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THE EFFECT OF NATURAL RUBBER ON THE FLEXURAL PROPERTIES OF COCONUT COIR (COCOS NUCIFERA) REINFORCED RED SAND COMPOSITES

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Abstract: In order to dramatically improve the mechanical properties of ceramic materials for structural applications, the ceramic material can be bonded with natural rubber and reinforced with natural fibre. Sand and water has been used for ages as the basic component in the development of building materials which can still be found in remote parts of Nigeria. This work studiesthe effect of natural fibres andrubber on the flexural properties of processed red sand for structural applications. This research was carried out using processed red sand as the matrix, natural rubber as the binder and coconut coir as reinforcement. Measured volume of natural rubber was mixed thoroughly with coconut powder/coir and poured into detachable mould and then compacted for about 10 minutes under an applied load of 25 KN to produce a composite material. The cast composite was detached from the mould and cured in air at room temperature for 28 days. Flexural and water absorption tests were carried out on the cured samples. The best composition was gotten from sample C_1 which has 700g red sand, 150g natural rubber and 4g of 10 mm fibre length which emerges as the best material in flexural and water repellent properties.

Keywords: Natural rubber, coconut coir, processed red sand, flexural properties and water absorptivity

INTRODUCTION

Increased environmental awareness and consciousness all over the world has enhanced a widespread of interest in natural fibre and its applications in various fields. Natural fibres are now considered as unique alternatives to synthetic fibres for use in various fields. The utilisation of natural fibres as reinforcement in both thermoplastics and thermosets matrix composite have provide positive environmental benefits with respect to ultimate disposability and best utilization of raw materials. Currently, studies on use of lignocelluloses bio-fibres in place of synthetic fibres as reinforcing materials are being pursued vigorously. These bio-fibres are being extensively used for the production of cost effective eco-friendly bio composites [1].

The advantages of natural fibres over traditionally reinforcing materials such as glass fibre, carbon fibre etc. are their specific properties, easy availability, light weight, ease of separation, enhanced energy recovery, high toughness, non-corrosive nature, low density, low cost, good thermal properties, reduced tool wear, reduced respiratory irritation, less abrasion to processing equipment, renewability and biodegradability. The World Commission on Environment and Development suggested the following definition for sustainable development: "sustainable development is the development that responds to the needs of the present, without abandoning the ability of future generations to supply their own needs". The influence of sustainable development on culture, economy, and ecology is of global significance, but there are specific measures for particular regions [2].

The major function of fibres in the matrix is in delaying and controlling tensile cracking of the matrix, their uses give rise to technical benefits that can be utilized in load bearing members and in semi-structural elements. The vegetable fibre reinforced cement structures have their applications tuned towards the production of panel for components where the ductility is an important characteristic [3].

These natural available fibres can be used in improving the properties of other materials during the development of composite materials. 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 [4].

Natural organic fibres have a very important role in alleviation of housing problem. They do not only occur in luxurious abundance in many parts of the world but can also lead directly to energy savings conservation of the world's most scarce resources and protect man and his environment. Natural vegetable plants and fibre have thus a unique irreplaceable role in the ecological cycle. Their natural abundance, plentiful supply, relative cheapness and swift replenish ability are the strongest argument to utilize them in the construction industry [5].

Natural rubber (abbreviated to NR) primarily comprises polyisoprene and is harvested from the milky white latex of a number of species of plants which flourish in the tropics, above all from the Spurge family. The rubber tree (Hevea brasiliensis) has achieved considerable commercial importance. It is made up of the following compositions (Water: 55-70%, Rubber: 30-40%, Resin: 1.5-2%, Protein: 1.5-3%, Ash: 0.5-1%, Sugar: 1-2%)[6]. Natural rubber mixtures possess the following properties: high static tensile strength (15-22 MPa); high elongation (600-900%); excellent elasticity at low temperature (up to – 10^{0}C doesn't change substantially); poor ozone and degradation stability; good confectionability because of excellent crude adhesion [7]. Natural rubber is a significant type of polymeric material; it is widely used due to its high and reversible deformability. Since the essential modulus and strength of neat rubber are low, an additional reinforcing phase is necessary for the practical uses of rubber materials [8].

The presence of natural rubber in the composite will gelatinise the processed red sand and impact it with ductility. This will also enhance the flexural strength of the composite at the long run.

Sand and water has been used for ages as a basic component in the development of building materials which can still be found in remote parts of Africa. Red sands and natural organic fibres on the other hand are new area of research for applications in building materials, their natural abundance, availability, relative cheapness and ability to be replenished are the strongest arguments for their utilization in the construction industry

The goal of this research was to apply synergetic potentials imbedded in the blend of ceramic (processed red sand), polymer (natural rubber) and Natural fibres (coconut coir). Ceramic material will provide compressive strength and thermal stability while polymer (natural rubber) will provides elastic strength. The natural fibre will act as the reinforcement to strengthen the composites. It is expected that the combination of these naturally occurring materials will lead to improved strength of the developed composite materials for structural applications. Figure 1 show the picture of a collapse building due to brittle fracture property of the mixture of red sand and water that was used for the production of the building blocks.

Figure 1: *Picture of collapsed building from red sand blocks*

MATERIALS AND METHODS

The materials used for this research work includes: coconut coir (fibres and powder form); natural rubber; red sand; water; ammonia solution; cellophane sheets; 150 x 50 x 35mm detachable metallic mould; sieve shaker; sieves; beaker; Pestle and mortar; shaker water bath; flexural moulding machine; universal testing machine and digital weighing machine.

PRODUCTION OF COCONUT COIR FIBRES AND PARTICULATES

The coconut coir (fibres and particulates) was procured from coconut fruits, after being harvested from a coconut tree, and sun dried for about two months to ease its extraction process. The coconut coir (fibre and particles) were manually extracted by detaching the outer layer (husk) of the coconut from its nut, followed by beating the coconut husk using mortar and pestle for easy extraction of both the fibres and particles respectively. Figure 2 show the coconut coir and the extracted particles.

The extracted fibres were carefully measured by meter rule into three different lengths of; 10, 15and 20 mm and each fibre were carefully and neatly sized using scissors according to their appropriate fibre lengths. The various dimensions of the extracted fibres were treated separately in different beakers for easy separation. The particulate coconut coir on the other hand was treated before size analysis was carried out. Sizing was carried out using different sieve sizes from where 425 and 300µ sizes are sorted out and used.

Chemical Treatment

The extracted coconut coir was treated with sodium hydroxide (NaOH) by dissolving 120 g of sodium hydroxide in 3000cm^3 of water and stirred thoroughly with a stirring rod to form sodium hydroxide solution. The coconut coir was soaked in the solution and then transferred into the shaker water bath where it is left for 4hours at a temperature of 50^{0}C. After this process is carried out, the treated fibres were removed from the water bath, washed with tap and distilled water to obtain a pH of about 7 followed by sun drying for 5 days.

Figure 2. *Sun drying of coconut coir (left) and extracted coconut coir particle (right)*

PROCUREMENT OF NATURAL RUBBER

The natural rubber (5 litres) was gotten from rubber tree plantation at Federal College of Agriculture, Akure(FECA) which was mixed with ammonia solution for preservation. The constituent of natural rubber was as shown in Table 1.

PROCUREMENT OF RED SAND

The red sand used for this research was gotten from Afuze, Owan east local government, of Edo State, Nigeria where such sand was highly found and used for building construction. The Geographical map of Edo State and Owan East Local Government where the red sand was gotten from can be seen below in Figures 3-4. The red sand was processed by cleaning and sieving from where the exact sieve sizes were obtained.

***Figure 3**: Map of Edo State*

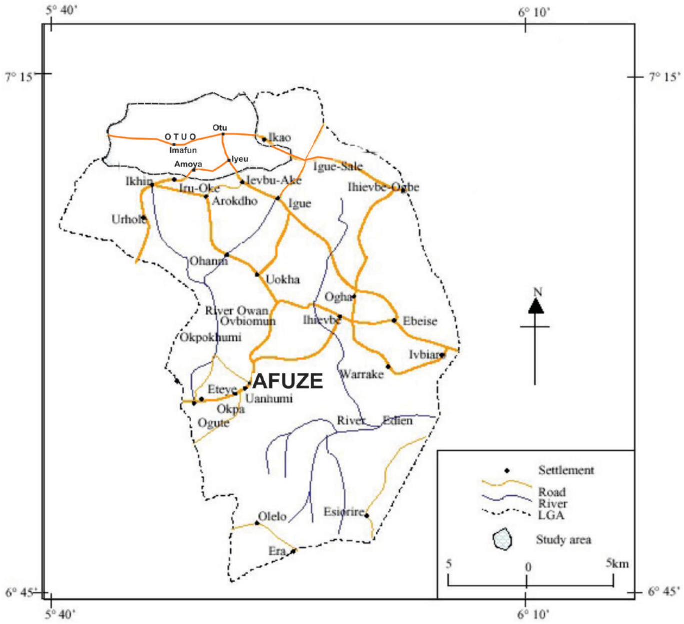

***Figure 4**. Map of Owan East Local Government*

MIXING AND COMPACTION OF THE COMPOSITE COMPONENTS

Processed dried mass of red sands were mixed together with dried coir fibre/particulate accordingly in predetermine proportions of the components. The entire mixture was thoroughly mixed and then poured to fill up the 100 x 30 x 20 mm mould and compacted with laboratory made compacting machine at a pressure of 20 KN for 5minutes. Prior to compaction, the top of the compacting mould was covered with cellophane sheet to enhance easy removal of the composite from the mould and prevent delamination. Once compacted, 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 for 28 days in the laboratory as shown in Figure 5. The composites were prepared for flexural and water absorptivity tests.

***Figure 5**. Composite samples prepared for flexural test*

Composite Formulation

For the production of the composites, the formulation consists of five series of different samples which are; A, B, C, D and E while the control sample was denoted as F. The compositions were as shown in Tables 1-6.

***Table 1:** Formulation table for the developed composites from the addition of coir particles of 300 µ*

Sample	300µ Red Sand (g)	Natural Rubber (g)	300µ Coir Particles (g)
A_1	700	170	14
A_2	700	190	28
A_3	700	210	42
A_4	700	220	56
A_5	700	140	-

***Table 2:** Formulation table for the developed composites from the addition of coir particles of 425 µ*

Sample	300 µ Red Sand (g)	Natural Rubber (g)	425 µCoir Particles (g)
B_1	700	170	14
B_2	700	190	28
B_3	700	210	42
B_4	700	220	56
B_5	700	140	-

Table 3: *Formulation table for the developed composites from the addition of 10 mm coir fibre*

Sample	*300 µ Red Sand (g)*	*Natural Rubber (g)*	*10 mm Coir Fibre (g)*
C_1	700	150	4
C_2	700	170	8
C_3	700	190	12
C_4	700	210	16

Table 4: *Formulation table for the developed composites from the addition of 15 mm coir fibre*

Sample	*300 µ Red Sand (g)*	*Natural Rubber (g)*	*15 mm Coir Fibre (g)*
D_1	700	150	4
D_2	700	170	8
D_3	700	190	12
D_4	700	210	16

Table 5: *Formulation table for the developed composites from the addition of 20 mm coir fibre*

Sample	*300 µ Red Sand (g)*	*Natural Rubber (g)*	*20 mm Coir Fibre (g)*
E_1	700	150	4
E_2	700	170	8
E_3	700	190	12
E_4	700	210	16

Table 6: *Formulation table for the control*

Sample	*300 µ Red Sand (g)*	*Water (g)*
F	700	130

PROPERTIES TEST

The dried composite samples were made to undergo both flexural and water absorption tests as follows;

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.

Water Absorptive Test

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

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

RESULTS AND DISCUSSION

The results were as shown and discussed below.

Flexural Test

Figure 6 shows the flexural strength at peak results for the samples. Considering the influence of coir particulate and fibre on the composites, it was observed that the fibre gave better enhancement of strength compared to the particles in all as revealed from the results.

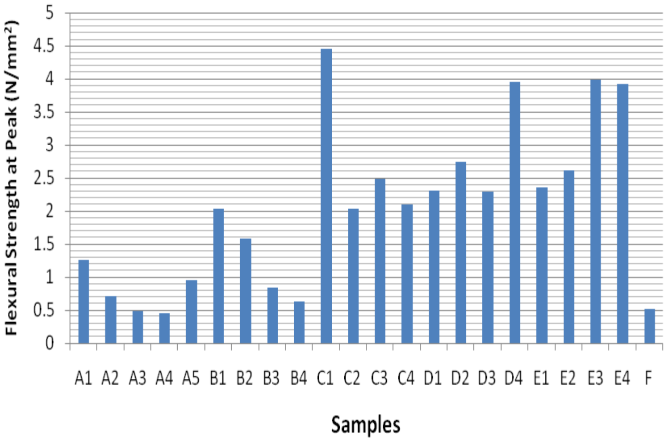

Figure 6*: Flexural Strength at Peak against Samples*

While all the fibre lengths show excellent perform at different levels compared to the control, the particulate show that 425 µ gave better results in all compared to 300 µparticles and the control. Also, the results showed that, the flexural strength at peak reduces as the particle content increases. However, it was observed from the results that, sample C_1 with composition (700: 150: 4) g has the highest flexural strength at peak with a value of $4.45N/mm^2$. This was followed by sample E_3 with composition (700: 190: 12) g which has a value of $3.98N/mm^2$. However, the control sample, F with composition (700: 130) g has a very low value of $0.51 N/mm^2$. With these results, it is obvious that the addition of natural rubber and coconut coir fibre sand 425 µparticulate respectively are potential means for the development of good and strong building materials for structural applications.

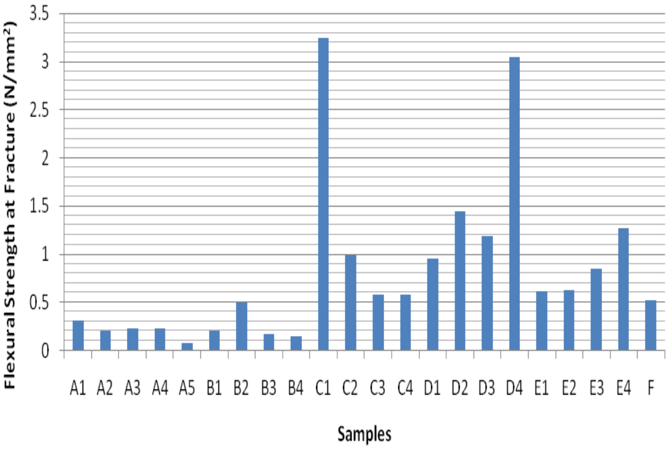

Figure 7*: Flexural Strength at fracture against Samples*

Figure 7 shows the bending strength at fracture results for the composite samples. Similar trend with flexural strength at peak was obtained with respect to the performance of coir fibre and particle in the developed composites. However, there is deviation from this trend with respect to the performance of the particles because the 300 µ particulate reinforced samples tends to give better results compared to 425 µ particulate reinforced samples. From the results, it was observed that sample C_1 with composition (700: 150: 4) g has the highest flexural strength at fracture with a value of 3.25

N/mm^2 followed by sample D_4 with composition (700: 210: 16) g having a value of 3.04N/mm^2. It was revealed from the graph that, the control sample F, with composition (700: 130) g has a fracture value of 0.51 N/mm^2 which is the same with the flexural strength at peak value. This shows that the material,as a ceramic material, is brittle and display brittle fracture property unlike the developed composites that exhibit ductile fracture. This was actually the goal of this work so as to avoid sudden failure in service. From the results, it was observed that the failure mode of the developed composites were different from that of the control sample. Nevertheless, the coir particulate reinforced samples exhibit poor fracture property with respect to the control.

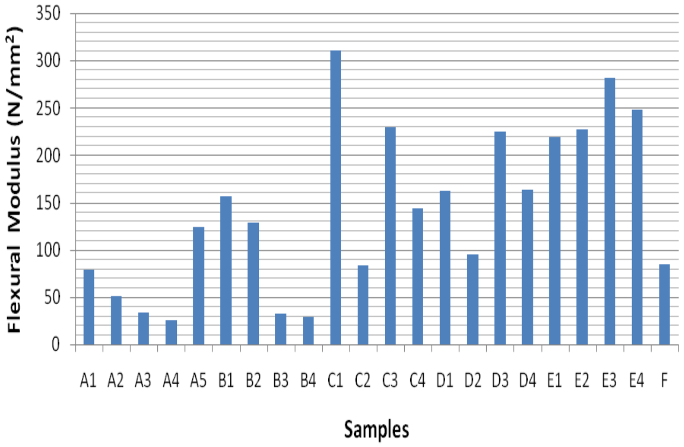

Figure 8: *Flexural Modulus against Samples*

The response of the materials to flexural modulus test was shown in Figure 8. From the results, it was observed that coir fibre reinforcement gave better enhancement in most of the samples compared to the particulate reinforcement. The performance of the particulate reinforced samples was similar to that of the bending strength at peak. From the results, it was observed that sample C_1 with composition (700: 150: 4) g has the highest flexural modulus with a value of 310.06N/mm^2 followed by sample B_5 with composition (700: 140) g which has a value of 302.37N/mm^2. This further confirms that, the addition of coconut coir and natural rubber to processed red sand is a potential way to develop of good and strong composites for structural applications.

The results of the flexural properties have shown that sample C_1 is the best composite. This was the case since is the only sample that has consistence results in all by emerging the best under in all the flexural properties examined. This actually means that the addition of natural rubber and 10 mm fibre length of low content are the best material combination for the development of good and low cost structural materials.

Water Absorptivity of the Composite samples and the control

The results of the water absorption properties were as shown in Figure 9. It was observed from the plot that, the rate of water absorption tends to increases as the amount of natural rubber increases. This was due to the fact that, the natural rubber contains water in its composition as stated by Sajeev et al [6]. Nonetheless, particulate reinforced samples, series A-B, absorbed more water than the fibre reinforced samples, series C-E. This suggests that the particles encourage the absorption of water than the fibre which implies that early degradation and failure of the composites will occur with the use of particulate reinforcement compared to fibre. However while sample D_4 was found to dissolve gradually as a result of loss in weight with time, the control sample F was found to have dissolved in water before the 6th hour. These show that, samples D_4 and F are materials that can experience catastrophic failure if subjected or encountered constant water challenge in service. The result has revealed that the addition of natural rubber and coconut coir can help stabilize the water absorption tendency of the developed composites if adequately or properly regulated.

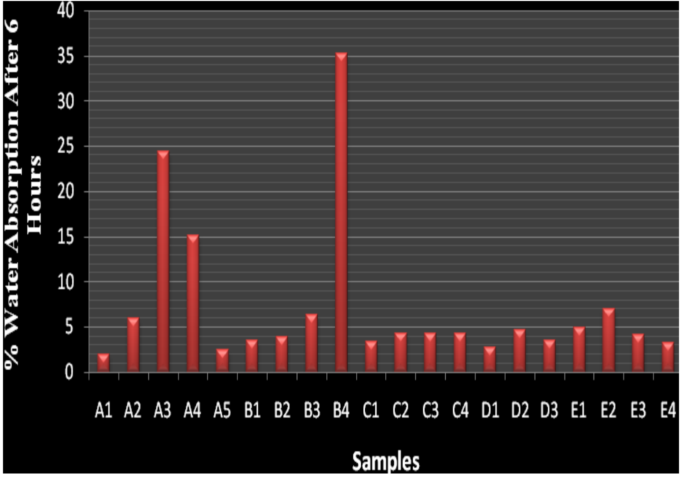

Figure 9*: Graph of water absorption test on the samples after 7 hours*

CONCLUSIONS

The results of the research into the influence of natural rubber and coconut coir on the flexural and water absorption properties of processed red sand reinforced composites has revealed the possibility of blending these materials together for the development of ductile fracture materials for structural applications. The work also show that by this development, the thermal property of polymers can be enhanced since the developed composites will not burnt easily due to the presence of ceramic based material. These materials are biodegradable materials which made them to be environmental friendly. From the results, the following can also be deduced;

- *The use of natural rubber as a binder for red sand produced better flexural properties than the conventional water bonded red sand samples.*
- *Addition of coir fibres gave better flexural and water repellent properties compared to coir particles as well as the unreinforced samples. The best composition was gotten from sample C_1 which has 700g processed red sand, 150g natural rubber and 4g of coir fibre of length 10 mm.*
- *The rate at which coir fibre reinforced samples absorb water is lower than that of coir particle reinforced samples.*

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