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# Tensile Behaviour and Hardness of Coconut Fibre-Ortho Unsaturated Polyester Composites

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**Abstract** - This work is aimed at investigating the effect of alkali treatment and fibre load on the tensile properties and hardness of coconut fibre-ortho unsaturated polyester composites. The short length fibres were incorporated into ortho unsaturated polyester resin. The treated and untreated fibre composite samples were subjected to tensile tests according to ASTM D638 using Instron model 3369. The tensile tests include tensile strength, modulus, load at break, tensile strain at break and extension at break. The Micro-hardness test was carried out by forcing a diamond cone indenter into the surface of the hardness specimen to create an indentation. The significant findings of the research showed that alkali treatment improved the tensile properties and hardness of the composite. The tensile properties at 10% fibre load where greatly enhanced while 15% fibre load is best for micro hardness.

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## 1. INTRODUCTION

Fibre Reinforced Polymer (FRP) is a relatively new class of composite material manufactured from fibre and resin and has proven efficient and economical for use in variety of engineering applications in different field such as aerospace, oil, gas and process industries[1]. Composite materials exhibit good resistance to temperature extremes and wear, especially in industrial settings. The tailorability of composites for a specific purpose has been one of its greatest advantages and also one of the more perplexing challenges for adopting them as alternative materials to metallic ones[2].

Thermoplastics or thermosets, can be used as matrix and fibres of various types as reinforcement in fibre reinforced polymer composite. Fibres provide increased stiffness and tensile capacity in the composites giving them their mechanical characteristics [3]. The resin offers high compressive strength and binds the fibres into a firm matrix. Many of our technologies require materials with unusual combination of properties that cannot be met by the conventional

metal alloys. The mechanical properties of fibre reinforced polymer composites make them ideal for widespread applications in construction worldwide [4].

The use of natural fibre for the reinforcement of the composites has received increasing attention both by the academic sector and the industry. Natural fibres have many significant advantages over synthetic fibres. Currently, many types of natural fibres have been investigated for use in plastics. These include flax, hemp, jute straw, wood, rice husk, wheat, barley, oats, rye, cane (sugar and bamboo), grass, reeds, kenaf, ramie, oil palm empty fruit bunch, sisal, coir, water hyacinth, pennywort, kapok, paper mulberry, raphia, banana fibre, pineapple leaf fibre and papyrus[5]. Thermoplastics reinforced with special wood fillers are enjoying rapid growth due to their many advantages; lightweight, reasonable strength and stiffness [6].

Natural fibres, as reinforcement, have recently attracted the attention of researchers because of their advantages over other established materials. They are environmentally friendly, fully biodegradable, abundantly available, renewable, cheap and have low density [7]. Plant fibres are light compared to glass, carbon and aramid fibres [8]. The biodegradability of plant fibres can contribute to a healthy ecosystem while their low cost and high performance fulfils the economic interest of industry.

However, although natural fibres and their composites are environmental friendly and renewable (unlike traditional sources of energy, i.e., coal, oil and gas), they have several bottlenecks. These include: poor wetability, incompatibility with some polymeric matrices and high moisture absorption [9]. Composite materials made with the use of unmodified plant fibres frequently exhibit unsatisfactory mechanical properties. To overcome this, in many cases, a surface treatment or compatibilizing agents need to be used prior to composite fabrication [10]. The properties can be improved both by physical treatments (cold plasma treatment, corona treatment) and chemical treatments (maleic anhydride organosilanes, isocyanates, sodium hydroxide, permanganate and peroxides)[11]. Mechanical properties of natural fibres are much lower than those of glass fibres but their specific properties, especially stiffness, are comparable to the glass fibres [12].Coconut fibre is one of the natural fibres abundantly

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available in tropical regions, and is extracted from the husk of coconut fruit. The common name, scientific name and plant family of coconut fibre is Coir, *Cocos nucifera* and Arecaceae (Palm), respectively [13]. The two types of coconut fibres include brown fibre extracted from matured coconuts and white fibres extracted from immature coconuts. Brown fibres are thick, strong and have high abrasion resistance while white fibres are smoother and finer but weaker. Coconut fibres are commercially available in three forms, namely bristle (long fibres), mattress (relatively short) and decorticated (mixed fibres). These different types of fibres have different uses depending upon the requirement [14]. However, for the purpose of this study, the brown fibres were used.

General advantages of coconut fibres are: they are moth-proof, resistant to fungi and rot, provide excellent insulation against temperature and sound, not easily combustible, flame-retardant, unaffected by moisture and dampness, tough and durable, resilient, springs back to shape even after constant use, totally static free and easy to clean [15]. The aim of this study therefore is to investigate the suitability of coir as reinforcement to polyester resin.

## II. MATERIALS AND METHODS

The brown coir fibre was extracted from the outer shell of matured coconuts harvested from Ballins Farms along College road Abata Nsugbe, Anambra East Local Government Area, Anambra State. Ortho polyester, accelerator, catalyst, as well as the other chemicals used for pretreatment of the fibres were bought from Poly Consult Venture (25 Ogunleti Street), Ojota Lagos.

### a) Preparation of the fibre

The brown coconut fibres were pulled out and extracted manually from the coconut stalk. To ensure proper interaction between fibre and matrix material, the outer most wax layer of the coir was removed by soaking the coir in hot water [16].

### b) Chemical pretreatment of fibres

The prepared coir fibres were cut into short length fibres of about 5mm to 10mm and divided into 2 separate portions. One portion was chemically pretreated with alkali (NaOH). 200ml of 10% NaOH was used to treat the fibres in a 600ml beaker for one hour. The fibres, were then washed in distilled water and finally dried, in an oven at 80°C for three hours to a constant weight. This was used to prepare the composite. The second portion of the fibres was untreated to serve as control.

### c) Preparation of Polyester Composite

The mould was first cleaned with cotton wool dipped in acetone to remove dirt and was allowed to dry. Poly Vinyl Alcohol (PVA<sub>(s)</sub>) was then applied uniformly on the surface of the mould with a short

wooden spatula. A thin film of PVA<sub>(s)</sub> formed on the mould when the PVA dried acted as the mould releasing agent. (Note that the aluminum mould was dismantled to ensure uniform coating of the mould surface and fixed again after it was dried).

The fibre sample and polyester were weighed using the electronic balance. The fibre was mixed with the polyester at room temperature and stirred continuously for 3 minutes until a homogenous mixture was observed. 2% (by weight of polyester) of the catalyst, methyl ethyl ketone peroxide (MEKP) was added using the syringe and stirred continuously for another 3 minutes. Finally, 1% (by weight of polyester) of the accelerator; cobalt octoate was added and stirred for another 3 minutes. The reaction temperature was taken and the composite was cast in the moulds and allowed to cure for one hour. The cured samples were removed from the mould and the overflow flakes were cut off using the small plier. The procedure was repeated for all the fibre volume fraction of 0.05, 0.10, 0.15 and 0.20 and for each sample of fibre viz: the NaOH treated fibre and the untreated fibre. To study the effect of the fibre reinforcement, the unreinforced (zero fibre volume) sample of the polyester was also prepared.

### d) Formulation of Fibre-Polyester Composite

Fibre polyester composite were formulated as shown on Table.

Table 1 : Formulation of Fibre-Polyester Composite

Reagents	Weight in Grammes			
	(5%) 5g	(10%) 10g	(15%) 15g	(20%) 20g
Parts by weight of coconut fibre				
Ortho unsaturated polyester	95.0	90.0	85.0	80.0
Methyl ethyl ketone peroxide (MEKP)	1.90	1.80	1.70	1.60
Accelerator – Cobalt Octoate	0.95	0.90	0.85	0.80
Reaction Temperature (°C)	44	43	41	41
Curing Temperature (°C)	45	43	42	42

### e) Characterization of the samples

#### i. Tensile Tests

Test for tensile properties were carried out as described in American Standard Testing and Measurement (ASTM) method D638, using the Instron universal testing machine at crosshead speed of 10mm/min using dumbbell test piece. Each tensile specimen was positioned in the Instron universal tester and then subjected to tensile load, as the specimen stretched the computer generated the graph as well as all the desired parameters until the specimen fractured. A graph of tensile stress versus tensile strain was plotted automatically by the computer.

#### ii. Micro hardness test

The Micro-hardness test was carried out by forcing a diamond cone indenter into the surface of the

Hardness specimento create an impression (indentation). Three hardness values were obtained for each specimen and the values were summed up to get an average for each specimen. The experiment was performed with the use of micro hardness tester.

### III. RESULTS AND DISCUSSION

#### a) *Tensile properties of the composites*

The test results of tensile properties of treated and untreated composite sample are as show in Tables 2 & 3, Fig. 1 – 5.

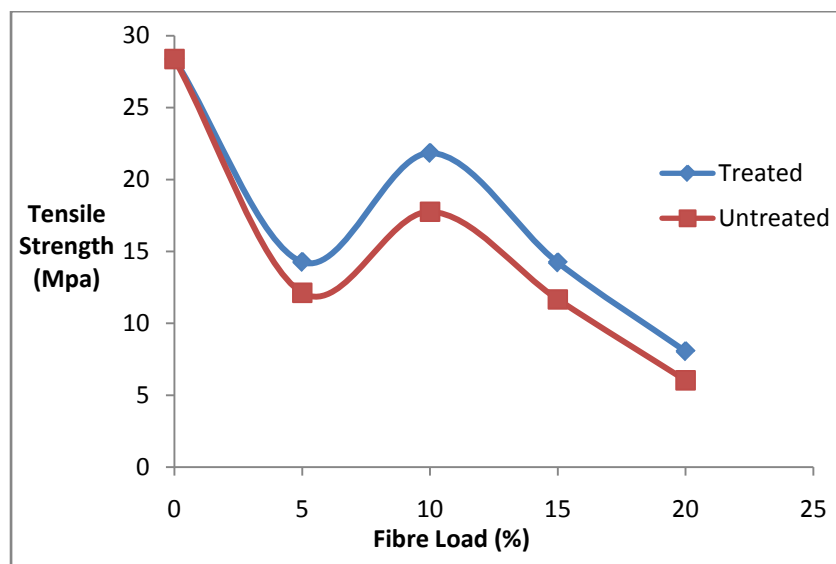
*Table 2 :* Tensile Results for Treated Fibre Composites

Property	0%	5%	10%	15%	20%
Tensile Strength (Mpa)	28.388	14.270	21.852	14.235	8.059
Modulus (Mpa)	856.849	553.871	815.343	667.635	594.841
Load at Break (N)	1082.634	509.169	912.690	584.982	107.479
Tensile Strain at Break (mm/mm)	0.0423	0.0413	0.0415	0.0399	0.0102
Extension at Break (mm)	4.117	3.328	2.324	2.345	2.569

*Table 3 :* Tensile Results for Untreated Fibre Composites

Property	0%	5%	10%	15%	20%
Tensile Strength (Mpa)	28.388	12.126	17.763	11.667	6.038
Modulus (Mpa)	856.849	595.895	726.422	397.773	349.263
Load at Break (N)	1082.634	510.508	728.593	478.829	287.659
TensileStrainatBreak(mm/mm)	0.0423	0.03684	0.0421	0.0456	0.0284
Exetension at Break (mm)	4.117	2.119	2.356	3.0274	2.2455

From Tables 2 and 3, the major determinants of the strength of material were plotted against the fibre load.



*Figure 1 :* Effect of Treatment on Tensile Strength

Fig. 1 shows a comparison of the tensile strengths of the composites using various loads of treated and untreated fibres. The treated fibre at low fibre load of 5% has a tensile strength of 2.144Mpa higher than the untreated fibre. At 10% fibre load, the tensile strength of the treated increased by 4.089Mpa against that of untreated. 2.568Mpa at 15% fibre load and at 20% fibre load the tensile strength of the treated has 2.021Mpa higher than that of the untreated. Thus, sodium hydroxide treatment can be seen to have caused a substantial increase in the tensile strength of the composite.

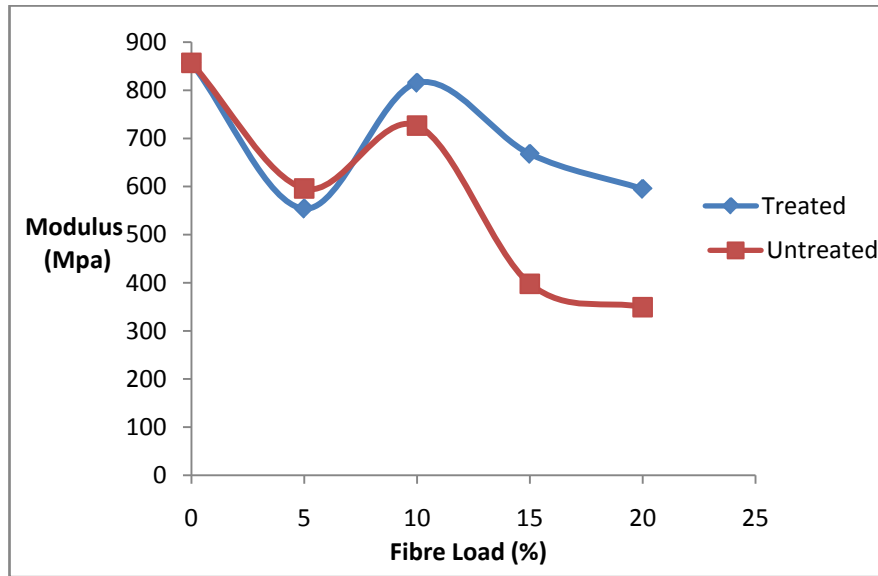


Figure 2: Effect of Treatment on Modulus

From Fig. 2, the composites of treated and untreated fibres show remarkable differences in their modulus which is a measure of stiffness and resistance to stress. At 5% fibre load, it is observed that the untreated fibre has a modulus which is 42.024Mpa

higher than the treated fibre. However, as the fibre load increases to 10%, 15% and 20% the modulus of the treated fibre composite becomes higher than the untreated fibre composite by 88.921Mpa, 269.867Mpa and 245.578Mpa respectively.

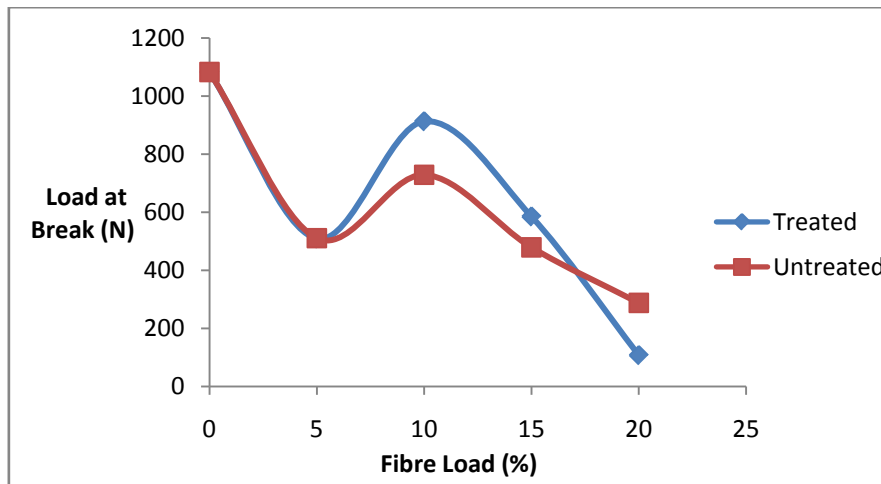


Figure 3: Effect of Treatment on Load at Break

From Fig. 3, the graph shows that at 5% volume ratio, the load at break for treated and untreated fibre composite are slightly the same. But at 10% and 15% fibre load, the treated fibre composite has a higher load at break while at 20% fibre load, the untreated fibre has a higher load at break.

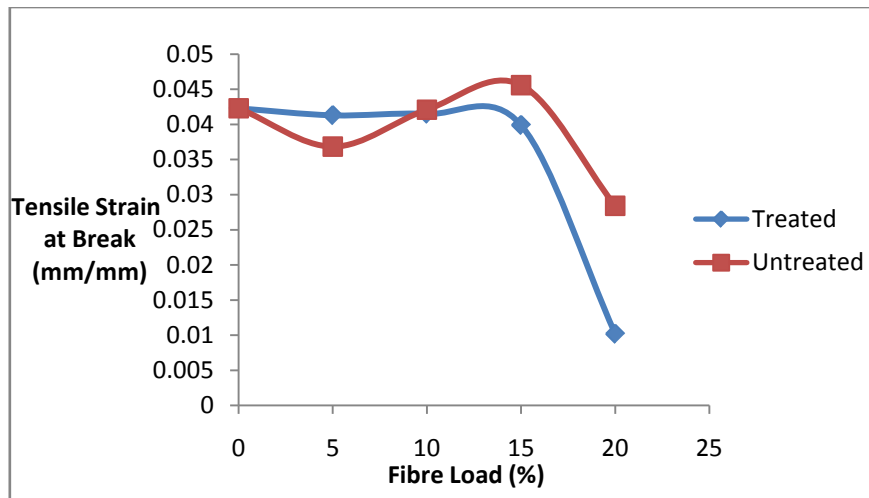


Figure 4 : Effect of Treatment on Tensile Strain at Break

Fig 4 shows also that the tensile strain at break on the composite is least on the treated fibre composite between 10% fibre loading and 20% fibre loading. This implies that permanent deformation is least detected on the treated fibre composite and mostly pronounced on

the untreated fibre composite. However, at lower volume ratio of 5%, the treated fibre composite is more prone to permanent deformation when compared with the untreated fibre composite which has a lower value of tensile strain at break.

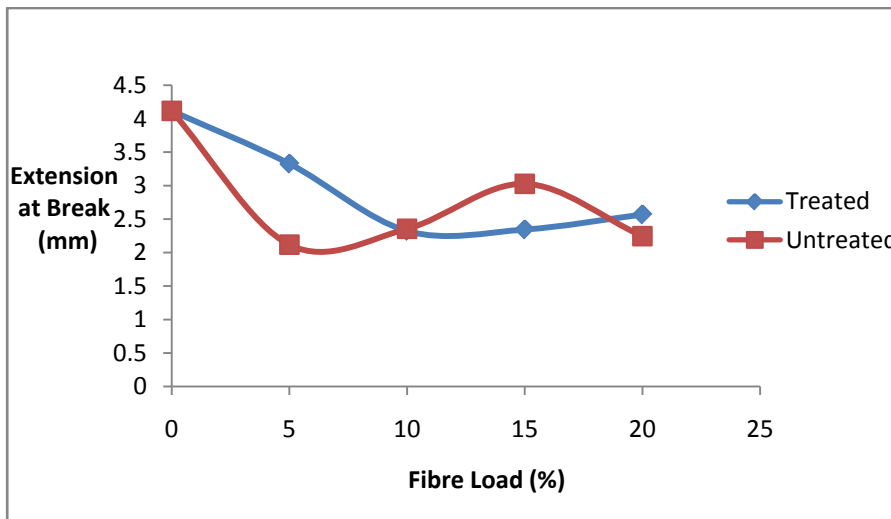


Figure 5 : Effect of Treatment on Extension at Break

Fig. 5 shows the effect of treatment on the extension at break of the treated and untreated fibre composites. Extension at break is a measure of the ductility of the composite. It can be observed from the graph that between 5% and 10% fibre load, the treated fibre composite has higher ductility than the untreated fibre composite. However, as the fibre load increases to 15%, the untreated fibre has a ductility which is 29.08% higher than the treated fibre composite while at 20% fibre load, the ductility of the treated fibre composite is 14.43% higher than that of the untreated fibre composite.

b) *Micro Hardness Properties of the Composites*

Test results for micro hardness are shown in Table 4 and Fig 6.

Table 4 : Micro Hardness for Treated and Untreated Fibre Composites

Sample	Untreated sample (HV)	Treated sample (HV)
0%	22.06667	22.06667
5%	18.13333	21.46667
10%	24.16667	26.46667
15%	15.23333	37.76667
20%	13.76667	26.36667

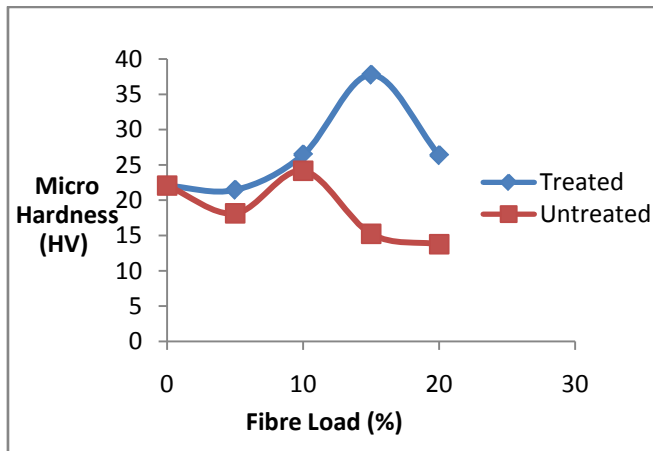


Figure 6 : Effect of Fibre Load and Treatment on Micro Hardness

From Fig. 6 above, it can be seen that treatment as well as increase in volume ratio improves the micro hardness of the fibre composite. While the treated fibre composite sample at 15% fibre load has the highest value, the untreated fibre composite sample at 20% fibre load has the least value.

#### IV. CONCLUSION

From the results generated, it can be established that NaOH pretreatment of coconut fibre has better reinforcing property than the untreated fibre. The treatment was observed to improve the tensile properties (tensile strength, modulus, load at break, tensile strain at break, extension at break) and micro hardness of the composite samples.

For tensile properties, 10% fibre load gave the best reinforcing property for treated fibre composites while 15% fibre load samples exhibited the best micro hardness.

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