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Strength and Sorption Properties of Cement Bonded Composites made from *Calamus deerratus* and *Laccosperma secundiflorum* Canes

O.O. Adefisan and A.O. Olorunnisola

Abstract
Two layered rattan cement composites were made from Calamus deerratus and Laccosperma secundiflorum particles using cement: sand: rattan mixing ratios of 1: 2: 0.2 and 1: 3: 0.2 and calcium chloride ($CaCl_2$) at two levels 0% and 3% (by weight of cement) and subjected to static bending and sorption tests after production. Results showed that rattan-cement mixes had low moduli of rupture, thickness swelling and water absorption rates but high moduli of elasticity and are suitable for low stress out-door applications. While the Calamus composites generally had low strength and high sorption properties than the Laccosperma cement mixes, peeling significantly reduced the strength properties of the Calamus cement composites possibly due to higher presence of cement inhibitors. Addition of $CaCl_2$ significantly enhanced both the strength and sorption properties of composites made from Calamus and Laccosperma particles.

Keywords: *Calamus deerratus, Laccosperma secundiflorum, Calcium chloride and rattan composites.*

O.O. Adefisan and A.O. Olorunnisola
Department of Agricultural and Environmental Engineering,
Faculty of Technology, University of Ibadan, Nigeria.
femiadefisan@yahoo.co.uk, abelolorunnisola@yahoo.com

Introduction

Cement Bonded Composites (CBCs) are lightweight concrete mixes containing approximately 30-70% by weight of wood in various forms and 70-30% cement (Goodell *et al.*, 1997; Youngquist, 1999). While cement encapsulates the wood particles and provides a durable surface that can be easily embossed and coloured for an attractive low maintenance finished product (Wolfe and Gjinolli, 1999), wood serves as low cost filler and /or reinforcing material. Wood however, is becoming scarce in many developing nations due to increasing demand for wood and wood products (Schuler and Adair, 2003). In Nigeria alone, about 80% of total annual lumber production estimated at 20 million cubic meters is consumed in building construction (Lucas and Olorunnisola, 2002). This has led to constant depletion of wood in the forest with an attendant scarcity of timber supply. Therefore there is a need for alternative furnish for CBC production. A probable candidate material available in many southern forests in Nigeria is rattan, the second most important forest resource after timber. Incorporation of rattan particles in CBC manufacture will serve as low cost furnish for cementitious composites thus alleviating the over exploitation of the dwindling timber resource in Nigeria. However, rattan contains sugars and extractives (Adefisan, 2010) which may likely hinder rattan-cement interaction.

Pre-treatment measures such as aqueous extraction, prolonged storage, carbon dioxide injection, biological treatment, addition of pozollans and incorporation of chemical accelerators are often times employed to enhance formation of strong crystalline bond (Semple and Evans, 2004; Adefisan,2010). The addition of chemical additives like calcium chloride is the commonest measure adopted in CBC production lines in Nigeria because chemical accelerators improve the strength and dimensional stability of CBCs by removing inhibitory compounds that hinder cement setting. This work examined the use of two rattan species (*Calamus deerratus* and *Laccosperma secundiflorum*) for production of cement composites and the effect of calcium chloride ($CaCl_2$) on the strength and sorption properties of the CBCs thus produced.

Materials and Methods

Matured stems of *Calamus deerratus* and *Laccosperma secundiflorum* canes were harvested from Gambari Forest Reserve Ibadan, Oyo state, Nigeria. These were identified through comparison with stocks kept in the herbarium of the Department of Botany, University of Ibadan. The harvested canes were separated into two parts. One part was manually peeled to remove the silified epidermis while the other part was left intact. Both the peeled and unpeeled canes were converted into billets of about 6 cm and hammer milled. The milled particles were collected and sieved using a set of 2.38 mm, 1.18 mm and 0.85mm sieves. Particles that passed through the 2.38 mm sieve and were retained in the 1.18 mm sieve were collected, air dried to 10% moisture content and separated into two portions i.e. those to be used 'as is' and those to be subjected to chemical pre-treatments.

Board Fabrication

Two-layered experimental rattan-cement composite boards consisting of sand-cement as face layer and sand-cement-rattan as back layer were made at the following production levels:

Cement: Sand: Rattan Ratio:	1: 2: 0.2 and 1: 3: 0.2
Rattan Particle Size:	1.18mm
Chemical Additive:	Calcium chloride
Additive Concentration:	0 and 3% (based on cement weight)
Board Thickness:	7mm

De-ionised water in which the chemical additive was dissolved was added at the rate of 0.25mL/g of cement, 0.23mL/g of sand + 2.7mL/g of rattan particles at 0 and 3% concentration levels. The mixing procedure was carried out separately for the face and back layers. The individual mixes were hand formed into a mat in a wooden deckle box placed on plastic caul plates, compacted with a tamping bar and cold pressed using a hydraulic press at a compacting pressure of 5Mpa. Five replicates of each sample boards were made. The composites were de-moulded after 24 – 48 hours, placed in a conditioning room at a temperature of 20 ± 3^0C and relative humidity of 65 ± 5% for another 27 days and then subjected to static bending and water resistance tests.

Static Bending Test

The static bending test was carried out in accordance with ASTM D 1037-89 (1998). Test specimens (60 x 150 x 7mm) were centred flat-wise on parallel supports using a 3-point test approach. The specimens were loaded perpendicularly at midspan at a uniform speed of 0.5mm / minute by a movable crosshead on a Universal Testing Machine (UTM) until definite failure occurred and the Moduli of Rupture (MOR) and Elasticity (MOE) were evaluated.

Water Resistance Test

The water resistance test was conducted in accordance with ASTM D 1037-89 (1998). Specimens were submerged horizontally in 25mm of de-ionised water maintained at room temperature. After 2 and 24 hours, the specimens were removed from water and drained. The water absorption (W.A in %) was determined from the increase in weight of the specimen while the thickness swelling (T.S) was expressed as a percentage of the original thickness

Results and Discussion

Modulus of Rupture (MOR)

The respective MOR of the *Calamus* and *Laccosperma* cement mixes ranged between 2.0 to 3.6 N/mm^2 and 1.6 to 2.9 N/mm^2 without pre-treatment and from 3.6 to 6.3N/mm^2 and 5.4 to 6.1 N/mm^2 when treated with 3% $CaCl_2$ (Table 1). These values are similar to those reported by Olorunnisola *et al.* (2005) but were lower compared with the ISO 1989 and composites made from hardwoods (Table 2). The relatively low MOR values of the rattan composites suggests that the rattan-cement mixes cannot be used in heavy load bearing applications.

Table 1: Moduli of Rupture of *Calamus* and *Laccosperma*-Cement Composites

	Modulus of Rupture (N / mm^2)			
	Untreated *Calamus*		3% $CaCl_2$-Treated *Calamus*	
Cement: Sand Ratio	Peeled	Unpeeled	Peeled	Unpeeled
1:2	2.7	3.5	4.3	6.0
1:3	2.0	3.3	3.6	6.3
	Untreated *Laccosperma*		3% $CaCl_2$-Treated *Laccosperma*	
1:2	2.5	2.9	5.7	5.4
1:3	1.6	1.6	5.6	6.1

Table 2: Strength and Sorption Properties of selected Cement Bonded Composites

	Moduli of Rupture (MOR, N/mm^2)	Moduli of Elasticity (MOE,N/mm^2)	Thickness Swelling (TS %)	Water Absorption (WA %)
Rattan (Laccos-perma Spp)	0.8 - 7.4	130.0 - 4253.1	0.2 - 1.8	2.2 - 28.6
Hardwoods	4.0 – 24.0	1149.0 – 8658.0	0.4 - 5.7	8.8 – 61.0
ISO (8335) 1987 Part 4 1989	9.0	3000.0	2.0	-

(Source: Badejo (1987; 1989); Fuwape and Oyagade, (1993); Fabiyi, (2004); Olorunnisola et al. (2005); Olorunnisola (2007))

Generally, the MOR of the rattan composites increased with increase in board density (Table 3) and chemical additive concentration but was negatively affected by peeling of silified epidermis and increased cement: sand ratio. The addition of chemical additives to rattan-cement mixes resulted in increased board densities and increased MOR. This observation is in line with the report of Badejo (1987; 1989) and Olorunnisola (2007) that increment in chemical additive concentration and cement content improved the bonding between lignocellulosic particles and cement. Also, pre-treating cement composites with chemical accelerators tend to increase composite densities and enhance the strength properties (Olorunnisola, 2007). *Laccosperma* composites pre-treated with 3% $CaCl_2$ generally had higher MOR values than the *Calamus* composites. What this suggests is that particles of the *Calamus* canes inhibited cement setting more than those of *Laccosperma* particles and that $CaCl_2$ enhanced the bond strength of the *Laccosperma* composites more than the *Calamus* composites. Adefisan (2010) had noted the preponderance of starches and tannins in the *Calamus* species with respect to the *Lacosperma* species. Higher presence of cement inhibitors in the *Calamus* cement mixes might have resulted in weak bond formation and hence low strength properties.

Duncan's multiple range tests revealed that the MOR was significantly affected ($p < 0.05$) by increase in the additive concentration but was not influenced by the cement: sand ratio used as shown in Table 4. However, while peeling did not significantly influence the MOR of the *Laccosperma* cement mixes, it caused significant reduction in MOR of the *Calamus* composites, possibly due to higher presence of cement inhibitors in the species.

Modulus of Elasticity (MOE)

The respective MOE of the *Calamus* and *Laccosperma* cement composites are shown in Table 5. The values obtained ranged between 3897.1 to 7002.9N/mm^2 and 4477.7 to 6803.0N/mm^2 without pre-treatment and from 5131.4 to 9677.8N/mm^2 and 6739.2 to 9688.2N/mm^2 for composites of the *Calamus* and *Laccosperma* respectively treated with $CaCl_2$. The relatively high MOE values obtained from the rattan-cement mixes are in conformity with that of ISO 1989 and are comparable with those of Olorunnisola *et al.* (2005); Olorunnisola (2007) (Table 2).

Table 3: Wet Densities of *Calamus* and Laccosperma Composites

Cement: Sand Ratio	Density (Kg / m^3) Untreated *Calamus* Peeled	 Unpeeled	 3% $CaCl_2$-Treated *Calamus* Peeled	 Unpeeled
1:2	1570	1640	1660	1660
1:3	1590	1510	1620	1670
	Untreated *Laccosperma*		3% $CaCl_2$-Treated *Laccosperma*	
1:2	1630	1540	1680	1670
1:3	1510	1580	1650	1680

Table 4: Duncan's Multiple Comparison for the MOR (N/ mm^2) of Rattan Composites

Levels	**Species** ***C. deerratus***	 ***L. secundiflorum***
Cement: Sand Ratio		
1:2	4.14^A	4.12^A
1:3	3.81^A	3.7^A
Processing		
Unpeeled	4.80^A	3.99^A
Peeled	3.16^B	3.87^A
Additive Concentration (%)		
0	2.90^B	2.16^B
3	5.06^A	5.70^A

Means with the same letters are not statistically different

Table 5: Moduli of Elasticity of *Calamus*-and *Laccosperma* Cement Composites

	Modulus of Elasticity (N / mm^2)			
	Untreated *Calamus*		3% $CaCl_2$-Treated *Calamus*	
Cement: Sand Ratio	Peeled	Unpeeled	Peeled	Unpeeled
1:2	6255.0	7002.9	6581.2	7850.0
1:3	3897.1	4353.0	5131.4	9677.8
	Untreated *Laccosperma*		3% $CaCl_2$-Treated *Laccosperma*	
1:2	6803.0	4477.7	9688.2	6739.2
1:3	4622.4	4689.5	9400.6	9180.0

Generally, the *Laccosperma* composite had higher MOE values than the *Calamus* composites. Increase in cement: sand ratio lowered the MOE of the composites while the addition of chemical additives enhanced the MOE of the rattan cement mixes. Also, improved MOE was obtained with increase in cement content in line with the findings of Fuwape and Oyagade (1993) while the addition of chemical accelerators improved the interfacial bonding between cement and the rattan particles (Olorunnisola, 2007). However, while peeling had minimal effects on the MOE of the *Laccosperma* composite it negatively affected that of the *Calamus* composites.

Duncan's Multiple range test (Table 6) revealed that the cement: sand ratio used did not have significant effect ($p < 0.05$) on the MOE. Furthermore the addition of $CaCl_2$ resulted in significant improvement in MOE. However, while peeling had no significant effect on the MOE of the *Laccosperma* composite, it caused significant reduction in the MOE of *Calamus* composites.

Thickness Swelling

The TS of the rattan composites ranged from 4.3 to 8.8% and 1.9 to 8.7% without pre-treatment and between 1.5 to 4.3% and 0.8 to 4.0% for *Calamus* and *Laccosperma* cement mixes pre-treated with 3% $CaCl_2$ respectively (Tables 7 and 8). These values are close to the maximum TS of 2% recommended in the ISO (1989) standard as shown in (Table 2). What the foregoing suggests is that the rattan composites are relatively dimensionally stable and may be suitable for outdoor applications. However, the *Laccosperma* composites seemed to be more dimensionally stable than *Calamus* composites. The dimensional stability of the rattan composites decreased with increase in cement: sand ratio and peeling probably due to reduced bonding and more void spaces but was enhanced by $CaCl_2$. Duncan's multiple range test (Tables 9 and 10) revealed that peeling did not have significant effect ($p < 0.05$) on the TS of the rattan composites suggesting that the rattan canes need no pre-processing prior to CBC manufacture. Also, while cement: sand ratio did not significantly influence the TS of the *Calamus* composites, increment in the cement: sand ratio had significant effect on the TS of *Laccosperma* cement mixes.

Water Absorption

The water absorption of the rattan composites are shown in Tables 11 and 12. The values ranged from 13.0 to 15.8% and 12.2 to 15.0% without pre-treatment and between 13.4 to

Table 6: Duncan's Multiple Comparison for the MOE (N/mm²) of Rattan Composites

Levels	Species *C. deerratus*	*L. secundiflorum*
Cement: Sand Ratio		
1:2	6922.3^{A}	6927.0^{A}
1:3	5764.8^{A}	69733.3^{A}
Processing		
Unpeeled	7220.9^{A}	6271.8^{A}
Peeled	5466.2^{B}	7628.6^{A}
Additive Concentration (%)		
0	5377.0^{B}	5148.2^{B}
3	7310.1^{A}	8752.2^{A}

Means with the same letters are not statistically different

Table 7: Thickness Swelling of untreated *Calamus* and *Laccosperma* Composites

	Thickness Swelling (%)			
	Peeled		Unpeeled	
Cement: Sand Ratio	2 Hrs	24 Hrs	2 Hrs	24 Hrs
		Calamus		
1:2	5.3	8.8	5	8.2
1:3	6.2	8.7	4.3	6.6
		Laccosperma		
1:2	2.1	4.2	1.9	3.8
1:3	5.7	8.7	2.7	4.2

Table 8: Thickness Swelling of $CaCl_2$ treated *Calamus* and *Laccosperma* Composites

	Thickness Swelling (%)			
	Peeled		Unpeeled	
Cement: Sand Ratio	2 Hrs	24 Hrs	2 Hrs	24 Hrs
		Calamus		
1:2	1.5	3.1	2.3	3.1
1:3	1.8	3.5	2.3	4.3
		Laccosperma		
1:2	2.0	2.8	0.8	2.0
1:3	1.6	3.0	2.5	4.0

Table 9: Duncan's Multiple Comparison for the Thickness Swelling (%) of *Calamus* Composites

Levels	Thickness Swelling (%) 2 Hrs	Thickness Swelling (%) 24 Hrs
Cement: Sand Ratio		
1:2	3.5^{A}	5.8^{A}
1:3	3.7^{A}	5.8^{A}
Processing		
Unpeeled	3.5^{A}	5.6^{A}
Peeled	3.7^{A}	6.0^{A}
Additive Concentration (%)		
0	5.2^{A}	8.1^{A}
3	2.0^{B}	3.5^{B}

Means with the same letters are not statistically different

Table 10: Duncan's Multiple Comparison for the Thickness Swelling (%) of *Laccosperma* Composites

Levels	Thickness Swelling (%) 2 Hrs	Thickness Swelling (%) 24 Hrs
Cement: Sand Ratio		
1:2	1.7^{B}	3.2^{B}
1:3	3.1^{A}	5.0^{A}
Processing		
Unpeeled	2.0^{A}	3.5^{A}
Peeled	2.8^{B}	4.7^{A}
Additive Concentration (%)		
0	3.1^{A}	5.2^{A}
3	1.7^{B}	3.0^{B}

Means with the same letters are not statistically different

Table 11: Water Absorption of untreated *Calamus* and *Laccosperma* Composites

	Thickness Swelling (%)			
	Peeled		Unpeeled	
Cement: Sand Ratio	2 Hrs	24 Hrs	2 Hrs	24 Hrs
Calamus				
1:2	13.4	15.1	13.0	14.7
1:3	14.7	15.8	13.7	15.5
Laccosperma				
1:2	14.5	15.0	12.9	14.2
1:3	13.2	14.2	12.2	12.6

Table 12: Water Absorption of $CaCl_2$ treated *Calamus* and *Laccosperma* Composites

	Thickness Swelling (%)			
	Peeled		Unpeeled	
Cement: Sand Ratio	2 Hrs	24 Hrs	2 Hrs	24 Hrs
Calamus				
1:2	17.5	20.3	13.4	14.9
1:3	14.0	15.6	14.0	15.9
Laccosperma				
1:2	11.2	13.1	9.2	11.3
1:3	9.0	11.1	8.0	10.1

20.3% and 8.0 to 13.1% for *Calamus* and *Laccosperma* cement mixes pre-treated with 3% $CaCl_2$ respectively. The rattan-cement mixes generally had low water absorption values comparable with composites made from hardwoods (Table 2). Peeling significantly ($p < 0.05$) increased the WA of the cement mixes (Tables 13 and 14) suggesting that the rattan canes need not be pre-processed prior to CBC production. The addition of $CaCl_2$ caused significant reduction in the WA of the *Laccosperma* composites but significantly increased the WA of the *Calamus* composites. Also, increment in the cement: sand ratio did not have significant effect on the WA of the *Calamus* composite but it positively influenced the WA of the *Laccosperma* composites.

Table 13: Duncan's Multiple Comparison for the Water Absorption (%) of *Calamus* Composites

Levels	Water Absorption (%) 2 Hrs	 24 Hrs
Cement: Sand Ratio		
1:2	14.3^{A}	6.2^{A}
1:3	14.1^{A}	15.7^{A}
Processing		
Unpeeled	13.5^{B}	15.2^{B}
Peeled	14.9^{A}	16.7^{A}
Additive Concentration (%)		
0	13.7^{B}	15.3^{B}
3	14.7^{A}	16.6^{A}

Means with the same letters are not statistically different

Table 14: Duncan's Multiple Comparison for the Water Absorption (%) of *Laccosperma* Composites

Levels	Water Absorption (%) 2 Hrs	 24 Hrs
Cement: Sand Ratio		
1:2	11.9^{A}	13.4^{A}
1:3	10.6^{B}	12.0^{B}
Processing		
Unpeeled	10.6^{B}	12.0^{B}
Peeled	12.0^{A}	13.3^{A}

Additive Concentration (%)		
0	13.2^{A}	14.0^{A}
3	9.3^{B}	11.4^{B}

Means with the same letters are not statistically different

Conclusions

The following were deduced from the study:

(i) Cement bonded composites can be fabricated from the two rattan species.

(ii) The rattan-cement mixes had relatively low strength and thickness swelling values suggesting possible utilization in out-door applications.

(iii) Composites from *Laccosperma* species were relatively stronger and more dimensionally stable than those from *Calamus* composites.

(iv) Increase in sand content negatively affected the strength and sorption properties of the rattan-cement composites.

(v) The two rattan species need not be peeled prior to CBC production.

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