BERKELEY LAB

LAWRENCE BERKELEY NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

Composite Joining Techniques: Adhesive Bonding

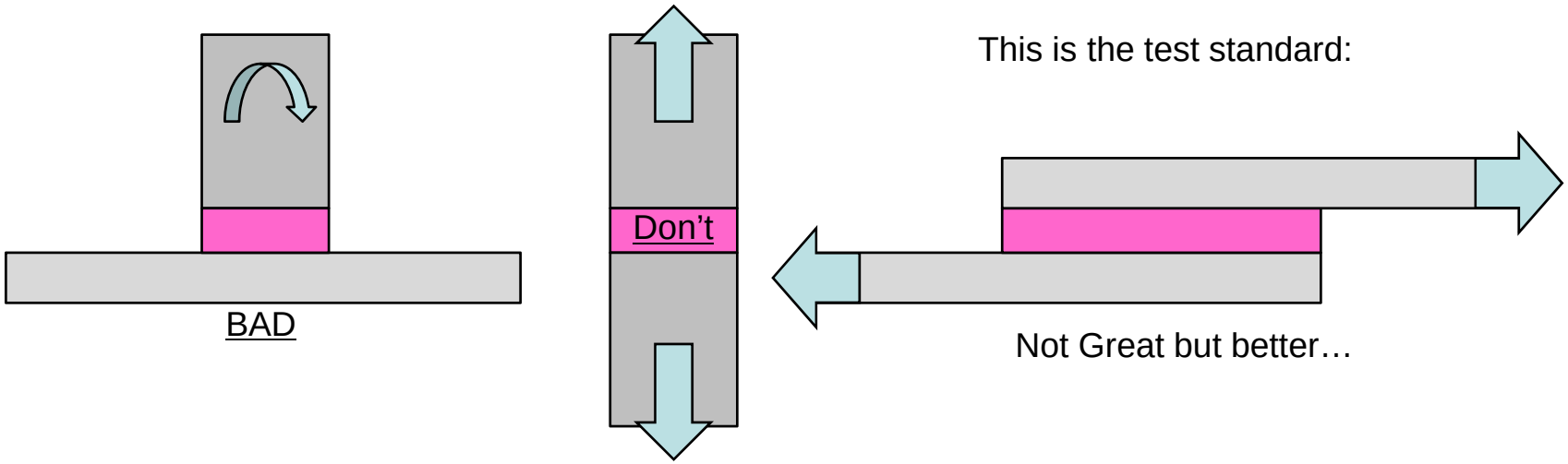
LBNL Composites Workshop

February 29-March 3, 2016

Adhesive Bonding

- Stresses in Bonded Joints
- Joint Design
- Adhesives
- Surface Preparation

Adhesive Joints

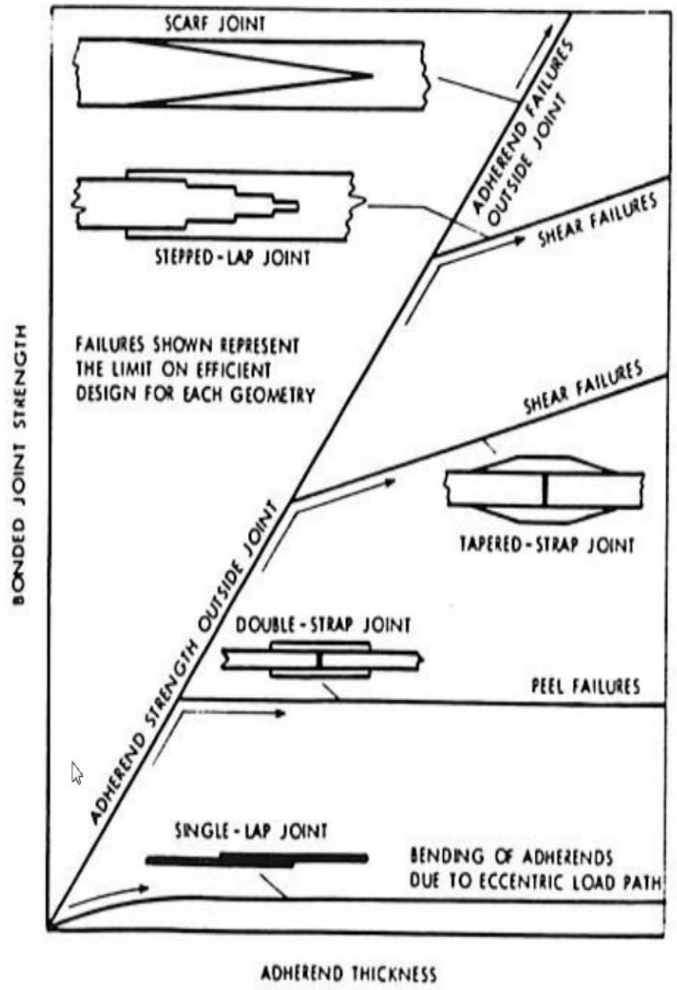


Designing an adhesive joint is NOT about choosing the right glue…

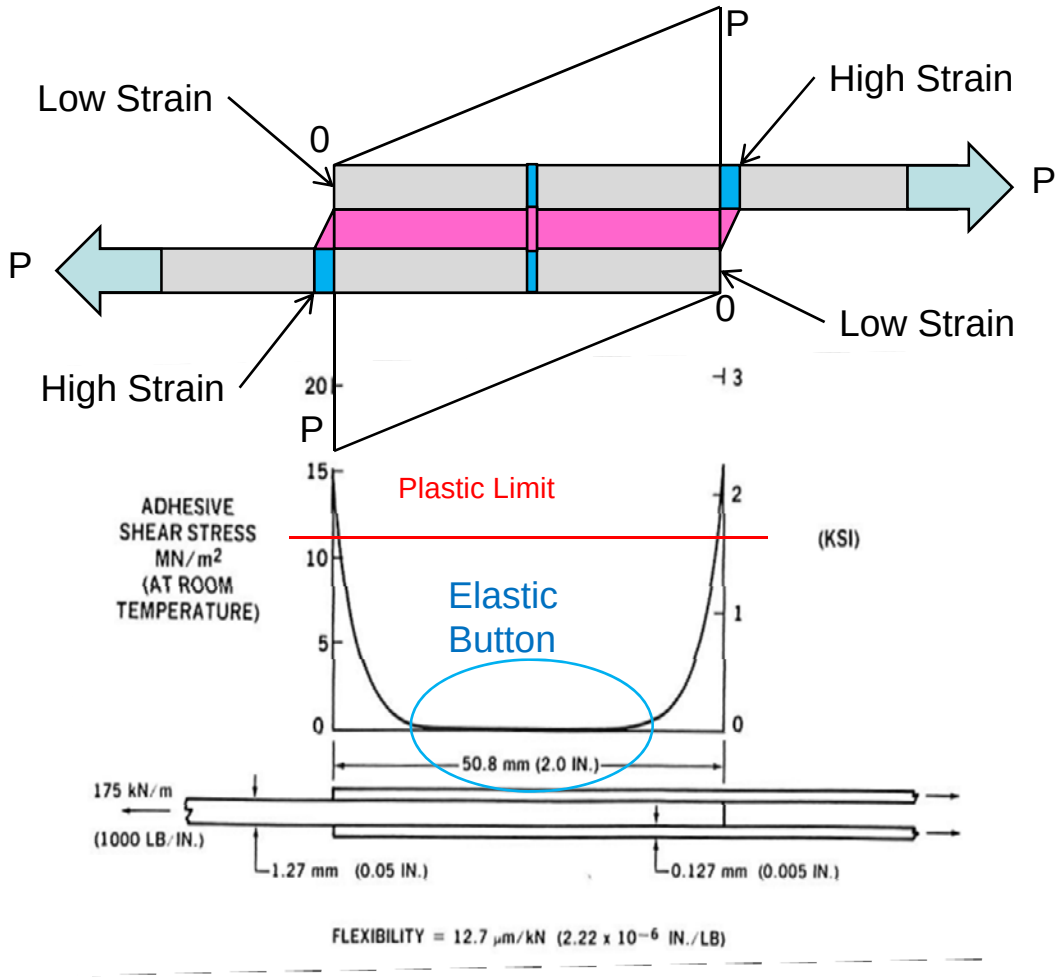
It is about designing the proper geometry.

Adhesive Joints

- Read the papers by Hart-Smith—all texts on adhesive joints refer to them
- Excellent source on joint design and improvement methods
- Designing an adhesive joint is not just choosing the right glue and overlap



Shear Lag Theory



Edge Effects on Adhesive Stress

- Stresses are highest at the edges of the joint
- Edge treatment is important, in particular for peel, but increased adhesive volume at the edge also reduces peak elastic stress
- Thin adhesive joints are not necessarily the strongest—typically 4-8mil (0.1-0.2mm) is ideal
- Peak stresses can exceed the plastic limit of the adhesive with no degradation in overall strength if joint is sufficiently long…

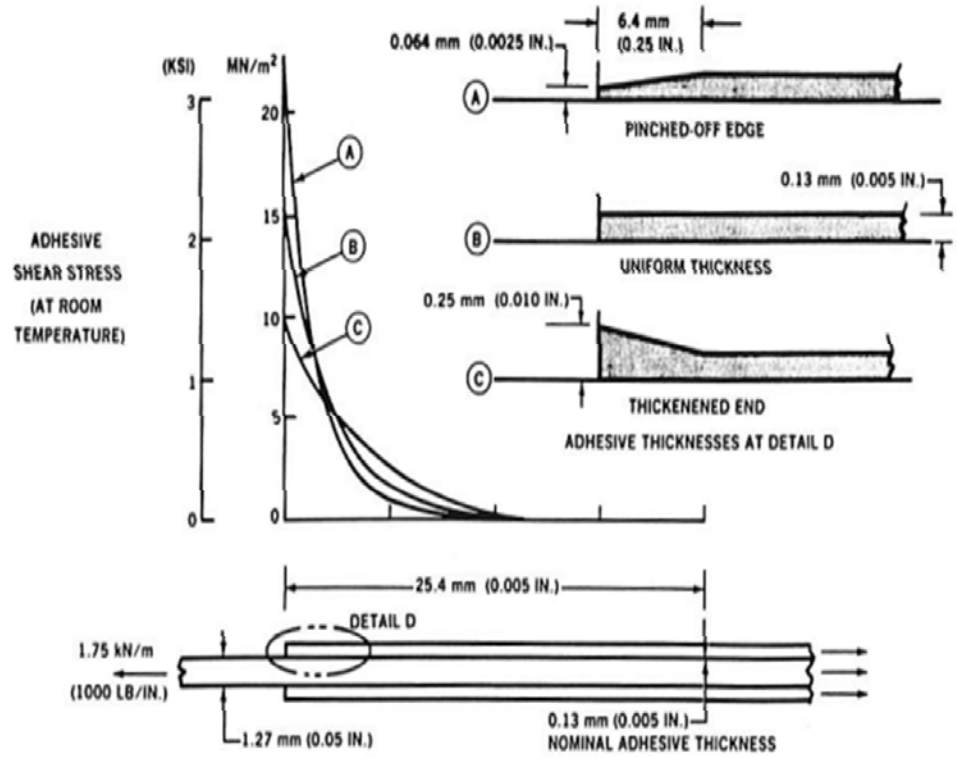


FIGURE 15. VARIATION OF PEAK INDUCED ADHESIVE STRESS WITH THICKNESS OF ADHESIVE AT ENDS OF OVERLAP

Figures from: "Further Developments in the Design and Analysis of Adhesive-Bonded Structural Joints" L.J. Hart-Smith 1980

Adhesive Joints are Fault Tolerant to Disbonds

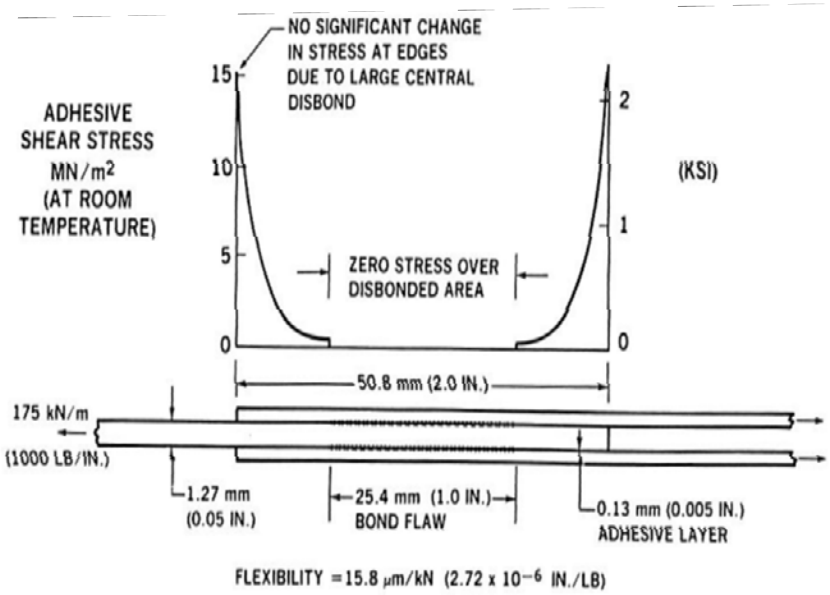


FIGURE 11. ADHESIVE STRESSES IN FLAWED BONDED JOINTS

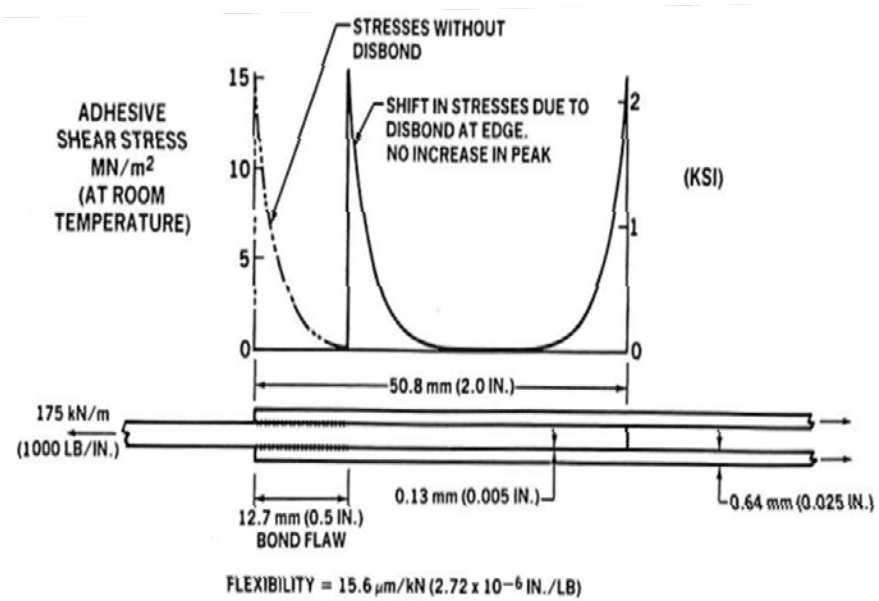
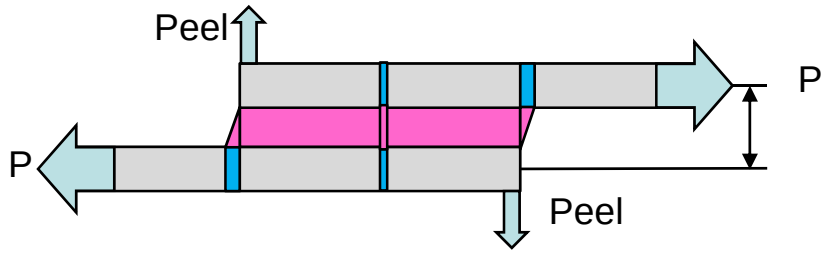


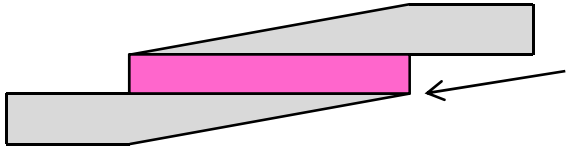
FIGURE 9. ADHESIVE STRESSES IN FLAWED BONDED JOINTS

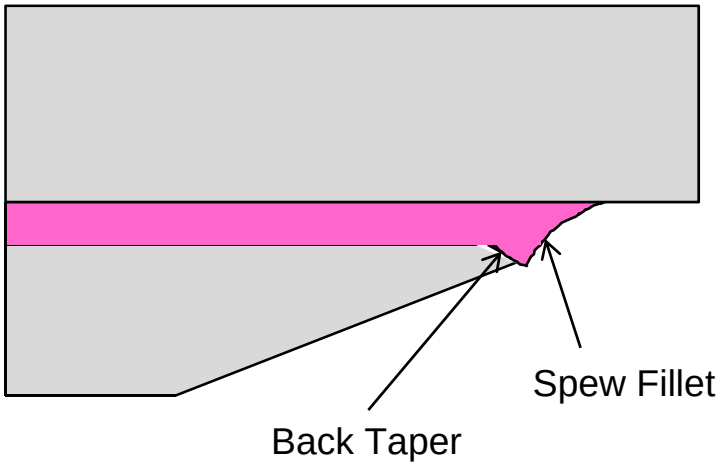
Figures from: “Further Developments in the Design and Analysis of Adhesive-Bonded Structural Joints” L.J. Hart-Smith 1980

Joint Design



Standard Test Sample tends to fail in Peel



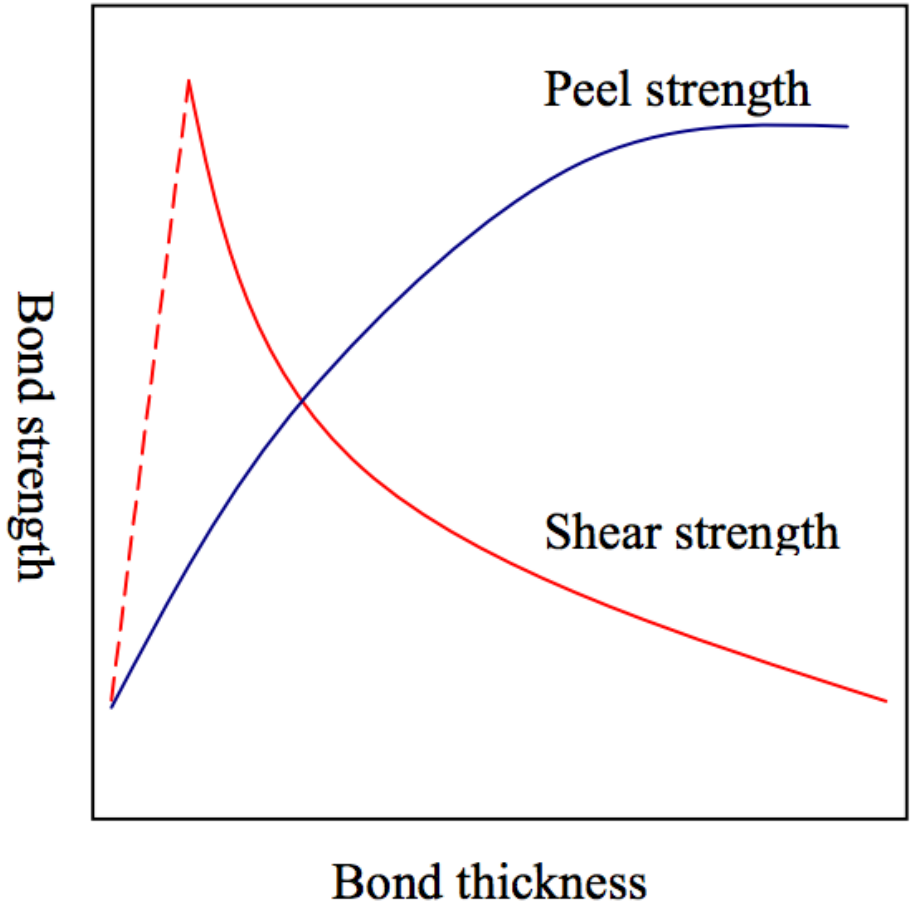


- Design the Adherends to take the load
- Design the joint to be stronger than the adherends
- Tapered adherends match stiffness better, reducing stress in the adhesive
- Spew Fillet increases volume at ends allowing for more strain in peel direction

Adhesive Selection

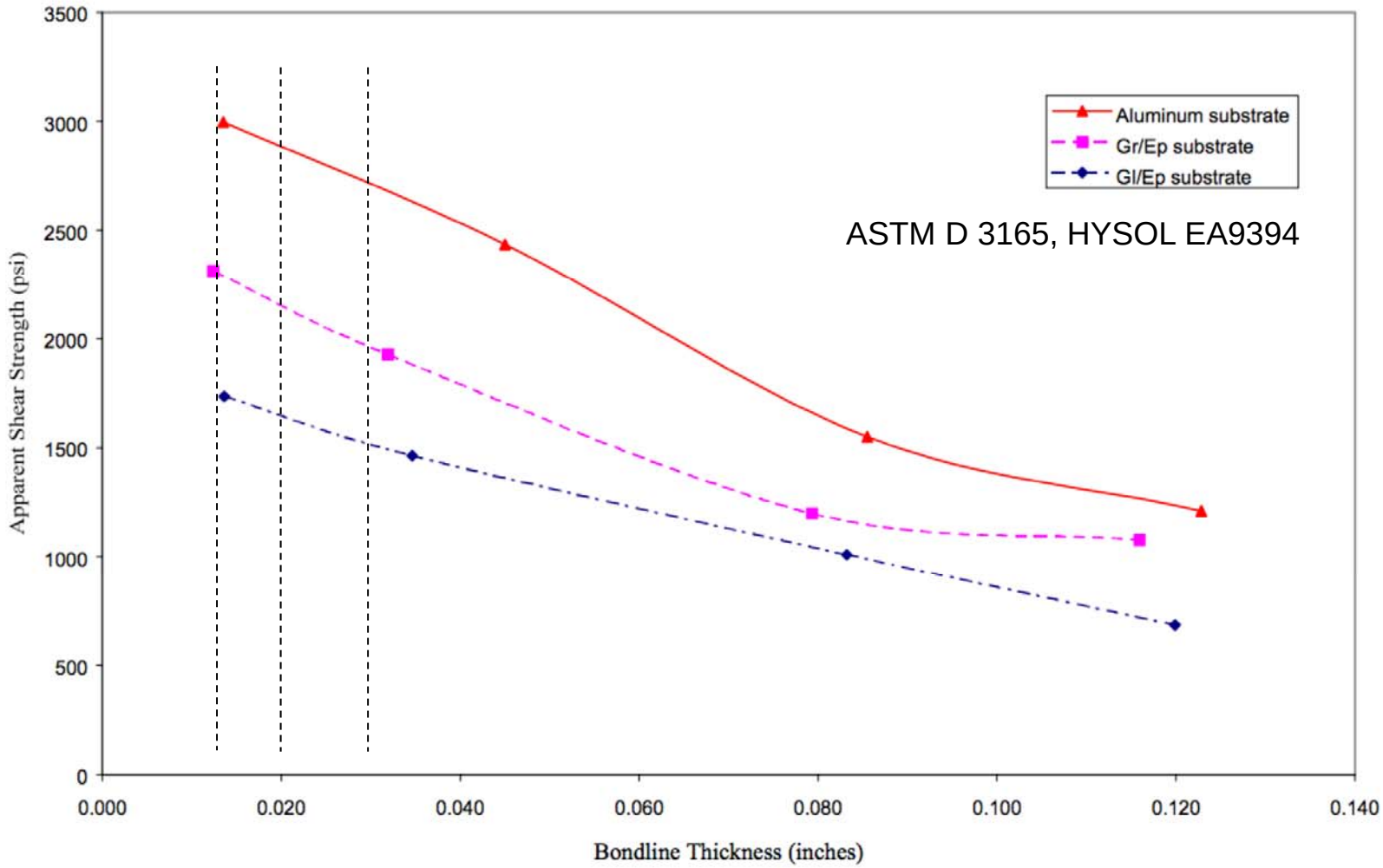
- While not more important than joint geometry, there is substantial variation among adhesives
- Strengths vary from 2000 to 5000 psi
- Bond line tolerance varies from 100 microns to millimeters
- Fillers can substantially alter adhesive viscosity and toughness, and can permit uses such as vertical applications

Effect of Bond Line Thickness



https://afendirojan.files.wordpress.com/2010/04/phddissertation9.pdf

Very Thick Bondlines



Achieving Bond Line Control

- Fillers in the adhesive such as glass beads
- Gap control materials
  - Shims
  - Monofilament
  - Wire
- Building gap into the joint design
  - Ridges or steps in bond region
  - But must be aware of high stress regions

Surface Treatment

- Abrasion
  - Increase surface bonding area
  - Remove surface contaminants
  - Increase surface energy (expose more energetic chemical structure)
  - Must reclean after abrasion
- Cleaning or etch treatment
  - Remove surface contaminants
  - Form highly adherent, stable surface
  - Bond within short time after treatment to maximise advantage

Hysol Surface Treatment Guide

Thermosets

Adherend Material	Cleaning	Abrasion or Chemical Treatment	Method
Epoxy, Epoxide Resins	Degrease with acetone or MEK.	Abrade using medium-grit emery paper.	• Repeat degreasing step.
Furane Resins	Degrease with acetone or MEK.	Abrade using medium-grit emery paper.	• Repeat degreasing step.
Melamine Formaldehyde Plastics (Formica)	Degrease with acetone or MEK.	Abrade using medium-grit emery paper.	• Repeat degreasing step.
Phenolics Polyester Polyurethane Resins	Degrease with acetone or MEK.	Abrade using medium-grit emery paper.	• Repeat degreasing step.
Polyimide (Vespel®, DuPont) (Ref 4)	(A) Degrease. (B) Degrease in acetone.	(A) Abrade with dry or wet abrasive blast. (B) Etch Solution Sodium Hydroxide 5 pbw Water 95 pbw (C) Plasma or Corona Treatment (Ref 10).	(A) • Repeat degreasing. • Dry. (B) • Etch for 1 min. at 140-194°F (60-90°C). • Rinse in cold water. • Dry in hot air.

http://www.loctite.ph/php/content_data/LT4536_TT_Aerospace_Surface_Preparation_Guide.pdf

Final Words on Adhesive Bonding

- First and foremost, joint geometry should be intelligently designed
- Bond line thickness must be well controlled
- Surfaces must be properly treated and bond performed within the specified time
- Choose the right adhesive (this is the least important element)
- A good joint will outperform the adherends – this should be the goal