Flexural behavior of petung bamboo strip notched reinforced concrete beams

Agus Setiya Budi and A.P. Rahmadi
Department of Civil Engineering, Sebelas Maret University,
Ir. Sutami Street, 36A Kentingan Jebres Surakarta 57126, INDONESIA
E-mail: agussb@staff.uns.ac.id

Abstract. In Indonesia, many bamboo trees are found, including Petung bamboo (Dendrocalamus Asper). Bamboo has a high tensile strength enough, especially on skin of bambu, so it has the opportunity to replace for steel reinforcing bars in reinforced concrete construction elements. This study will report the results of the use of Petung bamboo strips notched U shape as a reinforcement in concrete beams structural element. The bamboo strips notched U shape is expected to increase the bonding effects between bamboo reinforcement and concrete. Experimental studies were carried out in the laboratory. Distance between the notches are 5, 10, 15 cm with a high of notch size of 0.5 cm and width size of 1 cm and 2 cm. The specimens size test of the reinforced concrete beams is 11x15x170 cm. Based on test results, the bamboo strips notched U shape as reinforcing bars in concrete beams can improve the flexural capacity.

1. Introduction
At present, the manufacturing industry using natural materials has been activated in order to respond to issues of global warming and sustainable community life. In developing countries, bamboo that is fast-growing, widely expandable, low-cost, is expected to contribute significantly to seismic repair technology and earthquake-resistant building structures [1]. Development of structural elements has been widely carried out and studied in many elements of building construction. Investigations about increasing the bond of bamboo reinforcement with concrete and its durability have been carried out by many researchers. Therefore, it is necessary to introduce subjects about the use of bamboo as a structural material in technical schools and in universities both at the graduate and postgraduate levels so that they can establish specific regulations for the design of bamboo as structural elements [2].

All over the world, the number of bamboo species is more than 1200 species. Another alternative material that can be used in building construction that is very potential is bamboo. As a result of the lack of standardization of regulations, the use of bamboo as a component in building construction is currently limited to cultural traditions [3]. Polymer composites from agricultural plant materials have been widely researched and developed by countries with scarce forest resources. For the development of polymer composites and the design requirements of agricultural plants, one that is possible is bamboo. In order to create a sustainable future for bamboo, in addition to using bamboo in the traditional way is by means of industrial composites based on bamboo. Analysis and testing of composite-based bamboo fibers and their fiber characterization must be more advanced [4].

To increase the tensile capacity of concrete, steel is often used as reinforcement. Steel is an expensive and non-renewable material. Therefore, at present it seeks to find alternative local materials that are sustainable and at a low cost. In this study, evaluation of the feasibility of bamboo as reinforcement in
concrete was carried out with several experimental investigations. Evaluation of the ultimate strength and engineering properties of bamboo that is carried out is the local bamboo strip tensile test [5]. Bamboo trees are common in Asia. This bamboo tree is a tree that easily develops and grows. The main advantage of bamboo in relation to construction is the high tensile strength on the side of the bamboo skin. Some of them even have tensile strength that almost equals the tensile strength of round steel, so that bamboo reinforcement has the potential to replace steel reinforcement in structural elements. There are obstacles to the use of bamboo directly in construction. These obstacles are easy to slip between bamboo reinforcement and concrete. Therefore it is necessary to find a method to reduce the slip. The purpose of this paper will discuss the type of bamboo reinforcement which can reduce the effect of slip on concrete beam structural elements, so that the flexure capacity of the beam is increased.

2. Experimental Method

2.1 The properties material of bamboo
Bamboo is a natural resource available in many developing countries, easy and fast growing and affordable prices. From the comparison of the weight to strength ratio, bamboo has a superior potential than wood and steel construction. To improve the physical character of composite action in the application of concrete structures and to preserve their mechanical properties, a new technology has been developed in this study [6]. The tensile strength of bamboo is equivalent to the best wood used in construction, even with construction steel, based on the results of experimental tests carried out on the bamboo species Dendrocalamus Giganteus. In specimens without nodes, the average tensile strength of bamboo is around 280 MPa, and at specimens with nodes around 100 MPa. The tensile strength and Young Modulus of bamboo did not decrease at 60 times the cycle of wetting and drying in calcium hydroxide solution and tap water [7]. The characteristics of bamboo that are used and chosen are as follows, the age of bamboo has been at least three years old, bamboo has matured if the skin has brown color, select bamboo that has a large stem, straight, long, not cracked, no rot, no fungus and no holes because of white ants. Bamboo with high water content is weaker, therefore bamboo is not cut in wet conditions [8].

The type of Petung bamboo (Dendrocalamus Asper) which is 3 years old, is bamboo used in this study. Petung Bamboo is taken from Boyolali district, Central Java province, Indonesia. This type of bamboo has the following characteristics: the height of bamboo is about 10 meters to 20 meters, the thickness of the bamboo wall is around 15 mm to 30 mm, diameter rods are about 200 mm to 300 mm. The following are data on the physical and mechanical properties of Petung bamboo: tensile strength with node is 196.5 MPa, tensile strength without node is 233 MPa, the density is 1.231 g/cm3 and water content is 6.971 %. To get a strong bond between bamboo reinforcement and concrete, making a notch on the bamboo is made on both sides of the bamboo reinforcement. This notch on bamboo is expected to reduce the effect of slip on bamboo reinforcement.

2.2. Specimen test
The size of the U notch dimension discussed in this study can be seen in Figure 1. Before use, bamboo strips were dried for approximately 15 days at room temperature. Then bamboo strips are cut to a size of 0.5x2x165 cm and then notched in a U-shape at a distance of 5, 10 and 15 cm. At each distance between the notch, notched with dimensions of 20x5 mm and 10x5 mm. The determination of the distance between the notch and the notch dimensions is based on the reasons for the ease of the notching work. In this research, the positioning of the notch on both sides of the bamboo is aligned and bamboo strips in a vertical position, as shown in Figure 2.
In this research, in addition to using bamboo reinforcement, round steel reinforcement with a diameter of about 8 mm was used as a comparison. Based on the tensile strength test results of 5 steel reinforcement samples, the results showed that the average maximum tensile strength and average yield tensile strength were 539.43 MPa and 417.52 MPa, respectively. PPC (Portland Pozzolan Cement) is the type of cement used in this study that is in accordance with the SNI 15-0302-94 (Indonesian National Standard). The quality of concrete is obtained based on the compressive strength test of concrete that used normal cylinder test with size 15x30 cm. When a cylindrical concrete sample is 28 days of age, 7 cylindrical concrete samples are tested. The test results showed that with an average slump value of 12 cm, the average compressive strength of the concrete cylinder sample was 24.92 MPa.

2.3 Experimental setting
In Figure 3 below is presented bamboo strips notched placement as a reinforcing bars on a structural concrete beam.
Figure 3. Cross-section and the placement of bamboo strips notched as reinforcing bars

The dimension of the reinforced concrete beam specimens in this experiment is 110x150x1700 mm. In this experiment, there are 6 types of beams, each type are 6 pieces, so the total number of concrete beams tested are 36 pieces. Gradual static loading is carried out on concrete beam specimens, with a load increase step every 50 kg until the concrete beam collapses according to ASTM C78. Setting the loading method in this experiment is shown in Figure 4.

Figure 4. Experimental loading setting

2.4 Flexural capacity
The distribution of loading on the beam is shown in Figure 5. Based on the results of the loading test on the beam to collapse, which is carried out in the laboratory, the maximum load can be obtained.

Figure 5. The distribution load on the beam.

Calculation of the value of the flexural capacity is based on the maximum load data when it collapses, including calculating the weight of the beam itself. The value of the flexural capacity of the experimental results can be determined based on the moment static balance equation, which can be seen in Equation (2).

\[ R_{Av} = \frac{17}{30} qL + \frac{1}{2} P \] (1)
\[ M_{\text{max}} = \left( R_{\text{Av}} \cdot \frac{1}{2} L \right) - \left( q \cdot \frac{17}{30} L \cdot \frac{17}{60} L \right) - \left( \frac{1}{2} P \cdot \frac{1}{6} L \right) \]

\[ M_{\text{max}} = \frac{1}{2} P \frac{1}{3} L + \frac{221}{1800} qL^2 \]  

(2)

3. Results and Discussion

Based on the results of flexural tests on concrete beams in the laboratory according to ASTM C78, the collapse of Petung bamboo reinforced concrete beams shows the type of flexural collapse, with conditions similar to steel reinforced concrete beams.

The relationship between load and deflection on some specimens of bamboo reinforced concrete beams with notches, steel reinforced concrete beams and bamboo reinforcing concrete beams without notches, can be seen in Figure 6. While in Figure 7 is presented load and deflection relationship diagrams on bamboo reinforced concrete beams and steel reinforcement beam, at a distance between notches 5, 10 and 15 cm.

![Figure 6. The relationship of load and deflection of steel and bamboo strip without notch](image)

![Figure 7. The relationship of load vs deflection on steel and bamboo as reinforcing bars.](image)

Note:
P5cm-1cm, etc: beam with bamboo strip reinforcing (notch distance 5 cm and 1 cm wide notch), etc; P-NN: beam with bamboo strip reinforcement without notched; Steel-8mm: beam with round steel reinforcing bar diameter 8 mm.

According to Equation (2), the value of the average flexural moment of the experimental results for the bamboo strip notches at a distance of 5, 10, 15 cm with a width of 1 cm notch, are 353.71; 293.32;
286.41 kgm, respectively. On reinforcement bamboo strips notch at a distance of 5, 10, 15 cm with a width of 2 cm notch, are 368.44; 355.52; 346.76 kgm, respectively. Whereas for bamboo strips without notches is 236 kgm and for steel reinforcement with 8 mm diameter, the average flexural moment value is 568.19 kgm. In figure 8 is shown a diagram of the average flexural moment of the experimental results for the bamboo strip notches, steel reinforcement with 8 mm diameter and for bamboo strip without notches. In Figure 8 also shows that in general the value of the experimental results for bamboo strip notched increases compared to bamboo strips without notches. The increase value of the flexural moment of the experimental in bamboo strip notched width 1 cm and bamboo strip notched width 2 cm, compared to the value of bamboo strip without notched, are 31.84% and 50.95%, respectively. From these results it was found that the average value of the flexural moment of the experimental with bamboo strip notched width 2 cm is higher, averaging about 19.11% compared to bamboo strip notched width 1 cm.

![Figure 8](image.png)

**Figure 8.** Experimental flexural moment

4. Conclusions
The results of this study indicate that the U-shaped notch bamboo strips as reinforcement on concrete beams can increase flexural capacity compared to reinforcing bamboo strips without notches.

5. References

[1] Terai M 2011 Proc. Eng. 10 2967
[2] Ghavami K 1995 Cem. and Conc. Comp 17 281
[3] Sharma B 2015 Cons. Build. Mat. 83 95
[4] Khalil H.P.S. Abdul, Bhat I.U.H, Jawaid M, Zaidon A, Hermawan D, Hadi Y.S 2012 Mat. and Des. 42 353
[5] Atul Agarwal, Bharadwaj Nanda, Damodar Maity 2014 Cons. Build. Mat. 71 610
[6] Javadian A 2016 Cons. Build. Mat. 122 110
[7] Humberto C 2008 Mat. and Struct. 41 981
[8] Budi, A.S, Rahmadi AP 2017 AIP Conf. Proc. 1903 020010-1