קורס דבקים. פרק ג.
רקע תיאורטי לתופעת ההדבקה

ALPHA-TECH
Materials & Processes LTD.

Halahmi Izhar | General Manager

Adress: P.O.B 839 Hod-Hasharon 45100 Israel
Tel/Fax: +972 72 2448359
Mobile: +972 50 7790587
E-mail: izharhal@012.net.il
Home page: http://atmp.co.il/index.php

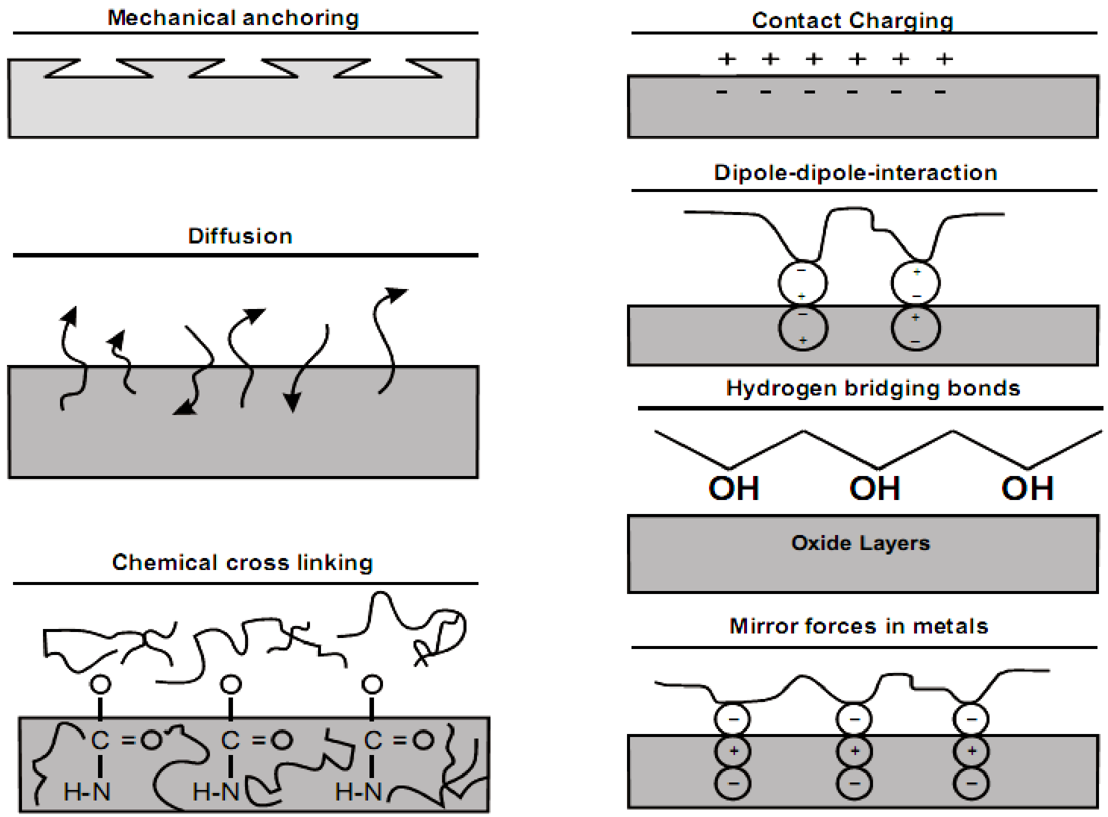


Figure 5: Physical and chemical causes for the adhesion of coatings to the substrate
Source: BASF Hand Book on Basic of Coating Technology 2003

מנגנוני חיבור שונים בין מצע ודבק

Table 1: Surface tensions of selected substrates

Substrate	**σ [mN/m]**
Stainless steel	1000
Phosphated steel	34
Mercury	480
Glass	74
Polypropylene	30-35
Polyamide	40-43
PVC	36
Polystyrene	32
Polycarbonate	37
Polyester	40-45

מתח פנים של מצעים שונים

Table 19.1 Comparison of adhesion interactions relative to length scale

Category of Adhesion Mechanism	Type of Interaction	Length Scale
Mechanical	Interlocking or entanglement	0.01–1000 μm
Diffusion	Interlocking or entanglement	10 nm–2 mm
Electrostatic	Charge	0.1–1.0 μm
Covalent bonding	Charge	0.1–0.2 nm
Acid-base interaction	Charge	0.1–0.4 nm
Lifshitz van der Waals	Charge	0.5–1.0 nm

מימדי הכוחות בין דבק ומצע

Table 3: Surface Tension of Polymers

Polymer	Surface Tension (dynes/cm)
Polyperfluoropropylene	16
Polytetrafluoroethylene (Teflon)	18.5
Polydimethyliloxane	24
Polyethylene	31
Polystyrene	34
Polymethylmethacrylate (acrylic)	39
Polyvinyl chloride (PVC)	40
Polyethylene terephthalate (polyester)	43
Polyhexamethylene adipate (nylon)	46

Source: Bikales, N.M., Adhesion and Bonding, Wiley-Interscience, New York, 1971.

מתח פנים של פולימרים שונים

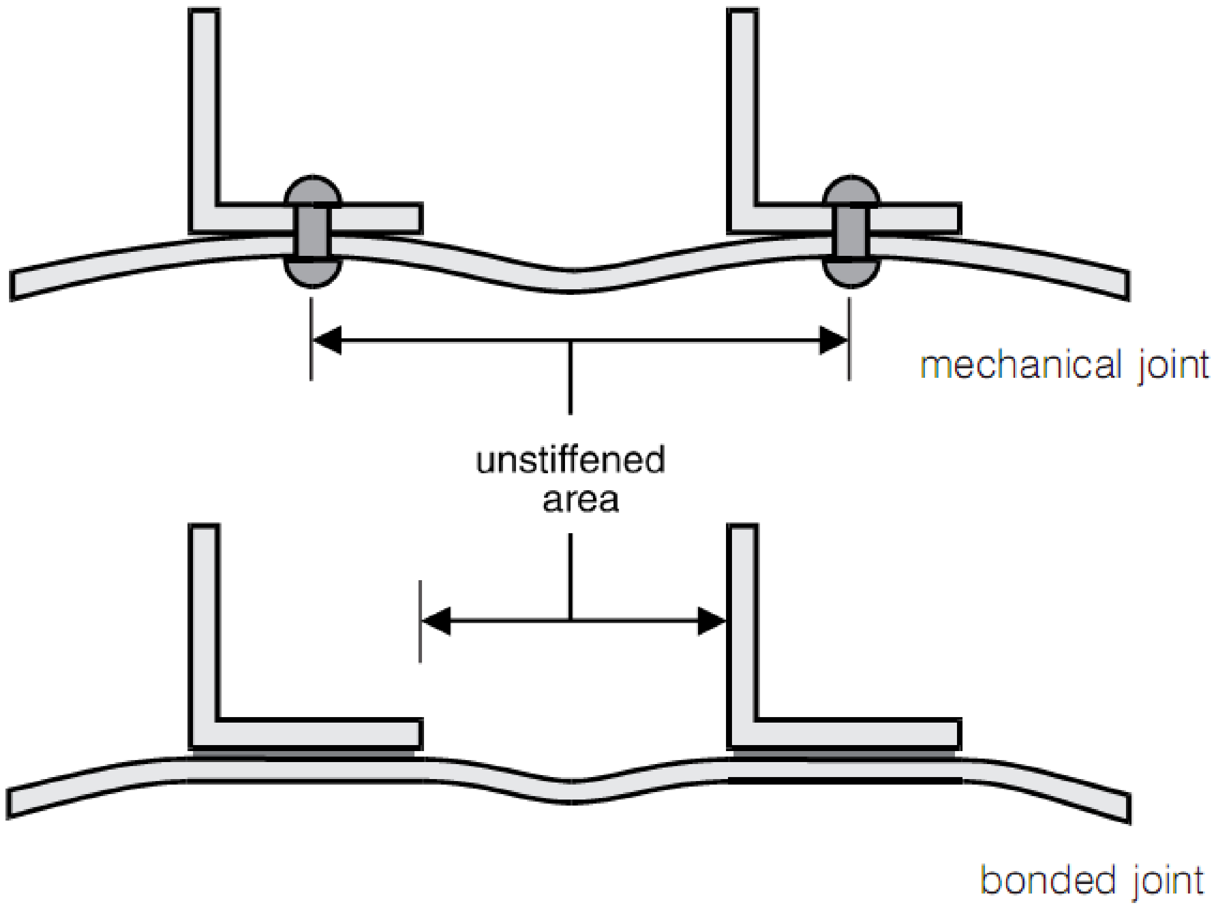
- Bonding saves weight.
- On large area joints, bonded assemblies are generally less costly than their mechanical joint counterparts; simpler design, easier assembly and simpler tooling.
- Bonded joints can allow for the assembly of dissimilar materials.
- Bonded joints are electrically insulating and prevent electrolytic corrosion of conductor metals.

היתרונות של חיבור בהדבקה

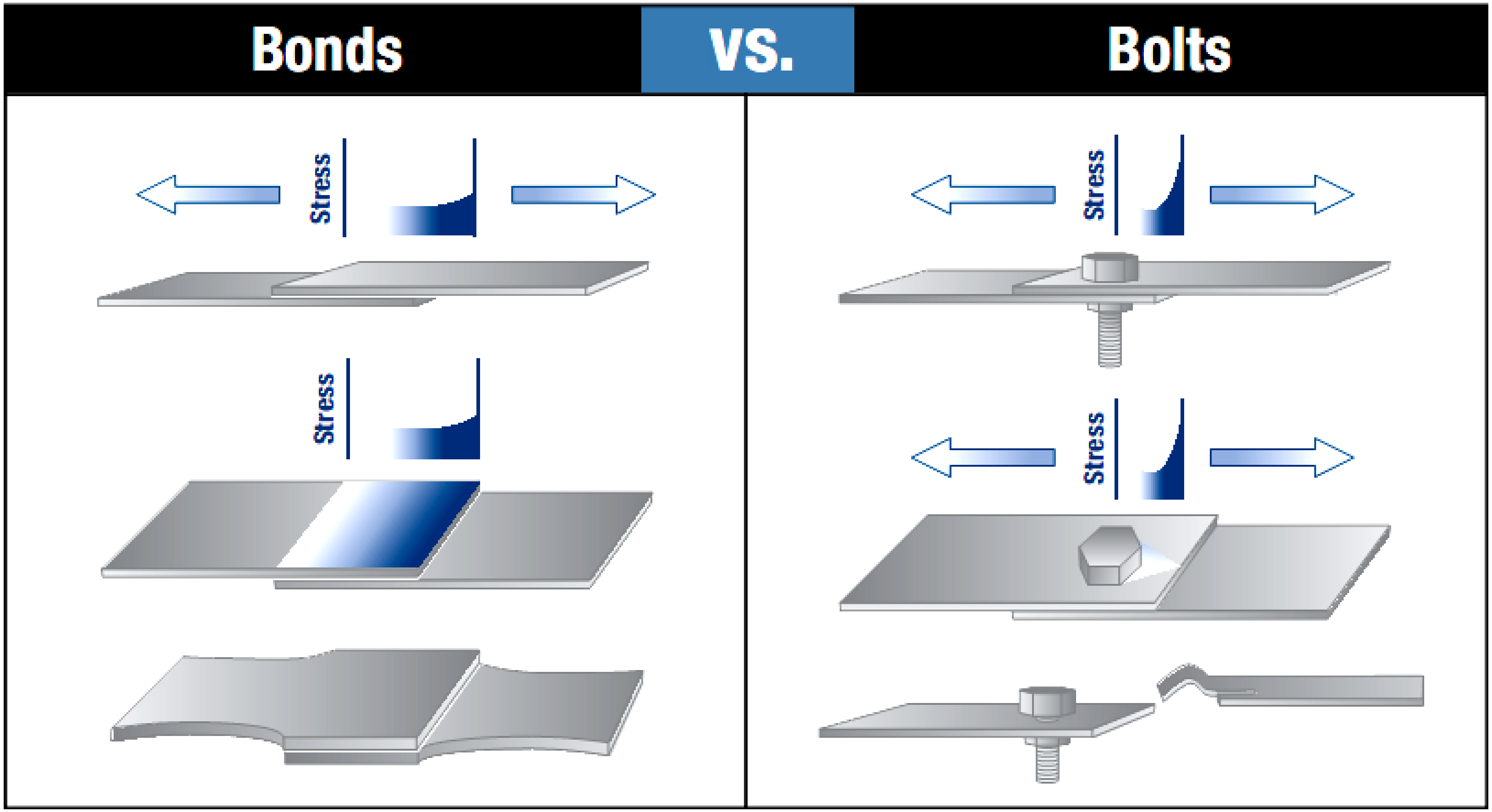
- Bonding joints enables the design of smooth external surfaces, and integrally sealed joints with minimum sensitivity to crack propagation.

- Bonded joints impart a stiffening effect compared with riveting or spot welding.

The diagram below shows how a joint may be designed to take advantage of the stiffening effect of bonding.
Adhesives form a continuous bond between the joint surfaces.
Rivets and spot welds pin the surfaces together only at localised points.
Bonded structures are consequently much stiffer and loading may be increased (by up to 30-100%) before buckling occurs.



ההבדל בין הדבקה לחיבור במסמרות



ההבדל בין הדבקה לחיבור במסמרות

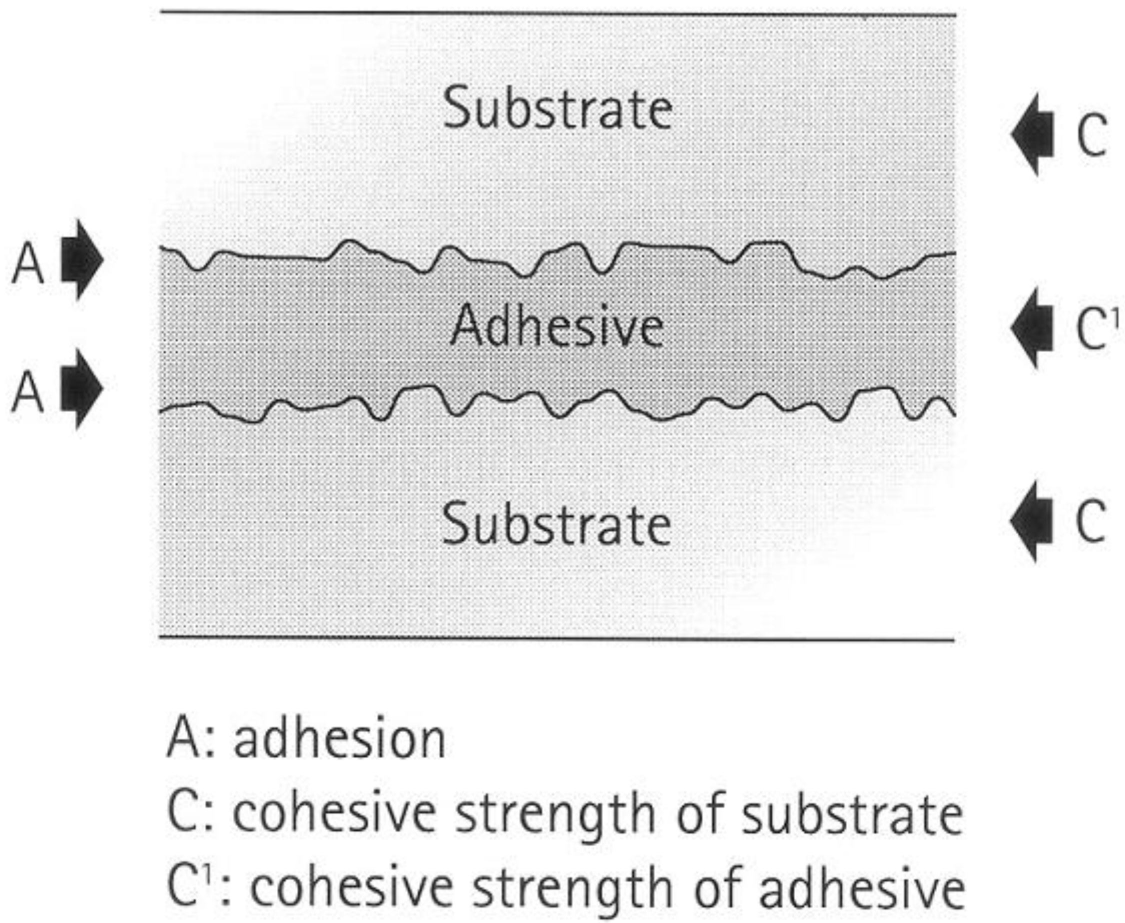
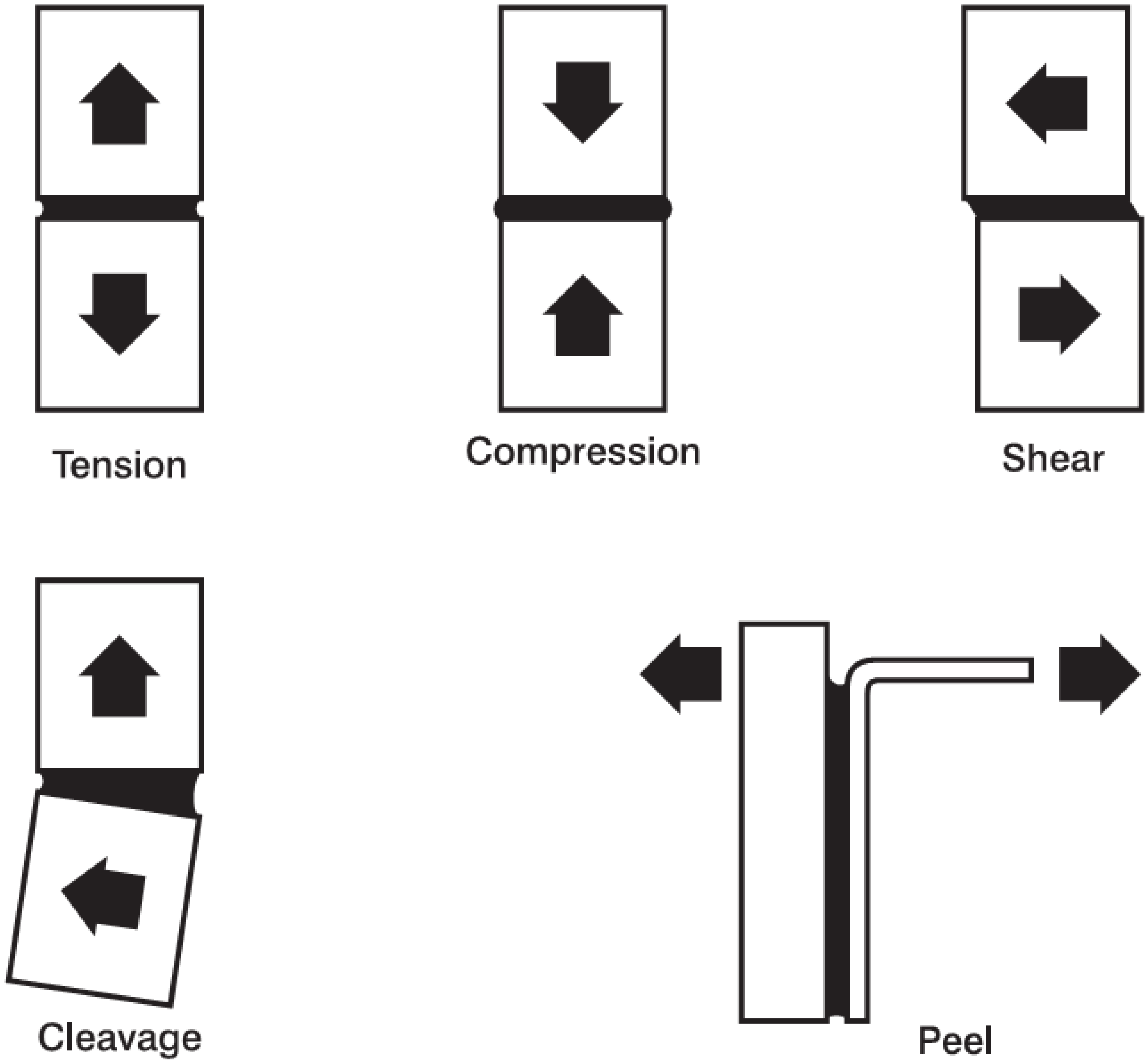
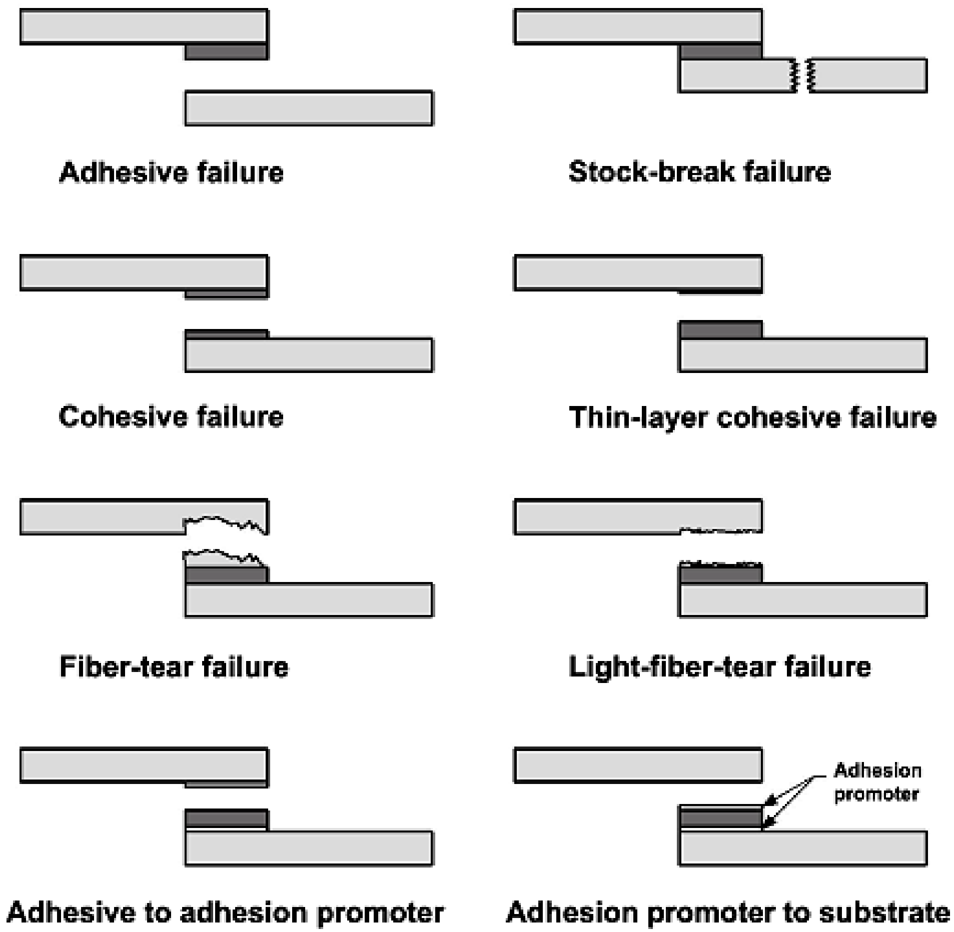


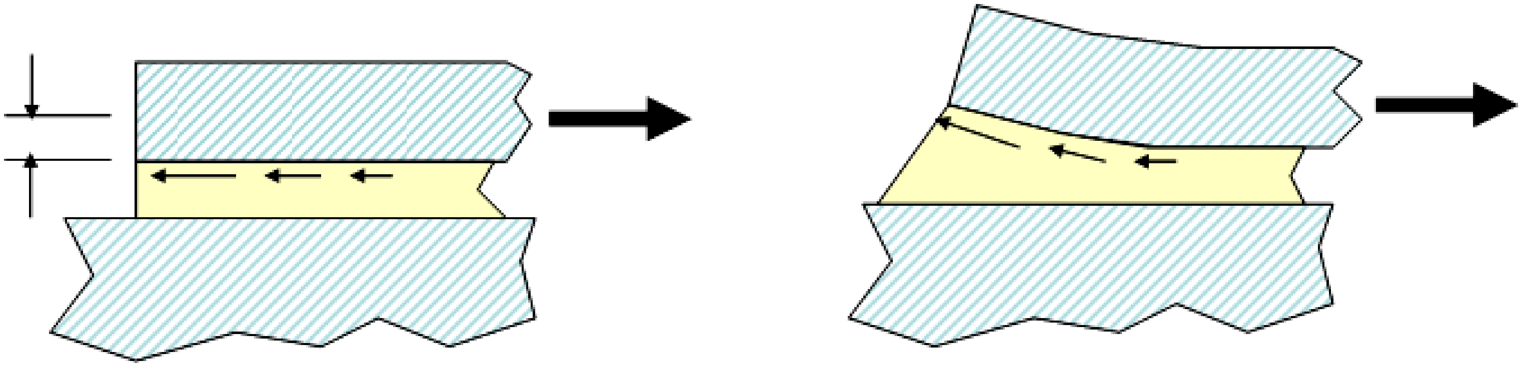
Figure 4. Forces operating in an adhesive bond


Tension
Compression
Shear
Cleavage
Peel

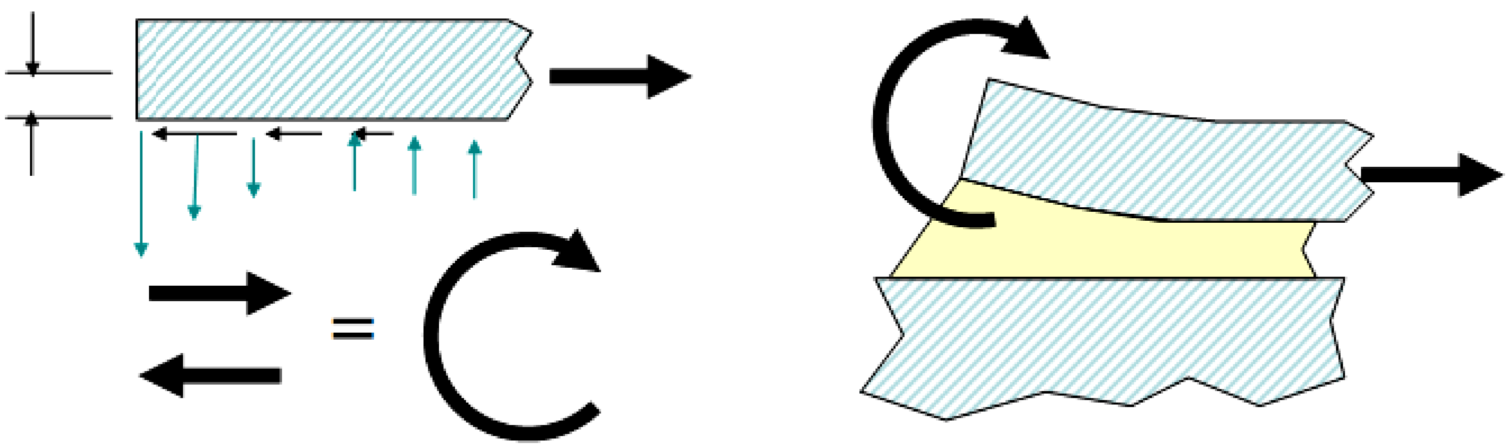
Failure Modes in Adhesively Bonded Joints

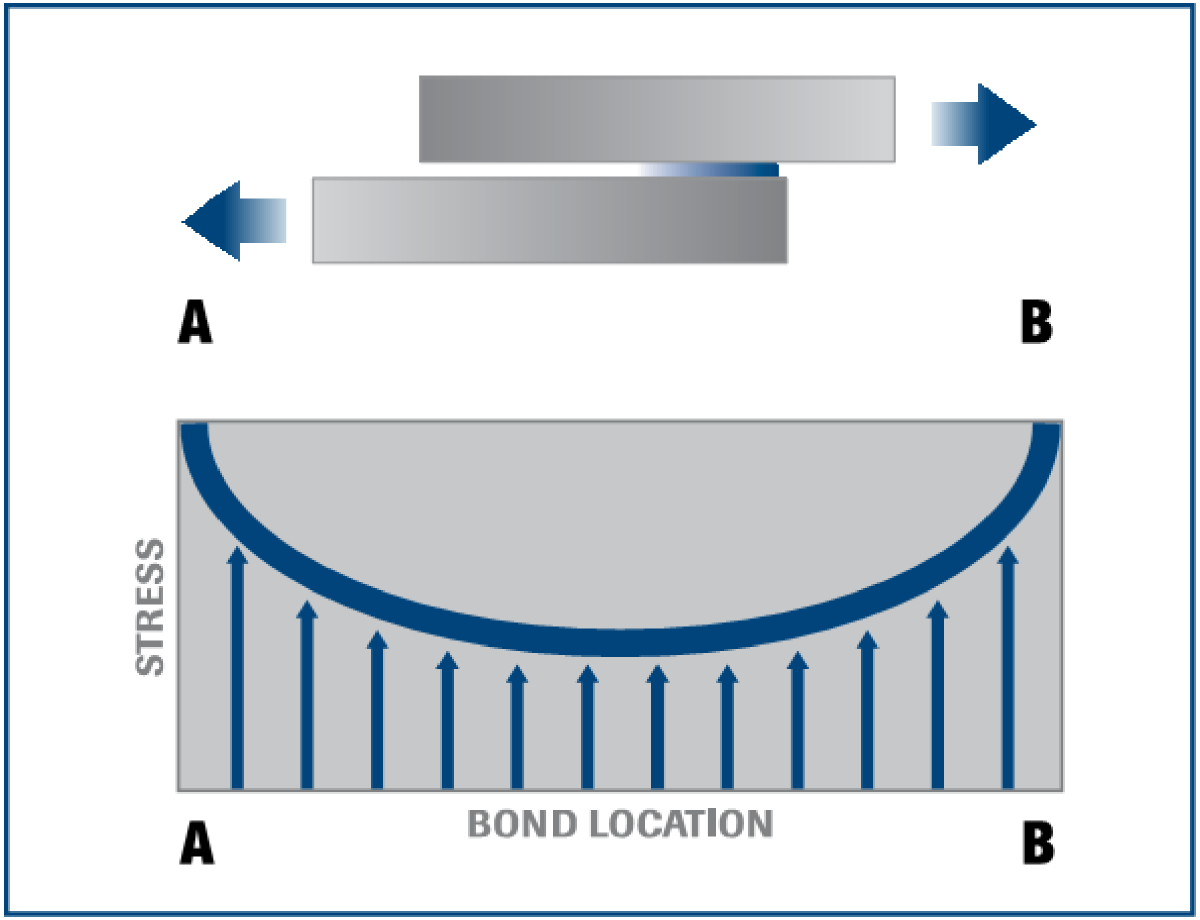


Shear and Peel Coupling



Shear stresses ---> Bending moment ---> Peel stresses

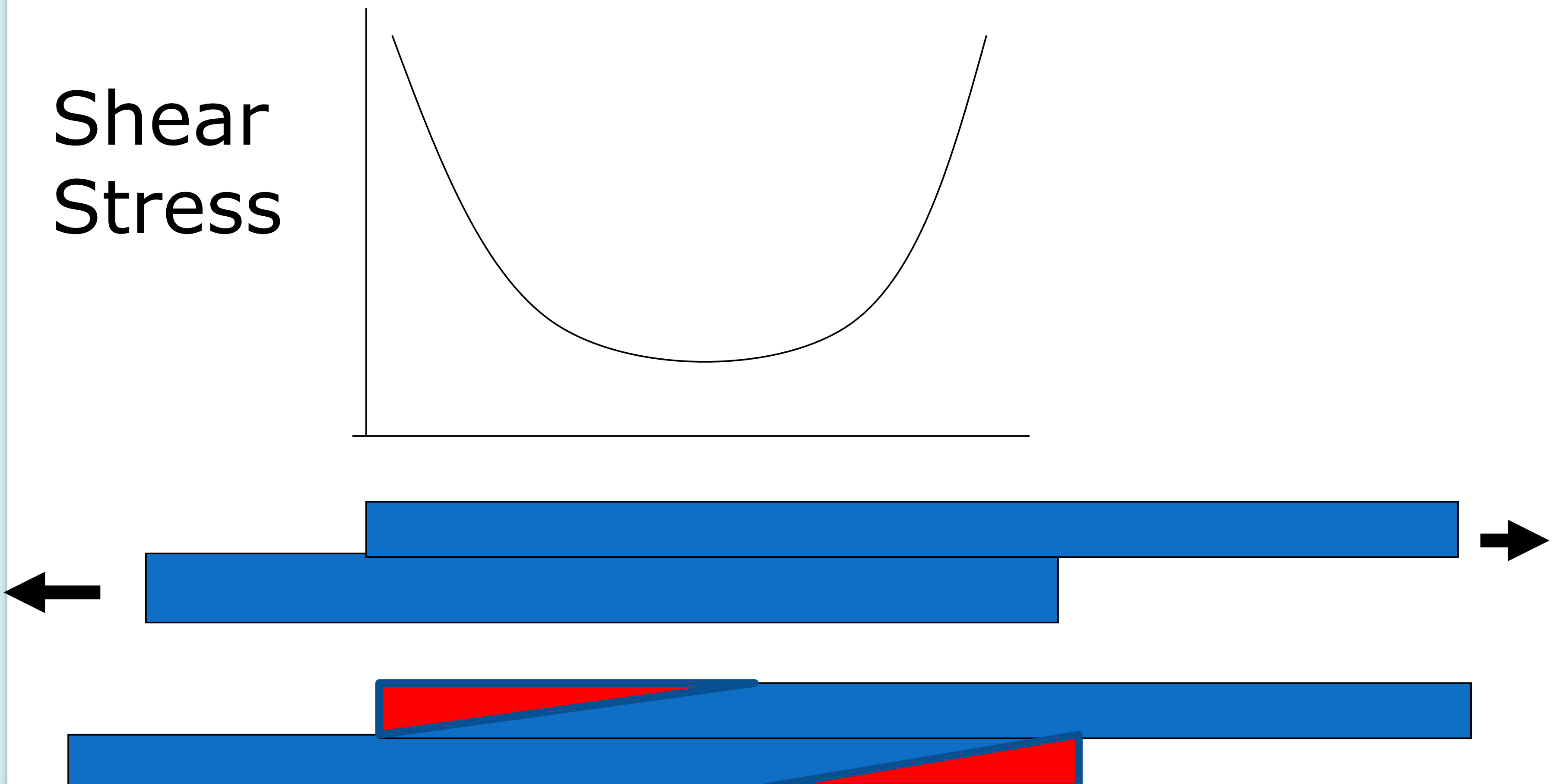




SHEAR STRESS: A shear stress results in two surfaces sliding over one another.

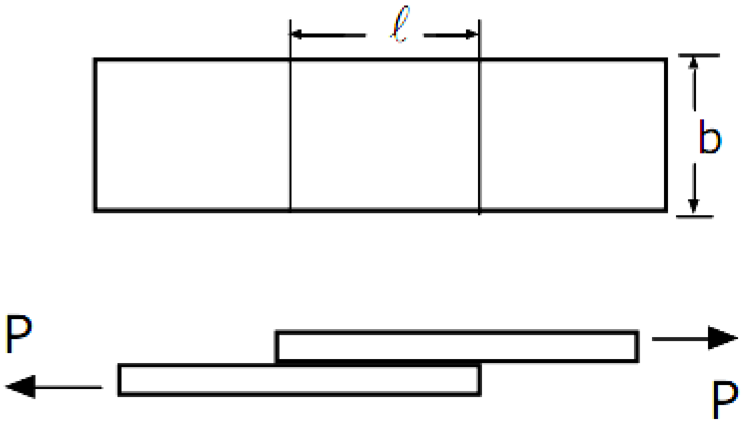
פיזור מאמצים בהעמסה בגזירה

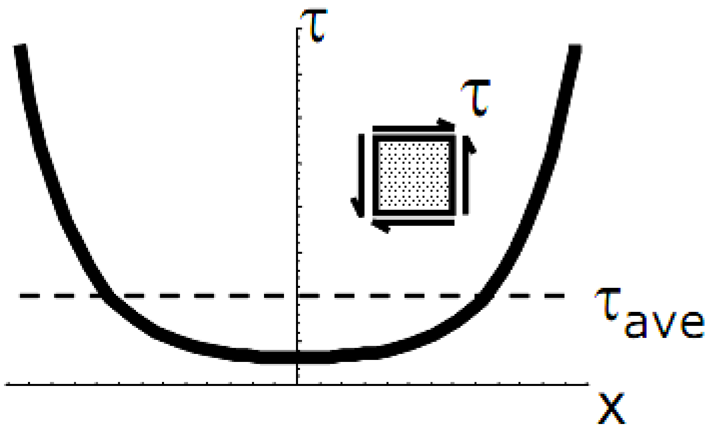
Shear stress along the length of an adhesive joint in tension



Solve the problem by tapering the ends.

Simplest Lap Joint Analysis





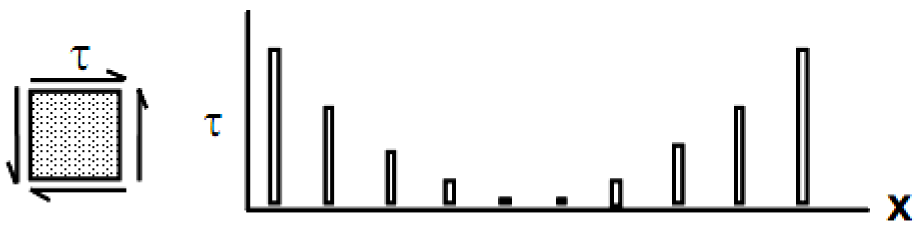
$$\tau \neq \frac{P}{A} = \frac{P}{b\ell}$$

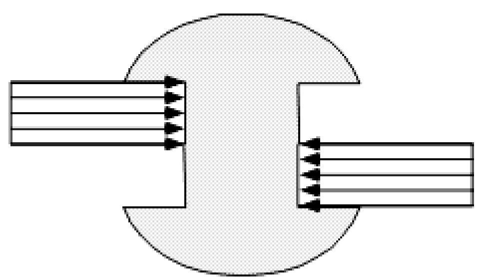
$$\tau_{ave} = \frac{P}{A} = \frac{P}{b\ell}$$

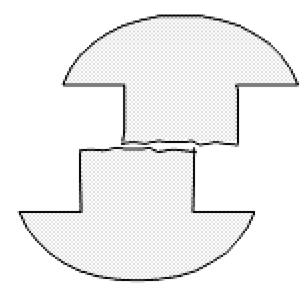
Common expression true only in an average sense.

The Rivet Problem Analogy

End rivets carry the load.

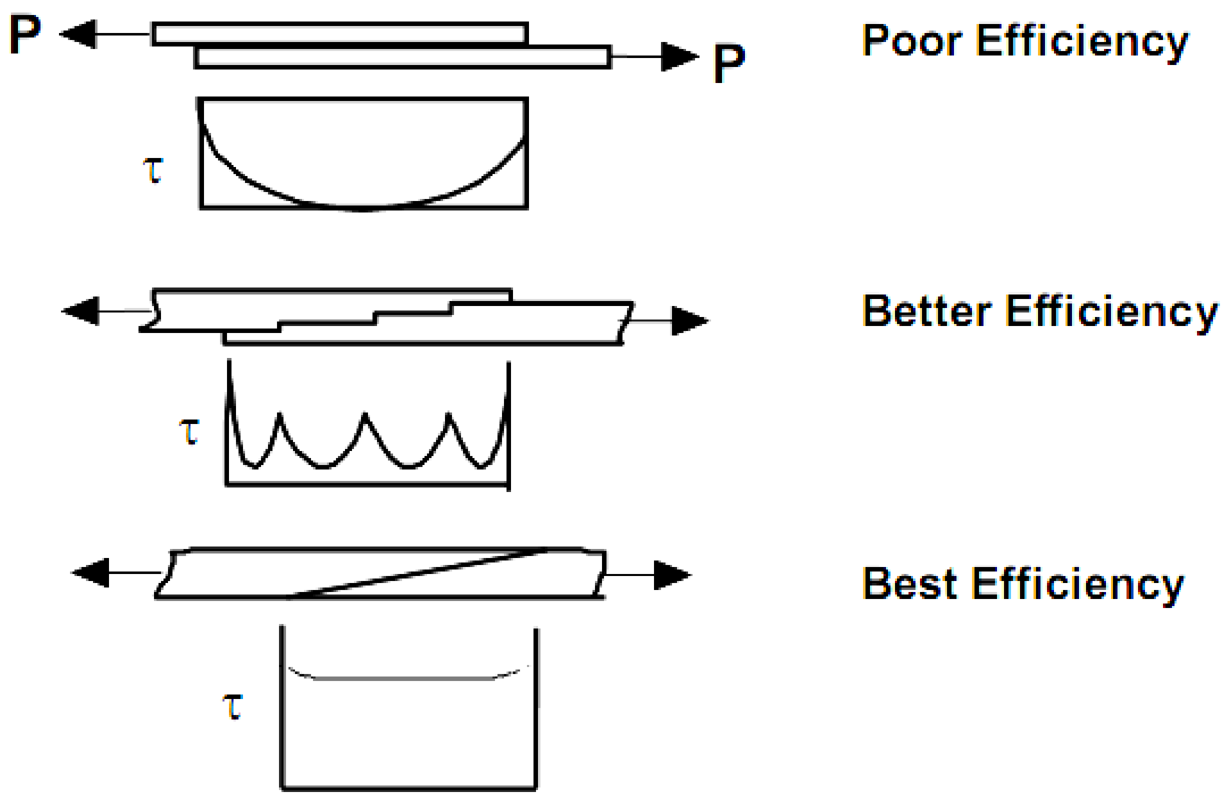


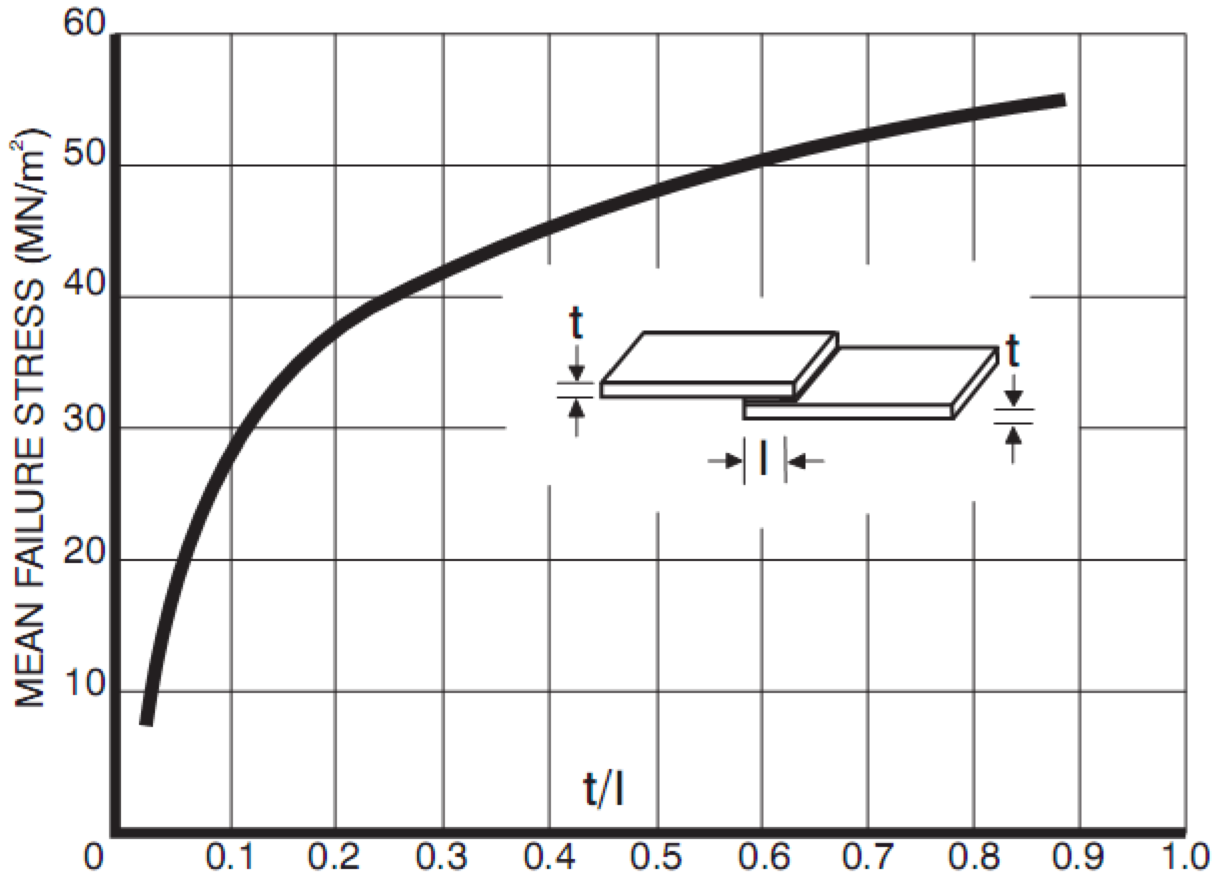




Shear Lag and Adherend Stiffness Change

Shear stresses are required anywhere there is a relative change in stiffness between the adherends. Abrupt changes in relative stiffness lead to large shear stress peaks; gradual changes result in more uniform stress stress distributions.





השפעת יחס עובי/רוחב בהעמסה בגזירה

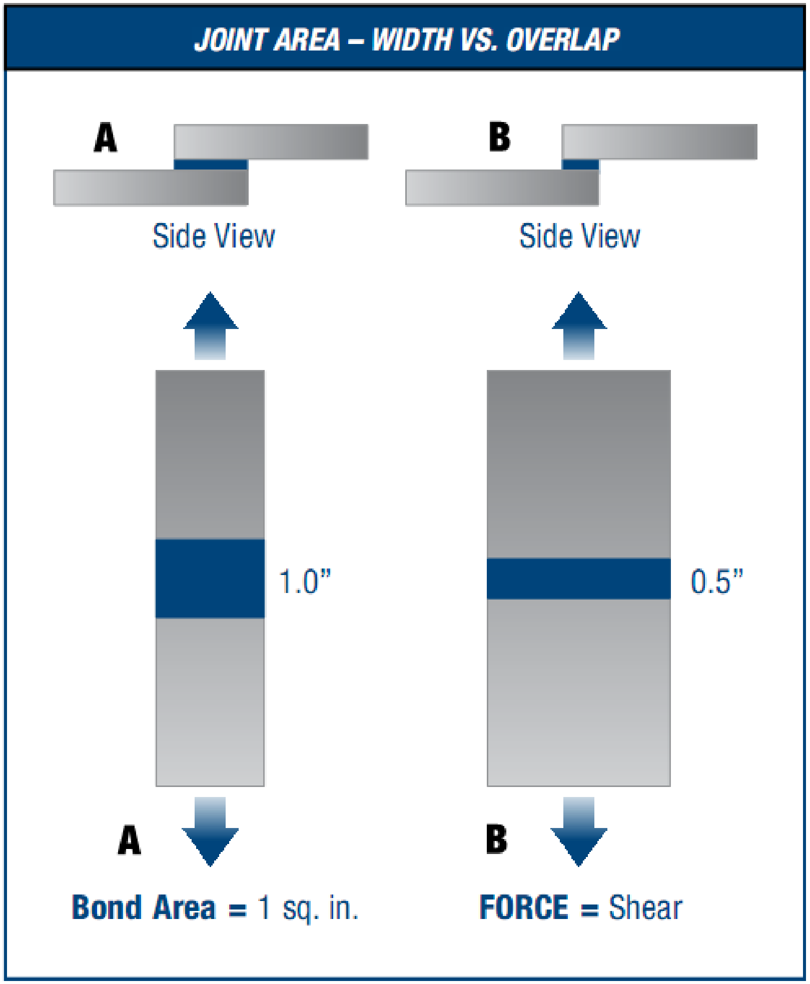
- **Joint Width More Important Than Overlap**

  Note from the shear stress distribution curve, that the ends of the bond receives a greater amount of stress than does the middle of the bond. If the width of the bond is increased, stress will be reduced at each end and the overall result is a stronger joint.

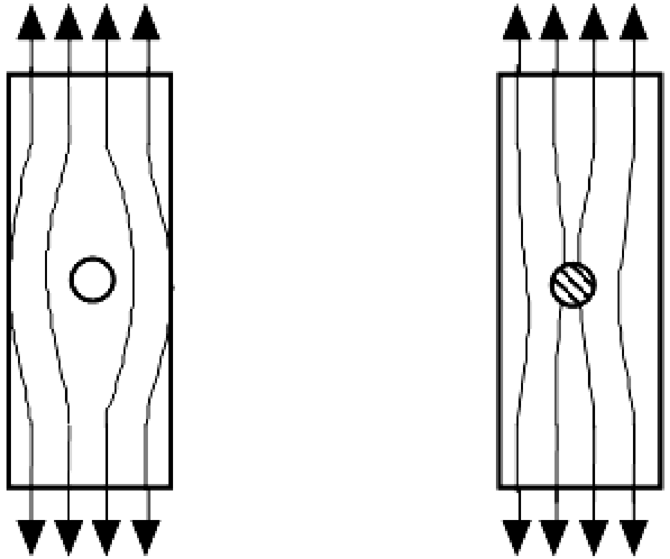
  In this same overlap joint, if the overlapping length is greatly increased, there is little, if any, change in the bond strength. The contribution of the ends is not increased. The geometry of the ends has not changed, thus their contribution to the bond strength has not changed.

- **Bond Shear Strength Width vs Overlap**

  As a general rule, increase the joint width rather than the overlap area ("wider is better").

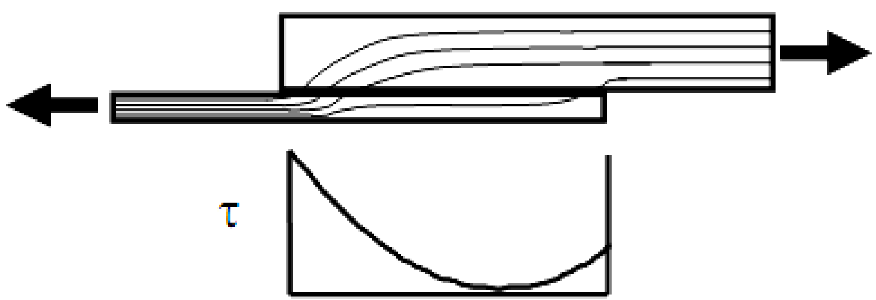


Stress "Seeks" Stiffest Path

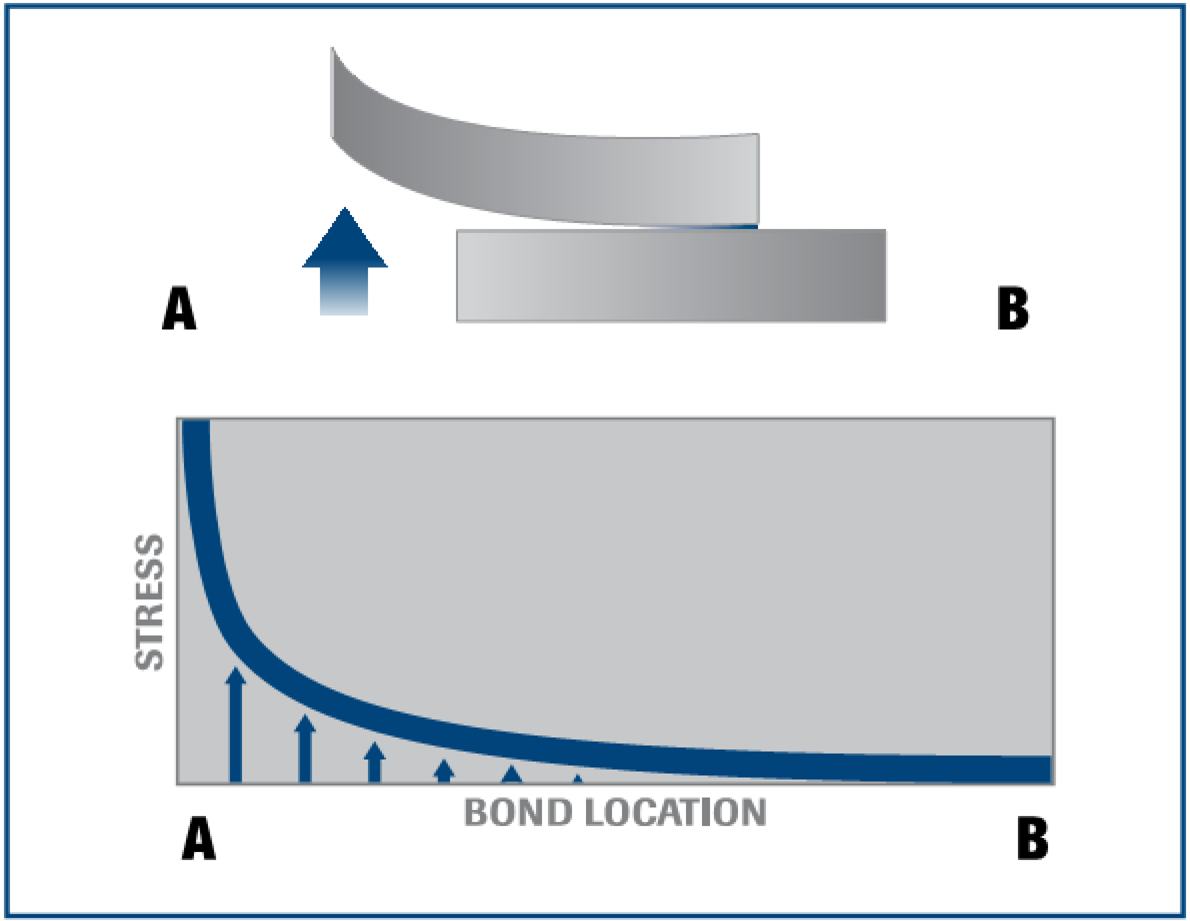


open hole　　　　filled hole

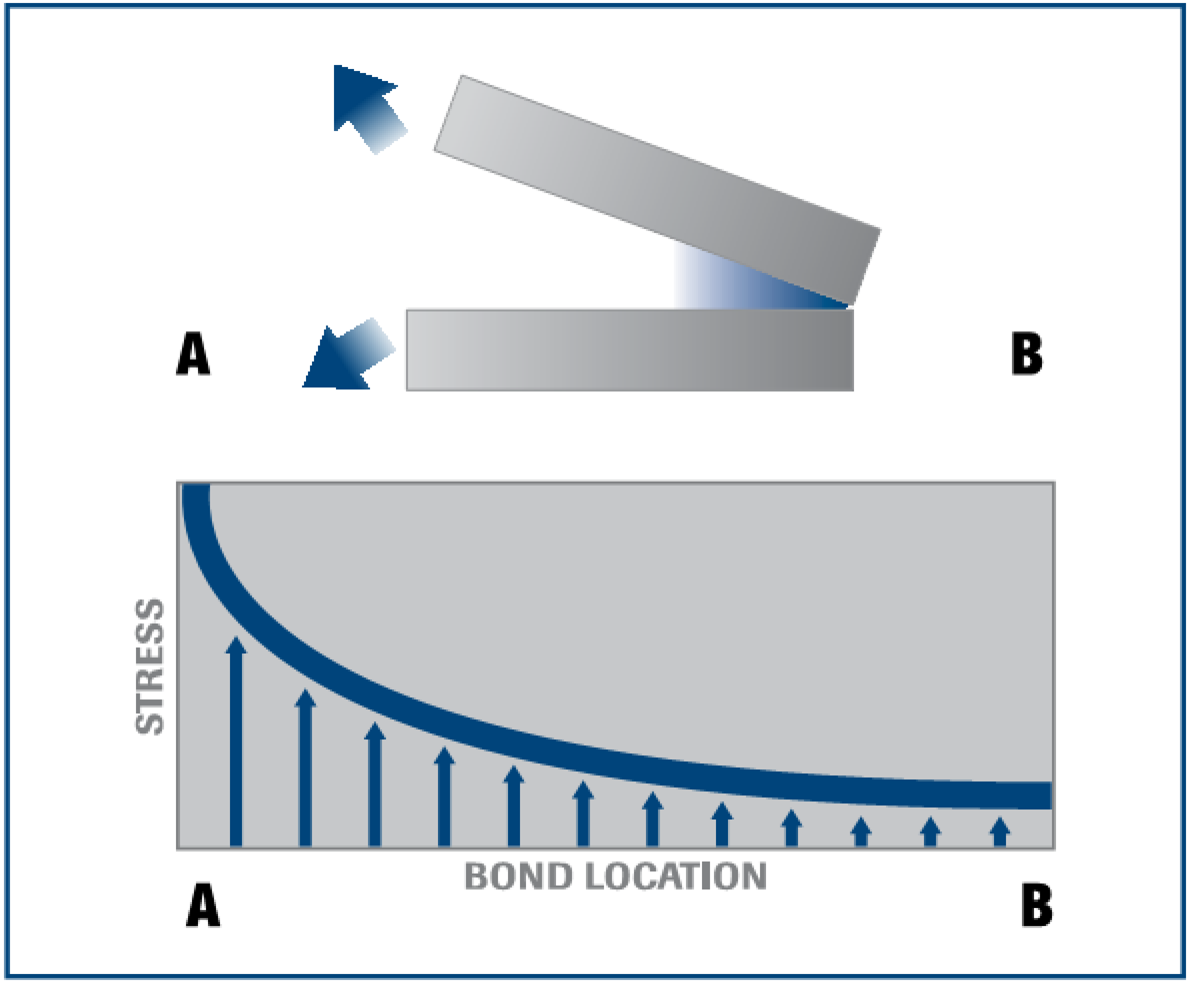
Stresses always concentrate in stiffer regions (seek stiffest path).



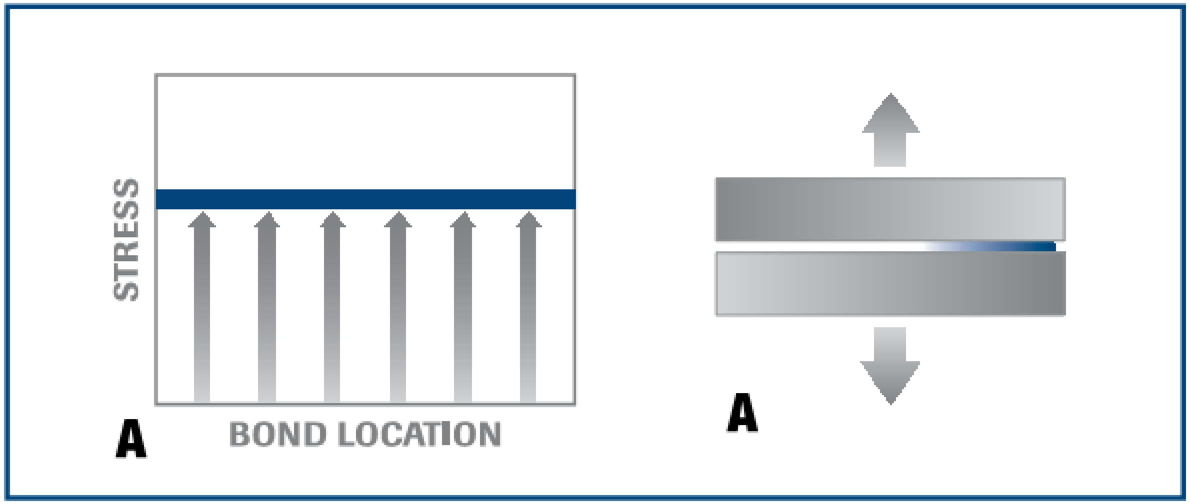
Shear stresses are higher at the end of the stiffer adherend.



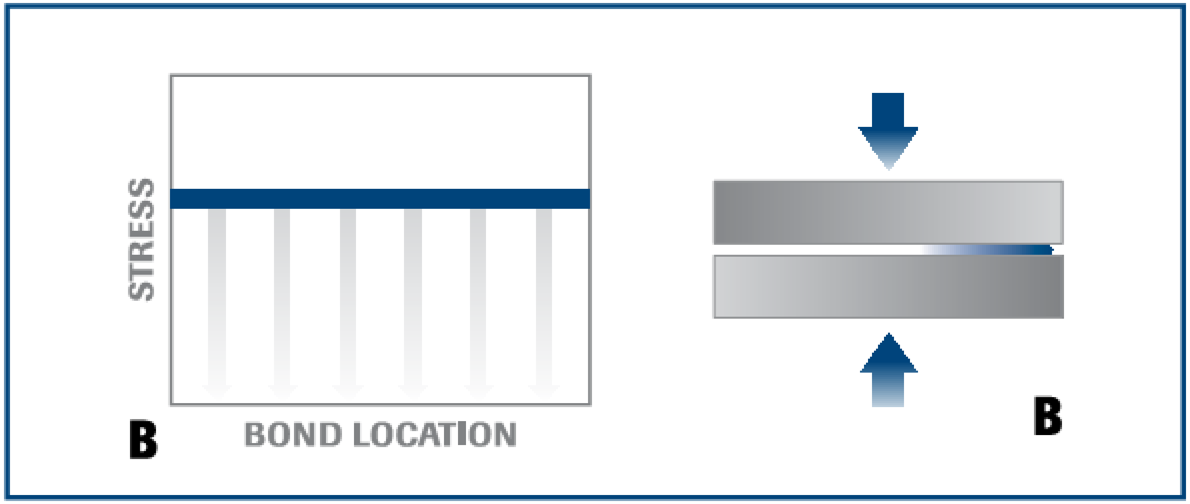
PEEL STRESS: A peel stress occurs when a flexible substrate is being lifted or peeled from the other substrate. *NOTE: The stress is concentrated at one end.*



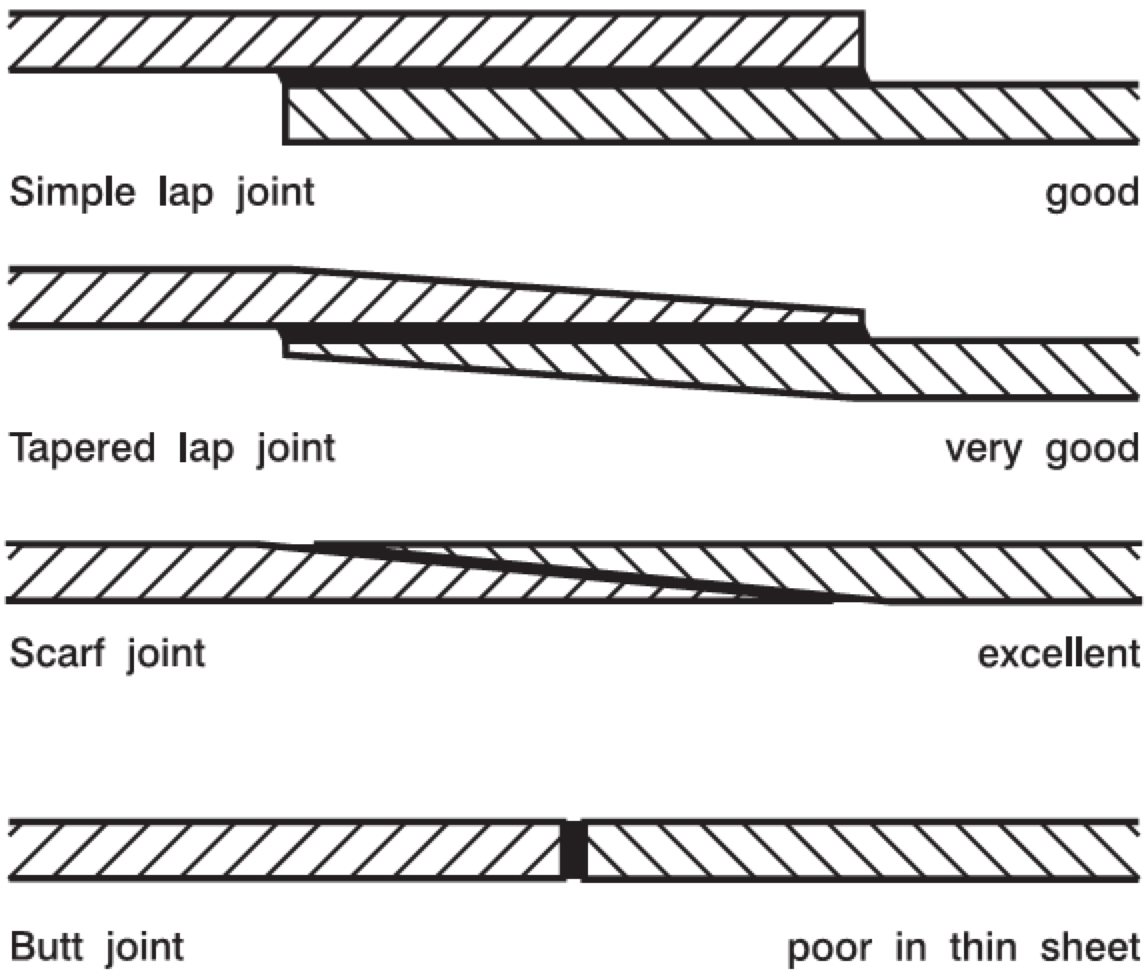
CLEAVAGE STRESS: A cleavage stress occurs when rigid substrates are being opened at one end. *NOTE: The stress is concentrated at one end.*

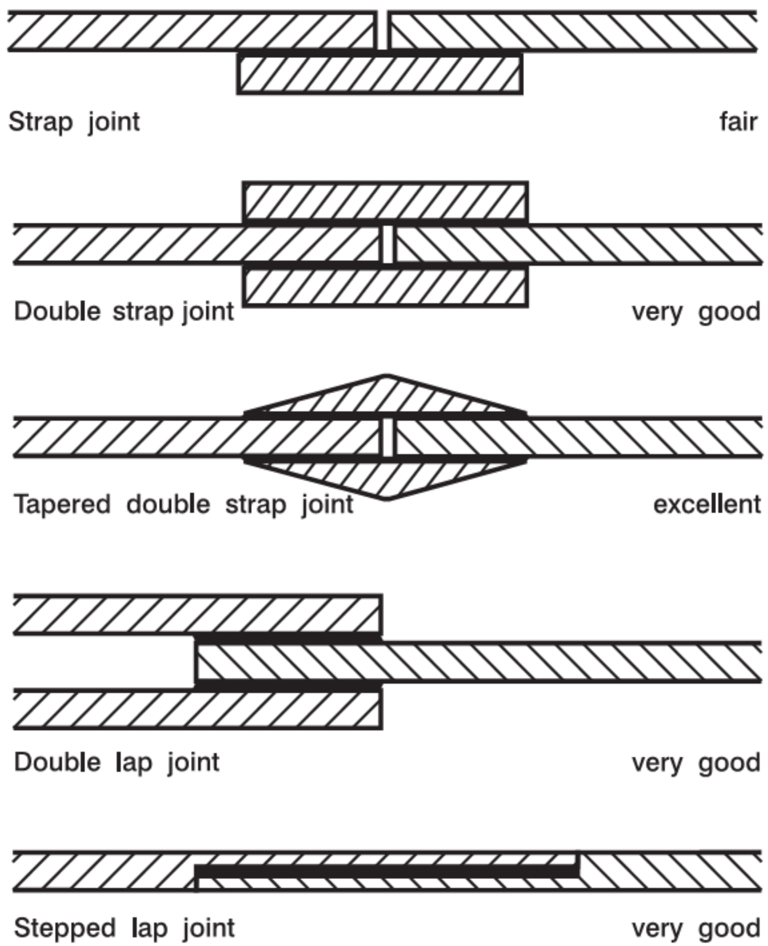


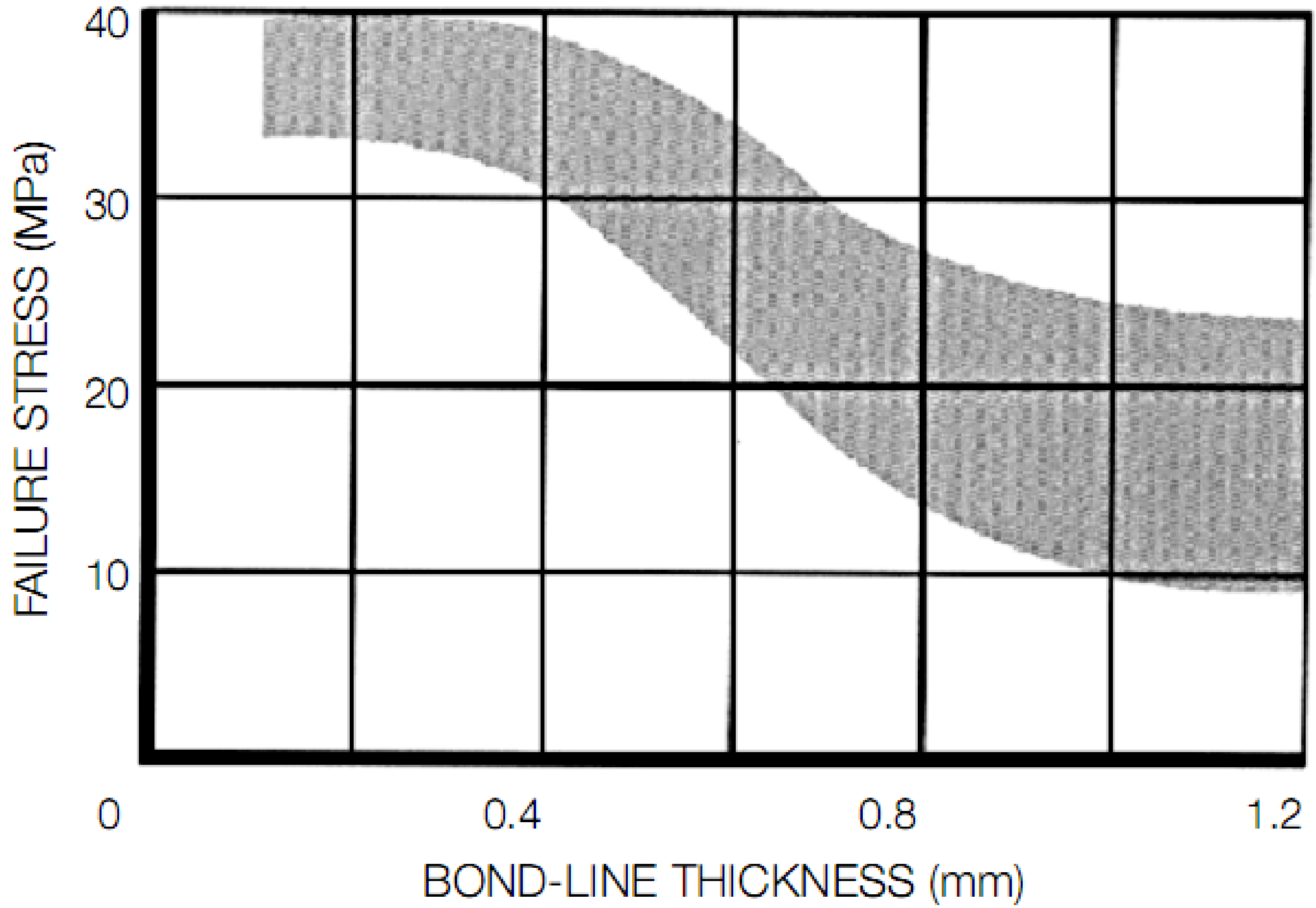
TENSION STRESS DISTRIBUTION: When a bond experiences a tensile stress, the joint stress distribution is illustrated as a straight line. The stress is evenly distributed across the entire bond. Tensile stress also tends to elongate an object.



COMPRESSION STRESS DISTRIBUTION: When a bond experiences a compressive stress, the joint stress distribution is illustrated as a straight line. The stress is evenly distributed across the entire bond.


Simple lap joint
good
Tapered lap joint
very good
Scarf joint
excellent
Butt joint
poor in thin sheet


Strap joint
fair
Double strap joint
very good
Tapered double strap joint
excellent
Double lap joint
very good
Stepped lap joint
very good



40
30
20
10
FAILURE STRESS (MPa)
0
0.4
0.8
1.2
BOND-LINE THICKNESS (mm)

- עובי דבק של בין 100 ל 300 מיקרון נותן שילוב אופטימאלי מבחינת יכולת לספוג מאמצים. עם זאת, הדבק חשוף יותר לפגעי סביבה, והמחבר פחות יציב ממדית (למשל בהדבקות אופטיות)
- שימוש בדבק שיש בו פאזה עוצרת סדק (toughened), מגדיל את יכולתו לעמוד בעומסים מחזוריים וכוחות קילוף, במחיר של פגיעה מסוימת בחוזק הגזירה.
- כדאי לתכנן על חוזק ארוך טווח של 25% עד 30% מחוזק הגזירה "המצוין בדפי היצרן".
- יש לתת דגש רב על תכנון גאומטריית המחבר לשם מניעת ריכוז מאמצים ועל הכנת השטח ומניעת קורוזיה

השגת מחבר אופטימלי

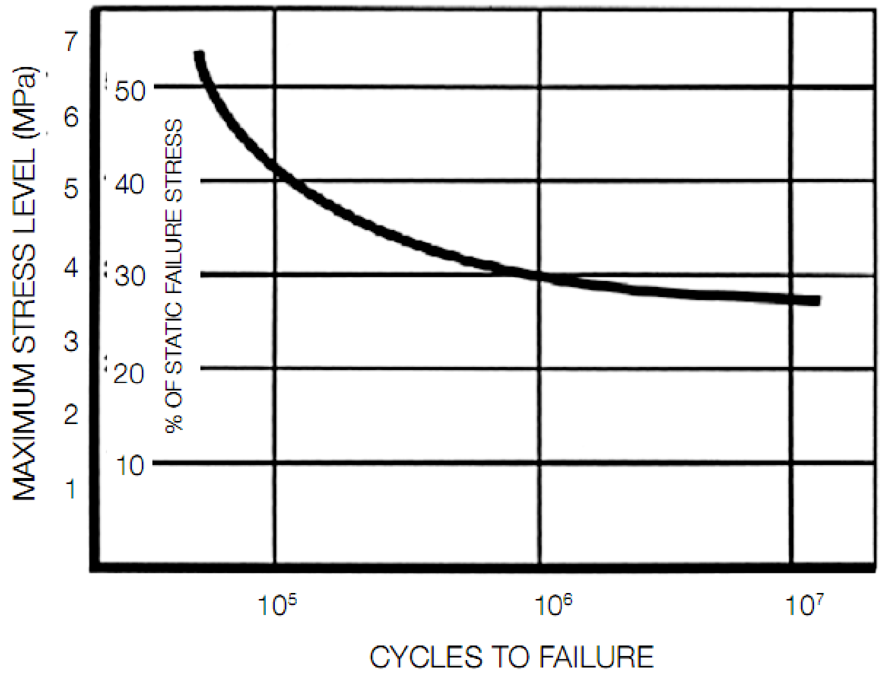


Fig.11 Fatigue strength (tensile) of lap joints

Fatigue strength of simple lap joints made with a cold-cured epoxy adhesive and tested to DIN 53 285. In this test program, the failure stress of control joints under static loading was 13 Mpa. The diagram shows that under fatigue loading the joints required to sustain 106 test cycles should not be stressed higher than 4.1 Mpa per cycle.

עמידות בהתעייפות

Partial Safety Factors for Adhesively Bonded Joints

Source of Adhesive Properties ($\gamma_{m,1}$)	
Typical or textbook values	1.5
Values obtained by testing	1.25
Method of Adhesive Application ($\gamma_{m,2}$)	
Manual application, no adhesive thickness control	1.5
Manual application, adhesive thickness controlled	1.25
Established procedure with controlled parameters	1.0
Type of Loading ($\gamma_{m,3}$)	
Long term loading	1.5
Short-term loading	1.0
Environmental Conditions ($\gamma_{m,4}$)	
Service conditions outside the adhesive test conditions	2.0
Adhesive properties determined for service conditions	1.0

EDCH (Clarke 1996)

ALPHA-TECH
Materials & Processes LTD.

Halahmi Izhar | General Manager

Adress: P.O.B 839 Hod-Hasharon 45100 Israel
Tel/Fax: +972 72 2448359
Mobile: +972 50 7790587
E-mail: izharhal@012.net.il
Home page: http://atmp.co.il/index.php