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Fresh Properties Characteristics and Compressive Strength of Fiber Self-Compacting Concrete Incorporated with Rice Husk Ash and Wire Steel Fiber

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Abstract: Self-compacting concrete (SCC) is one of the innovations in concrete technology to help constructors in the casting process in hard-to-reach locations and to reduce the possibility of pores. SCC can also be green concrete by mixing it with some waste material without reducing its strength. In this study, SCC uses two types of materials, namely rice husk ash and wire fiber to produce green concrete and increase strength. Several experimental activities were carried out to examine the fresh and mechanical properties of the compacting fiber concrete itself. Fresh properties testing performed consisted of L-Box Test, V-Funnel Test and J-Ring Test. Whereas the investigation on mechanical properties was carried out by testing the compressive strength at 7, 14 and 28 days. The total sample used in this study amounted to 180 samples with a diameter of 15 cm and a height of 30 cm. Variations in this study consisted of a proportion of a mixture of rice husk ash and wire fibers in concrete. The results of the fresh nature test revealed that the addition of rice husk ash and wire fiber in SCC with a certain ratio could be used and accepted as self-compacting concrete. Furthermore, the mechanical properties test results show that there is an optimal proportion of mixing of the two materials to achieve normal concrete compressive strength.

Keywords: Self-compacting concrete, mechanical properties, rice husk ash, wire tie

1. Introduction

Self-compacting concrete is the development of conventional concrete, the difference of it does not require a vibrator to make concrete into solid, this concrete has an excellent performance against the deformability and very high resistance to segregation, so it can solidify itself in the area of reinforcement without the need for compacting process (Akram, Memon, & Obaid, 2008). Self-compacting concrete first developed in Japan in the 1980s (Ozawa, Maekawa, Kunishima, & Okamura, 1989). In its development, self-compacting concrete has been applied to various infrastructures in various countries (Ouchi, Nakamura, Osterberg, & Hallberg, 2003) such as in the manufacture of prestressed girder beams (Pozolo, and Andrawes, 2011) applications on buildings (Khaloo, Molaei, Hosseini, and

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Tahsiri, 2014) and the utilization of self-compacting concrete on many dams (Beigi, Berenjian, Omran, Nik, & Nikbin, 2013).

In its development, self-compacting concrete not only uses the concrete material in general but can be added with various materials both organic and inorganic (Prayuda, Saleh, Maulana & Monika, 2018). Several studies have been done using fine aggregates and coarse aggregates from recycled aggregates (Manzi, Mazzotti, & Bignozzi, 2017), Waste of palm oil ash (Thomas, Kumar, & Arel, 2017), using fly ash, rice husk ash and meta-kaolin (Kannan, 2018), also a waste of bagasse ash (Moretti, Nunes, & Sales, 2018). So in this research will make innovations using the admixture materials of rice husk ash and fiber from wire tie in the production of fiber self-compacting concrete.

In Indonesia, there is still a considerable waste of agricultural production and plantations that are not well utilized, such as palm oil plantation waste in Sumatra and Borneo, plantation waste from the sugar cane industry in parts of Sumatra and Java, as well as waste from rice cultivation that is almost evenly distributed throughout the country. With the potential waste, this research will discuss the utilization of rice husk ash waste and the addition of wire fiber as fiber self-compacting concrete.

In this study, the cylindrical test specimens were 15 cm in diameter and 30 cm high with 90 test specimens divided by a total of 10 variations of mixed proportions. some of the tests carried out are the mechanical properties of fine aggregates and coarse aggregates (ASTM C33, 2016), tests of properties for fresh concrete consisting of slump flow, L-Box, V-Funnel and J-Ring (EFNARC, 2002) as well as concrete compressive strength testing at 7, 14 and 28 days (ASTM C39, 2017). Through this research, it is expected to utilize rice farm waste to be optimally used, can produce green self-compacting concrete, reduce cement used and reduce the production price of self-compacting concrete.

2. Materials and Test Method

This research was conducted in Structural and Construction Materials Laboratory, Universitas Muhammadiyah Yogyakarta, with total 10 variations of the proportion of constituent material. Each variation consists of 9 test specimens performed by compressive strength test at age 7, 14 and 28 days so that the total of test specimens is 90 cylindrical samples.

The main elements of Concrete generally consist of cement, water, and aggregate as well as certain added materials to improve the required performance. In this study, the concrete material comprises the following. Cement as the main constituent material using Gresik brand with Portland Pozzolan Cement type, the specific gravity of this cement is 3.15. Semen Gresik from East Java province, Indonesia.

Aggregates used in this study consist of fine aggregates and coarse aggregates. The aggregate overall is taken from Kulon Progo Regency, Special Province of Yogyakarta, Indonesia. In Fig. 1 shows the shapes of each aggregate used in both coarse aggregates and fine aggregates. Each aggregate is tested for mechanical properties referring to the standard (ASTM C33, 2016). Table 1 describes the results of sieve analysis fine aggregates test shows that the sand used is very fine sand with the fine grain modulus value of 2.93%. The water content test results of 6.80% indicate that this fine aggregate is still in very dry condition, while the mud content contained is 2.97% which still meets the safe limits of mud content on fine aggregates for the manufacture of concrete.

Table 1- Fine aggregate test result.

Testing Items	Result			Final Result
	Sample 1	Sample 2	Sample 3	
Grain Gradation	Very Smooth	Very Smooth	Very Smooth	Very Smooth
Fine Grain Modulus (%)	2.86	2.97	2.97	2.93
Spesific Gravity	2.52	2.44	2.44	2.47
Water Absorption (%)	8.80	9.10	9.60	9.17
Water Content (%)	4.36	7.12	8.91	6.80
Mud Content (%)	4.00	2.50	2.40	2.97
Unit Weight (g/cm³)	1.48	1.55	1.54	1.52

Table 2- Coarse aggregate test result.

Testing Items	Result			Final Result
	Sample 1	Sample 2	Sample 3	
Water Content (%)	3.11	3.42	3.45	3.33
Spesific Gravity	2.50	2.49	2.48	2.49
Water Absorption (%)	2.48	2.06	1.76	2.10
Unit Weight (g/cm³)	1.49	1.56	1.56	1.54
Mud Content (%)	13.20	12.40	9.00	11.53
Roughness Level (%)	36.10	36.00	37.20	36.43

In Table 2, the results of the test were from the coarse aggregate of the moisture content of 3.33%, in this case, it was categorized as a very dry aggregate because the water content in the aggregate was very wet. The mud content of the aggregate is 11.53%, it shows that the mud content is too high in the aggregate, so it is necessary to wash the whole aggregate because the mud content is required not more than 1%. While the absorption test aims to determine the level of aggregate roughness, as for the results of the roughness test of 36.63%, this still meets the requirements of not more than 40%. From the results of testing fine aggregates and coarse aggregates, it can be concluded that these two aggregates can be used as constituent materials.

a b

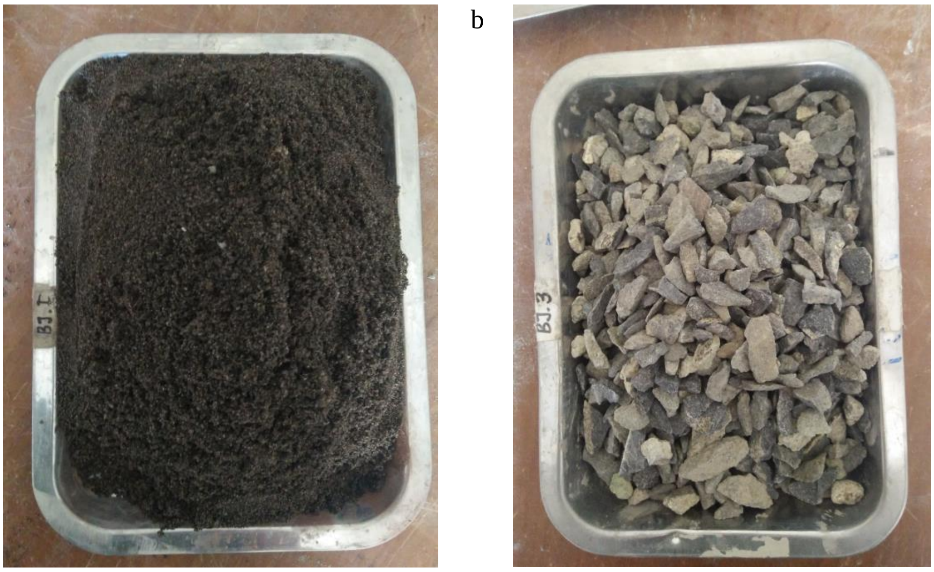

Fig. 1 - (a) Fine aggregate; (b) Coarse aggregate.

Rice husk ash was used in this study as an ingredient added to the cement substitute, the composition used depends on the variation of the test object whose percentage was taken from the composition of the cement for self-compacting concrete under normal conditions. Rice husk ash used was taken from agricultural waste in Bantul Regency, Yogyakarta Special Province. Before using it, this ash is first filtered with a sieve passes No 200. In Fig. 2(a) seen the shape of rice husk ash used in this research.

Superplasticizer is the most important part in making self-compacting concrete, in this study using Viscocrete-1003 type produced by PT. Sika Indonesia. Viscocrete-1003 is an addictive material used to make concrete with a high flowability value and reduce the use of water in large enough quantities up to 30%. Usefulness of this added ingredients is common for high flow concrete such as self-compacting concrete, high strength concrete, and mass concrete. The proportion of superplasticizer use in this study varies according to the variation used with the percentage of the weight of cement.

The wire tie used in this study looks like in Fig. 2(b), only before use, the wire is cut into small pieces up to 1-2 cm in size. The percentage of wire fiber used in this study varied based on the total concrete weight of the plan produced. The water used that meets the requirements for use by humans as a daily necessity. In this study, water was used from the Structure and Material Technology Laboratory, Muhammadiyah University of Yogyakarta.

a b

Fig. 2 - (a) Rice husk ash; (b) Wire as fiber.

In this study consists of 10 variations of test specimens, as for the type of variation can be seen in Table 3 below. The percentage of rice husk ash and Viscocrete-1003 used from the weight of the cement used, while the wire fiber of the wire tie taken from the total weight of the concrete produced by the mix design.

Table 3 - Variation of self-compacting concrete samples

Code	Variation
SCC – 01	Rice Husk Ash 10% + Viscocrete-1003 0,6 % + Wire Tie Fiber 0%
SCC – 02	Rice Husk Ash 10% + Viscocrete-1003 1,6 % + Wire Tie Fiber 0%
SCC – 03	Rice Husk Ash 10% + Viscocrete-1003 1,0 % + Wire Tie Fiber 0%
SCC – 04	Rice Husk Ash 5% + Viscocrete-1003 1,0% + Wire Tie Fiber 0%
SCC – 05	Rice Husk Ash 15% + Viscocrete-1003 1,0% + Wire Tie Fiber 0%
SCC – 06	Rice Husk Ash 10% + Viscocrete-1003 1,0% + Wire Tie Fiber 0,5%
SCC – 07	Rice Husk Ash 10% + Viscocrete-1003 1,0% + Wire Tie Fiber 1,5 %
SCC – 08	Rice Husk Ash 10% + Viscocrete-1003 1,0% + Wire Tie Fiber 1,0%
SCC – 09	Rice Husk Ash 10% + Viscocrete-1003 0,6 % + Wire Tie Fiber1,0 %
SCC – 10	Rice Husk Ash 10% + Viscocrete-1003 1,6% + Wire Tie Fiber 1,0 %

The number of constituent material requirements from each variation can be seen in Table 4 for each making in 1m3. Each variation in this research is made 27 concrete cylinders with diameter of 15 cm and height 30 cm.

Table 4 - The composition constituent materials for 1m^3.

Materials	The composition of Each Variation									
	SCC-01	SCC-02	SCC-03	SCC-04	SCC-05	SCC-06	SCC-07	SCC-08	SCC-09	SCC-10
Cement (kg)	436.50	436.50	436.50	460.75	412.25	436.50	436.50	436.50	436.50	436.50
Fine Agg (kg)	977.00	977.00	977.00	977.00	977.00	977.00	977.00	977.00	977.00	977.00
Coarse Agg (kg)	561.00	561.00	561.00	561.00	561.00	561.00	561.00	561.00	561.00	561.00
Water (L)	189.75	189.75	189.75	189.75	189.75	189.75	189.75	189.75	189.75	189.75
SP (L)	3.20	7.76	4.85	4.85	4.85	4.85	4.85	4.85	2.91	7.76
RHA (kg)	48.50	48.50	48.50	24.25	72.75	48.50	48.50	48.50	48.50	48.50
WTFiber (kg)	-	-	-	-	-	11.09	33.26	22.18	22.16	22.21
Weight (kg)	2215.9	2220.5	2217.6	2217.6	2217.6	2228.6	2250.8	2239.7	2237.8	2242.7
w/p	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39

In this study do several types of testing such for fresh concrete and hardened concrete. At the time of fresh concrete will be tested in the form of Flow Table, V-Funnel, L-Box, and J-Ring. After testing the fresh concrete, the hardened concrete cylinder was cured by soaking it into water then tested for compressive strength at 7, 14 and 28 curing days.

Slump flow and T500 testing are done to determine the level of workability in self-compacting concrete; this test uses a spread table and conical Abrams as in Fig. 3. Slump flow testing is categorized into 3 parts, namely SF1 with a scattering value of 550-650 mm which is suitable for construction with not a lot of reinforcement, casting with injection pumps and components with a small size. The second category is called SF2 with a spread value of 660-750 mm; this category is the best spread value for self-compacting concrete. While the third category with a scattering value of 760-850 mm is more suitable for vertical construction.

a

b

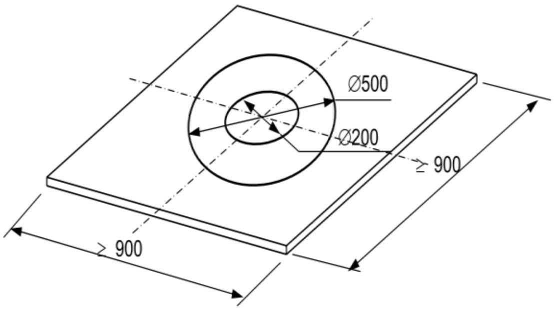

Fig. 3 - (a) Flow Table; (b) Flow Table dimension (EFNARC, 2005)

L-Box testing to determine the level of ability of fresh concrete flowing through reinforcement in limited space. This test uses L-shaped tool with 3 pieces of reinforcement in it as in Fig. 4. The conditions are determined according to EFNARC (2005) that the value of H2 / H1 must be greater than 0.80. The value of H2 / H1 approaching 1.00 indicates that there is no elevation difference between upstream and downstream of the test object, so it is concluded that barriers in the form of reinforcement do not affect the value of flow in self-compacting concrete.

a

b

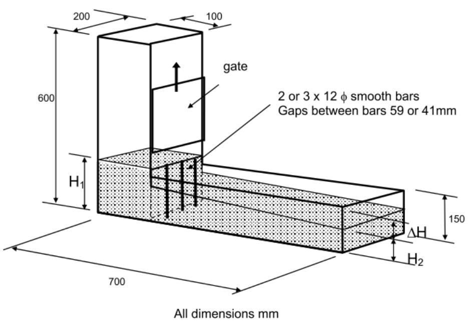

Fig. 4 - (a) L-Box Tool; (b) L-Box tool dimension (EFNARC, 2005).

V-Funnel test to determine the flow velocity of fresh concrete. In Fig. 5 shows the V-Funnel testing tool that is shaped like the letter V, in this test is recorded the total time needed for the concrete to flow until it is finished. This testing classification consists of 2 parts, if the time produced is less than 8 seconds, it shows that the concrete is very good at filling the sides of the formwork and will create a flat surface, but it is vulnerable to bleeding and segregation. If the time produced ranges from 9-25 seconds shows that the concrete produced can reduce the pressure during the casting process on the formwork and increase resistance to segregation, but the resulting surface is not neat.

a

b

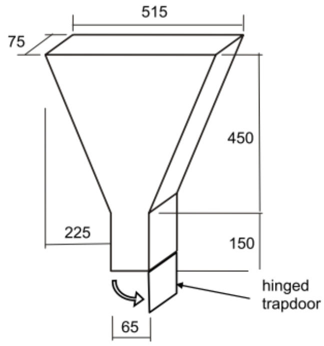

Fig. 5 - (a) V-Funnel tool; (b) V-Funnel tool dimension (EFNARC, 2005).

J-Ring testing is used to determine the ability of self-compacting concrete to pass through a gap or passing ability. This test uses the tool as in Fig. 6, in this test, requires the help of Flow Table and Abrams cone. The concrete compressive strength test is performed using a compression test machine where the compressive strength is obtained from the maximum load that can be received by concrete cylinders divided by the surface area of the concrete receiving load in MPa (Mega Pascal).

a

b

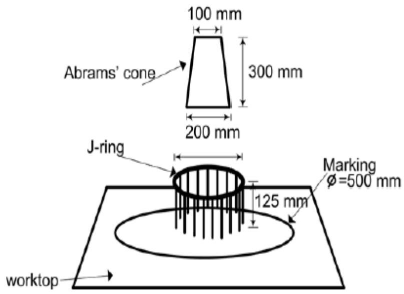

Fig. 6 - (a) J-Ring tool; (b) J-Ring Tool dimension (EFNARC, 2005).

3. Result and Discussion

Testing of fresh properties must be done on self-compacting concrete. This aims to ensure fresh concrete can really flow and there is no segregation. As for several factors that must be considered is the nature of concrete that can flow bring all the material in the form of concrete formwork and concrete ability in passing obstacles such as reinforcement. Fig. 7(a) describes the relationship between each variation of a test object and the results of slump flow testing. In slump flow testing, the SCC-05, SCC-07 and SCC-09 specimens were categorized as having low flow values even though they were still included in the self-compacting concrete category. SCC-05 produces the smallest slump flow because this variation uses the highest amount of rice husk ash added by 15%, so that the amount of water absorbed by the material also influences the flowability level of this variation, while the variation in SCC-07 also produces Low flowability because it uses the highest wire tie fiber of 1.5%. While for SCC-09 using rice husk ash as 10% and fiber by 1% and viscocrete-1003 use only 0.6% so with decreasing amount of superplasticizer also can influence workability value of self-compacting concrete.

In the L-Box test as in Figure 7(b) shows that all variations meet the specified standards where the L-Box test results must be at least 8.0 mm, whereas, in this test, all variations produce L-Box values above 8.00 mm. The V-Funnel test requires that for self-compacting concrete must be between 6 sec to 12 sec, the test results in that all samples meet the requirements, the SCC-10, SCC-08, and SCC-09 samples have the highest V-Funnel results, namely above 10 sec but still below 12 sec. The test from V-Funnel aims to check the speed of fresh concrete flowing, if the results obtained are more than 12 sec, it is feared that hardening will occur during the casting process before the concrete solidifies and evenly flattens. In the J-Ring test as in Figure 7(d) shows all test results are above the specified conditions, this shows that all variations used to meet the standard qualifications of the J-Ring test. Whereas in the T50 test requires that when testing slump flow, fresh concrete must have stopped spreading within a period of 2 sec to 5 sec, the results of the test can be seen in Figure 7(e) that all of these variations meet the standards of the T50 test. In the T50 test it was seen that the longest standing fresh concrete stopped spreading was SCC-09 and SCC-08 where it was similar to the result of V-Funnel By testing fresh properties it can be concluded that all variations in this study are eligible for use as self-compacting concrete, only for SCC-05, SCC-07 and SCC-09 are categorized as having low flowability value.

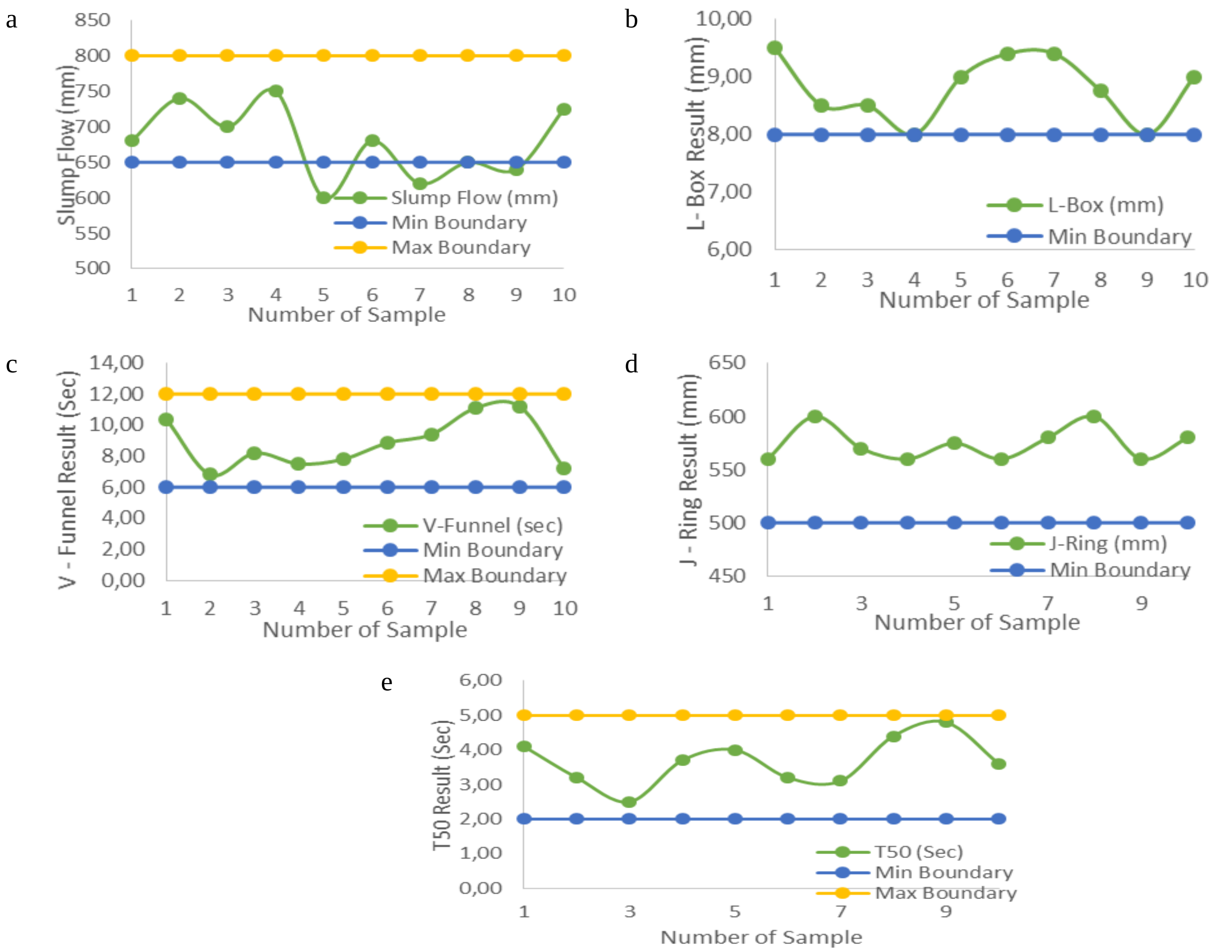

Fig. 7 - (a) Slump flow test result; (b) L-Box test result; (c) V-Funnel test result; (d) J-Ring test result; (e)T-50 test result.

Testing of compressive strength of concrete is done at the age of 7 days, 14 and 28 days. In Table 5 and Fig. 8 (a) shows that the concrete with the highest compressive strength at 28 days is SCC-03 with 72.38 MPa, this concrete is combining 10% rice husk ash, using 1% Viscocrete and 0 % wire tie fiber. Concrete by using wire tie fiber obtain the highest compressive strength is 67.70 MPa, mixed fiber used Wire tie 0.5%. Figure 8 (b) shows that the increasing age of concrete treatment will increase the compressive strength of the concrete. From all variations in this study, SCC-02 obtained the smallest compressive strength of 50.80 MPa at 28 days test age. SCC-02 is a variation consisting of 10% rice husk ash and Viscocrete 1003 as much as 1.6%. This suggests that too much use of the superplasticizer is also not good for concrete compressive strength although it has a fairly good flowability rate due to the superplasticizer properties that can make fresh concrete very dilute with minimum water content.

Table 5 - Compressive strength test result

Age	SCC-01	SCC-02	SCC-03	SCC-04	SCC-05	SCC-06	SCC-07	SCC-08	SCC-09	SCC-10
7	33.20	30.80	59.24	55.00	49.88	41.98	43.55	36.99	45.28	31.95
7	34.80	34.70	54.81	61.93	49.68	42.71	38.14	34.54	49.50	38.61
7	35.40	31.40	57.15	55.27	47.56	41.85	40.19	42.29	44.91	36.00
Average	**34.47**	**32.30**	**57.07**	**57.40**	**49.04**	**42.18**	**40.63**	**37.94**	**46.56**	**35.52**
14	32.40	41.60	62.88	59.69	59.93	38.28	46.23	48.60	52.19	48.44
14	37.70	36.30	72.86	56.69	54.53	49.001	48.47	44.59	57.44	53.96
14	35.90	39.70	55.36	60.32	58.20	47.74	46.31	49.36	55.34	49.34
Average	**35.33**	**39.20**	**63.70**	**58.90**	**57.55**	**45.01**	**47.00**	**47.52**	**54.99**	**50.58**
28	54.00	48.70	71.45	67.83	68.10	59.06	57.30	64.36	62.37	55.68
28	54.20	51.80	82.79	64.42	61.96	77.93	51.77	64.50	61.58	54.49
28	58.50	51.90	62.91	68.54	66.14	66.12	58.61	68.55	64.23	54.33
Average	**55.57**	**50.80**	**72.38**	**66.93**	**65.40**	**67.70**	**55.89**	**65.80**	**62.73**	**54.83**

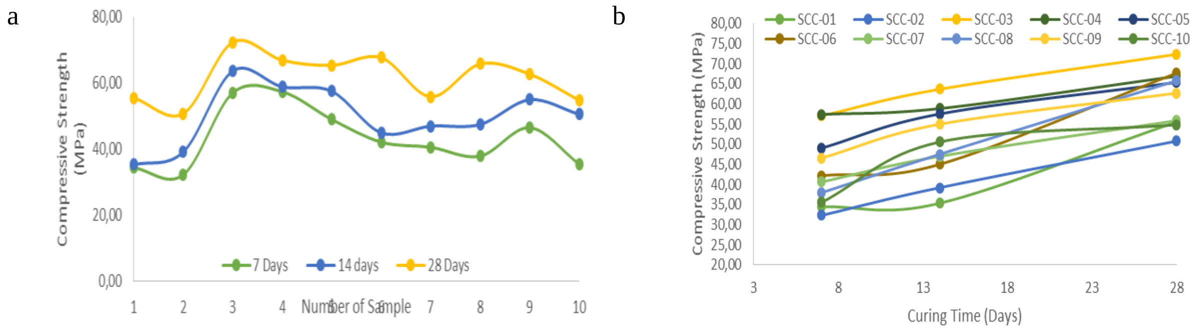

Fig. 8 - (a) The relationship of compressive strength with various test objects; (b) The relationship of compressive strength with curing time

In addition to analyzing the relationship of compressive strength with the curing period on concrete, this study also discusses the relationship of compressive strength with variations in rice husk ash, in Fig. 9(a) shows that there is an optimum percentage of rice husk as h in self-compacting concrete that is 10%. When using ash rice husk ash content less than 10% or more, it will be worried about reducing the compressive strength of concrete at the age of 28 days. Fig. 9(b) describes a compressive strength relationship with variations of wire tie fibers and superplasticizer doses. In this study resulted that self-compacting concrete will produce a higher compressive strength when not using wire tie fiber, but the difference is not too large, while the composition of suitable superplasticizer in the manufacture of self-compacting concrete is 1.1%. Whereas using more wire tie fibers shows that the compressive strength of the concrete will be smaller.

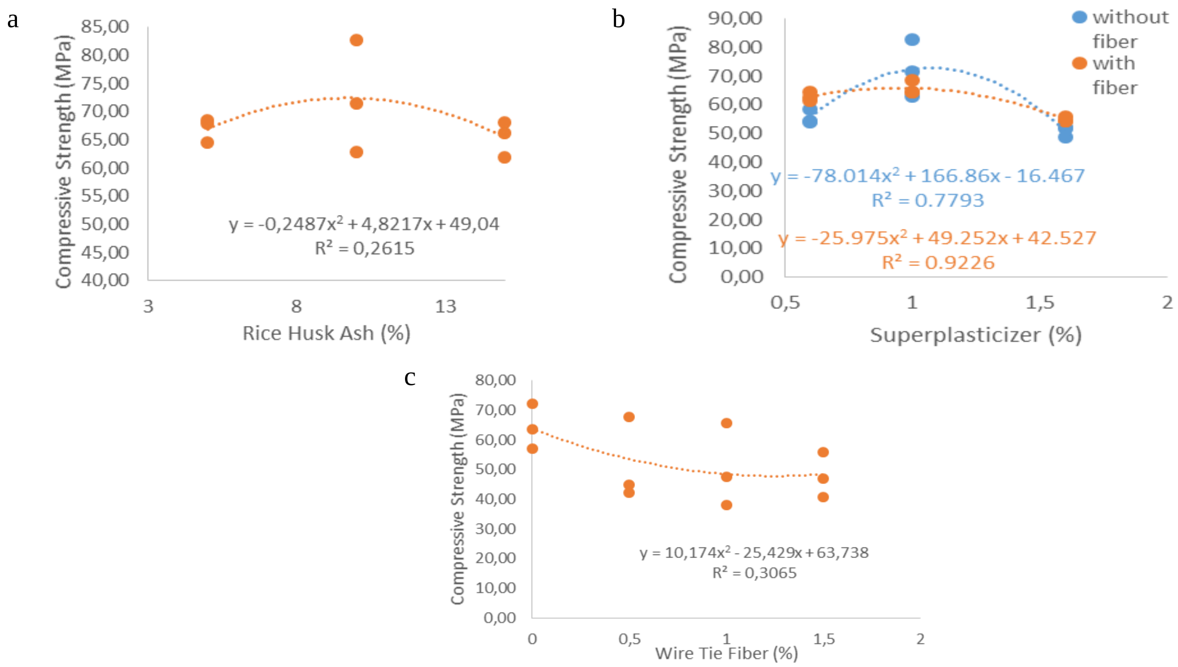

Fig. 9 - (a) The relationship between compressive strength with rice husk ash variations; (b) The relationship between compressive strength with superplasticizers variations; (c) The relationship between compressive strength with wire tie fiber.

Using various variations of rice husk ash mixture will certainly affect the value of flowability self-compacting concrete. This can be seen in Fig. 10(a) that is the relationship between the value of the slump flow and the rice husk ash variations, from the picture shows that the more rice husk ash used in self-compacting concrete will make the slump flow value smaller, this is because rice Husk ash is used in very dry conditions, with water levels reaching almost 0%. Of course, this ash absorbs a large enough amount of water so that the more rice husk ash is used, the more water will also be needed in order to keep the flowability value still meeting the standards, so that if more water is used it can reduce the compressive strength of the concrete.

In Fig. 10 (b) shows that the more proportion of superplasticizers used in self-compacting concrete will be able to increase the flowability value, whether using fiber or not, but the flowability of concrete with fibers will certainly be less than that of non-fiber concrete but all the flowability values in this study are still categorized as meeting the standards. The relationship between slump flow and wire fiber composition is shown in Figure 10(c) where more and more wire fibers are used to show that the slump flow value will also decrease.

Based on all variations of the test objects it can be seen that the weight of the concrete produced is also very varied. High enough weight samples obtained by SCC-07 are concrete with rice husk ash variation of 10%, viscocrete-1003 of 1.0% and using wire fiber of 1.5%. Whereas the smallest weight of the specimen is SCC-01 which is a mixture of 10% rice husk ash, 0.6% viscocrete and without wire tie fiber addition, so it can be concluded that the use of steel fiber can increase the weight of the concrete and cannot increase the compressive strength of the concrete.

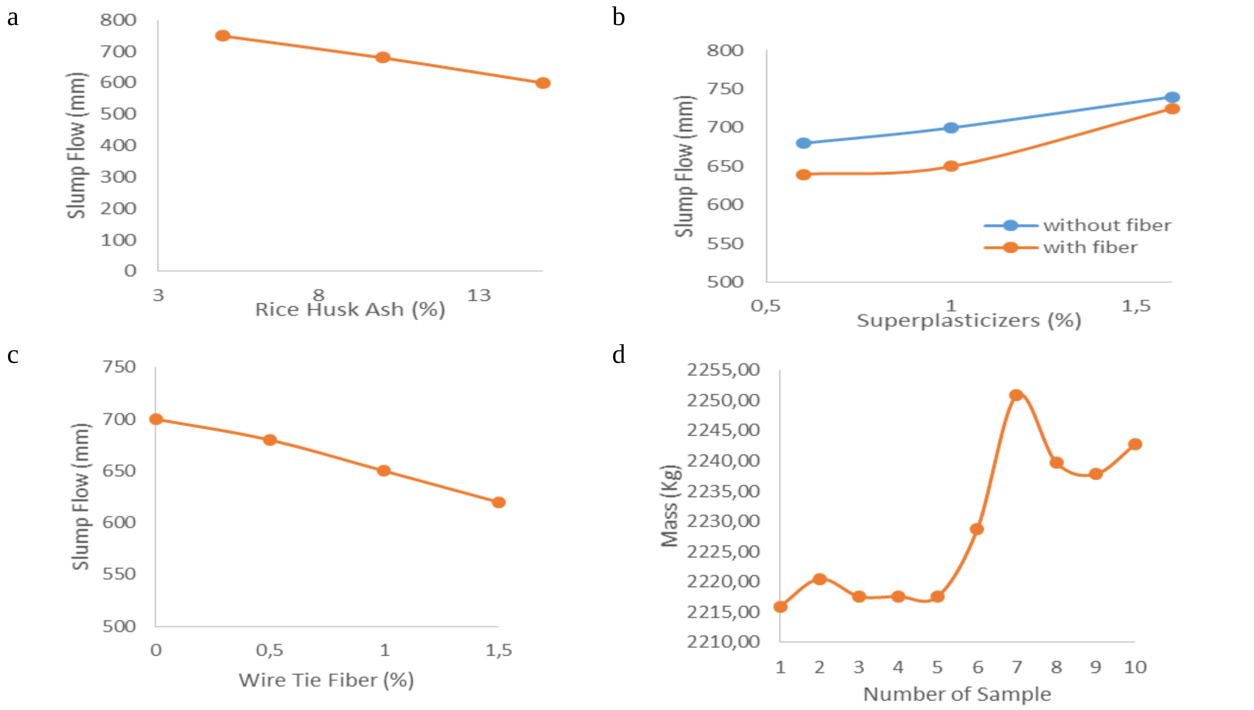

Fig. 10 (a) The relationship between slump flow with rice husk ash variations; (b) The relationship between slump flow with superplasticizers; (c) The relationship between slump flow with wire tie fiber proportion; (d) concrete weight in 1m^3

4. Conclusion

Based on the results and discussion above, the conclusion of this study is that all variations meet the fresh properties standard required for self-compacting concrete. The highest compressive strength without using fiber is 72.38 MPa while concrete using fiber added material only has the highest compressive strength of 67.70 MPa. The optimum percentage of rice husk ash which is appropriate for making self-compacting concrete is 10%. The percentage of superplasticizer material that is suitable for the manufacture of good self-compacting concrete is 1.1% of the weight of cement. Fiber Wire Tie does not affect the compressive strength of concrete; this is evidenced by the results of testing that concrete with wire tie fiber does not produce a higher compressive strength than concrete without fiber. In addition, the use of wire tie fiber can reduce the value of flowability of self-compacting concrete.

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