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FRESH AND MECHANICAL CHARACTERISTICS OF SELF-COMPACTING POLYPROPYLENE FIBER CONCRETE INCORPORATED WITH KAOLIN

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Abstract -- *Self Compacting Concrete (SCC) is concrete with high fluidity so that it can flow and fill the spaces in the mold without the compaction process. This study discusses the effect of the adding of kaolin and polypropylene fibers in order to increase the flowability, compressive strength, flexural strength, and tensile strength in self-compacting concrete. The additional material of kaolin was 5%, 10%, and 15% of the cement weight. The polypropylene fibers were 1%, 1.5%, and 2%. The flowability test, which was used, was Table flow, V-Funnel, and L-Box. Compressive strength testing was conducted when the concrete was 7, 14, and 28 days old. The flexural test was performed with a measurement of 150 x 150 x 600 mm as many as 18 specimens tested at the age of 28 days. The results showed that the addition of kaolin and polypropylene fibers met the flowability specifications of self-compacting concrete. The addition of polypropylene can increase the flexural strength and tensile strength of the concrete beam, but cannot increase the compressive strength of self-compacting concrete.*

Keywords: *Self-Compacting; Fiber Reinforced; Flexural Strength; Compressive Strength*

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INTRODUCTION

Self-compacting concrete first developed in Japan in the 1980s, this kind of concrete has an excellent performance level and high compressive strength [1][2]. Self-compacting concrete can flow on its own following a gravitational force without segregation and compaction [3][4]. Self-compacting concrete has many advantages. It can reach areas that are difficult to be compacted or a very complicated area with reinforcement [5]. In its development, self-compacting concrete does not only use general materials that makeup concrete but also adds a variety of additional ingredients, both organic and non-organic. The addition of this material is expected to improve the performance of self-compacting concrete and produce a type of green concrete that is environmentally friendly.

The use of additional materials such as industrial waste is expected to improve the quality of self-compacting concrete. Several studies that have been conducted added admixture material into self-compacting concrete. The studies are iron slag [6], fly ash and rice husk ash [7, 8, 9], palm oil waste ash [5][10], bagasse ash waste [11][12], red brick masonry [13][14], Zeollite and Silica Fume [15, 16, 17] and various other types of waste that have the potential to be developed.

The use of kaolin waste in the manufacture of self-compacting concrete aims to improve the quality of concrete. Meanwhile, the use of polypropylene fibers seeks to increase the flexural strength and tensile strength of self-compacting concrete. Kaolin is one of the tin waste products from Bangka Island, Bangka Belitung Province, Indonesia. Therefore, this study discusses the effect of the adding of kaolin and polypropylene fibers in order to increase the flowability, compressive strength, flexural strength, and tensile strength in self-compacting concrete.

METHOD

This study conducted four types of experiments on fresh concrete and three types of tests on hardened concrete. The variations used in this study were as many as six variations where the differences of SCC-01 to SCC-03 used different kaolin ingredients. In contrast, the variations of SCC-04 to SCC-06 used the kaolin composition of 5% of the weight of cement and various compositions of polypropylene fibers.

The main constituent in making this concrete consisted of cement with a type of Portland Pozzolan Cement with a specific gravity of 3.15. In addition, the other main ingredients used were water, coarse aggregates, and fine aggregates. Before using both types of aggregates, the mechanical properties must be examined first. The results of the properties test examination are seen in Table 1, where the components examined were consisted of specific gravity, moisture content, water absorption, sludge content, unit weight, and specific aggregate roughness for coarse aggregate.

Table 1. Fine and Coarse Aggregate Properties

Parameter	Fine Aggregate	Coarse Aggregate
Specific Gravity	2.49	2.61
Water Content (%)	5.50	3.32
Water Absorption (%)	2.10	0.09
Mud Content (%)	2.97	4.26
Bulk Density (gr/cm3)	1.52	1.54
Aggregate Abrasion (%)	-	36.11

The results of the examination show that all of these aggregates could be used as a base for making concrete [18].

The manufacturing self-fiber compacting concrete cannot be separated from the use of chemical additives, namely superplasticizers, which in this study were used with a constant amount. The additive material which was varied was kaolin and polypropylene fibers. Kaolin aims to improve the quality of self-compacting concrete and utilize waste, which until now has not been used optimally. Meanwhile, polypropylene fibers were used to increase the flexural strength and tensile strength of self-fiber compacting concrete. The form of these two additive materials can be seen in Figure 1.

This study used a total of 6 variations, where each variety would be tested for its compressive strength and flexural strength, and several variations would be tested for their tensile strength. Each variation used the same content of cement, water, aggregate, and superplasticizer. Specimens SCC-01 up to SCC-03, respectively, used variations of kaolin of 5%, 10%, and 15% taken from the weight of cement. Whereas in the variation of SCC-04-SCC-06 are used polypropylene fibers 1%, 1.5%, and 2% of the total weight of cement.

(a) (b)

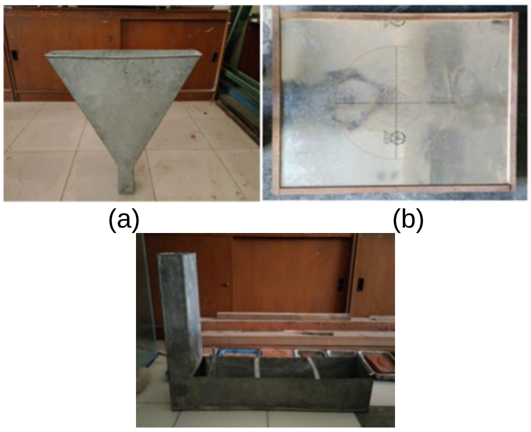
Figure 1. Additive Materials.
(a) Kaolin (b) Polyprophilene Fiber

In Table 2, the entire content of compacting concrete self-fiber per 1 m3 could be seen. Mix ID uses the same material of cement 485 kg, fine aggregate 977 kg, coarse aggregate 561 kg, and water 203 L.

Table 2. Mix Design of self-fiber compacting concrete for 1m^3

Mix ID	Kaolin (Kg)	Polypropylene Fiber (kg)	Superplasticizer (L)
SCC-01	24.25	-	4.85
SCC-02	48.50	-	4.85
SCC-03	72.75	-	4.85
SCC-04	24.25	4.85	4.85
SCC-05	24.25	7.28	4.85
SCC-06	24.25	9.70	4.85

The stirred concrete needed to be checked in its flowability. It aimed to make this concrete includes in the category of self-compacting concrete. In this study, the fresh concrete testing carried out was V-Funnel testing, L-Box testing, Flow Table, and T50 testing. The testing equipment was, as shown in Figure 2. The good self-compacting concrete should meet the standard of the fresh concrete test to prevent the segregation during the casting process [3]. In addition, this test is one of the ways to make sure that this fresh concrete flows and does not need compaction. After completing the fresh concrete test, all concretes were put into the formwork of the test specimen.



(a) (b)

(c)

Figure 2. Fresh properties of self-fiber compacting concrete: (a) V-Funnel, (b) Flow Table, and (c) L-Box

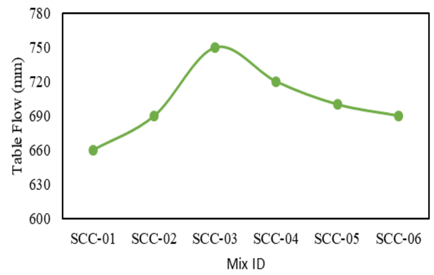
The testing of compression strength was conducted when the concrete's age was 7, 14, and 28 days old. Cylindrical compression test specimens have a diameter of 150 mm and a height of 300 mm [19]. Each variation consisted of nine specimens so that the total specimen for the compressive strength of self-fiber compacting concrete was 63 specimens. Flexural testing was conducted when the specimen was 28 days old, with the specimen in the form of a block of 150 mm x 150 mm x 600 mm [20]. Each of the variations in this study consisted of three specimens. So, for the concrete flexural test, there were 18 specimens. Meanwhile, the concrete tensile test was only carried out on the specimens given polypropylene fibers, namely specimens with the code SCC-04 up to SCC-06, with each variation consisting of nine specimens. The shape of the concrete tensile test specimen was the same as the concrete compressive strength specimen with a complete specimen of 36 cylinders.

RESULT AND DİSCUSSİON

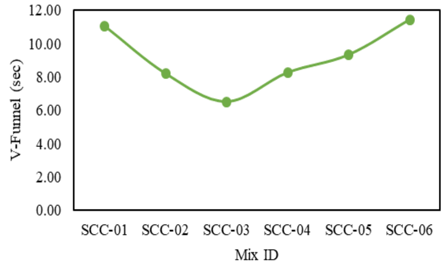
In the fresh concrete testing, what was done is table flow, V-Funnel, L-Box, and T50. The whole testing result can be seen in Figure 3. It was obtained the highest achievement in SCC-03 with the value of 750 mm. This variation has the best spreadability compared to the others. From the result of the Table flow, it can be concluded that all the specimens met the minimum specification of flowability value for the self-compacting concrete. According to the standard decided, the flowability value for self-compacting concrete should be between 650 mm up to 800 mm.

The V-Funnel test was conducted to know the flow time needed by self-compacting concrete. V-Funnel test required the result of the test should be in the ranges from 6.0 seconds to 12 seconds. From this test, it was obtained the smallest result at the specimen of SCC-03 with a duration of 6.50 seconds. Meanwhile, the longest flow time was obtained at the specimen of SCC-01 with duration 11.06 s and SCC-06 with duration 11.42 s. Through this test, it can be concluded that all the specimens met the specification and flow time for self- compacting concrete in which SCC-03 had the fastest flow time.

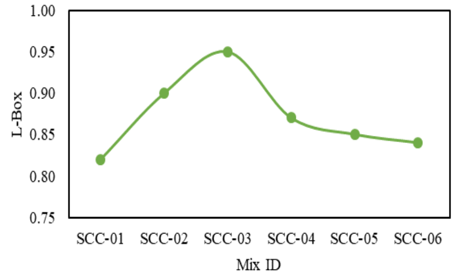
The L-Box test was done to know the passing ability of self-compacting concrete in reinforcement and obstacles. The result was obtained by comparing the altitude upstream and downstream, where the constraint in the form of steel reinforcement is set in the flow pattern. When the value is strictly equal to 1.0, then the composition of self-compacting concrete can flow through the reinforcement well. When carrying out the L-Box test, it is better to have the result no more than 0.8. In this test, a specimen with the highest value is the SCC-03 with 0.95, while the SCC-01 has the lowest value with 0.82. From the L-Box test, it can be concluded that the entire testing materials meet the required specifications because the specimens are resulting in more significant results than the predetermined minimum standard.



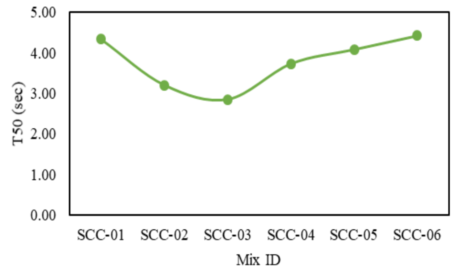
(a) Table Flow



(b) V-Funnel



(c) L-Box



(d) T-50

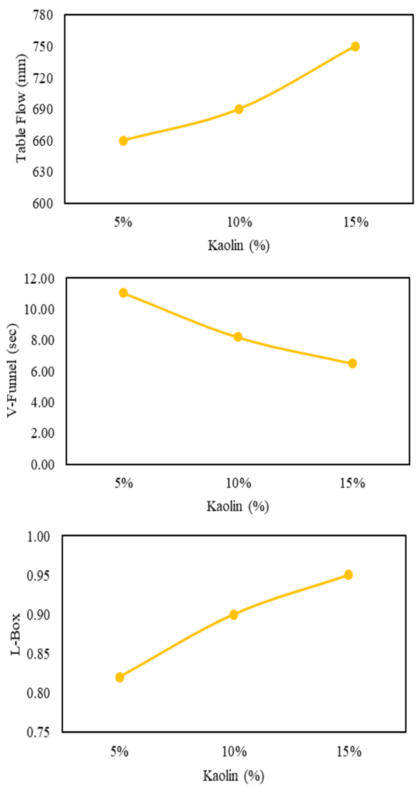
Figure 3. The Result of Fresh Properties Test on Self-Fiber Compacting Concrete

The T50 test was carried out with the table flow test. The purpose of this test is similar to the V-Funnel test, i.e., to know fast-flowing time from the self-compacting concrete. The results of the T 50 test should range from 2 seconds to 5 seconds. This test showed that the SCC-03 specimen has the lowest value of T50, i.e., 2.85 seconds. At the same time, the SCC-06 specimen has the most significant value of T50, i.e., 4.42 seconds. The test result showed that all specimens fulfill the predetermined specification.

Based on the test of fresh properties, it can be concluded that the entire compositions have the potency to be used as self-compacting concrete because they have fulfilled the predetermined specifications. SCC-03 specimen has the best value of fresh properties while SCC-01 and SSC-06 specimens have flowability values that are not good but still meet the specifications specified.

Figure 4 shows the relationship of fresh properties on additional materials, i.e., kaolin ash and polypropylene fiber. Several things that can be concluded are when the composition of kaolin increases then, the value of the flow table will increase. Also, it will enhance the ability of concrete to pass the reinforcement. However, the high amount of kaolin also has the potential to decrease the flow time the concrete. The situation can be seen through the results of the V-Funnel and T50 test, which show that the results are getting smaller if the composition of kaolin is increasing.

The use of polypropylene fiber has the potential to decrease the value of flow through the table flow test. Also, the V-Funnel test shows that increasing polypropylene fiber will reduce the ability of concrete in passing barriers. The intersection result was obtained through the V-Funnel test, which indicates that the increase of fiber has the potential to accelerate the spread time of self-compacting concrete. The same thing can also be concluded through the T50 test results.



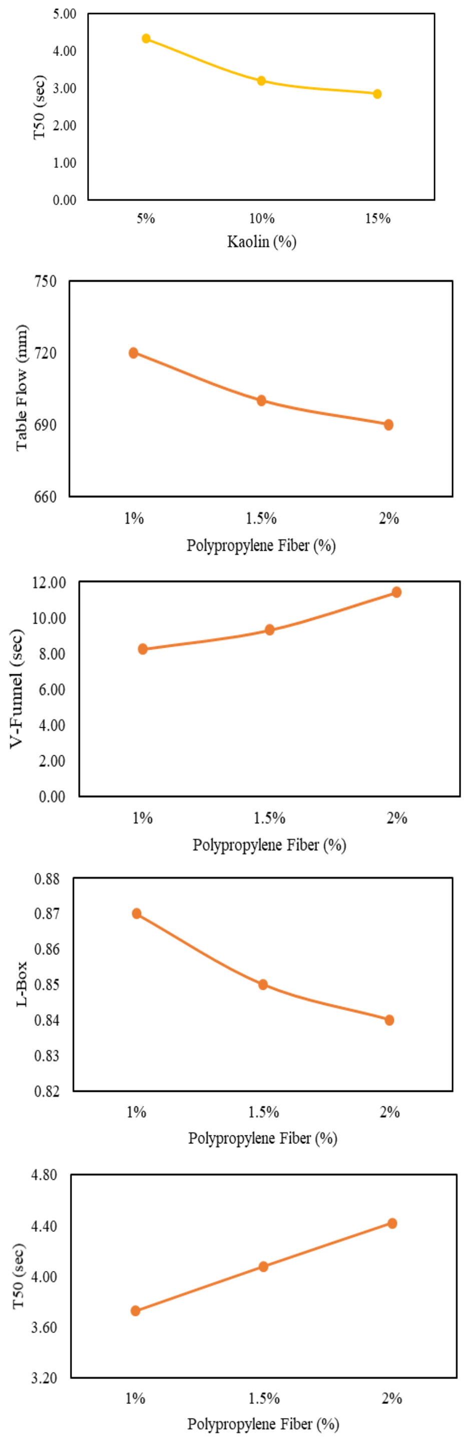


Figure 4. The relationship between the Test results of Fresh Properties with the Composition of Kaolin and Polypropylene Fiber

Based on the entire fresh properties test, it can be concluded that all variations are good enough even though they have the potential pattern to decrease the flowability value. The size of polypropylene fiber should be in the range of 1 cm to 2 cm. It is becoming a concern when the length of fiber is quite long because the fiber can be caught in reinforcement. As a consequence, the concrete flowing time will be disturbed. Furthermore, the thing that should be focused on is the size of the aggregate. The size of the aggregate needs to meet the specifications that have been determined.

The compression strength test was carried out at the age of maintenance; 7, 14, and 28 days. Figure 5 shows the test result of concrete compression strength. Based on the test result, it can be concluded that the increasing age of concrete will increase the concrete compressive strength. When the concrete is seven days old, the compressive strength obtained ranges from 21.6 Pa to 24.2 MPa. When the concrete is 28 days, the compressive strength obtained intervals from 28.7 MPa to 31.2 MPa. Each variation of the specimen does not have a deviation regarding concrete compressive strength. SCC-02 and SCC-04 have the highest compressive strength, respectively 31.2 MPa and 31.1 MPa. At the same time, the SCC-06 has the lowest compressive strength of 28.7 MPa.

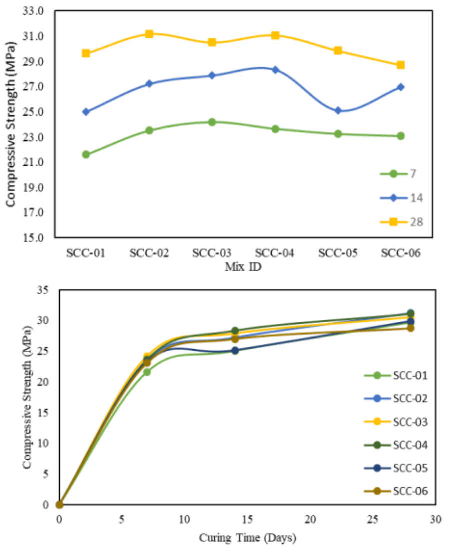


Figure 5. The Test result of Compression Strength of Self-Fiber Compacting Concrete

Figure 6 explains the relationship between compression strength with the composition of kaolin and polypropylene fiber. The optimum composition of kaolin in producing the concrete is 10%. The use of kaolin, more than 10%, will decrease the compression strength as well as the use of kaolin less than 10%. The polypropylene fiber has no significant effect against the compression strength, even reduces the value of compression strength. This description can be seen in Figure 6.

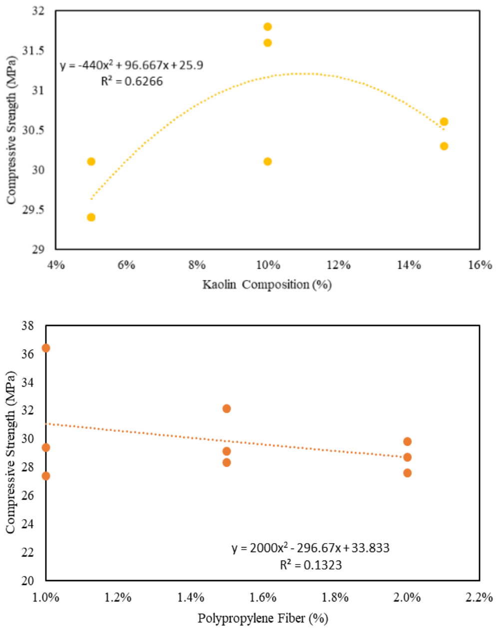


Figure 6. The Relationship between the Compression Strength with the Additive Materials of Kaolin and Polypropylene Fiber

The flexural strength test was conducted for a 150 x 150 x 600 mm concrete beam at 28 days of maintenance. Based on the test result in Figure 7, it can be seen that the SCC-06 specimen has the biggest flexural strength compared to the other specimens, i.e., 9.54 MPa. It can be concluded that the flexural strength of the concrete with the addition of polypropylene fiber is more significant than the concrete without the addition of polypropylene fiber. In Figure 7, the specimen of SCC-01 to SCC-03, resulting in the flexural strength under the flexural strength of SCC-04, where the test object was the use of 1% polypropylene fiber.

The value of displacement that resulting from the flexural strength test is quite multiform. The result of displacement for test object without using fiber is 6 mm - 8 mm. At the same time, for test objects with using fiber, the value of displacement is approx. 11 mm - 24.5 mm. This thing indicates the fiber can decrease the level of brittleness in concrete.

The addition of kaolin in self-fiber compacting concrete affects the flexural strength of concrete. From the result, it was obtained a 10% maximum level of kaolin to be the mixture material for concrete production. From Figure 8, it can be concluded that the use of kaolin will affect the value of concrete brittleness. The more kaolin being used, the smaller the displacement value will be obtained. As a consequence, the concrete will be more brittle.

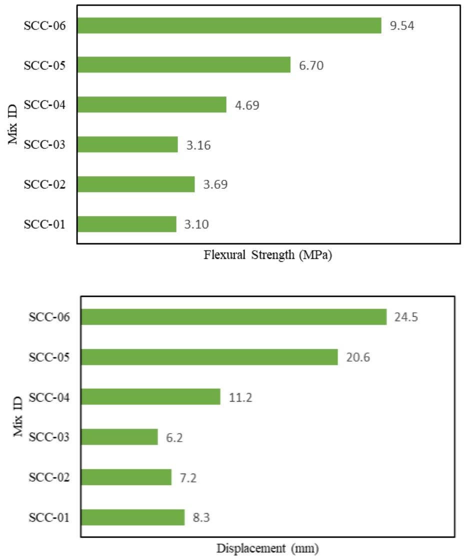


Figure 7. The Result of Flexural Strength and Displacement

The use of polypropylene fiber in the concrete can potentially improve the concrete flexural strength. As described in Figure 8, it can be seen that the more fiber being used, the flexure strength will be increasing. The polypropylene fiber can also decrease the level of concrete brittleness – the more fiber being used. The value of displacement will be more significant. As a consequence, the concrete will be more clayey.

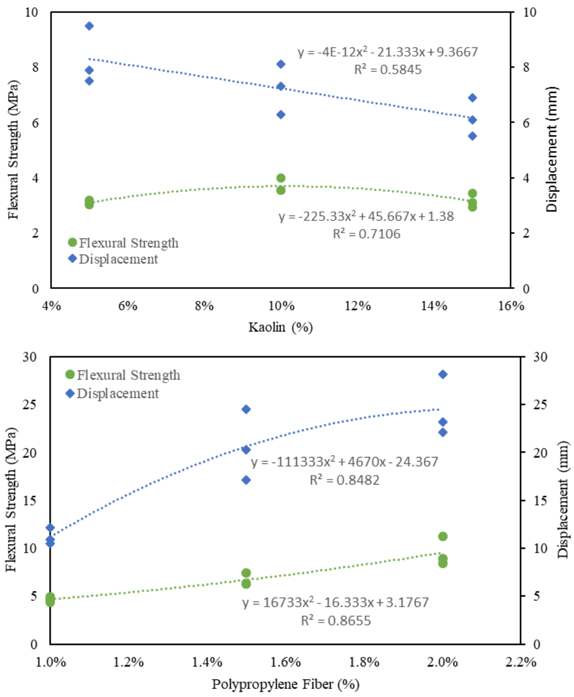


Figure 8. The Effect of Kaolin and Polypropylene Fiber Additions towards Flexure Strength and Displacement

Figure 9 shows the example of a specimen that has been tested by the flexure test. This test was using the load in the middle of the span. Displacement was measured in the middle of specimens by LVDT. The crack pattern resulted is the flexible crack pattern that only focuses on the middle of the span. The failure of this specimen is on the tensile strength. It can be seen from the location of the crack that the area of the tensile of the reinforced concrete beam.

Figure 9. the result of the flexure test; crack pattern in the concrete beam

The test of tensile strength is only carried out on concrete with a mixture of polypropylene fiber. Based on the test result in Figure 10, it can be seen that the highest tensile strength resulted from SCC-06, which has an objective test of high fiber level. The compression strength resulted in 7 days concrete is 1.76 MPa while the tensile strength of 28 days concrete is 2.27 MPa. Moreover, the lowest tensile strength resulted from specimen SCC-04, which using the composition of approx -1 % fiber.

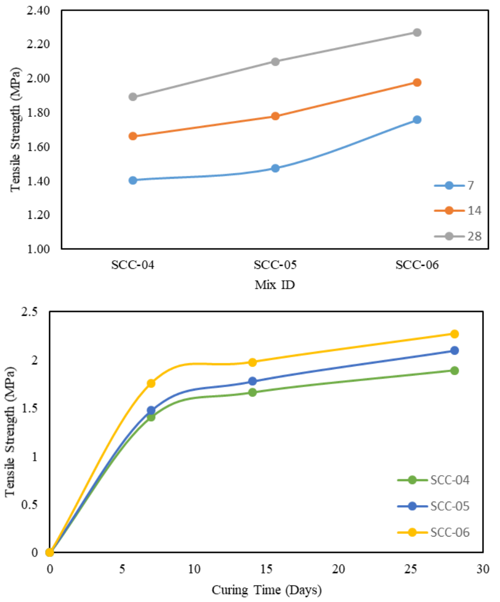


Figure 10. The test result of the tensile strength of concrete

Figure 11 can explain that the composition of polypropylene fiber impacts the value of tensile strength of self-fiber compacting concrete, i.e., the more fiber being used, the higher the tensile strength will be obtained. Further research needs to utilize more fiber to know the optimum level. Therefore, the suitable flexure and tensile strength for self-fiber compacting concrete will be obtained.

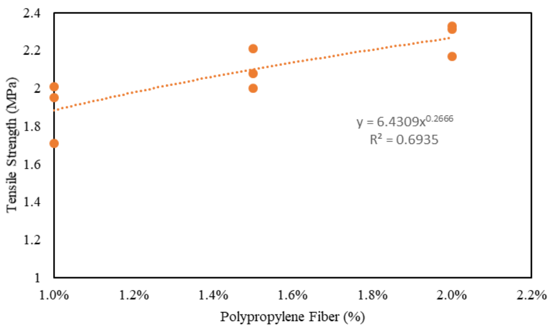


Figure 11. The relationship of the additional polypropylene fiber against tensile strength of concrete

CONCLUSIONS

Based on results and discussion in advance, it can be concluded the utilization of kaolin and polypropylene fiber in self-fiber compacting concrete fiber has no significant effect on compressive strength, but significantly affects flexure and tensile strength. The use of kaolin levels of 5; 10 and 15% and polypropylene fibers 1; 1.5 and 2% of cement weight can be used as self-fiber compacting concrete because it produces fresh properties that meet the specifications, and the optimum amount of kaolin which is good at making self-compacting concrete is 10%. It will produce optimum compressive strength and flexural strength.

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