Influence of polypropylene fiber on early strength of self-compacting concrete

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Abstract. One of the development of concrete technology in construction's world is Self-Compacting Concrete. Self-Compacting Concrete (SCC) is an innovative concrete that able to "flow" and condensed by gravity and its own weight with little vibration or even without a vibration device at all. However, these concrete still have deficiencies like general concrete that is weak to tensile. To increase the tensile strength of the concrete is by adding fiber into the mix. One type of fiber that can be used as an additive to the mix is Polypropylene fibers. This study aims to determine the effect of adding polypropylene fibers to the mechanical properties and characteristics of SCC concrete and to know the optimal polypropylene fiber content in the manufacture of Self Compacting Concrete. Fiber addition variations are 0 kg / m³; 0.25 kg / m³; 0.5 kg / m³ and 0.75 kg / m³. The result of the research showed that the variation of 0.5 kg / m³ and 0.75 kg / m³ addition of fibers didn't fulfill the requirements to be categorized as a SCC concrete. The results of hard concrete test showed the highest compressive strength that is on the SCC PP concrete of 22.31 MPa at the age of 1 day and 46.24 at the age of 28 days. The highest strength is on the SCC 0.25 PP concrete of 6.52 MPa at the age of 1 day and 10.07 at the age of 28 days. The highest flexural strength is on the SCC 0.25 PP concrete of 6.76 at the age of 1 day and 8.60 at the age of 28 days.

1 Introduction

Improper *quality control* in the field has been a problem with the quality of concrete in the world of concrete construction today. One of them is when the process of fresh concrete compaction with the help of vibrator. A poorly vibrated compaction process can cause bleeding and segregation of concrete [8]. As a result, it will create air cavities in the concrete that can reduce the durability of the concrete. Thus, in the late 1980s, Japanese researchers developed self-compacting concrete known as SCC [1] as a solution to the problem.

SSC (Self-Compacting Concrete) is a very plastic fresh concrete that can flow with its own weight and solidify without the aid of a vibrator. Concrete is known to have a good compressive strength but weak against tensile strength and tends to crack. Therefore, the researchers sought to improve the weakness by adding fiber to fresh concrete that is expected to reinforce the concrete and spread evenly to prevent early concrete cracks in the early hydration or loading period.

Various types of fiber that can improve the quality of concrete includes: steel, plastic (polypropylene), glass, and carbon (Suroushian & Bayasi, 1987). The author intends to examine normal concrete and self-compacting

concrete (SCC) using Fibrillated type polypropylene fiber as an added material to test the compressive strength, tensile strength and flexure strength in the early age of concrete.

2 Literature Review

Self-Compacting Concrete (SCC) is an innovative concrete capable of "flowing" and solidify itself by gravity and its own weight with a little vibration or even without the aid of vibrating devices at all. To obtain SCC concrete with high deformability and low possibility of segregation it is arranged so that concrete (1) has low aggregate content, (2) low air-binder factor and (3) using superplasticizer. With a mixture that is easy to deform but still able to maintain its viscosity, the SCC concrete will solidify itself and won't segregate [3].

The simple mix design method proposed by Okamura to get the concrete mix with high level of workability and high initial strength is to pay attention to the things which are [1]:

- Rough aggregate is limited to approximately 50% of the solid volume
- The fine aggregate volume is set at only 40% of the total mortar volume

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- The volume ratio for water and binder is maintained at a level of approximately 0.3
- The use of superplasticizer in the concrete mix for high workability level while reducing cement water factor.
- The addition of filler on the mixture of concrete such as Fly Ash and Silica Fume to improve the durability and strength of concrete

To produce the workability of a good concrete mixture on SCC, the fresh concrete mix must meet the following criteria [2]:

- *Filling ability*, which is the ability of fresh concrete mix to fill the space
- *Passing ability*, which is the ability of fresh concrete mixture to pass through a tightened reinforcement structure
- *Segregation resistance*, which is the resistance of fresh concrete mixture to the effect of segregation.

To be categorized as an SCC concrete, all three criteria must be met.

Polypropylene fibers are polymer fibers that can be used as an additive in SCC concrete manufacturing. The use of Fiber in the manufacture of SCC concrete is limited to less than 1 kg / m³ of concrete [2]. The more fiber usage will certainly further reduce the mixture workability.

Table 1. Polypropylene Fiber Specification

MasterFiber Fibrillated type 38mm	
Specific Gravity	0.91
Melting Point	169 °C
Flash Point	590 °C
Ingredient	Polymer
Color	Transparent
Length	1.5" (38mm)
Tensile Strength	83-96 ksi. (570-660 MPa)
Elasticity Modulus	5.38 Gpa
Absorbtion	-

Source: BASF

Fig. 1. MasterFiber Fibrillated type 38mm

Fig. 2. The detail of Polypropylene fibers

2.1 Research Method

The method used in this research is an experimental study at the Engineering Materials Laboratory Faculty of Engineering, University of Sumatera Utara. Fresh concrete test are Slump Flow, T50 Slump flow, V-funnel test for filling ability parameter, V-funnel T5min for segregation resistance parameter and J-ring test for passing ability parameter.

Hard concrete test are compressive strength test, tensile strength test, and flexural strength test. The samples used are cylindrical with 15 cm diameter with 30 cm height for compressive strength and tensile strength test and beam shape with 60 cm x 15 cm x 15 cm size for flexure strength test. The variation of polypropylene fiber used in sequence are 0 kg / m³ (SCC PP); 0.25 kg / m³ (SCC 0.25 PP); 0.50 kg / m³ (SCC 0.50 PP) and 0.75 kg / m³ (SCC 0.75 PP).

3 Result

3.1 Fresh Concrete Test

The results of fresh concrete test in this research are described in the following table:

Table 2. Fresh concrete test results

No.	Parameter	Requirement	Sample code			
			SCC PP	SCC 0.25 PP	SCC 0.50 PP	SCC 0.75 PP
1	Slumpflow	650-800 mm	685	650	600	530
2	Slumpflow T ₅₀	2-5 sec	3.2	3.5	4.5	5.4
3	J ring	0 – 10 mm	9	10	12	13
4	V funnel	8 – 12 sec	11	12	14	15
5	V funnel T _{5min}	+ 3 sec	13	15	17	19
	Information		Ok	Ok	Not Ok	Not Ok

Based on table 1 it is known that the non-fiber SCC concrete mixture and the SCC concrete of 0.25 kg / m³ fiber meets the requirements as SCC. While the mixture of concrete with the addition of 0.50 Kg / m³ and 0.75 Kg / m³ fiber cannot be categorized as SCC because it does not meet all criteria of SCC.

3.2 Hard Concrete Test

Hard concrete test is compressive strength test, tensile strength test and flexural strength test. Test results are as listed in the following table.

Table 3. Compressive Strength Test Results

No	Sample Code	Fiber variation (kg/m ³)	w/c ratio	Age	Average Actual Compressive Load (kN)	Average Compressive Strength (Mpa)
1	SCC PP	0	0.288	1	394.00	22.31
				28	816.67	46.24
2	SCC 0.25 PP	0.25	0.288	1	381.33	21.59
				28	686.67	38.88
3	SCC 0.50 PP	0.50	0.288	1	264.67	14.98
				28	622.00	35.22
4	SCC 0.75 PP	0.75	0.288	1	180.00	10.19
				28	443.33	25.10

Table 3 shows the highest average compressive strength obtained on the SCC PP mixture of 22.31 MPa at 1 day of age and 46.24 MPa at 28 days of age.

As for the variations of the addition of other fibers, the average compressive strength is actually decreases. This explains that the use of polypropylene fibers in this research is not effective to expect an increase in compressive strength on SCC concrete.

Fig. 3. Graph of Compressive Strength Results

Table 4. Tensile Strength Test Results

No	Sample Code	Fiber variation (kg/m ³)	w/c ratio	Age	Average Actual Tensile Load (kN)	Average Tensile Strength (Mpa)
1	SCC PP	0	0.288	1	140.33	6.24
				28	202.67	9.01
2	SCC 0.25 PP	0.25	0.288	1	146.67	6.52
				28	226.67	10.07
3	SCC 0.50 PP	0.50	0.288	1	112.00	4.98
				28	182.00	8.09
4	SCC 0.75 PP	0.75	0.288	1	90.00	4.00
				28	170.67	7.59

Based on Table 4 of the average tensile strength, the highest average tensile strength value is obtained in the mixture with fiber addition variations of 0.25 kg / m³ which is 6.52 MPa at 1 day of age and 10.07 MPa at 28 days of age. This shows an increase in tensile strength caused by the addition of polypropylene fiber compared to non-fiber SCC concrete by 4.49% for 1 day of age and 11.76% for 28 days of age. However, for 0.50 PP SCC concrete and 0.75 PP SCC, the average tensile strength decreases.

Fig. 4. Graph of Tensile Strength Results

For Flexure Strength Test, all samples are broken in the middle of the span. The test results as shown in Table 5 shows the highest flexure strength for 1 day of age and 28 days of age is on 0.25 PP SCC sample which is 6.76 MPa and 8.60 MPa. When compared to the SCC PP concrete, the concrete experienced a flexure strength increase for the 1 day of age of 18.75% and 18.05% at 28 days of age

Table 5. Flexure Strength Test Results

No	Sample Code	Fiber variation (kg/m ³)	w/c ratio	Age	Average Actual Flexure Load (kN)	Average Flexure Strength (Mpa)
1	SCC PP	0	0.288	1	32	5.69
				28	41	7.29
2	SCC 0.25 PP	0.25	0.288	1	38	6.76
				28	48.4	8.60
3	SCC 0.50 PP	0.50	0.288	1	33	5.87
				28	43.2	7.68
4	SCC 0.75 PP	0.75	0.288	1	33	5.87
				28	42	7.47

The use of polypropylene fiber is able to improve the flexure strength of SCC concrete. However, on the 0.75 PP sample, it did not provide a significant increase in the flexure strength when compared with the SCC PP concrete. The graph of the Flexure Strength test results is shown in Figure 3 below

Fig. 5. Graph of Flexure Strength Results

4 Conclusion and Suggestion

4.1 Conclusions

- Concrete mixture of 0.50 PP SCC and 0.75 PP SCC cannot be categorized as Self Compacting Concrete because it does not meet all the criteria of Filling Ability, Passing Ability and Segregation Resistance Ability.
- Test results of concrete compressive strength indicate as the addition of polypropylene fiber on SCC concrete is actually decrease the value of concrete compressive strength. The highest average value of concrete is on in the mixture of 0 PP SCC of 22.31 MPa at 1 day of age and 46.24 MPa at 28 days of age.
- The results of concrete tensile strength and flexure strength test shows the addition of polypropylene fiber as much as 0.25 kg / m³ is the optimum use. Increased tensile strength of concrete at 1 day of age is becoming to 6.52 MPa or increased by 4.49% of

non-fiber SCC concrete and at 28 days of age is becoming to 10.07 MPa or increased by 11.76% of non-fiber SCC concrete. The increase in value of the concrete flexure strength at 1 day of age is becoming to 38 kN or increased by 18.75% of non-fiber SCC concrete and at 28 days of age is becoming to 48.4 kN or increased by 18.04% of non-fiber SCC concrete.

4.2 Suggestion

- Polypropylene Fiber usage in concrete is recommended for non-beam casting only.
- In this research is using fiber with Fibrillated structure (nets). Research is need to be done by using other types of Polypropylene Fiber such as Monofilament, Collated Fibrillated Bundle, or Fibrillated Twisted Bundle type
- In manufacturing a mixture of Self Compacting Concrete, one must always consider the time during stirring and fresh concrete testing.

References

- Okamura, Hajime. "Self-compacting high-performance concrete." *Concrete international* 19.7 (1997): 50-54.
- EFNARC, Specification. "Guidelines for self-compacting concrete." *London, UK: Association House* 32 (2002): 34.
- Nugraha, Paul. "Antoni, 2007 "Teknologi Beton "." *Universitas Kristen Petra*. [in Indonesian]
- Nagamoto, Naoki, and Kazumasa Ozawa. "Mixture properties of self-compacting, high-performance concrete." *Special Publication* 172 (1999): 623-636.
- Anonim, S. N. I. "SNI 03-1974-1990." *Metode Pengujian Kuat Tekan Beton*. [in Indonesian]
- Umum, Departemen Pekerjaan. "Metode Pengujian Kuat Tarik Belah Beton SK SNI 03 2491-2002." (2002) [in Indonesian]
- SNI 03-4431-1997. 1997. Metode Pengujian Kuat Lentur Normal Dengan Dua Titik Pembebanan. Bandung: Badan Standarisasi Nasional [in Indonesian]
- Karolina, R., Muhammad, W., Saragih, M. D. S. M., & Mustaq, T. (2018, February). The effectiveness of stone ash and volcanic ash of mount Sinabung as a filler on the initial strength of self-compacting concrete. In *IOP Conference Series: Materials Science and Engineering* (Vol. 308, No. 1, p. 012045). IOP Publishing.