The Experimental Study On Laminated Beam By Mahang And Meranti Wood With Variations Connectors

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Abstract. Laminated of Mahang and Meranti wood were the efforts to improve the efficiency of hardwood (Meranti) and light wood (Mahang), so that to be used for structural timber. Variant of connectors were expected to increase laminate beam capacity compared to solid beams. Samples have been made include properties material samples and laminated beam samples with dimension 76 x 5 x 5 cm. Beam sampleswere 3 types of connector i.e. glues, nails and bolts. The capacity was obtained by provided one point load at the center of span. In addition to load force, deflection were also recorded which then analyzed the flexural capacity, MOR and MOE. The result showed that at the limit deflection, the glue laminated beam (BL LM) has a higher average capacity than the bolt laminated beam (BT BL) and the nail laminated beam (BL PK). In contrast, at the ultimate conditions, BL PK has a higher capacity rather than the others. At the same time, BL LM has a higher average of MOE of 6818.88 MPa and BL PK has average of MOR 3 times larger than Meranti solid beam (BL ME).

1. Introduction

Currently the use of wood in the construction industry is growing rapidly, this is because wood is still the choice of society as a substitute for other materials that are still lacking. Wood commonly used to build and renovate the house, fulfill the needs furniture and meet the needs of wood processing industry. Moreover, it also attracted researchers to develop the technology of utilizing light wood become laminated beams.

Laminate beams are one of the engineering products created to improve the quality of structural wood as well as completing the needs of ideal dimensions particularly for long spans. In the process of laminated beams, the preparation of each layer with connector can be modified so as to improve the strength of properties wood.

Mahang wood is a light type of wood with a density ranging 270-500 kg/m³ at a moisture content of 15%. The round shape, smooth, diameter can reach 70 cm, specific gravity (BJ) 0.45, durability class V and strength class III. This wood has a growing age shorter when compared with other wood. In area, particularly Bengkalis district, the use of this wood limited to non-structural.

Meranti Merah classified as hardwood with light to medium weight wood. This wood has specific gravity from 0.3 to 0.86 at a moisture content of 15%. Generally pink or bronze with durability class III-IV. This wood has not so resistant to the effects of the weather, so that not recommended for outdoor or directly contact with the soil. However, this wood is easily preserved with a mixture of diesel oil called creosote.

This research tries to utilize Mahang wood as light wood to be combined with Meranti wood as heavy wood to be laminate beam, so that the utilization of Mahang wood can be more economical and have higher selling value. This research funded by PNBP Politeknik Negeri Bengkalis in 2017.

Vol 3-Sep2018
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The main purpose of this research is to know the capacity of laminated wood of Meranti Merah combined with Mahang wood. In addition, to determine the modulus of elasticity (MOE) and modulus of rupture (MOR) of the wood laminate beam.

2. Literature Review

2.1. Laminate

According to SNI 7973-2013, laminate beam (glued laminated timber)) is a strength-separating product from a wood-laminated factory, including assembly of specially sorted and specially prepared laminated wood and combined with adhesive. All of laminate layer is approximately parallel in the longitudinal direction. The net thickness of each lamina does not exceed 50 mm and consists of:

1. One lamina
2. Lamina-lamina are put together end to end to form a certain length
3. Lamina-lamina that placed or glued side to the side to form a certain width
4. Lamina-lamina is bent during the adhesive process to obtain a curved shape.

Lamination technology is a technique of combining materials with adhesive, small building materials can be glued to form components of the material as needed. Lamination techniques are also a way of combining non-uniform materials or various qualities (Gunawan, 2007). For example, low quality wood combined with high quality wood is designed with the distribution of load type to the product. Thus the lamination technique is a technique of combining that highly efficient to produce effective building material products.

Factors to be observed when making laminate beams are as follows:

1. Types of adhesives used in laminate
2. The number of adhesives used for combined each layer
3. The type of wood used in the laminate
4. Connection type and position used in connection of laminate
5. Material size with weak point (failure) bending or shear.

For the purpose of improving the quality of Mahang wood on the laminate beam is used a cross section based on the concept of the beam stress as shown in Figure 1.

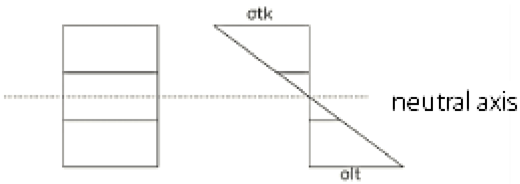


Figure 1. Bending stress distribution

At the top of the diagram shown maximum compressive stress due to a bending load on the laminate beam, on the other hand at the bottom it has the maximum tensile stress. Furthermore, in the middle (neutral axis) does not seen compressive stress or tensile. Because the closer the neutral axis the smaller the strength, then on that part does not need to use a type of wood that has the strength or high quality. In other words, high quality wood is placed on the outer side of the laminate beam.

2.2. Gluing

The adhesion is defined as a condition where the surface is put together by inter-surface forces which consists of the the valence force (interlocking action). The adhesive functions as a combination between two bonded substrates. The strength of the gluing is influenced by several factors such as the nature of the adhesive and the compatibility or suitability between the material that will glue and the adhesive (Oka, 2005).

According to Handayani (2009) in Pramudito J (2013), epoxy glue is a thermoset synthetic product of poloeposi resins with curing agents (acids / bases). Glue epoxy can be obtained in the form of one or two component systems. The one-component system includes liquid resin-free solvents, solution, resin pastes, liquids, powders, pallets and pastes. The two-component system consists of resin and curing agent mixed at the time of use, then immediately used for gluing.

Vol 3-Sep2018
ISSN: 2541-3023

Furthermore, Handayani (2009) in Pramudito J (2013) stated that epoxy glue also has advantages and disadvantages. The advantages remain unchanged despite being stored for years, resistant to oil, alkali, aromatic solvents, acids, alcohols, as well as heat and cold weather. While the deficiency is weak to ketones and esters, there is also a formulation not resistant to oil. In addition, epoxy glue will be damaged if the mixture is exposed to water for long periods. In the polomina and anhydride systems cannot stand at cold temperatures or frozen.

2.3. Modulus of Rupture (MOR)

The flexural strength often referred to as the Modulus of Rupture (MOR) determines the external load capacity capable of being retained by a beam.

Iensufrie (2009: 14) states, wood flexibility is the ability of wood to bend when holding the pressure on it. According to Dumanauw (1984: 24) said that the ability of bending is the ability to resist forces that will bend wood or to resist dead and living loads. The load mean is other than the blow load that should be retained by the wood, for example “blandar”. This value is calculated using eqs (1), the following:

$$MOR = \frac{3.P.L}{2.b.h^2} \quad (1)$$

P is the load (kg), L is the length of the beam testing span (cm), Δ is the deflection (cm), b is the width (cm), and h is the beam height (cm).

2.4. Modulus of Elasticity (MOE)

The elastic modulus is a measure of extension when a wooden beam is pulled, shortening when a wooden beam is subjected to pressure during loading with a constant loading speed.
The Elasticity Modulus (MOE) describes resistance to bending, which is directly related to stiffness (Akhtari et al., 2012). This value is calculated by using eqs (2), with P is load (kg), L is span of beam testing (cm), Δ: deflection (cm), b: width (cm), h: height (cm).

$$MOE = \frac{PL^3}{4\,\Delta\,b\,h^3} \quad (2)$$

In this research used the reference Indonesia Standard particularly about Procedure Planning Wood Construction to determine the mechanical strength. The following table of reference strengths is based on the mechanical sorting according to SNI 7973-2013. For the classification of wide-leaved laminate beams can be seen in Table 5B and for solid beam classification can be seen in Table 4.2.1 in SNI 7973-2013.

2.5. Reference strength

Sorting visually follows the standard visual sorting basic standard. The strong value of the wood mechanical reference can be seen in Table 2.2 based on the reference flexural elasticity modulus value (Ew). For the results of the laboratory test the strongest reference value can be calculated using the eqs (3).

$$F = \frac{F_{Avg} - (1{,}645\ .STD)}{\gamma_{DL}}\gamma_{KA} \quad (3)$$

With F_{Avg} is average , STD : deviation standard, γ_{DL} is time load factor, γ_{KA} is correction factor of water content.

Time load factor correction (γ_{DL}) account time-dependent behavior of wood. Wood gives high strength for short time loading and so the opposite. This correction factor is 1 for loading duration of 10 years. As for laboratory testing with duration of loading about 3 to 5 minutes, the correction factor is 1.65. The water content correction factor is considered to be equivalent to 1.0 for wood that have the average moisture content ranges from 12% to 15% (Awaludin Ali, 2011).

3. Research Methods

This research was experimental in the laboratory which then the result was analyzed using the existing equation. The materials used are Mahang and Meranti wood obtained from the Bengkalis island Riau

Vol 3-Sep2018
ISSN: 2541-3023

Province. Adhesives used there are 3 types i.e. epoxy glue Brand Qbond, bolt diameter 12 mm lengt 6 cm and 2 inch nail. Test specimens made for testing the properties of materials and laminated beam with different variations. The five specimens were used for property testing and 5 to 6 laminated beam specimens of each variation. Variations of laminated beams made of glue adhesive laminated beam (BL LM), laminated beam with spacing of nail 5 cm (BL PK) and laminated beam with 5 cm spacing of bolt (BL BT). Testing the material properties include moisture content, wood density, compressive strength parallel and perpendicular, shear strength, tensile strength. Furthermore, bending test of laminate beam has been done by giving one point load in the middle of the span with the distance of support 71 cm referring to SNI 03-3959-1995. The results obtained are the load and deflection that occur in the conditions allowed and the maximum conditions which will then be analyzed to determine the value of capacity, MOR and MOE.

Figure 2. setting up of specimen testing

4. Results And Discussion

Testing the material properties is done first to ensure that Mahang wood does have a lower quality of Meranti wood. The result of the material properties test was calculated average and the standard deviation from each sample, then determined the reference strength based on the eqs (3).

4.1. Properties materials of Mahang wood

The results of Mahang wood properties testing have been done in the form of physical and mechanical properties. The result can be seen on Table 1.

Table 1. Result of Mahang wood properties test

	Mahang wood		
	Average (MPa)	Standard deviation	Reference strength (MPa)
Moisture content		15.20	
Density		0.30	
Compressive strength parallel	23.27	1.14	12.97
Compressive strength perpendicular	5.41	0.99	2.29
Shear strength	2.15	0.05	1.25
Tensile strength	74.10	9.64	35.30
Bending Strength MOR	48.87	3.33	26.30
MOE		5141.09	

Tabel 1 shows that at a moisture content of 15.2%, the bending strength was 26.3 MPa, tensile strength of 35.3 MPa and MOE of 5141.09 MPa. These results indicate that this wood was on grade E5 based on SNI 7973 2013 classification.

4.2. Properties materials of Meranti wood

Meranti wood testing was similar to the tests that have been done on Mahang wood. The result of Meranti wood properties can be seen on Table 2.

Vol 3-Sep2018
ISSN: 2541-3023

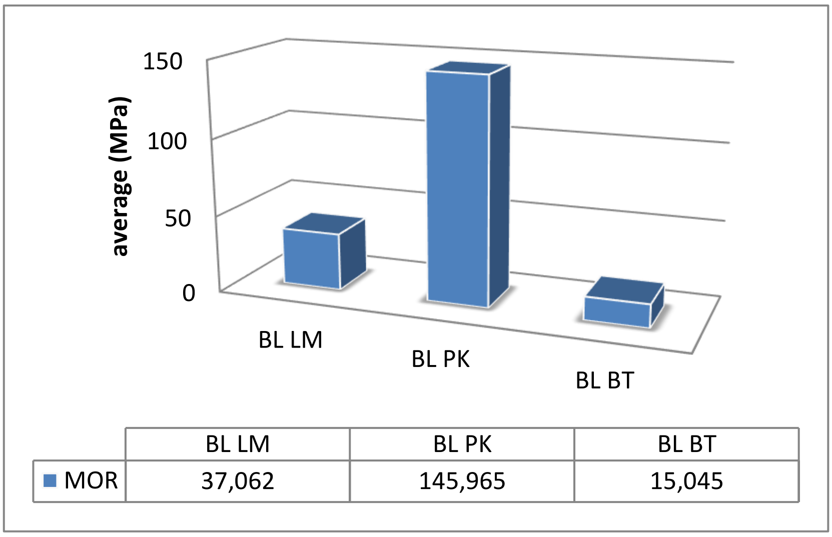
Table 2. Result of Meranti wood properties test

	Meranti wood		
	Average (MPa)	Standard deviation	Reference strength (MPa)
Moisture content		15.70	
Density		0.46	
Compressive strength parallel	30.14	1.56	16.72
Compressive strength perpendicular	6.38	1.71	2.16
Shear strength	2.68	0.11	1.51
Tensile strength	115.78	2.84	67.34
Bending Strength MOR	70.74	4.66	38.22
MOE		7726.60	

Tabel 2 shows that at a moisture content of 15.2%, the bending strength was 38.22 MPa, tensile strength of 67.34 MPa and MOE of 7726.60 MPa. These results indicate that this wood was on grade E7 based on SNI 7973 2013 classification. This proves that Meranti wood has a larger capacity compared to Mahang wood. So the placement of wood Mahang on the layer that closed to neutral axis of laminate beam was correct.

4.3. Modulus of rapture (MOR) laminate beam

MOR or bending strength determines the external load capacity capable of being retained by a beam (Yoresta, 2015). The average of MOR values for the three types of laminated beam variations can be seen in Figure 3.



5.

Figure 3 Test results Modulus of Rupture (MOR)

Based on Figure 3, Table 1 and Table 2, it can be seen that the MOR of the laminate beam has almost the same even higher than the solid beam (BS MA and BS ME on the Table 3). The MOR of BL PK higher than the others laminated beams of 145.96 MPa. These results indicate that the laminated beam was larger by 454.9% and 303.13% when compared to Mahang solid wood (BS MA) and Meranti solid wood (BS ME) respectively.

5.1.Capacity of the beam

The result of capacity analysis laminated beams for 3 types of adhesive variation and solid wood beam can be seen on Table 3.

Vol 3-Sep2018
ISSN: 2541-3023

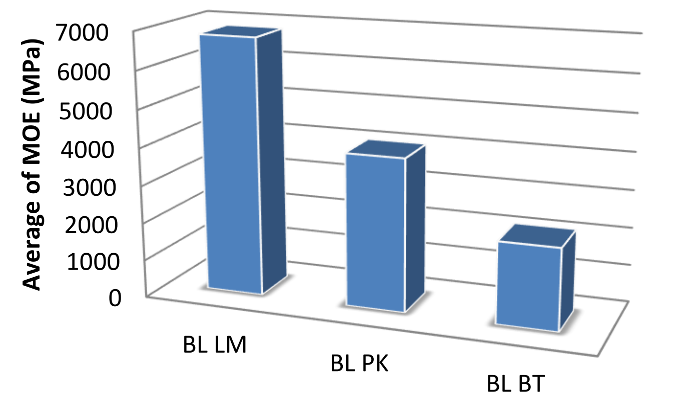
Table 3 The capacity analysis of laminated beam and solid beam

No	Sample	Δi (mm)	Pi (kN)	Mi (kN.m)	Δu (mm)	Pu (kN)	Mu (kN.m)
1	BS MA	2.37	1.37	0.24	15.85	5.80	1.03
2	BS ME	2.37	1.99	0.35	15.51	8.27	1.47
3	BL LM	2.37	2.11	0.37	17.28	8.19	1.45
4	BL PK	2.37	0.63	0.11	106.19	30.75	5.46
5	BL BT	2.37	0.46	0.08	40.28	4.10	0.73

At the limit deflection of 2.37 mm, BL LM was able to resist the largest load compared to other beams, so the capacity (Mi) was also large 2 to 3 times compared to others laminate beams even higher than solid beams (BS MA) and (BS ME). This shows that the use of glue (Epoxy) can increase the capacity and given strengthened to the layers on the laminate beam so that the laminated beam was more monolithic than the adhesive bolts and nails. In the ultimit condition, the variation of BL LM and BL PK has almost the same capacity even greater than the solid beam. BL PK has the largest capacity of the three variations of laminate beam, which was 5.46 kN.m. This showed that the use of heavy wood (Meranti) at the outer layer combined with the nail as adhesive can increase the capacity of lightweight wooden beams (Mahang) when analyzed by bending capacity. This was similar to that stated by (Handayani 2016) that laminated technology with heavy wood loading gives increased utilization to light wood. Specimens of BL BT obtained smaller capacity of all variations of laminate beam that was to 0.73kN.m or decreased 42.79% when compared with BS MA and decreased 58.44% when compared to BS ME. This occurs because of the reduction of the cross-sectional area in the tensile area due to the placement of the connector such as bolts and nails.

5.2. Modulus of elasticity

The lamination beam MOR test was recorded with the maximum deflection of the laminate beam The results have been analyzed using the eqs (2) to determine the modulus of elasticity. The results can be seen in Figure 4.



	BL LM	BL PK	BL BT
MOE	6818,88	4039,68	2161,02

Figure 4 Test results of modulus of elasticity (MOE)

Figure 4 shows that BL LM has the largest MOE of 6818.8 MPa, followed by BL PK with MOE of 4039.6 MPa and BL BT with MOE of 2161,02 MPa. This indicates that BL LM has greater stiffness than other laminated beams, and BL PK or BL BT have lesser stiffness when compared to BS MA and BS ME. The use of nails and bolts as adhesives or connector can make the beginning of laminate beam failure. This was similar to that research by (Basuki et al 2015), which states that the use of nails on LVL beams provides the pressure that causes LVL body beam damage so that faster cracks occur in the body of the beam and affect the MOE of the beam

Vol 3-Sep2018
ISSN: 2541-3023

5. Conclusion

Based on the results of laboratory testing and analysis results of laminated wood beams of Meranti and Mahang wood, several conclusions can be drawn:

1. At the deflection limit, glue adhesive laminate beam (BL LM) has a larger capacity than the laminate adhesive bolt (BL BT) and the nail adhesive (BL PK), in contrast at the ultimit condition, the BL PK has greater capacity than others.
2. The use of glue and nail as adhesive on the laminate beam can increase the beam capacity and increase the MOR of laminate beam when compared with solid Mahang beams (BS MA).
3. The use of glue adhesive can increase the modulus of elastic (MOE) of laminated beams when compared with solid beam of Meranti (BS ME) and solid beam of Mahang (BS MA).

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