

A Study on the Properties of Natural Sandwich Laminates

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Abstract

Objectives: To analyze the characteristic strengths which suits for structural applications on newly developed fiber reinforced laminates. **Methods/Analysis:** Four laminates were processed and prepared by including three types of reinforcements namely, natural, metallic and synthetic fibers at various combinations in polyester matrix resin. The reinforcement composition has been maintained as 30 % by weight and the polymeric resin composition has been maintained at 70 % by weight in all the laminates. The influence of reinforcements on the characteristics has been examined by changing the composition of reinforcements in each laminates. **Findings:** Mechanical strengths of the developed laminates under tension, compression, flexure and impact have been investigated. The work revealed that the pure natural composite is lacking in all characteristic strengths but showed an extended elongation at break. All the characteristic strengths are found to be good when there is an equal composition of natural, metallic and synthetic reinforcement. **Application/Improvement:** Introduction of new composites helps the end users to select an appropriate alternative to conventional materials. This research work aims to develop new hybrid composite with inclusion of natural, metallic and synthetic fibers as reinforcements

Keywords: Metallic Fiber, Mechanical Properties, Natural Fiber, Synthetic Fiber

1. Introduction

Polymer matrix composites are used as structural materials in wide range of industries. Properties of these composites could be tailor made as per the requirements by appropriate inclusions of reinforcements. When a new composite material is made, it is necessary to study its properties. Based on these properties, it would be put in suitable application where it is subjected to several machining operations¹. Mechanical characterization of synthetic reinforcements like glass, carbon and kevlar have been investigated by several researchers in the past. Characterization of natural reinforcements is being the interest of present day researchers as it provides immaculate properties when compared to synthetic reinforcements. A study on the tensile property of chemically modified coir fiber reinforced laminates reported that, increase in the length of fibers increases the tensile strength of the composite². Studies on flax and

glass fiber reinforced epoxy laminates reported that the fatigue performance of flax/epoxy composite is better than flax/glass/epoxy laminates³. In another study, roots of vetiveria zizanioides has been used as reinforcement along with jute and glass in vinyl ester polymericresin. Investigations on the mechanical characters revealed that by appropriate fiber composition, natural reinforcements could serve as a replacement for synthetic reinforcements⁴.

A research work on jute/glass reinforced epoxy laminates reported that the tensile and flexural strength of developed laminates are improved when glass reinforcement is used as extreme top and bottom layers in the laminates⁵. Sisal is an important natural reinforcement which is available in the form of twisted yarns, woven mat and as random fibers. An investigation on sisal reinforced poly lactic acid laminates reported that the water retention and thermal degradation behaviours are improved when sisal reinforcements are pre-treated with sodium hydroxide and hydrogen peroxide⁶. A

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study on the kenaf reinforced polypropylene laminates reported that the addition of kenaf reinforcements in polypropylene polymeric resin enhanced the characters like modulus of elasticity, elongation at break and impact strength⁷. In another research, water absorption and thermal degradation behaviours were studied on vetiver/jute/glass sandwich laminates. The results concluded that, water retention and thermal degradation resistance of pure natural sandwich laminate is better than natural/synthetic fiber sandwich laminates⁸. In a study basalt reinforced epoxy laminates are tested for its bending strength under an acidic medium and reported that the bending strength of developed laminates decreases by time⁹.

A research has been undergone to study the mechanical behaviour of three types of reinforcements namely hay, jute and coir. It has been reported that, the mechanical properties are found to be satisfactory in hay reinforced laminate when compared to that of the jute and coir reinforced laminates¹⁰. Metallic fibers like steel, copper and bronze have been used by very few researchers as reinforcements in polymeric resin¹¹. A research work on steel and glass reinforced polymeric laminates investigated the impact strength and reported that the toughness of the laminates are enhanced due to the inclusion of metallic reinforcement¹². Loofah is a natural reinforcement and is naturally woven with three dimensional cross linking. Due to this cross linking, the strength of the fiber seems to be higher than other common fibers¹³. The present research is aimed to develop four composite laminates by using three types of reinforcements like loofah, steel and glass. The developed laminates are tested for tension, compression, flexure and impact loads and the maximum load bearing capacity of laminates during each test are studied. In addition, the stress-strain behaviour of the laminates and the maximum elongation behaviour is also studied.

2. Experimental Procedures

Natural reinforcement used in the present study namely loofah has the biological name of *Luffacylindrica* and commonly known to be sponge guard. The loofah reinforcement is initially pre-treated by a series of experiments in order to improve its surface properties like bonding strength and also its mechanical strength. The first stage of pre-treatment is washing the reinforcement

in distilled water. This is followed by immersing the reinforcement in 5 % of sodium hydroxide solution for about 3 hours. Then the reinforcement is soaked in 5 % of hydrogen peroxide solution for about one hour¹⁴. During this stage, the unwanted cellulosic substances are removed. Then the reinforcement is washed in distilled water and then it was followed by heating in sunlight for about 6 hours and in furnace at 60°C for about 48 hours. Four sandwich laminates have been prepared by using hand lay-up process with varying proportions of reinforcements. Loofah and steel reinforcements are taken in random form and glass is taken in the form of woven mat. The resin and reinforcement are alternatively placed one over the other to make the sample with a thickness of 12 mm. The size of each laminate has been maintained at 500 mm x 500 mm. Methyl ethyl ketone peroxide is used as catalyst and cobalt naphtheate is used as an accelerator during the preparation of laminates¹⁵. The reinforcement composition in laminates and matrix are presented in Table 1. Out of the four laminates, first laminate is prepared with only loofah reinforcement and it was named as L. The second laminate is prepared with loofah and steel reinforcements and it is named as LS. The third laminate is prepared with loofah and glass reinforcements and it is named as LG. The fourth laminate is prepared with equal composition of loofah, steel and glass reinforcements and it is named as LSG.

Table 1. Composition of Laminates

Sample Number	Loofah Wt %	Steel Wt %	Glass Wt %	Polyester Resin Wt %
L	30	0	0	70
LS	20	10	0	70
LG	20	0	10	70
LSG	10	10	10	70

Mechanical properties are tested on the developed samples by conducting tension, compression, flexural and impact tests. The laminates are cut according to the ASTM standard dimensions for testing. Tensile and compression test are done on Instron make universal testing machine as per ASTM D638 and ASTM D695 standards respectively. During tension testing, the sample has been cut in the shape of a dog bone and during compression testing; samples have been cut in the shape of square blocks. Flexural strength is measured by conducting a three point bending test as per ASTM D790 standard and during this

test, the samples have been cut in the shape of rectangular bars. Charpy impact test is used to measure the impact strength of composites as per ASTM D256 standard and during this test, a 45° notch is created on the sample. For each test, three samples are cut on a laminate and all three samples are tested and readings are noted. The average of three readings has been taken as the strength of the corresponding laminate.

3. Results and Discussions

3.1 Tension Test Analysis

The tensile strength of all laminates is shown in Figure 1. A maximum tensile strength of 52 MPa is observed with laminate LSG which is followed by laminates LS and LG. A lowest tensile strength of 35 MPa is observed in laminate L. This shows that pure natural laminate is not suitable to bear high tensile loads. A 10 % inclusion of steel reinforcement enhanced the tensile strength by 17 % and a 10 % inclusion of glass reinforcement enhanced the tensile strength by 9 %. This shows that steel reinforcement is better than glass reinforcement considering tensile strength. When there is an equal composition of loofah, steel and glass reinforcement, tensile strength is improved by 49 %. Hence, laminate LSG is suitable to bear high tensile load and this shows that, when multiple reinforcements are used in a laminate, the tensile strength has been improved¹⁶.

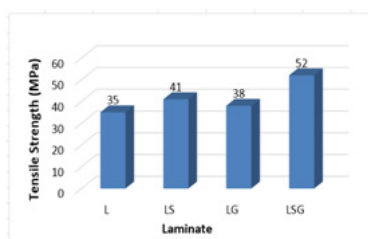


Figure 1. Tensile strength plot.

3.2 Compression Test Analysis

The compression strength of all laminates are presented in Figure 2. A maximum compressive strength of 82 MPa is observed in laminate LSG which is followed by laminates LG and LS. A lowest tensile strength of 66 MPa is observed in laminate L. This shows that pure natural laminate is not suitable to bear high compressive loads. A 10 % inclusion of steel reinforcement enhanced the tensile strength by 8 % and a 10 % inclusion of glass reinforcement enhanced the tensile strength by 15 %.

This shows that glass reinforcement is better than steel reinforcement to bear high compressive loads. When there is an equal composition of loofah, steel and glass reinforcement, compressive strength is improved by 24 %. Hence, laminate LSG is suitable to bear high compressive load and this shows that, when multiple reinforcements are used in a laminate, the compressive strength shows substantial improvement.

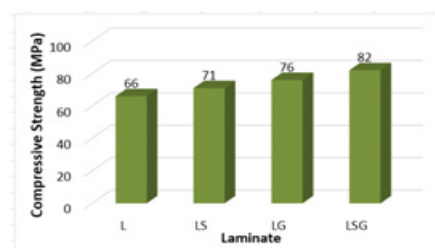


Figure 2. Compressive strength plot.

3.3 Flexural Test Analysis

Flexural strength is the resistance generated by the laminate when it is subjected to bending load. This is tested by conducting a three point bending test. The flexural strength of all laminates is presented in Figure 3. A maximum flexural strength of 223 MPa is shown by laminate LSG and this is followed by laminates LS and LG. A least flexural strength of 181 MPa is shown by laminate L. This shows that pure natural laminate is not suitable to bear high flexural loads. A 10 % inclusion of steel reinforcement enhanced the tensile strength by 12 % and a 10 % inclusion of glass reinforcement enhanced the tensile strength by 8 %. This shows that steel reinforcement is better than glass reinforcement to bear high flexural loads and this behaviour is quite similar to that of tensile behaviour of the laminates. When there is an equal composition of loofah, steel and glass reinforcement, flexural strength is improved by 23 % which is nearly equal to the compression behaviour. Hence, laminate LSG is suitable to bear high flexural load and this shows that, when sandwich laminates containing more than two layers improves the flexural strength considerably¹⁷.

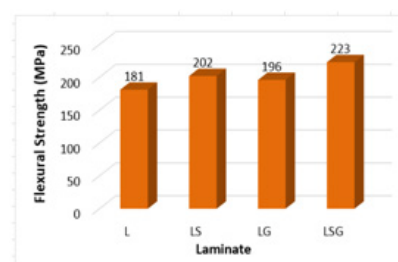


Figure 3. Flexural strength plot.

3.4 Impact Test Analysis

Impact strength is the energy absorbed by the laminate during fracture. It is otherwise called as toughness of the laminate. The impact strength of laminates is presented in Figure 4. Maximum impact energy of 28J is observed in laminate LSG which is followed by laminates LG and LS. This sequence is similar to that of the compressive strengths of the laminates. Lowest impact energy of 16 J is observed in laminate L. This shows that pure natural laminate is not suitable to bear high impact loads. A 10 % inclusion of steel reinforcement enhanced the tensile strength by 25 % and a 10 % inclusion of glass reinforcement enhanced the tensile strength by 50 %. This shows that glass reinforcement is better than steel reinforcement to bear high impact loads. Similar results have been reported in the earlier researches and confirm that the presence of glass reinforcement is very important to achieve good impact properties¹⁸. When there is an equal composition of loofah, steel and glass reinforcement, impact strength is improved by 75 %. Hence, laminate LSG is suitable to bear high impact load and this shows that, when multiple reinforcements are used in a laminate, the impact strength shows substantial improvement.

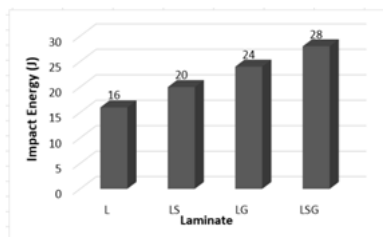


Figure 4. Impact strength plot.

3.5 Stress-Strain Analysis

The stress-strain plot of the tested laminates is shown in Figure 5. The curves of all laminates may be divided in to low strain region until 1.5 % of strain and high strain region after this value. It is clearly visible in the low strain region that all curves are linear and hence the stresses are proportional to strain. In the high strain region, all laminates shows non-linear increase of stress for increase in strain. This is called the plastic behaviour which is due to plastic deformation of the polymer matrix. Due to this plastic deformation, micro-cracks are formed in the matrix. These micro-cracks propagates as load increases and hence the bonding between the reinforcement and matrix decreases. Once the bonding strength approaches

zero, the stress decreases and this is followed by breaking.

The stress-strain curve of laminates LG and LSG almost show brittle behaviour. This brittle behaviour may be due to the presence of 10 % of glass reinforcement. The stress-strain curve of L and LS increases until their maximum tensile stress value and then decreases slightly before breaking. This shows that, behaviour of loofah and steel reinforcement are almost similar within their stress limit. The strain at break of laminates is presented in Figure 6. A maximum elongation of 8 % is shown by laminate L. This is followed by laminate LS and LSG. A least elongation of 6 % is shown by sample LG. The maximum elongation of laminate L shows that, loofah reinforcement extends much more before breaking due to three dimensional cross-linking. A low elongation of laminate LG and LSG shows that the brittle behaviour of glass reinforcement has much influence on the laminates and hence breaks at low strain.

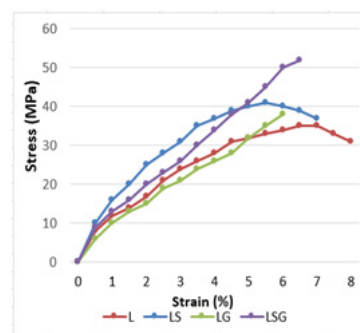


Figure 5. Stress-strain plot.

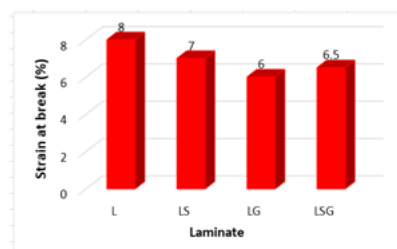


Figure 6. Strain plot.

4. Micro-Graphical Study

The micro-graphical images have been captured on the tensile fractured surface of the laminates by using Scanning Electron Microscope (SEM). The micrograph of laminate as presented in Figure 7 shows more pull outs of loofah reinforcement and there are clear visibility of cracks in the matrix. There seems to be good bonding between

the loofah and matrix which is because of the chemical pre-treatment given to the loofah reinforcement. This bonding helped the laminate to extend to a maximum of 8 % before breaking. The micrograph of laminate LS as presented in Figure 8, shows less pull out of steel reinforcement when compared to glass as seen in Figure 9. There is clear visibility of matrix breaking as seen in LS. The micrograph of laminate LG presents poor bonding between the reinforcement and the matrix. Also, there is clear visibility of glass pull outs and cavities spread all over. These reasons made the laminate LG to fail earlier than laminate LS. The micrograph of laminate LSG as presented in Figure 10 shows uniform distribution of resin and there are less pull outs of reinforcements. There seems to be proper bonding between the reinforcement and the matrix. These reasons made the laminate LSG to withstand higher tensile load when compared to remaining laminates.

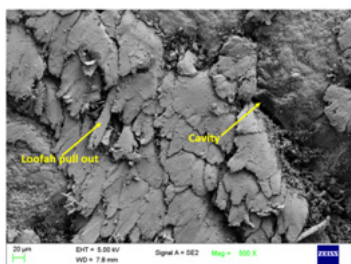


Figure 7. SEM image of sample L.

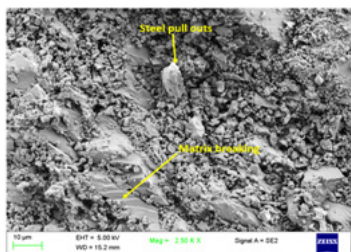


Figure 8. SEM image of sample LS.

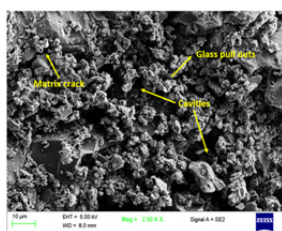


Figure 9. SEM image of sample LG.

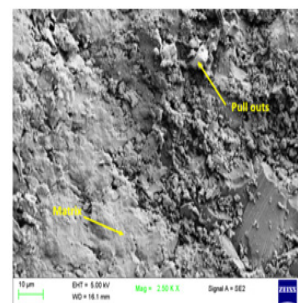


Figure 10. SEM image of sample LSG.

5. Conclusion

This research investigated the properties of composite laminates with natural, metallic and synthetic reinforcements. Tensile strength and flexural strength of laminate LS is better than laminates L and LG. Compressive strength and impact strength of laminate LG is better than laminates L and LS. All the mechanical strengths are higher in laminate LSG. This shows that, when there is an equal composition of natural, metallic and synthetic reinforcement, there is a considerable increase in mechanical strengths. The analysis also showed that the inclusion of fibers in sandwich form improved the strengths of the laminate. Although pure natural laminate L showed low mechanical strengths, it was good in elongation. Hence by using appropriate composition of natural, metallic and synthetic fibers, mechanical properties of composite laminates could tailor made for any suitable applications.

6. References

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