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Research Article

Mechanical Behaviour of Alkali-Treated Fabric-Reinforced Polymer Matrix Composites

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Polyethylene (PE) was used as a composite material to create a fabric containing 40% pineapple, 30% jute, and 30% cotton fibres by weight. The physical characterisation is carried out, like deterioration and water absorption tests. PE-based composites were shown to have a lower water absorption rate when dipped in deionized water to perform an absorption test. Fabric/PE composites decomposed slowly in the soil during the degradation test. Alkali solution of 5 percent, 7 percent, and 9 percent sodium hydroxide by weight for 60 minutes was studied as alkali impact mechanical characteristics: mechanical testing's like tensile strength and modulus, elongation at break, bending strength, and modulus. Data investigation exposed that the tensile strength and modulus, elongation at break, bending strength, and composite modulus values were 64 MPa and 871 MPa, 23.14 percent, 45 MPa, and 512 MPa. There were tensile strength and modulus, elongation at break, bending strength, and modulus of the neat polyethylene sheet that were 32Mpa and 342 MPa, 79 percent, 22 MPa, and 234 MPa, respectively. Compared to a polyethylene sheet, composite values for tensile strength and modulus, bending strength, and modulus raised by 107%, 156%, 110%, and 115% as a result of fabric reinforcing.

1. Introduction

Because natural fibre is biodegradable and environmentally beneficial, composites made with natural fibres have been of tremendous interest. Composites are both cheap and environmentally friendly [1]. Fibre-reinforced materials (FRM) have long been known for their advantages over unreinforced materials, and their usefulness in a variety of industries has led to their widespread use. There are numerous applications for FRM, including aerospace and construction [2, 3]. Additionally, net or extended continuous fibre-strengthened materials are utilized in the medicinal field.

Natural fibres have shown promising results in reinforcing composites, although synthetic fibres are currently the most used [4–6]. Synthetic fibre-reinforced polymers, in addition to being expensive, can have a detrimental impact on the environment. Natural cellulose-based fibres are being used to alleviate this problem. Natural fibres coupled with thermoplastic materials are becoming increasingly popular in order to achieve both high volume and low cost [7]. Nonpolar thermoplastic material can be used to remove natural fibres' inherent polarity and hydrophillicity. In the absence of environmental impact, these characteristics are not taken into account. Replacement of synthetic fibres with natural fibres that possess similar structural and mechanical qualities is becoming more important to scientists and engineers alike [8, 9]. In addition to considering the suitability of natural fibres, other factors like rate, environmental effect, cleanliness, elasticity, collecting convenience, and accessibility should be taken into account when selecting raw materials. Natural fibres are a long-term option because they are a renewable resource, as well as affordable and hygienic [10]. Processing natural fibres is also cost-effective and gives a wide range of useful mechanical and physical characteristics. Pineapple Leaf Fibre (PALF) is a leftover product from the farming sector that is extensively grown throughout Asia [11, 12]. Pineapple is one of the few tropical fruits that is absolutely required (Ananas comosus). Because of the fruit's high commercial worth, pineapple leaves can be used to make natural fibres. Its chemical composition is holocellulose (70–82%), lignin (5–12%), and ash (1.1 percent). Since holocellulose makes up a larger fraction of this material, its mechanical qualities are exceptional [13]. Consequently, reinforced polymer composite manufacturing can benefit from its use. Several Asian countries, such as China, India, Pakistan, and Bangladesh, produce a significant amount of cotton [14]. Ninety-four percent of cotton fibre is made up of cellulose. Cotton fibre strength is affected by microfibril alignment, chained molecular weight, highly crystalline purity, and microfibril convolution angles. As another significant natural fibre, jute is produced in a number of countries and regions around the world, primarily in Bangladesh and India [15, 16]. Clothing, ropes, purses, and floor mats are just a few of the items made from jute fibre. It may also be used as a reinforcing agent for polyethylene and other hydrophobic composite specimens, such as low-density polyethylene and unsaturated polyester resin [17–20].

In addition to being lightweight, lucrative, and less in mass, it has other advantages. It also possesses a low elongation at break, a high tensile modulus, and excellent availability. The alpha-cellulose that makes up 82 percent of the holocellulose is responsible for the fibre's outstanding mechanical properties. Jute and cotton fibres were utilized in order to create a low-cost, lightweight composite [21, 22]. Polyethylene has been utilized extensively with natural fibres in the manufacture of composites. Polyethylene (PE) is a thermoplastic amorphous polymer widely utilized in engineering because of its many desirable properties, including its more heat deformation temperature, its spark resistance, and its more impression strength. When it comes to other applications, PE is versatile [23, 24]. The potential of polyethylene composites including natural fibres is growing by the day. Fabric-reinforced partly biodegradable composites were tested for mechanical and degradation properties. Alkali effects on composite and water uptake profiles were also examined [25–27]. Thus, our goal is to create a fabric having 40% pineapple, 30% jute, and 30% cotton fibres by weight and then immerse the composites in 5%, 7%, and 9% sodium hydroxide to assess mechanical properties. Physical characterisation is carried out, like deterioration tests and water absorption tests.

2. Materials and Methods

2.1. Materials and fabrication. The cloth had a thread count of 52 threads per square inch in the warp and 40 threads per square inch in the weft directions. The local market provided the alkali (NaOH) and the PE granules. Polyethylene granules are a robust, thermoplastic substance that is still widely utilized in commodities as well as the food sector. PE's chemical formula is (C2H4)n. Two plates of a heat press machine were used to press polyethylene granules into sheets. An industrial heat press machine was employed for 5 minutes at 180°C with a weight of 2000 kg. The heat press machine was used to chill the sheets as shown in Figure 1. The precut PE sheet and cloth were used for composite manufacturing. Fabric was sandwiched between two sheets of PE, and the technology for producing PE sheets was used to construct composites [28]. Thirty percent of the composites' weight was made up of textiles.

2.2. Mechanical Properties of Composites. With an initial clamp spacing of 20 mm and a tensile and bending force of 10 mm/min, the Hounsfield series testing equipment was used to measure the composites' strength and the setup is shown in Figure 2. It determines the amount of force necessary to fracture a composite material as well as the elongation of the specimen. Material dimensions were $60 \times 10 \times 1.60\ mm^3$ for the fabric/PE composites. For three days prior to testing, the test samples were kept at a temperature of 25°C and a moisture of 50%. According to the vertical warp direction, mechanical tests were conducted. At least five samples were used to calculate the average of the results for each test value.

2.3. The Composites' Water Absorption Profile. Polymer composite-bonded utilizing natural fibres seem to be susceptible to external factors like moisture. Water absorption studies are performed to assess how much water is added at specific settings. ASTM D-570 was used to evaluate the fabric/PE composite for water absorption. Three fabric/PE composite specimens (specimen 1, specimen 2, and specimen 3) were tested for water absorption. At 25 degrees Celsius (room temperature), specimens of the mixtures were weightage and placed in glasses with 500 mL of deionized water for an hour [29]. The specimens were then removed from the glass, wiped with paper towels, and reweighed following the time interval. After 40 minutes of testing, there was still no uptake, so we continued the exam for an

Figure 1: Hot press machine setup.

additional hour, in accordance with the following procedure:

$$\text{Water absorption (\%)} = \left[\frac{\text{Wet weight} - \text{Dry weight}}{\text{Dry weight}}\right] \times 100. \quad (1)$$

Chemical treatment is amongst the most effective procedures for removing compound organic materials. The major processes involved in alkali treatment seem to be solvation and saponification, which cause particulate organics to expand, making the cellular components more vulnerable to enzymatic assault and so enhancing the biodegradability of the solid phases. Using alkali to test the composites' effects on alkali was done. For 24 hours, aqueous solutions of 5%, 7%, and 9% sodium hydroxide (NaOH) were applied to the composites. It took 24 hours to eradicate the NaOH from the specimens by washing them in water. After that, they were dried for an hour at 70°C to determine their mechanical qualities. The mechanical characteristics of the composites were evaluated by soil dilapidation experiments after a given amount of time in contact with the soil [30]. The fabric/PE composites were subjected to a soil degradation test lasting up to 24 weeks. For a variety of lengths of time, soil samples were placed in a variety of composites. Samples were carefully removed after a three-week period. Tensile and bending characteristics of the specimens were computed after they had been washed and dehydrated at 25°C for one day.

Figure 2: Tensile test analysing machine.

3. Results and Discussion

3.1. Mechanical Characteristics of Composites. Data on the mechanical characteristics of PE matrix and fabric/PE composites can be found in Tables 1 and 2 of this paper. For example, a sheet of polypropylene has 32 MPa tensile strength, 342 MPa tensile modulus, 79% Eb percent, 22 MPa bending strength, and 234 MPa modulus bending. There were TS, tensile modulus, BS, and BM of 64, 871, 45, and 485 MPa for the fabric/PE composites. Concluded matrix PE, PE composites made from pineapple leaves, cotton, and jute fibres received a 107% rise in TS and a 101% rise in bending strength [31]. TM and BM on the other hand showed a 156 percent and 115 percent increase in performance over the matrix material PE, respectively.

There were noticeable improvements in mechanical properties in the 30 percent fabric/PE composite after analysing the data. However, when compared to PE, the Eb percent was substantially lowered. Researchers said that PALF/PE composite (30 percent fibre content) had the following properties: TS, elongation break %, bending strength, and BM of the Pineapple Leaf Fibre/PE composite (30%fibre content), respectively [32]. The inclusion of jute and cotton fibre lowered the mechanical characteristics when compared to the current investigation. The inclusion of jute and cotton fibre reduced stress in the matrix PP, changing its

Table 1: Tensile characteristics of polyethylene (PE) and fabric/PE composites.

Materials	Tensile characteristics		
	Tensile strength (MPa)	Tensile modulus (MPa)	Elongation at break (%)
Polyethylene	32 ± 1.8	342 ± 28	79 ± 4.87
Fabric/polyethylene	64 ± 3.24	871 ± 62	23.14 ± 1.9

Table 2: Bending characteristics of polyethylene (PE) and fabric/PE composites.

Materials	Bending characteristics	
	Bending strength (MPa)	Bending modulus (MPa)
Polyethylene	22 ± 1.51	234 ± 19
Fabric/polyethylene	45 ± 2.82	512 ± 29

mechanical properties. Sandwich construction had a considerable impact on the mechanical characteristics of this material because of the core layer (fabric). The results of this study showed that PE composites based on pineapple leaf, cotton, and jute fibres had mechanical property values that were more than double those of the matrix material alone. Pineapple, jute, and cotton fibres' cellulose content proved advantageous in this situation.

3.2. The Composite Water Absorption Profile. The water absorption capabilities of the composite were demonstrated using the absorption test. Figure 3 shows water absorption measurements on three samples of fabric/PE composites across time and temperature. When the soaking time was increased to 40 minutes, the amount of water absorbed increased to the point where no more water could be absorbed. [33]. The fabric/PE composite was found to have a water absorption rate of 1.6%. No further water absorption was observed after 50 minutes of incubation, and water uptake percentage was 1.46 percent for the PALF/PE composite (30 percent fibre content). Due to the varying fibre composition of the fabric/pp composite, little fluctuation was seen.

The fibre cellulose contains hydroxyl (–OH) groups, which are accountable for water absorption. The sturdy hydrophilic nature of fabric can be illuminated by the occurrence of hydroxyl (–OH) groups in the fibre. Polyethylene, when sandwiched between polyethylene sheets, is very hydrophobic and resists water penetration when used to fabricate composites [34]. As a result, fabric/PE composite water uptake values were lower than they should have been. The strong hydrophilic characteristic of the fabric is due to the cellulose in the fabric. Fabric can be sandwiched between two Polyethylene sheets to keep water out of composites because polyethylene is highly hydrophobic in nature. The cut edge of the composite absorbed water, lowering the water uptake values of the fabric/PE composite.

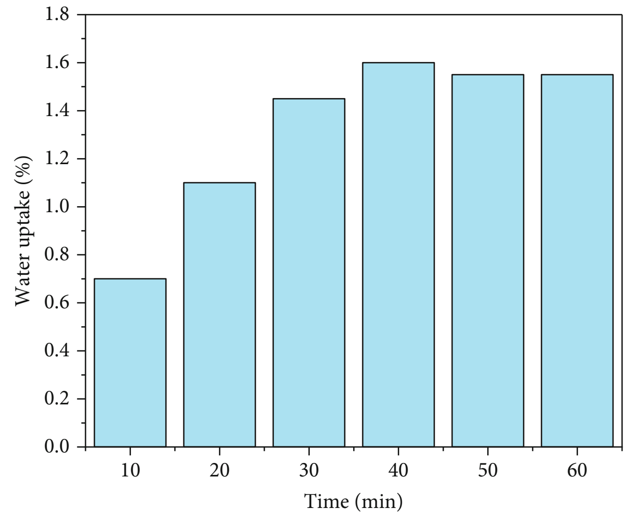

Figure 3: Water uptake % of fabric/PE composites.

3.3. Effect of Alkali. An alkali test on composites (5%, 7%, and 9% NaOH) was passed out for 24 hours at room temperature. It is easy to see in Figure 4 that shows how much the material can stretch before it breaks, how much it can bend, and how much it can elongate before it breaks. Mechanical characteristics in fabric/PE composites deteriorated in all circumstances of the analysis. As demonstrated in the figures, the mechanical characteristics of the mixtures were suggestively reduced where the mixtures were processed with a 9 percent NaOH solution. TS, TM, Eb percent, BS, and BM levels dropped by 23 percent, 31 percent, 34 percent, 25 percent, and 29 percent, respectively, following 24 hours of 9 percent alkali treatment. To increase the mechanical characteristics of natural fibre, which contains cellulose and is alkali treated, the crystal structure of fibres was considerably improved. However, the mechanical characteristics of the natural fibre-strengthened mixtures changed when they were exposed to alkali. Mercerization is a good explanation for the change in mechanical characteristics. Over time, the fabric may have lost its elasticity. Composites become more prone to breaking as a result of mercerization.

3.4. Composite Degradation Test in the Soil. For up to 24 weeks, the composites were exposed to soil degradation tests. There are six measurements presented in Figure 5. The TS, tensile modulus, and Eb% of the fabric/PE composites dropped over time as seen in the figures. Over 24 weeks of soil deprivation, the tensile strength, TM, and Eb percent consumed by fabric/PE composites were 48 percent and 49 percent, respectively. The BS and BM dropped in a similar manner, as seen in Figure 4. After 24 weeks, soil degraded the fabric/PE composites by 45 and 47 percent of their starting BS and BM rates, respectively. Fabric/PE composites, on the other hand, lost about 40% of their mass over the course of 24 weeks. Pineapple leaf, cotton, and jute are examples of natural biodegradable fibres that absorb water quickly due to their hydrophilic nature. In soil, cellulose has a remarkable ability to break down. PE is a hydrophobic material by

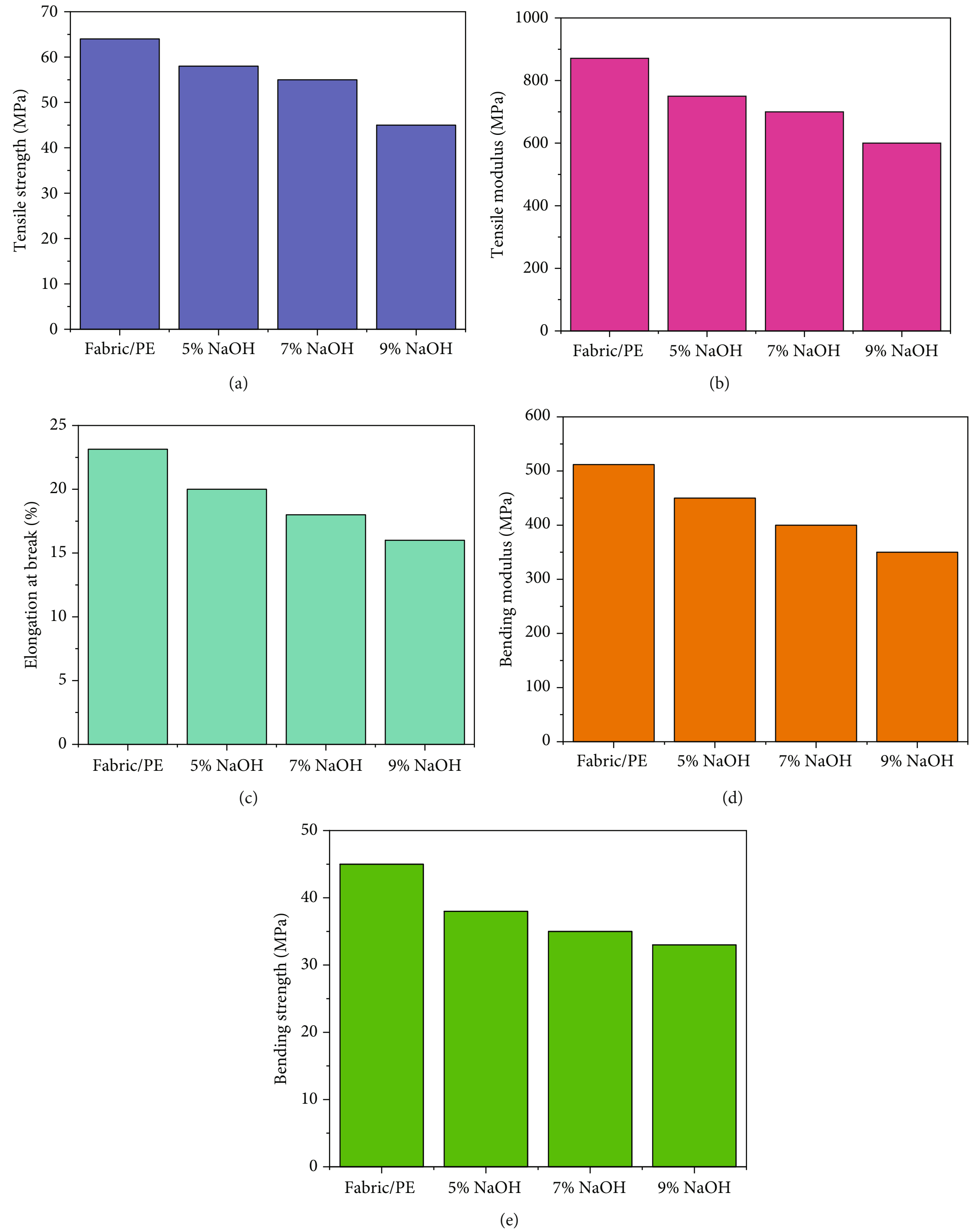

Figure 4: Alkali's effect on the composites' mechanical characteristics: (a) tensile strength, (b) tensile modulus, (c) elongation, (d) bending modulus, and (e) bending strength.

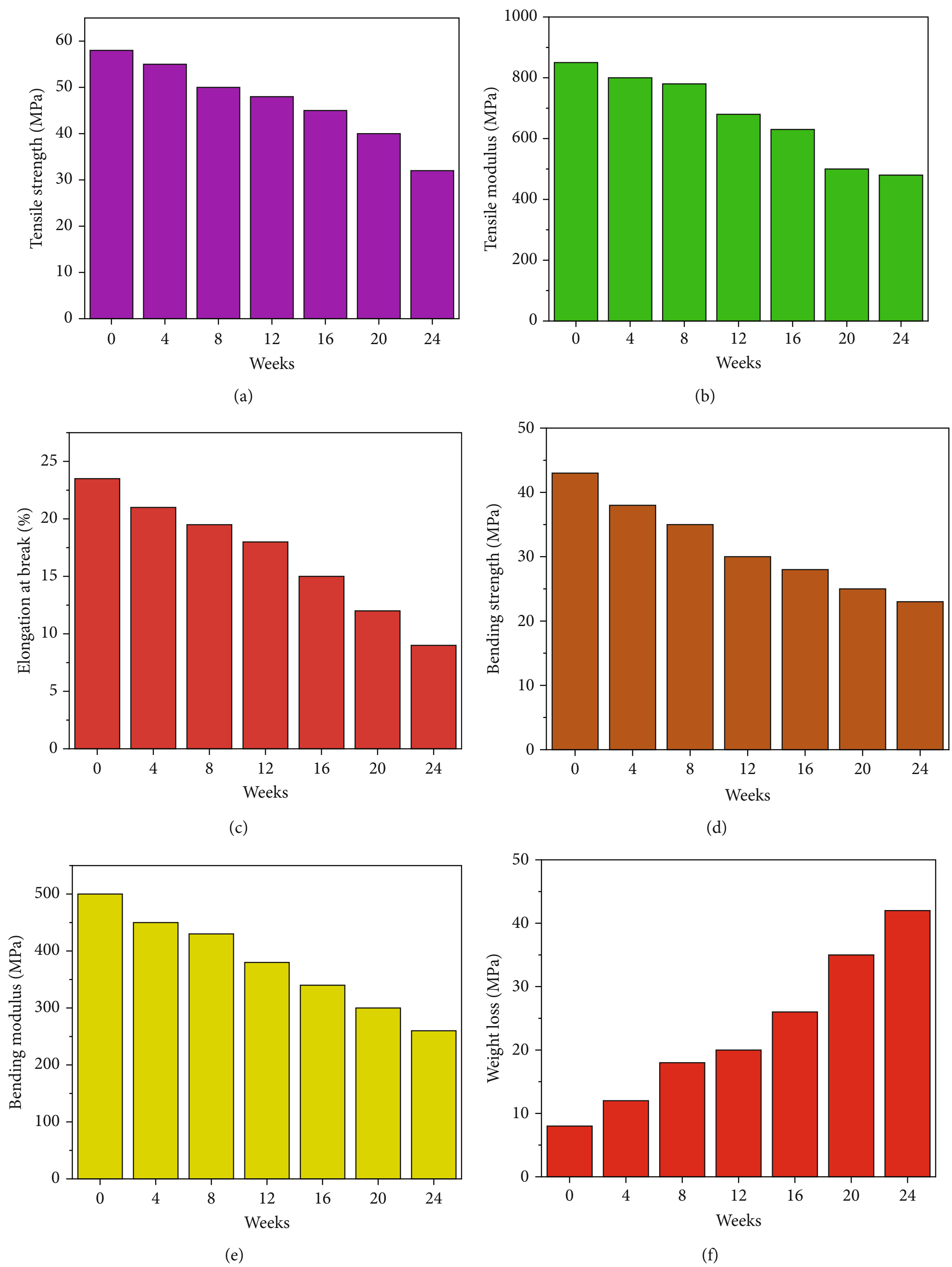

Figure 5: A soil degradation testing of the composites: (a) tensile strength, (b) tensile modulus, (c) elongation, (d) bending strength, (e) bending modulus, and (f) weight loss.

design. While the soil degradation tests, water seeped into the composites through the cut edges, degrading the cellulose and reducing its mechanical characteristics significantly. A 24-week soil degradation test of a natural fibre (jute fibre) strengthened PE-based composite (50 percent fibre weight) showed that 40 percent, 46 percent, 36 percent, and 35 percent, respectively, were lost. After soil degradation testing, the tensile characteristics of the soil have not changed much. However, variations in the fabric/PE composite's fibre % and mix resulted in some bending property changes.

4. Conclusions

Fabric-reinforced successfully manufactured and characterised polyethylene-based composites were obtained. The composite material's mechanical properties were designed to be improved in evaluating the composite material.

(i) There was an improvement of 107% and 156% in the fabric/PE composite TS and TM compared with the PE matrix (64 MPa and 871 MPa, respectively).

(ii) The BS and BM values observed for fabric/PE composites were 110 percent and 115 percent greater than those found for the matrix material, respectively, at 45 MPa and 512 MPa

(iii) When jute and cotton fibres were added to a composite, the mechanical characteristics decreased, but water uptake remained relatively stable

(iv) The mechanical characteristics of fabric/PE composites were lowered by alkali. Six months of soil degradation testing of the fabric/PE composites showed that the composites kept around 50% of their initial mechanical capabilities

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 paper.

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