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The Effect of Banana Leaves Lamination on the Mechanical Properties of Particle Board Panel

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Abstract

Laminated composites were made by laminating the binderless banana stem particle boards with banana leaf tapes using adhesive in the form of a double-sided tape. The effect of the lamination on the tensile and flexural properties of the particle board panel was investigated. Results obtained showed that increasing the number of layers of banana leaf tapes altered the mechanical properties of the particle board. Particle board with four layers gave the highest flexural strength. Flexural modulus also increased with the increase in the number of layer of banana leaf tapes. There is also an improvement in tensile strength with the number of layers of banana leaf tapes. Particle board panel laminated with four layers of banana leaf tapes showed the highest tensile strength. The tensile modulus, on the other hand, decreased with increasing layer of banana leaf tapes. The fibre orientation in the banana leaf tapes also influenced the mechanical properties of the particle board. Particle board with the banana leaf fibre orientation parallel to the test direction showed higher tensile strength. The effect of banana leaf tape fibre orientation on the flexural strength was not significant.

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Keywords: Banana leaf; mechanical properties; green composite; particle board

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1. Introduction

In the last few decades, many researchers tried to find the new material that would be used in the industry with better properties and environmentally friendly. Today people are more concern about green material consumption in the industry that could protect the environment. Much research was carried out until today to find the alternative of the existing materials used in the industry. Natural fibre reinforcement was discovered in the early 1900's but truly received much attention in the late 1980's. Natural fibres are cheaper and lighter compared to glass fibre. Some properties of the natural fibre are comparable to glass fibre even though its strength is not as strong as glass fibre. Sisal, kenaf, hemp, jute and coir were found to be suitable to replace glass in fibre reinforced plastic[1]. However, there are two main issues that need to be concerned when comparing between natural fibre and glass fibre; their resin compatibility and water absorption. Uses of natural fibre give various benefits as compared to conventional fibre in term of reinforcement material[2,3].

Conventionally, natural fibres are usually mixed with the polymer matrix to provide reinforcement in composites. The coconut shell was used as a particulate filler as reported in the literature[4]. Sapuan et al.[5] found that woven banana fibre reinforced epoxy composites have very stable mechanical properties under different mechanical tests. Luo et al.[6] studied the mechanical and thermal properties of the environmentally friendly green composite from pineapple leaf fibre with poly (hydroxybutyrate-co-valerate) resin. Mechanical properties are important in composite materials because to understand their capability to withstand load and to estimate how long will last during their application of their usage .Gassan et al.[7] found that treating jute-epoxy composite fibre with silane can improve their tensile, stiffness and flexural strength.

There is another method that can be used to reinforce materials with natural fibre. The method is lamination. Lamination is the technique of producing composites in multiple layers so that the composite material achieves improved strength, stability, sound insulation, appearance or other properties from the use of differing materials. A laminate is usually permanently assembled by heat, pressure, welding, or adhesives. Dhakal et al.[8] showed that impact strength of hemp-reinforcement specimen with 0.21% fibre fraction (four layer lamination), are comparable to chopped strand mat E-glass reinforced with the same fibre fraction of unsaturated polyester composite

In this study, lamination was the main focus, where tensile and flexural properties of a banana stem particle board panel laminated with banana leaf tape layer were measured.

2. Methodology

2.1. Production of banana leaves tapes

Banana leaf sheets with dimensions of 21.0 cm x 21.0 cm were cut from the banana leaves and then soaked in tap water and brushed to remove any dirt. The cleaned sheets were soaked in a solution of 1 part of glycerine in 3 parts of distilled water at 80^oC for 3 seconds. After soaking, the sheets were pressed using the hot press at 70^oC at a pressure of 100 kg/cm^2 until they were completely dried. Banana leaf tapes were made by attaching a double-sided tape on the bo

ttom surface of the banana leaf sheets followed by cold pressing at a pressure of 100 kg/cm^2 for 5 seconds.

2.2. Production of banana stem particle board panel

Small pieces of the banana stem from the species of *Musa paradisiaca* var. *awak* (locally known as 'pisang awak'), obtained from the banana plantation in Balik Pulau, Penang, Malaysia, and were dried at 100^oC in a convection oven for 24 hours. Then the dried pieces were ground using a high speed grinder fitted with a screen of mesh number of 150 µm to get particle size needed.

About 110.25 g of the ground banana stem was mixed with 35.0 mL of water, at room temperature. The resulting mixture was then transferred into a mould (dimensions of 21.0 cm x 21.0 cm x 0.5 cm). The mould was pressed with a pressure of 100 kg/cm^2 at 180^{o}C for 5 minutes and then the pressure was released to allow water vapour to escape. After that the pressure was applied again at the same temperature for another 20 minutes. The resulting panel was allowed to cool down to room temperature under the same pressure for 30 minutes. During pressing, a 0.5 cm thickness bar was placed in between the press plates to produce panel of target density of 0.5 g/cm^3.

2.3. Production of laminated panel

The backing of the double-sided tape was removed from the banana leaf tape. The adhesive side of the banana leaf tape was applied onto the banana stem panel and cold pressed with pressure of 100 kg/cm2 for 5 minutes. During pressing, the 0.5 cm thickness bar was placed in between the press plates to maintain panel thickness.

Panels laminated with various layers of banana leaf tapes and also of different banana leaf tapes fibre orientation were produced using the technique described above. For parallel orientation, each leave layers is overlapped over each other by following fibre grain, or fibre direction. While for crisscross orientation, fibre alignment layer overlapped perpendicular each other.

2.4. Measurement of mechanical properties of panels

Test specimens were cut from the panels for tensile and flexural (three-point bending) tests using a band saw (Hitachi Cb75f). The tensile test was carried out with a Universal Testing Machine (Instron 5582). The crosshead speed was set at 5 mm/min. The average thickness of the specimen was about 0.5 cm. Other parameters of the tensile machine and conditioning of the tensile specimens followed ASTM D882. Specimen with size (160 mm x 2 mm) were used to flexural test, performed using a Universal Testing Machine (Instron 5582) according to ASTM D1037 at a crosshead speed of 5mm/min. All these tests were conducted at room temperature, and the average value of five repeated tests was recorded for each composition.

3. Results and Discussion

3.1 Tensile Properties

Fig. 1 shows the tensile strength of the laminated board panels. Parallel lamination of four layer particle board panel, displayed the highest (2.2 MPa) tensile strength, while one layer lamination of crisscross showed the lowest (0.65 MPa). Based on this result, it shows that 4 layer of lamination is better than lower layer of lamination. It shows that the more lamination layer applied, more strength is required to break the laminated board panel. Seung-Hwan et al.[9] stated that when the fibre composition is increased, the tensile strength automatically gradually decreased; because of matrix composition is decreased. The observed relationship between tensile strength and the number of layers of banana leaf tape is due to the fact that the different panels were made by laminating the core material of the same composition with different layers of banana leaf tapes. Since banana leaf tape is stronger than the core material in the panels, increasing the number of layers of banana leaf tapes increases the tensile strengthTheir analogy is like a strength determination of individual fibre and a bundle of fibre, tensile strength of bundle fibre is better than individual fibre strength.

Parallel orientation shows higher tensile strength than crisscross orientation for all the lamination layers. This could be due to the fact that the banana fiber was aligned in the test direction and therefore, the tensile strength is increased. In parallel orientation, grain along fibre help in giving strength and support to resist stress, but crisscross orientation stress was applied against grain, its only depends on fibre of banana leaf to resist stress.

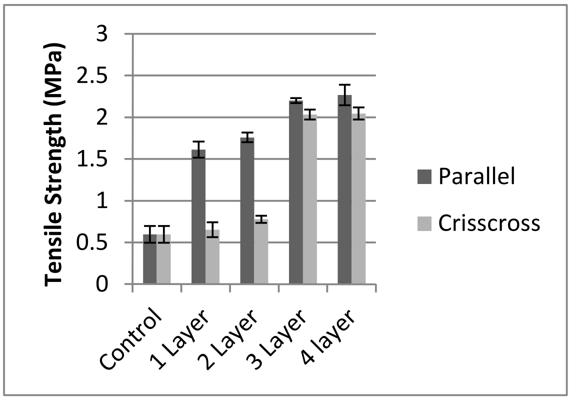

Fig. 1 : Tensile strength of laminated board panels.

Fig. 2 shows that the tensile modulus decreases with increasing layers of banana leaf tapes. The decrease in the tensile modulus with increasing layers of banana leaf tapes is due to the increase in the amount of adhesive used to laminate the banana leaf tapers to the panels. Since the adhesive is soft and elastic, increasing the adhesive amount will reduce tensile modulus. This translated in high tensile strength but lower modulus as shown in Figure 1 and 2.

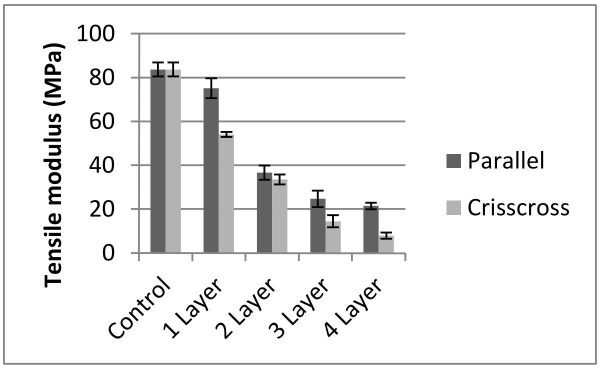

Fig. 2 : Tensile modulus of laminated board panels.

3.2 Flexural Properties

Flexural strength of laminated board panel can be observed in Fig. 3. It shows similar trend as in tensile strength. Parallel lamination with 4 layers of banana leaves shows the highest flexural strength (2.13 MPa) while, one layer crisscrosss lamination shows the lowest flexural strength (0.73 MPa). This is because in bending test, the fibre in the banana leaf tapes will bear most of the load Control board has weakest flexural strength, because it's purely banana fibre without any reinforcement and binder. Khalil et al.[10] stated that the weak fibre matrix bonding contributed to poor flexural properties. Increasing the layers of banana leaf tapes increases the amount of fibre that can bear the bending force and thus will increase the flexural strength

There is not much difference in flexural strength in term of orientation, either parallel or crisscross. As can be seen in Fig. 3, as the number of banana leaves layer increased, the flexural strength is also increased but not much effect based on the orientation of layer. This due to flexibility properties on banana leaves laminate layer.

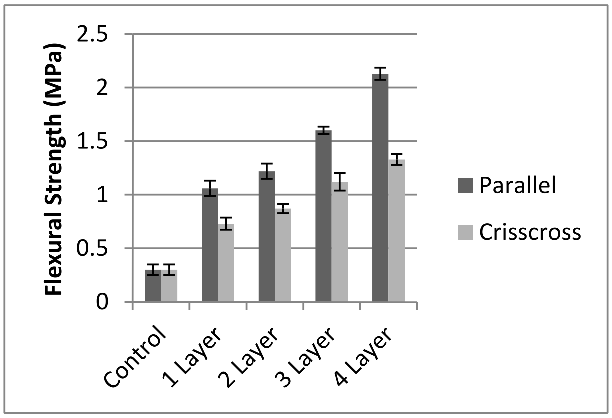

Fig. 3: Flexural strength of laminated board panels.

Fig. 4 shows that flexural modulus of laminated board panels. The flexural modulus increases with banana leaf tapes layers. The effect of banana leaf tapes on the flexural modulus is the opposite to that observed in tensile modulus, as shown in Fig. 2. The difference in the effect is because the mode of deformation of the panels in tensile and bending tests is different. In tensile test, the specimen is pulled or elongated. The adhesive will elongate first during the test and after the adhesive cannot elongate anymore, the load is transferred to the fibre in the banana leaf tape. In bending test, the load is applied on one side of the specimen. Therefore, the side of the specimen where the load is applied will be compressed and the opposite side will be stretched. In this mode of deformation, the stretching side will bear most of the load and the load is bore by the fibre in the banana leaf tapes. The effect of adhesive will be small because the adhesive is not stretched as much in the tensile test. Result also shows that the four layer of parallel lamination has the highest flexural modulus (2.13 MPa). The lowest flexural modulus is for one layer lamination with crisscross orientation (0.72 MPa). Sathishkumar et al.[11] noted that the flexural strength depends upon the fibre content and the fibre length. So as increase number of layer of banana leaf tape, it gradually increases the fibre content on particle board panel, hence will increase the flexural properties of board.

It seems that there is not much difference in the value of flexural modulus for based on the orientation of lamination. Orientation of lamination layer, either parallel or crisscross does not affect flexural modulus significantly.

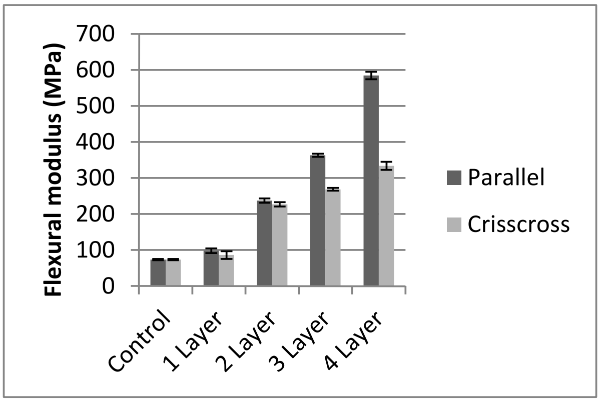

Fig.4: Flexural modulus of laminated board panels.

4. Conclusion

The tensile strength of the composites increased with the number of layers of banana leaf tape. Tensile modulus decreased with the number of layers of banana leaf tape. While flexural properties also increased with the number of layer of banana tape. An increase in the number of layers of banana leaves as lamination on surfaces of the panel has improved the mechanical properties of laminated board panel.

Particle board panel with banana stem fibre orientation parallel to the test direction have higher tensile strength than those with the crisscross fibre orientation. While for flexural strength, fibre orientation has no significant effect.

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