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Tensile Behaviour of Oil Bean Pod Shell and Mahogany Sawdust Reinforced Epoxy Resin Composite

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Abstract: The influence of fillers loading rate on the tensile behaviours (tensile strength, Young Modulus, tensile energy, tensile strain and Stress at LOP) of reinforced epoxy composites were investigated in this research. Both filler materials (OBPS and SD) where treated with 5(w/v)% Sodium hydroxide solution for 1 hour at ambient temperature of 27±3°C. The composite samples were prepared with five different volume (10, 15, 20, 25 and 30 vol%) of OBPS and SD in the ratio of 1:1, using the hand lay-up method. All the composite samples were prepared and tested according to ASTM standards, using the Universal Testing Machine. Results from this present research showed that the fillers loading had significant ($P \leq 0.05$) effect on all the tensile behaviors investigated. In addition, the results showed that all the five tensile behaviours of the samples increased gradually with increase in fillers loading. The tensile strain increased by 53.18%, as the fillers loading increased from 10% to 30 vol.%.in addition the tensile strength increased from 7.86 to 27.47 MPa, while the Young modulus increased from 668.4 to 1235.93 MPa. Results obtained from this study can be helpful in the production of composite boards for industrial applications.

Keywords: Mahogany, Sawdust, Tensile Properties, Oil Bean Shell, Epoxy Composite

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1. Introduction

Nigeria forests contain large varieties of plants with different fibre content. Mahogany tree (*Swietenia mahagnoni*) is a straight-grained, reddish-brown hardwood. Mahogany resists wood rot, making it attractive in boat construction and outdoor decking [1]. Mahogany is also used in musical instruments, mostly the wooden parts of acoustic and electric guitars. In addition, it is used in drum shells because of its ability to produce a very deep, warm tone, when compared to other woods, such as maple or birch [2-3]. In addition, mahogany seed contains so many health benefits that it is very sought after in some countries. Studies have established that mahogany seed contributes greatly in lowering cholesterol. This could be attributed to the reasonable amount of flavonoid contained in the seed, which can help in blood circulation. Furthermore, mahogany is rich in saponins, which help in preventing blood clotting and enhancing better heart condition [4].

Composite materials composed of two or more components combined in a ratio that allows the new materials to be distinct and identifiable. The initial components add strength and other tensile behaviours to a composite, therefore, the product often compensates for the weaknesses of each individual components. The tensile properties of composites are strongly dependent on the properties, distribution and the interaction among the constituent materials. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way, thereby resulting in more improved properties [5-6]. Over the years, applications of composites materials have increased tremendously. The use of composites depend on many factors such as; working, lifetime requirements, complexity of product shape, costs savings, and on the experience and skills the designer in tapping the optimum potential of composites [5].

Composite materials are classified by the type of reinforcement used with the matrix. The reinforcement is incorporated into a matrix which holds it together. The reinforcement is used to strengthen the composite products.

For instance, in a resin composite board, the matrix is the resin and the reinforcement can be corn husk, sawdust, fiberglass, straw etc. Common composite types include random-fiber or short-fiber reinforcement, continuous-fiber or long-fiber reinforcement, particulates reinforcement, flake reinforcement, and fillers reinforcement [6]. Natural materials reinforced composites have been increasingly used in widespread engineering and textile applications. For instance, jute, flax and sisal fibres are used nowadays in automotive industry [7]. The applications of natural fibres in composites depend on their composition, physical and mechanical properties [8]. Limitations of natural fibres applications in industrial practice can be attributed to their relatively high hydrophilic behaviours. This affects the interfacial adhesion between the fibres and the polymer matrix, hence reducing the mechanical properties of their composites [9]. Some advantages of natural fibres over synthesized fibres are their low density, high toughness, comparable specific strength properties, ease of separation and moulding, environmental friendliness, low cost and improved stiffness [8, 10, 11].

Many researchers have investigated the tensile properties of various natural fibres composites. Aji *et al* [12] studied the mechanical properties of kenaf/PALF fibres reinforced polyethylene composites. Their results showed that fibres loading ratios and finres length had effect on the storage modulus of the hybrid composites. Furthermore, Taib [13] reported in their study that the impact strength and elongation at break of ethylene acrylate-modified kenaf fibre reinforced polylactic acid composites were improved by increasing the modifier content but an opposite trend was observed for the tensile strength and modulus. The effects of alkaline treatment on the mechanical properties of bagasse fibre reinforced composites were investigated by [14]. Their results showed that the mechanical properties of the composites made from the treated fibres were better than the untreated fibres. They reported approximately 13% improvement in tensile strength, 14% in flexural strength and 30% in impact strength had been found, respectively. Furthermore, John [15] studied the potential of carbonized bagasse (waste from sugar cane) as fillers in composites. They reported that as the filler loading increased the tensile strength, abrasion resistance, and hardness properties improved. In addition, they observed that decreased in the fillers loading enhanced the elongation at break and compression set properties. In addition, [16] studied the tensile strength and modulus of chemically extracted elephant grass fibre composites. They reported that the above mentioned mechanical properties increased approximately 1.45 times to those of elephant grass fibre composite extracted by retting.

Even though, much work have been done on natural materials composites, research works on the oil bean pod shell (OPBS) and mahogany sawdust (SD) composites are scanty. Therefore, the objective of this research was to study and evaluate the tensile properties of OBPS and SD reinforced epoxy composites, to establish its usefulness in industrial applications.

2. Materials and Methods

2.1. Samples Collection and Preparation

The oil bean pod shells used for this research were picked from environment of the Delta State Polytechnic, Ozoro, Nigeria. The collected shells were ground using a burr mill, to reduce them to particulates size, which was later treated with 5% NaOH for 1 hour to enhance their tensile properties. Lastly, the particulates were sieved with 150 μ stainless steel sieve.

Mahogany timber was obtained from local timbers dealer in Oleh, Delta State, Nigeria. In order to obtain sawdust from the timber; it was sawed with fine teeth saw blade. The saw dust obtained was treated with 5% NaOH solution for 1 hour at ambient temperature of 27±3°C, dried in laboratory oven at 100°C for 8 hours, and sieved through with a 300 μ stainless sieve. The Epoxy resin and hardener used for this research were purchased from an industrial chemical shop located at Onistha in Anambra State, Nigeria.

2.2. Composite Preparation

The composite samples were prepared by hand lay-up technique. A wooden mould of dimension 200 × 150 × 5 mm^3 (based on ASTM standard) was used for the casting. A thin wax film was first applied to the mould, to facilitate the release of the composite from the mould. The composite samples were made with fillers (Oil bean pod shell and saw dust) loadings of 10%, 15%, 20%, 25% and 30%, in the ratio of 1:1. The epoxy and hardener were mixed in the ratio of 4:1 to produce the matrix. During the casting, measured quantities of OBPS, SD and the resin were poured into a plastic bucket and stirred thoroughly for 30 minutes to obtain a homogeneous mixture. After that, the right quantity of the hardener was added to the mixture in the plastic bucket and again stirred carefully again for 10 minutes; before the mixture was poured into the already prepared mould. The casted composite was kept under a dead load of 20 kg at ambient 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 [10]. Finally, after the curing, the composite board was cut into the tensile samples shape based on ASTM D638 standard.

2.3. Tensile Testing

The tensile strength of the composite samples was measured at the material testing laboratory of National Centre of Agricultural Mechanization, Ilorin, Kwara State, Nigeria. The samples were tested with the Universal Testing Machine (UTM) (Testometric model), in accordance with the ASTM D638 procedure. Ten replicas were done on each composite sample and the average values of tensile behaviours (tensile strength, Young Modulus, tensile energy, tensile strain and Stress at LOP) were recorded.

2.4. Statistical Analysis

Data obtained from this present study were subjected to

Analysis of variance using SPSS statistical software (version 20.0, SPSS Inc, Chicago, IL). In addition, the mean values of the parameters were separated using Duncan's multiple range tests at 95% confidence level.

3. Results and Discussion

The Analysis of Variance (ANOVA) results of the effect of fillers loading on the tensile properties of epoxy composites are presented in Table 1. From Table 1, it can be seen that the fillers loading had significant ($P \leq 0.05$) effect on all five tensile behaviours investigated in this research. Summary of the regression equations are shown on the regression in Table 2. The high correlation values ($r \geq 0.90$) in Table 2 showed that strong relationship existed between the fillers loading and the various tensile behaviours.

Table 1. *ANOVA for response of tensile behaviour of Epoxy/OBPS/SD composite to fillers loading.*

Source of variation	Dependent variable	df	Sig
L	Tensile strength	4	2.69E-11*
	Young modulus	4	4.84E-08*
	Stress at LOP	4	4.97E-09*
	Tensile energy	4	3.19E-08*
	Tensile strain	4	1.38E-10*

L = filler loading rate; * =Significant at ($P \leq 0.05$); df = degree of freedom.

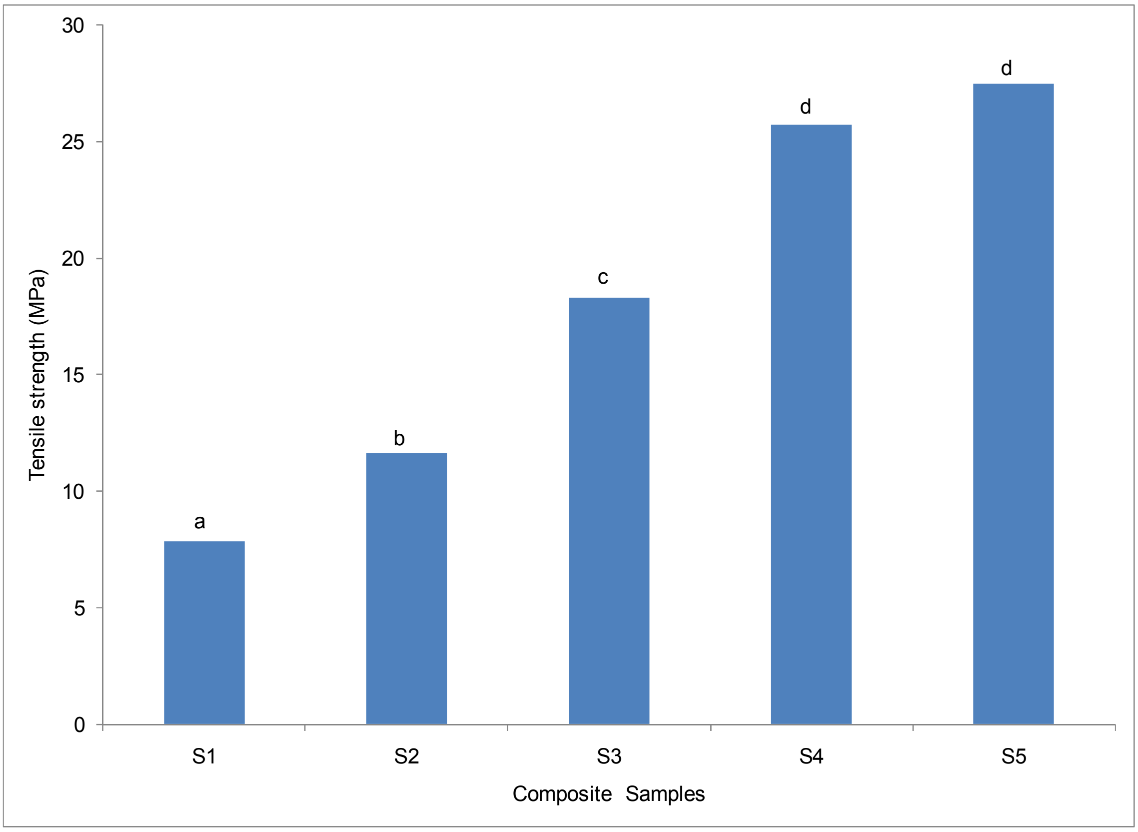
Table 2. *Regression equations of the effect of fillers loading on the tensile behaviour of Epoxy/OBPS/SD composite.*

Parameter	Linear equation	R^2	Power equation	R^2	r
Tensile strength	$y = 5.332x + 2.204$	0.971	$y = 10.31\ x^{0.74}$	0.946	0.987
Young Modulus	$y = 143.5\ x + 507.8$	0.992	$y = 638.6\ x^{0.383}$	0.956	0.996
Tensile energy	$y = 1.346\ x + 5.404$	0.989	$y = 6.539\ x^{0.361}$	0.969	0.994
Stress at LOP	$y = 1.592\ x + 3.578$	0.964	$y = 4.963\ x^{0.501}$	0.966	0.982
Tensile strain	$y = 1.151\ x + 2.33$	0.975	$y = 3.443\ x^{0.497}$	0.923	0.988

Where y = the parameter, x = composite sample, R^2 = coefficient of determination, r = correlation.

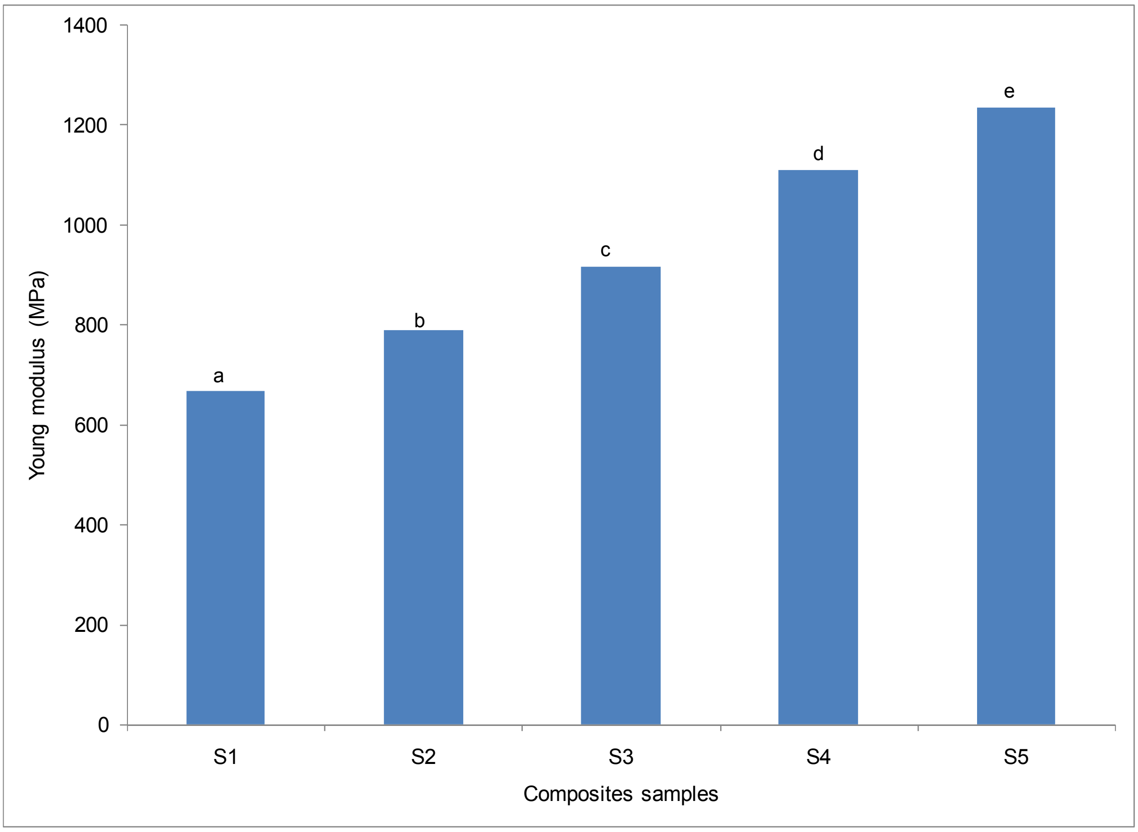
The results of the effect of fillers loading the tensile behaviours of composites samples, obtained from this study are presented in Figures 1 to 5. From the results, it was clear that the fillers application improved the tensile properties of the composites samples. Figure 1 showed the effect of fillers (OBPS and SD) loading on the tensile strength of the composite board. From the Figure 1, it can be clearly seen that the tensile strength of the composite board increased with increase in the fillers loading. The maximum tensile strength of 27.47 MPa was recorded at 30 % volume fillers ratio. As shown in Figure 1, no significant difference ($P \leq 0.05$) was observed between the tensile strength of composite samples 4 and 5. In addition, from the results, the Young modulus increased by 45.92% with the addition of the fillers. The tensile strain of the OBPS and SD reinforced composite specimens are presented in Figure 5. As shown in the plot (Figure 5), the tensile strain was increased by 11.13%, 34.55%, 47.98% and 53.18% for the samples S2, S3, S4 and S5 respectively as compared to the sample S1. In addition, from the plot in Figure 5, no significant difference ($P \leq 0.05$) was observed in the tensile strain between samples 1 and 2. Similar result was obtained for Iroko timber sawdust and oil bean pod shell reinforced epoxy composites, where tensile strength increased up to 50% fillers loading before it started decreasing [10].

Furthermore, from previous study, the specific tensile strength of banana, sisal and okra fibres composites increased with increasing volume fraction of fibre linearly up to the volume fraction of 20.4% [17]; additionally, the tensile strength of bagasse fibre composites increased from 16.5 to 23.5 MPa, as the fibre content increased from 20 to 65(wt %) [14]. Motaleb studied the influence of alkaline treatment on mechanical properties of pineapple and jute fabric reinforced polyester resin composites. He observed the tensile strength of the composites reinforced with alkaline treated fabric increased by approximately 30% when compared to the pompposities reinforced with untreated fabric [18]. In the study of Kalam [19], the tensile strength for OPFBF/epoxy composites at 35 vol% was 47.8 MPa and for OPFBF/epoxy composites at 55 vol% was 46.1 MPa. Furthermore, another research stated that tensile properties of short-fibre-reinforced composites strongly depend on fibre length, fibre volume fraction, fibre dispersion, fibre orientation and fibre /matrix interfacial strength [20]. A similar trend was reported for short pineapple leaf fibre (PALF) treated with 2% NaOH improved the tensile strength and tensile modulus of the composites board by 12% and 31%, respectively, compared with the untreated fibre composites [21]. The better tensile strength results obtained from the alkaline-treated reinforcement materials could be attributed to the improved adhesive characteristics of fibre/filler surfaces. This is caused by the removal of the natural and other impurities from the reinforcement materials, thereby producing a rough surface topography. In addition, alkaline treatment leads to fibre fibrillation, i.e. breaking down of the fibre bundles into smaller fibres. This increased the effective surface area of the fibre and the matrix [21-22].



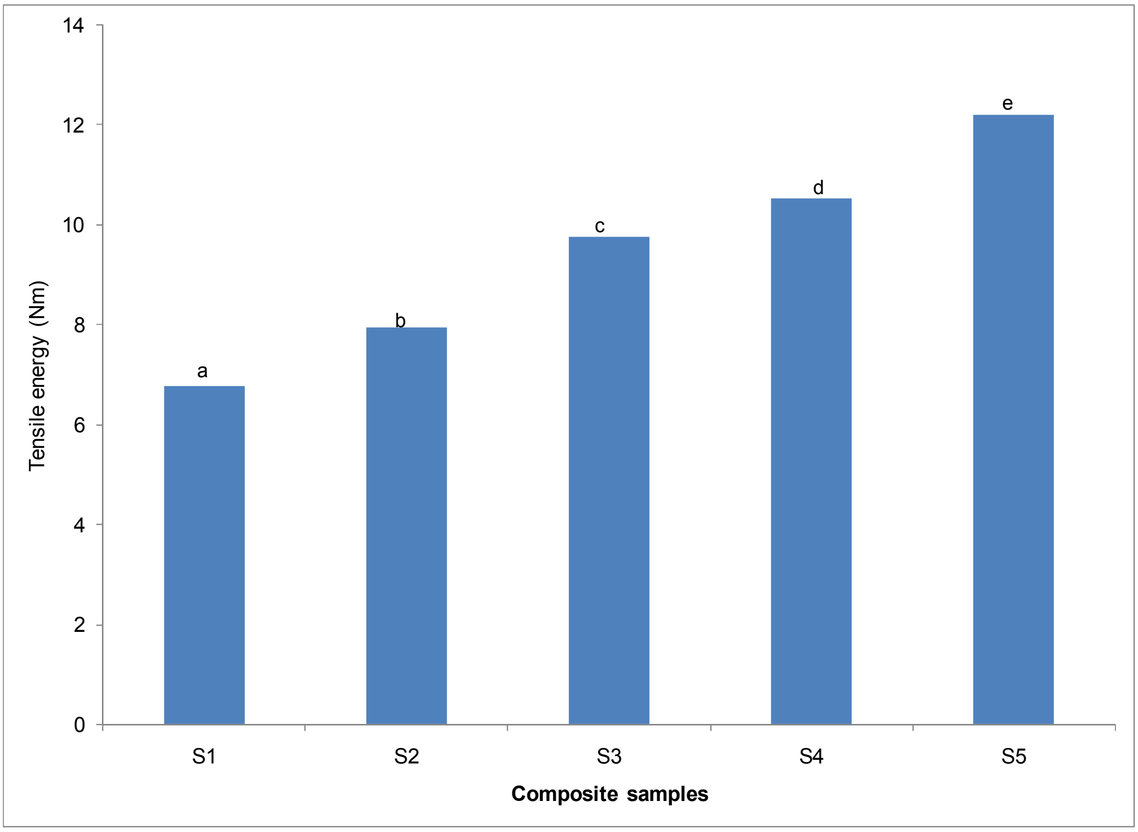
Bars with the same common letters means that they are not significant different at (P ≤0.05).

Figure 1. *Effect of fillers loading on the tensile strength of composite samples.*



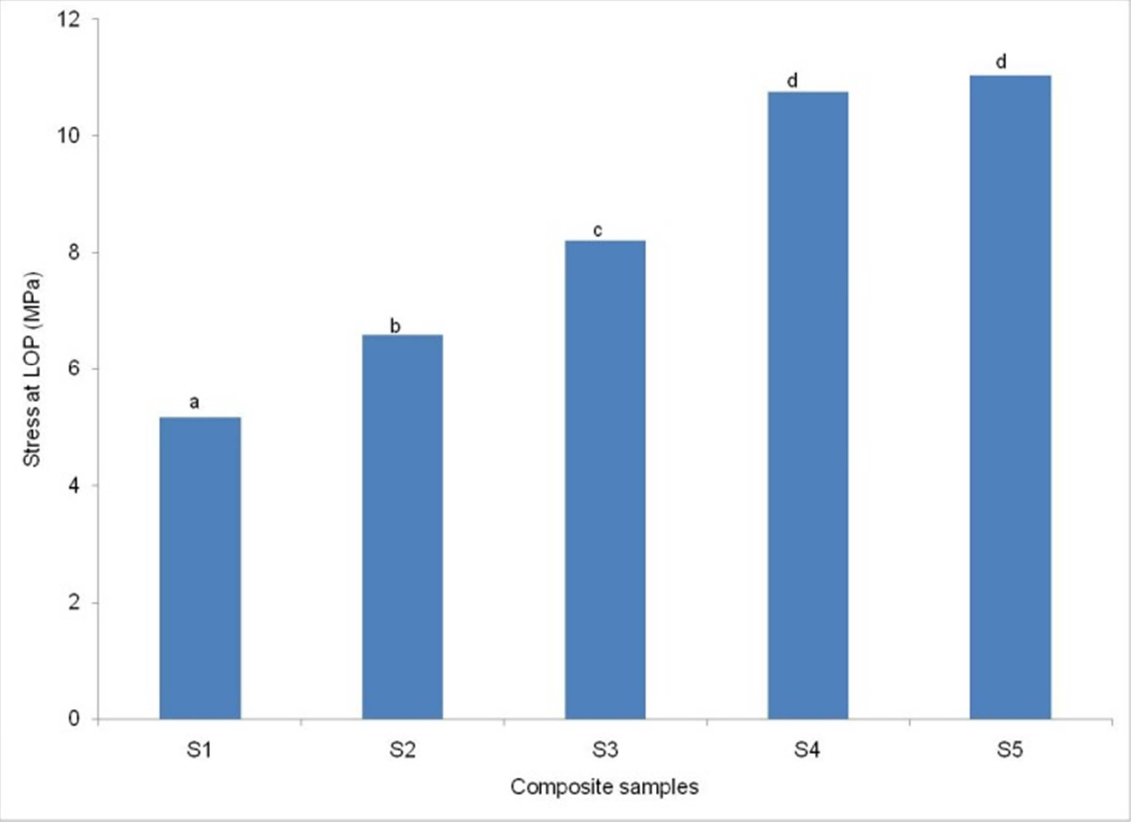
Bars with the same common letters means that they are not significant different at (P ≤0.05).

Figure 2. *Effect of fillers loading on the Young modulus of composite samples.*



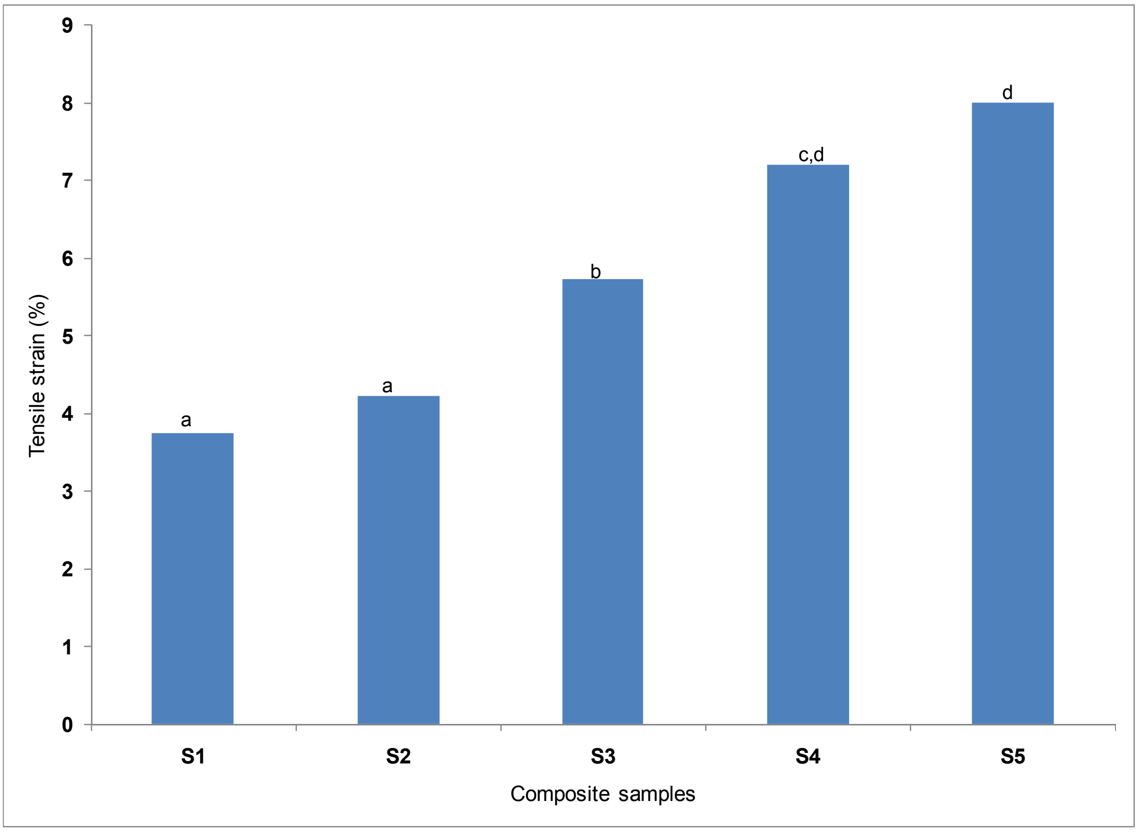
Bars with the same common letters means that they are not significant different at (P ≤0.05).

Figure 3. *Effect of fillers loading on the tensile energy of composite samples.*



Bars with the same common letters means that they are not significant different at (P ≤0.05).

Figure 4. *Effect of fillers loading on the stress at LOP of composite samples.*



Bars with the same common letters means that they are not significant different at (P ≤0.05).

Figure 5. *Effect of fillers loading on the tensile strain of composite samples.*

4. Conclusions

In this study, the tensile behaviours of OBPS and SD reinforced epoxy composite samples were investigated. The results obtained in this research also showed that fillers loading rate affects the mechanical properties of the composite materials. From the results obtained, it was found that the tensile behaviours showed an increasing trend as the fillers rate increased up 30% volume. The tensile strength showed remarkably increment with the fillers loading. Young modulus of the composite samples was increased by 45.92%, while the tensile strain was increased by 53.18%. Data gotten from this present research can be useful in the production of composite boards for engineering applications.

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