Welds,
Arc Welding Processes
Types of Welds
Welding Symbols

MORGAN STATE UNIVERSITY

SCHOOL OF ARCHITECTURE AND PLANNING

LECTURE XII

Dr. Jason E. Charalambides

AVANT-GARDE ENGINEERING LLC

CONSULTING ARCHITECTS/ENGINEERS

Reading

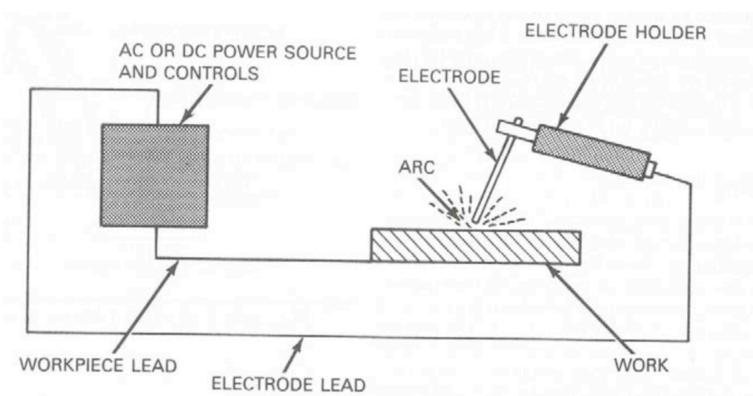
- Main
  - AISC Specification and Commentary: Section J2
- Additional References
  - *AISC Design Guide No. 21 – Welded Connections – A Primer for Engineers*
    - American Institute of Steel Construction
  - *Structural Welding Code – Steel*
    - American Welding Society Standard D1.1
  - *Welding Handbook*
    - American Welding Society
  - *The Procedure Handbook of Arc Welding*
    - Lincoln Electric Company
  - Other publications by:
    - American Welding Society (www.aws.org)
    - Lincoln Electric Company (www.lincolnelectric.com)

Overview

- Definition of Welding
  - Joining of materials by heating until molten and allowing to flow together and resolidify. Welding may or may not include the addition of a molten filler metal to the joint.
- Welding Processes
  - Electric Arc Welding (most common for structural steel)
  - Electric Resistance Welding
  - Oxyacetylene Welding
  - Thermit Welding
  - Laser Beam Welding
  - Electron Beam Welding

Electric Arc Welding

- Heat needed to melt metal is generated by an electrical arc.
- Basic electric arc welding circuit:



Electric Arc Welding

- Basic Features Common to all Electric Arc Welding Processes
  - 3) Shielding
    - Protects molten metal from reacting with air (prevents brittle welds).
    - Stabilizes and controls the arc.

Electric Arc Welding

- Basic Features Common to all Electric Arc Welding Processes cont.
  - 3) Shielding
    - Protects molten metal from reacting with air (prevents brittle welds).
    - Stabilizes and controls the arc.

Methods of Shielding

- Flux Shielding.
  - Flux is a granular material that is placed as a coating on the outside of the electrode, placed inside a hollow electrode, or applied separately to the joint prior to welding. When subject to the heat of the electric arc, portions of the flux vaporize, forming a gas that surrounds the arc and molted metal, protecting it from contact with the atmosphere. Flux also typically contains various alloying and purifying elements that mix with the molten metal. The purifying elements will rise to the top of the molten metal and form a slag coating.

Methods of Shielding

- Gas Shielding.
  - The arc and molten metal are surrounded by an externally supplied gas. Typical shielding gases: argon, helium, carbon dioxide
- Flux and Gas Shielding
  - The above two methods are used in combination.

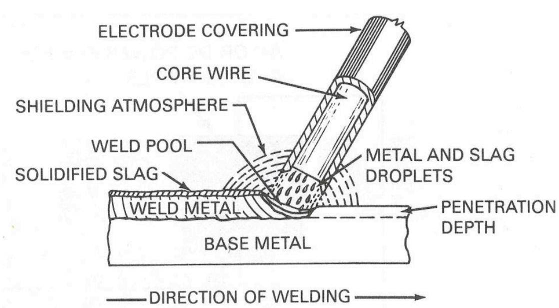
Common Electric Arc Welding Processes

- Shielded Metal Arc Welding (SMAW)
- Submerged Arc Welding (SAW)
- Flux Cored Arc Welding (FCAW)
- Gas Metal Arc Welding (GMAW)

  - Note: The choice of welding process is usually left to the fabricator and erector..

Shielded Metal Arc Welding (SMAW)

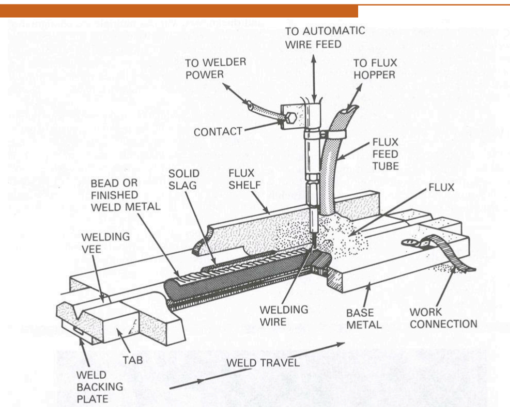
- Also called “stick” or “manual” welding.
- Electrode:
  - rods, typically 9" to 18" in length
  - core wire: typically 1/16" to 5/16" diameter
  - provided with a flux coating on the outside
- Very widely used, versatile welding process. Least expensive equipment and least amount of operator training required



Shielded Metal Arc Welding (SMAW)

- Welding rod must be replaced as it is used up. Therefore, welding must be periodically stopped for electrode replacement.
- SMAW is generally not the best choice for high speed and high production welding. Electrical current must travel entire length of electrode, resulting in relatively high resistance heating of the electrode. Electric current must be limited in order to avoid excessive resistance heating that would damage the flux coating. Limiting the current limits welding deposition rates. Welding is further slowed by need to periodically replace electrode.

Submerged Arc Welding (SAW)

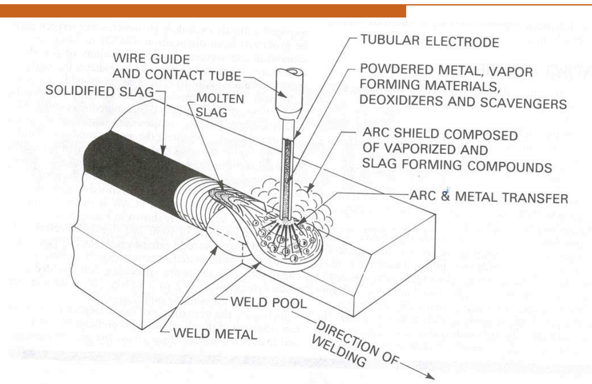


- Uses a bare wire continuous electrode, fed from a reel.
- Granular flux is deposited separately, ahead of the arc.

Submerged Arc Welding (SAW)

- Arc is completely submerged within the flux; there is no visible arc.
- SAW can be semi-automatic or fully automatic operation; fully automatic is most common.
- Can achieve very high welding rates with very deep penetration of weld metal into base metal. Welding deposition rates can be up to 10 times greater than possible with SMAW.
- For structural steel welding, SAW is most commonly used in the shop (rather than in the field). SAW is well suited to long continuous welds; for example, welds used for built-up shapes.
- SAW is generally restricted to flat position welding

Flux Cored Arc Welding (FCAW)

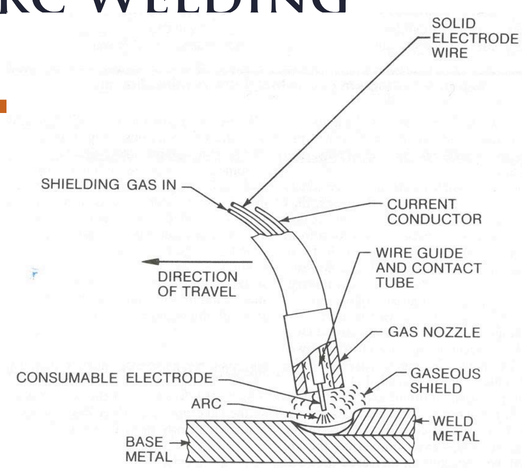


- Flux is contained with hollow core of electrode; electrode is continuous and fed from a reel.

Flux Cored Arc Welding (FCAW)

- As compared to SMAW, there is no time loss in changing electrodes and no material loss in electrode stubs. Can use higher currents and therefore achieve higher deposition rates than SMAW
- FCAW can be a semi-automatic or fully-automatic operation; semiautomatic is most common.
- FCAW can be used with or without additional gas shielding.
  - No additional gas shielding: "self shielded FCAW"
  - With additional gas shielding: "gas shield FCAW."
- Self shielded FCAW is very commonly used for high production field welding of structural steel.

Gas Metal Arc Welding (GMAW)

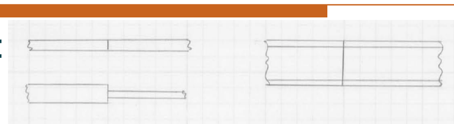
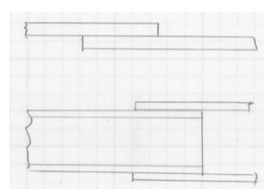
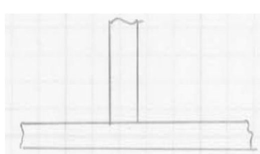
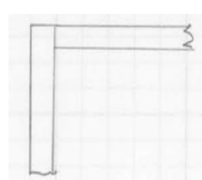


- Also called MIG welding (Metal Inert Gas)

Gas Metal Arc Welding (GMAW)

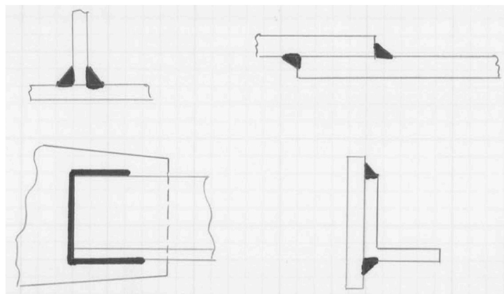
- Uses a bare wire continuous electrode, fed from a reel.
- Shielding is provided by an externally supplied shielding gas, fed through the electrode holder.
- GMAW can be a semi–automatic or fully automatic operation; semiautomatic is most common.
- Not commonly used for field welding. Wind can disturb shielding gas.

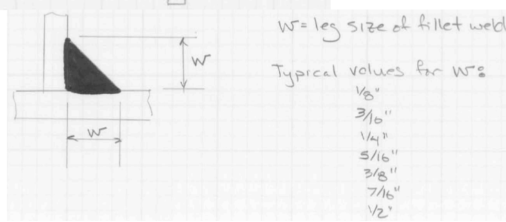
Types of Joints

- Butt Joint: 
- Lap Joint: 
- Tee Joint: 
- Corner Joint: 

Types of Welds

- Fillet Welds:

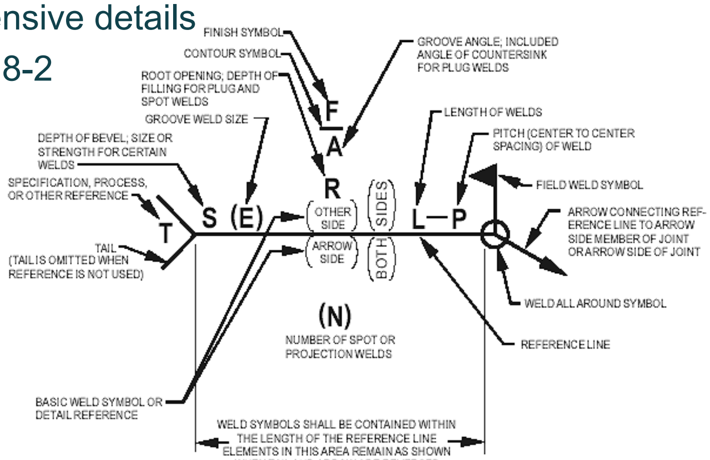




  - The most common
  - No special preparation required
  - Usually have equal legs

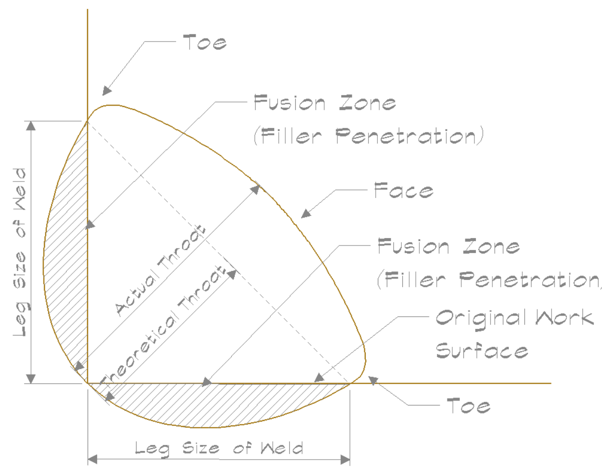
Welds Symbology

- For more extensive details refer to Table 8-2 pp 8-34,35



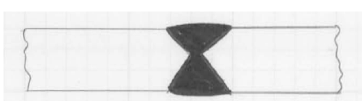
Types of Welds

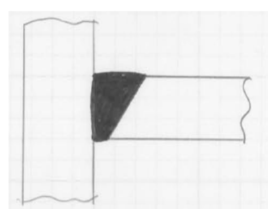
- Fillet Welds:



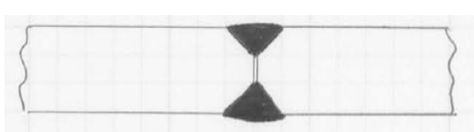
Types of Welds

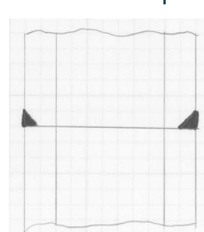
- Groove Welds:
  - Complete joint penetration





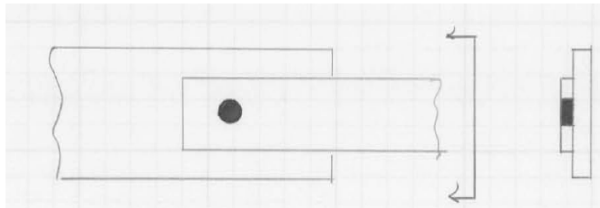
    - CJP groove welds develop the full strength of the connected plate
  - Partial joint penetration



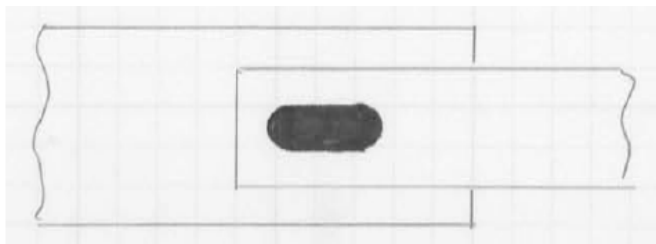


Types of Welds

- Plug and Slot Welds:
  - Plug:



  - Slot:



Fillet Welds

- Anatomy of a fillet weld:
  - By employing trigonometry for Theoretical OR Effective Throat

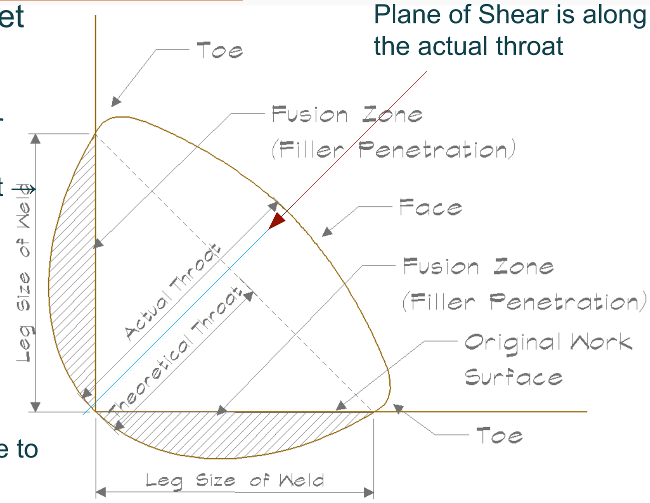
$$Throat = \frac{\sqrt{2}}{2} * Leg$$

i.e.

$$Throat = 0.7071 * Leg$$

  - This is the value to use by default.

Plane of Shear is along the actual throat



Fundamentals on Welds

- How do welds behave?
- Fundamental principles:
  - Length of weld and limits

    The length of a weld does not indefinitely add strength at the same rate. e.g. a weld that is x times longer than another does not necessarily give x times the amount of strength. A factor (β) applies to determine the effect of on its strength, with a condition that if the length is larger than 300 times the leg size, β=0.6.

$$\beta = 1.2 - 0.002\frac{L}{w} \leq 1 \qquad \text{(J1-1)}$$

Welding Metals

- Different types of weld filler metal:
  - Just as there are several types of steel to use (and we will put more weight on a couple or so) there are different types of welding fillers.
  - For the most part we will be using the E70XX which is a filler that carries a shear capacity of fw=70 ksi.

User Note: The following User Note Table summarizes the AWS D1.1/D1.1M provisions for matching filler metals. Other restrictions exist. For a complete list of base metals and prequalified matching filler metals see AWS D1.1/D1.1M, Table 3.1.

Base Metal		Matching Filler Metal
A36 ≤ ¾ in. thick		60 & 70 ksi filler metal
A36 > ¾ in. A588* A1011	A572 (Gr. 50 & 55) A913 (Gr. 50) A992 A1018	SMAW: E7015, E7016, E7018, E7028 Other processes: 70 ksi filler metal
A913	(Gr. 60 & 65)	80 ksi filler metal

*For corrosion resistance and color similar to the base metal, see AWS D1.1/D1.1M, subclause 3.7.3.

Notes:
Filler metals shall meet the requirements of AWS A5.1, A5.5, A5.17, A5.18, A5.20, A5.23, A5.28 or A5.29.
In joints with base metals of different strengths, use either a filler metal that matches the higher strength base metal or a filler metal that matches the lower strength and produces a low hydrogen deposit.

Design Strength of Fillet Welds

- How do welds behave?
- Continuing with basics:
  - Failing on Shear plane

    Essentially, the weld will shear, whether it is perpendicular or parallel to the direction of the stress. (pg. 16.1-115)

$$\varphi R_n = \varphi * F_{nw} * A_{we} = 0.75\left[0.60 * F_{EXX} * \left(1 + 0.5 * \sin^{1.5}\theta\right)\right] * \left[\frac{\sqrt{2}}{2}\beta * Leg * thickness\right] \quad \text{(J2-3)}$$

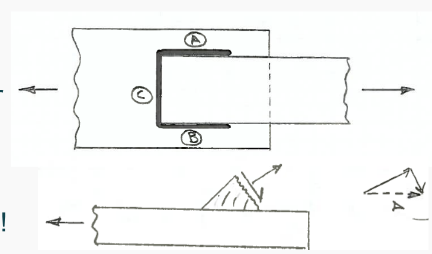
OR (simplified if applicable!) $\varphi R_n = 0.3182 * Length * Leg * F_{EXX} * \beta$

Where:

- F_{nw} is the nominal stress of the weld metal
- A_{we} is effective area of the weld
- F_{EXX} is the Filler Metal Classification Strength (e.g. 70 ksi)
- θ is the angle on which the load is applied (assume perpendicular or parallel most of the time, i.e. 90º or 0º)

Design Strength of Fillet Welds

- At a fundamental level, the strength of the weld is considered along the lines of "how long it is"
- The truth is that the direction actually does play a significant role.
  - Take the following example:



- Welds A & B produce the known shear
- Weld C on the other hand may differ!
- We have both shear and tensile stress!

$$0.6F_{EXX} * \beta < Stress\,@\,fracture\ of\ Weld\ C < F_{EXX}$$

- Consequently, weld C will be stronger than welds A & B.
- In general, transversely loaded fillet welds, depending on the angle between applied load and weld axis, are 1.4 to 1.6 times stronger

For further investigation, refer to AISC manual pg. 16.1-116
For this course this option will not be applied

In Class Example

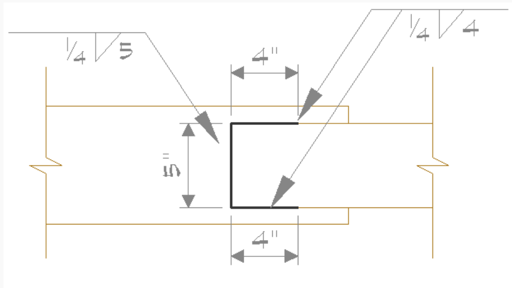
- Determine the capacity ΦPn of the following weld design.
- Use of E70 electrodes
  - a) determine factor "β"

$$\beta = 1.2 - 0.002\frac{L}{w} \leq 1$$

$$1.2 - 0.002\frac{13^{inch}}{0.25^{inch}} = 1.09 > 1.0$$

$$\rightarrow \beta = 1.0$$

  - b) apply formula:



$$\varphi R_n = 0.3182 * Length * Leg * F_{EXX} * \beta$$

$$\rightarrow \varphi R_n = 0.3182 * 13^{inch} * 0.25^{inch} * 70^{ksi} * 1 = 72.4^{kips}$$

Note: The dark thick lines are not usually shown on design drawings.

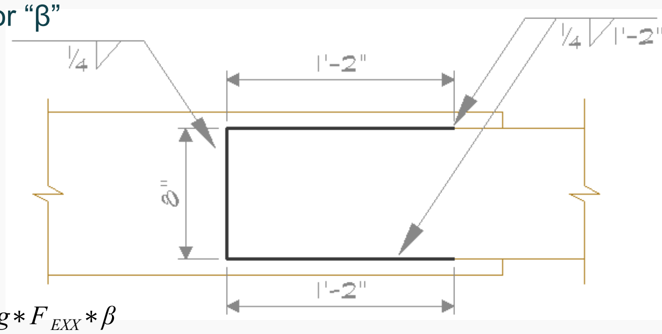
In Class Example

- Determine the capacity ΦPn of the following weld design.
- Use of E70 electrodes
  - a) determine factor "β"

$$\beta = 1.2 - 0.002\frac{L}{w} \leq 1$$

$$1.2 - 0.002\frac{36^{inch}}{0.25^{inch}} = 0.912$$

  - b) apply formula:



$$\varphi R_n = 0.3182 * Length * Leg * F_{EXX} * \beta$$

$$\varphi R_n = 0.3182 * 36^{inch} * 0.25^{inch} * 70^{ksi} * 0.912 = 183^{kips}$$

Note: The dark thick lines are not usually shown on design drawings.