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EFFECT OF PARTICLE SIZE ON THE MECHANICAL AND PHYSICAL PROPERTIES OF COW BONE PARTICLE REINFORCED POLYESTER COMPOSITE

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ABSTRACT
This research work studied the effect of different particle sizes of cow bone particles on some physical properties and mechanical properties of cow bone particulate filled polyester composite. The cow bone particles were sun dried for several days, ground and sieved to different micro sizes and used to reinforce unsaturated polyester resin. Hand lay-up technique was used in the composite manufacture. It was observed that the particle size of 300µm gave the best tensile modulus and best compressive strength while the particle size of 180µm gave the best tensile strength. The water absorption of the composite increased with increase in particle size while the density of the composite increased as a result of the reinforcement. The developed composite has good compressive strength and can be useful in application with minimum requirement on strength and light weight such as floor and wall tiles.

***Key words**: Cow bone particles, Particle size, Bio-composite, Mechanical Properties, Water absorption*

1.0 INTRODUCTION
Polymeric composites are being used extensively in various applications from domestic house hold items to industrial, automobile and aerospace applications due to their high strength to low weight ratios. [1]. Pure polymeric materials do not have such wide application in engineering because of their low mechanical properties. These mechanical properties can be greatly improved by using techniques from nature where most special structural materials are indeed a mixture of different materials which indicate composites with enhanced properties.

Polymers are often combined with fillers and/or fibers to improve their mechanical and/or physical properties. The fillers usually consist of wood flour, china clay, quartz powder or other powdered minerals. The filler is incorporated not only to improve the physical property of the composite but sometimes to reduce the polymer content and hence the cost. The costs of most commonly used composite fillers are high such as talc, calcium carbonate, kaolin, silica, and carbon black. Most of them are also non biodegradable.

The problem in most developing countries is that unused natural biomaterials are being treated as a waste instead of being used as an industrial input. Animal bones are of typical example and constitute a big environmental problem (environmental pollution) and so its productive use will rid the environment of these wastes. Indeed environmental, economic/cost issues are the basis for utilization of agricultural bio-waste products in the industry, and this has been the focus of considerable research in recent times [2-3].

In recent times, there has been increased legislation and awareness about our having a clean environment through clean energy and production of biodegradable materials. Cow bones seen in various abattoirs are dehydrated waste products only used for animal feed supplements in most developing countries. It presents a serious environmental problem if not properly disposed. Cows are killed every day and as such the volume of this cow bone generated daily is on the increase as only a limited quantity is used by animal feed mills. Its use in composite manufacture will introduce a new dimension to its applications and will not only help clean up our environment but will find value addition and good economic returns for cow owners/butchers.

Recently, extensive research work has been carried out on other biodegradable reinforcements such as natural fibers as replacement for synthetic fibers in polymer reinforced composites [4-8]. Many have also worked on the use of various particulates with outstanding results [9-14].

This paper is an extension of the search for biodegradable materials for use as polymer composite reinforcements for various applications. The focus is to investigate the effect of cow bone particle size on the physical and mechanical properties of an unsaturated polyester resin composite in order to determine its usefulness or otherwise in engineering applications. The very approach of drying and grinding them for use as composite reinforcement adopted in this research has not only provided a sure solution to environmental problems but has opened a door way to its value addition for various domestic and industrial applications.

2.0 MATERIALS AND METHODS

2.1 Materials

The raw cow bones were obtained from Nsukka Ikpa/Ogige market abattoir. Polyester resin and Methyl Ethyl Ketone Peroxide (MEKP) were obtained from Ndidiamaka Chemicals Enugu, while Cobalt 2-ethylhexanoate and mould release agent were obtained from Manweb Nigeria Ltd Lagos. The metal moulds were supplied by ICE-JEB Technical Services. Acetone mould cleansing agent was obtained from Lavans Chemicals Company Ltd, Nsukka.

(a)


(b)


(c)


***Plate1**:(a) Raw cow bone dumped as waste at Ikpa market Nsukka.(b) washed and sun-dried cow bone (c) ground and sieved cow bone particles*

2.2 Methods

2.2.1 Conversion of Cow Bones into Particulate Fillers

The cow bones were collected from the abattoir at Ikpa/Ogige market, Nsukka, Nigeria. They were washed with detergent and a local spurge in a rotating bath to remove the oily part and traces of dirty contaminants. The washed cow bone was rinsed with clean water and sprayed on a mat at room temperature for 24 hours to remove water. They were sun dried in an open air hot sun environment for 5 days. Bone crusher was used to crush the bone to fine particles. Sieving was done using different sets of sieves having mesh sizes of 180µm, 300µm and above 300µm. After sieving, the different sizes were used as reinforcement of the matrix.

2.2.2 Manufacture of the Composite

Flat metal moulds with 4.5mm wall thickness were prepared and hand lay–up method was used in making the composite. Here, the unsaturated polyester resin was measured into a beaker and the cow bone particles were added and then stirred vigorously until even dispersion was achieved. Addition of about 1.5% weight of catalyst and 1% accelerator were added and stirred for some time before casting the sample in the mould. Samples were made for unreinforced polyester resin and for180µm, 300µm and >300µm particle sizes at volume fraction of 40% each.

(a)

(b)

Plate2: *Moulds for producing (a) Tensile Specimens (b) Compressive and impact specimens*

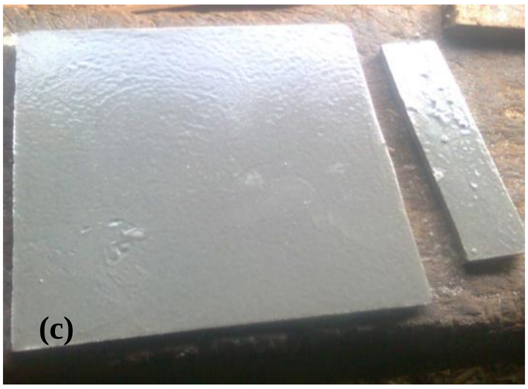

Plate3*: Sample of the developed composite*

Various test specimens were cut according to ASTM standards for polymer composites: ASTM638 for tensile Test; ASTM D695 for compression Test and ASTM D370 for impact Test.

2.2.3 Testing

The tests carried out on the produced samples are: Physical Properties Test (Density and Water Absorption test) and Mechanical Properties Test (Tensile, Compressive and Impact test).

Density Testing

The density of the samples was determined by first measuring the dimensions of the samples to calculate the volume and measuring on a digital weighing balance the mass of each sample. The density (ρ) of each sample was obtained using the following equation

$$\rho = \frac{Mass}{Volume} \quad (1)$$

Water Absorption Test:

The water absorption was determined by first weighing each sample using a digital weighing balance to obtain the initial weight w_1, Thereafter the samples were immersed in water for 24 hours, removed, dried with towel and then allowed to dry in an open air for 30 minutes at room temperature and the weight (W_2) recorded. The percentage of water absorption was calculated according ASTM D570] as follows.

$$\% \text{ Weight gained} = \frac{W_2 - W_1}{W_1} x100 \qquad (2)$$

where W_2 is the wet weight and W_1 is the dry weight of the samples

Tensile Testing

Hounsfield Tensometer was used for the tensile test. The samples were cut to standard (ASTM D638) and each sample was subjected to test by loading to its maximum load carrying capacity, after which the tensile strength was calculated using the standard formula.

Compressive Test

The compressive Strength was also tested using the Hounsfield Tensometer. The samples were cut to standard (ASTM D695-96). They were also subjected to their highest compressive load carrying capacity and the compressive strength was calculated using standard formula.

Impact Testing

The Impact testing was carried out on the samples using the Charpy Impact testing machine to determine the impact energy. The specimens were cut according to standard (ASTM A370). Each sample was then placed on the machine, and the pendulum was allowed to hit the specimen when it swings under gravity. The Impact energy was obtained by reading energy loss of the pendulum as a result of hitting the sample, directly from the machine. The impact strength was calculated from the relation.

$$G_c = U/A \ (J/m^2) \qquad (3)$$

3.0 RESULTS AND DISCUSSIONS

The results of the tests conducted on the control sample (ctrl) and the developed composites with 180µm, 300µm and above 400µm air dried cow bone particle sizes are presented as follows

3. 1 Density of Composite

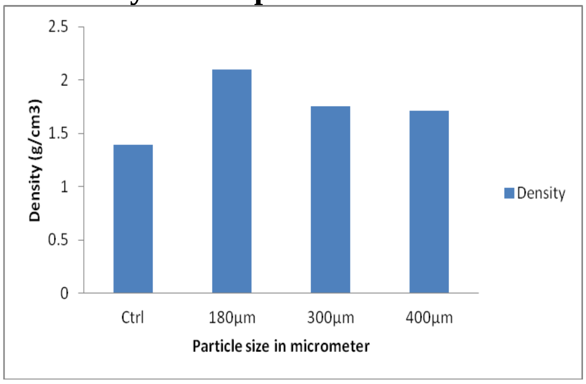

Fig 1.1: *Effect of particle size on the density of sun dried cow bone- polyester composite.*

From Figure 1.1, it is deduced that the density of polyester was increased as a result of the particles added to reinforce it. It was also observed that the smaller the particle size the higher the density such that 180µm developed composite is denser than others. This property is not favorable for applications where weight to strength ratio is of much consequence.

3.2 Water Absorption

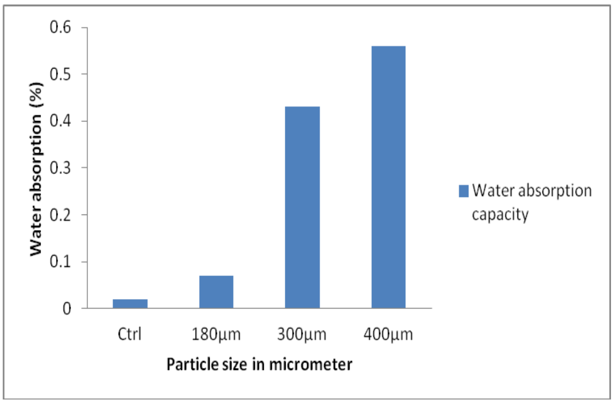

Fig 1.2: *Effect of particle size on the water absorption of cow bone- polyester composite.*

From Figure 1.2 it is observed that the higher the particle sizes of the cow bone particles, the higher the percentage of water absorption of the composite. This is because increase in the size of the particles increases the pore spaces for water percolation.

3.3 Tensile Properties

The result of the tensile strength and tensile modulus are presented in Figure 1.3a and Figure 1.3b respectively.

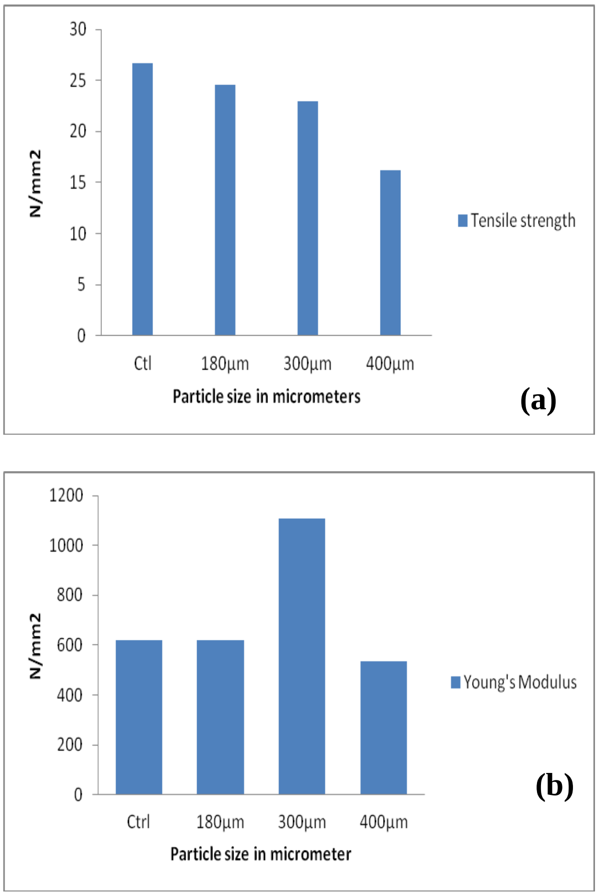

Fig 1.3: *Effect of particle size on the (a) Tensile strength (b) Young's Modulus of cow bone- polyester composite.*

From Figure 1.3, it is observed that the tensile strength decreased with increasing particle sizes of the cow bone particles. This is due to the fact that the finer particles develop a larger interfacial area with the matrix, thereby providing for more efficient load transfer to the particles. On the hand, there was a remarkable increase in the tensile modulus at 300µm particle size while other sizes of 180µm and 400µm did not show any improvement which is an indication of under reinforcement and over reinforcement respectively. This proves that the optimum reinforcement particle size is 300µm when stiffness is of primary consideration.

3.4 Compressive Strength

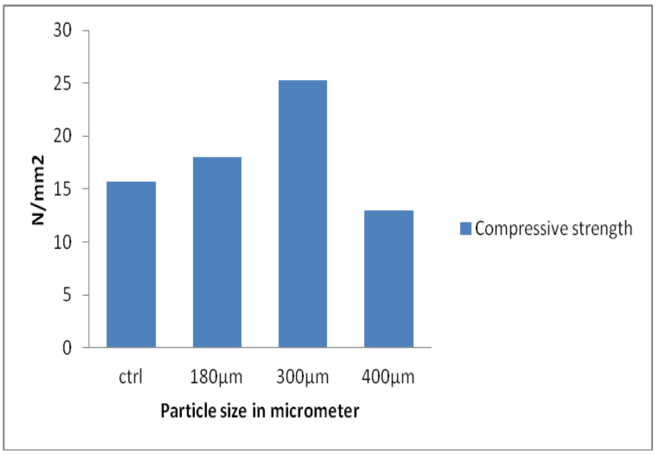

Fig 1.4: *Effect of particle size on the compressive strength of cow bone- polyester composite.*

From Figure 1.4, it is observed that variation in particle sizes of the cow bone particles does not show any linear relationship in their compressive strength. The sample with cow bone particle size of 300µm possesses the highest compressive strength.

3.5 Impact Strength

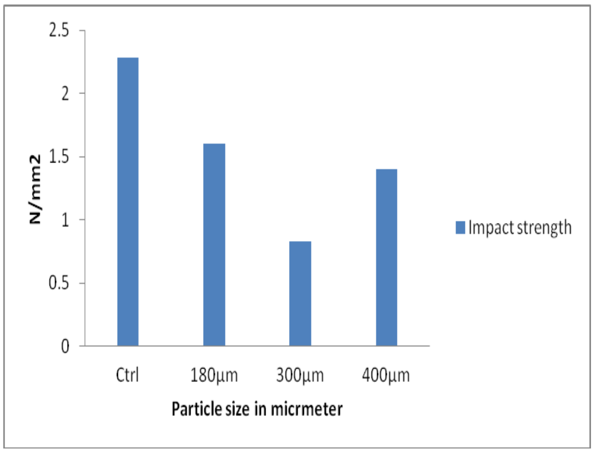

Fig 1.5: *Effect of particle size on the impact strength of cow bone-polyester composite.*

From Figure 1.5 presenting the Impact test results, there is no linear relationship between the impact strength of the samples and the particle size. The results show that impact strength decreased as the particle size increased: however there was a further increase of strength with particle size 400µm.

4.0 CONCLUSION

The results of this investigation show the possibility of using cow bone particles as reinforcement in composites production in areas where compressive strength is a major requirement. In this research, the density increased with the reinforcements but decreased with increase in particle size. The particles size of 300µm gave the best combination of tensile strength, tensile modulus and compressive strength but had the least impact strength. The water absorption of the composite increased with increase in particle size due to bigger pore spaces for water percolation as particles size increased. Due to good compressive strength, the cow bone particle /polyester composite can be a good replacement for high cost ceramic tiles for walls and floors.

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