PAPER • OPEN ACCESS

Utilization of local West Sumatra bamboo for laminated bamboo board with different adhesives

Utilization of local West Sumatra bamboo for laminated bamboo board with different adhesives

Sahadi Didi Ismanto[1(a)] and Neswati[1]

[1]Department of Agricultural Products Technology, Faculty of Agricultural Technology, Andalas University, Kampus Unand Limau Manis Padang 25163,Indonesia.[a] Corresponding author: sahadididiismanto@ae.unand.ac.id

Abstract. The purpose of this study was to study the physical and mechanical properties of laminated bamboo boards by using several types of adhesives for different purposes of use. The research design is done explorative, ie reveal facts that may or may not be revealed. Where each observation is done 3 times repetition and the data obtained will be discussed descriptively. The research treatment was A = PVAc adhesives; B = Gambier Adhesives and C = Phenol Adhesives. The results of Laminated bamboo research with 3 types of PVAc adhesive, Gambier and Phenol Formaldehyde were found that the difference of adhesive type usage on bamboo laminated has significant effect on density, fracture (MOR) and internal stickiness (IB) and delamination, but no significant effect on water. All laminated bamboo test parameters obtained meet National Standard Indonesia for plywood. The best laminated bamboo is using Phenol Formaldehyde adhesive with the density value of 1.02g/cm3, water content 13.00%, brokenness 486.84 kg/cm2, internal stickiness 8.40 kg/cm2 and delamination 1.77% . Based on the research that has been done, it is advisable to do advanced research of bamboo laminated with bamboo arrangement with different angle.

1. Introduction

Industries engaged in forest products, especially wood processing at this time faced with the problem of availability of raw materials. The high demand for wood-based products is not matched by the availability of adequate raw materials, so the resulting product is limited and the price becomes expensive. According to the Ministry of Environment [1], the current national timber demand is 57.1 million m3 per year with the ability of natural forests and plantations to provide 45.8 million m3 per year. Under these conditions, there is a wood demand deficit of 11.3 million m3 per year, which encourages the development of composite products as an alternative in the fulfilment of timber industry needs. To overcome the inability of forests to meet the increasing need for timber, anticipatory measures should be taken by looking for raw materials other than wood that can be used as wood substitution from natural forests. One of them by utilizing non-wood forest products in the form of bamboo. Bamboo (*Dendrocalamus asper*) has many advantages such as strong, hard, light, easy to get, fast growing, easy to work, and have better mechanical properties in parallel direction of fibre. The specialty of the bamboo is making the business optimization of its use continues to be done both as a construction material, as well as for panel products. [2] has developed the use of bamboo reed as construction truss space while [3] use it as raw material for cement boards.

From these advantages, it is very possible to develop bamboo panel products as a form of diversification of wood panel products. Diversified forms of bamboo produce imitation board diverse forms including particle board, fibreboard, bamboo or bamboo plywood (bamboo ply) and bamboo laminated [4]. Based on the potential and superiority of bamboo Betung to be used as bamboo lamina,

Bamboo Laminated research is very possible applied in West Sumatra. The purpose of this study was to study the physical and mechanical properties of laminated bamboo boards by using several types of adhesives for different purposes of use.

2. Material and Method

2.1. Materials and Tools
The materials used in this study were Betung bamboo (*Dendrocalamus asper*) approximately 3-4 years old, borax acid, aquadest and polyvinyl acetate. The equipment used for making these laminated bamboos is saws, machetes, modified grinders, analytical scales, aluminium plates, desiccators, ovens, mouds, cold presses, physical and mechanical properties of bamboo laminated.

2.2. Research Design
The research is carried out in an explorative manner, which reveals facts that may or may not be revealed. Where each observation is done 3 times repetition and the data obtained will be discussed descriptively. The research treatment is:
A = PVAc adhesive
B = Adhesive Gambier
C = Phenol adhesive

2.3. Research Implementation

2.3.1. Preparation of Bamboo Sheet
Betung bamboo used is taken in the Mungka area, Payakumbuh Regency, Indonesia. Bamboo which is still in round and long shape is cut into blades with a size of 20 cm x 1 cm x 0.5 cm. Bamboo is shaved until the surface is smooth and put in an oven at a temperature of 40-45oC to get 8-10% moisture content.

2.3.2. Material Calculation [5]
The calculation of the materials needed in the action of bamboo laminated is based on the research of [5] with the following details:
1. The size of the panel made is 20 x 20 x 1.5 cm^3
2. Density 1 g/cm3
3. The surface area of bamboo laminated is 400 cm2
4. Weight of Polyvinyl Acetate Adhesive 39.06 g
5. Gambier Adhesive Weight 39.06 g
6. Phenol Adhesive Weight 39.06 g

The calculation of the adhesive usage is as follows: GPU = (S X A) /(2048.2) (g)
Information:
GPU = Gram pick up
S = The amount of glue that is blended
A = Area of area to be sealed

For the amount of adhesive to be bonded, according to [6], in plywood the amount of adhesive given to the fin generally ranges from 35-45 lb of adhesive per 1000 square feet of single adhesive line. However, some studies use the amount of glue that is blended is 50 lb. Such as glue spread, which is usually used for laminated bamboo adhesives is 50 lb / MDGL, but this amount can vary less or more depending on the nature or condition of the surface of the bamboo material to be bonded [7].

2.3.3. Adhesive Preparation
Polyvinyl Acetate was weighed using analytical scales according to the desired weight, ie 9.76 g for one side (39.06 g for double spread / MDGL gluing). Then the adhesive is coated on the sides of the bamboo blade.

2.3.4. Making of Laminated Bamboo [8].
After the material is cut into desired sizes and the water content is 8-10%, then making laminated bamboo. The stages of making bamboo laminated as follows:
1. Cut the bamboo with a length of 20 cm according to the mould
2. Cut the bamboo and separate it between blades and slabs with a size of 20 cm x 1 cm x 0.5 cm
3. Selected straight bamboo blades with water content reaching approximately 8-10%
4. Soak the blades with a borax solution ± 19.06 g/L
5. Drying
6. Giving polyvinyl acetate adhesive 39.06 g for the four planned sides of the blade. Then print with a print size of 20 x 20 x 1.5 cm3. The shape of the bamboo slats is that the lower part of the bamboo laminated is arranged horizontally, the middle part of the bamboo laminated is arranged vertically and the upper part of the bamboo laminated is arranged horizontally again
7. After collecting one section of the blade in one mould. Then the layer of the blade is felt according to the treatment
8. Conditioning, prior to testing the conditioning process is carried out for 1 week, so that the bamboo water content of laminated reaches a maximum equilibrium moisture content of 14%.
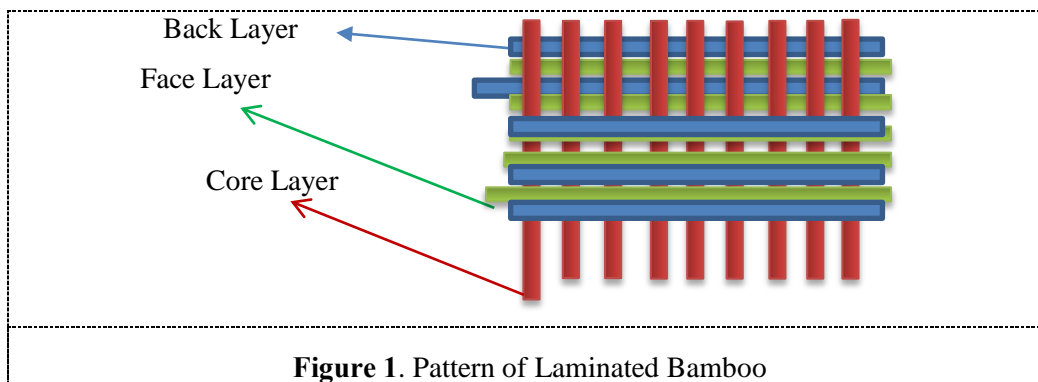9. The pattern of laminated bamboo arrangement can be seen in Figure 2.

Back Layer

Face Layer

Core Layer

Figure 1. Pattern of Laminated Bamboo

2.4. Observation

2.4.1. Test Sampling
After the conditioning process, sheets of laminated bamboo are cut into parts of the test sample as shown in Figure 2.
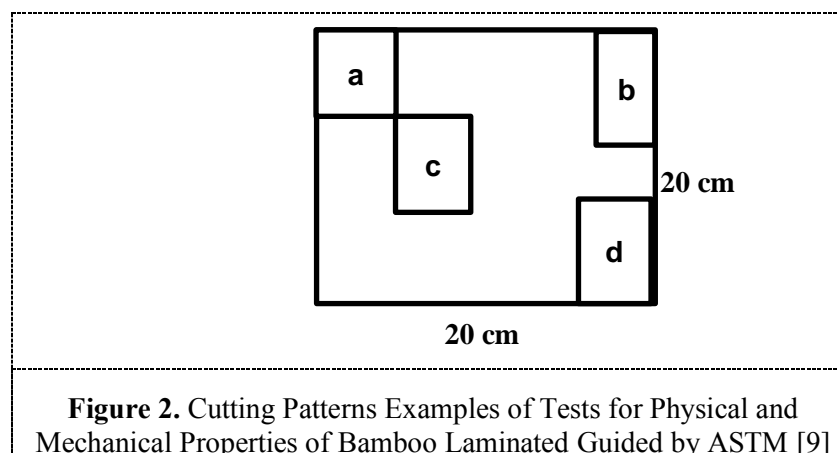

a

b

c

20 cm

d

20 cm

Figure 2. Cutting Patterns Examples of Tests for Physical and Mechanical Properties of Bamboo Laminated Guided by ASTM [9]

Information : a =Samples of density and moisture test, measuring 5 cm x 5 cm
b= Sample of a brokenness test, measuring 5 cm x 10 cm
c= Sample of internal stickiness test, measuring 5 cm x 5 cm
d= Samples of delamination test, measuring 7.5 cm x 7.5 cm

2.4.2. Observation of Physical Properties of Bamboo Laminated

2.4.2.1 Density [10]
The density of bamboo laminated is calculated based on air dry weight and volume. The test sample volume is calculated using the formula:

V = P x L x t = T

Information:
V = sample test volume (cm3)
P = Test sample length (cm)
L = Test sample width (cm)
T = Thick test sample (cm)

2.4.2.2 Determination of Water Content [11]
The test sample size (5 x 5 x 1.5) cm3 is weighed to determine the initial weight, then put it in the oven at a temperature of 100-105oC. After drying and storing in a desiccator, the test sample is weighed and dried again until the weight remains (oven dry weight), with an interval of 1 hour for each weighing. Scales used with the accuracy of at least four decimals. The water content value is calculated using the formula:

$$\text{Water Content} = \frac{BA - BKO}{BKO} \; X \; 100 \; \%$$

Information:
BA = Initial weight (g)
BKO = oven dry weight (g)

2.4.3. Observation of Mechanical Properties of Bamboo Laminated

2.4.3.1 Broken Strength (MOR)[10]
Broken firmness shows the strength of the wood in holding the load. The test sample used is size (10 x 5 x 1.5) cm3. The test sample is pressurized perpendicular to the surface of the sample is broken or damaged. MOR values can be calculated using the formula:

$$MOR = 3 \; PL \; / \; 2bh^2$$

Information:
P = maximum weight (kg)
L = distance (cm)
b = Test sample width (cm)
h = Thick test sample (cm)

2.4.3.2 Internal Bonding (IB) (SNI 01-5008.2-1999 Plywood)[10]
Adhesive strength was calculated using the UTM Instron machine as well as testing for bending strength and fracture firmness. The size of the test sample used is 5 cm x 5 cm x 1.5 cm. The internal stickiness value can be calculated using the formula:

$$\text{Internal stickiness} = P \; / \; A$$

Information:
P = Maximum load (Kgf)
A = surface area of the test sample (cm^2)

2.4.3.3 Testing of Delamination [11]
The test sample used was 7.5 cm x 7.5 cm x 1.5 cm soaked in hot water at a temperature of ± 35oC for 2 hours, then dried in an oven at a temperature of ± 60oC for 3 hours. The test sample is examined and

the length of the peeling part is measured. Delamination value can be calculated by the following formula:

Delamination = (total length of delamination)/(total length of the adhesive line) x 100

3. Results and Discussion

3.1. Physical Properties of Bamboo Laminated

3.1.1. Moisture Content
Water content is one of the physical properties of laminated bamboo which shows the water content of bamboo laminated in equilibrium with the surrounding environment. [6] define water content as the weight of water expressed in percent by weight of water-free wood or dry furnace. On testing the moisture content of laminated bamboo obtained ranged between 12.63 - 13.38%. The average value of laminated bamboo water content can be seen in Table 1.

Table 1. Average Laminated Bamboo Water Levels with Treatment Types of Adhesives Used.

Treatment	Moisture Content (%)
PVAc Adhesive	13.09 ± 0.03
Gambier Adhesive	13.08 ± 0.05
Phenol Adhesive	13.00 ± 0.03

The water content obtained from the manufacture of laminated bamboo is in accordance with [11] bamboo laminated which is below 14%. The results of measurements of moisture content of laminated bamboo are also in accordance with the standards set by [12] which is a maximum of 15%. [13] obtained an average water content for bamboo cross laminated around 12.79%, [8] also obtained an average water content for laminated bamboo around 12.7%, while [14] obtain water content for laminated beams and Betung bamboo blades around 12.48%. The higher the water content will reduce the strength of wood, if the water content is below the saturation point of the fibre, there will be an increase in wood strength. The increase in strength is influenced by the increasingly compact structure of wood cell walls [15]. Furthermore, according to Bowyer et al (2003) which affects the amount of water bound in the cell wall is the process of drying the material and the environment where the end product is stored. The bamboo drying process used in this study was able to reduce the water content bound to the cell wall so that the final water content of the product was below 14%. Reduced water content in bamboo laminated is caused by the duration of pressing where the more adhesive type is, the longer the laminated bamboo gets pressure from the press and causes a small portion of adhesive to come out of the laminated bamboo, this will cause the laminated bamboo moisture content to decrease even though the decrease not significant. According to [16], the amount of sodden adhesive, laminated thickness, number of laminated layers, wood density, adhesive water content and procedures used in the gluing process (cold or hot pressing) are factors that will determine the final water content of a laminated product. The results showed that the value of laminated bamboo water content ranged from 13.00 - 13.09%, as shown in Figure 3.

3.1.2. Density
Density is one of the factors that influence the properties of laminated bamboo, so that the higher the resulting density will be directly proportional to the mechanical properties of the resulting laminated bamboo. The density is the ratio between the weight and dry volume of the board, namely the volume of bamboo laminated after drying for 7 days which aims to achieve an equilibrium moisture content of 13%. According to [6], the higher the overall density of the board of certain materials, the higher the strength of the board. The higher the board density, the less water absorption and thick board development. The value of the density of bamboo laminated produced ranged from 0.96 to 1.02 g/cm^3. The highest density was found in the treatment using Phenol Formaldehyde adhesive, which was 0.79

g/cm³, while the lowest density was found in the treatment with PVAc adhesive, which was 0.96 g/cm3. The average value of bamboo laminated board density is presented in Table 2.
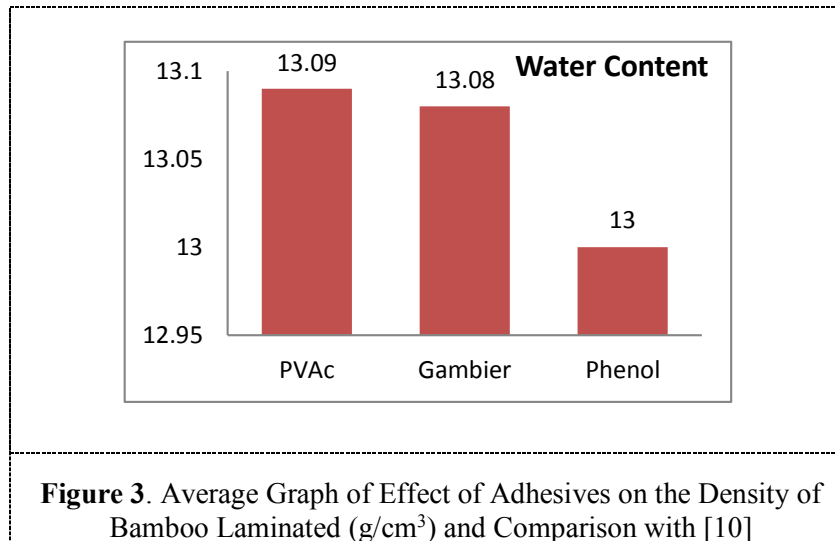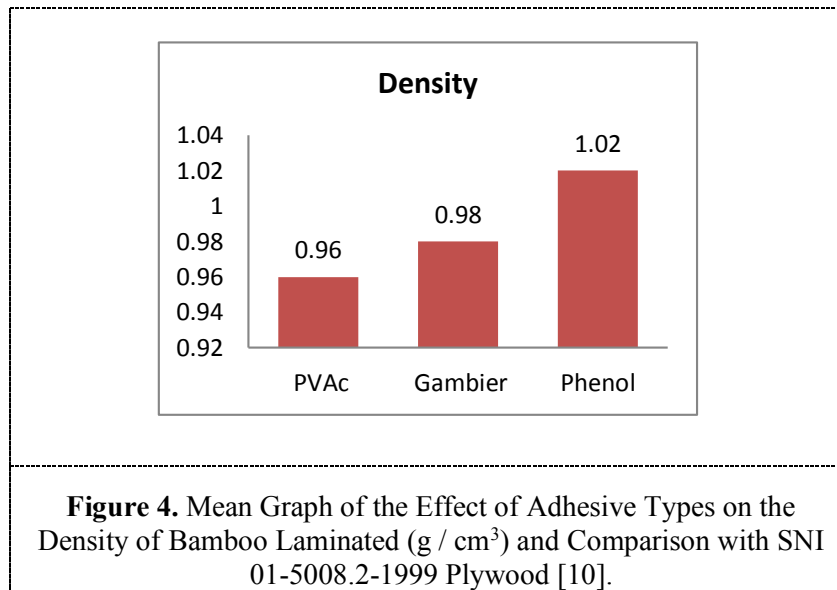

Figure 3. Average Graph of Effect of Adhesives on the Density of Bamboo Laminated (g/cm³) and Comparison with [10]

Table 2. Average Density of Laminated Bamboo with Treatment Types of Adhesives Used.

Treatment	Density (g/cm³) ± CD
PVAc Adhesive	0.96 ± 0.04
Gambier Adhesive	0.98 ± 0.05
Phenol Adhesive	1.02 ±0.04
Coefficient of Diversity = 2.26 %	

From Table , the average value obtained can be seen the density of bamboo laminated with PVAC adhesive has not met the designed density target of 1.0 g /cm³. This is caused by PVAC being semi-rubber so that the volume of bamboo laminated will expand again after pressing. But the value of laminated bamboo density obtained has accepted [10] that is > 0.56 g / cm³.

[18] obtained the density values in laminated bamboo ranging from 0.53-0.67 g/cm³ [13] obtained an average density for cross laminated bamboo around 0.66 g /cm³ while Ref. [14] obtained the density values for gala and betung bamboo laminated beams around 0.598 g/cm³. Following this, the average value of the resulting laminated bamboo density is presented in Figure 5. From the graph under it can be seen that the average value of laminated bamboo density increases by using Gambier and Phenol Formaldehyde adhesives. Factors that influence the nature of the laminated beam, namely the type and amount of adhesive material and the pressing process of the laminated beam in question.

Figure 4. Mean Graph of the Effect of Adhesive Types on the Density of Bamboo Laminated (g / cm^3) and Comparison with SNI 01-5008.2-1999 Plywood [10].

Whereas according to Ref. [7], process technology is closely related to the resulting density. Based on the measurement results of the laminated bamboo density obtained showed that the laminated bamboo was included in the category of strong class I wood which is wood with a specific weight range of 0.9 - 1.2 [18].

3.2. Mechanical Properties of Bamboo Laminated

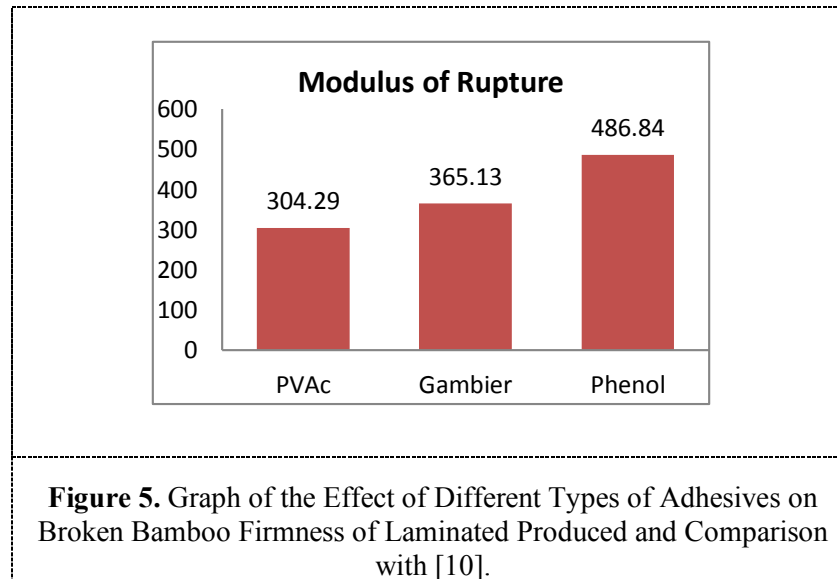#### 3.2.1. Modulus of Rupture (MOR)
Broken modulus is the ability of bamboo laminated to hold the load in a perpendicular direction to the surface that tries to break it [19]. The value of fracture constancy shows the resistance possessed by a material to not break when given a load. The constancy value of laminated bamboo fractures produced ranged between 304.29 - 486.84 kg / cm^2. The highest value of fracture firmness lies in the treatment of using Phenol Formaldehyde adhesive which is 486.84 kg / cm^2 and the lowest value of fracture firmness on the use of PVAC adhesive which is 304.29 kg/cm^2. The average value of the strength of broken laminated bamboo is presented in Table 3.

Table 3. Average Laminated Broken Bamboo Firmness with Treatment Types of Adhesives Used.

Treatment	Modulus of Rupture (Kg/cm^2) ± SD
PVAc Adhesive	304.29 ± 1.68
Gambier Adhesive	365.13 ± 2.06
Phenol Adhesive	486.84 ± 3.24

Based on Table 5, the average value of firmness of broken laminated bamboo with higher phenol formaldehyde adhesive compared to PVAc and Gambier adhesive. Ref. [13] obtained the value of fracture firmness for bamboo cross laminated around 105,14-244,36 Kg/cm^2. The value of broken fracture obtained met the minimum standard of JAS [12] which required 300 kg /cm^2 but the value of broken bamboo The resulting laminated is higher than [10] which is > 15 kg/cm^2. Comparison of the mean value of the firmness of the resulting laminated bamboo fracture is presented in Figure 5. From Figure 6 under it can be seen that laminated bamboo with a longer type of compression adhesive has a higher fracture constancy value compared to laminated bamboo with a shorter type of compression adhesive.

This is because the density of bamboo laminated with longer press duration has a higher density value as shown in Table 6 so that the process of gluing bamboo laminated becomes more perfect. This makes the strength of broken laminated bamboo stronger with the duration of press.

Figure 5. Graph of the Effect of Different Types of Adhesives on Broken Bamboo Firmness of Laminated Produced and Comparison with [10].
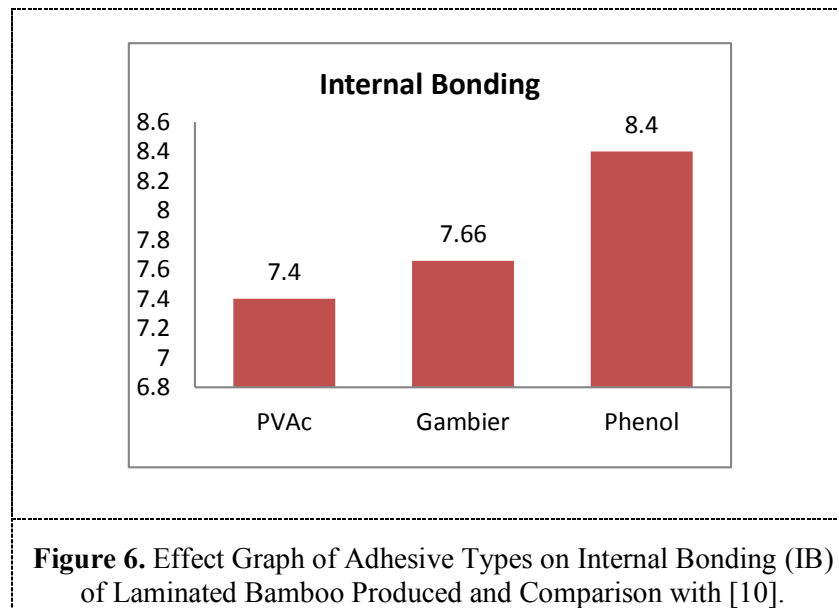
3.2.2. Internal Bonding (IB) Firmness
The value of internal bonding firmness is a value that shows the amount of bond between the blades so that it maintains its unity as a laminated bamboo. In the research that was carried out, it was found that the values of internal stickiness were varied. The value of internal bonding firmness in laminated bamboo ranges from 7.40 - 8.40 kg/cm2. The highest value of internal bonding firmness was found in the use of phenol formaldehyde adhesive which was 8.40 kg/cm^2 and the lowest value was found in the treatment of using PVAc adhesive which was 7.40 kg/cm^2. The average value of the internal stickiness of the resulting laminated bamboo is presented in Table 4.

Table 4. Average Internal Adhesion of Laminated Bamboo with Treatment Types of Adhesives Used.

Treatment	Internal Bonding(Kg/cm^2) ± CD
PVAc Adhesive	7.40 ± 1.67
Gambier Adhesive	7.66 ± 1.98
Phenol Formaldehyde Adhesive	8.40 ± 1.76
Coefficient of Diversity (CD) = 2.12 %	

As shown Table4, the internal bonding strength of laminated bamboo produced meets SNI 01-5008.2-1999 [10] Type I Plywood which is in the range of values > 7 Kg/cm2. So this laminated bamboo can meet the standards set by SNI 01-5008.2-1999 [10] concerning Plywood. The effect of different types of adhesives on the internal stickiness of bamboo laminated can be presented in Figure 6. From Table 6 above, it can be observed that the average value of internal stickiness of each treatment tends to increase. Laminated bamboo with a longer type of compression adhesive has a higher internal adhesive strength. According to [10] Plywood the value of type I internal bonding firmness is > 7 Kg/cm2 and type II is 3.5 - <7 Kg/cm2. From under Figure 7 , it is explained that the value of internal adhesive strength increases with the use of gambier and Phenol Formaldehyde adhesives, all treatments meet [10] with a value of > 7 kg / cm2. In addition to the type of adhesive, the firmness of the internal glue is also influenced by the water content of the bamboo used. Water levels that are too high will reduce the firmness of the internal glue because the water in the bamboo will prevent the adhesive from reacting with the bamboo component in the cell wall, whereas if the water content is too low there will be damage

to the cell wall. This condition is not good for gluing because the bamboo is too dry, sucks more adhesive so that the amount of adhesive on the adhesive line is too little to cause delamination [20].


Figure 6. Effect Graph of Adhesive Types on Internal Bonding (IB) of Laminated Bamboo Produced and Comparison with [10].

3.2.3. Delamination
Delamination is the release of the bond between the adhesive and the material glued together and is used to test the adhesive ability to unite the material. The purpose of delamination testing is to see the adhesive resistance factor to the pressure of development and shrinkage due to humidity and high heat [21]. In the research that was carried out obtained the value of delamination varied. The delamination value of laminated bamboo ranges from 1.77 to 3.53%. The highest delamination value was found in the PVAc adhesive treatment which was 3.57% and the lowest value was found in the treatment of using phenol formaldehyde adhesive which was 1.77%. The average value of delamination based on the type of adhesive used in bamboo is presented in Table 5.

Table 5. Average Laminated Bamboo Delamination with Different Treatment Types of Pressing Adhesives Used.

Treatment	Delamination (%)
PVAc Adhesive	3.53 ± 0.03
Gambir Adhesive	4.73 ± 0.50
Phenol Formaldehida Adhesive	1.77 ± 0.02

From Table 5 above the value of laminated bamboo delamination has met the standards set out in [11] concerning laminated bamboo in general use that is not more than 10%. The value of delamination is influenced by the area of shear, type of adhesive, and the interaction of both [22]. Adhesive bonding is a determining factor whether or not the construction of cross-laminated bamboo-forming layers. The graph of the relationship between types of adhesive and delamination is presented in Figure 7. The pressing process and type of adhesive affect the process of delamination. The cold pressing process requires a longer press time compared to hot pressing. Press time that is too short is not good because the gluing is immature or the gluing compacting process is not perfect.

Figure 7. Graph of Effect of Adhesive Types on Laminated Bamboo Delamination Compared with [10].
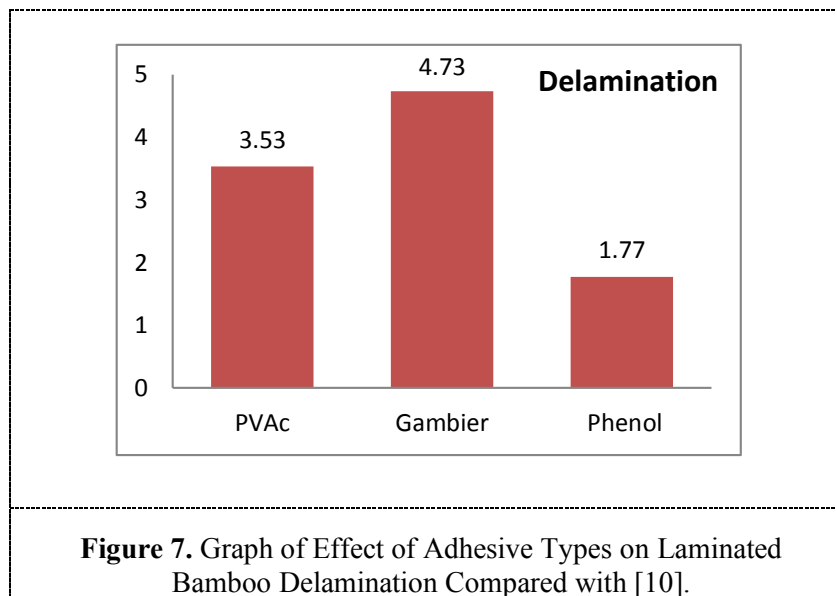
3.2.4. Recapitulation of the Properties of Bamboo Laminated
Recapitulation of data from the properties of bamboo laminated is presented in Table 6.

Table 6. Recapitulation of the Properties of Laminated Bamboo

Adhesive Type	Density g/cm³	WC (%)	MOR kg/cm²	IB kg/cm²	Delamination %
SNI 01-5008.2-1999	> 0,56	<14	> 15	>7	< 10
PVAc Adhesive	0.96	13.09	304.29	7.40	3.53
Gambier Adhesive	0.98	13.08	365.13	7.66	4.73
Phenol Formaldehide Adhesive	1.02	13	486.84	8.4	1.77

Information : WC= Water Content; MOR= Modulus of Rupture; IB= Internal Bonding

Judging from Table 6 the above data recapitulation shows that the differences in the use of adhesive types provide average density values, moisture content and fracture firmness of laminated bamboo that have complied with plywood standards referred to in [10]. Based on the recapitulation table above it can be concluded that the best treatment is the use of phenol formaldehyde adhesives. This treatment was chosen because the resulting lamina bamboo has the best physical and mechanical properties with SNI plywood standards and SNI for laminated bamboo.

4. Conclusions
Differences in the use of adhesive types in the manufacture of laminated bamboo provide different values for density, fracture firmness (MOR) and internal stickiness (IB) and delamination, but do not give different values to moisture content. All laminated bamboo test parameters obtained meet SNI for plywood. The best laminated bamboo is the one using phenol formaldehyde adhesive with a density value of 1.02 g /cm3, 13.00% moisture content, 486.84 kg/cm2 fracture constancy, 8.40 kg/cm2 internal adhesive and 1 delamination 77%.

Based on the research that has been done, it is recommended to conduct further research on bamboo laminated with a bamboo arrangement with different angles; For bamboo slats, you should use a slicing machine to get a finer straight and flat blade; trying to use other synthetic adhesives that have good adhesion but are easy and inexpensive to obtain.

References

[1]   Ministry of Forestry. 2012. Want to Know About Bamboo. Ministry of Forestry Forestry Human Resource Counseling and Development Agency Forestry Extension Center: Jakarta.

[2]   Bachtiar, G., Surjokusumo S., Hadi YS., and Nugroho N. 2009. Bamboo Reed Application for Stem Space Construction. Journal of Tropical Wood Science and Technology, Vol. 7 (1): 22-26

[3]   Suhasman., Bakri., Massijaya M.Y. 2008. Fundamental Properties of Cement Board made from Bamboo. pp 453–454.

[4]   Widjaja, W. S. 1995. Behavioral Mechanics of Structural Structures of Bamboo Lamina Composite and Phenol Formaldehyde, [Thesis] Post Graduate Program of Gadjah Mada University, Yogyakarta.

[5]   Mujiman, H., Priosulistio., Sulistio D., and Prayitno. 2015. Effect of Zigzak Laminated Dimensions and Shapes on Shear Strength and Bending of Laminated-Vertical Beams of Petung Bamboo. Journal of Civil Engineering Volume 22 No. 2.

[6]   Bowyer, J.L., Shmulsky R., and Haygreen J.G. 2003. Forest Products and Wood Science: An Introduction. 4th ed. Iowa State Press, Ames, IA 553 pp.

[7]   Prayitno, T.A. 1996. Wood Gluing. Faculty of Forestry, Gadjah Mada University. Yogyakarta.

[8]   Eratodi, B., Morisco., and Prayitno T.A. 2008. Laminated Bamboo Press Strength and Its Application at Traditional Balinese Bamboo Houses. Civil Engineering Forum No. XVIII / 1-January. Pp. 702-711.

[9]   American Standard Test Methods. 2000. D 143-94. Standard Test Methods for Small Clear Speciments of Timber. Annual Book of ASTM Standard. Philadelphia. Volume 9-11.

[10]   National Standardization Agency. 1999. SNI 01-5008.2-1999 / Revision of SNI 01-2704-1992 Plywood and Block Board General Use. National Standards Agency. Indonesia.

[11]   National Standardization Agency. 2014. SNI 7944: 2014. General Use of Bamboo Laminated. National Standards Agency. Indonesia.

[12]   Japanese Agricultural Standardt. 2007. Japanese Agricultural Standard for Glued Laminated Timber. Ministry of Agriculture, Forestry and Fisheries / MAFF, Notification No. 1152.

[13]   Agustina, A., Nugroho N., Bahtiar E.T., and Hermawan D. 2015. Characteristics of Cross Laminated Bamboo as Structural Composite Material. Journal of Agricultural Industry Technology. 25 (2): 174-181

[14]   Gunawan, P. 2007. Effect of Adhesives on Sliding Shear of Laminated Galar and Vertical Bamboo of Petung. Faculty of Engineering, Civil Engineering Department, Sebelas Maret University: Surakarta. Pp. 99-110.

[15]   Tsoumis, G. 1991. Science and Technology wood Structur, Properties, Utilization. Van Vostrand Reinhold Inc. USA.

[16]   Oka, G. M. 2005. Analysis of Grained Adhesive on the Making of Petung Bamboo Laminate Beams. SMARTek Journal, Vol. 3, No. 2, May 2005: 93 – 100

[17]   Mahdie, M F., and Rinaldi, A. 2007. Effect of Laminate Arrangement of Rope Bamboo Beams Against Broken Density, Delamination and Firmness. Journal of Forestry Science Vol I. No. 2.pp 22-29

[18]   National Standardization Agency. 2002. Procedures for Wood Construction Planning. SNI-5. Jakarta.

[19]   Massijaya, M.Y., Hadi Y.S., Tambunan, B., Bakar E.S and Sunanrni, I. 1999. Study of Making Particle Boards from Wood and Plastic Polystyrene Waste. Journal of Forest Product Technology 12 (2):31-34.

[20]   Budiman. 1995. Barito Pacific Timber Group Adhesion Process: North Maluku Congregation.

[21]   Vick, C.B. 1999. Wood Handbook : Wood as an Engineering Material, Struktur, Southern Forest Product Association. Wisconsin.

[22]   Ekawati, D. 1998. Effect of Adhesives and Arrangement of Meranti Wood (Shorea spp) and Coconut (Cocos nucifera) on Physical and Mechanical Properties of Lamina Beams Small Examples of Disability Free. [Essay]. Faculty of Forestry, IPB. Bogor.