© 2018 IJSRSET | Volume 4 | Issue 8 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology

Effect of Fillers Loading on the Mechanical Properties of Hardwood Sawdust/Oil Bean Shell Reinforced Epoxy Hybrid Composites

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ABSTRACT

There is an increasing interest in development of bio-composite materials and their applications in various fields, to replace synthetic fiber reinforced composites. In this study, mechanical properties such as tensile characteristics, flexural characteristics, and compressive characteristics of hardwood sawdust (HSD) and oil bean pod shell (OBPS) hybrid composites in epoxy (EP) matrix were investigated as a function of filler loading. Hybridized composite sample was prepared with 20, 30, 40, 50, and 60% reinforcements of sawdust and oil bean pod shell particulate (the fillers) in the ratio of 1:1 and cured for 21 days. The prepared composites were tested according to ASTM standards, and the results showed that the filler reinforcement had strong effect on the tensile, compressive and flexural characteristics of the composite board. The tensile strength, transverse rupture strength, Bending Modulus and compressive strength increased progressively up to 50 % filler loading, before their values dropped at 60 % filler loading; while percentage elongation at fracture only increased to 40 % before it started decreasing. The results of this study showed that composite could be successfully developed using HSD, OBPS and epoxy would be a substitute for wood-based material in many applications.

Keywords: Epoxy Resin, Sawdust, Oil Bean Shell, Hybrid Composites, Mechanical Properties.

I. INTRODUCTION

The African oil bean (Pentaclethra macrophylla Benth) is a tropical tree in the family Leguminosae (Mimosoideae), native to tropical Africa. The fruit is a long green pod which slowly darkens with maturity, 36–46 cm long and 5–10 cm broad; each pod contains up to 10 seeds and at maturity, the pod splits open explosively scattering its seeds up to a distance of 20 m from the tree [1]. Although the synthetic fiber reinforced composites have excellent strength and hardness they are high cost and non-biodegradable. The growing interest in using the natural fibers is due to their availability, satisfactory specific strength and modulus [2], light weight, low cost and biodegradability [3]. Also, synthetic fibers, like carbon fibers and glass fibers create several ecological, and health hazard problems for the workers employed in manufacturing of their corresponding composites as compared to composites derived from natural fibers [4]. Due to this, the demands of natural fibers reinforced composites are increasing with more roles in automotive parts for light-weight elements, plastic and packaging [5]. There are lots of natural composite materials available in this part of the world such as jute, abaca, sawdust, sisal, ramie, hemp, etc. Apart from the low cost of agro-waste there is particular interest nowadays to environment and biodegradability properties of materials to actualize the scale up production of agro waste plastic composites by the formation and synthesis of these filler fibers, various methods are required which involve mixing of filler husks at different filler loading per weight [6]; [7]; [8]. Despite the attractive of natural fibre reinforced polymer matrix composites, they are suffering from the lower modulus, lower strength and relatively poor moisture resistance compared to synthetic fiber reinforcement composites such as glass and carbon fibre reinforced plastics [9]. Natural fibre reinforced polymer matrix composites are very sensitive to influences from environmental agents such as water [10].

In recent years, major industries such as automotive, construction and packaging industries have shown enormous interest in the development of new bio-composite materials and are currently engaged in searching for new and alternate products to synthetic fiber reinforced composites [11]. Many researchers had studied the mechanical properties of composite materials and highlighted that these composites have acceptable dynamic mechanical properties for many industrial applications. Reference [5] investigated the effect of temperatures on the compressive strength of Napier grass filled unsaturated polyester resin and found that the elastic modulus and compressive strength of modified resin are significantly affected by Napier based filler contents and temperatures. Reference [11] studied the mechanical behaviour of novel bio-based composite materials prepared using groundnut shell particles as reinforcement of an epoxy resin, by varying the volume content and size of fillers, they found out that samples having 40% in volume and 0.5 mm size of groundnut shell particles, had the highest tensile modulus, tensile strength, flexural strength and impact strength. In addition, [12] studied the effect alkali treatments on the mechanical properties of bagasse fibre biodegradable composites and found that the mechanical properties of the composites made from alkali treated fibres were superior to the untreated fibres/ Composites of treated fibres with NaOH showed better results, approximately 13% improvement in tensile strength, 14% in flexural strength and 30% in impact strength had been found, respectively. The chemical treatment of the natural fabre to be used composite materials is necessary, as it enhances their mechanical and thermal properties [12]. Chemical treatment of fabre permits a better make contact with fiber-matrix and diminishes the thermal contact resistance significantly [13]; and it has been reported that NaOH chemical treatment of fiber allows major increase of thermal and mechanical properties of composites [11].

Hybridization of two or more different types of materials can offer some advantages over using each of the material alone in a single polymer matrix. Hybrid composite materials offer a combination of strength and modulus that are either comparable to or better than many pure materials [14]. Pervious researchers have developed hybrid composites containing both natural and synthetic fillers, which showed better mechanical properties than mono filler materials [15]; [16]. In addition, investigation into the flexural strength—the resistance to fracture—of raffia palm fibre-cement composites for low cost roofing tiles results showed that, addition of raffia palm fibre to cement composites increases the flexural strength by more than 100% in comparison with the control, with zero per cent fibre volume fractions [17]. Currently, there is dearth of information on the hybridization of oil bean shell pod shell (OBPS) and hard wood sawdust (HSD) composite production, hence in this present work, epoxy-based hybrid composites were produced with hard wood sawdust and oil bean pod nut shell particulate as the reinforcing materials.

II. MATERIALS AND METHODS

Oil bean pod shell and wood sawdust reinforced polymer composite specimens were prepared by varying three parameters, namely, particle size, weight percentage of reinforcement material and matrix material.

2.1 Samples preparation

Epoxy resin (matrix):

Araldite LY556 resins with HY951 hardener are used as matrix material. LY556 is an epoxy resin, with good fiber impregnation properties, and exhibits excellent mechanical, dynamic and thermal properties, exhibits extremely high resistance to alkali, and good solvent resistance. It has good electrical properties over a range of frequencies and temperature [11].

Extraction and modification of oil bean pod shell using Sodium Hydroxide

A complete seed of oil bean is called a pod and outer layer of oil bean seed is called oil bean pod shell. The oil bean shells were collected from a Delta State Polytechnic Ozoro, Delta State, Nigeria; and were washed with distilled water to remove impurities. The shells were sundried and ground, and the resulting particles treated with 10% NaOH (soaked for three hours, and washed with acidified water), and oven dried at 80^{o}C for 10 hours. The particles were sieved with stainless steel sieve into these categories of 150 µ, 300 µ and 450 µ shell particles.

Modification of the wood sawdust using Sodium Hydroxide

The iroko (Chlorophora excelsa) the hard wood was obtained from a local wood contractor in Ozoro, Delta State, Nigeria, and was sawed with fine teeth sawblade to obtain the fine sawdust obtained from the timber. The saw dust was treated with 10% NaOH solution for 5 hours at room temperature, washed with acidified water, and oven dried at 80˚C for 10 hours. The particles were sieved through 300 µ, 450 µ and 600 µ standard test sieves to get different particles sizes.

Hybrid composite board preparation

The preparation of the composites was carried out by hand lay-up technique. A mould of 200 × 150 × 5 mm^3 made of wood, which was first applied with a very thin film of wax, to facilitates fast release of the composite was used for the casting of the composite board. The composites were prepared with 20, 30, 40, 50, and 60% reinforcements of sawdust and oil bean shell particulate in the ratio of 1:1 (Table 1). Measured quantities of the wood sawdust, oil bean pod shell particulate and resin were put in a plastic container and stirred thoroughly for 25 minutes to get homogeneous mixture. Then measured quantity of hardener was added to the mixture and again stirred thoroughly for 15 minutes; and the mixed mixture was poured into mould and compressed uniformly, rolled using a roller to ensure good contact and freedom from porosity. The casted mould was kept under a load of 40 kg at room temperature for 24 hours to expel any entrapped air from it; after which, it was stripped off from the mould and cured at room temperature for 21 days. After curing the composite board was cut into the shape of standard specimens. The epoxy resin and hardener were mixed in the ratio of 10:4 by weight. Table 1 shows the percentage composition of saw dust/oil bean shell particulate/epoxy hybrid composite, of the composite board.

Table 1. The percentage composition of saw dust/oil bean shell particulate/epoxy hybrid composite

Reagent	Size (µmm)	Wt% (g)				
		S_1	S_2	S_3	S_4	S_5
Sawdust	150	10	15	20	25	30
OBSPS	150	10	15	20	25	30
Matrix		80	70	60	50	60

2.2 Mechanical Testing

Tensile Test

The tensile strength of the composites was measured with Universal Testing Machine (UTM) (Testometric model, series 500-532), in accordance with the ASTM D638 procedure. The UTM gripped each end of the specimen and slowly pulling it until fracture occurs (Figure 1). Five replications were done on each sample and the average values of tensile strength and elongation at fracture were calculated.

Figure 1. A composite board undergoing tensile testing

Figure 2. A composite board undergoing compression loading

Flexural test

The flexural test was performed using the Universal Testing Machine; and was done in accordance with ASTM D790 - 17 standard of using the 3-point bending fixture, utilizing centre loading on a simple supported beam. The values of the modulus of rupture (MOR) and modulus of elasticity (MOE) were determined by using the following equations.

Compression test

The samples were subjected to unaxial compression test according to ASTM D695 standard, by using the Universal Testing Machine (Testometric model, series 500-532), with a cross speed rate was fixed at 1mm/min (Figure 2). The compressive properties such as elastic modulus and maximum compressive strength were determined.

III. RESULTS AND DISCUSSION

3.1. Tensile test

Tensile strength

The tensile strength of the HED and OBPS filled epoxy resin composite material results are presented in figure 3. The results showed that the filler loading had significant effect on the tensile strength of the composite board. In reference to Figure 3, the tensile strength increases with the increase in HSD and OBPS up to 50%, afterward it decreases, this could be attributed to the poor bonding or the reinforcement materials caused by low volume (percentage) of the matrix in the mixture, creating maximum void contents and weak interfacial adhesion in the process. According to [18], during tensile loading partially separated micro spaces are created that obstructs stress propagation between the fibre and the matrix. Our result is in similar trend with [19], on Raffia Palm Fibre/Groundnut Shell Reinforced Epoxy Hybrid Composites; and Reddy and Reddy for okra fibre reinforced polymer composites. Tensile strength which is the ability of a material to withstand a pulling force., is one of the most important properties of materials used in structural applications.

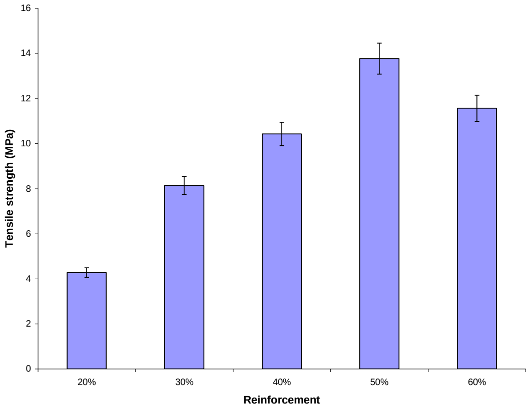

Figure 3. Effect of filler reinforcement on tensile strength of HSD/OBPS composite

Percentage elongation at fracture

The percentage elongation obtained by conducting the tensile test is shown in Figurer 4. As shown in Figure 4, the percent elongation at fracture of the hybrid composite board increased to a maximum at 40% loading and decreased with further increase in loading (filler reinforcement). Similar result was obtained by [19] for Raffia palm fibre/groundnut Shell reinforced epoxy hybrid composites, where they recorded decreased in the percentage elongation at fracture after 20 % filler loading.

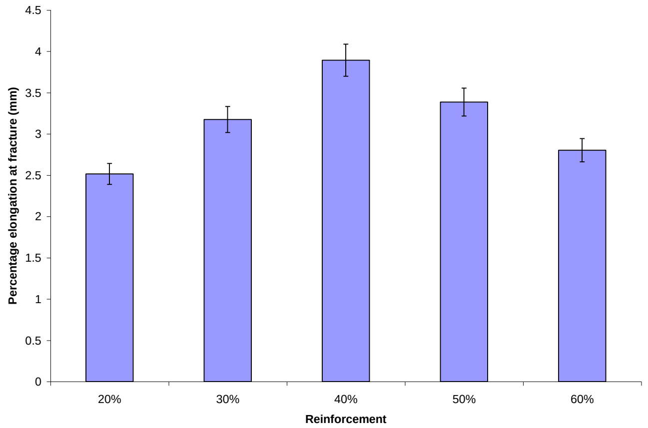

Figure 4. Effect of filler reinforcement on percent elongation at fracture of HSD/OBPS composite

3.2 Flexural test

The experimental results show that the transverse Rupture Strength and the Bending Modulus increased up to 50 % reinforcement, and then decreases again (Figures 5 and 6). This could be attributed to weak adhesion of the fillers by the matrix at higher reinforcement percentage. The mechanical properties of particulate-filled polymer micro and nano-composites are affected by particle size, particle content and particle/matrix interfacial adhesion [16] [20]. Similar results have been reported by previous researchers, [21] reported that the tensile, flexural strength, and hardness of the composites increased with increasing fiber loading up to 43 vol.% and decreased above this value for the composites. In addition, [22] reported that a fiber content of both 30% and 40% by weight proved to provide adequate reinforcement to increase the strength of the polypropylene powder. Flexural properties of materials play vital role in structural applications.

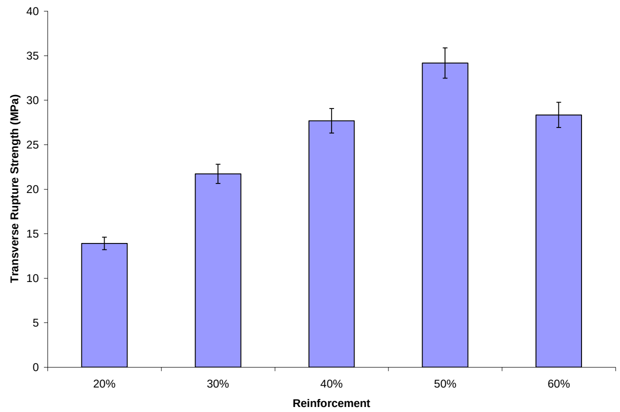

Figure 5. Effect of filler reinforcement on Transverse Rupture Strength of HSD/OBPS composite

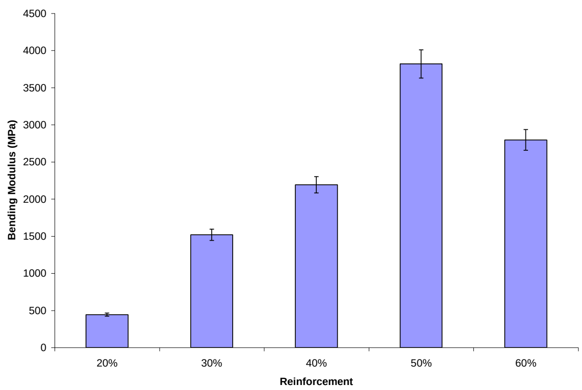

Figure 6. Effect of filler reinforcement on Bending Modulus of HSD/OBPS composite

3,3 Compressive test

Compressive strength

The experimental results show a steady increase in the compressive strength of the composite board with increased in the filler percentage up to 50 % before it deceases again (Figure 7). This may be attributed to the weak interfacial interaction between the filler and matrix as well voids and agglomeration of fillers for higher filler content [19]. Similar behaviour of the composite specimens was also observed by [23].

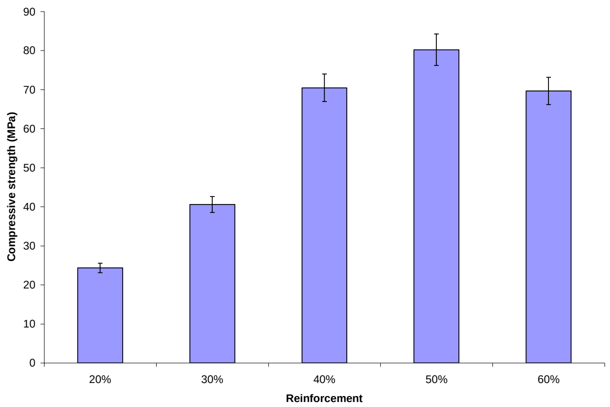

Figure 7. Effect of filler reinforcement on compressive strength of HSD/OBPS composite

IV. CONCLUSIONS

The results of the experiment shown that, filler loading had impact on the mechanical properties of the composite boards. The mechanical test results show that, the addition of natural fillers to epoxy matrix improved the mechanical properties of the composite board up to point (50 % percentage weight), after which, further increment in the weight of the fillers lead to decreased in the mechanical properties. From the results, it can be seen that composite mechanical properties are strongly affected by filler loading and matrix adhesion. The results of this study showed that composite could be successfully developed using HSD, OBPS and epoxy matrix which would be a substitute for wood-based material in many applications.

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