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Effect of Using Laminated Bamboo Reinforcement and Micro Polypropylene Fibers on the Concrete Slab

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***Abstract*—Reinforced concrete is a composite material that has had an impact on development in recent decades. Based on this condition, it is necessary to anticipate the reinforced concrete forming materials, one of which is the steel reinforcement. Bamboo is a material that can be renewed by nature, possibly as an alternative to the reinforcement. The basic weakness of bamboo is weathering problems, so that innovation is needed, namely by laminating it with fiberglass. In addition, to overcome the problem of initial cracking in reinforced concrete, it was tried by adding micro polypropylene fibers. Concrete mix design using SNI 7656: 2012. From the test results, the effect of using bamboo reinforcement coated with fiberglass gives good results with an increase in the flexural test carried out. Meanwhile, with the addition of micro polypropylene fibers according to the applicable standards, it has not been seen to help properly to overcome the initial crack width that occurs as a whole, although there are several conditions that appear to give differences to the existing test results.**

Keywords—cracks, load, reinforced

I. INTRODUCTION

The use of reinforced concrete material every year continues to increase, so it is possible that one of the reinforcement materials will soon run out. With this condition, we need a reinforcement made of carbon iron, which is likely to be able to minimize the use of steel as reinforcement in concrete. As we know, concrete has better compressive strength than its tensile strength, so the weak tensile strength of concrete is given reinforcement which is able to help support the concrete tensile strength. From the condition of limited material resources for steel material used as reinforcement in concrete, then try to replace steel reinforcement with laminated bamboo (coated with fiberglass). Previous research showed that the strength of bamboo as a substitute for reinforcing steel can be said to be close to the strength of steel reinforcement at the

time of initial cracking, with a difference of 12.9% [1]. The bamboo problems that were encountered after a few months of this research were carried out, namely weathering problems caused by water disturbances at the beginning of mixing the concrete. The hope is by adding fiberglass to bamboo, in addition to increasing strength in bamboo, it also minimizes the occurrence of weathering on bamboo.

Significant thing happened after loading in reinforced concrete, besides the change in deflection also cracks. Cracks on reinforced concrete basically starts from small cracks which can also be called initial cracks. As the load increases, the initial cracks will continue to expand, and finally reinforced concrete breaks will occur. So, with this condition that needs to be minimized, namely the occurrence of initial cracks in reinforced concrete material. One way to minimize initial cracks is by adding fiber to the concrete. Addition of fiber has an impact on increasing tensile strength and minimizing crack width on reinforced concrete structures [2]. Addition of fiber also helps the concrete slow down the crack openings that occur after the initial cracks which continue to widen as the load increases [3]. With the addition of fiber can also affect compressive strength [4,5]. Various kinds of fibers that can be mixed into reinforced concrete, both rigid and flexible. In this study the added fiber is flexible like a thread called micro polypropylene. Polypropylene and Nylon fibers are used to improve the impact resistance. Many developments have been made in the fiber reinforced concrete [6]. Besides affecting compressive strength, fiber also affects the slump value and will affect the ease of implementation of work in the field [7].

II. MATERIALS AND METHODS

The object to be tested is a slab with a size of 140cm x 70cm x 10cm with one-point loading. reinforcement used in concrete diameter of 8mm for steel reinforcement. Laminated bamboo is coated with 2mm thickness fiberglass on 6mm bamboo, so the diameter of the bamboo becomes 8mm as in figure 1. Fiber used as a layer to form fiberglass is MAT tissue mixed with a catalyst and resin.

Fig. 1. Laminated bamboo.

Additional fibers mixed into the wet concrete mix at the minimum and maximum allowed of the industry, in figure 2 is a form of fiber used in the concrete mixture. The minimum and maximum allowed industry of 600gr/m3 and 900gr/m3 or 0.025% and 0.0375% by weight of the volume of reinforced concrete.

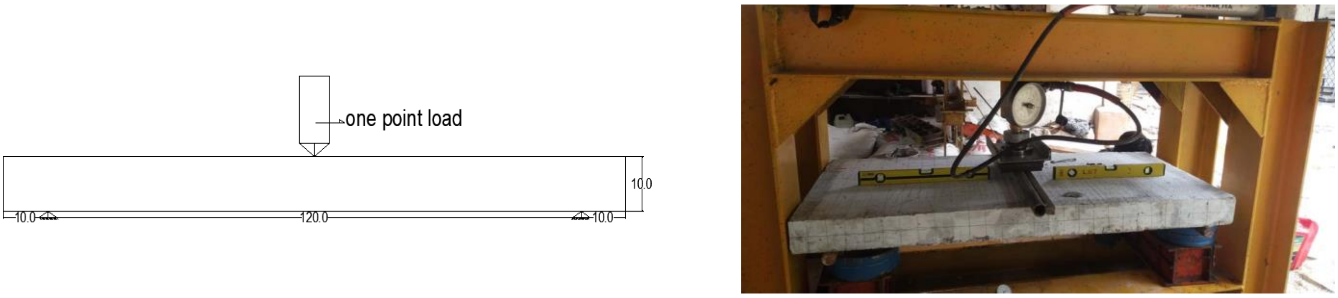
Fig. 2. Micro polypropylene fiber.

This experiment was in full-scale test specimen, 1:1. It tested until it reached the maximum crack condition "Table 1" and used the simple support on both sides "Figure 3".

TABLE I. 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

(ACI Committee 224)



(A) (B)

Fig. 3. (A) Loading scheme and testing. (B) Field testing.

The concrete mix design based on SNI 7656:2012, fc' = 20 MPa. The fiber used is micro polypropylene fiber with material properties:

- Fiber length: 12 mm
- Specific gravity: 0.91 g/cm3
- Fiber thickness: 18 and 30 microns
- Modulus young: 5500-7000 MPa
- Tensile strength: 350 N mm2
- Melting point: 1600ºC
- Recommended dosage: 0.6 to 0.91 Kg / m3 (12mm fiber)

The slump is used with a value of10cm±2cm. The experiment samples of compressive strength and tensile created using a cylinder. After the specimens in the form of reinforced concrete slab was only 28 days, a static load test is performed against the initial cracks and the maximum allowed cracks. Reinforcement uses fy = 240 MPa and reinforcement lamination bamboo as a comparison. Specimens were subjected to a load line, started from zero to the first crack, and then continued until it reaches the maximum crack allowed according to the rules of the ACI committee 224 as shown in table 1. Load (P) can be read on proving ring at intervals of 100kg per one strip reading.

III. Results and Discussion

Based on the rules in SNI 7656: 2012, the slump obtained from the results of the planned concrete material mixing is 17cm, so according to the desired slump needs 10cm±2cm, the addition of concrete material excluding water around 9,24%. in table 2 below is the slump value obtained from the test results.

TABLE II. SLUMP VALUE

Fiber value (%)	Slump (cm)
0	11
0,025	7
0,0375	5

From figure 4, addition of fiber to the concrete mixture causes a change in the slump. This condition will also be related later to the difference in strength according to the test life that has been set for 28 days. There are 3 samples used for each additional number of fibers for compression and tensile testing.

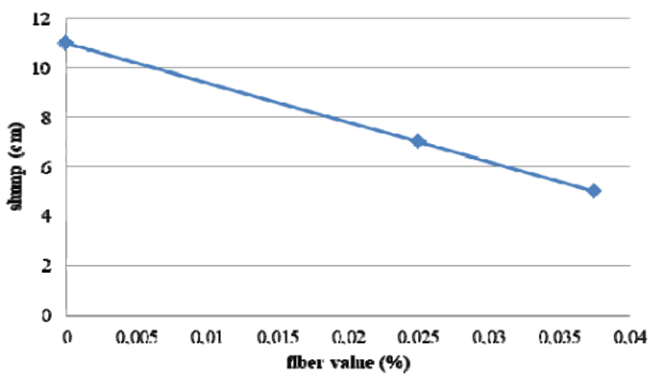


Fig. 4. Slump value with the addition of fiber.

Based on initial conditions by following the planned slump value so that there is additional material from the calculated job mix design, resulting in a relatively large decrease in compressive strength as shown in Table 3 and Figure 5.

TABLE III. EFFECT OF FIBER ON COMPRESSIVE STRENGTH

Fiber value (%)	Compressive Strength, f'c (MPa)
0	11,1
	13,4
	11,1
0,025	13,2
	11,9
	13,5
0,0375	6,2
	7
	6,8

The amount of decrease that occurred from the planned pressure condition to the results obtained was around 40,6%. With the addition of fiber to the concrete, there was also a change in the existing compressive strength, this happened when the fiber value of 0,025% increased by 8.4% and the fiber value of 0,0375% decreased by 43.8%.

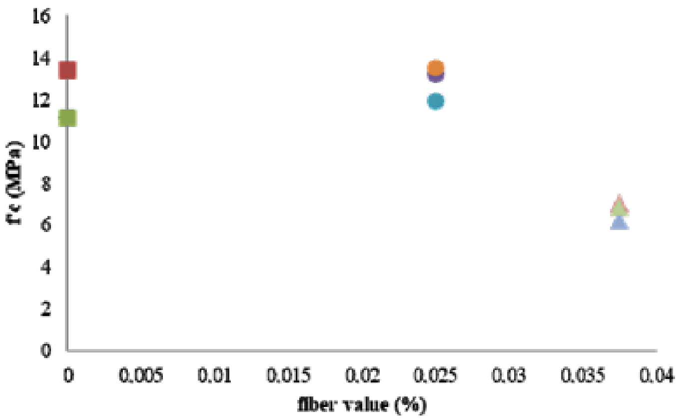


Fig. 5. Sorted by fiber value on compressive strength.

Table 4 and Figure 6 are the results of the tensile test. In contrast to the compressive conditions, the tensile condition along with the addition of fiber continues to decline. The amount of decrease in tensile strength that occurs with the addition of fiber value 0,025% by 22.8% and fiber value 0,0375% by 36.8%.

TABLE IV. EFFECT OF FIBER ON TENSILE STRENGTH

Fiber value (%)	Tensile Strength, ft (MPa)
0	2
	1,8
	1,9
0,025	1,5
	1,3
	1,6
0,0375	1,3
	1,3
	1

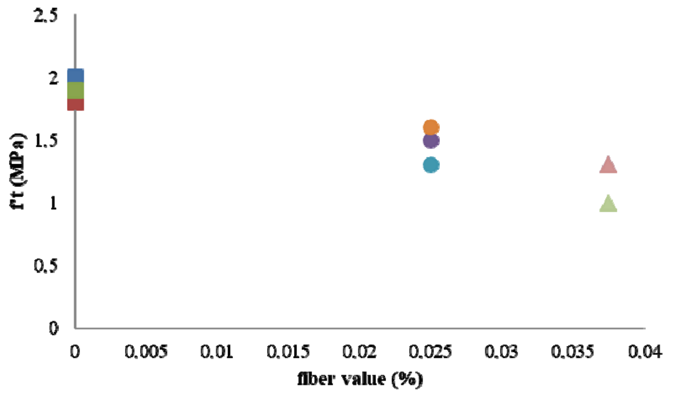


Fig. 6. Sorted by fiber value on tensile trength.

Table 5 shows the initial crack width results of the tested slab specimen.

TABLE V. INITIAL CRACK WIDTH

Reinforcement	Fiber value (%)	Dimension (mm)	Initial Crack Width (mm)	Load (kN)
Steel(SR)	0	8	0,2	12
	0,025	8	0,14	13
	0,0375	8	0,2	9,5
Bamboo (BR)	0	8	0,4	12
	0,025	8	0,4	12
	0,0375	8	0,28	9

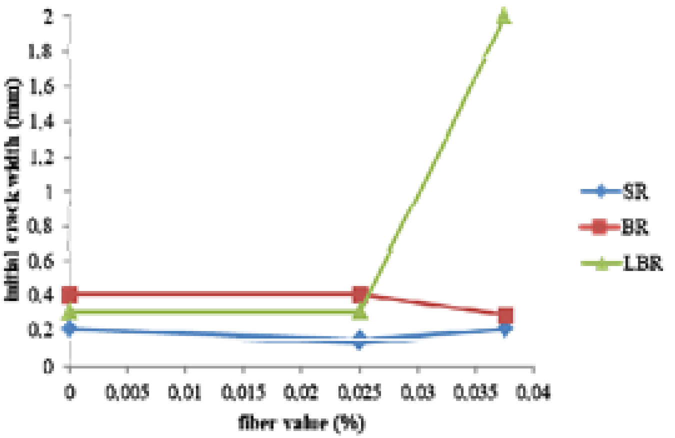


Fig. 7. Initial crack width of slab using rebar, bamboo and laminatedbamboo reinforcement.

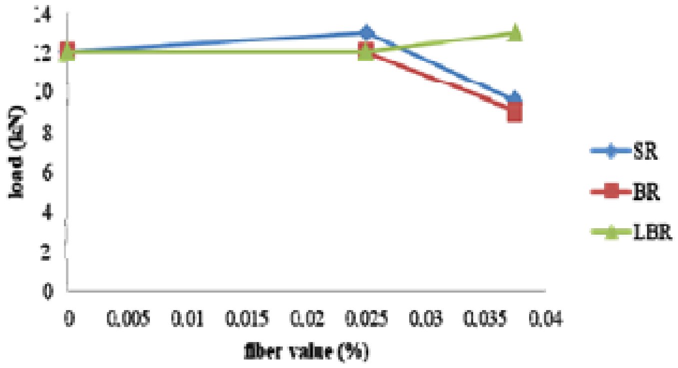


Fig. 8. Initial crack load of slab using rebar, bamboo and laminated bamboo reinforcement.

From Figures 7 and 8, it can be seen that there is an effect that exists on concrete using fiber and without using fiber, it is also seen the effect on the use of reinforcement from steel, bamboo and laminated bamboo. In the steel reinforcement slab with the addition of fiber at 0,025% there is a decrease in the initial crack width by 30% of the slab without additional fiber, and also increased the load by 8.3%. Whereas the slab with the addition of 0,0375% of fiber undergo the same initial crack width as the concrete slab without fiber, but there was a decrease in the load by 20.8%.

Unlike the condition of the bamboo reinforcement slab without fibers, the initial crack width that occurs is greater, namely 0.4mm or twice that of the steel reinforcement with the same load. Whereas in bamboo reinforcement using an additional fiber of 0,025%, the initial crack increased nearly three times compared to the slab using steel reinforcement, and also decreased by 7,6% load. Likewise for the bamboo reinforcing slab with the addition of 0,0375% fiber, there was an increase in the initial crack width by 40% of the reinforcing slab, and the initial crack load decreased by 5,2%. Whereas on the slab using laminated bamboo reinforcement there is a difference, namely a decrease in the initial crack width of the bamboo reinforcing slab by 25%, even though the initial crack load is the same. However, when compared to the steel reinforcing slab, the initial crack width of the laminated bamboo reinforcing slab was 33,3% greater than the crack width of the reinforcing slab with the same load. For the initial crack width ratio of the reinforcing slab laminated bamboo to steel reinforcement by 114%, with the same initial crack load. The interesting thing that is obtained from the use of laminated bamboo reinforcement is when the concrete is added with 0,0375% of fiber, although the initial crack width that occurs is greater than the slab with steel reinforcement, but for the load the initial crack width has increased quite significantly. The initial crack width that occurs is ten times that of the steel reinforcement, with a large increase in the initial crack load by 36.8%. this is possible because the laminate of fiberglass provides good reinforcement to the bamboo when it reaches the initial crack width of the existing concrete slab. Figure 9 is a form of crack that occurs in the slab.

Fig. 9. Cracks formed in all flexure tested slabs.

After the initial crack occurs, the crack will continue to the maximum crack, causing the concrete to break. Table 6 is the maximum crack width value that occurs in the tested slab.

TABLE VI. MAXIMUM CRACK WIDTH

Reinforcement	Fiber value (%)	Dimension (mm)	Max Crack Width (mm)	Load (kN)
Steel(SR)	0	8	0,2	12
	0,025	8	0,4	17
	0,0375	8	0,2	9,5
Bamboo (BR)	0	8	0,4	12
	0,025	8	0,4	12
	0,0375	8	0,28	9
Laminated Bamboo (LBR)	0	8	0,3	12
	0,025	8	0,3	12
	0,0375	8	2	13

Figure 10 shows the ratio of the load to the maximum crack width of the slab which has different reinforcement. In the condition that the maximum crack width corresponds to the maximum allowable crack width, only the steel reinforcement with added fiber 0,025% has the strength to resist up to the maximum allowable cracking.

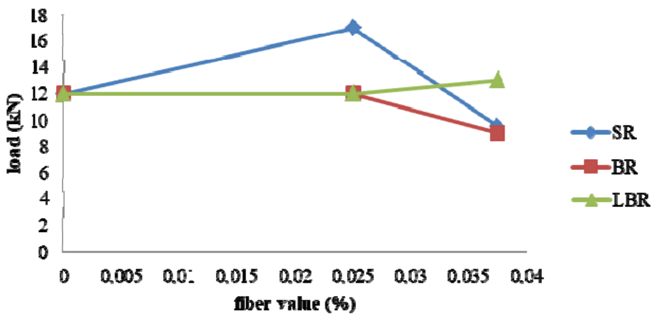


Fig. 10. Maximum crack load of slab using rebar, bamboo and laminated bamboo reinforcement.

It can be seen in Figure 11 that there is an increase in the load reaching the maximum allowable crack width by 30.7%of the initial crack width load.

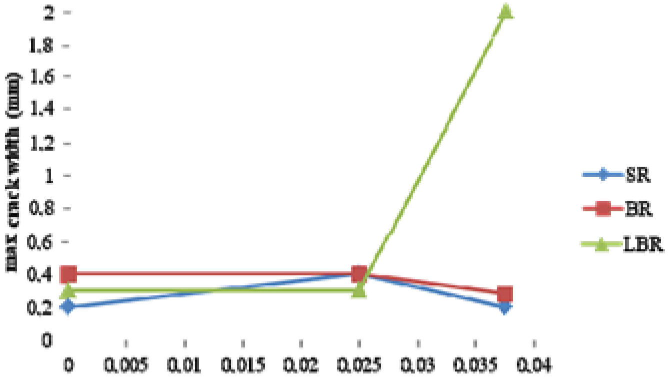


Fig. 11. Maximum crack width of slab using rebar, bamboo and laminated bamboo reinforcement.

The recorded load is related to the maximum allowable crack width by 0.41mm, and that obtained from the test results by 0.4mm. While the reinforcing slab, especially those without additional fiber and 0,0375% fiber when given an additional after an initial crack still maintaining the condition of the concrete, but it has passed the maximum allowed cracks. In the reinforcement of laminated bamboo and bamboo, after the initial crack occurs, then the load is increased, the concrete immediately breaks and the absence of resistance of bamboo reinforcement and laminated bamboo maintains the condition of the existing concrete slab.

IV. CONCLUSIONS

Fiberglass lamination given to bamboo has a good impact on bamboo, as seen by the increase in the flexural test results on the slab. While the addition of the desired fibers to overcome micro polypropylene crack width has not had a large impact. One of the things that may make the fiber not yet seen to give results to overcome the crack width that occurs, could be due to the planned drop in compressive strength. It could also make further research for the future.

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