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Composite Based Mixed Recycled Plastic with Tropical Wood Dust: Mechanical And Physical Properties

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ABSTRACT

Background: Improper waste disposal is an ongoing problem in Malaysia. It causes flash floods that damage wood furniture because of their long-term exposure to water. **Objective:** This study aims to investigate the fabrication of composites based on the mechanical and physical properties of waste resources. Coupling agents in this composite production increase the compatibility between plastic (hydrophobic properties) and wood dust (hydrophilic properties) to improve the mechanical properties. In this paper, recycled high-density polyethylene plastic was mixed with sawdust and 3 wt.% maleic anhydride as coupling agents. Compounding and hot press were used to produce this composite. **Results:** Tensile, flexural, and water absorption tests were conducted to determine the mechanical and physical properties of the composite. **Conclusion:** The combination of recycled plastic and wood dust with the coupling agent produces a composite with excellent mechanical properties and serves as an alternative to wood polymer composite.

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INTRODUCTION

Every year, the demand for wood resources increases, but the supply of wood continues to decrease and become limited. The production of wood polymer composite (WPC) enables us to use a small amount of timber or to utilize the waste of the timber industry if possible. The composite has better mechanical strength, lower diversity, and increased spread of the stress than solid wood (Abdul Khalil Shawkataly, Rokiah Hashim, 2004). Composite materials have a lower density compared to conventional materials such as iron and aluminum (Altenbach, H., 2004). The specific stiffness property of composite can be compared with conventional alloys.

Composites are fabricated by a conventional plastic processing, such as extrusion and injection molding. In the common extrusion or injection molding, thermoplastic polymer is suitable in the production of polymer composites (Strong A.B., 2006). An additive or filler is added to modify the physical properties and characteristics required by composite materials (Oksman, K., C. Clemons, 1998). Coupling agents (CA) are used to improve the interfacial properties of lignocelluloses and matrix materials. A small amount of CA is used to enhance the surface bonding between wood dust and plastic surfaces (Jin Kuk Kim, Kaushik Pal, 2010). In the production of WPC, incompatible interfacial bonding between sawdust and polymer reduces mechanical strength and ductility caused by the inability of the matrix to transfer the applied stress to the filler (Raj, R.G., B.V. Kokta, 1991).

Experimental Procedure:

In this work, recycled high density polyethylene (rHDPE) was cleaned with water to remove impurities. The plastic bottles were oven-dried at 60 °C for 12 h to remove moisture and crushed into small pieces of ≤6 mm using a plastic granulator machine (model CAS-20F). Wood dust from tropical hardwood was separated using 1 mm mesh to obtain ≤1 mm fiber. The separated wood dust was oven-dried for 24 h at 102 °C until moisture content was between 2% to 3%. The CA, maleic anhydride (MA) with 98.06 g/mol molecular weight, and 51°C to 54 °C melting point were used. WPC was produced with different compositions of rHDPE, sawdust, and CA, as shown in Table 1.

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Table 1: Composition of plastic, wood and CA.

Composition	rHDPE(%)	Sawdust (%)	CA (%)
100	100	-	-
60	60	40	3
70	70	30	3
80	80	20	3

RESULT AND DISCUSSION

In this study, tensile, flexural, and water absorption tests were implemented to identify the mechanical and physical properties of the composite. The experiments were performed using three different samples to obtain their average.

Tensile Test:

Figure 1 shows the ultimate tensile strength of wood plastic composite. The graph indicates that the ultimate tensile strength (UTS) of WPC is between 19.231 Mpa and 22.782 Mpa. Overall, the UTS increases as the plastic percentage increases, and it slightly decreases for 70% rHDPE and 30% wood dust. Although this composition indicates the lowest strength value, its strength is still higher than 100% rHDPE plastic. Overall, the UTS increases with the increase in rHDPE and with the decrease in wood dust percentage [9].

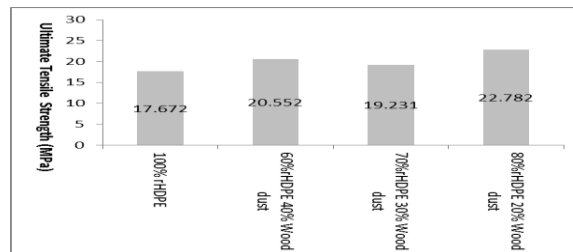
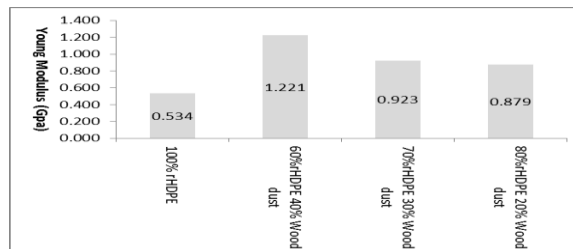
**Fig. 1:** UTS for WPC with different compositions.

Figure 2 shows the results of the Young's modulus obtained from the tensile test. WPC, which has a small amount of rHDPE plastic, has 64.61% greater strength than 100% rHDPE. The overall value of the Young's modulus decreases as the percentage of recycled plastic increases in the production of WPC (Raj, R.G., B.V. Kokta, 1991).

**Fig. 2:** Young's modulus of WPC with different compositions.

Flexural Test:

The flexural strength of wood plastic composites, as shown in Figure 3, is between 44.144 MPa and 58.645 MPa. These values of flexural strength decrease as rHDPE increases and the amount of sawdust decreases (Ashori, A., 2008).

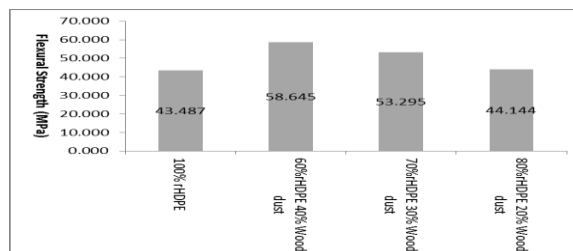
**Fig. 3:** Flexural strength of WPC with different compositions.

Figure 4 shows the results of the elasticity modulus obtained from the flexural test. The elasticity modulus of WPC is between 0.512 GPa and 1.130 GPa. The elastic modulus value of WPC decreases with the decrease in wood dust percentage unlike that in 100% rHDPE plastic (Ashori, A., 2008).

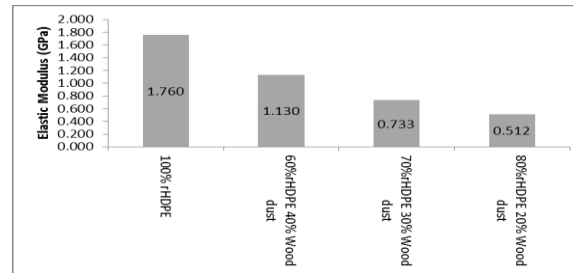


Fig. 4: Elastic modulus of WPC with different compositions.

Water Absorption:

The percentage of water absorption is shown in Figure 5. In the water absorption test, the WPC was immersed in water for 2 h and 24 h. A minimal percent of wood dust can absorb less water compared with a high percentage. Therefore, the presence of wood dust as an agent helps the composite to absorb more water (Stokke, D.D., D.J. Gardner, 2003).

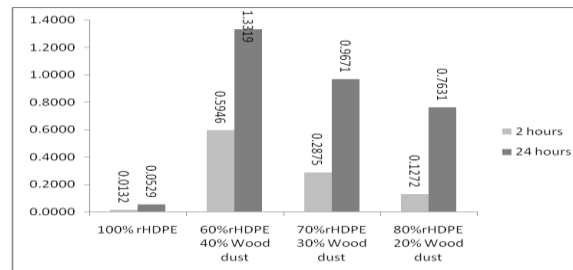


Fig. 5: Percentage of water absorption of WPC for 2 h and 24 h after water immersion.

Figure 6 shows the percentage of swelling of the composites after the water absorption test. WPC, which has a small percentage of wood dust, exhibits less swelling.

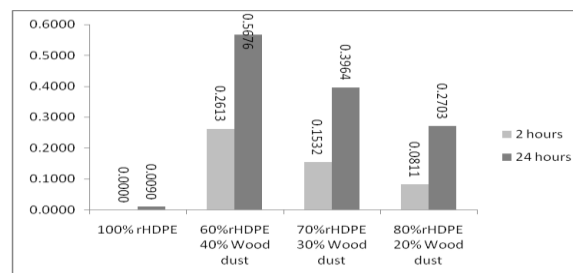


Fig. 6: Percentages of swelling of WPC for 2 h and 24 h after water immersion.

Optical Microscopic Scanning:

The microstructure of the WPC composite was observed using an optical microscope, which enables the identification of compatibility between plastic and sawdust. Figure 7 shows the effect of CA on the surface of plastic and sawdust in the yellow area. The microstructure also indicates that the interfaces of both materials are not fully fixed (Stokke, D.D., D.J. Gardner, 2003).

Conclusion:

Compounding and hot press methods successfully produced a composite with excellent mechanical and physical properties. Hot press produced a composite with greater tensile strength than flexural strength. WPC has high mechanical properties with the ultimate tensile strength increase by 28.92% of the composition 80% rHDPE and 20% wood dust. However, the composition should be obtained to determine the final application of

the product. This composite overcame the water damage in furniture because of the ability of the composite to absorb less water.

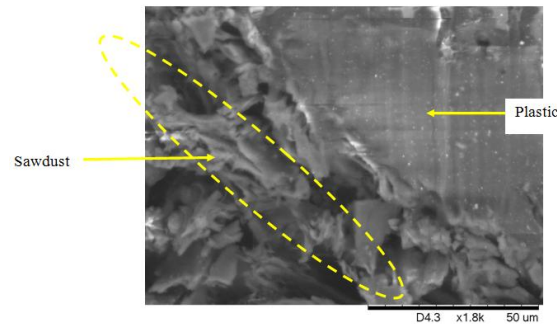


Fig. 7: Interfaces of plastic and wood dust.

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