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Bonding from a Honeycomb Core Perspective

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18 June 2004

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Remarks Based On:

- 30+ years in aramid technical development, applications research, technical marketing, market development
- Started with basic research in high strength fibers and progressed to applications research in aerospace sandwich structures
- Personal experience as DuPont technical respondent for honeycomb cored composite sandwich structures.
- Bonding failures (and part failures) arise from:
  - Non-optimum materials and process
  - Contamination
  - Design errors
- Objective is to identify and promote proven and successful practices

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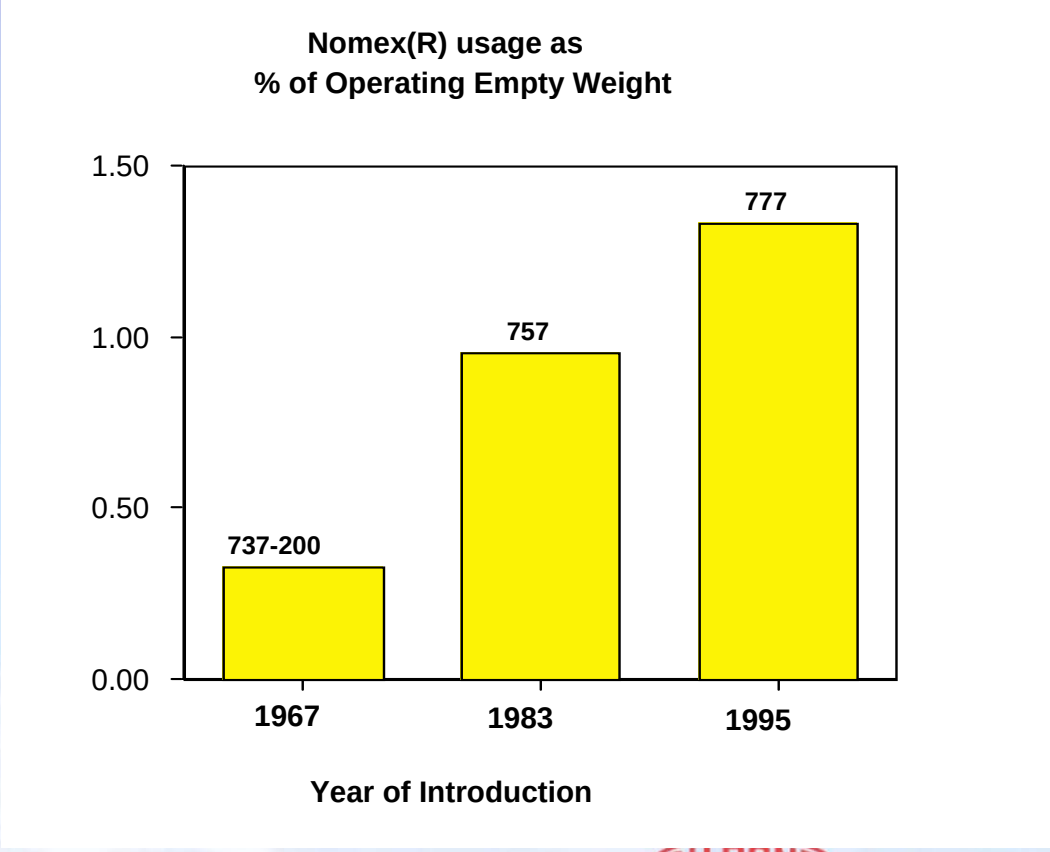
Why Worry About Composite Honeycomb Construction?

Honeycomb cored composite structures are widespread on modern commercial transport aircraft.

- **25% of exterior surface, all of interior**



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Why Focus on Composite Honeycomb Construction?

Honeycomb cored composite structures are widespread on modern commercial transport aircraft.

- **25% of exterior surface, all of interior**

Durability "incidents" stretch back 50+ years, especially for metallic honeycomb structures.

For the past 30 years, the vast majority of composite honeycomb cored structures are completing an aircraft lifetime without problems.

Honeycomb cored composite sandwich structure is expected to grow further thanks to structural efficiency and relative ease of manufacture.

We must collect & document the technology of honeycomb and other bonded structures, including critical safety issues and certification considerations

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Bonding is critical, but there are other issues too.

Failure in bonded structures is not necessarily strictly related to bonding issues.

Materials system failure
- Matrix microcracking
- Erosion, wear, impact, fatigue

Structural overload
- Bearing stress
- Sizing error
- Residual stress

Sealing problems

This talk will focus on honeycomb core bonding

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Bond Between Honeycomb and Face Sheet Has the Elements of a Secondary Bond

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 followed by solvent evaporation can cause soluble contaminants to migrate to the bonding surface.

Honeycomb core bonding deserves the attention due any secondary bond!

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Drum Peel Test for Simple Verification of Bonding

- If failure is in the honeycomb core, the full mechanical properties of the honeycomb can be realized.
- If failure is in the bond or adhesive, the full honeycomb properties may not be realized.
- Bond or adhesive 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!

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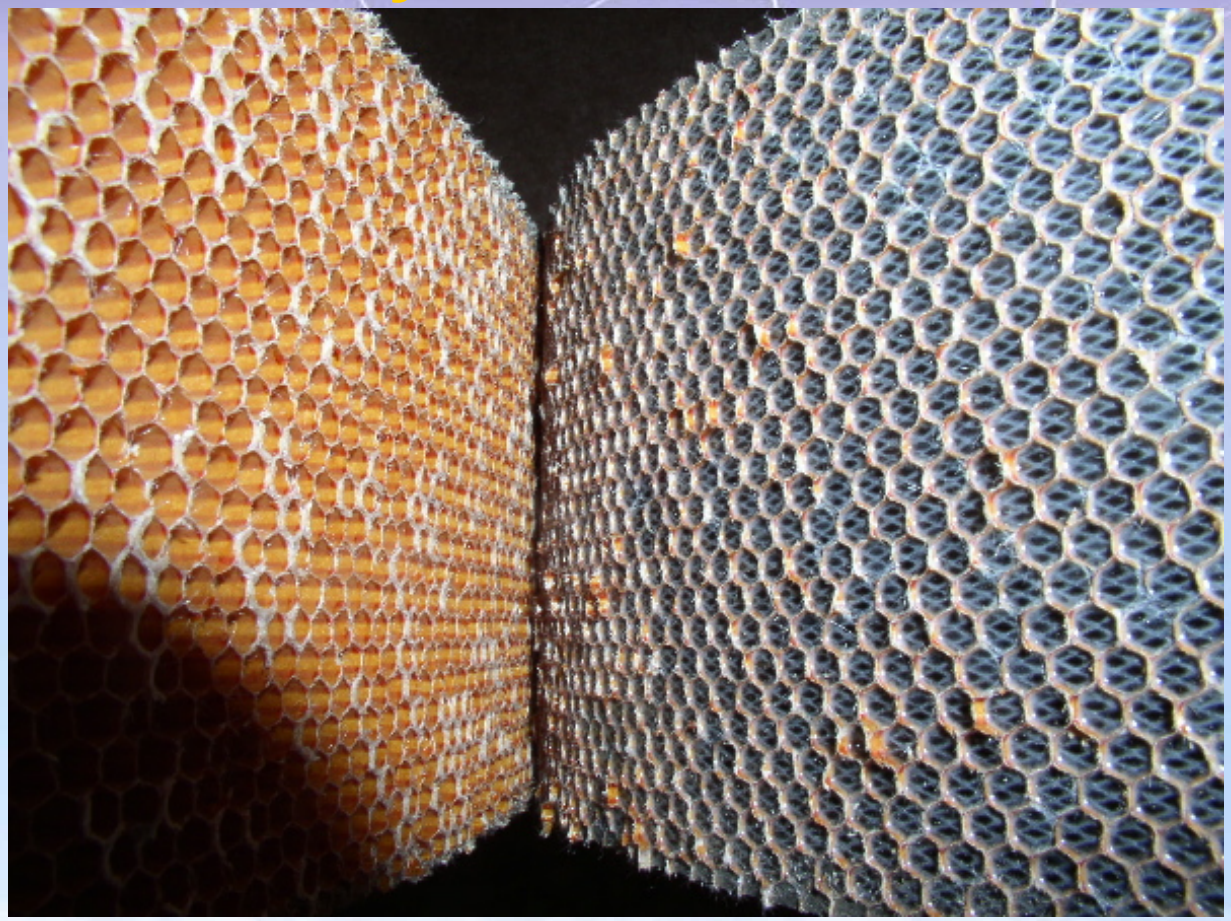
Predominantly Core Failure in Peel



Predominant core failure indicates robust process

Honeycomb core mechanicals drive performance.

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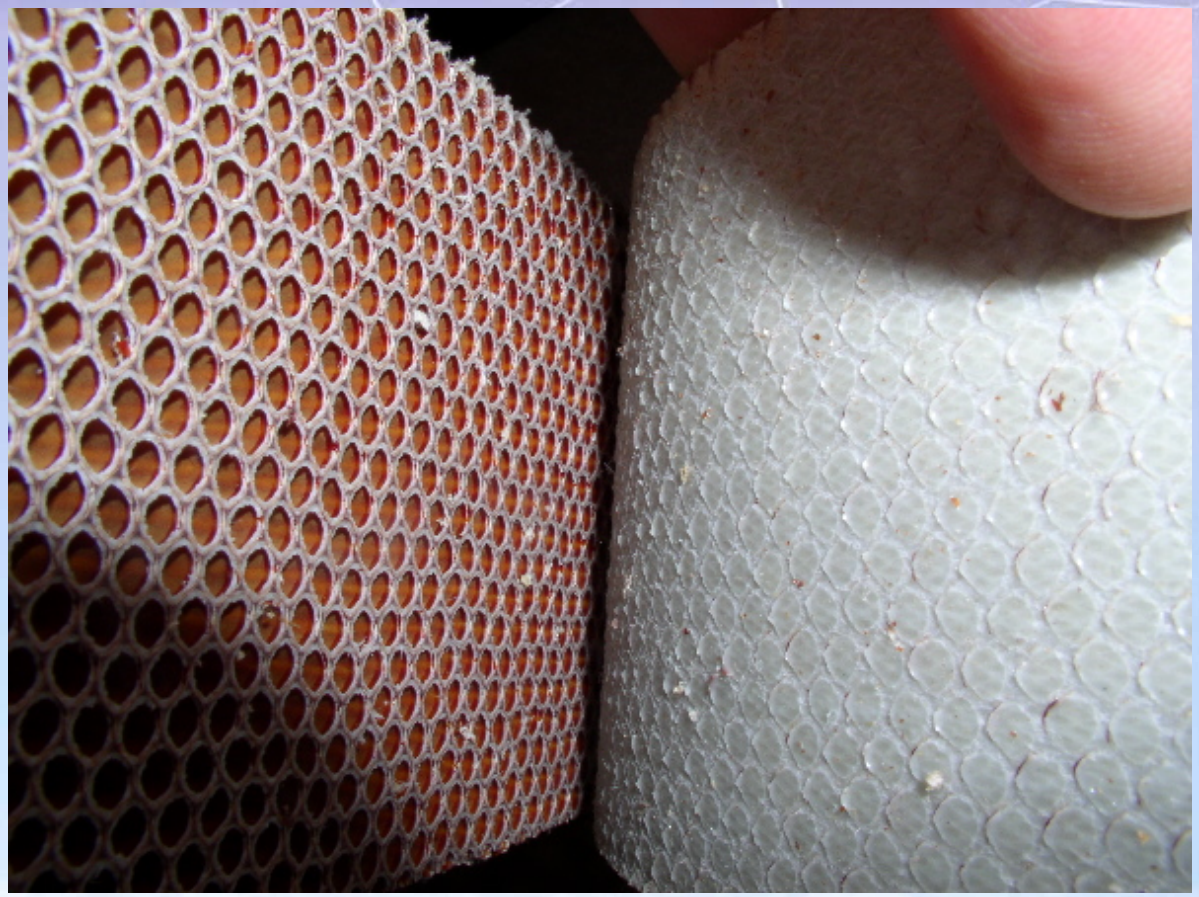
Interfacial Failure Next to Prepreg



Interfacial failures are variable, unpredictable and unacceptable

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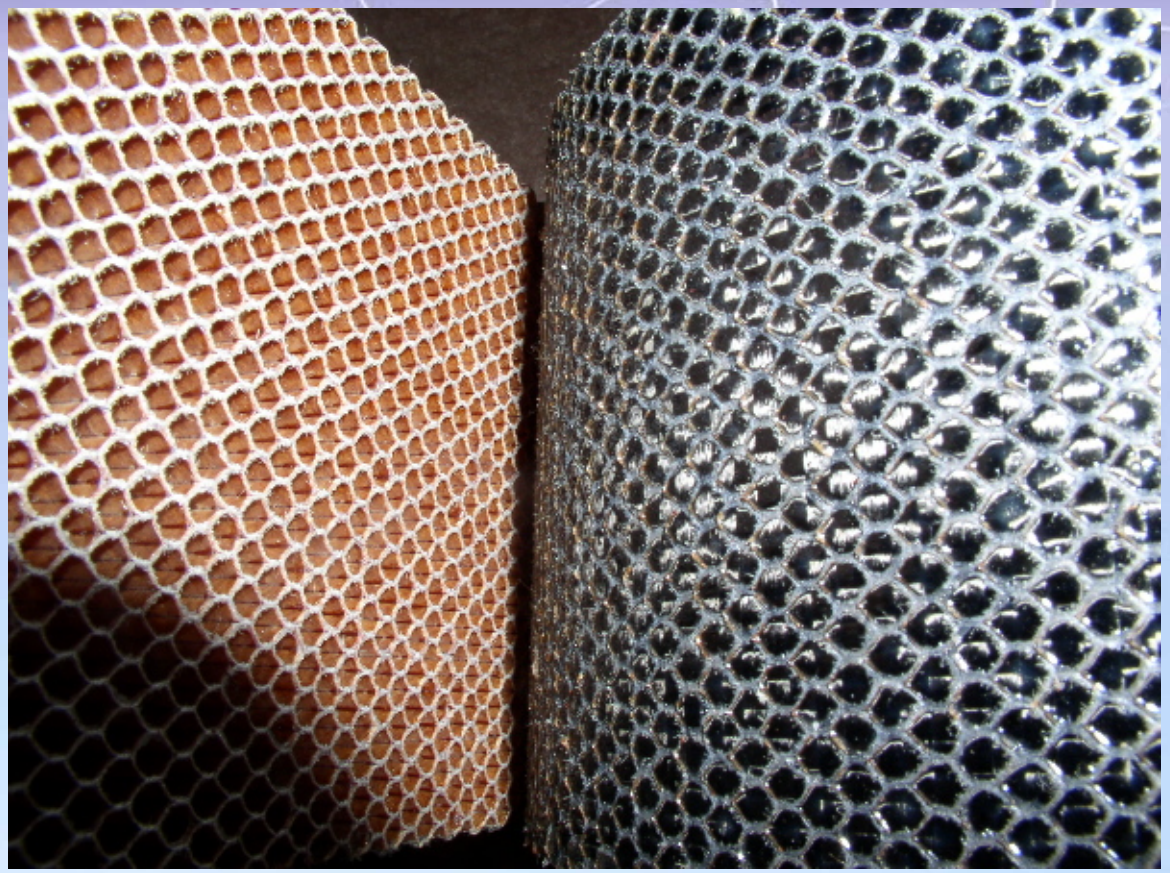
Failure Next to Core



This is another unacceptable transition area failure, often seen when core was solvent treated or otherwise contaminated!

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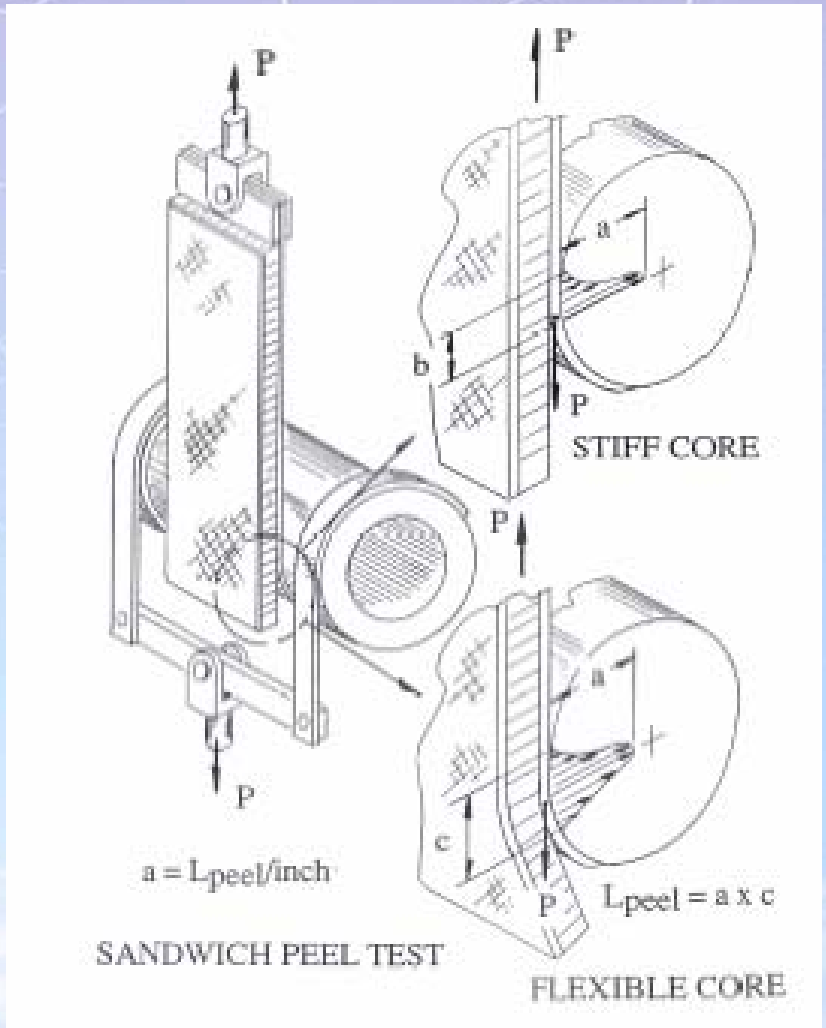
Drum Peel Test is Very Sensitive to Modulus of Honeycomb and Adhesive

Drum peel is valuable for process quality control.

It is not suitable for comparing different materials



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Flatwise Tension Test on Well-Bonded Specimen Directly Measures Material Strength

	LS, PSI	FT, PSI
KEVLAR®-1/8-3.0	260	550
NOMEX®-1/8-3.0	180	310

Higher strength materials require better bonding.

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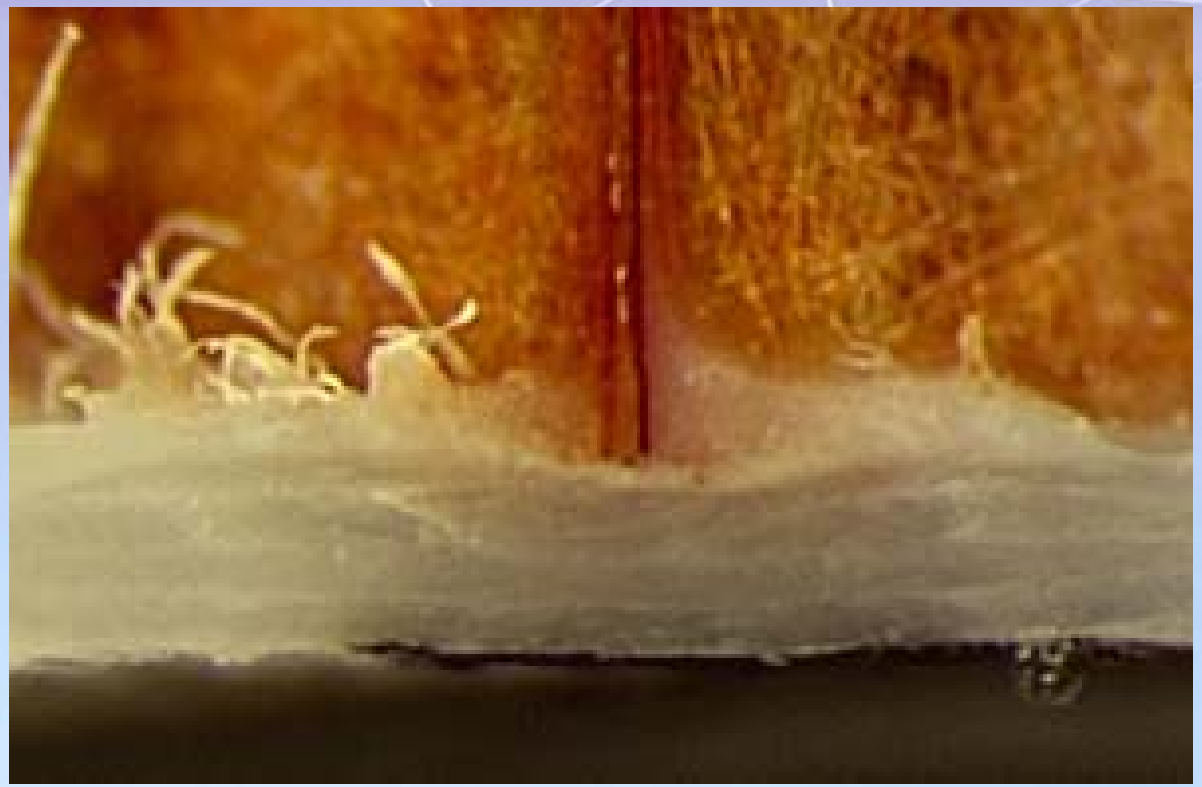
Fillet formation is critical to core bond



This micrograph shows poor fillet on right , no fillet on left

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Material change gives system change

Higher web strength and less contact surface reveals adhesion limit
"Equivalent" resins revealed to not be equivalent

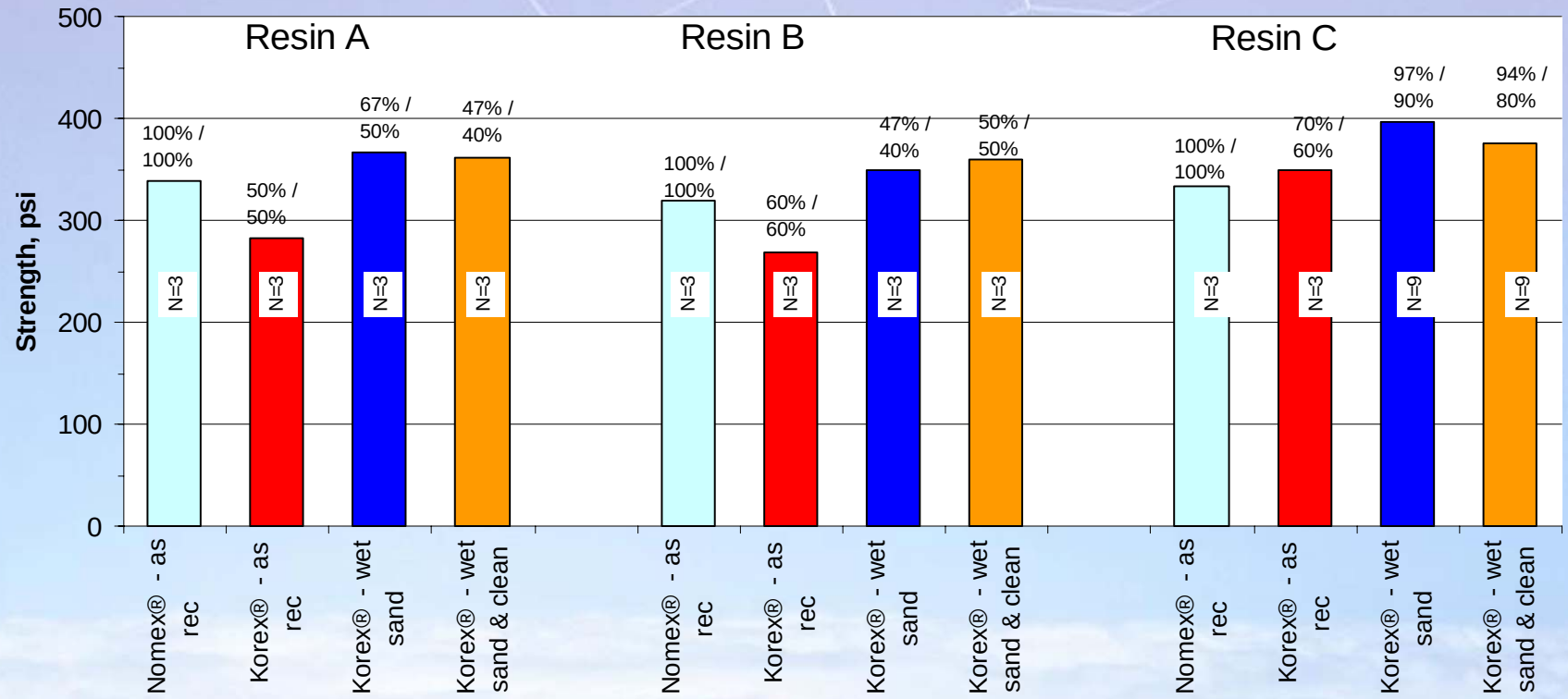
Korex® Bonding Study

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



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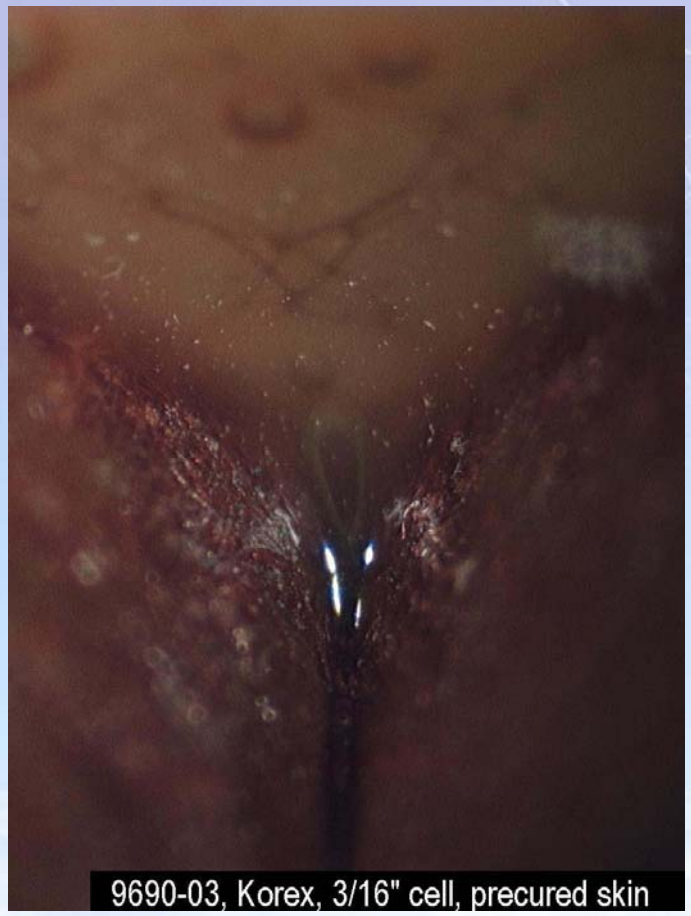
Bond Surface prep can be critical



9690-03, Korex, 3/16" cell, precured skin

9690-03, Korex, 3/16" cell (unworked), precured skin

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Conclusions from Bonding Examples

Nominally analogous materials and process might give different results with different materials

- Low thermal ramp rate gives low flow in curing operation so that surface fuzz changes filleting mechanism
- Higher flow resin system shown to be insensitive to core surface fuzz
- “Equivalent” resins can react very differently to materials and process changes.

The drum peel test is an excellent indicator of bond quality, but not of bond strength, especially with different materials and constructions

- Visual inspection of test specimen is key
- Flatwise tension test should be used to compare different materials and constructions

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