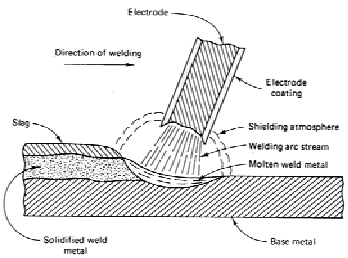
# CE 388 – FUNDAMENTALS OF STEEL DESIGN

## 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

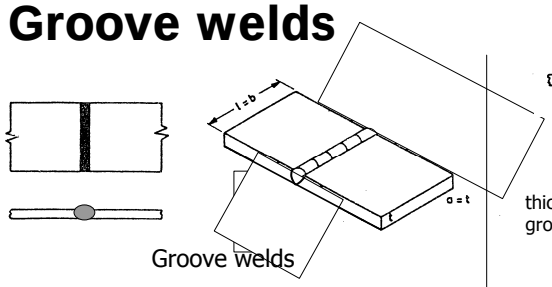
## Advantages / Disadvantages

- 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

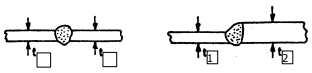
## Types of welds

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

# Groove welds



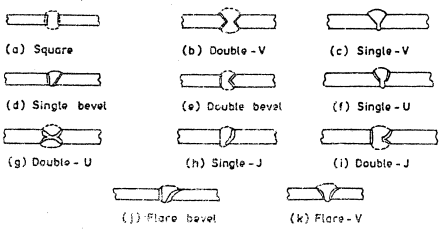

Groove welds



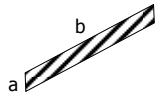
$a = t$ $\qquad$ $a = \min(t_1, t_2)$

thickness of groove weld $\qquad$ thickness of plate

Thickness




Various types

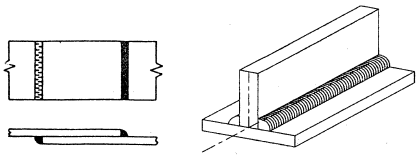



$A = b.a$

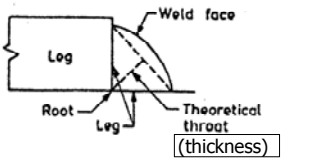
effective area of groove weld $\qquad$ width of plate $\qquad$ thickness of groove weld

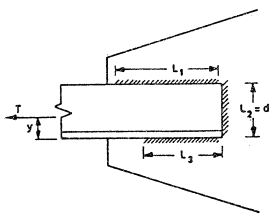
Effective area

# Fillet welds



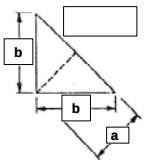
Fillet welds



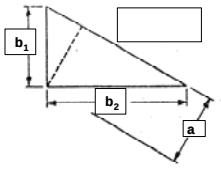




$A = \sum L.a = (L_1 + L_2 + L_3)a$

Effective area




$a = \dfrac{b}{\sqrt{2}}$




$a = \dfrac{b_1 b_2}{\sqrt{b_1^2 + b_2^2}}$

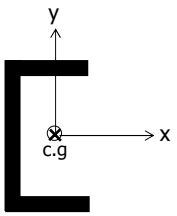
Thickness

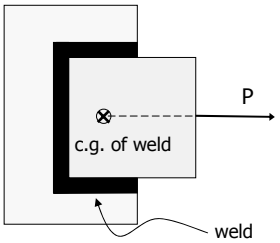
# Stresses in welded connections

- 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



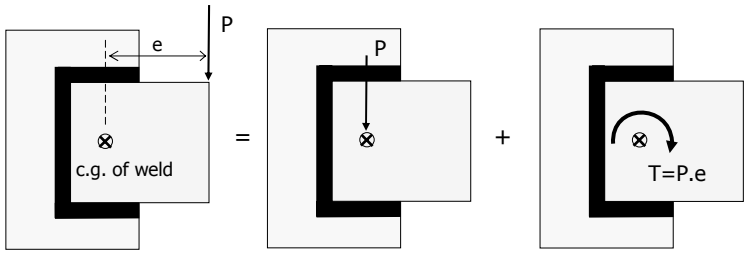

At every point on the weld:

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

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

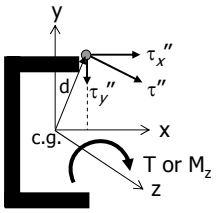



Concentric load  Torsional moment

- 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 $\tau''$,

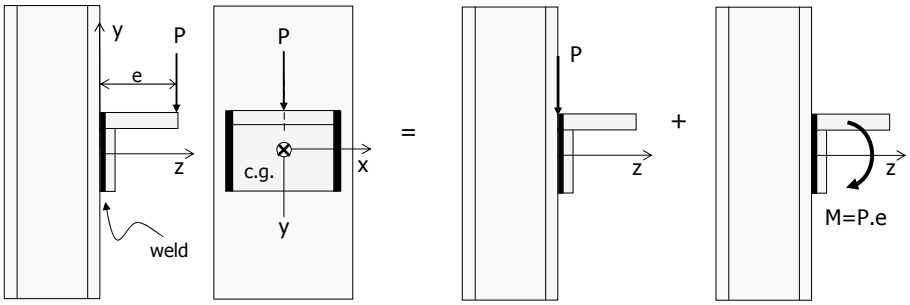
$$\tau''_x = \frac{M_z y}{J} \qquad \tau''_y = \frac{M_z x}{J}$$

- 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)

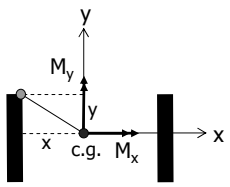



- Shear stresses due to P:

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 $M_y$



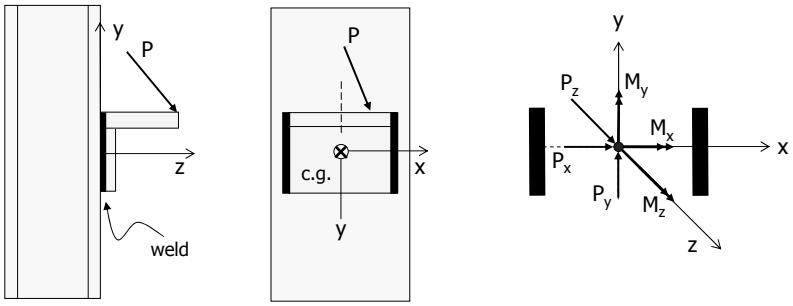

Bending moment about x-axis

Bending moment about y-axis

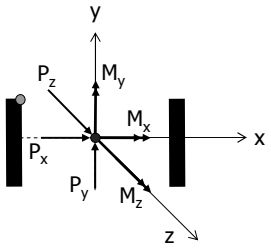
$$\sigma_z = \sigma''_z = \frac{M_x y}{I_{xx}} + \frac{M_y x}{I_{yy}}$$

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

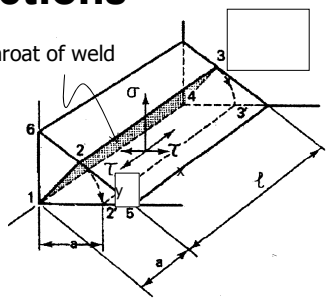
Computed shear stress in groove welds → $\tau = \frac{P}{b.a} \le \tau_{all}$ ← Allowable shear stress in groove welds

| Type of stress | Type of steel | | | |
|---|---|---|---|---|
| | St37 | | St52 | |
| | EY | EIY | EY | EIY |
| Normal ($\sigma_{all}$) | 1400 | 1600 | 2400 | 2700 |
| Shear ($\tau_{all}$) | 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

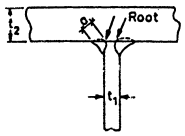
Allowable value for resultant stress in fillet welds

| 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):



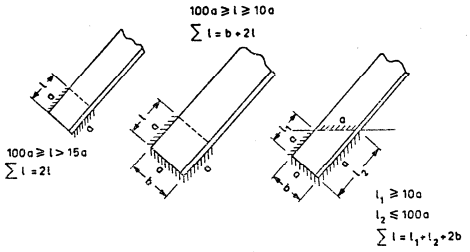

$t_1 < t_2$ □

$3\,mm \leq a \leq 0.7\,t_1$

Recommendation : □

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

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




## Design and analysis of welded connections

Example Problems