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European Journal of Applied Engineering and Scientific Research, 2017, 5 (1): 28-33

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ISSN:2278-0041

Dimensional Stability and Mechanical Properties of Wood Plastic Composites Produced from Sawdust of *Anogeissus leiocarpus* (Ayin) with Recycled Polyethylene Teraphthalate (PET) Chips

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ABSTRACT

Wood Plastic Composite panels were produced using a locally fabricated extruding machine at a temperature of about 170˚C-200˚C. the Sawdust of Anogeissus leiocarpus(Ayin) and Recycled Polyethylene Teraphthalate (PET) Chips were mixed in the ratio 1:1 to 1:5 and densities of 770.58 kg/mm^3, 888.65 kg/mm^3, 1,114.71 kg/mm^3, 1,117.58 and 1, 141.84 kg/mm^3 respectively. The quantity of recycled polyethylene teraphthalate (PET) Chips and sawdust used in the panels production were later weighed as 10 g of wood, 90 g of plastic; 8 g of wood, 92 g of plastic; 6 g of wood, 94 g of plastic; 4 g of wood, 96 g of plastic and 2 g of wood, 98 g of plastic. The components were mixed and fed into the extruder where they were melted, blended and consolidated. The material was then extruded through a die into a mould of dimensions 3.2 mm × 12.7 mm × 125 mm, 12.7 mm × 12.7 mm × 25.4 mm based on ASTM D 790 and ASTM D 695 for both flexural modulus and compression tests. It was observed that the test sample with wood-plastic ratio 1:5 had the highest Impact Strength, MOR and MOE values of 42.33 J/m^2, 3.86 N/mm^2 and 642.00 N/mm^2 respectively. Panels produced from mixing ratio 1:5 had the lowest values of 0.00 and 1.10% for both water absorption and thickness swelling respectively, while the specific gravity and density for the panel with mixing ratio 1:1 is the lowest with values 0.77 and 770.58 kg/m^3 respectively, after 2 days or 48 hours immersion test. Analysis of variance showed that there were significant differences ($Pr < 0.05$) in all the physical and strength properties tests.

Keywords: Impact strength, Specific gravity, Modulus of elasticity, Modulus of rupture, Thickness swelling, Water absorption, Density, Extruding machine

INTRODUCTION

Wood Plastic Composite is a material made from combination of wood and plastic wastes mixed in the right proportion and extruded inside a specially designed extruding machine at temperature of about 170˚C - 200˚C [1].

Wood plastic composite has a lot advantages over wood which include high durability, relatively high strength and stiffness, low maintenance cost, affordable prices among others [1]. The term strength applied to a material such as WPC refers to its ability to resist external forces tending to change its shape [2]. Also, according to Nurudeen et al. [3], the physical and mechanical properties, which are present in wood plastic composite, decide purpose to which WPC can be sustainably put. During utilization, when external forces such as heavy loads are applied to a given sample of wood plastic composite, internal forces generated within the WPC which resist changes size and alteration in shape. These forces are called stress. The changes in size and shape are known as deformations, strains. If the stress is small, the deformation is small, and when the stress is removed there is a complete or partial recovery to the original size and shape, depending on the elasticity of the wood plastic composite [4]. The equilibrium condition at which every stress applied has a noticeable corresponding strain or deformation on the wood plastic composite; this point is called the limit of proportionality. Beyond this point of proportionality, deformation or strain increases rapidly than the stress applied, when the stress is removed, recovery is not complete, and that is, the initial shape, size and orientation of the wood plastic composite cannot be regained. If the stress applied exceeds the forces of cohesion between the tissues a rupture or failure occurs [5].

MATERIALS AND METHODS

The study was carried out at the Agricultural and Environmental Engineering Department of Faculty of Technology, University of Ibadan, Ibadan, Nigeria. Saw dust of Anogeissus leiocarpus were collected from the circular saw machine at Bodija Market, Ibadan, Oyo State. Soaked sawdust was later air-dried and subsequently dried in an oven at 102 ± 2°C for 12 hours to a percentage moisture content of about 5% and sieved with 1.00 mm wire mesh sieve to remove the impurities and oversized particles wire mesh. Polyethylene teraphthalate (recycled plastic container) used for the study was collected from waste management company in University of Ibadan, Oyo State, Nigeria. The quantity of PET and saw dust used in the production of WPCs was weighed to 10 g of wood, 90 g of plastic; 8 g of wood, 92 g of plastic; 6 g of wood, 94 g of plastic; 4 g of wood, 96 g of plastic and 2 g of wood, 98 g of plastic. A locally fabricated extruding machine was then used to extrude the mixture at temperature of about 270˚C into WPC panels. Extruding processes begun with collection of wood and plastic wastes, followed by processing of sawdust by soaking into two drums for about 96 hours (4 days) in other to eliminate the water soluble extractives. A locally designed extruding machine was connected to a power source which was left for about three hours in order to allow the heater unit of the machine in attaining temperature of about 170˚C - 200˚C. This is necessary to melt the mixture into a molten form and later passed through a die which was collected in locally fabricated moulds of dimensions 3. mm × 12.7 mm × 125 mm, 12.7 mm × 12.7 mm × 25.4 mm based on ASTM D 790 and ASTM D 695 for both flexural modulus and compression tests. The physical and mechanical properties carried out were water absorption, thickness swelling, density, specific gravity, Impact strength, modulus of elasticity and modulus of rupture respectively. The materials and equipment used in carrying out physical and strength properties include; Potentiometer, Hatt-Turner Impact machine, electronic weighing balance, ruler, hacksaw, digital vernier calliper, plastic bucket, cardboard among others. The different parameters were calculated using the equation [6] Molten WPCs formed were later allowed to cool gradually and pressed at the pressing section with a cold press. It was then conditioned for about 24 hours. Finished wood plastic composites were later transferred to cross-cutting machine to trim and then sanded with a sanding machine to make coating of material easy and possible. The modulus of elasticity (MOE) and modulus of rupture (MOR) was calculated by the formulas:

$$MOE = \frac{PL^3}{4\Delta bd^3} \text{----------Equation1.}$$

$$MOR = \frac{3PL}{2bd^2} \text{---------- Equation 2.}$$

Where; P = Load in (Newton), L = Span in (mm), b = Width in (mm), d = Depth in (mm),

Δ = Change in deflection. The S.I. unit of MOE is N/mm^2. Specific gravity was calculated by the formula:

$$S.G \frac{Density\ of\ WPC}{Density\ of\ water} \text{----------Equation 3.}$$

Water Absorption is calculated in percentage according to the standard for composites using the formula;

$$A(\%) = \frac{W_2\text{-}W_1 \times 100}{W_1} \text{---------- Equation 4.}$$

Where; A = Water Absorption in (%), W_1 = Weight of WPC before soaking in (mm),

W_2 = Weight of WPC after soaking in (mm). Thickness swelling is calculated in percentage according to the standard for composites using the formula;

$$G(\%) = \frac{T_2 - T_1 \times 100}{T_1} \text{---------- Equation 5.}$$

Where; G = Thickness swelling in (%), T_1 = Thickness before soaking in (mm),

T_2 = Thickness after soaking in (mm). Density is calculated by the formula;

$$Density(\rho) = \frac{weight\ by\ mass\ of\ WPC}{Volume\ of\ the\ test\ sample} \text{----------Equation 6.}$$

The unit is kg/m^3

RESULTS AND DISCUSSIONS

Table 1: Physical and mechanical properties of WPC

Wood Plastic Ratio	Water Absorption (%)	Thickness Swelling (%)	Density (kgm^{-3})	Specific Gravity	Impact Strength h(J/m^2)	MOE (N/mm^2)	MOR (N/mm^2)
01:05	0	1.1	1141.84	1.14	42.33	642	3.86
01:04	0.54	1.3	1117.58	1.12	28.22	535	3.86
01:03	2.25	1.91	1114.71	1.11	28.22	482	2.89
01:02	5	2.4	888.65	0.89	14.11	321	1.93
01:01	12.5	4.41	770.58	0.77	14.11	201	1.81
Mean	4.06	2.22	852.56	0.83	25.4	436	2.87

Physical properties

Water absorption

It was observed that the water absorption of WPC tends to increase as the percentage of the wood content increases. The values for water absorption for densities 770.58, 888.65, 1114.71, 1117.58 and 1141.84 kg/mm^3 respectively after 48 hours immersion were presented in Table 1 and Figure 1. The values were 0.00, 0.54, 2.25, 5.00 and 12.50% respectively. 12.50% is the highest water absorption percentage for wood-plastic ratio 1:1, followed by 5.00% for 1:2 and 1:5 has the lowest with value 0.00% as found in Figure 1. The variation in water absorption also conforms to Donaldson and Frankland [7] submission that when water enters the cell wall, it occupies spaces between the micro-fibrils, so if the micro-fibril angle is large, there is more swelling along the grain as water is added. The reverse applies as water is removed from the cells. This property confirms effectiveness of WPC for exterior use. The analysis of variance shows that the water absorption is significant.

Thickness swelling

The result from Table 1 shows that the thickness swelling of WPC tends to increase as the percentage of the wood content increases. The values for thickness swelling for densities 770.58, 888.65, 1114.71, 1117.58 and 1141.84 kg/mm^3 respectively after 48 hours immersion were presented in Figure 2. The values were 1.10, 1.30, 1.91, 2.40 and 4.41% respectively. 4.41% is the highest water absorption percentage for wood-plastic ratio 1:1, followed by 2.40% for 1:2 and 1:5 has the lowest with value 1.10% as found in Figure 2. The variation in thickness swelling conforms to Donaldson and Frankland [7] submission that when water enters the cell wall, it occupies spaces between the micro-fibrils, so if the micro-fibril angle is large, there is more swelling along the grain as water is added. The reverse applies as water is removed from the cells. This property confirms effectiveness of WPC for exterior use. The analysis of variance shows that the thickness swelling is significant.

Specific gravity

The results of specific gravity decreases slightly with increase in wood content. 1.14 is the highest specific gravity for wood-plastic ratio 1:5, followed by 1.12 for 1:4 and 1:1 has the lowest with value 0.77 as found in Figure 3. Therefore, as the density and wood/ plastic ratio increases, specific gravity also increases. The study reveals that as the plastic content in the composites increases According to Winandy et al. [8], late wood versus early wood cell wall thickness variations, and the prevalence of fibres, ray and density of plastic affects the anatomical properties of WPC. The analysis of variance shows that the specific gravity is significant.

Mechanical properties

Impact strength

Also, it was observed that the impact bending strength of WPC tends to decrease as the wood content increases. The value ranges from 14.11 to 42.33 J/m^2 with mean 25.40 J/m^2. 1:5 is the highest (42.33 J/m^2), followed by 1:4 and 1:3 (28.22 J/m^2) each and the least is 1:1 and 1:2 (14.11 J/m^2) each as shown in Figure 4. The variations in the impact bending strength agrees with [9] submission that impact bending varies as a result of change in density. The analysis of variance shows that the impact bending is significant.

Modulus of elasticity

Modulus of elasticity ranges from 201.00 to 642.00 N/mm^2 with mean 436.00 N/mm^2 which shows that WPC has a consistent trend in MOE with 1:5 being the highest, followed by 1:4 and 1:1 is the lowest as shown in Figure 5. This implies that, MOE decreases as the wood content in WPC increases. The stiffness determined for both formulations using this method is within ten percent of results from previous research in determining apparent modulus of elasticity for WPC material [10]. The analysis of variance shows that the MOE is significant.

Modulus of rupture

It was also observed that MOR of WPC tends to decrease as the wood content increases and it ranges from 1.81 to 3.86 N/mm^2 with 1:5 and1:4 being the highest of 3.86 N/mm^2 each, while the least is 1:1 of 1.81 N/mm^2 as demonstrated in Figure 6. Previous comparisons of modulus of rupture (MOR) showed similar differences between coupon and near full-size section test results [11]. The analysis of variance reveals that the Modulus of Rupture is significant.

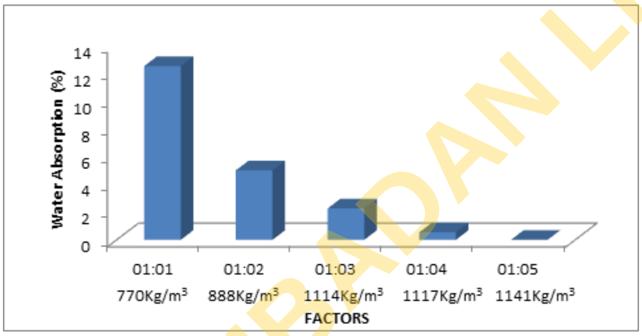

Figure 1: Effect of densities and wood-plastic ratio on water absorption of WPC after 48 hours water immersion test

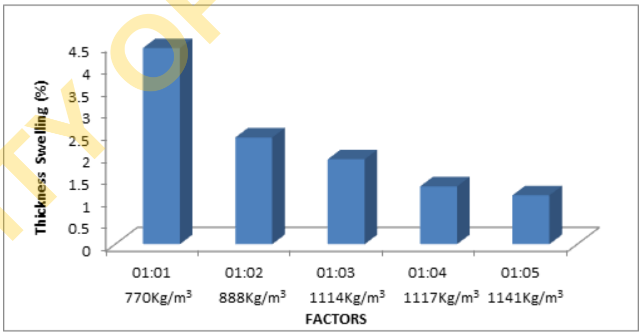

Figure 2: Effect of densities and wood-plastic ratio on thickness swelling of WPC after 48 hours water immersion test

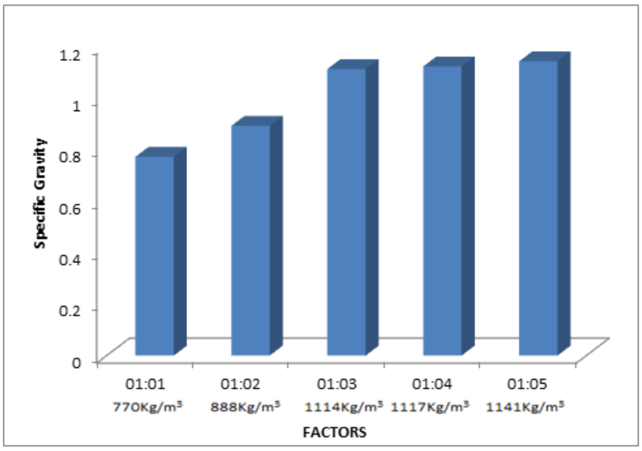

Figure 3: Effect of densities and mixing ratios on specific gravity of WPC after 48 hours of water immersion test

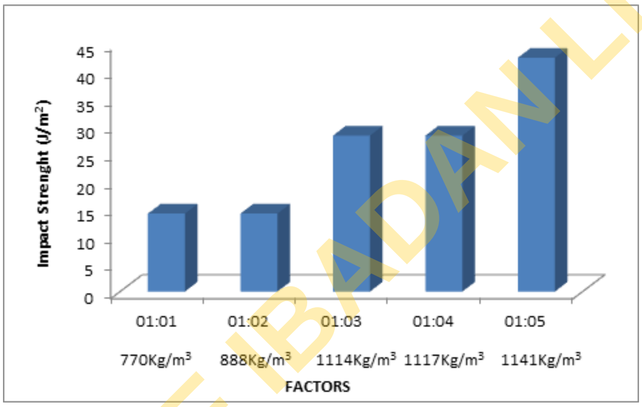

Figure 4: Effect of densities and mixing ratios on impact strength of WPC after 48 hours of water immersion test

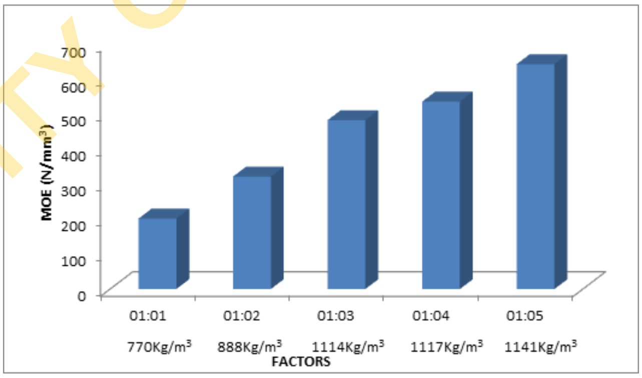

Figure 5: Effect of densities and wood-plastic ratio on MOE of WPC after 48 hours of water immersion test

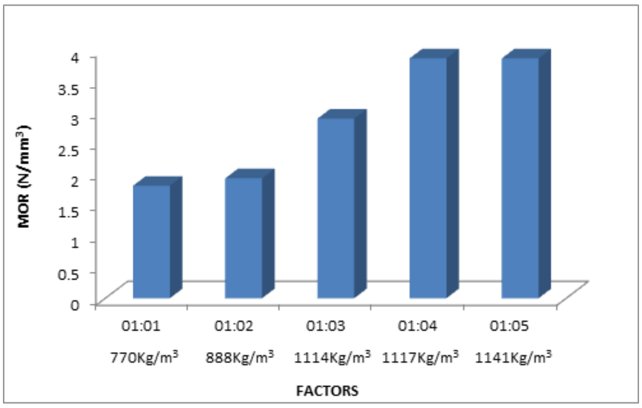

Figure 6: Effect of densities and wood-plastic ratio on MOR of WPC after 48 hours of water immersion test

CONCLUSION

Based on the research findings of this work, it can be finally concluded that the higher the wood content in the wood plastic composite, the better is the strength properties of the board produced and the lower the wood content in the product, the higher the dimensional stability of the wood plastic composite boards which suggests the effectiveness of WPC boards for exterior uses. Also, density has considerable effects on both the strength and dimensional stability of the board produced.

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