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EFFECT OF COMPRESSION PRESSURE, WOOD COMBINATION, AND ITS INTERACTION ON THE QUALITY OF LAMINATED BOARD

Pengaruh Tekanan Kempa, Jenis Kombinasi Kayu dan Interaksinya Terhadap Kualitas Mutu Papan Laminasi

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ABSTRACT

Lamination technology is an effort to overcome various problems resulting from the wood industry experiencing difficulties in finding raw materials to support its operations. Developing environmentally friendly materials such as laminate products is also becoming a concern in the construction sector. This research will use fast-growing wood species with bamboo, namely rajumas wood, sengon wood, and petung bamboo. Several factors, including the type of wood, type of adhesive, adhesive melt weight, and compression pressure, influence the manufacture of laminated boards. This research aims to see the effect of the type of wood combination (sengon and rajumas) with petung bamboo and the effect of pressure and their interactions on their physical and mechanical properties. The experimental design was a factorial design with 2 factors (compression pressure and combination type) with four treatments and three replications. Based on the results of testing laminated boards' physical and mechanical properties, several conclusions can be drawn, such as density testing, which shows that the type of wood combination has a significant effect. At the same time, compression pressure and its interactions have no significant effect. Moisture content testing showed that pressure had a significant effect, while the type of wood combination and its interactions had no significant effect. The thickness expansion test shows that the type of wood combination and its interactions have a significant effect, while the compression pressure has no significant effect. Thickness shrinkage testing shows that the type of wood combination, compression pressure, and their interactions do not significantly affect it. Modulus of Elasticity (MoE) testing shows that the type of wood combination, compression pressure, and their interactions do not significantly affect it. Modulus of Rupture (MoR) shows that the type of combination has a significant effect, while the compression pressure and its interaction have no significant effect.

Keywords: combination type; compression pressure; laminated board

ABSTRAK

Teknologi laminasi merupakan salah satu upaya dalam mengatasi berbagai permasalahan akibat industri perkayuan mengalami kesulitan dalam mencari bahan baku untuk mendukung operasionalnya, selain itu pengembangan material ramah lingkungan sebagai bahan produk laminasi menjadi perhatian dalam bidang kontruksi. Penelitian ini akan menggunakan jenis kayu cepat tumbuh dengan bambu yaitu kayu rajumas (*Duabanga moluccana*) dan sengon (*Albizia chinensis*) serta bambu petung (*Dendrocalamus asper*). Pembuatan papan laminasi dipengaruhi oleh beberapa faktor antara lain jenis kayu, jenis perekat, berat labur perekat dan tekanan kempa. Penelitian ini bertujuan untuk melihat pengaruh jenis kombinasi kayu sengon dan rajumas dengan bambu petung serta pengaruh tekanan dan interaksinya terhadap sifat fisika dan mekanikanya. Rancangan percobaan yang digunakan rancangan faktorial dengan 2 faktor (tekanan kempa dan jenis kombinasi) dengan empat perlakuan dan tiga kali ulangan. Berdasarkan hasil pengujian sifat fisika dan mekanika papan laminasi maka dapat ditarik beberapa kesimpulan yaitu pengujian kerapatan menunjukan jenis kombinasi kayu berpengaruh nyata sementara untuk tekanan kempa dan interaksinya tidak berpengaruh nyata. Pengujian kadar air menunjukan tekanan kempa berpengaruh nyata sementara jenis kombinasi kayu dan interaksinya tidak berpengaruh nyata. Pengujian pengembangan tebal menunjukan jenis kombinasi kayu dan interaksinya berpengaruh nyata sementara tekanan kempa tidak berpengaruh nyata. Pengujian penyusutan tebal menunjukan jenis kombinasi kayu, tekanan kempa dan interaksinya tidak berpengaruh nyata. Pengujian Modulus of Elasticity (MoE) menunjukan jenis kombinasi kayu, tekanan kempa dan interaksinya tidak berpengaruh nyata. Modulus of Rupture (MoR) menunjukan jenis kombinasi berpengaruh nyata sementara tekanan kempa dan interaksinya tidak berpengaruh nyata.

Kata kunci: jenis kombinasi; papan laminasi; tekanan kempa

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A. INTRODUCTION

Lamination technology is an effort to overcome various problems due to the timber industry experiencing difficulties in finding raw materials to support its operations. Besides, developing environmentally friendly materials such as laminated products is a concern in construction (Lestari *et al.* 2020). Lamination technology is one solution to obtain broader and longer sortiments. This laminated wood is made from pieces of wood blocks glued together with adhesives so that they become wood that can be reused (Wulandari *et al.* 2022). Some of the advantages of laminated technology over solid wood are that the size can be made higher, wider, longer stretches, curved cross-sectional shapes can be fabricated easily, pre-drying each layer of wood can reduce changes in shape, and strength reduction due to wood defects (e.g., knots) becomes more random so that the wood cross-section is more homogeneous and allows for making products of high artistic value (Teguh *et al.* 2017).

Research related to laminated boards that have been carried out includes: Properties of randu wood (*Ceiba pentandra* (L.) Gaertn) laminated boards with variations in lamina sawn pattern and layer direction (Rofii *et al.* 2022); Analysis of flexural strength and compressive strength of laminated beams of petung bamboo (*Dendrocalamus asper*) and coconut fiber as a component of ship construction (Manik *et al.* 2022); Analysis of flexural mechanical properties of laminated boards of *D. asper* and ater bamboo combinations (Belatrix 2022). This research will use fast-growing wood species with bamboo, which is expected to increase physical and mechanical strength. The types of fast-growing wood used are rajumas and sengon, and the bamboo used is *D. asper*.

Rajumas (*Duabanga moluccana*/*D. moluccana*) and sengon (*Albizia chinensis*/*A. chinensis*) are two wood species with low specific gravity and strength (Lessy *et al.* 2018; Wulandari and Suastana 2022). Woods with these properties have great potential to be used as board products, allowing the adhesive to penetrate well into the wood surface to form a strong bond (Wulandari *et al.* 2023). *D. asper* has a wall thickness of 10-30 mm, a straight trunk, and is not susceptible to pests. *D. asper* that meets the requirements for making laminated boards must be 3 to 5 years old from its growth period (Wulandari *et al.* 2024).

The feasibility of laminated boards as a substitute for solid wood can be seen by testing the physical and mechanical properties to determine the strength class of the laminated boards produced. The results of testing physical and mechanical properties can be a recommendation for using boards according to their strength class. Physical properties are tests that describe the actual conditions of wood physics that affect its wettability, and mechanical properties show the ability of the board to withstand the load above it (Kasmudjo 2001). The manufacture of laminated boards is influenced by several factors, including the type of wood, type of adhesive, adhesive weight, and compression pressure (Amin & Wulandari 2023). This research aims to analyze the effect of combining wood (*A. chinensis* and *D. moluccana*) with *D. asper* and the effect of pressure and its interaction on its physical and mechanical properties.

B. METHODS

Materials and Tools

The equipment used were adhesive/brush attachment, digital scales, desiccators, meters, cutting machines, ovens, and clamping (cold felts). The materials used in this research were PVAc glue brand (Rajawali), *D. moluccana* wood sticks, *A. chinensis* wood sticks, and *D. asper* sticks.

Research Design

The research design used in this study was a factorial complete randomized design (CRD) with two factors and four treatments. The first factor was compression pressure, which was treated with two compression pressure treatments of 20 N/m^2 and 30 N/m^2. The second factor is the type of combination with two treatments of *D. moluccana*/*D. asper* and *A. chinensis*/*D. asper.*

Procedures

1. Raw Material Preparation

It is the sorting of wood and bamboo pieces according to predetermined sizes. Raw materials are shavings first before making wood sorting. Sortiments are made using a cutting saw machine with a size of (80 x 4 x1) cm^3. The sanding process uses sandpaper with a sandpaper size of 220 grit so that the surface becomes flat to facilitate the gluing process. Next, the oven process was carried out for 2 days with an oven temperature of 60°C, which homogenized the moisture content. This temperature is ideal for drying because it can accelerate the drying rate and will not cause scorching of the product to be dried (Mochin *et al.* 2014).

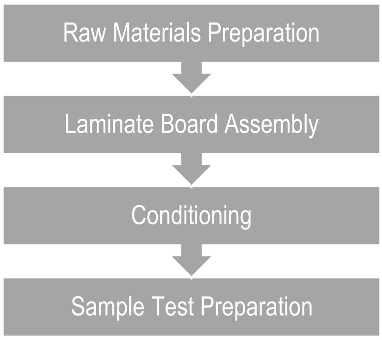


Figure 1. Research flowchart

2. *Laminate Board Assembly*

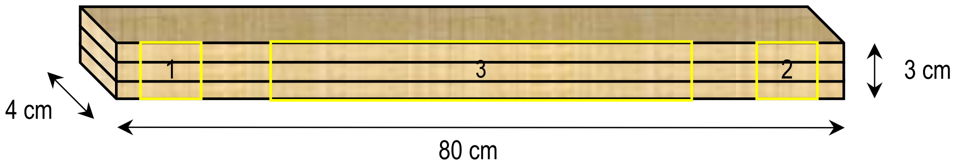
After uniform moisture content, the wood and bamboo were assembled using PVAc adhesive with a labor weight of 150 g/m^2. Furthermore, the process of clamping or cold forging for 24 hours with a compression pressure of 20 N/m^2 and 30 N/m^2.

3. *Conditioning*

The assembled laminated boards were kept in a constant room for approximately one week to homogenize the moisture content in the wood.

4. *Sample Preparation*

The cutting pattern of the laminated board test samples for testing physical and mechanical properties can be seen in Figure 2.



Description:
1. Density and moisture content test sample (4 cm x 4 cm x 3 cm)
2. Dimensional change test sample (4 cm x 4 cm x 3 cm)
3. MoE and MoR test sample (4 cm x 3 cm x 45 cm)

Figure 2. Illustration of the test sample

Testing Parameters

The physical and mechanical properties of laminated beams were tested based on JAS 234-2007 for glue laminated timber (JSA 2007). The physical properties tested were moisture content, density, thickness swelling, and thickness shrinkage. The mechanical properties are MoE and MoR.

Data Analysis

Suppose the calculated F value exceeds the F table ($P < 0.05$). In that case, the Duncan Multiple Range Test (DMRT) is carried out to compare the difference in parameter and DMRT values obtained to determine different treatment levels.

C. RESULTS AND DISCUSSION

Density

Wood density testing is one of the physical properties that shows the ratio between the object's mass and volume (Megawati *et al.* 2016). The highest density at pressure T1 was 0.51 g/cm^3 and combination type J1 was 0.54 g/cm^3. This value has met the JAS 234-2007 standard of 0.40-0.80 g/cm^3. When compared with research conducted by Darwis et al. (2014) on coconut wood laminated boards with densitys ranging from 0.33 -0.38 g/cm3, the value is higher. The difference in density is influenced by the type of wood, the amount of compression pressure, cell wall thickness, moisture content, and the gluing process (Somadona *et al.* 2020). Some factors affecting the quality of laminated wood are the raw material, the shape of the joint, the gluing process, the forging, and the application of excessive adhesive (Purwanto 2011). Differences in wood species affect the quality of laminated wood, one of which is the density (Wulandari & Amin 2022). Wood density affects the strength of wood. The greater the density of wood, the more strength the wood has, or vice versa (Wulandari & Latifah 2022). To see the relationship between compression pressure, type of combination, and their interaction on density, a diversity test (ANOVA) was conducted.

Table 1. Density of laminated board

Compression pressure	**Combination Type**		**Average (g/cm³)**
	J1	J2	
T1	0.53	0.50	0.51
T2	0.54	0.46	0.50
Average (g/cm³)	0.54	0.48	0.51

Notes: J1 = *D. moluccana*/*D. asper*, J2 = *A. chinensis*/*D. asper*, T1 = 20 N/m^2 compression pressure, T2 = 30 N/m^2 compression pressure

The analysis of variance test results in Table 2 shows that only the treatment of wood combination types significantly affects the density of laminated boards, which is characterized by a significance value of 0.006. Meanwhile, the compression pressure and the interaction between compression pressure and wood type did not significantly affect the density of laminated boards, which was characterized by a significance value of 0.458 and 0.155, respectively. Although there are significant treatments, the DMRT is not carried out because the wood-type treatment has only two factors.

Table 2. ANOVA of Density

Source of Diversity	**Sum of Squares**	**db**	**Mean Square**	**Fhit.**	**Sig.**
Compression pressure	0.001	1	0.001	0.609	0.458
Wood type	0.012	1	0.012	13.566	0.006
Compression pressure * Wood Type	0.002	1	0.002	2.465	0.155
Error	0.007	8	0.001		
Total Correction	3.097	12			

Moisture Content

Moisture content testing is the amount of water contained in wood or wood products expressed as moisture content (Wulandari & Latifa 2022). The moisture content and fiber density of the forming material affect the manufacture of laminated boards (Widiati *et al.* 2018).

Table 3. The moisture content of laminated board

Compression pressure	**Combination Type**		**Average (%)**
	J1	**J2**	
T1	14.29	14.02	14.16
T2	14.47	14.50	14.48
Average (%)	14.38	14.26	14.32

Notes: J1 = *D. moluccana*/*D. asper*, J2 = *A. chinensis*/*D. asper*, T1 = 20 N/m^2 compression pressure, T2 = 30 N/m^2 compression pressure

The highest content value of laminated boards at T2 pressure is 14.48%, and the type of combination J1 is 14.38%. This value has met the JAS SE-7 2007 standard with a value of ≤ 14%, and this value has met the requirements of SNI.01-0608-89 for the requirements for the moisture content of wood furniture raw materials, which is a maximum of 15%. The moisture content of wood is influenced by the hygroscopic properties of wood species, storage temperature and humidity, and the properties of the wood used, such as the number of pores, texture, wood structure, strength class, hardness, specific gravity, and so on (Purwanto 2011). The value of this study, when compared with research conducted by Darwis et al. (2014) on palm trunk laminated boards with moisture content values ranging from 12.10% to 12.87%, is higher. The ideal moisture content for making laminated boards is 12% or slightly below because that moisture content facilitates the process of connecting laminated boards, and the value of 12% is the balance moisture content, which is generally for interior use so that it is more stable against weather changes (Wulandari & Amin 2023). An ANOVA test was conducted to see the effect of compression pressure, type of combination, and their interaction on moisture content.

The analysis of variance test results in Table 4 shows that the treatment of wood species and the interaction between compression pressure and wood species have no significant effect on the moisture content of laminated boards, which is characterized by a significance value of 0.200 and 0.118, respectively. Compression pressure treatment significantly affects the moisture content of laminated boards, which is characterized by a significant value of 0.005. Although there is a significant treatment, DMRT was not conducted because there are only two factors in the treatment of compression pressure.

Table 4. ANOVA of moisture content

Source of Diversity	Sum of Squares	db	Mean Square	Fhit.	Sig.
Compression pressure	0.314	1	0.314	14.855	0.005
Wood type	0.041	1	0.041	1.952	0.200
Compression pressure * Wood Type	0.065	1	0.065	3.064	0.118
Error	0.169	8	0.021		
Total Correction	2460.537	12			

Thickness Swelling

Changes in wood dimensions occur in line with changes in moisture content contained in wood cell walls due to OH (hydroxyl) groups and other oxygen (O2) in cell walls that attract water vapor through hydrogen bonds (Wulandari *et al.* 2022).

Table 5. Thickness swelling of laminated board

Compression pressure	Wood Type		Average (%)
	J1	J2	
T1	2.48	2.44	2.46
T2	1.30	4.15	2.72
Average (%)	1.89	3.29	2.59

Notes: J1 = *D. moluccana*/*D. asper*, J2 = *A. chinensis*/*D. asper*, T1 = 20 N/m^2 compression pressure, T2 = 30 N/m^2 compression pressure

The highest laminated board thickness swelling value at pressure T2 was 2.72%, and combination type J2 was 3.29%. This value has met the JAS SE-7 2007 standard, which requires a thick development value of ≤ 20%. This study was compared with research conducted by Rinasari et al. (2012) regarding the characteristics of laminated beams from coconut trunks and candlenut wood, which had a value range of 1.57-1.59%. Dimensional changes are a sign of changes in moisture content in wood due to the ability of wood cell walls to bind water caused by differences in density where density varies between different types of trees and between trees of the same species (Widiawati *et al.* 2018). Another factor in the difference is due to the treatment and raw materials used in the study (Wulandari *et al.* 2023). ANOVA test was conducted to see the effect of pressure, type of combination, and their interaction.

Table 6 shows that the treatment of compression pressure does not significantly affect the thickness swelling, which is characterized by a significance value of 0.574. The treatment of wood type and the interaction between pressure and wood type significantly affected the thickness swelling with a significance value of 0.014 and 0.012. Although there were significant treatments, the DMRT was only carried out on the interaction treatment between compression pressure and wood type because there were only two factors in the wood type treatment.

Table 6. ANOVA of thickness swelling

Source of Diversity	Sum of Squares	db	Mean Square	Fhit.	Sig.
Compression pressure	0.206	1	0.206	0.344	0.574
Wood type	5.898	1	5.898	9.840	0.014
Compression pressure * Wood Type	6.294	1	6.294	10.501	0.012
Error	4.795	8	0.599		
Total Correction	97.727	12			

In Figure 1, it can be seen that the T1J1 and the T2J2 treatments show a significant difference. Furthermore, the T2J1 and the T2J2 treatment showed a significant difference. The T1J2 and T2J2 treatment also show a significant difference. Meanwhile, the T2J2 treatment showed a significant difference between all treatments.

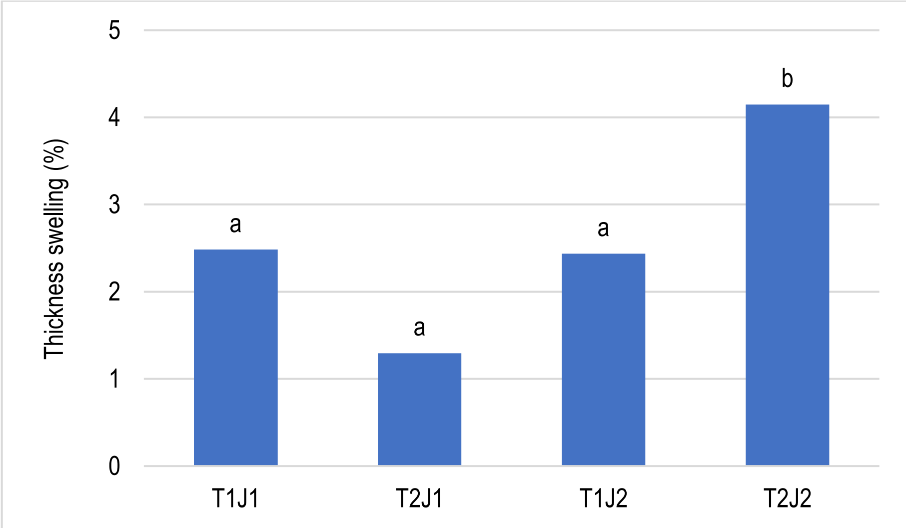


Figure 1. DMRT of interaction treatment of compression pressure with type combination

Thickness Shrinkage

Shrinkage is a reduction in wood dimensions due to decreased wood moisture content. Shrinkage occurs when the moisture content decreases below the fiber saturation point (<30%). It significantly affects the change in wood dimensions (Darwis *et al.* 2014).

Table 7. Thickness shrinkage of laminated board

Compression pressure	Wood Type		Average (%)
	J1	J2	
T1	2.87	1.60	2.24
T2	2.65	2.34	2.50
Average (%)	2.76	1.97	2.37

Notes: J1 = *D. moluccana*/*D. asper*, J2 = *A. chinensis*/*D. asper*, T1 = 20 N/m^2 compression pressure, T2 = 30 N/m^2 compression pressure

The highest shrinkage value of laminated board thickness at pressure T2 was 2.50%, and combination type J2 was 2.76%. This value does not meet the SNI 03-2105-2006 standard of 6.5-9.5%. The shrinkage value of this study is lower than the research on *A. chinensis* wood and *D. asper* laminated boards conducted by Wulandari *et al.* (2023), with thick shrinkage values ranging from 1.60 - 2.34%. The difference is due to differences in the use of raw materials for laminated boards (Belatrix 2022). The greater the amount of free water contained in a laminate constituent material, the greater the moisture content to reach the fiber saturation point, affecting the constituent material's dimensional stability (Sailana *et al.* 2014).

The results of the analysis of variance test in Table 8 showed that all treatments did not significantly affect the thickness shrinkage characterized by significance values of 0.603, 0.138, and 0.341, respectively, so the DMRT did not need to be done.

Table 8. ANOVA of thickness shrinkage

Source of Diversity	Sum of Squares	db	Mean Square	Fhit.	Sig.
Compression pressure	0.199	1	0.199	0.293	0.603
Wood type	1.846	1	1.846	2.719	0.138
Compression pressure * Wood Type	0.697	1	0.697	1.027	0.341
Error	5.433	8	0.679		
Total Correction	75.375	12			

Modulus of Elasticity

MoE is the ability of wood to withstand the pressure of the working load without any change in shape and volume (Lestari *et al.* 2020). The highest MoE of laminated board at pressure T1 was 9700.892 kgf/cm^2, and combination type J1 was 10420.262 kgf/cm^2. This value does not meet the standard JAS 234: 2007, which requires a minimum MoE of 75,000. This value when compared to research conducted by Wulandari & Fauzan (2024) on laminated boards of a combination of *A. chinensis* wood and *D. asper* with MoE ranging from 8093.626 kgf/cm^2 -12696.064 kgf/cm^2. Different wood species and spreading weight cause the difference in value. Factors affecting laminated boards' quality include raw materials, spreading weight, gluing, and gluing processes (Wulandari *et al.* 2021). The MoE of laminated boards can be influenced by the type of raw material used, the arrangement of laminated slats, the pressure of the felts, the kind of adhesive used, the amount of adhesive applied, the variation in blade thickness, and the arrangement of each laminated layer (Belatrix 2022). An ANOVA was conducted to determine the effect of compression pressure, the type of combination, and their interaction.

Table 9. MoE of laminated board

Compression pressure	**Wood Type**		**Average (kgf/cm²)**
	J1	**J2**	
T1	11308	8094	9701
T2	9532	9346	9439
Average (kgf/cm²)	10420	8720	9570

Notes: J1 = *D. moluccana*/*D. asper*, J2 = *A. chinensis*/*D. asper*, T1 = 20 N/m² compression pressure, T2 = 30 N/m² compression pressure

The results of the analysis of variance in Table 10 show that all treatments do not significantly affect the MoE of the laminated board which is characterized by significance values of 0.748, 0.063, and 0.090, respectively. Therefore, DMRT is not necessary.

Table 10. ANOVA of MoE

Source of Diversity	**Sum of Squares**	**db**	**Mean Square**	**Fhit.**	**Sig.**
Compression pressure	205096.545	1	205096.545	0.110	0.748
Wood type	8672118.329	1	8672118.329	4.671	0.063
Compression pressure * Wood Type	6879525.474	1	6879525.474	3.706	0.090
Error	14852164.053	8	1856520.507		
Total Correction	1129663879.299	12			

Modulus of Rupture

MOR is one of the mechanical properties of wood that shows the strength of wood in resisting the load acting on it (Widiawati *et al.* 2018).

Table 11. MOR of laminated board

Compression pressure	**Wood Type**		**Average (kgf/cm)²**
	J1	J2	
T1	318	239	278
T2	334	247	291
Average (kgf/cm²)	326	243	285

Notes: J1 = *D. moluccana*/*D. asper*, J2 = *A. chinensis*/*D. asper*, T1 = 20 N/m² compression pressure, T2 = 30 N/m² compression pressure

The highest MoR of the laminated board at pressure T2 was 291 kgf/cm², and combination type J1 was 326 kgf/cm². This value has met the JAS 234-2007 standard (at least 300 kgf/cm²). This study compared to research conducted by Supriadi et al. (2017) on bamboo laminates on jabon wood boards with an MoR of 568 kgf/cm² is lower. Fracture toughness is closely related to moisture content, specific gravity, the adhesive material's amount and composition, and the solidity between the bonded material and the adhesive material (Yoresta 2014). The higher the moisture content, the lower the fracture toughness, and the higher the density, the higher the fracture toughness (Wulandari *et al.* 2023). This is supported by the statement of Violet & Agustina (2018) that fracture toughness (MoR) is closely related to moisture content, specific gravity, the amount and composition of the adhesive material, and the solidity between the bonded material and the adhesive material. The higher the moisture content will reduce the fracture toughness, and the higher the density will increase the fracture toughness value (Wulandari *et al.* 2024).

The analysis of variance test results in Table 12 shows that only the treatment of wood type significantly affects the MOR of laminated board, which is characterized by a significance value of 0.001. In comparison, the treatment of compression pressure and the interaction between compression pressure and wood type did not significantly affect the MOR of laminated board, which was characterized by a significance value of 0.472 and 0.812. However, the treatment of wood type does not need to be tested using DMRT because only two factors determine the differences between treatments.

Table 12. ANOVA of MOR

Source of Diversity	Sum of Squares	db	Mean Square	Fhit.	Sig.
Compression pressure	448.279	1	448.279	0.569	0.472
Wood type	20968.552	1	20968.552	26.613	0.001
Compression pressure * Wood Type	47.529	1	47.529	0.060	0.812
Error	6303.334	8	787.917		
Total Correction	999352.287	12			

D. CONCLUSION

Several conclusions can be drawn based on the results of testing the physical properties and mechanics of laminated boards. The density shows an average value of 0.51 g/cm^3. The treatment of wood combination types has a considerable effect with a significance of 0.006. In contrast, the compression pressure and their interactions have no significant effect, with a significance of 0.458 and 0.155, respectively. The moisture content test showed an average value of 14.32%. Compression pressure had a significant effect of 0.005, while the type of wood combination and its interaction had no significant effect, with a significance of 0.200 and 0.118, respectively. The thickness swelling test showed an average value of 2.59%. The type of wood combination and its interaction had a significant effect, with a significance of 0.014 and 0.012, respectively, while the compression pressure had no significant effect, with a significance of 0.574. The thickness shrinkage test showed an average value of 2.37%. The type of wood combination, compression pressure, and their interaction had no significant effect, with a significance of 0.603, 0.138, and 0.341, respectively. The MoE test showed an average value of 9570 kgf/cm^2. The type of wood combination, compression pressure, and their interaction had no significant effect, with a significance of 0.748, 0.063, and 0.090, respectively. MOR showed an average value of 285 kgf/cm^2. The type of combination had a significant effect, with a significance of 0.001, while compression pressure and its interaction had no significant effect, with a significance of 0.472 and 0.812, respectively.

REFERENCES

Belatrix. (2022). Analisis Sifat Fisika dan Mekanika Papan Laminasi Kombinasi Bambu Petung dan Bambu Ater. *Jurnal Inersia, 18*(1), 1–8.

Darwis, Atmawi, Massijaya, M. Y., Nugroho, N., dan Alamsyah, E. M. 2014. Karakteristik Glulam dari Batang Kelapa Sawit. *Jurnal Ilmu Teknologi Kayu Tropis, 12*(2), 157-168.

Kasmudjo. 2001. Pengantar Teknologi Hasil Hutan Bagian V Papan Tiruan Lain. Universitas Gadja Mada.

Lestari, A., T. (2020). Sifat Keterbasahan Pada Bidang Tangensial dan Radial Kayu Rajumas (*Duabanga moluccana Blume*). *Perennial, 16*(1): 7–10.

Manik P, Samuel S, Tuswan T, Jokosisworo S, Nadapdap RK. 2022. Mechanical Properties of Laminated Bamboo Composite as A Sustainable Green Material For Fishing Vessel: Correlation Of Layer Configuration In Various Mechanical Tests. *Journal of the Mechanical Behavior of Materials, 31*(1): 673–690. De Gruyter Open Ltd.

Megawati, F., Usman, & Tavita, G. (2016). Physical and Mechanical Properties of Wood Gerunggang (*Cratoxylon arborescen* Bl) Densified by Time Steaming and Pressing Time. *Journal of Sustainable Forests, 4*(2), 163–175.

Mochsin, Fadillah, H. & Mochsin, U. (2014). Stabilitas Dimensi Kayu Berdasarkan Suhu Pengeringan dan Jenis Kayu. *Jurnal Hutan Lestari, 2*(2), 229-241.

Purwanto, D. (2011). Pembuatan Balok dan Papan Dari Limbah Industri Kayu. Balai Riset dan Standardisasi Industri Banjarbaru. *Jurnal Riset Industri, 5*,13–20.

Rofii, M. N., Prasetyo, V. E., Listyanto, T., Primaningtyas, A., Suranto, Y., Prayitno, T. A., & Widyorini, R. (2022). Sifat Papan Laminasi Kayu Randu (*Ceiba pentandra* (L.) Gaertn) dengan Variasi Pola Gergajian Lamina dan Arah Lapisan. *Jurnal Ilmu Kehutanan, 16*(1), 101–107.

Sailana, G. E., Usman, F. H., & Yani, A. (2014). Physical and mechanicalmproperties of mahang wood (*Macaranga hypoleuca* (reichb.f.etzoll.)m.a) are densification by steam time and temperatur felts. *Jurnal Hutan Lestari, 2*(1), 1–10.

Somadona, Sonia, Sribudiani,E. Valencia,D.E. (2020). Karakteristik Balok Laminasi Kayu Akasia (*Acacia mangium*) dan Meranti Merah (*Shorea leprosula*) berdasarkan Susunan Lamina dan Berat Labur Perekat Styrofoam. *Wahana Forestra: Jurnal Kehutanan*, *15*(2), 53-64.

Supriadi, Achmad, I.M. Sulastiningsih & Subyakto. (2017). Karakteristik Laminasi Bambu Pada Papan Jabon. *Jurnal Penelitian Hasil Hutan*, *35*(4), 263-272.

Wicaksono, T.M. Awaludin, A. & Siswosukarto. A. (2017). Analisis Perkuatan Lentur Balok Kayu Sengon Dengan Sistem Komposit Balok Sandwich (Lamina dan Plate). Departemen Teknik sipil dan Lingkungan Universitas Gadjah Mada. Inersia, Vol. 9(2), pp:129-140.

Violet & Agustina. (2018). Variasi Arah Aksial Batang (Pangkal dan Ujung) Terhadap Sifat Mekanika Papan Laminasi Kayu Kelapa (*Cocos Nucifera* L) dan Kayu Nangka (*Arthocarpus Heterophyllus*.L). *Jurnal Hutan Tropis*, *6*(1).

Widiati, K. Yuli, B. Supraptono, & A. B. Y. Tripratono. (2018). Karakteristik Sifat Fisika dan Mekanika Kayu Lamina Kombinasi Jenis Kayu Sengon (*Paraserianthes falcatar*ia (L.) Nilsen) dan Jenis Kayu Merbau (*Intsia* Spp.). *Jurnal Hutan Tropis*, *2*(2), 93–97.

Wulandari, & Amin, R. (2023). Sifat Fisika Papan Laminasi Kombinasi Kayu Sengon dan Bambu Petung (*Dendrocalamus asper*). *Jurnal Emperiscm, 4*(1), 1-8.

Wulandari F.T., Rini, D., S., & Wahyuningsih, E. (2021). Pemanfaatan Papan Laminasi Bambu Petung (*Dendrocalamus Asper* (Schult. F.) Kayu. *Jurnal Media Bina Ilmiah, 15*(8), 1-12.

Wulandari F.T. & Latifah, 2022. Karateristik Sifat Fisika dan Mekanika Papan Laminasi Kayu Bayur (*Pterospermum diversifolium*) Sebagai Bahan Substitusi Papan Solid. *Jurnal Kehutanan Wahana Forestra, 17*(2), 1-15.

Wulandari F.T. & Radjali Amin. (2022). Sifat Fisika dan Mekanika Papan Laminasi Kayu Sengon. *Jurnal Hutan Tropika, 17*(1), 40-50.

Wulandari F.T., Amin, R, & Atmaja I.G.D. (2022). Pengaruh Berat Labur Perekat Terhadap Sifat Fisika dan Mekanika Papan Laminasi Jati Putih (*Gmelina arborea* Roxb). *Binawakya, 16*(9), 7333 – 7342.

Wulandari, F. T., Amin, R., and Raehanayati, R. (2022). Karateristik Sifat Fisika dan Mekanika Papan Laminasi Kayu Sengon dan Kayu Bayur. *Euler: Jurnal Ilmiah Matematika, Sains dan Teknologi, 10*(1), 75–87. DOI: 10.34312/euler.v10i1.13961

Wulandari, F. T., & Suastana, I. M. W. 2022. Sifat Fisika Kayu Rajumas (Duabanga Moluccana Blume) Berdasarkan Arah Aksial dan Arah Radial Dari Desa Sambik Elen Kabupaten Lombok Utara. *Journal of Forest Science Avicennia, 5*(1): 13–24. Doi: 10.22219/Avicennia.V5i1.19655.

Wulandari, F. T., Putu, N., Lismaya, E., & Suryawan, I., G., A. (2023). Analisis Sifat Fisikadan Mekanika Papan Laminasi Bambu Petung (*Dendrocalamus asper* Roxb) dan Papan Laminasi Kayu Bayur (*Pterospermum javanicum*). *Journal of Forest Science Avicennia*, *6*(1): 39–50. DOI:10.22219/avicennia.v6i1.23738

Wulandari, F., T., Habibi, & Amin, R. (2023). Sifat Fisika dan Mekanika Papan Laminasi Bambu Petung (*Dendrocalamus Asper*) dengan Susunan Bilah Ke Arah Lebar. *Jurnal Hutan Tropika*, *18*(1), 1–8.

Wulandari, F.T & Fauzan Fahrussiam. 2024. Analisis Pengaruh Berat Labur, Jenis Kombinasi dan Interaksinya Terhadap Sifat Fisika Mekanika Papan Laminasi Kombinasi Kayu Kemiri Bambu Petung dan Sengon Bambu Petung. *Jurnal Tengkawang*, *14*(1), 1-12.

Wulandari, Lestari D, & Dewi, N., P., E., L. (2023). Analisis Pengaruh Jenis Papan, Berat Labur Perekat dan Interaksinya Terhadap Sifat Fisika dan Mekanika PapanLaminasi. *Jurnal Daun*, *10*(1), 1-17.

Wulandari, Radjali Amin & Dini Lestari. (2024). Analisis kekuatan fisika mekanika papan laminsi kombinasi kayu rajumas bambu petung, sengon bambu petung dan bambu petung sebagai bahan kontruksi. *Jurnal Taman Vokasi, 12*(1), 15-26.

Wulandari, Ningsih, R. V., & Shabrina, H. (2024). Pengaruh Berat Labur, Jenis Kombinasi Serta interaksinya Terhadap Sifat Fisika Mekanika Papan Laminasi Kombinasi Rajumas Bambu Petung dan Kemiri Bambu Petung. *Jurnal Sylva Scienteae*, *7*(3), 1-10.

Yoresta, F.S. (2014). Studi eksperimental perilaku lentur balok glulam kayu pinus (*Pinus merkusii*). *Jurnal Ilmu Teknologi Kayu Tropis*, *12*(1), 33–38.