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JUTE AND COTTON COMPOSITES REINFORCED UNSATURATED POLYESTER

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Abstract: In this study, the effect of adding two different types of reinforcing natural fibers (jute and cotton) singly and in combination as a hybrid to unsaturated polyester resin was investigated. At the first discontinuous random fibers used in (5)mm length are added separately with different weight fraction as (3, 4.5, 6, and 7.5 wt.%) for both types fibers, then these fibers were mixed at (3.75 wt.% jute, 3.75 wt.% cotton) in (5)mm long. and The mechanical tests (hardness, Impact, and compression), as well as moisture absorption, are performed. The results show an increase in these properties with increasing weight fraction of fibers (jute & cotton) and reach the maximum amount at the addition of weight fraction of (7.5 wt.%) of both fibers (jute and cotton) separately. All composite specimens reinforced with jute fibers showed the highest hardness, Impact, compression, and moisture absorption among the composite specimen reinforced by cotton fibers and higher than in combination as a hybrid it was (93.1, 28.81 KJ/m2, 205 Mpa., and 1.4%) respectively.

Keywords: *natural fiber, jute, cotton, unsaturated polyester, polymer matrix composites*

1. Introduction

A composite is made up of two materials, one of which is the reinforcing phase, which is made up of fibers, sheets, or particles, and is embedded in the other materials, which is called as matrix phase. Metal, ceramic, or polymer may be used as reinforcement and matrix materials. The main load-bearing members in composites are usually fiber or particle phases that are stiffer and stronger than the continuous matrix phase. The matrix serves as a load transfer medium between fibers, and in less optimal situations where the loads are complex, the matrix may be required to bear loads that are transverse to the fiber axis. Because the matrix is more ductile than the fibers, it provides toughness for composite [1]. Composites are classified as materials composed of, chemically and physically, two or more phases separated by a featured interface the composites material is becoming a necessary part of the substances of today. They are commonly used in the manufacturing of aircraft frames, electronic medical device packaging, and space vehicles for home building [2]. In composites, each material retains its individual properties, and when combined, their combined properties increase their individual solid properties [3]. Natural resources have taken on greater significance in recent years as a result of the need to protect our natural environment. These environmentally friendly materials are known as eco-materials or biomaterials. The term eco-material refers to material structures that are

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safe for humans and other living things at all times. Natural fiber-reinforced composites are becoming increasingly important, both in terms of engineering applications and research. These natural fibers are 100% renewable, environmentally friendly, have a high specific strength, are non-abrasive, are low in cost, and are biodegradable [4].

Bledzki & Zhang [5] studied the complex mechanical behavior of jute fiber reinforced epoxy foams. The effect of various fibers and microvoid material on shear modulus, frequency, and log decrement was discussed. Experimental results indicated that the fiber content of 42 vol.% the shear modulus increases greatly. The shear modulus and frequency have decreased with the increasing microvoid content in the epoxy matrix. As reinforcement, the jute fiber influences the temperature of the log decrement peak. Increased fiber and microvoid content caused the peak log decrease values to decrease and increase respectively.

Dhakal et al [6] investigated the effect of water absorption on the mechanical properties of UP-reinforced hemp fiber composites. Composite samples containing (0, 10, 15, 21, and 26 percent) fiber volume fractions were prepared. The water absorption test was Performed by soaking the samples at various times in a bath of de-ionized water at 25°C and 100°C. In both aging cases, tensile and flexural properties are checked and compared with samples of drying composites for the water immersed samples exposed. The moisture absorption increased due to higher cellulose content as the volume fraction of the fiber increased. The results showed a decrease in composite samples' flexural and tensile characteristics, as the percentage of moisture increased.

Aziz [7] investigated the mechanical properties of Kevlar-carbon hybrid fiber unsaturated polyester resin. The tensile, flexural, impact, hardness, and strength properties were determined as a woven roving (0°-45°) for composite materials reinforced by hybrid Kevlar-carbon fibers. In various reinforcement percentages (20%, 40%, and 60%), the unsaturated polyester resin was mixed with fibers and the effect on the above mechanical properties was investigated. The results showed that the improvements in the mechanical properties after fiber reinforcement and mechanical property values increased with the increase in the percentage of reinforcement.

Balaji & Senthil Vadivu [8] used the hand lay-up method to prepared various types of composite materials with randomly focused chopped coir and cotton fiber reinforced with unsaturated polyester resin. Measured mechanical properties such as tensile strength, flexural strength, and impact strength for the composite, and to analyze the interfacial properties, internal cracks, and internal structure of the broken surfaces, the Scanning Electron Microscope (SEM) was carried out on the manufactured composite. Compared to other combinations of coir/cotton fiber strengthened with unsaturated polyester, cotton fiber reinforced with unsaturated polyester has stronger mechanical properties and it can become a replacement for plywood and medium-density fiberboards used in packaging applications.

Amuthakkannan et al [9] used a compression molding machine to examine the properties of short basalt fiber reinforced polyester resin composites with varying fiber content (21, 32, 43, 55, 64, 67, 68, 71, wt.%) and varying length (4 mm, 10 mm, 21 mm, and 50 mm). They showed that the length and content of the fiber have a major effect on the mechanical properties of composites. The tensile strength and flexural strength of the Basalt fiber composites at 68% of the fiber content and 10 mm of the fiber length had stronger properties. In all of the percentages of fiber, the impact strength of the 50 mm long reinforced basalt fiber composite displayed the maximum impact energy absorption.

Zamri et al [10] investigated the mechanical properties of jute/glass reinforced polyester in the presence of water. Composites are exposed to a variety of water conditions, and experiments were carried out by soaking composite specimens in three different water environments. This research examined the effects of soaking composite specimens in three different water environments, distilled water, seawater, and acidic water, at room temperature for three weeks, as well as the influence of the various water environments on the flexural and compression characteristics. It was discovered that the jute composite is unsuitable for underwater use.

Siddaramaiah et al [11] investigated the influence on the mechanical, physical, and thermal properties of glass fiber-reinforced epoxy and unsaturated polyester (UP) composites in different aggressive environments (heat, water aging, lubricating oil, fuel, and seawater). They showed that there was a decline in the composite's mechanical properties after exposing them to hostile conditions. Water aging and salt spray have greatly degraded the mechanical properties.

This study aims to achieve the desired properties when combined polymers with natural fibers and used in a structural application. as an example (partitions interior walls, exterior building wall, phone covers, as well as some parts of the automobile like the dashboard, bumper,.. etc.

2. Materials and Experimental Work

2.1 Material used

Unsaturated polyester resin has been used as a matrix material and is a form of thermosetting polymer. Unsaturated polyester is a viscous liquid resin that converts to the solid-state using a curing catalyst (as a PMC preparation), cobalt naphthenate accelerator has been added to the matrix resin at a rate of 0.5 g per 100 g of resin according to the supplying firm. A methyl ethyl ketone peroxide (MEKP) treatment catalyst at a concentration of 2 percent by weight in the matrix. This polyester was supplied by the Turkish Turkuas Polyester Firm (TP100). This resin system was chosen due to its availability and low cost. Table (1) shows the properties of the unsaturated polyester as obtained from this company.

Table 1. Properties of Unsaturated Polyester According To The Product Company.

Density	1.15 – 1.2 (g/cm³)
Viscosity	350-500 cp
Monomer ratio	31 – 36
Sour type	Orthophthalic
Glycol type	Glycol Standard

Two kinds of fibers (jute fibers and cotton fibers) were used in this study as reinforcing materials with weight fraction of (3, 4.5, 6, and 7.5%) and (5) mm length it was added to UP singly and then combined as a hybrid with weight fraction (3.75% and 3.75%). Table (2) shows the properties of (jute and cotton) fibers [12].

Table 2. Properties of Natural Fibers [12]

Fiber	Jute	Cotton
Density (g/cm3)	1.3	1.5-1.6
Elongation (%)	1.5-1.8	7.0-8.0
Tensile strength (Mpa)	393-773	287-597
Young modulus GPa)	26.5	5.5-12.6

3. Preparation Technique

3.1 Mould preparation

The molds of specimens used in the water absorption test and mechanical test are fabricated from silicone rubber, the shape and measurements of all molds are manufactured for each test according to the standard dimensions (ASTM).

3.2 Preparation of Polymer Matrix Composites

Polymer matrix composites (PMCs) were prepared from additives (jute and cotton fibers) filled unsaturated polyester matrix at different weight fraction (3, 4.5, 6, 7.5) wt.%. In the present work, the electric vibrator is used to reducing the void contents inside the molded composites and to ensure the penetration of the base material in all parts of the mold. The steps of samples manufacture can be described as following:

1. The weighting of jute fiber, and cotton fiber according to the required weight fraction (3, 4.5, 6, 7.5) wt.%. of unsaturated polyester resin.
2. Jute fiber and cotton fiber mixed individually and in combination as hybrids with UP resin for approximately (20) minutes continuously and slowly at room temperature to achieve a homogeneous mixture and to prevent bubbling during mixing.
3. Add the hardener (MEKP methyl ethyl ketone peroxide) to the mixture at 2 percent Wt. of unsaturated polyester resin. The mixture is then poured into the mold until it is filled regularly. On an electric vibrator, the mold is mounted. The mixture was left for (24 hours) in a mold at room temperature for solidification.
4. Placed the cast in the drying oven (Post Curing) at 50°C for 2 hours, to complete the polymerization, eradicate residual stresses and achieve the best coherence, this step is very necessary.

4. Mechanical Tests

4.1 Impact Test

Using a pendulum impact testing device (HSM41 Pendulum Impact Tester), made in German the Charpy impact test on unmatched samples was studied. The test is carried out according to the standard ISO-179 [13] with specimen dimensions: length (55 mm), width (10 mm), and height (5mm). Sample dimensions can be calculated from the equation: (A=b*h) where A is the specimen's cross-sectional area. The width and thickness of the sample are b, h. The weight of the hammer used in this study is (2.5) Kg. Hammers with (5 Jules) fracture energy are used. The standard impact specimen is shown in Fig. (1). The impact strength can be calculated by the equation below [14].

$$IS = UC/A \quad (1)$$

Where:

IS: Impact strength (KJ/m2)

UC: Fracture energy (J)

A: Cross-section area (m2)

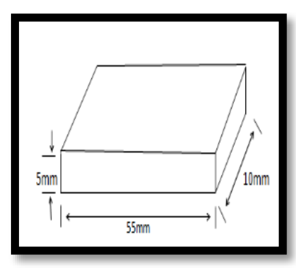

Figure1. Standard Impact Specimen.

4.2 Hardness Test

Hardness is a measure of resistance to surface penetration, as it is a function of stress needed to create certain forms of surface deformation [13]. A Digital Micro Shore D (Durometer)

(QUALITEST HPE) unit (ASTM D2240) was used in this test and is manufactured in the USA [15]. To calculate the average value, seven hardness measurements were made on the specimens at different locations. The standard test sample is shown in figurer (2).

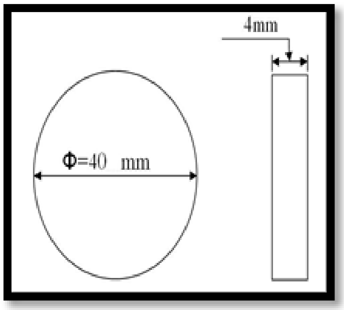

Figure 2. Standard hardness specimen.

4.3 Compression Test

Samples were tested at room temperature according to (ASTM D695-85) [16] with a speed rate of approximately 1 mm/ min. The standard compression specimen is shown in Fig. (3). A universal mechanical testing machine ((Model RH1 5DZ, Tiniusoisen Ltd)) was used to conduct the test. The stress can be calculated using the following equation [17] :

$$\sigma c = Pc / A \qquad (2)$$

Where:

σ_c: Compressive Strength (MPa).

P_c: Compressive load (N).

A: Cross-section Area (m^2).

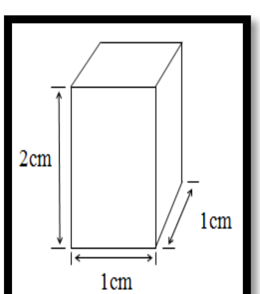

Figure 3. Standard Compression Specimen.

4.4 Water Absorption Test

This test was found according to the ASTM D570-98 [18]. The specimens were soaked at room temperature for 24 hours in distilled water and the weight of the specimens was measured using a sensitive balance with a range of (0.0001g - 200 g). The standard dimensions sample is shown in figure (4). The amount of water absorption (WA percent) is measured by the formula below [19].

$$Water\ Absorption\ \% = \frac{W2-W1}{W1} * 100 \qquad (3)$$

Where:

W1: Weight of sample before immersion (g)

W2: Weight of sample after immersion (g)

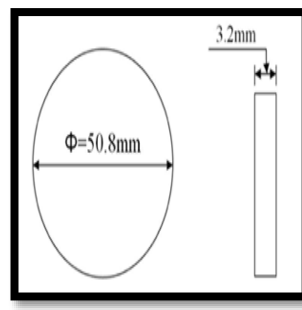

Figure 4. Standard Dimensions Sample.

5. Results and Discussions

5.1 Impact Strength

The material's ability to resist fracture when the load is applied at high speed is referred to as impact strength [20]. Figure (5) shows the relation between the strength of the impact and the weight fraction of the jut and the cotton fibers added to the matrix of the UP. The findings showed that the largest impact strength (28.81 kJ/m2 at 7.5 percent) and (27.35 kJ/m2 at 7.5 percent) for jute and cotton fibers, respectively, as compared to the impact strength of the pure UP (3.1 kJ/m2). The increase in the fiber concentration lead to increases the matrix's ability to absorb energy and thereby increases the toughness so that the strength of impact increases [13]. Because of its tight interfacial bond between the fiber and the matrix, the results obtained show that the fiber can absorb energy. The impact strength of UP + (3.75% wt. jute fiber / 3.75% wt. cotton fiber) (hybrid composites) is shown in Figure (6) where it was (28.32 kJ/m2). Since the jute fiber has high toughness, the jute samples have a higher impact strength value than cotton samples and when hybrids, which suggests a greater force is needed to spread a crack during impact through the interface.

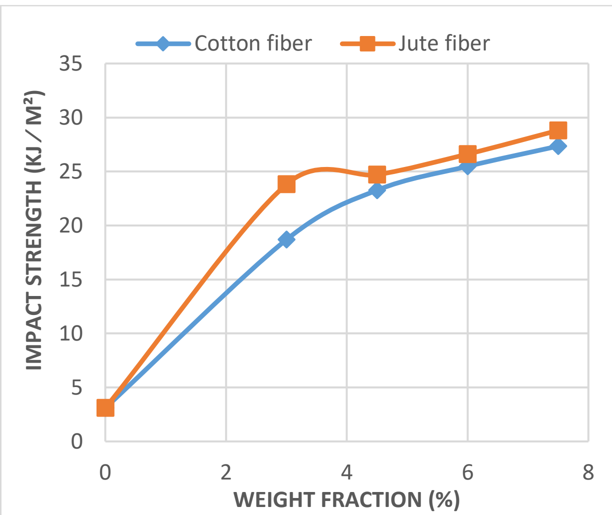

Figure 5. Effect of (Jute and cotton) fibers on the impact strength of unsaturated polyester resin.

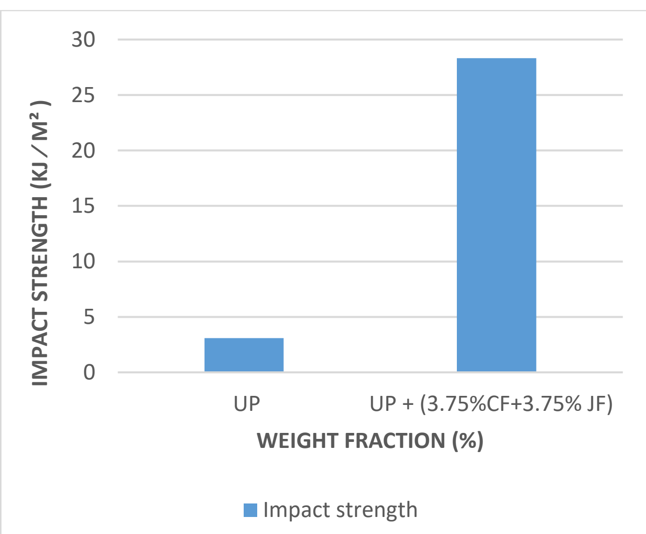

Figure 6. Impact strength of hybrid composites

5.2 Hardness Test

The relation between the hardness shore D and a weight fraction for jute and cotton fibers that are added to the UP matrix are indicated in figure (7). Results show a higher value for hardness shore D is (93.1 at 7.5%), and (87.6 at 7.5%) for jute fiber and cotton fiber respectively, compared to the hardness shore D of the pure (84). Figures (7) illustrate that the hardness increases with increasing the fiber weight fraction of (jute & cotton) fibers. This is because, as compared to the matrix polymer, the composite becomes stiffer and harder due to the rise in fiber content. These fibers also have superior mechanical characteristics, such as hardness, modulus, strength, etc. Therefore, the hardness of the composite increases as additional high strength fibers increase [21]. The hardness shore D of UP + (3.75% wt. jute fiber / 3.75% wt. cotton fiber) (hybrid composites) is shown in Figure (8) where it was (88.7). The samples reinforced with jute fiber gave better hardness results than the samples reinforced with cotton fiber and higher the (jute & cotton) fibers hybrids because jute fibers have higher hardness and elasticity modulus than cotton fibers.

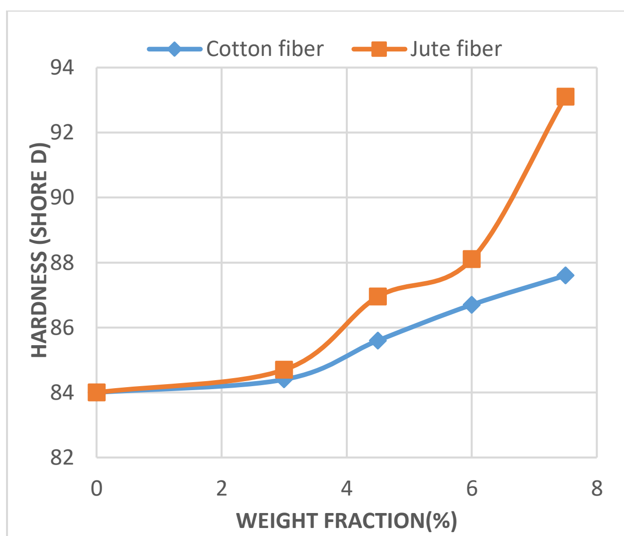

Figure 7. Effect of (jute and cotton) fibers on the hardness shore D of unsaturated polyester resin

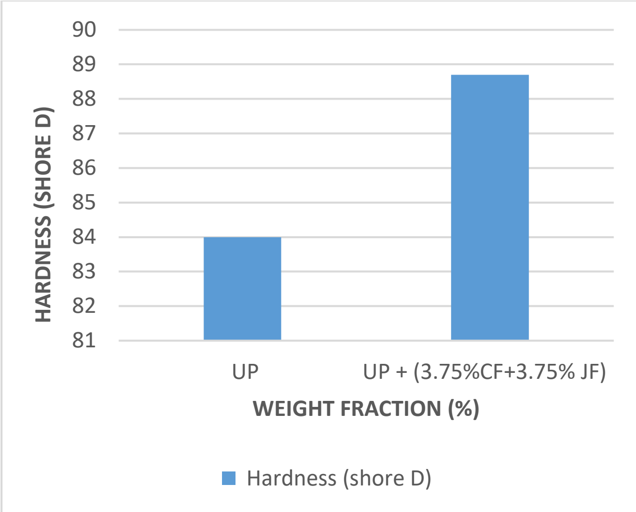

Figure 8. Hardness shore D of hybrid composites

5.3 Compression Test

The relation between the compression strength and a weight fraction of jute and cotton fibers that are added to the UP matrix is indicated in the figure (9). It can be seen from the figure that the compression strength of specimens increases by increasing the weight fraction of two types of fibers, the increase in compression strength is due to the capacity of fibers to reinforce the matrix and improve mechanical bonding between fibers and matrix (UP) that provides better compressive strength by increasing fibers [22]. The compression strength values of pure unsaturated polyester resin are approximately (127.4 MPa) while the higher compression strength values of the composite sample are improved by (jute and cotton) fibers found at 7.5% wt. and reach, respectively (205 MPa & 188 MPa). The compression strength of UP + (3.75% wt. jute fiber / 3.75% wt. cotton fiber) (hybrid composites) is shown in Figure (10) where it was (189.4 MPa). In compression strength, Jute fibers have a better effect this is because jute fibers have good mechanical properties that, compared to cotton fiber lead to given the samples better performance.

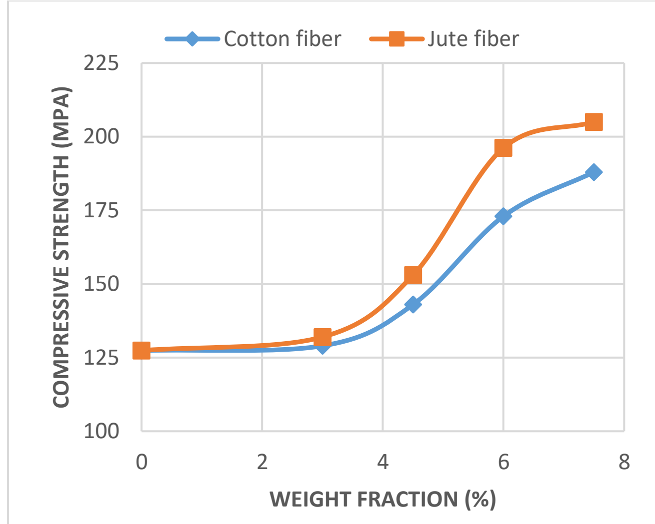

Figure 9. Effect of (jute and cotton) fibers on the compressive strength of unsaturated polyester resin.

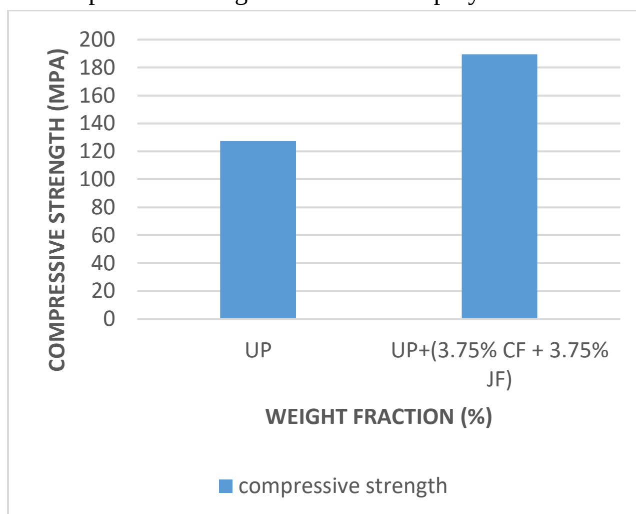

Figure 10. Compressive strength of hybrid composites

5.4 Water absorption

Figure (11) shows the relation between the water absorption and the weight fraction of (jute and cotton) fibers that were added to UP resin after (24 hours). Figures indicate that the absorption of water increases with an increase in the fractional weight of (jute and cotton) fibers. The pure UP specimen has the lower value of water absorption that equal (0.163%), while composite specimen with (jute and cotton) fibers have a higher value that reaches (1.4%) and (0.392%), respectively at the optimum condition of fiber weight (7.5%) after (24 hours). Figure (12) shows The moisture absorption of UP + (3.75% wt. jute fiber / 3.75% wt. cotton fiber) (hybrid composites) where it was (0.408%) after (24 hours). This is due to the fiber's preference for moisture and may also be due to the high degree of moisture absorption in the polymer matrix from natural fibers occurring from the polar hydroxide groups in the fibers [19]

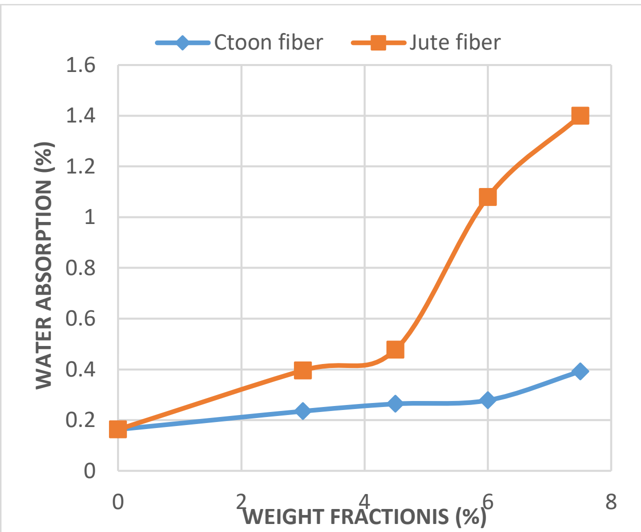

Figure 11. Effect of (jute and cotton) fibers on water absorption of unsaturated polyester resin.

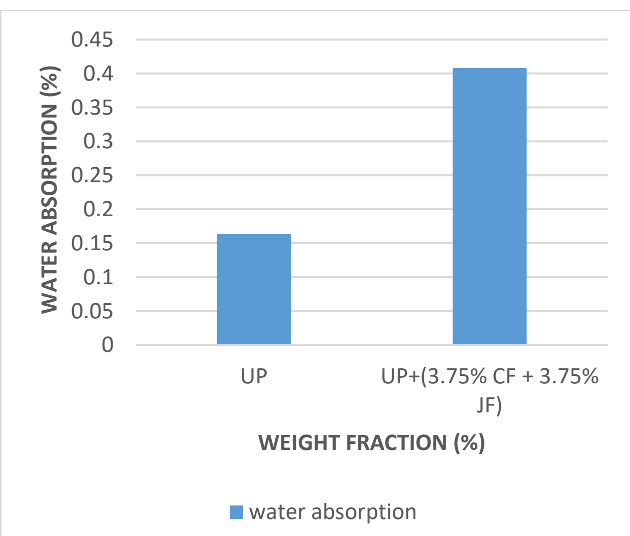

Figure 12. Water absorption of hybrid composites

6. Conclusions

The following conclusions were drawn as a result of the experimental investigations for the composite material that was prepared in this study:

1. The impact strength increases as the weight fraction of both types of fibers increases, the highest value was found in the jute samples (28.81 kJ/m2) and was found at (7.5 wt. %).
2. Hardness increases as the fiber weight fractions of both types of fibers increase, with the maximum value of hardness, was (93.1) for jute samples at (7.5 wt. %).
3. The compression strength of both types of fibers increases with increasing weight a fraction, with the highest value (205 MPa.) for jute specimens obtained at (7.5 wt. %).
4. Water absorption rises as the weight fraction of both types of fibers increases, with the highest value (1.4%) for jute samples obtained at (7.5 wt.%).

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Conflict of interest

The author confirms there are no conflicts of interest in publication of this research.

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