A Comparative Study between Commercially Available Type 1 Plywood and Plymer, a HDPE and Pineapple Leaves Composite

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Abstract. Pineapple in the Philippines, with an annual production rate of more than 2 million tons, is ranked the third largest pineapple producing country in the world, with 172,000 acres dedicated to its production. Under this scenario, pineapple is a subtropical fruit with a considerably higher proportion of by-products consisting of peels, stems and leaves, leading to a high production of agricultural waste. In particular, pineapple leaves fiber as one of the most abundant by-products rich in cellulose. The researchers compared the properties and composition of commercially available type 1 plywood to a mixture of high density polyethylene plastic chips with dried pineapple leaves called Plymer. The ratio of the Plymer was 80% HDPE and 20% leaves. The series of tests carried out by DOST-FPRDI were screw removal, static bending and tensile strength. The researchers used the statistical tooltest to compare the results of the test. In conclusion, Plymer is the best option for static bending and tensile strength testing.

1. Introduction
The increase in the economic growth of the Philippines and the increase in the purchasing power of the Philippines amplifies the rate of construction and furniture industries in the country[1]. With the country reaching the "Golden Age" of infrastructure, continuous improvement in the expansion of residential and commercial buildings has resulted in an increase in the raw materials needed[2]. It has been reported that the country's construction industry is expected to grow by about 50 percent and $47 billion by 2020 with an annual growth rate of 9.22%[3].

Furniture produced in the Philippines is made up of various materials, from indigenous raw materials such as rattan and bamboo to synthetic materials such as plastics. Almost 100 years have passed since the discovery of manufacturable plastics[5]. With the help of plastics, the discovery of different technological inventions was made possible in the modern era. Plastics has made people's lives more sustainable and comfortable; it contributes to the modernization and development of these different fields and industries[6]. From simple grocery bags to high-tech devices such as computers and cell phones, and also to the modern medical industry, it contributes to such a wide range of applications that make life easier.

One type of plastic is thermoplastic. Thermoplastic includes the fact that it can be heated and reshaped from a liquid form to a solid state when cooled[7]. This type of plastic includes a known type
of plastic called Polyethylene, which can also be specified as high density polyethylene, also known as HDPE[7,8].

HDPE plastics are known to have different uses and, as many people have not been familiar with, these plastics have been commonly used in different products that can be found throughout households. Products include milk and household cleaner bottles, grocery bags, construction film and agricultural mulch; and injection molded pails, caps, appliances and toys[8].

With this dependence on plastics, however, there is a great deal of use, an increase in the level of consumption and an increase in the amount of disposal that leads to enormous damage to the environment. It has been argued that plastic is generally a durable material whose durability has caused the problem, since it is considered to be resistant to natural biodegradation processes[9].

In order to reduce the waste disposal of plastics, different methods of recycling and processes that would reuse the material will come to life[10]. In addition, the use of natural resources or bio-based substances to make plastic composites is also making an impact on today's plastic waste dilemma, where the process of replacing the usual synthetic fiber with a natural fiber extracted from different plants is considered [11].

Pineapple is considered to be one of the major fruit crops, and large-scale production also means a large amount of waste. The leaves of the said fruit are often thrown out, and farmers usually have a problem with how to dispose of it. Fiber extracted from pineapple leaves is called Pina, which has useful properties. As stated by Kengkhetkit et al.[12], the fiber that is abundantly available and used very little is pineapple leaf fiber (PALF). In addition to its availability, PALF is also attractive in terms of its mechanical properties, which should be suitable for plastic reinforcement.

This study therefore covers the production of plywood using high-density polyethylene plastic mixed with pineapple leaves and a comparison with type 1 plywood was made. The aspects considered are the properties of pineapple leaves, high density polyethylene and type 1 plywood, the heating of pineapple leaves for the production of fibre, and high density polyethylene, and the molding of high density polyethylene with pineapple fibre.

2. Methodology

2.1. Research Design
A comparative analysis of plywood type 1 made from high density polyethylene plastic chips mixed with dried pineapple leaves. Testing analysis consisting of static bending, screw withdrawal and tensile strength was conducted.

2.2. Subject and Study Side
The Department of Science and Technology – Forest Products Research Development in Los Banos, Laguna, was the study site for this research. In this facility, structural tests will be carried out specifically for the removal of screws, static bending and tensile. They are known to be the standard test facility for woods and particle boards. Subjects for this research include test results from standard type 1 plywood commercially available on the Philippine market and high density polyethylene plastic chips mixed with dried pineapple leaves. Research is a comparative type that uses a t-test because the samples are less than 30.

2.3. Material
Fresh pineapple leaves were collected from vendors in Caloocan City. Gathered leaves were left in the open space to air-dry within 3 weeks. The dried pineapple leaves were cut and ground into smaller pieces with a food processor. As for HDPE Plastic, empty plastic bottles were collected from different households in Metro Manila. Used plastic bottles have been segregated to identify HDPE plastics. HDPE plastics have been cleaned and dried. Plastics have been delivered to a machine shop to be converted into pellets. The authors finished with 630 grams of dried pineapple leaves and 126 grams of HDPE pellets. For the testing process, three 8x4 inches of Plymer were needed. The proportion was
80 percent-20 percent for HDPE pellets and dried pineapple leaves, respectively, for one piece of Plymer (8x4 inches). Proportionately dried pineapple leaves and HDPE have been placed in a tray covered with parchment paper. Melted HDPE with dried pineapple leaves had been placed in a wood mold to form and could hardly be pressed by the use of C-clamp. Within 10-15 minutes, Plymer was left to harden and form within the mold.

2.4. Plymer Laboratory Test
Three tests were carried out, including a screw withdrawal test, a static bending test and a tensile strength test. For the screw-removal test, the screw is driven opposite to the essence of the wood example, leaving at any rate 0.5 inch of the bar uncovered. The base apparatus contains a gap opening, rather than a channel opening, and the purpose of the screw is generally held utilizing a Jacob's sort toss. All tests are conducted at a cross-head removal rate of 0.06 in / min. The explicit properties of the wood being tested and the range of nail and screw details shall determine the requirement for a low or medium power limit and a tabletop or floor standing test machine. For the static bending test, the bending loads are connected to the wood shaft examples by a 3-inch head that measured 2 x 2 x 30 inch for basic examples, or a 1.5-inch that measured 1 x 1 x 16 inch for auxiliary examples, at a steady cross-head uprooting rate. Crosshead dislodging rate is set to 0.10 in / min for key examples and 0.05 in / min for auxiliary examples. The tensile test of wood is directed parallel and opposite to the grain of wood, using both large and small examples.

2.5. Mode of Data Analysis
Samples collected for this research are less than 30, which makes the t-test type applicable. Using the two samples with unequal t-test variances due to the fact that there are two different variables to be tested. The variable 1 is from the plywood sample, while the other variable 2 is from the Plymer sample. The result of the t-test serves as a reliable comparison between the plywood type 1 plywood and the particle board made of high density polyethylene mixed with dried pineapple leaves. The cost benefit analysis was carried out in order to compare the estimated Plymer quantity with the retail prices of 1/4 type 1 ordinary plywood available commercially in the Philippines.

3. Result and Discussion

3.1. Screw Withdrawal
The results of the F-test and T-test for the withdrawal of the screw are shown in Table 1. Based on Table 1, for the screw withdrawal test, the p value is greater than the alpha value, which is to accept the null hypothesis that the mean screw withdrawal value for the screw withdrawal test of commercially available plywood is greater than or equal to the mean screw withdrawal value of Plymer.

| Variable  | Plywood | Plymer | Variable  | Plywood | Plymer |
|-----------|---------|--------|-----------|---------|--------|
| Mean      | 344.3305 | 187.61625 | Mean      | 344.3305 | 187.61625 |
| Variance  | 5e-07   | 3196.121176 | Variance  | 0       | 3196.121176 |
| Observation | 2      | 2       | Observation | 2      | 2       |
| Df        | 1       | 1       | Hypothesized Mean Difference | 0 | |
| F         | 1.5644E-10 |        | Df        | 1       |        |
P(F<=f) One tail 7.96257E-06  
F critical one tail 0.006193959  
P(T<=t) one-tail 0.079501256  
t Critical one-tail 6.313751515

3.2. Static Bending
The results of the F-test and T-test for static bending are shown in Table 2. Based on Table 2, the static bending test resulted in a p value less than alpha that rejects the null hypothesis and accepts the alternative hypothesis that the mean rupture modulus for the static bending test of commercially available plywood is greater than or equal to the mean rupture modulus of Plymer.

| Variable   | Plywood  | Plymer  | Variable   | Plywood  | Plymer  |
|------------|----------|---------|------------|----------|---------|
| Mean       | 14.19014086 | 5.978226292 | Mean       | 14.19015 | 5.978233333 |
| Variance   | 0.342880043 | 1.385426144 | Variance   | 0.342880043 | 1.385426144 |
| Observation| 2        | 3        | Observation| 2        | 3        |
| Df         | 1        | 2        | Pooled     | 1.037910777  |

3.3. Tensile Strength
The results of the F-test and T-test for tensile strength are shown in Table 3. Based on Table 3, the tensile strength concluded that p is less than alpha, which rejects the null hypothesis that the mean tensile strength of commercially available plywood is greater than or equal to the mean tensile strength of Plymer.

| Variable   | Plywood  | Plymer  | Variable   | Plywood  | Plymer  |
|------------|----------|---------|------------|----------|---------|
| Mean       | 17.21758586 | 2.460276222 | Mean       | 17.2176  | 2.46025 |
| Variance   | 3.99856E-10 | 0.137238517 | Variance   | 0        | 0.137235605 |
| Observation| 2        | 2        | Observation| 2        | 2        |
Df 1 1  Hypothesized Mean Difference 0
F 2.91358E-09
P(F<=f) One tail 3.43632E-05
P(T<=t) one tail 0.005649559
F critical one tail 0.006193959
t Critical one tail 6.313751515

3.4. Cost Benefits Analysis

The total cost of the plymer is shown in Table 4. LPG costs PHP 61.18 per kilogram from the retail price of PHP 673.00. With the total amount of PHP 1,264.00, the authors, with the said materials, developed five 8x4 inch pieces of Plymer, considering that the LPG use of La Germania Gas Oven is 16.6 Mj / Hr. 1 kg LPG is 45.26 Mj. Thus, the authors used the prototype in the oven for 3 hours. Total oven energy consumption is 0.37 kg / h. As a result, 1.11 kg of LPG was used for the production of Plymer.

Table 4. Total Cost For Plymer

| MATERIALS       | QUANTITY       | COST (Php) |
|-----------------|----------------|------------|
| HDPE Bottles    |                |            |
| Mold            | 2 pcs. (8x4)   | 200.00     |
| Pineapple Leaves|                |            |
| Parchment Paper | 20 pcs         | 41.00      |
| LPG             | 11 Kg          | 673.00     |
| C-clamp         | 3 pcs.         | 350.00     |
| Total           |                | **Php1,264.00** |

The total cost for 5 piece Plymer is stated in Table 6. Total cost for creating five pieces of 8x4 inch prototype is Php 83.67. For a piece is equivalent to, Php 16.73. Comparing with the ¼ type 1 commercial plywood price with the given dimension of (8x4) feet with the computed cost of one piece of (8x4) feet Plymer. The total cost of Plymer (8x4) feet is equal to PHP 200.76. The cost of 1/4 common plywood ranges from Php 345.00 to Php750 depending on the type of plywood. Thus, among the other commercially available 1/4 plywood, Plymer has the least cost.

Table 5. Total Cost For 5 Pcs Plymer

| MATERIALS       | QUANTITY | COST (Php) |
|-----------------|----------|------------|
| HDPE Bottles    | -        | -          |
| Pineapple Leaves| -        | -          |
| Parchment Paper | 5 pcs    | 10.25      |
| LPG             | 1.2 Kg   | 73.42      |
| TOTAL           |          | **Php83.67** |

Finally, Plymer reduces waste specifically to plastic and pineapple leaves. It also concludes that the Plymer is a viable alternative to commercially available plywood, which not only provides a better result in tensile strength and static bending tests, but costs less than the different plywood currently available on the market.
4. Conclusion

Various types of plastics are currently the most common type of packaging used in industrial products. Using these resources generates non-biodegradable waste that, without the incentive to recycle, can create environmental problems and ultimately affect the human population. This study has been demonstrated by the use of Plymer as a means of recycling such waste and as an alternative to building material as a composite material. The authors would like to promote the process of recycling and developing composites to make the environment cleaner and safer. By comparing Plymer's different properties with Type 1 plywood, it is claimed that only in the screw removal test did the result fail. Both the static bending and tensile strength tests produced favorable results. As a result, with a limited number of tests carried out, there is still a chance of better improvement to further enhance the product in order to be more competitive or equal to the properties of plywood.

5. References

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