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# Strength properties and potential uses of rattan–cement composites

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**Abstract**—Wood–cement particleboard (WCP) was produced from rattan (*Laccosperma secundiflorum*) particles. Contrary to conventional practice, the boards were fabricated in the laboratory without pressure application. The effects of rattan particle size and content on the density and bending and compressive strength properties of the boards were investigated. The boards were produced using two rattan particle sizes, i.e., those passing through a 0.85 mm sieve but retained on 0.6 mm sieve, and a 50 : 50 mixture (by weight) of particles retained on 1.2 mm and 0.85 mm sieves, three cement–rattan mixing ratios (by weight of cement) of 1 : 0.11, 1 : 0.19 and 1 : 0.25 respectively, i.e., rattan contents of 10, 15 and 20%. Board density ranged between 764 and 1340 kg/m$^3$, indicating that the composite is a lightweight concrete. The mean modulus of elasticity (MOE = 130.2–2830.7 N/mm$^2$) and modulus of rupture (MOR = 0.8 and 5.2 N/mm$^2$) of the boards decreased with increasing rattan particle size and content. The mean compressive strength of boards (1.3–22.0 N/mm$^2$) also decreased with decreasing board density. Cement–rattan mixing ratio, rattan particle size and the interaction of both variables had significant effects on the density, modulus of rupture and the compressive strength of the composites. The density and the compressive strength properties of the composites suggest that they could find suitable application in the production of insulation boards and bricks (with the addition of sand), for erection of bearing walls in low-rise buildings.

*Key words*: Rattan–cement composite; bending strength; compressive strength.

## INTRODUCTION

Rattans, a group of spiny climbing palms, are numbered among the important commercial non-timber forest products in many parts of the tropics. They are reputed to be the second-most important source of export earnings (after timber) from tropical forests, accounting for about US$ 7000 million annually [1]. Although most of the 600 identified rattan species are native to South and Southeast Asia,

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a few also grow in many parts of West Africa, including Nigeria. The most commercially exploited part of rattans in Nigeria is their flexible stem, used mainly for making cane furniture and other cane products [2].

Liese [3] reported that the loss due to waste during rattan cane processing into furniture products is about 30%. Also, only between 8 and 20% of the 600 identified rattan species are of any commercial value due to factors, such as relatively high variability in the structural composition of the stem (within and between species), inflexibility, susceptibility to breakage and poor mechanical properties [3, 4].

There is a need to explore alternative uses for rattans that will address the issues of a relatively high level of waste during furniture production and under-utilization of numerous species due to unacceptable quality attributes. One such alternative use, yet to be fully explored, is in the production of cement-bonded particleboard. Cement-bonded particleboard, a lightweight concrete produced from a mixture of wood particles and cement, is used primarily for exterior and interior non-structural applications such as cladding, ceiling and floor panels, as well as fire-resistant partitions. These panels are environmentally friendly as they do not emit gasses or leak harmful chemicals [5–7].

A major advantage of the use of rattan in cement-bonded particleboard production is the possibility of complete material utilisation, since there would be no need for pre-sorting and discarding of canes, as is done in rattan furniture manufacture. Even canes discoloured by staining fungi that are often discarded during furniture manufacturing could be used for the manufacture of rattan-cement boards. This is because, through their activities, these fungi (usually blue staining fungi) reduce the quantities of low-molecular-weight sugars that tend to retard the hydration of wood–cement mixtures [8–10].

Few studies have been reported on the production of cement-bonded particleboard using rattan. Olorunnisola and Adefisan [2] produced cement-bonded particleboard using rattan furniture waste (in the form of strands), while Olorunnisola *et al.* [11] investigated the hydration behaviour of rattan converted into particles and mixed with Portland cement. However, currently there is a dearth of information on the strength properties of rattan–cement particleboard products.

This work examines the strength properties of wood–cement particleboard (WCP) manufactured using the rattan cane particles.

## MATERIALS AND METHODS

### *Material collection and preparation*

Mature, freshly harvested rattan canes, sourced from the wild, were obtained from harvesters at Sapele, Delta State, Nigeria. The canes, properly identified anatomically as *Laccosperma secundiflorum*, were manually scraped (deglazed) to remove the silicified epidermis (skin), air-dried for 4 weeks and hammer-milled. The particles obtained after hammer-milling were sieved using a set comprising

2.4 mm, 1.2 mm, 0.85 mm and 0.6 mm sieves. Thereafter, particles retained on 1.2 mm, 0.6 mm and 0.85 mm sieves, respectively, were kept for experimental purposes. Portland cement of class strength 32.5 R grade (graded in accordance with BS EN 197-1: 2000) [12], was procured for use.

### *Experimental design*

Two variables used for composite production were rattan–cement mixing ratio (by weight) and rattan particle size. The three cement/air-dry rattan mixing ratios used were 1 : 0.11, 1 : 0.19, and 1 : 0.25, i.e., 10, 15 and 20% rattan contents, respectively, while the two rattan particle sizes used were (a) rattan particles that passed through the 0.85 mm sieve but retained on the 0.6 mm and (b) 50 : 50 mixture (by weight) of rattan particles that passed through the 2.4 mm sieve but were retained on the 1.2 mm sieve, and those that passed through the 1.2 mm sieve but that were retained on the 0.85 mm sieve.

### *Composite production and testing*

For each composite, the rattan cane particles were dry-mixed manually in a container with cement. Preliminary tests indicated that water-cement-aggregate mixing ratio of 0.25 ml/g cement + 2.7 ml/g rattan, in accordance with Moslemi and Lim [9], was adequate for producing a workable concrete. To minimize possible contamination, distilled water was used for mixing. Mixing continued until the particles were thoroughly coated with the cement paste. The blend was then poured into a plastic mould and compacted with a tamping bar. The mould size for the test specimens was 50 mm (length) × 50 mm (breadth) × 50 mm (height) for axial compression strength test samples, and 250 mm (length) × 50 mm (breadth) × 50 mm (height) for static bending strength test samples. The boards were kept in the mould under wet cloth for 24 h.

After de-moulding, the composites were left under wet towels at normal room temperature (20 ± 2°C) for another 6 days to prevent moisture loss through evaporation. They were then transferred to a conditioning room maintained at a constant temperature of 20 ± 2°C and a relative humidity of 65 ± 5% for another 21 days before testing. Prior to testing, each composite was weighed and its dimensions measured. The green (wet) density of each specimen was calculated by dividing the weight by its volume and the mean of three replicates was obtained. Dry density was obtained by making corrections for the average moisture content obtained from the fragments of the tested specimens.

The composites were tested for stiffness in bending, i.e., modulus of elasticity (MOE), modulus of rupture (MOR) and compressive strength. The three-point test approach was adopted for the bending tests. The specimens were loaded perpendicular to the direction of casting on a 100 kN capacity servo-hydraulic universal testing machine (UTM) and tested at cross-head speed of 0.5 mm/min. The compression tests were conducted on the UTM at a crosshead speed of

1 mm/min. The test results were subjected to statistical analysis involving analysis of variance (ANOVA) and comparison of means using Student's *t*-test.

## RESULTS AND DISCUSSION

### *Dry density of the composites*

The densities of the rattan–cement composites produced using the two particle sizes are shown in Table 1. The values obtained ranged between 764 kg/m$^3$ (for composites produced using a cement–rattan mixing ratio of 1 : 0.19, i.e., 20% rattan content, and a mixture of 0.85 mm and 1.2 mm rattan particles) and 1340 kg/m$^3$ (for composites produced using a cement–rattan mixing ratio of 1 : 0.11, i.e., 10% rattan content and 0.6 mm rattan particles). Generally, the higher the rattan content, the lower the composite density. This is a common phenomenon in wood–cement composites since wood particles generally tend to have lower bulk densities always than cement.

As shown in Fig. 1, the 0.6 mm rattan cane particles produced relatively denser composites than the 0.85/1.2 mm particles. A possible reason for this is that smaller

**Table 1.**
Dry density of the rattan–cement composite boards

| Board code No. | Rattan particle size (mm) | Rattan content in board (%) | Mean board density (kg/m$^3$) |
|---|---|---|---|
| 1 | 0.6 | 10 | 1340 ± 27.4 |
| 2 | 0.6 | 15 | 1081 ± 40.9 |
| 3 | 0.6 | 20 | 937 ± 79.9 |
| 4 | 0.85 and 1.2 | 10 | 1272 ± 52.0 |
| 5 | 0.85 and 1.2 | 15 | 896 ± 33.1 |
| 6 | 0.85 and 1.2 | 20 | 764 ± 54.5 |

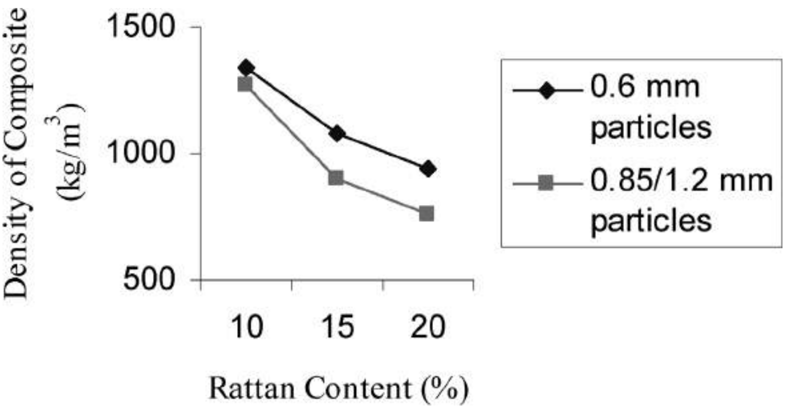

**Figure 1.** Effects of rattan content and particle size on board density.

**Table 2.**
Analysis of variance on the effects of mixing ratio and particle size on properties of the composites

| Source of variation | Degrees of freedom | Mean squares Density | MOE | MOR | Compressive strength |
|---|---|---|---|---|---|
| Replication | 2 | 1363.96 | 225 794.50 | 0.015 | 1.217 |
| Treatment | 5 | 150 517.99* | 3 124 695.0* | 8.87* | 186.10* |
| Particle size (PS) | 1 | 89 509.42* | 71 472.24 | 5.41* | 82.35* |
| Mixing ratio (MR) | 2 | 32 536 473.0* | 6 903 960.0* | 16.17* | 382.15* |
| PS × MR | 2 | 6175.53 | 872 041.6* | 3.30 | 41.92* |
| Error | 10 | 1922.91 | 147 699.4 | 0.30 | 1.93 |
| Coefficient of variation (%) | | 4.18 | 30.56 | 16.44 | 16.06 |

* Significant at 5% level.

particles are likely to be better bonded with the Portland cement (with a closer particle size) than with bigger particles, thereby minimising the presence of air voids. Analysis of variance (Table 2) showed that particle size and cement : rattan mixing ratio both had significant effects on the density of the composites at 5% level of significance. The interaction of both variable was, however, not significant, suggesting that the effect of mixing ratio did not vary with the change in rattan particle size.

The density of the rattan–cement composites fall within the density range for low to moderate density categories of lightweight concrete, which is between 300 and 1350 kg/m$^3$ [13]. The uses of such lightweight concrete range from the production of non-structural thermal insulation materials to the fabrication masonry blocks which requires the inclusion of sand in the mix.

### *Bending properties of the composites*

The MOE and MOR values for the composites are shown in Table 3. MOE ranged between 130 and 2830 N/mm$^2$, while MOR ranged between 0.8 and 5.2 N/mm$^2$. For the rattan particle sizes used the MOE and MOR of the composites decreased with increasing rattan particle size and content (Figs 2 and 3), with those produced with 0.6 mm particles and 10% rattan content having the highest values.

The inverse relationship observed between bending properties and rattan particle size conforms with the findings of Huang and Cooper [14] who noted that the geometry of the furnish material, in terms of the particle length and the aspect ratio, tends to influence the bending properties of wood- cement composites. MOE and MOR tend to increase as the particle size decreases due to increase in adhesion between cement and furnish. As shown in Table 2, the cement–rattan mixing ratio had a significant effect (at 5% level of significance) on the MOE and the MOR of the composites, while the rattan particle size had a significant effect only on the MOR of the composites. The interaction of both variables also had a significant

**Table 3.**
Mean strength properties of the rattan–cement composite boards

| Board code No. | Rattan particle size (mm) | Rattan content in board (%) | MOE ($N/mm^2$) | MOR ($N/mm^2$) | Compressive strength ($N/mm^2$) |
|---|---|---|---|---|---|
| 1 | 0.6 | 10 | 2078 ± 1067 | 4.5 ± 0.6 | 22.0 ± 0.98 |
| 2 | 0.6 | 15 | 1243 ± 415 | 4.6 ± 0.3 | 9.0 ± 1.0 |
| 3 | 0.6 | 20 | 639 ± 139 | 2.5 ± 0.1 | 1.3 ± 0.96 |
| 4 | 0.85 and 1.2 | 10 | 2830 ± 391 | 5.2 ± 0.7 | 13.0 ± 0.85 |
| 5 | 0.85 and 1.2 | 15 | 620 ± 372 | 2.5 ± 1.2 | 3.8 ± 2.6 |
| 6 | 0.85 and 1.2 | 20 | 130 ± 27 | 0.8 ± 0.2 | 2.7 ± 0.4 |

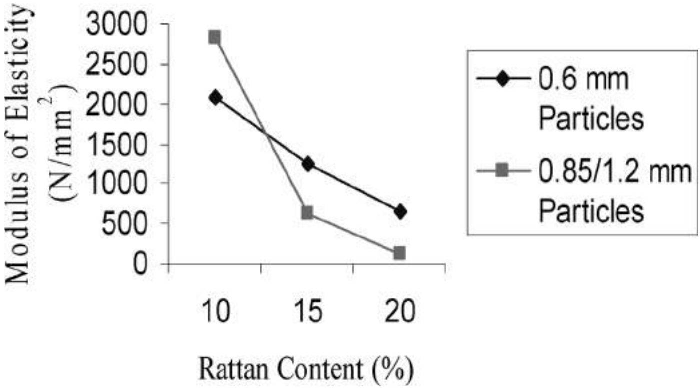

**Figure 2.** Effects of rattan content and particle size on modulus of elasticity.

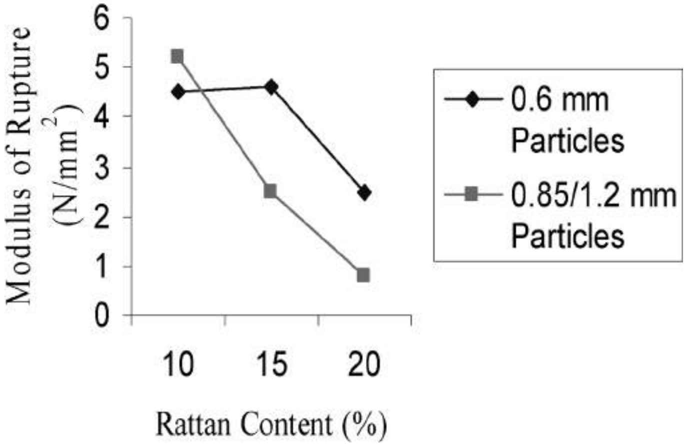

**Figure 3.** Effects of rattan content and particle size on modulus of rupture.

effect only on the MOE of the composites. A comparison of means (at 5% level of significance) between the two rattan particle sizes at the same mixing ratio however showed that only the mean MOE values at 1 : 0.11 mixing ratio, i.e., 10% rattan content, were significantly different from each other.

The flexural strength of the rattan–cement composites is relatively low compared with that of composites made with wood/vegetable fibre-reinforced cement composites [15]. The reason is that cement is weak in tension and hence requires some kind of reinforcement to resist tensile stresses. In the present study, rattan particles could not provide much reinforcement, as the aspect ratio and tensile strength were relatively low. A possible means of increasing the stiffness of rattan–cement composites is the use of additives such as aluminium sulphate, water glass and calcium chloride ($CaCl_2$). Olorunnisola and Adefisan [2] reported a general increase in the MOE and MOR of rattan–cement composites treated with 2.5–3% (by weight of cement) $CaCl_2$.

## *Compressive strength of the composites*

The compressive strengths of the composites (Table 3) ranged from 1.3 to 22.0 N/mm$^2$. For the rattan particle sizes used, the compressive strength of the composites decreased with decreasing composite density and increasing rattan particle size and content (Fig. 4). The compressive strength values fall within the range of values reported by Karade [16] for cork–cement composites with 10–30% cork incorporation, i.e., 1.05 to 26.18 MPa.

The cement–rattan mixing ratio, the rattan particle size and the combination of both variables had significant effects on the compressive strength of the composites (Table 2). A comparison of mean values of compressive strength (at 5% level of significance) between the two rattan particle sizes at the same mixing ratio however showed that the values obtained at 1 : 0.11 and 1 : 0.19 mixing ratios, i.e., 10% and 20% rattan contents, respectively, were significantly different from each other. Also, as shown in Fig. 5, there was a strong correlation ($R^2 = 0.84$) between dry density and the mean compressive strength of the composites. This

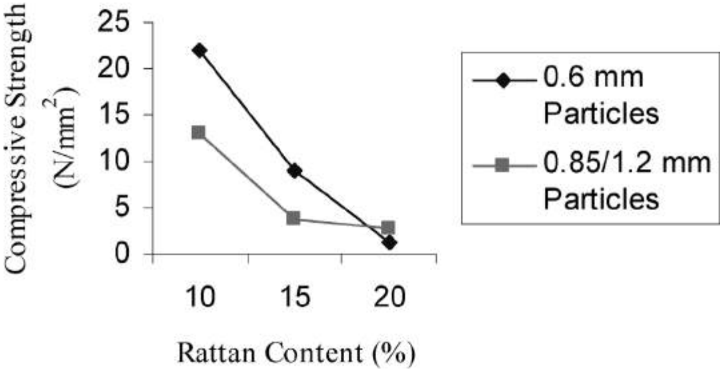

**Figure 4.** Effects of rattan content and particle size on compressive strength.

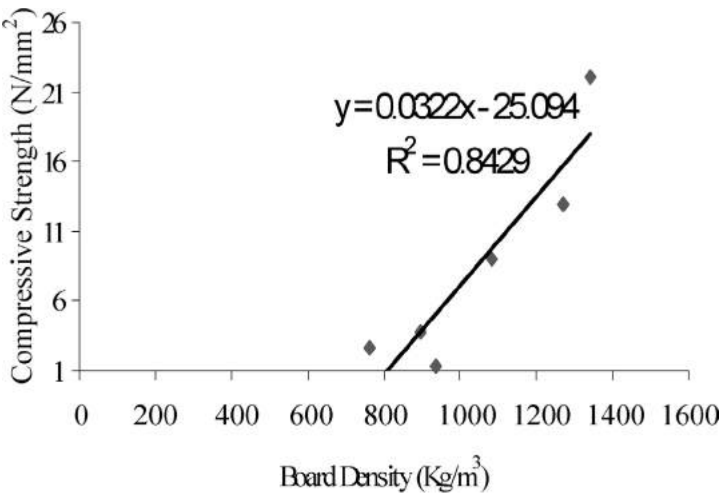

**Figure 5.** Correlation between density and compressive strength.

relationship again closely matches that of lightweight concrete produced from cork waste by Karade [16], who used similar specimen sizes and test conditions. He also reported an inverse relationship between cork granule particle size and density/compressive strength of the cork–cement composites tested. A plausible explanation for this phenomenon was provided by Li [17], who described the effects of the presence of various fibres on the compressive strength of cementitious materials. The strength properties of cement-based materials are influenced by porosity (i.e., volume of voids). At low levels (0.5–1.0% by volume) of inclusion, fibres enhance compressive strength by resisting the growth of cracks. However, higher fibre content increases porosity of the composite material and results in loss of compressive strength. Other possible reasons for an increase in porosity at higher levels of rattan addition include the higher amount of water input and poor compaction [16].

Even with the exclusion of sand in the mix, the compressive strength values of all the composites, except those produced using 0.6 mm rattan particles and $1:0.19$ cement–rattan mixing ratio, were higher than 1.4 N/mm$^2$, the recommended compressive strength of for bricks for use as bearing walls for bungalows and single-storey buildings in Nigeria [18]. Hence, the possibility of using rattan–cement composite for wall construction in residential buildings in the country may be explored.

## CONCLUSIONS

Composites were produced from rattan (*Laccosperma secundiflorum*) using different cement–rattan mixing ratios and rattan particle sizes. When tested for static bending and axial compressive strength, composites with the lowest cement–rattan mixing ratio (1 : 0.11) and the smallest rattan particles (0.6 mm) gave the highest density, bending and compressive strengths. Cement–rattan mixing ratio, rattan particle size and the interaction of both variables had significant effects on the density, modulus of rupture and the compressive strength of the composites. The overall compressive strength results indicated that using rattan particles as a lightweight aggregate, even with the exclusion of sand in the mix, low to moderate strength (1.3 to 22 $N/mm^2$) concrete, the type used in producing insulation boards and bricks for erection of bearing walls in low-rise buildings could be made.

## RECOMMENDATIONS

Based on the findings of this study the following areas of further research are recommended:

1. Evaluation of the effects of incorporating various rattan particle sizes on the density and strength properties of rattan–cement composites.
2. Investigations on the effects of compaction and chemical pre-treatment, e.g., $CaCl_2$ addition, on the density and strength properties of rattan–cement composites.
3. Experimental investigations on the thermal and acoustic properties of rattan–cement composites.
4. Fabrication and field evaluation of actual rattan–cement composites for durability and wider application.
5. Evaluation of other rattan species for rattan–cement composite production.

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## REFERENCES

1. I. R. Hunter and Y. Lou, Presentation of INBAR's programme on rattan, in: *Rattan Current Research Issues and Prospects for Conservation and Sustainable Development*, J. Dransfield, F. O. Tesoro and N. Manokaran (Eds), pp. 43–48. FAO, Rome (2002).
2. A. O. Olorunnisola and O. O. Adefisan, Trial production and testing of cement-bonded particleboard from rattan furniture waste, *Wood and Fiber Science* **34** (1), 116–124 (2002).
3. W. Liese, Challenges and constraints in rattan processing and utilization, in: *Rattan Current Research Issues and Prospects for Conservation and Sustainable Development*, J. Dransfield, F. O. Tesoro and N. Manokaran (Eds), pp. 35–42. FAO, Rome (2002).
4. T. C. H. Sunderland and J. Dransfield, Species profiles: Rattan (Palmae calamoideae), in: *Rattan Current Research Issues and Prospects for Conservation and Sustainable Development*, J. Dransfield, F. O. Tesoro and N. Manokaran (Eds), pp. 9–22. FAO, Rome (2002).

5. A. C. Ramirez-Coretti, C. C. Eckelman and R. W. Wolfe, Inorganic bonded composite wood panel systems for low-cost housing: A Central American perspective, *Forest Products Journal* **48** (4), 62–68 (1998).
6. R. W. Wolfe and A. Gjinolli, Durability and strength of cement-bonded wood particle composites made from construction waste, *Forest Products Journal* **49** (2), 24–31 (1999).
7. M. M. Alberto, E. Mougel and A. Zoulalian, Compatibility of some tropical hardwood species with Portland cement using isothermal calorimetry, *Forest Products Journal* **50** (9), 83–88 (2000).
8. E. J. Biblis and C. Lo, Sugar and other wood extractives: Effect on the setting of southern pine-cement mixes, *Forest Products Journal* **18** (8), 28–34 (1968).
9. A. A. Moslemi and Y. T. Lim, Compatibility of southern hardwoods with Portland cement, *Forest Products Journal* **34** (7–8), 22–26 (1984).
10. L. Zhengtian and A. A. Moslemi, Effect of western larch extractives on cement setting, *Forest Products Journal* **36** (1), 53–54 (1986).
11. A. O. Olorunnisola, A. Pitman and H. Mansfield-William, Hydration characteristics of cement-bonded composites made from rattan cane and coconut husk, *Journal of Bamboo and Rattan* **4** (2), 193–202 (2005).
12. BS EN 197-1: 2000, *Cement Part 1: Composition, Specifications and Conformity Criteria for Common Cements*. British Standard, London (2000).
13. *ACI Guide for Structural Lightweight Aggregate Concrete*. ACI 213R-87 Manual of concrete practice, Part-1, Materials and general properties of concrete, p. 27. ACI, Farmington Hills, MI (1987).
14. C. Huang and P. A. Cooper, Cement-bonded particleboard using CCA-treated wood removed from service, *Forest Products Journal* **50** (6), 49–56 (2000).
15. S. D. S. Guimaraes, Vegetable fiber-cement composites, in: *Vegetable Plants and their Fibres as Building Materials Proceedings of the Second International Symposium sponsored by RILEM (The International Union of Testing and Research Laboratories for Materials and Structures) and organised by Universidade Federal da Bahia*, Brazil, H. S. Sobral (Ed.), pp. 98–107 (1990).
16. S. R. Karade, An investigation of cork-cement composites, PhD Thesis, Buckinghamshire Chilterns University College, Brunel University, High Wycombe (2003).
17. V. C. Li, A simplified micromechanical model of compressive strength of fiber-reinforced cementitous composites, *Cement and Concrete Composites* **14**, 131–141 (1992).
18. A. P. Opoko, Structural materials for housing and construction industry, paper presented at the *Nigeria Materials Congress organised by the Materials Society of Nigeria*, 2004, held at the Engineering Materials Development Institute (EMDI), Akure, Ondo State (2004).