

Performance of petung bamboo strip with anchor screw nails on the reinforced concrete beams

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Abstract: Steel is the main material used as reinforcement in reinforced concrete structures. Naturally, the number of steels used rapidly increase every year. The increase has an effect on the availability of steel's main raw materials which is iron ore, a non-renewable natural resource. Therefore, an alternative steel replacement material is needed. Bamboo is chosen as an alternative substitute for reinforcing steel in reinforced concrete structures. In this study, petung bamboo caps anchored using screw nails was used as flexible reinforcement in reinforced concrete beams. This study aimed to analyze the behavior of load and deflection relationships in the flexural capacity of bamboo reinforced concrete beams against steel reinforced concrete beams. There were 6 beams used as specimens, consisting of 2 bamboo reinforced concrete beams with 1cm long screws, 2 bamboo reinforcing beams with 2 cm long screw nails, and 2 beams with 12 mm diameter steel reinforcement as a control beam. The results showed the flexural strength of bamboo reinforced concrete beams with 1 and cm hook length was 44.32 kN and 46.98 kN or 48.64% and 51.56 compared to steel reinforced concrete beams with flexural strength values of 91.10 kN.

1. Introduction

This study was conducted due to an increase in the need for reinforcing steel in reinforced concrete structures. The increase need will lead to scarcity of steel because the supply of basic steel materials in the form of iron ore is limited. Thus, the production of reinforcing steel is impossible to increase. Based on data published by SEAISI (South East Asia Iron and Steel Institute) through the official website of the IISIA (Indonesian Iron and Steel Association), in 2016, national steel use in Indonesia exceeded 13-14 million tons. The increase of 11% compared to 2015 was as much as 11.3 million tons. The increasing need for steel surely has a direct impact on the availability of its main raw materials which is non-renewable natural resources called iron ore. On the other hand, iron ore mining activities can also have a negative impact on the morphology of the land because it causes derivative impacts in the form of abrasion around the mining area [1].

Bamboo can be chosen as an alternative substitute for reinforcing steel in reinforced concrete structures. Bamboo is considered very feasible because it is a natural material that is renewable, inexpensive, easily cultivated, and relatively fast growth in the range of 3 to 4 years. Bamboo grows almost in all regions of Indonesia. There are more than 120 types of bamboo, 56 of which have very high potential in the economy sector [2]. Additionally, in terms of mechanical properties, bamboo has a high tensile strength almost close to the tensile strength of steel [3]. The tensile strength of bamboo reaches 100-400 MPa, equivalent to 0.25-0.5 of the ultimate stress of steel [4].



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Several studies had been conducted on the use of bamboo in reinforced concrete beam structures. In general, those studies aimed to increase the adhesion between bamboo and concrete reinforcement. There were several modifications made in an effort to increase the adhesion of bamboo reinforcement. One of the modifications made was by loading notches on bamboo reinforcements at a certain distance. The use of V-shaped notches on bamboo reinforcement can increase the bending moment capacity of bamboo reinforced beams at a notch between 20 mm and 30 mm [5]. U-shaped notch bamboo as reinforcement on concrete beams can increase bending capacity compared to bamboo stream reinforcement without a notch [6].

Based on several advantages and disadvantages of bamboo as well as in effort to make bamboo as an alternative material for reinforcing concrete structures, further development is still needed in order to make the performance of bamboo as reinforcement can be similar to the performance of steel in reinforced concrete structures. The difference between this research and other studies is, In this study will use screw nails to improve the bond between bamboo and concrete. In addition, this study will also optimize the use of bamboo skin parts, by maintaining a natural curve on the surface of the bamboo without reducing the tensile area on the cross section of the reinforcing bamboo.

2. Experimental method

2.1. The characteristics of petung bamboo

Bamboo is one of the natural construction materials grown in tropical area. The use of bamboo is well known, especially in the civil construction. However, there are only a few types of bamboo commonly marketed in Indonesia such as Petung bamboo, Wulung bamboo, Tali bamboo, and Duri bamboo [7].



Figure 1. Petung bamboo.

Petung bamboo has some characteristics such as having 3.5 – 5 m² diameter of each bamboo clump, having around 28 – 41 stems bamboo sticks, a stem length of about 14.5 – 1.65 m, a number of segments ranging from 41 – 46 segments, and the length of the section at the base of 20 cm. Toward the end of the stem, the length is longer. It can even reach 40 – 60 cm [8].

The growth of bamboo is fast because it is one of *Bambusoideae* which is included in grasses sub-family. There are some factors influence the strength of bamboo [9]:

- The tensile strength of bamboo will decrease with increasing water content.
- The maximum tensile strength of the outer part of bamboo stem is greater than the other parts.
- The existence of nodal in bamboo which has a lower strength than the internode part.

Elastic modulus with or without nodal in some types of bamboo has been studied with results as presented in **Table 1** below [10]:

Table 1. Modulus of bamboo bending elasticity.

Types of Bamboo	Minimum		Maximum		Mean	
	With Nodal	Without Nodal	With Nodal	Without Nodal	With Nodal	Without Nodal
	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
Petung	3267	12247	26672	31547	10329	21658
Temen	2862	3667	29596	22789	5662	12139
Ampus	1075	1340	17033	19359	5751	12133

Every bamboo structure has nodal and internode. Considering the structure has to be designed based on the weakest part, the study of tensile strength of parallel fiber was carried out in internode and nodal. The results of the study can be seen in **Table 2** below [11].

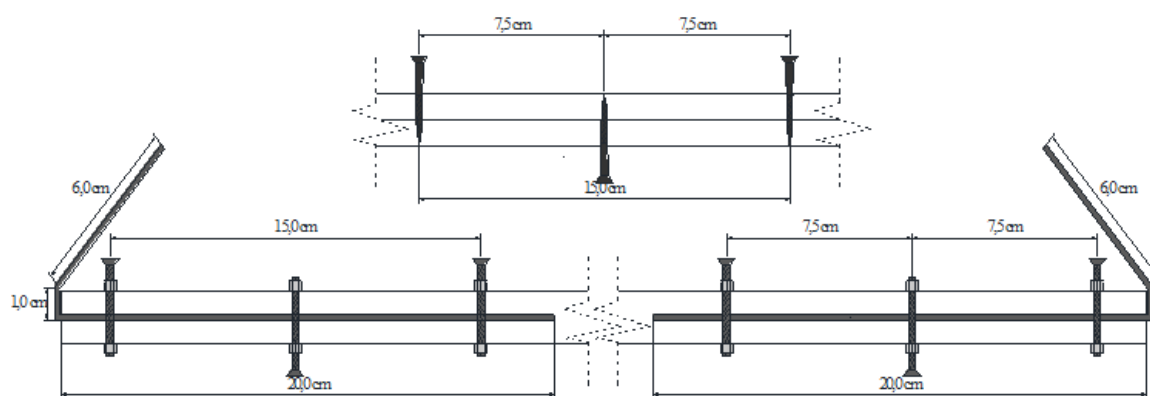
Table 2. Tensile strength of parallel fiber in Internode and nodal.

Types of Bamboo	Tensile Strength of Parallel Fiber (MPa)		
	Internode	Nodal	Mean
Petung	190	116	153
Ori	291	128	210
Ampus	151	55	103

Due to the advantages of bamboo, in this study bamboo was used as a substitute for longitudinal reinforcement in reinforced concrete beams. The type of bamboo used is Petung bamboo because it has a relatively abundant availability and has tensile strength that almost similar to steel reinforcement.

2.2. Bamboo reinforcement design

Bamboo reinforcement was made with an arrangement of bamboo slats. Those slats were tied/clamped using screw nails with a distance between 30 cm screw nails. There were 2 types of length of screw nails used which were screws with a length of 1 cm and 2 cm. Details of bamboo reinforcement was visualized in **Figure 2** below:

**Figure 2.** Bamboo reinforcement design.

The variables of this study were the length of screw nails' hook (L_k) anchored on bamboo reinforcement. The first screw nail (L_{k-10}) has the hook length of 1 cm, and the second screw nail (L_{k-20}) has the hook length of 2 cm. Details of the L_{k-1} and L_{k-2} variables can be seen in **Figure 3**.

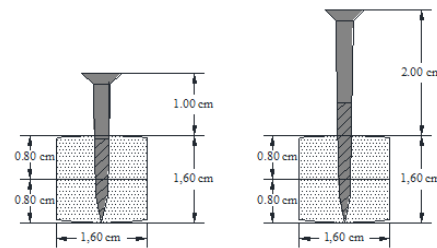


Figure 3. The hook length of screw nails used in the bamboo reinforcement.

2.3. Instrument preparation for the testing

The test beam dimension was 200×300×2500 mm. There were 6 test beams consisting of 2 bamboo reinforced concrete beams with 1 cm long screw nails (TLBB -1a and TLBB-1b), 2 bamboo reinforced concrete beams with 2 cm long screw nails (TLBB-2a and TLBB-2b), and 2 steel reinforced concrete beams with steel diameter of 12 mm (TLBJ-1 and TLBJ-2) as the control beams. Whereas, all reinforced concrete beams used stirrup reinforcement with a diameter of 6 mm.

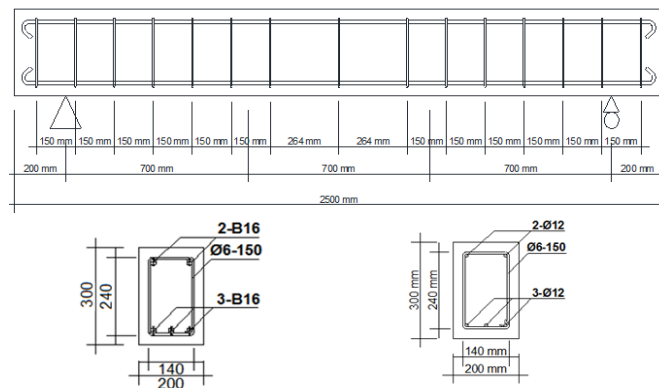


Figure 4. Design of bamboo and steel reinforced concrete beams.

The tests on the reinforced beams were carried out by providing third-point static-monotonic load with reference to *ASTM-C78*. Beam specimens were given burden until they were collapse.

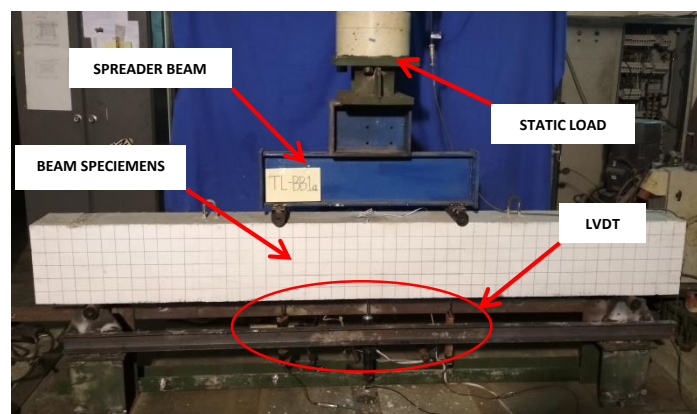


Figure 5. The tests on the beam specimens.

The load was placed on the 1/3 span of the reinforced concrete beam or as long as 700 mm from the pedestal by exaggerating the side of the tip with a support along 1/3 of the beam height or 200 mm. The

load was placed using hydraulic jack and load cell in order to determine the deflection that occurs. After that, 3 of LVDT were placed at the bottom of the beam with each location under load and in the middle of the span.

3. Test result and discussion

3.1. Analysis of Bamboo Reinforced Concrete Beams (TLBB-1 and TLBB-2)

Based on the results of the test conducted on bamboo reinforced concrete beams with 1 cm (TLBB-1) and 2 cm (TLBB-2) hook length, a graph of the relationship between load and deflection was presented in **Figure 6** below.

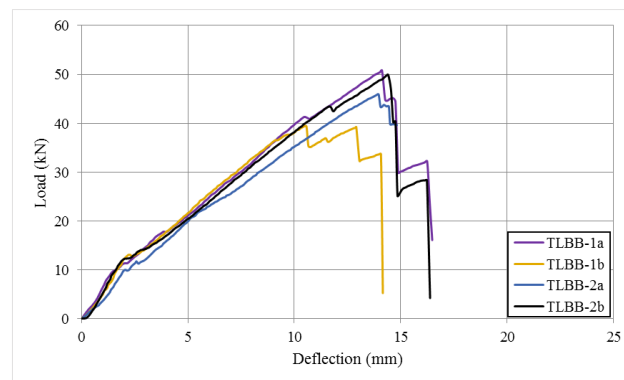


Figure 6. The relationship between load and deflection of bamboo reinforced concrete beams.

There were no significant differences in beam bending behavior between reinforced concrete beams (TLBB-1a and TLBB-1b) and bamboo reinforced concrete beams (TLBB-2a and TLBB-2b). The highest maximum load among 4 beams indicates that the maximum load obtained on the beam (TLBB-1) reached 50.44 kN with the deflection of 14,02 mm. In conclusion, the addition length of screw nail did not give any significant contribution on the bending behavior of reinforced concrete beams.

3.2. Analysis of Bamboo Reinforced Concrete Beams and Steel Reinforced Concrete Beams

Analysis of steel reinforced concrete beams (TLBJ) and bamboo reinforced beams (TLBB-1 and TLBB-2) were presented in graph of relationship between load and deflection in **Figure 7** below.

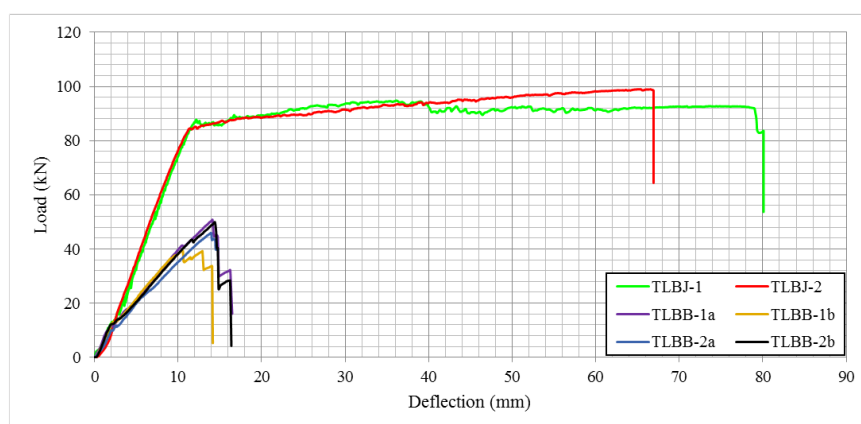


Figure 7. Relationship between load and deflection of steel and bamboo reinforced concrete beams.

There was a very significant difference in bending behavior between steel reinforced beams and bamboo reinforced beams. The maximum load obtained indicates that steel reinforced concrete beam (TLBJ) got the highest maximum load of 98,67 kN with the largest maximum deflection of 65,52 mm. Meanwhile, the maximum load obtained by bamboo reinforced concrete beams (TLBB) was 50.44 kN with the maximum deflection of 14,02 mm. Thus, it can be concluded that the use of bamboo as reinforcements in concrete beams indicates a decrease in maximum load capacity of 51.12%.

4. Conclusion

Based on the tests and analysis carried out on bamboo and steel reinforced concrete beams, the following conclusions were made:

- The use of long screw nail hooks on bamboo reinforcement did not have a significant effect on the bending behavior of reinforced concrete beams. However, the use of screw nail hooks on bamboo reinforcement had proven to be effective in increasing the bond between bamboo and concrete reinforcement.
- The flexural load of bamboo reinforced concrete beam with 1 and 2 cm hooks was 44.90 kN and 47,85 kN or 47,00% and 50,08% compared to steel reinforced concrete beams with flexural strength of 95,54 kN.
- Based on the evaluation of the parameters of the maximum load value (P_{max}) of bamboo reinforced concrete beams against steel reinforced concrete beams, the possibility of using bamboo as reinforcement in reinforced concrete can be intended for structural elements that do not carry the main load or structural elements with controlled loads such as diaphragms on bridges.

Acknowledgment

The authors would like to extend their gratitude to UPPM POLBAN for the support by funding the research. The authors also thank the support from Department of Civil Engineering State Polytechnic of Bandung that has provided and allowed authors to use the structure and material laboratory facility in order to finish this research.

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