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The Mechanics and Behavior of Hybrid Sandwich Structures

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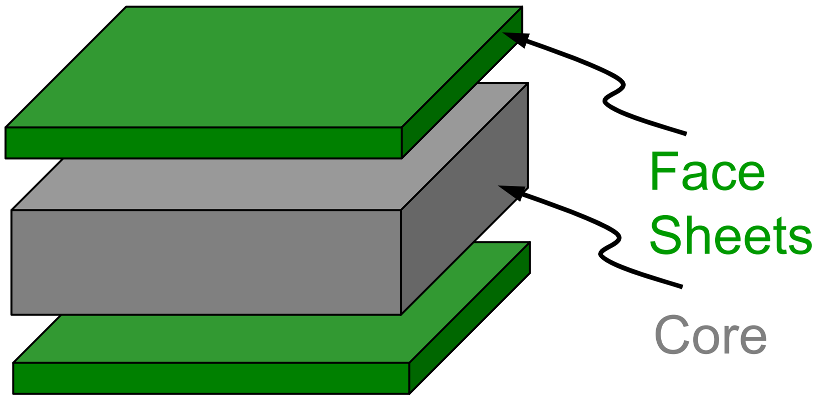
26 October 2006
FEMCI Workshop 2006

Funding provided by: NASA Goddard SFC DDF Program and Lockheed-Martin Maritime Systems

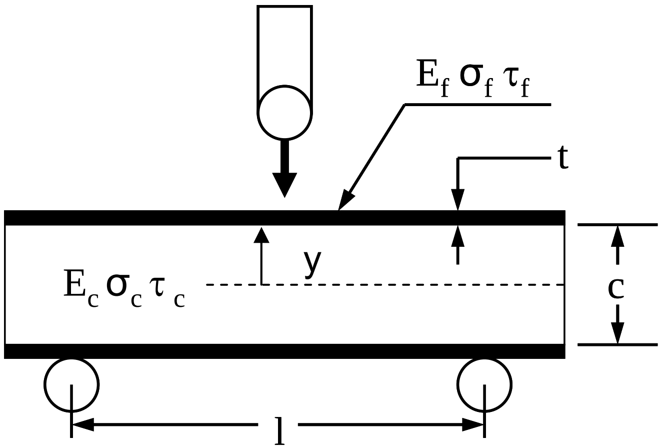
Introduction to Sandwich Panels



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

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

$$\sigma = \frac{My}{I}; I = \frac{bh^3}{12}$$



- 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.

$$\bar{\rho} = \left(\frac{\rho_c}{\rho_s} \right)$$

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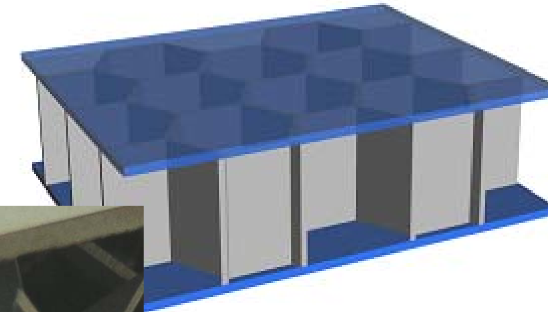
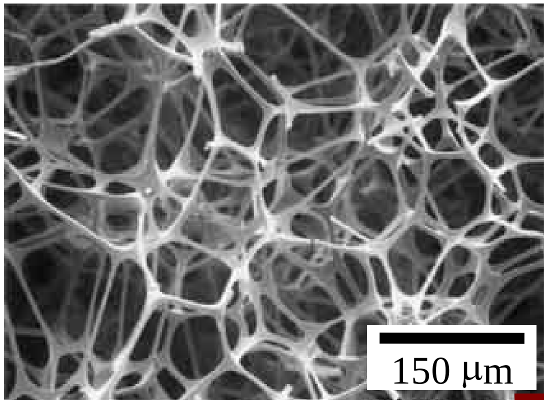
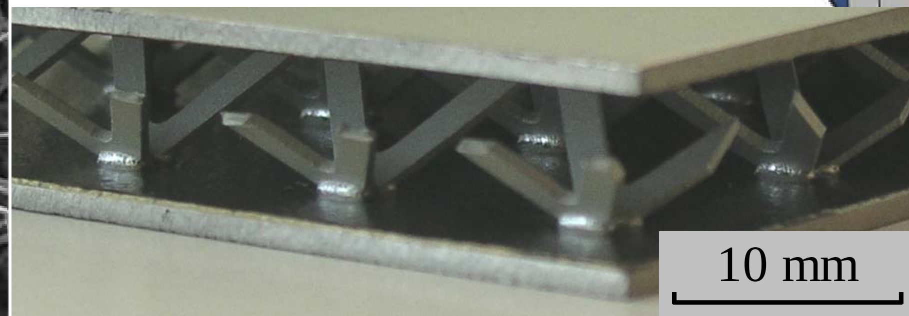
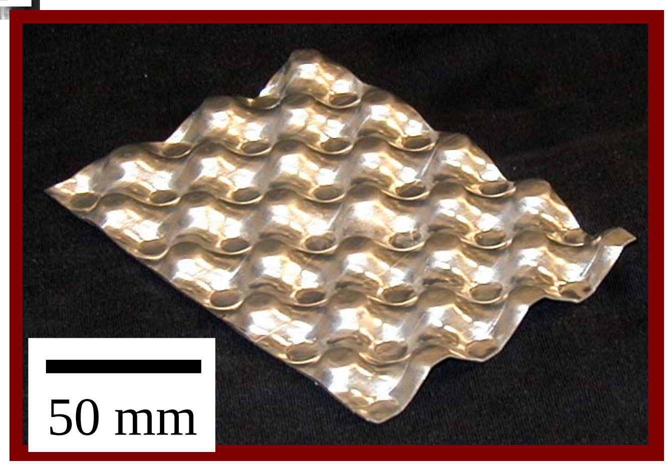
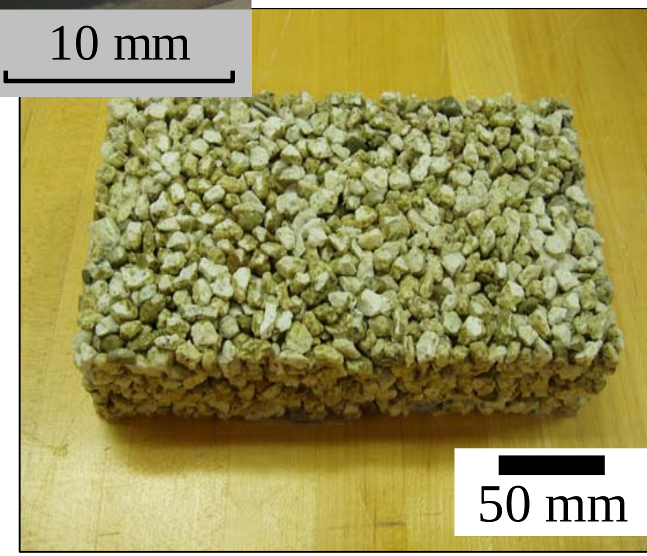
Core Topologies

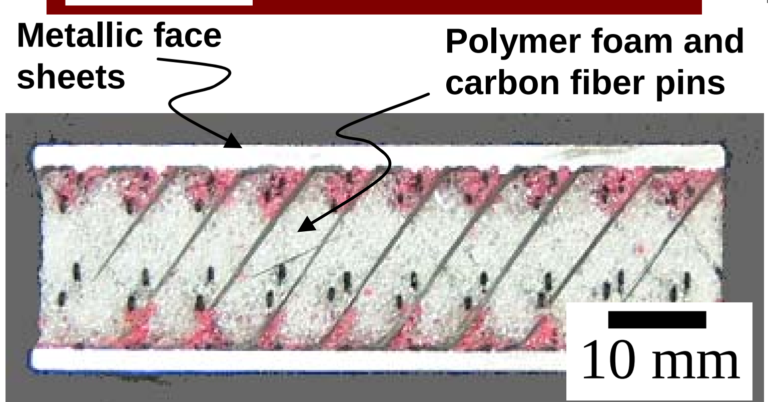


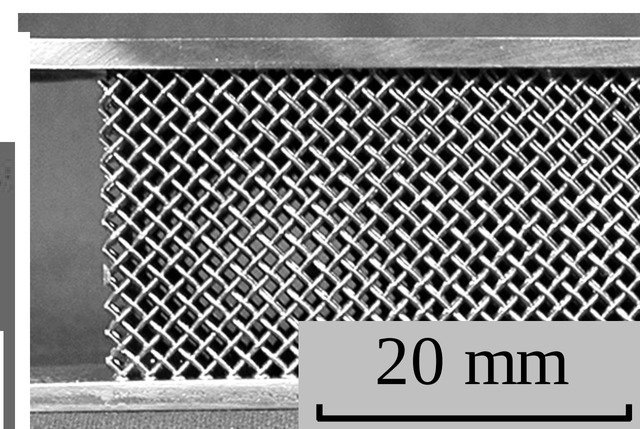






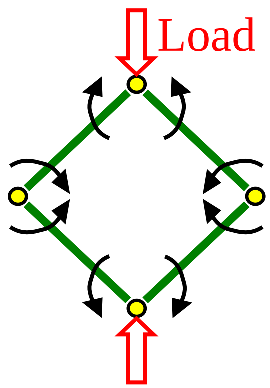


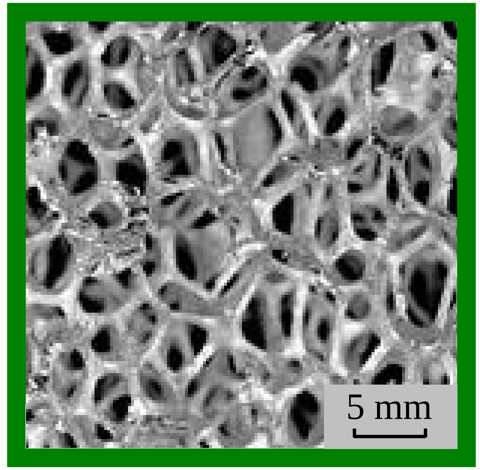




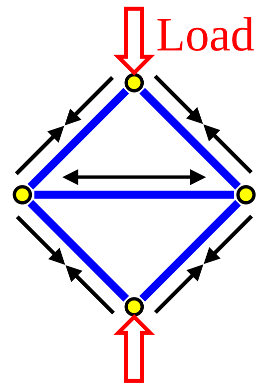
Core Classification

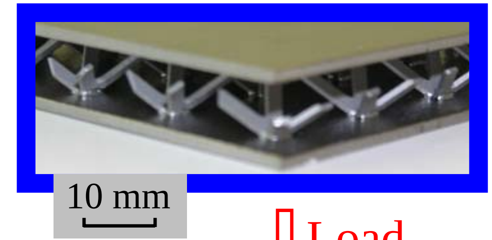
Bending Architecture

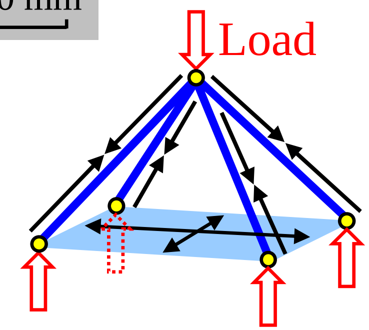


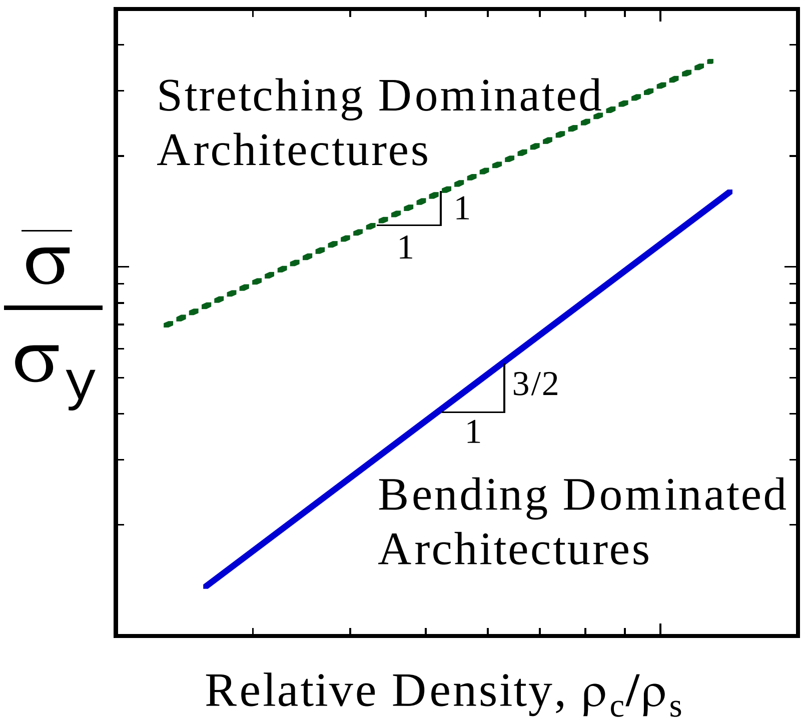


Stretching Architecture





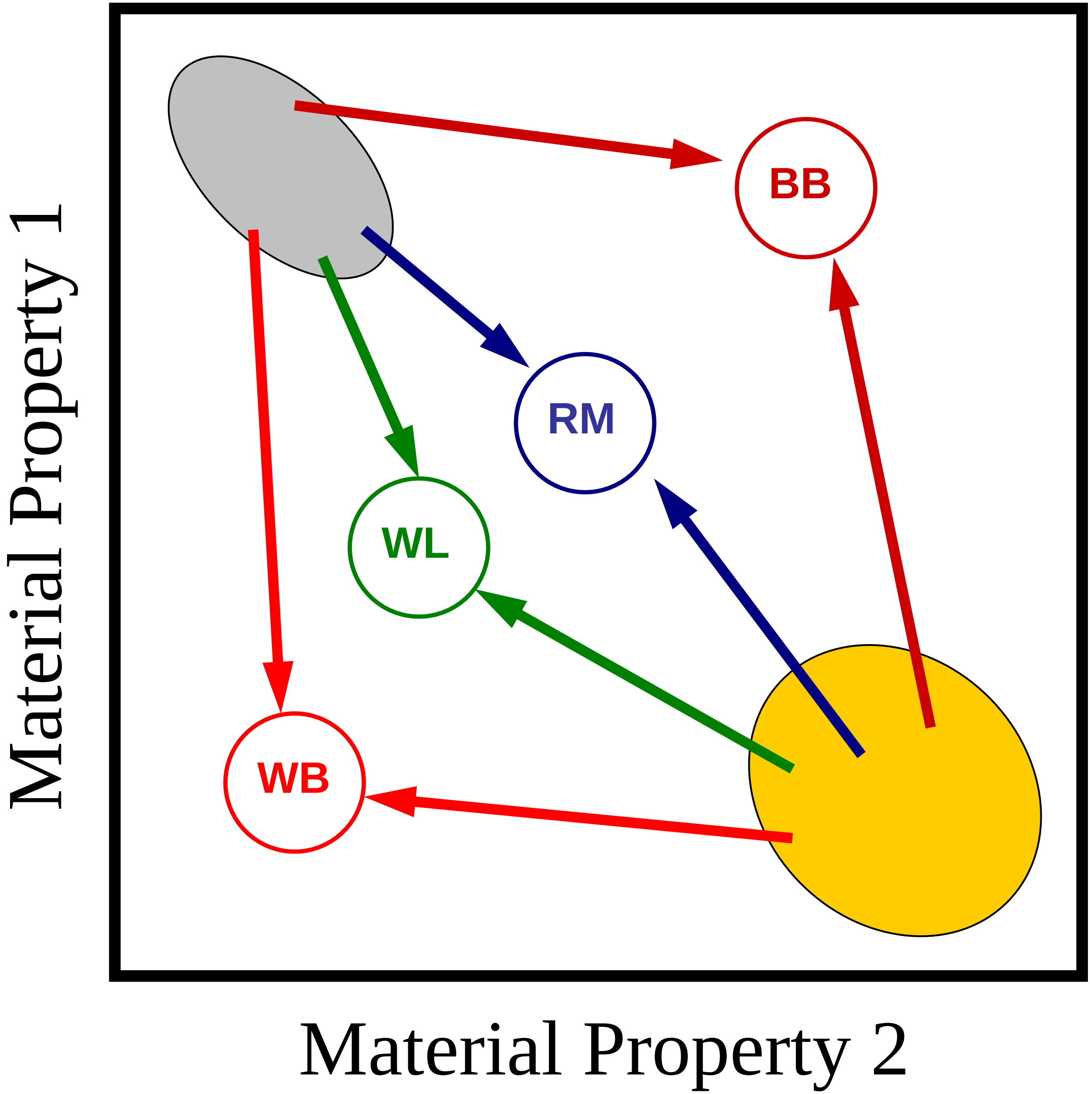




- For the same relative density material the modulus and *initial* yield strength of a stretching-dominated core is much greater than that of bending dominated core.

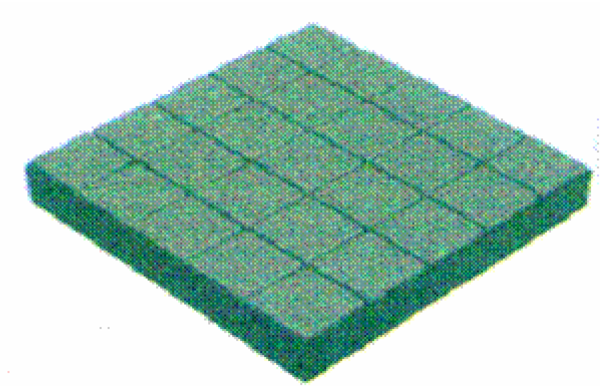
Deshpande, V.S., Ashby, M.F., and Fleck, N.A. "Foam Topology bending vs stretching dominated architectures," *Acta Materialia, Volume 49,* 2001.

Hybrid Materials



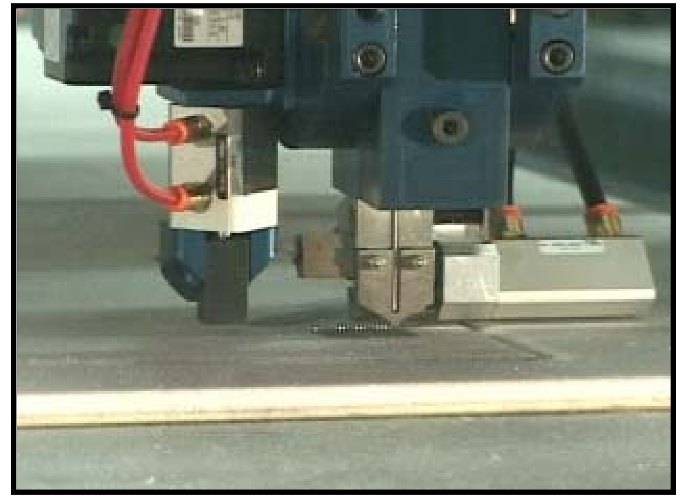
Adapted From Ashby

Hybrid Sandwich Panels



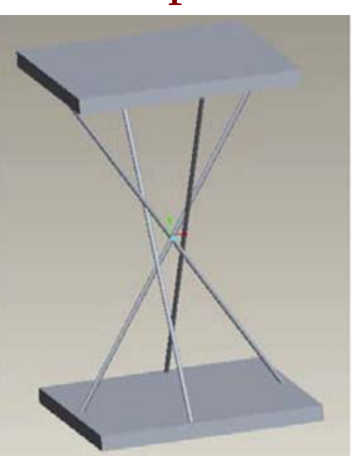
Polymer foam

Insertion of the rods



Lay-up and cure face sheets

Specifics: Foam Density 31kg/m^3

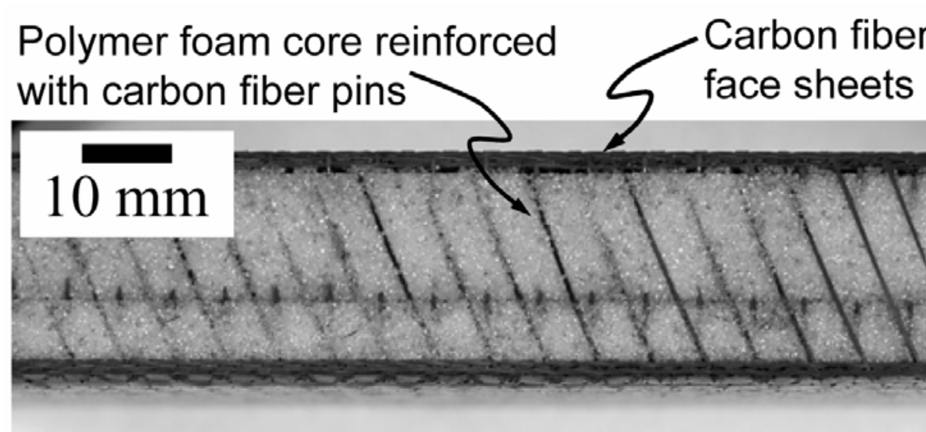


Pin Volume Fraction 3%

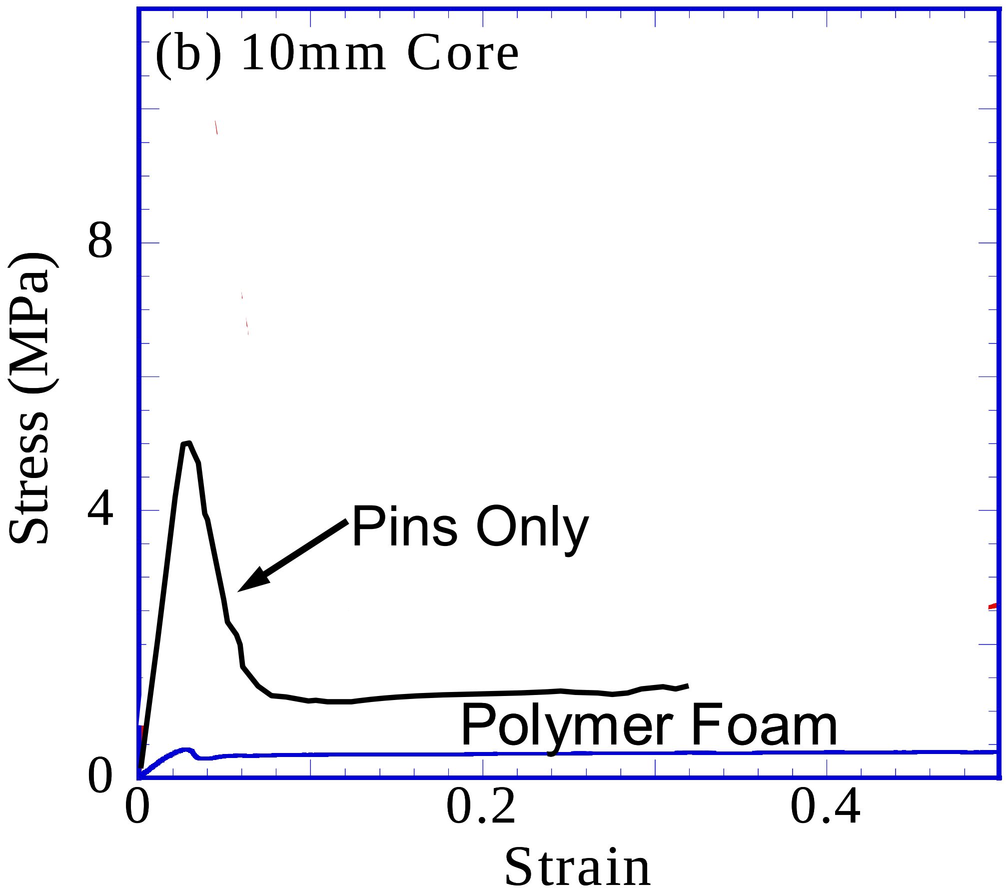
Pin Angle 22°

Face Sheet

Thickness 1.5mm



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.

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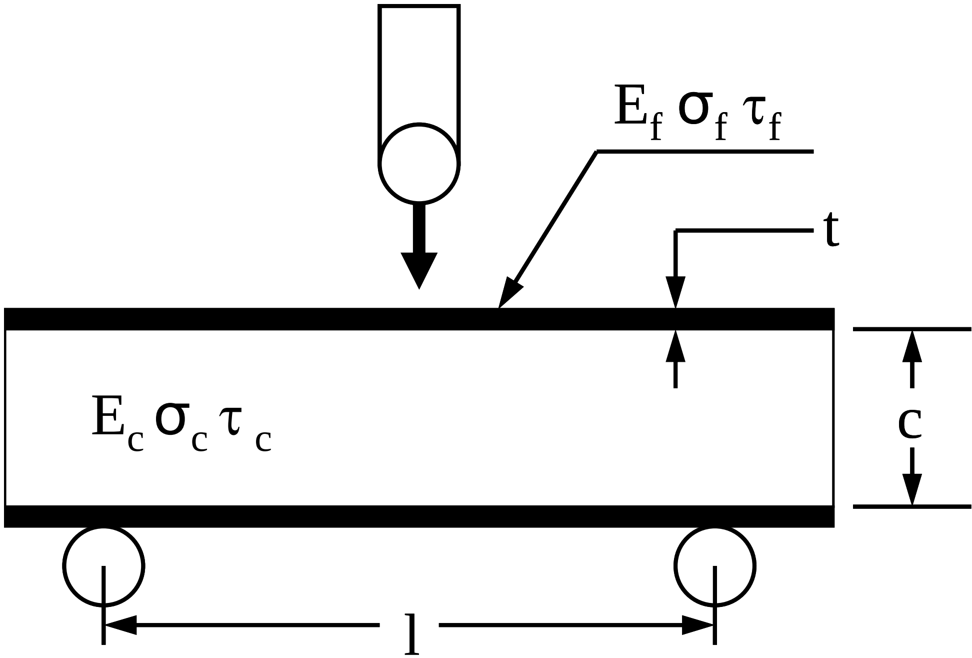
Sandwiches in Three-Point Bend:

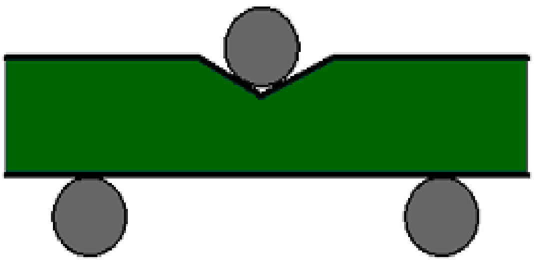
- In order to take full advantage of the structural efficiency gains offered by sandwich panels, a robust understanding of the bending response is needed.

- 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:

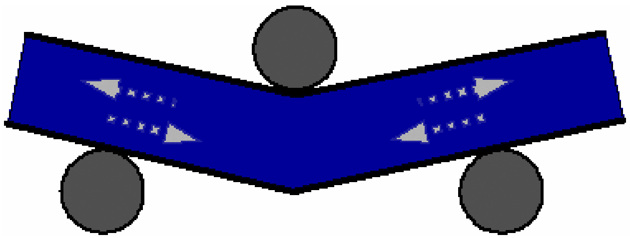
INDENTATION:



$$F = 4bt\sqrt{\sigma_f \sigma_c}$$

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

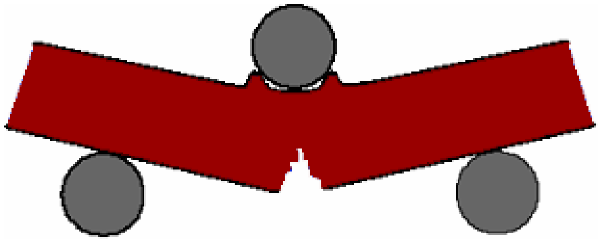
CORE SHEAR:



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

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.

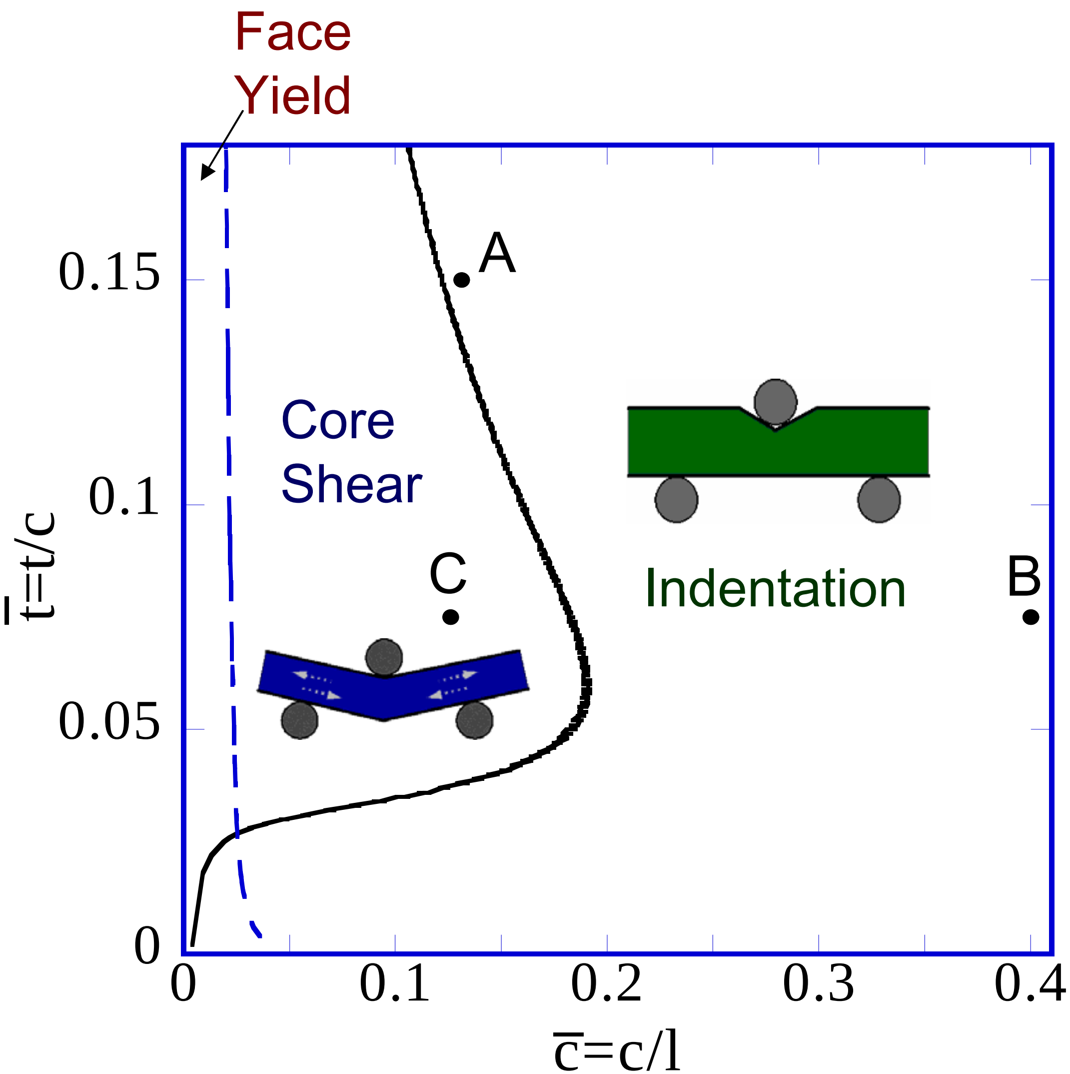
FACE FAILURE:



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

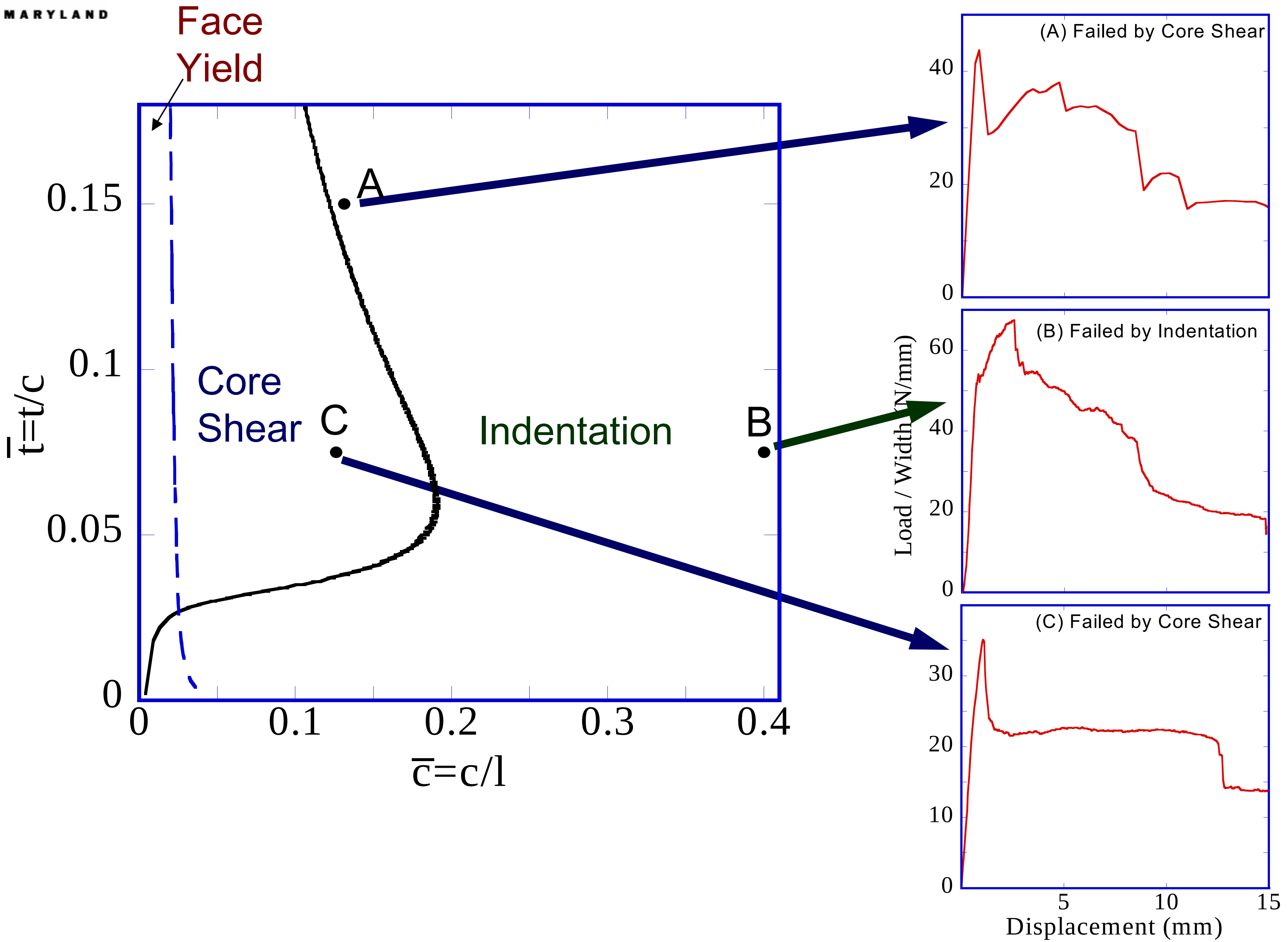
Failure of the face sheets is typical of beams with thin cores and long spans owing to the tensile or compressive stresses resulting from the bending moment.

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:



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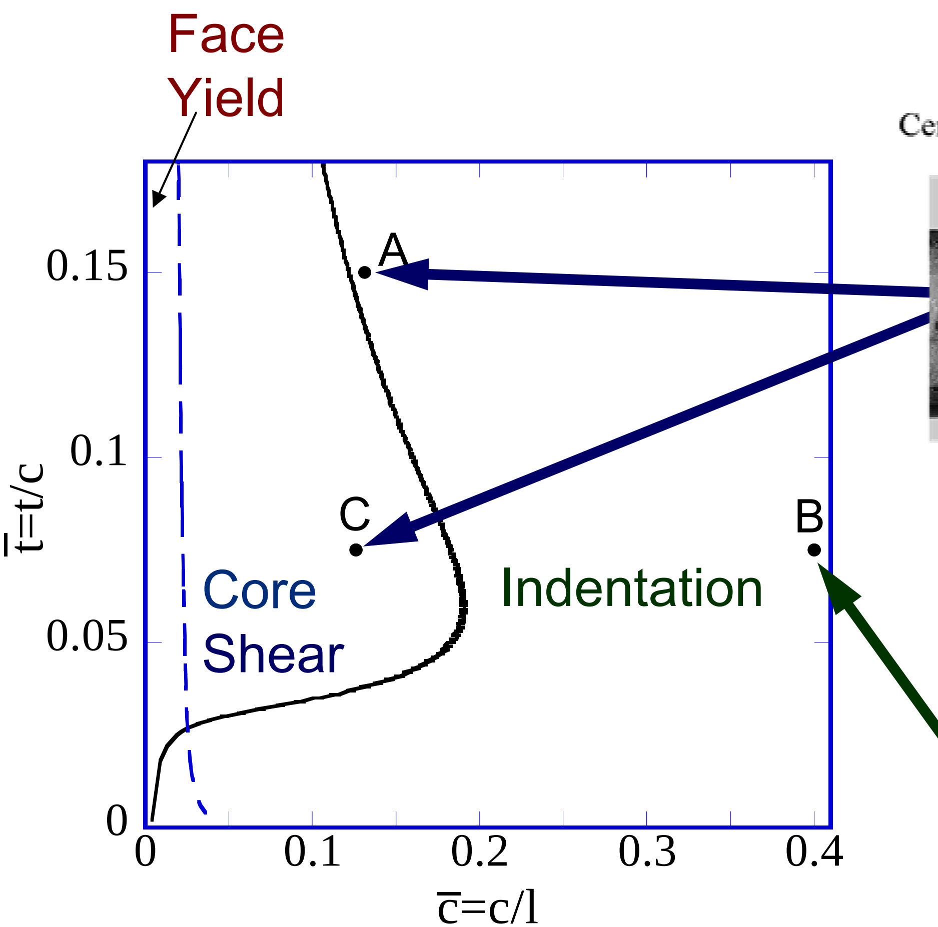
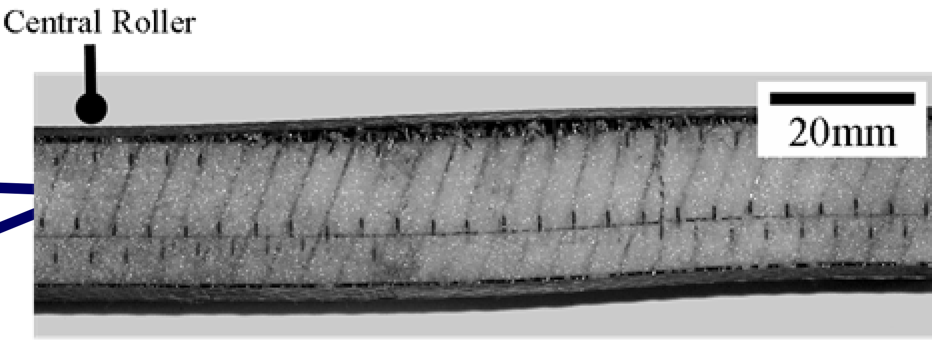
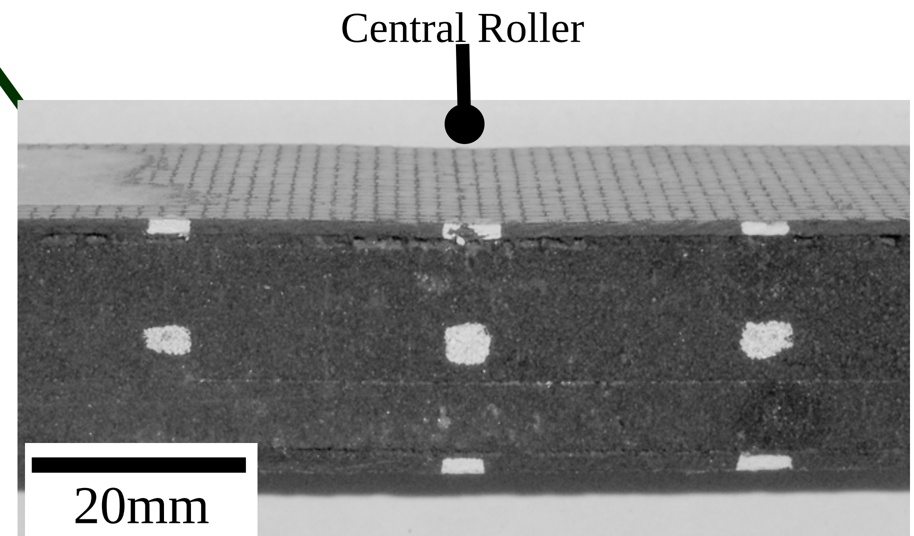
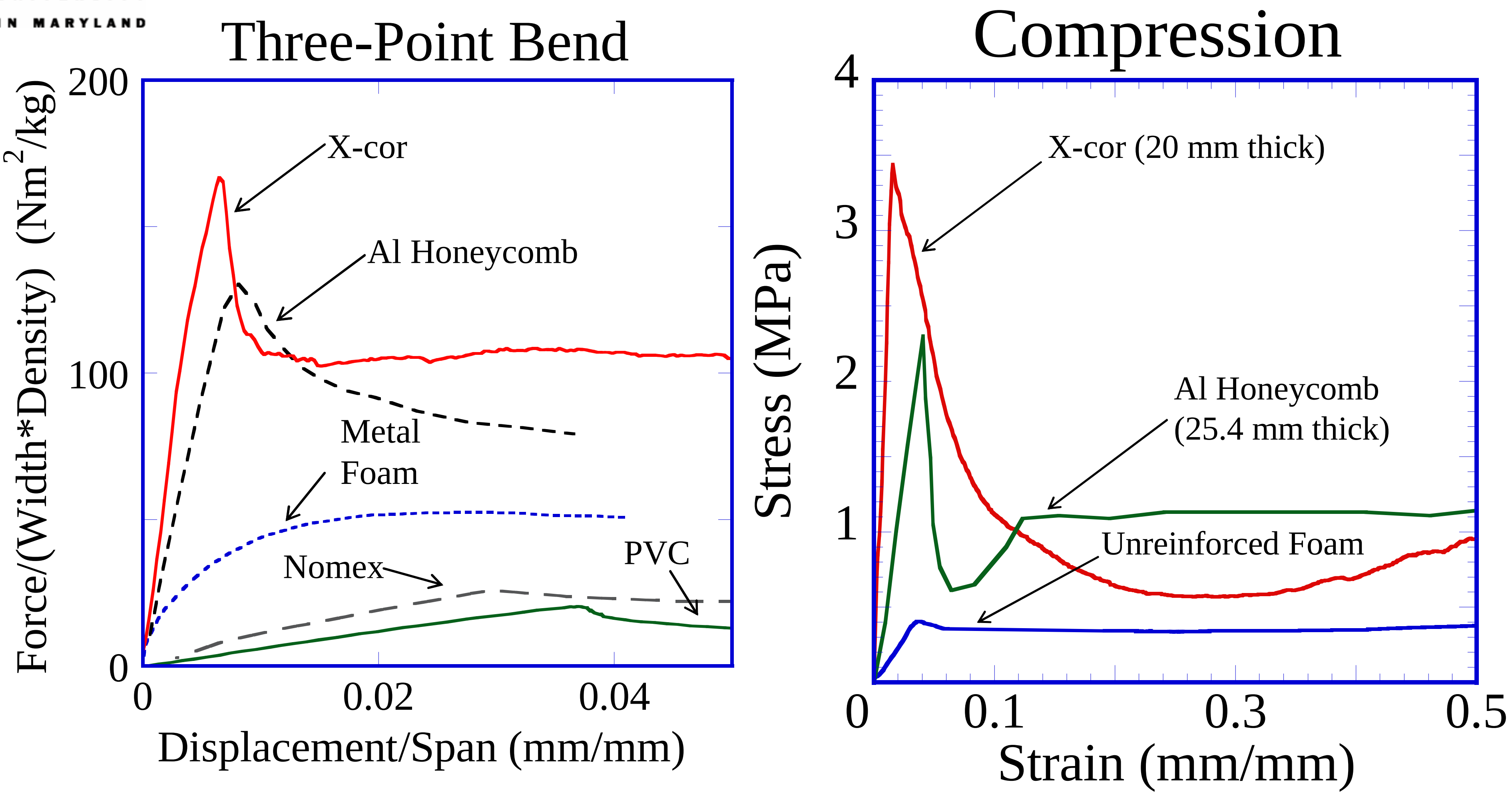
Analysis of Failure Modes:







Comparison with Competing Cores:

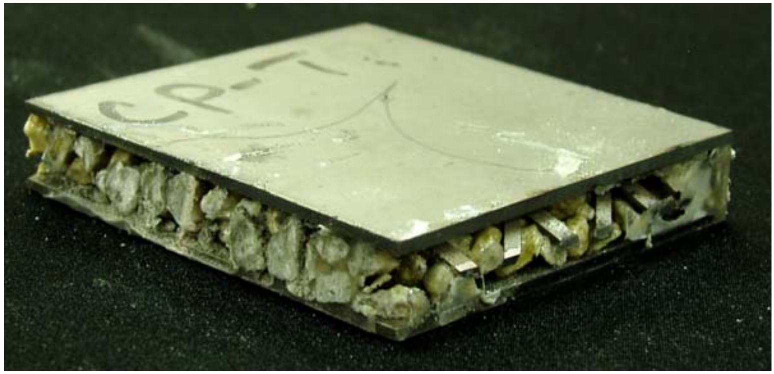


Pin reinforced cores exhibit a dramatic increase in stiffness as well as a much higher failure load prior to collapse.

References: Tagarielli, V.L. and Fleck, N.A., 2003
Steeves, C. A and Fleck, N.A., 2004

Stochastic Cores- Pumice

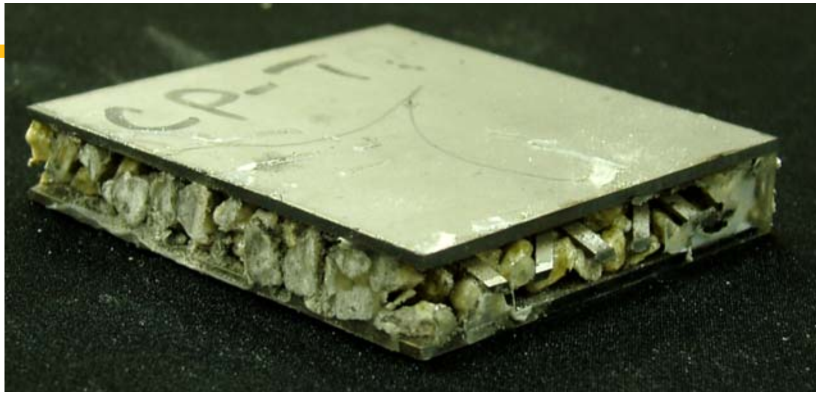
•Pumice is a natural aggregate formed during volcanic eruptions with properties similar to an engineering ceramic foam.

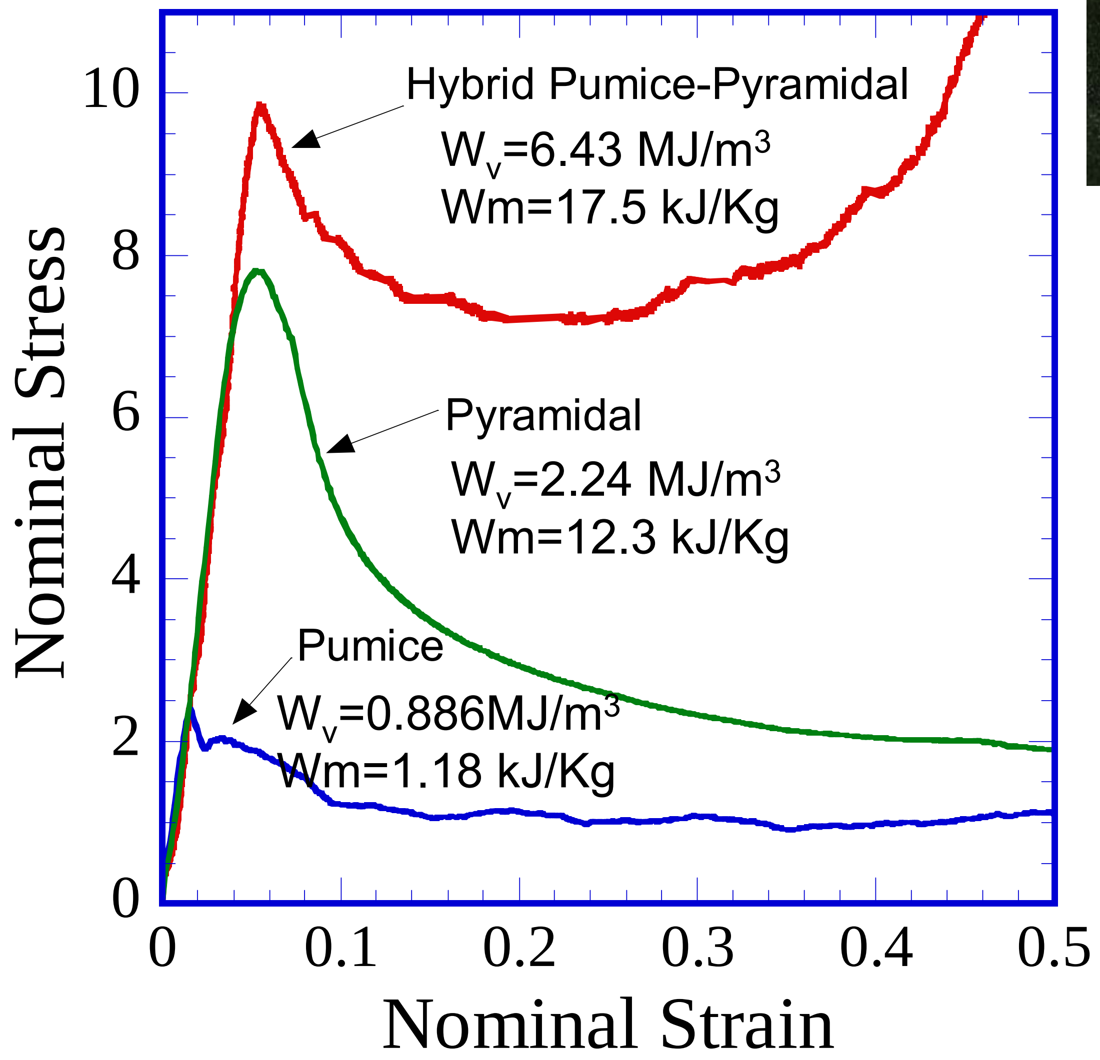


•Very Inexpensive

•Can be combined with a pyramidal core to produce a hybrid type sandwich structure

Pumice Pyramidal Hybrid





- 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.