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Selected Properties of Wood Polymer Cement Composites of *Tectona grandis*

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ABSTRACT

The indiscriminate disposal of wood waste and discarded polystyrene foams used as packaging are sources of environmental pollution. Production of composite products from these items could help contain this menace. It is necessary that some important properties of such composite products be adequately tested and ascertained to inspire confidence for specification and general use. Therefore, wood polymer cement composites were produced from mixtures of particles of Tectona grandis, polystyrene and cement in wood: cement and polystyrene ratios of 1:4:0.5; 1:4:1 and 1:4:1.5. The fabricated composites were cured at room temperature and tested for flexural strength and water sorption properties. The results obtained revealed that the composites had low strength values (3.3 – 3.8 N/mm^2), moderate dimensional stability (10.3 - 34.7%) in comparison with 3.9 N/mm^2 and 10.9 – 16.6% obtained for the control experiments. These items can suitably be used as indoor insulating components in building construction. Water pre-treatment of the wood particles and incorporation of polystyrene did not enhance the flexural strength and the sorption properties of the composites.

Keywords: Wood-polymer cement composites, *Tectona grandis*, polystyrene, pre-treatment

1. INTRODUCTION

Cement Bonded Composites (CBCs) are moulded or compressed blocks and /or panels containing approximately 30-70% by weight of wood or other lignocellulosics in various forms and 70-30% cement. They are low-cost building components being used in the construction industries around the world for interior / exterior wall cladding, highway sound barriers, pre-cast building members etc. Their use in building construction is due to their admirable inherent properties such as excellent sound absorption, fire resistance, thermal insulation as well as sound structural performance [1, 2, 3].

Cement composites have also been used for the full construction of schools, theatres, hospitals and residential homes in many countries in North and Central America and Europe [4, 5] and are currently being investigated as alternative non conventional construction materials in developing countries like Nigeria [6, 7, 8].

However, despite the numerous admirable properties of cement-based composites, the incompatibility between the lignocellulosics and cement binder hinders the development of new CBCs products. Therefore, pre-treatment measures such as soaking in water for 30 – 60 minutes have been devised to remove inhibitory substances that hamper the formation of strong crystalline bonds [3, 9, 10]. Also, CBCs are susceptible to inordinate water absorption and dimensional instability. Therefore, their use outdoors is sometimes limited. The incorporation of polystyrene, a polymer of styrene which is impervious to water may be a means of curtailing this setback. This is more so since wood composites bonded with polystyrene were reported to have moderate strength (4.9 – 32.0 N/mm^2) and sorption properties (2.2 – 19.6%) which can be integrated into low cost building components adapted for interior and exterior uses [11, 12, 13].

Also, deployment of polystyrene and wood waste in composite production could be a means of containing the environmental pollution caused by the discarded polystyrene foams used as packaging and the wood waste generated in the wood mills. Moreover, the paucity of information on properties of polystyrene based composites mixed with cement is a challenge. Therefore, this work examined the effects of polystyrene incorporation on the strength and water absorption characteristics of wood polymer cement composites made form particles of Tectona grandis (Teak) wood.

2. MATERIALS AND METHODS

2.1 Board Formation and Testing

Particles of Teak woods (Tectona grandis) obtained from a local sawmill in Ibadan, Oyo state, Nigeria were air dried for 2 weeks to 10% moisture content and sieved. The particles passing through 4.75mm sieve were collected and used for composites production. Prior to board formation, some particles of Teak wood were soaked in tap water for 30 minutes, drained and mixed with locally sourced Portland cement (32.5R) and molten polystyrene at water to cement ratio of 0.4. Cement composites were manufacture in five replicates in accordance with the procedures adapted from Olorunnisola [8] in wood: cement and polystyrene ratios of 1:4:0.5; 1:4:1 and 1:4:1.5.

The composites were de-moulded and cured at room temperature of 25±2 ◦C and relative humidity of 65±5% for 28 days. Densities of the composites were then computed as the ratio of mass to the volume while samples of the fabricated composites were subjected to 3-point bending test loaded perpendicular to the direction of casting on a 100kN capacity servo-hydraulic Universal Testing Machine (UTM) at a cross-head speed of 1 mm/min. Samples for the water absorption test (WA) were completely submerged horizontally in tap water maintained at room temperature. Water absorption after 2, 24 and 48 h, respectively, were calculated from the increase in weight of the specimen during submersion. Data obtained were subjected to statistical analyses (Duncan's) at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Density and Flexural Strength

The results of the density and flexural tests are shown in Table 1. As shown, the densities ranged from 934.8 to 1340.4kg/m^3 indicating that the composites generally had high densities. Increase in polymer content and cold water soak did not enhance the densities of the composites. This may suggest that the inclusion of polystyrene and pre-treatment with water did not result in good interfacial bonding between particles of T. grandis and cement. This observation may possibly suggest that incompatibility existed between the wood particles, molten polystyrene and cement during production. Statistical analyses (Duncan's range test) revealed that the polymer content and water soak treatment significantly ($p< 0.05$) affected the density of the composites (Table 2). As shown in Table 1, the moduli of rupture and elasticity (MORs and MOEs) of the composites were between 3.3 and 3.9 N/mm^2 and 1050.2 - 4052.8 N/mm^2 respectively. The values of the MORs were low in comparison with those obtained for wood cement composites (4.0 – 24.0N/mm^2) [4, 14, 15].

Table 1: Densities and Flexural Properties of T. grandis Composites

Polymer Content / Treatment	Density (kg/m^3)	MOR (N/mm^2)	MOE (N/mm^2)
Control (None)	1340.4^a(14.44)	3.9^a(0.18)	2650.4^b(87.21)
10%	1169.5^{cd}(13.08)	3.7^{ab}(0.26)	4052.8^a(42.91)
20%	1136.0^d(13.24)	3.8^{ab}(0.11)	2247.8^{bc}(69.90)
30%	947.5^f(12.26)	3.4^{cd}(0.09)	1759.1^c(11.19)
Water Pre-treatment	Density (kg/m^3)	MOR (N/mm^2)	MOE (N/mm^2)
None	1180.6^{bc}(10.7)	3.6^{abc}(0.04)	1904.7^c(30.25)
10%	1075.3^e(13.0)	3.3^d(0.41)	1050.2^d(12.08)
20%	1212.7^b(7.53)	3.6^{abc}(0.20)	3830.5^a(23.24)
30%	934.8^f(14.8)	3.5^{bcd}(0.06)	1832.0^c(27.56)

* Means with the same letters and columns are not significantly different

Table 2: Duncan's Range Test of the Effects of Polymer Content and Pre-treatment on the Density and Flexural Properties of T. grandis Composites

Variable	Density (kg/m³)	MOR (N/mm²)	MOE (N/mm²)
Polymer Content			
Control (None)	1260.5[a](19.71)	3.7[a](0.20)	2277.5[b](50.17)
10%	1122.4[c](17.13)	3.5[b](0.39)	2551.5[b](80.56)
20%	1174.4[b](20.18)	3.7[a](0.16)	3039.2[a](65.23)
30%	941.2[d](25.44)	3.4[b](0.09)	1795.5[b](75.23)
Pre-treatment			
None	2677.5[a](84.56)	3.7[a](0.24)	1148.3[a](36.10)
Cold Water	2154.3[b](57.62)	3.5[b](0.25)	1100.8[b](21.38)

* Means with the same letters and columns are not significantly different
Standard deviation in parentheses

What this implies is that the composites had low strength and cannot be used for structural purposes but as insulating components such as panelling. However, the MOEs of the composites compared favourably with those obtained by these researchers (1149.0 - 8658.0N/mm²). Generally, the recorded MORs and MOEs decreased with increasing polymer content and water pre-treatment.

Again, this observation may imply that the incorporation of polystyrene and water pre-treatment did not result in good interfacial bonding between the particles of T. grandis and cement. The results obtained may again suggest that the wood particles and molten polystyrene were not compatible with cement. Statistical analyses (Duncan's) revealed that the polymer content and water soak treatment had significant effects ($p < 0.05$) on the MORs and MOEs of the composites Table 2.

3.2 Water Absorption (WA)

The results of the water absorption (WA) are shown in Table 3. The WA ranged from 10.3 to 24.8% and 16.6 to 34.7% after 2 and then 48 hr soak in water respectively. These values suggest that the composites had moderate dimensional stability and can suitably be used as indoor components. The recorded WA compared favourably with 2.2 – 61.0% [4, 15, 16] for wood cement composites. As shown in Table 3, there was a partial reduction in the WA of the cement mixes with increase in polymer content.

This observation may mean that the incorporation of molten polystyrene may have created impervious layers within the cement mixes thus reducing the water sorption properties. However, the high sorption values (20.3 – 32.7 for the untreated composites and 21.6 – 34.4% - water-treated composites) may again suggest incompatibility between the wood particles, polystyrene and cement.

Statistical analyses (Duncan's) revealed that the polymer content, soaking time and water soak treatment had significant effects ($p < 0.05$) on the WAs of the composites (Table 4).

Table 3: Water Absorption of T. grandis Composites

Polymer Content / Treatment	Water Absorption (WA%)		
	2h	24h	48h
Control (None)	10.9^{mn}(3.80)	13.1^{m}(1.00)	16.6^{l}(1.54)
10%	10.3^{n}(0.39)	16.6^{l}(4.20)	20.5^{ijk}(3.50)
20%	20.3^{ijk}(0.21)	26.4^{fg}(0.49)	27.4^{ef}(0.96)
30%	16.3^{l}(2.70)	22.8^{hi}(3.00)	32.2^{bc}(2.67)
Water Pre-treatment			
None	22.3^{ij}(0.66)	27.5^{ef}(0.31)	29.3^{de}(0.47)
10%	24.8^{gh}(0.35)	30.6^{cd}(0.22)	33.9^{ab}(0.89)
20%	12.5^{mn}(1.39)	18.7^{kl}(1.53)	21.5^{ij}(1.52)
30%	19.8^{jk}(0.83)	26.1^{fg}(1.01)	34.7^{a}(1.34)

* Means with the same letters and columns are not significantly different
Standard deviation in parentheses

Table 4: Duncan's Range Test of the Effects of Polymer Content and Pre-treatment on the Water Absorption of T. grandis Composites

Variable:	
Polymer Content	WA (%)
Control (None)	19.9^{d}(7.22)
10%	22.8^{b}(8.43)
20%	21.1^{c}(5.09)
30%	25.4^{a}(6.92)
Soaking Time (h)	
2	17.1^{c}(5.42)
24	22.7^{b}(6.00)
48	27.0^{a}(6.63)
Pre-treatment	
None	19.4^{b}(6.90)
Cold Water	25.2^{a}(6.40)

* Means with the same letters and columns are not significantly different
Standard deviation in parentheses

4. CONCLUSIONS

Wood polymer cement composites were produced from particles of Tectona grandis. The fabricated composites had moderate dimensional stability with low strength properties which can be suitably deployed as indoor insulating components. The incorporation of polystyrene partially enhanced the sorption properties but negatively affected the flexural strength possibly due to incompatibility between the wood particles, polystyrene and cement.

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