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Mechanical characterization of coir/palmyra waste fiber hybrid composites

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Abstract. In the present days, the utilization of palmyra fiber in automotive and aerospace applications has increased drastically due to its high strength and low weight. This research focuses on the development of composite materials using palmyra waste and coir fiber with polyester as a matrix. The mechanical properties such as tensile, flexural and impact strength of composites were investigated. Palmyra waste fiber and coir fiber with relative varying weight percentage in the ratio of 50:50, 40:60, 30:70 and 20:80 had been considered for the study. The composites were prepared by the compression moulding method. In addition, the prepared composites were subjected to moisture studies for 24 hours, 48 hours and 72 hours to know the composite resistance to water absorption. The results showed an increase in all the mechanical properties from the addition of palmyra waste. After analysing the results obtained from the study, a suitable application in the automobile and aerospace industries is suggested for the new developed composite.

1. Introduction

The utilization of composite materials with two natural fibers as the reinforcement is finding extensive applications in automotive and aerospace industries due to their high strength and better mechanical performance when subjected to various environmental conditions. From the study on the palmyra fruit fiber reinforced with epoxy matrix that was carried out by Narayanan *et al.* [1], it is inferred that the tensile strength and tensile modulus will increase proportionally with the increase in fiber content. The use of coir fiber composites along with polymer composites is due to its high strength, modulus and rigidity as had been analysed and reviewed in detail by Verma *et al.* [2]. It is also reported that the coir fiber reinforced composites have found their applications in packaging, furnitures, etc. The effect of hybridizing oil palm fruit fiber with glass fiber has show a tremendous increase in the mechanical and physical properties as reported by Myrtha Katrina *et al.* [3]. Based on the results, a large increase of about 350% in flexural strength was obtained by the hybrid composites, apart from showing a better resistance in terms of moisture absorption.

Studies on oil palm empty fruit fiber with polypropylene as the matrix, and different manufacturing techniques that provided specific importance to the fiber loading, reported that the tensile and flexural strengths increased for 20% wt [4]. By using hand layup technique, study on mechanical performance of oil palm reinforced epoxy composites was carried out by Mohd Suri *et al.* [5,6], which inferred that the tensile and flexural strengths decreased with the increase in fiber loading. More studies continued on the same combination, with special reference to the hybrid of woven type jute fiber arrangement along with oil palm that provided higher strength [7, 8]. Mohaiman *et al.* [9] performed the hybrid composite studies on the woven kenaf/glass fiber reinforced polyester composites and noted that the reinforcement of kenaf over glass fiber increased the tensile strength and compressive strength. Sanjay *et al.* [10] carried out mechanical properties studies on jute and glass fiber reinforced epoxy matrix and reported that the results were very good in comparison to jute fiber composites alone. Also, the same hybrid composite studies of banana and sisal fiber had been done by Hemant Patel *et al.* [11].

Nonetheless, from the thorough literature study, it can be inferred that no study on the mechanical properties of palmyra waste and coir fiber hybrid composites with weighted ratio method has been carried out before.

2. Experiment details

2.1. Materials

Natural fiber coir and palmyra waste fibers were used as reinforcement. General purpose unsaturated polyester resin, which was most appropriate for indoor and outdoor application, was used as the matrix material in the composite.

2.2. Fabrication of composites

The fiber reinforced composites were been prepared by compression moulding technique. The coir and palmyra waste fibers were cut into two different lengths of 3 cm and 4 cm, respectively, which was the most optimized length obtained from previous studies. The prepared mould was coated initially with a releasing agent (paraffin wax). The general purpose unsaturated polyester resin was taken with 1:1 weight percentage to the fiber used. 1% weight percentage of accelerator (cobalt napthenate) and 1% weight percentage of catalyst (methyl ethyl ketone peroxide) were added to the unsaturated polyester resin. The mixture was then stirred until it became homogenic mixture. After that, the resin was poured over the fibre that was placed on the mould cavity. The fibers were arranged in a random manner with the layering pattern of alternate palmyra waste and coir fiber. A final coat was done after the removal of the excess resin and the mould was then closed with the match die. The mould was later kept in the compression moulding machine at room temperature for four to six hours for curing and finally, the specimen was taken out from the mould.

2.3. Mechanical testing

Tensile test was conducted on the cured composite samples using the universal testing machine with a cross head speed of 2 mm/min according to ASTM D3039. The standard size of specimen for tensile strength test is 250 x 25 x 3 mm. Flexural tests were also conducted on the cured samples using the universal testing machine with a cross head speed of 2 mm/min according to ASTM D790-10. The standard specimen for flexural strength was 127 x 13 x 3 mm. Furthermore, impact tests were done as per ASTM D256-10 using an impact tester. The standard specimen for impact strength was 65 x 13 x 3 mm. For all mechanical tests, five samples were taken and the results were averaged.

3. Results and discussions

3.1. Tensile studies on palmyra waste/coir hybrid composites

Figure 1 shows the tensile strength value of the palmyra waste/coir hybrid composites. The increase in weight percentage increased the tensile strength value slightly in the case of 3 cm fiber length up to the ratio 40:60, but then it started to decrease. Similarly, for the 4 cm length fiber, the maximum strength was observed for the same 40:60 ratio. In other words, the reinforcement of 40%wt palmyra waste and 60%wt coir fiber possesses the highest strength. The reason may be the accommodation of more short fibers created no gap and they also strongly held by the matrix. The same trend was observed from the microscopic studies image shown in Figure 2, in which the fractured surface showed few bunch fibers that were held by the matrix. This gives evidence of a high strength. On the other hand, from Figure 3, the presence of large gap demonstrated the complete failure of the composites, which resulted in a low strength.

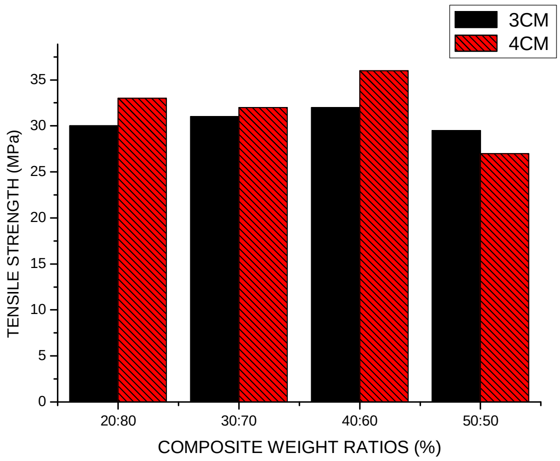

Figure 1. Tensile strength of palmyra waste/coir hybrid composites

Figure 2. Microscopic image (magnification 200MP) of the fractured surface after the tensile test of palmyra waste fiber (40%wt) and coir fiber (60%wt) of fiber length 3 cm hybrid composites

Figure 3. Microscopic image (magnification 200MP) of the fractured surface after the tensile test of palmyra waste fiber (50%wt) and coir fiber (50%wt) of fiber length 4 cm hybrid composites

3.2. Flexural studies on palmyra waste/coir hybrid composites

Figure 4 depicts the flexural strength value of the palmyra waste/coir hybrid composites. A consistent increase in flexural strength can be observed with the increase in fiber percentages for the 4 cm fiber length composites. Overall, the highest flexural strength of 55 MPa was obtained for this 4 cm fiber length hybrid composite. On the other hand, for 3 cm fiber length, there was gradual decrease in the flexural strength with increase in weight percentage ratio up to 60% and 40%. After that, it started to increase slightly. The reason for this irregular trend is due to the short fibers being randomly arranged without proper orientation, which resulted in irregular distribution of fibers. This caused the composite not being able to withstand the bending strength.

From the microscopic images shown in Figure 5, it can be observed that the fibers were arranged one above the other. The shining surface indicated that the matrix flowed over both the fibers and strongly bonded them together, which gave a high strength. The next image in Figure 6 showed the non uniform arrangement of coir and palmyra waste fiber, which led to high fiber-to-fiber interactions and dispersion problems with the increase in weight percentage, resulting in the decreased flexural strength.

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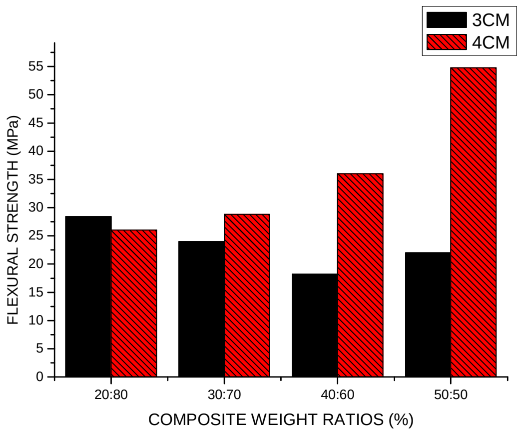

Figure 4. Flexural strength of palmyra waste/coir hybrid composites

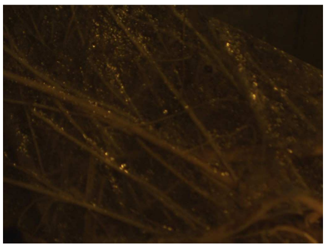

Figure 5. Microscopic image (magnification 200MP) of the fractured surface after the flexural test of palmyra waste fiber (50%wt) and coir fiber (50%wt) of fiber length 4 cm hybrid composites

Figure 6. Microscopic image (magnification 200MP) of the fractured surface after the flexural test of palmyra waste fiber (40%wt) and coir fiber (60%wt) of fiber length 3 cm hybrid composites

3.3. Impact studies on palmyra waste/coir hybrid composites

Figure 7 shows the impact strength value of the palmyra waste/coir hybrid composites. Impact strength is the ability of the composites to absorb energy and withstand the high impact loading. Similar to the flexural strength, the composite combination of 4 cm length and 40:60 ratio possessed the highest impact strength value of 8.5 kJ/cm^2. It is expected that, if more natural fibers are arranged between each other, the composite will have an even higher strength. Since both palmyra waste and coir natural fibers were reinforced, the impact strength was very high for the high weight percentage. However, in the case of 3 cm fiber length, there was a sudden decrease in the 40:60 ratio that might be due to the arrangement pattern of the fibers.

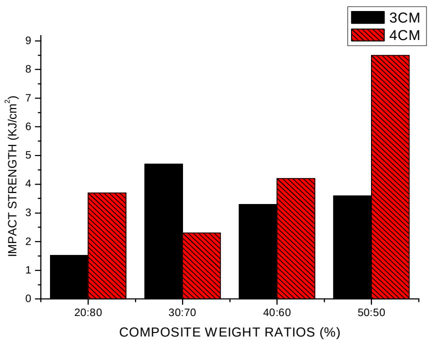

Figure 7. Impact strength of palmyra waste/coir hybrid composites

From the microscopic images shown in Figure 8 and Figure 9, it can be observed that the fibers were strongly bonded together when the matrix was spread over the layers of palmyra as well as coir fibers. These bundles of short fibers had the capability of absorbing more energy, which in terms had also a high load withstanding capability.

Figure 8. Microscopic image (magnification 200MP) of the fractured surface after the impact test of palmyra waste fiber (50%wt) and coir fiber (50%wt) of fiber length 4 cm hybrid composites

Figure 9. Microscopic image (magnification 200MP) of the fractured surface after the flexural test of palmyra waste fiber (30%wt) and coir fiber (70%wt) of fiber length 4 cm hybrid composites

3.4. Moisture studies on palmyra/coir hybrid composites

The moisture absorption studies have been carried out by measuring the weight loss of the composites before and after immersion in both distilled water and salt water. The percentage of water absorbed by the palmyra waste/coir fiber composites is shown in Table 1.

Table 1. Moisture absorption of palmyra waste/coir fiber composites

Sample No.	Fiber Length	Fibers Weight Ratios	Percentage of Water Absorbed					
			Distilled Water			Salt Water		
			24 hrs	48 hrs	72 hrs	24 hrs	48 hrs	72 hrs
1	3 cm	20:80	9	2.0	1.0	6.5	2.5	0.5
2		30:70	11	3.0	0.3	8.5	2.8	0.8
3		40:60	17	3.0	1.0	13.0	3.0	1.0
4		50:50	14	3.0	1.0	13.0	2.7	0.6
5	4 cm	20:80	7.9	2.1	0.4	5.6	2.5	0.5
6		30:70	13	2.3	0.8	9.0	2.6	0.7
7		40:60	15.3	2.6	0.6	11.0	3.0	1.0
8		50:50	12.4	2.1	0.7	10.0	2.8	0.8

Interestingly, it is noted that in all cases, as the day progresses from day 1 to day 3, the percentage of water absorption decreased. This is due to the random orientation of coir and palmyra waste fibers, resulting in the water particulates to occupy the space locations. In addition, based on this observation, the potential of the composites to be used in moisture related applications is well highlighted.

4. Conclusions

In this mechanical performance study on palmyra waste/coir fiber hybrid composites, the composites were successfully fabricated by compression moulding method. Mechanical properties such as tensile, flexural and impact strengths of the palmyra waste fiber filled hybrid composites showed a potential increase in strength by the inclusion of coir fiber. Tensile strength increased by 37% and the impact strength increased by 60% by incorporation of the coir fiber. Among various composite combinations, palmyra waste with 40% weight and coir fiber with 60% weight had the highest tensile, flexural and impact strength properties. Moisture absorption studies were also performed, in which the specimens were placed under water for 24 hours, 48 hours and 72 hours. The same ratio Palmyra waste with 40% weight and coir fiber with 60% weight composite had the highest percentage of water absorption. This type of hybrid composites were suitable for making indoors of aeroplane, aircraft dome, dies, helmets, sports good and also in moisture related applications.

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