

Combined Effect of Fibre Loading and Silane Treatment on the Flexural Properties of Oil Palm Empty Fruit Bunch Reinforced Composites

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Abstract: Overtime, protection of fishing nets was sought by dipping in hot pine tar. The tars were effective because their constituents were toxic to microbial growth including the protection of fibre from moisture penetration, thereby retarding microbial growth. Probably, these stimulated the quest for surface treatment of natural fibres for composite utilization. In the current work, the use of age-long hand lay-up method was adopted in the production of oil palm empty fruit bunch reinforced polyester composites for the study of effect of fibre loading and silane treatment on the flexural properties for loss prevention and reliability in process selection for sustainable development. The result showed that flexural strength values of both green and treated fibre composites increased with increased fibre content, but started to drop after 40% loading. The effect of silane treatment as overcoming the inherent limitations of the fibres was significant. The issues of wettability preceding 40% fibre content as influencing the flexural properties was established, especially for the use of intended applications in automobile, building and packaging industries.

Keywords: oil palm, empty fruit bunch, composites, loading, treatment, flexure, strength, modulus.

1. INTRODUCTION

The increasing deterioration of world environments caused by the extensive exploration of petroleum resources, the quest for decreasing dependence on petroleum products, increasing interest in maximizing the use of renewable materials and natural resources, and the continuous expansion of synthetic product market including the encouragement in the use of cheaper and abundantly available indigenous materials has given rise to the exploration of viable alternatives in material application in engineering design.

Various kinds of materials have emerged and are being developed for use in engineering and in various aspects of the economy. The development of fibre reinforced composite-based products to substitute traditional engineering materials is becoming a trend in engineering application. Particularly attractive are the new materials in which a good part is based on natural renewable resources like those in the Palmaceae family. These renewable and biodegradable materials are in abundance in the tropics, including Nigeria and have been in use for hundreds of years for many applications such as in making ropes, beds and bags. The use of these materials as alternative fibres in composite production is becoming increasingly important because of their chemical, mechanical and environmental characteristics (Rozman et al., 2006).

Oil palm trees are found in abundance in most parts of the tropics where the extracted fruits are processed for the pharmaceutical and allied industries. The empty fruit bunch (EFB), from where the fruits are extracted is often discarded as wastes without proper utilization. However, this biodegradable material from the oil palm empty is of low-density, and a source for production of fibres for industrial cost-efficient utilization, especially for the production of low-to-medium flexural strength applications.

However, the efficiency of the natural fibre-based composites depends on the fibre-matrix interface and the ability to transfer stress from the matrix to the fibre. The main obstacles in the use of natural fibres have been the poor compatibility between the fibres and the matrix that may lead to micro-cracking of the composite and degradation of mechanical properties. Various treatments have been used to improve the matrix-fibre adhesion in natural fibre reinforced composites (Rowell et al., 1997).

Related studies on composite materials included the works of Azman et al., 2010, which inferred that oil palm fibers and commercially available polymers offer some specific properties which could be compared to conventional synthetic fiber composite materials.

Rozman et al., 2005, reported that oil palm EFB consists of a bunch of fibres in which palm fruits are embedded. The work stated that materials have been used in the production of potassium fertilizers as well as mulching even as they are of high fibre content, and that a great deal of potential is derived from using oil palm EFB as fillers in thermoplastic composites, which finds useful applications in

engineering as well as alleviating environmental problems related to the disposal of oil palm wastes and produce materials, including the offer as a favorable balance of quality, performance and cost.

Some recent studies on the effect of surface treatment and fibre loading on the mechanical properties of oil palm fibres as composites included the work of Ahmad et al, 2010, on the compressive, tensile and flexural strength properties of the concrete. The addition of 1% oil palm trunk fibre as crack arrester at low dosage improved the resistance against NaOH and NaCl attack of the composites.

Rozman et al. (2006), in their work on incorporation of oil palm EFB into the polymer matrix reported that the poor filler-matrix interaction resulted in the low flexural strength, reduced tensile strength and elongation at break of composites. Additionally the results showed that both flexural and tensile modulus of PE and PP composites improved upon the addition of fillers.

Anyakora and Abubakre (2011) reported that the composites of oil palm EFB exhibited improved impact strength properties from 10% fiber content to 60% fiber content after which problems of poor wetting set-in.

Other researchers who worked on oil palm EFB HDPE composites included Rozman et al. (2005), which reported that tensile modulus increased with filler increment, while the tensile strength decreased with filler increment. Their result indicated that the treatment of fibre did not show any significant influence on the strength of the composites, while the oil palm EFB fillers imparted greater stiffness to HDPE composites, in agreement with the other lignocellulose-filled thermoplastics.

Brydson (2001) reported that oil palm EFB fibre exhibited low elasticity and high degree of plasticity when compared to coconut empty fruit fibres.

Ramli and Suffain (2004) reported in their work that fibres of oil-palm empty-fruit bunch were highly lignified with less cellulose.

Nor et al. (2009) reported that modifying the fiber surface by using chemical treatment could enhance bond strength between fiber and matrix and thus recommended the adoption of chemical treatment as an effective way to modify the fibre surface by increasing the surface roughness. Also reported in the same work was the incorporation of oil palm EFB fibre as increasing the flexural strength and modulus of composites at smaller fibre size, including the decrease in both flexural strength and flexural modulus at higher oil palm EFB fibre size, believed to be due to poor interfacial bonding between oil palm EFB and matrix.

Razak and Kalam (2012) reported that the fractured surfaces of composites oil palm EFB using scanning electron microscope indicated that the treatment improved the interfacial bonding between fibre and matrix.

The hand lay-up process of composite fabrication is a low volume, labor intensive method suited especially for high volume and large components as needed in the automobile, building and packaging industries. Although the process is age-long for the production of low-to-medium quality products, the method of removal of entrapped air by manually squeezing the rollers to complete the laminates structure, improves the product quality, at least for the intended applications where high quality is not desirable.

The current efforts therefore, are geared towards utilizing the combined effects of fibre loading and silane treatment on the flexural properties of oil palm EFB reinforced polyester composites. Essentially, the flexure composites will be applied as valid and viable alternative to the production of various low-to-medium structural and medium quality products in the automobile, building and packaging industries. The conversion wastes as potential raw material for other industries achieved in this work, will in no small measures actualize the Goals 9 and parts of Goal 12 and 15 of Sustainable Development Goals of engaging people meaningfully to offer employment, create wealth, achieve the Circular Economy Quest, and solve environmental problems associated with improper disposal of agricultural wastes, and most importantly, ensure that these fast depleting these non-renewable resources that are gradually becoming depleted is preserved.

2. MATERIALS AND METHODS

2.1 Materials

Oil palm EFB with varying diameters of 0.45mm - 0.81mm and lengths of 12.00mm - 36.90mm were extracted from mature plants of three to five years, collected from Nigerian Institute for Oil Palm Research (NIFOR) and Umuahia Forestry Departments. These plants, with known age, were collected, with emphasis on trees that have fruited, but felled and used within two weeks. These extracts were processed at the Pulp and Paper section of Federal Institute for Industrial Research, (FIIRO) Oshodi, Lagos, Nigeria into tangled mass of varying diameters of 0.45mm - 0.81mm and lengths of 12.00mm - 36.90mm.

The Polymer used was Siropol 7440 un-saturated polyester resin purchased from Dickson Chemicals Ltd, Lagos, Nigeria with specific gravity of 1.04, viscosity of 0.24 Pa.s at 25°C. Other chemicals used were; cobalt in styrene, diglycidylethers and phenylsilane procured from Zayo - Sigma Chemicals Limited, Jos, Nigeria.

A two-part mould facility (mild steel flat 4mm thick sheet) - of 150mm x 150mm with active surfaces ground, pre-designed cavity of 5mm depth, with clamping bolts in place, fabricated at the Dantata & Sawoe Mechanical Workshop, Abuja, was adopted in the production of test specimen plates. Other equipment used were Universal Testing Machine, Instron, Model 3369, Compact Scale/Balance (Model – FEJ, Capacity – 1500g, 1500A).

2.2 Methods

2.2.1 Fibre extraction

The collected EFB of oil palm fibres were extracted by chemico-mechanical process. The process involved the impregnation of sample with ‘white liquor’ and conversion of the softened sample into fibre by mechanical action, followed by thorough washing, screening and drying. The extracted fibres were separated, re-washed and dried in the forced-air circulation type oven. The fibres were subsequently weighed and percentage yield determined.

2.2.2 Surface treatment of the extracted fibre

The process adopted in this work was the silane treatment preceded by the sodium hydroxide treatment. 10%, 20%, 30%, 40%, 50% 60% and 70% weights of extracted oil palm EFB fibres were soaked in prepared known volume of 0.5 mol/litre of NaOH for 2 hours. The products were removed and washed with distilled water before air-drying. Subsequent processes included soaking the surface-treated fibres in 2% phenylsilane solution for 24 hours. Subsequently, the product was removed, dried at 60°C and stored in specimen bag ready for use.

2.2.3 Production of test specimen

The test specimen composite panels of fibre content % by weight were produced by hand lay-up process. Curing was assisted by placing the composite in an oven operated at 110°C. The laminates were removed from the oven after 30 minutes and conditioned following the BS ISO 1268-3:2000 Instructions and Guidelines.

2.2.4 Composite characterization

Five (5) test samples each of green and surface-treated laminates were cut into the standard test dimensions by using a hacksaw. The 3-Point loading technique in compliance with BS2782 - 10, Method 1005 of 1997 for the determination of flexural properties of fibre reinforced composites was employed. The Instron Universal Testing machine of 10KN capacity was subsequently operated at a crosshead speed of 5 mm/min, until the loading blocks are brought in contact with upper surface of the beam, and load applied until the piece fractured. The span to depth ratio was maintained at 9 when determining the flexural strength of each of the specimens of green and treated-fibre composites. The load at fracture and other measurements were recorded and used for the evaluation of flexural strength.

3. RESULTS & DISCUSSION

3.1 The flexural strength of oil palm EFB fibre reinforced polyester composite

Figure 1 shows the effect of fibre content and silane treatment on the flexural strength oil palm EFB fibre reinforced polyester composite. It was evident from figure 1 that the flexural strength of oil palm empty fruit bunch fibre polyester composite increased with increased fibre loadings, even as the fibre treatment showed significant influence on the flexural strength properties of the composites. These results were corroborated in some other findings (Razak and Kalam, 2012), that the increase of oil palm EFB fibre size resulted in increased flexural strength, and modulus at smaller oil palm EFB fibre size.

A decrease of both flexural strength and flexural modulus was observed at higher fibre loading, which was believed to be due to the poor interfacial bonding between oil palm EFB and matrix. The result in this study does not corroborate the second part of finding above, because the no decrease in flexural strength was observed at increased fibre loading. This suggests that the composite production method adopted may have considerable influence on the results, thus use of appropriate production method is necessary for the production of standardized products for a particular application.

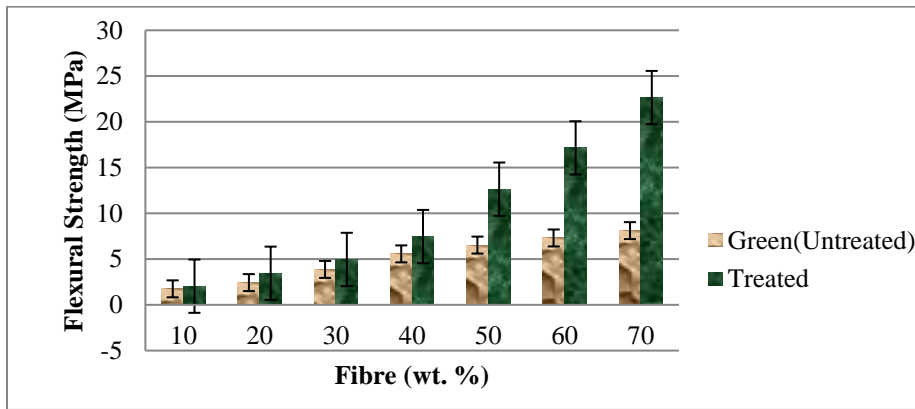


Figure 1: Effect of fibre content and silane treatment on the flexural strength of oil palm EFB fibre reinforced polyester composite.

3.2 The flexural modulus of oil palm EFB fibre reinforced polyester composite

Figure 2 shows the effect of fibre content and silane treatment on the flexural modulus of oil palm EFB fibre reinforced polyester composite. As observed in figure 2, fibre content and surface treatment had significant influence on the flexural modulus of oil palm EFB composites from 10% to 40% fibre loading. The values started dropping beyond 40% fibre loading. These results corroborated part of other findings (Razak and Kalam, 2012), who noted that a decrease of both flexural strength and flexural modulus was observed at higher oil palm EFB fibre size, which was believed to be due to the poor interfacial bonding between oil palm EFB and matrix.

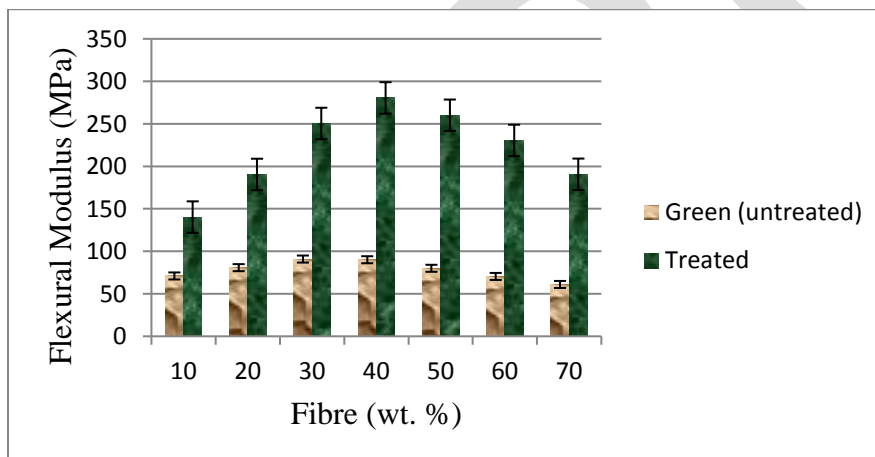


Figure 2: Effect of fibre content and silane treatment on the flexural modulus of oil palm EFB fibre reinforced polyester composite.

4. CONCLUSION

Based on the results from this work, the following deductions were made; (a) the flexural strength of oil palm EFB fibre reinforced with polyester matrix increased with increased fibre loadings. The silane treatment of fibres showed significant influence on the flexural strength of the composites at higher fibre loadings, (b) the flexural modulus of oil palm EFB reinforced with polyester matrix was significantly influenced upon on fibre loading and silane treatment at loadings of 40% and below. (c) Surprisingly, there was a sudden drop in flexural modulus values beyond 40% fibre loading, which may be due to a combination of unstable morphology of the fibre, that is common to most natural plant materials, and the composite production method adopted in the work. Thus, the use of silane treated oil palm EFB fibre reinforced polyester composites can offer suitable and viable alternative for applications in the automobile, building and packaging industries, which is in line with the “closing the loop” quest of the Circular Economy of utilizing ones waste as raw material for another.

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