Properties of Bio-Composite Product from Acacia Strand and Coconut Veneer

Siti Nadrah M. Omar [1*], Wan Mohd Nazri Wan Abdul Rahman [2], Nor Yuziah Mohd Yunus [3] and Nur Atiqah Nabilah Johari [4]

Faculty of Applied Sciences, Universiti Teknologi MARA (Pahang) Malaysia[1, 2, 3]
Faculty of Applied Sciences, Universiti Teknologi MARA, Shah Alam, Malaysia[4]
stnadrah@ymail.com

Abstract

Properties of bio-composite product from Acacia strand and coconut veneer were ascertained. The effects of strand size and layer arrangement were determined. Different strand sizes (10 mm, 15 mm and 20 mm) were used to create different combinations of layer arrangement; strand-veneer-strand (SVS) and veneer-strand-veneer (VSV). Comply, a bio-composite product, was assessed for the mechanical properties (bending and internal bonding) and physical properties (thickness swelling and water absorption) in accordance with the European Standard. The value of modulus of rupture (MOR) and modulus of elasticity (MOE) were found to be not significant when comparing SVS (10 mm and 15 mm) with 100% strand. Meanwhile, it was found that SVS (10 mm) and 100% strand had the highest value of internal bond and thickness swelling (TS). Both layer arrangements were then being compared with plywood made by coconut veneer. The result showed that plywood had the highest value of MOR (51.54 MPa) and IB (0.66 MPa), VSV had the highest value of MOE (8037.79 MPa). For physical property the plywood had the best value of TS (12.19%).

Keywords: Bio-composite product, Comply, Acacia strand, Coconut veneer, Strand size, Layer arrangement

1. INTRODUCTION

Over the past decade, the demand for wood composite which is normally used as building material has continuously increased. Moreover, the quantity and quality of wood resources, from the forest as a raw material for this application have been decreasing. Thus, the search for alternative or substitute materials has been focused (Malanit et al., 2010). In Malaysia, composite plywood (comply) is a new wood composite panels. Subsequently, less information can be found on tropical species which include the lack of studies on Acacia (*Acacia mangium*) wood species and coconut palm (*Cocos nucifera*) conducted. Other than using Acacia strand as raw material for this research, coconut veneer had also been used. Both materials were combined together to produce a Bio-composite product or commonly known as composite plywood (comply).

2. LITERATURE REVIEW

2.1 *Acacia mangium*

Acacia *(Acacia mangium)* belongs to the Family Leguminoseae and Sub-Family Mimosoideae. It is generally known as Mangium, Brown Salwood, Black Wattle, Hickory Wattle and Sabah Salwood (Chuan and Tangau, 1991). Acacia is one of the most popular fast-growing tree species with high bond strength as well as good mechanical properties (Hoong et al., 2009). *Acacia mangium* is a medium-quality wood of light density and belongs to diffuse porous species. In less than 10 years, a stand average tree diameter can reach more than 20 cm and a height of 25 m (Cienciala et al., 2000).

2.2 Coconut Palm (*Cocos nucifera)*

Coconut (*Cocos nucifera*) belongs to the family of the Arecaceae (Palmae), and the subfamily Cocoideae. There are primarily two distinct groups of coconut i.e. tall and the dwarf. The tall varieties grow slow and they bear fruits 6 to 10 years after planting. Its oil, fiber and copra (dried kernel from which oil is extracted) are of good quality. This type is comparatively hardy, and it can reach to a matured age of 80 to 120 years. In contrast, the dwarf varieties are fast growing and bear early i.e. takes 4 to 5 years. The nuts are yellow, orange, green and red colored. These varieties are less hardy and they require favorable climatic conditions and soil type for better yield (Deb Mandal and Mandal, 2011).

Coconut trunk produces lumber which is utilized as raw material for furniture, building construction, and other wood-based products (Okai et al., 2004). The coconut (*Cocos nucifera)* is an important fruit tree in the world. It provides food for millions of people, especially in the tropical and subtropical regions. It is often called the "tree of life" because it has many uses (Deb Mandal and Mandal, 2011).

2.3 Oriented Strand Board (OSB)

Oriented strand board (OSB) industry uses various wood species without specific requirements regarding diameter or straightness of the logs. Moreover, a material from short rotation forests had been used by many OSB plants around the world. This denotes an advantage compared to plywood which requires large diameter logs obtained from long rotation forests. Logs obtained from short rotation forests usually comprise of a higher proportion of juvenile wood yet have lower costs than raw material obtained from natural forests. In addition, juvenile wood becomes a determinant factor in OSB manufacturing when working on the basis of short rotations since it constitutes the main part of the wood volume. The trees harvested during the thinning treatments achieved in short rotation plantations can be used for OSB manufacturing, increasing even more the need for information on the influence of juvenile wood on OSB performance (Cloutier et al., 2007).

2.4 Plywood

Plywood comprises of thin veneer wood layers (plies) bonded together into sheet form by using an adhesive. Usually, each ply is placed perpendicular to the prior ply to increase in-plane dimensional stability. The outer plies are called faces, and the inner plies are cores. The core might be lumber, particleboard, or veneer (Rowell, 2005). Plywood panels commonly have an odd number of veneers. The terms 3-ply and 5-ply are commonly used and refer to the number of veneers used to make a panel (Rowell, 2013).

2.5 Comply

Composite structural beams can be produced by combining several elements (Rowell, 2005). According to Kral et al. (2014), in the furniture and construction industries, it can be seen that there is increased demand for lightweight, high-performance, and low-maintenance materials with specific properties. Increased demand requires testing of new and composite materials to find viable alternatives to classical materials. In this study, composite plywood will be prepared and tested for their physical and mechanical properties by using three different sizes of Acacia strands and coconut veneers. In addition to the static properties of combined plywood materials, they show various other characteristics, such as thermal and acoustic insulation. A composite material of better properties than the individual materials is formed through the combination of these two materials characteristics.

3. MATERIALS AND METHODS

In this study, Acacia strands and coconut veneers were used as raw materials in the making of bio-composite product which can be referred as comply. Acacia strands and coconut veneer were combined together to form a board. The board consist of three-layer of comply. Several Acacia trees were cut down from Universiti Teknologi MARA (UiTM), Pahang reserve forest. The age and diameter of the trees were measured before the trees were felled. The logs of Acacia were cut into small billets (quarter of a log). The wood was converted into flake by using wood flakers machine to produce small strand with various sizes. The sizes of the strands produced are 10 mm, 15 mm and 20 mm. The width and thickness of strands are 75 mm and 1 mm respectively. Meanwhile, coconut veneers were also supplied by the Department of Wood Industry, Universiti Teknologi MARA (UiTM), Pahang. Sample of coconut veneers were cut and dried to less than 8% moisture content in an oven dryer. Phenol Formaldehyde (PF) resin was used as the adhesive for making the board. PF was obtained from Malayan Adhesives and Chemicals Sdn. Bhd. The processes taken to complete this study were carried out at the Department of Wood Industry, Universiti Teknologi MARA (UiTM), Pahang.

4. RESULTS AND DISCUSSIONS

4.1 Effects of Strand Size

Figure 1 shows that modulus of rupture (MOR) for strand-veneer-strand (SVS) combinations. MOR for SVS-10 mm (39.10 MPa) is higher than both SVS-15 mm (29.63 MPa) and 100% strand (37.63 MPa). Higher MOR is expected for SVS-10 mm as the strands are smaller and will form more compact surface on the face and back of the comply board. Despite the large differential, statistically there is no significant difference observed for MOR between the three treatments.

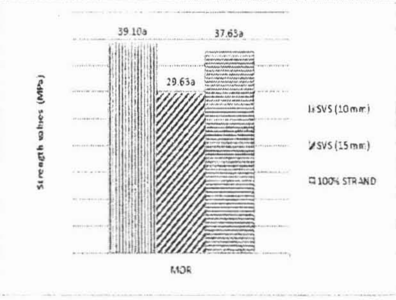

Fig 1: Effects of strand size on MOR

Significant differences of modulus of elasticity (MOE) were however observed, between sample treatment of SVS-10 mm, SVS-15 mm and the 100% strand as shown in Figure 2. Based on the previous research by Nishimura et al., (2004) it indicated that smaller strand size gives higher MOR and MOE values when SVS was formed. The packing uniformity and density which can be done for the face and back of the comply board with smaller sized strands helped to improve the rupture and rigidity of the board.

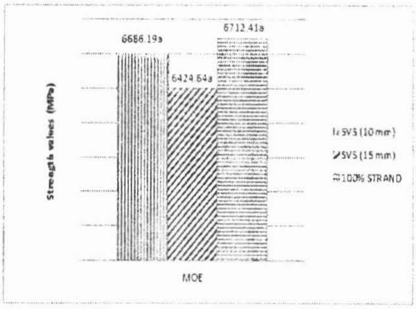

Fig 2: Effects of strand size on MOE

For internal bond (IB) , the results in Figure 3 shows that there is no significant difference was found between samples made from SVS-15 mm and sample made from 100% strands. One reason for this may have been caused by lack of resin amount applied during mat forming. According to Suzuki and Takeda (2000), the IB values should be discussed in reference to the resin content, because it strongly depends on the amount of resin applied.

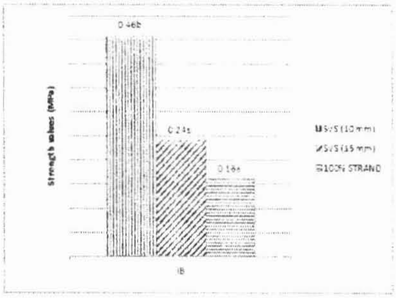

Fig 3: Effects of strand size on IB

Figure 4 looks at sample treatment made from SVS-10 mm having a significant difference to SVS-15 mm and 100% strand on thickness swelling (TS). Salari et al., (2012) found that large numbers of porous tubular structures present in wood accelerate the penetration of water by the capillary action. The packing factor by the smaller strands is better thus slower capillary action will be observed. For 100% strands, the entire board will contribute to water absorption thus the highest TS of 23.7% is registered.

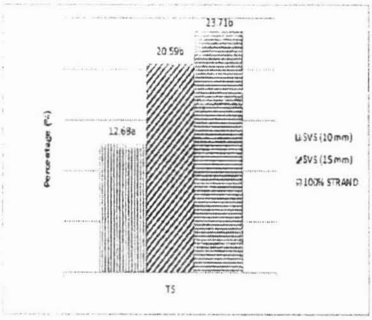

Fig 4: Effects of strand size on TS

4.2 Effects of Layer Arrangement

Effects of layer arrangement on bending strength were determined by measuring the values of MOR and MOE. For MOR the SVS and veneer-strand-veneer (VSV) are giving values of 34.4 MPa and 26.4 MPa respectively (Figure 5). This is statistically not significant. A similar study carried out by Kilic et al., (2010) showed that the layer organization doesn't influence the bending strength. This could be due to the material combination of strands and veneers still have the same flaws and/or advantages despite the arrangement. When plywood (100% veneer) was produced and compared for MOR, it gave 51.5 MPa, a significant difference.

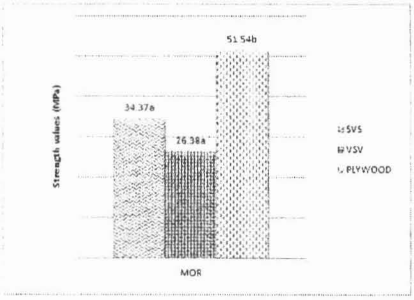

Fig 5: Effects of layer arrangement on MOR

The MOE values of VSV and plywood in Figure 6 shows that there is no significant difference (8038 MPa and 7673 MPa respectively) due to the same arrangement of face and back of both samples, which is made up from veneer. MOE is a flexibility related measurement. Here, the rigidity of the veneers (VSV, 8038 MPa) versus strands (SVS, 6555 MPa) are found to be significantly different.

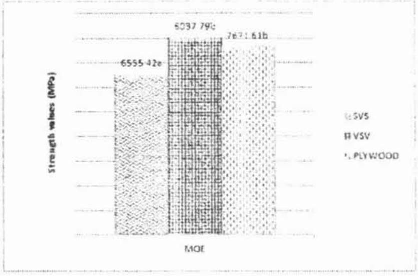

Fig 6: Effects of layer arrangement on MOE

Effects of material and layer arrangement on internal bond strength is more dramatic and are presented in Figure 7. The results shows that there is a significant difference between the treatment samples made from SVS, VSV and plywood (VVV, control sample). For SVS the IB failure mechanism can occur between strand to strand or strand to veneer (core). Plywood will fail at the veneer to veneer interface. VSV major failure is likely at core for strand to strand. Subsequently, the IB (in MPa) strength follows:

VSV (0.19) < SVS (0.35) < plywood (0.66)

The IB failures occur in the core layer, and strengths are indications of the bond quality between elements in the core layer of mat formed panels as also observed by (Suzuki and Miyagawa, 2003). Smaller substrate lead to lower IB at same resin treatment.

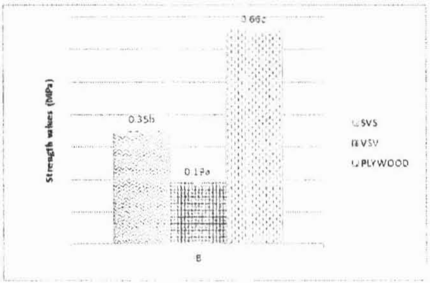

Fig 7: Effects of layer arrangement on IB

TS behaviour of the layer arrangement can be seen in Figure 8. Anova indicates that the value of TS is not significant between all three samples. Nevertheless, the TS values for SVS, VSV and plywood were 16.6 %, 14.9% and 12.2% respestively. The SVS will have more open surface for face and back as well as the strands layer edge. VSV have edge absortion at strands portion. Thus highest the thickness swelling is seen for the SVS. According to Evans et al., (2013) the edges of the composite absorb more water than the interior of boards. In addition, absorbed water causes wood strands in OSB to swell and it permanently tries to recover from strains imposed when the composite was pressed. Interestingly, the value of TS is quite low as the resin used is PF a resin normally used for water resistance.

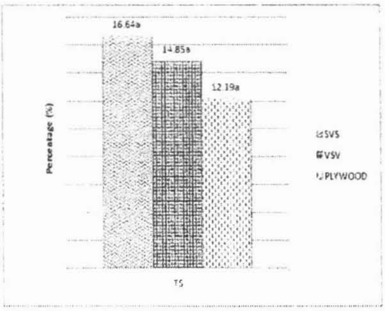

Fig 8: Effects of layer arrangement on TS

5. CONCLUSIONS

The objectives of this study were to determine the mechanical and physical properties of bio-composite product as well as to evaluate the effects of strand size and layer arrangement.

In conclusion, strand size and layer arrangement factors affect the mechanical and physical properties of all types of bio-composite products in this study. Sample treatment of SVS with smallest size and sample treatment of plywood had the best result in both physical and mechanical properties in terms of MOR, MOE, IB, and TS.

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REFERENCES

Chuan, T. T., & Tangau, W. M. (1991). Cultivated and Potential Forest Plantation Tree Species with Special Reference to Sabah. Kuala Lumpur: Institute for Development Studies (Sabah)

Cienciala, E., Kucera, J., & Malmer, A. (2000). Tree Sap Flow and Stand Transpiration of Two *Acacia mangium* Plantations in Sabah, Borneo. Journal of Hydrology, 236:Pp109–120

Cloutier, A., Ananias, R. A., Ballerini, A., & Pecho, R. (2006). Effect of Radiata Pine Juvenile Wood on the Physical and Mechanical Properties of Oriented Strand Board. Holz Roh Werkst, 65:Pp157-162

Deb Mandal, M., & Mandal, S. (2011). Coconut (*Cocos nucifera L.*: Arecaceae): In Health Promotion and Disease

Prevention. Asian Pacific Journal of Tropical Medicine, Pp241-247

Evans, P. D., Miesner, M., & Rogerson, D. (2013). Machined Tapers Reduce the Differential Edge Swelling of Oriented Strand Board Exposed to Water. Composites: Part B, Pp15-21

Hoong, Y., Paridah, M., Luqman, C., Koh, M., & Loh, Y. (2009). Fortification of Sulfited Tannin from the Bark of *Acacia mangium* with Phenol-Formaldehyde for Use as Plywood Adhesive. Industrial Crops and Products, 30 : Pp416-421

Kiliç, Y., Burdurlu, E., Elibol, G. C., & Ulupinar, M. (2010). Effect of Layer Arrangement on Expansion, Bending Strength and Modulus of Elasticity of Solid Wood and Laminated Veneer Lumber (LVL) Produced from Pine and Poplar. G.U. Journal of Science, 23(1): Pp89-95

Kral, P., Klimek, P., Mishra, P. K., & Wimmer, P. R. (2014). Preparation and Characterization of Cork Layered Composite Plywood Boards. Bioresources, 9(2):Pp1977-1985

Malanit, P. (2011). Physical and Mechanical Properties of Oriented Strand Lumber Made from an Asian Bamboo (*Dendrocalamus asper* Backer). Eur. J. Wood Prod., Pp69:27-36

Nishimura, T., Amin, J., & Ansell, M. P. (2004). Image Analysis and Bending Properties of Model OSB Panels as a Function of Strand Distribution, Shape and Size. Wood Sci Technol, Pp38:297-309

Okai, R., Frimpong-Mensah, K., & Kwarteng, J. O. (2004). Characterization of Mechanical Strength Properties of Coconut Wood Infested with The Cape St Paul Wilt Disease. Holz Roh Werkst, 62:Pp390–392

Rowell, R. M. (2005). Handbook of Wood Chemistry and Wood Composites. *U.S: CRC Press Taylor & Francis Group*

Rowell, R. M. (2013). Handbook of Wood Chemistry and Wood Composites. *U.S: CRC Press Taylor & Francis Group*

Salari, A., Tabarsa, T., Khazaeian, A., & Saraelan, A. (2012). Effect of Nanoclay on Some Applied Properties of Oriented Strand Board (OSB) Made from Underutilized Low Quality Paulownia (*Paulownia fortunei*) Wood. The Japan Wood Research Society, 58:Pp513-524

Suzuki, S., & Takeda, S. (2000). Production and Properties of Japanese Oriented Strand Board I: Effect of Strand Length and Orientation on Strength Properties of Sugi Oriented Strand Board. The Japan Wood Research Society, 46:Pp289-295

Suzuki, S., & Miyagawa, H. (2003). Effect of Element Type on the Internal Bond Quality of Wood-Based Panels Determined by Three Methods. The Japan Wood Research Society, 49:Pp513–518