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# DEVELOPMENT OF RATTAN PARTICULATE REINFORCED PAPER PULP BASED COMPOSITES FOR CEILING APPLICATION USING WASTE PAPERS

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**Abstract**: This research was carried out to produce a rattan particulate reinforced paper pulp based composite with satisfactory flexural and water absorptivity that can serve in applications such as household ceiling and partitioning board. Paper pulp was produced by chopping waste papers into smaller piece and soaked in boiled water after which it was stirred thoroughly to form paper pulp. Rattan particulate was also produced by beating, chopping and milling of rattan canes. The rattan particles were sieved from where particle size of 437 μ was used.Varying mass of paper from 300-400 g and particulate rattan in treated and untreatedform within the range of 2-8 g were mixed and bonded with natural rubber that serves as binders for the various samples produced. The mixtures were thoroughly mixed and poured into 150x50x30mm detachable mould and compacted for 5 minutes using a laboratory compaction machine. The composite were allowed cure at room temperature for 21 days after which flexural and water absorptivity tests were carried out on the samples. It was found that the composite samples denoted as $NRT_4$ and $NR_5$ happen to be the best in terms of flexural strength properties while the addition of rattan particulate fiber aid water repellent potential for the developed composites.
**Keywords**: Rattan; Particulate; Paper pulp; Composite; Flexural strength

## 1. INTRODUCTION

Solid waste generation is a continually growing problem at global, regional and locallevels. Solid wastes are those organic and inorganic waste materials produced by variousactivities of the society, which have lost their value to the first user. Improper disposal of these solid wastes pollutes all the vital components of the living environment (i.e., air, landand water) at local and global levels [10]. Urban society rejects and generates solid materialregularly due to rapid increase in production and consumption. The problem is moreacute in developing nations than in developed nations, as their economic growth as wellas urbanization is more rapid. This necessitates management of solid waste at generation, storage, collection, transfer and transport, processing, and disposal stages in anenvironmentally sound manner, in accordance with the best principles of public health, economics, engineering, conservation, aesthetics and environmental considerations. Thus, solid waste management includes all administrative, financial, legal, planning, and engineering functions [11].

Solid waste management has emerged as one of the greatest challenges facing state and local government environmental protection agencies in Nigeria. The volume of solid waste being generated continues to increase at a faster rate than the ability of the agencies to improve on the financial and technical resources needed to parallel this growth. The wastes are heavier, wetter and more corrosive in developing cities than developed cities [9].The concept of Waste-to-Wealth literally means moving waste from a platform of exhausted utility to valuable and desirable level. Its transformation: in engineering, requires some form of energy, and in economics requires factor of production [4]

A composite material is defined as a combination of two or more materials that results in better properties than when the individual components are used alone. A composite is designed to display a combination of the best properties of each of the component materials. [3].It is well known that composite consist of two or more chemically distinct phases, separated by a distinct interphase and it is important to be able to specify their constituents. The constituent that is continuous surrounds the other constituent and it is often but not always present in greater proportion in the composite and it is term the matrix. Normally it is the property of the matrix that is being improved on by incorporating another constituents termed the reinforcement phase to produce a composite. The reinforcement can either be a fibrous or particulate; they are always harder or stronger than the matrix phase and they are also called the discontinuous phase. The reinforcements strengthen the matrix and improve the overall mechanical properties of the matrix. Properties of composite are strongly dependent on the properties of their constituent materials, their distributions, and the interaction among them [3]. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way resulting in improved or better properties. Apart from the nature of the constituent materials, the geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent. The concentration, distribution, and orientation of the reinforcement in the matrix also affect the properties of the composite. The interface has characteristics that are not depicted by any of the component in isolation. The interface is a bounding surface or zone where a discontinuity occurs, whether physical, mechanical, chemical etc. To obtain desirable properties in a composite, the applied load should be effectively transferred from the matrix to the fibres via the interface [7].

Rattan isa member of the bamboo family, it has been utilized as construction material in certain areas for decades, but its application as reinforcement in paper had received little attention. It is a non-corrosive material in nature and thermally non-conductive.It possessed good mechanical properties such as stiffness, hardness and strength. Rattans are extensively used for making furniture andbaskets. Due to its durability, sections of rattan can be used as staves or canes for martial arts. [1]. Rattans have properties that make them very popular as raw materials for furniture, construction, handicraft and other industries – they are durable, elastic, light weight, lustrous and flexible [1]. ithas the tenacity and strength that is high enough to enable it usage as reinforcement for structural application.The average tensile strength of sega, a species of rattan (*Calamus caesius*) is about 183.20 N / $mm^2$at thenodes and 193.26 N / $mm^2$ between the nodes [6].

Paper is made from a mixture of fibres and water sprayed on a net that travels of a speed of 500-1800 m/min [6]. Due to the manufacturing process all the fibres but the shortest ones are oriented in the plane [2]. Paper is therefore an anisotropic material. For many reasons the principal axes of the material properties are functions of position in the cross-direction of the paper web. But this minor difference in direction of the principal axes is mostly neglected and therefore paper is almost always considered orthotropic which makes it possible to describe the material in the elastic region with only nine constitutive parameters, compared to 21 for a fully anisotropic material [8].

In this research work, rattan particulate reinforced paper pulp based composite was developed using natural rubber as binder. Dried pulverised paper pulp was used as the matrix, while rattan particulate was used as the reinforcement. The matrix and the reinforcement was bonded using rubber latex to produce composite materials that will be used in structural applications such as ceiling sheets and partitioning boards.

## 2. MATERIALS AND METHODS

Materials for this research work includes waste newsprint paper, rubber latex, rattan canes, water, ammonia solution, potassium hydroxide solution, gas cooker, pot, plastic buckets with cover, pestle and mortar, 150 x 50 x 30 mm detachable metal mould, compacting machine, electronic weighing balance, Testometric universal machine, sieve shaker, milling machine, measuring cylinder, paper cutter, sieve, hacksaw, hammer and die, stirring rod.

## 3. PRODUCTION OF PAPER PULP

The waste papers were chopped into smaller piece using paper cutter; the chopped paper was soaked in boiled water for 3days in a plastic bucket to form pulp. It was stirred thoroughly to form paper pulp slurry. The pulp was sieved and sun dried for 5days as shown in Figure1. Various weight of the dried pulp was weighed using electronic weighing balance into some plastic bowls. The varying mass are: 400, 380, 360, 340, 320, 300g.

Having measured the paper pulp, it was soaked with 1200$cm^3$ of water for 15 minutes to wet the texture of the pulp .The wet pulp was pulverized to a slurry form using a milling machine.

**Figure 1.** Wet (left) and dry samples (right) of paper pulp

## 3. PRODUCTION OF RATTAN PARTICULATES

The rattan canes were beating into sheet by using a metallic hammer and die. The canes sheets were later chopped into smaller particle as shown in Figure 2. The chopped canes were reduced to shredded form by the used of mortar and pestle. Half (50 %) of the shredded canes were treated with potassium hydroxide (KOH) solution to increase the adhesive nature of the canes as well as removing impurities from the canes. This was also done to preserve and to reduce the rate of contamination of the particles when it is incorporated in to the matrix. The rattan was sun dried to remove the moisture content. The rattan particles were pulverized for further size reduction using a milling machine. The milled particles of the cane were made to undergo sieve analysis to separate the particles into various particle sizes. However the particle size that was used for this work is 437 µ. The milled particles were weighed into various weights which includes; 2, 4, 6, and 8 g. This was done for both the treated and untreated particles.

**Figure 2.** Rattan canes in whole form (left) and in shredded form (right)

## 4. CHEMICAL TREATMENT

The rattan fiber was treated with potassium hydroxide by dissolving 112 g of potassium hydroxide in 2000 $cm^3$ of water, which is stirred thoroughly with a stirring rod to form a potassium hydroxide solution. The fibres are then soaked in the solution and then transferred into the water bath where it is left for 4 hours at a temperature of 50 $^oC$. After this process is carried out, the fibres were removed from the water bath and later washed until it attains the neutral status and sun dried for 5 days.

## 5. SOURCING OF RUBBER LATEX

Five litres (5) of rubber latex was sourced from the Federal College of Agriculture (FECA) in Akure and it was treated with ammonia solution for preservation.

## 6. MIXING AND COMPACTION OF THE COMPOSITE COMPONENTS

The wet slurry of milled paper pulp were mixed with the pulverized rattan particles and these was done at some predetermine ratio of the components. However the viscous rubber latex was used as binder for various samples of the composites.

The entire mixture was thoroughly mixed and then poured to fill up the 150 x 50 x 30 mm mould and compacted under a pressure using the laboratory made compacting machine and the pressure was maintained at 20 KN for 5minutes. Before casting, the top of the compacting mould was covered with cellophane to enhance easy removal of the composite from the mould and prevent delamination. Having done this process, the mould was disassembled and the cast composite was removed and then transferred to a wooden board where it is allowed to cure in air in the laboratory as shown in Figure 3. The composite were prepared for flexural and water absorptivity tests.

**Figure 3.** Samples prepared for flexural test

## 7. VARIATION OF COMPONENTS

In the production of this paper pulp based composite, the following parameters were varied.

- » Rattan particulate mass was varied from 2-8 g.
- » The paper pulp mass was varied from 300-400 g.
- » The rubber latex mass varied from 0-100 g.

The variation of the components of the composites in % mass is as shown in Tables 1 and 2.

**Table 1.** Variation of components with paper pulp and natural rubber

| Designation of samples | Paper pulp : Rubber latex (g) |
|---|---|
| A | 400:0 |
| $NR_1$ | 380 : 20 |
| $NR_2$ | 360 : 40 |
| $NR_3$ | 340 : 60 |
| $NR_4$ | 320 : 80 |
| $NR_5$ | 300 : 100 |

**Table 2.** Variation of components with paper pulp, natural rubber and rattan particulate fibres (Treated and Untreated)

| Designation of samples | | Paper pulp: Rubber latex : Rattan particulate (g) |
|---|---|---|
| Treated | Untreated | |
| A | A | 400 : 0 : 0 |
| $NRT_1$ | $NRU_1$ | 300 : 98 : 2 |
| $NRT_2$ | $NRU_2$ | 300 : 96 : 4 |
| $NRT_3$ | $NRU_3$ | 300 : 94 : 6 |
| $NRT_4$ | $NRU_4$ | 300 : 92 : 8 |

In this work, the sample with designation "A" denotes paper pulp only while designation "NR" denotes the combination of paper pulp and natural rubber latex.

It is expected that the proportion of the reinforcement should either be one third or one fourth of the matrix but in this work, we discovered that large volume of the rattan particles does not form a uniform phase with the matrix phase. So the volume of the reinforcement was drastically reduced so as to form a uniform phase as well as to strengthen the matrix phase.

The mass of the rubber latex was measured by relating its density to the fixed mass of the desired binder in order to obtain the required volume of the binder needed. The density of the rubber latex was 0.96g/cm$^3$.

## 8. PROPERTIES TEST

The dried sample was made to undergo both flexural and water absorption tests as follows;

### 8.1 Flexural Test

The flexural test was carried out using Instron Universal Tensile Testing Machine that works on a three point flexural technique. The test speed was 50.00mm/min over a span of 100.00mm.

### 8.2 Water Absorptivity Test

Since this material is likely to come in contact with water as a ceiling sheet, so it will be necessary to carry out water absorbtivity test to determine the extent to which the formed composite can absorb water in case of roof leakage.

In determining the water absorption property of the composite samples, each of the composite were weighed in air and then immersed in 700cm$^3$. This test was done for 7 hours for the various samples of the composites. The composites were weighed in air when dried with the aid of an electronic weighing balance and then soaked in water. The weight after 7 hours was taken once they are removed and cleansed. The percentage weight gained was used to determine the water absorptivity.

## 9. RESULTS AND DISCUSSION

### 9.1. Flexural Test

The major mechanical test carried out on the developed composites is the flexural test. This was done because the material in serve will be exposed to bending load or stress in most cases when suspended in the house as a ceiling sheet. The results were as shown and discussed below.

Figure 4 shows the bending strength at peak results for the samples. From the results, it was observed that sample $NRT_4$ with composition (300 : 92 : 8) g has the highest bending strength at peak with a value of 1.34 N/mm$^2$. This was followed by sample $NR_5$ with composition (300 : 100) g and value 1.31 N/mm$^2$. Sample A which has paper pulp alone was with a value of 0.70 N/mm$^2$. With these results, it is obvious that the addition of treated rattan particulate fiber to natural rubber and paper pulp is best for the development of good and strong paper board ceiling sheet for structural applications.

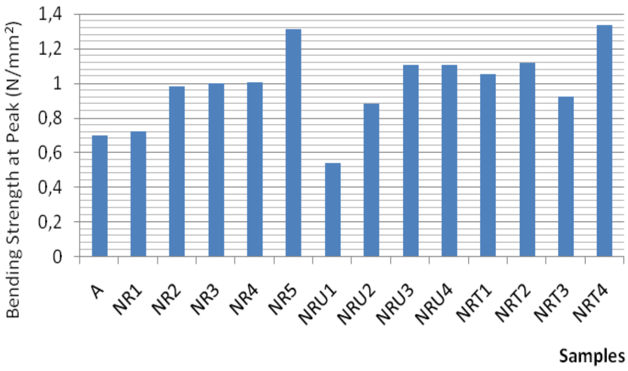


**Figure 4.** Variation of bending strength at peak with samples

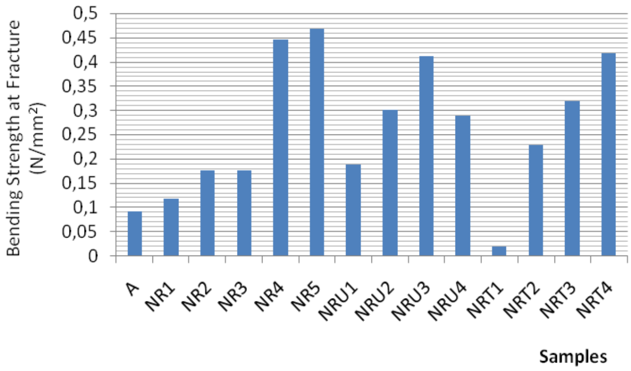


**Figure 5.** Variation of bending strength at fracturewith the samples

Figure 5 shows the bending strength at fracture results for the composite samples. From the results, it was observed that sample $NR_5$with composition (300 : 100) g has a value of 0.47 N/mm$^2$ followed by sample $NR_4$ with composition (320 : 80 ) g which has a bending strength at fracture of 0.45 N/mm$^2$. Sample A which has paper pulp alone was with a value of 0.09 N/mm$^2$. The delay in fracture was observed in these ($NR_5$ and $NR_4$) samples compared to the rattan particulate fiber reinforced samples as well as the 100 % paper pulp samples because they are more ductile than others due to the presence of more natural rubber that serves as binder. The results show that the fracture strength increases as the natural rubber content increases for the three different categories of compositions considered.

Figure 6 shows the bending modulus results for the composite samples. Similar trend as for the bending strength at peak was observed. From the results, it was observed that sample $NRT_4$ with composition (300 : 92 : 8) g has the highest bending modulus with a value of 38.49 N/mm$^2$. This was closely followed by sample $NR_5$ with composition (300 : 100) g and value 38.13 N/mm$^2$.

When compared to these two samples, sample A which has paper pulp alone has the least bending modulus of 12.45 N/mm$^2$. This further confirmed that, the addition of treated rattan particulate fiber to natural rubber and paper pulp is a potential means of developing good and strong paper board ceiling sheet for structural applications.

It was observed from Figures 4-6 that the bending strength at peak, bending strength at fracture and bending modulus follow similar trend where these properties tend to increaseas the rattan particulate fiber and natural rubber increases. It was also discovered that composite samples with treated rattan fibres possess higher bending strength at peak, fracture and modulus than those with untreated rattan fibers. This was due to the enhancement of the strength of adhesion between the treated rattan fiber, paper pulp matrix and the natural rubber.

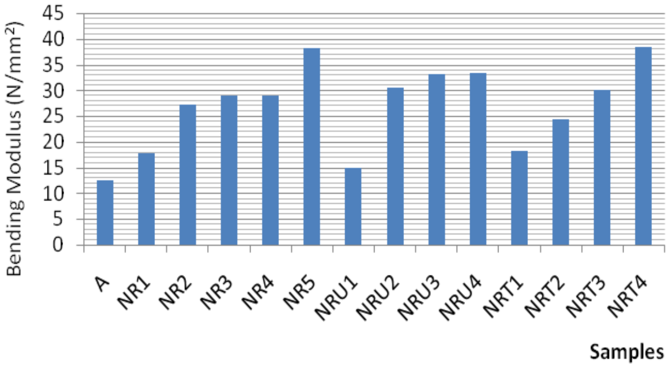


**Figure 6.** Variation of the bending modulus of the composite samples

### 9.2 Percentage Water Absorptivity of the Composite Samples

It was observed from Figure 7 during the comparative study of the percentage water absorptivity of the samples that, the rate of water absorption increases with increase in the amount of natural rubber while it decreases as the amount of rattan particulate added increases in both treated and untreated conditions. This shows that the addition of the rattan can help reduce the water absorption tendency of the developed composites. Considering the three major component considered, the untreated rattan fiber reinforced samples gave the best set of results followed by the natural rubber bonded samples. The rattan was a very strong and tough material commonly used as furniture material. The result show thatNR$_2$ with composition (360 : 40)possess the best water repellant property after 7$^{th}$ hours of soaking in waterby absorbing the least amount of water with 212 % followed by sample denoted as NRU$_4$ having (300: 92 : 8 ) composition with a value of 243 % compared to the pure paper bonded sample (A) with a value of 253 %.

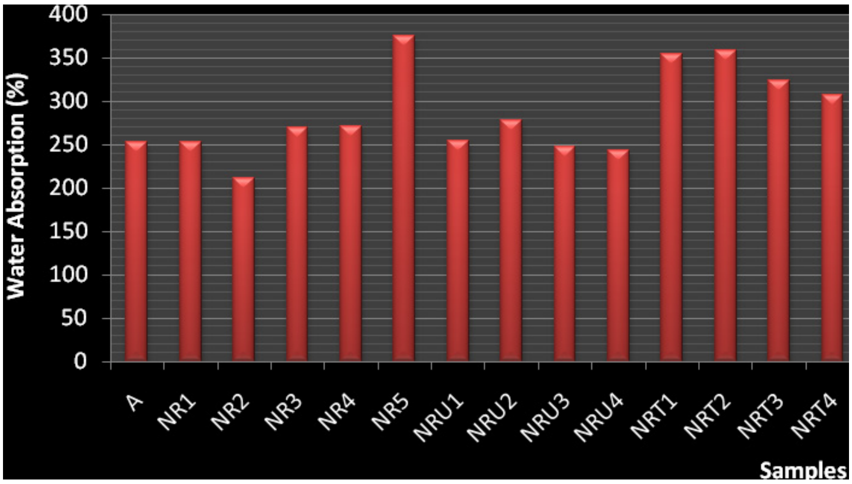


**Figure 7.** Percentage water absorption test on the samples after 7 hours

### 10. CONCLUSION

After considering the flexural and water absorption properties of rattan particulate reinforced paper pulp based composites for ceiling application using waste paperswhich are all biodegradable and readily available materials that can be used as low cost building materials, it was observed that;

The addition of treated and untreated particulate rattan fibres as well as natural rubber has a great effect on the flexural and water absorption properties of the developed composites. While treatment of the rattan particulate enhances the bending strength at peak and modulus the of the paper pulp based composite, the untreated rattan particulate enhances water repellent capability and natural rubber improves the bending strength at fracture. These shows that the combination of these selected environmentally friendly materials are promising materials for structural applications.

The use of this waste paper that constitute nuisance in the environment as an engineering material will further add value to what would have been a treat to humanity.

### REFERENCES

[1.] Akinyele, J. O. and Olutoge, F. A. Properties of Rattan Cane Reinforced Concrete Façade Subjected to Axial Loading. Journal of Civil Engineering and Architecture, ISSN 1934-7359, USA, Volume 5, No. 11 (Serial No. 48), pp. 1048-1052, 2011.

[2.] Akker, J.A.v.d. The Elastic and Rheological Properties of Papermaking Fibers. Tappi Journal 33(8): 398-402, 1950.

[3.] Callister, .Materials science,. An Introduction: Fifth Edition, JohnWiley, andSons Inc. New York, pp. 162,163,180-185, 511-17, 2001

[4.] Egun N, Kingsley. The Waste to Wealth Concept: Waste Market Operation in Delta State, Nigeria. Greener Journal of Social Sciences ISSN: 2276-7800 Vol. 2 (6), pp. 206-212.2012.

[5.] [5.] Fellers, C. Procedure for Measuring the Interlaminar Shear Properties of Paper. Svensk Paperstidning, 80(3): pp 89-93, 1997.

[6.] [6.] Fellers, C., and Anderson, H., Bristow, J.A., Koleseth, P. The Definition and Measurement of the Thickness and Density, Paper Structure and Properties, New York, Basel, Marcel Dekker, pp 151-167, 1986.

[7.] Haron Ismail. Mechanical Properties of Rattans. In proceeding of the International Rattans Seminar, ChiangMai, Thailand, 1987.

[8.] Kakani S.L and AmitKakani, Material Science, 1$^{st}$edition, 2:3, New Age International (P) Limited, Publishers 4835/24, Ansari Road, Daryaganj, New Delhi – 110002,pp.22, 83, 2004.

[9.] Karasudhi, P. Foundations of Solid Mechanics, Dordrecht, Netherland, Kluwer Academic Publisher, 1991.

[10.] Ogwueleka, T. C. Municipal Solid Waste Characteristics and Management in Nigeria, Iran. J. Environ. Health. Sci. Eng., Vol. 6, No. 3, pp. 173-180, 2009.

[11.] Ramachandra, T.V. and Shruthi Bachamanda, Environmental audit of Municipal Solid Waste Management. International Journal of Environmental Technology and Management, Vol. 7, Nos. 3/4, pp369-391, 2007.

[12.] Ramachandra, T.V. and Varghese, S.K. Exploring possibilities of achieving sustainability in solid waste management. Indian Journal of Environmental Health, Vol. 45, No. 4, pp. 255–264, 2003.

[13.] Ramachandra, T.V. Management of Municipal Solid Waste. Capital Publishing Company, New Delhi, 2006.


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