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Comparison bending strength of simple reinforced concrete beams with bamboo reinforcement in the form of circle and square sections

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Abstract

Steel reinforcement is well known as an important component in forming building structures. However, as the community's need for reinforcing steel is increasing, the main material for forming steel reinforcement is decreasing so that the price is getting higher. The alternative that is suggested as a substitute for tensile steel reinforcement which is economical and easy to get is bamboo. The purpose of this study was to determine the ratio of beam bending using circular and square bamboo reinforcement and to determine the bending load that can be accepted by circular and square bamboo reinforcement. In this study an experimental method was used by conducting a series of tests ranging from preserving bamboo and testing aggregates as a building block for concrete. The cross sections of bamboo reinforcement used are square and circle shapes with a diameter of 10mm with beam dimensions of 900 mm x 150 mm x 150 mm. The results showed that the flexural strength produced by steel reinforcing concrete beam was 11,36 MPa, circular cross section bamboo reinforcing beam 8,73 MPa and rectangle cross section bamboo reinforcing concrete beam of 9,04 MPa.

Keywords: concrete beam, maximum load, flexural strength, bamboo reinforcement

1. Introduction

Along with population growth, the construction of residential houses using reinforced concrete has also increased. One of the materials used in reinforcing concrete is steel reinforcement. The increasing need for the use of steel reinforcement will have an impact on the reduced availability of iron ore material, so that it will certainly trigger an increase in the price of iron ore to become more expensive [1]. An increase in the price of building materials will clearly have an impact on people's purchasing ability if it is not balanced with an increase of income.

Considering the importance of steel reinforcement in the manufacture of reinforced concrete, it is necessary to innovate alternative materials as a substitute for steel reinforcement because steel reinforcement is a product of mining processing that cannot be renewed by nature. One alternative to steel reinforcement in a reinforced concrete structure is bamboo. Bamboo is considered to be able to replace the function of steel reinforcement in reinforced concrete with almost similar capabilities.

The results of previous studies showed that bamboo (*Dendrocalamus asper)* has a tensile strength parallel to the fiber of 350.9741 MPa, yield stress of 242.47 MPa and bamboo adhesive strength to concrete of 0.341 MPa. Based on these results, the physical properties of bamboo have exceeded the quality of U-22 steel with a yield stress of 220 MPa, but the adhesive strength of bamboo to concrete is smaller than that of plain steel reinforcement with a diameter of 10 mm, which is 3.267 MPa. As for the flexural strength, the use of bamboo reinforcement in beams has a lower flexural strength value than the theoretical flexural strength so that the use of bamboo reinforcement should be used in simple constructions such as simple beams [2].

In addition, bamboo is also considered a more economical material compared to steel reinforcement [3], [4]. However, it is necessary to conduct research on the cross-sectional shape of bamboo as a substitute for steel reinforcement in order to obtain the most optimum shape for use in

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reinforced concrete structures. With this research, it is hoped that it can help in overcoming when there is a shortage of steel reinforcement during the construction process.

1.1 Concrete

Concrete is a mixture of cement, coarse aggregate, fine aggregate, and water, with or without additives that form a solid mass [5]. Coarse aggregates that are often used in the manufacture of concrete are natural stone and rock produced by the stone crusher industry. While the fine aggregate that is generally used is natural sand which is the result of mining from rivers or other quarry.

1.2 Beam

Beams are one of the structural elements in a building. In some construction buildings there may be several types of beam dimensions because they receive different loads so that the reinforcement is planned differently for each type of beam dimension [6]. Beams are generally made of reinforced concrete or steel. In reinforced concrete, there is steel reinforcement that serves to withstand the tensile forces experienced by the concrete. Several previous studies have tried to replace steel reinforcement with materials with strengths that are close to or can even exceed the strength of steel. One of the materials that is often studied to replace steel reinforcement in reinforced concrete is bamboo. Bamboo with its strong and hard but ductile stem so that it is easy to shape can be an alternative to be used as a substitute for tensile steel reinforcement [7]. Bamboo has a relatively high tensile strength, which is around 100-400 MPa or equivalent half to quarter to of the ultimate stress of iron [2], [8]–[10]. Bamboo has parallel fibers, so the strength against normal forces is quite good. The moment of inertness of bamboo is quite high due to its pipe-like shape so that bamboo is good enough to withstand bending moments and also the weight of bamboo is about 1/9 of the weight of iron [11]. In addition, bamboo is also relatively cheap compared to other building materials because it is commonly found around.

1.3 Bamboo

Dendrocalamus asper is a type of bamboo whose diameter can reach 30 cm. This bamboo can grow to a height of 20 m with a distance between bamboo segments of about 40-60 cm. This bamboo generally grows in areas with elevations above 300 meters above sea level which are hilly and have a wet climate. The strength of *Dendrocalamus asper* is quite good and has a hard texture, making this type of bamboo are often used as a building construction material. Several bamboo preservation techniques have also been carried out to obtain stronger and more durable bamboo [12].

1.4 Flexural Strength of Beams

The flexural strength of a concrete beam is the ability of a concrete beam to withstand forces in a direction perpendicular to the axis of the test object being tested by placing the beam on two supports until the test object breaks [13]. This test is carried out to determine the magnitude of the moment that the beam can withstand. The magnitude of the maximum moment by the external load on the test object can be described as follows:

$$M_{max} = \frac{1}{4} P_{max} \, . L + \frac{1}{8} \, q \, L^2 \qquad \text{Eq. 1}$$

2. Method

This research was conducted using experimental methods in the laboratory. The materials used in this study were coarse aggregate, fine aggregate, portland cement, P.10 mm steel reinforcement, P.8 mm steel stirrup reinforcement, concrete wire, concrete with compressive strength about 20 MPa and types of bamboo is *Dendrocalamus asper* with variations of square and circle cross section reinforcement in 10 mm diameter. This study uses 9 reinforced concrete beams with dimensions of 900 mm x 150 mm x 150 mm. Each beam is given a variety of reinforcement, namely steel reinforcement and bamboo reinforcement.

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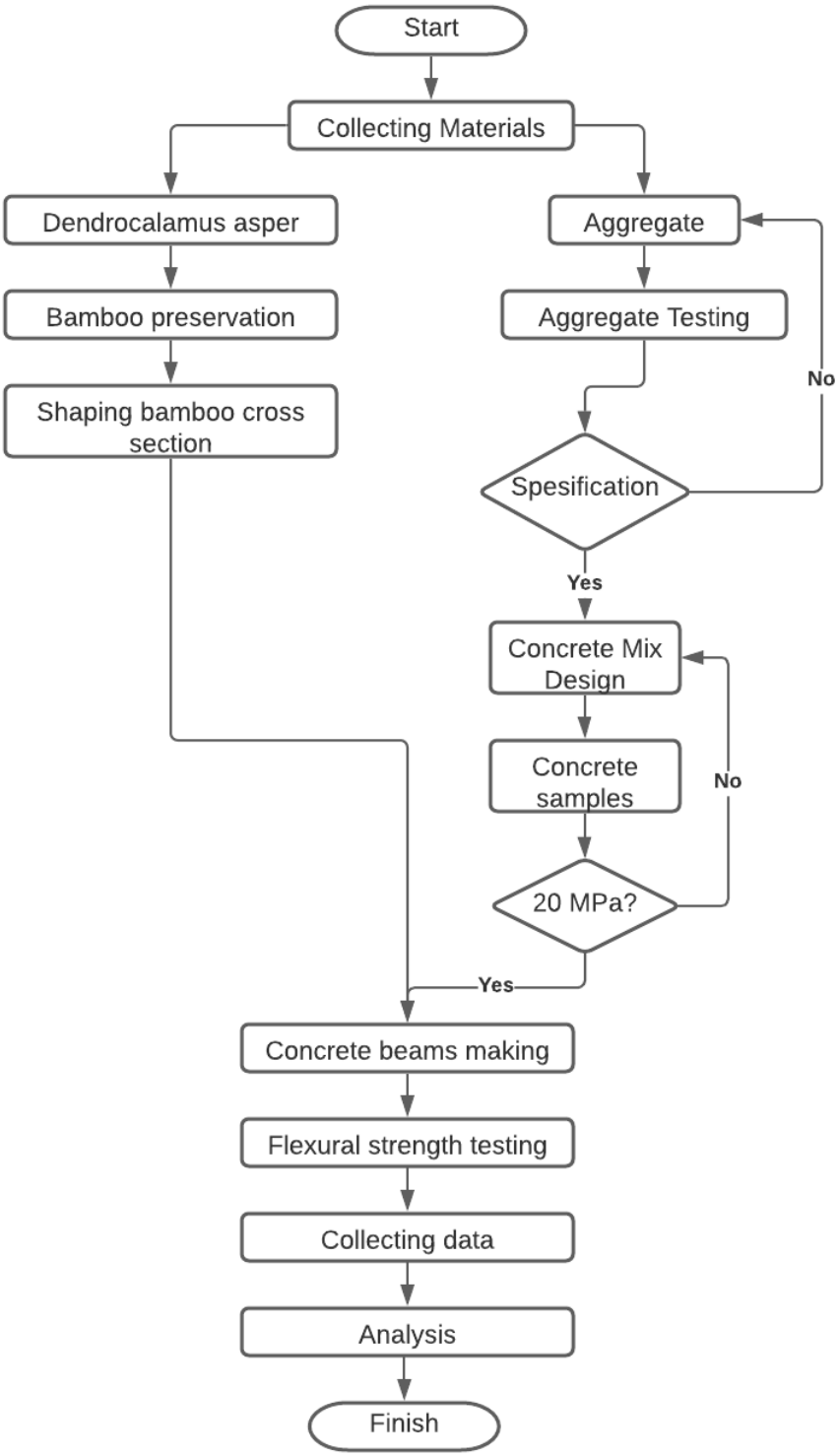

Figure. 1 Research Flowchart

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2.1 Specimens Design

The specimens were beams measuring 900 mm x 150 mm x 150 mm, 9 beams were made with details of the use of reinforcement 3 steel reinforced concrete beams 10 mm, 6 bamboo reinforced concrete beams each with circle and square reinforcement shapes. Shear reinforcement used reinforcement 8 mm. Testing of reinforced concrete beams in this study was carried out using the four point load method [11], [14].

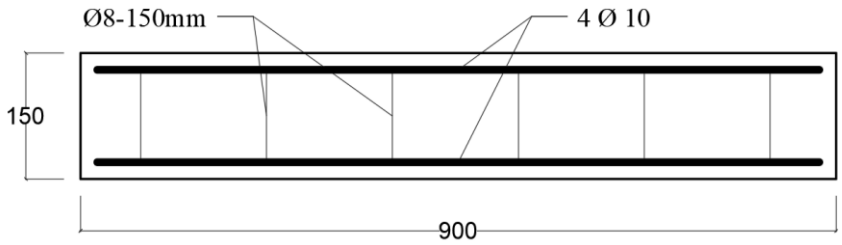

Figure 2. Longitudinal section of specimens

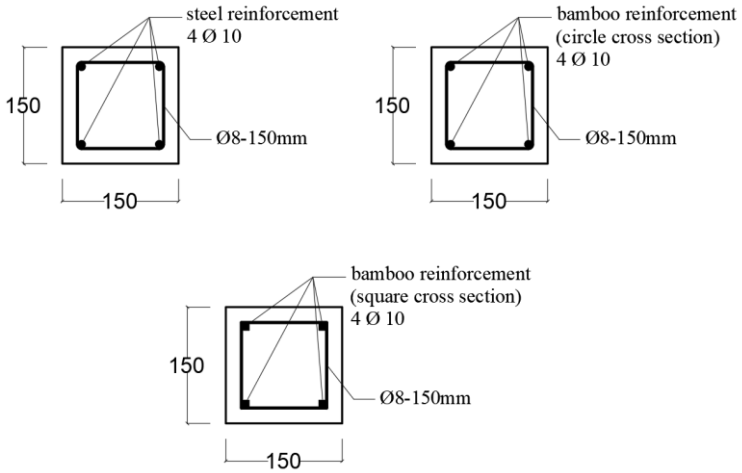

Figure 3. Cross section of specimens

3. Result and Discussion

3.1 Aggregate Test Results

The material used as the basic material in this study was tested for aggregate characteristics in the laboratory with the results obtained as follows:

Table 1. Coarse aggregate test results

Testing	Results	Specification (ASTM)	Remark
Water content	1,91	0,5% - 2%	qualify
Density:			
• Loose	1,70	1,6 – 1,9	qualify
• Compacted	1,65	1,6 – 1,9	qualify
Slurry content	0,65	0,2% - 1%	qualify
Specific gravity:			
• Bulk	2,53	1,8 – 3,2	qualify
• SSD	2,56	1,8 – 3,2	qualify
• Apparent	2,59	1,8 – 3,2	qualify
Water absorption	0,92	0,2% - 2%	qualify
Abrasion	6,03	0 – 40%	qualify

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Table 2. Fine aggregate test results

Testing	Results	Specification (ASTM)	Remark
Water content	4,91	3% - 6%	qualify
Density:			
• Loose	1,46	1,6 – 1,9	qualify
• Compacted	1,45	1,6 – 1,9	qualify
Slurry content	4,00	0,2% - 1%	qualify
Specific gravity:			
• Bulk	2,53	1,8 – 3,2	qualify
• SSD	2,56	1,8 – 3,2	qualify
• Apparent	2,62	1,8 – 3,2	qualify
Water absorption	1,30	0,2% - 2%	qualify

3.2 Concrete compressive strength results

The results of compressive strength concrete testing at the age of 28 days is 20.44 MPa and it according to compressive strength plan of 20 MPa, so that the proportion of the mixture can be used in making beam specimens.

Table 3. Compressive strength test results

Concrete age (day)	Sample	Load (kN)	Compressive strength (kg/cm^2)	(MPa)
7	I	168	96,99	9,51
	II	162	93,53	9,17
	III	171	98,72	9,68
	average		96,41	9,45
14	I	270	155,88	15,29
	II	250	144,33	14,15
	III	275	158,76	15,57
	average		152,99	15,00
28	I	368	212,46	20,83
	II	350	202,06	19,82
	III	365	210,72	20,66
	average		208,41	20,44

3.3 Flexural strength test of beams

The beams flexural strength test was carried out on 9 specimens. Beams with steel reinforcement as many as 3 specimens, beams with bamboo reinforcement with circle cross section as many as 3 specimens and beams with bamboo reinforcement with square cross section as many as 3 specimens. The results of the beam flexural strength test are presented in Table 4..

Table 4. Flexural strength test results

No.	**Code**	**L (m)**	**P_{retak} (kN)**	**P_{Maks} (kN)**	**q (kN)**	**Flexural strength (MPa)**
1.	BI	0.7	24,0	49,5	45,55	11,39
2.	B2	0.7	29,0	46,0	45,55	10,77
3.	B3	0.7	26,5	52,5	45,55	11,91
			average			**11,36**
4	LI	0.7	15,0	36,0	45,55	9,02
5	L2	0.7	13,0	32,0	45,55	8,32
6	L3	0.7	18,5	35,0	45,55	8,85
			average			**8,73**

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7	PI	0.7	17,5	35,5	45,55	9,02
8	P2	0.7	15,5	37,0	45,55	9,16
9	P3	0.7	15,0	36,0	45,55	9,02
			average			**9,04**

B : beam with steel reinforcement
L : beam with circle cross section bamboo reinforcement
P : beam with square cross section bamboo reinforcement

The results of the flexural strength test for beams with maximum steel reinforcement were 11.91 MPa and the average flexural strength for 3 specimens of beams with steel reinforcement was 11.36 MPa. The results of the flexural strength test of beams with circle cross section bamboo reinforcement, the maximum was 9.02 MPa and the average flexural strength for 3 specimens of beams was 8.73 MPa. The results of the flexural strength of beams with square cross section bamboo reinforcement the maximum was 9.16 MPa and the average flexural strength for 3 specimens of beams.

From these results, the flexural strength of the steel reinforcement beam is higher than the bamboo reinforcement beam, this is because the steel reinforcement can expand and experience a fairly high deflection. In contrast to the beam using bamboo reinforcement which can experience deflection but cannot expand. This is what makes the flexural strength of beams using bamboo reinforcement lower than steel reinforcement because from research conducted when the maximum moment occurs, the bamboo reinforcement does not expand but cracks or breaks. For the results, the flexural strength of beams with bamboo reinforcement with circle cross sections is lower than beams with bamboo reinforcement with square cross section which are relatively higher.

4. Conclusion

From the results of the study, it can be concluded that the average flexural strength for concrete beams with steel reinforcement was 11.36 MPa, concrete beams with sircle cross section bamboo reinforcement was 8.73 MPa and concrete beams with square cross section bamboo reinforcement was 9.04 MPa. The results of this test indicate that the flexural strength of beams with square cross section bamboo reinforcement was higher than the concrete beam with circle cross section bamboo reinforcement. The difference in the average flexural strength of the beam with square and circle cross section was 0.31 MPa.

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