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FLEXURAL BEHAVIOR OF REINFORCED CONCRETE BEAM USING ABACA FIBER

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ABSTRACT

The use of concrete today is still the main choice in the development of both functioning as a structure and non-structure. Poor properties of concrete can be corrected by adding fibers to the concrete mix or called fibrous concrete. The addition of fiber to the concrete mortar aims to reinforce concrete with pieces of uniformly distributed fibers (uniform) into the concrete mortar with a random orientation, so as to prevent cracking. The purpose of this study is to discuss the flexural behavior of reinforced concrete beams using abaca fibers. The test specimens in this study were made 6 pieces of test specimens measuring 150 mm x 200 mm x 3300 mm consisting of 3 beams made of normal concrete (NRC) and 3 concrete beams using abaca fiber (FRC). To identify the melt in the reinforcement strain gauge mounted on the tensile reinforcement and in the concrete strain gauge is also installed in the cross-sectional area. The beam is statically loaded and LVDT installed to measure displacement in the center of the beam. Abaca fiber composition used is 0.15% of concrete concrete with a fiber length of 50 mm. The results were obtained for the bending moment capacity of the fibrous beams at the time of the first crack, when the steel yield and the ultimate load, each giving an increase of: 32.02%; 3.87% and 3.77% of the normal beam. Deflection in the abaca fibrous beam at the first crack and at the ultimate load, an increase of 32.21% and 7.52% of the normal beam. The relationship of load to the strain of the abaca fibrous beam at the time of the first crack and at the ultimate load, an increase of 50.55% and 12.64% of the normal beam. The crack length on normal concrete beams is longer and in concrete beams that use fiber, there are more multiple cracks.

Keywords: Flexural behavior, Reinforced concrete beam, Abaca fiber

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1. INTRODUCTION

The development of science and technology in the field of material engineering as well as the development of environmental issues demands new breakthroughs in obtaining high quality and environmentally friendly materials. The final use of metal and ceramic materials will leave a residue in nature, because these materials are difficult to destroy by nature in a short time. Therefore, the use of plant fibers as an environmentally friendly material solution, being able to be recycled and being able to be destroyed by nature itself is a technological demand today. Research activities are continuing to produce alternative strengthening techniques that are better. The emergence of new materials in this case natural fibers, namely plant fibers in the group of leaf fibers, namely: abaca, banana, sisal, pineapple. Abaca fiber is one of the natural fibers with high tensile strength compared to other natural fibers, with folding strength, buoyancy, high porosity, resistance to saltwater damage, and fiber length of 2-4 meters [1]. Today there have been growing demands for the need for strengthening techniques both for the need for capacity building and for the need for structural improvement. This demand has encouraged researchers to develop technology and science related to strengthening techniques. Several reinforcement techniques have been developed, one of the strengthening technique methods is the addition of fiber to concrete. [2] concluded that the presence of fiber in concrete will increase stiffness and reduce deflection (deflection) that occurs. The addition of fiber can also increase the plasticity of the concrete, so that the structure will avoid sudden collapse due to excessive loading. The use of abaca fibers in concrete as reinforcement has been done by research by [3] in which the results show that the abaca fibers for concrete with an ideal fiber composition can provide an optimal contribution of 0.25% fiber of concrete weight, with a fiber length of 50 mm which gives an effect positive for the modulus of rupture of concrete. It also provides an adequate increase (8%) in the compressive strength of fiber concrete against normal concrete. The addition of fiber significantly changes the composite energy absorption capacity and also contributes to a 39% increase in fracture energy compared to unconstrained concrete mixes. In addition the effect of fiber is evaluated in terms of load and deflection behavior in fiber concrete with an average increase of 21%.

2. MATERIAL

2.1. Abaca Fiber

Abaca (musa textillis nee), a natural plant that is included in the banana plant (family musacease) originating from the Philippines which has been known and has been developed since 1519. Abaca banana plants are categorized as male bananas (do not produce fruit) shown in Figure 1.

Figure 1. Abaca fiber from a banana plant (not bearing fruit)

Abaca fiber based on the physical properties of fiber is the strongest natural fiber of all other natural fibers with high tensile strength and folding strength, buoyancy, high porosity, resistance to saltwater damage, and fiber length of 2-4 meters. Table 1 shows the comparison of physical properties of abaca with other natural fibers [1].

Table 1. Physical properties of abaca fiber with other natural fibers [15]

Physical properties	Abaca	Hemp	Sisal	Linen	Cotton
Density (g/cm^3)	1.5	1.46	1.33	1.4	1.54
Fibre length	2-4 m	3-3.5 m	1 m	Up to 90 cm	10-65 mm
Fibre diameter	150-260 microns	60-110 microns	100-300 microns	12-60 microns	11-22 microns
Tensile strength	857	400-800	600-700	800	400
Elongation (%)	1.10	1.80	4.30	2.7-3.5	3-10
Moisture regain (%)	5.81	13.75	11.00	10-12	8.50
Young's modulus	41	20-25	17-22	50-70	-

2.2. Fibrous Concrete

Fiber reinforced concrete (FRC) is defined as a concrete material made from a mixture of cement, fine aggregate, coarse aggregate, water and a number of fibers that are randomly scattered in a matrix of fresh concrete mix [4]. Fiber reinforced concrete (FRC) is defined as a concrete material made from a mixture of cement, fine aggregate, coarse aggregate, water and a number of fibers that are randomly scattered in a matrix of fresh concrete mix [4].

The behavior of fibrous concrete is determined by several factors, including the physical properties of the matrix and fiber and the attachment between the fiber and the matrix [4], namely: a) The physical properties of the fiber and matrix where the main factors that determine the ability of the fiber material are the physical properties of the fiber and the matrix and the attachment strength between the two. The average stress of the fiber is two to three times greater than the stress collapse matrix, this will cause the concrete to crack before the maximum tensile strength of the fiber is reached. b) Effect of Fiber Length and Diameter ie the ratio of fiber length and diameter (aspect ratio) will affect the attachment between the fiber and the matrix. Fiber with a ratio of $l/d > 100$ has a greater attachment to concrete than a short fiber with a ratio of $l / d < 50$.

According to [5], the addition of steel fibers can increase the tensile strength of lightweight concrete slabs to 165% and can even exceed the tensile strength of normal concrete with the same steel fiber added material. The addition of steel fibers also increases the flexural strength of lightweight concrete up to 91%.

Adding fiber to the concrete mixture is also proven to be able to inhibit the rate of cracking due to concrete shrinkage effectively. According to [6].

[7], conducted an experimental test to determine the effect of the addition of steel fibers measuring 60 mm in length and 0.75 mm in diameter to the mechanical strength of concrete and the flexural behavior of reinforced concrete beams. The results showed that the addition of steel fibers of 60 kg/m³ could increase the tensile strength of concrete slabs by 54% and flexural strength by 46%. In the testing of reinforced concrete beams, also seen an increase in the flexural capacity and ductility of concrete.

According to [8], the ability of fiber concrete to inhibit cracking can reduce the amount of tensile stress acting on reinforcing steel so that the ultimate capacity of concrete can be increased.

[9], a mixture of abaca fiber concrete with a composition of 0.15% and a fiber length of 50 mm gave the best results in testing: compressive strength, tensile strength and flexural strength.

3. RESEARCH METHODOLOGY

This type of research is a laboratory experimental study based on the composition of the abaca fiber in concrete mixes using the dry mixing method which will be applied to reinforced concrete beam specimens.

3.1. Design of Normal Concrete Mixture for 25 MPa Concrete Quality

Table 2. Concrete mix concrete design 25 MPa

Concrete material	Weight / M3 Concrete	Remarks
Cement	425,00	Tonasa cement
Sand	638,68	River sand
Gravel	1057,40	Stone breaks
Water	188,00	Clear water
Superplasticizer	0,2% weight of cement	Viscocrete 5115N

3.2. Composition of a Mixture of Abaca Fibrous Concrete

The composition of a mixture of Abaca fiber concrete with a fiber amount of 0.15 of concrete weight and fiber length of 50 mm [9]. Mixing is done through a concrete mixer and a fresh concrete mixture slump test [10].

Figure 2. Abaca fiber and fiber length

3.3. Preparation of Test Specimens Abaca Fiber-Reinforced Concrete Beams

The reinforcement details of reinforced concrete beams are shown in Figure 3. The steel reinforcement area consists of 100.6 mm² in the compressive area of the concrete section and 265.6 mm² in the tensile area of the concrete section. Abaca fiber is applied to three beams in a concrete mixture and three beams in a concrete mixture without fiber. The beam flexural test is carried out according to the standard ASTM.

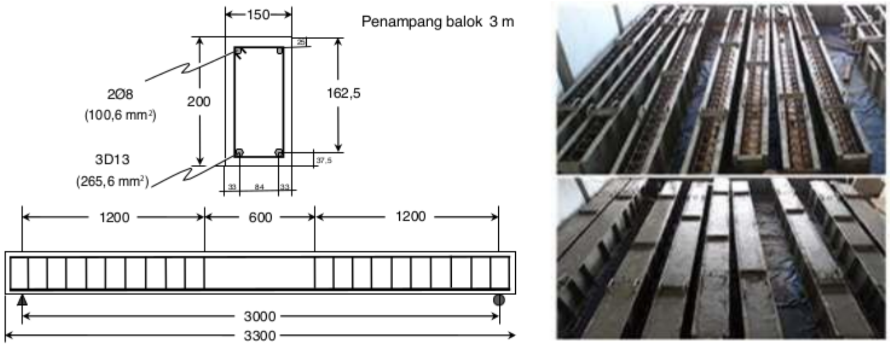

Figure 3. Detail of steel reinforcement beams at static load

Strain gauge mounting position on the beam, as shown in Figure 4. To measure the strain of the concrete a strain gauge is installed in the center of the span on the outermost side of the beam in the upper area (SC1), 33.3 mm below the body of the test object (SC2), 66.6 mm below the test specimen (SC3) and 100 mm below the test specimen (SC4). Whereas to measure tensile strain a strain gauge is installed on the D-13 mm steel reinforcement in the center span (SS1, and SS2). The gauges are applied using epoxy-resin and covered with a protective silicone coating. The measuring cable is placed longitudinally along the underside of the rod so as to exit the beam in one place.

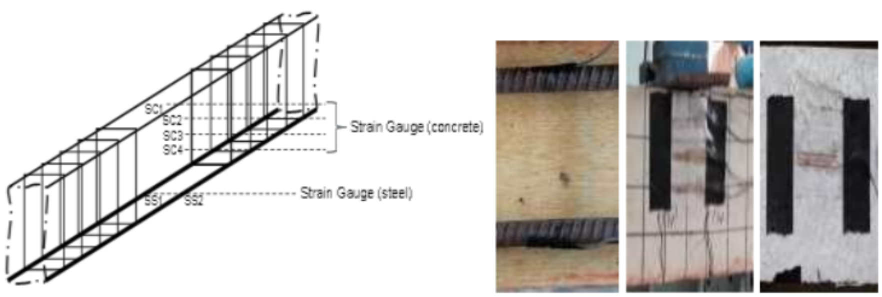

Figure 4. Placement of strain gauge for reinforced concrete beams

Deformed blocks are recorded with three LVDT (Linear Variables Displacement Transducers). First, LVDT 3 is installed in the middle of the upper span of the beam and recorded vertical displacement. Two LVDT are placed under each load to record vertical displacement (symbolized LVDT 1 and LVDT 2) can be seen in Figure 5. This average value and subtracted from LVDT 3 to get deflection from the beam. Test specimens that are ready to be placed on a loading frame with a pedestal conditioned roller joints at both ends. Loading is carried out at two points symmetrically with a distance of 600 mm between the loading points and as far as 1200 mm from each pedestal. Loading is carried out with the help of a hydraulic jack with a capacity of 500 KN and a load cell with a capacity of 200 kN which is used to provide centralized loading in the center of the beam span. The beam test set-up for static loading is shown in Figure 5.

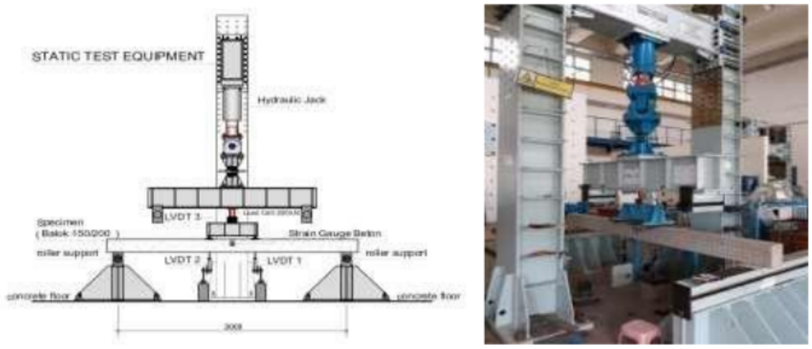

Figure 5. Set up beam testing

4. RESULTS AND DISCUSSION

4.1. Flexural Capacity of Reinforced Concrete Beams

The flexural capacity of Abaca fibrous reinforced concrete beams and normal reinforced concrete beams, the results are presented in Table 3 for the load during the first crack and during the ultimate load of each normal beam test specimens (NRC1, NRC2, NRC3) and fibrous beam specimens (FRC1), FRC2, FRC3).

Normal beam test specimens (NRC), after being burdened up to the first crack condition with an average load of 3.33 kN and fibrous beam specimens (FRC), the load on the first crack condition averaged 4.40 kN or an increase of 32.02% of normal beams. In the yield steel conditions the normal beam test object (NRC) where the average load is 28.88 kN and the fibrous beam test object (FRC), the average load when the steel yield is 29.92 kN or an increase of 3.87% of the normal beam. In the ultimate load conditions for normal beam test specimens (NRC), the average ultmate load is 31.17 kN. For fibrous beam specimens (FRC), the average ultimate load is 32.32 kN or an increase of 3.77% over normal beams.

Table 3. Test results of reinforced concrete beams

Test specimen	Load (P)			Deflection		
	P ***first crack*** **(kN)**	**P** ***steel yield*** **(kN)**	**P (kN)**	**P** ***first*** **(mm)**	**P** ***steel yield*** **(mm)**	**P (mm)**
NRC1	2.93	28.19	30.59	0.88	22.67	68.28
NRC2	3.40	28.72	30.92	1.48	25.98	62.18
NRC3	3.67	29.52	31.98	0.95	22.28	57.21
FRC1	4.13	29.79	31,99	1.21	22.23	68.78
FRC2	4.40	28.66	31.79	1.81	21.34	70.75
FRC3	4.67	31.32	33.25	1.36	22.33	62.24

4.2. Load Relation to Deflection

The relationship of the load to the deflection produced in the bending test of reinforced concrete beams can be seen in Table 3 and Figure 6. Deflection that occurs during the first crack on normal reinforced concrete beams (NRC), the average deflection is 1.10 mm and deflection on reinforced concrete beams with abaca fiber (FRC), the average deflection is 1.46 mm or an increase of 32.21 %. Deflection that occurs during yield steel in normal reinforced concrete beams (NRC), the average deflection is 23.64 mm and deflection in reinforced concrete beams with abaca fiber (FRC), the average deflection is 21.97 mm. Deflection that occurs when the ultimate load on normal reinforced concrete beams (NRC), the average deflection is 62.55 mm and deflection on reinforced concrete beams with abaca fiber (FRC), the average deflection is 67.26 mm or an increase of 7.52%.

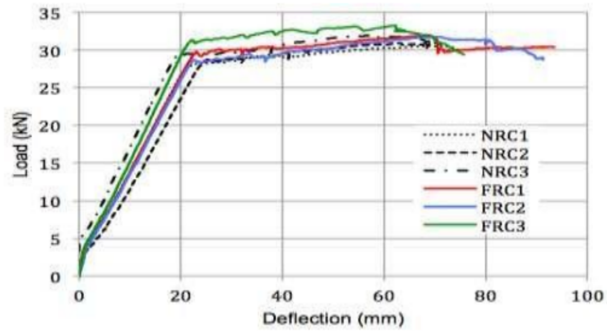

Figure 6. Load relation to deflection

4.3. Load Relation to Concrete Strain

The relationship of load to concrete strain can be seen in Table 4 and Figure 7, where the average strain that occurs during the first crack of normal reinforced concrete beams (NRC = 0.000091) and beam specimens with fiber (FRC = 0.000137) or an increase of 50.55% of the normal beam. The average strain that occurs when the steel yield in normal reinforced concrete beams (NRC = 0.001224) and beam test specimens with fiber (FRC = 0.001250). The average strain that occurs when the ultimate load on normal reinforced concrete beams (NRC = 0.002595) and beam specimens with fiber (FRC = 0.002923) or an increase of 12.64% of normal beams.

Table 4. Load relation to concrete strain

Test specime	Load (kN)			Concrete strain (x 10^{-6})		
	P *first crack*	P *steel yield*	P	P *first crack*	P *steel*	P *ultimate*
NRC1	2,93	28.19	30.59	75.96	1128.85	2627.88
NRC2	3.40	28.72	30.92	101.92	1287.50	2565.38
NRC3	3.67	29.52	31.99	95.19	1256.73	2593.27
FRC1	4.13	29.79	31.99	146.15	1264.42	3248.08
FRC2	4.40	28.66	31.79	137.50	1136.54	2992.31
FRC3	4.67	31.32	33.25	127.89	1348.08	2527.88

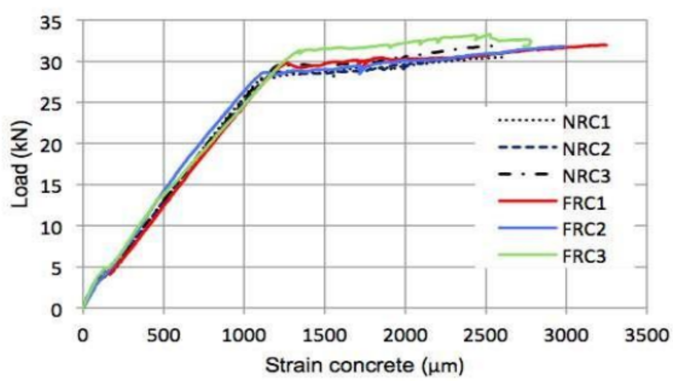

Figure 7. Relationship of load to concrete strain

4.4. Load Relation to Steel Strain

Comparison of strain results of experiments can be seen in Table 5 and Figure 8 which shows for all specimens receiving load proportionally where the first crack occurs, under the condition of steel yield to the ultimate load condition. The first post-crack loading until the steel yield of each reinforcement for all test specimens does not make a large difference in the steel strain. Post steel yield loading conditions until the maximum load conditions occur steel strain differences between the fiber beam (FRC) to normal beam (NRC).

Table 5. Load relation to steel strain

Test specimen	Load			Steel strain (x 10^{-6})		
	P *first crack* (kN)	P *yield* (kN)	P*ultimate* (kN)	P *first crack*	P *yield*	P*ultimate*
NRC1	2.93	28.19	30.59	50.94	2247.17	2401.89
NRC2	3.40	28.72	30.92	102.83	2229.25	2515.09
NRC3	3.67	29.52	31.99	58.49	2357.55	2768.87
FRC1	4.13	29.79	31.99	174.53	2577.36	7668.87
FRC2	4.40	28.66	31.79	154.72	2302.83	4349.06
FRC3	4.67	31.32	33.25	106.60	2742.45	3279.25

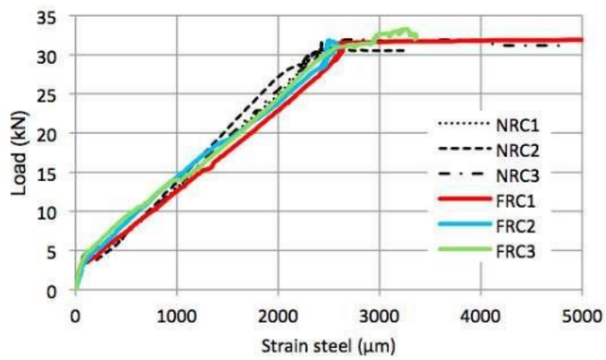

Figure 8. Load relation to steel strain

4.5 Beam Crack Pattern

The crack pattern as shown in Figure 9 is a bending crack that dominates the test beam. The method used in observing crack patterns is by drawing / sketching the test object. Crack patterns on all normal reinforced concrete beams (NRC), and crack patterns of reinforced concrete beams with abaca fibers (FRC). The first crack of the beam occurred in a flexible region, when the average load was 3.53 kN for normal beams (NRC), and beams with fiber (FRC) were 4.40 kN. Along with the increase in load will cause the spread of cracks leading upwards to the neutral line of the beam and the occurrence of new cracks. Then the normal beam (NRC) was destroyed at an average ultimate load = 31.17 kN and the fibrous beam (FRC) was destroyed at an average ultimate load = 32.34 kN. In general, the number of cracks is greater in beams with fiber (FRC), compared to cracks in normal beams (NRC). Inversely proportional length of bending crack propagation that occurs in normal beams (NRC) is longer than in fibrous beams (FRC).

Figure 9. Crack pattern of test specimens (NRC) and (FRC)

5. CONCLUSION

The results of testing and discussion carried out can be concluded as follows:

- The moment capacity of the fibrous beam at the time of the first crack, when the steel is melted, at the ultimate load, each giving an increase of 32.02%, 3.87%, 3.77% of the normal beam.
- Deflection in the abaca fiber reinforced concrete beam during the first crack increased by 32.21% and when the ultimate load gave an increase of 7.52% to the normal beam.
- The relationship of load to the strain of Abaca fibrous reinforced concrete beams during the first crack increased by 50.55% and when the maximum load gave an increase of 12.64% to the normal beam.
- The length of cracks in normal concrete beams is longer and in concrete beams that use fiber, there are more multiple cracks.

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