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THE REINFORCED CONCRETE BEAM DEFLECTION AND CRACKING BEHAVIOR WITH ADDITIONAL FIBER STEEL

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The classic theory mentions that the assessment of deflection and crack width should be taken to minimize those two behaviors. This research itself has the objective to examine whether the additional fiber steel and increased reinforcement ratio has any significant impact on the deflection and existing crack width. This test used the reinforced concrete beams with a size of 15 cm x 25 cm x 180 cm which placed on a simple pedestal. The test was done gradually in every 108 kg until the reinforced yield reached. The fiber increased from 0%, 1.57%, 3.14% and 4.71% while the performance rebar ratio increased from 2 # 10, 2 # 12, and 2 # 14. The result shows that additional 4.71% of maximum fiber decrease compressive strength and rupture modulus while the tensile strength increased. The additional fiber reached a maximum in 4.71% and the additional diameter of 10 mm, 12 mm, and 14 mm increased the deflections and crack width.

Keywords: Compressive strength, Rupture modulus, Tensile strength.

1 INTRODUCTION

Compressive strength of the concrete is relatively higher than its tensile strength. Its compressive strength during 28 days ranged between 10-65 MPa (Mulyono 2004). Additional deflection has an impact on cracking phenomenon in the reinforced concrete. It caused a reduction in bending stiffness at the crack. To improve the bending reinforcement bar it may add some fiber.

According to Deluce and Vechio (2013), the addition of fibers in concrete can improve the behavior of structural elements, post-fracture behavior, and crack control. The long term loading also impact the existing crack, while the addition of fiber is the most effective way to control the crack (Vasanelli *et al*. 2012).

Relationship between fiber volume (V_f) and fiber content (W_f), fiber ratio (lf/df), and the material properties, crack width, and crack length are the focal points of this study. In accordance with crack regulations: SNI 03-2847-2002 and comparison to previous studies, mention the parameter such as steel stress (f_s), reinforcement bar diameter (d_b), and concrete cover (c). Another crack related parameters that may examine further are reinforcement bar ratio (ρ), spacing reinforcement bar (s) thus the formulation of crack width is more flexible to be implemented.

The objective of this research is to determine how the effect of adding steel fibers and improving ratio of rebar. The addition of steel fibers (W_f) and increased variations of the reinforcement bar ratio (ρ_r) also directly affects the deflection and crack width (w) hence it can be measurably known how much those parameter influence. The addition of steel fibers (W_f) and increased variations of reinforcement bar ratio (ρr) have an impact the cost. Therefore, how much costs incurred become one of the aims in next study.

2 MATERIALS AND METHODS

The study was conducted at the Laboratory of Building Materials and Concrete, Civil Engineering Department, Universitas Brawijaya. The test object was a beam with dimension of 15 cm x 25 cm x 180 cm with two-point loading (Figure 1). According to ACI, maximum crack width allowable for protective condition is 0.41 mm (Table 1). This experiment was in full scale test specimen, 1:1. It tested until reach the under reinforced condition and used the simple support on both sides.

Table 1. Maximum crack width allowable.

Exposure Condition	**Crack width**	
	in	mm
Dry air or protective membrane	0.016	0.41
Humidity , moist air, soil	0.012	0.30
Deicing chemicals	0.007	0.18
Seawater and seawater spray, wetting and drying	0.006	0.15
Water-retaining structures	0.004	0.10

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The concrete mix design based on SNI 03-2834-2000, fc' = 20 MPa (Table 2). Steel fiber used in this research is the fabrication steel fiber: Dramix RC-80/60-BN with l/d = 80 and its minimum tensile strength is 1,050 N/mm^2. Deflection testing and crack width use the fiber mixed with concrete by the initial slump 15 cm ± 2 cm. The experiment samples of compressive strength and tensile created using a cylinder (Table 3).

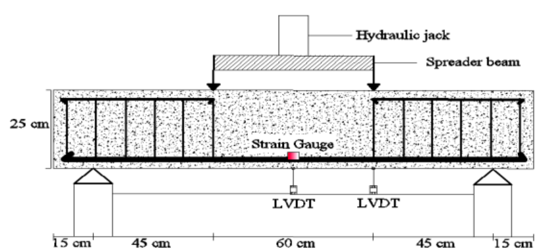

Figure 1. Loading scheme and testing.

Table 2. Concrete mix proportion.

Type of material	Total (Kg)
Cement	410.00
Water	205.00
Coarse Aggregate	802.04
Fine Aggregate	980.27

After the specimen reaches the age of 28 days, then test was carried out examine the static deflection, width crack and strain that occurs. Reinforcement use the Fy = 240 MPa and a tensile test in accordance with SNI 07-2052-2002 formulated in Eq. (1) and depicted in Table 4. Specimens were subjected to a load line, started from zero to yield.

$$\varepsilon_y = \frac{f_y}{E_s} \quad (1)$$

where: ε_y = Yield stress
f_y = Force yield (MPa)
E_s = Steel elasticity (MPa)

Table 3. Concrete mix proportion.

Percentage of fibers (%)	Function of fibers	Amount (unit)	Total (Kg)
0	Beam	3	0
1.56	Beam	3	3.113
3.14	Beam	3	6.226
4.71	Beam	3	9.340
0	Cylinder	6	0
1.56	Cylinder	6	0.489
3.14	Cylinder	6	0.978
4.71	Cylinder	6	1.467

Table 4. Experiment of steel tensile.

∅reinforcement	ρ_r(%)	*fy* exp (MPa)
10	0.523	324.93
12	0.76	269.02
14	1.048	260.21

Load (P) can be read on proving ring at intervals of 108 kg per two strips reading, until it reached strength beam limit, which is characterized by its yield tensile at the bottom of the beam. The observation made between crack width as well as the tension deflection that occurs in reinforced concrete, both before and after adding steel fiber concrete, and subjected to reinforcement variations

3 RESULT AND DISCUSSION

The slump average value with reached maximum fiber accounted for 64.78%. The average compressive strength has decreased. The addition of fiber 1.57% decreased its compressive strength of 0.67%. When it adds fiber 3.14% and 4.71%, the compressive strength decreased 1.33% and 2.00% (Figure 2).

The modulus of rupture decreased with the fiber addition. If 1.57% fiber was added, the modulus of rupture decreased by 0.85%. If the fiber added by 3.14% and 4.71%, compressive strength decreased to 1.69% and 2.54%. By increasing fibers in reinforcement bar diameter of 10 mm until reaches its maximum, which is 4.71%, decreased its maximum load by 1.86%. On the other hand, in the reinforcement bar diameter 12 mm and 14 mm, the maximum load decreased by 3.73% and 2.66% (Figure 3).

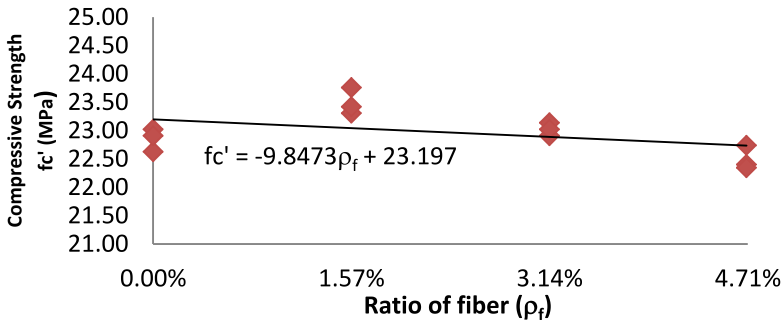

Figure 2. Concrete's compressive strength with the additional fibers.

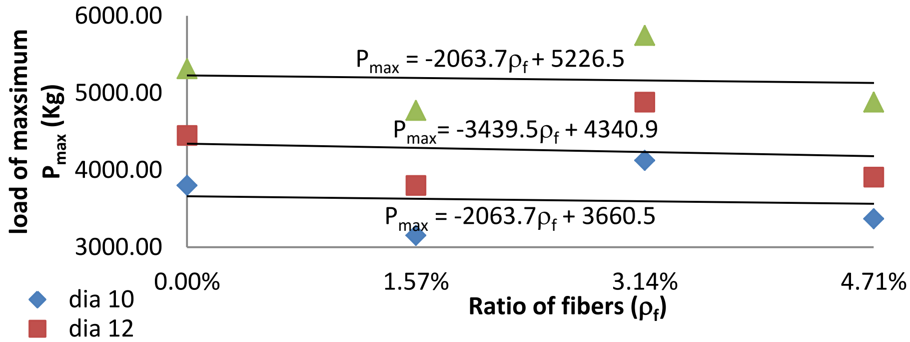

Figure 3. Maximum load (Pmax).

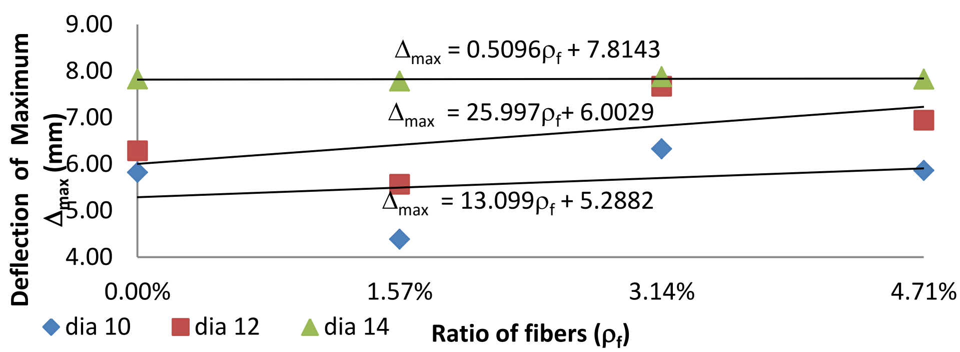

Figure 4. Maximum deflection (Δmax).

Adding maximum fibers of 4.71%in reinforcement bar diameter of 10 mm, deflection was increased by 0.31%. In reinforcement bar diameter 12 mm and 14 mm increased its deflection by 20.4% and 11.68% (Figure 4).

By the fiber addition to maximum of 4.71%, in the reinforcement diameter 10 mm, increase the crack width by 4.22%. In the reinforcement diameter 12 mm and 14 mm, increase the crack width by 8.49% and 9.9% (Figure 5).

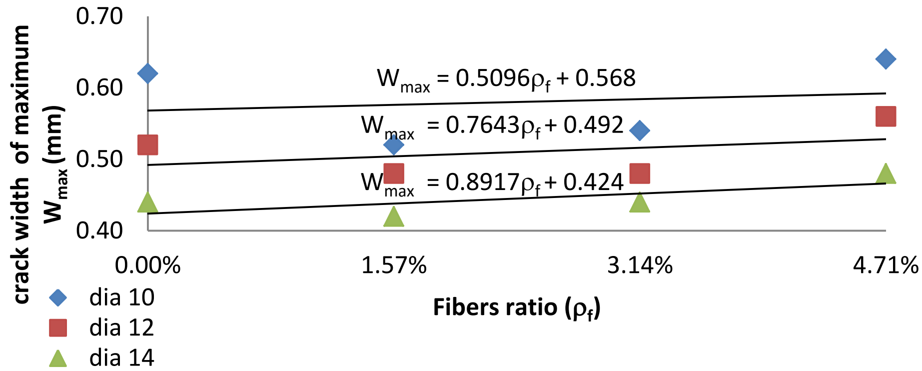

Figure 5. Maximum crack width (Δmax).

4 CONCLUSIONS

1) The maximum fiber addition resulting in decreased compressive strength by 2% and decreases the modulus of rupture by 2.54%. An increase in fibers to a maximum point of 4.71%, using the reinforcement bar diameter of 10 mm, decreased its loading by 1.86%. In the reinforcement bar diameter of 12 mm and 14 mm decrease the average maximum load by 3.73% and 2.66%.

2) Maximum deflection by the addition of fibers 4.71%, in the reinforcement bar diameter 10 mm increased by 0.31%. In the reinforcement bar diameter of 12 mm and 14 mm increased its maximum deflection by 20.4% and 11.68%.

3) When the maximum fiber increased by 4.71%, in the reinforcement bar diameter 10 mm, its crack width increased by 4.22%. In the reinforcement bar diameter of 12 mm and 14 mm, crack width increased by 8.49% and 9.9%.

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