CE470 Lecture 15: Welds

- Introduction
- Types of Welds
- Weld Processes
- Weld Symbols
- Groove Welds
  - Strength
  - Example
Structural Welding

- Common method for connecting structural steel
- Many fabrication shops prefer to weld rather than bolt
- Welding in the field is avoided if possible due to welding condition requirements
- There are several welding processes, types, and positions to be considered in building construction
Welding is the process of fusing multiple pieces of metal together by heating the filler metal to a liquid state.

A properly welded joint is stronger than the base metal.
Strength of Structural Welds

### Available Strength of Welded Joints

<table>
<thead>
<tr>
<th>Load Type and Direction Relative to Weld Axis</th>
<th>Pertinent Metal</th>
<th>Nominal Strength ($F_{bm}$ or $F_w$)</th>
<th>Effective Area ($A_{bm}$ or $A_w$)</th>
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(Part of AISC Table J2.5)

- Welds may be loaded in shear, tension, compression, or a combination of these.
- Capacities for welds given in AISC Section J2 (2010).
- The strength of a weld is dependent on factors including: base metal, filler metal, type of weld, throat and weld size.
• Shown above are types of structural joints which are established by positions of the connected material relative to one another.

• Lap, tee, and butt joints are most common.
Common Types of Welds

- Fillet Welds
- Groove Welds
- Plug and Slot Welds
Common Types of Welds

- **Fillet Welds**

  - The most commonly used weld is the fillet weld
  - Fillet welds are theoretically triangular in cross-section
  - Fillet welds join two surfaces at approximately right angles to each other in lap, tee, and corner joints
Common Types of Welds

Groove Welds

- Full penetration single bevel
- Partial penetration single bevel

Partial joint penetration welds are used when it is not necessary for the strength of the joint to develop the full cross section of the members being joined.
Groove Welds

- Groove welds are specified when a fillet weld is not appropriate for the job
  - Configuration of the pieces may not permit fillet welding
  - Strength greater than that provided by a fillet weld is required
Common Types of Welds

Plug and Slot Welds
- Least common
- Might be used when weld in interior of plate necessary (e.g. doubler plates)
There are four recognized welding positions:

- **Flat** – The face of the weld is approximately horizontal and welding is performed from above the joint
- **Horizontal** – The axis of the weld is horizontal
- **Vertical** – The axis is approximately vertical or in the upright position
- **Overhead** – Welding is performed from below the joint

The flat position is preferred because it is easier and more efficient to weld in this position.
Weld Size

- Some welds may meet the required size after a single pass of the welder
- Larger weld sizes may require multiple passes to meet the size requirement
- Common single pass welds include fillet welds up to and including 5/16 inch
- The weld in the above picture is a multiple pass fillet weld
Weld Accessibility

Access holes are required for some welds, such as the welded flange connection shown to the right:

- The top access hole allows for a continuous backing bar to be placed under the top flange.
- The bottom access hole allows for complete access to weld the entire width of the bottom flange.

A detail of a weld access hole for a welded flange connection is shown below.
Welding Processes

- Shielded Metal Arc Welding (SMAW)
- Gas Metal Arc Welding (GMAW)
- Flux Cored Arc Welding (FCAW)
- Submerged Arc Welding (SAW)
Shielded Metal Arc Welding (SMAW) is also known as manual, stick, or hand welding.

An electric arc is produced between the end of a coated metal electrode and the steel components to be welded.

The electrode is a filler metal covered with a coating.
The electrode’s coating has two purposes:

- It forms a gas shield to prevent impurities in the atmosphere from getting into the weld
- It contains a flux that purifies the molten metal
SMAW electrodes

http://readerfeedback.labs.wikimedia.org/wiki/Shielded_metal_arc_welding
Gas Metal Arc Welding (GMAW) is also known as MIG welding.

It is fast and economical.

A continuous wire is fed into the welding gun.
GMAW

- The wire melts and combines with the base metal to form the weld
- The molten metal is protected from the atmosphere by a gas shield which is fed through a conduit to the tip of the welding gun
- This process may be automated
GMAW

www.nr.edu/welding/processes.htm
**FCAW Welding**

- Flux Cored Arc Welding (FCAW) is similar to GMAW, but the filler wire has a center core which contains flux.

- With this process it is possible to weld with or without a shielding gas (This makes it useful for exposed conditions where a shielding gas may be affected by the wind).
• Submerged Arc Welding (SAW) is only performed by automatic or semiautomatic methods

• Uses a continuously fed filler metal electrode

• Weld pool is protected from the surrounding atmosphere by a blanket of granular flux fed at the welding gun
SAW

- Results in a deeper weld penetration than the other process
- Only flat or horizontal positions may be used

Figure 10-60. Process diagram—submerged arc welding.

http://www.weldprocedures.com/fig10-60.jpg
Equipment used for welding will vary depending on the welding process and whether the welding is being done in the shop or in the field.

- (Left) FCAW machine for shop welding
- (Right) SMAW machine for field welding
Weather Impacts on Welding

- Welding in the field is avoided if possible due to welding condition requirements
- Field welding is not to be performed while it is raining, snowing, or below 0° F
- In certain ambient temperatures preheating of the material to be welded is required
- AWS Code D1.1 specifies minimum preheat and interpass temperatures, which are designed to prevent cracking
Fillet weld is less expensive than groove weld
- No special preparation
- No backing required
- Less volume of weld

Partial penetration groove weld is less expensive than full penetration groove weld

Labor represents the majority of the cost associated with welding
• Bolting is generally a faster operation than welding
• Bolting does not have the temperature and weather condition requirements that are associated with welding
• Unexpected weather changes may delay welding operations
Weld symbols are used to communicate the specific details and requirements of each weld to the welder.

Weld symbols are included on fabrication and erection drawings.
Weld Symbols

- Horizontal Weld Line
- Leader Line
- Field Weld Symbol
- Tail

Note (Indicating this is a typical weld)

Length and Spacing of weld (in inches)

Basic Weld Symbol (Fillet weld symbol shown)

Size of weld (in inches)
Welding Symbols

AISC Table 8-2

Weld Symbol
Below line indicates weld on "arrow side"
Above line indicates weld on opposite side
Groove Welds – Geometry

**Complete-joint-penetration (CJP)**

effective throat, \( t_e = 'a' \) dimension shown

**Partial-joint-penetration (PJP)**

See Table J2.1 – depends on process, bevel angle, etc.
Groove Welds – Strength

**Base Metal**

\[
\phi R_n = \phi F_{nBM} A_{BM}
\]

- Depends on limit state
- Nominal strength (ksi)
- Cross-sectional area \((\text{in}^2)\) of welded part

**Weld**

\[
\phi R_n = \phi F_{nw} A_{we}
\]

- Nominal strength (ksi)
- Effective area \((\text{in}^2)\) of weld

AISC J2.4
Matching Weld Metal

Match Base Metal (BM) and Weld Metal (W)

For example:

A36 (3/4” thick or less) 60 ksi & 70 ksi electrodes
A572 Gr. 50 70 ksi
A992 70 ksi
A913 Gr. 65 80 ksi
CJP Groove Welds – Strength

AISC Table J2.5 – strength is controlled by base metal (with matching filler metal)...

\[ \phi R_n = \phi F_{nBM} A_{BM} \]

\[ \phi R_n = \phi F_{yl} t_e l_w \]

\[ \phi R_n = 0.9(36 \text{ksi})(1')(6'') = 194 \text{kips} \]
# AISC Table J2.5

## Available Strength of Welded Joints

| Load Type and Direction | Pertinent Metal | $\Phi$ and $\Omega$ | Nominal Strength ($F_{\text{bm}}$ or $F_{\text{w}}$) | Effective Area ($A_{\text{bm}}$ or $A_{\text{w}}$) | Required Filler Metal Strength Level
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*(a) (b) (c)*
AISC Table 8-2 Prequalified Welded Joints

CJP Groove Welds – Example

Note: choice of configuration may depend on access, forces, residual stress, distortion, etc. (AISC p. 8-27)