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EXPERIMENTAL INVESTIGATION ON FLEXURAL PROPERTIES OF GLULAM TIMBER BEAM REINFORCED BY BAMBOO STRIPS

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ABSTRACT

Usage of timber and bamboo as building materials were very promising for now and future. As renewable resources, they have high mechanical properties, lightweight, environmentally friendly and economic. Utilization of bamboo as material to reinforced glued laminated (glulam) timber was rarely published. Therefore, this study focused on strengthening the flexural capacity of glulam timber beam in term of stiffness, strength, and load carrying capacity. This research was conducted in the laboratory to examine the flexural strength of the beam by attaching bamboo strip at tension side or bottom fiber of the beam. The results showed that there was significant increase in term of flexural properties of the beam by strengthening tension side with bamboo strip reinforced compare with the beam without reinforcement. The highest improvement at 20% in the laboratory test occurred on BLM02 specimens of 25% compared with without reinforcement.

Keywords: bamboo strip, flexural properties, glulam and reinforcement.

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1. INTRODUCTION

Wood is a renewable resource, sustainable material and can be recycled with high mechanical strength, light weight, environmentally friendly, and economical. Limitations of the size of the structural wood need to be overcome with the development of laminate wood technology Lamination technology is an alternative way of wood processing that is relevant to achieve the expected goal, because it can produce dimensions of either length, width, or thickness that is in accordance with what we need.

The laminated wood commonly called glulam, according to ASTM D3737 in Moody and Hernandez (1997)[1] is a material bonded from selected lumber of wood (lamina) at specific temperatures and pressures in a straight or curved form, in which the fiber direction is parallel to the longitudinal axis of the stem. The process of designing laminated wood is influenced by several factors such as the level of designer's skill, the factor of wood used and its combination, the adhesive and the adhesive process and the process of clamping.

Many attempts have been made to reinforce wood or Glulam timber beam by using carbon fiber reinforced plastic(CFRP) Nikolaos and Thanasis (1992), glass fiber reinforced plastic (GFRP), Gentile, et al. (2002), Fiorelli and Dias (2003), aramid fiber reinforced, steel, Issa and Kmeid(2005) etc.[2,3,4,5]. A new approach to reinforced glulam beams by using compressed wood have been studied by Anshari, et.al (2010a, 2010b), Anshari, et al(2012,2014,2015), Anshari, et al(2017)[6,7,8,9,10,11]. The result showed that the reinforcement could enhance bending capacity of the glulam beams in term of initial stiffness, and load carrying capacity.

One of alternative natural material could be used to reinforced glulam beam is bamboo. Bamboo is a renewable material and saving natural resources with the potential of sustainable building construction materials. There are about 1250 species of bamboo around the world and about 500 species in China. Li, Shen et al. (2012),[12]. Several studies about bamboo have been conducted i.e. Liu, D., et al(2012)[13] examined Bamboo fiber and its reinforced composites, Wei, et al (2017)[14] studied flexural performance of bamboo scrimber beams strengthened with FRP, Zhong, Y.,et al (2017)[15] also studied Bending properties evaluation of newly designed reinforced bamboo scrimber composite beams. Anshari, et al,(2017)[16] studied about utilization bamboo dowel as fastener in bamboo connection. The result show that there was an improvement about 41% with thickness of adhesive 2 mm compared with without adhesive.

The aim of study is to investigate the reinforcement of glulam timber beams by using variation of placement of bamboo strips at bottom extreme fiber to obtain the optimum flexural strength of the glulam beams.

2. MATERIALS & EXPERIMENTAL PROCEDURES

2.1. Materials and equipment

The materials mainly consist of Bajur Wood, Petung Bamboo and Melamin Formaldehyde as waterproof adhesive. The equipment were used in this study, for instance; drying oven, universal testing machine, caliper, digital weigh, tensile testing machine, hydraulic jack, etc.

2.2. Methods

This experimental study conducted to examine flexural strength of glued laminated beam. There were 25 specimen in total by four variation of bamboo reinforced location for each beam. The testing method have been used in this study were two pont loading or four point bending moment. The testing procedure based on SNI 03-3972-1995.

2.2.1. Specimen

The beam specimens consist of three layer lamina and two strips of bamboo with specific thickness. The comparison volume between wood and bamboo are 91.15% and 4.85%. The recapitulation of detail specimen can be seen in Table 1.

Table 1 Summary of reinforcement glulam beam variation

Specimen code	Amount of layer	Size (mm)			Amount of specimen
		L (length	B (width)	d (depth)	
BLM01	3	1600	55	75	5
BLM02	3	1600	55	75	5
BLM03	3	1600	55	75	5
BLM04	3	1600	55	75	5
BLM05	3	1600	55	75	5

The variation of reinforcement by bamboo strip on the tension side of Glulam beam and the beam without reinforcement as control specimen can be illustrated in Figure 1(a)-(e) below.

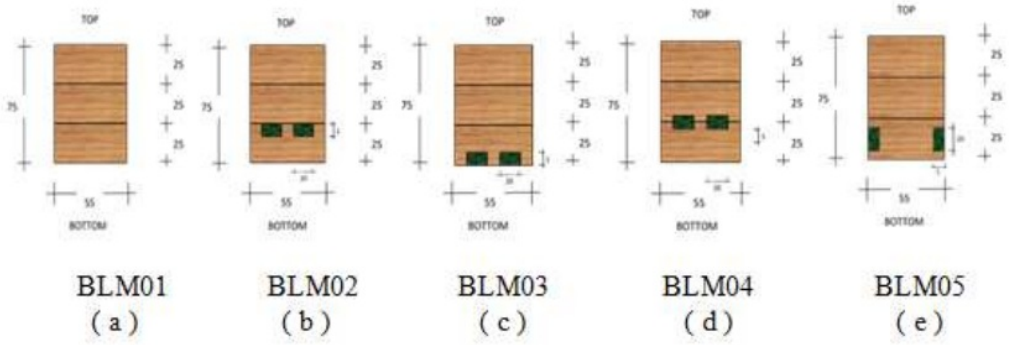
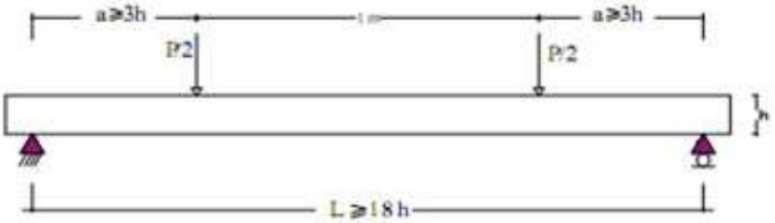


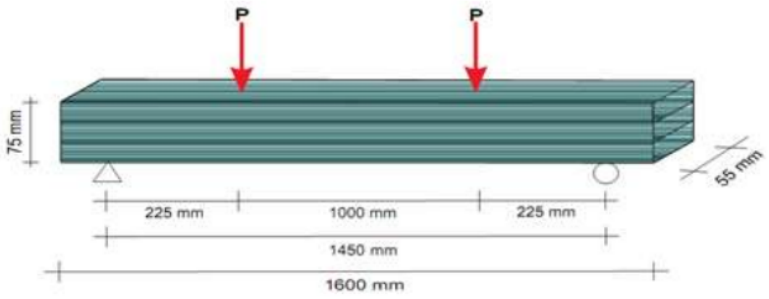
Figure 1 Geometric of glulam beam with variation bamboo reinforcement

2.2.2. Beam testing

Preparation of laminate beam test specimen refers to Structural Strength Test Method of Structural Wood Based on the provisions of SNI 03-3972-1995. The size of the specimen with the total length of L_{tot} = 6h + 1m + 2h (cm), the span length between the support is L = 18h (cm) i.e. the length of the laminated beam 160 cm as shown in Figure 2.



(a) Setting up of bending test



(b) Dimension of glulam beam specimen

Figure 2 Setting up of testing and beam geometry

3. RESULTS AND DISCUSSION

Flexural strength test in this research is conducted by two point load method. The laminated wooden beam uses 1600 mm long dimensions, 55 mm wide and 75 mm high with a thickness of each layer is 25 mm. This research uses 4 types of reinforcement variation. As the control variable used laminate wooden beam without reinforcement.

3.1. Glulam beam without reinforcement (BLM01)

As a controlled specimen, it consists of the three layer of lamina with thickness of 25 mm as shown in Figure 3. From testing, The BLM01 glulam beam result in the maximum average load can be carried by 17.3 kN at 18.13 mm deflection, meanwhile, the average bending strength of 37.73 MPa was obtained.

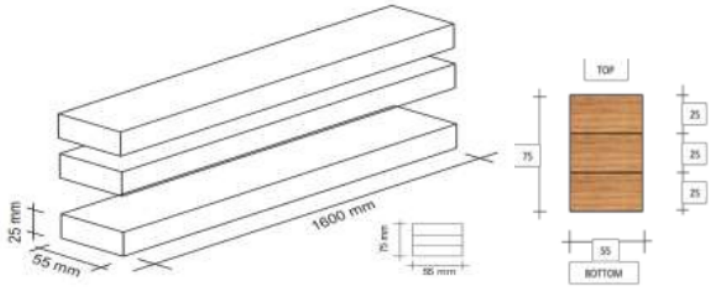


Figure 3 Glulam beam without reinforcement

3.2. Glulam beam with first reinforcement (BLM02)

The first bamboo reinforcement put on upper side of the lowest layer as shown in Figure 4. In this variation (BLM02), it was reached the maximum average load carrying capacity of 21.6 kN at 19.3 mm deflection. In other word, the average bending strength can be obtained about 47.15 MPa. In compared with the control (BLM01), it is increase by 25%.

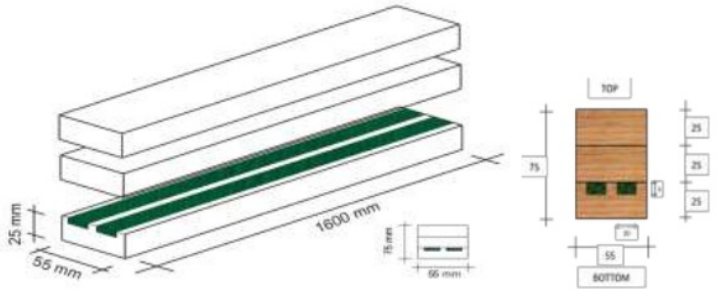


Figure 4 Glulam beam with upper bottom reinforcement

3.3. Glulam beam with bottom reinforcement (BLM03)

The second variation of reinforcement was placement the bamboo strips at bottom extreme fiber as exposure as shown in Figure 5. In this variation (BLM03), it was reached the maximum average load carrying capacity of 18.0 kN at 16.8 mm deflection. Otherwise, the average flexural strength can be achieved about 39.4 MPa. In compared with the control (BLM01), it is improved by 4.3%.

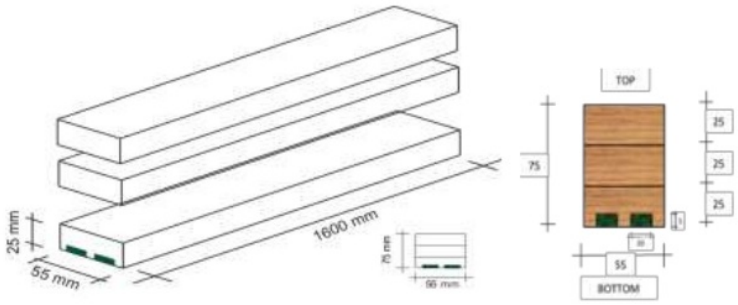


Figure 5 Glulam beam with extreme bottom fiber reinforcement

3.4. Glulam beam with half upper bottom reinforcement (BLM04)

The third variation of reinforcement was placement the bamboo strips at about one third upper side of the lowest lamina as shown in Figure 6. In this variation (BLM04), it was reached the maximum average load carrying capacity of 18.4 kN, at deflection of 16 mm. Otherwise, the average flexural strength can be obtained about 40.1 MPa. From this results, the value of flexural strength was close to the previous specimen BLM03. i.e improvement of 4.3%.

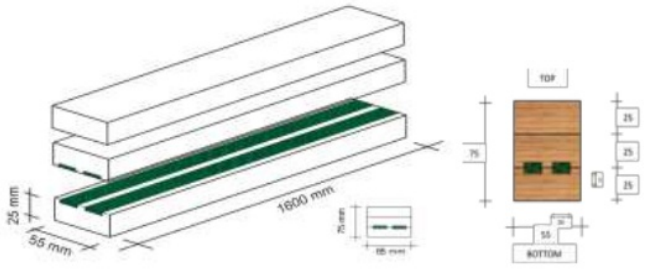


Figure 6 Glulam beam with half upper bottom fiber reinforcement (BLM04)

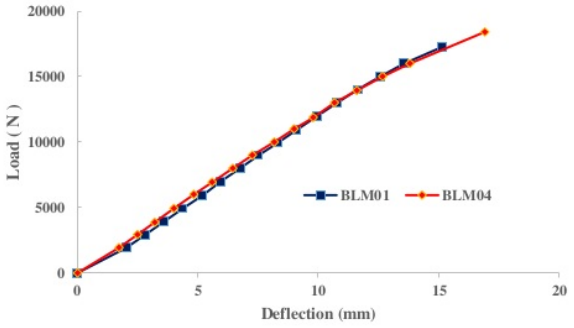


Figure 7 Load against Deflection BLM04 compared with the control specimen

Figure 7 illustrated that the relationship between load and deflection of glulam beam BLM04 compared with the control specimen. The glulam beam which reinforced with half upper bottom fiber reinforcement could resist load slightly higher the unreinforced beam. It is indicated that the failure load of BLM04 beam by 6.4% higher than the control one.

3.5. Glulam beam with outer side of lowest lamina reinforcement (BLM05)

The third variation of reinforcement was placement the bamboo strips at outer depth side of the lowest lamina as shown in Figure 8. The results of this variation (BLM05) indicated that it was reached the maximum average load carrying capacity of 17.6 kN, at deflection of 19 mm. Moreover, the average flexural strength can be obtained about 38.4 MPa. It represents the weakest reinforced glulam beam in this study.

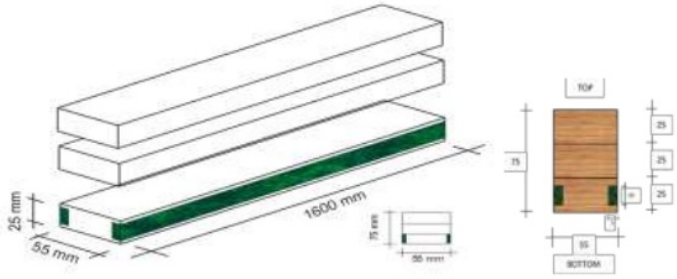


Figure 8 Glulam beam with outer depth side extreme bottom fiber reinforcement

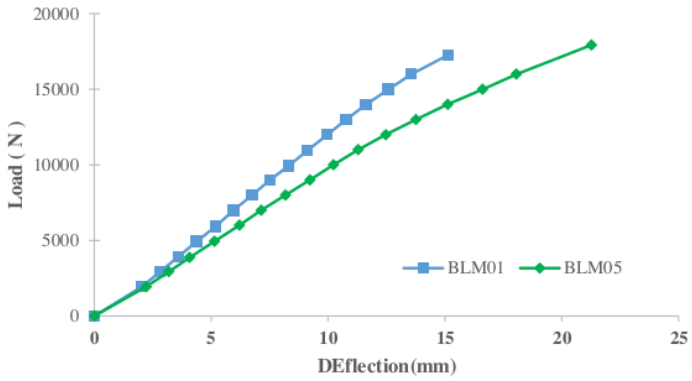


Figure 9 Load against Deflection BLM05 compared with the control specimen

Figure 9 described that the relationship between load and deflection of glulam beam BLM05 compared with the control specimen. The glulam beam which reinforced with outer side of bottom fiber reinforcement produced lower stiffness compared with the unreinforced beam. However, in term of failure load occurred at 17.6 kN for beam reinforced by bamboo strips at outer side which is slightly higher the control one by 17.3 kN. In other words, this type of reinforcement had no significant improvement compared with unreinforced beam.

Flexural destructive testing of glued laminated beam in the laboratory resulted in a bending strength increase glulam beams reinforced with bamboo strips. Based on the data of laminate beam test result of each test specimens BLM01, BLM02, BLM03, BLM04 and BLM05 of the average strength bending respectively 37.8 MPa, 47.2 MPa, 39.4 MPa, 40.1 MPa and 38.45 MPa as described in Table 2.

Tabel 2 Average flexural strength of each glulam beam variaation

No.	Specimen code	Bending strength (Mpa)	improvement (%)
1	BLM01	37.73	0.00
2	BLM02	47.15	24.98
3	BLM03	39.36	4.32
4	BLM04	40.14	6.40
5	BLM05	38.45	1.93

Table 2 shows that the largest bending strength increased occurred in the combination of laminated wood blocks BLM02 of 9.42 MPa with the ratio of bending strength of 24.98% and the lowest in the combination of BLM05 laminated wood beam of 0.73 MPa with a ratio of bending strength increase of 1.93% to the bending strength of specimen control BLM01.

4. CONCLUSION

The results showed that there was an increase in the strength of bending glulam timber beams reinforced by bamboo strips compared to glulam timber beams without bamboo strips reinforcement. The highest increase of bending strength in laboratory test occurred on BLM02 specimens of 9,42 MPa or 24,98%, then respectively BLM04 specimens were 2,41 MPa or 6,40%, BLM03 specimens were 1,63 MPa or 4,32 % and the lowest BLM05 specimens of 0.73 MPa or 1.93%.

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