Epoxy/Banana Fibre Composites Characterization for their Mechanical Behaviour

Gyanendr Kumar Kushwaha[1], Satish Shejkar[2]

Department of Mechanical Engineering, Sagar Institute of Research and Technology-Excellence, Bhopal-462041, Madhya Pradesh, India

Abstract

The present work comprises of fabrication of epoxy-based composites with banana fibre as a reinforcement. The effect of fibre loading and surface modification of banana fibre were discussed in detail. In this work, mainly mechanical properties are discussed. The properties investigated are tensile strength, flexural strength, compressive strength and impact energy. From the investigation, it was observed that the various mechanical properties under investigation increases with fibre loading as a linear function. It is further observed from the experimental investigation that the composites prepared with sodium hydroxide treated banana fibre delivers superior properties as compared to their counterpart. The said trend is obtained because of the improved compatibility between the two phases.

Keywords: *Polymer, natural fibre, NaOH treatment, Mechanical properties.*

Introduction

Natural fibres recently attracted the attention of scientists and technologists because of the advantages that these fibres provide over conventional reinforcement materials, and the development of natural fibre composites has been a subject of interest for the past few years. These natural fibres are low-cost fibres with low density and high specific properties. These are biodegradable and non-abrasive, unlike other reinforcing fibres. Also, they are readily available and their specific properties are comparable to those of other fibres used. It has been believed that natural fibre-reinforced polymer composites can replace glass fibre-reinforced polymer composites in various light-duty structural applications. Among the various natural fibres, Banana fibre is one of them obtained from the pseudo-steam of banana plants. Apart from various natural fibres, it has been seen that banana fibre has good specific strength properties comparable to synthetic fibre i.e. glass fibre. This is the main reason banana fibre was investigated by many researchers in past.

Raghvendra et al. [1] used banana fibre with rubber and established natural rubber-based composites. They studied the mechanical properties of the fabricated composites. Venkateshwaran et al. [2] found that fibre length and its content were the most influential factor which determines the mechanical properties of the composites. Ramesh et al. [3] also fabricated banana fibre-reinforced polymer composites with thermoset polymer epoxy and experimentally determined its mechanical properties. In their analysis, they reported that the inclusion of banana fibre in the epoxy resin improves the properties of the composites. Jorden et al. [4] improve the interfacial bonding between banana fibre and LDPE matrix with the help of chemical treatment.

Muktha and Gowda [5] focused their work on the water absorption and fire resistance behaviour of banana fibre-reinforced polyester composites. Komal et al. [6] studied the effect of surface modification of banana fibre on the mechanical properties of polypropylene-based composites. They also investigated the thermal properties of the composites prepared with untreated and treated fibres. Pham et al. [7] study the effect of processing parameters of the acrylonitrile butadiene styrene-reinforced banana fibre composites. Mohan and Kanny [8] studied the mechanical characteristics of unmodified and nano-clay-treated banana fibre-reinforced epoxy composite cylinders. Eze et al. [9] studied the effect of various surface treatments on the banana fibre on the mechanical properties of polyester-based composites. From the analysis, they concluded that acetic acid and sodium sulphite are good surface treatment reagents but less effective than 3-aminopropyltriethoxysilane silane solution for the improvement of the tensile properties of banana pseudo-stem fibre-reinforced polyester composites for different industrial applications. Balaji et al. [10] studied the mechanical and thermal properties of epoxy composites reinforced with short banana fibres. From the experimentation, they reported that the various mechanical properties like tensile strength, flexural strength and impact strength increase with fibre loading and show maximum strength values at 15 wt. % of the fibre and decrease thereafter. Subramanya et al. [11] prepared samples using alkali-treated and untreated banana fibres. The effects of alkali-treated fibres were studied. Nguyen et al. [12] studied the mechanical and thermal behaviour of epoxy composites reinforced with banana fibre. In very recent work, Aseer et al. [13] studied the water absorption rate and the tensile properties of polyester/banana fibre composites. Dilipkumar et al. [14] created epoxy/banana fibre composites and examined how fibre content and length impacted the mechanical and acoustic properties of the samples.

Material considered

Epoxy is taken as the matrix material in the present investigation. It is used with its corresponding hardener. Banana fibre in the form of short fibre is used as a reinforcement. Sodium hydroxide with distilled water is used to modify the banana fibre The aqueous solution of sodium hydroxide is prepared to make it with 2 moles of concentration. The fibres are placed in the solution for a specified duration of time for proper treatment of the fibre.

Composite Fabrication

The two categories of composites are prepared with a simple hand lay-up method. The fibre loading varies from 5 wt. % to 20 wt. % in the prepared samples. In total four sets are prepared in each category. Hence, eight samples are where the tests are performed. The samples are prepared as per ASTM standards in their respective moulds. For conducting each test, three samples are prepared and the average value is presented.

Experimental details

The tensile strength of the composites is measured with a computerized Instron 1195 universal testing machine by the ASTM D638 procedure by applying uni-axial load through both ends. Static uniaxial compression tests on specimens are carried out using the same computerized universal testing machine. The method by which the compression test is conducted is ASTM D695. The three-point bend test was carried out by ASTM D790 to measure the flexural strength of the composites. Impact tests were performed to understand the toughness of the material. During the test, specimens were subjected to a large amount of force for a very short interval of time. The tests are performed as per ASTM D256 standard.

Results and Discussion

The tensile strength of all the fabricated samples of categories I and II are measured by a universal testing machine and is shown in Figure 1. From the figure, it is observed that the tensile strength of the composite increases with an increase in fibre content. The tensile strength of neat epoxy is measured to be 30.5 MPa. With the inclusion of 20 wt. % raw banana fibre, the tensile strength of the composite increased to 39.9 MPa. This is an increment of 30.82 %. The composites prepared with raw banana fibre are category I composites. For category II composite, the tensile strength further increases and for a similar fibre loading of 20 wt. % it reaches a much higher value of 42.4 MPa. This is an increment of 39 %.

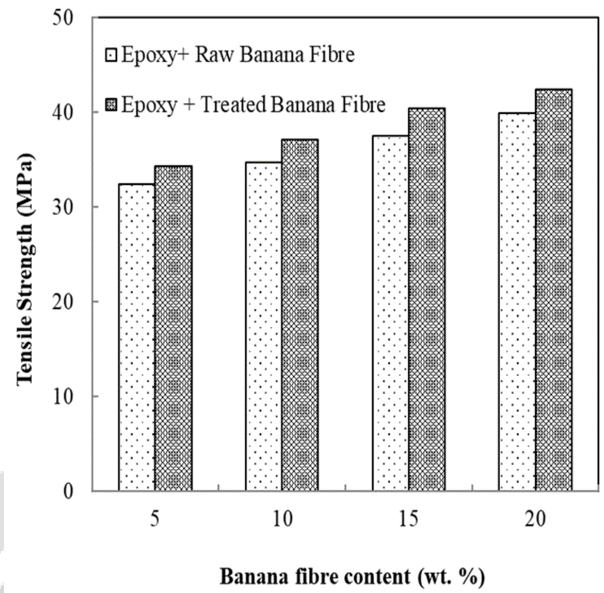

Figure 1 Variation in the tensile strength of epoxy/banana fibre composites

The flexural strength of the composites under investigation is present in Figure 2. It is clear from the figure that the inclusion of banana fibre in the epoxy matrix gainfully increases the flexural strength of the composite body. The increasing trend obtained is for all categories of the composites under investigation. The flexural strength of the neat epoxy is 33.8 MPa. For category I composite, the flexural strength increases to 42.7 MPa registering an improvement of around 26.33 %. The maximum strength is obtained for a fibre loading of 20 wt. %. For a similar fibre loading of 20 wt. %, for category II composites, the maximum flexural strength obtained is 46.8 MPa. This is a remarkable improvement of 38.5 %. For category II composites, the rate of increase in flexural strength is higher as compared to the category I composite because of better adhesion and improved compatibility between the epoxy matrix and banana fibre when the fibres are treated with an aqueous solution of NaOH.

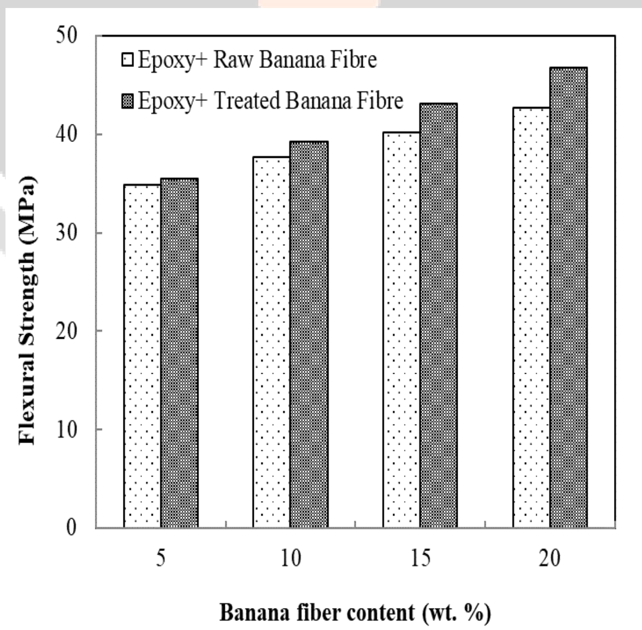

Figure 2 Variation in the flexural strength of epoxy/banana fibre composites

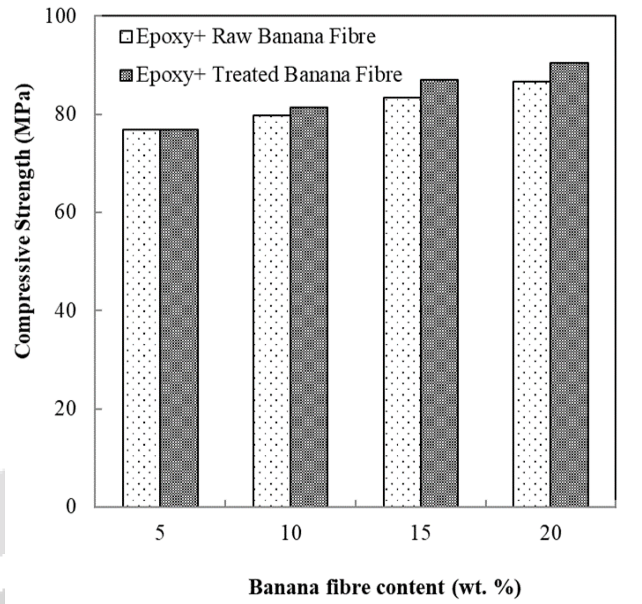

Figure 3 Variation in the compressive strength of epoxy/banana fibre composites

The compressive strength of the epoxy/banana fibre composites for all categories under investigation is presented in Figure 3. It is visible from the figure that the inclusion of banana fibre enhances the compressive strength of the epoxy composites. The compressive strength of neat epoxy is 75.7 MPa. When 20 wt. % of raw banana fibre is added to the epoxy, and the compressive strength of the composite measured is 86.6 MPa. It is observed that the inclusion of raw banana fibre improves compressive strength by 14.4 %. This improvement of compressive strength is further improved when the NaOH-treated banana fibre is added to the epoxy matrix. For a similar fibre loading of 20 wt. %, category II composites deliver a compressive strength of 90.4 MPa registering a healthy improvement of 19.4 % over neat epoxy.

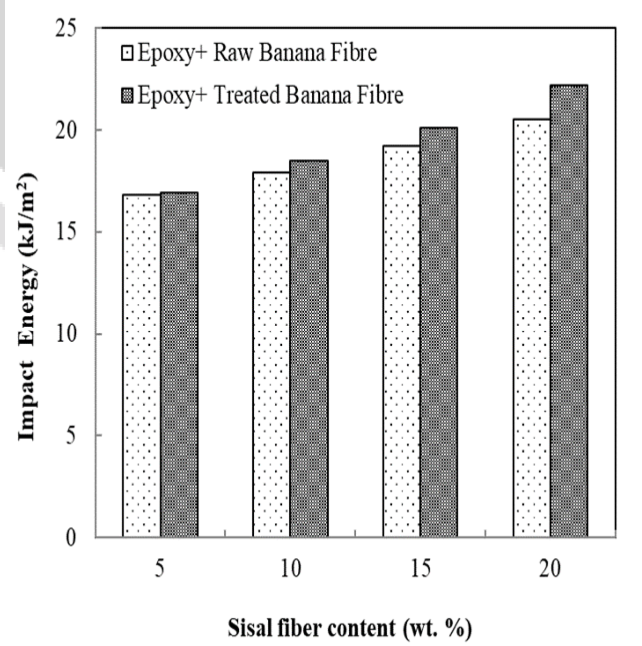

Figure 4 Variation in the impact energy of epoxy/banana fibre composites

The improvement in compressive strength with filler loading and surface modification is due to the better adhesion and improved compatibility between the epoxy matrix and banana fibre. The effect of fibre content on the impact energy of the fabricated composite for Category I, and Category II composites is shown in Figure 4. It is observed from the figure that the addition of fibre in the matrix leads to improved impact energy of the composites. The impact energy increases with the increase in the fibre loading of the composites. The impact energy of unfilled epoxy is 15.4 kJ/m2. The maximum stored energy reported is 20.5 kJ/m2 and 22.2 kJ/m2 for the composite of categories I and II respectively for a banana fibre loading of 20 wt. %. This increment is around 33.11 % for Category I composites and 44.1 % for Category II composites. The impact energy with the surface-modified banana fibre slightly improved mainly due to proper wetting and improved adhesion of banana fibre with the epoxy matrix.

Conclusions

This experimental investigation on short banana fibre-reinforced epoxy composites has led to the following specific conclusions:

1. On increasing the fibre content, the tensile strength of the epoxy-based composites increases marginally. For maximum fibre reinforcement of 20 wt. % gives the maximum value of tensile strength. The maximum tensile strength reported is 39.9 MPa for category I composites and 42.4 MPa for category II composites.
2. The compressive strength of the fabricated composite increase with the increase in fibre content. The maximum value of compressive strength for epoxy composite with 20 wt. % banana fibre. The measured maximum values are 86.6 MPa for category I composites and 90.4 MPa for category II composites.
3. The flexural strength of the fabricated composite increases with an increase in fibre content. The maximum value of flexural strength for epoxy composite with 20 wt. % banana fibre is reported to be 42.7 MPa and 46.8 MPa for category I and category II composites respectively.
4. The impact energy also increases with fibre loading. The maximum value of impact energy for epoxy composite with 20 wt. % banana fibre is reported to be 20.5 kJ/m2 and 22.2 kJ/m2 for category I and category II composites respectively.
5. Based on mechanical properties, it is concluded that the composites prepared with treated banana fibres are better than their counterpart.

Reference

1. Raghavendra, S., Lingaraju, P., Shetty, B., &Mukunda, P. G. (2013). Mechanical properties of short banana fibre reinforced natural rubber composites. International Journal of Innovative Research in Science, Engineering and Technology, 2(5), 1652-1655.
2. Venkateshwaran, N., ElayaPerumal, A., &Jagatheeshwaran, M. S. (2011). Effect of fibre length and fibre content on mechanical properties of banana fibre/epoxy composite. Journal of Reinforced Plastics and Composites, 30(19), 1621-1627.
3. Ramesh, M., Atreya, T. S. A., Aswin, U. S., Eashwar, H., &Deepa, C. (2014). Processing and mechanical property evaluation of banana fibre reinforced polymer composites. Procedia Engineering, 97, 563-572.
4. Jordan, W., & Chester, P. (2017). Improving the Properties of banana fibre reinforced polymeric composites by treating the fibres. Procedia Engineering, 200, 283-289.
5. Muktha, K., &Gowda, B. K. (2017). Investigation of Water Absorption and Fire Resistance of Untreated Banana Fibre Reinforced Polyester Composites. Materials Today: Proceedings, 4(8), 8307-8312.
6. Komal, U. K., Verma, V., Aswani, T., Verma, N., & Singh, I. (2018). Effect of chemical treatment on mechanical behavior of banana fiber reinforced polymer composites. Materials Today: Proceedings, 5(9), 16983-16989.
7. Van-Pham, D. T., Tri Nguyen, M., Nguyen, C. N., Duyen Le, T. T., Nhu Pham, T. Y., Nguyen, K. T., ... & Tran-Cong-Miyata, Q. (2018). Effects of processing parameters on mechanical properties and structure of banana fiber-reinforced composites. Journal of Renewable Materials, 6(6), 662-670.
8. Mohan, T. P., & Kanny, K. (2019). Compressive characteristics of unmodified and nanoclay treated banana fiber reinforced epoxy composite cylinders. Composites Part B: Engineering, 169, 118-125.
9. Ike-Eze, I. E., Aigbodion, V. S., Ude, S. N., Omah, A. D., & Offor, P. O. (2019). Experimental study on the effects of surface treatment reagents on tensile properties of Banana fiber reinforced polyester composites. Journal of Materials and Environmental Science J, 10(5), 402-410.

10. Balaji, A., Purushothaman, R., Udhayasankar, R., Vijayaraj, S., & Karthikeyan, B. (2020). Study on mechanical, thermal and morphological properties of banana fiber-reinforced epoxy composites. Journal of Bio-and Tribo-Corrosion, 6(2), 1-10.
11. Subramanya, R., Reddy, D. S., & Sathyanarayana, P. S. (2020). Tensile, impact and fracture toughness properties of banana fibre-reinforced polymer composites. Advances in Materials and Processing Technologies, 6(4), 661-668.
12. Nguyen, T. A., & Nguyen, T. H. (2021). Banana fiber-reinforced epoxy composites: mechanical properties and fire retardancy. International Journal of Chemical Engineering, 2021.
13. Aseer, J. R., Sankaranarayanasamy, K., Elsen, S. R., & Thakur, A. K. (2022). Experimental studies on water absorption properties of acetic acid treated banana fiber composites. Materials today: Proceedings, 49, 453-456.
14. Dhilipkumar, T., Vasumathi, M., Begum, S. R., Sathyaseelan, P., Gnanavel, B. K., & Ghfar, A. A. (2024). Evaluation of Acoustic and Structural Behavior of Banana Fiber Reinforced Polymer Composites. Fibers and Polymers, 1-12.