J. Bamboo and Rattan, Vol. 15, Nos. 1-4, pp.1-12 (2016)

Effects of Rattan Particle Treatments on the Strength and Sorption Properties of Cement Bonded Composites

O.O. Adefisan[1*], **J.S. Fabiyi**[2] and **A.G. McDonald**[3]

[1]Department of Agricultural and Environmental Engineering, Faculty of Technology, University of Ibadan, Oyo State, Nigeria. Tel: +234-8038080422.

[2]Department of Forestry and Wood Technology, Federal University of Technology, PMB 704, Akure, Ondo State, Nigeria.

[3]Renewable Materials Program, Department of Forest, Rangeland and Fire Sciences, University of Idaho, Moscow, ID 83844-1132, U.S.A.

Abstract: The effects of pre-treatments on the strength and sorption properties of rattan cement composites were investigated. Two rattan species (*Eremospatha macrocarpa* (*EM*) and *Laccosperma secundiflorum* (*LS*) canes) were cold water extracted, treated with 3% $CaCl_2$ or $Al_2(SO_4)_3$ and compared with control (untreated particles) . The particles (either 0.85 or 1.0 mm particle size) were used to produce cement bonded composites at 5 and 10% rattan content. Composites were tested for flexural strength and water resistance after 28 days of curing. Composites made from *EM* particles had higher flexural modulus of rupture than those from *LS* but the difference in the flexural modulus of elasticity between the two species was not significant. Pre-treatments of the particles caused significant reduction in the water absorption and thickness swell. $CaCl_2$ treatment significantly improved the strength and sorption properties than cold water or $Al_2(SO_4)_3$ treated composites. Also, increased particle size and rattan content reduced the strength properties and water resistance of the rattan cement composites.

Key words: Rattans, *Eremospatha macrocarpa*, *Laccosperma secundiflorum*, Pre-treatment, Cement composites

INTRODUCTION

Wood or other lignocellulosic materials serve as low cost filler and/or reinforcing components in cement bonded composites (CBCs). Reinforcing cement with lignocellulosic materials greatly improve its stiffness, fracture toughness, strength to weight ratio, creep deflection, thermal and acoustic resistance (Goodell *et al*., 1997). The content, particle size and chemical constituents of the wood used are some of the major factors influencing the strength properties of CBCs (Badejo, 1988; Olorunnisola, 2005). Higher contents of wood particles in CBCs have been found to lower the mechanical strength due to insufficient cement coating and poor bond formation (Huang and Cooper, 2000). However, Fuwape and Oyagade (1993) noted that increased proportions of wood in CBC at reduced cement/wood ratio improved the flexural properties. This is because the increased volume of wood particles in

* To whom correspondence should be addressed: femiadefisan@hotmail.com

cement composites diffuses the region of stress concentration and improved the resistance of boards to an applied stress.

The deployment of wood in the form of strands was found to impart greater flexural properties and lower thickness swelling of CBCs than particles thus enhancing the use of much lower cement wood ratio (Olorunnisola *et al*., 2005a). However, poor interfacial adhesion between large furnish and cement often results in low strength properties (Olorunnisola *et al.,* 2005a). Karade *et al*. (2003) and Olorunnisola (2007) observed that smaller lignocellulosic particles were well encapsulated with cement than larger particles thereby reducing the presence of air voids. The inclusion of smaller particles in production of CBCs also provides valuable information on the maximum possible effect of wood extractives. This is as a result of more surface area being exposed to the cement paste and thus more extractives entering into the solution (Karade *et al*., 2003).

Unfortunately, lignocellulosic materials are noted to contain components such as tannins, terpenes, and flavanoids which often times have deleterious effects on cement resulting in delayed de-moulding and impairment of composites strength (Olorunnisola, 2007). These effects are mostly curtailed by biological pre-treatment to reduce the sugar contents, carbon dioxide injection to hasten setting time, application of pozzolans to improve strength properties, aqueous (hot or cold water) extraction of soluble sugars and application of chemical additives to remove or reduce inhibitory substances that impair cement bond (Giemer *et al*., 1992; Simantupang *et al*., 1995; Semple and Evans, 2002; Sensale, 2006). Also, many of the lignocellulosics used as furnish for CBC production are often produced in small quantities at different locations. Hence, the collection and transportation of these items are expensive. Olorunnisola (2006) noted that the choice of any particular lignocellulosic as furnish for CBC production is dependent on availability and processing cost. Therefore, rattan canes are now being considered as candidate furnish for CBC production (Adefisan and Olorunnisola, 2007). This is due to the fact that they are abundant in the forests of western Nigeria. They have short rotation; therefore, can be harvested in less than seven years after planting. They can also be processed with simple and relatively inexpensive technology (Olorunnisola, 2005b).

Of the three rattan species available in the forests of western Nigeria, two, namely, *Calamus deerratus* and *Laccosperma secundiflorum (LS)* have been tested for CBC production (Olorunnisola, 2005b; Olorunnisola, 2007; Adefisan and Olorunnisola, 2007; Olorunnisola, 2008). The information on the strength and sorption properties of *Eremospatha macrocarpa (EM)* CBC has not been found in literature. The availability of this information is very much important because different rattans exhibit different physical, anatomical and chemical properties (Adefisan, 1999; Dahunsi, 2000), which may affect CBC manufacture and therefore a need to assess its viability for local use. Adefisan (1999) reported that *E. macrocarpa* has diameter of 10-17 mm and stem length of 20-25 mm while *L. secundiflorum* has diameter of 10-20 mm and stem length of 10 mm. The study of the anatomical property showed that *L. secundiflorum* has higher proportions of sclerenchyma than parenchyma cells (Dahunsi, 2000). Conversely, the proportion of sclerenchyma cells is lower than that of parenchyma cells in the *E. marcocarpa* and *C. deerratus*. The differences in the proportions of sclerenchyma and parenchyma cells in the rattan species may affect the hydration behavior when mixed with cement as well as the physico-mechanical property of the CBC produced from them. This is because the function of sclerenchyma and parenchyma cells differs in that the former serves as strengthening tissues while the latter serves as the storage tissues. Also, the chemical property reveals that the sugar content of *L secundiflorum* and *E. marcocarpa* differed with *L. secundiflorum* having the highest carbohydrate content which may cause it to be more inhibitory to cement hydration (Dahunsi, 2000).

Indeed, cement composites produced from rattan canes have been investigated using cold water extraction and 3% $CaCl_2$ pre-treatment approach. These composites were dimensionally stable with moderate strength applicable to both exterior and interior applications (Olorunnisola *et al*., 2005b; Olorunnisola and Adefisan, 2002). The implication on the use of other chemical additives like $Al_2(SO_4)_3$ on the strength and sorption properties of rattan CBC is limited. This study therefore investigated the effects of cold water treatment, $CaCl_2$ and $Al_2(SO_4)_3$ on the strength and sorption properties of *EM* and *LS* rattan mixed with cement.

MATERIALS AND METHODS

Mature *EM* and *LS* from wild stands were harvested from Gambari Forest Reserve (between longitude 50° 44' E and latitude 7° 14' N) in Ibadan, Oyo state, Nigeria. The canes were cross-cut into lengths of about 6 cm, air-dried for four weeks and pulverized in a hammer-mill fitted with a sieve size of 6 mm. The particles were further air-dried to a moisture content (MC) of about 10%. The particles were sieved (1.18, 1.0 and 0.85 mm) and the particles retained on 1.0 and 0.85 mm sieves were collected and subsequently used. The particles were either untreated henceforth referred to as control, water (cold) soaked for 30 min, drained and dried to 10% MC or treated with 3% $CaCl_2$ or $Al_2(SO_4)_3$.

Board formation

CBC were produced from mixtures of rattan particles (5 or 10% based on cement weight), Portland cement (purchased at a local hardware store, Moscow, Idaho State, USA) (400 g), 3% $CaCl_2$ or $Al_2(SO_4)_3$ based on cement weight and water required in a mould of 10 mm (thickness) × 50 mm (width) × 170 mm (length). The quantity of water used was cement and rattan particle dependent (0.45 ml/g of cement + 2.7 ml/g of rattan particle) (Adefisan and Olorunnisola, 2007). The rattan particles was placed in a large mixing bowl to which water and 3% $CaCl_2$ or $Al_2(SO_4)_3$ (dissolved in part of the water required for CBC production) were added and thoroughly hand mixed to a homogeneous slurry. The mix was immediately hand felted to ensure even distribution on the caul plate that has been covered with polyethylene (PE) sheet. After felting, another PE sheet was placed on the mattress before the top caul plate was positioned.

The PE sheet prevented cement paste from sticking on the caul plates and thus ensured easy removal of the board from the caul plates. The boards were pressed to the required thickness size of 10 mm using a hydraulic press. The CBC were de-moulded and cured under wet cloth at room temperature (20±2°C) for a period of 6 days and further conditioning performed in a controlled chamber (20±2°C and a relative humidity of 65±5%) for another 22 days.

Cement bonded composites testing

Water resistance testing was performed on 10 mm × 50 mm × 50 mm specimens that were completely submerged in water at 20±2°C. The water absorption (WA) and thickness swelling (TS) after 2 and then 24 h were determined from dimensional changes on three replicates per sample type. The cured composites were subjected to three point flexural tests (MOR and MOE) in accordance with ASTM D 1037-00 (2003). Three replicate samples were performed for each formulation (10 mm × 50 mm × 170 mm) on an Instron 5500R-1132 Universal Test Machine equipped with a 454 kg load cell and tested at cross-head speed of 1 mm/min. Data was collected and processed using Bluehill software v2 (Instron). The analysis of variance of the data collected was conducted using Statistical Analysis System (SAS) software. Duncan's Multiple Range Test was used to separate the significant differences in the mean.

RESULTS AND DISCUSSION

Water absorption and thickness swelling

The WA and TS of rattan cement composites are showed in Tables 1 to 2. The range of WA after 2h of water soak for *LS* control samples were 8.7 to 16.9% while that after 24h were 11.3 to 18.7%. Control composites made of *EM* samples had WA that ranged from 11.6 to 17.1% after 2h and 13.5 to 18.4% after 24h. The respective TS were 1.1 to 2.1% and 1.3 to 2.9% after 2 and 24h for the *LS* composites and 1.3 to 1.6% and 1.7 to 3.0% for the *EM* composites. Likewise, the WA of the treated rattan composites ranged from 5.4 to 16.5% and 6.8 to 18.3% after 2h and 24h for the *LS* samples and 5.3 to 21.5% and 6.1 to 23.0% for the *EM* composites. The respective TS were 0.8 to 1.7% and 1.2 to 2.2 % after 2h and 24h for the *LS* composites while those of the *EM* composites were 0.8 to 2.0% and 1.1 to 2.4%. These values were comparable with those reported by Olorunnisola (2007) and those of CBC made from hardwoods (Badejo, 1989; Fuwape and Oyagade, 1993; Fabiyi, 2004). This is an indication that the rattan CBCs were generally dimensionally stable and are suitable for both interior and exterior applications.

Pre-treatment generally had significant effect in the WA and TS of the rattan CBCs. The greatest significant improvement was recorded for rattan based composites treated with $CaCl_2$ (Tables 1, 2, 3). This implies that treatment with $CaCl_2$ enhanced the dimensional stability of the rattan composites than either cold water or $Al_2(SO_4)_3$ treatment. In addition, significant increase in water absorption was obtained with increased particle size and rattan content while TS was influenced by rattan content (Tables 1, 2, 3). The reduction in particle size and content may have resulted in less air voids due to the relative closeness with cement and hence low water absorption potentials of cement boards (Badejo, 1988; Brandt, 1995; Olorunnisola, 2005). Most of the CBCs produced in this study had thickness swelling after 24 hours within the maximum requirement of 1.2-1.8 % set forth for structural application by Bison and CETRIS Companies, India and British standard specifications for cement bonded particleboards (Bison, 1978; IS 14276,1995; BSI 2007; CETRIS, 2014).

Table 1: Water Absorption of *E. macrocarpa and L. secundiflorum* Cement Composites

Rattan Content %	Particle Size (mm)	Treatment	*E. macrocarpa*		*L. secundiflorum*	
			2h(%)	24h(%)	2h(%)	24h(%)
		Control	14.9^{GHI} ± 1.17	16.2 ^{EFG} ± 1.24	15.3 ^{CE} ± 0.30	16.7 ^{AC} ± 0.47
5%	0.85	$CaCl_2$	5.3 ^{O} ± 0.57	6.1 ^{O} ± 2.01	5.4 ^{O} ± 0.67	6.8 ^{NO} ± 2.66
		$Al_2(SO_4)_3$	13.1 ^{JKL} ± 0.97	14.7 ^{GHI} ± 1.78	11.6 ^{GHJK} ±0.45	13.0 ^{EGH} ± 0.86
		Water	12.0 ^{JKL} ± 1.00	12.7 ^{IJK} ± 1.04	12.2 ^{GHJ} ± 0.67	13.1 ^{EGH} ± 1.28
	1.0	Control	11.6 ^{JKL} ± 1.18	13.5 ^{HIJK} ± 0.76	8.7 ^{KN} ± 0.26`	11.3 ^{HJK} ± 0.49
		$CaCl_2$	9.1 ^{N} ± 0.87	11.3 ^{KLM} ± 0.15	7.1 ^{NO} ± 1.11	9.3 ^{JK} ± 0.63
		$Al_2(SO_4)_3$	10.4 ^{LMN} ± 0.70	11.5 ^{JKL} ± 0.72	10.5 ^{JK} ± 0.94	11.8 ^{GHJ} ± 0.76
		Water	11.9 ^{JKL} ± 0.54	12.9 ^{IJK} ± 0.37	11.5 ^{HJK} ± 4.33	13.7 ^{CEGH} ± 4.34
	0.85	Control	17.1 ^{DEF} ± 0.32	18.4 ^{CD} ± 0.41	16.9 ^{A} ± 0.44	18.7 ^{A} ± 0.34
10%		$CaCl_2$	9.3 ^{MN} ± 1.17	13.4 ^{HIJK} ± 1.06	8.4 ^{N} ± 0.30	12.4 ^{EGH} ± 0.13
		$Al_2(SO_4)_3$	19.0 ^{CD} ± 0.31	19.9 ^{BC} ± 1.43	16.0 ^{AC} ± 0.23	16.9 ^{A} ± 0.51
		Water	18.3 ^{CDE} ± 1.71	20.1 ^{BC} ± 0.66	16.5 ^{AC} ± 3.12	18.3 ^{A} ± 2.66
	1.0	Control	13.4 ^{HIJK} ± 0.95	14.4 ^{GHI} ± 0.98	14.5 ^{CEG} ± 0.67	15.9 ^{AC} ± 0.43
		$CaCl_2$	9.3 ^{MN} ± 2.49	13.7 ^{HIJ} ± 2.65	6.5 ^{NO} ± 1.31	10.6 ^{JK} ± 1.30
		$Al_2(SO_4)_3$	21.5 ^{AB} ± 0.27	23.0 ^{A} ± 0.58	14.0 ^{CEGH} ± 0.82	15.1 ^{CE} ± 0.34
		Water	15.5 ^{FGH} ± 1.23	17.2 ^{DEF} ± 1.67	14.2^{CEGH} ± 0.02	15.1 ^{CE} ± 0.30

*Means with the same letters are not statistically different.

Table 2: Thickness Swelling of *E. macrocarpa and L. secundiflorum* Cement Composites

Rattan Content %	Particle Size (mm)	Treatment	EM		LS	
			2h(%)	24(%)	2(%)	24(%)
		Control	1.3 ^{DEF} ± 0.36	2.8 ^{A} ± 0.45	1.7 ^{CDE} ± 0.71	2.8 ^{AB} ± 0.44
5%	0.85	$CaCl_2$	0.8 ^{F} ± 0.56	1.1 ^{EF} ± 0.42	0.8 ^{F} ± 0.79	1.6 ^{CDEF} ± 0.35
		$Al_2(SO_4)_3$	1.1 ^{EF} ± 0.12	1.2 ^{DEF} ± 0.07	1.2 ^{DEF} ± 0.38	1.4 ^{CDEF} ± 0.20
		Water	1.1 ^{EF} ± 0.36	1.2 ^{DEF} ± 034	1.1 ^{EF} ± 0.07	1.2 ^{EF} ± 0.07
	1.0	Control	1.2 ^{DEF} ± 0.39	1.7 ^{CDEF} ± 0.32	1.1 ^{EF} ± 0.19	1.3 ^{DEF} ± 0.33
		$CaCl_2$	1.3 ^{DEF} ± 0.15	1.5 ^{DEF} ± 0.10	1.1 ^{EF} ± 0.21	1.3 ^{CDEF} ± 0.19
		$Al_2(SO_4)_3$	1.3 ^{DEF} ± 0.13	1.6 ^{CDEF} ± 0.24	1.3 ^{CDEF} ± 0.11	1.6 ^{CDEF} ± 0.05
		Water	1.4 ^{DEF} ± 0.04	1.6 ^{CDEF} ± 0.02	1.4 ^{CDEF} ± 0.03	1.6 ^{CDEF} ± 0.02
	0.85	Control	1.6 ^{CDEF} ± 0.28	3.0 ^{A} ± 0.75	2.1 ^{BCD} ± 0.89	2.9 ^{A} ± 1.04
10%		$CaCl_2$	1.1 ^{EF} ± 0.82	1.5 ^{CDEF} ± 0.29	1.0 ^{EF} ± 0.64	1.3 ^{CDEF} ± 0.85
		$Al_2(SO_4)_3$	2.0 ^{BCDE} ± 0.78	2.1 ^{BCD} ± 0.72	1.7 ^{CDE} ± 0.46	2.2 ^{ABC} ± 0.30
		Water	1.8 ^{CDE} ± 0.87	2.4 ^{ABC} ± 1.40	1.5 ^{CDEF} ± 0.42	1.7 ^{CDE} ± 0.55
	1.0	Control	1.4 ^{DEF} ± 0.41	1.8 ^{CDE} ± 0.31	1.6 ^{CDEF} ± 0.29	1.8 ^{CDE} ± 0.20
		$CaCl_2$	1.3 ^{DEF} ± 0.18	1.7 ^{CDE} ± 0.04	1.2 ^{EF} ± 0.24	1.4 ^{CDEF} ± 0.32
		$Al_2(SO_4)_3$	1.5 ^{CDEF} ± 0.18	1.8 ^{CDE} ± 0.04	1.5 ^{CDEF} ± 0.26	1.7 ^{CDE} ± 0.24
		Water	1.7 CDE ± 0.21	1.9 CDE ± 0.20	1.7 CDE ± 0.31	1.8 CDE ± 0.37

*Means with the same letters are not statistically different.

Table 3: Duncan's Multiple Comparison of the effect of treatment, rattan content and particle size on the WA and TS of Rattan cement composites

	Water Absorption		Thickness Swelling	
	E. macrocarpa	*L. secundiflorum*	*E. macrocarpa*	*L. secundiflorum*
Treatment (N =24)				
Control	14.9 ^{B} (2.26)	14.7 ^{A} (3.13)	1.8 ^{A} (0.73)	1.9 ^{A} (0.81)
$CaCl_2$	9.7 ^{C} (3.22)	8.3 ^{B} (2.48)	1.3 ^{B} (0.45)	1.2 ^{C} (0.50)
$Al_2(SO_4)_3$	16.3 ^{A} (4.92)	14.0 ^{A} (2.86)	1.6 ^{A} (0.50)	1.6 ^{B} (0.37)
Water	15.4 ^{B} (2.91)	14.0 ^{A} (2.63)	1.7 ^{A} (0.64)	1.5 ^{B} (0.36)
Rattan Content (%) (N = 48)				
5	11.7 ^{B} (3.0)	11.1 ^{B} (3.37)	1.4 ^{B} (0.50)	1.4 ^{B} (0.53)
10	16.5 ^{A} (4.08)	14.4 ^{A} (3.47)	1.8 ^{A} (0.66)	1.7 ^{A} (0.62)
Particle Size (mm) (N = 48)				
0.85	14.4 ^{A} (4.58)	13.6 ^{A} (4.11)	1.6 ^{A} (0.83)	1.6 ^{A} (0.77)
1.0	13.8 ^{B} (4.0)	11.9 ^{B}(3.2)	1.6 ^{A} (0.28)	1.5 ^{A} (0.31)

Significant at 5% level of probability. Standard deviation given in parentheses "Means with the same letters within a column are not statistically different".

Flexural properties of rattan CBCs

The MOR and MOE of the rattan based CBC are given in Table 4. The MOR ranged from 2.4±0.3 to 3.1±0.2 N/mm^2 and 2.6±0.3 to 3.4±0.1 N/mm^2 for the control *EM* and *LS* composites respectively, due to particle size and rattan content. Likewise, the MOR for treated *EM* and *LS* composites ranged from 2.5±0.2 to 4.8±0.3 N/mm^2 and 2.2±0.5 to 4.5±0.3 N/mm^2 respectively. The respective MOE were between 1965.9±1601.5 to 3738.1±1071.3 N/mm^2 and 2986.7±424.8 to 5568.0±1971.8 N/mm^2 for the control and 2001.2±172.9 to 4816.6±1644.9 N/mm^2 and 2582.3±120.8 to 4931.0±1702.0 N/mm^2 for the treated *EM* and *LS* composites due to particle size and rattan content. The MOR values obtained in this study were similar to those of Olorunnisola *et al.* (2005a) and Olorunnisola (2007) but were approximately 40% lower compared with those of composites made from hardwoods (Badejo, 1989; Fuwape and Oyagade, 1993; Fabiyi, 2004). The MOR and MOE obtained in this study compared favourably with commercial (Bison and CETRIS Companies), India and British standard specifications for cement bonded particleboards (Bison, 1978; IS 14276,1995; BSI 2007; CETRIS, 2014). Both Bison (1978) and Indian Standard IS 14276 (1995) set the same minimum requirement for MOR and MOE of CBC as 9 N/mm^2 and 3000 N/mm^2, respectively. The MOR minimum requirement for CBC by CETRIS Company (2014) and British standard (2007) were the same as that of Indian standard (9 N/mm^2).

However CETRIS Company standard (2014) and class 1 CBC by British standard for MOE is 4500 N/mm^2 but class 2 by British standard (2007) for MOE is 4000 N/mm^2. The MOR values obtained in this study were lower than any of these standard requirement set forth for structural applications with few exceptions. $CaCl_2$ treated *EM* and *LS* composites produced from particle sizes of 0.85 and 1.00 mm exceeded the minimum requirement (MOE = 3000 N/mm^2). This implies that the rattan composites cannot be utilised for structural purposes except for low stress indoor applications.

Table 4: Moduli of Rupture and Elasticities of *E. macrocarpa* and *L. secundiflorum* Cement Composites

Rattan Content %	Particle Size (mm)	Treatment	*E. macrocarpa*		*L. secundiflorum*	
			MOR (N/mm^2)	MOE (N/mm^2)	MOR (N/mm^2)	MOE (N/mm^2)
5%	0.85	Control	2.4 ^{F} ± 0.26	3498.1 ^{ABCDE} ± 469.6	3.4 ^{BC} ± 0.12	3117.2 ^{BCDE} ± 694.7
		$CaCl_2$	4.6 ^{AB} ± 0.72	4743.1 ^{AB} ± 678.6	3.8 ^{AB} ± 0.18	4419.1 ^{ABCD} ± 298.4
		$Al_2(SO_4)_3$	3.3 ^{CDEF} ± 0.73	4151.7 ^{ABC} ± 1219.0	3.0 ^{BCD} ± 0.30	4108.8 ^{ABCDE} ± 298.4
		Water	3.7 ^{BCDE} ± 0.57	2882.1 ^{CDE} ± 443.6	3.3 ^{BCD} ± 0.15	2582.3 ^{DE} ± 120.8
	1	Control	2.8 ^{DEF} ± 0.28	3738.1 ^{ABCD} ± 1071.3	3.2 ^{BCD} ± 0.54	5568.0 ^{A} ± 1971.8
		$CaCl_2$	3.7 ^{BCD} ± 0.85	3244.0 ^{BCDE} ± 354.8	3.3 ^{BC} ± 1.03	4931.0 ^{AB} ± 1702.0
		$Al_2(SO_4)_3$	2.9 ^{DEF} ± 0.55	4816.6 ^{A} ± 1644.9	2.2 ^{D} ± 0.52	3217.6 ^{BCDE} ± 558.4
		Water	2.5 ^{F} ± 0.20	2362.8 ^{ED} ± 344.6	2.8 ^{CD} ± 0.56	2775.3 ^{DE} ± 1196.8
10%	0.85	Control	3.1 ^{DEF} ± 0.19	1965.9 ^{E} ± 1601.5	3.1 ^{BCD} ± 0.26	2986.7 ^{CDE} ± 424.8
		$CaCl_2$	4.8 ^{A} ± 0.26	2158.7 ^{E} ± 416.7	4.4 ^{A} ± 1.31	3628.7 ^{BCDE} ± 336.8
		$Al_2(SO_4)_3$	2.8 ^{DEF} ± 0.21	2535.5 ^{ED} ± 122.4	2.7 ^{CD} ± 0.17	2807.0 ^{CDE} ± 328.9
		Water	3.6 ^{BCDE} ± 0.75	3393.0 ^{ABCD} ± 537.9	3.4 ^{BC} ± 0.45	3167.9 ^{BCDE} ± 801.5
	1	Control	2.7 ^{EF} ± 0.51	3427.3 ^{ABCD} ± 782.6	2.6 ^{CD} ± 0.26	3526.3 ^{BCDE} ± 1047.2
		$CaCl_2$	4.2 ^{ABC} ± 0.48	3488.3 ^{ABCD} ± 782.6	4.5 ^{A} ± 0.29	4561.6 ^{ABC} ± 928.5
		$Al_2(SO_4)_3$	2.5 ^{F} ± 0.62	2001.2 ^{E} ± 172.9	2.6 ^{CD} ± 0.17	2695 ^{DE} ± 780.2
		Water	3.2 ^{DEF} ± 0.42	2914.6 ^{CDE} ± 416.7	2.7 ^{CD} ± 0.37	2555.8 ^{E} ± 1017.6

*Means with the same letters are not statistically different

Generally, composites made from *EM* particles had higher MOR than those of *LS* (Table 4). This observation is in agreement with the previous study on compatibility testing conducted by Adefisan *et al*. (2012) who reported that *EM* canes were more compatible with cement than *LS*. The higher sugar content in the *LS* canes in comparison with *EM* (Dahunsi, 2000) may have hindered formation of strong crystalline bonds. However, pre-treatment significantly enhanced the MOR of the rattan CBC relative to control (Table 4). The greatest improvement was recorded for composites treated with 3% $CaCl_2$. This is an indication that $CaCl_2$ was more effective than either cold water extraction or the incorporation of $Al_2(SO_4)_3$ in curtailing the deletreious effects (delay in cement setting and impairment to the bonding of cement with lignocellulosic material) of soluble sugars and extractives in the rattan composites. The bonds formed due to the unfilled orbital of the Ca^{2+} and Al^{3+} are responsible for the reactivity of the metallic ions with the active sites (i.e. functional groups, mainly the hydroxyl and carbonyl groups) of the inhibitory soluble sugars and extractives of the lignocellulosic materials. This would be responsible for rendering inhibitory chemicals inactive (Moslemi *et al*., 1983). The inhibitory chemicals removal by cold water or rendering inactive by chelation of the metallic ions (Ca^{2+} or Al^{3+}) encouraged the formation of strong bond between cement and treated rattan species. $CaCl_2$ was more effective than $Al_2(SO_4)_3$ because Ca^{2+} (group 2 element in the periodic table) is more reactive than Al^{3+} (a transition element in group 13 formerly classified as group 3 element). Additionally, differences occurred in the effectiveness of $CaCl_2$ and cold water extraction because $CaCl_2$ masked (by reacting) the inhibitory chemicals while cold water extraction only removed the cold water soluble extractives leaving insoluble phytochemicals that could still hinder cement setting. This is corroborated by Adefisan *et al*. (2012) who classified (based on maximum hydration temperature) the control *EM* and *LS* as 'intermediately suitable' for the production of CBC.

The chemical (including water) treated *EM* and *LS* were classified as 'suitable' except the $Al_2(SO_4)_3$ treated *LS* which was ranked as “intermediately suitable” for the production of cement bonded boards. In addition, increment in particle size from 0.85 to 1.0 mm caused a reduction in MOR. The effects of particle geometry on the CBC strength properties have been investigated by several researchers; however, contradictory observations have been reported. Badejo (1988) reported an improvement in moduli of elasticity and rupture with increase in flake dimensions of hardwood-cement composites produced from wood flakes while Olorunnisola *et al.* (2005b) reported a decrease in compressive strength, MOR and MOE with increasing particle size for *L. secundiflorum*–cement composites produced from particle sizes that ranged from 0.6 to 1.2 mm. Anonymous (2013) reported that the CBC produced from *Macaranga gigantea* particle sizes of 0.5 mm, 1.0 mm and 2.0 mm had MOR of 8.58, 5.47 and 11.43 N/mm^2, respectively with MOE of 2804.82, 1334.61 and 2959.47 N/mm^2, respectively. This show that decrease in particle sizes below 1.0 mm caused increase in MOR and MOE which is similar to the trend observed in *EM* and *LS* composites. Detail explanation for the reduction in the MOR with increase in particle size is not clear and further study is required to understand this phenomenon. A plausible reason may be due to insufficient cement coating by the larger particles.

Table 5: Duncan's Multiple Comparison of the effect of treatment, rattan content and particle size on the MOR and MOE of Rattan cement composites

	MOR		MOE	
	E. macrocarpa	*L. secundiflorum*	*E. macrocarpa*	*L. secundiflorum*
Treatment (N=12)				
Control	2.7^{C} (0.39)	3.0^{B} (0.42)	3157.3^{A} (1165.0)	3799.5^{AB} (1485.7)
$CaCl_2$	4.3^{A} (0.67)	4.0^{A} (0.89)	3408.5^{A} (1035.1)	4385.1^{A} (1015.7)
$Al_2(SO_4)_3$	2. 9^{BC} (0.57)	2.6^{B} (0.40)	3376.3^{A} (1486.1)	3207.3^{BC} (734.0)
Water	3.2^{B} (0.67)	3.0^{B} (0.47)	2888.1^{A} (534.2)	2770.3^{C} (795.9)
Rattan Content (%)(N= 24)				
5	3.2^{A} (0.85)	3.1^{A} (0.62)	3679.6^{A} (1116.1)	3352.2^{A} (1379.2)
10	3.4^{A} (0.86)	3.2^{A} (0.88)	2735.6^{B} (856.7)	3728.9^{A} (891.9)
Particle Size (mm) (N= 24)				
0.85	3.5^{A} (0.90)	3.4^{A} (0.66)	3166.0^{A} (1150.8)	3839.9^{A} (747.7)
1.0	3.1^{B} (0.74)	3.0^{B} (0.88)	3249.1^{A} (1054.7)	3241.2^{B} (1500.6)

Significant at 5% level of level of probability. Standard deviation given in parentheses “Means with the same letters within a column are not statistically different”.

The MOE of the rattan cement composites were in conformity with those reported on other rattan species (Olorunnisola *et al*., 2005a; Olorunnisola, 2007) and hardwood based CBC (Badejo, 1989; Fuwape and Oyagade, 1993; Fabiyi, 2004). Generally, the MOE of *LS* and *EM* rattan CBC was not significantly different. However, pre-treatments significantly enhanced the MOE of the rattan CBC relative to control (Tables 4 and 5). The greatest improvement was obtained for composites treated with $CaCl_2$ and shows a clear reduction in the inhibitory effects of soluble sugars and extractives on the cement hydration. Also, while significant reduction occurred with increase in rattan content attributable to poor interfacial bonding, the particle size (differences in the particle surface area) did not have significant effect on the MOE of the *LS* composites (Tables 4 and 5). Increase in the particle size (fiber length) caused decrease in the MOR for both *EM* and *LS* based CBC irrespective of the fiber content and the chemical treatment applied. The MOR of $CaCl_2$ treated rattan composites increased with increase in rattan fiber content for both *EM* and *LS* species. This could be attributed to the ability of fibers to diffuse the regions of stress concentration thereby improving the resistance of the composites to the applied stress (Fuwape and Oyagade, 1993). However, increase in the rattan fiber content generally caused decrease in the MOR of control and $Al_2(SO_4)_3$ treated *EM* and *LS* CBC samples.

The increase in the fiber length did not show any specific pattern of variation in the MOE of the control and chemical treated *EM* and *LS* based CBC. However, increase in the fiber content generally reduced the MOE irrespective of the fiber length used and treatment applied except for the water treated *EM* and *LS* based CBC. Savastano *et al*. (2000) also observed that MOE decreased with increase in fiber content. This could be attributed to the fact that MOE is highly dependent on the quantity of the fiber and cement matrix; when wood occupies more volume in the board, the areas of stress concentration around the component particles are more diffused, thereby reducing the MOE (Fuwape and Oyagade, 1993). The CBC with low fiber content (5%) had higher cement than the CBC with 10% fiber content, hence higher cement content caused the lower fiber content CBC to have higher MOE.

CONCLUSION

Pre-treatments (cold water extraction, aqueous $CaCl_2$ and $Al_2(SO_4)_3$) were shown to have significant effects on rattan CBC properties. Fibre treatment generally caused significant reduction in the WA and TS of the rattan CBC. An increase in particle size and rattan content also caused significant increase in WA. Composites made from *E. macrocarpa* particles had higher MOR than those of *L. secundiflorum*. The greatest improvement in the MOR and MOE was experienced by the 3% $CaCl_2$ treated rattan CBC.

ACKNOWLEDGEMENT

This study was conducted at the Renewable Materials Laboratory, University of Idaho, Moscow USA with the grant received from John D. and Catherine T.

MacArthur Foundation through University of Ibadan, Nigeria. The support is acknowledged with thanks.

REFERENCES

Adefisan, O.O. 1999. Utilisation of rattan cane residues for cement-bonded particleboard production. M.Sc. Thesis, Dept. of Agric. Engrg., Univ. of Ibadan, Nigeria.101p.

Adefisan, O.O. and Olorunnisola, A.O. 2007. Compatibility of Rattan Particles with Ordinary Portland Cement. *Journal of Applied Science Engineering and Technology*. 7(1):51-56

Adefisan, O.O. Fabiyi, J.S. and MacDonald, A.G. 2012. Hydration and Infrared Spectroscopy of Pre-treatments Effects on Portland Cement-*Eremospatha macrocarpa* and *Lacosperma secundiflorum* Systems. *Journal of Applied Sciences*. 12(3):254-262

American Society for Testing and Materials ASTM D 1037-00. 2003. Standard Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials. Vol. 04, 10

Anonymous. Production and properties of wood cement boards from *Macaranga gigantea*. www.slideshare.net/izzahnoah/wood -cement-board. Posted July 2013. Accessed January 20, 2014

Badejo, S.O.O. 1988. Effect of flake geometry on properties of cement-bonded particleboard from mixed tropical hardwoods. *Wood Science and Technology*. 22:357-370.

Badejo, S.O.O. 1989. Influences of pre-treatment temperature and additive concentration on the properties of cement-bonded particleboard from plantation–grown tropical hardwoods. *Tropical Science*. 29: 285-296

Bison. Bison Wood Cement Board. Bison-Report, p. 10, 1978.

Brandt, A.M. 1995. Cement-Based Composites: Materials, Mechanical Properties and Performance. E & F Spon, London. 470 p

BSI 2007. British Standards Institution. Cement-bonded particleboards specifications- Part 2: Requirements for ordinary Portland cement bonded particleboards for use in dry, humid and external conditions. British Standard BS EN 634-2: 2007. 12p

CETRIS Company. Basic Properties of CETRIS Cement Bonded Particleboard, 30P. Accessed January 20, 2014, http://www.cetris.cz/en/advice-and-information/cetris-boardproperties

Dahunsi, B.I.O. 2000. The Properties and potentials application of rattan canes as reinforcement materials in concrete. Ph.D. Thesis. Department of Agricultural Engineering. University of Ibadan.

Fabiyi, J.S. 2004. Effects of chemical additives concentrations on the strength and sorption properties of cement-bonded boards. *Journal of Tropical Forest Science* 16 (3) 6p

Fuwape, J.A. and Oyagade, A.O. 1993. Bending strength and dimensional stability of tropical wood-cement particleboard. *Bioresources Technology* 44: 77-79

Giemer, R.L. Souza, M.R. Moslemi, A.A. Simatupang, M.H. 1992. Carbon-dioxide application for rapid production of cement particleboard. *In*: Proceedings, Inorganic-bonded Wood and Fibre Composite Materials. Conference; 1992. Sept. 27-30; Spokane, W.A.

Goodell, B. Daniel, G. Liu, J. Mott, L. and Frank, R. 1997. Decay resistance and microscopic analysis of wood-cement composites. *Forest Products Journal* . 47(11/12): 75 – 80.

Huang, C. and Cooper, P.A. 2000. Cement bonded particleboard using CCA-treated wood removed from service. *Forest Products Journal.* 50(6):49-56

Indian Standard IS 14276: Cement Bonded Particle Boards- Specification. 1995.

Karade, S.R., Irle, M and Maher, K. 2003. Assessment of wood-cement compatibility: A new approach. *Holzforschung* 57(6):672-680

Moslemi, A.A., Gracia, J.F. and Hofstrand, A.D. 1983. Effect of various treatment and additives on wood-Portland cement systems. Wood Fiber Science 15(2): 164-176

Olorunnisola, A.O. 2005. Dimensional stability of cement-bonded composites boards from rattan cane particles. *Journal of Bamboo and Rattan* 4.2:173-182

Olorunnisola, A.O. Pitman, A. and Mansfield-William, H. 2005a. Hydration characteristics of cement–bonded composites made from rattan cane and coconut husk. *Journal of Bamboo and Rattan* 4.2:193-201

Olorunnisola, A.O. Pitman, A. and Mansfield-William, H. 2005b. Strength Properties and potential uses of Rattan-Cement Composites. *Journal of Bamboo and Rattan* 4.4: 343-352

Olorunnisola, A.O. 2006. Strength and water absorption characteristics of cement-bonded particleboard produced from coconut husk. *Journal of Civil Engineering Research and Practice* 3.1:41- 49

Olorunnisola, A.O. 2007. Effects of particle geometry and chemical accelerator on strength properties of rattan–cement composites. *African Journal of Science and Technology (AJST) Science and Engineering Series* 8(1): 22 – 27

Olorunnisola, A.O. 2008. Effects of pre-treatment of rattan (*Lacosperma secundiflorum*) on the hydration of Portland cement and the development of a new compatibility index. *Cement and Concrete Composites* 30.1:37-43

Savastano, H. Warden, P.G. Coutts, R.S.P. 2000. Brazilian waste fibres as reinforcement for cement-based composites. Cement and Concrete Compo. 22: 379–384.

Semple, K. and Evans, P.D. 2002. Screening of Inorganic Additives for ameliorating the inhibition of hydration of Portland cement by heartwood of *Acacia mangium*. *In*: Evans, P.D. (ed.) wood-Cement Composites in Asia-Pacific region. Proceeding of a Workshop held at Rydges Hotel, Canberra, Australia 10 December, 2000. p 29-39

Sensale, G.R. 2006. Strength development of concrete with rice-husk ask. *Cement and Concrete Composites*. 286:158-160

Simantupang, M.H., Habighorst, C., and Neubauer, A. 1995. Investigations on the influence of the addition of CO_2 on the production and properties of rapidly set wood-cement composites. Cement and Concrete Composites 17:187-197