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Flexural Behavior of Sandwich Composite Panels Under 4-Point Loading

Syed Mudassir[1], Dr. D.V. Ravi Shankar[2], Dr. M. Manzoor Hussain[3]

[1]Research Scholar, Mechanical Engineering Department, JNTUH Hyderabad, India.
[2]Professor & Principal, TKR College of Engg. and Technology, Hyderabad, India.
[3]Professor & Principal, Dept. of Mechanical Engineering, JNTUCE,Sultanpur, India.
E-mail: smudassir.07@gmail.com, manzoorjntu@gmail.com, shankardasari@rediffmail.com

Abstract

The sandwich panels performed in order to characterize fully complex mechanical behavior of such a heterogeneous material. To determining the flexural properties of rigid polyurethane and Phenolic foam cores, glass/epoxy skin sandwich composites the experimental studies has been done. Fabrication of sandwich composites are in the shape of panels by using glass fabric/ epoxy as skin material and polyurethane foam (PUF) and Phenolic foams as core with two different densities. The sandwich panels were tested under 4 point loading condition.

This work deals the study of the mechanical behavior in 4- point bending, in static mode, of two different composite sandwiches laminate foam with two different orientations of fiber. The skin face consisted of Balance symmetry [0/90/90/0]2 and Quasi-isotropic [0/45/90/-45]2 orientations. The tests in the static mode permitted the determination of the mechanical behavior of the materials. The results obtained from the experiment are compared with the analytical one.

Keywords: PU, PHNOLIC, GFRP, Mechanical Testing.

INTRODUCTION

The modern technology application for a new material is necessary to increase the demand and performance. It is difficult to perform high standard for one material, hence new materials fabricated by combining two or more conventional materials. Sandwich structured composites[1] are a special class of composite materials which have become very popular due to high specific strength and bending stiffness. The main concept of sandwich composite structures is its high bending stiffness and high strength to weight ratio [2]. In addition, sandwich constructions are preferred over conventional materials because of its high corrosion resistance [3]. With its many advantages, composite sandwich structures have been widely used in the automotive, aerospace, marine and other industrial applications. This composite material also draws a lot of interest in the construction industry and is now beginning to be in use for civil engineering applications [4]. They are also significantly lighter in weight than concrete panels. The use of composite GFRP sandwich panels in building applications started in the 1970s [5]. The main concept behind sandwich structure is that the skins carry the in-plane compressive and tensile stresses resulting from the induced bending moment, while the main function of the lightweight core is to keep the two skins apart, at a desired distance, and also to resist and transmit the induced shear forces to the supporting points.

Many researches have studied the behavior of sandwich composite structures for its failure modes in flexure [6-11]. In these studies, sandwich specimens are tested in the flat wise position as it is commonly used as structural panels for roof, floor, walls and bridge decks. The skins located at the top and bottom carries the flexural load and the inner core, the shear. The present work is focused on flexural behavior of two different sandwich composite panels using a rigid or soft polyurethane foam core or Phenolic foam core sandwiched between two layers of Glass-FRP (GFRP) and adhered by a layer of resin such as epoxy. This core were resists shear stresses and also contributes to the moment of inertia of the panel by acting as a spacer that maintains the GFRP skins spaced apart at a desired distance.

2. MATERIAL SELECTION AND FABRICATION OF SPECIMENS

The sandwich panels are made of Glass/Epoxy skin and polyurethane foam core with 40 kg/m^3 density and phenolic foam core with 45 kg/m^3 with a core thickness of 15 mm and the face sheet thickness were 1 mm, length of the beam was 200 mm and 75 mm width respectively. The sandwich panels were manufactured using the hand lay-up process. This method is one of the oldest methods which is the best suited for short production series. The process uses a two-sided mold made with Aluminum. The glass fiber fabric was places on the mold after spraying the releasing agent so that the final product does not stick to the mold. After face coat impregnated, foam material placed on top of the fabric. Another coat of resin uniformly distributed on the surface of the foam core and another 4 layers of fabric was places. The mold was clamped down to force the sandwich panels such that total thickness of the sandwich was not greater than 25 mm. after curing time which is about 24 h, mold was opened and the required dimensions of 200 mm *25 mm according to the ASTM C 393/ 393 M[11]. The same procedure was carried out for all the sandwich panels with different orientations.

3. THEORETICAL PREDICTIONS AND SANDWICH PANEL CHARACTERIZATION

The characterization of the fiber composite skin and core materials has been performed using four point bending (FPB) flexural tests specimen standard configuration following ASTM standards ASTM C-393/C-393M-06 and ASTM D

7250/D 7250M-06 [12] for Load-deflection data and other calculations. To observe the possible failure mechanisms of the skins, specimens with span length of S = 200 and b = 75 mm with thickness t = 25 mm for the sandwich structure with Polyurethane core and Phenol core.

3.1. Analytical Formulation Used for the calculation of the Mechanical Properties

This study calculated the mechanical properties using the simplified beam theory as proposed by ALLEN [13], Initial evaluation on the effect of gluing on the stiffness of the composite sandwich beam was conducted. The Flexural stiffness, EI of the sandwich panel is being calculated using the elastic properties of the fiber composite skins and core material and simple sandwich beam theory. For a sandwich beam, the equivalent flexural rigidity $(EI)_{eq}$ consists of the sum of the rigidities of the faces and core measured about the centroidal (neutral) axis M-M of the entire cross section as shown in the figure 2. The standard 4- point loading have the centerlines of the support bars separated by a distance of L= 75 mm as shown in figure 1. The support bars are free rotation of the specimen at the loading and support point.

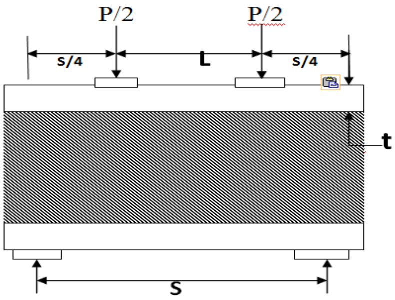

Fig 1: 4- Point Loading

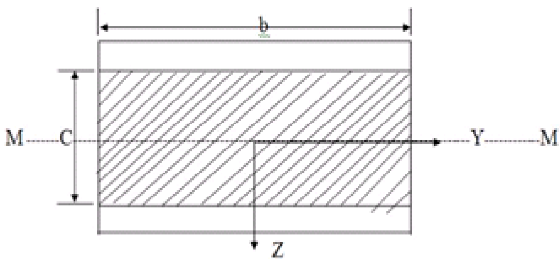

Fig 2: Cross sectional area of the specimen

The calculation of core and facing flexural stiffness are given below.

$$\mathbf{(EI)_{core}} = \frac{bc3}{12} E_C \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where:

$\mathbf{(EI)_{core}}$ = Flexural Stiffness of Core Material

$(EI)_{face}$ about M-M axis = $E_f I_{face}$

I_{face} can be calculated from the parallel axis theorem.

$I_{face} = 2 [I_{faces} + \text{Area } (d/2)^2]$

$$\mathbf{(EI)_{faces}} = E_f [bt^3/12 + btd^2/2] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The standard formulas for flexural stiffness was calculated using ASTM standards

$$\mathbf{EI} = \left[\frac{bt^3}{6} + \frac{btd^2}{2}\right] E_S + \frac{bC^3}{12} E_C \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where:
EI = Flexural Stiffness
b = width of the specimen
t = Skin thickness
c = Core thickness
d = Specimen thickness
E_s, E_c = Skin and core Young's Modulus

The deflection of the beam was then calculated using ASTM D 7250/D 7250M-06 standard.

$$\delta = \frac{P\,(2S^2 - 3SL^2 + L^3)}{96EI} + \frac{P\,(S - L)}{4U} \qquad \text{........................ (4)}$$

Where:
P = Load applied on the specimen (N)
L = Load span Length (mm)
U = Transverse shear rigidity (Mpa)
S = Support span length (mm)

4. EXPERIMENTAL INVESTIGATION

4.1 Test set-up and procedure

The static flexural test of composite sandwich beams was performed in accordance with the ASTM C 393/ 393 M standard. The load was applied at the quarter point of the span (fig.3) through a MCS 60 UTE- 60 universal testing machine with a loading rate of 60 mm/min... The loading pins and the supports had a diameter of 10 mm to prevent local indentation failure on the beam is the actual test set-up and instrumentation for the static flexural test of the composite sandwich beams. The applied load, displacement and strains were recorded and obtained using a data logger system.

Fig 3: Quarter point loading test

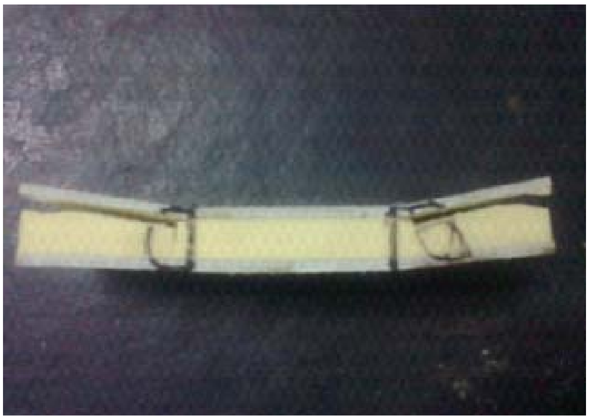

Fig 4 : Specimen Delamination after Loading

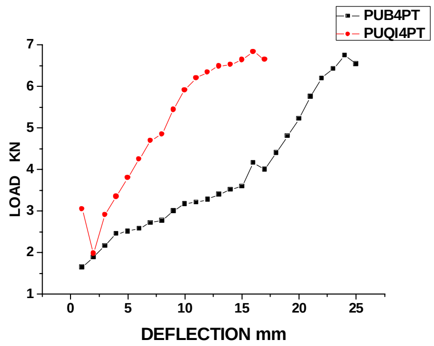

Fig 4: Load Vs Deflection for PU foam

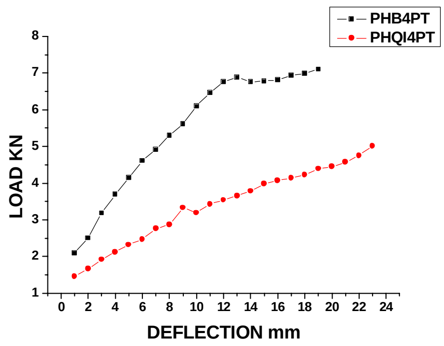

Fig 5: Load Vs Deflection for Phenolic foam

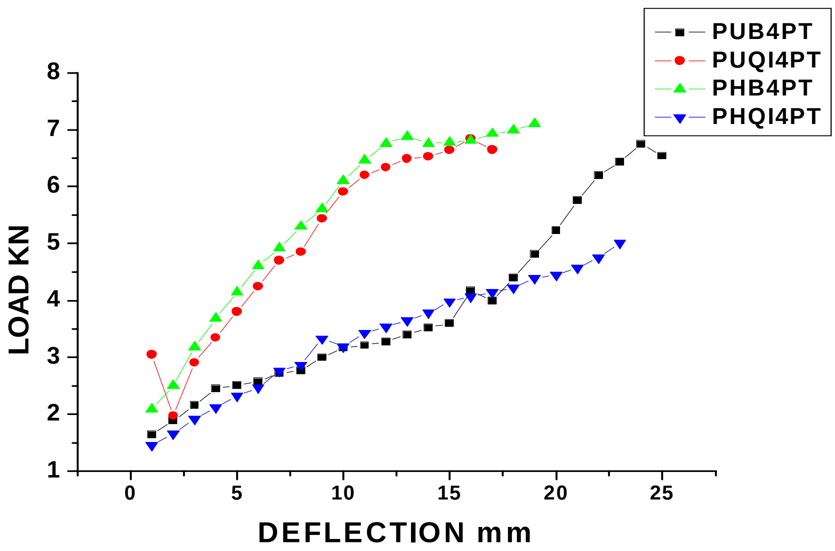

Fig 6: Experimental Results Graph on Both PU and Phenolic foam core sandwich panels

5. NUMERICAL ANALYSIS

The simulations of all the experimental tests have been carried out by using the Ansys 10.0 code and isoperimetric quadrilateral plane elements type PLANE42 (four nodes element) and PLANE82 (eight nodes element). Considering the non-linear behavior of the materials constituting the skin and the core, as well as the large displacements that precede in general the failure of the sandwich structure, all simulations have been performed by means of non-linear analyses. As an example (Fig 7) shows the meshed and numerical model (1040 elements) used to simulate the FPB test, whereas (Fig 8) shows the corresponding load–midspan deflection curve provided by the non-linear FEM analysis:

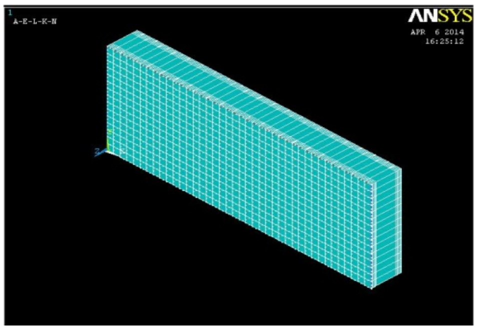

Fig 7: meshed model

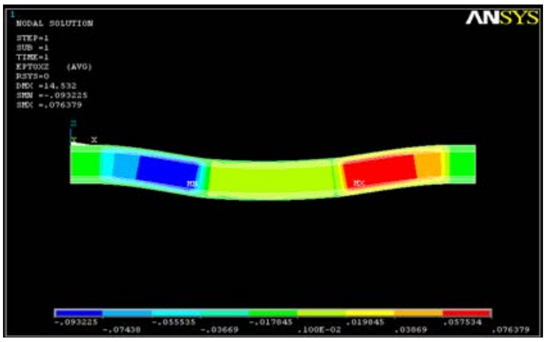

Fig 8: deflection in Z direction

RESULTS

To determine the flexural stiffness of the sandwich composite panels the deflection test has been performed. The experimental deflection results are compared with numerical results. As E-Glass, fiber properties are similar in 0^0 and 90^0 directions. The properties of balance symmetric and quasi-isotropic orientations of skin have been done by classical laminate theory (14).

Table: 1. Load Vs Deflection Results comparison from experimental and simulation of sandwich foam core specimens.

4-POINT BENDING Balance Symmetry (0/90/90/0)2				
S.No	**Foam**	**Load (N)**	**DEFLECTION (mm)**	
			Experimental	**Analytical**
1	PU	6540	25	26.72
2	Phenolic	7080	19.5	18.3
4-POINT BENDING Quasi Isotropic (0/45/90/-45)2				
3	PU	6780	16.8	18.08
4	Phenolic	4980	23.5	20.56

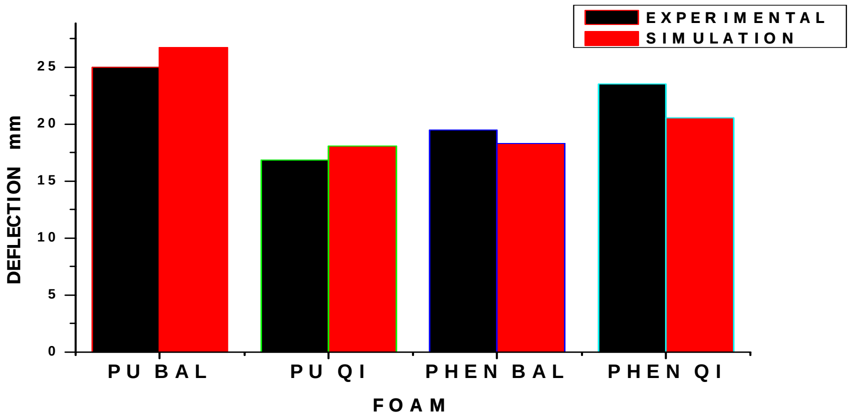

Fig 9: Deflection Results Comparison

Table: 2. Flexural stiffness Experimental and Numerical Results

S.NO	ORIENTATION	LOAD (N)	Experimental FLEXURAL STIFFNESS (N-mm^2)	Numerical FLEXURAL STIFFNESS (N-mm^2)
1	BAL(PU)	6540	20921584.61	18783478.72
2	QI (PU)	6780	50052715.85	41868272.67
3	BAL(PHENOLIC)	7080	57481105.3	71990238.61
4	QI(PHENOLIC)	4980	17229709.3	21821409.15

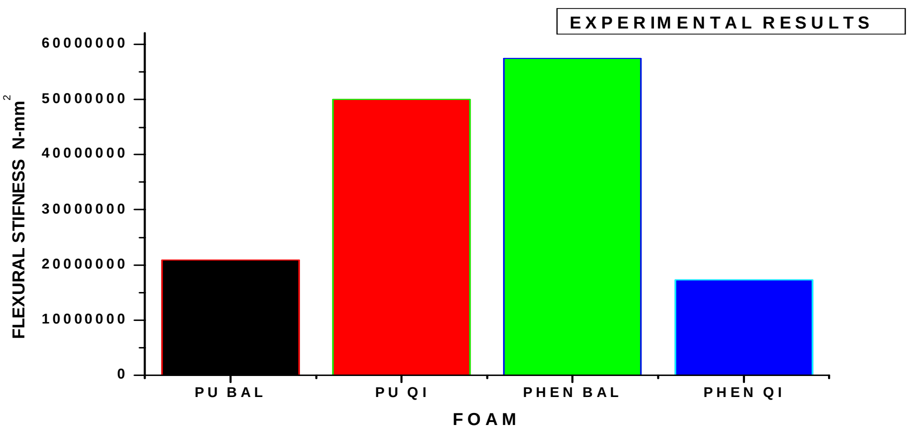

Fig 10: experimental results on flexural stiffness

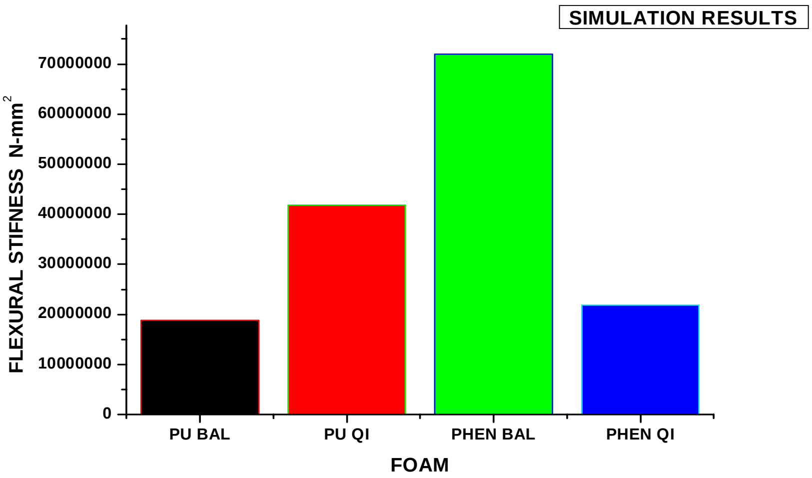

Fig 11: Simulation results on Flexural stiffness

CONCLUSIONS

The flexural behavior of a composite sandwich beam has been studied experimentally, analytically and numerically. The experimental investigation showed that under flexural loading, the composite beams failed with sudden brittle type failure.

In the present work, the actual mechanical behavior and failure mechanisms of the two types of sandwich structures have been investigated. It has been observed that the balance symmetry orientation of Phenolic foam core sandwich panel have got maximum flexural stiffness in experimental results, and balance symmetry orientation of Phenolic foam core sandwich panel have got maximum flexural stiffness in numerical results. The deflection results show that polyurethane Qusi isotropic orientation of sandwich composite panels got minimum deflection as compare to other laminates in experimental results. Moreover, balance symmetry orientations of phenolic foam core sandwich panel have minimum deflection in numerical results. The flexural stiffness has increased due to which deflection is reduced. The contribution of the strength of core and fiber orientation in the flexural stiffness is to be included to determine the overall performance of the sandwich composite beams. The results of this study showed the high potential of this innovative sandwich composite beam for structural laminated panels. An increase in flexural stiffness due to sandwich effect suggest the application of sandwich composite beam in the outer most layers to carry tensile and compressive stresses.

Finally, the behavior of different foam cores with the different fiber orientations of sandwich composite panels bonded together should be investigated further for development of structural components from this composite.

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