ScienceVolks Open Access

SVOA MATERIALS SCIENCE & TECHNOLOGY

(ISSN: 2634-5331)

Research Article

https://sciencevolks.com/materials-science/

Volume 2 Issue 1

Influence of Bamboo Stem Ash on Some Properties of Polyester Matrix

Daramola O O[1], Ogunronbi M O[1],Ojo A S[2],Abere D V[1]*,Uzuh F D[1], Goyol C. G [1], Abubakar UBS[1], Oluwagbemi T S[1], S.J. Danbauchi[1]

[1]*National Metallurgical Development Centre, Jos Nigeria*

[2]*Mechanical Engineering Department, University of Akron, USA*

***Corresponding Author:** Abere D V*, *National Metallurgical Development Centre, Jos Nigeria.*

***Accepted:** January 24,2020* ***Published:** March 05, 2020*

Abstract:

This work investigated the influence of bamboo stem ash reinforcement on some properties of polyester matrix composites. Open mold technique was used for production of the polyester composites of 2, 4, 6, and 8wt % reinforcement. The density of the unreinforced polyester obtained is 1.190 g/cm^3 while the values obtained from the composites are 1.194, 1.191, 1.185 and 1.182 g/cm^3. The bamboo stem ash has no significant effect on the density of the polyester (matrix) since they have nearly the same density. The percentage porosity of the unreinforced polyester is 0.84 but the percentage porosity of the composites is 0.17, 0.084, 0.17 and 0.25 %. The influence of the bamboo stem ash on the polyester reduces the porosity of the composites. The polyester matrix composites produced exhibit the same stress-strain deformation behavior as the unreinforced polyester irrespective of the reinforcement weight percent. The average tensile strength of the unreinforced polyester (B0) is 12, while that of the composites being 17.8, 16, 15.7 and 14 MPa. The composition 2% RHA gave the optimum tensile strength. The result obtained reveals that the more the reinforcement the lower the tensile strength of the composite. Likewise, the fracture toughness of the unreinforced polyester is 0.032 MPam$^{1/2}$, the values of the fracture toughness of the composites is 0.058, 0.045, 0.04, and 0.042 MPam$^{1/2}$. The optimum value of the fracture toughness obtained is also at 2 wt% reinforcement of bamboo stem ash. As the reinforcement increases, the fracture toughness decreases. The strain energy of the unreinforced polyester is 0.45 J whereas the values obtained for the composites are 0.45, 1.5, 1.0, 0.7 and 0.63 J. The highest energy that can be stored prior to deformation was obtained at the sample BS1. The strain energy decreases with increase in the reinforcement. The flexural strength of the unreinforced polyester is 27.0 MPa but the flexural strength of the composites produced is 28.2, 29.3, 29.5 and 29.3 MPa. The optimum flexural strength was attained at 29.5 MPa by sample with the composition 6 wt% bamboo stem ash (BS3). The flexural strength also increases with increase in weight percent of the bamboo stem ash in the composites. The bending strength of the unreinforced polyester is 3010.40 MPa whereas the bending strength of the composites formed is 3491.9, 4381.3, 5945.7 and 6862.4 MPa. The bending strength of the composites increases with increase in bamboo stem ash. The water absorption by the composites increases with immersion time.

Keywords: reinforcement, composites, polyester, matrix, deformation, porosity, fracture toughness

1.0 Introduction

Composite materials with polymer matrices are competing favorably with metal based materials for a good number of industrial applications and in a number of cases have exhibited higher level of competence (Oladele et al., 2010).This is due to property advantages of polymer matrix composites (PMCs) such as versatile processing and fabrication routes, low processing cost, good wettability between the polymer matrices and the reinforcing materials, good rang of mechanical properties among others (Ishaket al., 2009 and Dhakalet al., 2007). PMC's are classified according to whether the matrix is a thermoset or thermoplastic. Thermoplastic matrix composites are by tradition far more common, but thermoset matrix composites are under rapid development. Before the last four decades, it was rather difficult to conceive the idea of designing high performance materials which were not metallic based. Today technology has advanced in materials science and technology, ceramics and polymer based materials for structural and other high performance applications are now available (Goodman, 1998, Pradhan et al., 2004 and Pino et al., 2006). In existence are enormous corpus literatures on natural fibre and filler reinforced PMCs which have been applied in designing components and parts such as door panels, seat backs, headliners, dashboards, interior parts, package trays, furniture, packaging, building and constructions and, even military vehicles and aircraft spare parts among others (Singh et al., 2012 and Idicula et al, 2005). For these applications, polyester based composites are notably one of the most utilized PMCs.

Polyester is a prominent thermosetting polymer which has been used widely for the development of polymer based composites. Its attraction is mainly due to its low cost in comparison with other notable thermosetting polymer matrix materials like epoxy, gross cross linking tendency, excellent process-ability, its good wetting characteristics, and average mechanical properties when cured (Pothanet al., 2007).

There has been a general drive towards the reduction of the cost of producing PMCs while at the same time improving the mechanical and physical properties (Habibi et al., 2008). This has given impetus to research targeted towards the use of agro based waste materials such as natural fibres and ashes processed from controlled burning of plant leaves and stems as reinforcements. The advantages of the agro wastes (natural fibres and fillers) are availability in large quantities, low cost of processing, low density, acceptable specific strength, good thermal insulation properties, reduced health threats such as dermal and respiratory irritation common with the use of synthetic reinforcing materials, renewability and ease of recycling, and creation of a more eco-friendly environment (Jacobson et al., 2001). One of the most abundant agro resources in Nigeria is the bamboo tree. However, there is currently limited literature on the use of bamboo stem ash as reinforcement in PMCs. The motivation for choosing to incorporate bamboo stem ash (BSA) reinforcement into polyester is to ascertain the viability of developing polyester matrix composites with improved mechanical and water absorption properties. This study therefore investigated the influence of bamboo stem ash on the polyester matrix composites.

2. Materials and Methods

2.1 Materials

The materials utilized in this research include: Unsaturated Polyester (UP) resin as matrix, Methyl Ethyl Ketone Peroxide (MEKP) and Cobalt Naphthanate which were used as precursor and catalyst respectively. The bamboo stem was obtained from the premises of the Federal University of Technology Akure, Ondo State, Nigeria. The apparatus and equipment used are: Instron Universal Testing Machine, Octagon Digital Sieve Shaker, Weighing Balance, Aluminium Molds, Beakers, Stirring Rod and Latex Hand Glove.

2.2 Methods

2.2.1 Filler Preparation

The reinforcing filler was produced by burning some bamboo stem using a metallic drum which served as burner. The dried bamboo stem was ignited using charcoal and allowed to burn completely inside the drum. The ash obtained from the process was calcined in a furnace at a temperature of 6500C for 4 hours to reduce the volatile and carbonaceous constituents of the ash before subjecting it to sieve size analysis using a digital sieve shaker. Particle sizes of 75µm were utilized as the reinforcing filler.

2.2.2Composite Fabrication

Open molding method was used to prepare the bamboo stem ash reinforced polyester composites. The process started with the determination of the quantities of bamboo stem ash required to produce 2, 4, 6 and 8wt% reinforcements. The determined quantities of the polyester resin, bamboo stem ash particles were measured on an electronic weighing balance. The polyester was poured into a beaker; 2% of Cobalt Naphthanate (catalyst) and 1% of Methy Ethyl Ketone Peroxide (MEKP) (accelerator) were added and stirred with a magnetic stirrer to achieve homogenization. Thereafter, the reinforcing phase (bamboo stem ash) was added and stirred for few minutes until an even dispersion was achieved. The mixture was then cast into already prepared aluminum molds which were pre-coated with polyvinyl alcohol (PVA) for easy removal of the cast samples from the molds. The mixture was left for about one and half hours in the mold to cure before they were removed. This procedure was repeated for all samples prepared.

2.2.3 Density Measurement

The experimental density of each grade of composite produced was determined by dividing the measured weight of a test sample by its measured volume; while the theoretical density was evaluated by using the formula:

$$\rho_{polyester/BSA} = (wt_{fpolyester} \times \rho_{polyester}) + (wt_{f\cdot BSA} x \rho_{BSA})$$

Where: $\rho_{polyester/BSA}$ = density of composite

$wt_{fpolyester}$ = weight fraction of Polyester

$\rho_{polyester}$ = density of polyester

$wt_{f\cdot BSA}$ = weight fraction of Bamboo stem ash

ρ_{BSA} = density of Bamboo stem ash

The experimental densities for each composition of the polyester matrix composites produced were compared with their respective theoretical densities, and it served as basis for evaluation of the percentage porosity of the composites using the relations (Alaneme and Adewale, 2013):

$$\% \text{ porosity} = \{(\rho_T - \rho_{EX}) \div \rho_T\} \times 100\%$$

Where: ρ_T= Theoretical Density (g/cm^3)

P_{EX} = Experimental Density (g/cm^3)

2.2.4 Mechanical Characterization

The mechanical attributes of the composites determined are as followed:

Tensile Test

The tensile test was carried out in accordance with ASTM D3038M-08 (American Society of Testing and Materials, 2008). The test was performed at room temperature using an Instron universal testing machine operated at a strain rate of $10^{-3}/_{s.}$ Five samples of each composition were prepared and the average values were taken and the stress – strain curve was plotted.

Flexural Test

The flexural strength of the composites was evaluated by performing flexural three-point bending tests on the composites. The test was performed at room temperature using a tensiometric universal testing machine operated at a crosshead speed of 0.3mm/min. The testing procedure and flexural strength determination were performed in accordance with ASTM D7264M -07 standard (American Society of Testing Materials, 2007). The values obtained were then plotted.

2.2.5Water Absorption Test

Water absorption tests were carried out according to ASTM D5229M-12 (American Society of Testing and Materials, 2012). Five samples of each composite grade were oven dried and weighed. The average weight of each composition was recorded as initial weight of the composites. The samples were placed in distill water which was maintained at room temperature at 24 hours interval. The samples were removed from the water, cleaned and weighed. The weight of the samples was weighed periodically at 24 hours interval. The average weights obtained were plotted against time.

3.0 Results and Discussion

The results obtained in this work are presented as follow: table 1 presents the density and percentage porosity of the composites. The stress-strain curve for the polyester composite is presented in figure 1 while figure 2 presents the ideal stress-strain deformation schematic model for the Polyester matrix composites. Figure 3 shows the variation of ultimate tensile strength of the bamboo stem ash reinforced composite whereas figure 4 represents the fracture toughness of the composites. The strain energy of the composites is presented in figure 5. Figure 6 presents the flexural strength of the composite. Figure 7 presents the bending strength of the composite while the Water absorption curve for the composites formed is indicated in figure 8.

Sample Designation	Composition of RHA (wt%)	Theoretical Density (g/cm^3)	Experimental Density (g/cm^3)	% Porosity
B0	0	1.2	1.190	0.84
BS1	2	1.196	1.194	0.17
BS2	4	1.192	1.191	0.084
BS3	6	1.187	1.185	0.17
BS4	8	1.185	1.182	0.25

Table 1: Density and percentage porosity of the Composites Produced

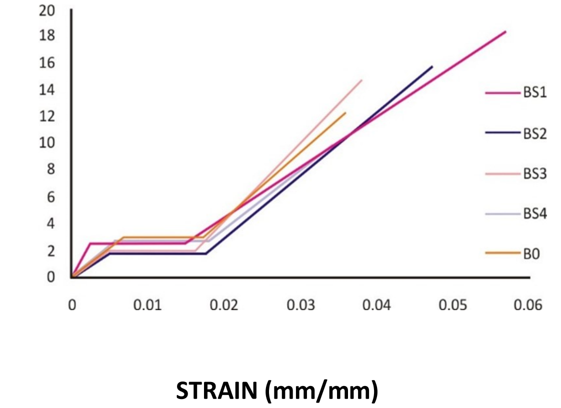

Figure 1: Stress-Strain curves for the polyester composite reinforce with bamboo stem ash

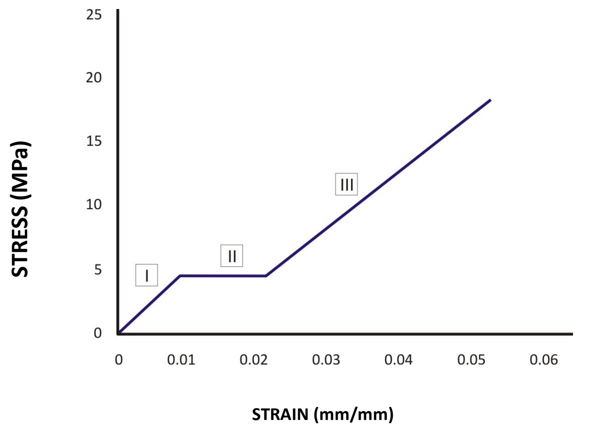

Figure 2: Idealized Stress-Strain deformation schematic model for the Polyester matrix composites produced showing the three deformation stages

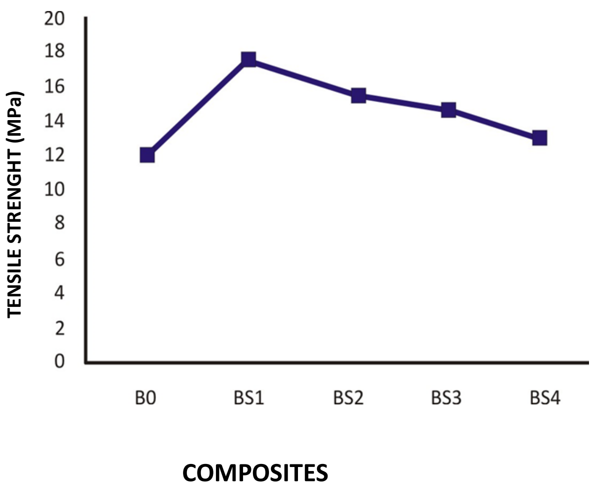

Figure 3: Tensile strength of the composite

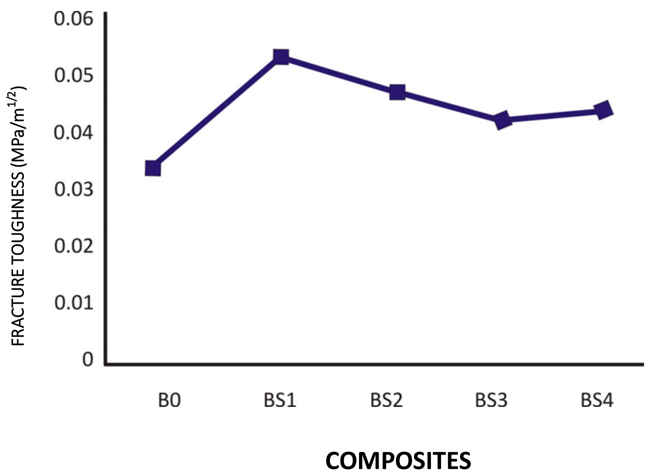

Figure 4: Fracture toughness of the composites

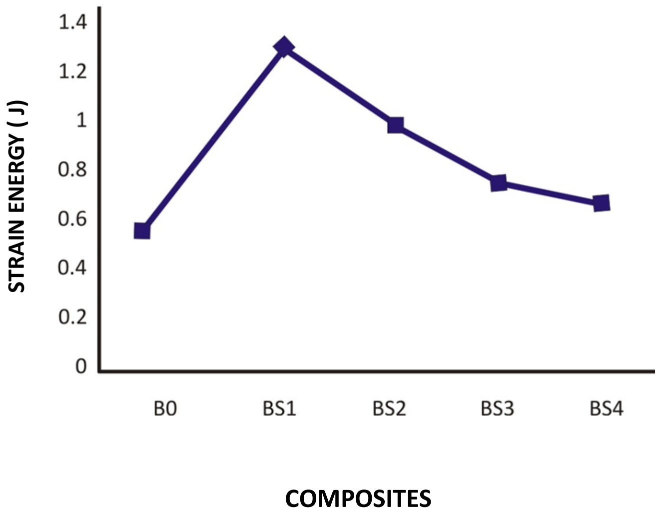

Figure 5: Strain energy of the composites

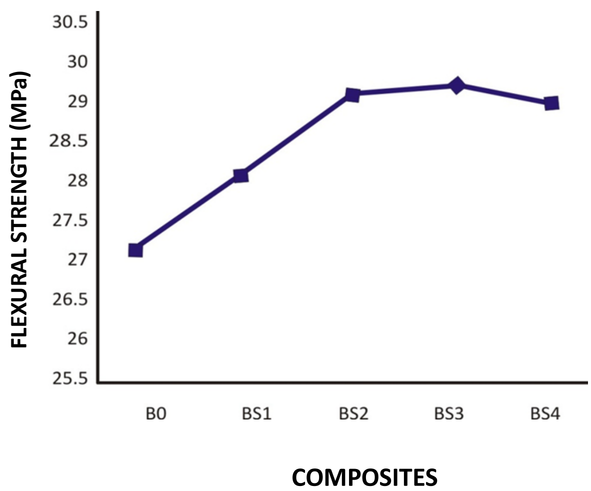

Figure 6: Flexural strength of the composite

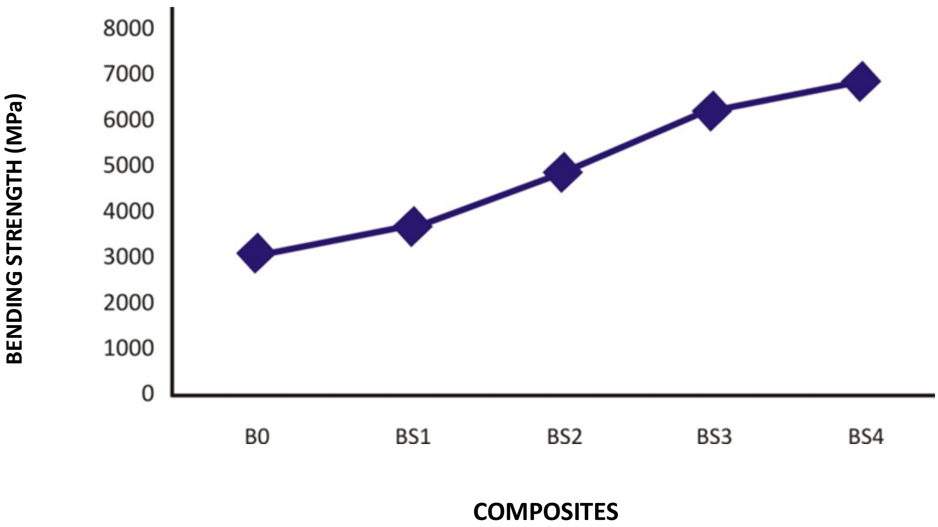

Figure 7: Bending strength of the composite

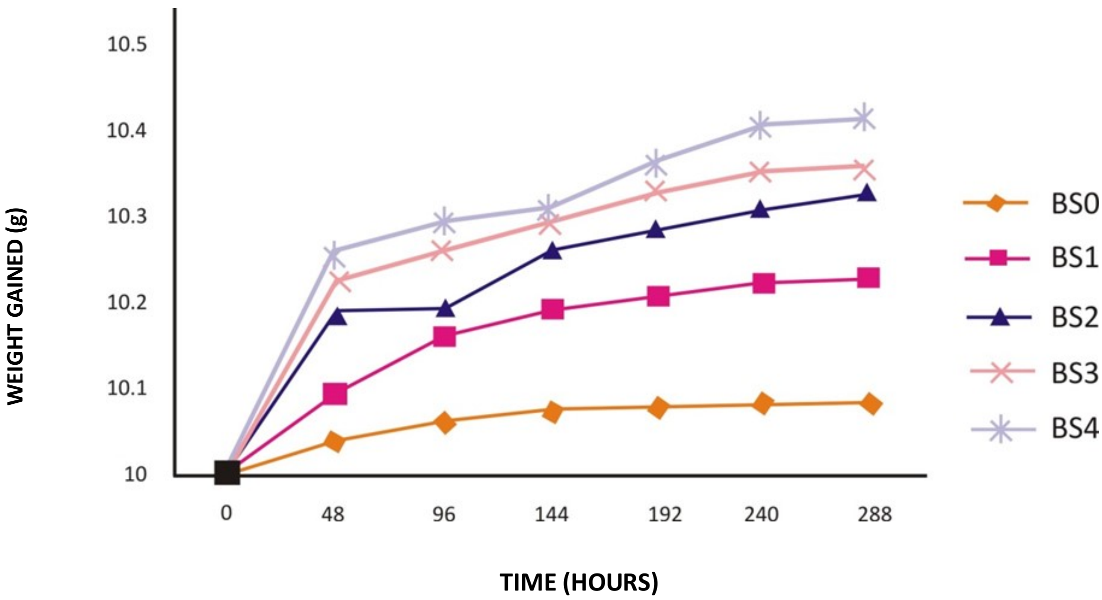

Figure 8: Water absorption curve for composites produced

3.1 Density and Percentage Porosity

From table 1, the density of the unreinforced polyester (B0) obtained is 1.190 g/cm^3. The density of the composites BS1, BS2, BS3 and BS4 are respectively 1.194, 1.191, 1.185 and 1.182 g/cm^3. It can be observed that the density of the unreinforced polyester matrix and that of the composites produced are approximately equal i.e. the bamboo stem ash has no significant effect on the polyester (matrix). However, the percentage porosity obtained from B0, BS1, BS2, BS3 and BS4 are 0.84, 0.17, 0.084, 0.17 and 0.25 % accordingly. The percentage porosity of the unreinforced polyester is higher than that of the composites formed. The influence of the bamboo stem ash on the polyester reduces the porosity of the composites. Also, the level of the porosity in the composites is less than 0.5 % which indicates that the open mold fabrication method adopted for the production of the composites is reliable (Singh et al., 2012).

3.2 Stress strain deformation

From the stress-strain deformation curves of the composites produced as presented in Figure 1, it can be observed that the rate of deformation of the composites increases in three well defined deformation stages which can be confirmed in Figure 2. Hence, the mechanism of deformation of the polyester matrix is very vital in explaining the deformation attributes of the composites.

Stage I is characterized by linear elastic deformation in which the stress acting on the composites increases linearly with strain while stage II is characterized by visco-elastic deformation where plastic strain increases at a constant plastic (yield) stress; and stage III is characterized by work hardening as the stress increases significantly with further increase in plastic strain (Alaneme and Adewale, 2013). The deformation mechanism in stage I can be attributed to the little resistance posed by the composites to the stretching of the atomic bonds in polyester matrix which is a thermosetting polymer. At this stage, elastic deformation is influenced by the stretching of the polyester chains, a process which is reversible once the applied stress is removed (Alaneme and Adewale, 2013). For stage II deformation, the constant yield stress accompanying the increasing plastic strain of the composites may be due to the unwinding of the cross linked bonds in thermosetting polymers. This process can thus be sustained at low stress level without accompanying increase in stress. Whereas, the nature in stage III is due to the combine effect of the motion of polyester chains which act on each other and the strengthening due to the presence of the reinforcement. The strength of the reinforcement contributes greatly to the higher stress level the polyester matrix can withstand prior to fracture (Alaneme and Adewale, 2013).

3.3 Tensile Properties

The average tensile strength obtained according to figure 3 is 12, 17.8, 16, 15.7 and 14 MPa respectively for BO, BS1, BS2, BS3, and BS4. The tensile strength of the polyester reinforced with bamboo stem ash is higher than that of the unreinforced polyester. The optimum tensile strength is obtained from the composite with the composition 2% RHA i.e. BS1; and this might be attributed to the high forces of attraction between the matrix and reinforcement which allows strength to be transferred from the reinforcement to the matrix thereby improving the strength of the composite (Abdalla et al., 2010). Also, the higher the reinforcement the lower the tensile strength of the composite.

From figure 4, the values of the fracture obtained are 0.032, 0.058, 0.045, 0.04, and 0.042 MPam1/2 for B0, BS1, BS2, BS3 and BS4 respectively. The fracture toughness of the composite formed is also higher than the unreinforced polyester matrix. The highest value of the fracture toughness obtained is also at 2 wt% reinforcement of bamboo stem ash (BS1). As the reinforcement increases, the fracture toughness decreases. It can also be observed that the fracture toughness of the composite decreases after attaining the optimum level and this might be due to decrease in the forces attraction between the matrix and reinforcement (American Society of Testing and Materials, 2008). The strain energy values obtained according to figure 5 are 0.45, 1.5, 1.0, 0.7 and 0.63 J for BS0, BS1, BS2, BS3, and BS4 respectively. It can be observed that the highest energy that can be stored prior to deformation can be obtained at the BS1 since it has the optimum strain energy. The strain energy decreases with increase in the reinforcement and hence decreases in the energy that can be stored in the composite before deformation. The strain energy absorbed is a measure of the amount of energy absorbed per unit volume at fracture (Osman et al., 2012). It provides a good measure of the ductility as well as the toughness of a material. Thus it could be said that sample BS1 has the best combination of strength, toughness, and ductility of all the composites produced.

3.4 Flexural Strength

The result of the flexural strength indicated in figure 6 shows that B0, BS1, BS2, BS3 and BS4 has respective flexural strength 27.0, 28.2, 29.3, 29.5 and 29.3 MPa. The composition with 6 wt% bamboo stem ash (BS3) has the optimum flexural strength. It is observed that the flexural strength which is a measure of a materials resistance to deformation under load is higher for the composite grades containing bamboo stem ash. It is also observed that the flexural strength increases with the increase in weight percent of the bamboo stem ash in the composites (Osman et al., 2012; Najafi and Kordkheili, 2011). The bending strength obtained in figure 7 shows that B0, BS1, BS2, BS3 and BS4 has 3010.40, 3491.9, 4381.3, 5945.7 and 6862.4 MPa respectively. It can be observed that the bending strength of the composites increases with increase in BSA content. It can as well be observed from figure 7 that sample BS4 with 8wt% of bamboo stem ash has the optimum bending strength of 6862.4 MPa. Also, the addition of bamboo ash improves the bending strength of the composites formed when compared to the unreinforced polyester material which has a value of 3010.40 MPa.

3.5 Water Absorption

From figure 8, it can be observed that the water absorption by the composites increases with immersion time whereas the rate of absorption decreases with increase in time. The water absorption attains equilibrium after 240 hours which implies that at equilibrium, the composites attain saturation point as far as water absorption in concerned (Pradeep and Rakesh, 2010).

Conclusion

The effect of bamboo stem ash reinforcement was examined on some properties of polyester matrix composites. The bamboo stem ash has no significant effect on the density of the polyester (matrix). The influence of the bamboo stem ash on the polyester reduces the porosity of the composites. The composition 2% RHA gave the optimum tensile strength. Increase in the reinforcement result in decrease in tensile strength of the composite. The optimum value of the fracture toughness obtained is also at 2 wt% reinforcement of bamboo stem ash. As the reinforcement increases, the fracture toughness decreases. The highest energy that can be stored prior to deformation was obtained at 2 wt% reinforcement of bamboo stem ash. The strain energy decreases with increase in the reinforcement. The optimum flexural strength was attained at 29.5 MPa by sample with the composition 6 wt% bamboo ash. The flexural strength also increases with increase in weight percent of the bamboo stem ash in the composites. The bending strength of the composites increases with increase in bamboo stem ash. The water absorption by the composites increases with immersion time.

References

1. Abdalla, A.A.R., Mohd, S.S., Khalina. A., Megat, M. &Hamdan, M.P. (2010). Water Absorption Behaviour of Kenaf Reinforced Unsaturated Polyester Composites and Its Influence on their Mechanical Properties. Journal of Science and Technology; 18 (2), pp 433 – 440.
2. Alaneme, K. K. &Adewale, T. M. (2013). Influence of Rice husk Ash/Silicon Carbide Weight Ratios on the Mechanical Behaviour of Aluminium Matrix Hybrid Composites. Tribology in Industry; 35(2), pp. 163 – 172.
3. American Society of Testing and Materials (2007). Standard Test Method for Flexural Property of Polymer Matrix Composite Materials 2007, Philadephia, USA. ASTM D7264M-07.
4. American Society of Testing and Materials (2008). Standard Test Method for Tensile Property of Polymer Matrix Composite Materials 2008, Philadelphia, USA. ASTM D3039M-08.
5. American Society of Testing and Materials (2012). Standard Test Method for Moisture Absorption Property and Equilibrium Condition for Polymer Matrix Composite Materials. ASTM 2012, ASTM D5229M-12.
6. Attama, A. A. & Esinmore C. O.(2009). Polymer Applications. Publishedby Jolyn Publishers Nsukka. Pp 1, 7-8.
7. Bismarck, A., Askargorta, I. A., Springer, J., Lampke, T., Wielage, B., &Stamboulis, A. (2002). Surface Characterization of Flax, Hemp and Cellulose Fibres; Surface Properties and the Water Uptake Behaviour. Polymer Composite; 23, 872 – 94
8. Budinski, K. G. &Budinski, M. K (2008). Engineering Materials Properties and Selection. Eight Edition. Published by Prentice-Hall of India Private Limited, New Delhi. Pp 12, 17.
9. Chinomso, M., Ewulonu, & Isaac, O. I (2012). Properties of Oil Palm Empty Fruit Bunch Fibre Filled High Density Polyethylene. Int. Journal of Engineering and Technology; 3 (6), pp 458 -471.
10. Chun, K. S., Husseinsyah, S. &Azizi, F. N. (2011). Characterization and Properties of Recycled Polypropylene/Coconut Shell Powder Composite: Effect of Sodium Dodecyl Sulphate Modification, Polymer-Plastic Technology and Engineering. 52 (3), pp. 287 – 294.
11. El-Tayeb, N.S.M (2009). Development and Characterization of Low-cost Polymeric Composite Materials. Journal of Materials and Design (30) 1151.
12. Kord, B. &Kiaeifar, A. (2010). Hygroscopic Thickness Swelling Rate of Wood Polymer Nanocomposite. Reinforced Plastic Composite; 29(23), pp. 3480 - 3485.
13. Munday, D. L. & Cox, P. L. (2002). Compressed Xanthan and Karaya Gum Matrices: Hydration, Erosion and Drug Release Mechanisms. International Journal of Pharmacy, 2002; 203, 179-192.
14. Najafi, S. K. &Kordkheili, H. Y. (2011). Effect of Sea Water on Water Absorption and Flexural Properties of Wood-Polyproplene Composites. European Journal for Wood Production; 69, pp. 553 – 556.
15. Oladele, I. O., Akinwekomi, A.D., Aribo, S. &Aladenika, A.K. (2010). Development of Fibre Reinforced Cementious Composite for Ceiling Application. Journal of Minerals & Materials Characterization & Engineering; 8(8), pp. 591-598.
16. Osman, E. A., Vakhguelt, A., Sbarski, I. &Mutasher, S. A. (2012). Kenaf/Recycled Jute Natural Fibres Unsaturated Polyester Composites: Water Absorption/Dimensional Stability and Mechanical Properties. Int. Journal of Computational Materials and Engineering; 1(1), pp. 1-17.
17. Pradeep, K. K. & Rakesh, K. (2010). Studies on Water Absorption of Bamboo-Polyester Composites: Effect of Silane Treatment of Mercerized Bamboo. Polymer-Plastics Technology and Engineering; 49; pp. 45-52.

18. Singh, V. K, Gope, P. C., Chauhan, S. &Bisht, D. S. (2012). Mechanical Behaviour of Banana Fiber Based Hybrid Bio Composites. Journal for Materials Environmental Science; 3 (1): pp. 185 – 194.

19. Singh, V. K. &Gope P. C. (2010). Silica-Styrene-Butadiene Rubber Filled Hybrid Composites: Experimental Characterization and Modeling, Journal of Reinforced Plastics and Composites; 29(16), pp. 2450 – 2468.

Citation: Abere D V*, Daramola O O, Ogunronbi M O, Ojo A S, Uzuh F D, Goyol C. G, Abubakar UBS, Oluwagbemi T S, S.J. Danbauchi. et al. **"Influence of Bamboo Stem Ash on Some Properties of Polyester Matrix "** SVOA Materials Science and Technology 2:1 (2020) 01-08.