# Physical and Mechanical Properties of Particleboard Utilizing Pili Nut (Canarium Ovatum) Shells

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*Abstract*— **This study aims to make a 200 mm x 200 mm particleboard with nine millimeter thickness using Crushed Pili Nut Shells (CPNS) and sawdust as raw materials with the ratios (CPNS: sawdust) 100:0, 75:25, and 50:50 by weight and determine their physical and mechanical properties. Also, the results were compared to the standard properties of commercial particleboard set classified by the Philippine Standard Association (PHILSA). The raw materials were mixed with High-Density Polyethylene (HDPE) as an adhesive. All particleboards have passed and exceeded the PHILSA standard for particle board where 100:0 mixtures with density of 1204.09 kg/m3 has the highest MOR of 110 MPa and lowest thickness swelling of 1.11%. Therefore, particleboard made from Pili nut shells has an outstanding property compared to commercial particleboards that depends on its application.**

*Index Terms*- **Particleboard; Physical property; Pili nut; Mechanical property; High-Density Polyethylene (HDPE)**

## I. Introduction

One of the very common construction materials used until now is wood that is manufactured into different forms depending on its application such as particleboard [1]. Particleboard is composed of wood wastes and adhesive or resin to bind the raw materials together with hot compress [2]. It is much cheaper, lighter and more readily accessible than plywood and medium-density board (MDF) but low in strength and not being suitable for areas with high humidity [1]. Nowadays, many alternative raw materials are used in making particleboard to come up with better qualities. Alternative materials such as almond shell particles, peanut shells, bamboo wastes, sugarcane bagasse and corn stalks are used in making particleboard in some studies.

This study aims to use Pili nut shells as a raw material in making particleboard. A study shows that Pili nut shell has good mechanical property with a force at fracture for longitudinal position of 2.66 to 3.15 kN and 1.48 to 1.60 kN for transverse position. The result shows that at any moisture content level, the kernel of the nut can be freed fully from its shell with longitudinal position [3]. Pili are very abundant in Bicol Region where 23, 221 metric tons of pili nuts are being produced since 2011 [4]. Pili nut shells were used for the study because Pili nut companies in Bicol, Philippines commonly consider it as waste and it has an outstanding hardness. In making the particleboard, plastic bags or HDPE was used as an adhesive. According to American Chemistry Council (2015), HDPE are bonded ethylene molecules that are widely used for various purposes. It is a lightweight and strong kind of plastic that can be easily remolded into different shapes [5]. This study also helps in lessening non-biodegradable wastes and be useful as a resin. This study specifically aims the following objectives:

- To determine its physical property such as density, unit weight and thickness swelling,
- To determine the mechanical property, specifically Modulus of Rupture (MOR).
- To compare the results to the standard properties for commercial particleboard from Philippine Standard Association (PHILSA) if it will pass or exceed the given standards.

The mixture of raw materials used in making the particleboard are the ratio (CPNS: sawdust) 75:25, 50:50 and 100:0 by weight. 50% of HDPE was used for each particleboard. These materials will undergo the process of crushing, melting, mixing, hot compress, conditioning and testing that will help in obtaining the objectives of the study. The results were compared with standards by PHILSA where there are 3 types of particleboard classified based on its properties. For Modulus of Rupture, Type 100 should have at least 7.84 MPa, Type 150 is 13.73 MPa and Type 200 is at least 17.65, while the standard percentage for thickness swelling is 20% or below.

## II. Materials and Methods

This study was conducted in Technological Institute of the Philippines (TIP), Manila from May 6 to 23, 2017. The particleboards were manufactured at Materials Science Division (MDS) laboratory in Department of Science and Technology (DOST) and were tested in Construction and Material Testing (CMT) laboratory in TIP, Manila.

### *A. Crushed Pili Nut Shells (CPNS)*

Pili nut shells were obtained for free from Ester's Pili Nut Candies, a food company that specializes in Pili nut products based in Naga, Camarines Sur, Philippines. The shells are considered as a waste product of the company. The crushed Pilli nut shells that passed with 2 mm and 600 micrometer sieves was used for the particleboards.

### *B. Sawdust and Resin*

Wood particles were also obtained for free from a hardware located in Bocaue, Bulacan. The sawdusts were sieved to pass through 2 mm screen. The material was processed from wood processing, which is a common practice in particleboard manufacture. The kind of resin that was used in binding the mixtures of CPNS and sawdusts were High-Density Polyethylene (HDPE). The HDPE were melted using two roll

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mill machines in Department of Science and Technology (DOST) in Taguig City, Philippines.

### C. *Manufacturing and Testing*

Crushed Pili Nut Shells (CPNS) were uniformly mixed with sawdusts at 100:0, 75:25 and 50:50 weight ratios with 250:0, 125:125, 187.5:62.5 grams of CPNS: sawdust, respectively. The Lab Tech Engineering Two Roll Mill was set to 180 degree Celsius. The HDPE was melted using Two Roll Mill and the CPNS-sawdust mixture was mixed with the melted HDPE. The complete mixture was formed into mats using a 20.32 cm x 20.32 cm (8 in. x 8 in.) forming a box.

The specimens were subjected in ASTM D1037-12 for the Thickness Swelling and ASTM D1037-12 for Static Bending Test procedures respectively [6]. The thickness swelling and modulus of rupture were then calculated and the results were compared to classification and minimum specification of particleboard by the Philippine Standard Association.

## III. Results and Discussion

The data in Table 1 shows that the particleboards made have an area from 38809.67mm$^2$ to 39 070.67 mm$^2$ and weighs from 0.422 kg to 0.429 kg. The densities are around 1220.01 kg/ m$^3$ to 1204.09 kg/ m$^3$ and the unit weights were from 11 964.15 N/ m$^3$ to 11 808.03 N/ m$^3$. The graph in Figure 1 shows an increase in load and stress from the mixture of 75/25 with the lowest results, 50/50 to the mixture with the highest result, 100:0.

**Table 1. Average Stress, Density and Unit weight of Samples**

| Ratio | Trial | Weight (kg) | Area (mm$^2$) | Load (kN) | Stress (MPa) | Density (kg/ m$^3$) | Unit weight (N/ m$^3$) |
|---|---|---|---|---|---|---|---|
| **75:25** | 1 | 0.414 | 39 204 | 2.83 | 0.07 | **1220.01** | **11 964.15** |
| | 2 | 0.438 | 39 200 | 3.46 | 0.09 | | |
| | 3 | 0.435 | 38 808 | 3.53 | 0.09 | | |
| | ***Average*** | ***0.429*** | ***39 070.67*** | ***3.24*** | ***0.08*** | | |
| **50:50** | 1 | 0.432 | 39 204 | 6.16 | 0.16 | **1225.35** | **12 016.55** |
| | 2 | 0.428 | 38 809 | 3.51 | 0.09 | | |
| | 3 | 0.424 | 38 416 | 3.82 | 0.10 | | |
| | ***Average*** | ***0.428*** | ***38 809.67*** | ***4.383*** | ***0.12*** | | |
| **100:0** | 1 | 0.430 | 38 612 | 6.37 | 0.16 | **1204.09** | **11 808.03** |
| | 2 | 0.402 | 39 600 | 5 | 0.13 | | |
| | 3 | 0.434 | 38 612 | 6.43 | 0.16 | | |
| | ***Average*** | ***0.422*** | ***38 941.33*** | ***5.933*** | ***0.15*** | | |

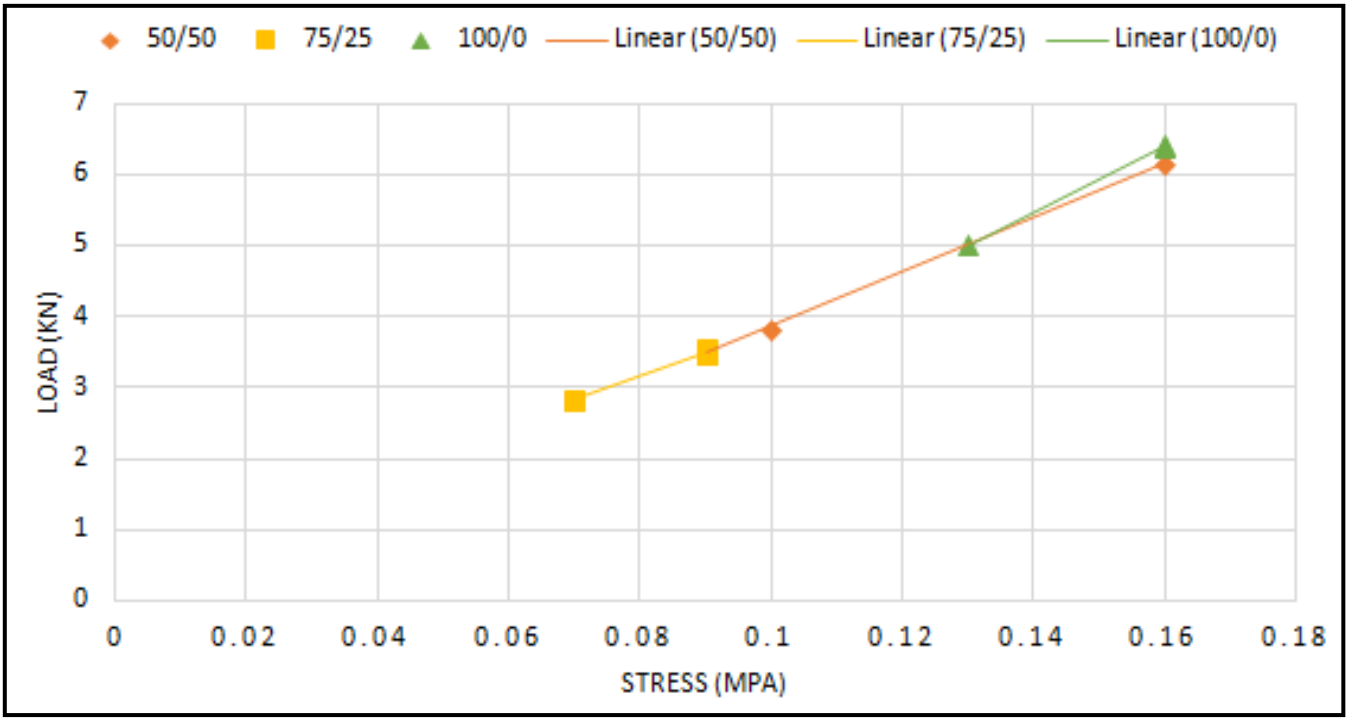


**Figure 1. Load *vs* Stress Relationship of Samples**

Table 2 shows the result for Modulus of Rupture (MOR) were it shows that 100:0 has the highest value with 110 MPa as an average result, 50:50 reached 83.27 MPa and 75:25 has the lowest value with 61.28 MPa MOR.

**Table 2. Average Modulus of Rapture of Samples**

| Ratio | Average Modulus of Rupture (MPa) |
|---|---|
| 75:25 | *61.28* |
| 50:50 | *83.27* |
| 100:0 | *110.00* |

The thickness swelling shown in Table 3 of the finished particleboards ranges from 0 to 2.78% only. The table shows that particleboard with ratio of 75/25 and 50/50 have the same percentage of thickness swelling while the 100:0 mixture has almost no thickness swelling.

**Table 3. Thickness Swelling of Samples**

| Ratio | Weight (g) | | | Dimensions (mm) | | | | Thickness swelling (%) |
|---|---|---|---|---|---|---|---|---|
| | Initial | Final | % Difference | Initial | | Final | | |
| 75:25 | 0.438 | 0.440 | 0.46 | 194 | 200 | 199 | 205 | 2.5 |
| 50:50 | 0.424 | 0.426 | 0.47 | 196 | 196 | 200 | 200 | 2.04 |
| 100:0 | 0.434 | 0.434 | 0 | 196 | 196 | 200.5 | 200.5 | 2.30 |

Table 4 shows the classification and minimum specification of particleboard according to the Philippine Standard Association (PHILSA). Table 5 on the other hand, shows the summary of results of particleboards in different ratio which have passed the PHILSA minimum standards for particleboards. Moreover, the particleboard with pure CPNS has an outstanding value compared to particleboard made from pure sawdust with a value of 59.93 MPa in MOR and other mixtures.

**Table 4. Classification and Minimum Specification of Particleboard by the Philippine Standard Association** [7]

| TYPE | MOR (MPa) | TS (%) |
|---|---|---|
| 200 | 17.65 | |
| 150 | 13.73 | 20 or less |
| 100 | 7.84 | |

**Table 5. Remarks Based on Philippine Standard Association (PNS)**

| Ratio | Results | | REMARKS | | |
|---|---|---|---|---|---|
| | MOR (MPa) | TS (%) | Type 200 | Type 150 | Type 100 |
| 75:25 | 61.28 | 2.5 | PASSED | PASSED | PASSED |
| 50:50 | 83.27 | 2.04 | PASSED | PASSED | PASSED |
| 100:0 | 110.00 | 2.30 | PASSED | PASSED | PASSED |

Based on the results from thickness swelling test and static bending test, the particleboards in all ratio passed the minimum specification in type 200, 150 and 100 particleboard of PHILSA. The ratio with 100:0 has the highest modulus of rupture (MOR) with 110 MPa while the particleboard with 50:50 ratio has the least thickness swelling percentage at 2.04 %. The particleboards made are in the area of 38809.67 $mm^2$ to 39070.67 $mm^2$ with 9 mm thickness and weight of 0.422 kg to 0.429 kg. The density of the particleboards range from 1220.01 kg/ $m^3$ to 1204.09 kg/ $m^3$. These particleboards made of pili nut shells are denser than the commercial particleboard with 650 kg/m³ and 750 kg/m³ density. With these properties, it shows that particleboard

made of pili nut shells and HDPE does not absorb much water that causes the swelling of finished particleboards. It also shows an outstanding result for bending strength that it surpassed the standard MOR for commercial particleboard.

## CONCLUSION

From the foregoing, it can be seen that the use of Pili Nut Shells in the production of particleboards either alone or as a component significantly increased both the physical and mechanical properties of the particleboard. The structure of the specimens created, regardless of the ratios, was composed of HDPE plastics; therefore, it cannot absorb much water to cause swelling. After the specimens have gone through the specified tests (i.e. Flexural stress and thickness swelling), the results showed that the physical and mechanical properties of the pili board with 100:0, 50:50 and 75:25 ratio of CPNS: sawdust easily surpassed the Philippine Standard Association (PHILSA) for particle boards. Moreover, the results showed that the 100:0 ratio gave an enormous increase of modulus of rapture difference of about 173.388% compared to minimum requirement set by the Philippine Standard Association for particleboard.

It is concluded that using Pili nut shells as a raw material for particleboard creates a super-strong yet low-cost construction material all the while maintaining its purpose of taking care of the unnecessary Pili nut industry wastes of the country.

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