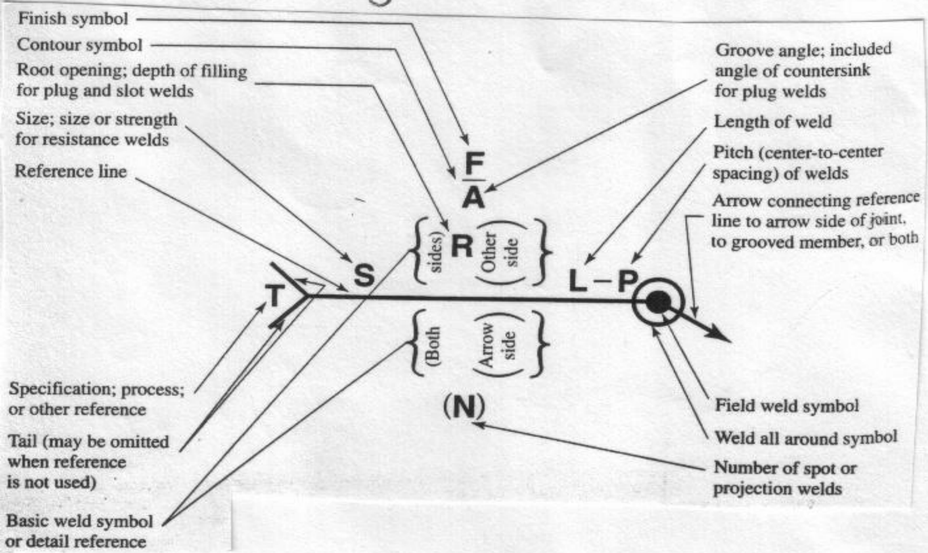
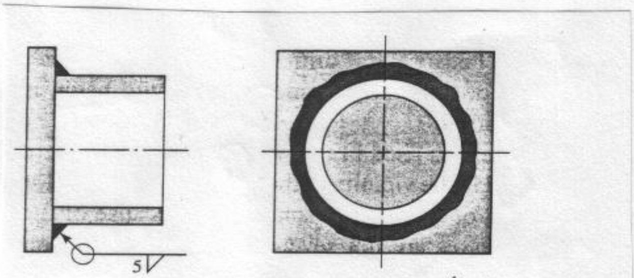
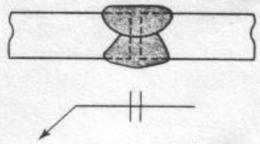
Welded, Brazed, and Bonded Joints

- Welding, brazing (kaynak, lehim), soldering (lehim), cementing (macunlama), and gluing are particularly used to join thin sections.
- Welding symbols

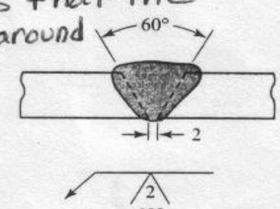




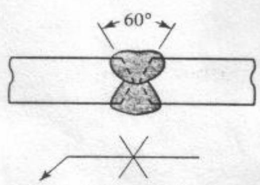
the circle indicates that the welding is to go all around



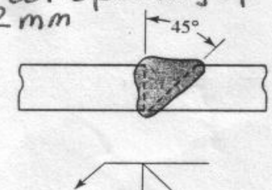
square butt-welded on both sides
(a)



single V with 60° bevel and root opening of 2 mm
(b)

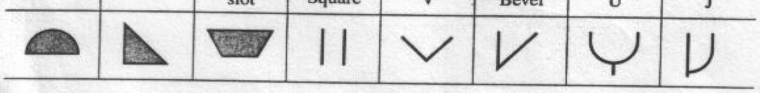


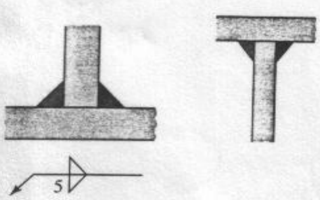
double V
(c)



single bevel
(d)

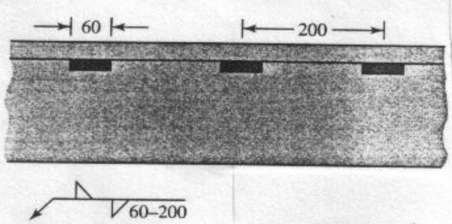
Type of weld							
Bead (kordon)	Fillet	Plug or slot	Groove				
			Square	V	Bevel	U	J





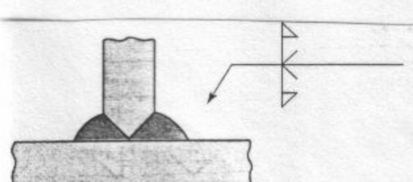
(a)

the number indicates the leg size

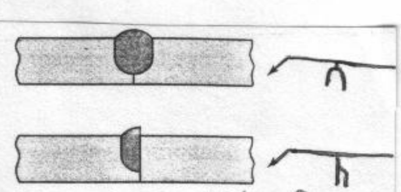


(b)

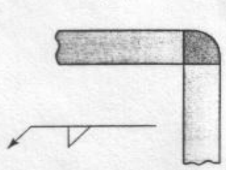
the welds are intermitted (aralıklı) and staggered (zikzak) 60 mm along on 200 mm centers



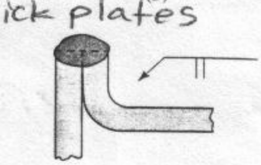
T joint for thick plates
(a)



U and J welds for thick plates
(b)

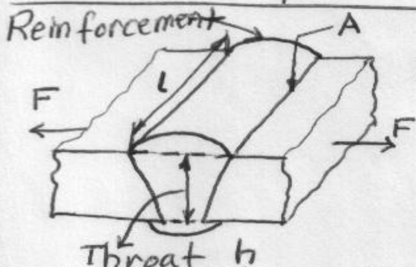


corner weld
(c)



edge weld
(d)

Butt (alın) and fillet (köşe) welds

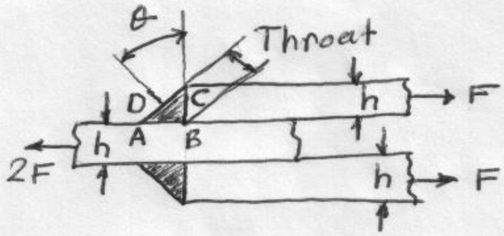


$$\sigma = \frac{F}{h \cdot L}$$

$$\tau = \frac{F}{h \cdot L}$$

A typical butt joint

A: stress concentration point



A transverse fillet weld

$$\tau = \frac{F_s}{A} = \frac{F}{hL}(\sin\theta\cos\theta + \sin^2\theta)$$

F_s → shear force

$$\sigma = \frac{F_n}{A} = \frac{F}{hL}(\cos^2\theta + \sin\theta\cos\theta)$$

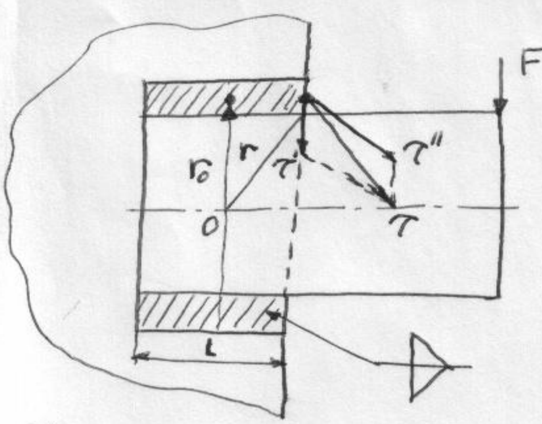
F_n → normal force

Use failure theories to take into account both normal and shear stresses.

$$\sigma_{eq} = \frac{1}{2}\left(\sigma + \sqrt{\sigma^2 + 4\tau^2}\right) \leq \sigma_y \quad \Leftarrow \text{maximum normal stress hypothesis}$$

$$\tau_{max} \leq \tau_y \quad \Leftarrow \text{maximum shear stress hypothesis}$$

Stresses in welded joints in torsion



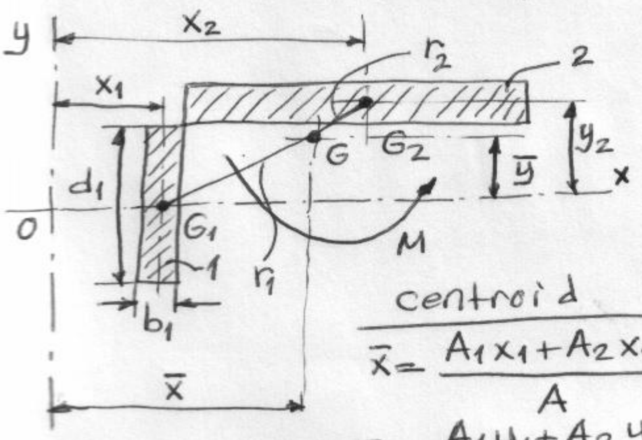
$$\tau' = \frac{V}{A}$$

τ': primary shear; V → shear force; A → throat area of all the welds

$$\tau'' = \frac{Mr}{J}$$

τ'': secondary shear; r → distance from the centroid; J → second polar moment of area of the weld group

A moment connection



$$A = A_1 + A_2 = b_1 d_1 + b_2 d_2$$

centroid

$$\bar{x} = \frac{A_1 x_1 + A_2 x_2}{A}$$

$$\bar{y} = \frac{A_1 y_1 + A_2 y_2}{A}$$

weld 1

$$I_x = \frac{b_1 d_1^3}{12} \qquad I_y = \frac{d_1 b_1^3}{12}$$

$$J_{G_1} = I_x + I_y = \frac{b_1 d_1^3}{12} + \frac{d_1 b_1^3}{12}$$

weld 2

$$J_{G_2} = \frac{b_2 d_2^3}{12} + \frac{d_2 b_2^3}{12}$$

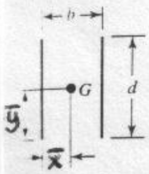
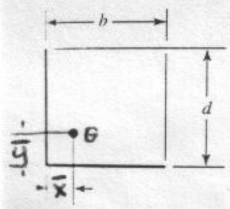
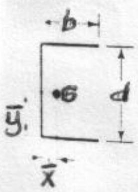
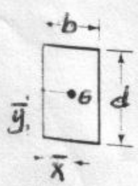
$r_1 = [(\bar{x}-x_1)^2+\bar{y}^2]^{1/2}$ $r_2 = [(y_2-\bar{y})^2+(x_2-\bar{x})^2]^{1/2}$

Using the parallel-axis theorem,

$$J = (J_{G1} + A_1 r_1^2) + (J_{G2} + A_2 r_2^2)$$

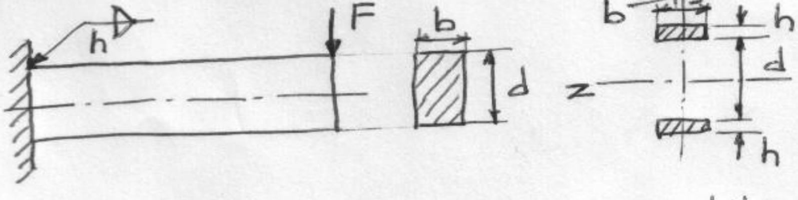
b_1^3 and d_2^3 can be set equal to unity and we treat each fillet weld as a line

Torsional properties of fillet welds

Weld	Throat Area	Location of G	Unit Second Polar Moment of Area
	$A = 0.707hd$	$\bar{x} = 0$ $\bar{y} = d/2$	$J_u = d^3/12$
	$A = 1.414hd$	$\bar{x} = d/2$ $\bar{y} = d/2$	$J_u = \frac{d(3b^2+d^2)}{6}$
	$A = 0.707h(2b+d)$	$\bar{x} = \frac{b^2}{2(b+d)}$ $\bar{y} = \frac{d^2}{2(b+d)}$	$J_u = \frac{(b+d)^4 - 6b^2d^2}{12(b+d)}$
	$A = 0.707h(2b+d)$	$\bar{x} = \frac{b^2}{2b+d}$ $\bar{y} = d/2$	$J_u = \frac{8b^3+6bd^2+d^3}{12} - \frac{b^4}{2b+d}$
	$A = 1.414h(b+d)$	$\bar{x} = b/2$ $\bar{y} = d/2$	$J_u = \frac{(b+d)^3}{6}$
	$A = 1.414\pi hr$		$J_u = 2\pi r^3$

[illegible] of weld group; *h* is weld size; plane of torque couple is in the plane of the paper; all welds are of unit width.

Stresses in welded joints in bending



A rectangular cross-section cantilever welded to a support at the top and bottom ages

→ primary shear

$$\tau' = \frac{V}{A}$$

Treating the two welds as lines

$$I_u = \frac{bd^2}{2}$$

$$I = 0.707\,h\,I_u$$

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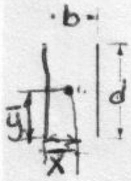
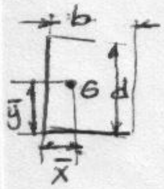
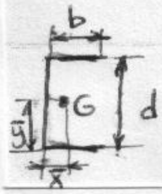
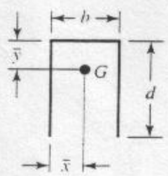
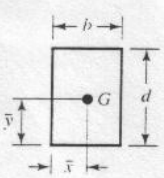
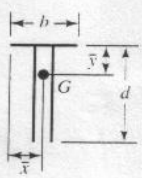
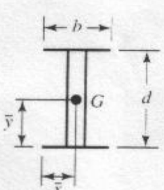
$$\tau = \frac{Mc}{I} = \frac{1.414\,M}{bdh}$$

Weld	Throat Area	Location of G	Unit Second Moment of Area
	$A = 0.707hd$	$\bar{x} = 0$ $\bar{y} = d/2$	$I_u = \frac{d^3}{12}$
	$A = 1.414hd$	$\bar{x} = b/2$ $\bar{y} = d/2$	$I_u = \frac{d^3}{6}$
	$A = 1.414hb$	$\bar{x} = b/2$ $\bar{y} = d/2$	$I_u = \frac{bd^2}{2}$
	$A = 0.707h(2b + d)$	$\bar{x} = \frac{b^2}{2b + d}$ $\bar{y} = d/2$	$I_u = \frac{d^2}{12}(6b + d)$
	$A = 0.707h(b + 2d)$	$\bar{x} = b/2$ $\bar{y} = \frac{d^2}{b + 2d}$	$I_u = \frac{2d^3}{3} - 2d^2\bar{y} + (b + 2d)$
	$A = 1.414h(b + d)$	$\bar{x} = b/2$ $\bar{y} = d/2$	$I_u = \frac{d^2}{6}(3b + d)$
	$A = 0.707h(b + 2d)$	$\bar{x} = b/2$ $\bar{y} = \frac{d^2}{b + 2d}$	$I_u = \frac{2d^3}{3} - 2d^2\bar{y} + (b + 2d)$
	$A = 1.414h(b + d)$	$\bar{x} = b/2$ $\bar{y} = d/2$	$I_u = \frac{d^2}{6}(3b + d)$
	$A = 1.414\pi hr$		$I_u = \pi r^3$

* I_u, unit second moment of area, is taken about a horizontal axis through G, the centroid of the weld group, h is weld size; the plane of the bending couple is normal to the plane of the paper and parallel to the y-axis; all welds are of the same size.

The strength of welded joints

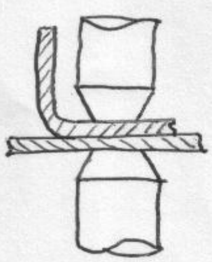
- All steels can be welded, but most proper ones are G10140 ~ G10230 (tensile strength ~ 420 --- 480 MPa)
- The designer can choose factors of safety

Stresses permitted by the AISC code for weld metal

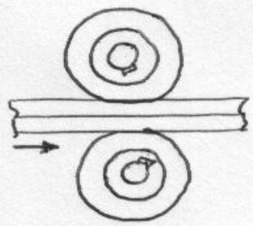
Type of loading	Type of weld	Permissible stress	n
Tension	Butt	$0.60\, S_y$	1.67
Bearing	Butt	$0.90\, S_y$	1.11
Bending	Butt	$0.60 \sim 0.66\, S_y$	$1.52 \sim 1.67$
Simple compression	Butt	$0.60\, S_y$	1.67
Shear	Butt or fillet	$0.30\, S_{ut}$	

Resistance welding

The heating and consequent welding that occur when an electric current is passed through several parts that are passed together is called resistance welding.



Spot welding



seam welding

Failure of a resistance weld occurs either by shearing of the weld or by tearing of the metal around the weld.

The spot or seam is usually loaded in pure shear:

$$\tau = \frac{V}{A}$$

Adhesive bonding and design considerations

- Reduced weight, sealing capabilities, reduced part count and assembly time, improved fatigue and corrosion resistance
- Adhesives are substances that are used to join two or more components together through attractive forces acting across the interfaces.
- Types of adhesive may be classified in a variety of ways depending on their chemistries (epoxies, polyurethanes, polyimides), their form (paste, liquid, film, pellets, tape), their type (hot melt, reactive hot melt, thermosetting, pressure sensitive, contact), or their load carrying capability (structural, semistructural, nonstructural)

Two basic stress distribution concepts

- Shear lag

Good design practice normally requires that adhesive joints be constructed in such a manner that the adhesive carries the load in shear rather than tension.

$$\tau(x) = \frac{P\omega}{4b\sinh(\omega L/2)}\cosh(\omega x) + \left[\frac{P\omega}{4b\cosh(\omega L/2)}\left(\frac{2E_o t_o - E_i t_i}{2E_o t_o + E_i t_i}\right) + \frac{(\alpha_i - \alpha_o)\Delta T\omega}{(1/E_o t_o + 2/E_i t_i)\cosh(\omega L/2)}\right]\sinh(\omega x)$$

$$\omega = \sqrt{\frac{G}{h}\left(\frac{1}{E_o t_o} + \frac{2}{E_i t_i}\right)}$$

E_o, E_i : the moduli of the outer and inner adherends

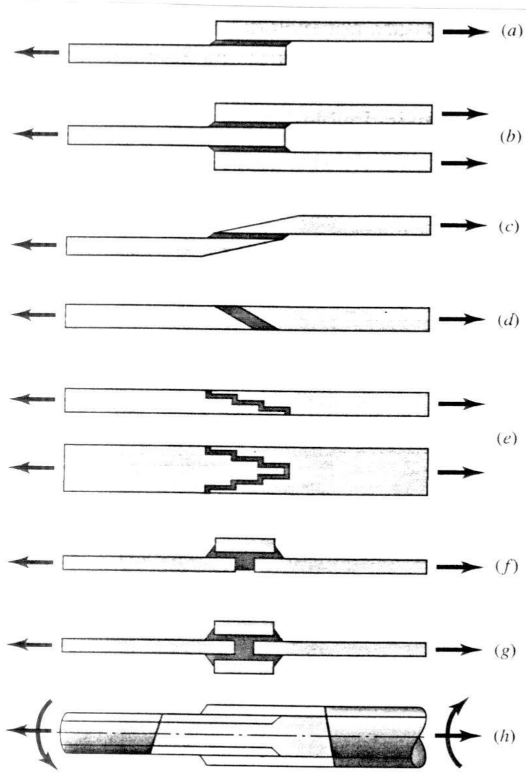
t_o, t_i : the thicknesses of the outer and inner adherends

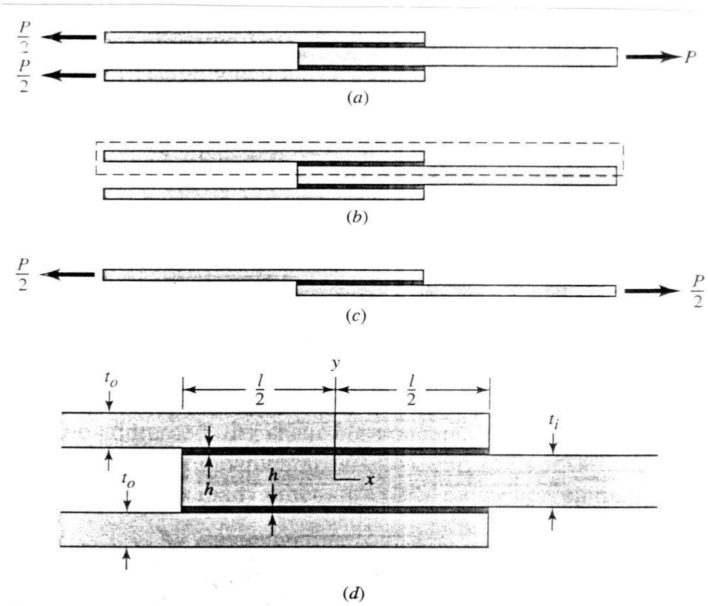
h : thickness of the adhesive layer

G : shear modulus of the adhesive

L : Length of the bond

b : the width of the bond

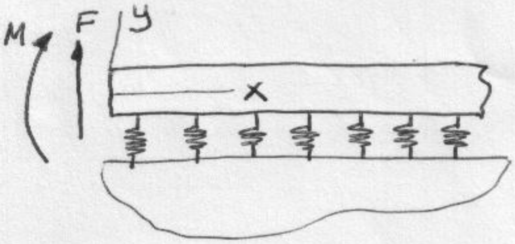




Double-lap joint analysis

- Beam on elastic foundation

We assume that the adherend acts as a simple beam resting on the adhesive, which acts as an elastic foundation, represented by a continuous series of axial springs as seen in the following figure.



$$\sigma(x) = \frac{E_a}{2hEI\beta^3} e^{-\beta x} \{F\cos(\beta x) + M\beta[\cos(\beta x) - \sin(\beta x)]\}$$

$$\beta = \sqrt[4]{\frac{E_a w}{4EIh}}$$

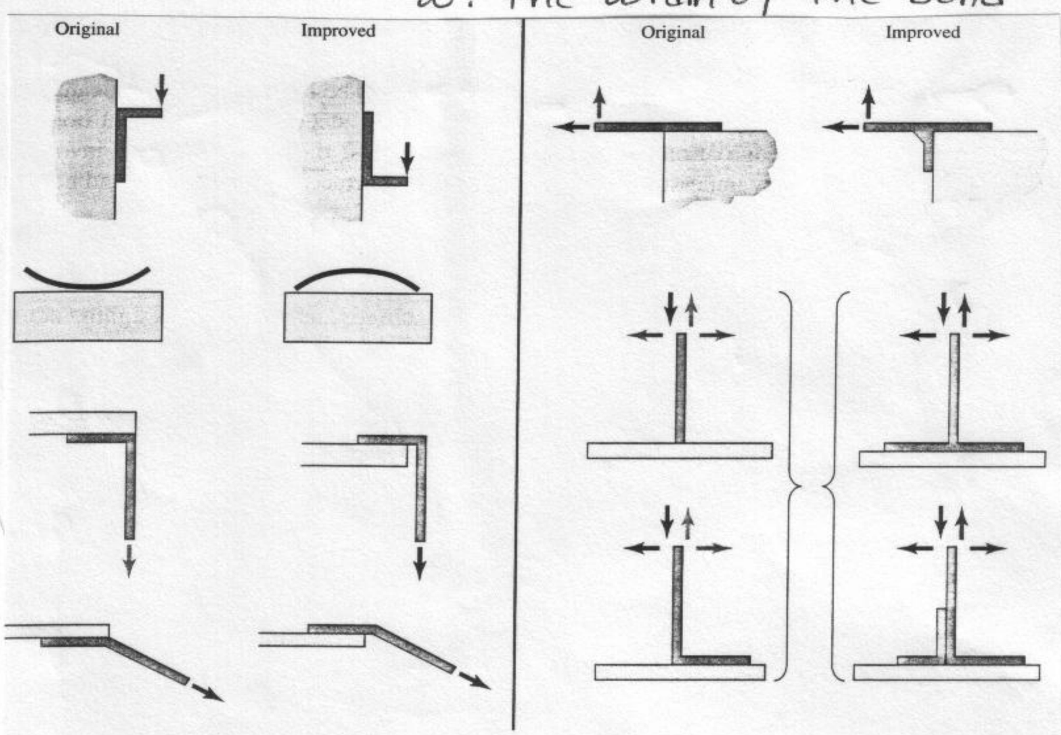
E_a: modulus of the adhesive

h: thickness of the adhesive

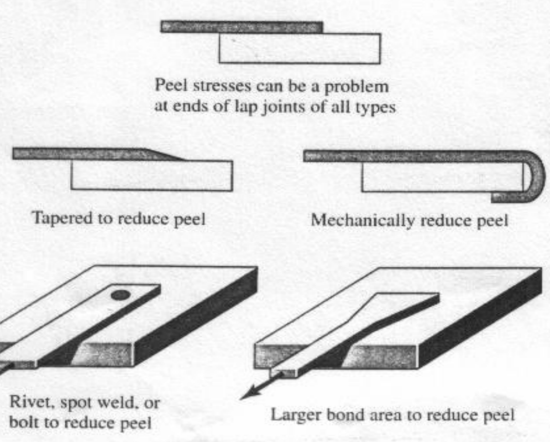
E: modulus of the adherend beam

I: the second moment of area of the adherend beam

w: the width of the bond



(a)



(b)

Design practices which improve adhesive bonding
(a) original resulting strength is poor
(b) to reduce peel stresses in lap-type joints