5 |
| SCCSP0.7_B | 0.3 | Normal | 325 |
| SCCSP0.7_C | 0.5 | Normal | 307 |
| SCCSP0.7_D | 0.12 | delignification | 375 |
| SCCSP0.7_E | 0.3 | delignification | 317 |
| SCCSP0.7_F | 0.5 | delignification | 310 |

carried out based on ASTM C-39 for 7, 14, and 28 days test. Splitting tensile test determined by ASTM C-293 for

28 days test. The compressive strength test of all specimens can be tabulated in Table 9 and Figs.7



(a) The slump flow value test



(b) compressive strength of specimens

Figure 6 (a) The slump flow value in different percentages dosage of banana fibers, (b) The compressive strength of specimen in different dosages of superplasticizer

Table 9: The Result of Hardened Concrete of Specimens

| Mix ID | Compressive strength test | | | Splitting tensile test (MPa) | treatment |
|------------|---------------------------|--------|--------|------------------------------|-----------------|
| | (MPa) | 14days | 28days | 28 days | |
| SCCSP0.7 | 26.51 | 32.98 | 32.88 | 3.51 | Normal |
| SCCSP0.7_A | 31.03 | 39.45 | 38.84 | 3.80 | Normal |
| SCCSP0.7_B | 34.32 | 34.11 | 36.17 | 4.13 | Normal |
| SCCSP0.7_C | 23.63 | 27.54 | 25.48 | 4.21 | Normal |
| SCCSP0.7_D | 28.67 | 40.48 | 47.47 | 4.13 | delignification |
| SCCSP0.7_E | 21.58 | 28.97 | 32.88 | 3.80 | delignification |
| SCCSP0.7_F | 28.56 | 30.41 | 30.41 | 3.64 | delignification |

Based on the result, the compressive strength of SCCSP0.7 as a control specimen is 32.88 MPa. The maximum compressive strength of 47.7MPa was recorded by SCCSP0.7_D for 28 days, containing 0.12% of banana fibers and delignification treatment. Moreover, the higher compressive strength of 38.84 MPa was also indicated by SCCSP0.7_A, which similar dosage of banana fibers but the untreated process. Similar to SCCSP0.7_C and SCCSP0.7_F, which indicated that the higher compressive strength for specimen with delignification treatment. Moreover, SCCSP0.7_E results

differ from those of the others, which can be an error in the delignification process. From Figure 6, it can be concluded that there is a significant effect of compressive strength for specimens with NaOH or delignification treatment. In line with [26][27], this result showed that banana fiber composite treated with 5% NaOH concentration could improve the mechanical properties. Contrastly, the test results described that the compressive strength decreased gradually by increasing the percentage of banana fibers in both mixtures compositions (normal and delignification). Compared to the control

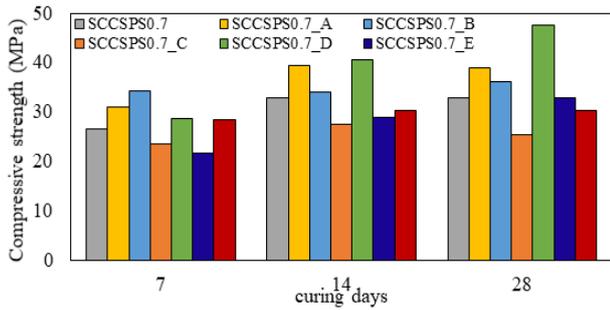


Figure 7: The compressive strength of specimens in different dosage percentages of banana fibers and treatment process

specimen, the additional banana fiber up to 0.3% still increases the compressive strength. It was observed that SCCSPS0.7_C and SCCSPS0.7_F, which higher dosage of banana fibers (0.5% of cement weight), did not qualify the standard requirement of fresh concrete based on EFNARC 2005. Moreover, the compressive strength of SCCSPS0.7_E decreased slightly around 7.5% compared to the control specimen of SCCSPS0.7. Similar observations were studied by Chandak et.al.[22], which stated that the additional 0.5% banana fibers could alleviate workability and compressive strength. According to Fig.8, the specimen with the adding banana fiber of 0.12% by weight of cement and NaOH delignification indicated a decrease in the workability and inversely can

increase compressive strength up to 44.36% if compared to the variation of control concrete. Untreated specimens more decreased compressive strength than treated specimens using NaOH Solution. This could be attributed to the presence of a proper proportion of NaOH Concentration and alkalization reaction. Alkalization can remove certain parts of unwanted elements such as lignin, cellulose, hemicellulose, natural oils, wax from the surface of banana fibers. This treatment also could produce a rough and clean fiber surface which can enhance the surface area, bonding between fiber, and performance of banana fibers [28][29]. Tensile test results of untreated and treated banana fiber in SCC mixture increased compared to control specimen without banana fiber can be shown in Table 8(a).

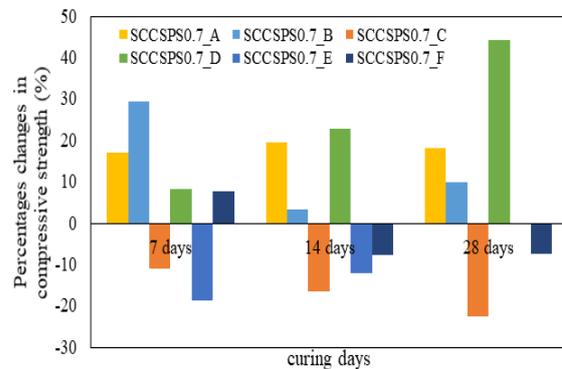
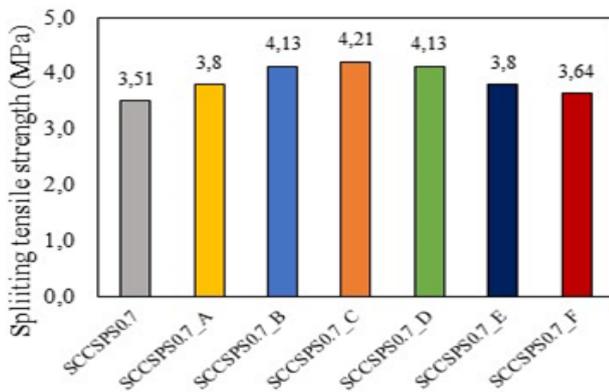
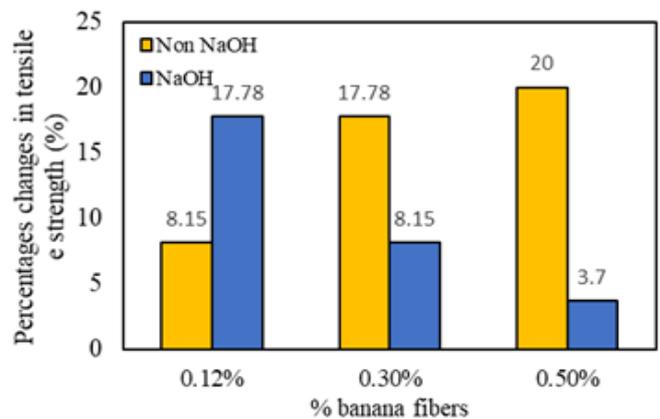


Figure 8: The percentage change in strength of specimen in different dosage of banana fibers and treatment process



(a) The splitting tensile strength



(b) The percentage change in tensile strength

Figure 9: The splitting tensile strength of specimens and the percentage change in tensile strength of the specimen

Figure 9(b) showed the ultimate tensile strength of banana fiber specimens. It can be concluded that the addition of banana fiber in the SCC mixture could enhance the tensile strength of concrete. In this experiment, SCCSPS0.7_C, adding 0.5% of banana fiber, showed the highest tensile strength result at 4.21 MPa and 20% higher than the control specimen SCCSPS0.7.

CONCLUSION

Based on the report research about the utilizing fiber for self-compacting concrete, the following conclusion are

drawn:

1. The effect of adding superplasticizer to self-compacting concrete increases the values of the fresh concrete according to the EFNARC 2005
2. The effect of adding banana stem fiber to self-compacting concrete decreases in the values of the fresh concrete results
3. The delignification process using NaOH improves the SCC mechanical performance of specimens in terms of compressive and tensile strengths.

4. Based on this experiment, it can be stated that the additional 0.12% of banana fiber that was alkaline treatment had a higher mechanical strength that can be applied for self-compacting concrete.
5. Based on the above result, it can be recommended to apply the utilizing banana fiber on two stages of concrete application.

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