12 Flural

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Flexural Strength of Self Compacting Fiber Reinforced Concrete Beams using Polypropylene Fiber: an Experimental Study

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Abstract. One of the methods to increase the tensile strength of concrete is adding a fiber material into the concrete. While to reduce a noise in a construction project, a self compacting concrete was a good choices in the project. This paper presents an experimental study of flexural behavior and strength of self compacting fiber reinforced concrete (RC) beams using polypropylene fiber. The micro monofilament polypropylene fibers with the proportion 0.9 kg/m^3 of concrete weight were used in this study. Four beam specimens were cast and tested in this study. Two beams were cast of self compacting reinforced concrete without fiber, and two beams were cast of self compacting fiber reinforced concrete using polypropylene. The beams specimen had the section of (180×260) mm and the length was 2000 mm. The beams had simple supported with the span of 1800 mm. The longitudinal reinforcements were using diameter of 10 mm. Two reinforcements of Ø10 mm were put for compressive reinforcement and three reinforcements of Ø10 mm were put for tensile reinforcement. The shear reinforcement was using diameter of 8 mm. The shear reinforcements with spacing of 100 mm were put in the one fourth near to the support and the spacing of 150 mm were put in the middle span. Two points loading were used in the testing. The result shows that the load-carrying capacity of the self compacting reinforced concrete beam using polypropylene was a little bit higher than the self compacting reinforced concrete beam without polypropylene. The increment of load-carrying capacity of self compacting polypropylene fiber reinforced concrete was not so significant because the increment was only 2.80 % compare to self compacting non fiber reinforced concrete. And from the load-carrying capacity-deflection relationship curves show that both the self compacting polypropylene fiber reinforced concrete beam and the self compacting non fiber reinforced concrete beam were ductile beams.

INTRODUCTION

Concrete is a material for building construction which is made from portland-cement, water, fine and coarse aggregates. The concrete material is good in compressive strength, but very weak in tensile strength. To increase the tensile strength, usually the concrete was added by fiber materials.

There are several types of fiber materials that were usually used in concrete such as steel fibers, glass fibers, carbon fibers, and polypropylene fibers [1]. Investigation of fiber concrete using steel fibers had already been done by several reseachers in several decades ago [2-6]. It was shown that steel fibers improve the mechanical properties of concrete especially in the modulus of rupture and the splitting tensile strength [7]. However, steel fibers have disadvantages such as easily to corrode, higher weight, easily to damage the mixer, magnetic interference, and higher price [8]. Therefore, another fiber material was developed and used in concrete such as polypropylene fibers. Investigation of fiber concrete using polypropylene fiber was already done by researchers [8-10]. It was shown that polypropylene can improved the tensile strength of concretes.

To reduce a noise in the project due to the sound of vibrator in pouring of concrete, a self compacting concrete is a good choices. Application of self compacting concrete is more practical and faster than normal concrete. Investigation on self compacting concrete was also extensively carried out in several decades ago [11-13]. However,

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study on self compacting concrete using polypropylene is still rare. Therefore, study on self compacting concrete using polypropylene is still needed.

EXPERIMENTAL PROGRAM

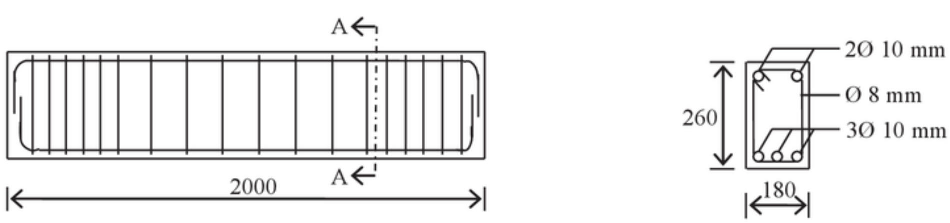
Materials

Materials of concrete (portland-cement, water, fine and coarse aggregates) were taken from local material. Silica fume was added in the concrete with the proportion 10 % of portland-cement weight. Superplasticizer with the proportion 1.1% of Portland-cement weight was used. Micro monofilament polypropylene fibers with the proportion 0.9 kg/m^3 of concrete weight were used in this study. The proportion of polypropylene fibers was based on the study of [14] that the optimum proportion of polypropylene fiber was 0.9 kg/m^3 of concrete.

Preparation of Specimens

To get the compressive strength, tensile strength, and modulus of elasticity of self compacting concrete, 54 cylinder specimens with the size of (150 mm×300 mm) were made. While to get the modulus of rupture 18 cylinder specimens with the size of (200 mm×200 mm×700 mm) were made. The non fiber concrete specimen was marked with BN, while the polypropylene fiber concrete specimen was marked with BS.

Four beam specimens were cast and tested in this study. Two beams were cast of self compacting reinforced concrete without fiber, and two beams were cast of self compacting fiber reinforced concrete using polypropylene. The beams specimen had the section of (180×260) mm and the length was 2000 mm. The beams had simple supported with the span of 1800 mm. The longitudinal reinforcements were using diameter of 10 mm. Two reinforcements with diameter of Ø10 mm were put for compressive reinforcement and three reinforcements with diameter of Ø10 mm were put for tensile reinforcement. The shear reinforcement was using diameter of 8 mm. The shear reinforcements with spacing of 100 mm were put in the one fourth near to the support and the spacing of 150 mm were put in the middle span. The size and detailing of beam specimen can be seen in Fig. 1.



(a) Reinforcement of the beam (b) Section A-A (unit in mm)

FIGURE 1. Detail of beam specimen

Properties of Fresh Concrete Testing

To get the properties of fresh self compacting concrete, three type properties of fresh self compacting concrete were tested. The testing of fresh self compacting concrete is following the European standard [15] and the properties to be tested were:

- Flowability/filling ability using slump-flow test
- Viscosity using T_{500} slump-flow test
- Passing ability using L-shape box.

Cylinder and Beam Specimen Testing

The compressive strength, splitting tensile strength, modulus of elasticity, and modulus of rupture testing were performed according to ASTM [16]. Universal Testing Machine (UTM) with capacity of 30,000 kgf was used to test the compressive strength, splitting tensile strength, modulus of elasticity, and modulus of rupture of concrete. The testing of compressive strength, splitting tensile strength, modulus of elasticity and modulus of rupture were conducted at the age of concrete of 28 days.

While testing of beam specimens were conducted in loading frame with the set-up specimen is depicted in Fig.2.

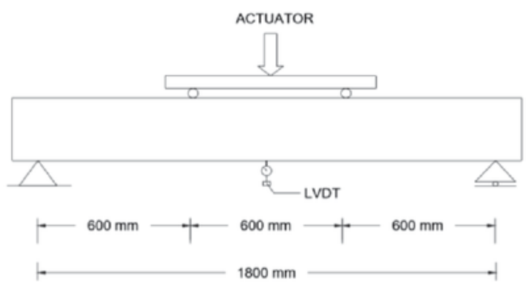


FIGURE 2. Set-up of beam specimen

The beam specimen was testing under load control. A load was given by the actuator with the capacity of 250 kN through the transfer beam, so the beam specimen was subjected two point loading as depicted in Fig. 2. A Linear Variable Differential Transformers (LVDT) was used to measure deflection of the specimen. The LVDT was placed at the middle of the specimen to measure the displacement in the vertical direction. Measured data of load and deflection were read through a computer driven data acquisition system using data logger.

RESULT AND DISCUSSION

The Properties of Fresh Concrete

To get the properties of fresh concrete, three type properties of fresh concrete were tested according to the European standard [14]. The results properties of non fiber concrete (BN1 and BN2) and polypropylene fiber concrete (BS1 and BS2) can be seen in Table 1.

TABLE 1. The result properties of fresh concrete

Code	Filling ability	Passing ability	Viscosity
	Slump flow (mm)	L-shape box (h_2/h_1)	T_{500} Slump flow (second)
BN1	710	0.90	3.4
BN2	713	0.95	3.0
BS1	650	0.85	4.0
BS2	646	0.83	4.2

According to European standard [14] that the range of filling ability is in between 550-850; the range of passing ability is in between 0.8-1.0; while the range of viscosity is in between 2-5. So, according to the result of fresh concrete testing in Table 1, it can be said that the concrete in this study can be classified as self compacting concrete.

Mechanics Properties of Concrete

The compressive strength of self compacting non fiber concrete and self compacting polypropylene fiber concrete at age 28 days can be seen in Table 2. The result shows that the compressive strength of self compacting polypropylene fiber concrete was lower than the self compacting non fiber concrete. The decreasing compressive strength of self compacting polypropylene fiber concrete was 28.89 % compare to self compacting non fiber concrete.

TABLE 2. The compressive strength of concrete.

Cylinder	Compressive strength (MPa)	Average (MPa)
BN1	45.96	
BN2	49.03	49.90
BN3	50.78	
BS1	34.72	
BS2	35.02	35.48
BS3	36.71	

The splitting tensile strength of self compacting non fiber concrete and self compacting polypropylene fiber concrete at age 28 days can be seen in Table 3. The splitting tensile strength of self compacting polypropylene fiber concrete was higher than self compacting non fiber concrete. The increasing splitting tensile strength of self compacting polypropylene fiber concrete was 2.64 % compare to self compacting non fiber concrete.

TABLE 3. The splitting tensile strength of concrete.

Cylinder	Splitting tensile strength (MPa)	Average (MPa)
BN1	4.38	
BN2	4.09	4.35
BN3	4.59	
BS1	4.58	
BS2	4.24	4.47
BS3	4.58	

The modulus elasticity of self compacting non fiber concrete and self compacting polypropylene fiber concrete at age 28 days can be seen in Table 4. The modulus elasticity of self compacting polypropylene fiber concrete was lower than self compacting non fiber concrete. The decreasing modulus elasticity of self compacting polypropylene fiber concrete was 9.98 % compare to self compacting non fiber concrete.

TABLE 4. The modulus elasticity of concrete.

Cylinder	Modulus of elasticity (MPa)	Average (MPa)
BN1	26.38×10^3	
BN2	30.65×10^3	28.53×10^3
BN3	28.56×10^3	
BS1	24.13×10^3	
BS2	26.93×10^3	25.68×10^3
BS3	25.98×10^3	

The modulus rupture of self compacting non fiber concrete and self compacting polypropylene fiber concrete at age 28 days can be seen in Table 5. The modulus rupture of self compacting polypropylene fiber concrete was higher than self compacting non fiber concrete. The increasing modulus rupture of self compacting polypropylene fiber concrete was 3.63 % compare to self compacting non fiber concrete.

TABLE 5. The modulus of rupture of concrete.

Cylinder	Modulus of rupture (MPa)	Average (MPa)
BN1	4.60	
BN2	4.67	4.66
BN3	4.70	
BS1	4.71	
BS2	4.85	4.83
BS3	4.92	

Load-carrying Capacity of Beam Specimen

The load carrying capacity-deflection curve of the beam specimens can be seen in Fig. 3. It can be seen that in general the curve of load-carrying capacity-deflection relationship in the lower load is increasing linearly. After first crack, the curve is increasing nonlinearly up to a value than the curve increasing almost horizontally up to failure. This phenomenon indicates that the beam specimen is ductile for both self compacting polypropylene fiber reinforced concrete beam as well as the non fiber reinforced concrete beam.

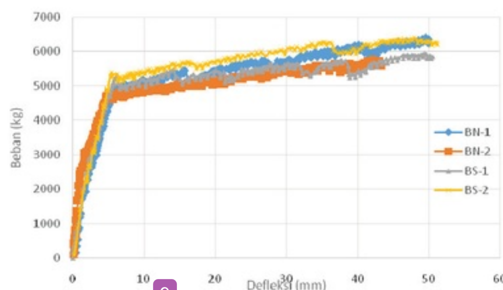


FIGURE 3. Load-carrying Capacity vs Deflection

The maximum load-carrying capacity of the beam specimen is shown in Table 6. It can be seen from Table 6 that the average load-carrying capacity of self compacting polypropylene fiber reinforced concrete was a little bit higher than self compacting non fiber reinforced concrete. The increment of load-carrying capacity of self compacting polypropylene fiber reinforced concrete was not so significant because the increment was only 2.80 % compare to self compacting non fiber reinforced concrete.

TABLE 6. The load-carrying capacity of beam specimens.

Beam	Load-carrying capacity (kg)	Average (kg)
BN1	61.96×10^2	59.68×10^2
BN2	57.39×10^2	
BS1	59.49×10^2	61.35×10^2
BS2	63.21×10^2	

Crack Pattern of Beam Specimen

The crack pattern of the self compacting non fiber reinforced concrete beams were shown in Fig. 4 and Fig. 5. The first crack was occurred in the bottom side of the beam in the middle span at the load of 24.12 kN and 24.59 kN for beam BN1 and BN2, respectively. The crack propagated vertically as the load increasing. Another flexural crack was occurred during the increasing of the load and then shear crack was occurred near to the support as shown in Fig. 4 and 5. After reaching the maximum load, then the beam was failure.

FIGURE 4. The crack pattern of BN1

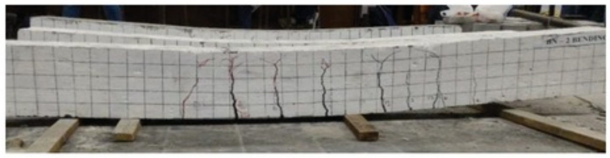


FIGURE 5. The crack pattern of BN2

The crack pattern of the self compacting polypropylene fiber reinforced concrete beams were shown in Fig. 6 and Fig. 7. The first crack of the beam BS1 and BS2 was occurred at 25.18 kN and 23.12 kN, respectively. Generally the crack pattern of self compacting polypropylene fiber reinforced concrete beam is similar to the non fiber reinforced concrete beam. The crack pattern of beam BS1 and BS2 is shown in Fig 6 and 7, respectively.

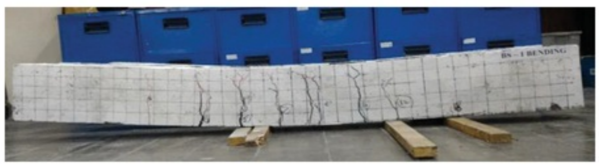


FIGURE 6. The crack pattern of BS1

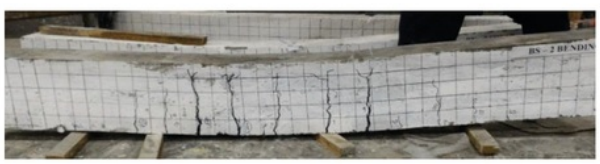


FIGURE 7. The crack pattern of BS2

CONCLUSION

Based on the experimental program, the following conclusion can be drawn:

- The compressive strength of self compacting polypropylene fiber concrete was lower than self compacting non fiber concrete. The decreasing compressive strength of self compacting polypropylene fiber concrete was 2[illegible].892 % compare to self compacting non fiber concrete.
- The splitting tensile strength of self compacting polypropylene fiber concrete was higher than self compacting non fiber concrete. The increasing splitting tensile strength of self compacting polypropylene fiber concrete was 2.644 % compare to self compacting non fiber concrete.
- The modulus elasticity of self compacting polypropylene fiber concrete was lower than self compacting non fiber concrete. The decreasing modulus elasticity of self compacting polypropylene fiber concrete was 9.983 % compare to self compacting non fiber concrete.

- The modulus rupture of self compacting polypropylene fiber concrete was higher than self compacting non fiber concrete. The increasing modulus rupture of self compacting polypropylene fiber concrete was 3.629 % compare to self compacting non fiber concrete.
- The average load-carrying capacity of self compacting polypropylene fiber reinforced concrete was a little bit higher than self compacting non fiber reinforced concrete. The increment of load-carrying capacity of self compacting polypropylene fiber reinforced concrete was not so significant because the increment was only 2.798 % compare to self compacting non fiber reinforced concrete.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8