# The Performance of Particleboard Made from Rice Husk and Coconut Husk based On Type Density and Type of Raw Material

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**Abstract**

The increase in waste production from agricultural waste has contributed to various environmental problems. In Malaysia, agricultural is a main sector industry including rice and coconut production. Coconut husks and rice husks residues generated during the processing, are available in abundant quantities in many parts of the tropics but are often treated as a waste material. This study investigated the performance of particleboard made from rice husk and coconut husk based on density (500kg/m³, 600kg/m³, 700kg/m³) and type of raw material (rice husks, coconut husk and mixing). Material type gave the effect on board properties. For mechanical modulus of rupture (MOR) and modulus of elasticity (MOE) and physical properties thickness swelling (TS) and water absorption (WA), there was high significant difference between materials. Material with have fibre structure like coconut husk resulted in higher value of MOR, MOE and internal bond (IB) compared to rice husk and mixture. Even so, in TS testing, mixed sample recorded highest value in percentage after coconut husk and rice husk sample. But in WA, coconut husk samples show more resistant to water compared to others. Density also gave great impact on properties of particleboards. The higher density (700kg/m³) gave more strength in mechanical properties (MOR, MOE and IB) than lower density (500kg/m³ and 600kg/m³) and resulted in more resistant towards water. The developed particle board composites can be used for general purpose requirement, such as panelling, ceilings or furniture.

Keywords: coconut husks, rice husks, density, water absorption and thickness swelling

## 1. INTRODUCTION

Particleboard had been used extensively in this modern world. Wood particleboards are manufactured as panels from dry wood particles that have been sprayed or dusted (speckled) with binder resin, and are bonded together with pressure and heat. Particles for the boards can be made from almost any type of wood. Since the sources from timber are getting low, there are other sources needed to make particle board. As an alternative source, agriculture waste is being used to make green product that are friendlier to environment. Specifically in Malaysia, government had urged the use of more recycling sources such as saw dust, bagasse and rice husk.

Rice husk is one of the most widely available agricultural wasted in many rice producing countries around the world especially country around Asia including Malaysia. Globally, approximately 600 million tons of rice paddies are produced every year. On average 20% of the rice paddy is husk, giving annual total production of 120 million tonnes (Giddel and Jivan, 2007). Mohd Kamal & Nuruddin, (2001) added that in most of the rice producing countries, the husk produced from processing of rice is either burnt or dumped as waste. Another raw material is the coconut husk or coconut fibers. The coconut industries in the world are in a lower growth as it is less popular to others. Coconuts are typically found in coastal areas of tropical countries for instance Brazil and Malaysia. The husk, which is known to yield the coarse coir fiber, is abundantly available as cheap residue from coconut production in many areas. In Malaysia, the coconut husk is being abandoned since the technology for green development is less used in Malaysia. Coconut husk were considered to be the raw materials offering greatest potential for manufacture of thermal insulation since the fibres allows good air movement (Manohar et al., 2006).

There are many raw materials that can be used to make a particleboard either with logs or part of wood such as saw dust. The most common type of raw material is from the rubberwood (*Hevea brasiliensis*) since it is easier to get the materials, as Malaysia has one of the largest rubber production in the world. Second is the log production from natural forest for example *acacia* and *kelempayan* wood. In a bio-composite term, we can use recycle material such as rice husk, coconut husk or even an oil palm trunk (OPT). Utilisation of these new resources is suitable in order to handle the pressure of timber demand.

The objectives of the study are to determine the type of density effect on particleboard and to determine the type of material raw effect on particleboard. Generally, particleboards are used for many building applications or furniture such as pool table, kitchen table, casing for oven, floor, ceilings and other industrial product applications. In tourism sector, particleboard is used as small gift, casing for hand phone for tourist, and begs. It is also used in cabinet for musical instrument such as pianos, pallets, containers and packaging cases (panel, 2002).

## 2. MATERIAL AND METHODS

### 2.1 Materials preparation

The rice husk and coconut husk are clean to ensure there are no other particles mixed with the raw material. Vibrating screener is used to separate the material from dust or small stone. The average length for the paddy husk is around 4mm to 6 mm. The coconut husks were cut by scissor into required average length of 4cm to 7cm. After it has been done, the raw materials are ready for the process. Figure 1 shows the stages of manufacturing particleboard process.

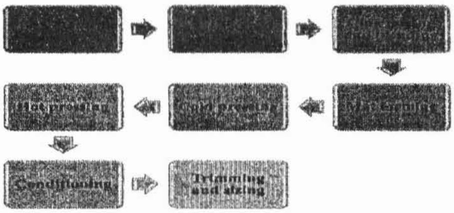

Figure 1: Stages of manufacturing particleboard process.

### 2.2 Drying

The raw materials need to be dry to prepare it for the next step. The method of drying either traditional method by placing in an open places to dry under the sun or using oven with the temperature maintain until the weight are constant. The raw material should have less than 5% moisture content so it will not affect or blow while making the particleboard.

### 2.3 Glue mixing and blending

The raw materials that have been dried will be mixer with the phenol formaldehyde (PF). The three type's combination of particleboard is: rice husk, coconut husk and mixture of rice husk and coconut husk. The PF resin were sprayed onto the particles by spray nozzles and mixed together in the rotating mixer. The amount of resins is based on requirement of the particleboard by using specific formula. The same procedure of blending is repeated using different type of raw material and the density being used.

### 2.4 Mat forming

After blending with resins, the particles were manually transferred into a wooden mould size 350mm x 350mm to form a particleboard mat. Before being pressed, mould release agents were sprayed at the tray to avoid the particles stick on the tray.

### 2.5 Cold pressing and hot pressing

Cold press or known as pre-pressing is important process because it initiates bonding between the particles. The benefits of cold press are to reduce the mat thickness and ensuring mat is flat before being transferred to the hot press process. Through hot press process, the mats are placed in the press accommodating one sheet at a time and put between a pair of heated platens bottom and top. The temperature depends on situation like weather or type of resins used. The process of hot press is to cure the resins and achieved the final thickness that increases the strength of the board.

### 2.6 Conditioning

Pressed board was transferred to conditioning room under a normal condition until it reaches the equilibrium moisture content (EMC). It is to make handling for sizing process easier because it is hard to cut or trim if the board is at high temperature.

### 2.7 Trimming and cutting

After the board cooled down, it is ready for edge trimming to get the 350mm x 350mm x 6mm. Then, the boards were cut into specific specimen according to the European standard. Figure 2 show the cutting design of the standard.

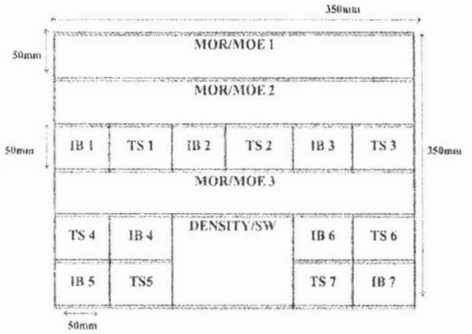


Figure 2: Cutting standard

## 3. TESTING METHODS

Boards were tested for mechanical properties such as Modulus of Rupture (MOR), Modulus of Elastic (MOE) and Internal Bonding (IB). This is for determine the strength, stiffness and the bonding performances of the boards. According to European Standard (EN 310), value for MOR and MOE should be greater than 18N/mm$^2$ and 2550N/mm$^2$ respectively. Meanwhile for IB the results should be greater than 0.45 N/mm$^2$.

Physical properties' testing includes thickness swelling and water absorption test. The purpose of this test is to measure the ability of the boards to absorb water. Based on European Standard (EN 317) thickness swelling should be lower than 14%.

### 3.1 Bending test

Using the Universal Instron machine with marked samples, the samples were tested until it broke and the result were measured in MPa. Calculation of MOE and MOR is as given:

$$MOE = \frac{1}{4} \times \frac{Fpl \times L^3}{bd^3 \times \Delta}$$

L = Span between supports (mm)

Fpl = Maximum force at proportional limit (N)

b = Width (mm)

d = Depth (mm)

$\Delta$ = Deformation (mm)

$$MOR = \frac{3}{2} \times \frac{F\max X\ L}{b\ X\ d}$$

Where;

L = Span between supports (mm)

F max = Maximum load (N)

b = Width (mm)

d = Depth (mm)

### 3.2 Internal bond test

Internal bonding test was used to determine the tensile strength of the board. The specific specimen dimension was 50 mm x 50 mm. Marked, measured and bonded to two metal blocks with epoxy. It was then tested by using Instron Universal machine. The machine gives a pull from upper and below of the board and the sample was tested until it cracks. Values calculated as follow and were determined in MPa.

$$IB = \frac{F\max}{L\ X\ W}$$

Where;

L = Length (mm)

W = Width (mm)

F max =Maximum load (N)

### 3.3 Thickness swelling test

This process put the sample immersed in water for 24 hours to determine the durability of the particleboard to water. We need to make sure that board are all properly immersed to have accurate results. The formula used to calculate thickness swelling test are shown below.

$$TS\ (\%) = \frac{\text{Thickness after} - \text{thickness before}}{\text{Thickness before}}\ X\ 100$$

### 3.4 Water absorption test

The test started when all the sample specimens are put in the water to allow the board to absorb the water. The objective of the test is to determine how the samples absorb with the water and identify if the board are durable to water. The formula used in calculation to know the percentage of water absorption:

$$WA = \frac{\text{weight after soaked} - \text{weight before soaked}}{\text{weight before soaked}} \times 100$$

## 4. RESULTS AND DISCUSSIONS

### 4.1 Effect of material raw type on mechanical properties

Table 1: Effect types of material on mechanical properties

| Variable | MOR | MOE | IB | Thickness Swelling | Water Absorption |
|---|---|---|---|---|---|
| RH | 4.03a | 659.58a | 0.0417a | 38.58c | 133.51c |
| MIX | 6.69b | 924.12b | 0.0679b | 36.33b | 121.29b |
| CH | 8.13c | 927.93b | 0.1158c | 32.07 | 109.69a |

Note: MOR: Modulus of Rupture, MOE: Modulus of Elasticity, IB: Internal Bonding, RH: Rice Husk, CH: Coconut Husk, MIX: Mixing

Table 1 shows the effect of species on the modulus of rupture (MOR), modulus of elasticity (MOE) and internal bonding (IB). The mechanical properties were also shown in Figure 3 for direct comparison. For MOR, coconut husk particleboard gave a better value than rice husk and mixed particleboard. This higher value is due to the structure or dimensions of the material particle. According to Van Dam et al., (2004), coconut husk comprised of 30% coir fibres and 70% pith. Ruihong Zhang (2005), stated that high quality particleboards of high strength, smooth surface, and equal swelling are normally obtained by using a homogeneous material with a high degree of slenderness (long and thin particles), but without oversized particles, splinters, and dust.

While, the rice husk particleboard gave the lowest value in MOR because rice husk have lower cellulose and lignin content than wood, but higher amounts of silica which reduce the interactions with adhesive, (Liu et al., 2004). The mixing rice husk and coconut husk particleboard made it balance between the two material types because sharing of properties.

For MOE, there is not significantly different between coconut husk and mixed particleboard. This is due of the presence of coconut husk that contribute the elasticity properties. As suggested by Bentur and Mindess,(1990), the major role of particles and fibres in particleboard is to improve the ductility of the material. In performing this role, distance (spacing) between the discrete fibres/particles is a significant parameter controlling the composite performance which be done in forming. While, the rice husk particleboard achieved minimum value due to its properties which is highly porous and lightweight, with very high external surface area according to Kozlowski & Helwig, (1998). Maiti & Lopez, (1992), stated that composites with fillers (porous condition) produced lower tensile strength.

The internal bonding (IB) strength of coconut husk particleboard was higher than those of particleboard made from rice husk or mixed material. This explained by Luttge Kluge & Bauer, (1992) stated that lignin content was higher in coconut husk fibers that make its more rigid. In additional, Van Dam et al (2004) observe the presence of pith as a resin absorber is one of the factor too. While, for the rice husk which had the lowest value for the internal bonding, it is explained by Lee et al., (2006) that waxy and silica layer encapsulating the rice husk surface inhibit sufficient direct contact between the binder and the rice husk particle.

The significant amounts of silica and waxes reduce its interactions through secondary forces (hydrogen bonds) with the polar resins. Meanwhile, the mixed particleboard is balancing the two types of material type properties that cause the internal bonding strength in between the material type.

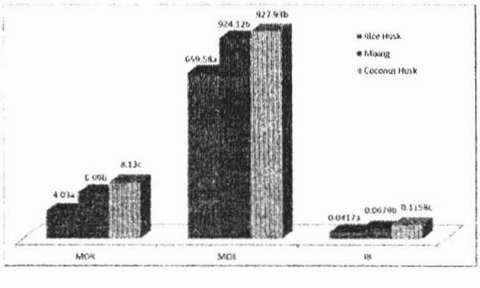


Figure 3 Effect of material raw type on mechanical properties

**4.2 Effect of material raw type on physical properties**

Figure 4 shows the effect of species on the thickness swelling (TS) and water absorption (WA). For TS, there is significant different between all particleboards even though it is can be count high percentage of thickness swelling. In a previous study according to Torkaman (2010), similar results were also observed for the TS values.

The silica and the waxy water repellent cuticle cover almost the entire outer layer of the rice husk. The outer thin waxy layer of the rice husk particles also lowers their wettability, which may influence the bond quality of the water-based formaldehyde resins. While, the coconut husk has significant different compared to rice husks particleboard. This may be attributed to the excellent water holding capacity of coconut husk as reported by Sindhumole (2008). For the mixed particleboard, it record high percentage of thickness swelling. According to Xu and Suchlan (1999), mixing of wood species in particleboard manufacturing may relate to variation of density thus may affect the thickness swell. Olorunnisola (2007) added that homogeneous and heterogeneous species give effect to the physical properties.

For WA, the three types of material are significantly different from each other. The highest WA is from rice husk particleboard. According to Matsuo (1998), the surfaces of the rice husks are composed of hard epidermal cells containing a large amount of SiO2 (silicon dioxide) and setae. Many continuous voids remained in the composites because the contact portions among the rice husks had not sufficiently been compressed despite a high molding pressure application in the hot press molding process. The water absorption of the composites is mainly caused by the capillary action through such voids of the composites. Meanwhile, coconut husk particleboard is low in percentage of WA since coconut husk has a great affinity for water. Endowed with millions of capillary micro-sponges, it is able to absorb and hold large quantities of water, up to eight times its own weight (Sindhumole, 2008). While mixed particle shared the properties both of rice husk and coconut husk properties making it at the middle point of behaviour.

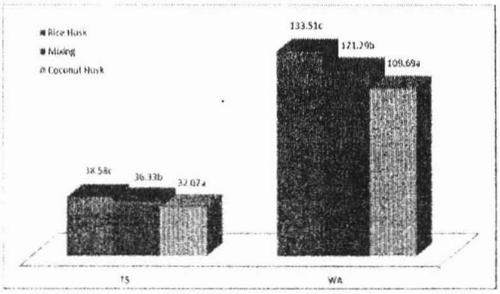


Figure 4: Effect of material raw type on physical properties

**4.3 Effect of density on mechanical properties**

Figure 5 and Table 2 shows the effect of density on the modulus of rupture, modulus of elasticity and internal bonding. For MOR and MOE, 700kg/m$^3$ density gave a better value than 600kg/m$^3$ and 500kg/m$^3$ particleboard density. This was explained by Ayrilmis (2012) where the increase mechanical properties were due to the availability of more particles at higher density thus increasing the bonding ability of the particle.
According to Yang, Kim & Kim, (2003), the MOE value is high the board tend to be brittle and as the value of MOE is low the board is more flexible. As explained by Jani and Izran (2013) that density of a board is influenced by the amount of particle used in the board. The higher the density the larger amount of particles used. Larger amount of particles in the particleboards enhance its' resistance to rupture.

Table 4.2: Effect types of density on physical properties

| Variable (kg/m$^3$) | MOR | MOE | IB | TS | WA |
|---|---|---|---|---|---|
| 500 | 2.59a | 396.67a | 0.0237a | 39.77c | 171.36c |
| 600 | 6.31b | 869.46b | 0.0621b | 28.95b | 117.45b |
| 700 | 9.57c | 1245.51c | 0.1347c | 23.45a | 75.20a |

Note: MOR: Modulus of Rupture, MOE: Modulus of Elasticity, IB: Internal Bonding

Table 2: Effect of density on mechanical and physical properties

It means for the IB, the higher density board gives the higher IB values due to the amount of particles which occupied the space of the board that otherwise will have more voids. The voids can cause failure on internal bonding between the particles (Ashori and Nourbakhsh, 2008).

Figure 4.3 Effect types of density on mechanical properties

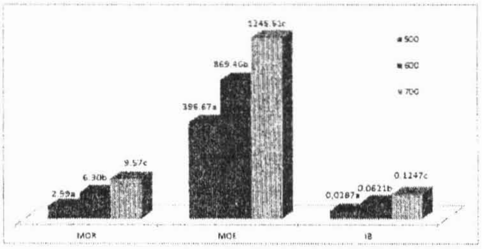


Figure 5: Effect of density on mechanical

**4.4 Effect of density on physical properties**

Figure 6 shows the effect of density on the TS and WA. For TS, 500kg/m³ show low percentage of TS and followed by 600 kg/m³ and 700 kg/m³. There were significant differences between all the board densities. The density of board has affected the percentage of TS, the low density of board increased in TS values. This is due to the existing free spaces in the board and water was penetrating the board or moisture has been absorbed by the board (Loh et al., 2010).

The higher density boards the lower the percentage for water absorption. Therefore, the spaces between the particle are compact, and it can be implied that more compressive deformation that has been imparted onto the particles during hot pressing and the particles were under great compressive set (Wong et al., 1999). This situation could reduce the formation of voids and reduce water absorption.

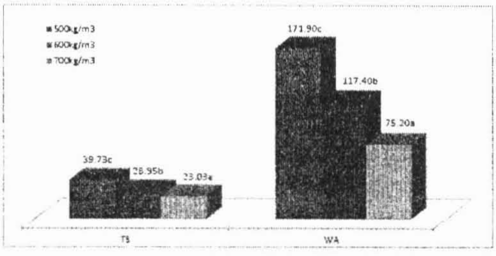


Figure 6 : Effect of density on physical properties

## 5. CONCLUSIONS

Two different material, rice husks and coconut husks with different density, 500kg/m³, 600kg/m³, and 700kg/m³ were used to analyze the effect of this factor on properties of particleboard. Material type gave the effect on board properties. For mechanical (MOR and MOE) and physical properties (TS and WA), there were high significant between material. Material with have fiber structure like coconut husk resulted in higher value of MOR, MOE and IB compared to rice husk and mixed. Even so, in TS testing, mixed sample recorded highest value in percentage after coconut husk and rice husk sample. But in WA, coconut husk samples show more resistant to water compared to other. Density also gave great impact on properties of particleboards. The higher density (700kg/m³) gave stronger bonding strength in mechanical properties (MOR, MOE and IB) than lower density (500kg/m³ and 600kg/m³) and resulted in more resistant towards water.

In conclusion, it was found that the raw material type is not suitable material for particleboard. All the board does not meet the requirement of the EN standard for exterior type particleboard.

**Acknowledgements**

The author would like to thanks to supervisor, Madam Zaimatul Aqmar Binti Abdullah and co-advisor, Prof. Dr. Jamaludin Bin Kasim, for all the useful comments and time and guidance to complete this project. Also to project coordinator, Prof. Madya Said Ahmad and Sir Amran Bin Shafie as the head of Bio-composite Programme for their help to coordinate this final year project for the last semester. This report are not gonna be perfect without guide and time from Miss Nurus Syahidah Binti Tahreb as language advisor. This project also not will be success without contribution from Sir Mohd Anuar from BERNAS Company for the rice husks and TNM enterprise for the coconut husk contribution.

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