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Experimental Study on The Effect of Aspect Ratio on Flexural Behavior of Aluminum Sandwich Composite

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HIGHLIGHTS

- Aluminium sandwich composite panel is one of the popular materials in structural applications particularly targeting for aesthetic appearance.
- Flexural behavior of these structural importance composite panel will have a research outcome for the benefit of material research industries.
- Investigation on the effect of aspect ratio on the flexural behavior of this sandwich composite will be a new attempt in this kind.

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ABSTRACT

Sandwich composites are one such kind of light-weight composites developed for structural and vehicle body buildings etc. Due to their remarkable features such as high specific strength, high toughness and resistance to inter laminar shear strength. In this study, commercially available aluminium sandwich composite (ASC) laminate was considered for investigating its flexural behavior and buckling behavior as it was mostly used for various structural applications. Flexural analysis was done for different aspect ratios in order to analyze the influence of cross section of the specimen and support span on the flexural capability of the sandwich beam. The composite specimens prepared for flexural test consist of length 150 mm and widths 15, 12 and 10 mm. The flexural test was done for support span of 90, 110 and 130 mm respectively. The performance measures of flexural test are maximum bending load, deflection, flexural stiffness and inter-laminar shear stress. The flexural analysis revealed the fact that the aspect ratio appreciably affected the flexural capacity of the sandwich composite laminates. Maximum flexural capacity with bending load around 3.5 to 4 kN and flexural stiffness around 2.5 to 4.7 kN/mm respectively was observed for the sandwich speciumen for the aspect ratios L/t = 30 and b/t = 5. Being a anisotropic structure, the flexural behavior of this sandwich composite exposed as a combination of bending and shear failure. The soft core material and ductile skin face sheets resulted in a combined failure against flexural load in static condition.

1. Introduction

In the recent times, particularly in the materials engineering, everyday a new material emerges targeting for a tailor-made application. Composite materials have a vital role in materials engineering in replacing the conventional materials targeting for various application in automotive, aerospace, bio medical and structural applications [1]. High performance light-weight composites are being developed in order to suit for very critical applications due to their remarkable properties such as very high specific strength, high corrosion and wear resistance. Sandwich composite laminates are materials where metal–polymer–metal sandwich sheets bonded together with adhesive layers. Sandwich panels are composite materials consisting of two thinner, lightweight outer face sheets. These type of materials are mainly characterized by their stiffness [2-4]. Though the thickness of the core in the composite is high, sandwich composites are light and have relatively high flexural strength. Aluminium sandwich composite is a sandwich panel often three layers consisting of two sheets of aluminium pre-coated on the faces bonded with a core of different material for properties required by the application. These sandwich composite panels are considered as excellent materials for indoor as well as outdoor applications, which require light-weight, good dimensional stability, and elegant appearance [5].

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Though many researchers and academicians contributed appreciably in the area of composite materials and particularly with polymer matrix composites, there exist still a scope for characterizing the special type of polymer metal sandwich laminates against flexural behaviour so that it can be recommended in future for wide range of structural applications [6-8]. In this study, a special category of polymer based composite called sandwich composite laminate was taken for investigating its flexural behaviour against various aspect ratios so that making it suitable for many structural applications in real time. Aspect ratio is the key factor considered in the study in order to study in detail about its influence on flexural behaviour of the composite laminate. A detailed literature review was carried out related to development and characterization of sandwich composite panels and arrived with the following findings:

1) Flexural mechanical properties increased with a relatively higher core density but lower specific resin uptake.
2) Through experience, we noticed that the greater the thickness of the compound, the greater the effects and damages that are applied to it from the process of bending and shearing.
3) It was noticed that the properties and specifications of the sandwich differ in terms of hardness and flexibility through the different composite materials in it.

The failure of sandwich composite structure is the result of multiple failure modes, include fiber failure, fiber-matrix shear failure, sheet delamination, interface deboning and foam failure.

2. Methodology

The materials used in the study was Aluminium sandwich composite (ASC) with the composition such as Core: Black High-density polyethylene of 2.4 mm thick and Face sheets: Aluminium of 0.3 mm thick each on either side of core. The fundamental properties of core and face sheet material are shown in Table 1. Commercially available aluminium sandwich composite (ASC) laminates are prepared for various cross sections to carry out the flexural test by three-point bending test conducted in bending tester machine of 20 kN capacity. The specimens are prepared with three different widths of 15, 12 and 10 mm for a standard length of 150 mm. The flexural test was carried on the specimens for different support spans such as 90, 110 and 130 mm. The experimental methodology was represented in Figure 1. Each test was repeated for three times in order to ensure the accuracy of the results obtained. The output measures such as maximum bending load, corresponding deflection and flexural stiffness were computed from the load-deflection curve obtained through the Data Acquisition System (DAQ) attached to the experimental set up with necessary sensors , whereas the inter laminar shear stress was calculated analytically [9]. The load applied in experimentation is concentrated type and applied manually. The experimental set up and sample output was shown in Figure 2 (a) and 1(b) respectively. The experimental results obtained from the flexural test was shown in Table 2.

Table 1: Properties of Black High-density polyethylene

Black High-density polyethylene		**Aluminium sheet**	
Property	***Value***	***Property***	***Value***
Temperature resistance	-50 to 80°C	Density	2.7 g/cm³
Flatwise shear	8.94 MPa	Melting Point	652 °C
Bending strength	78.4 MPa	Thermal Expansion	24 x10^-6 /K
Thermal expansion coefficient	2.36 x 10^{-5} mm/°C	Modulus of Elasticity	71 GPa
Weight	4.45 kg/m^2	Thermal Conductivity	165 W/mK
Tensile yield	58.24 MPa	Electrical Resistivity	0.041 x10^-6 Ω .m
Flatwise tensile	10.14 MPa	Proof Stress	245 MPa
		Tensile Strength	261 MPa
		Brinell Hardness	95 HB

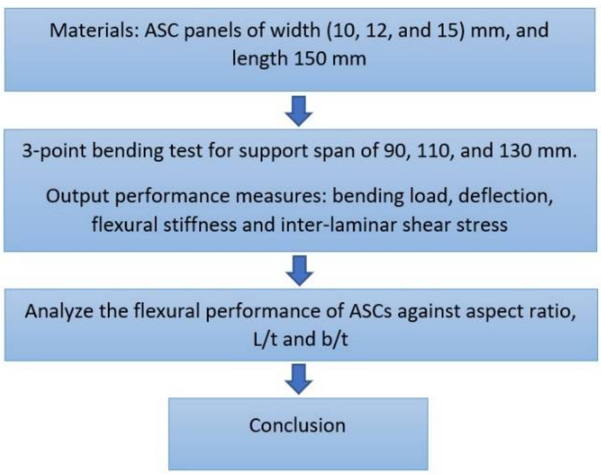

Figure 1: Experimental methodology flow chart

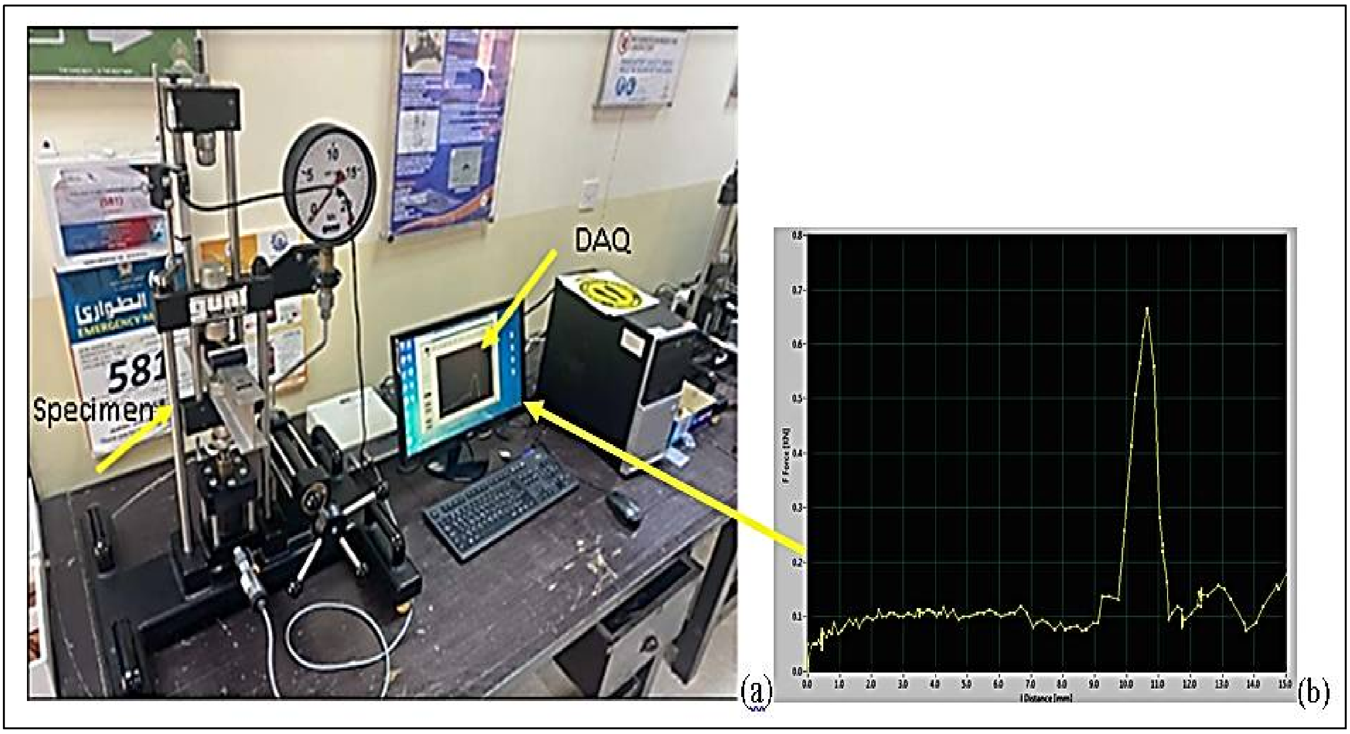

Figure 2: (a) Experimental set up for flexural test and (b) Output sample

Table 2: Experimental results of flexural test of ASC laminate

S.No.	L/t	b/t	Maximum bending load(kN)	Maximumdeflection (mm)	Flexuralstiffness (kN/mm)	Interlaminar shear strength(kN/mm^2)
1	30	5	3.672	9.912	4.75	0.0612
2	30	4	2.267	9.931	1.5	0.0472
3	30	3.3	2.040	8.427	2.5	0.051
4	36.67	5	0.489	13.599	2.4	0.00815
5	36.67	4	0.395	13.121	0.4	0.00822
6	36.67	3.3	0.511	12.973	0.14	0.0127
7	43.33	5	3.892	19.678	2.5	0.0648
8	43.33	4	2.867	19.873	4.5	0.0597
9	43.33	3.3	2.964	19.318	3.6	0.0741

3. Results and Discussion

The output measures from the flexural study such as maximum bending load, maximum deflection, flexural stiffness and inter-laminar shear stress are shown in Figures 3 - 6. The aspect ratio considered in the study, L/t and b/t significantly affected the flexural performance of the sandwich composite laminate. The maximum bending load in Figure 3 showed a decreasing trend with respect to the aspect ratio L/t for all the values of b/t. Anyhow, the least bending load was observed for 12 mm width composite laminates corresponding to 0.4 to 0.5 kN for all the values of support span. Lower and higher width of the laminates resulted in better bending resistance rather than the medium width of 12 mm. This may be due to the fact that the width of 12 mm was unable to offer the sufficient resistance against bending with the combined effect of resistance offered by the core and face sheets [10]. Compared to that of bending load, the maximum deflection had no influence with the aspect ratio, L/t as shown in Figure 4. The bending deflection increases with the decrease in the width of the laminates. Decrease in the width of the laminates decreases the moment of inertia, which in turn reduces the resistance against bending and thereby increases the deflection. From the Figure 5, it was observed that the flexural stiffness decreases with decrease in width of the laminates as well as decrease in the aspect ratio, L/t. Maximum stiffness of 4.75 kN/mm was observed for sandwich specimen with aspect ratios, L/t=30 and b/t=5 respectively. Decrease in width and increase in support span reduces the deformation resistance considerably on the combined core and face sheet constituents. Inter-laminar shear stress is a unique feature observed during the flexural analysis of a material when the support span is very short, where the shear stress dominates more in the flexural behavior [11-13]. It was observed from Figure 6, the inter-laminar shear stress was least for the aspect ratio 36.67 irrespective to the width of the laminates. At minimum support span, the behavior of the beam was similar to short beam with shear stress as more dominant than the transverse stress. Overall, the flexural behavior was better for L/t=30 and b/t= 5. The optimized values of width and support span for better flexural capcity was found to be 15 mm and 90 mm respectively.

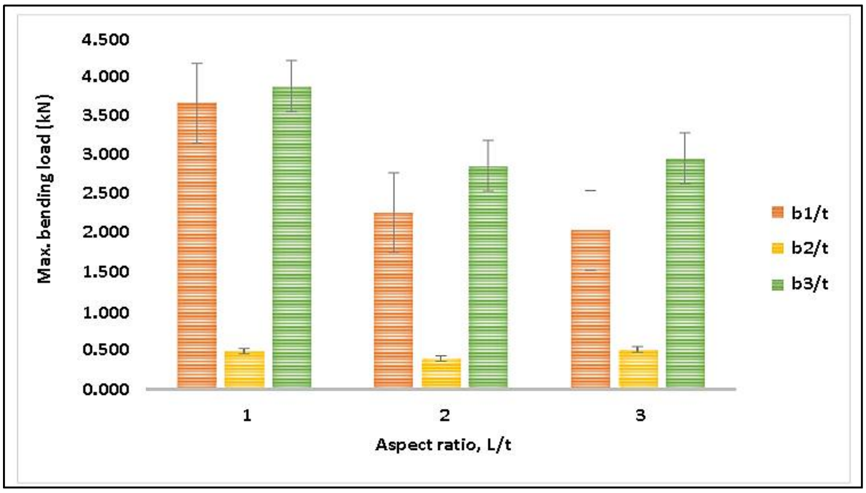

Figure 3: Maximum bending load for various aspect ratios

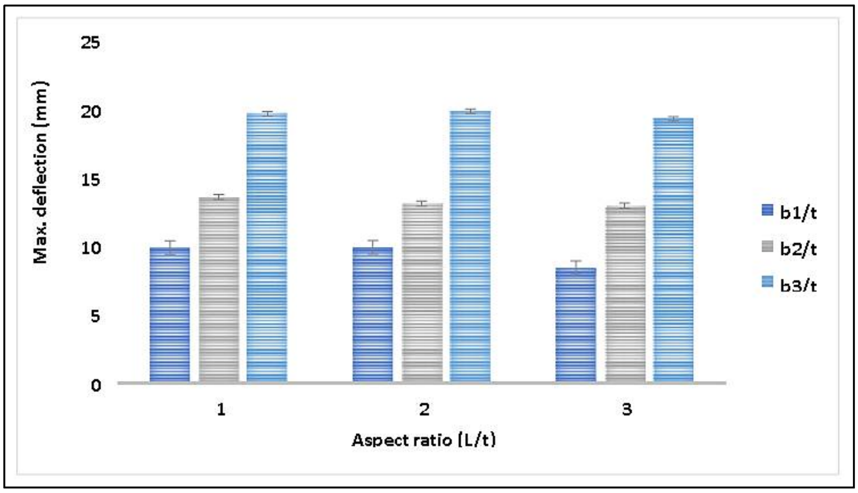

Figure 4: Maximum deflection (bending) for various aspect ratios

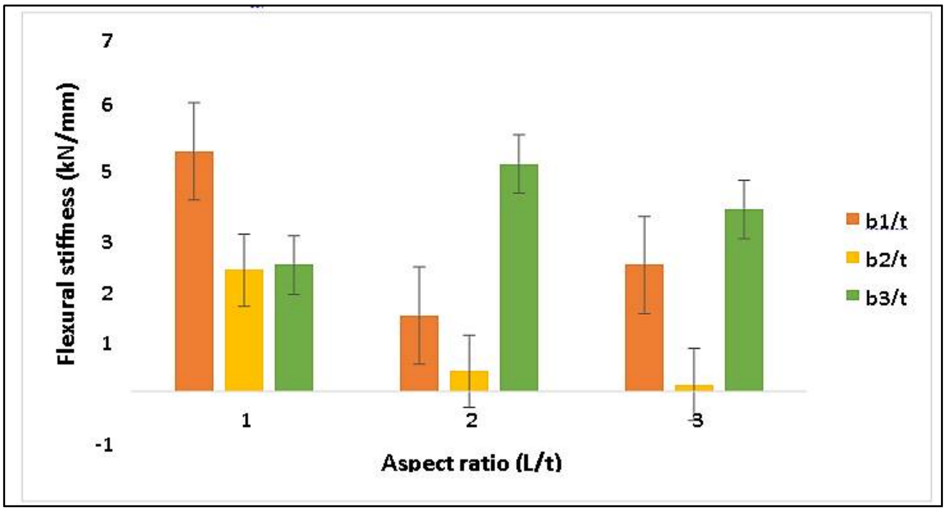

Figure 5: Flexural stiffness for various aspect ratios

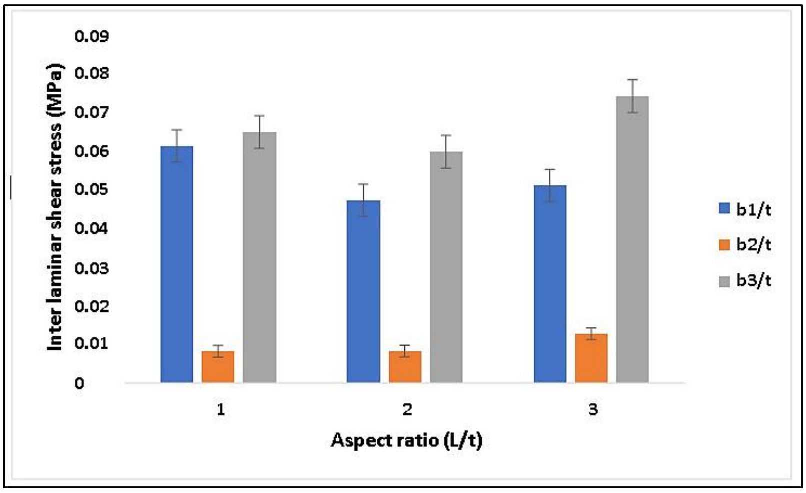

Figure 6: Inter laminar shear stress for various aspect ratios

4. Conclusion

The following are the conclusions drawn from the study of flexural analysis of Aluminium sandwich composite laminates (ASCs):

1) The results of flexural test on sandwich composite laminates revealed the fact that the aspect ratio, L/t and b/t i.e., support span and width of the laminate specimens affected the flexural stability largely.
2) Maximum bending load and maximum flexural stiffness of around 3.6 kN and 4.75 kN/mm respectively was observed for least support span of 90 mm and highest width of the laminate 15 mm. Higher the width, higher was the resistance offered against bending and similarly when the support span increases during bending, the intensity of spring back reduces and leads to permanent bending.
3) Maximum inter-laminar shear stress was observed for laminate widths 10 mm and 15 mm, whereas least for the width 12 mm. Therefore the optimum width of the specimen for the length 150 mm of the specimen was 12 mm in order to resist the delamination shear of the laminate.

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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