UCSB Bond Structure Characterization Work

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Effects of Surface Preparation on the Long-Term Durability of Composite Adhesive Bonds

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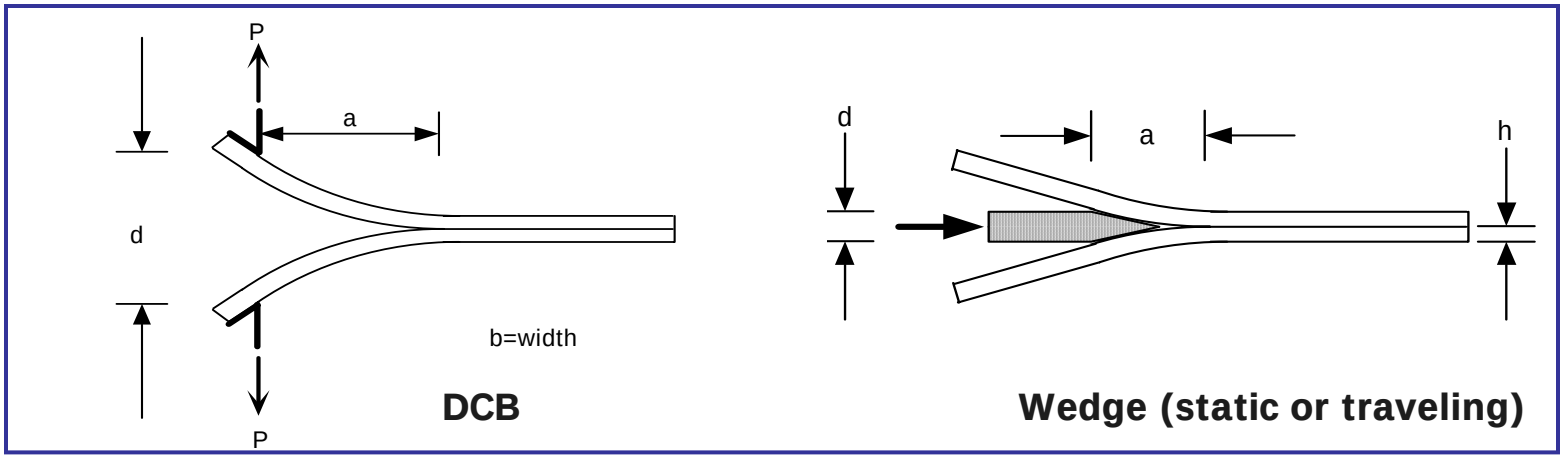
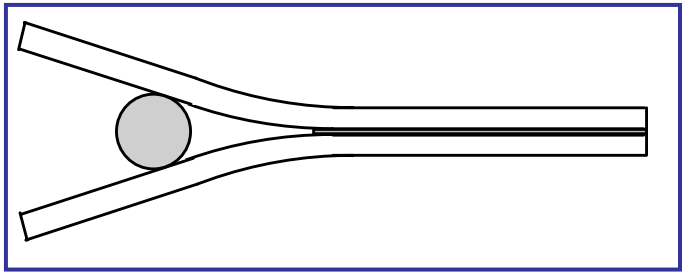
Mechanical Testing Investigation



- Similar test geometries—can compare results
- DCB: pull apart adherends at constant rate
- Static wedge: insert wedge, place in environment, observe crack
- Traveling wedge: force wedge through bondline at slow velocity, verified against established DCB

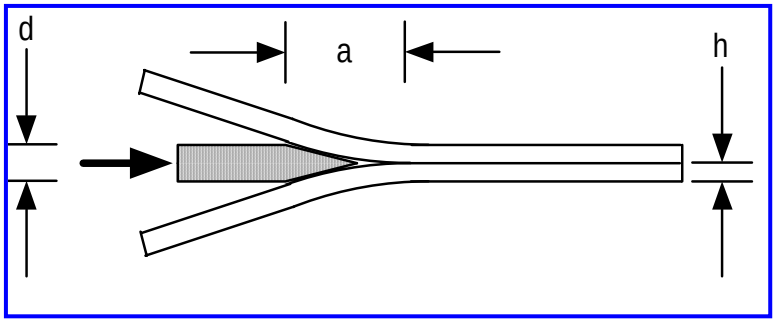
Static Wedge Test

- Same specimen as traveling wedge
- Insert 1/8” steel dowel pin with hammer
- Soak in acidic, basic, or pH-neutral de-ionized room temperature (71° F) H2O
- Crack growth usually stabilized within several hours
- 8 preparation types, 4 specimens per group, up to 510 hours exposure

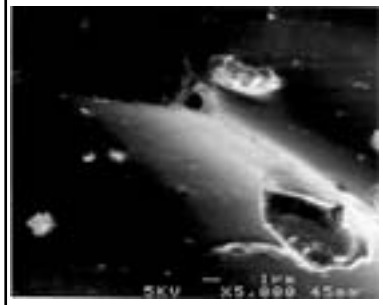
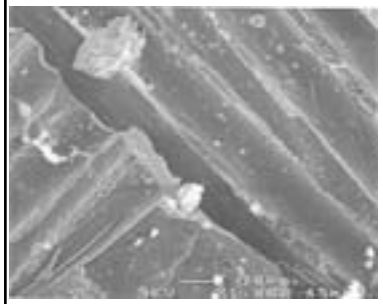
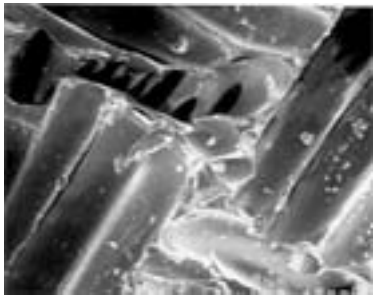
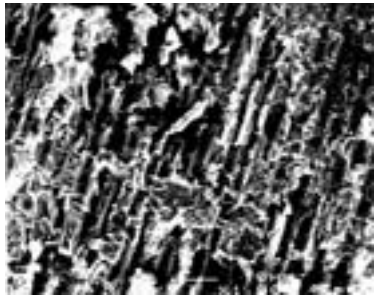
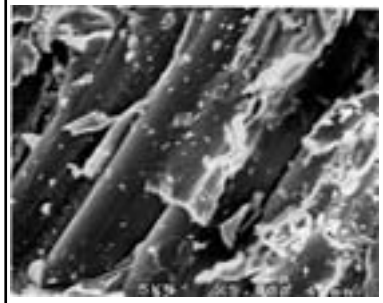
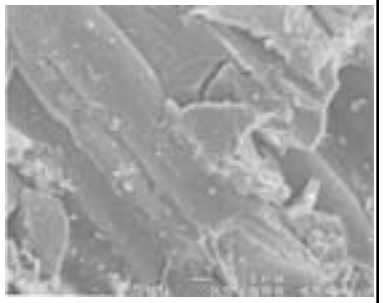
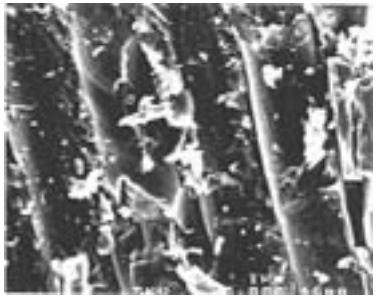


Traveling Wedge Test

- Variant on DCB & static wedge test where wedge is forced slowly (0.125 $^{in}/_{min}$ quasi-static loading condition) through specimen
- Simple specimen fixturing and testing
- Analysis based on fracture mechanics / Beam-On-Elastic-Foundation
- Test results extremely sensitive to crack length measurement (4^{th} power term)



Scanning Electron Microscopy

	FEP (release film)	NAT (peel ply)	SRB (release fabric)	VLP (peel ply)
No blast				
Blast				

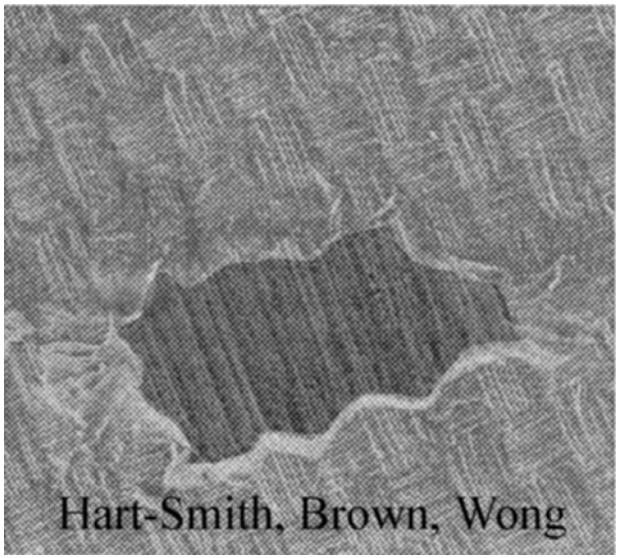
Qualitative visual assessment of surface preparation

Conclusions: Test Methods

test method	values measured	pros	cons	notes
traveling wedge	G_{Ic}, failure mode, cleavage force	simple, straightforward	crack measure, disturb frac. Surf.	best overall for short-term
DCB	G_{Ic}, failure mode, failure load	straightforward, widely accepted	fixtures, short-term test	good for measuring G_{Ic}
static wedge	durability, failure mode, G_{Ia}	easy, $$$, no equipment, G_{Ia}	test chamber, test time	less distinction between preps
shear	avg shear strength, failure mode	database, simple, real loading	peel, poor service prediction	poorly suited
floating roller peel	peel load, failure mode	simple	requires plastic deformation	use for metal only
hammer/wedge	failure mode	easy, $$$, fast	no engineering value	quick, qualitative feedback
X-ray photo	crack front shape	see crack front in opaque sample	$$$, qualitative	confirm specimen configuration
SEM	surface morphology	surface details, abrasion analysis	$$$, qualitative, specimen prep	good for morph. feedback
XPS	surface chemistry	simple	$$$	good chem analysis
EDX	surface chemistry	in conjunction with SEM	$$$, specimen prep	no useful results

Surface Preparation Effects on Long-Term Durability

- Motivation – Technical
  - Minimization or prevention of interfacial failure in adhesive bonds to polymer matrix composites
  - Characterization of the effects of the following on bond durability:
    - Chemical contamination from release fabric, peel ply, or release film
    - Surface preparation
  - Develop recommended practices
    - for bagging, preparation, and
    - bonding to ensure consistent
    - bonds



Surface Preparation Variables

- **Adherend Material**
  - Composite matrix vs. metal
  - Boeing / Lancair / Cirrus Design composites
- **Layup of Adherends**
  - $0°_{[n]}$ layup
  - Alternate layup
- **Solvent Wiping**
  - Vary type of solvent (acetone, isopropyl alcohol, etc.)
  - Vary number of wipes
  - Vary applicator material
  - Air dry vs. wipe dry
- **Grit Blast**
  - Vary pressure
  - Vary grit size
  - Vary grit media type
  - Vary frequency of changing out re-used media
  - Vary number of passes
  - Vary speed of passes
  - Vary distance / angle of blaster from surface
- **Hand Abrasion**
  - Vary abrasive material
  - Vary grit size
  - Vary number of passes
  - Vary applied pressure
- **Release Fabric/Peel Ply/Release Film Variations**
  - Vary material (nylon, polyester, etc.)
  - Vary direction of removal (angle relative to outer ply)
  - Vary time between removal and adhesive application
- **Compressed Air Blowing**
  - Vary length of exposure
  - “Shop” air vs. dry Nitrogen tank
- **Paste Adhesive Preparation**
  - Mix by hand or by machine
  - Apply vacuum to remove trapped air
- **Filler Material in Adhesive**
  - Vary filler type
  - Vary percentage of filler in adhesive
- **Bondline Thickness Control**
  - Glass microbeads—silane treatment
  - Wires
  - Tabs/tape
  - Film adhesive carrier cloth
  - Applied pressure
- **Adhesive Cure**
  - Use vacuum bag or not
  - Elevated temperature vs. room temperature cure
- **Humidity Exposure**
  - Vary humidity
  - Vary length of exposure
  - Expose adherends before bonding
  - Expose adherends after bonding
  - Expose adherends while performing wedge test
- **Water Bath**
  - Vary water temperature
  - Vary length of exposure
  - Soak adherends before bonding
  - Soak adherends after bonding
  - Soak adherends while performing wedge test
- **Temperature Exposure**
  - Vary temperature
  - Vary length of exposure
  - Expose adherends before bonding
  - Expose adherends after bonding
  - Expose adherends while performing wedge test

Surface Preparation Findings

- Results show that peel plies and release fabrics are entirely different materials that are not interchangeable
- Any surface to be secondarily bonded must be cured against a peel ply, not a release fabric
- Pre-bond abrasion of adherends is recommended but can be omitted in certain cases if process and material control is strict

Evaluation of Bonded Lap Joints with Variable Thickness Adhesive Layers

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Background and Motivation

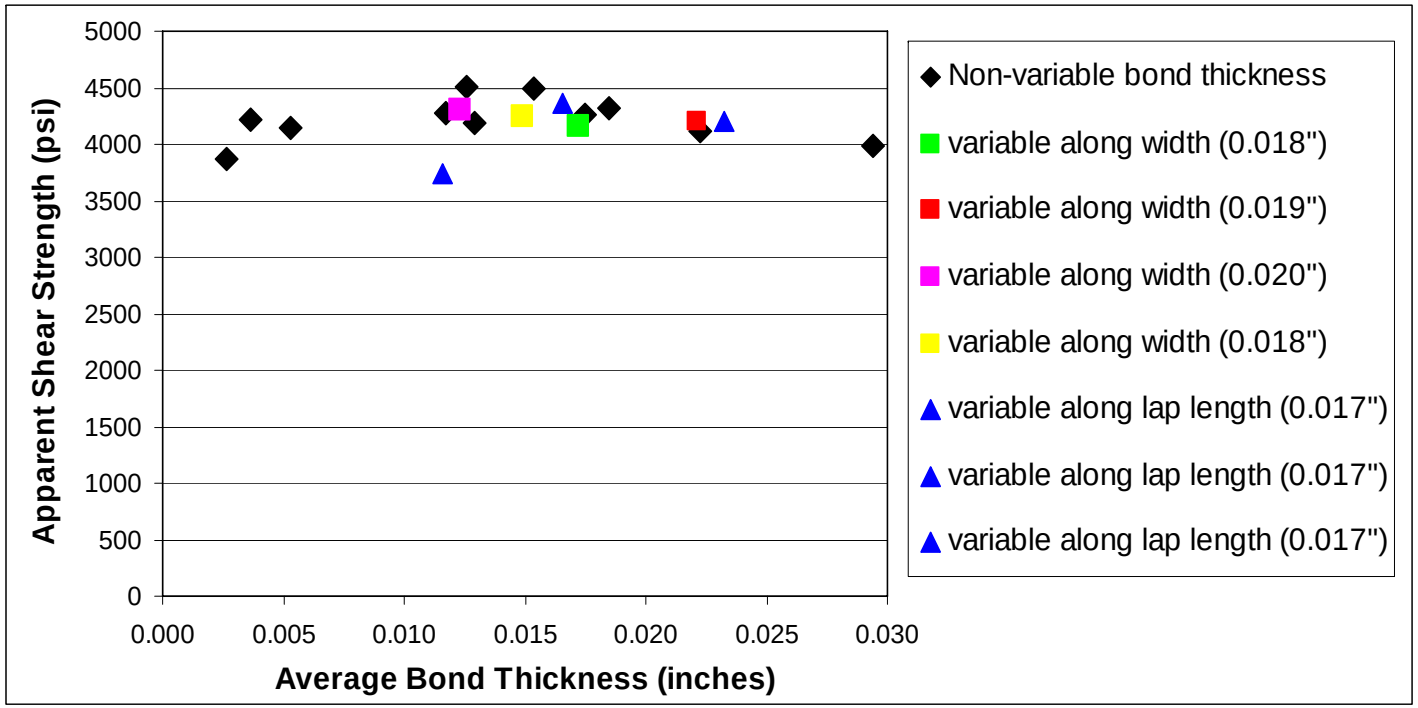
- An appreciation of load transfer in adhesively bonded joints
- Potential utilization of extensive test database on bonded lap joint coupons
- ASTM's most commonly cited single lap joint, ASTM D1002/99 and comparison with double lap joint configuration
- Potential variation in shear strength for different thickness adhesive layers
- Tolerance to variations in thickness
- Importance of both adhesive shear and peel stress components
- Candidate methods of analysis for interpretation and evaluation

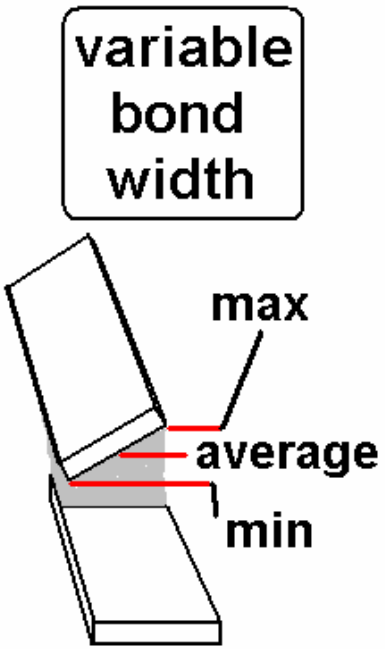
Lap Shear Performance of 2-Part Epoxy Adhesives*

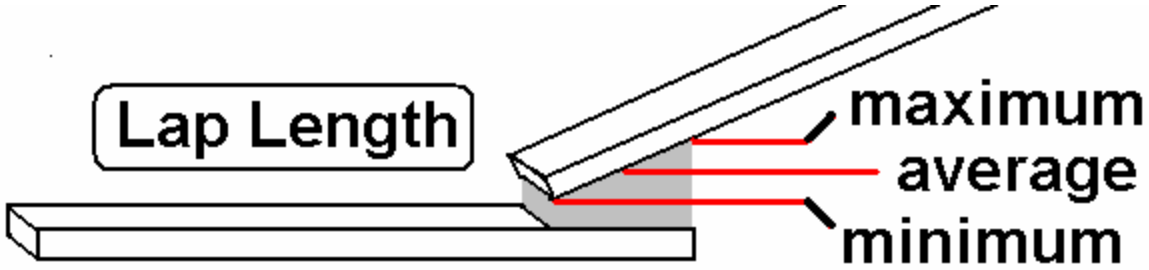
	Test Temperature (˚C)			
Product	-55	25	82	Generation
1838 B/A	2,200	3,000	800	0
2216 B/A	2,400	3,300	500	1
3569 B/A	4,500	4,500	2,200	3
9323 B/A	5,000	5,500	3,200	3
DP 460	**4,500**	**4,500**	**2,500**	**3**
DP 420	4,500	4,500	2,500	3

**Typical lap shear values in psi*
Ref. Hartshorn (3M)

Single Lap Coupons







Work-in-Progress

- Complete series of titanium and composite tapered bondline tests (width, length)
- Selected comparisons of double lap configurations
- Nonlinear Evaluation (Adhesive nonlinearity only)
- Surface chemistry and morphology studies
- Cyclic loading tests