Figure 5.1: Sandwich samples of different facesheet and core thickness

Material	*Flexural strength in N/mm² (σ)*	*Elastic modulus in Gpa (E)*
Sandwich Structure (2mm Face sheet & 10mm core thickness)	137.49	8.077
Sandwich Structure (2mm Face sheet & 20mm core thickness)	110.84	14.97
Sandwich Structure (2mm Face sheet & 30mm core thickness)	80.96	19.169
Sandwich Structure (4mm Face sheet & 10mm core thickness)	186.15	14.345
Sandwich Structure (4mm Face sheet & 20mm core thickness)	149.23	21.662
Sandwich Structure (4mm Face sheet & 30mm core thickness)	65.26	31.728
Sandwich Structure (6mm Face sheet & 10mm core thickness)	192.5	20.022
Sandwich Structure (6mm Face sheet & 20mm core thickness)	183.22	25.156
Sandwich Structure (6mm Face sheet & 30mm core thickness)	160.31	31.128

6. Results and Graphs

Flexural strength of the polyurethane core sandwiched glass/epoxy laminate samples of size 250 x 30 mm were tested according to ASTM standard D790. In this test, the specimens were loaded in a three point bending fixture of computer controlled UTM of 10 kN capacity at Raghavendra Spectro Metallurgical Laboratory, Bangalore.

6.1 Flexural Strength

In this mode a large span thickness ratio (L/D) is used. The distance between the two supports was maintained according to the standard. The data is recorded during the 3-point bend test to evaluate the flexural strength using below equation 1 [8]:

$$\sigma = \frac{3FL}{2BD^2} \qquad \text{eqn(1)}$$

Where,

σ = Flexural strength, F= Load at fracture point in N, B= width of rectangular section, D= thickness of rectangular section.

6.2 Elastic Modulus

The Elastic modulus is used as an indication of a material's stiffness. A flexural load involves the ability of the material to bend. Elastic modulus is calculated using below equation 2:

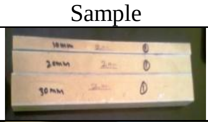
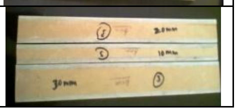
$$E = \frac{ML^3}{4bd^3} \qquad \text{eqn(2)}$$

Where,

E=Elastic modulus in Gpa, L=Length of support span in mm,b=Width of beam tested in mm, M=Slope of the tangent to the initial straight line portion of the load deflection curve calculated as M= (Y1-Y2/X1-X2).

Using the above equations flexural strength & elastic modulus can be calculated as shown in table 6.1.

Table 6.1: Flexural strength, Elastic modulus and Flexural stain of specimens

Sandwich structure	Sample
Face sheet of 2 mm thick and core materials of 10, 20 & 30 mm	
Face sheet of 4 mm thick and core materials of 10, 20 & 30 mm	
Face sheet of 6 mm thick and core materials of 10, 20 & 30 mm	

6.3 Effect of Core Thickness and Facesheet Thickness on the Flexural Strength

The effect of PU core thickness and facesheet thickness on the flexural strength of PU/glass/epoxy sandwich structure is shown in figure 6.1 & 6.2. From the graph 6.1 it is observed that, the flexural strength decreases with increase in core thickness. That is, flexural strength is inversely proportional to the core thickness.

Form graph 6.2 the flexural strength increases with increase in facesheet thickness. In general the flexural strength can be related as

$$\sigma \; \alpha \; \frac{T_f}{T_c}$$

Where

T_f thickness of facesheet and T_c is thickness of core material.

The maximum value of flexural strength is found to be 192.5 Mpa for 6 mm facesheet and 10 mm core thickness.

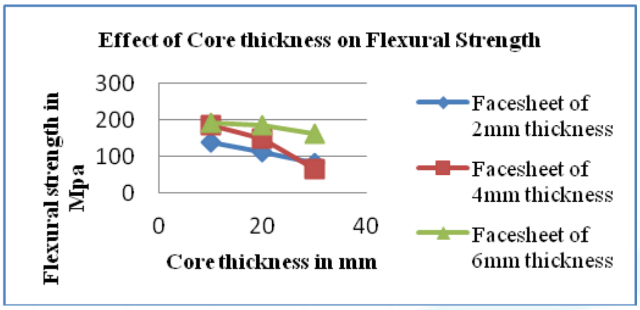


Figure 6.1: Effect of core thickness on flexural strength

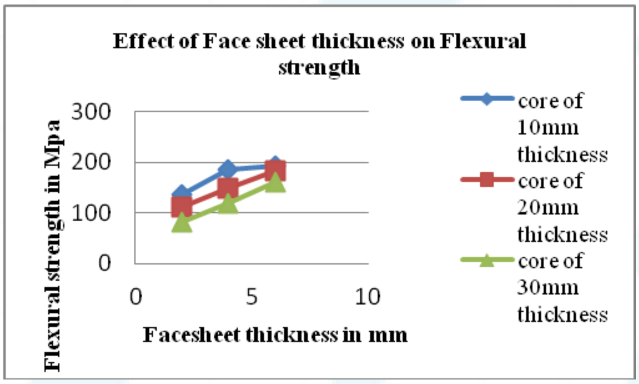


Figure 6.2: Effect of facesheet thickness on flexural strength

6.3 Effect of Core Thickness and Facesheet Thickness on the Elastic Modulus

The effect of PU core thickness and facesheet thickness on the Elastic modulus of PU/glass/epoxy sandwich structure is shown in figure 6.3 & 6.4. From the graph 6.3 it is observed that, the elastic modulus increases with increase in core thickness. That is, elastic modulus is directly proportional to the core thickness. Form graph 6.4 the elastic modulus increases with increase in facesheet thickness. In general the elastic modulus can be related as σ α T_f and σ α T_c. The maximum value of elastic modulus is found to be 31.728 Gpa for 4 mm facesheet and 30 mm core thickness.

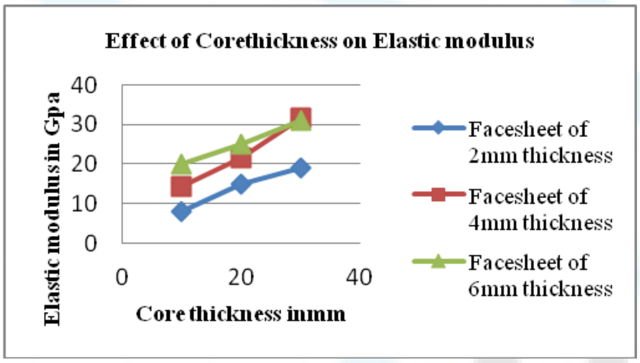


Figure 6.3: Effect of core thickness on elastic modulus

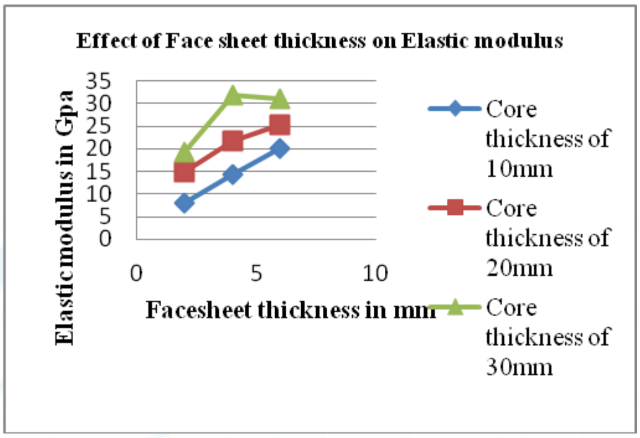


Figure 6.4: Effect of Face sheet thickness on elastic modulus

7. Conclusion and Future Work

7.1 Conclusion

From the experimental results of flexural strength of PU core sandwiched glass/epoxy composite structure following conclusions are drawn.

1. The most significant factor for flexural strength is facesheet thickness contributing 61.53% of influence and for elastic modulus is core thickness contributing 49.2% of influence.
2. The maximum value of flexural strength can be achieved for the sandwich structure having greater facesheet thickness lower core thickness values. In this project the maximum value of flexural strength achieved is 192.5Mpa.
3. The maximum elastic modulus can be achieved for the greater thickness of core and in this project 31.72 Gpa elastic modulus is achieved for 30 mm core thick sandwich structure.
4. During the flexural loading, the complete load is first taken by the facesheet and gradually transferred to the core material.

7.2 Future Work

The project can be continued to study with different composition of facesheet materials and core materials. The mechanical properties such as tensile and fatigue can be studied for different orientation of the fibers for facesheet thickness.

References

[1] Liviu Marsavina, Tomasz Sadowski, “Dynamic fracture toughness of polyurethane foam”, Elsevier, Polymer testing 27(2008) 941-944.

[2] Amir Shahdin, Laurent Mezeix, Christophe Bouvet, Joseph Morlier, Yves Gourinat, “Farication and mechanical testing of glass fiber entangled sandwich beams: comparison with honeycomb and foam sandwich beams”, Elsevier, Composite structure 90 (2009) 404-412.

[3] Mohammad Mynul Hossain, Kunigal Shivakumar, “Compression fatigue performance of fire resistant syntactit foam”, Elsevier, Composite structure 94(2011) 290-298.

[4] K.Kanny, Hassan Muhfuz, "Flexural fatigue characteristics of sandwich structures at different loading frequencies" Composite structures, Volume 67 (2005), pages 403-410.
[5] O. Velecela, M.S. Found, C, Soutis, " Crushing energy absorption of GFRP sandwich panels and corresponding monolithic laminates" ,Elsevier, Composites : Part A 38 (2007) 1149-1158
[6] Mojtaba Sadighi, Seyyed Ahmad Hosseini, "Finite element simulation and experimental study on mechanical behavior of 3D woven glass fiber composite sandwich panels", Elsevier, Composites: Part B 55 (2013) 158–166.
[7] G.S. Langdon a, C.J. von Klemperer b, B.K. Rowland a, G.N. Nurick a, "The response of sandwich structures with composite face sheets and polymer foam cores to air-blast loading: Preliminary experiments", Elsevier, Engineering Structures 36 (2012) 104–112.
[8] Tayor and francis group LIC by2007, ket Telephone, Inc.