



Structural response of hybrid sandwich panels with aluminium foam core and thin Aluminium face sheets under bending loading

Kaveh R.Kabir, Tania Vodenitcharova and Mark Hoffman

School of Materials Science and Engineering, University of New South Wales

Sydney, NSW 2052, Australia



Aim

Develop a set of design parameters to manufacture aluminium-skinned metal foam sandwich panels which can resist three-point bending loading

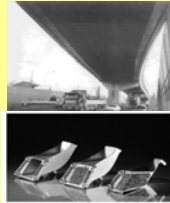
Why metallic foams?

Characteristics:

- ✓ Low density
- ✓ High energy absorption
- ✓ Low thermal conductivity
- ✓ High acoustic absorption
- ✓ Mechanical damping

Applications:

- ✓ Light-weight structures
- ✓ Energy absorbers
- ✓ Sound absorbers
- ✓ Heat exchangers
- ✓ Multi-functional structures



Materials

Foam core

- ✓ Closed cell aluminium foam (Trade name ALPORAS)
- ✓ Density = 0.2-0.3 g/cm³
- ✓ Relative density = 7-11%
- ✓ Pore size = 2.5 mm
- ✓ Modulus of elasticity¹ = 1.1 GPa
- ✓ Yield strength¹ = 1.4-1.6 MPa
- ✓ Bending strength¹ = 2.5-3.1 MPa



Skin

- ✓ Thin aluminium sheet
- ✓ AA 3104-H19
- ✓ Thickness 0.32 mm
- ✓ Thin aluminium sheet

Adhesive

- ✓ Epoxy adhesive film (Redux 322)

Materials characterization

Vickers hardness test

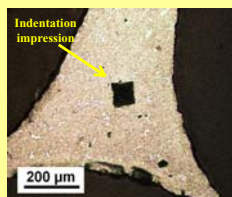
On cell walls of the foam

MPa

Tension test

On dog-bone samples of the skin

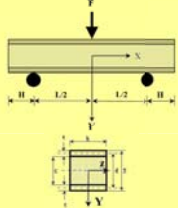
$E = 70$ GPa
 $\sigma_{y(skin)} = 230$ MPa



Sample preparation and test method

Sample preparation

- ✓ Cutting foam panels and Al sheet
- ✓ Degreasing and Abrading of foam core and skins
- ✓ Assembling sandwich panels
- ✓ Employing hot press machine to cure the adhesive



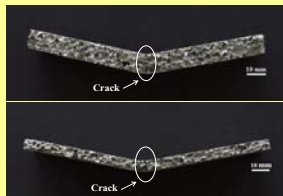
Test method

- ✓ Three-point bending
- ✓ Foam only & sandwich panels
- ✓ ASTM C 393-06
- ✓ 50 and 100 mm span lengths
- ✓ Foam thickness 6 and 12 mm

Failure modes and failure load of foam panels

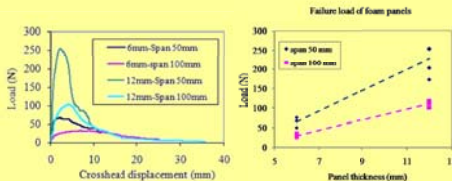
Deformation behaviour

- ✓ Similar deformation behaviour observed in both thicknesses and span lengths
- ✓ Crack observed in all samples at mid-span; initiated at the tensile side of the beam and propagated by further loading



Failure load

- ✓ Increased with panel thickness
- ✓ Higher for smaller span length



Failure modes and deformation behaviour

Deformation behaviour

Failed in two different mode

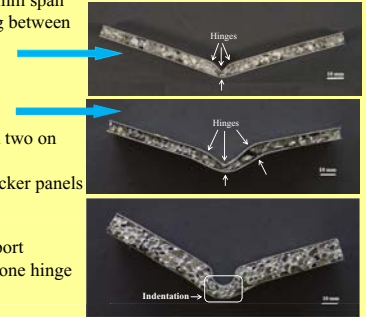
Symmetric deformation

- Observed in both thicknesses but only in 100 mm span
- ✓ Four hinges, indentation mark and shearing between supports observed



Asymmetric deformation

- ✓ Observed in beams with 50 mm span
- ✓ Five hinges observed - three on top skin and two on back face
- ✓ Indentation mark observed, specially in thicker panels
- ✓ Smaller span length → higher shear force

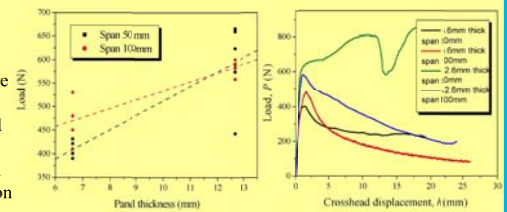


Two plastic hinges in both skins above one support developed and the foam core shears there; only one hinge above the other support

Asymmetric deformation

Failure load

- ✓ Increasing by increasing core thickness
- ✓ Higher in thinner panels and larger span
- ✓ Higher in thicker panels and smaller span, due to indentation

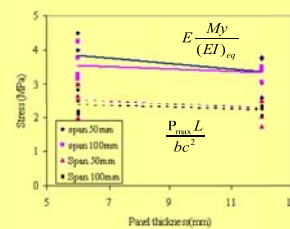


Bending Strength

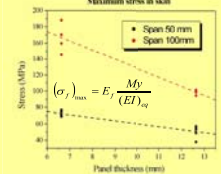
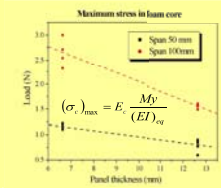
$$\sigma_{max} = \begin{cases} E \frac{My}{(EI)_{eq}} & \text{Fully elastic material} \\ \frac{P_{max} L}{bc^2} & \text{One hinge failure mechanism} \end{cases}$$

$$(EI)_{eq} = E_f \frac{btd^2}{2}$$

Foam panels



Sandwich panels



- ✓ Higher in larger span
- ✓ Lower in thicker panel

Dissipated energy

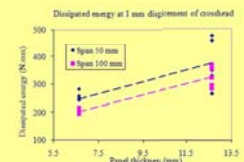
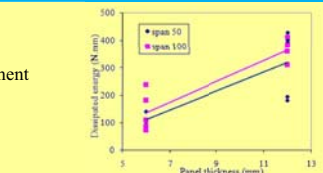
Calculated by the area under load vs. displacement

Foam panels

- ▶ Calculated up to failure load
- ▶ Higher for thicker panels
- ▶ Higher for larger span

Sandwich panels

- ▶ Calculated up to 1 mm of crosshead displacement
- ▶ Higher for smaller span length
- ▶ Higher for thicker panels



Conclusions:

- I. Bending strength, failure load and dissipated energy increased dramatically by laminating foam panels
- II. The failure mode depends on span length