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The Effect of Reinforcement Ratio of Hibiscus Skin with a Resin Coating on Lightweight Concrete Beam under Bending

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Abstract. The use of natural fibers as an alternative of reinforcement for the structure of light weight concrete beam is highly encouraging. The use of natural fiber was chosen because of its easy availability; easy to process, abundant in number, renewable, inexpensive, and relatively high tensile strength. Indeed, it is an environmentally friendly material. One of natural fiber is skin of hibiscus. Hence, the objective of this study is to investigate the effect of reinforcement ratio of hibiscus skin with a resin coating towards the flexural strength of light concrete beam. This study was conducted at Laboratory Structures and Materials, Mataram University. The dimensions of concrete beams were 15× 20× 150 cm and the variation of tensile reinforcement from hibiscus skin were 3, 6, and 8 with a diameter of 12 mm. In addition, the ratio of reinforcement was 0,014; 0,031; and 0,046. The yield strength of hibiscus skin with a resin coating in tension was 43,67 MPa. Furthermore, the largest ultimate load (P_u) for the ratio reinforcement of 0,014; 0,031; and 0,046 were 7,564 kN, 12,811 kN, and 14,19 kN respectively. Meanwhile, the ultimate moments (M_u) were 2,125 kNm, 3,125 kNm and 3,625 kNm for for the ratio reinforcement of 0,014; 0,031; and 0,046 respectively. Therefore, the greater the ratio of the reinforcement results the higher of the load resistance. Thus, the hibiscus reinforcement has the ability to increase the beam resistance against the flexural load.

BACKGROUND

The application of concrete structures in construction civil society is broad and growing rapidly. Concrete is widely used in various civil constructions because of its characteristic as able to sustain high compressive forces, easy in operating and maintaining, affordable and it can be combined with other materials. On the other hand, concrete is weak to tensile forces. In other to overcome the low tensile strength; therefore, concrete is combined with the reinforcement.

Generally, steel is used as reinforcement. However, the price is quite high so it is necessary to consider the alternative materials for replacing steel reinforcement which has a sufficiently high tensile strength, more economical, easy to find and it can cultivated. Also, it is environmentally friendly.

The utilization of pumice as aggregate light weight for light weight concrete is profitable because it has properties as light weight, soundproof, high insulation, and more resistant to fire and heat. In addition, it is suitable for acoustics. Due to the light weight property, it is suitable for element structures such as beam to be more resistance to seismic load.

A beam is a structural element which has function to transfer vertical load in horizontal from the existing structural members on it as dead load, live load, and others. Due to the load acting, the beam experience bending [1,2,3,4]. As a result of bending occurs, then it requires strength in resisting tension as by placing reinforcement in the tension region.

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Furthermore, one of the alternative materials that used as steel replacement is natural fiber composites. The use of natural fiber was chosen because of its easy availability, easy to process, abundant in number, and renewable, cheap. Also, it has relatively high tensile strength and it is such an environmentally friendly materials.

In addition, one of the alternative materials located in Lombok area that can be used as the alternative for steel is natural fiber composites in a form of twisted hibiscus skin [5,6,7,8]. It can be considered to produce light weight concrete beam with the hibiscus skin twist as the reinforcement as studied in this research.

METHOD

Production of Hibiscus Skin Reinforcement

Prior to the utilization for the reinforcement, the hibiscus skin was twisted using a tool. The final form is shown in Fig 1. In addition, the twisted reinforcement was coated using liquid resin to produce more rigid reinforcement. The twisted hibiscus reinforcement was arranged to form a diameter of 12 mm.

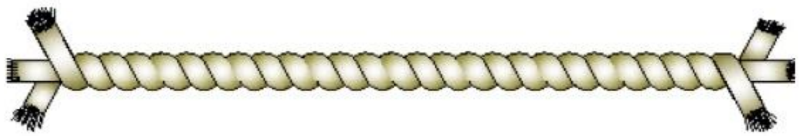


FIGURE 1. Twist of Hibiscus Skin

Testing of Hibiscus Reinforcement

Properties of the hibiscus reinforcement were investigated for obtaining the tensile strength and modulus elasticity. The testing was conducted by Universal testing Machine (UTM). The procedure of was based on ASTM 638-03 [10]. The 3 pieces of sample were provided in this testing.

Beams Specimens

In this study, the test object was a lightweight concrete beam with the dimension of 150×200×1500 mm. Three types of tensile reinforcement from twisted hibiscus on each beam were used. In addition, pineapple leaf fiber reinforcing concrete beam were also provides as a comparison [8]. The reinforcement ratio of the beams [11,12] is show in Table 1.

TABLE 1. Variation of beam reinforcement

Specimen	Ratio ρ	Diameter (mm)	Number of Test Objects	Information
BTKW3	0,014	12	3	Fiber
BTKW6	0,031	12	3	Fiber
BTKW8	0,046	12	3	Fiber

BTKW code is a code for lightweight concrete beam with twisted hibiscus reinforcement. In addition, numbers 3, 6 and 8 shows the amount of tensile reinforcement on each beam. For example, BTKW3 means the type of lightweight concrete beam with 3 pieces of twisted hibiscus as the tensile reinforcement.

Testing of Concrete Cylinder

The test of cylinder compressive strength [13,14,15] is carried out using Compression Testing Machine (CTM). Dimensions of the test object with a diameter of 15 cm and a height of 30 cm. The purpose was to find out compressive strength of the concrete.

Flexural Testing of Beams

Testing was conducted using a flexural testing machine with two centralized loads of 50 cm apart from the support. The supports were placed at a distance of 5 cm from the end of the beam. Furthermore, a dial gauge with 0.01 mm accuracy was placed in the middle of the span. Loading was given at intervals of 1 kN until the beam collapsed. Besides, Deflection measurement was carried out at each loading interval in conjunction with cracking occurrence [15].

RESULTS AND DISCUSSION

Aggregate Material for Concrete

Prior to be used as concrete mixture material, the materials especially aggregate must be confirmed to meet the minimum standard. The properties of the aggregate is shown in Table 2.

TABLE 2. Material inspection results

No.	**Properties of aggregate**		**Aggregate type**	
			Sand	Pumice
1.	Aggregate unit weight	average unit weight (gr/cm^3)	1,514	0,356
2.	Type of aggregate weight	average solid unit weight (gr/cm^3)	1,625	0,401
		specific gravity average dry condition	2,461	0,757
		specific gravity average SSD condition	2,578	1,132
3.	Absorption (%)		4,733	49,525
4	Finess modulus	grain fine modulus	3,248	6,920
5	Muds level (%)		2,080	-
6	Pumice abrasion resistance (%)		-	
	without soaking			
	a. 100 rounds			13,65
	b. 500 rounds			50,96
	With soaking			
	a. 100 rounds			11,33
	b. 500 rounds			41,03

TABLE 3. Test Results for Compressive Strength of Concrete Cylinders

Specimen	**Density (kg/m^3)**	**Average Density (kg/m^3)**	**Modulus of elasticity (MPa)**	**Compressive strength (MPa)**	**Average of Compressive strength (MPa)**
BTKW3-1	1.594,716	1.599,434	11.335,762	16,136	16,985
BTKW3-2	1.604,152			17,834	
BTKW6-1	1.589,054	1.691,885	11.349,313	17,270	17,269
BTKW6-2	1.594,716			17,268	
BTKW8-1	1.632,460	1.613,588	11.816,588	18,117	17,975
BTKW8-2	1.594,716			17,834	
Average		1.634,969	11.501,552		17,409

Concrete Cylinder Compressive Strength

Based on the test results, the concrete compressive strength have been meet the requirements, which average is 17 MPa as shown in Table 3.

Tensile Strength of Twisted Hibiscus Reinforcement

The results of the tensile strength of hibiscus reinforcement can be seen in Table 4.

TABLE 4. Tensile Strength Test of Hibiscus Reinforcement

Specimen	Diameter (mm)	Cross-sectional area (mm^2)	Yield stress, f_y (MPa)	Ultimate stress, f_u (MPa)	Strain (%)	Modulus of elasticity, E (MPa)
1	12,00	113,04	28,00	41,00	43,90	63,78
2	11,40	102,02	24,00	46,00	34,80	68,97
3	11,32	100,59	22,00	44,00	48,04	45,45
Average	11,57	105,22	24,67	43,67	42,25	59,40

Based on Table 4, the hibiscus reinforcement is showing the ultimate stress average of 43,67 MPa and the modulus of elasticity average of 59,40 MPa.

Beam Bending Strength

The beam flexural testing test was carried out after the beam has passed the curing time for 28 days. The method of bending test is conducted by calculating the load maximum beam in advanced, then according to the result, the interval load and reading deflection were determined. Table 5 gives the results flexural testing.

TABLE 5. Test Results of Beam Bending

Specimen	P_u Experimental (kN)	P_u Theoretical (kN)	Differences
BTKW3	9,00	7,564	1,436
BTKW6	11,00	12,811	1,811
BTKW8	14,00	14,139	0,139

Based on Table 5 above, the result of the maximum load for each beam type is 9 kN for BTKW3, 11 kN for BTKW6, and 14 kN for BTKW8. It can be seen that the differences between maximum experimental load and theoretical load is 1,436 kN for BTKW3, 1,811 kN for BTKW6, 0,139 kN for BTKW8.

Crack Pattern

From the test, the collapse that happened to all the test block objects begins with the occurrence of small cracks which located in the vicinity of the loading point. As the load increasing, the number of increasing crack is followed by crack propagation in the vertical direction. Crack pattern is recognized as a characteristic of flexural cracks, because the direction of the crack perpendicular to the cross-sectional axis. Figure 2a, 2b and 2c are the crack pattern in each of the test beam type.

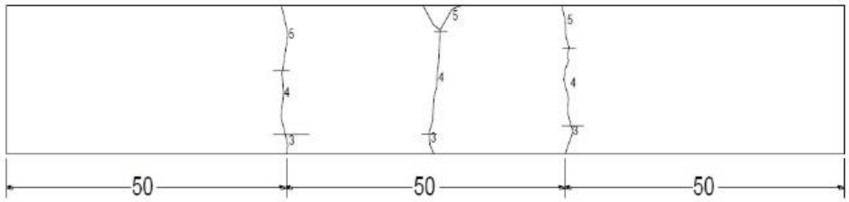


FIGURE 2 a. The Crack Pattern of BTKW3

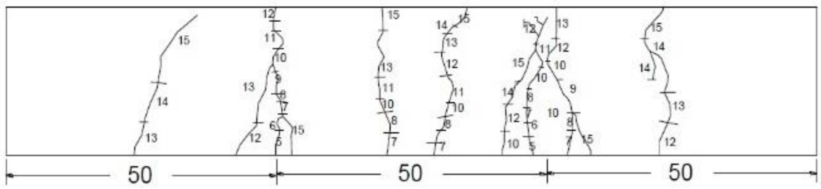


FIGURE 2 b. The Crack Pattern of BTKW6

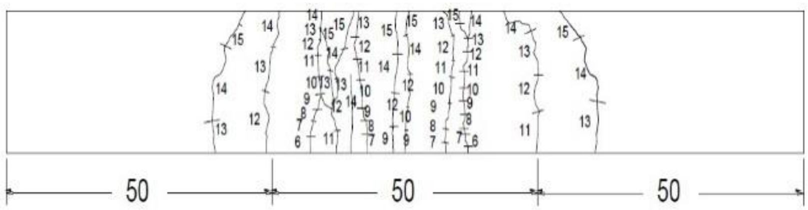


FIGURE 2 c. The Crack Pattern of BTKW8

The picture above illustrates the occurrence shear cracks of diagonal or sloping crack patterns. It is the result of flexural cracking. The crack pattern that occurs begins with a flexural crack, the direction of the crack is perpendicular to the axis of the cross section and the shear crack is up to total collapse.

The number of cracks that occur in each type of beam is different, caused by load and reinforcement ratio. The greater value of the ratio reinforcement, the workload is getting bigger which is followed by an increase in number of cracks.

Moment and Initial Crack

The initial crack was observed carefully on each side of the beam when applying the load during bending testing. The depiction of the crack pattern occurs to the beam and continues until the beam has completed collapse. The load and moment which causes initial cracks in each type of test beam can be seen in Table 6. The largest experimental initial crack load is found in BTKW8 specimen.

TABLE 6. Comparison of the Theoretical Initial Cracking Moment and Experiment

Block Code	Ratio Reinforcement ρ	Theoretical		Experimental	
		P_{cr} (KN)	M_{cr} (KNM)	P_{cr} (KN)	M_{cr} (KNM)
BTKW3	0,010	8,654	2,164	3,00	0,75
BTKW6	0,030	8,726	2,182	3,00	0,75
BTKW8	0,050	8,903	2,226	3,50	0,88

Ultimate Bending Moment

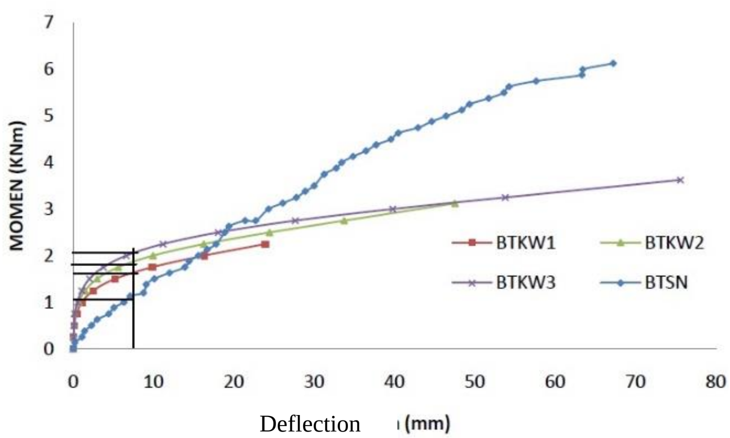
The ultimate bending moment is given in Table 7. The amount of ultimate bending moment (M_u) based on the experimental testing is not much different from theoretical ultimate moment.

TABLE 7. Comparison of ultimate bending moment theoretical and experimental

Block Code	Ratio reinforcement ρ	M_u Theoretical (KNm)	M_u Experiment (KNm)
BTKW3	0,014	1,89	2,13
BTKW6	0,031	3,21	3,13
BTKW8	0,046	3,55	3,63

Service Moment

The cross-sectional service moment of the beam is moment of limitation that regulated in SNI with allowable deflection parameter. Permit deflection for beams with a typical light structure based on SNI-03-2847-2002 is L/240 where the beam span is 1500 mm, so that the allowable deflection is 6.25 mm. The permit moment of the cross section of the beam is obtained based on the graph of the relationship between moment and deflection by drawing a vertical line on X (6.25mm). Then it connected with a horizontal line on the Y as Fig. 3 shows and the results is written in the Table 8.



Deflection

FIGURE 3. Relationship of moment and deflection

TABLE 8. Service moment of beam section

Block Code	Ratio Reinforcement ρ	Allowable Deflection (mm)	Service Moment (kNm)	Service Load (kN)
BTKW3	0,014	6,25	1,55	6,22
BTKW6	0,031	6,25	1,79	7,16
BTKW8	0,046	6,25	1,97	7,87
BTSN	0,040	6,25	1,00	4,00

There is an improving in moment service (M_s) and service load (P_s) in line with increasing reinforcement ratio value (ρ) on the beam. As a comparison, the service moment and service load of hibiscus reinforced beam is bigger than pineapple leaf fiber reinforced beam (BTSN) [8].

Beam Deflection

Table 9 provides the maximum bending load and bending strength of the beams

TABLE 9. The results of beam bending test

Specimen	Ratio ρ	P_{th} (kN)	P_{eks} (kN)	Differences (kN)	$σ_{th}$ (mm)	$σ_{eks}$ (mm)	Differences (mm)
BTKW3	0,014	7,56	9,00	1,44	23,92	23,50	0,42
BTKW6	0,031	12,82	12,50	0,32	47,53	36,25	11,28
BTKW8	0,046	14,20	14,00	0,20	47,80	36,80	11,00
BTSN	0,040	11,84	16,50	4,66	58,51	37,72	20,79

P_{th} = theoritical Load $σ_{th}$ = theoritical Strength
P_{eks} = experimental Load $σ_{eks}$ = experimental Strength

Based on the data obtained from flexural testing of hibiscus reinforced concrete beams in laboratory, the relationship between the load and the deflection for the entire specimens shows almost the same as the improving in deflection beam linearly either during elastic condition until ultimate moment. Furthermore, the ultimate load for specimens of BTKW3, BTKW6, BTKW8 and BTSN are 9 kN, 12,5 KN, 14 KN, and 16,5 kN respectively.

The experimental deflection for each beam including pineapple leaf fiber reinforced beam, BTKW3, BTKW6, BTKW8, and BTSN is 23,5 mm, respectively, are 36,25 mm, 36,8 mm, and 67,25 mm. The greater the value of the reinforcement ratio (ρ) then the bigger the load that can be endured as well as the deflection. Based on the discussion above, it can be concluded that the tensile strength of hibiscus beam is still lower than pineapple leaf fiber reinforcement beam under bending.

CONCLUSION

The hibiscus reinforcement has the ability to increase the lightweight concrete beam resistance against the flexural load. Higher reinforcement ratio (ρ) of the twisted hibiscus beam increases resistance ultimate load (P_u) and ultimate moment (M_u) under bending. The twisted hibiscus skin reinforced beam has smaller ability than reinforced pineapple leaf fiber reinforced concrete beam under bending.

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