Flexural and Inter- Laminar Shear Strength of Glass/ Carbon Fabric Reinforced Composite

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Abstract. Polymer composites are reinforced with synthetic fibres like aramid, glass and carbon give more benefits like advantages of low in weight, higher stiffness and greater strength, because of this polymer composite are widely used. This research is aimed to estimate the FS and ILSS of glass fabric and carbon fabric composite. In this recent study, the effects of fabric laminate sequence of glass fabric and carbon fabric have been investigated by the test namely Short beam shear (SBS) test. SEM evaluations are carried out to study the mechanism of failure. The laminates were fabricated by the hand lay-up method. The fabrication and also the evaluation of specimen are according to the standards’ of ASTM. Here the results indicates the ILSS & FS values are greater for carbon fabric reinforced composite when compared to glass fabric reinforced composite.

1. Introduction
Polymer matrix composites are most commonly used. Generally, the mechanical properties of polymer composite are not enough for some structural applications. When compared to ceramics and metals polymer matrix composites are having low stiffness and strength. To avoid this problem polymer composites are reinforced with other composite materials. The fabrication of polymer composite needn’t absorb air mass and do not need extreme temperatures and also the equipment needed for fabrication of polymer composites is easier. For these reasons, polymer composites developed quickly became most popular for structural usage.

There are a few examinations have been researched to find out the ILSS and FS of laminated composite. In this we are demonstrating different examinations. Sabeel Ahmed et al. [1] have investigated the impact of fiber orientation/stacking sequence on ILSS, FS and tensile behaviour of glass polyester/texture and jute hybridized composite laminate. The flexural and SBS examination is very much characterized by standards of ASTM D790 and D2344 are generally employed technique to characterize the FS and ILSS of prepared polymer composite. As this procedures require simple setup and easy to manufacture the sample [2-3]. Davies I J et al. [4] Find out the FS of carbon fiber and silicon carbide (SiC) one directional fiber strengthened polymer composite; it’s has a combination of carbon fibers and SiC with various spans and depth proportions. After the test, results indicate the FS of SiC or CFRP composite is less when compared to hybrid composites. There are a few examinations to develop the mechanical behaviour of hybridized composite [5-14]. However, the FS of the composite laminate is affected by tensile stress and shear stress. Consequently, the boundary layers interlaminar fracture behaviour plays an important role [15-19]. Some restricted examinations regarding the hybridization impact of unidirectional fabric & bidirectional fabric composite (hybrid composite) have less flexural loading (FL). Hence, this paper is basically focusing on the investigation of
ILSS and FS of the laminated (Carbon/Glass fabric) composite; these mechanical properties most important for design engineers in industries to choose correct raw materials for specific use.

2. Experimental
2.1. Fabrication of composite
For preparing the laminate, LY556 grade epoxy is utilize as basic matrix; hardener HY 5200 grade, carbon/glass fabric are employed to prepare the composite laminate. By hand lay-up technique, glass/carbon fabric laminates were prepared. First, we have to cut the required fabric plies of 390mmx340mm size from carbon/glass fabric. Now take ten glass/carbon fabric plies. At that point, the textures resin (LY556) and hardener (HY 5200) was gauged. Then with the help of a stirrer both the Hardener (HY 5200) and epoxy resin was mixed. Care is to be taken while mixing, to avoid the entrapment of air. In case of air bubbles are jammed in a matrix material will reveal the material failure. Now for preparation of laminates first, we have to apply the wax to the moulding surface and next polymer coating is applied to the sheets of glass/carbon fabric. Now place the glass fabric ply on to the die as it should be rolled properly, generally rolling was completed by steel rod (Cylindrical). Then repeat the cycle up to ten layers of glass/carbon fabric. For good surface finishing, Polymer covering is over on the top ply and next apply the wax onto the punch part after that with the help of hydraulic press machine 20 kgf load is applied on to the composite material and leave 7 hours for hardening & curing the polymer composite. This process is repeated for preparing both (glass/carbon fabric) laminates. Once curing is done, by ASTM guidelines with Isomet precision cutting machine the samples were cut. According to standards’ of ASTM D790 and D2344, FS and ILSS samples with the dimensions 78x8x3 mm, 48x8x3 mm of rectangular in shape.

2.2. Mechanical characterization
2.2.1. Flexural strength
FS is a material property. It could be also called bend strength; modulus or fracture strength and defined as, the strain in a specific material earlier than its yields point. In this, the samples either cross section of rectangular/circular is bent up to yield strength or fracture strength by a three-point bend flexural method. Flat specimen is generally used to find the FS and during the test uniaxial loads are applied on two ends of the sample. When we are conduct testing the sample/specimen include: maximum stress, UTS; which shows a point just lower than the begin of permanent/plastic deformation; and the fracture point where the trial sample divided into pieces and the flexural test is completed by using UTM, and the obtained results are considered to analyze the properties (flexural strength) of the composite sample/specimen. Specimen dimensions are: span 48mm, Length 78mm, thickness 3mm and width 8mm.

2.2.2. ILSS
This is essential material property for the plan of laminated composite subjected to bend loads. Interlaminar shear strength (ILSS) was found out by the SBS test. Three-point bending is the familiar technique to demonstrate the ILSS of the FRP composite laminate (ASTMD2344). So many investigations were conducted to find out the strength of this particular test. In this study, involving analyzation of laminate, FEM analysis. The SBS is best and it will give the good quality results. ILSS test drawback is that deformation during indentation at loading condition, concentration of the shear and compressive stresses. Specimen dimensions are: span19.5mm, Length 48mm, thickness 3mm and width 8mm.

3. Results and discussions
FS and ILSS of Glass and carbon fabric polymer composite were evaluated and analyzed as per standards of ASTM D790 and D2344 respectively. The detailed discussion is mentioned in following sections.
3.1 FS
3-point bend test is carried out standards of ASTMD790 and specimen geometry is 78mm of length, 8mm of width, 48mm of span and 3mm of thickness. The results are given in Table 1 and 2. From the table 1 the average FS value of glass fabric composite is found to be 131.24 Mpa and from table 2 average FS value of carbon fabric is 526.18 Mpa. For one specimen the load Vs displacement data for both the composites is shown in figure 1 and 2.

Table 1. FS of glass fabric composite

| Specimen number | Length in mm | Span in mm | Width in mm | Thickness in mm | Max. Load in N | FS in MPa |
|-----------------|--------------|------------|-------------|-----------------|----------------|-----------|
| 1               | 78           | 51         | 6.96        | 3.1             | 152.5          | 148       |
| 2               | 78           | 51         | 6.96        | 3.1             | 138.2          | 130       |
| 3               | 78           | 51         | 6.96        | 3.1             | 110.4          | 120.29    |
| 4               | 78           | 51         | 6.96        | 3.1             | 122.6          | 126.68    |

Average FS value of glass fabric 131.24

Figure 1. Load Vs displacement (FS of specimen 1)

Table 2. FS of Carbon fabric composite

| Specimen number | Length in mm | Span in mm | Width in mm | Thickness in mm | Max. Load in N | FS in MPa |
|-----------------|--------------|------------|-------------|-----------------|----------------|-----------|
| 1               | 78           | 51         | 6.96        | 3.17            | 502.9          | 550.07    |
| 2               | 78           | 51         | 6.96        | 3.17            | 478.4          | 523.26    |
| 3               | 78           | 51         | 6.96        | 3.17            | 473.7          | 518.14    |
| 4               | 78           | 51         | 6.96        | 3.17            | 468.4          | 513.26    |

Average FS value of carbon fabric 526.18
Figure 2. Load Vs displacement (FS of specimen 1)

The average values of FS for glass and carbon reinforced (fabric) composite are 131.24Mpa and 526.18Mpa respectively. This clearly shows that carbon fabric composite flexural strength is four orders of magnitude higher relative to glass fabric composite. This may be due to high modulus and strength of carbon fibres. Three point bend method is used and according to ASTM standard D790.

3.2 ILSS
Short beam shear (SBS) test is used to find out the ILSS of both the composites. Specimen geometry is as per ASTM standards i.e., 48mm of length, 8mm of width, 3mm of thickness and 19.5 of span. The detailed results are included in table 3 and 4. The average values of ILSS are 29.015Mpa and 6.27Mpa of both glass and carbon fibre reinforced composites respectively. This test was conducted by using 3-point bend method. An obtained result clearly indicates that carbon fabric composite having much greater value as compared to glass fabric composite. The higher values of carbon fabric composite are due to the high strength and modulus of carbon fabric. Based on this results these carbon fabric reinforced composite can be used for advanced structural applications. Figures 3 and 4 clearly show variation of Load with displacement for glass and carbon fabric composites respectively (for one specimen in each case).

Table 3. ILSS of glass fabric composite

| Specimen number | Length in mm | Span in mm | width in mm | Thickness in mm | Max. Load in N | FS in MPa |
|-----------------|--------------|------------|-------------|-----------------|----------------|-----------|
| 1               | 48           | 19.5       | 6.97        | 3.02            | 171.32         | 5.22      |
| 2               | 48           | 19.5       | 6.97        | 3.02            | 165.41         | 5.19      |
| 3               | 48           | 19.5       | 6.97        | 3.02            | 151.23         | 4.55      |
| 4               | 48           | 19.5       | 6.97        | 3.02            | 138.26         | 4.26      |

Average ILSS value of glass fabric 6.27
Table 4. ILSS of carbon fabric composite

| Specimen number | Length in mm | Span in mm | width in mm | Thickness in mm | Max. Load in N | FS in MPa |
|-----------------|--------------|------------|-------------|-----------------|----------------|-----------|
| 1               | 48           | 19.5       | 6.97        | 3.24            | 974.7          | 32.66     |
| 2               | 48           | 19.5       | 6.97        | 3.24            | 862.2          | 28.91     |
| 3               | 48           | 19.5       | 6.97        | 3.24            | 845.5          | 28.25     |
| 4               | 48           | 19.5       | 6.97        | 3.24            | 783.6          | 26.24     |

Average ILSS value of carbon fabric **29.015**

Figure 3. Load Vs displacement (ILSS of specimen 1).

Figure 4. Load Vs displacement (ILSS of specimen 1).

3.3 Fractography
SEM Fractograph of carbon fabric reinforced composite (Fig.5) clearly shows that pullout of carbon fibres during the fracture. This requires more amount of fracture energy to propagate the crack. In case of glass fabric reinforced composite (Fig.6) bundle of glass fibres were observed and pullout of fibres is very minimal. SEM image of carbon fabric reinforced composite also
shows step like morphology. Each step indicates different cleavage mechanism and it requires more fracture energy for failure. These are may be the reasons for FS and ILSS values variation between the two composites namely glass fabric composite and carbon fabric composite.

![Figure 5. SEM image of glass fabric composite.](image1)

![Figure 6. SEM image of carbon fabric composite.](image2)

**4. Conclusions**

From the above detailed experimental analysis, the following conclusions are drawn.

1. Hand layup technique is used to fabricate GFRP and CFRP composites.
2. FS behaviour of the carbon fabric composite is four times greater than glass fabric reinforced composite.
3. ILSS of carbon fabric reinforced composite five times greater than glass fabric reinforced composite.
4. All the obtained FS and ILSS values were correlated and justified by using SEM analysis. Fibre pull-out and step like morphology are key mechanisms played vital role to increase ILSS and FS of Carbon Fabric composite.

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