

Characteristics of Tropical Wood Species filled with High Density Polyethylene Composites

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ABSTRACT

The influence of wood species on the physical and mechanical properties of wood plastic composites (WPC) produced from selected tropical wood species were investigated. The composites were produced from *Cordia milenii*, *Triplochyton scleroxylon* and *Nesogordonia papaverifera* at 60/40 plastic/wood mixing proportions. Compression molding method was employed in the production of the composites and the physical properties (water absorption and thickness swelling) and strength properties (compressive, shear and flexural strength) of the WPC were determined in accordance with British Standard Methods. Results showed that the strength properties ranged from 23.44 to 29.54 N/mm² for compressive strength, 19.66 to 29.27 N/mm² for shear strength, 3454.68 to 4774.93 N/mm² for Modulus of Elasticity (MOE) and 13.97 to 23.72 N/mm² for Modulus of Rupture (MOR). Water absorbed was under 8.44% while the thickness swelling was not more than 0.09%. *C. millenii*. and *T. scleroxylon*. were more dimensionally stable while *N. papaverifera* had the best performance in terms of strengths properties. The results also showed that wood species had great influence on the properties of wood plastic composites. The comparative study showed that Wood Plastic Composites (WPC) are better in terms of compressive and shear strength and more stable dimensionally but lower in flexural MOE than solid wood.

Keywords: Wood species, Plastic Composite, strength stability,

INTRODUCTION

The performance of Wood Plastic Composites is influenced by the type of components, the amount of each component, and the technology used to manufacture the product. According to Youngquist, choice of plastics, wood, and additives, and the amount of each component in wood plastic composite as well as processing parameters will

drastically impact the final products [1].

Wood Plastic Composites production has focused on the use of few selected wood species [2]. The influence of wood species on the melt flow index, specific gravity, mold shrinkage, heat deflection, impact energy, tensile, and flexural properties of WPC as well as the microstructure of wood and mechanical adhesion to plastic

has been reported [3]. The effects of wood species on water sorption, biodegradation, weathering and metal corrosion of WPC have been studied [2,4,5]. Although there are many studies on the effect of temperate wood species on the WPC properties, there is little information on the effects of tropical wood species. Most researches using wood flour as filler for thermoplastics have been conducted with a limited number of wood species. In this study, the influence of tropical wood species namely, *Cordia millenii*, *Triplochyton scleroxylon* and *Nesogordonia papaverifera*

MATERIALS AND METHODS

Materials

The three tropical wood species, *C. millenii* (d = 480), *T. scleroxylon* (d = 380) and *N. papaverifera* (d = 780) where d = density were obtained from a wood processing factory in Akure, Ondo State while High Density Poly Ethylene (HDPE) with density 0.95 ~ 0.97 g/cm³, melting point of 164 ± 3°C and Melt Flow Index of 0.3 g/min. was obtained from Nulec factory in Sagamu, Ogun State.

Methods

The WPC were produced using compression molding techniques. The composites were produced using 60/40 plastic/wood mixing proportions. Each of the wood species and HDPE were mixed using an in house heated roll mill, with a mixing temperature of 180 °C at about 20

min. The processing condition involved melting the HDPE in the heated roll-mill for 5 min. Well-dried wood flour were then added gradually, until all of the particles were perfectly embedded into the HDPE matrix. The compounded specimens were discharged from the mixing instrument, and compression moulded immediately in an electrically heated hydraulic press, using a rectangular mould of dimension 220 mm X 105 mm X 22 mm, a pressure of 4 N/mm² was applied. After cooling, the WPC were machined and edge trimmed to dimension of 200 mm × 100 mm × 20 mm.

WPC properties testing

The properties of the WPC were tested according to the British Standard Institute Methods (BSI) [6]. The physical properties determined were: observed density (OD), water absorption (WA) and thickness swelling (TS) and the mechanical properties were: compression, shear strength and Modulus of rupture (MOR) and flexural modulus of elasticity (MOE). Each test was conducted using three numbers of observations making a total of 45 WPC samples and 45 solid wood samples. The data were analysed using ANOVA and Duncan's New Multiple.

RESULTS

The effect of wood species on the properties of composites

The mean values for all the WPC properties are tabulated in Table 1. The

result showed that wood species significantly affect most of the properties of the WPC.

Density

The predetermined density was 900 Kg/m³, but the measured densities of the composites ranged between 1000 and 1240 Kg/m³ (Table 1). The lowest density being 1099.9 Kg/m³ was found in composites made from wood species of *T. scleroxylon* (density of 380 Kg/m³) whereas the highest density 1239.8 Kg/m³ was found in composites made from wood species of *N. papaverifera* with density 780 Kg/m³. These results compared favourably with those reported in literature [7].

Sorption properties (Thickness swelling (TS) and water absorption (WA))

The thickness-swelling of composite ranges between 0.01 % and 0.09 % while water absorption ranges between 0.91 % and 8.4 %. (Table 1). *Nesogordonia papaverifera* had the highest WA where *C. milenii* had the lowest WA. In the 24-hour water-soak test, *N. papaverifera* absorbed as much as 8.44 % water, whereas those of *T. scleroxylon* and *C. milenii* absorbed only 0.93 % and 0.9 % respectively.

Compressive and Shear strength

The values obtained for compressive strength of wood-filled HDPE composite ranged from 24.41 N/mm² to 28.61 N/mm², while the values for shear strength ranged from 21.69 N/mm² to

27.99 N/mm² (Table 2). *Nesogordonia papaverifera* with highest board density (1239.78 kg/m³) had the highest compressive and shear strength of 28.61 N/mm² and 27.99 N/mm² respectively while *T. scleroxylon* with the lowest board density (1099.89 kg/m³) had the lowest of 24.41 N/mm² and 21.69 N/mm² respectively. Compressive strength showed a strong relationship with wood density ($R = 0.99$ and $R^2 = 0.99$), shear strength too had a strong relationship with wood density ($R = 1.00$ and $R^2 = 0.999$).

Flexural MOE and MOR

Strong relationships were found between wood density and the MOR of their respective WPC ($R = 0.99$ and $R^2 = 0.98$) as well as MOE ($R = 0.98$ and $R^2 = 0.96$). MOR and MOE increased with increase in wood density. Significant differences were observed in the MOR and MOE of the WPC from the three wood species. The Duncan Multiple Range Test (DMRT) showed that the MOR and MOE of *N. papaverifera* based WPC were significantly high compared to the WPC produced from *T. scleroxylon* and *C. millenii*.

Comparing WPC with Solid wood

The compressive and shear strength showed that WPC is superior to their corresponding solid wood (Table 1). The results showed that the flexural strength of WPC is less than the flexural strength of the solid wood (Table 2).

Discussion

Influence of Wood Species on the Physical and Mechanical Properties of WPC

Observed Density

Significant difference was observed in the density of the WPC from the three wood species. This may be as a result of the densities of the wood species used and the incorporation of plastic into the wood fibre matrix.

Sorption properties

From the result (Table 1), it was noticed that WPC from *N. papaverifera* had the highest water absorption (WA) (8.44%) and thickness swelling (TS) (0.09 %). There was no significant difference in TS between *C. milenii* and *T. scleroxylon*. Although, *N. papaverifera* had the highest water absorption (WA) (8.44%), this is relatively low to WA of solid wood which can be up to 60% and above. Hence, all the WPC had low WA. The result showed that sorption properties of WPC were greatly influenced by the species of wood. Duncan Multiple Range Test (DMRT) shows that *N. papaverifera*-based WPC significantly differed in WA and TS but TS of *T. scleroxylon* and *C. milenii* were not different. This result corroborated the findings of Shuie *et. al.* [7].

Compressive and shear strength

The compressive and shear strength are, generally, related to wood species density [9]. There was an increase in the compressive and shear strength as the

wood density increases. It is expected that the WPC from *C. millenii* and *N. papaverifera* will have high compressive and shear strength due to their densities as well as the incorporation of plastic into the WPC because the plastic component is to further increase the resistance against compressive and shearing forces compared to wood. The DMRT showed that there were significant differences ($p \geq 0.05$) in both the compressive and shear strength of WPC produced from the three wood species used.

Flexural moduli of rupture and elasticity

Both MOR and MOE increased linearly with increase in wood species density as well as WPC actual densities. Shuie *et al.*, [7] and Peng and Hwang [8] got similar results. WPC produced from *N. papaverifera* had the highest MOR and MOE (Fig. 4) while *T. scleroxylon* had the lowest. Strong relationships were found between wood density and the MOR of their respective WPC ($R = 0.99$ and $R^2 = 0.98$) as well as MOE ($R = 0.98$ and $R^2 = 0.96$). The MOR and MOE increased with increase in wood density.

Comparing WPC with Solid wood

The comparative study shows that compressive and shear strength of WPC is superior to their corresponding solid wood (Table 1) but the flexural strength of WPC is less than the flexural strength of the solid wood (Table 2). This finding was in contrast to the observation made by Nour El-Din [10] where wood plastic

composites outperformed conventional wood regarding their mechanical properties.

Conclusion

The results of the preliminary work on the three tropical wood species show that wood species have different effects on the properties of the WPC. The strength properties and dimension stability of the

composite are higher than that of commercial solid wood species but in terms of flexural MOE, WPC is inferior to solid wood. Further research will be made on the other in-service performance attributes, such as biological degradability and weathering characteristics of WPC from tropical wood species.

Table 1: Properties of wood-filled HDPE produced from different wood species

Source of Variation	Density (Kg/m ³)	T.S (%)	W.A (%)	Compr. (N/mm ²)	Shear (N/mm ²)	MOE (N/mm ²)	MOR (N/mm ²)
<i>T. scleroxylon</i>	1099.89 ^a	0.01 ^{ab}	0.93 ^{ab}	24.41 ^a	21.69 ^a	3877.12 ^b	16.08 ^b
<i>C.milenii</i>	1189.56 ^b	0.01 ^a	0.91 ^a	25.89 ^b	23.38 ^b	3824.43 ^a	14.84 ^a
<i>N.papaverifera</i>	1239.78 ^c	0.09 ^c	8.44 ^c	28.61 ^c	27.99 ^c	4421.97 ^c	23.72 ^c

Means with the same superscripts vertically are not significantly different at $p \leq 0.05$

Table 2: Comparison of solid wood with their respective WPC

Wood species	Density (Kg/m ³)	Compr. (N/mm ²)	Shear (N/mm ²)	MOE (N/mm ²)	MOR (N/mm ²)
<i>T. scleroxylon</i> WPC	1099.89 ± 1.0	24.41 ± 0.19	21.69 ± 0.31	3877.12 ± 35.09	16.08 ± 0.44
<i>C.milenii</i> WPC	1189.56 ± 3.6	25.89 ± 0.05	23.38 ± 0.47	3824.43 ± 21.14	14.84 ± 0.59
<i>N.papaverifera</i> WPC	1239.78 ± 3.8	28.61 ± 0.5	27.99 ± 0.65	4421.97 ± 34.41	23.72 ± 0.29
<i>T. scleroxylon</i> S.W	380 ± 0.1	9.15 ± 0.05	13.72 ± 0.21	5041 ± 0.1	71.02 ± 0.05
<i>C.milenii</i> S.W	480 ± 0.05	9.99 ± 0.05	14.74 ± 0.13	5331 ± 0.05	79.46 ± 0.11
<i>N.papaverifera</i> S.W	720	13.84 ± 0.01	20.84 ± 0.01	9781	101.64 ± 0.93

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