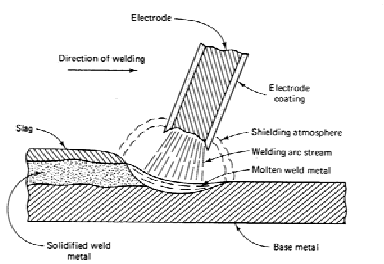
CE 388 – FUNDAMENTALS OF STEEL DESIGN

8

CHAPTER 7: WELDING

Introduction

- Welding is a process of connecting metallic pieces by heating their surfaces to a plastic or fluid state and allowing the parts to flow together and join



Welding

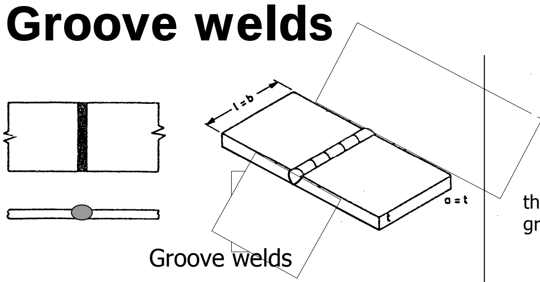
Advantages / Disadvantages

- Advantages:
  - Usually more economical than bolted connections
    - The need for a large percentage of gusset and splice plates (necessary for bolted structures) is eliminated
    - No reduction in the cross-section for tension members, resulting in smaller member sizes
    - Requires considerably less labor than does riveting
  - A wider range of application than bolting
  - Forming more rigid connections and structures
- Disadvantages:
  - Requires more costly inspection and control
  - It is more difficult to disassemble or alter a welded connection than a bolted connection

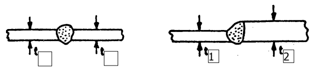
Types of welds

- Groove or Butt welds (Küt kaynak)
- Fillet welds (Köşe kaynağı)

Groove welds



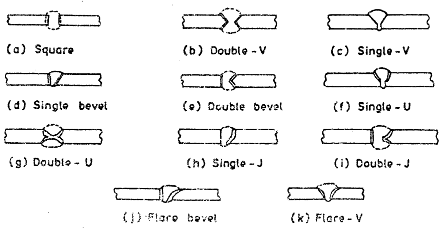
Groove welds



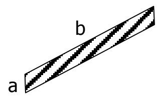
$a = t$ $\qquad$ $a = \min(t_1, t_2)$

thickness of groove weld $\qquad$ thickness of plate

Thickness



Various types

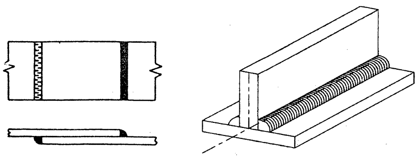


$A = b.a$

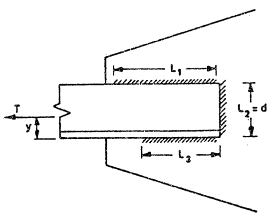
effective area of groove weld $\qquad$ width of plate $\qquad$ thickness of groove weld

Effective area

Fillet welds

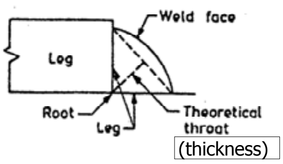


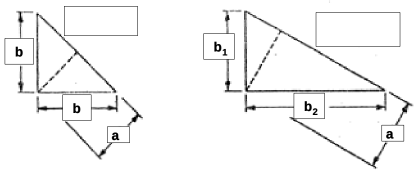
Fillet welds



$$A = \sum L.a = (L_1 + L_2 + L_3)a$$

Effective area





$$a = \frac{b}{\sqrt{2}} \qquad a = \frac{b_1 b_2}{\sqrt{b_1^2 + b_2^2}}$$

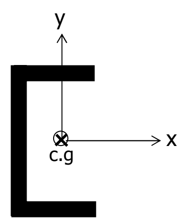
Thickness

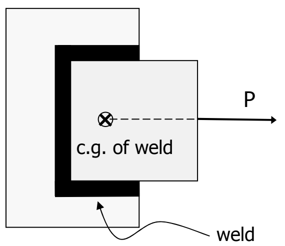
Stresses in welded connections

- Welded connections might be subjected to the following state of loading:
  - Shear only
  - Shear and torsion
  - Shear and bending
  - The most general case

Welded connections subjected to shear only

- The resulting load remains in the plane of the weld
- It passes through the c.g. of the weld area





At every point on the weld:

$$\tau_x = \tau'_x = \frac{P_x}{A} \qquad \tau_y = \tau'_y = \frac{P_y}{A}$$

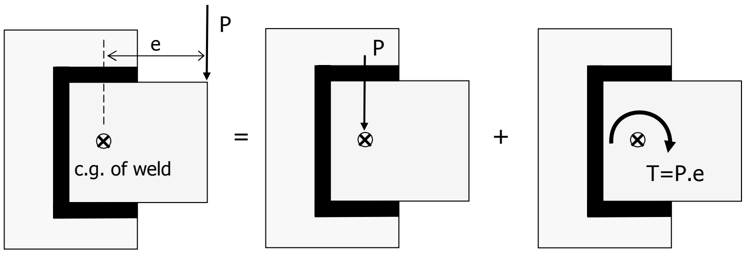
shear stress in x-direction

total weld area

shear stress in y-direction

Welded connections subjected to shear and torsion

- The resulting load remains in the plane of the weld
- It does not pass through the c.g. of the weld area



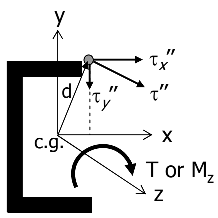
Concentric load

Torsional moment

- Shear stresses due to P: At every point on the weld,

$$\tau'_x = \frac{P_x}{A} \qquad \tau'_y = \frac{P_y}{A}$$

- Shear stresses due to T (M_z): At a point on the weld,



$$\tau'' = \frac{M_z d}{J} = \frac{M_z d}{I_x + I_y}$$

shear stress due to torsion

Polar moment of inertia of the weld ($J = I_x + I_y$)

In terms of x and y components of τ'',

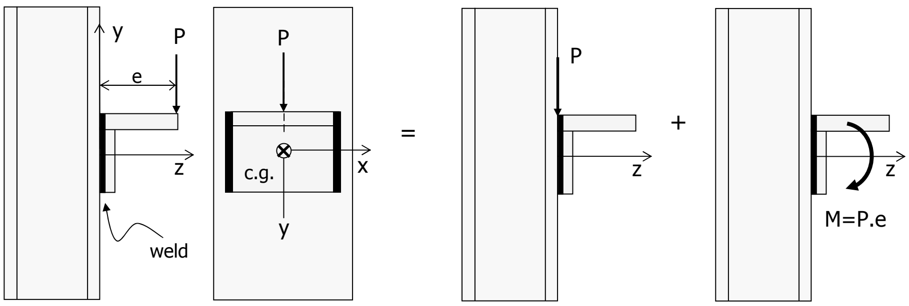
$$\tau''_x = \frac{M_z y}{J} \qquad \tau''_y = \frac{M_z x}{J}$$

- Total shear stresses due to P and T:

$$\tau_x = \tau'_x + \tau''_x = \frac{P_x}{A} + \frac{M_z y}{J} \qquad \tau_y = \tau'_y + \tau''_y = \frac{P_y}{A} + \frac{M_z x}{J}$$

Welded connections subjected to shear and bending

- The resulting load remains out of the plane of the weld
- It passes through the z-axis located at c.g. of the weld (no torsion)



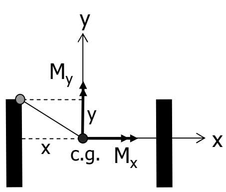
Concentric load   Bending moment

- Shear stresses due to P:

At every point on the weld,

$$\tau_x = \tau'_x = \frac{P_x}{A} \qquad \tau_y = \tau'_y = \frac{P_y}{A}$$

- Normal stresses due to bending moments M_x and M_y



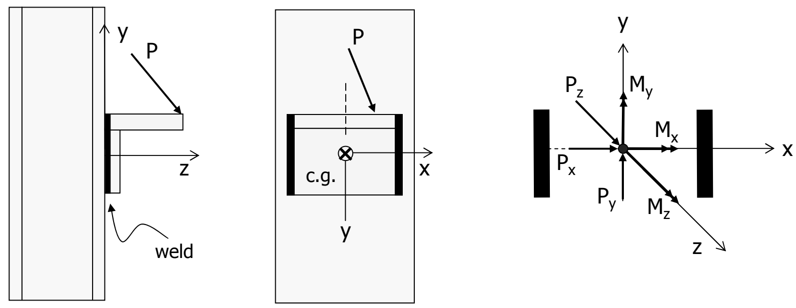
Bending moment about x-axis

Bending moment about y-axis

$$\sigma_z = \sigma''_z = \frac{M_x y}{I_{xx}} + \frac{M_y x}{I_{yy}}$$

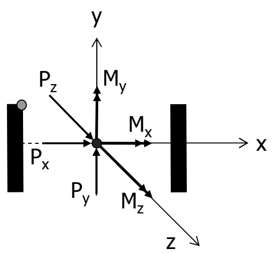
normal stress due to bending moment

Welded connections subjected to a general load case



A general load case:

(shear+axial force+bending + torsion)



- Stresses due to P_x, P_y and P_z:

$$\tau'_x = \frac{P_x}{A} \qquad \tau'_y = \frac{P_y}{A} \qquad \sigma'_z = \frac{P_z}{A}$$

- Stresses due to M_x, M_y and M_z:

$$\tau''_x = \frac{M_z y}{J} \qquad \tau''_y = \frac{M_z x}{J} \qquad \sigma'_z = \frac{M_x y}{I_{xx}} + \frac{M_y x}{I_{yy}}$$

- Resulting stresses:

$$\tau_x = \tau'_x + \tau''_x = \frac{P_x}{A} + \frac{M_z y}{J} \qquad \tau_y = \tau'_y + \tau''_y = \frac{P_y}{A} + \frac{M_z x}{J}$$

$$\sigma_z = \sigma'_z + \sigma''_z = \frac{P_z}{A} + \frac{M_x y}{I_{xx}} + \frac{M_y x}{I_{yy}}$$

Design of Welded Connections

- Groove welds:
  - Normal and shear stresses are considered in a conventional manner

Computed normal stress in groove welds → $\sigma = \dfrac{P}{b.a} \le \sigma_{all}$ ← Allowable normal stress in groove welds

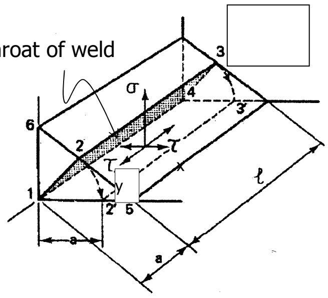
Computed shear stress in groove welds → $\tau = \dfrac{P}{b.a} \le \tau_{all}$ ← Allowable shear stress in groove welds

Type of stress	Type of steel			
	St37		St52	
	EY	EIY	EY	EIY
Normal (σ_{all})	1400	1600	2400	2700
Shear (τ_{all})	1100	1250	1700	1900

Allowable stresses in groove welds (kgf/cm^2)

Design of Welded Connections

- Fillet welds:
  - The throat of the weld is considered to be the critical section
  - A resultant stress on the throat is computed approximately as



$$\sigma_v = \sqrt{\sigma_z^2 + \tau_x^2 + \tau_y^2} \le \sigma_{v,all}$$

Resultant stress on throat of weld

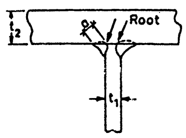
Allowable value for resultant stress in fillet welds

Type of stress	Type of steel			
	St37		St52	
	EY	EIY	EY	EIY
Normal, Shear and Resultant	1100	1250	1700	1900

Allowable stresses in fillet welds (kgf/cm^2)

TS3357 Requirements

- Requirement 1 (minimum and maximum weld thickness for fillet welds):



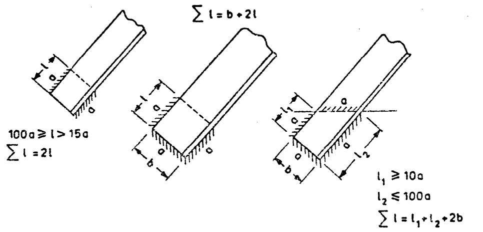
$t_1 < t_2$

$3\text{mm} \leq a \leq 0.7\,t_1$

Recommendation :

$a = \sqrt{t_2 - 0.5} \geq 3\text{mm}$

- Requirement 2: minimum and maximum lengths for fillet welds:



Design and analysis of welded connections

Example Problems