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Mechanical Behaviors of Galar Laminated Boadr on Variation of Adhesive

Daniel Lay Moy

Lecturer In Engineering Education Program Building, PTK FKIP Undana Kupang, Indonesia

Email: laymoydaniel@yahoo.com

Abstract

The rapid growth of home industry, due to population growth, consequently increases the need of wood for construction material. Further, the wood growth tends to decrease. To cope with this problem, a solution is required to substitute the use of limited wood resources. One such solution is to maximize the use of bamboo as construction material. Petung bamboo is one of the types suitable for laminated board due to its thicker stem. In making the laminated board, it is required to have a strong but environmentally friendly adhesive. The use of urea formaldehyde adhesive is harmful for the environment. Thus, it is important to find alternative environmentally friendly adhesive such as those made from sago starch. This type of adhesive is traditionally easy to make. This research studied the use of sago starch as the adhesive in the making of laminated galar board, and compared its adhesiveness with urea formaldehyde. The objective of this study was to identify influence of adhesive variations on the mechanical behavior of laminated galar bamboo that still retains the outer skin. In order to identify the physical and mechanical characteristic of petung bamboo, it is necessary to take a preliminary test based on ISO standards. Laminated galar board specimens were made in two variations: adhesive variation and galar composition variation. Sixteen specimens of laminated galar board were made in various dimensions. For flexural testing, the specimens were made in 16x140x600 mm dimension. For flexural testing of galar board, sample and shear strength testing to the adhesive; the specimens were made to ISO standards. In the making of laminated galar board, urea formaldehyde (UA-125) and sago starch were used as the adhesive. The Compression process was done in two

methods: hot and cold compression. Cold compression applied 2 Mpa pressure and hot used 198 Bar pressure. Results of this research showed that variation of adhesive substance and galar composition significantly influenced the values of MOE, MOR and the shear strength to the adhesive. Sago starch adhesive values were still below the values resulted by urea formaldehyde adhesive. The respective values of MOR and MOE, resulted by the two adhesives to the type I board composition, were 104.43 Mpa and 14,139.16; to the type II were 33.34 Mpa and 2.299,45 Mpa; to the type III were 42.67 Mpa and 4,021.77 MPa and to the type IV were 24, 92 Mpa and 1.777,67 Mpa. Shear strength of gluing line for board type (1), type (ii), and type (iii) were 3.424 MPa, 0.622 MPa and 0.762 Mpa, respectively.

Keywords: *laminated galar board, petung bamboo, adhesive, flexural strength and shear strength*

Introduction

Bamboo is a type of easy-to-grow crop with relatively a short growing period (3-5 years). Due to the limited supply of woods, bamboo is a potential substitute for wood in construction. In maximizing the utilization of bamboo to substitute wood, technology is required such as lamination. Petung bamboo is one type of bamboo which is high suitability to be used for laminating material because it has a thicker stem. One of the examples of the utilization is galar board that has been developed by people to substitute the use of wood boards for walls. However, this board is not in laminated form. Therefore, in order to shape the galar board to become a laminated galar board, a strong and environmentally friendly adhesive is required. One of the easy to fin and low-cost adhesive types is sago starch. It is commonly known to be much more environmentally friendly, in comparison to other types of adhesive such as synthetic adhesives.

This research used sago starch adhesive for galar bamboo lamination and compared its gluing strength to urea formaldehyde adhesive. The objective of this research was to identify the influence of various adhesive substances to the mechanical behavior of laminated galar board, due to lateral load by carrying out flexural and shear strength testing.

Research Method

Materials

Materials used in this research consisted of Petung bamboo taken from Dusun Kledokan Desa Umbulmartani, Sub Regency Ngemplak, the Regency of Sleman, Yogyakarta. Adhesives used were urea formaldehyde, from PT. Palmolite Adhesive Indonesia (PAI) Probolinggo Jawa Timur, and sago starch from the Regency of Poso.

Instruments

Instruments used in this research included preparation and processing tools for main materials, laminated galar board making tools and testing tools. This equipment was available in the Laboratory of wood Resources of the Faculty of Forestry and laboratory of Structural engineering, Gadjah Mada University:

Specimens

Preliminary specimens

Specimens for physical and mechanical testing were made based on ISO 3129-1975, with thickness adjusted to available main materials.

Laminated galar board specimens

Mechanical testing carried out to the laminated galar bard samples included the flexural and shear testing. Figure 1 below shows the dimensions used in the testing.

Setting Up of the Test

Set up of the test was carried out by using one loading point at ½ of the span (see Figure 3.2).

Results

Petung bamboo Physical and Mechanical Characteristics

Physical Characteristics

a. Water Content

   Based on the testing, water content of Petung bamboo was between 12.56% to 14.15%, with 13.59% in average.

b. Density

   The density value, of Petung bamboo based on preliminary testing ,was 0.88 – 0.89 gram/cm^3 or 880 - 890 kg/ m^3. Based on PKKI-1961, such density classified Petung bamboo in the Strong II class, in which the density in this class is 0.60 – 0.9 gram/cm^3

c. Mechanical Characteristics

   Preliminary testing, to identify the mechanical characteristics of Petung bamboo, was carried out at 13.59% average water content. Complete results of the testing for Petung bamboo, form Dusun Kledokan – Sleman based on Testing Standard of ISO 1975, are presented in Table 3.

Testing Results of Mechanical Characteristics of Laminated Galar Board

Optimum Length of Laminated Board

Optimum length of laminated galar board, based on the preliminary testing values, up to shear and flexural failures, resulted by using the following formula:

$$Lo = \frac{\sigma . h}{2\tau} = \frac{158{,}32x1{,}6}{2x7{,}08} = 17{,}88\ cm\ or\ 178{,}80\ mm$$

Where σ = Flexural strength resulted from Petung bamboo mechanical testing

h = Specimen thickness

τ = Bamboo Shear Strength

It was expected in this research to have flexural failure. Therefore, the board span used was 50 cm.

Flexural strength (MOR and MOR) of laminated galar board

Flexural testing, given to laminated galar board in 50 cm or 500 mm span, was carried out on laminated galar boards in 1.6 x 14 x 60 cm dimensions. This testing used two adhesive variations: *urea formaldehyde* (UA-125) consisting of two types of galar board composition (parallel and perpendicular to fiber direction) and sago starch adhesive consisting of the same two compositions. Results of Modulus of Rupture (MOR) testing for the four types of laminated galar board are presented in Table 4.

Average MOR values (in table 4) shows that the MOR value of sago starch adhesive is only 40.86%, of *urea formaldehyde,* for board Type I, and 74.74% for board Type II to board type IV. Modulus of Elasticity (MOE) testing results, for laminated galar board, is presented in Table 5. The Table shows that the MOE value of sago starch is only 28.44% of *urea formaldehyde* for board Type I & Type III, and 77.31% for board Type II & Type IV. In order to identify the mechanical behaviors of laminated galar board, based on ISO testing standards, it is required to test 16x20x280 mm specimens taken randomly. The results of *Modulus of Rupture* (MOR) testing

on laminated galar board sample are shown in Table 6 below. Table 6 shows that the MOR values, of laminated galar board samples, with sago starch adhesive, are 110.59% higher than that of *urea formaldehyde* adhesive for board Type I to Type III. Results of *modulus of elasticity* testing, of laminated galar board samples, are shown in table 7. Table 7 shows that the MOE value of Sago starch is only 81.04% of *urea formaldehyde* for board Type I to Type III

Shear strength of gluing line

Results of shear strength of gluing line, to the laminated galar board sample, is as shown the following Figure 2. The graphic shows that the shear strength value, of sago starch gluing line, is only 22.25% of the shear strength value of *urea formaldehyde* gluing line, for board Type I to Type III.

Conclusions and Recommendations

Conclusions

1. Results of flexural testing, on laminated galar board of Petung bamboo, showed that, for Type I, the MOR and MOE was 104.43 MPa and 14,139.16 MPa; for Type II, the MOR and MOE was 33.34 MPa and 2,299,.45 MPa; for type III, the MOR and MOE was 42.67 MPa and 4,021.77 MPa; and for type IV, the MOR and MOE was 24.92 MPa and 1,777.67 MPa.
2. Based on the shear strength testing, of gluing lines of laminated galar board sample, the values were 3.424 MPa, 0.622 MPa and 0.762 Mpa for type (i), type (ii), and type (iii), respectively.

3. Based on flexural (MOE, MOR) testing and shear strength testing results to the gluing line, the use of sago starch showed an unequal strength in comparison to the *urea formaldehyde* adhesive.

Recommendations

1. To obtain high stiffness between the gaps, galar blade is to be made not less than 1.5 cm.
2. In gluing the galar layers, it is recommended to put the galar in zigzag arrangement, towards the galar width, between the galar layers.
3. To obtain gluing strength equal to the value of synthetic/conventional adhesive, further study is required on the addition of *hardener* and emulsified at particular concentrations, as well as the use of smaller composition between water and starch.
4. To obtain a high strength (MOR and MOE values) for laminated galar board compositions with perpendicular fiber direction, it is suggested to use a size similar triplex, because it uses the same length of fiber that may increase the stiffness value.

Table 1. Types of testing and numbers of preliminary specimens

No.	Types of Testing	Numbers of	Testing Standards
1.	Water content and density	3	ISO 3130-1975 (E) and
2.	Compressive testing parallel	3	ISO 3787-1975 (E)
3.	Compressive testing	3	ISO 3132-1975 (E)
4.	Tensile parallel to fiber	3	ISO 3346-1975 (E)
5.	*Shear* parallel to fiber	3	ISO/DIS 3347-1975 (E)
6.	Flexural strength	3	ISO 3133-1975 (E) and ISO 3349-1975 (E)
	Sum	18	

Table 2. Code and sizes of laminated galar board flexural testing specimens

Codes of the boards	Length (mm)	Width (mm)	Height (mm)	Sum
Type I (PLM UF H)	600	140	16	4
Type II (PLM UF V)	600	140	16	4
Type III (PLM PTi H)	600	140	16	4
Type IV (PLM PTi V)	600	140	16	4
Sum				16

Table 3. Values of Mechanical Characteristic Testing for Petung bamboo from Dusun Kledokan-Sleman

No	Types of Testing	Specimens Strength (MPa)			
		1	2	3	Average
1	Compressive // fiber	50.51	42.62	53.54	48.89
2	Compressive ⊥ fiber	17.82	16.80	17.93	17.93
3	Tensile // fiber	223.40	265.80	241.70	243.60
4	Flexural (MOR)	178.30	185.50	111.20	158.328
5	Flexural (MOE)	12,417.23	8,985.48	5,663.36	9,022.02
6	Shear//fiber	8.87	5.32	7.04	7.08

Table 4. MOR Values of Laminated Galar Board

Repetition	MOR (MPa)			
	Type I	Type II	Type III	Type IV
1	98.00	33.84	38.18	26.34
2	91.56	33.71	43.35	26.21

3	112.50	36.73	42.35	22.99
4	115.66	29.07	46.69	24.13
Average	104.43	33.34	42.67	24.92

Table 5. MOE values of Laminated Galar Board

Repetition	MOE (MPa)			
	Type I	Type II	Type III	Type IV
1	12,767.44	1,937.38	4,175.88	1,895.55
2	12,505.66	2,528.03	5,370.00	2,336.22
3	16,328.24	3,173.14	2,984.93	1,366.92
4	14,955.30	1,559.27	3,556.30	1,511.97
Average	14,139.16	2,299.45	4,021.77	1,777.67

Table 6. MOR values of Laminated Galar Boar Samples

Repetition	MOR (MPa)			
	Type 1	Type 2	Type 3	Type IV
1	53.31	42.95	49.64	-
2	56.52	39.95	68.78	-
3	50.34	45.24	51.91	-
4	52.68	42.17	65.12	-
Average	53.22	42.58	58.86	-

Table 7. MOE values of Laminated Galar Board Sample

Repetition	MOE (MPa)			
	Type 1	Type 2	Type 3	Type IV
1	6,301.33	1,866.03	6,743.84	-
2	7,714.96	1,564.87	7,161.00	-
3	7,772.12	4,993.66	6,445.22	-
4	9,670.24	2,863.30	5,144.09	-
Average	7,864.66	2,821.96	6,373.54	-

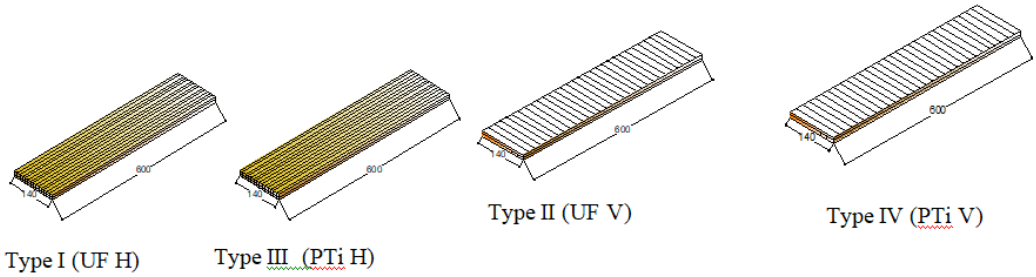
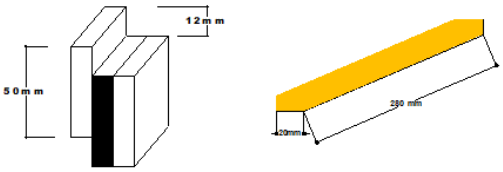


Figure 1. Types and dimensions of laminated galar boards



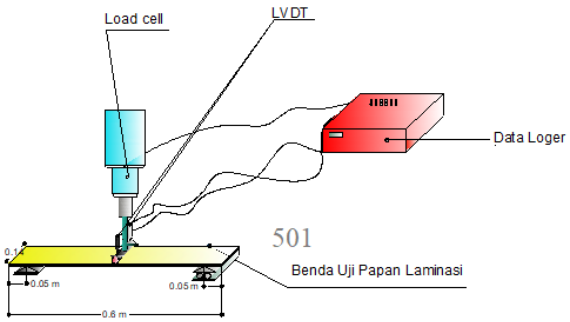
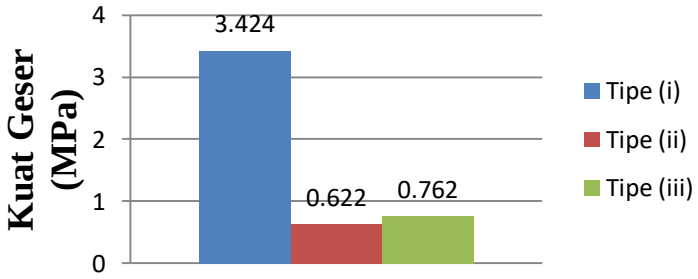


Figure 2. Setting up of the test by using one laminated loading point



Graphics of shear strength testing results to the gluing line of laminated galar board sample

References

Barly, 2005, Bamboo Research Notes R & D center of Forest Products Technology , Proceedings of the National Seminar on Development of Perbambuan in Indonesia , Yogyakarta Perbindo.

Balfas, J, 1995, Laminate Technology In The Alternative In Utilization Logs Results Spacing , Duta Rimba XX (183-184) : 31-34

Falk, R. H. dan Lolling, F, 1995, Laminating Effects in Glued – Laminated Timber Beams, Journal of Structural Engineering, 121(12): 1857-1863.

Jansen, J.J.A, 1998, Buliding With Bambu, Intermediate Technologu Publication, London

Morisco, 1999, Bamboo Engineering, trumpets Offset, Yogyakarta

Morisco, 2006, Bamboo Technology, Materials Lectures, Master Program Building Materials Technology Faculty of Engineering, University of Gadjah Mada, Yokyakarta