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Flexural Behavior of Sandwich Structure with AA 8011 Honeycomb Core and Al 1100 Face Skins

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ABSTRACT:

This paper details the fabrication and flexural testing of sandwich structure with Aluminium honeycomb core with Aluminium face skins. The material for the face skin is aluminium 1100 and for the core is Aluminium AA8011. The cell size obtained by fabrication is 7mm. The specimen is prepared and tested as per the ASTM standard C393/C393M-11 on a three-point bending test to obtain the ultimate core shear strength and the face skin strength. Finite element analysis is also carried out to validate the experimental test.

KEYWORDS:

Sandwich panels; Aluminium honeycomb core; Core shear strength; Finite element analysis

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1. Introduction

High strength to weight ratio of structural composites finds a wide range of application that includes mostly in the area of aeronautics and automobile industries. Sandwich structural composites generally consist of face sheets, core and adhesives. The face sheets can be made of Aluminium, Steel/Stainless Steel, Carbon/Epoxy, Fibreglass, Aramid and Plywood. The core must be light in weight and strong enough to oppose the loads acting in the normal direction to the panels [1]. The core must be strong enough in shear to prevent the slipping of the face sheets over each other. If this is not fulfilled, the face sheets act as two independent panels and the sandwich effect is lost. In addition, the core should be strong enough to stabilize the thin face sheets, otherwise local buckling of the face sheets may happen [2-3]. Current lightweight structural cores are classified into honeycomb, balsa and foam. The primary aim of the project is to fabricate the sandwich structure made of Aluminium face sheet and Aluminium honeycomb core and then test the same by using three point bending test to find out the failure modes. The theoretical calculations are carried out to find out the ultimate core shear strength and the face skin strength, followed by finite element analysis (FEA) to validate these test results.

2. Specimen preparation and test setup

The core sheet is made of Aluminium alloy AA8011. It is cut as per the required dimension. Then the sheet is rolled by multiple passes in corrugated roll forming machine to form the semi-hexagonal shape. Two formed corrugated sheets, as shown in Fig. 1, are joined to get a single hexagonal cell structure using adhesive formulated from Araldite AW 106 resin [4] and HV953 IN hardener. The resin and hardener are mixed in the ratio of 100:80. A 0.10mm thick layer of adhesive is applied and cured at room temperature for 8 hours. The cured honeycomb core is shown in Fig. 2.

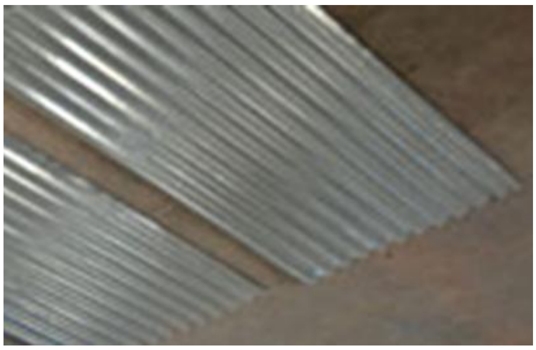

Fig. 1: Roll formed sheet

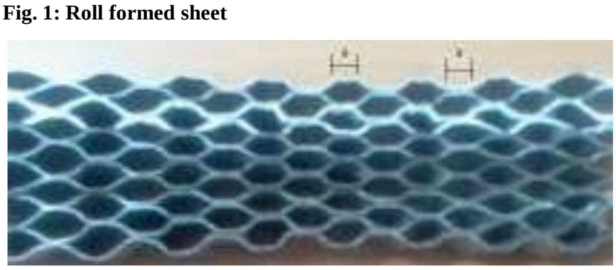

Fig. 2: Stacked core post curing

Face-sheets and honeycomb cores are joined as two discrete solid-phases through a secondary bonding. An adhesive film is applied to the top and bottom surfaces of the honeycomb, upon which the resin flows and makes a clear bond line between the face sheets and honeycomb core. For a reliable bond at the interface of the core, the resin should spill out of the sheet and create a symmetric fillet on the honeycomb wall surrounding the interface between the honeycomb wall and the face sheet. The fabricated sandwich honeycomb test specimen is shown in Fig. 3. The standard method to calculate the core shear strength of sandwich structure through beam flexure is given by ASTM C393/C393M-11 [5]. The experimental test setup is shown in Fig. 4. The specimen dimensions and test parameters are listed in Table 1.

Fig. 3: Fabricated sandwich test specimen

Fig. 4: Specimen loaded in three point bending test

Table 1: Specimen dimensions and flexural test inputs

Parameter	Description	Value
L	Length (mm)	200
S	Support rollers span (mm)	170
b	Width (mm)	50
t	Face skin thickness (mm)	0.8
c	Core thickness (mm)	25
d	Total thickness (mm)	26.6
E	Elastic modulus, sheet (MPa)	70000
ν	Poisson ratio, sheet	0.3

3. Experimental results

The load-displacement curve from the three point bend test of the fabricated specimen is shown in Fig. 5. The force-displacement curve is examined to see if there are any significant changes, a 10% or more change in its slope. Initially, the specimen behaviour is in a linear manner that ends in reaching a peak load value of about 4575 N. After this peak value, there is a sudden fall from the peak value due to local cells buckling. After buckling, a folding mechanism appears. Increasing the compressive displacement, the cells tend to deform with a periodic shape. If the compression displacements keep on increasing, the cell walls reach a level at which they cannot accommodate further more folds, and consequently the load-displacement curve shows a sudden increase of the load. After buckling, the cell walls under the roller try to fold and results in a "local densification point"[3]. The peaks from the three point bending test curve are listed in Table 2. The second folding occurs at applied load of 4.518 kN with a total deflection of 37.4 mm. The ultimate core shear strength can be calculated from the test using,

$$\tau = \frac{P}{(d+c)b} \tag{1}$$

Where P is the maximum test load prior to failure. The facing stress can be calculated using,

$$\sigma = \frac{P*S}{2t(d+c)b} \tag{2}$$

Substituting the specimen dimensions from Table 1 and the peak test load from Table 2 into Eqns. (1) and (2), the core shear strength and facing stress from the test are calculated as 1.87 MPa and 224.08 MPa respectively.

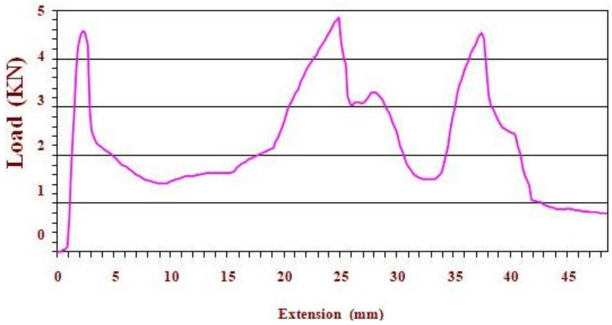

Fig. 5: Three point bending test - Load vs. Deflection

Table 2: Maximum load and displacement from the test curve

Max. load (kN)	Deflection (mm)
4.575 (Peak)	2.2
4.846 (Ist Fold)	24.8
4.518 (IInd Fold)	37.4

4. Finite element analysis

The finite element analysis (FEA) is carried out using MIDAS NFX software [6] to validate the test results. Honeycomb core is modelled using 2D shell elements as shown in Fig. 6. The face skin and the bond between the core and face skins are modelled using 3D solid elements. A cross-section view of idealised finite elements of the sandwich structure is shown in Fig. 7. The nodes at the contact of the support rollers are constrained in TZ = 0 to idealise a simply supported boundary condition. The nodes at the contact of loading roller are constrained in TX = 0 and TY = 0 to idealise no-slip condition during loading. A vertical load in Z-direction is applied at the master node of loading roller idealised using a rigid body element [7]. The applied load is 4846 N. The fringe plots of the displacement, core shear stress and facing stress from the FEA are presented in Figs. 8 to 10 respectively. Table 3 shows that the test results correlate well with FEA results.

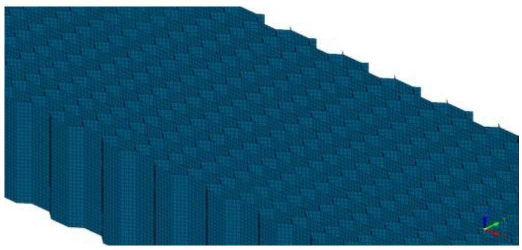

Fig. 6: 2D shell model of honeycomb core

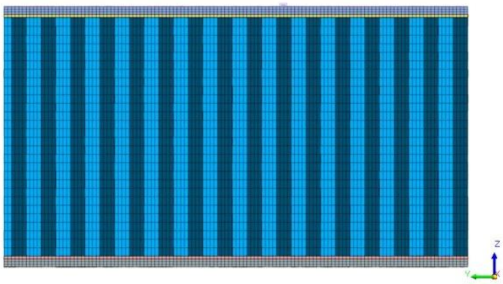

Fig. 7: Cross-section view of assembled sandwich structure model

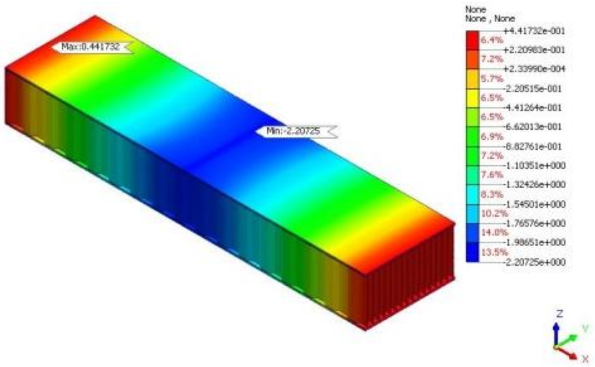

Fig. 8: Flexural displacement fringe plot

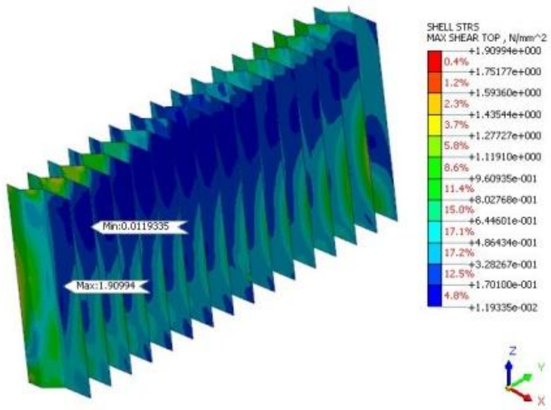

Fig. 9: Critical core shear stress fringe plot

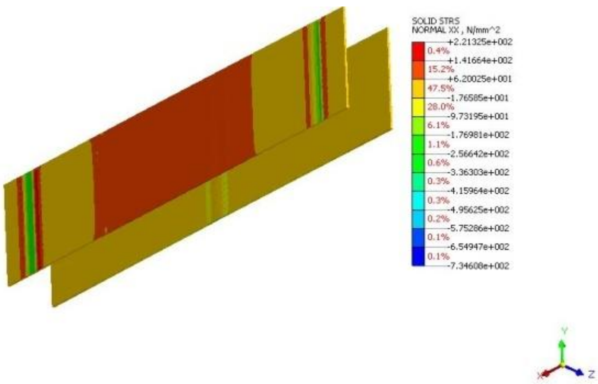

Fig. 10: Facing stress fringe plot

Table 5: Experimental results vs. FEA results

Result	Test	FEA	Diff. (%)
Deflection (mm)	2.2	2.207	0.32
Core shear stress (MPa)	1.87	1.9	1.57
Facing stress (MPa)	224.08	221.32	-0.10

5. Conclusion

The sandwich panel using aluminium honeycomb core and aluminium face skins was fabricated and then three point bending test specimens were prepared in a controlled environment. The specimens withstood a maximum load of 4.84 kN. Detailed FEA was carried out to validate the flexure test. The FEA included the effect of bond between the honeycomb core and the face skins. The comparison of ultimate core shear strength, face skin stress and deflection has validated well the experimental test results.

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