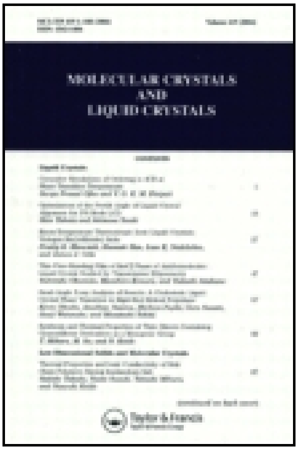

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Utilization of non wood material as raw material in wood industry would be increase in the future because environmentally issues. The objective of this research were to evaluate characteristic of coir, recycled polypropylene (RPP), and tali bamboo (Gigantochloa apus) as raw material in composite board and find out the optimum quality of composite board made from its material. The board samples target density was 0.7 g/cm^3*. The board construction type was core type composite board (three layers). The bamboo sheet wide was 1 cm and 2 cm with and without bark. The bamboo matting was used in angle and perpendicular orientation to length of the board. The results showed that coir, RPP, and tali bamboo suitable for composite board material. Utilization of bamboo matting layers increases the mechanical properties of board, except internal bond. All of composite board made from coir and RPP with bamboo matting layers fulfill the JIS A 5908 standard in density and thickness swelling after 2 and 24 hours of water immersions. However, only composites with bamboo matting layers with bark and sheet wide 1 cm fulfill JIS A 5908 standard for veneered particleboard in MOE.*

Keywords: bamboo matting layers; coir; composites board; recycled polypropylene

INTRODUCTION

The use of non-wood raw materials in a composite product is more preferred due to environmental pressure and timber scarcity. Coir (coconut fiber) and recycled polypropylene plastics (RPP) are potential materials of composite boards because of its abundances in Indonesia. FAO [1] estimated that Indonesia was producing 1 million ton of coir every year. Recently, most of them was burned and become waste.

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In previous study, Setyawati and Massijaya [2] found that composite board made from coir and RPP have high dimension stability but low modulus of elasticity. It means the strength of the composite board requires to be improved, for example, with veneer overlaying at surface of composite board. From result of study by Setyawati *et al.* [3]. known that composite board from coir, recycled polyethylene (RPE) and veneer layer fulfill JIS A 5908 standard for veneered particleboard in modulus of elasticity. However, as the timber supply or veneer production is diminishing, other materials are employed as veneer substitutes. One of potential material is bamboo because of its fast growth rate, short rotation age, and high tensile strength. A study by Lee *et al.* [4] revealed that the use of bamboo was proven to improve mechanical characteristics of composite boards.

In this study, we used combination of coir, RPP, and bamboo in form of mat to make composite board. Coir and RPP were applied as core, while bamboo matting was used as face and back layer. This combination was expected to yield in better physically and mechanically composite boards.

The objectives of this study were to know the characterization of coir, tali bamboo (*Gigantochloa apus*), and RPP as raw material to composite board; and to analyzed the effect of bamboo matting layer types to physical and mechanical properties of composite board.

MATERIALS AND METHODS

Materials

Coir from small industry in Ciamis, West Java and RPP from PT Sapari, Cianjur West Java was chosen as raw material. Tali bamboo (*Gigantochloa apus* Bl. Ex (Schult.f.) Kurz) matting (30 cm in width and length, and 2 mm in thickness) was used as the face and back layer. The bamboo matting consisted of perpendicular (0/90°) and diagonal (45°) orientation to the board length direction. Each of them consisted of large bamboo strips (2 cm wide) and small bamboo strips (1 cm wide) with or without bark. *Alstonia sp.* veneer of 2 mm thickness was used as comparison.

Characterization of Raw Material

The coir anatomy was analyzed by scanning electron microscopy (SEM). Density of coir was analyzed by volumetric method, and dimension of coir fiber was analyzed after maceration by Forest Product Laboratory method. The chemical component of coir were analyzed by TAPPI (1996) for hot and cold water extractives (T 204

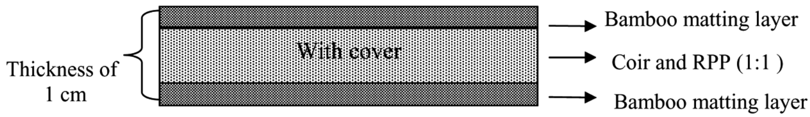


FIGURE 1 The construction of composite board.

om-93), cellulose (T-17m-55), holocellulose (TAPPI T 9m-54), lignin (T222 om-88) and ash (T 211 0m-85), whereas the tensile strength referred to ASTM D-882 standard. Analysis of physical and mechanical of tali bamboo referred to Nuriyatin (2000), meanwhile the melting point of RPP analyzed by differential scanning calorimetric (DSC).

Effect of Bamboo Matting Layer Types to Physical and Mechanical Properties of Composite Board

The composite board samples were com-ply type (three layers) as shown in Figure 1. Composite boards were made in 30 cm × 30 cm in width and length with 1 cm in thickness and target density of 0.70 g/cm^3.

The 5 cm length of coir was oven dried at 60°C for 24 hours reaching moisture content of 4–6%. The mixing of coir and pellet of RPP was done manually. Ratio of coir and RPP was 1:1. During assembling, the surface layer (veneer or bamboo matting) was attached on the face and back surface of composite board subsequently continued with hot pressing at 180°C for 20 minutes. The board then conditioned for a week before cut and tested according to JIS 5908 standard.

RESULT AND DISCUSSION

Characterization of Raw Material

Coir

Results of determination of properties of coir at this research were presented at Table 1.

Specific gravity coir at this study almost the same with coir from India that is 1.15 [5] while from Srilanka 1.25 (FAO, 2003). Lignin content of coir was higher than its cellulose content. This aspect appropriate to research by Nangia and Biswas [5] that found the cellulose content of coir was 37–43%, while its lignin content was 42–45%. The difference of value among this research possibility because of difference of place growth. One of the advantages of this aspect was coir durability. Determination of tensile strength of coir showed that the tensile strength of coir tends higher with the bigger of fiber diameter size, with equation $Y = 0.055x - 0.4464$ and $R^2 = 0.89$.

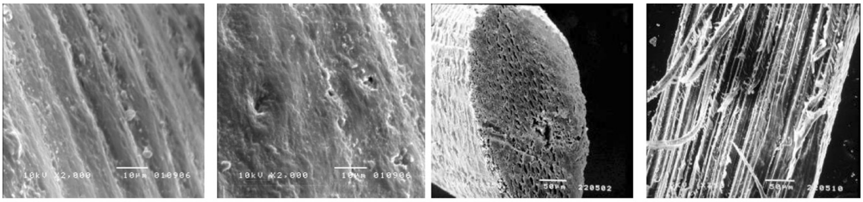
TABLE 1 Properties of Coir

Properties	Values
Physical properties	
Specific gravity	1,14
Moisture content (%)	7,6–8,4
Thickness swelling after immersion of 24 hrs (%)	11–12
Fiber length (μm)	624,8–1285,7
Fiber diameter (μm)	71,4–100
Fiber lumen diameter (μm)	34,3–80
Mechanical properties	
Tensile strength (kgf)	1,035–3,058
Chemical properties	
Ash	3,82–3,42
Cold water extraction (%)	2,21–2,54
Hot water extraction (%)	4,148–4,501
Holloselulose content (%)	49,63–51,17
Lignin content (%)	28,84–32,64
Cellulose content (%)	24,83–27,94

Observed by using scanning electron microscope showed that the fiber surface is covered with protrusions and many pinholes, which is known as pith. (Figs. 2a and 2b). In principal, these aspects can facilitate the resin impregnation onto the fiber in adhesion processed 2005 [6]. The cross section of the coir is rounded to polygonal in shape with cavity in the middle of its (Fig. 2c). The structure of coir is quite simple vascular bundle. In longitudinal section, it was very clear that coir consist of several fibers which are interconnected to each other (Fig. 2d). Dimension of the fiber presented at Table 1.

Tali Bamboo (Gigantochloa apus Bl. Ex (Schult.f.) Kurz)

Result of determination of physical and mechanical properties of tali bamboo presented in Table 2.



(a) (b) (c) (d)

FIGURE 2 SEM image of coir a) protrusions b) pinhole c) cross section d) longitudinal section.

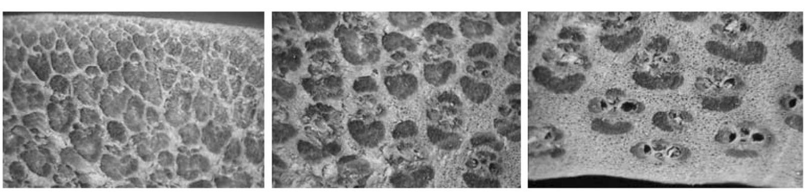
TABLE 2 Physical and Mechanical Properties of Tali Bamboo

Properties	Base	Upper part
Specific gravity	0,52	0,57
Moisture content (%)		
– green	37,31	25,18
– at equilibrium	16,06	15,81
MOE (kg/cm^2)		
– With bark	70.282	83.220
– Without bark	41.338	76.415
MOR (kg/cm^2)		
– With bark	691	561
– Without bark	639	557

Specific gravity of bamboo increased from base to the upper part, whereas moisture content on the contrary. This result appropriate to research by Nuriyatin [7]. The difference of specific gravity was caused by percentage of sclerenchim, which presence in vascular bundle, in the base part is higher than its in the upper part. Moreover, the base part of bamboo was formed by long and thin of fiber cell with big diameter of lumen, whereas the upper part was contrary so that contain lower moisture content. In general, bamboo with bark more strength than bamboo without bark. It's caused of arrangement of vascular bundle bamboo at the outer part more compact and tight than at the middle and at the inner part (Fig. 3).

Recycled Polypropylene

The size of pellet RPP in present study was 3,28–3,93 mm in length and 1,95–2,39 mm in width. Specific density of RPP was 0,84.



A B C

FIGURE 3 Cross section of coir A) outer part B) middle part, and C) inner part.

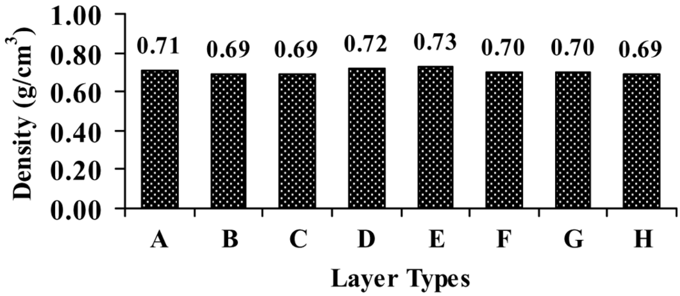


FIGURE 4 Composite board density at different layer types Legend: A = composite board without layers (control); B = veneer layer; C = bamboo matting layers without bark, perpendicular pattern of 1 cm wide slices; D = bamboo matting layers without bark, diagonal pattern of 1 cm wide slices; E = bamboo matting layers with bark, perpendicular pattern of 1 cm wide slices; F = bamboo matting layers with bark, diagonal pattern of 1 cm wide slices; G = bamboo mating layers without bark, perpendicular pattern of 2 cm wide slices; H = bamboo matting layers without bark, diagonal pattern of 2 cm wide slices.

Analyzed by DSC showed that RPP have two peak of melting point, that is 126°C and 162,7°C (Fig. 4).

According to Osswald and Menges [8], specific gravity of pure PP is 0,90 and its melting point is 170°C indicating of degraded and impure of RPP. The RPP in this research is possibility mixed with polyethylene or other materials which have lower melt temperature than its PP.

Effect of Bamboo Matting Layer Types to Physical and Mechanical Properties of Composite Board Density

The composite board densities were 0,69–0,72 g/cm^3 as shown in Figure 4. The results indicated that the board density was relatively uniform as shown by the small of board density range.

Moisture Content

The tested composite board moisture contents were 1.93% to 3.54%. The highest and the lowest moisture content was from control and composite boards surface covered with bamboo matting with bark, respectively, as shown in Figure 5.

The control board moisture content was significantly higher that the others. According to JIS 5908 [9] standard, all of board moisture content was under the required value, i.e., 5–13%. This is due to the

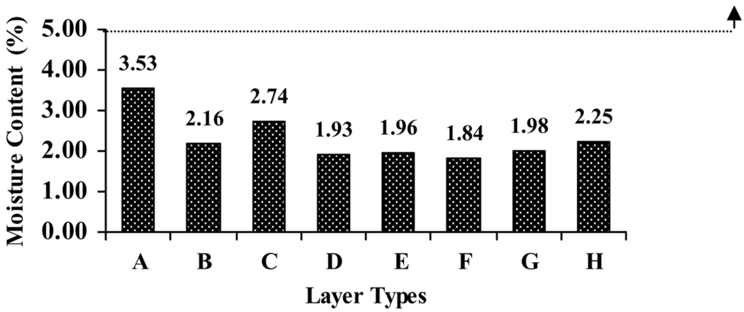


FIGURE 5 Moisture content of the composite board at different layer types Legend: see Figure 4.

RPP used as adhesive is hydrophobic leading to less water- absorbing composite boards.

Water Absorption

The average value of water absorption of the composite boards soaked for 2 and 24 hours was ranging from 4.74% to 9.61% and from 13.88% to 21.59%, respectively (Fig. 6).

The water absorption of surface cover composite boards was higher than control because good ability of veneer and bamboo matting layer to absorb and keep water compared to core or board made from coir and RPP. Composite board with bamboo matting layer with bark, exhibited lower water absorbing capacity than the other types. The presence of wax layer of the bamboo outer part facilitated the inhibition of water absorption.

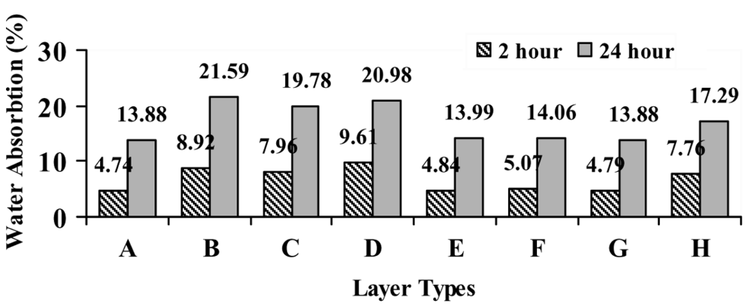


FIGURE 6 Water absorption of the composite board at different layer types Legend: see Figure 4.

Thickness Swelling

The average thickness swelling of the composite boards soaked for 2 and 24 hrs was ranging from 0.29–2.83% and 1.34–4.28%, respectively (Fig. 7).

The values of thickness swelling for all boards fulfill the JIS A 5908 [9] viz. 12% for maximum thickness swelling of 24 hrs soaking. The low thickness swelling values of the respective boards were in accordance with a study by Zheng [10] as the adhesive used is hydrophobic leading to a more water-resistant composite board. The thickness swelling in composite boards is generally positively correlated with water absorption; more high absorption leads to higher thickness swelling.

Modulus of Elasticity (MOE)

The average MOE of the composite boards was presented in Figure 8.

In these figure, it is clear that bamboo matting which used as face and back layer of the composite board was proven to increase MOE up to 200 to 750% compared to control (without face and back layer). It is due to bamboo matting on the board surface enable larger capability of board to hold a load. This is similar to the findings by Lee *et al.* [4] and Suhasman *et al.* [11] stating that surface cover is able to increase board strength.

Composite boards with perpendicular orientation bamboo matting layer showed higher MOE than those diagonal orientation, for both with and without bark. The grain angle causes the decline in bending strength as well as the compression parallel to grain [12]. When receiving loads, the board will distribute the load to the grains resulting maximum tensile strength on the surface. Composite board with diagonal orientation of layer would not be able to completely transfer the load because of grain discontinuity.

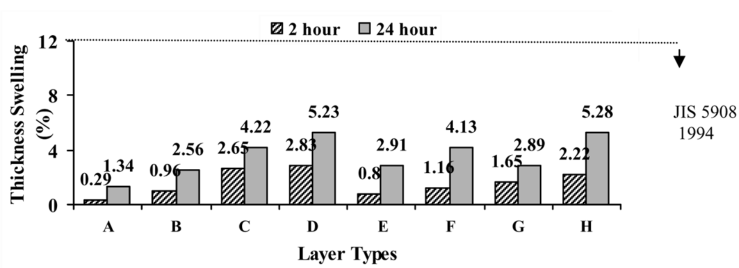


FIGURE 7 Thickness swelling of the composite board at different layer types Legend: see Figure 4.

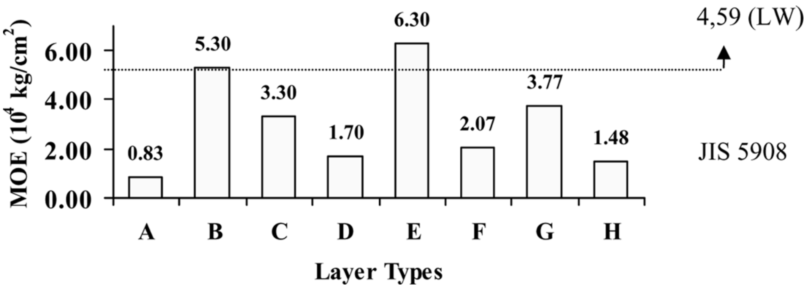


FIGURE 8 Modulus of elasticity of composite board at different layer types Legend: see Figure 4.

According to JIS A 5908 [9] standard, the minimum of MOE parallel to the grain are $4.59 \times 10^4\,kg/cm^2$ to veneered particleboard. It means, only board with veneer and bamboo matting layer with perpendicular orientation and bark fulfill the requirement. It is clear that almost all of bamboo matting layer types cannot fulfill the JIS 5908 A standard [9] for MOE perpendicular to the grain because bamboo in form of mat consisted two direction of the grain, that is parallel and perpendicular at once.

Modulus of Rupture (MOR)

The average of composite board MOR can be seen in Figure 9.

The MOR of composite boards in present study tends to increase as the face and back layer added, except on diagonal bamboo matting of 2 cm strips without bark. The highest to the lowest MOR were respectively as follow: $397\,kg/cm^2$ (veneer), $303\,kg/cm^2$ (perpendicular bamboo matting with bark), and $215\,kg/cm^2$ (perpendicular bamboo

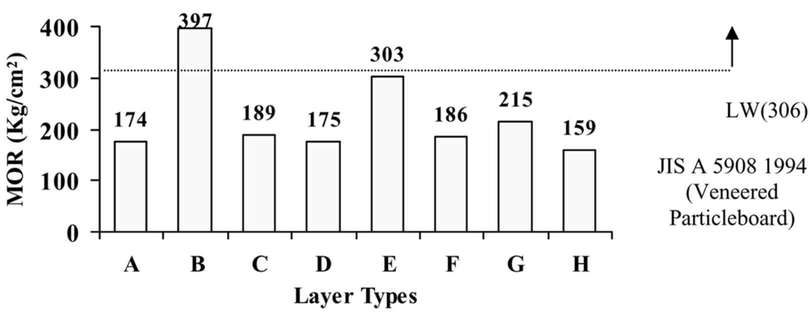


FIGURE 9 Modulus of rupture of composite board at different layer types Legend: see Figure 4.

matting of 2 cm slices without bark). Bamboo matting layer with diagonal orientation pronounced to have lower MOR than the perpendicular matting. The explanation of the reasons is similar to that of MOE, since MOR and MOE are closely related resulting to the assessment of MOR based on the MOE. The minimum MOR parallel to the grain of JIS 5908 [9] standard to veneered board is 306 kg/cm^2, and hence, only board with veneer layer fulfills the requirement.

Internal Bond

The average of composite board internal bond were 1,38–10,33 kg/cm^2 (Fig. 10).

The internal bond of composite board decreased as the bamboo matting layer added. The lowest internal bond occurred for bamboo matting with bark viz. 1.40 kg/cm^2 and 1.38/cm^2 for perpendicular and diagonal orientation, respectively. This is because the bark or outer layer of bamboo, is overlaid with waxy and silica layer, which impeded the epoxy adhesive used to completely fix the testing equipment to the board's surface. Hence, the testing value resulted did not reflect the actual internal bond. This delinquency only present for the bamboo matting did not fully attached to board core.

This flaw was also eventuated in the bamboo matting without bark. The strips in bamboo matting which were unconfined to the core, acting as the weakness point in the testing. A wider strips used in bamboo matting yielded in lower value of internal bond. Based of sample evaluation, it was clear that all of the broken area were in the face and back layer and at the layer between the mat and the board particularly the plastic layer. This occurrence indicated that the bond strength of composite board consisting coir and RPP are much larger than the bond strength of face and back layer.

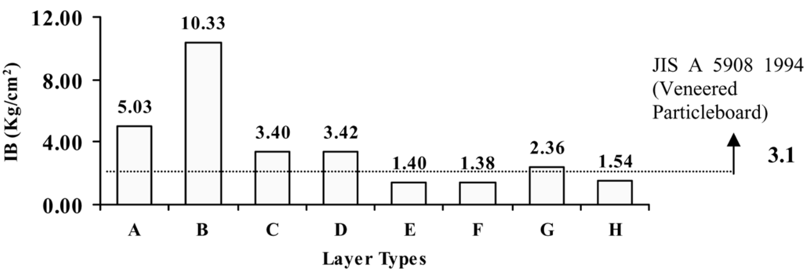


FIGURE 10 Internal bond of composite board at different layer types Legend: see Figure 4.

From result of this research is known overlaying board by bamboo matting layer with bark and perpendicular pattern of 1 cm slice given the physical and mechanical properties better than other bamboo matting types (except internal bond). However to industrial scale applied, usage of bamboo matting with bark cause extravagance of raw material because of its low recovery that is about 16–20%. Thus, usage of bamboo matting without bark more is suggested, especially with perpendicular pattern of 1 cm slice of bamboo because of the small of tali bamboo diameter.

CONCLUSIONS

1. Determination of characteristic coir, RPP, and tali bamboo showed that those material suitable for composite board material.
2. The addition of surface cover on the composite was able to increase the mechanical properties of composite board, except for the internal bond.
3. The MOE of composite boards with surface covers of perpendicular bamboo plait of 1 cm slices fulfill JIS A 5908 (1994) standard for veneered particleboard in modulus of elasticity. However, from efficiency of material, the perpendicular bamboo matting without bark is preferred to industrial scale applied.

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