Investigating Mechanical Properties of Hybrid Polymer Composite Reinforced with S-Glass and Luffa Fibres

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Abstract. The mix of two different type of fibres, one is natural and another one is synthetic fibres were employed as reinforcing media in this study, and epoxy based polymer resin was employed as the matrix phase. S-glass and luffa fibres had been bonded with epoxy matrix to create a novel composite by compression moulding and to measure the effect of this hybridization in composite laminate utilising five different sequencing. To determine the mechanical characteristics of this composite material using tensile, flexural, and compression strength, a specimen named 'SL4' had shown the highest mechanical strength, resulting in a tensile properties of 253 MPa, compression strength of 234 MPa, and flexural characteristics of 237 MPa. The increment in mechanical characteristics is found to exhibiting around 20% increase comparing to the specimen having next higher value in all the properties. The results evidenced that the presence of luffa fibre layers at the interior most portion of the composite displayed the progressive values in all the investigated mechanical characteristics.

Keywords: S-Glass; luffa; composite; mechanical properties; hybrid composite.

1. Introduction
In a prepared composite material, the mix of natural and synthetic fibres can result in distinct physical and chemical characteristics. These one-of-a-kind characteristics help to boost product efficiency while lowering environmental impact [1, 2]. Natural or synthetic composites can be made separately with the corresponding fibres. A typical composite is wood, which is made up of cellulose (wood fibres) and lignin. Lignin is an ordinary pasty material that would help in binding the fibres and further, it would strengthen wood [3, 4]. Engineers create several composites in different composition of fibre and matrix material. However, the use of natural fibres along with the artificially created fibres can enhance the mechanical characteristics of the polymer based composites, significantly [5, 6].

Outside factors would almost certainly affect the loading of designed structures, and this can be expected to happen during maintenance, assembly, and administration tasks [7, 8]. One of the major unknowns in matrix polymer composites is impact resistance. Composites are extremely sensitive to
loading; as a result, following this type of stacking, they are seriously injured, and their mechanical qualities are reduced. The term "hybrid" refers to the process of merging two or more types of fibres within the polymer matrix composite with the intended properties [9, 10]. Hybridized composites are manufactured by combining the extremely different kind of fibres. High modulus fibers, such as graphite, have an exceptionally great S/W ratio, but their inherent quality is typically viewed as fairly low contrasted with standard steel and aluminium alloys, as well as with glass fibre reinforced composites [11, 12]. As a result, using natural fibres alone in a polymer matrix is insufficient to meet all of the particular demands of a fiber-reinforced composite. To create an unrivaled, but practical composite, a natural fibre may be amalgamated with a man-made synthetic fibre in a comparable matrix material to take use of the synergetic qualities of utilized fibres. It would help to produce a distinct kind of hybrid fibre composite [13]. In comparison to other synthetic strands, glass fibre is the most well-known designed fibre used in these composite samples because of its convenience and ease of accessibility [14, 15]. For most materials, graphs of power against elongation provide the underlying protection against power or modulus, as well as the total it reaches before breaking. Examining elasticity curves may reveal a lot about the material being tested and it can even help to predict how it will behave. It is commonly measured in terms of stress [16, 17]. It has become a crucial concept in design, especially in the researches including mechanical testing of materials. The specific indentation, which has been dislodged from testing equipment under a specific load, is used in hardness testing strategies. Stand time was frequently used to describe space. The term "large scale hardness" refers to testing with a load of greater than 10 N. For tiny sample quantities, plated surface, or thin films, microhardness test with stresses ≤ 10 N is often used [18].

Composite reinforced with plant fibres, particularly flax fibre reinforced polymers, are particularly fascinating (FFRP). To explore the mechanical characteristics of the composites made-up of banana and E-Glass, a vacuum packing process was developed. Elasticity, flexural properties, swaying quality, and hardness are the mechanical qualities that are evaluated [19]. Glass–jute fibre reinforced polymer composites have been tested for mechanical qualities [20]. In the earlier studies, the glass-jute combination of hybridized composites were prepared and tested for their mechanical ability. The results were surprising that the hybridization enhanced the mechanical characteristics to a greater extent. SEM was used to thoroughly examine cracked surfaces in order to determine the atomic crack pattern [21]. The consequences showed that by uniting the right amount of jute yarns, the inclusive feature of the glass fibre reinforced hybridized composites could have been improved, and price savings more than 25% could have been achieved. As a result, it's reasonable to conclude that hybridization might be a particularly promising solution to obtain the greater strength of the materials, predominantly for the partial changeover of more expensive glass fibres in light weight holding applications [22]. As equivalent mass percentage of banyan tree fibres and neem tree fibres were utilized, the water intake as well as hardness values had been improved. However, the water absorbing capability was found to be meager compared to the measured hardness of the hybridized composites. The literatures were strongly proved that the hybridization of two extremely different natures of the fibre materials within the polymer matrix would help to produce the hybrid composite, which would possess the greater mechanical characteristics. The research problem was identified as a result from the above details well about composite material; in this work, the mixture of luffa fibre (natural) and S-glass (synthetic) fibres were experimented as the reinforcement with epoxy based matrix to investigate the influence of such combination with the differing straums of fibre series on the mechanical properties of the hybrid composite material.

2. Materials and Methods

2.1. Materials used
The S-glass is a synthetic fibre, and luffa is a natural fibre, both of which were obtained from the local suppliers to prepare the hybrid composite of high mechanical qualities. The epoxy and the hardener were purchased from the local market, which was the intended matrix material for the composite. The
S-glass fibre was procured in the form of a fabric, whereas the luffa fibre was cut into mats to fabricate the composites.

2.2. Experimental
In this present investigation, hybrid fibre (containing equal quantity of luffa and S-glass) of 40% and the epoxy matrix of 60% had been selected as the composition of the composite material preparation. The composite plates were fabricated using the compression molding machine as shown in the Figure 1.

![Compression moulding machine](image)

**Figure 1.** Compression moulding machine employed in the work.

The fibres and the matrix were poured inside the molding box in the required sequence after applying the releasing agent. After the arrangement of the fibres and the epoxy, the compression machine was loaded hydraulically. The plates were taken after the required period of time from the mold box and cut into the pieces of pre-determined dimensions for the purpose of conducting different mechanical testing. The fixed quantity of epoxy was used in the composite samples. The ratio of S-glass as well as luffa fibres was varied from 4:0 to 0:4. The sequence of fibre and matrix for the different samples are presented in Table 1.

| Sample | Order of loading |
|--------|------------------|
| SL1    | S-S-S-S          |
| SL2    | L-S-S-L          |
| SL3    | S-S-L-L          |
| SL4    | S-L-L-S          |
| SL5    | L-L-L-L          |
2.3. Mechanical testing
The tensile testing is done on the composite material according to ASTM 638 standard at ambient temperatures with a slow loading rate (1 mm/min), and compression test is performed on the composite material according to ASTM 3410 standard using same parameters as the tensile test [23]. The universal testing machine was employed to conduct both the testing procedures with the five different composite samples. For the each test, three samples from each composition were tested and the mean values were taken for the analysis.

The flexural test samples, which were made from a hybrid composite, had been prepared according to ASTM Standard D790-03. The each specimen measured 127 mm x 12.7 mm x 5 mm in size. The flexural test was carried out utilizing the Lloyd instrument LR 100 kN at 32°C and 60% relative humidity. The beam moved at a speed of 2 millimetres per minute. The flexural strength and flexural loads were measured when the material was loaded till the core fractured. The flexural modulus values were calculated [24]. Three samples were examined for each composition, and the average values were given.

3. Results and discussion

3.1. Strength of hybrid Epoxy Composite
Figure 2 shows the tensile strength of epoxy composite with different arrangement of S-glass/luffa fibres. According to the results of this tensile test, the arrangement fibres influence strongly over the strength of the composite. The tensile strength of the samples SL1, SL2, SL3, SL4 and SL5 had been determined as 212 MPa, 193 MPa, 166 MPa, 253 MPa, and 108 MPa, respectively. The lowest strength was recorded with the presence of luffa fibres in all layers (SL5). The utilization of the S-glass fibre in all the layers of the composite (absence of luffa) had shown the decent tensile strength. Further, the application of luffa at the outermost layer showed the greater decrement in the tensile characteristics of the composite. Surprisingly, the application of luffa layers sandwiched between the S-glass (SL4) had shown the better improvement in tensile strength comparing to other samples. The SL4 sample had shown 19.34% enhancement in tensile strength comparing to the composite with the single S-glass fibre (SL1).

![Figure 2. Tensile characteristics of the S-glass/luffa hybrid polymer composite.](image)

3.2. Compressive characteristics of epoxy hybrid composite
The compressive strength of hybrid laminated composites had been determined for the five different specimens of S-glass/luffa composite laminates and presented in Figure 3. The compression strength of the samples SL1, SL2, SL3, SL4 and SL5 had been identified as 189 MPa, 171 MPa, 143 MPa, 234 MPa, and 101 MPa, respectively. When the layer of S-glass fibre is increased, the compressive strength of the hybrid composite increases, and the compression strength is having more inclination to
the stacking sequence. The minimum value of compressive strength was noted with the absence of S-glass fibres in all layers (SL5). The sample containing S-glass in layers is showing the good value of the compression characteristics. Similar to the case of tensile strength, the hybrid sample with presence of luffa at the farthest stratum displayed the larger slope in the compressive characteristics. Astoundingly, the sample SL4 containing the luffa layers inserted between the S-glass had publicized the superior enhancement in compressive strength comparing to any other samples. In this way, the SL4 sample had displayed 23.81% augmentation in compressive strength comparing to the sample SL1.

![Figure 3. Compressive characteristics of the S-glass/luffa hybrid polymer composite.](image)

3.3. *Flexural characteristics of epoxy hybrid composite*

The three-point bending test was used to determine the flexural strength of this composite material, which was determined for the different stack sequence effect of S-glass/luffa fibres and the progressive force put on the direct contact of components. During this test, the flexural strength of the

![Figure 4. Flexural characteristics of the S-glass/luffa hybrid polymer composite.](image)
composite material was determined for a 3 mm deflection. Figure 4 exhibits the flexural values of the different samples, which were determined as 202 MPa, 180 MPa, 151 MPa, 237 MPa, and 103 MPa, respectively for the samples SL1, SL2, SL3, SL4 and SL5. As like other two cases, the sample SL4 containing luffa fibres at the interior layers had exhibited the better flexural value comparing to the sample with S-glass fibre layers alone (SL1), and the improvement was noted as 17.33%.

4. Conclusion
The hybrid polymer composite plates were prepared by stacking five different sequences of S-glass/luffa fibres within the epoxy resin based polymer matrix using the compression moulding machine. The effect of sequence of the fibres had been investigated. The results proved that the stacking sequences are having a strong impact on the mechanical characteristics of the hybridized composite samples. Particularly, the sample SL4 exhibited the better mechanical characteristics, which contains the luffa fibre layers at the innermost part of the composites, comparing to any other combinations. The enhancement in tensile, compressive and flexural characteristics of the composite was determined as 19.34%, 23.81%, and 17.33%, respectively comparing to the SL1, which possessed next higher values in all the properties. Hence, it can be ascertained that the stacking sequence of the fibres are having a strong influence over the mechanical characteristics, when S-glass/luffa fibres are used in the epoxy based hybrid polymer composites.

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