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The effect of filler content and size on the mechanical properties of unsaturated polyester/coconut empty fruit shell and fiber composite

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Abstract

Unsaturated resin was reinforced using coconut empty fruit shell (CEFS) floor and coconut fruit fiber (CFF). Each reinforced composite was tested for different temperature (50 – 70^{0}C), baking time (1 – 5hrs), particle sizes (150, 300, 355, 500 and 850 microns) and percentage composition (5 – 25%). For each reinforced composite compressive and tensile strengths were tested as a function of particle size, baking temperature, baking time and percentage compositions. Result shows that maximum reinforcement was attained by particle size of 150 microns when subjected to various conditions. The compressive strength of the composite baked between 50 – 70^{0}C and between 1 – 5hrs revealed an increase in strength up to 25% composition by weight of filler at 70^{0}C and for 5hrs. After 25% composition, there was a drop in compressive strength. Tensile strength increased with increase in percentage composition.

1. Introduction

The use of natural fiber/filler in today's technology continues to grow in the engineering sector of development economies. Reasons for this growth include the weight reduction upon excellent strength/weight ratio, low cost and appreciable aesthetic properties. Wood-derived fillers/fibers have several advantages over inorganic fillers based on their lower density, less abrasiveness to processing equipment, and low cost(Zani et al., 1996).

Studies are ongoing to find ways to use natural fibers in place of synthetic fibers as reinforcing fillers. These natural fillers are especially being sought since the production of composite using natural substances as reinforcing filler is not only inexpensive but also able to minimize the environmental pollution caused by the characteristic biodegradability (Premalal et al., 2002), enable these composite to play an important role in resolving future environmental problems. The need for materials that are non-toxic to the human body and have appropriate characteristics for specific purposes is ever increasing due to lack of resources and increasing level of environmental pollution (Han-Seung et al., 2004).

Nowadays, the application of polymer composites as engineering materials has become very important (Bledzki and Gassan, 1999). Unsaturated polyester (UP) resins are among the most widely used thermosetting polymers and extremely versatile in properties and applications and have been a popular thermoset used as the matrix in polymer composite such as fiber reinforced plastics and polymer concretes (He at al., 2001; Jadhar and Kantoe, 1999; Jadhar and Kantoe, 1991).

There are various types of natural fillers that can be added to polyester resin, these include saw dust, rice-husk, sugarcane bagasse and wood flour among others. In this present study, the coconut empty fruit shell (CEFS) flour and coconut fruit fiber (CFF) which are waste products of the agricultural industry has been chosen as filler material because of low cost, abundance in nature, low density and biodegradability are used to develop composites using thermosetting polymer as matrix. Coconut palm tree is also a native commercial crop in Nigeria.

This study is not only to evaluate the mechanical properties of the composite formed but to also provide property data from which designers can draw from and provide a foundation upon which further work can be carried out.

2. Materials

The unsaturated polyester resin was received by Almarinal Port Harcourt River State, with specification 268 QTN. Almarinal also supplied Methyl ethyl ketone peroxide (MEKP), dimethyl phathalate and cobalt II ethyl hexanoate. Paraffin was procured from the market. The reinforcing filler in the composite were coconut shell and fibres (husk). The coconut fruits (*cocos nucifera*) were procured from local market and the husk and shell carefully removed from the edible nuts inside. The chemical constituents of the coconut shell is shown in Table 1.

Table 1
Chemical Constituents of the Coconut Shell Flour

	Holocellulose	*Lignin*	*Cellulose*	*Ash*	*Extractive*
Coconut	79.29	35.54	26.49	1.17	1.86

values are percentage by weight.
The overall calorific value of the coconut shell powder was estimated to be 20.3kj/g. The particles of materials varied in sizes and were graded accordingly.

3. Preparation of test sample

Test samples used in the work were prepared by mixing the polyester resin accelerator, and then the catalyst. The external mould release agent was melted and applied on the surface of the mould and then left to solidify. T his allowed the forming of a thin film on the surface of the mould. The shelf powder graded in different particle sizes, mixed also in different proportions for effective study in this work was introduced. Tables 2, 3, 4, 5 shows the different treatments of specimens and their characteristics.

Table 2
Different specimen and varying particle size

Specimen	*Particle size (μ_m)*	*Composition (%)*
A_{150}	150	10
A_{355}	355	10
A_{500}	500	10
A_{850}	850	10

This treatments were used to determine the effect of particle size variation on the tensile and compressive strength of the resin.

Table 3
Different specimen and varying percentage composition

Specimen	*Particle size (μ_m)*	*Composition (%)*
B_5	355	5
B_{10}	355	10
B_{15}	355	15
B_{20}	355	20

These specimens were used to investigate the effect of particle distribution density on the tensile and compressive strength of the resin.

Table 4
Specimen used to determine the effect of baking time on compressive and tensile strength of the resin

Specimen	*Particle size (μ_m)*	*Baking Temperature (^0C)*	*Composition (%)*	*Baking time (hrs)*
C_1	500	50	10	1
C_2	500	50	10	2
C_3	500	50	10	3
C_4	500	50	10	4

These specimen were used to determine the effect of baking time on the compressive and tensile strength of the resin.

Table 5
Specimen used to determine the effect of fibre reinforcement on compressive strength of the resin in the presence of shell powder particles

Specimen	*Particle size (μ_m)*	*Composition (%)*	*No of Fibre*
A_{f150}	150	10	2
A_{f355}	355	10	2
A_{f500}	500	10	2
A_{f850}	850	10	2

This was used to determine the effect of fibre reinforcement on the compressive strength of the resin in the presence of shell powder particles.

Table 6
Specimen for determination of effect of baking temperature on compressive and tensile strength of the resin

Specimen	*Particle size (μ_m)*	*Baking Temperature (^0C)*	*Composition (%)*	*Baking time (hrs)*
D_{50}	850	5	50	1
C_{55}	850	5	55	1
C_{60}	850	5	60	1
C_{65}	850	5	65	1

This is for determination of effect of baking temperature on the compressive and tensile strength of the resin.

4. Testing of the sample

When the samples had passed through the necessary production processes, tensile and compressive tests were carried out on them. With the aid of Hounsfield (Monsato) tensometer, model number SW8889, static bending, compressive, shear, tensile, clearage, hardness tests were executed. The harness test was of the Brinnel indicator and Bending. A total range of 180 to 360 tests were made on the different samples considering the need of investigation.

5. Result and discussion

Mock test was carried out of the specimens for different particle sizes, percentage compositions, baking time and baking temperature to ascertain how the compressive and tensile strength of each reinforcement varied as a function of the definite variables; the particle size and percentage composition against certain system parameters.

From the mode tests, particle size of 150μm gave the highest strength and was used to check compressive and tensile strength as a function of particle distribution density, baking time and baking temperature.

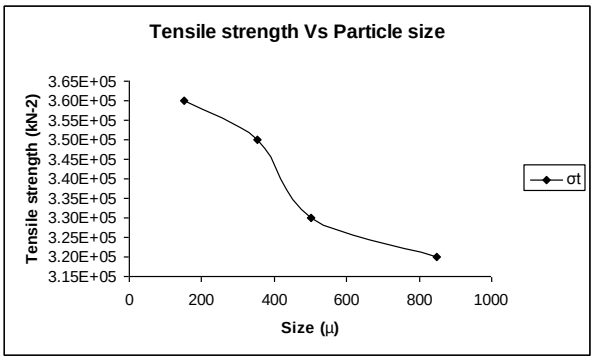


Fig.1. The graph of tensile strength against particle size.

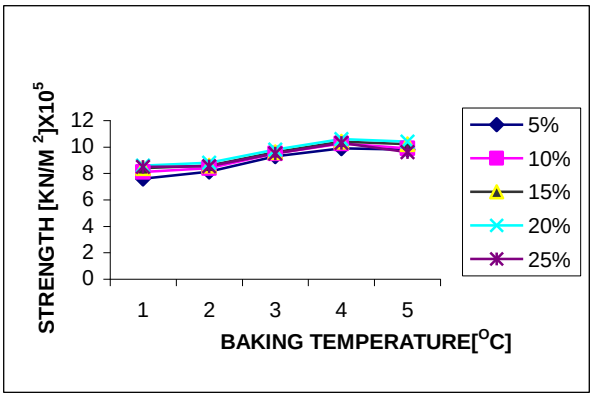


Fig.2. A graph of compressive strength against baking temperature for different % composition.

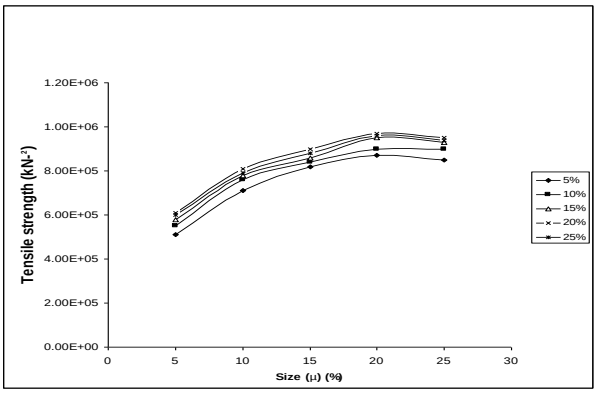


Fig. 3. Variation of tensile strength with particle size for different 5 composition.

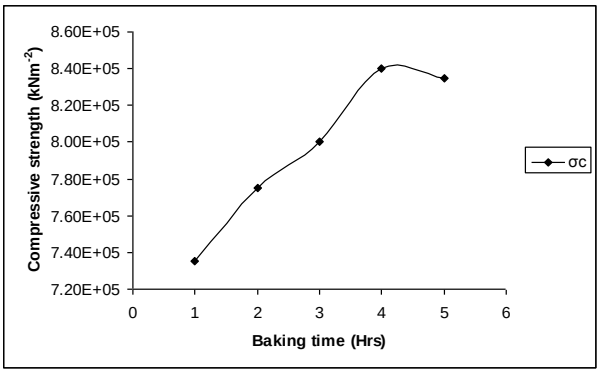


Fig. 4. Variation of compressive strength against baking time for the control experiment.

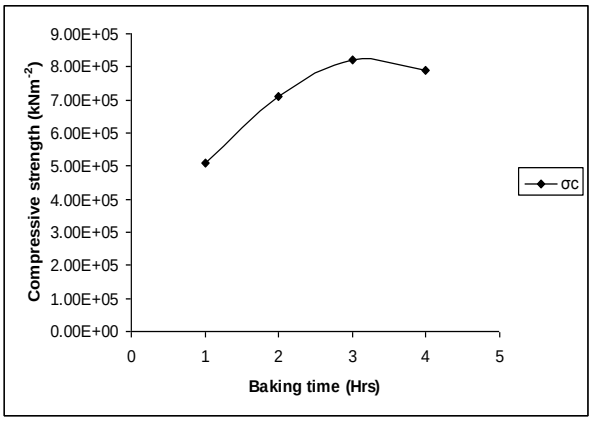


Fig 5. A graph of stress against baking time for control specimen.

Table 7
Shows a summary of the variation of compressive strength with baking time for different % composition

Baking Time / *% Composition*		*1 hour*	*2 hour*	*3 hour*	*4 hour*	*5 hour*
5%	Force	102 kN	110 kN	115 kN	112 kN	120 kN
	Strength	$5.1x10^5$	$5.5x10^5$	$5.8x10^5$	$6.1x10^5$	$6.0x10^5$
		KN/M^2	KN/M^2	KN/M^2	KN/M^2	KN/M^2
10%	Force	142 KN	151 KN	156 KN	162 KN	158 KN
	Strength	$7.1x10^5$	$7.6x10^5$	$7.8x10^5$	$8.1x10^5$	$7.9x10^5$
		KN/M^2	KN/M^2	KN/M^2	KN/M^2	KN/M^2
15%	Force	164 KN	167 KN	172 KN	180 KN	175 KN
	Strength	$8.2x10^5$	$8.4x10^5$	$8.6x10^5$	$9.0x10^5$	$8.8x10^5$
		KN/M^2	KN/M^2	KN/M^2	KN/M^2	KN/M^2
20%	Force	173 KN	180 KN	189 KN	194 KN	191 KN
	Strength	$8.7x10^5$	$9.0x10^5$	$9.5x10^5$	$9.7x10^5$	$9.6x10^5$
		KN/M^2	KN/M^2	KN/M^2	KN/M^2	KN/M^2
25%	Force	170 KN	179 KN	185 KN	190 KN	186 KN
	Strength	$8.5x10^5$	$9.0x10^5$	$9.3x10^5$	$9.5x10^5$	$9.4x10^5$
		KN/M^2	KN/M^2	KN/M^2	KN/M^2	KN/M^2

Table 8
Shows the variation of compressive strength with baking temperature for different % composition

Baking Time / *% Composition*		*50*	*55*	*60*	*65*	*70*
5%	Force	152 KN	162 KN	168 KN	172 KN	170 KN
	Strength	$7.6x10^5$	$8.1x10^5$	$8.4x10^5$	$8.6x10^5$	$8.5x10^5$
		KN/M^2	KN/M^2	KN/M^2	KN/M^2	KN/M^2
10%	Force	164 KN	167 KN	172 KN	176 KN	171 KN
	Strength	$9.3x10^5$	$9.5x10^5$	$9.6x10^5$	$8.8x10^5$	$8.55x10^5$
		KN/M^2	KN/M^2	KN/M^2	KN/M^2	KN/M^2
15%	Force	186 KN	190 KN	195 KN	195 KN	190 KN
	Strength	$8.2x10^5$	$8.4x10^5$	$8.6x10^5$	$9.0x10^5$	$9.5x10^5$
		KN/M^2	KN/M^2	KN/M^2	KN/M^2	KN/M^2
20%	Force	198 KN	205 KN	208 KN	212 KN	205 KN
	Strength	$9.9x10^5$	$10.25x10^5$	$10.4x10^5$	$10.6x10^5$	$10.3x10^5$
		KN/M^2	KN/M^2	KN/M^2	KN/M^2	KN/M^2
25%	Force	195 KN	198 KN	203 KN	207 KN	192 KN
	Strength	$9.8x10^5$	$9.9x10^5$	$9.9x10^5$	$10.4x10^5$	$9.6x10^5$
		KN/M^2	KN/M^2	KN/M^2	KN/M^2	KN/M^2

6. Discussion

Particles of size 150 microns gave the highest compressive strength when compared with the control specimen, see fig. 1.0 For this reason, this particle size was used to check the compressive and tensile strength as a function of particle distribution density, baking time and baking temperature as well as the effect of fibre inclusion on the compressive strength.

As a function of the particle size distribution density, the compressive strength increased progressively up to 20% composition by weight of the shell powder. At 25% there was a drop in the compressive strength of the composite material by about 7 percent.

When the compressive strength was plotted as a function of baking time, for different composition i.e. 5% to 25% composition by weight, there was a general increase in the strength as baking time increased, for the composite became reinforce from 15% by weight composition. Below this percentage composition there was generally a drop in the compressive strength i.e. from 5% to 10%. As a function of baking time the strength increases although it exhibited a general drop in strength at time 5 hours since heating effect seem to affect the process negatively.

Baking temperature as a function of compressive strength exhibited similar curve characteristic when the compressive strength was plotted as a function of baking temperature for various composition of shell

powder. Between 5% to 10% composition by weight, there was a drop in the strength of the composite by about 4%. The composite became reinforced when percentage composition increase to about 15%. The strength however increased generally as the particle distribution density increase up to about 20%. At 25%, there was a drop in the compressive strength at all composition and at a critical temperature of 70^0C especially for 5 – 10%.

Specimen E into which some fibre was incorporated exhibited a progressive drop in the compressive strength at all composition. Plot of strength against the percentage composition revealed that the interface or point of contact between the fibre and the particle acts as a site for crack initiation and as such results to a drop in the strength. Compressive strength however increases with increase in the composition of the particle size. The case however is different for the tensile strength as the fibre tend to increase it's strength. However, the finer the powder particle, the better the reinforcement obtained. If fibre is incorporated into the composite, at 25% composition the particle, distribution density is high resulting in many contact point between shell powder particle and fibre. This result to an increase in site for crop propagation which increases with increase in particle size and is responsible for the low compressive strength of the reinforced material.

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