Effects of Sandwich Material Selection and Design Parameters on Aramid Honeycomb Sandwich Bonding

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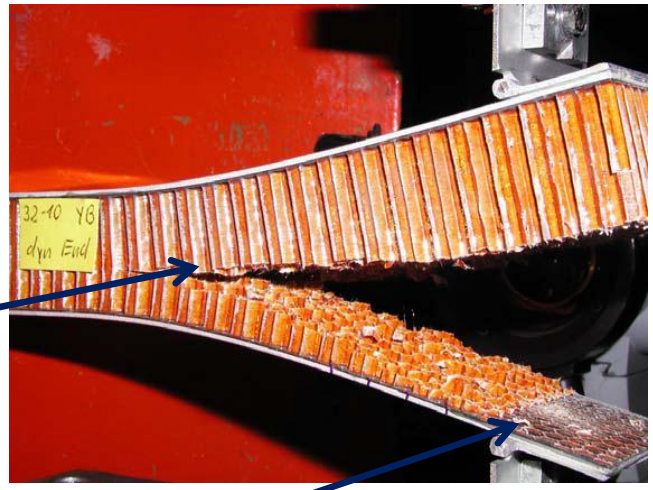
Purpose

To educate designers and fabricators of aramid honeycomb sandwich structures on key aramid honeycomb material properties and sandwich fabrication techniques that affect sandwich structure failure modes

Failure Modes Discussed:

1. **Face sheet-to-core disbond**
2. **Core fracture**

Figure from Airbus Presentation to Sandwich Disbond TG (R. Hilgers)



Discussion Points

- **Nomex® vs. Kevlar® N636 honeycomb cores**
- **Face sheet-to-core bonding**
  - Honeycomb core surface cut quality
  - Contamination / Cleaning
  - Adhesive selection
- **Core fracture**
  - Fracture toughness
- **Industry resources and efforts to increase understanding**
  - Composite Materials Handbook-17 – new Sandwich Structures Volume 6
  - CMH-17 Disbond / Delamination Task Group

Nomex® vs. Kevlar® N636 Honeycomb

Kevlar® N636 HC Properties Enhanced vs. Nomex® HC*:

Shear strength and modulus

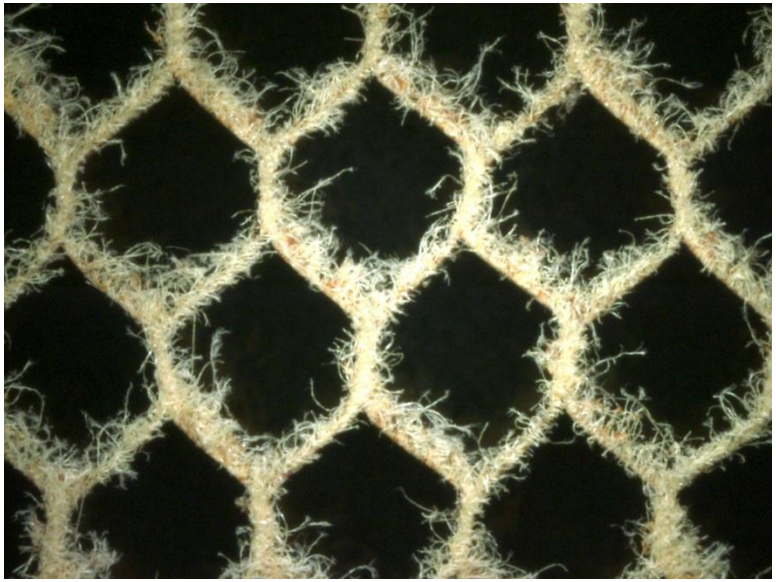
Shear and compressive fatigue

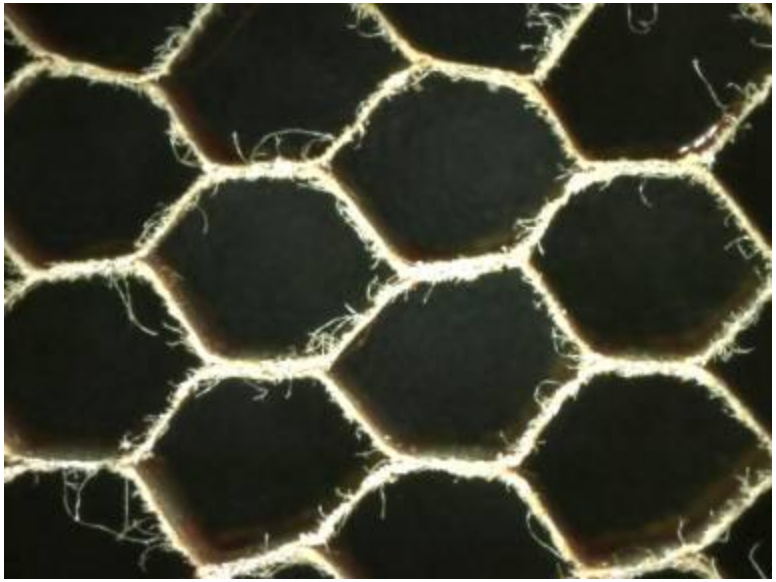
Flatwise tensile strength

Hot/wet strength retention

* Comparative data for reference at end of presentation

Aramid Honeycomb Surface Cut Quality Varies

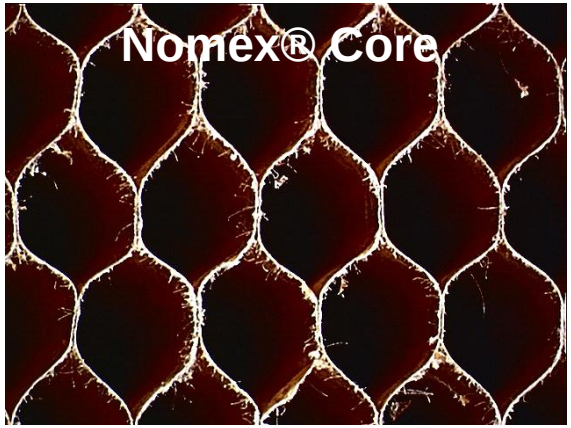




Kevlar® N636 Core from 2 Suppliers

Fuzzy surface may affect:

- **Good fillet formation**
- **Bond strength**
- **Impact resistance**
- **Damage tolerance**



Contamination of Face sheet-to-Core Bonds

The bonding surface of honeycomb is a distinct solid phase. Honeycomb does not flow or mix during the part manufacturing process.

Honeycomb is subject to surface contamination.

Polymeric solids (including composite honeycomb) can exude substances such as low molecular weight oligomers. These substances can interfere with bonding, especially if they become concentrated at the bond line.

Solvent exposure of composite honeycomb (e.g. during cleaning) followed by solvent evaporation can cause soluble contaminants to migrate to the bonding surface.

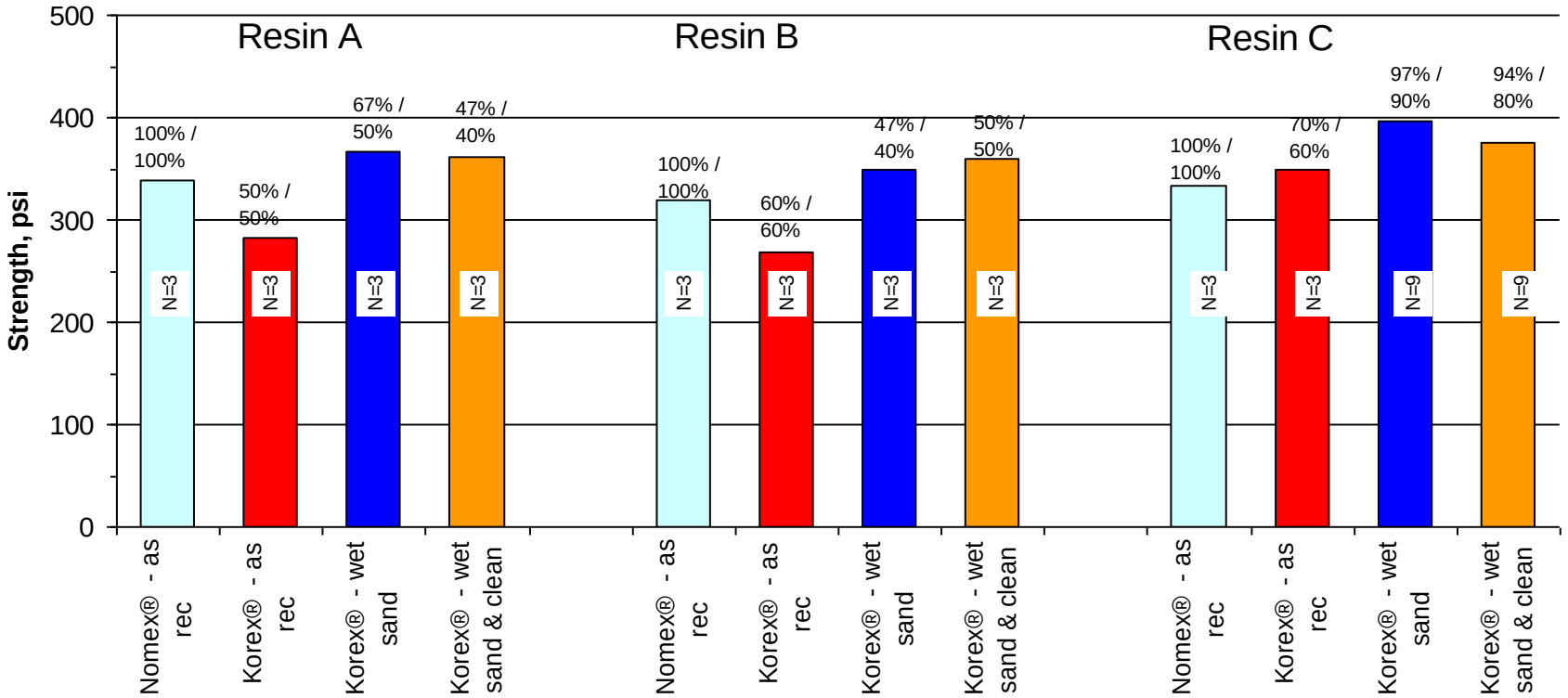
Adhesive Selection is a Key Parameter

Korex® Bonding Study
Flat Wise tension

% core failure
ave / min

N = Number of Samples tested

Nomex® 1/8"-3 pcf
Korex® 3/16"-2 pcf
All adhesives 0.03 psf with mat
0.062" thk G11 face sheets



"Equivalent" resins revealed to not be equivalent

FSP 11/00

Film adhesive vs. self-adhesive prepreg, amount of adhesive present, and resin flow characteristics important to bond quality and strength

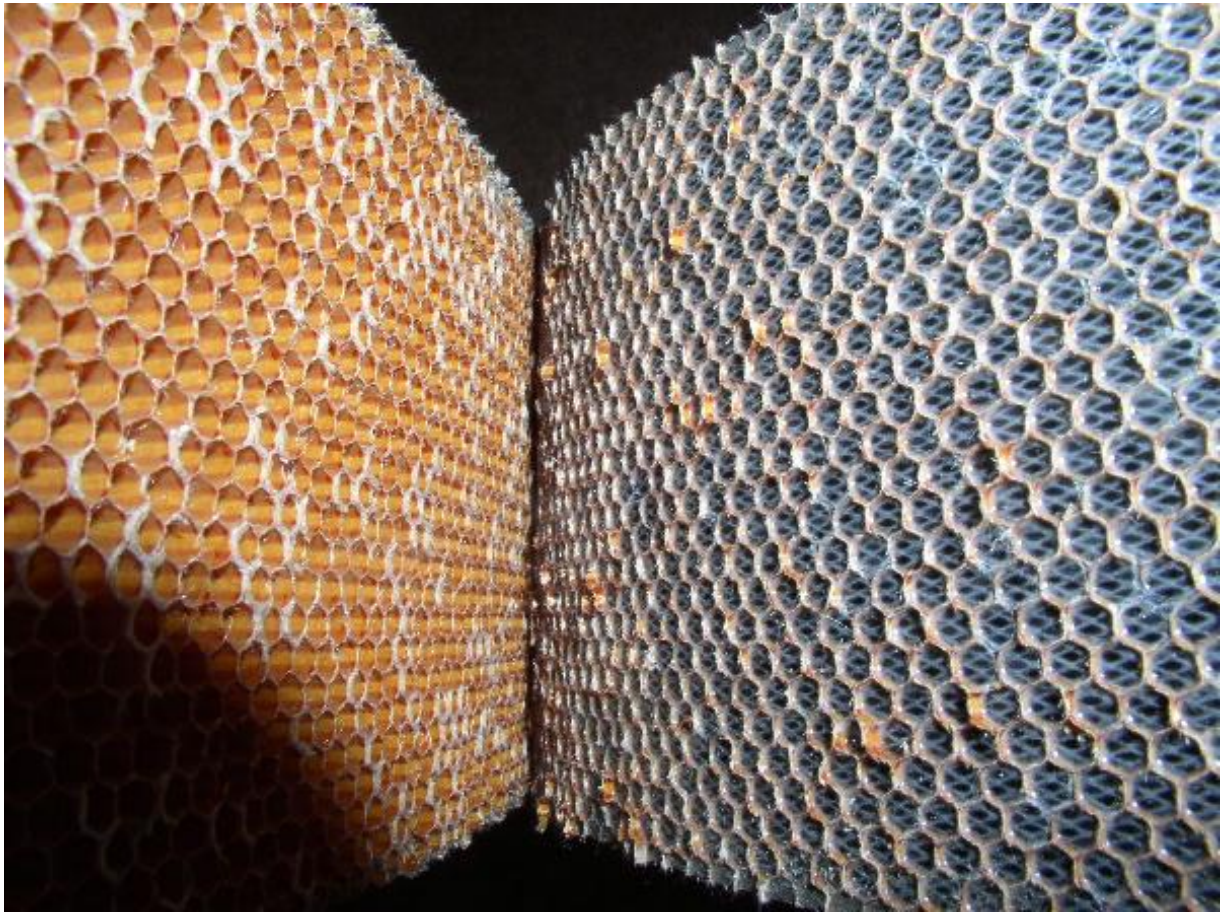
Drum Peel Test for Verification of Bonding

Failure in honeycomb core = full mechanical properties of honeycomb are realized

Adhesive or cohesive failure in bond line = full honeycomb properties not realized

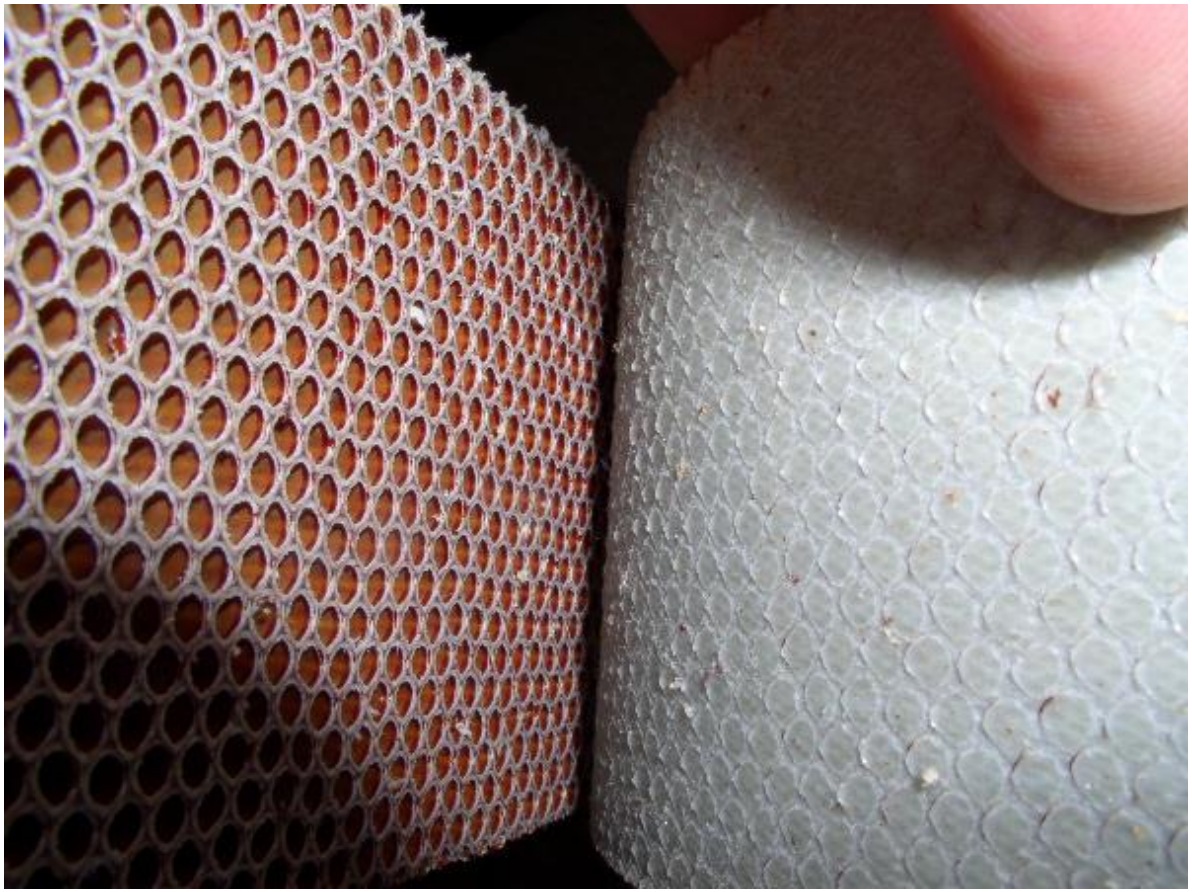
Adhesive or cohesive bond line failures are poorly understood and poorly characterized. Performance after ageing or fatigue is not defined. Such failures are not acceptable even if test values are high!

Predominantly Core Failure in Peel



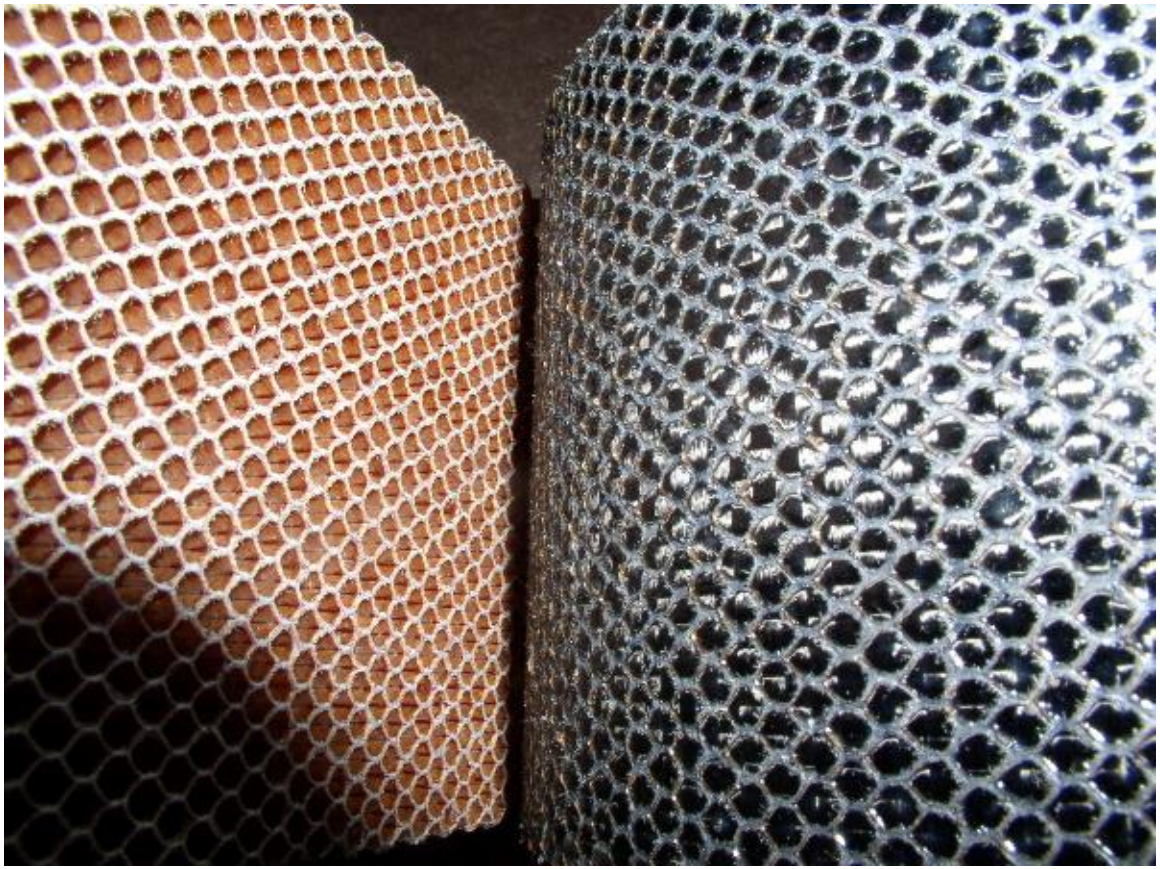
- Predominant core failure indicates robust process
- Honeycomb core mechanicals drive performance

Interfacial Failure Next to Prepreg



Interfacial failures are variable, unpredictable and unacceptable

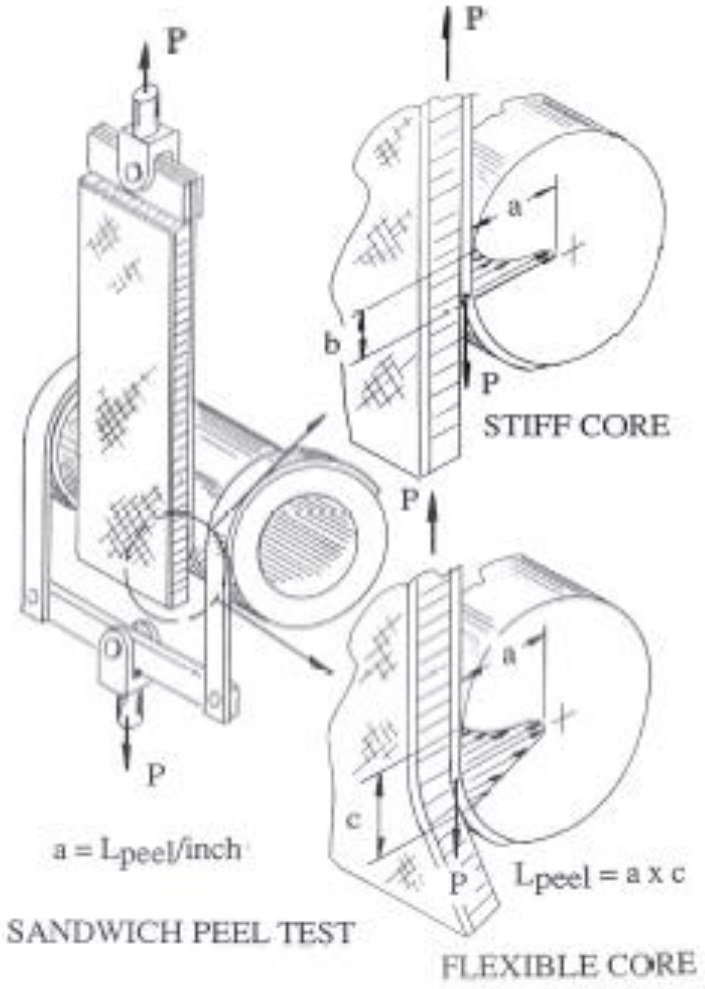
Failure Next to Core



- Another unacceptable transition area failure
- Often seen when core was solvent treated or otherwise contaminated

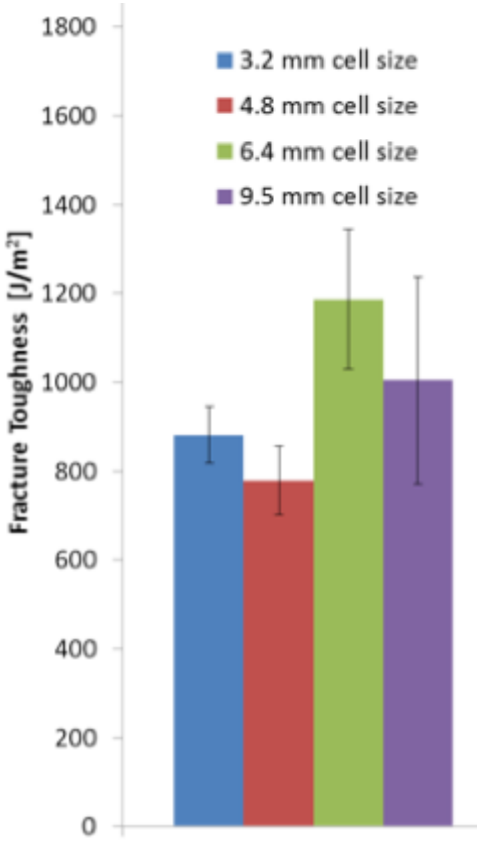
Drum Peel Test is Very Sensitive to Modulus of Honeycomb and Adhesive

- Drum peel is valuable indicator of bond quality, not bond strength
- Visual test specimen inspection is key
- Good for process quality control
- Not suitable for comparing different materials
- Flatwise tensile test should be used to compare different materials and constructions



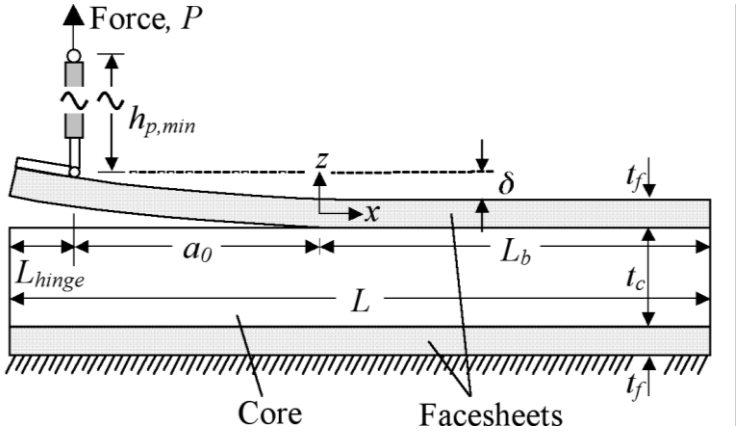
Paper Thickness & % Resin Affect Fracture Toughness

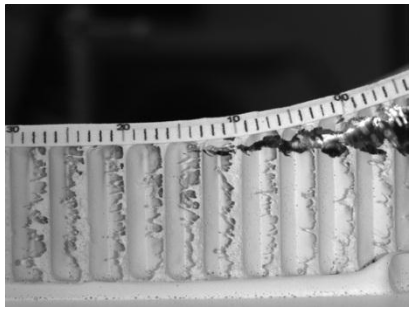
Fracture Toughness



Cell size	Density	Paper Thickness	% Resin
3.2mm	48 kg/m3	51 um	30%
4.8mm	48 kg/m3	51 um	53%
6.4mm	50 kg/m3	76 um	46%
9.5mm	48 kg/m3	76 um	63%

SCB Test Method Measures Fracture Toughness





Analysis of data from M. RINKER, J. RATCLIFFE, D. ADAMS, and R. KRUEGER, *Characterizing Facesheet/Core Disbonding in Honeycomb*, NASA/CR-2013-217959, NIA report no. 2013-0115, 2013.

Industry Resources and Efforts for Increased Understanding

- **Composite Materials Handbook-17 (CMH-17) is publishing Volume 6 on Structural Sandwich Composites in Fall 2013**

  Volume 6 is an update to the cancelled Military Handbook 23 (Reference 1.2), which was prepared for use in the design of structural sandwich polymer composites, primarily for flight vehicles. The information presented includes test methods, material properties, design and analysis techniques, fabrication methods, quality control and inspection procedures, and repair techniques for sandwich structures in both military and commercial vehicles.

- **CMH-17 Disbond/Delamination Task Group coordinates ongoing efforts to improve understanding of honeycomb sandwich bonding issues**

  FAA, EASA, Airbus, and NIA coordinate task group efforts with continuing participation by industry, academia, and regulatory bodies

Acknowledgements

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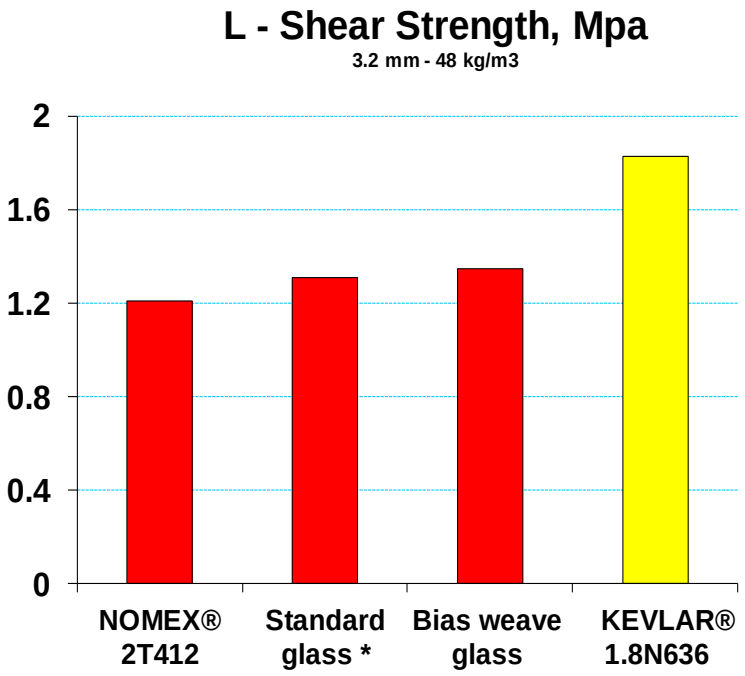
REFERENCE DATA COMPARING HONEYCOMBS OF:

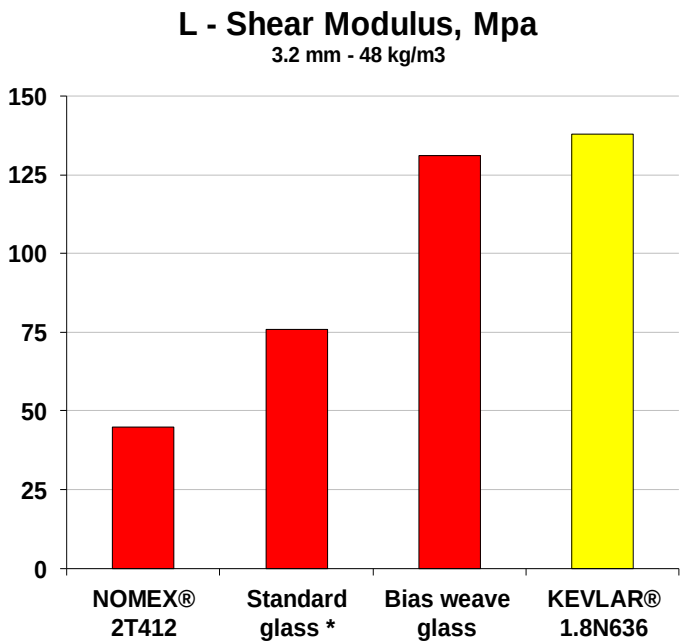
KEVLAR® N636

NOMEX®

GLASS

Kevlar® N636 Honeycombs Improve Shear Strength and Modulus vs. Nomex® and Glass



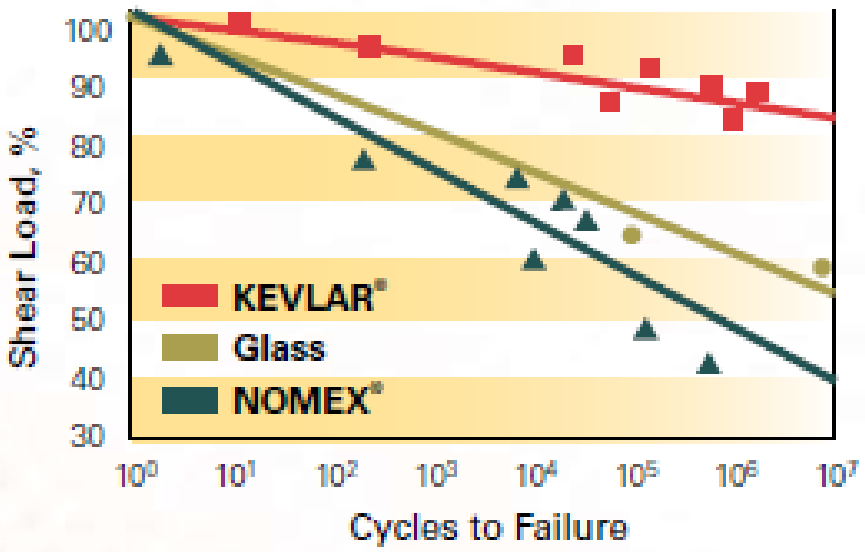


* Standard Glass 9.6mm – 51 kg/m3 normalized to 48 kg/m3

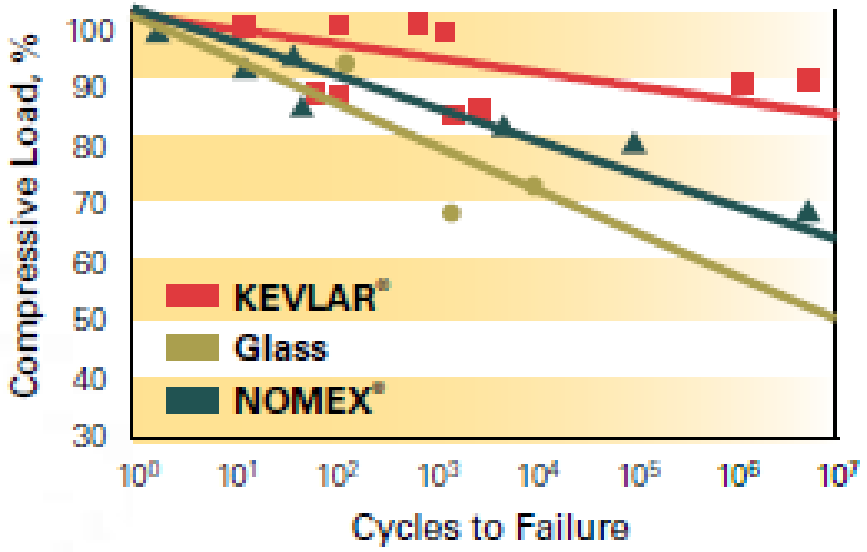
Honeycombs in Shear and Compressive Fatigue

KEVLAR® honeycomb improved over NOMEX® and glass honeycombs

Short Beam Shear Fatigue



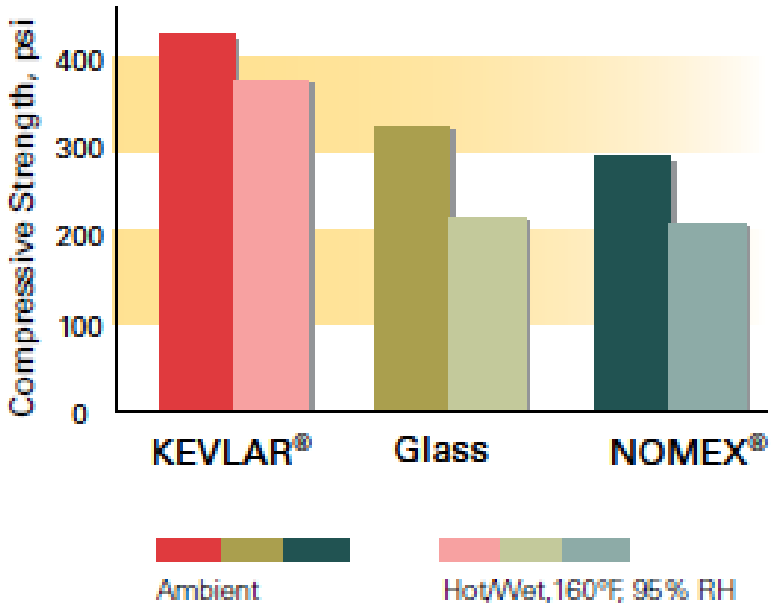
Compressive Fatigue



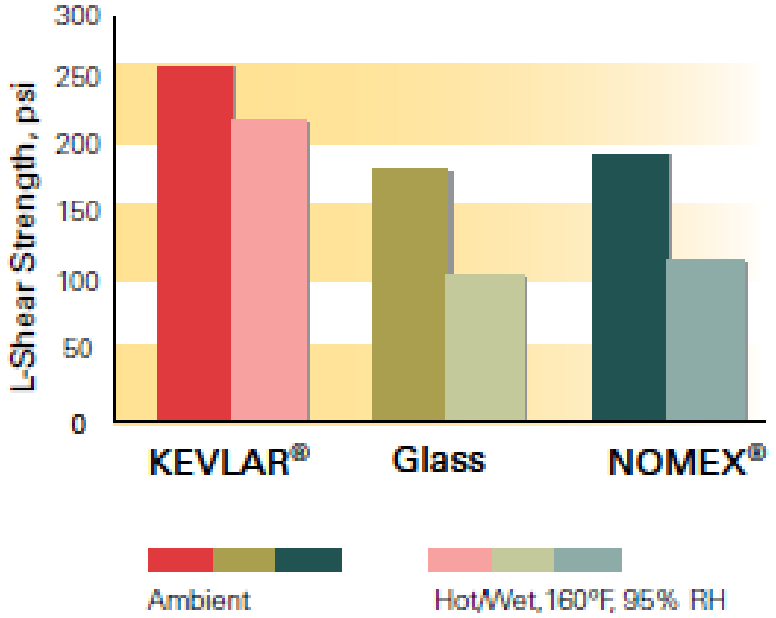
Honeycomb Hot/Wet Property Comparisons

KEVLAR® honeycomb improved over NOMEX® and glass honeycombs

Hot / Wet Compression



Hot / Wet Shear



- **All cores tested were 3.2 mm cell size – 48 kg/m^3 (same density)**
- **Glass core was bias weave**

KEVLAR® N636 Shows Improved Flat-Wise Tension vs. NOMEX® in Honeycomb