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Bending Moment of Aluminium Alloy Glass Fiber Sandwich Panel

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ABSTRACT: The main objective of this project is to prepare an aluminium alloy glass fiber sandwich panel and test for the bending moment properties of the sandwich panel using universal testing machine. This paper theoretically calculates the bending behavior of sandwich panel. The recent need to develop a new range of materials has resulted in the development of high performance lightweight composites with excellent properties. Metal-composite systems consist of alternating layers of metal and fiber-reinforced polymer composites which are bonded by an adhesive. Sandwich beams were tested under Air Bending. Stress-strain, stress-displacement, load-displacement, strain-Time, Stress-Time, displacement-time and load-time were recorded by using AIMIL UTM. The beam face sheets exhibited a softening non-linearity on the bending side. Experimental results were in good agreement with predictions from simple models. On an overall basis, the sandwich panel exhibited better bending moment performance than the monolithic Aluminium.

KEYWORDS: Composite material, Aluminium plate, Glass fiber plate, binder material, Rectangular structure, sandwich panel composite, Universal Testing Machine [UTM].

I. INTRODUCTION

Sandwich structured composites are a special class of composite materials which have become very popular due to high specific strength and bending stiffness. Low density of these materials makes them especially suitable for use in aeronautical, space and marine applications. Sandwich composites primarily have two components namely, skin and core. If an adhesive is used to bind skins with the core, the adhesive layer can also be considered as an additional component in the structure. The thickness of the adhesive layer is generally neglected because it is much smaller than the thickness of skins or the core. The properties of sandwich composites depend upon properties of the core and skins, their relative thickness and the bonding characteristics between them. Other advantages offered by sandwich construction are elimination of welding, superior insulating qualities and design versatility. Even if the concept of sandwich construction is not very new, it has primarily been adopted for non-strength part of structures in the last decade. This is because there are a variety of problem areas to be overcome when the sandwich construction is applied

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to design of dynamically loaded structures. To enhance the attractiveness of sandwich construction, it is thus essential to better understand the local strength characteristic of sandwich panel/beam members. Fig.1 shows the structure of simple sandwich panel. A great deal of work has been published on the behavior of sandwich structures in the last few decades. Many analytical and computational models are available to describe the behavior of sandwich beams, panel sand shells under different loading conditions.

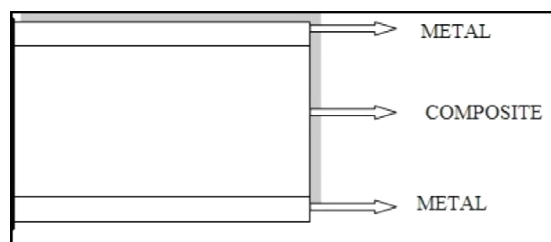


Fig. 1 Structure of a Sandwich Panel

Isaac M. Daniel, Jandro L. Abot [1] has studied exural behavior of composite sandwich beams and compared the results with predictions of theoretical models. Craig A. Steeves, Norman A. Fleck [2] have studied three-point bending collapse strength of sandwich beams with composite faces and polymer foam cores. S. Belouettar, A. Abbadi, Z. Azari, R. Belouettar, P. Freres [3] have studied static and fatigue behaviors of honeycomb sandwich composites, made of aramid fibers and aluminium cores, are investigated through four-point bending tests. Henrik Herranen, Ott Pabut, Martin Eerme, Jüri Majak, Meelis Pohlak, Jaan Kers, Mart Saarna, Georg Allikas, Aare Aruniit [4] have studied Design and testing of sandwich structures with different core materials . Hualin Fan, Lin Yang, Fangfang Sun, Daining Fang [5] has studied to restrict de bonding, carbon fiber reinforced lattice-core sandwich composites with compliant skins were designed and manufactured. Jin Zhang, Peter Supernak, Simon Mueller-Alander, Chun H. Wang [6] have studied bending strength, stiffness and energy absorption of corrugated sandwich composite structure were investigated to explore novel designs of lightweight load bearing structures that are capable of energy absorption in transportation vehicles. V. Crupi, G. Epasto, E. Guglielmino [7] has studied comparison of static and low-velocity impact response of two aluminium sandwich typologies: foam and honeycomb sandwiches. M.M. Venugopal, S K Maharana, K S Badarinarayan [8] has studied modeling approach to predict response of composite sandwich panels under static bending conditions. Kaveh Kabir, Tania Vodenitcharova, Mark Hoffman [9] have studied the response of aluminium sandwich panels comprising thin foam cores and thin face sheets of low and high yield strength was investigated under three-point bending load. Dipak G. Vamja, G. G. Tejani[10] have studied Tensile strength, bending strength has been carried out on Universal Testing Machine (UTM) to optimize of mass of composite material.

II. MATERIAL SELECTION

The materials used in the fabrication of the test specimens were:

1. Aluminium alloy sheets - AA 1050 H 14 [Table 1]; 1.5 mm
2. E-glass fibers reinforced in epoxy resin matrix; 2mm
3. Epoxy resin as adhesive.

The Aluminium thickness fraction is defined as the ratio between the aluminium thickness and the total thickness of the hybrid laminate. Aluminium alloy sheet [Grade AA 1050 H 14 supplied by HINDALCO] was uniformly roughened on one side so as to get good bonding with the epoxy resin. An acrylic mould as per the specimen shape was made. The surfaces of the aluminium were wiped and cleaned using acetone. Chopped strand mats [CSM] made of E – glass fiber were cut to the sample shape. Epoxy resin LY 556 and hardener Araldite were mixed in the ratio 100 parts to 10 parts by weight respectively.

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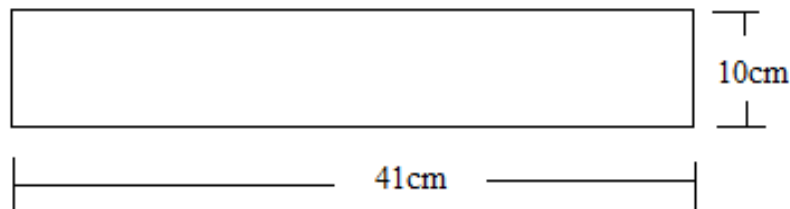


Fig. 2 Dimensions of Sandwich panel

Fig. 2 shows the rectangular specimens of sandwich panel. Length of the specimen is 41 cm and width of the specimen is 10 cm. Sandwich panel is a mixture of aluminium and glass fiber. Chopped stand mats are also placed in between each sheet to stick properly.

Copper	4.3-4.5%
Manganese	0.5-0.6%
Magnesium	1.3-1.5%
Silicon, Zinc, Nickel, Chromium, Lead and Bismuth.	less than a half a percent
Aluminium	remaining

Table.1 Aluminium alloy composition.

Table. 1 shows the properties of the constituent materials. Aluminium alloy is a mixture of copper, manganese, magnesium, silicon, zinc, nickel, chromium, lead and bismuth. All constituent materials with respective percentage are mixed with pure aluminium material to make it an alloy.

S.No	Material	Elastic modulus (GPa)	Yield strength (MPa)	Ultimate strength (MPa)	Specific weight (kg.m-3)
1	Aluminium	68	120	145	2700
2	E-Glass Fiber	72	1950	3450	2540
3	Epoxy	3.5	161	95	1100

Table.2 Material properties.

Table. 2 show the material properties of monolithic material. Properties include elastic modulus in GPa, yield strength in MPa, ultimate strength in MPa and specific weight in kg.m. These properties of aluminium, E-Glass fiber and Epoxy resin and hardener are mentioned separately.

III. EXPERIMENTAL PROCEDURE

The surface of the aluminum sheet and the inner surface of the mould cavity were coated with wax. The aluminium sheet was placed inside the mould with the roughened surface facing up. A coating of the resin-hardener mixture was applied over the aluminium surface followed by placing the CSM over the above coating. Two layers of unidirectional [UD] fibers wetted with resin hardener mixture were then placed over the CSM. A CSM layer was again placed over which the outer aluminium sheet was placed. The mould cavity was closed by a wax coated acrylic sheet. Weights were placed over the sheet in such a way that uniform pressure was obtained. The set up was left for curing for 6 hours at

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room temperature. The surfaces of the aluminium alloy glass fiber sheet were wiped and cleaned using acetone to remove the wax attached during experiment in mould cavity.

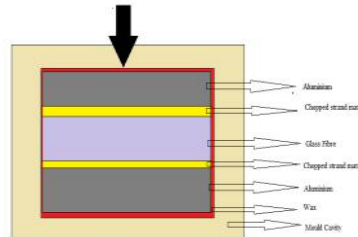


Fig.3 sheets placed in mould cavity

Fig.3 shows the sheets placed in mould cavity. Light orange color indicates mould cavity, Red color indicates wax, black color indicates aluminium sheets, Yellow color indicates chopped stand mats and light purple color indicates glass fiber. Arrow facing downward indicates force applied on mould cavity.



Fig.4 3D view of specimen

Fig.4 shows a 3D view of the specimen produce after the above procedure. A force which is applied on mould cavity in such a way that applied force is distributed at all corners of the sandwich panel. Perfect sandwich panel as shown in figure is produced if the above procedure is followed.



Fig.5 Bending test of specimen

Fig.5 shows the Bending test of specimen conducted on AIMIL UTM machine. Testing method is three points testing method. The main advantage of a three point flexural test is the ease of the specimen preparation and testing. Above figure is a mixture of five figures which shows the bending test on specimen. Figure shows the gradual downward movement of load on the specimen.

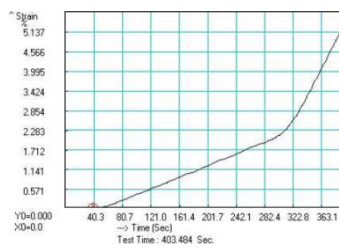
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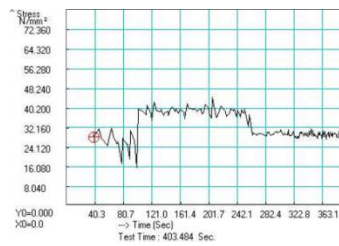
IV. RESULT

The following results have been attained after testing the aluminium alloy glass fiber sandwich panel for its bending moment. Failure was governed by the compressive strength of the face sheet, which was higher than the compression strength for monolithic material measured under direct compression. The ultimate compressive strain recorded was 1.2%.



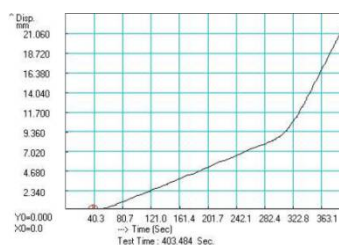
Graph.1 Strain – Time

Graph.1 shows a Strain – Time curve. Strain percentage starts at a time of 40.30 seconds and slowly increases as the time passes. Total strain percentage taken by the specimen is 5.137% and total time taken by the specimen to get strain is 403.484 seconds.



Graph.2 Stress – Time

Graph.2 shows a Stress – Time curve. Stress starts at a time range of 24.120-32.160 seconds and slowly increases and decreases as the time passes. Total Stress obtained by the specimen at a range of 40.200-48.280 N/mm² and total time taken by the specimen to get Stress is 403.484 seconds.



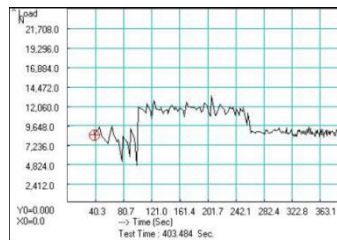
Graph.3 Displacement – Time

Graph.3 shows a Displacement – Time curve. Displacement starts at a time of 40.30 seconds and slowly increases as the time passes. Maximum displacement obtained after testing the specimen is 2.34 cm and total time taken by the specimen to get displacement is 403.484 seconds.

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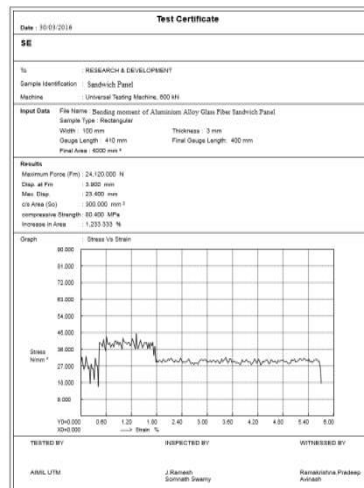
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Graph.4 Load – Time

Graph.4 shows a Load – Time curve. Applied load slowly increases as the time passes. Load to time curve increases and decreases gradually. Maximum load applied after testing the specimen is 24120N and total time taken by the specimen to get load is 403.484 seconds.



Certificate.1 Stress – strain

Certificate.1 shows a Stress – strain diagram. The certificate generated by AMIL UTM shows the stress-strain relationship along with the result values of maximum displacement, Cross-section area, Increase in area, Maximum force. Stress starts at a point between 27000-36000 N/mm² and ends at 18000N/mm². Strain starts with 0% and ends between 5.40-6.00%.



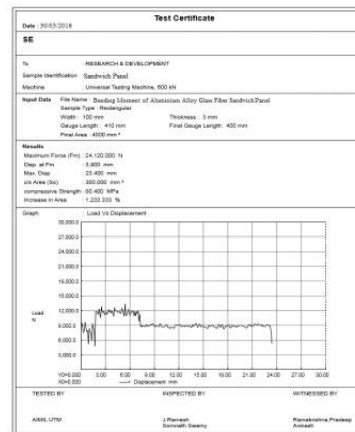
Certificate.2 Stress - Displacement

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Certificate.2 shows a Stress - Displacement diagram. The certificate generated by AMIL UTM shows the stress-displacement relationship. Stress starts at a point between 27000-36000 N/mm² and ends at 18000N/mm². Displacement starts at 0 mm and ends between 21.00-24.00mm.



Certificate.3 Load – Displacement

Certificate.3 shows a Load - Displacement diagram. The certificate generated by AMIL UTM shows the Load - Displacement relationship. Load starts at a point between 9-12N and ends between 6-9N. Displacement starts at 0 mm and ends between 21.00-24.00mm.

V. CALCULATIONS

Dimensions:

Length (l) =0.4 m, Width (w) =0.1m, thickness (t) =0.003m

Area (A) =0.04 m² Force = 24120 N

Displacement = 2.34 cm

Mechanical properties:

$$\text{Stress} = \frac{\text{Load}}{\text{Area}} = \frac{24120}{0.04} = 603 \text{ KN/m}^2$$

$$\text{Strain} = \frac{\text{Change in Length}}{\text{Original Length}} = \frac{0.01}{0.4} = 0.25$$

$$\text{Bending stiffness} = \frac{\text{Force Exerted}}{\text{Displacement}}$$

$$= \frac{24.12}{2.34} = 1030 \times 10^3 \text{ N/m}$$

$$\text{Young's modulus} = \frac{FL_0}{A_0 \Delta L}$$

Where, F: Force exerted L₀: Original length
A₀: Cross sectional area ΔL: Change in length

$$= \frac{24120 \times 0.4}{0.004 \times 0.02} = 1072 \times 10^6 \text{ N/m}^2$$

$$\text{Shear Modulus} = \frac{FL}{A \Delta x}$$

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Where, Δ_x : Transverse Displacement

$$= \frac{24120 \times 0.4}{0.004 \times 0.03} = 804 \times 10^5 \text{ N/m}^2$$

Bending stress = $\frac{3PL}{2Wt^2}$

$$= \frac{3 \times 24120 \times 0.4}{2 \times 0.1 \times 0.003} = 16080 \times 10^6 \text{ N/m}^2$$

Carbon/epoxy Property	Value
Fiber-volume ratio, V_f	0.65±0.70
Longitudinal Elastic Modulus, E_1 (GPa) (Msi)	146.6 (21.26)
Transverse elastic modulus, E_2 (GPa) (Msi)	10.35 (1.50)
In-plane shear modulus, G_{12} (GPa) (Msi)	7.6 (1.1)
Major Poisson's Ratio	0.28
Minor Poisson's Ratio	0.02
Longitudinal tensile strength, F_{1t} (MPa) (ksi)	2386 (346)
Longitudinal compressive strength, F_{1c} (MPa) (ksi)	1627 (235)
In-plane shear strength, F_{12} (MPa) (ksi)	71 (10.3)
Ultimate tensile strain, ϵ^u (%) _{1t}	1.45
Ultimate compressive strain, ϵ^u (%) _{1c}	1.36
Ultimate in-plane shear strain, ϵ^u (%) ₁₂	1.50
Transverse tensile strength, F_{2t} (Mpa) (ksi)	64 (9.3)
Transverse compressive strength, F_{2c} (Mpa) (ksi)	228 (33)

Table. 3 Mechanical properties of unidirectional AS4/3501-6 carbon/epoxy

Table.3 shows the mechanical properties like Fiber-volume ratio, Longitudinal Elastic Modulus, In-plane shear modulus, longitudinal tensile strength, longitudinal compressive strength, Ultimate tensile strain, Ultimate compressive strain etc., of unidirectional carbon/epoxy sheet. Values of all these are also mentioned.

Mechanical Properties	Sandwich Panel
Bending stiffness	$1030 \times 10^3 \text{ N/m}$
Young's modulus	$1072 \times 10^6 \text{ N/m}^2$
Shear modulus	$804 \times 10^5 \text{ N/m}^2$
Bending Stress	$16080 \times 10^6 \text{ N/m}^2$

Table.4 Mechanical Properties of Sandwich panel after testing

Table.4 shows the mechanical properties like Bending stiffness, Young's modulus, Shear modulus and Bending Stress of sandwich panel which are calculated in calculation part. All these values shows that sandwich panel have more strength than that of monolithic aluminium and carbon/epoxy sheet.

VI. CONCLUSION

Bending test is conducted on the aluminium alloy glass fiber sandwich panel and it is observed that aluminum alloy glass fiber sandwich panel has more strength to weight ratio compared to uniform aluminum. From bending test on the

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aluminum alloy glass fiber sandwich panel specimen it was observed that the start of plastic deformation could be delayed, resulting in increase of ultimate strength. The experimental tests have demonstrated that the light weight Aluminium panels have good properties of energy dissipation and the amount of energy absorption under bending test can be highly improved by reinforcing them by means of Glass fiber sheets, which can be designed according to the application of the sandwich. The future developments of this study consist of the analysis of failure maps of the aluminium and glass fiber sandwiches subjected to bending tests. Bending analysis is done on aluminium alloy glass fiber sandwich panel and there will be scope for study on square, TPS (flat walls) and TPS (corrugated walls) panels. In addition to the importance of reinforcement and matrix in polymer composites, the bonding between the sheets is key issue for overall metal fiber laminate performance. An adequate surface treatment of the metallic layer is required to assure a good mechanical and adhesive bond between the sheets.

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