COMPATIBILITY OF *CALAMUS DEERRATUS* AND *LACOSPERMA SECUNDIFLORUM* RATTAN PARTICLES WITH ORDINARY PORTLAND CEMENT

***Adefisan, O.O. and A.O. Olorunnisola**
Department of Agricultural and Environmental Engineering
University of Ibadan, Nigeria.

ABSTRACT

An investigation was conducted to determine the optimum water to cement ratio for a locally manufactured Portland cement for use in wood composites. The effects of pre-processing and calcium chloride ($CaCl_2$) on the compatibility of two rattan canes (Calamus deerratus and Lacosperma secundiflorum) with cement were also assessed using the compatibility factor (C_A) approach. An optimum water: cement ratio of 0.45 was obtained. Generally the two rattan species were compatible with cement. The C_A factors increased with increasing levels of $CaCl_2$ concentration (65.2% to 101.5% for C. deerratus and 71.2% to 103.5% for L. secundiflorum at 0 to 3% concentrations). Removal of the silified epidermis (pre-processing) had more significant effect ($P \leq 0.05$) on the compatibility of C. deerratus with cement than in the L. secundiflorum species. Also, the particles of the Lacosperma species were more compatible with cement than those of the Calamus species probably due to the anatomy and other variations in the two species.

Keywords: Rattan, Calcium chloride, cement compatibility
* Corresponding author: e-mail: femiadefisan@yahoo.co.uk

INTRODUCTION

The search for alternative lignocellulosic material for cement bonded composites (CBC) production continues in the light of the dwindling timber supply in many parts of the world. In this regard, a number of lignocellulosic materials including manufacturing and agricultural wastes have been tested for CBC production (Badejo, 1992; Xu *et al.*, 2004; Ajayi, 2003; Bilba *et al.*, 2003 Olorunnisola, 2005; Ajayi, 2006). However, not all such materials are suitable for CBC production due to the problem of incompatibility with cement. This problem has generally been associated with the extractive contents of the materials which tend to hinder the formation of strong crystalline bonds (Badejo, 1992; Semple and Evans, 2002). Hence, preliminary evaluation of candidate furnish materials for CBC production is often recommended.

The first step in assessing the compatibility of a lignocellulosic material with cement is to determine its hydration characteristics (Semple *et al.*, 2002). However, the choice of any particular lignocellulosic material is dependent on the availability and processing cost (Olorunnisola, 2005). Lucas and Dahunsi (2004) reported that rattans are abundant in the forests of western Nigeria. Amongst the four rattan genera endemic to Nigeria, *Lacosperma secundiflorum* and *Calamus deerratus* are most widespread and commonly used. Olubanjo (2002) and Lucas and Dahunsi (2004) reported that rattan canes can be used for structural purposes and as concrete reinforcement of low stressed elements, while Olorunnisola and Adefisan (2002) found that furniture wastes of mixed rattan canes are feasible for cement-bonded particleboard production. However, it is necessary to investigate the suitability of different rattan species for cement-bonded particleboard production. This will further compliment the existing knowledge base of rattan canes as low-cost construction material.

In order to ensure uniform mixing and adequate strength in wood-cement composites, it is important to use an appropriate water : cement ratio. This is because different types of cement require variable quantities of water. Water-cement ratios of between 0.25 and 0.6 have been reported for different types of Portland cement of American, Australian, Brazilian and Hungarian origins (Qi *et al.*, 2006; Bejo *et al.*, 2005; Okino *et al.*, 2005; Semple *et al.*, 2002; Huang and Cooper, 2000, Hachmi *et al.*, 1990). While different brands of Portland cement available in Nigeria are commonly used for construction works and composite productions, it is necessary to determine the optimum water-cement ratio of the locally produced Ordinary Portland cement.

The objectives of this work were (1) to determine the optimum water to cement ratio for a locally manufactured Portland cement, and (2) to examine the effects of calcium chloride ($CaCl_2$) and rattan pre-processing method on the compatibility of *Calamus deerratus* and *Lacosperma secundiflorum* with Portland cement.

MATERIALS AND METHODS

Preparation of Raw materials.

Mature stems of two rattan species namely *Calamus deerratus* and *Lacosperma secundiflorum* were harvested from Gambari forest reserve in Oluyole local government area of Ibadan, Oyo state, Nigeria. The harvested canes were separated into two parts. One part was manually peeled to remove the silified epidermis, while the other part was not peeled. Both the peeled and the unpeeled canes were converted into billets of about 6cm and hammer milled. The milled particles were collected and sieved using a set of sieves of sizes 1.18mm, 0.85mm and 0.60mm. Particles that passed through the 0.85mm sieve and were retained in the 0.60mm sieve were collected and air-dried for two weeks to an average moisture content of 10%.

Determination of Optimum Water: Cement Ratio

A well known brand of Ordinary Portland cement locally manufactured in Nigeria was purchased at the manufacturer's depot in Ibadan for use. The optimum water to cement ratio was determined in accordance with the procedure adopted by Hachmi *et al.*, (1990). 200g of Ordinary Portland cement was mixed with different levels of de-ionized water ranging from 60ml to 100ml in increments of 5ml in a polythene bag. After homogeneous slurries were obtained, the cement mixtures were placed in a thermally sealed thermos flask. Temperature rise was monitored until the maximum temperature was obtained. Three replicates were made at each level.

The maximum temperature (T_2), time to reach the maximum temperature (t_2) and the room temperature (T_r) were recorded and used in the determination of the optimum water to cement ratio (i.e. uniform mixing index) expressed as:

$$UM = \frac{(T_2 - T_r)t_2}{2}$$

Hydration test

The suitability of the samples of *Calamus deerratus* and *Lacosperma secundiflorum* canes for CBC production was assessed using the hydration temperature test method and the best UM index obtained. 15g of the rattan particles, 200g of Ordinary Portland cement and 93ml of de-ionized water were mixed in a polythene bag to form homogeneous slurry. For the control experiment, 200g of neat cement was mixed with 90ml de-ionized water as in Hachmi *et al.* (1990). $CaCl_2$ was dissolved in de-ionized water before use at four concentration levels, i.e. 0, 1, 2 and 3% (by weight of cement).

The hydration tests were performed in well insulated thermos flasks. Temperature rise was monitored for 24 hours using a T-type thermocouple. Three replicates of each mixture were prepared. The compatibility index (C_A factor) was determined based on the ratio of the area under the hydration curve of rattan-cement mixture to that of the cement control as in Hachmi *et al.* (1990).

Results and Discussions

Optimum Water: Cement Ratio

The water to cement ratios as expressed by uniform mixing indices (UM) are shown in Table 1. The UM increased generally with an increase in water to cement ratio. UM values ranging from 106.8 – 137.0^{0}C.h were obtained. A maximum UM of 137.0^{0}C.h was obtained at 0.45 water-cement ratio. This value is close to 0.4 obtained by Hachmi *et al.*, (1990), Semple *et al.*, (2002) and Okino *et al.*, (2005). However, Hachmi *et al.*, (1990) noted that the optimum water to cement ratio vary among cement types in different countries. 0.45 seemed to be the optimum water to cement ratio for the cement tested.

Table1: Uniform Mixing Index for Portland Cement

Water :Cement Ratio	Maximum Hydration Temperature (°C)	Time to Reach Maximum Temperature (Hrs)	Uniform Mixing Index (°C.h)
0.30	66.5	5.0	106.8
0.35	64.8	6.0	124.2
0.40	61.6	6.5	127.1
0.45	61.3	7.0	137.0
0.50	56.8	7.5	127.6

Compatibility Factors (C_A)

The compatibility factors (C_A) of *Calamus deerratus* and *Lacosperma secundiflorum* are shown in Table 2. The C_A factors of 65.2% and 72.6% were obtained for particles of the peeled and unpeeled *Calamus deerratus* without the addition of $CaCl_2$. Values of 71.1% and 71.2% were respectively recorded for the peeled and unpeeled *Lacosperma* species without $CaCl_2$. Based on the classifications by Hachmi *et al.*, (1990) and Semple and Evans (2000), untreated particles of the *Lacosperma* species and the unpeeled *Calamus* were compatible with cement. The untreated particles of the peeled *Calamus* were not compatible. Visual examination showed that whereas strong bonds were formed between particles of the *Lacosperma* species and the unpeeled *Calamus* with cement after 24 hours of experimentation, no cohesive bonds were noticed in the mixtures of particles of the peeled *Calamus* and cement.

Effects of Peeling on Compatibility

The removal of the silified epidermis seemed to have had a negative effect on the compatibility of the *Calamus* species as against those of the *Lacosperma* species. This observation may suggest that inhibitory substances are concentrated in the core of the stem of the *Calamus* species. Dahunsi (2000) noted anatomical differences between *Calamus deerratus and Lacosperma secundiflorum* canes obtained in the forests of western Nigeria. Higher presence of strengthening tissues (sclerenchyma) was noticed in the *Lacosperma* species as against the increased concentration of storage tissues (parenchyma) in the *Calamus* species.

The prominence of parenchyma cells in the *Calamus* species may indicate that inhibitory substances are more pronounced in the stem. It may however be that the presence of cement inhibitors is concentrated in the core of the *Calamus* stem than at the periphery. This needs to be investigated. However, statistical analyses ($P \leq 0.05$) showed significant differences between the peeled and unpeeled *Calamus* while no significant difference existed between the peeled and unpeeled *Lacosperma* (Table 2 and 5). This again may indicate that the removal of the silified epidermis had negative effects on the compatibility of the *Calamus* species.

Table 2: Compatibility Factors (%) of Rattan Species

Particles& Cement Mixtures	*Calamus deerratus* Unpeeled	*Calamus deerratus* peeled	*Lacosperma secundiflorum* Unpeeled	*Lacosperma secundiflorum* peeled
Rattan Only	72.6^{C}	65.2^{D}	71.2^{G}	71.1^{G}
Rattan + 1% $CaCl_2$	91.5^{B}	66.3^{D}	89.4^{F}	91.7^{F}
Rattan + 2% $CaCl_2$	99.3^{A}	65.9^{D}	99.5^{E}	100.8^{E}
Rattan + 3% $CaCl_2$	101.5^{A}	65.9^{D}	102.4^{E}	103.5^{E}

Means with the same letters are not statistically different

Effects of Calcium chloride on Compatibility

Increase in $CaCl_2$ from 1 to 3% concentration improved the compatibility of the *Lacosperma* species and the unpeeled *Calamus*. The greatest improvement was obtained at 3% additive concentration (i.e. 102.4% and 103.5% for unpeeled and peeled *Lacosperma* and 101.5% for unpeeled *Calamus*). This suggests that the C_A factor increased with increasing levels of additive concentration.

Unlike the *Lacosperma* species and the unpeeled *Calamus*, reductions in the C_A factors occurred as the additive concentration increased from 1 to 3% in cement mixes containing particles of peeled *Calamus*. The highest C_A for the peeled *Calamus* was obtained at 1% additive concentration. This again may suggest that cement setting inhibitors may be concentrated in the core of the *Calamus* stems thus hindering the formation of strong cement bonds. Also, $CaCl_2$ was not effective in removing / rendering the inhibitory substances present in the peeled *Calamus* inactive. This observation is similar to those of Semple and Evans (2002) who noted that $CaCl_2$ may not be as effective as magnesium chloride ($MgCl_2$), iron chloride ($FeCl_3$) and Aluminum chloride ($AlCl_3$) in rendering inactive some inhibitory types of polyphenols. The inhibitory substances present in the *Calamus* *deerratus* species and the effects of other chemical additives on the cement compatibility of this species needs to be investigated.

Except for the peeled *Calamus*, the C_A factors recorded in this study were higher at all levels of $CaCl_2$ concentrations than those of peeled *Lacosperma* reported by Olorunnisola *et al.* (2005) (i.e. 55% to 97%). Differences in the C_A factors may be attributed to variation in the brands of cement used in both studies. While Portland cement of strength class 42.5R was used in this study, Olorunnisola *et al.* (2005) used that of class strength 32.5R. Also, differences in geographical locations may have contributed to variation in C_A factors obtained in both studies. Rattan canes used for this study were extracted from Gambari forest of Oyo state while those employed by Olorunnisola *et al.* (2005) were from Delta state Nigeria.

The C_A factors of *Lacosperma* species were generally higher than those of the *Calamus* species. The addition of $CaCl_2$ at 1 to 3% concentration levels to the unpeeled particles of both *Calamus* and *Lacosperma* species resulted in slight improvements in the C_A factors of the *Lacosperma* species over those of the *Calamus* species. However, there were substantial increments in the C_A factors of the peeled *Lacosperma* over those of the peeled *Calamus* as the $CaCl_2$ concentrations increased from 1 to 3%. This finding may again indicate that pre-processing (removal of the epidermis) negatively affected the compatibility of the *Calamus* species and may imply the concentration of inhibitory substances in the core of the *Calamus* stem.

Statistical analyses ($P \leq 0.05$) revealed significant differences in the additive concentration levels used for the *Lacosperma* species and the unpeeled *Calamus* (Table 3). The interaction of additive concentration and processing was significant in *Calamus* species (Table 4). This suggests that the levels of additive concentration used and pre-processing of the *Calamus* canes affected the cement compatibility of the species. This was not the case with the *Lacosperma* species and may be attributed to differences in the anatomy of the rattan species.

Although 3% additive concentration gave the highest C_A factor for the *Lacosperma* species and unpeeled *Calamus*, no significant difference existed between 2% and 3% concentration level (Table 2). This may indicate 2% as the optimum concentration level for the raw particles of these species. However, no significant difference existed in the additive concentrations (0-3%) used for the peeled *Calamus*. This again may indicate that $CaCl_2$ was not effective in rendering inactive the inhibitory substances present in the peeled *Calamus*.

Table 3: Analysis of Variance for testing the effect of additive concentration on C_A

Source of Variation	Df	Mean Square Values			
		Calamus deeratus		*Lacospema secundiflorum*	
		Unpeeled	Peeled	Unpeeled	Peeled
Additive Concentration	3	520.56*	0.564	597.34*	646.93*
Error	6	3.98	0.359	7.48	3.79

* significant at 0.05 level of probability

Table 4: Analysis of variance for testing the effects of additive concentration and processing method on C_A

Source of Variation	Df	Mean Square Values	
		Calamus deerratus	*Lacosperma secundiflorum*
Additive Concentration (C)	3	272.64*	1242.76*
Processing (P)	1	3876.3*	7.94
C x P	3	248.49*	1.52
Error	16	2.97	13.63

* significant at 0.05 level of probability

Table 5: Multiple comparison of the effect of processing method on rattan-cement compatibility

Factor	Levels	*Calamus deerratus*	*Lacosperna secundiflorum*
Processing	Unpeeled	91.2^A	90.6^C
	Peeled	65.8^B	91.8^C

Means with the same letters are not statistically different

Table 6: Multiple comparison of the effect of rattan species on cement Compatibility

Factors	Levels	C_A (%)
Species	*Lacosperma secundiflorum*	91.2
	Calamus deerratus	78.5

At all levels of additive concentrations, the C_A factors of the unpeeled *Calamus* were higher and statistically different from those of the peeled samples (Table 2). This suggests that pre-processing (i.e. removal of the silified epidermis) had effects on the cement compatibility of the *Calamus* species and that inhibitory substances may be concentrated in the core of the *Calamus* stem. However, the C_A factors of the peeled *Lacosperma* were slightly higher but not statistically different from those of the unpeeled at 1-3% additive concentrations. This may indicate that the inclusion of silified epidermis had minimal effect on the cement compatibility of the *Lacosperma* species

The *Lacosperma* species had C_A factors that was higher and statistically different from those of the *Calamus* species (Table 6) and may suggest that particles of the *Lacosperma* canes formed stronger bonds than those of the *Calamus* species. This again may be attributed to the anatomical differences between the species.

Conclusions

The following conclusions can be drawn from this study:

(i) The optimum water to cement ratio for the brand of Ordinary Portland cement tested is 0.45.

(ii) *Lacosperma secundiflorum* and *Calamus deerratus* canes are compatible with cement.

(iii) While of the inclusion of the silified epidermis (pre-processing) in cement mixtures significantly improved the compatibility of particles of *Calamus deerratus* used for this work, the effect was insignificant in the *Lacosperma* species

(iv) $CaCl_2$ was not effective in rendering the inhibitory substances present in the peeled samples of *Calamus* species inactive.

RECOMMENDATIONS

Based on the findings of this study it is recommended that the effects of other chemical additives and other pre-treatment measures on the compatibility of *Lacosperma secundiflorum* and *Calamus deerratus* with cement be investigated.

REFERENCES

Ajayi, B. 2003. Investigation of the dimensional stability of cement bonded composite boards fabricated from coffee husks. *Nigerian Journal of forestry* 33(2):88-93

Ajayi, B 2006. Properties of maize stalk based cement bonded composites. *Forest products Journal* 56(6): 51-55

Badejo, S.O. 1992. Trial production and testing of cement-bonded particleboard from three Nigerian crop residues. *Journal of Tropical Forest Resources*. 7:45-57.

Bejo, L.; Takas,P. and Vass, N. 2005. Development of cement bonded composite beams. *Acta silvi Lign Hung* 1:111-119

Bilba,K; Arsene, M.A.; Quensanga,A. 2003. Sugar cane bagasse fibre reinforced cement composites. Part I. Influence of botanical components of bagasse on the setting of bagasse/cement composite. *Cement and concrete* 25: 91-96

Dahunsi, B.I.O. 2000. The Properties and Potentials Application of Rattan Canes as Reinforcement Materials in concrete. Ph.D. Thesis in the Department of Agricultural Engineering, Faculty of Technology, University of Ibadan.

Hachmi, M.; Moslemi, A.A. and Campbell, A.G.1990. A New Technique to Classify the Compatibility of Wood with Cement. *Wood Science and Technology* 24(4): 345-354

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

Lucas, E.B. and Dahunsi, B.I.O. 2004 a Characteristics of Three Western Nigerian Rattan Species in relation to their utilisation as Construction Material. *Journal of Bamboo and Rattan* 3(1):45-56

Okino,E.Y.A.; de Souza, M.R.; Santana, M.A.E.; Alves, M.V.; de Souza, M.E. and Teixeira, D.E. Physico-mechanical properties and decay resistance of Cupressus Spp cement –bonded particleboards. *Cement and concrete* 27:333-338

Olorunnisola, A. O. and Adefisan, O.O. 2002. Trial Production and Testing of Cement-Bonded Particleboard from

Rattan Furniture Waste. *Wood and Fibre Science*. 34(1): 116-124.

Olorunnisola, A.O. 2005. 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.; Pitman, A. and Mansfield-william, H. 2005. Hydration Characteristics of Cement-bonded composites made from rattan cane and Coconut husk. *Journal of Bamboo and Rattan* 4 (2) 193-201

Olubanjo, O.O. 2002 Extensive Rattan Production-To- Consumption System in Southern Nigeria: A Case Study. International Network for Bamboo and Rattan (INBAR), Beijing

Semple, K and Evans, P.D. 2000. Adverse Effects of Heartwood on the Mechanical Properties of Wood-Wool Cement Boards Manufactured from Radiata Pine Pine Wood. *Wood and Fibre Science*.32(1):37-43

Semple, K and Evans, P.D. 2002. Screening inorganic additives for ameliorating the inhibition of hydration of Portland cement by heartwood of Acacia mangium. In: P.D. Evans ed. Proceedings Wood-Cement Composites in the Asia-Pacific region. Canberra, Australia , P29-39

Semple, K., Cunningham, R.B. and Evans, P.D. 2002. Compatibility of Eucalyptus species with Portland Cement. In: P.D. Evans ed. Proceedings Wood-Cement Composites in the Asia-Pacific region. Canberra, Australia , P40-46.

Qi, H.; Cooper,P.A. and wan, H. 2006. Effects of CO_2 injection on the production of wood cement composites from medium density fiberboard (MDF). *Waste management* 26(5):509-515

Xu, X., Zhou, D., Wu, Q and Vlosky, R.P. 2004. Agric-Based Composites in China: Oppurtunities and Challenges. *Forest Products Journal* 54(5):8-15.