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Effects of *Cissus populnea* gum and rubber latex on physico-mechanical properties of cement-bonded rattan composites

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In this study, the effects of partial replacement of ordinary Portland cement with natural polymers on selected physical and mechanical properties of cement-bonded rattan composites was investigated. Fibrous particles of *Laccosperma secundiflorum* rattan cane species were mixed with cement mortar at two levels, that is, 2.5 and 5.0%. For experimentation, Portland cement was partially replaced at four levels, first with *Cissus populnea* gum (0, 10, 20, and 30%) and then natural rubber latex (0, 2.5, 5.0, and 10%). All test specimens were prepared and tested in accordance with ISO 8335 standard. Results obtained showed that the moisture content, density, water absorption, thickness, and bending strength of the composites met the minimum standard requirements, except for samples produced using 30% *C. populnea* and 5% rattan fibre that fell short of the 9 N/mm^2 minimum bending strength requirement. Partial replacement of cement with the two polymers resulted in a general increase in density. Analyses of variance showed that *C. populnea* gum had a significant effect (p<5%) on water absorption after 24 h of immersion, while natural rubber latex and *C. populnea* gum had significant effects on thickness swelling at 2 and 24 h of immersion, respectively. Also, *C. populnea* gum and rattan fibre contents had significant effects on the bending strength of the composites. It was concluded that Portland cement could be partially replaced with up to 20% of *C. populnea* gum or up to 2.5% of rubber latex in rattan-cement composite manufacture without adverse effects on the basic composite properties tested.

Key words: Rattan cane, *Cissus populnea*, rubber latex, cement, composites.

INTRODUCTION

Cement–bonded composites are made from the strands, particles or fibres of light-weight agro-forestry residues such as sawdust, tea waste, oil palm shells, hazelnut shell, and cork waste, among others (Bentur and Aekers, 1989; Demirbas and Aslan, 1998; Wolf and Gjinolli, 1999; Basrri et al., 1999; Karade et al., 2002; Karade, 2003). The matrix is usually cement paste or mortar and the fibre content can be as high as 10% by mass of cement (Mallari et al., 1999; Baski et al., 2003). The resulting low density products are largely employed in thin-sheet (6 to 10 mm thick) components such as flat and corrugated roofing tiles, ceiling boards and shingles. In the past thirty-five years, research has continued on acceptable non-wood materials for composite manufacture in the

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wake of dwindling wood resources in many regions of the world.

Rattans are spiny, climbing, monocotyledonous palms generally found near water courses. Their distribution is largely confined to tropical and subtropical forests of Asia, Africa and the pacific where ten of the thirteen known genera and 600 species are endemic, but *Laccosperma secundiflorum* is the most widespread (Sunderland and Dransfield, 2002). Rattan utilization for furniture manufacture is quite prominent in virtually all the countries where rattans are found. However, only about 20% of the 600 known rattan species is of commercial value in furniture making (Dransfield and Manokaran, 1993). Again, over 30% of rattan canes harvested at any particular time is usually discarded largely due to wood-staining fungi infestation, among other reasons (Liese, 2002). Nevertheless, previous studies by Olorunnisola (2007, 2008) and Adefisan and Olorunnisola (2010) have shown that rattan canes, including the fungus-stained ones, are a viable feedstock for cement-bonded composite since the wood-staining fungi tend to consume the low molecular weight sugars present in rattans that tend to inhibit cement hydration.

There is, however, a growing concern about the huge amount of fossil fuel combustion involved in cement manufacture, the associated CO_2 emission and the attendant significant contribution to global warming. One way of addressing this challenge is through partial substitution of Portland cement with polymers, a well-known practice in the concrete industry that is yet to be fully explored in the production of cement-bonded composites. One of the commercially available polymers commonly used in fibre-reinforced polymer-cement mortar is styrene-butadiene rubber (Shirai and Ohama, 1995). A well designed polymer modification can bring in several technical benefits such as increased tensile and flexural strength as well as enhanced water resistance (Neville and Brooks, 2006). Deriving such polymers from natural sources is also advantageous since they are eco-friendly.

Two candidate natural polymers that could be explored are *Cissus populnea* gum and natural rubber latex. The *C. populnea*, a woody liana (climber), is indigenous to the tropical rainforest zones of East, West and Central Africa that exudates gum (Iwe et al., 2004; Ojekale et al., 2006). Natural rubber latex, on the other hand, is typically obtained from the sap of the *Havea brasiliensis* rubber tree. The latex, a natural polymer of isoprene, may be whitish or yellowish in colour.

The objective of this study was to investigate the effects of the partial substitution of Portland cement with *C. populnea* gum and rubber latex on selected physical and mechanical properties of cement-bonded rattan composites.

MATERIALS AND METHODS

Mature, freshly harvested samples of *L. secundiflorum* rattan cane were duly identified in a standard herbarium, cross-cut into about 5 cm long billets, air dried for 4 weeks and then hammer-milled. Only the fibrous particles retained on a 2 mm sieve were used for composite production. Fresh *C. populnea* stems were procured, cut into 20 cm long billets, peeled and soaked in water at room temperature for 72 h to promote gum exudation. The mucilaginous exudate obtained was collected and filtered to remove extraneous materials. Rubber latex tapped from a plantation-grown rubber tree (*H. brazillences*) was procured, stored under air-tight condition, and preserved with Ammonia to prevent coagulation. Portland cement and river sand were also procured and used as binder and fine aggregates, respectively. The sand was washed with water, air-dried and sieved. Only particles that passed through a 2 mm sieve were used. Distilled water was used for all mixing operations.

For composite manufacture, the air dried rattan fibrous particles (Figure 1) were manually mixed with sand and cement in the control samples. Rattan contents of 2.5 and 5%, respectively were employed. For the experimental samples, *C. populnea* gum (Figure 2) and rubber latex (Figure 3) were separately used as partial replacements of cement at 10, 20 and 30% and 2.5, 5.0, and 10% by mass of cement, respectively as shown in Table 1. Preliminary studies had shown that rubber latex inclusion above 10% of the mass of cement was unacceptable. Triplicate samples of each matrix was poured into metallic moulds and vibrated for 60 s to get

Figure 1. Rattan cane particles.

Figure 2. *C. populnea* gum.

Figure 3. Rubber latex.

Table 1. Mix proportions for the composites.

Composite	Sand (g)	Water (g)	2.5% Rattan (g)	5.0% Rattan (g)	Portland Cement	Polymer (g)
Control	1125	281.3	14.1	28.1	562.5	-
10% *C. populnea*	1125	281.3	14.1	28.1	506. 3	56.3
20% *C. populnea*	1125	281.3	14.1	28.1	450	112.5
30% *C. populnea*	1125	281.3	14.1	28.1	393.8	168.8
2.5% rubber latex	1125	281.3	14.1	28.1	548.5	14.1
5% rubber latex	1125	281.3	14.1	28.1	534.4	28.1
10% rubber latex	1125	281.3	14.1	28.1	506.3	56.2

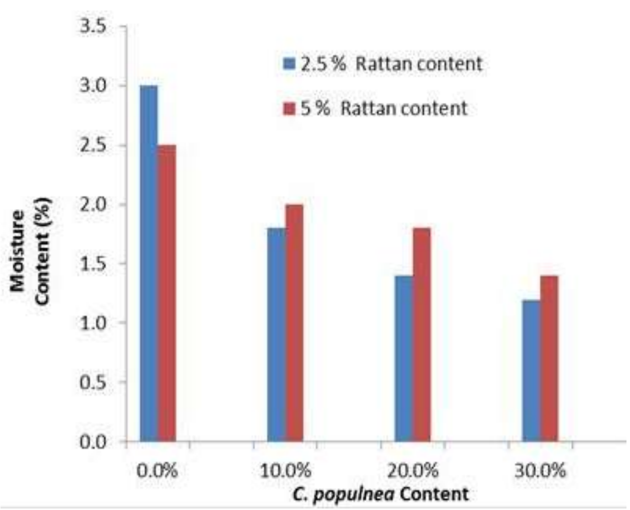

Figure 4. Effects of *C. populnea* and Rattan content on the moisture content of the composite.

rid of entrapped air. The samples were de-moulded after 24 h. Following the procedure adopted by Shirai and Ohama (1995), the specimens were damp-cured for 7 days at room temperature (about 25°C) and subsequently air-dried for 21 days. The moisture content, density, water absorption, thickness swelling and bending strength of the composites were then determined in accordance with ISO 8335 (1987) standard. The test results obtained were subjected to descriptive and inferential statistical analyses, including two-way analysis of variance at 5% level of significance.

RESULTS AND DISCUSSION

Moisture content and density

The moisture contents and densities of the composites are shown in Figures 4 and 5. The moisture contents of all the composite samples were relatively low (<3%) and in conformity with the ISO 8335 (1987) standard which stipulates a moisture content of below 12% for fibre-

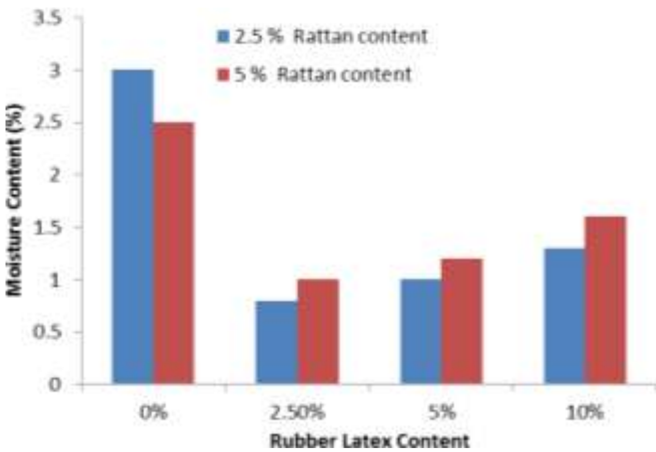

Figure 5. Effects of rubber latex and rattan content on the moisture content of the composite.

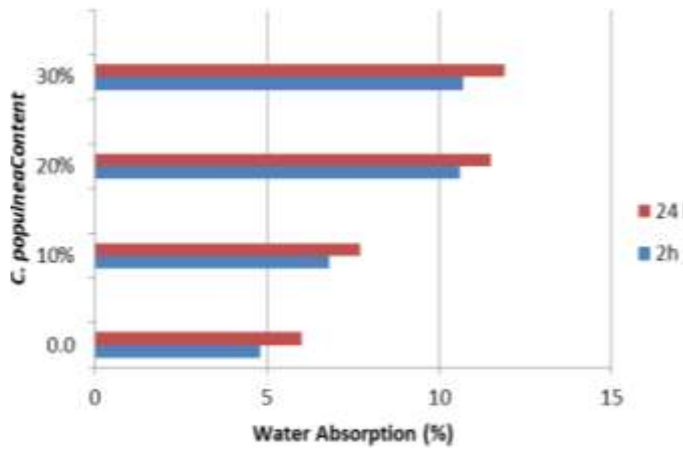

Figure 8. Effect of *C. populnea* on water absorption (%) of the composites at 2.5% rattan fibre content.

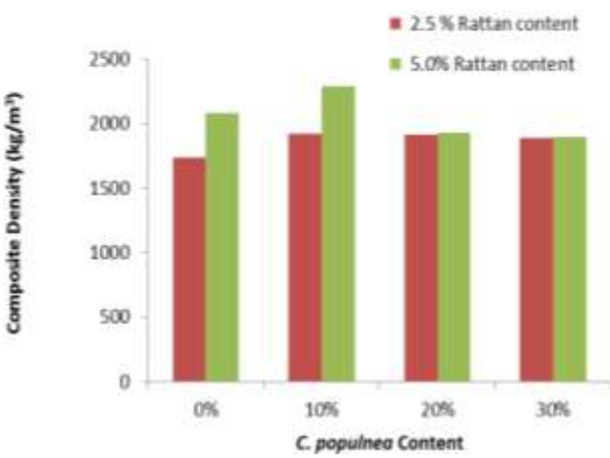

Figure 6. Effects of *C. populnea* and rattan content on the density of the composites.

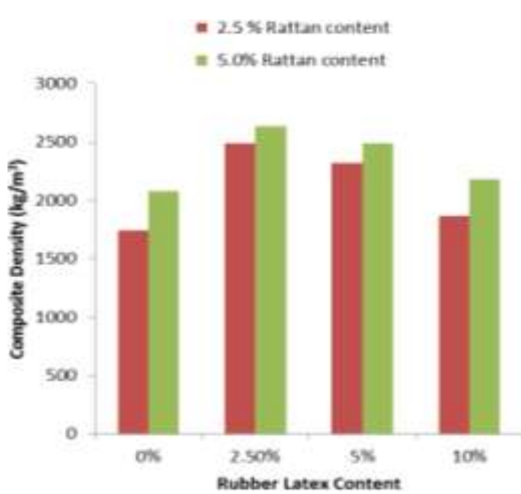

Figure 7. Effects of rubber latex and rattan content on the density of the composite.

cement composites. Partial replacement of cement with *C. populnea* gum and rubber latex resulted in a general decrease in moisture content, regardless of the rattan content.

As shown in Figures 6 and 7, the mean densities of the control samples containing 2.5 and 5% rattan fibre were 1737 and 2080 kg/m^3, respectively. The corresponding ranges of values for samples containing *C. populnea* gum and rubber latex were 1890 to 2289 and 1867 to 2629 kg/m^3, respectively. These values meet the ISO 8335 (1987) standard requirement of a density above 1000 kg/m^3. They also compare favourably with the range of values (1650 to 2400 kg/m^3) reported by Neville and Brooks (2006) for polymer concretes, but are lower than the range (1209 to 1365%) reported by Sudin and Swamy (2006) for bamboo and wood fibre cement composites who also partially replaced cement with natural rubber latex. Both the *C. populnea* gum and rubber latex contributed to a general increase in composite density. The increase was more pronounced in samples containing rubber latex in which the level of partial replacement of cement was lower, that is, 2.5 to 10% and the quantity of cement was greater. This was apparently due to the relatively higher specific gravity of the rubber latex. Freshly tapped natural rubber latex has a specific gravity of 0.97 to 0.98 depending on its dry rubber content which varies from 30 to 35%.

Dimensional stability

The Water Absorption (WA) values for the different composite mixtures are shown in Figures 8 to 11. The range of values obtained (4.8 to 11.9%) were much lower than the 2.2 to 28.6% reported by Olorunnisola (2005) for normal rattan-cement composites, but were consistent with those reported by Sudin and Swamy (2006) for wood-latex-cement composites. Partial replacement of

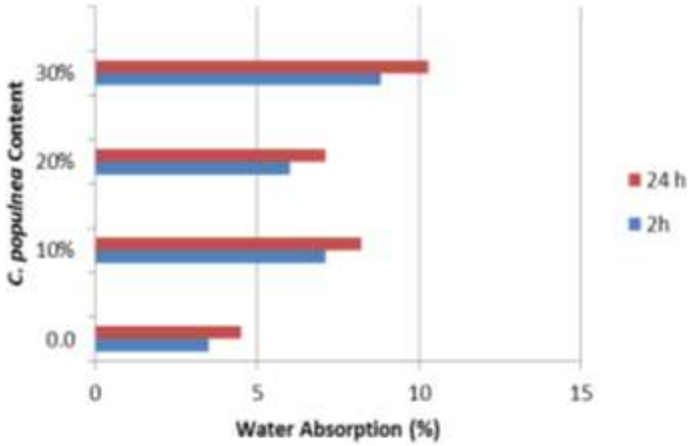

Figure 9. Effect of *C. populnea* on water absorption (%) of the composites at 5% rattan fibre content.

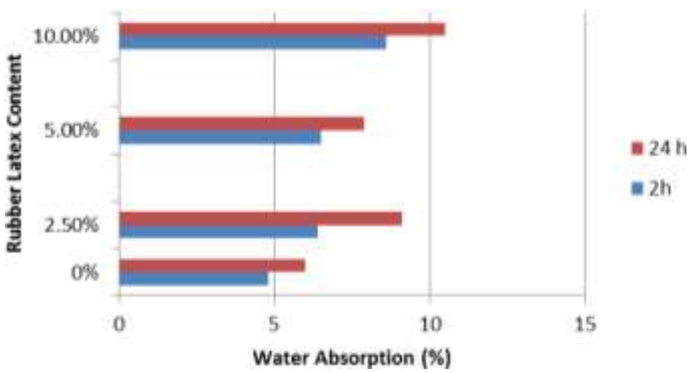

Figure 10. Effect of rubber latex on water absorption (%) of the composites at 2.5% rattan fibre content.

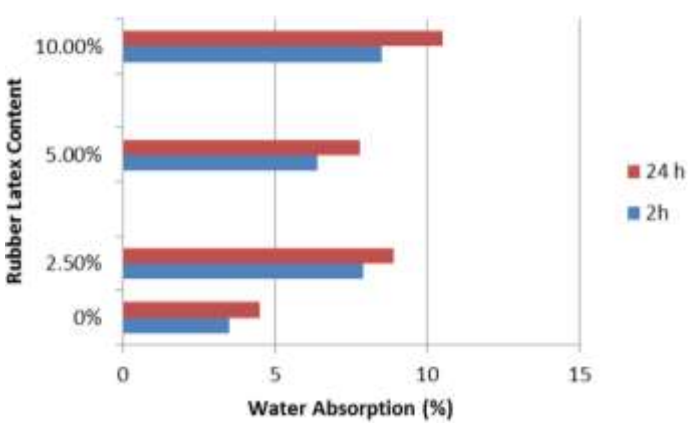

Figure 11. Effect of rubber latex on water absorption (%) of the composites at 5% rattan fibre content

cement with the two polymers resulted in an increase in WA across board, but particularly more so in the *C.*

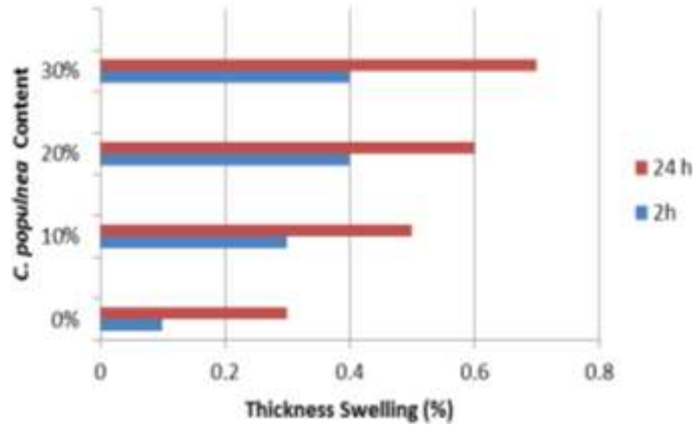

Figure 12. Effect *C. populnea* on thickness swelling (%) of the composites at 2.5% rattan fibre content.

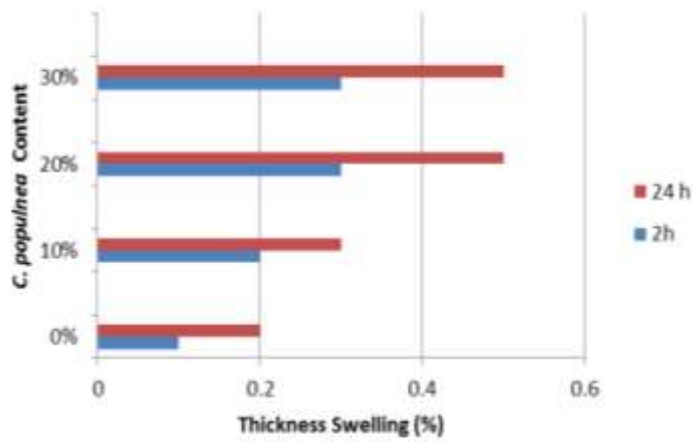

Figure 13. Effect of *C. populnea* on thickness swelling (%) of the composites at 5% rattan fibre content

populnea gum samples. A similar increase in WA due to partial replacement of cement with natural rubber latex in bamboo and wood fibre cement composites was reported by Sudin and Swamy (2006). Two-way analysis of variance, however, showed that only *C. populnea* gum had significant effect (p<5%) on WA after 24 h of immersion.

The corresponding Thickness Swelling (TS) values for the composite samples are shown in Figures 12 to 15. The values fell within the acceptable limits of 1.6 and 1.9% (after 1 and 24 h of immersion, respectively) as stipulated in BS 5669 (1989), and less than 2% (after 24 h of immersion) as stipulated in ISO 8335 (1987), respectively. These are clear indications that the composites were all dimensionally stable. However, two-way analyses of variance showed that the replacement of cement with natural rubber latex and *C. populnea* gum had significant effects (p<5%) on TS at 2 and 24 h of immersion, respectively.

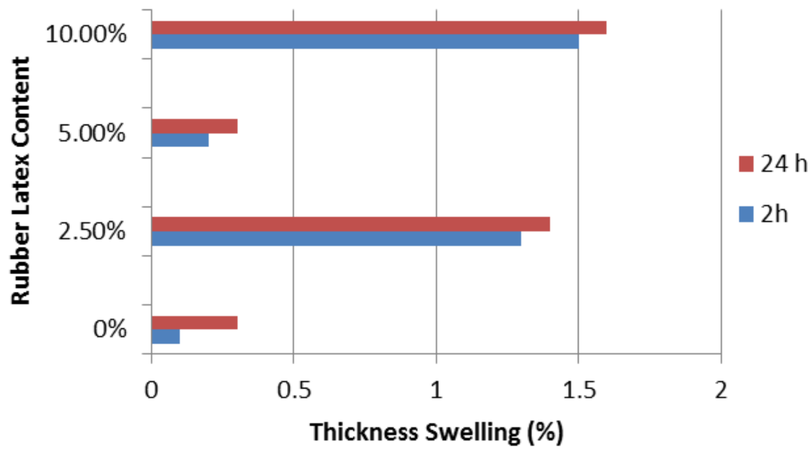

Figure 14. Effect of rubber latex on thickness swelling (%) of the composites at 2.5% rattan fibre content.

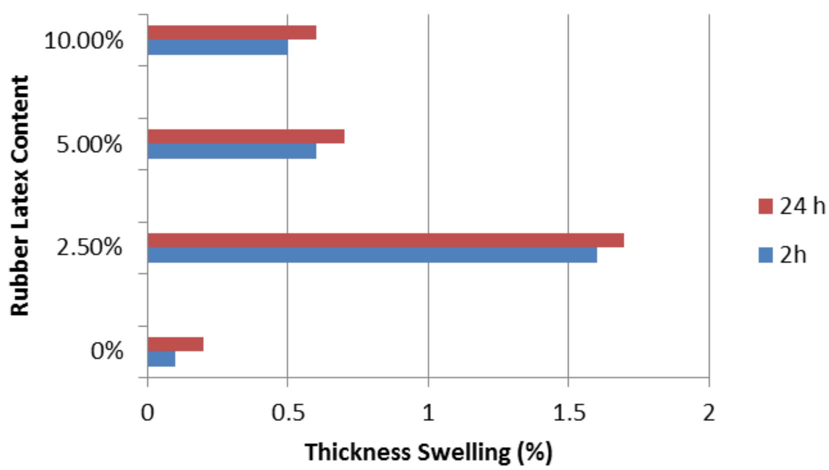

Figure 15. Effect of rubber latex on thickness swelling (%) of the composites at 5% rattan fibre content.

Table 2. Bending strength of the rattan-polymer-cement composites.

Level of cement replacement	2.5% Rattan content (N/mm^2)	5.0% Rattan content (N/mm^2)
0% (Control)	39.8 ± 3.46	24.0 ± 0.72
10% *C. populnea*	32.3± 1.62	18.9± 5.57
20% *C. populnea*	30.0± 3.04	28.4 ± 14.33
30% *C. populnea*	22.24± 5.86	6.8 ± 1.16
2.5% rubber latex	33.4 ± 2.98	30.9 ± 13.86
5.0% rubber latex	28.8 ±1.16	24.8 ± 4.90
10.0% rubber latex	15.4 ± 5.13	16.5 ± 5.94

Bending strength

The bending strengths of the composites are shown in Table 2. The values are consistent with those published in literature for fibre-reinforced composites (Balaguru and Shah, 1992; Savastano et al., 2003; O'Donnell et al.,

Table 3. Two-Way ANOVA on the effects of rattan and *C. populnea* contents on the bending strength of the composites.

Source of variation	SS	df	MS	F	P-value	F crit
Rattan Rattan	535.460	1	535.4596	14.46019	0.0052169	5.3177
C. populnea	701.221	3	233.7403	6.31220	0.0167097	4.0662
Interaction	135.148	3	45.04933	1.21657	0.364755	4.0662
Within	296.239	8	37.02993	-	-	-
Total	1668.07	15	-	-	-	-

Table 4. Two-Way ANOVA on the effects of rattan and rubber latex contents on the bending strength of the composites.

Source of variation	SS	df	MS	F	P-value	F crit
Rattan	112.201	1	112.201	2.98789	0.12215	5.3177
Rubber Latex	689.906	3	229.969	6.12401	0.018126	4.0662
Interaction	161.520	3	53.8399	1.43374	0.303174	4.0662
Within	300.416	8	37.5520	-	-	-
Total	1264.04	15	-	-	-	-

2004). Except for the samples containing 30% *C. populnea* and 5% rattan fibre, the bending strength of all the composites met the minimum standards of 9 N/mm^2 and 10 N/mm^2 specified by ISO 8335 (1987) and BS 5669 (1989), respectively. There was a general reduction in the bending strength with increases in rattan and *C. populnea* gum contents. A similar reduction in bending strength with increase in rubber latex content was observed in composite samples produced with 2.5% rattan fibre. Sudin and Swamy (2006) had noted that a decrease in bending strength in polymer-cement composites may be attributed to interference of the polymer with early stages of cement hydration resulting retardation and incomplete bond formation. Two-way analysis of variance (Table 3) showed that rattan and *C. populnea* contents had significant effects (p<5%) on the bending strength, though the interaction of both variables had no significant effect.

However, partial replacement of cement with 20% *C. populnea* gum and 2.5% rubber latex resulted in about 18.3 and 30% increases, respectively in the bending strengths of the composite samples produced with 5% rattan fibre. Two-way analysis of variance (Table 4) confirmed that only the partial replacement of cement with natural rubber latex had significant effect (p<5%) on bending strength.

Conclusions

The aim of this study was to determine the effects of partial replacement of Portland cement with two natural polymers and rattan content on the physical and strength properties of cement-bonded composites reinforced with rattan cane fibre. Findings showed that the selected properties of the polymer-cement composites were generally in conformity with ISO specifications. In conclusion, it is possible to partially replace Portland cement with up to 20% *C. populnea* gum or up to 2.5% rubber latex in the production of rattan-polymer-cement composites. However, for *C. populnea* gum-cement composites, the rattan fibre content should be less than 5%.

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REFERENCES

Adefisan OO, Olorunnisola, AO (2010). Effects of selected pre-treatment methods on the hydration behaviour of rattan-cement mixtures. J. Bamboo and Rattan 9(3&4):151-158.

Balaguru PN, Shah SP (1992). Fiber reinforced cement composites, McGraw Hill, New York.

Baski S, Srikanth G, Biswas S (2003). Composites- material for the future. Proc. Conf. on Advances in Polymeric Building Materials organized by the Central Building Research Institute, Roorkee, India, 6-7 March, 2003, pp. 64-76.

Basrri HB, Mannan MA, Zain MFM (1999). Concrete using waste oil palm shells as aggregate. Cem. Concr. Res. 28(8):619-622.

Bentur AO, Aekers SA (1989). The Microstructure and ageing of cellulose fibre -reinforced cement composites cured in a normal environment. Int. J. Cem. Compos. Lightweight Concr. 11(2):99-110.

BS 5669 (1989). Particleboard Part 4. Specifications for cement bonded particleboard. British Standard.

Demirbas A, Aslan A (1998). Effects of ground hazelnut shell, wood and tea waste on the mechanical properties of cement. Cem. Concr. Res. 28(8):1101-1104.

Dransfield J, Manokaran N (eds) (1993). Plant resources of South-East Asia-Rattans. PROSEA, Jakarta.

ISO (1987). International standard for Cement-bonded particleboards-boards of Portland or equivalent cement reinforced with fibrous wood particles: ISO 8335, first edition, 1987-11-15.

Iwe MO, Obaje PO, Akpapunam MA (2004). Physicochemical properties of cissus gum powder extracted with the aid of edible starches. Plant Foods Hum. Nutr. 59:161-168.

Karade SR, Irle M, Maher K, Caldiera F (2002). Cork granules as lightweight aggregate. In: Dhir RK, Dyer TD, Halliday JE (Eds.), Sustainable concrete construction, Thomas Telford, London, pp. 253-262.

Karade SR (2003). An investigation of cork-cement composites. Ph.D. thesis, Buckinghamshire Chilterns University College, Brunel University, U.K. P 212.

Liese W (2002). Challenges and constraints in rattan processing and utilization, in: Rattan Current Research Issues and Prospects for Conservation and Sustainable Development, Dransfield J, Tesoro FO, Manokaran N (eds) FAO, Rome, pp. 35-42.

Mallari Jr VC, Pulido OR, Cabangon RJ, Novicio LA (1999). Development of a rapid curing process for cement-bonded board manufacture in, Moslemi AA (ed.) Proc. 5th Inorganic Wood and Fiber Composite Materials., Forest Products Research Society, Madison, WI, USA pp. 147-152.

Neville AM, Brooks JJ (2006). Concrete Technology. Published by Pearson Educational Ltd., New Delhi, India.

O'Donnell A, Dweib MA, Wool RP (2004). Natural fiber composites with plant oil-based resin. Compos. Sci. Technol. 64:1135-1145.

Ojekale AB, Lawal OA, Lasisi AK, Adeleke TI (2006). Phytochemistry and spermatogenic potentials of extract of *Cissus populnea* (Guill and Perr) Stem bark. Sci. World J. 1:176-182.

Olorunnisola AO (2005). Dimensional stability of cement-bonded composite boards produced from rattan cane particles. J. Bamboo Rattan 4(2):173-182.

Olorunnisola AO (2007). Effects of particle geometry and chemical accelerator on strength properties of rattan–cement composites. Afr. J. Sci. Technol. 8(1):22-27.

Olorunnisola AO (2008). Effects of pre-treatment of rattan (*Laccosperma secundiflorum*) on hydration of portland cement and the development of a new compatibility index. Cem. Concr. Compos. 30(1):37-43.

Savastano Jr. H, Warden PG, Coutts RSP (2003). Potential of alternative fibre cements as building materials for developing areas. Cem. Concr. Compos. 25:585-592.

Shirai A, Ohama Y (1995). Flexural behavior and application of polymer-ferrocements with steel and carbon fibers, in Fiber reinforced concrete, modern developments in Banthia N, Mindess S (eds.) University of British Columbia, Vancouver, Canada, pp. 201-212

Sudin R, Swamy RN (2006). Bamboo and wood fibre cement composites for sustainable infrastructure regeneration. J. Mater. Sci. 41:6917-6924.

Sunderland TCH, Dransfield J (2002). Species profiles: Rattan (Palmae calamoideae), in Rattan current research issues and prospects for conservation and sustainable development, Dransfield J, Tesoro FO, Manokaran N (eds.) FAO, Rome, Italy. pp. 9-22.

Weiner G, Liese W (1993). Generic identification key to rattan palms based on stem anatomical characters. IAWA J. 14(1):55-61.

Wolf RW, Gjinolli A (1999). Durability and strength of cement-bonded wood particle composites made from construction wastes. Forest Prod. J. 49:24-31.