Hindawi
Advances in Materials Science and Engineering
Volume 2023, Article ID 9836015, 1 page
https://doi.org/10.1155/2023/9836015

Retraction

Retracted: Investigation of Mechanical and Physical Behaviours of Polyester Resin Matrix from Recycled Polyethylene Terephthalate with Bamboo Fibre

Advances in Materials Science and Engineering

Received 26 December 2023; Accepted 26 December 2023; Published 29 December 2023

This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] N. Kaliappan, V. Govindarajan, T. C. Anil Kumar et al., "Investigation of Mechanical and Physical Behaviours of Polyester Resin Matrix from Recycled Polyethylene Terephthalate with Bamboo Fibre," *Advances in Materials Science and Engineering*, vol. 2022, Article ID 4233302, 8 pages, 2022.

Hindawi
Advances in Materials Science and Engineering
Volume 2022, Article ID 4233302, 8 pages
https://doi.org/10.1155/2022/4233302

Research Article

Investigation of Mechanical and Physical Behaviours of Polyester Resin Matrix from Recycled Polyethylene Terephthalate with Bamboo Fibre

Nandagopal Kaliappan,[1] Venkatesan Govindarajan,[1] T CH Anil Kumar,[2] R. Vishnu Kumar,[3] S. Muthukumaran,[4] Maqusood Ahamed,[5] Mahadeo A. Mahadik,[6] and Mebratu Markos[7]

[1]*Department of Mechanical Engineering, Haramaya Institute of Technology, Haramaya University, Dire Dawa, Ethiopia*
[2]*Department of Mechanical Engineering, VFSTR, Vadlamudi, Andhra Pradesh, India*
[3]*Department of Mechanical Engineering, Panimalar Engineering College, Chennai 600123, Tamil Nadu, India*
[4]*Department of Mechanical Engineering, University College of Engineering Panruti, Panruti, Tamil Nadu, India*
[5]*Department of Physics and Astronomy, College of Science, King Saud University, Riyadh 11451, Saudi Arabia*
[6]*College of Environmental & Bioresource Sciences, Chonbuk National University, Iksan 570752, Republic of Korea*
[7]*Department of Mechanical Engineering, College of Engineering, Wolaita Sodo University, Wolaita Sodo, Ethiopia*

Correspondence should be addressed to Mebratu Markos; mebratumarkos@wsu.edu.et

Received 26 December 2021; Accepted 22 January 2022; Published 10 March 2022

Academic Editor: Palanivel Velmurugan

In this research article, we investigate the physical and mechanical properties of composites comprised of unsaturated polyester resin (UPR) and recycled polyethylene terephthalate (PET) with 10% to 40% volume of bamboo fibre (BF). Chemical evaluation of BF revealed that BF has a cellulose content of 49.86%, hemicellulose content of 25.17%, and lignin content of 7.14%. As the UPR's different connections, FTIR identified an interconnecting framework between the styrene monomer (ST) and the unsaturated polyester (UP). It was found by TGA-DTG that there were two breakdown phases. UPR's physical and mechanical properties were found to be affected by increasing the amount of fibre in the material, with the water absorption rising from 0.7% to 2.81% and the density (1214.38 to 1168.83 kg/m), flexural strength (51.81 to 28.92 MPa), flexural modulus (2.78 to 2.83 GPa), and tensile strength (9.71 to 3.86 MPa) all decreasing at the same time. On the other hand, the hardness increased from 82.4 Shore D to 67.9 Shore D. Fibre distribution flaws in the UPR were found, affecting the composites' mechanical characteristics. By repurposing two waste products, this study helps create new materials that are better for the surroundings.

1. Introduction

There are several advantages of using agricultural waste instead of reinforced plastic composites, including its biodegradability, non-toxicity, and ease of supply [1]. Polymeric composites might benefit from employing this waste since it includes cellulose, hemicelluloses, lignins, pectins, and waxes, which can be used to strengthen polymeric fibres [2, 3]. Because of its high mechanical resilience, cellulose is the most significant polymer in the creation of composites from plant fibres. Table 1 illustrates the chemical makeup of several plant fibres which have good thermal and mechanical qualities [4].

Polyester resins are the most cost-effective resin systems utilized in engineering, but they have limited applicability in more excellent composites. They may be made to have a wide range of qualities, including soft and malleable to rigid and brittle. PET is the most recycled plastic on the planet, yet it still accounts for a large portion of landfill waste. PET is a terephthalic acid (TPA) and ethylene glycol (EG)-based

Table 1: Composition of certain plant fibres.

S.No.	Fibre type	Percentage of cellulose	Percentage of hemicellulose	Percentage of lignin
1	Jute fibre	61 to 71.6	13.6 to 20.4	12 to 13
2	Flax fibre	71.0	18.6 to 20.7	2.3
3	Hemp fibre	70.3 to 74.5	18.0 to 22.5	3.8 to 5.8
4	Ramie fibre	68.7 to 76.3	13.2 to 16.8	0.7 to 0.8
5	Kenaf fibre	31 to 39	21.6	16 to 19
6	Sisal fibre	67.1 to 78.2	10.1 to 14.3	8.1 to 11.1

synthetic polyester (EG). Because of its low weight, durability, and chemical resistance, it is widely utilized in manufacturing textile fibres and packaging materials across the globe. Bottles made of PET, a crystalline thermoplastic polyester, are used in the production of water and beverage containers and other products such as fibres for use in textiles and engineering plastic. PET is a widely discarded substance, despite the fact that it poses no direct environmental concern [5–8]. This is due to PET's large volume and strong resistance to breakdown by applying ecological and environmental components. It is possible to recycle PET chemically in a variety of ways depending on the depolymerization of PET, such as hydrolysis, methanolysis, or by employing excess glycol and zinc acetate as catalysts under pressure and heat, all of which are extensively utilized in the production of UPR [9, 10]. Ammonolysis, glycation, and carboys, the type of glycol used in the PET depolymerization technique, all directly impact the physical and mechanical qualities of UPR. Glycolic solution based on ethylene glycol (EG) exhibits lower elasticity, higher fracture toughness, and lower humidity resistance in the UPR synthesis [11].

Composite materials made from UPR and natural fibres such pineapple leaves, coconuts, and sugarcane bagasse were tested for their mechanical and physical qualities. Composites made from post-consumer PET strengthened with natural fibres, like rice husk, coconut, kenaf, and acacia, have been developed recently [12, 13]. The impact of fibre content, fibre surface handling, and fibre length on composite characteristics was examined. Although pieces of bamboo have been utilized in the creation of composite materials, such as husks and stalk, they have not been employed as a whole, which is necessary to maximize the utilization of this waste [14]. PG-based UPR is used solely for the production of polymer concrete and polymer mortar. An unsaturated polyester resin generated from polyethylene terephthalate garbage by glycolysis and bleaching was investigated for its physical and mechanical properties in this research endeavour, together with all of its components (stalk/husk/leaf/cob) [15, 16].

2. Experimental Procedure

2.1. Material Selection. The chemical treatment changed the superficial of BF with sodium hydroxide (NaOH). A variety of chemicals were employed to determine the chemical composition of the sample: EDTA, sodium dihydrogen phosphate, sodium tetraborate decahydrate, cetyltrimethylammonium bromide, and sulfuric acid. The flakes were made by collecting and cutting PET debris from soft drink bottles [17, 18]. Pre-polymerization of UPR was carried out using the following materials: PG; zinc anhydride; MA; ST; BPO; DMA; and AZn, the latter of which was employed in the synthesis of UPR. The purity of all reagents was more than 99.99%.

2.2. Fibre Treatment. BF was soaked in a NaOH solution of 5% for two hours at room temperature, rinsed three times, and dehydrated in an oven at 110°C for 5 h with distilled water to remove excess alkali to remove waxes and pectins.

2.3. Pre-Polymerization of UPR. Glycolysis was employed to synthesise pre-polymerized UPR, as has been done in prior studies. Soft drink bottle PET flakes and a 4-stage procedure were used to produce this product [17–20]. To begin with, PET flakes were depolymerized using the glycolysis process in a Syria Vessel type reactor, which was combined with mechanical stirrer for two hours at 200°C to produce bis (2-hydroxy propyl terephthalate) (BHPT). The proportion of molecular weights of 1 : 1.6 BHPT: AM was used in the second stage, which was held at 200°C for 2 h with 2 h of stirring [21]. At this point, UP, ST, and PBO were all added to ST and stirred for 30 minutes at different weight ratios of 100 : 35 : 0.25 each. Final step: the ST-benzoyl peroxide combination was added to the unsaturated polyester and the composite was continuously stirred until the mixture was homogeneous. After that, 100 : 0.2 UP:DMA weight proportion was added as a catalyst and remixed the mixture.

2.4. Preparation of UPR-BF Composites. Nomenclature and formulation of unsaturated polyester resin-BF mixtures are shown in Table 2. Polymerization was carried out in an oven at 55°C for one hour after the mixtures were dissolved in a mechanical stirrer and compressed in steel moulds conferring to ASTM specifications [22].

2.5. Characterization. Bamboo fibre is a bamboo-derived renewed cellulose fibre. The starchy pulp is created from bamboo stems and leaves through alkaline hydrolysis and multi-phase bleaching. In order to determine the BF's chemical composition, three methods were used. In order to make a neutral detergent solution for neutral detergent fibre (NDF), NaOH, EDTA, Na_2HPO_4, and $Na_2B_4O_7.10H_2O$ were used (ISO 16472 : 2005 standard). Acerbic cleansing fibre was determined by preparing a cleaning solution with an acidic content containing CTAB and H_2SO_4 (ISO 13906 : 2008 standard). ADL, a 72% solution of H_2SO_4, was used in

Table 2: Nomenclature and formulation of UPR-BF composites.

S.No.	Composite nomenclature	UPR-bamboo fibre formulation based on volume percentage	
		Percentage of bamboo fibre content	Percentage of UPR content
1	UPR	0	100
2	Bamboo fibre-10	10	90
3	Bamboo fibre-20	20	80
4	Bamboo fibre-30	30	70
5	Bamboo fibre-40	40	60

this (ISO 13906 : 2008 standard). FTIR study of BHPT, UP, and UPR was conducted to determine the functional groups present. Testing for thermal stability following polymerization was carried out using thermogravimetric equipment from TA Instruments, which scanned 5 mg samples at 10 °C/min up to 800 °C in an environment of air. An ASTM D 570 water absorption test was performed using three rectangular specimens that were weighed dry and saturated with water for 24 hours at 23°C. The samples were then roughly dried before being weighed again. According to ASTM D 792, compactness was determined by a change in capacity utilizing purified water at 23°C. Conferring to ASTM D 790 standards, the flexural stiffness and compressive strength of the material were restrained utilizing a universal testing machine as shown in Figure 1 at 1 mm/min and a length ratio of 16 : 1. Conferring to ASTM D 638, mechanical properties were restrained using the similar kit used in the flexural test, at 5 mm/min, the rate at which the specimen moves [23]. Figure 2 reveals the impact tester. Conferring to ASTM D 2240, a Shore D durometer was used to measure the hardness of the material. Figure 3 reveals the flexural testing setup.

Figure 1: Universal testing machine.

3. Results and Discussion

3.1. Chemical Characterization of BF. Chemical examination of BF yielded cellulose, hemicellulose, and lignin concentrations of 48.97%, 24.06%, and 6.59%, respectively. When compared to other kinds of vegetable fibre, these were shown to be chemically similar (Table 1). BF has a higher cellulose content than kenaf. All fibres have hemicellulose concentration that is close to that of hemp. BF's lignin level is lower than that of sisal, jute, and kenaf.

3.2. Characteristics of the UPR

3.2.1. FTIR. The transmittance axis was randomly shifted for these spectra. Bands at 3400 cm^{-1}, 2973 cm^{-1}, and 2884 cm^{-1} correlate to frequency band of CH3, CH2, and CH in BHPT's FTIR spectrum. Frequency ranges at 1720 cm^{-1} are indicative of bending of C-O and C-O-C bonds, accordingly. The aliphatic ring's C–H bonds vibrate in the 875–525 cm^{-1} range. BHPT's frequency band does not include the O-H bond band at 3520 cm^{-1}, the CH3, CH2, and C bond elongating harmonic resonance band at 2982 cm^{-1}, the C-O bond straining peak at 1720 cm^{-1}, the C-C bond resonance frequency integrated by MA peak at 1645 cm^{-1}, and the C-O-C bond straining peak at 979 cm^{-1}. The C-O-C bond straining peak is excluded from the BHPT spectrum. There was no band at 1645 cm^{-1} correlated with the UP's C-C bond at 1645 cm^{-1} in UPR spectrum, and thus it indicates that crosslinking happened via unsaturated fatty acid of the polyester in UP.

3.2.2. Thermogravimetric Analysis. The thermogravimetric curves have exhibited the effect of DTG, weight % of fiber, and temperature in polymerized UPR based PG. It is revealed that the two pounds of fatty acid were detected in TGA, with the first being 78 percent from 35 to 445°C and the second being 22 percent from 445 to 575°C, which is attributable to the random, more manageable pieces of the constant sequences that may be freely connected generated during the first disintegration. Each peak in the DTG curve corresponds to one of the mass losses in TGA curves. At 363 and 547°C, the highest degradations are seen on the curve, and it is shown in Figure 4.

3.3. Fibre Content's Significant Impact on the Physical and Mechanical Qualities

3.3.1. Water Absorption. As shown in Figure 5, the water absorption of unsaturated polyester resin and the BF-10 to BF-40 samples ranged from 0.7% to 2.8% depending on the concentration of BF. Due to its hydrophobic nature, unsaturated polyester resin had a less value than UPR-BF mixtures, and when BF concentration grew, absorption of water increased in UPR-BF mixtures, as BF has a hydrophilic character. When combined with the UPR's superior

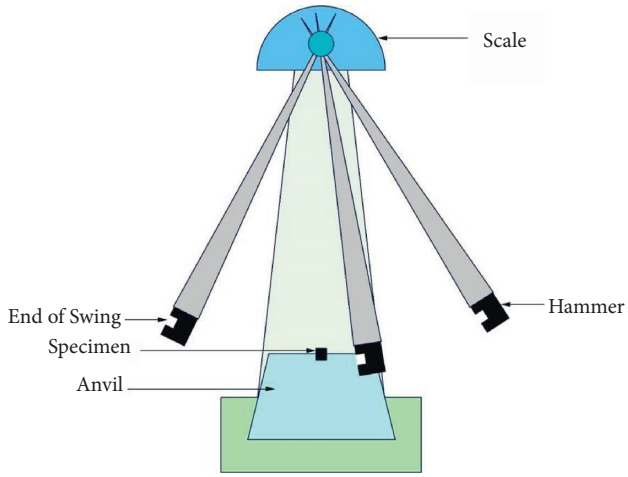

Figure 2: Impact tester.

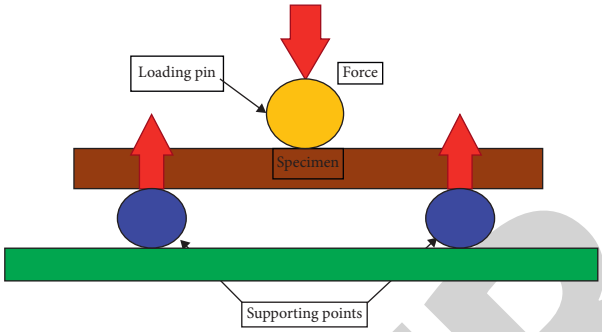

Figure 3: Flexural testing setup.

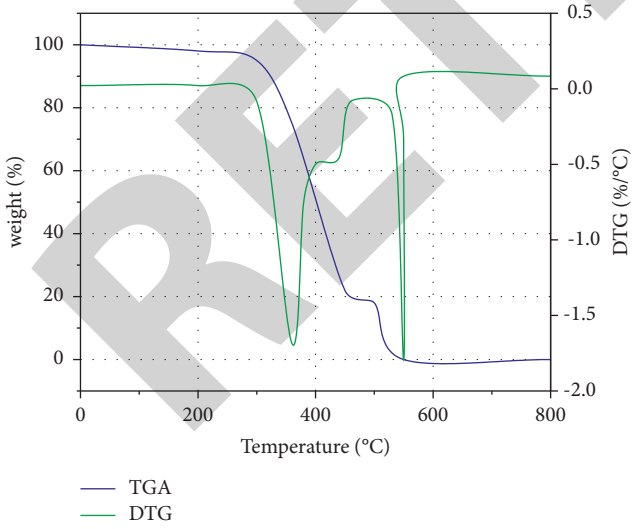

Figure 4: Thermogram of polymerized UPR-based PG.

absorption and mechanical interlock, it becomes more effective; the fibre was treated with NaOH, removing impurities like waxes, oils, and other hydrophilic substances, and this reduced the fibre's hydrophilicity. Additionally, unsaturated polyester resin-based PG was utilized, which offered water absorption ability (hydrophobic composites) by protecting ester bonds from the p-ester.

3.3.2. Density. According to the curve in Figure 6, from 1214.23 kg/m^3 to 1168.31 kg/m^3, there is an increase in the percentage of beryllium (BF) in UPR and BF-10 through BF-40. Unsaturated polyester resin had a high density than the unsaturated polyester resin-BF content, according to the results [24, 25]. BF-UPR composites had less density than the polymeric matrix, which was attributable due to the lower rate of natural fibres' density than the polymeric matrix. On the other hand, a low void content is desirable because it allows for excellent interaction between the UPR and the BF. Post-consumer PET UPR and acacia sawdust have both been shown to have similar densities.

3.3.3. Flexural Strength and Flexural Modulus. Flexural strength (MPa) and flexural modulus (GPa) are plotted in Figure 7 for UPR, and the range is from 10% to 40% of the total content of BF. The flexural strength (50.58 MPa) was near to that of an actual marketable UPR, and it dropped significantly in BF-10 (67.42% less than UPR) to 16.48 MPa. BF-10 had increases in fibre content of 21.43 MPa (30.03%), 25.43 MPa (18.67%), and 26.98 MPa that were all less than the previous increases from BF-10 (6.1%), respectively, for BF-20, BF-30, and CF-40. The flexural modulus of UPR was greater than that of the UPR-BF composites (2.66 GPa) in comparison. With an increase in fibre content, the value increased to 2.26 GPa (33.73%) for BF-10, 2.56 GPa (13.27%) for BF-20, and 2.29 GPa (10.55%) for BF-40 before decreasing to 2.29 GPa again for BF-40. In the case of BF-10, this translates to a 36.47 percent decrease in pressure from UPR to 1.69 GPa. We may deduce from these findings that the decrease in toughness and elasticity from UPR to BF-10 could be due to the BF content not being sufficient to strengthen the unsaturated polyester resin and the random distribution of the BF inside the UPR matrix [26]. Because of the difficulty of wetting it, the increase in flexural strength was smaller than expected from BF-30 to 40, which might be related to an interaction between the material and the UPR. The flexural modulus exhibited a similar pattern of development; however, the BF-40 value declined in this instance.

3.3.4. Tensile Strength and Tensile Modulus. A BF content (percentage) vs. tensile property graph is shown in Figure 8 for UPR and BF-10 to BF-40, respectively. Another work that synthesised base PG for the UPR showed similar tensile strength values for the UPR (7.93 MPa). From BF-10 to BF-20, 7.42 MPa (14.86 percent) dropped, 7.53 MPa (14.82 percent) dropped from BF-20 to BF-30, and 3.84 MPa (35.69 percent) dropped from BF-40. UPR had a tensile modulus of 1.18 GPa, BF-10 had a tensile modulus of 1.008 GPa, and BF-20, 30, and 40 had values of 0.87, 1.72, and 0.43 GPa, respectively. Compounds made with UPR and cotton-kapok fibres showed similar tensile properties which were ascribed to three features. By increasing the amount of BF content in composites to an unacceptable level, it causes poor fibre

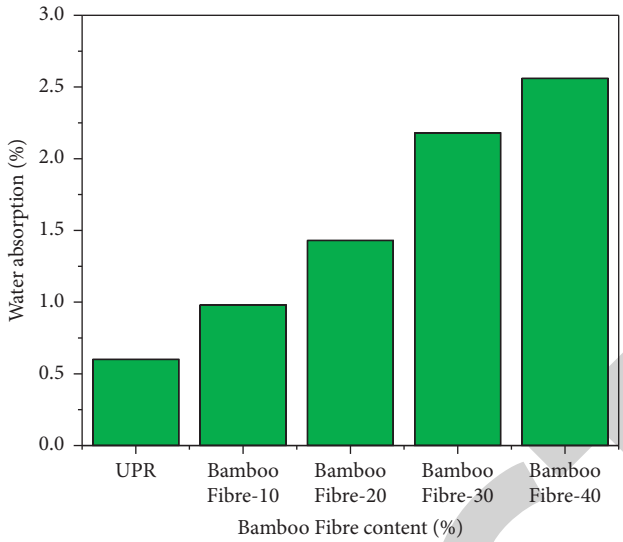

Figure 5: Water absorption in unsaturated polyester resin-bamboo fibre composites is influenced by the amount of bamboo fibre present.

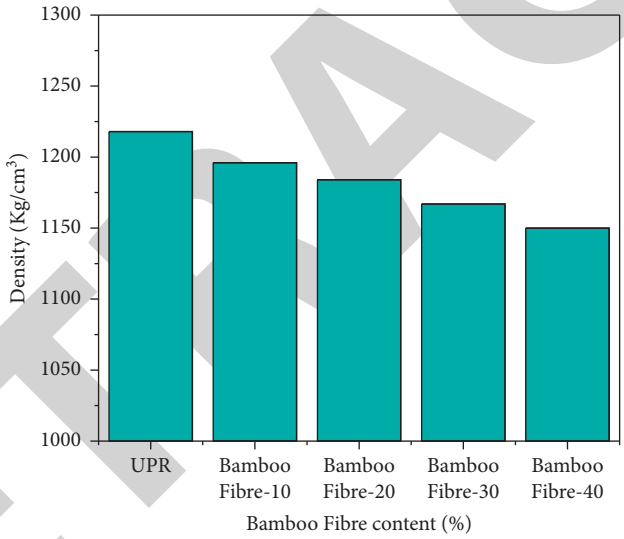

Figure 6: Effect of bamboo fibre content on density in UPR-bamboo fibre composites.

wettability and adhesion, hence the production of voids at the unsaturated polyester resin and beryllium impact, which reduces the transmission of loads among these two materials [27, 28]. Increases in the BF specimens in mixtures result in less fibre hydrophilicity and adherence to the UPR, which leads to the creation of voids at the unsaturated polyester resin and bonding fibre interface. There may be gaps and unreinforced areas in the UPR due to an uncontrolled distribution of bonding fibres (BF), and when the BF content in the UPR matrix grew, fibre agglomerations formed in the UPR matrix, creating stress concentrations that encourage fracture propagation.

3.3.5. Hardness Test. Hardness (Shore D) ranges from 81.67 to 65.67 Shore D for the UPR and BF-40, with BF concentration (percentage) shown in Figure 9. The hardness of UPR composites was found to be greater than that of UPR-BF composites. To account for this, jute-based composites with commercial UPR showed a similar decrease in hardness as they increased in BF content. The apparent decrease in hardness from BF-30 to BF-40 may be due to the fact that the maximum allowable BF content has been exceeded and there is no good interfacial relationship with UPR.

To get BF with longitudinal rupture, the alignment and homogeneous dispersion of the fibres are critical, as they are placed in different positions. Superior mechanical properties of composite materials have the high adherence of the fiber to the UPR was blamed for its fracture, which resulted in an uneven BF cross-section. Mechanical testing revealed smooth grooves in the matrix created by fibres that had been pulled out, indicating that the BF and UPR's connection is weak in some regions [29–31]. The fatigue caused tyre tracks (striations) to appear in the UPR matrix, which were spotted.

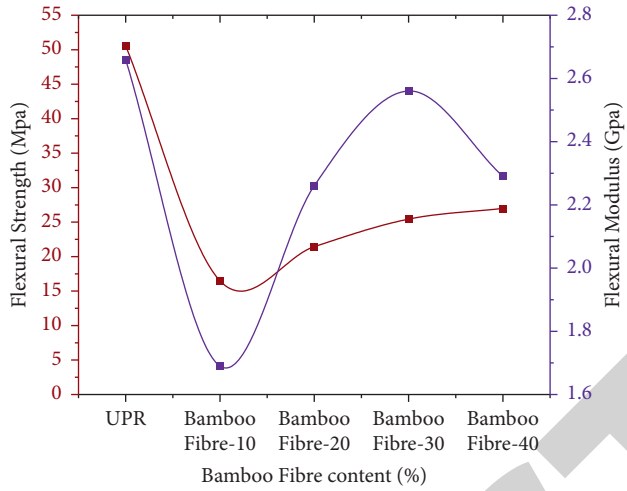

Figure 7: Flexural strength and modulus of UPR-bamboo fibre composites may be improved by increasing the bamboo fibre content.

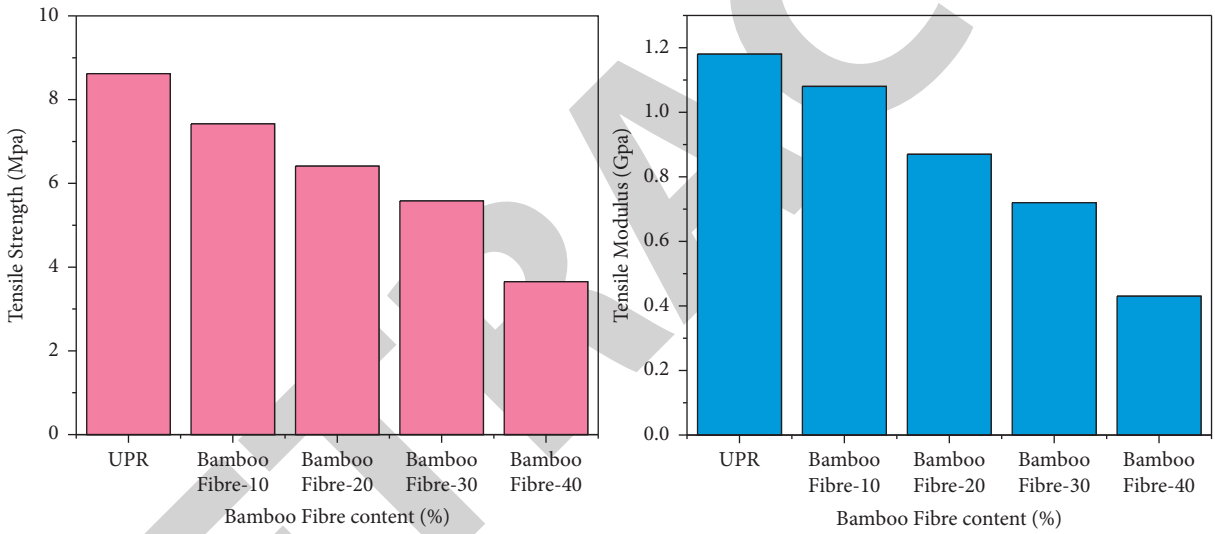

Figure 8: Impact of bamboo fibre content on tensile strength and tensile modulus in unsaturated polyester resin-bamboo fibre composites.

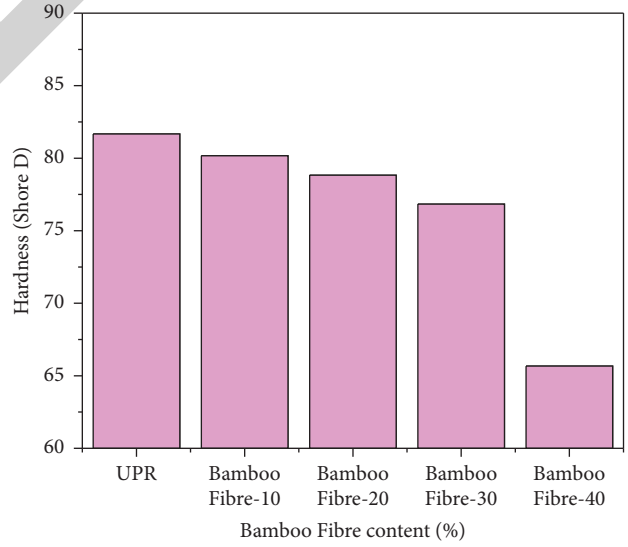

Figure 9: Impact of bamboo fibre content on hardness in unsaturated polyester resin-bamboo fibre composites.

The fibres of the UPR were found to have uneven ruptured surfaces as a result of crack arrest. Fibre dispersion in the UPR was found to be ineffective in some areas where the fibres did not entirely disseminate. This means that there is a low BF content and its dispersion is not uniform, which encourages crack propagation and so does nothing to strengthen the UPR [32]. It is clear from the results that the BF dispersion is generally homogeneous throughout the UPR, but some agglomerations were found, and stress concentration in composite materials and a decrease in flexural and tensile strength were connected to these changes. As a result, the presence of these agglomerations did not help reinforce the composite material in the zones where they were present.

4. Conclusions

Recycled polyethylene terephthalate depolymerization with excess PG yielded UPR-BF composites with BF (10%–40%), which were effectively developed. The degradation of UPR was discovered to have two separate stages. The first was attributed to the breaking of RPI bonds and the second to unrestrained continuous chains (TGA-DTG analysis). Though hydrophilic, BF had a lower density than its polymeric matrix, and hence the composites' water absorption ranged from 0.7% to 2.81%. Natural fibres were blamed for this since they were less dense than the polymeric matrix, which is why the density fell. A loss in mechanical qualities such as hardness and toughness might be due to random dispersion and aggregates of BBF as well as the lack of reinforcement provided by the mixture of stalks, husks, leaves, and bamboo.

When force was applied to the BF, it cracked, but the remnants of BF remained interlocked in the UPR both longitudinally and transversely. This indicates a strong interfacial connection between the BF and the UPR. However, certain places had low concentrations of BF, while others had high concentrations, albeit with agglomerations in between. There was no benefit to the UPR from the BF in either case. It was unable to improve UPR-BF composite strength because of the defects in the unsaturated polyester resin matrix, and the distributed occurrences of the BF were found to be the reason for their low mechanical characteristics. Due to its great availability, cheap cost, and nontoxicity, the UPR-BF produced represents an ecological option.

Data Availability

The data used to support the findings of this study are included within the article. Further data or information is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

The authors appreciate the support from Haramaya University, Ethiopia. The authors would also like to thank Panimalar Engineering College, Chennai, and King Saud University, Saudi Arabia, for providing technical assistance to complete this experimental work. The authors thankful to Researchers Supporting Project (RSP-2021/129), King Saud University, Riyadh, Saudi Arabia.

References

[1] N. Saravanan, V. Yamunadevi, V. Mohanavel et al., "Effects of the interfacial bonding behavior on the mechanical properties of E-glass fiber/nanographite reinforced hybrid composites," *Advances in Polymer Technology*, vol. 2021, Article ID 6651896, 9 pages, 2021.

[2] R. Rangaraj, S. Sathish, T. L. D. Mansadevi et al., "Investigation of weight fraction and alkaline treatment on *catechu linnaeus/Hibiscus cannabinus/sansevieria ehrenbergii* plant fibers-reinforced epoxy hybrid composites," *Advances in Materials Science and Engineering*, vol. 2022, Article ID 4940531, 9 pages, 2022.

[3] A. R. Lara-Vázquez, A. Sánchez, and I. Valdez-Vazquez, "Hydration treatments increase the biodegradability of native wheat straw for hydrogen production by a microbial consortium," *International Journal of Hydrogen Energy*, vol. 39, no. 35, pp. 19899–19904, 2014.

[4] Y. Ma, S. Wu, J. Zhuang, J. Tong, Y. Xiao, and H. Qi, "The evaluation of physio-mechanical and tribological characterization of friction composites reinforced by waste corn stalk," *Materials*, vol. 11, no. 6, p. 901, 2018.

[5] H. Ye, Y. Zhang, Z. Yu, and J. Mu, "Effects of cellulose, hemicellulose, and lignin on the morphology and mechanical properties of metakaolin-based geopolymer," *Construction and Building Materials*, vol. 173, pp. 10–16, 2018.

[6] L. Y. Mwaikambo and M. P. Ansell, "Chemical modification of hemp, sisal, jute, and kapok fibers by alkalization," *Journal of Applied Polymer Science*, vol. 84, no. 12, pp. 2222–2234, 2002.

[7] A. K. Mohanty, M. Misra, and L. T. Drzal, "Surface modifications of natural fibers and performance of the resulting biocomposites: an overview," *Composite Interfaces*, vol. 8, no. 5, pp. 313–343, 2001.

[8] A. K. Mohanty, M. Misra, and G. Hinrichsen, "Macromolecular mater," *Engineering Times*, vol. 276, no. 277, p. 1, 2000.

[9] C. Pudack, M. Stepanski, and P. Fässler, "PET recycling - contributions of crystallization to sustainability," *Chemie Ingenieur Technik*, vol. 92, no. 4, pp. 452–458, 2020.

[10] M. M. Lubna, K. S. Salem, M. Sarker, and M. A. Khan, "Modification of thermo-mechanical properties of recycled PET by vinyl acetate (VAc) monomer grafting using gamma irradiation," *Journal of Polymers and the Environment*, vol. 26, no. 1, pp. 83–90, 2018.

[11] M. E. Çınar and F. Kar, "Characterization of composite produced from waste PET and marble dust," *Construction and Building Materials*, vol. 163, pp. 734–741, 2018.

[12] R. Park, V. Sridhar, and H. Park, "Taguchi method for optimization of reaction conditions in microwave glycolysis of waste PET," *Journal of Material Cycles and Waste Management*, vol. 22, no. 3, pp. 664–672, 2020.

[13] K. Ragaert, L. Delva, and K. Van Geem, "Mechanical and chemical recycling of solid plastic waste," *Waste Management*, vol. 69, pp. 24–58, 2017.

[14] G Maruthupandian, R Saravanan, S Suresh Kumar, and B. G Sivakumar, "A study on bamboo reinforced concrete slabs," *Journal of Chemical and Pharmaceutical Sciences*, vol. 9, no. 2, pp. 978–980, 2016.

[15] K. Ertas and G. Güçlü, "Alkyd resins synthesized from glycolysis products of waste PET," *Polymer - Plastics Technology & Engineering*, vol. 44, no. 5, pp. 783–794, 2005.

[16] K. Dutt and R. K. Soni, "A review on synthesis of value added products from polyethylene terephthalate (PET) waste," *Polymer Science - Series B*, vol. 55, no. 7, pp. 430–452, 2013.

[17] C. J. Larez V and G. A. P. Mendoza, "Unsaturated polyesters, III. Polyester from maleic anhydride and 1,4-butylene glycol," *Journal of Applied Polymer Science*, vol. 43, no. 9, pp. 1605–1607, 1991.

[18] J. Scheirs and T. E. Long, *Modern Polyesters: Chemistry and Technology of Polyesters and Copolyesters*, John Wiley & Sons, New Jersey, USA, 2005.

[19] B. C. Trivedi and B. M. Culbertson, "Alternating addition copolymerizations," *In Maleic Anhydride*, pp. 307–458, Springer, New York, NY, USA, 1982.

[20] O. M. Musa, *Handbook of Maleic Anhydride Based Materials*, Springer, Berlin, Germany, 2016.

[21] S. H. Aziz, M. P. Ansell, S. J. Clarke, and S. R. Panteny, "Modified polyester resins for natural fibre composites," *Composites Science and Technology*, vol. 65, no. 3–4, pp. 525–535, 2005.

[22] S. Das, A. K. Singha, A. Chaudhuri, and P. K. Ganguly, "Lengthwise jute fibre properties variation and its effect on jute-polyester composite," *Journal of the Textile Institute*, vol. 110, no. 12, pp. 1695–1702, 2019.

[23] N. H. Sari, C. I. Pruncu, S. M. Sapuan et al., "The effect of water immersion and fibre content on properties of corn husk fibres reinforced thermoset polyester composite," *Polymer Testing*, vol. 91, Article ID 106751, 2020.

[24] G. L. E. Prasad, B. S. K. Gowda, and R. Velmurugan, "Comparative study of impact strength characteristics of treated and untreated sisal polyester composites," *Procedia Engineering*, vol. 173, pp. 778–785, 2017.

[25] S. Nimanpure, S. A. R. Hashmi, R. Kumar et al., "Mechanical, electrical, and thermal analysis of sisal fibril/kenaf fiber hybrid polyester composites," *Polymer Composites*, vol. 40, no. 2, pp. 664–676, 2019.

[26] M. Gargol, T. Klepka, Ł. Klapiszewski, and B. Podkościelna, "Synthesis and thermo-mechanical study of epoxy resin-based composites with waste fibers of hemp as an eco-friendly filler," *Polymers*, vol. 13, no. 4, p. 503, 2021.

[27] A. Raji, A. Devaraju, R. Gopi, and R. Venkatesh, "Fabrication and mechanical characterization of hybrid composite bike safety helmet," *Materials Today Proceedings*, vol. 39, pp. 892–896, 2021.

[28] F. S. da Luz, V. S. Candido, A. C. R. Da Silva, and S. N. Monteiro, "Thermal behavior of polyester composites reinforced with green sugarcane bagasse fiber," *Journal of the Minerals Metals & Materials Society*, vol. 70, no. 10, pp. 1965–1971, 2018.

[29] U. Shehu, O. Aponbiede, U. S. Ishiaku, T. Ause, and R. Mat Taib, "The effect of surface treatment on the mechanical properties of Poly (lactic acid)/Guinea corn husk particulate Bio-composites," *Journal of Materials and Environmental Science*, vol. 7, no. 10, pp. 3750–3758, 2016.

[30] N. M. Abdullah and I. Ahmad, "Potential of using polyester reinforced coconut fiber composites derived from recycling polyethylene terephthalate (PET) waste," *Fibers and Polymers*, vol. 14, no. 4, pp. 584–590, 2013.

[31] I. Ahmad, Z. Mosadeghzad, R. Daik, and A. Ramli, "The effect of alkali treatment and filler size on the properties of sawdust/UPR composites based on recycled PET wastes," *Journal of Applied Polymer Science*, vol. 109, no. 6, pp. 3651–3658, 2008.

[32] S. Wu, J. Zhao, M. Guo, J. Zhuang, and Q. Wu, "Effect of fiber shape on the tribological, mechanical, and morphological behaviors of sisal fiber-reinforced resin-based friction materials: helical, undulated, and straight shapes," *Materials*, vol. 14, no. 18, p. 5410, 2021.