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# The Influence of Rigid Foam Density on the Flexural Properties of Glass Fabric/Epoxy-Polyurethane Foam Sandwich Composites

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**Abstract:** Sandwich composites with glass fabric and epoxy matrix as the skin and rigid polyurethane foam (PUF) as the core were prepared in the shape of panels. Three panels were fabricated with the rigid foam densities of 125, 250 and 500 kg/$m^3$, separately. The Flexural properties were compared and detailed analyses done, on the influence of different foam densities on otherwise identical sandwich composite beams, prepared from the panels. All the panels were fabricated with the skin weight maintained to about 40% of the foam weight.
**Key words**: Rigid Foam Density, Rigid Poly Urethane Foam, Sandwich Composites, Flexural Properties.

## Introduction

The sandwich composites are used in various applications and there are different techniques employed to fabricate the sandwich composites. In this investigation, the sandwich composite panels were fabricated by the vacuum bagging technique for rigid foam densities of 125, 250 and 500 kg/$m^3$ separately. The employed technique is suitable for small batch production of complex shapes and structures that cannot be obtained through normal temperature and pressure. The flexural test was performed on the sandwich composite beams of different foam densities for a complete mechanical characterisation in order to evaluate their flexural properties. The obtained results show that there is an influence of different foam densities on sandwich properties that are fabricated by vacuum bagging technique. For the same weight ratio between the skin and the core, the obtained mechanical properties were compared and the results analysed.

## Experimental Method

To fabricate the sandwich specimens for three different rigid foam densities, Glass fabric, Poly Urethane Foam, Epoxy Resin and Hardener were used. The glass/epoxy skin and PUF were used as the skin and core materials. For getting good stiffness the weight of the glass fabric skin should be nearly half of the PUF weight. The epoxy resin and hardener were mixed and applied to the glass fabric & PUF. The sandwich specimen had three, five and nine glass fabric skin layers on either side of the core for 125, 250 and 500 kg/$m^3$

panels respectively. The core used in sandwich panels for the three different rigid foam densities was of 50mm thickness. For a detailed understanding of the poisson's ratio of foams refer to reference [1]. The vacuum bagging technique was used to fabricate the sandwich panels. The part was compacted by the atmospheric air applying pressure on the evacuated part and good bonding was formed between the PUF core and glass fabric/epoxy skins. In all the panels a volume fraction of 0.3 $V_f$ was maintained for the fabric against the epoxy resin. Froud, Gibson, Srikant et al and Hemnath and Padmanabhan have earlier investigated the effect of skin: core weight ratios on the flexural properties of sandwich composites [2, 3, 4, 5]. Here, in all the three panels the skin: core weight ratio was maintained at ~ 0.4:1. Figure 1 shows the vacuum bag process. Once the vacuum bagging process was completed the sandwich panels were removed from the bag and cut into specimens for the bend test in a Universal Testing Machine.

Bending tests were carried out in order to calculate the flexural rigidity for the sandwich specimens and shear stresses in the core for comparing the influences of three different rigid foam densities. The bending test for the three different panels was carried out in a Universal Testing Machine as per the ASTM standard guide lines [6,7]. Four specimens from each panel were tested in the UTM & the load deflection plots were noted. The UTM consists of two supports and a central load is applied from the top. The support span to thickness ratio was maintained at 16:1 for each sandwich composite beam specimen as shown in figure 2. A strain rate of 0.01 $s^{-1}$ was maintained for the testing of the beams.

**Fig 1: The vacuum bagging technique**

**Fig 2: Specimen under three point bending test**

## Results and Discussion

The results obtained for the vacuum bagging technique were compared for the mechanical properties. Figure 3a shows the load-defection plots of the sandwich beam specimens. The parameters like flexural rigidity, bending stress, shear stress, normal stress, shear deflection and shear strain were calculated and these properties compared for the sandwich specimens with three different densities of foams. The average values of all the parameters were taken and compared with the average values for the other densities. A rigid foam 500 $kg/m^3$ panel takes the highest load. The shear deflection and the shear strains show a decreasing trend for the 250 kg/cu.m panel but their values are slightly higher for the 500 kg/cu.m panel. As we gather from [1] that light density rigid foams have a higher poisson's ratio than the medium density foams, the same is reflected here in the shear deflection and shear strain values for the three densities. The flexural rigidity and the bending strength per unit width increase with an increase in the rigid foam densities. Table I gives the bending stress, shear stress and the other flexural properties comparisons for the three sandwich composites investigated here. A comparison has been made for the shape factor designs also. As more layers of skin are required to maintain the same weight ratio for denser foams, the shape factors decrease with an increasing foam density. The flexural rigidity of a sandwich beam can be calculated from the elastic considerations at a long span or a fixed span. Figure 3b shows that the actual fixed span flexural rigidities of the beams are much lower than those for long span considerations, more so for higher foam densities.

**Table-I: Comparison of Mechanical Properties of Three Sandwich Panels**

| Sandwich Description | G/E- PUF 125 kg/cu.m | G/E-PUF 250 kg/cu.m | G/E- PUF 500 kg/cu.m |
|---|---|---|---|
| Maximum Bending Stress ($N/mm^2$) | 231.30 | 142.12 | 112.72 |
| Flexural Rigidity( $N\text{-}mm^2$) | $6.5807\times10^{8}$ | $2.10753\times10^{9}$ | $9.77586\times10^{9}$ |
| Flexural Rigidity($N\text{-}mm^2/mm$) per unit width | $6.32\times10^{6}$ | $2.07\times10^{7}$ | $8.89\times10^{7}$ |
| Shear Deflection(mm) | 18.23 | 10.22 | 12.31 |
| Shear Strength in Core, At y=0 mm distance($N/mm^2$) | 3.286 | 6.051 | 16.783 |
| Shear Strain at maximum load | 0.044 | 0.024 | 0.028 |
| Maximum Normal Stress ($N/mm^2$) | 231.3 | 142.1 | 112.50 |
| Bending Shape Factor for Stiffness | 121.13 | 33.58 | 11.16 |
| Bending Shape Factor for failure | 5.25 | 1.43 | 0.41 |
| Bending Strength(N-mm) | $2.01\times10^{5}$ | $4.49\times10^{5}$ | $1.36\times10^{6}$ |
| Bending Strength(N-mm/mm) per unit width | $2.01506\times10^{3}$ | $4.34935\times10^{3}$ | $1.242318\times10^{4}$ |

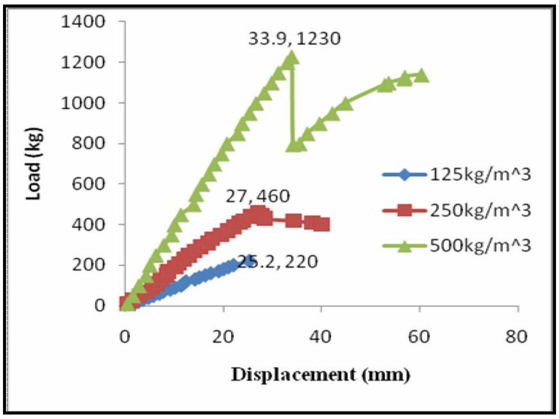


**Fig 3a: Load vs Displacement, thickness (t)=2x Width(2W).**

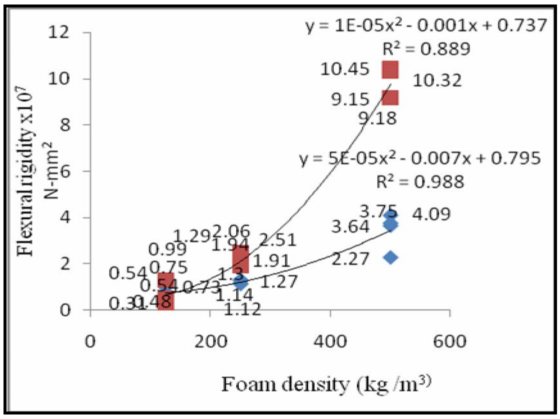


**Fig 3b: A Comparison of flexural rigidity considering long span (Red) and 16:1 span (Blue)**

## Conclusions

The properties for the three rigid foam density sandwich panels were calculated and obtained from three-point bending test in a UTM. The bending test results show that with an increase in foam density, parameters like bending stress, shear stress and normal stress decrease. Parameters like flexural rigidity, bending strength and centre deflection increase with increase in the foam density of sandwich panels. The shear deflection and the shear strain decrease for the 250 kg/cu.m density beam and increase marginally for the 500 $kg/m^3$ foam, which is attributed to the poissons ratios of the foams.

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