The Mechanics and Behavior of Hybrid Sandwich Structures

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Introduction to Sandwich Panels

The equations governing the response of a beam in bending can be given by:

\[
\frac{F}{\delta} = \frac{48EI}{l^3}
\]

\[
\sigma = \frac{My}{I}; \quad I = \frac{bh^3}{12}
\]

• Define the relative density, \( \bar{\rho} \), of a panel as the mass of the panel divided by the mass of a solid block with the same enclosed volume.

\[
\bar{\rho} = \frac{\rho_c}{\rho_s}
\]
Core Topologies

Metallic face sheets

Polymer foam and carbon fiber pins

150 μm

50 mm

10 mm

20 mm
Core Classification

Bending Architecture

Stretching Architecture

- For the same relative density material the modulus and initial yield strength of a stretching-dominated core is much greater than that of bending dominated core.

Hybrid Materials

Material Property 1

Material Property 2

Adapted From Ashby
Hybrid Sandwich Panels

Polymer foam

Insertion of the rods

Lay-up and cure face sheets

Specifics: Foam Density 31kg/m³
Pin Volume Fraction 3%
Pin Angle 22°
Face Sheet
Thickness 1.5mm

Polymer foam core reinforced with carbon fiber pins
Carbon fiber face sheets

10 mm
Uniaxial Compression Results:

- Pins can be thought of as Euler columns on an elastic foundation.
- Synergistic interactions between the pins and foam.
- The foam reinforces the “Euler columns” by stabilization against buckling.
Sandwiches in Three-Point Bend:

• In order to take full advantage of the structural efficiency gains offered by sandwich panels, a robust understanding of the bending response is needed.

• We identify possible collapse modes for each beam geometry and use an upper bound work balance analysis to predict collapse loads.
Sandwich Beam Collapse Modes:

**INDENTATION:**

\[ F = 4bt \sqrt{\sigma_f \sigma_c} \]

Indentation is likely to occur in panels with weak cores and thin face sheets, or in panels with high core thickness to span ratios.

**CORE SHEAR:**

\[ F = \frac{4bt^2}{l} \sigma_f + \frac{4bc}{3} \sigma_c \]

Relatively thick panels loaded transversely carry the shear loading primarily in the core of the panel and can initiate collapse by the shearing failure of the core.

**FACE FAILURE:**

\[ F = \frac{4bt(c + t)}{l} \sigma_f + \frac{bc^2}{l} \sigma_c \]

Failure of the face sheets is typical of beams with thin cores and long spans owing to the tensile or compressive stresses resulting from the bending moment.
Failure Mode Map

- Map displays the initial collapse of a simply supported sandwich beam.

- Map takes axes of non-dimensional ratios of core thickness to face sheet thickness as a function of core thickness to beam span.

- Plotting non-dimensional parameters, the map displays all possible beam geometries for a given material.
Bend Experimental Results:

(A) Failed by Core Shear

(B) Failed by Indentation

(C) Failed by Core Shear
Analysis of Failure Modes:

- Face Yield
- Core Shear
- Indentation

Graph shows points A, B, and C with labels.
Comparison with Competing Cores:

Pin reinforced cores exhibit a dramatic increase in stiffness as well as a much higher failure load prior to collapse.

References: Tagarielli, V.L. and Fleck, N.A., 2003
Steeves, C. A and Fleck, N.A., 2004
Stochastic Cores- Pumice

- Pumice is a natural aggregate formed during volcanic eruptions with properties similar to an engineering ceramic foam.

- Very Inexpensive

- Can be combined with a pyramidal core to produce a hybrid type sandwich structure
Pumice acts as a reinforcing phase to the pyramidal cores.

The resultant strength behavior is additive.
Conclusions:

• Hybrid sandwich structures offer exciting potential in weight critical applications.

• Comparison of the hybrid pin reinforced sandwich core response with competing cores demonstrates that the panels outperform other sandwich structures in both stiffness and load carry capacity.

• Hybrid Pumice Pyramidal panel results show that this topology can exhibit increased strength and energy absorption capabilities.

• Future studies on these hybrid panels are required for further understanding of the deformation mechanisms.