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Natural filler based composite materials

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ABSTRACT

Purpose: The first goal is to get rid of waste and reduce environmental pollution, and the other goal is to investigate the effect of these fibres on properties (resistance of composite materials for bending and tensile testing) of polyester and use them in applications. Also, The moisture environment effect on the properties of composite materials was studied.

Design/methodology/approach: It uses natural fibres, which are considered waste, namely eggshell and sawdust with polyester. Several samples were prepared with different weight percentages (30% and 40%), and their mechanical properties were studied and immersed in water for 15 days. And studying the effect of water on these properties. It was found that it is possible to use these fibres (waste) with polyester and benefit from them. It was found that when adding fibres to polyester, the tensile strength decreases, but the bending increases the strength. Finally, it was found that when the samples are immersed in water, the material weakens, and its mechanical properties decrease.

Findings: It can be noticed that adding natural fibres by 40% and 30% improved the mechanical properties of polyester in the bending test, where the bending test increased with increased volume fraction of fibre. It can be noticed that adding natural fibres by 40% and 30% decreased the mechanical properties (tensile strength) of polyester in a tensile test. When the natural composite materials were treated with water for 15 days, water decreased the mechanical properties in bending and tensile test.

Research limitations/implications: One of the limitations of this research that was found through the work is that when increasing the weight ratios of the fibres added to polyester leads to the failure of polyester, so we recommend using lower weight ratios of fibre.

Practical implications: One of the limitations of this research that was found through the work is that when increasing the weight ratios of the fibres added to polyester leads to the failure of polyester, so we recommend using lower weight ratios of fibre.

Originality/value: The original value of this research is the use of fibres that are considered waste, their reuse, and utilization in some applications that do not require composite materials with high mechanical properties.

Keywords: Polyester resin, Composite natural materials, Tensile and bending test

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PROPERTIES

1. Introduction

The goal of this work is to reduce the number of Carophyllum trees in our community. The fibres are physically extracted by hand peeling and moulded into a mat shape for shaping purposes, and the material is manufactured according to ASTM specifications. The effect of mesquite fibres can be discovered by combining them with other fibres, such as banana/sisal/glass and epoxy resin, in various compositions. The fibres were assembled in a mould in an alternate pattern before being placed in the universal testing machine. Various tests were performed on the extracted composite materials, including flexural, water absorption, tensile, impact testing and hardness. The matrix composition of the broken tensile material was determined using scanning electron microscopy (SEM) [1]. The core layer is made up of three different weaving patterns: plain, basket, and twill. The face layer is made of tough glass fabric, while the core layer is made of comparatively weak sisal natural fabric. Comparing sandwich composites with woven fabric plain sisal as layer core to composites with twill fabric woven as layer core and basket, researchers discovered that composites with plain woven sisal fabric as core layer have better properties. To better understand the fracture behaviour of sandwich composites, scanning electron microscopes are used to examine the fracture surfaces of tensile and flexural specimens [2]. A fique fibre-reinforced composite and an E-glass fibre-reinforced composite were created. examined in terms of mechanical and dynamic vibratory characteristics. The materials were created utilizing a bioepoxy resin and a vacuum infusion manufacturing process. Tensile tests were used to determine the mechanical properties of each arrangement according to ASTM standards. The composite with E-glass fibre had greater stiffness and strength values, according to the data. The dynamic vibrational investigation was conducted using experimental modal analysis, which yielded highly comparable responses for each material. Scanning electron microscopy was used to examine the interface between the materials, revealing low natural fibre-to-resin adhesion, which affected the fique composite's mechanical and dynamic capabilities compared to the E-glass composite [3]. Experiments were conducted to investigate the mechanical properties and physical of a natural hybrid fibre polymer composite (Epoxy with Hemp fibres, Jute, Sisal, and Banana) with epoxy resin at different percentages of weight (24 and 16). Natural fibres such as jute, banana, sisal, and hemp have been discovered to have good capacity for usage as composite materials reinforcement. The findings of the studies were given in order to estimate various mechanical parameters and physical of hybrid natural composites fibre using fibres (hemp). The tests were performed on a 100 kN servo universal hydraulic machine test (UTM) with the goal of improving properties. According to a thorough investigation, the wt. percent (24) of hybrid natural fibres has better mechanical properties than the other wt. percent (16) of hybrid natural fibres combinations. In addition, a biodegradation oxidative test was performed in accordance with ISO standards [4]. To determine the structural properties of newly identified Pandanus fibre (PF) and coconut bunch fibre (CF) composites made of reinforced epoxy and Al_2O_3 nanoparticles. A manual water treatment procedure was used to remove Pandanus fibre from the stem of a screw pine tree. The fibre from a coconut bunch was removed. The panels were made by compression moulding with different weight percentages and fibre lengths and then compared with (NCF, NPF) and without Al_2O_3 nanoparticles (CF, PF). The composites' tensile, compression, impact energy, hardness, and natural frequency were measured and plotted. When Nano-particles are added to the panel, the result value tends to improve the panel's strength when compared to when Nano-particles are not added. In comparison to the Coconut Bunch fibres, the Pandanus fibre was significantly stronger and more reliable. The majority of businesses is researching natural fibres due to their low cost and ability to be recycled [5]. different composites were created using bagasse, coconut coir dust, and luffa fibre with different reinforcement types (coir dust as particulate reinforcement, bagasse as short fibres, and luffa in mat form). The material parameters (impact strength, flexural strength, and tensile strength) were measured and investigated [6]. The current study focuses on improving the Mechanical properties of a hybrid composite consisting of (woven kevlar29 laminate, woven flax laminate reinforced with epoxy) with and without filler. For varying amounts of aluminium (2.7 percent, 5.4 percent, and 8% by weight), the effect of filler material has been examined. The hand lay-up technique is used to create specimens that meet ASTM requirements. Mechanical properties such as tensile, compression, flexural, toughness, and hardness are investigated through experiments. Due to the incorporation of filler material in natural and synthetic fibre-reinforced hybrid composites, the results obtained from the foregoing experiments are highly encouraging. The mechanical properties of the filler material have been found to increase as the composition of the filler material increases [7,8]. The mechanical properties of natural composites utilise both theoretical and experimental evidence. For tensile strength and tensile modulus evaluation, series and parallel, Halpin-Tsai, Modified Halpin-Tsai, and Hirsch models were utilized. The universal testing machine was used to perform experimental characterization in accordance with ASTM

D638 type-I. The experimental results were compared to the theoretical values of tensile strength and modulus. The highest tensile strength of jute composite at 40% fibre weight was found to be 44 MPa, whereas the minimum tensile strength of coir fibre at 10% fibre weight was determined to be 16.25 MPa [9]. High-performance materials provide an exceptional combination of properties and design possibilities. Its promise rests in Biomedical Application, which has a 25 percent annual growth rate and the fastest demand for engineering and rubber plastics. The advantages of low weight, non-toxicity, abrasion resistance, availability, low cost, and biodegradability are the key reasons for this. Although synthetic fibres have superior mechanical qualities like tensile strength and tensile strength, natural fibres have specific tensile strength and other specific properties (specific properties/weight) based on fibres. When compared to composites, it produces satisfactory results. Biofuels have recently received a lot of interest in the automotive, building, packaging, and medical industries, where environmental sustainability is becoming increasingly crucial. Handcrafted materials are used. High-strength composite materials are used to test the mechanical properties of natural fibre compounds on samples [10]. Cenosphere is a powdery substance produced by thermal power plants burning coal. This industrial waste is rich in ceramics, is readily available, and has the potential to improve the characteristics of composites when used as a filler material. This research looks at the effects of cenosphere as filler material on the mechanical properties of (Hemp/Glass) reinforced (Epoxy Hybrid Composites). Industrial hemp (fibre/fabric), which is created by the bast of the hemp tree, is joined with Glass fibres in this hybrid composite with cenosphere as (a filler material) and epoxy as the (matrix material). To create composite specimens with varying weight fractions, the hand lay-up technique is used. The mechanical properties of composite specimens made according to relevant ASTM standards were examined to determine the influence of cenosphere and glass fabrics in the laminates with Hemp fabrics. The influence of filler material on several of the attributes of hybrid composite samples has been discovered to be greatly amplified. This hybrid composite can be used as a replacement for plastic mudguards in automobiles [11]. The mechanical properties of banana and palmyra fibre reinforced epoxy composites as a function of weight ratio and fibre %. To make hybrid composites with varied fibre percentages, the banana and palmyra fibres were inserted in various weight ratios (1:1, 1:3, and 3:1) and then mixed with the epoxy matrix using a manual lay-up procedure (10, 20, 30, and 40 percent). The following properties are measured and compared: water absorption, density, impact strength, tensile strength, hardness, and flexural strength. According to the findings, adding up to 30% banana and palmyra fibre to the matrix material increased the fibre content by 30%, increases mechanical characteristics and results in a little change in weight ratios. The internal failures and microstructure of the tested material were studied using a scanning electron microscope (SEM) [12]. The mechanical properties of waste natural composite materials as base materials for creating new composite materials. The waste natural composite is pulverized into small particles (sawdust, walnut peels with polyester) (9.5 mm, 4.75 mm, and 2.36 mm). The particles were then blended with polyester (10, 15, and 20 percent mass fraction). The mechanical qualities were investigated using a compression static test. The elastic modulus of polyester increased (improved) when 10% particles from Peels walnuts with 2.36 mm, 4.75 mm, and 9.5 mm were added, the percentages increased by 30.0%, 35.5%, and 40%, respectively, and when 10.0% particles from saws dust were added, the percentages climbed by 40.0%, 30.0%, and 3.0%, respectively [13].

2. Materials and method

2.1. Materials

Polyester is a form of thermal resin that is commonly utilized in the fabrication of composite materials due to its low cost and wide range of applications. Polyester is a transparent liquid substance that was obtained from resin sales centres and mixed as a foundation material with the hardener, which is of the kind of ethyl methyl ketone peroxide, at a ratio of (3 ml) per (100 ml) of resin. The resin and hardener are shown in Figure 1.

Fig. 1. Polyester and hardener

2.2. Eggshells

Eggshells were collected from spent egg waste. Eggshells were washed with water to remove suspended matter and then left in the air to dry. After it is ground by an electric mill, a sieve is used to get the proper size. As shown in Figure 2, cleaning the eggshell in water to get rid of the remaining substances inside the eggs. Figure 2a shows the eggshell after cleaning and air drying. Figure 2b shows eggshell during the filtering after the grinding process and show non-grinded materials. Figure 2c shows the final result of the eggshells after being passed through the washing, grinding and filtering process is shown as a precise powder.

a) b) c)

Fig. 2. Eggs shell: a) after cleaning, b) through filtering, c) powder

2.3. Sawdust

Sawdust was obtained from the carpentry lab. It was ground and filtered to equal particles, as shown in Figure 3. Figure 3a shows sawdust before any process occurs, and Figure 3b – sawdust during the filtering after the grinding process and shows non-grinded materials. Figure 3c presents the final result of sawdust after grinding and filtering as particles.

a) b) c)

Fig. 3. a) Sawdust, b) during filtering, c) particles

2.4. Tools

The mould used in this research is made of glass with dimensions (40 cm x 40 cm x 0.5 cm) covered with a glass plate to obtain a smooth surface of the prepared specimens. as shown in Figure 4a. Volume ratios of natural materials mixed with polyester resin were measured using a graduated glass cylinder (250 ml). as shown in Figure 4b. The volume of polyester resin was measured and mixed with natural materials by using a glass beaker with a volume of (1000 ml) [14].

a) b)

Fig. 4. a) Glass mould, b) glass measurement

3. Specimen preparation

The castings were prepared in a glass mould filled at a volume of (800 ml). The polyester was mixed with the hardener [15], and then the strengthening materials were added to it, namely eggshells and sawdust, each separately, in volume ratios of 30% and 40%. The mixing was done gradually inside the glass beaker; then the materials were poured into a glass mould with dimensions of cm (length 40 × width 40 × thickness 0.5) After covering the mould with an oily substance to prevent the casting from sticking to the mould and easy to extract after the hardening process. Then these castings were used to prepare samples for the purpose of tensile and bending testing [13,16,18].

In preparing sawdust samples, (560 ml) of polyester was mixed with (240 ml) of sawdust, and then (480 ml) of polyester was mixed with (320 ml) of sawdust. Before preparing eggshells samples, the mould size was reduced to provide a sufficient number of eggshells, (350 ml) of polyester was mixed with (150 ml) of eggshells. Finally, (300 ml) of polyester was mixed with (200 ml) of eggshells. Then the castings were cut into tensile samples according to international specifications (ASTM-D638M) with dimensions (190 mm x 19 mm x 5 mm) and bending samples with dimensions (192 mm x 19 mm x 5 mm).

3.1. Samples classification

The samples were classified into five groups, as shown in the Table 1.

3.2. Tensile and bending samples

The tensile and bending samples were manufactured after completing the casting process using a CNC machine, as shown in Figure 5, and half of the samples were treated with water for 15 days.

Table 1.
Samples group

Group No.	Polyester, %	Sawdust, %	Eggshell, %
1	100	0	0
2	70	30	0
3	60	40	0
4	70	0	30
5	60	0	40

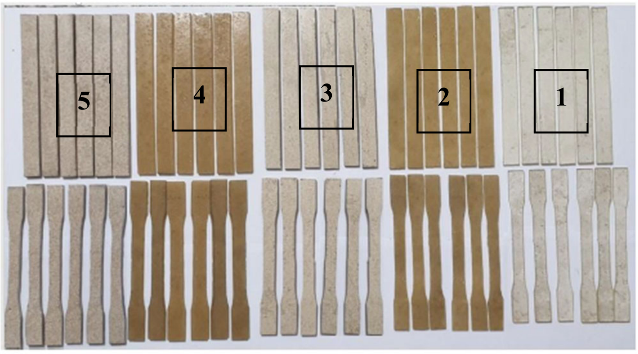

Fig. 5. Bending and tensile samples

4. Experimental works

4.1. Tensile test

Tensile testing is a material science and engineering test in which a sample is subjected to a controlled amount of tension until it breaks. The ultimate tensile strength, maximum elongation, and breaking strength are all determined via a tensile test. The following traits can also be determined using these metrics: Mechanical features include Young's modulus, yield strength, Poisson's ratio, and strain-hardening characteristics, all examples of strain-hardening properties [13]. A universal testing machine (UTM) is used to test the tensile strength of specimens according to ASTM-D638M for tensile testing. (190 mm x 19 mm x 5 mm) is the sample size. This machine features two crossheads, one for adjusting the specimen length and the other for applying tension to the test specimen, as illustrated in Figure 6. To generate the stress-strain diagram and determine the maximum stress and maximum strain, the machine is connected to an output device (computer).

The test is now performed for dry samples; after entering the sample data (dimensions and velocity), each sample is inserted between the handles of the device. When the device is turned on, it begins to apply increasing loads to the sample. The sample load is recorded by the control system and accompanying software and extension throughout the testing period. Figure 6 shows the test of a 100% polyester sample with stress strain after the failure.

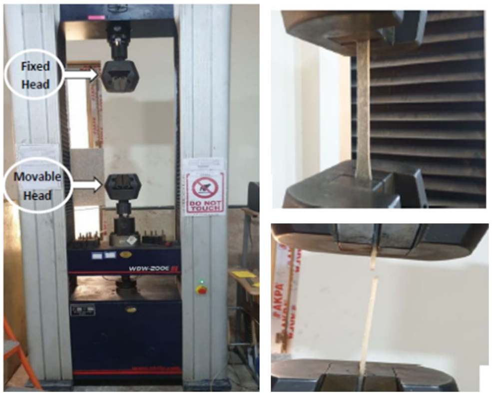

Fig. 6. Tensile machine

4.2. Bending test

In the bending test, the material's modulus of elasticity, flexural strain, flexural stress, and flexural stress-strain response are all important by the three-point bending flexural test. The convex side of the sample or plate is tensioned, and the outer fibres are exposed to maximum stress and strain in a 3-point bend test. Failure occurs when the strain or elongation surpasses the material's limits [14]. The maximum stress applied to the sample is computed using universal testing equipment with a three-point bend fixture and a control panel attached to the instrument. The bending machine with the control panel is shown in Figure 7.

Fig. 7. Bending machine

The test now performed for dry samples; the sample dimensions are (192 mm×19 mm×5 mm) with a distance of

(100 mm) is maintained between the supports, crosshead speed (5 mm/min), and a load of (50 kg). Through the control panel, the maximum stress applied to the sample was recorded, the bending load was not excessive, and no fractures occurred. Figure 7 shows the test of a 100% polyester sample after the bend.

5. Results and discussion

All results obtained from bending and tensile testing are included, as can be seen in Figure 8, Figure 9 and Figure 10 and Table 2. It can be seen that when adding natural fibres to polyester, the tensile stress of polyester decreases, since the addition of fibres reduces the strength of the material to resist tensile stress. Otherwise, it can notice that polyester's resistance to bending stress increases when adding natural fibres, with an increase in the percentage of fibres.

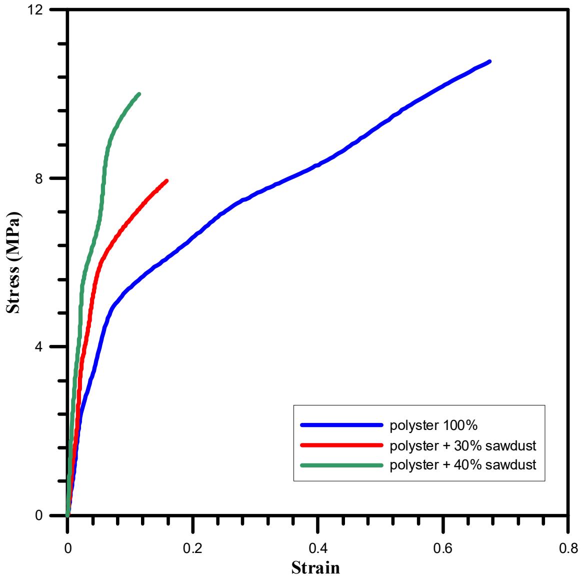

Fig. 8. Stress-strain curve for polyester with sawdust before immersed in water

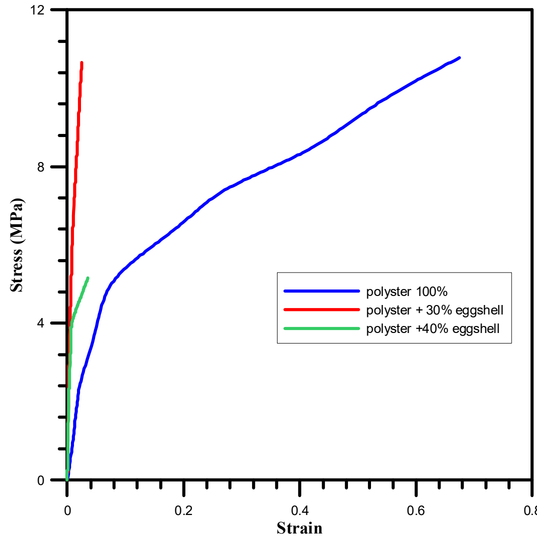

Fig. 9. Stress-strain curve for polyester with eggshell before immersed in water

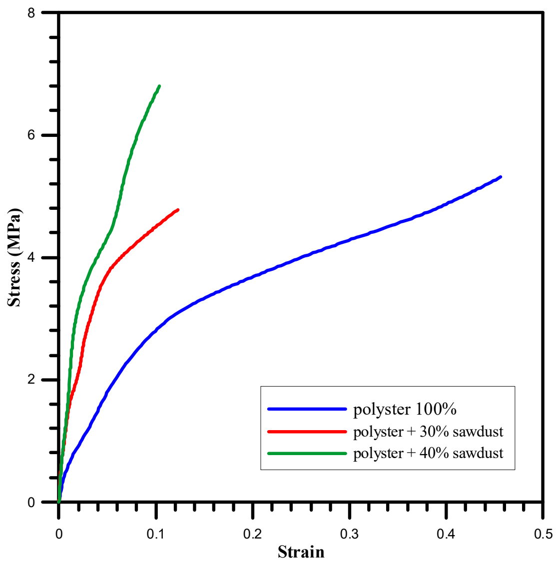

Fig. 10. Stress-strain curve for polyester with sawdust after immersed in water

Table 2.
Maximum bending of stress for a different group of composite materials before and after being immersed in water

Group of composite	Before being immersed in water	After being immersed in water
	Maximum stress, MPa	
Polyester 100% (1)	3.53	5.37
Polyester + 30% sawdust (2)	9.2	4.81
Polyester +40% sawdust (3)	14.41	6.62
Polyester + 30% eggshell (4)	13.8	3.8
Polyester + 40% eggshell (5)	19.16	4.77

On the other hand, the effect of water treatment samples will be clarified, as it was found that when samples were left in water for two weeks, they reduced mechanical properties because water treatment reduced the strength of polyester and the composite. It is due to the action of penetrating water molecules in the compounds, as shown in Figure 11 to Figure 15 and Table 2.

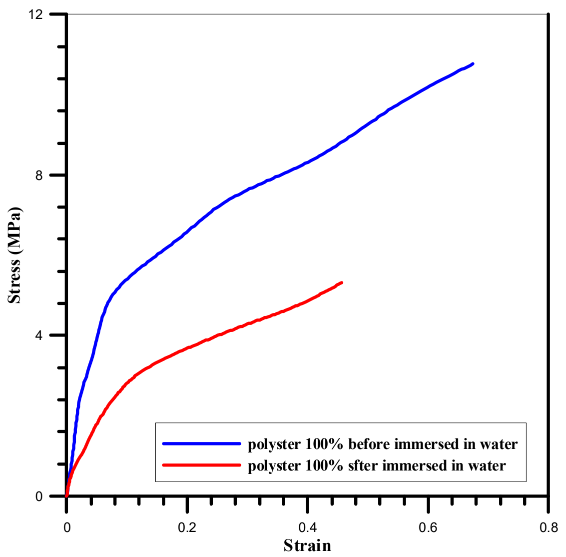

Fig. 11. Stress-strain curve for polyester before and after being immersed in water

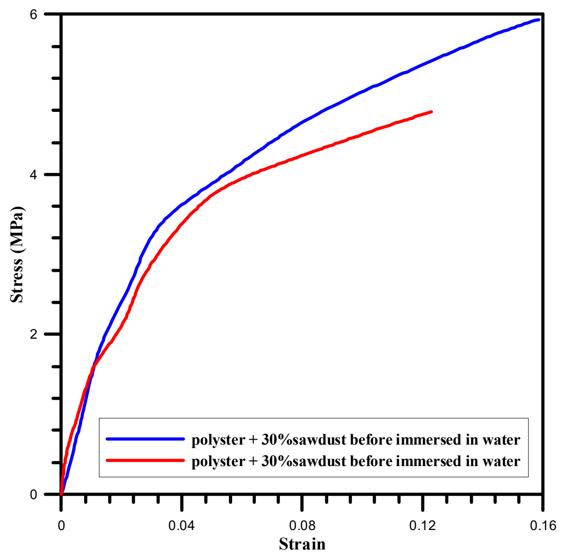

Fig. 12. Stress-strain curve for polyester + 30% sawdust before and after immersion in water

The maximum bending of stress for a different group of composite materials before being immersed in water is shown in Figure 16. The maximum bending of stress for a different group of composite materials after being immersed in water is shown in Figure 17.

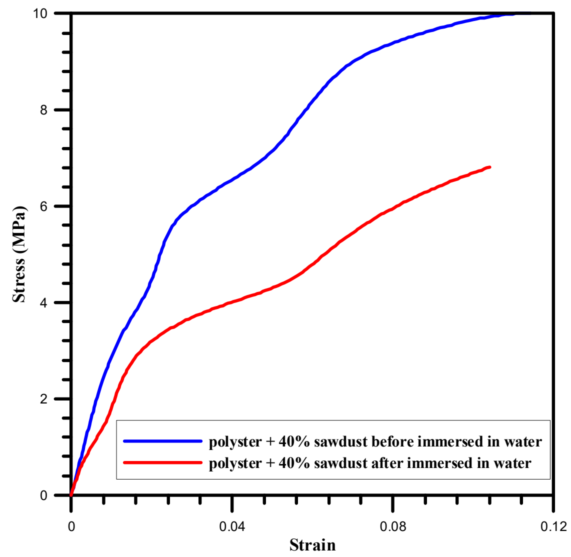

Fig. 13. Stress-strain curve for polyester + 40% sawdust before and after immersion in water

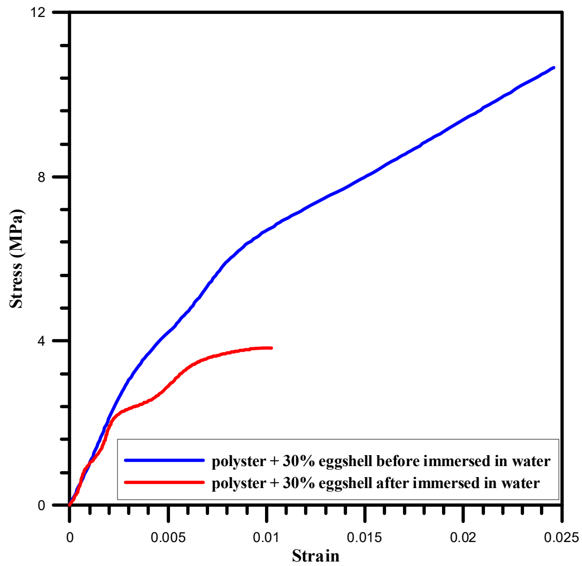

Fig. 14. Stress-strain curve for polyester + 30% eggshell before and after immersed in water

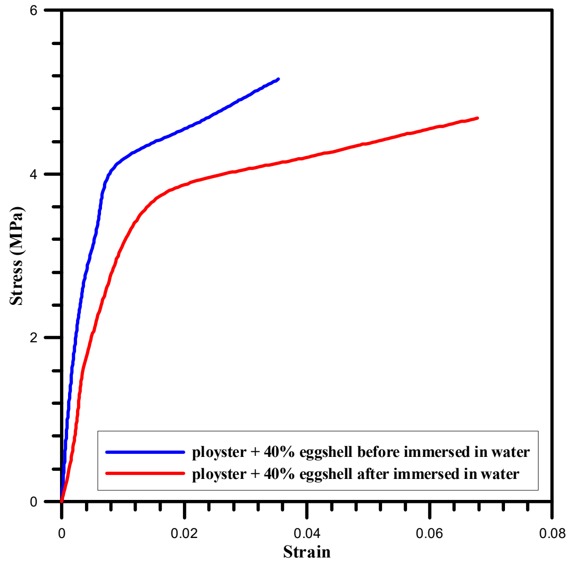

Fig. 15. Stress-strain curve for polyester + 40% eggshell before and after immersion in water

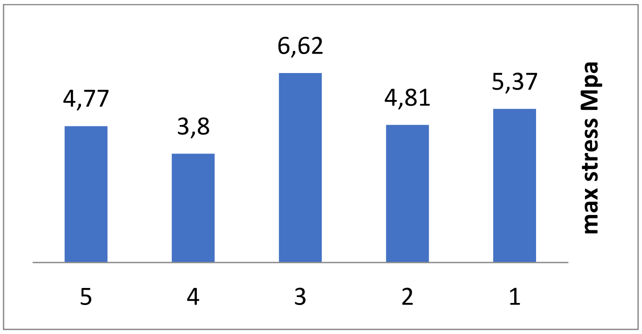

Fig. 16. Maximum bending of stress for a different group of composite materials before immersed in water

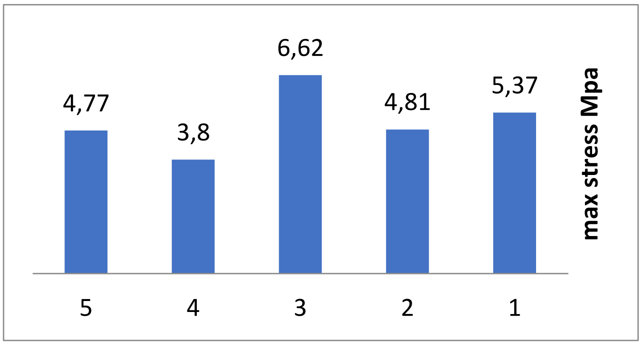

Fig. 17. Maximum bending of stress for a different group of composite materials after immersed in water

6. Conclusions

1. It can be noticed that adding natural fibres by 40% and 30% improved the mechanical properties of polyester in the bending test, where the bending test increased with an increased volume fraction of fibre.
2. It can be noticed that adding natural fibres by 40% and 30% decreased the mechanical properties (tensile strength) of polyester in a tensile test.
3. When treating the natural composite materials with water for 15 days, water decreased the mechanical properties in bending and tensile test.
4. The limitation in this research that was found through the work is that when increasing the weight ratios of the fibres added to polyester leads to the failure of polyester, so we recommend using lower weight ratios of fibre.

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