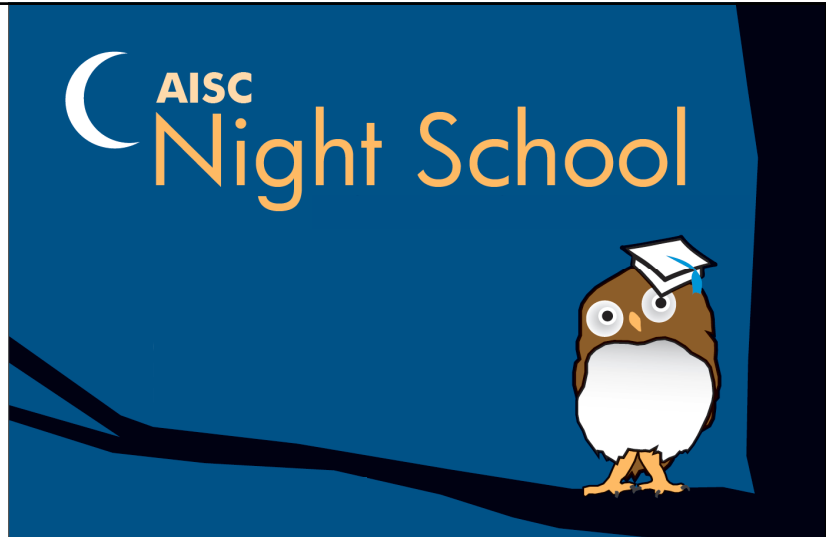


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Welded Connections

A Primer for Engineers



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Course Description

21.3 Welded Connection Details
October 29, 2019

This session will address welded connection details. The session begins with a review of types of joints. Topics such as weld backing, weld tabs and weld access holes will be explained. Various weld types including CJP and PJP groove welds, fillet welds and plug welds will be addressed. The session concludes with a discussion on weld metal strength.





Learning Objectives

- Identify various welded joints.
- Identify when weld back must be removed and when it can be left in-place.
- List characteristics of prequalified CJP groove weld details.
- List characteristics of prequalified PJP groove weld details.



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Night School 21 Course Schedule

- 10/8/2019 1. Introduction and Weld Processes
10/15/2019 2. Principles of Welded Connections
10/29/2019 3. Welded Connection Details
11/5/2019 4. Metallurgy and Cracking
11/19/2019 5. Fatigue of Welded Connections
11/26/2019 6. Seismic Welding Issues
12/3/2019 7. Special Welding Applications
12/10/2019 8. Problems and Fixes



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Night School 21 Welded Connections -- A Primer for Engineers

Session 3: Welded Connection Details
October 29, 2019



Duane K. Miller, PE, ScD
Manager of Engineering Services and Welding
Design Consultant



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WELDED CONNECTION BASICS

Chapter 3: Welded Connection Basics

- 3.1 Joints
- 3.2 Weld Types—General
- 3.3 Complete-Joint-Penetration Groove Welds
- 3.4 Partial-Joint-Penetration Groove Welds
- 3.5 Fillet Welds
- 3.6 Plug/Slot Welds
- 3.7 Puddle Welds



WELDED CONNECTION BASICS



Chapter 3: Welded Connection Basics

- 3.8 Interaction of Joint Types and Weld Types
- 3.9 Selection of Weld Types
- 3.10 Required Filler Metal Strength
- 3.11 Determining Weld Strength
- 3.12 Specific Requirements for Various Joints
- 3.13 Weld Symbols



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DETAILS OF WELDED CONNECTIONS



Chapter 4: Details of Welded Connections

- 4.1 Principles of Connection Design
- 4.2 Welded Connection Details
- 4.3 Specific Welded Connections
- 4.4 Special Welds



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WELDED CONNECTION DETAILS

Outline

- Joints
- CJP Groove Welds
- PJP Groove Welds
- Fillet Welds
- Plug and Slot Welds
- Tack Welds
- Weld Metal Strength



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WELDED CONNECTION DETAILS

Outline

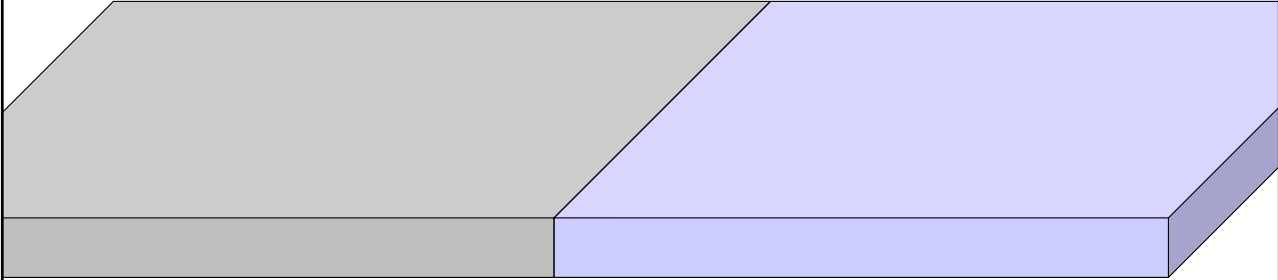
- ➔ • Joints
- CJP Groove Welds
- PJP Groove Welds
- Fillet Welds
- Plug and Slot Welds
- Tack Welds
- Weld Metal Strength





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BUTT JOINTS

Butt Joint – same width, same thickness



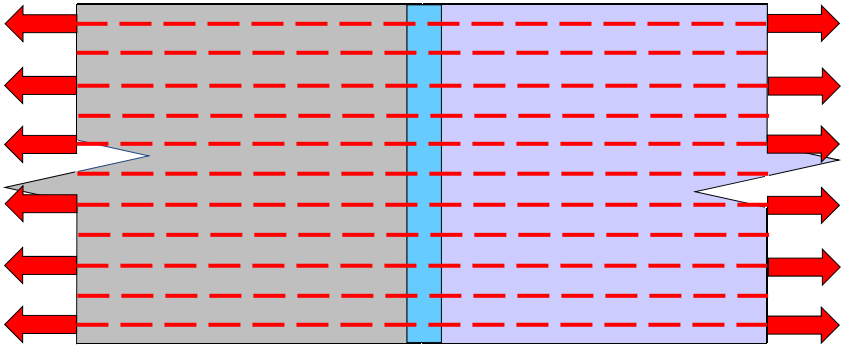
A 3D perspective diagram showing two rectangular plates, one gray and one light blue, joined at their ends. The ends of both plates are beveled at a 45-degree angle. The plates are shown in a perspective view, with the top and bottom surfaces visible. The joint is a simple butt joint with no weld visible.





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BUTT JOINTS

Butt Joint – same width, same thickness



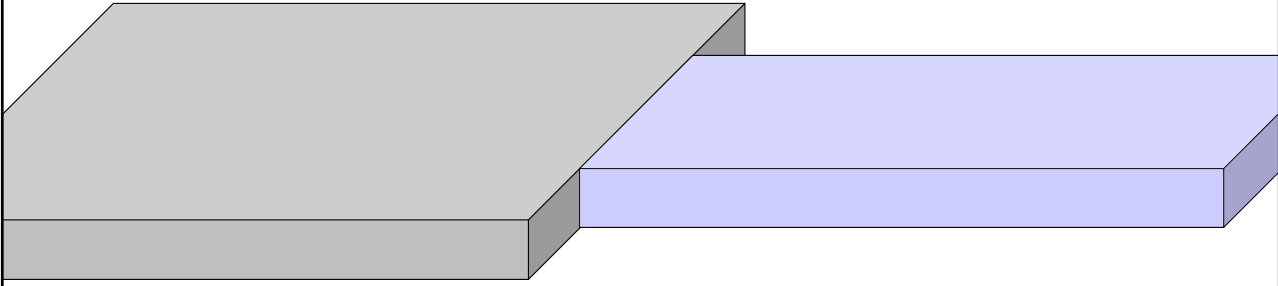
A 2D cross-section diagram of a butt joint. Two plates, one gray and one light blue, are joined at their ends. The ends are beveled. A vertical blue line represents the weld. Red dashed lines and red arrows indicate tension forces applied to the plates. The arrows point outwards from the plates, and the dashed lines represent the internal stress distribution. The joint is shown under tension, with the weld line clearly visible.





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BUTT JOINTS

Butt Joint – different widths, same thickness



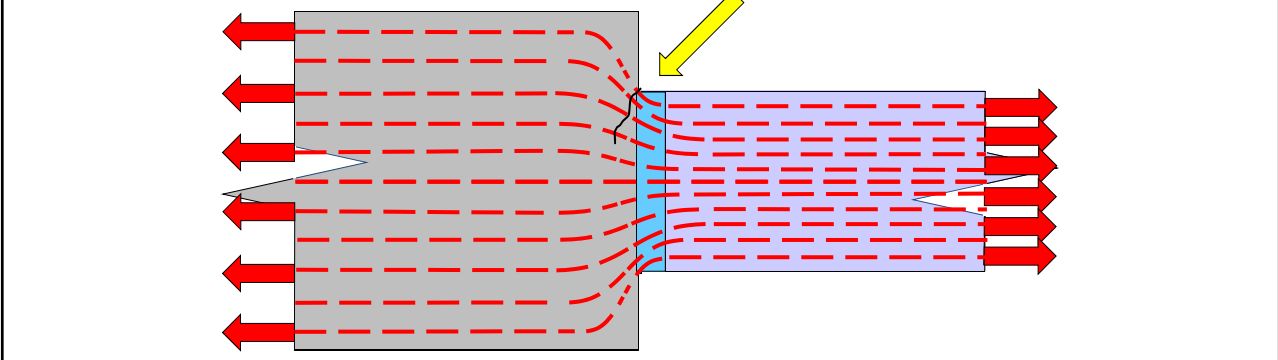
A 3D perspective diagram showing two rectangular plates of different widths but the same thickness. The plate on the left is wider and colored grey, while the plate on the right is narrower and colored light blue. They are positioned to be joined at their ends.





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BUTT JOINTS

Butt Joint – different widths, same thickness



A 2D cross-sectional diagram of the butt joint. The grey plate on the left is wider than the light blue plate on the right. Red dashed lines represent the stress distribution across the joint. On the left side of the grey plate, red arrows point left, and on the right side of the blue plate, red arrows point right. The stress lines are straight in the uniform sections but curve and concentrate at the joint interface. A yellow arrow points to the joint area. A white arrow on the left points to the edge of the grey plate, and another white arrow on the right points to the edge of the blue plate.




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BUTT JOINTS

One piece of steel

The diagram illustrates a butt joint where two steel plates are joined. Red dashed lines represent the path of stress flow, which is continuous across the joint. Red arrows on the left and right indicate the direction of applied forces. A yellow arrow points to the joint area. A small inset in the top right corner shows a book cover titled 'Welded Connections - A Primer for Engineers'.




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AWS D1.1: 2015 Structural Welding Code – Steel

Butt Joint – different widths

The diagram shows a butt joint between a wider steel member (grey) and a narrower steel member (blue). The transition is achieved through a chamfered edge. Dimensions are provided: a chamfer length of 2.5, a chamfer thickness of 1.0, and a chamfer angle of 22°. Red double-headed arrows indicate the width of each member. A small inset in the top right corner shows a book cover titled 'AWS D1.1: 2015 Structural Welding Code - Steel'.

2.17.1.2 Provide transition for cyclically loaded members with width changes.




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BUTT JOINTS

Butt Joint – different widths, same thickness

The diagram shows a 3D perspective of a butt joint. On the left, a wider, grey-colored steel plate tapers towards the right. On the right, a narrower, light blue-colored steel plate is shown. The two plates meet at a central vertical weld line. Red dashed lines represent the path of force, starting from the left, passing through the taper, and continuing through the narrower section to the right. Red arrows on the left point left, and red arrows on the right point right, indicating the direction of force flow. A small inset in the top right corner shows a thumbnail of the presentation slide.




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BUTT JOINTS

Butt Joint – different thicknesses

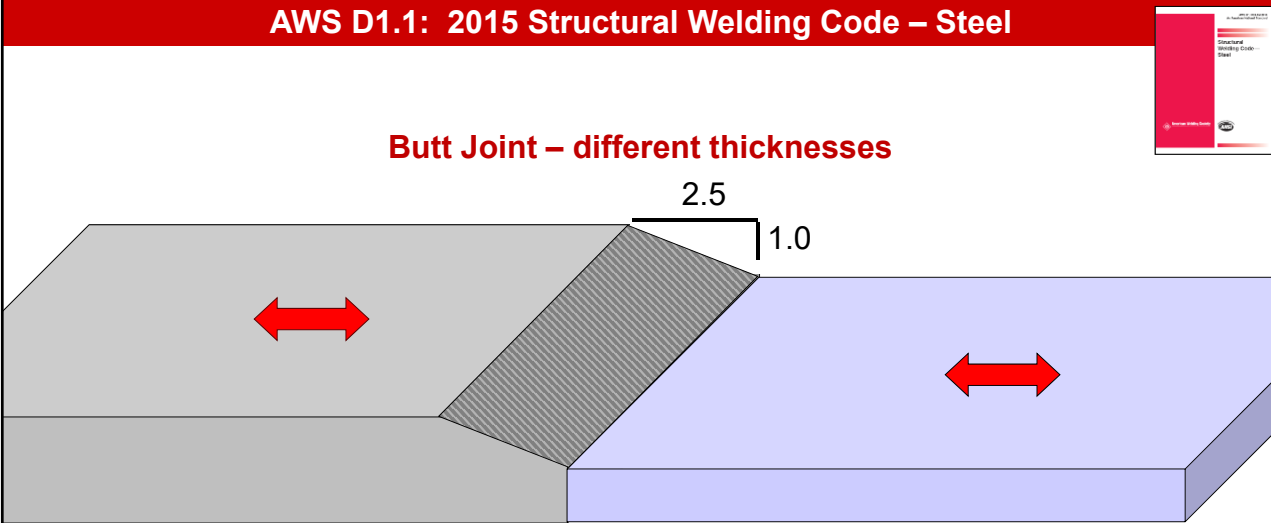
The diagram shows a 3D perspective of a butt joint between two plates of different thicknesses. The left plate is grey and thicker, while the right plate is light blue and thinner. The two plates are joined at a central vertical weld line. Red double-headed arrows are placed on the top surface of each plate to indicate their respective thicknesses. A small inset in the top right corner shows a thumbnail of the presentation slide.





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AWS D1.1: 2015 Structural Welding Code – Steel

Butt Joint – different thicknesses

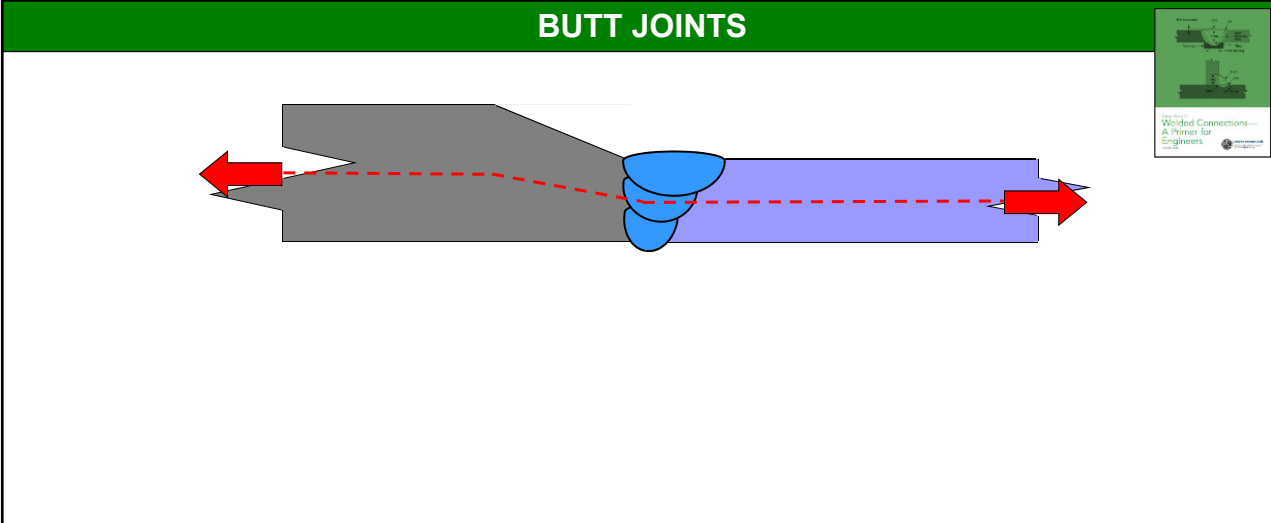


2.17.1.1 Provide transition for cyclically loaded members with thickness changes.





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BUTT JOINTS

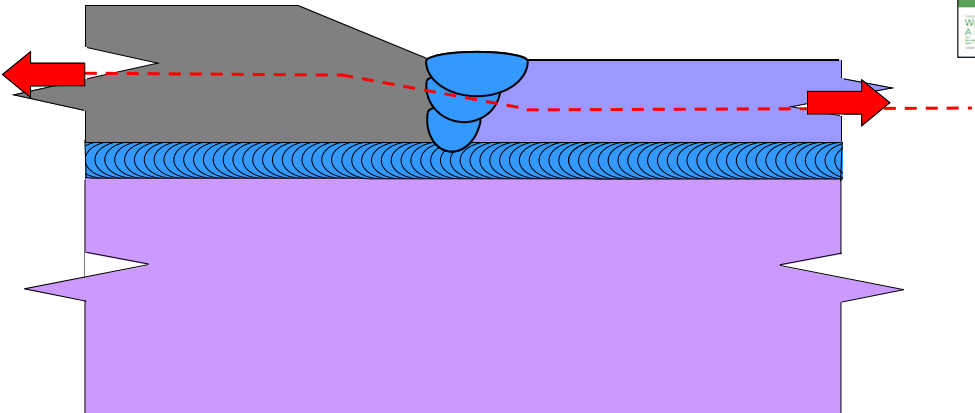


Secondary stresses due to eccentricity.





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BUTT JOINTS

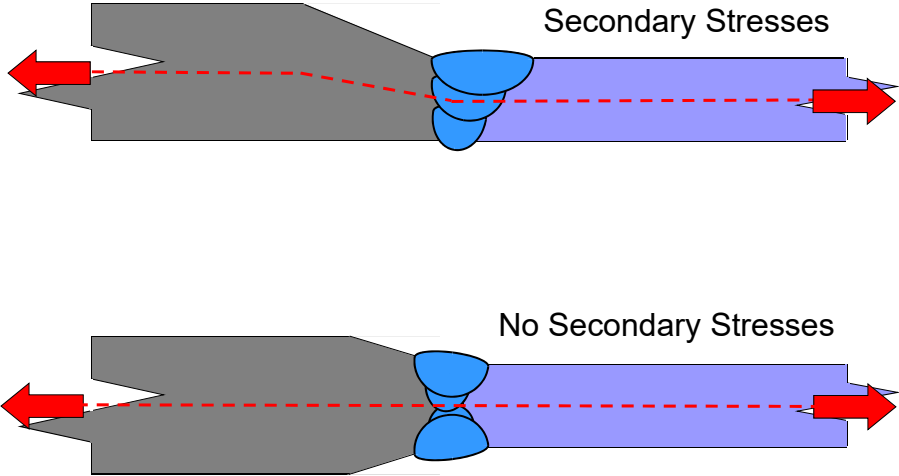


Web restricts rotation due to secondary stresses.





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BUTT JOINTS




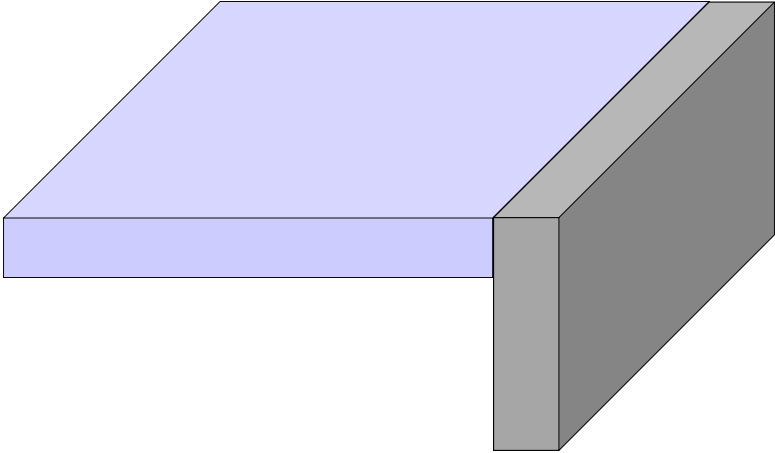
Secondary Stresses

No Secondary Stresses



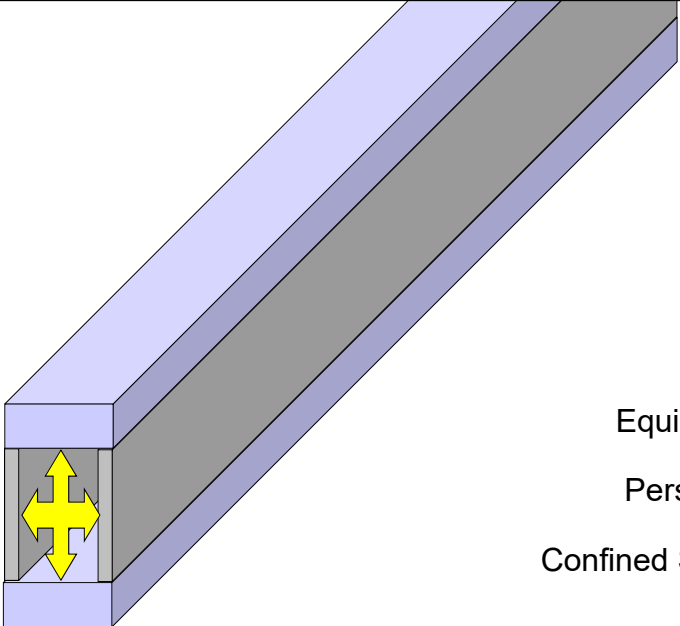
26

CORNER JOINTS




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CORNER JOINTS

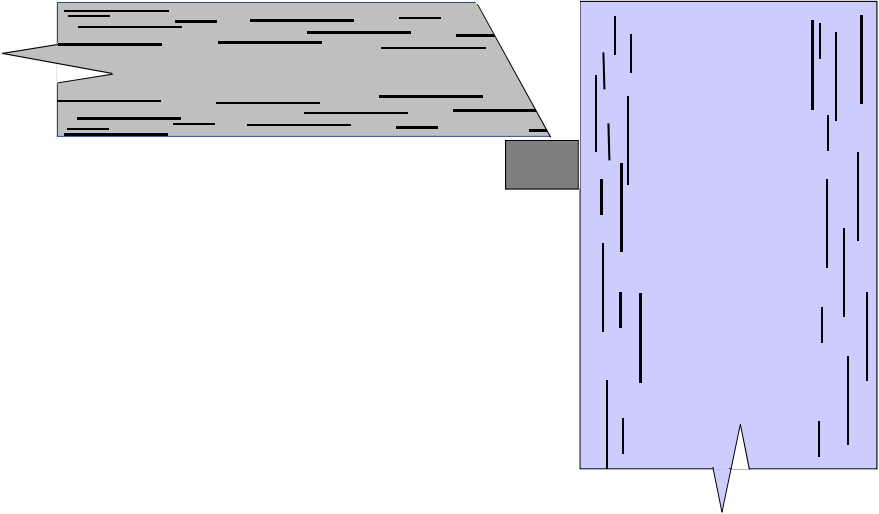


Equipment?
Personnel?
Confined Space?




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CORNER JOINTS

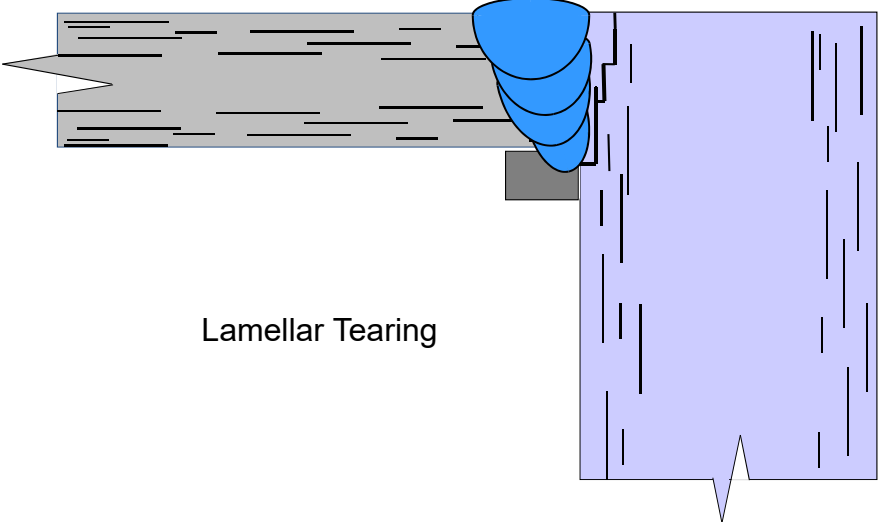


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CORNER JOINTS



Lamellar Tearing

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AWS D1.1: 2015 Structural Welding Code – Steel



2.7.3 Base Metal Through-Thickness Loading

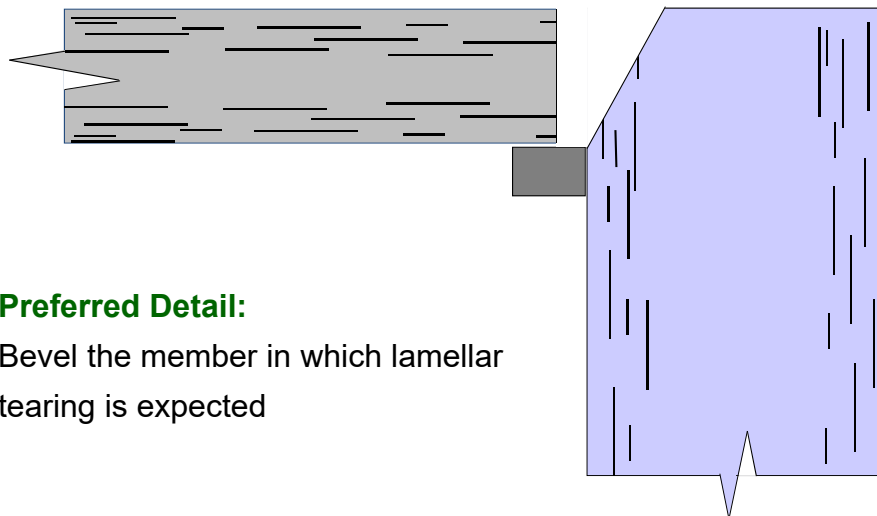
T- and corner joints whose function is to transmit stress normal to the surface of a connected part, especially when the base metal thickness of the branch member or the required weld size is $3/4"$ [20 mm] or greater, shall be given special attention during design, base metal selection and detailing. Joint details which minimize stress intensity on the base metal subject to stress in the through-thickness direction shall be used where practical. Specifying weld sizes larger than necessary to transmit

- calculated stress shall be avoided.



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CORNER JOINTS



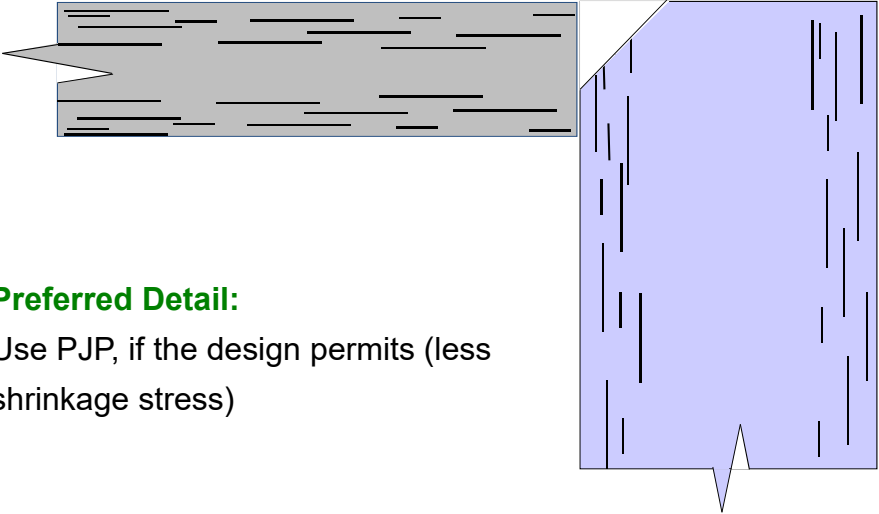
Preferred Detail:

Bevel the member in which lamellar tearing is expected





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CORNER JOINTS





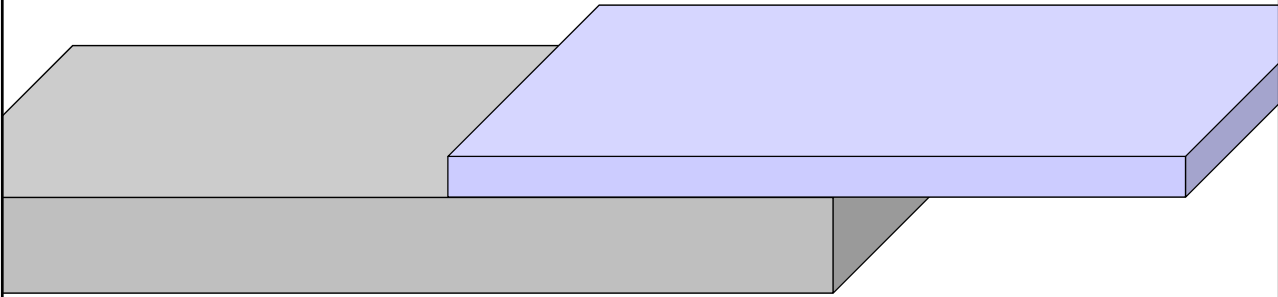
Preferred Detail:
Use PJP, if the design permits (less shrinkage stress)



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LAP JOINTS

Lap



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AISC 360-16 Specification J2.2b

J2.2b(f)

(f) In **lap joints**, the minimum amount of lap shall be five times the thickness of the thinner part joined, but not less than 1 in. (25 mm).

$5t \text{ min.}$
not < 1 in. [25 mm]

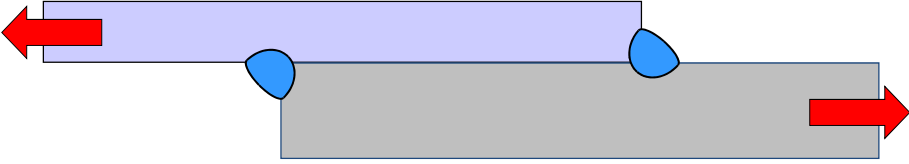
Also addressed in AWS D1.1:2015 clause 2.9.1.2

LAP JOINTS

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AISC 360-16 Specification J2.2b

Lap Joints

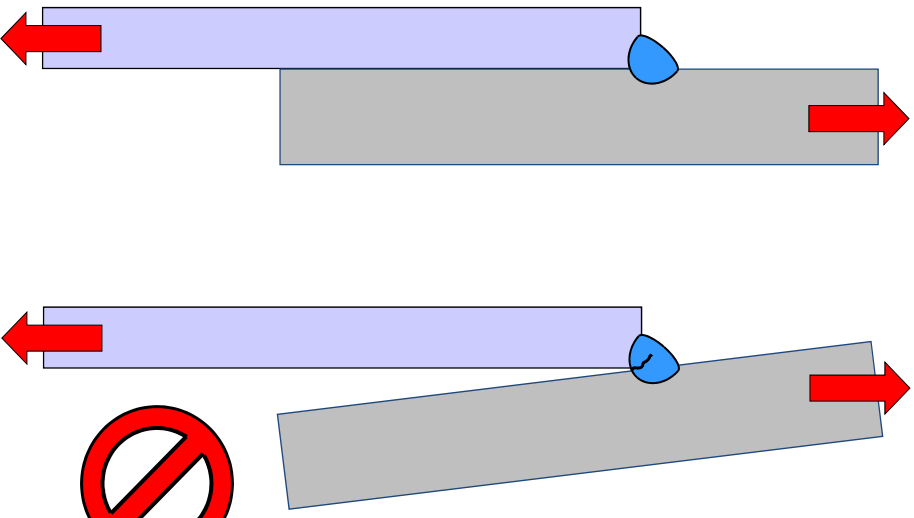


Lap joints joining plates or bars subjected to axial stress that utilize transverse fillet welds only shall be fillet welded along the end of both lapped parts, except where the deflection of the lapped parts is sufficiently restrained to prevent opening of the joint under maximum loading.


Also addressed in AWS D1.1:2015 clause 2.9.1.2

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LAP JOINTS



Welded Connections—A Primer for Engineers
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LAP JOINTS

Plug or slot weld Acceptable

Acceptable

Mechanical Support




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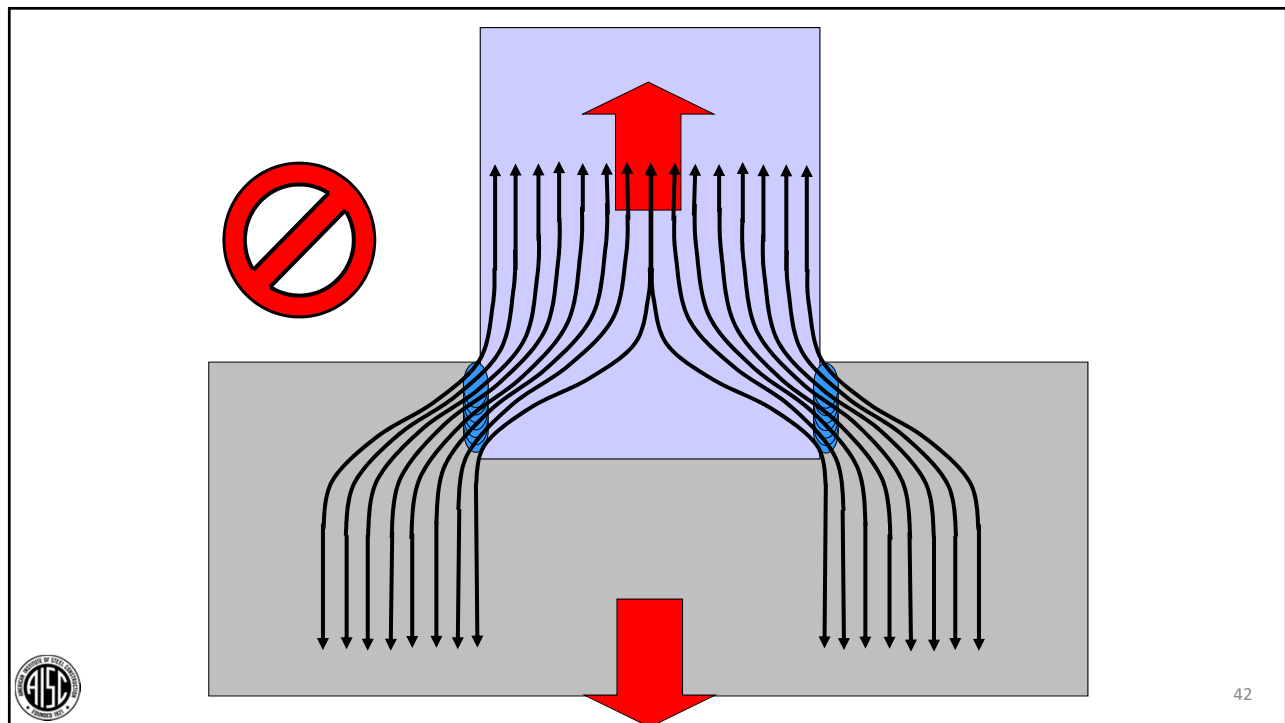
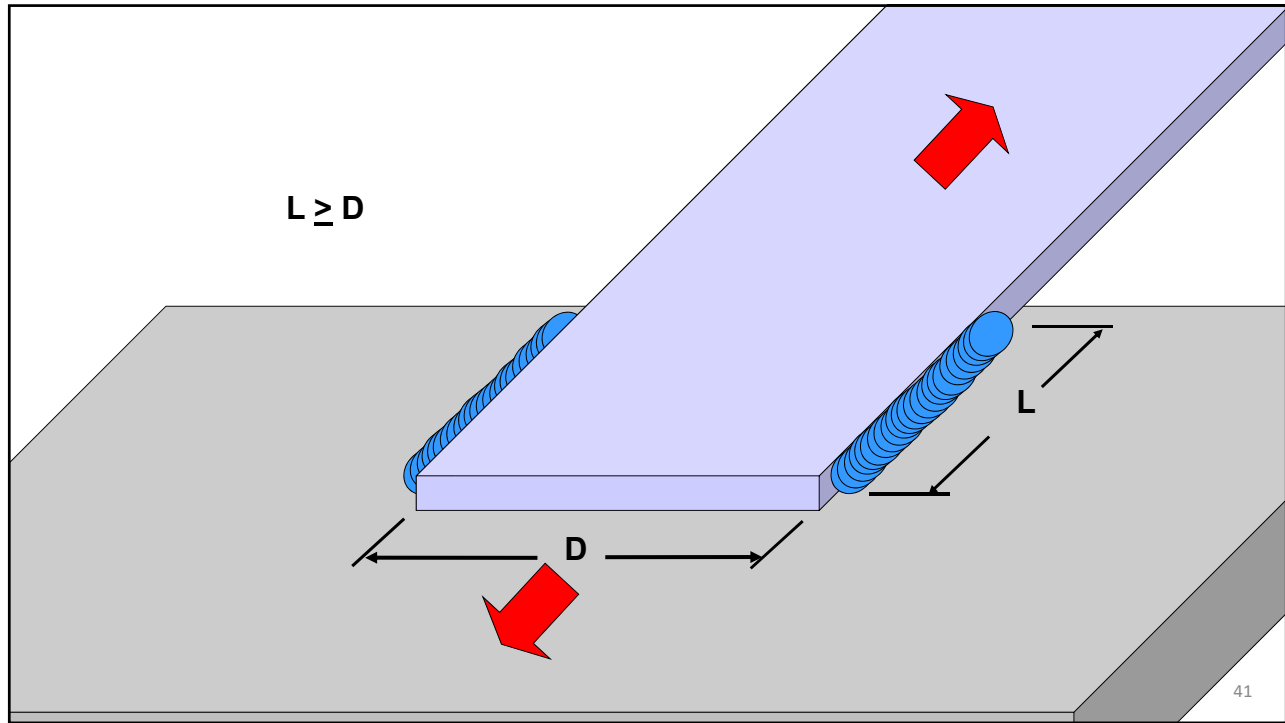
AWS D1.1:2015 clause 2.9.2

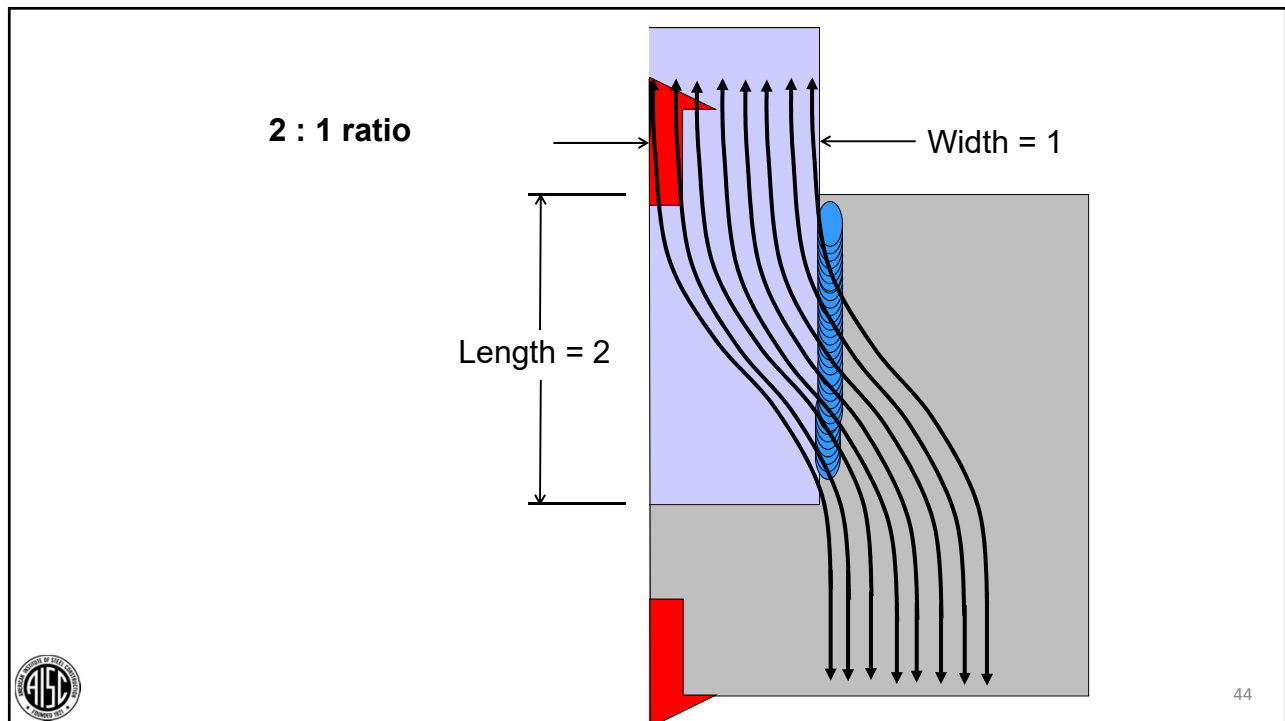
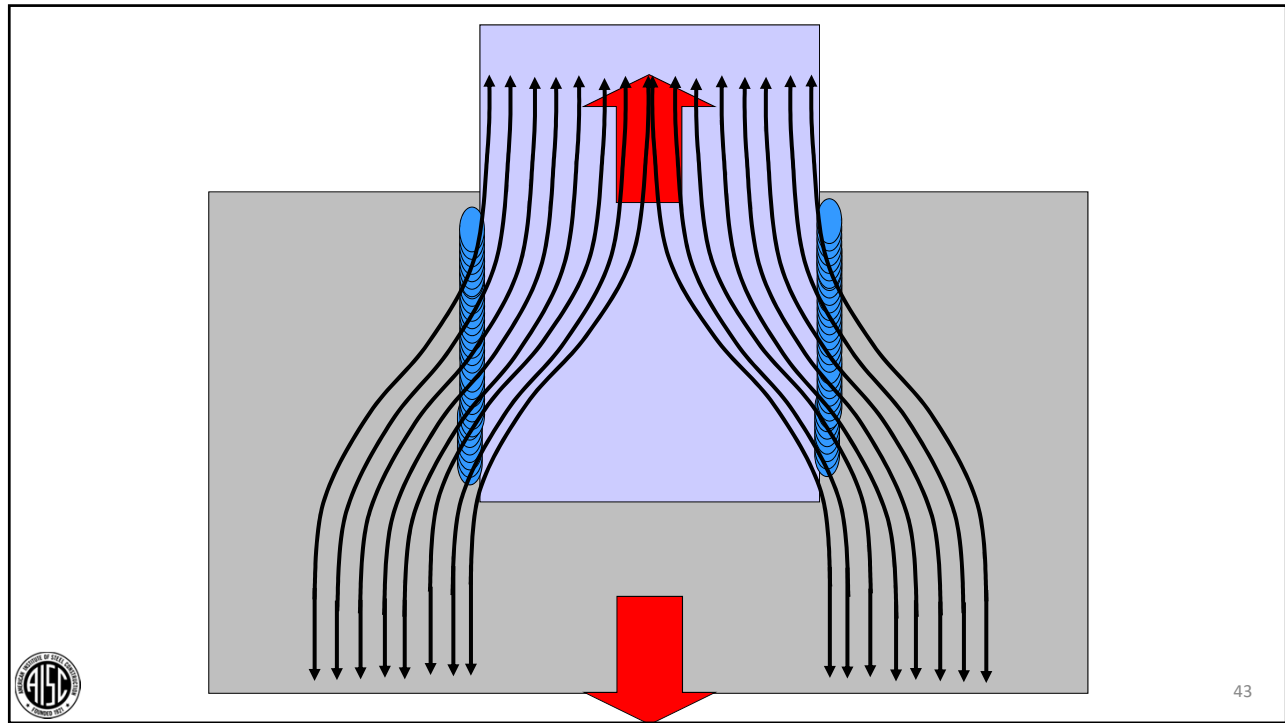
Lap Joints

If longitudinal fillet welds are used alone in lap joints of end connections of flat bar or plate members, the length of each fillet weld shall be no less than the perpendicular distance between them.

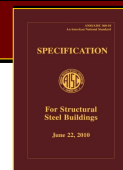


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AISC 360-10 SPECIFICATION



J2.2b:

...If longitudinal fillet welds are used alone in end connections of flat-bar tension members, the length of each fillet weld shall be not less than the perpendicular distance between them. For the effect of longitudinal fillet weld length in end connections upon the effective area of the connected member, see Section D3....



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AISC 360-16 Specification for Structural Steel Buildings



GLOSSARY

Shear lag. Nonuniform tensile stress distribution in a member or connecting element in the vicinity of a connection.

Effective net area. Net area modified to account for the effect of shear lag.



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AISC 360-16 Specification for Structural Steel Buildings



COMMENTARY

Shear lag is a concept used to account for the uneven stress distribution in connected members when some but not all of their elements (flange, web, leg, etc.) are connected.



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AISC 360-16 Specification for Structural Steel Buildings



D3. EFFECTIVE NET AREA

The gross area, A_g , and net area, A_n , of tension members shall be determined in accordance with the provisions of Section B4.3.

The effective net area of tension members shall be determined as

$$A_e = A_n U \quad (D3-1)$$

where U , the **shear lag factor**, is determined as shown in **Table D3.1**.

For open cross sections such as W, M, S, C, or HP shapes, WT, ST, and single and double angles, the shear lag factor, U , need not be less than the ratio of the gross area of the connected element(s) to the member gross area. This provision does not apply to closed sections, such as HSS sections, nor to plates.



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AISC 360-16 Specification for Structural Steel Buildings

TABLE D3.1

Shear Lag Factors for Connections to Tension Members

8 examples

6 welded examples

TABLE D3.1
Shear Lag Factors for Connections to Tension Members

Case	Description of Element	Shear Lag Factor, U	Example
1	All tension members where the tension load is transmitted directly to each of the cross-sectional elements by fasteners or welds (except as in Cases 4, 5 and 6).	$U = 1.0$	—
2	All tension members, except HSS, where the tension load is transmitted to some but not all of the cross-sectional elements by fasteners or by longitudinal welds in combination with transverse welds. Alternatively, Case 7 is permitted for W, M, S and HP shapes. (For angles, Case 8 is permitted to be used.)	$U = 1 - \frac{\bar{x}}{l}$	
3	All tension members where the tension load is transmitted only by transverse welds to some but not all of the cross-sectional elements.	$U = 1.0$ (a) A — value of the directly connected elements	—
4(a)	Flats, angles, channels with welds at heels, toes, and W shapes with connector elements, where the tension load is transmitted by longitudinal welds only (see Case 2 for definition of l).	$U = \frac{a^2}{a^2 + l^2} \left(1 - \frac{\bar{x}}{l} \right)$	
5	Plated HSS with a single concentric gusset plate through slots in the HSS.	$l \geq 1.30D, U = 1.0$ $D \leq l < 1.30D, U = 1 - \frac{D}{l}$ $D = \frac{D_o}{2}$	
6	Rectangular HSS with a single concentric gusset plate	$l \geq H, U = 1 - \frac{D}{l}$ $H = \frac{D_o^2 - D_i^2}{4(D_o + D_i)}$	
	with two side gusset plates	$l \geq H, U = 1 - \frac{D}{l}$ $H = \frac{D_o^2}{4(D_o + D_i)}$	
7	In W, M, S or HP shapes, or less out from those shapes (if U is calculated per Case 2, the larger value is permitted to be used)	with flange connected with three or more fasteners per line in the direction of loading	$b_f \geq \frac{h}{2}, U = 0.90$ $b_f < \frac{h}{2}, U = 0.85$
		with web connected with four or more fasteners per line in the direction of loading	$U = 0.70$
8	Single and double angles (if U is calculated per Case 2, the larger value is permitted to be used)	with four or more fasteners per line in the direction of loading	$U = 0.80$
		with three fasteners per line in the direction of loading (with lower than three fasteners per line in the direction of loading, see Case 2)	$U = 0.60$

D = overall width of rectangular HSS member, measured (GP) to the plane of the connection, in (mm); D_o = outside diameter of round HSS, in (mm); D_i = inside diameter of round HSS, in (mm); h = overall height of rectangular HSS member, measured in the plane of the connection, in (mm); H = depth of section, in (mm); for flats, l = length of the section from which the toe was cut, in (mm); l = length of connection, in (mm); a = width of plate, in (mm); s = spacing of connection, in (mm); l = length of connection, in (mm); s and l shall not be less than 4 times the weld size.



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TABLE D3.1

Shear Lag Factors for Connections to Tension Members

Case	Description of Element	Shear Lag Factor, U	Example
1	All tension members where the tension load is transmitted directly to each of the cross-sectional elements by fasteners or welds (except as in Cases 4, 5 and 6).	$U = 1.0$	—
2	All tension members, except HSS, where the tension load is transmitted to some but not all of the cross-sectional elements by fasteners or by longitudinal welds in combination with transverse welds. Alternatively, Case 7 is permitted for W, M, S and HP shapes. (For angles, Case 8 is permitted to be used.)	$U = 1 - \frac{\bar{x}}{l}$	

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TABLE D3.1

Shear Lag Factors for Connections to Tension Members

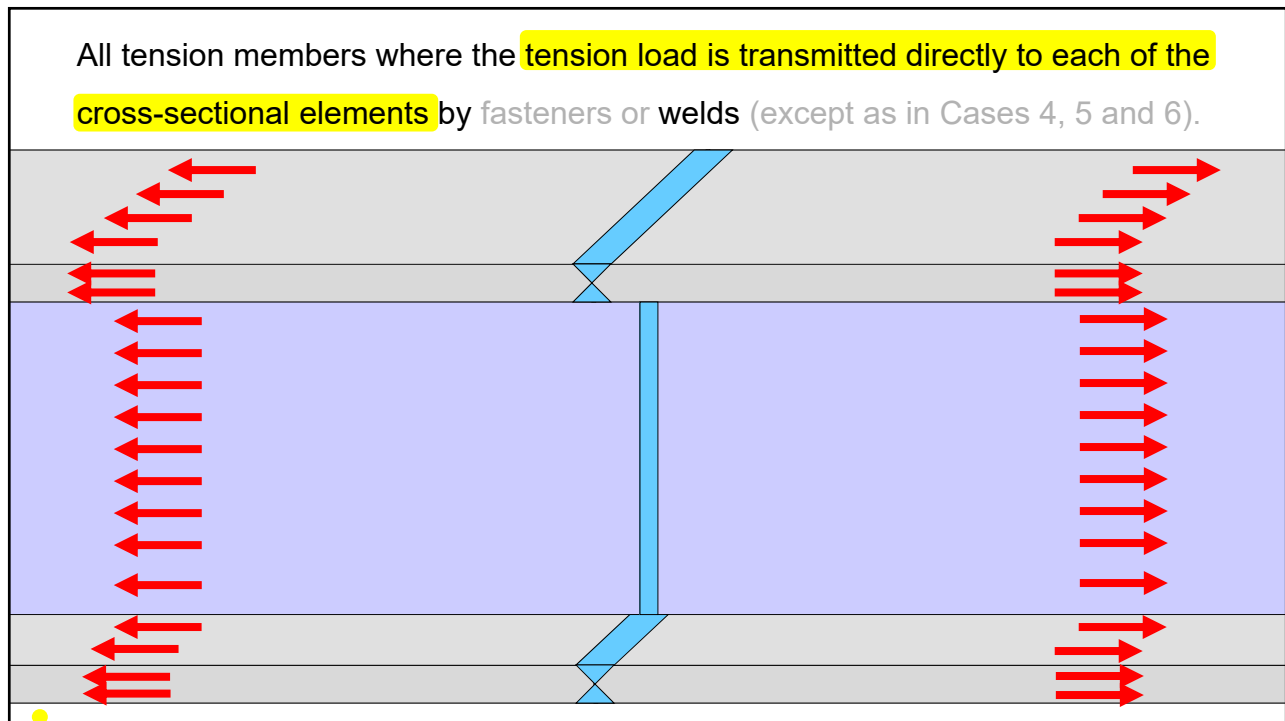
Case	Description of Element	Shear Lag Factor, U	Example
1	All tension members where the tension load is transmitted directly to each of the cross-sectional elements by fasteners or welds (except as in Cases 4, 5 and 6).	$U = 1.0$	–

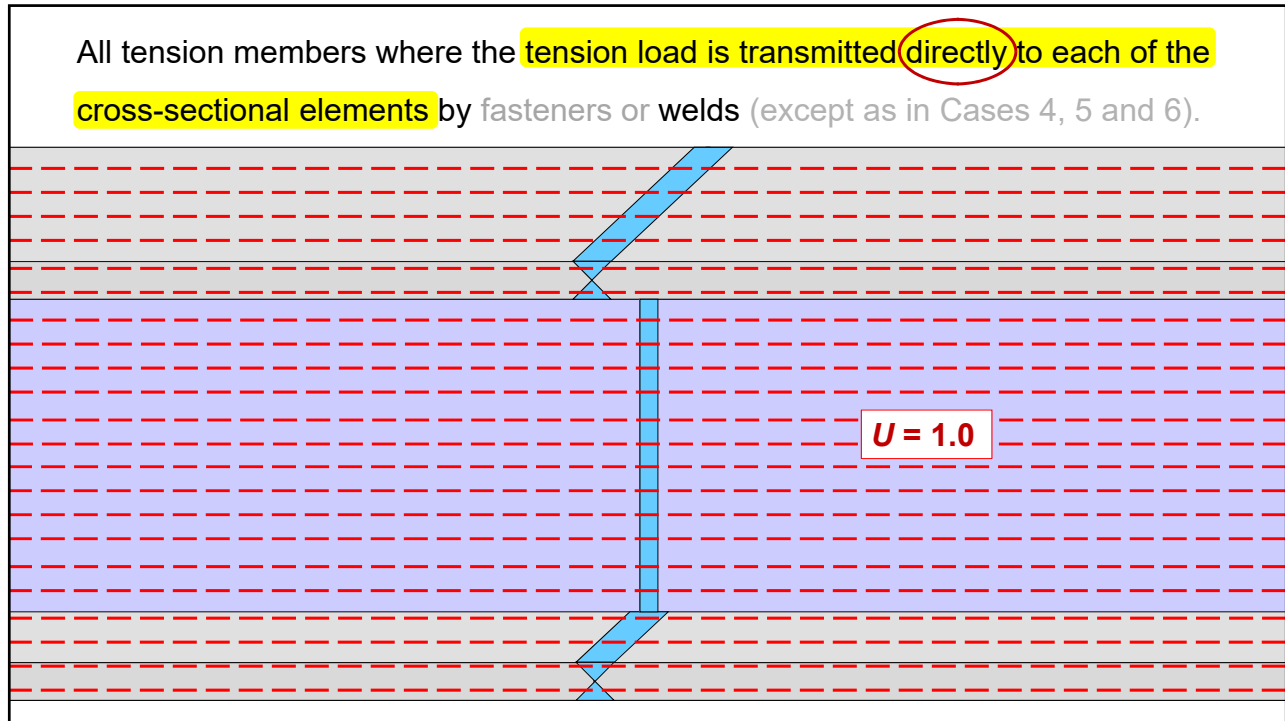
All tension members where the tension load is transmitted directly to each of the cross-sectional elements by fasteners or welds (except as in Cases 4, 5 and 6).

$U = 1.0$

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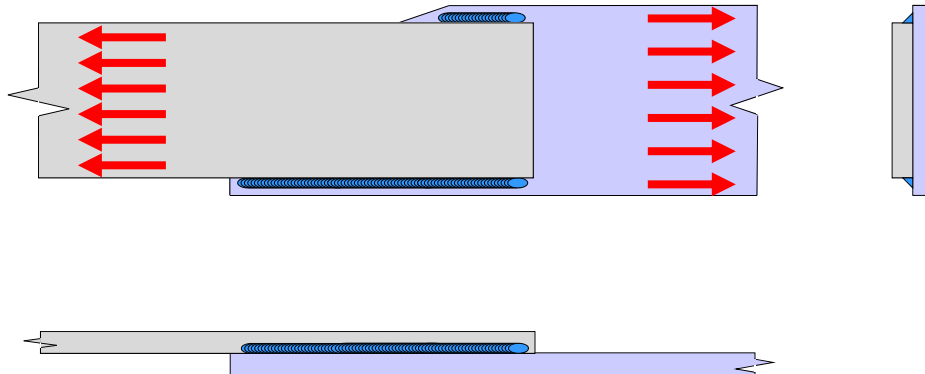




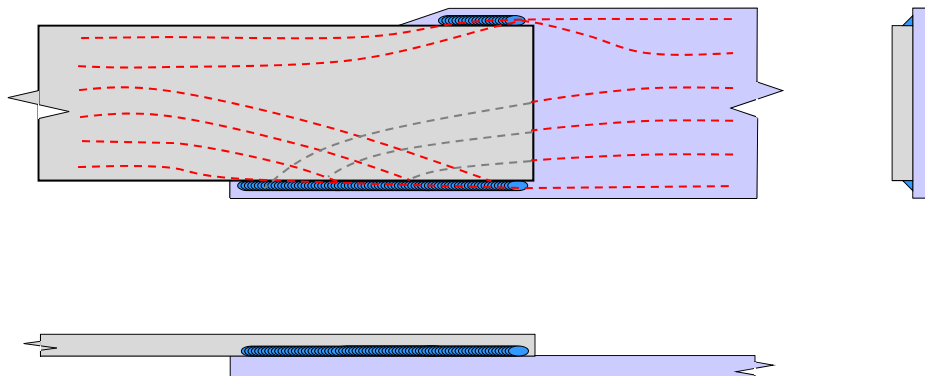
AISC 360-16 Specification for Structural Steel Buildings			
TABLE D3.1			
Shear Lag Factors for Connections to Tension Members			
Case	Description of Element	Shear Lag Factor, U	Example
4[a]	Plates, angles, channels with welds at heels, tees, and W-shapes with connected elements, where the tension load is transmitted by longitudinal welds only. See Case 2 for definition of \bar{x} .	$U = \frac{3l^2}{3l^2 + w^2} \left(1 - \frac{\bar{x}}{l} \right)$	
Plates, angles, channels with welds at heels, tees, and W-shapes with connected elements, where the tension load is transmitted by longitudinal welds only. See Case 2 for definition of x .			



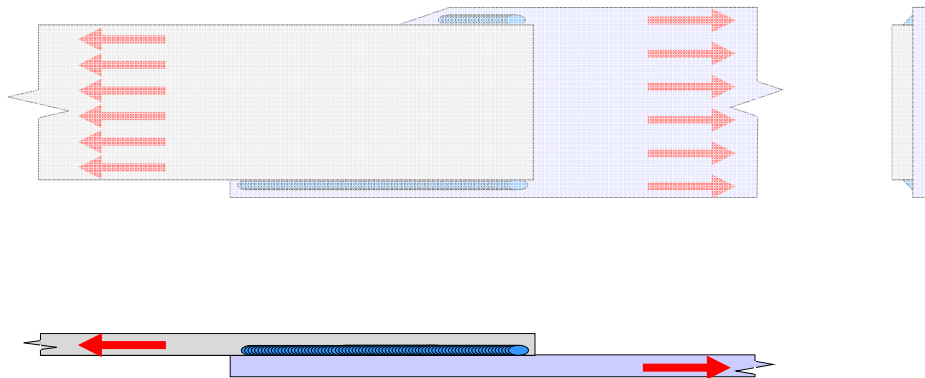
Plates, angles, channels with welds at heels, tees, and W-shapes with connected elements, where the tension load is transmitted by longitudinal welds only. See Case 2 for definition of \bar{x} .



Plates, angles, channels with welds at heels, tees, and W-shapes with connected elements, where the tension load is transmitted by longitudinal welds only. See Case 2 for definition of \bar{x} .

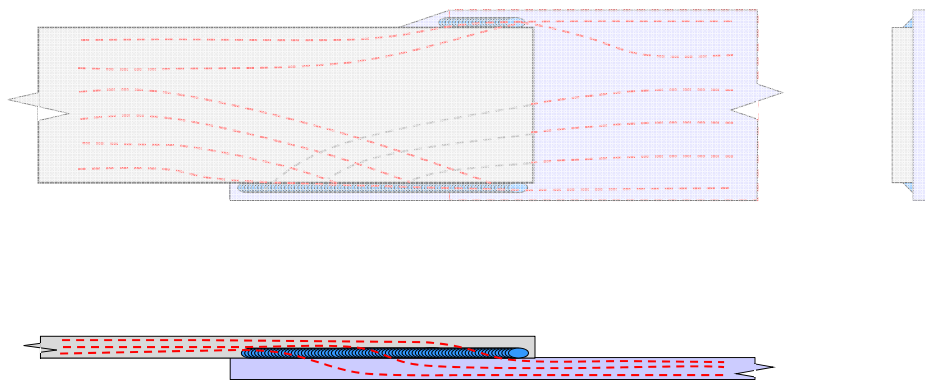


Plates, angles, channels with welds at heels, tees, and W-shapes with connected elements, where the tension load is transmitted by longitudinal welds only. See Case 2 for definition of \bar{x} .



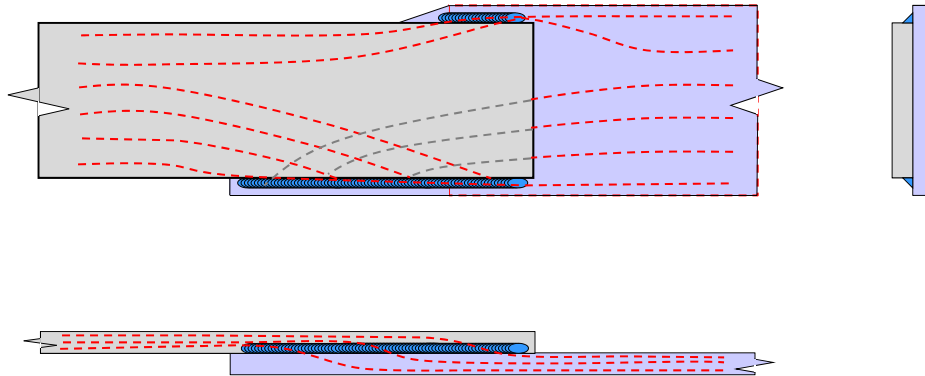
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Plates, angles, channels with welds at heels, tees, and W-shapes with connected elements, where the tension load is transmitted by longitudinal welds only. See Case 2 for definition of \bar{x} .

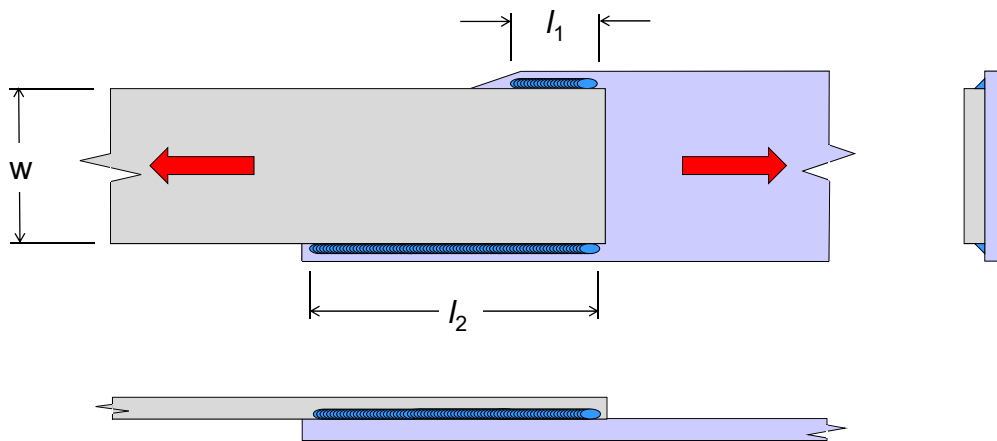


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Plates, angles, channels with welds at heels, tees, and W-shapes with connected elements, where the tension load is *not directly* transmitted by longitudinal welds only. See Case 2 for definition of \bar{x} .



$$U = \frac{3l^2}{(3l^2 + w^2)} \left(1 - \frac{\bar{x}}{l}\right) \quad l = \frac{l_1 + l_2}{2}$$



\bar{x} = eccentricity of connection, in. (mm)

$$U = \frac{3 I^2}{(3 I^2 + w^2)} \left(1 - \frac{\bar{x}}{l}\right)$$

$$I = \frac{l_1 + l_2}{2}$$

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Let $l_1 = l_2$

$$U = \frac{3 I^2}{(3 I^2 + w^2)} \left(1 - \frac{\bar{x}}{l}\right)$$

$$I = \frac{l_1 + l_2}{2}$$

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Let $l_1 = l_2$ and $l = 2w$ $\bar{x} = t/2$

$$U = \frac{3l^2}{(3l^2 + w^2)} \left(1 - \frac{\bar{x}}{l}\right) \qquad l = \frac{l_1 + l_2}{2}$$

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Let $l_1 = l_2 = 4$, $w = 2$, and $t = 1/2$

$U = 0.87$ $U = \frac{3l^2}{(3l^2 + w^2)} \left(1 - \frac{\bar{x}}{l}\right)$ $l = \frac{l_1 + l_2}{2}$ **$\bar{x} = t/2 = 1/4$**

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AISC 360-16 Specification for Structural Steel Buildings



D3. EFFECTIVE NET AREA

The gross area, A_g , and net area, A_n , of tension members shall be determined in accordance with the provisions of Section B4.3.

The effective net area of tension members shall be determined as

$$A_e = A_n U \quad A_e = 0.87 A_n \quad (D3-1)$$

where U , the shear lag factor, is determined as shown in Table D3.1.

For open cross sections such as W, M, S, C, or HP shapes, WTs, STs, and single and double angles, the shear lag factor, U , need not be less than the ratio of the gross area of the connected element(s) to the member gross area. This provision does not apply to closed sections, such as HSS sections, nor to plates.



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LAP JOINTS

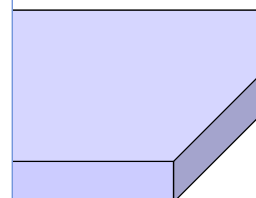
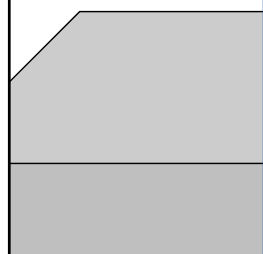


Note:

While shear lag has been covered as part of lap joint details, the concept of shear lag applies to more than lap joints.

Shear lag applies to end loaded connections.

Shear lag does not account for eccentricity.



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AISC 360-16 Specification for Structural Steel Buildings

Commentary
D3 EFFECTIVE NET AREA



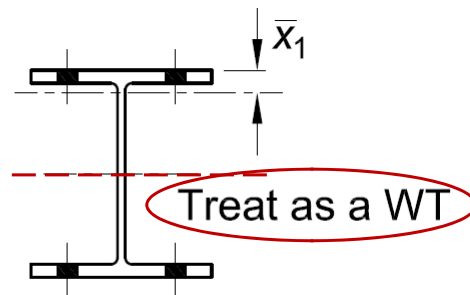
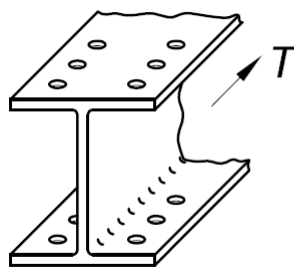
For any given profile and configuration of connected elements, \bar{x} is the perpendicular distance from the connection plane, or face of the member, to the centroid of the member section resisting the connection force, as shown in Figure C-D3.1.



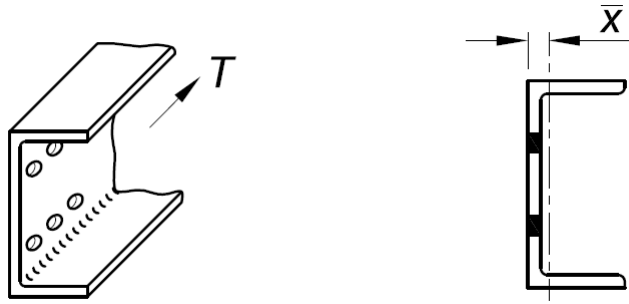
AISC 360-16 Specification for Structural Steel Buildings


Commentary Figure C-D3.1

Determination of \bar{x} for U



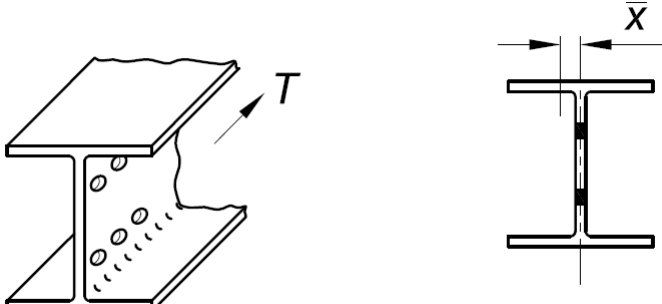
AISC 360-16 Specification for Structural Steel Buildings
Commentary Figure C-D3.1
Determination of \bar{x} for U






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AISC 360-16 Specification for Structural Steel Buildings
Commentary Figure C-D3.1
Determination of \bar{x} for U





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TABLE D3.1

Shear Lag Factors for Connections to Tension Members

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TABLE D3.1

Shear Lag Factors for Connections to Tension Members

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TABLE D3.1

Shear Lag Factors for Connections to Tension Members

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TABLE D3.1

Shear Lag Factors for Connections to Tension Members

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TABLE D3.1

Shear Lag Factors for Connections to Tension Members

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TABLE D3.1

Shear Lag Factors for Connections to Tension Members

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WELDED CONNECTION DETAILS

Outline

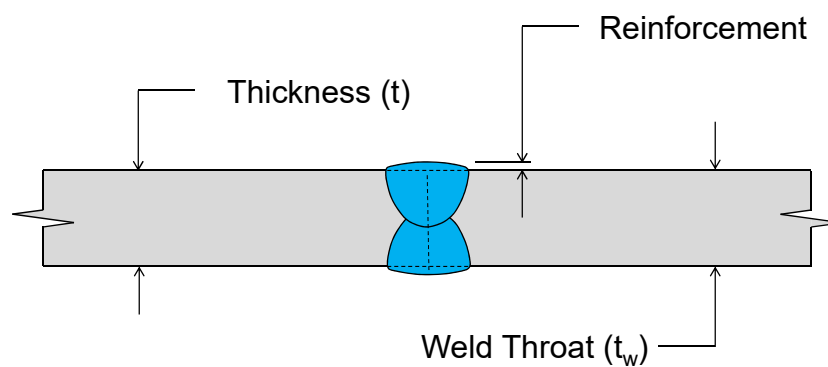
- Joints
- ➔ • CJP Groove Welds
- PJP Groove Welds
- Fillet Welds
- Plug and Slot Welds
- Tack Welds
- Weld Metal Strength



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CJP GROOVE WELDS

Weld Throat Dimension (t_w)

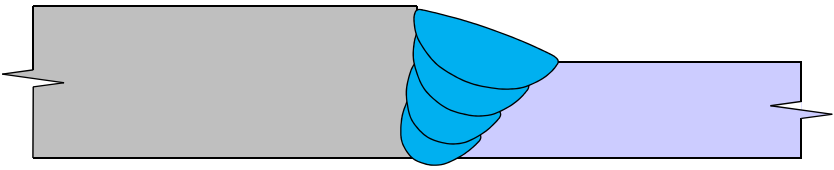


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CJP GROOVE WELDS

Complete-Joint-Penetration Groove Weld (CJP)

Two thicknesses



The diagram shows two horizontal plates, one grey on the left and one light blue on the right, joined by a double-sided groove weld. The weld is represented by a blue, multi-layered, semi-circular shape that penetrates the root of the joint from both the top and bottom. The plates are shown with jagged ends to indicate they are part of a larger structure.

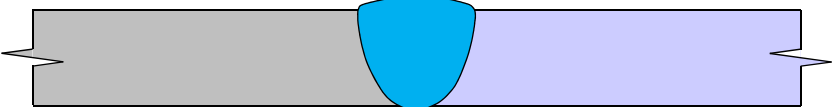


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CJP GROOVE WELDS

Complete-Joint-Penetration Groove Weld (CJP)

Single sided



The diagram shows two horizontal plates, one grey on the left and one light blue on the right, joined by a single-sided groove weld. The weld is represented by a blue, semi-circular shape that penetrates the root of the joint from the top side only. The plates are shown with jagged ends to indicate they are part of a larger structure.

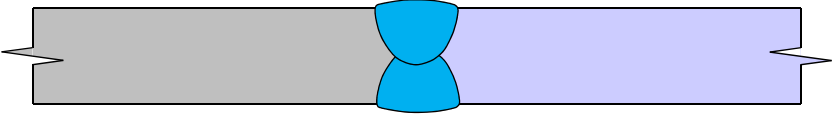


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CJP GROOVE WELDS

Complete-Joint-Penetration Groove Weld (CJP)

Double sided



The diagram shows two horizontal steel plates, one grey on the left and one light blue on the right, joined at their ends. A blue, double-sided groove weld is shown at the joint, with two distinct weld ripples on each side of the interface. The plates have jagged ends on the far left and right, indicating they are part of a larger structure.

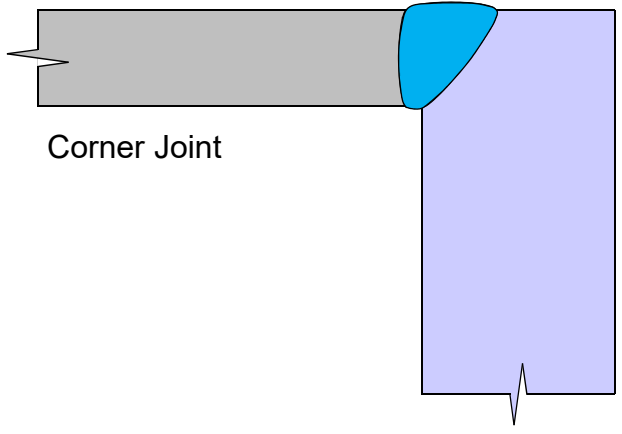


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CJP GROOVE WELDS

Complete-Joint-Penetration Groove Weld (CJP)

Corner Joint



The diagram shows a horizontal grey steel plate on the left and a vertical light blue steel plate on the right, meeting at a 90-degree corner. A blue, single-sided groove weld is shown at the corner, with one distinct weld ripple. Both plates have jagged ends, indicating they are part of a larger structure.

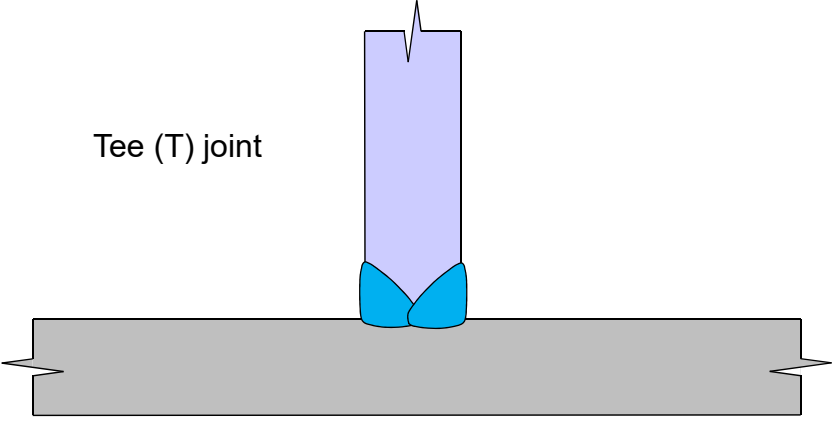


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CJP GROOVE WELDS

Complete-Joint-Penetration Groove Weld (CJP)

Tee (T) joint



Welded Connections—
A Primer for
Engineers




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CJP GROOVE WELDS

AWS D1.1 Prequalified CJP Groove Weld Details

- An essential part of a prequalified Welding Procedure Specification (WPS)
- Incorporates geometric features conducive to consistent through thickness fusion and overall weld quality
- Includes root conditions that encourage fusion and proper width-to-depth profiles to discourage solidification cracking
- In some cases, but not all, reflects welding economics

Welded Connections—
A Primer for
Engineers



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Square Groove Weld: CJP

Square-groove weld (1)
 T-joint (T)
 Corner joint (C)

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Gas Shielding for FCAW	Notes
		T ₁	T ₂	Root Opening	Tolerances				
					As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)			
SMAW	TC-L1b	1/4 max.	U	$R = \frac{T_1}{2}$	+1/16, -0	+1/16, -1/8	All	—	d, e, g
GMAW FCAW	TC-L1-GF	3/8 max.	U	R = 0 to 1/8	+1/16, -0	+1/16, -1/8	All	Not required	a, d, g
SAW	TC-L1-S	3/8 max.	U	R = 0	±0	+1/16, -0	F	—	d, g



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AWS D1.1: 2015 Structural Welding Code – Steel



Single V Groove Weld: CJP

Single-V-groove weld (2)
 Butt joint (B)

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation		Allowed Welding Positions	Gas Shielding for FCAW	Notes
		T ₁	T ₂	Root Opening	Groove Angle			
				As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)			
				R = +1/16, -0	+1/4, -1/16			
				α = +10°, -0°	+10°, -5°			
SMAW	B-U2a	U	—	R = 1/4 R = 3/8 R = 1/2	α = 45° α = 30° α = 20°	All F, V, OH F, V, OH	— — —	e, j e, j e, j
GMAW FCAW	B-U2a-GF	U	—	R = 3/16 R = 3/8	α = 30° α = 30°	F, V, OH F, V, OH	Required Not req.	a, j a, j
SAW	B-L2a-S	2 max.	—	R = 1/4	α = 45°	F	—	j
SAW	B-U2-S	U	—	R = 5/8	α = 20°	F	—	j



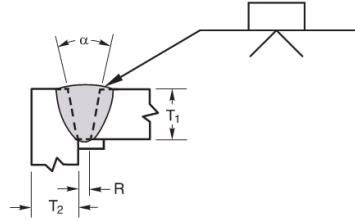
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Single V Groove Weld: CJP

Single-V-groove weld (2)
 Corner joint (C)



Tolerances	
As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)
R = +1/16, -0	+1/4, -1/16
$\alpha = +10^\circ, -0^\circ$	+10°, -5°

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation		Allowed Welding Positions	Gas Shielding for FCAW	Notes
		T ₁	T ₂	Root Opening	Groove Angle			
SMAW	C-U2a	U	U	R = 1/4	$\alpha = 45^\circ$	All	—	e, j
				R = 3/8	$\alpha = 30^\circ$	F, V, OH	—	e, j
				R = 1/2	$\alpha = 20^\circ$	F, V, OH	—	e, j
GMAW FCAW	C-U2a-GF	U	U	R = 3/16	$\alpha = 30^\circ$	F, V, OH	Required	a
				R = 3/8	$\alpha = 30^\circ$	F, V, OH	Not req.	a, j
				R = 1/4	$\alpha = 45^\circ$	F, V, OH	Not req.	a, j
SAW	C-L2a-S	2 max.	U	R = 1/4	$\alpha = 30^\circ$	F	—	j
SAW	C-U2-S	U	U	R = 5/8	$\alpha = 20^\circ$	F	—	j



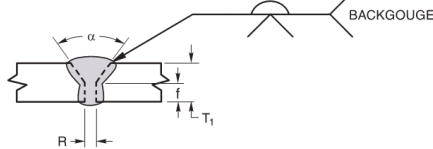
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Single V Groove Weld: CJP

Single-V-groove weld (2)
 Butt joint (B)



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation		Allowed Welding Positions	Gas Shielding for FCAW	Notes
		T ₁	T ₂	Root Opening	Tolerances			
				Root Face	As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)		
SMAW	B-U2	U	—	R = 0 to 1/8	+1/16, -0	+1/16, -1/8	All	—
				f = 0 to 1/8	+1/16, -0	Not limited		
GMAW FCAW	B-U2-GF	U	—	R = 0 to 1/8	+1/16, -0	+1/16, -1/8	All	Not required
				f = 0 to 1/8	+1/16, -0	Not limited		
SAW	B-L2c-S	Over 1/2 to 1	—	R = 0	R = ±0	+1/16, -0	F	—
				f = 1/4 max.	f = +0, -f	±1/16		
				$\alpha = 60^\circ$	$\alpha = +10^\circ, -0^\circ$	+10°, -5°		
SAW	B-L2c-S	Over 1 to 1-1/2	—	R = 0	R = ±0	+1/16, -0	F	—
				f = 1/2 max.	f = +0, -f	±1/16		
				$\alpha = 60^\circ$	$\alpha = +10^\circ, -0^\circ$	+10°, -5°		
SAW	B-L2c-S	Over 1-1/2 to 2	—	R = 0	R = ±0	+1/16, -0	F	—
				f = 5/8 max.	f = +0, -f	±1/16		
				$\alpha = 60^\circ$	$\alpha = +10^\circ, -0^\circ$	+10°, -5°		



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Double V Groove Weld: CJP

Double-V-groove weld (3)
 Butt joint (B)

BACKGOUGE

		Tolerances	
		As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)
		$R = \pm 0$	$+1/4, -0$
		$f = \pm 0$	$+1/16, -0$
		$\alpha = +10^\circ, -0^\circ$	$+10^\circ, -5^\circ$
Spacer	SAW	± 0	$+1/16, -0$
	SMAW	± 0	$+1/8, -0$

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Gas Shielding for FCAW	Notes
		T ₁	T ₂	Root Opening	Root Face	Groove Angle			
SMAW	B-U3a	U Spacer = 1/8 × R	—	R = 1/4	f = 0 to 1/8	$\alpha = 45^\circ$	All	—	d, e, h, j
				R = 3/8	f = 0 to 1/8	$\alpha = 30^\circ$	F, V, OH	—	
				R = 1/2	f = 0 to 1/8	$\alpha = 20^\circ$	F, V, OH	—	
SAW	B-U3a-S	U Spacer = 1/4 × R	—	R = 5/8	f = 0 to 1/4	$\alpha = 20^\circ$	F	—	d, h, j



AWS D1.1: 2015 Structural Welding Code – Steel



Double V Groove Weld: CJP

Double-V-groove weld (3)
 Butt joint (B)

BACKGOUGE

		For B-U3c-S only	
		T ₁	S ₁
		Over	to
		2	2-1/2
		2-1/2	3
		3	3-5/8
		3-5/8	4
		4	4-3/4
		4-3/4	5-1/2
		5-1/2	6-1/4
		For T ₁ > 6-1/4 or T ₁ ≤ 2 S ₁ = 2/3 (T ₁ - 1/4)	

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Root Opening	Root Face	Groove Angle	Tolerances		Allowed Welding Positions	Gas Shielding for FCAW	Notes
		T ₁	T ₂				As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)			
SMAW	B-U3b	U	—	R = 0 to 1/8	f = 0 to 1/8	$\alpha = \beta = 60^\circ$	$+1/16, -0$	$+1/16, -1/8$	All	—	d, e, h, j
GMAW FCAW	B-U3-GF	U	—	R = 0 to 1/8	f = 0 to 1/8	$\alpha = \beta = 60^\circ$	$+1/16, -0$	Not limited	All	Not required	a, d, h, j
SAW	B-U3c-S	U	—	R = 0	f = 1/4 min.	$\alpha = \beta = 60^\circ$	$+1/16, -0$	$+1/4, -0$	F	—	d, h, j
To find S ₁ , see table above: S ₂ = T ₁ - (S ₁ + f)											



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Single Bevel Groove Weld: CJP

Single-bevel-groove weld (4)
 Butt joint (B)

		Base Metal Thickness (U = unlimited)		Groove Preparation		Allowed Welding Positions	Gas Shielding for FCAW	Notes	
Welding Process	Joint Designation	T ₁	T ₂	Root Opening	Groove Angle				
						SMAW	B-U4a	U	—
R = 3/8	$\alpha = 30^\circ$	All	—	c, e, j					
GMAW FCAW	B-U4a-GF				U	—	R = 3/16	$\alpha = 30^\circ$	All
		R = 1/4	$\alpha = 45^\circ$	All			Not req.	a, c, j	
		R = 3/8	$\alpha = 30^\circ$	F, H			Not req.	a, c, j	
SAW	B-U4a-S	U	—	R = 3/8	$\alpha = 30^\circ$	F	—	c, j	
				R = 1/4	$\alpha = 45^\circ$				

Tolerances	
As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)
R = +1/16, -0	+1/4, -1/16
$\alpha = +10^\circ, -0^\circ$	+10°, -5°



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Double Bevel Groove Weld: CJP

Double-bevel-groove weld (5)
 T-joint (T)
 Corner joint (C)

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Root Opening	Root Face Groove Angle	Tolerances		Allowed Welding Positions	Gas Shielding for FCAW	Notes
		T ₁	T ₂			As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)			
SMAW	TC-U5b	U	U	R = 0 to 1/8 f = 0 to 1/8 $\alpha = 45^\circ$	+1/16, -0	+1/16, -1/8	All	—	d, e, g, h, j, k	
GMAW FCAW	TC-U5-GF	U	U	$\alpha = 45^\circ$	+1/16, -0 +10°, -0°	Not limited +10°, -5°	All	Not required	a, d, g, h, j, k	
SAW	TC-U5-S	U	U	R = 0 f = 1/4 max. $\alpha = 60^\circ$	± 0 +0, -3/16 +10°, -0°	+1/16, -0 $\pm 1/16$ +10°, -5°	F	—	d, g, h, j, k	



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Single U Groove Weld: CJP

Single-U-groove weld (6)
 Butt joint (B)
 Corner joint (C)

Tolerances	
As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)
$R = +1/16, -0$	$+1/16, -1/8$
$\alpha = +10^\circ, -0^\circ$	$+10^\circ, -5^\circ$
$f = \pm 1/16$	Not Limited
$r = +1/8, -0$	$+1/8, -0$

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation				Allowed Welding Positions	Gas Shielding for FCAW	Notes
		T ₁	T ₂	Root Opening	Groove Angle	Root Face	Bevel Radius			
SMAW	B-U6	U	—	R = 0 to 1/8	$\alpha = 45^\circ$	f = 1/8	r = 1/4	All	—	d, e, j
				R = 0 to 1/8	$\alpha = 20^\circ$	f = 1/8	r = 1/4	F, OH	—	d, e, j
GMAW FCAW	C-U6-GF	U	U	R = 0 to 1/8	$\alpha = 45^\circ$	f = 1/8	r = 1/4	All	—	d, e, g, j
				R = 0 to 1/8	$\alpha = 20^\circ$	f = 1/8	r = 1/4	F, OH	—	d, e, g, j
GMAW FCAW	B-U6-GF	U	—	R = 0 to 1/8	$\alpha = 20^\circ$	f = 1/8	r = 1/4	All	Not req.	a, d, j
				R = 0 to 1/8	$\alpha = 20^\circ$	f = 1/8	r = 1/4	All	Not req.	a, d, g, j



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Double U Groove Weld: CJP

Double-U-groove weld (7)
 Butt joint (B)

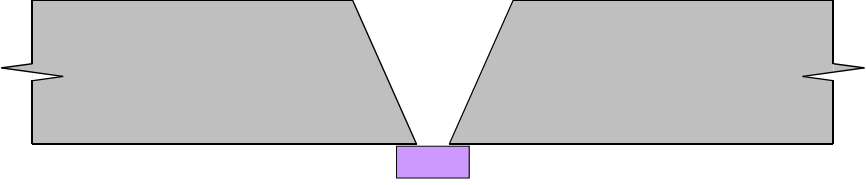
Tolerances	
As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)
For B-U7 and B-U7-GF	
$R = +1/16, -0$	$+1/16, -1/8$
$\alpha = +10^\circ, -0^\circ$	$+10^\circ, -5^\circ$
$f = +1/16, -0$	Not Limited
$r = +1/4, -0$	$\pm 1/16$
For B-U7-S	
$R = +0$	$+1/16, -0$
$\alpha = +10^\circ, -0^\circ$	$+10^\circ, -5^\circ$
$f = +0, -1/4$	$\pm 1/16$
$r = +1/4, -0$	$\pm 1/16$

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation				Allowed Welding Positions	Gas Shielding for FCAW	Notes
		T ₁	T ₂	Root Opening	Groove Angle	Root Face	Bevel Radius			
SMAW	B-U7	U	—	R = 0 to 1/8	$\alpha = 45^\circ$	f = 1/8	r = 1/4	All	—	d, e, h, j
				R = 0 to 1/8	$\alpha = 20^\circ$	f = 1/8	r = 1/4	F, OH	—	d, e, h, j
GMAW FCAW	B-U7-GF	U	—	R = 0 to 1/8	$\alpha = 20^\circ$	f = 1/8	r = 1/4	All	Not required	a, d, j, h
SAW	B-U7-S	U	—	R = 0	$\alpha = 20^\circ$	f = 1/4 max.	r = 1/4	F	—	d, h, j

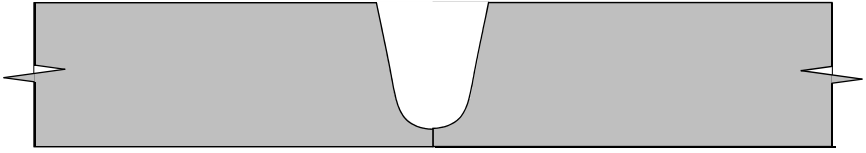



CJP GROOVE WELDS: V versus U

Single V: 1" plate, 45° included angle, 1/4" root opening




Single U: 1" plate, 20° included angle, 1/4" radius, 1/8" root face*





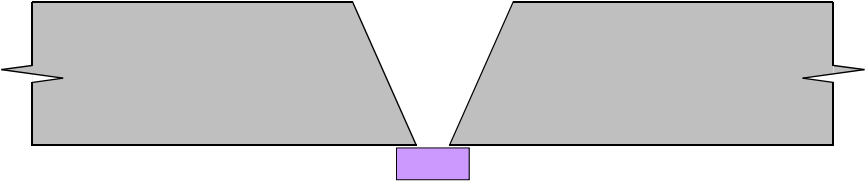
Welded Connections—
A Primer for
Engineers



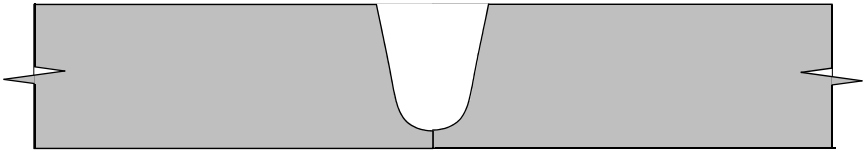
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CJP GROOVE WELDS: V versus U

Single V: 1" plate, 45° included angle, 1/4" root opening




Single U: 1" plate, 20° included angle, 1/4" radius, 1/8" root face*





Welded Connections—
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*plus backgouging



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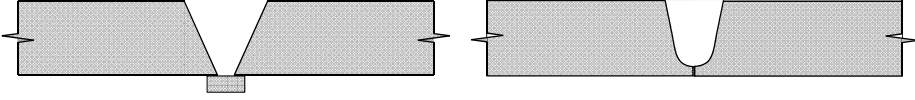
CJP GROOVE WELDS: V versus U

The diagram illustrates two types of groove welds for a CJP (Complete Joint Penetration) connection. The top diagram shows a V-groove weld, where the two plates meet at a sharp V-shaped joint. The bottom diagram shows a U-groove weld, where the joint is a smooth, rounded U-shape. Both diagrams include a small rectangular weld bead at the bottom center of the joint. The plates are shaded with a fine grid pattern. The AISC logo is in the bottom left, and a small thumbnail of the presentation is in the top right. The number 97 is in the bottom right.

CJP GROOVE WELDS: V versus U



This diagram is identical to the one on slide 97, comparing V-groove and U-groove CJP welds. It shows the cross-sections of the plates and the resulting weld bead. The AISC logo is in the bottom left, and a small thumbnail of the presentation is in the top right. The number 98 is in the bottom right.

CJP GROOVE WELDS: V versus U



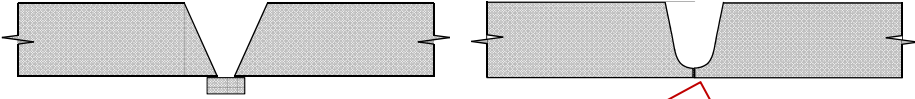
Advantages

- Only two planar cuts
- All one-sided welding
- Accommodates variable root opening, included angles
- No backgouging required
- No machining, special gouging required
- Less weld metal in thicker materials; much less in thick material
- Easy to make root pass
- Grooves can be accurately machined
- Grooves can be cut with automatic air-arc gouging



99



CJP GROOVE WELDS: V versus U



Advantages

- Only two planar cuts
- All one-sided welding
- Accommodates variable root opening, included angles
- No backgouging required
- No machining, special gouging required
- Less weld metal in thicker materials; much less in thick material
- Easy to make root pass
- Grooves can be accurately machined
- Grooves can be cut with automatic air-arc gouging



Mostly issues of concern to the contractor



100

CJP GROOVE WELDS: SELECTION OF GROOVE TYPE

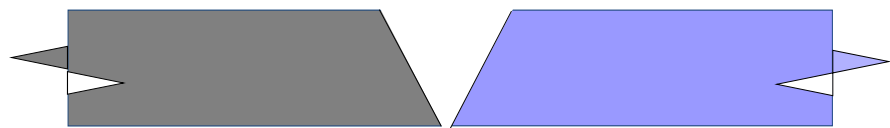
The selection of which groove weld type is used (square, vee, bevel, U, J, etc.) is typically best left up to the group responsible for welding. Many factors that influence the selection of the optimal groove type are unknown to the designer, such as what welding process will be used, what position the welding will be done in, whether the part can be rotated or not, etc.





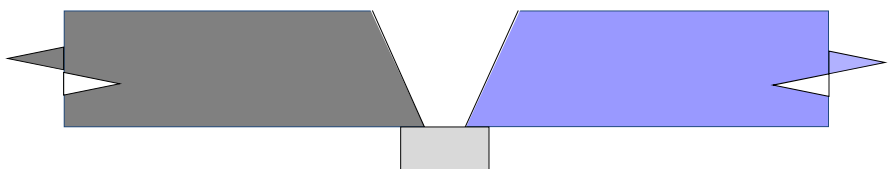
101

CJP GROOVE WELDS

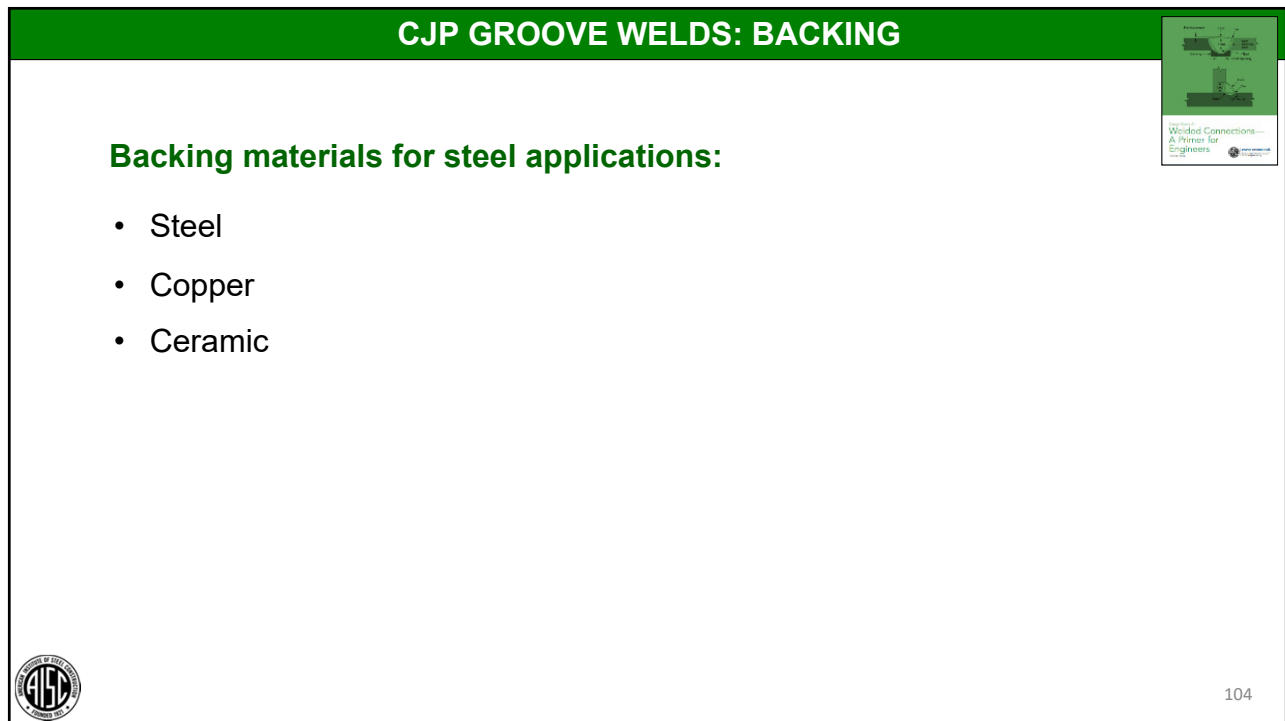
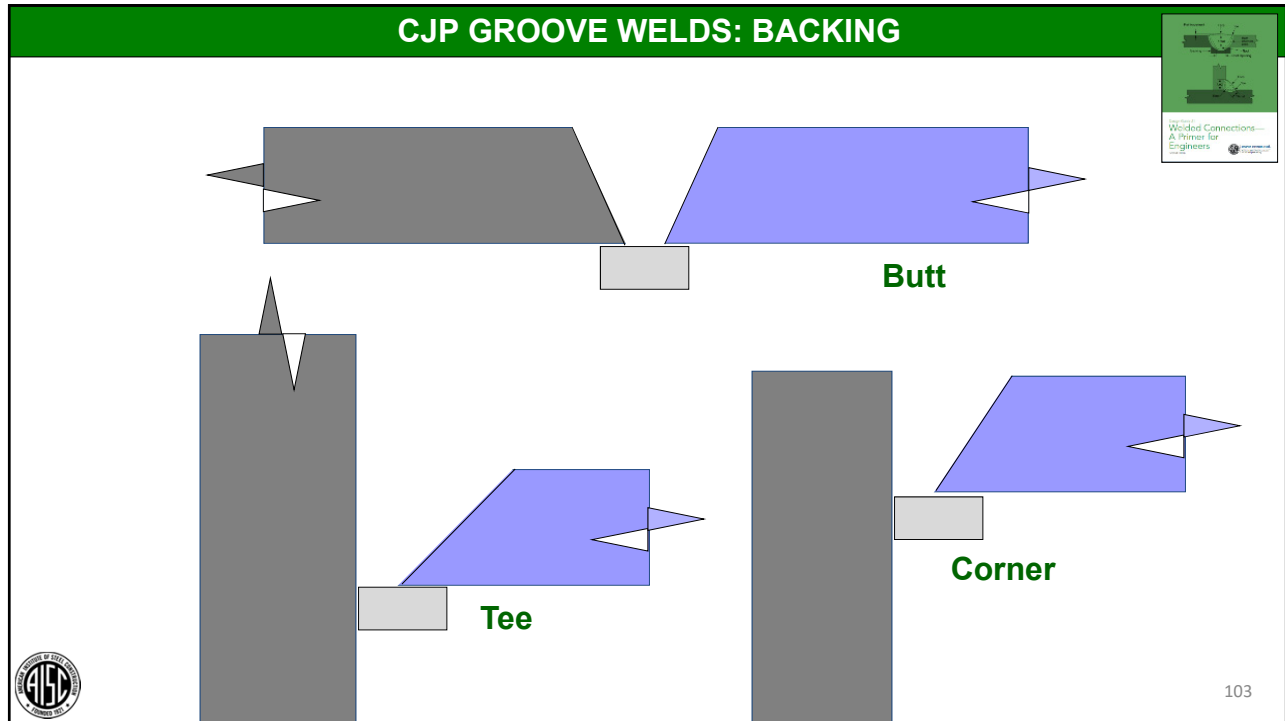
Open Root



With Backing



102



CJP GROOVE WELDS: BACKING

Steel backing:

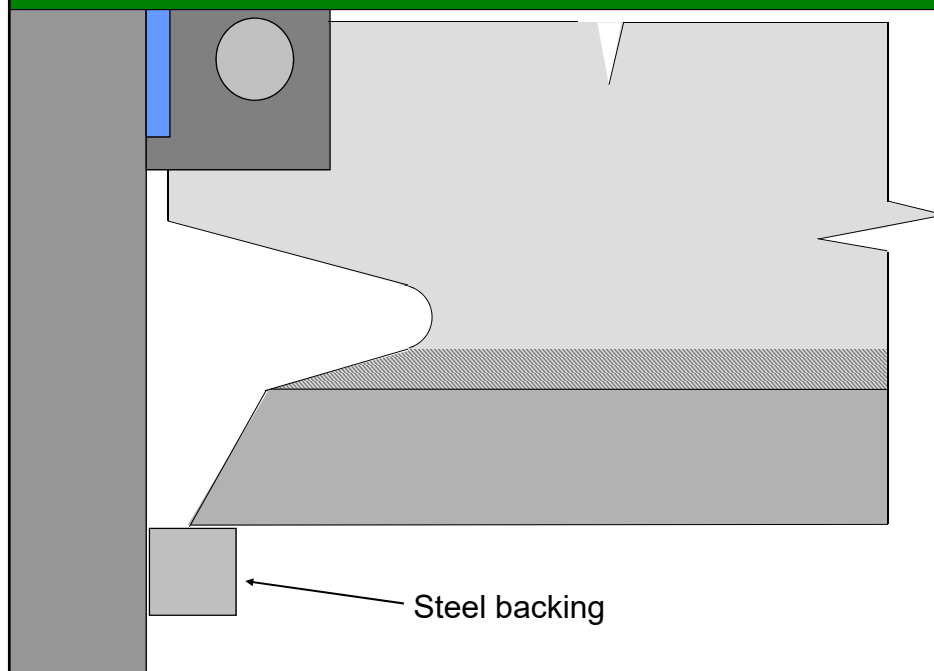
- Permanent (unless deliberately removed)
- May be called “fusible” backing
- Becomes part of the weldment
- May introduce notches (depending on the joint type and direction of loading)
- Removal is expensive
- Most common form of backing



105

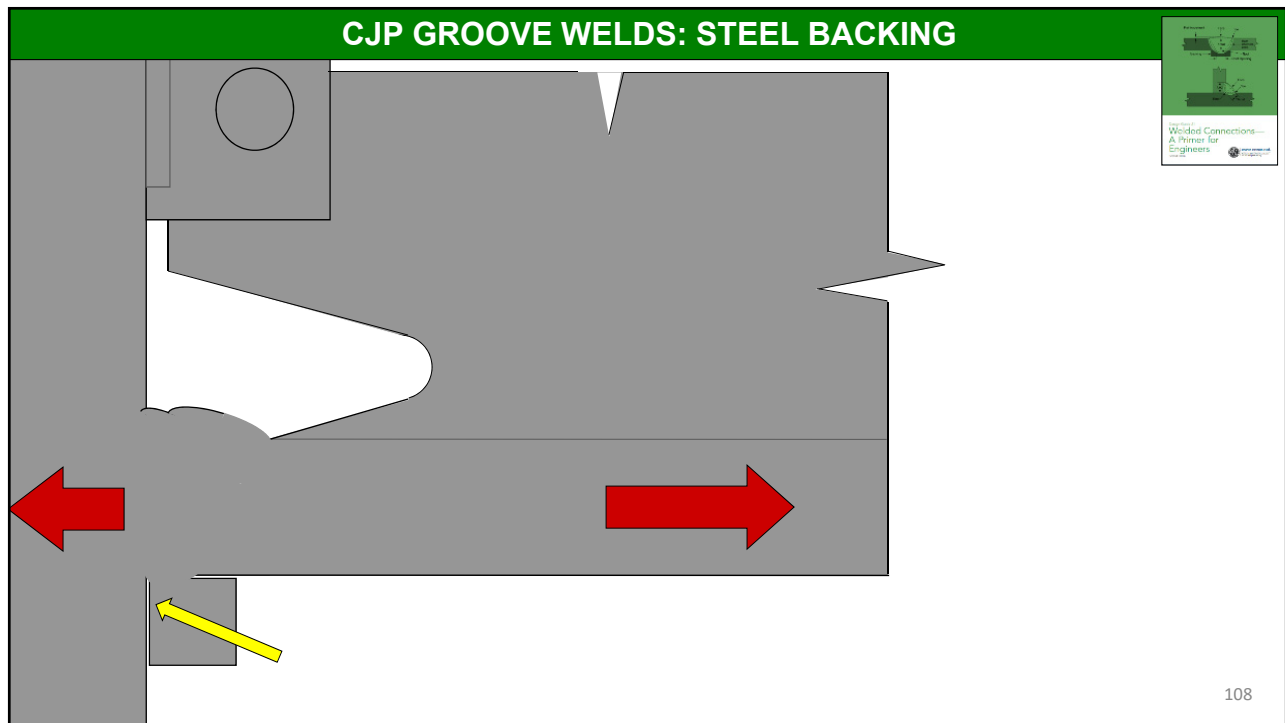
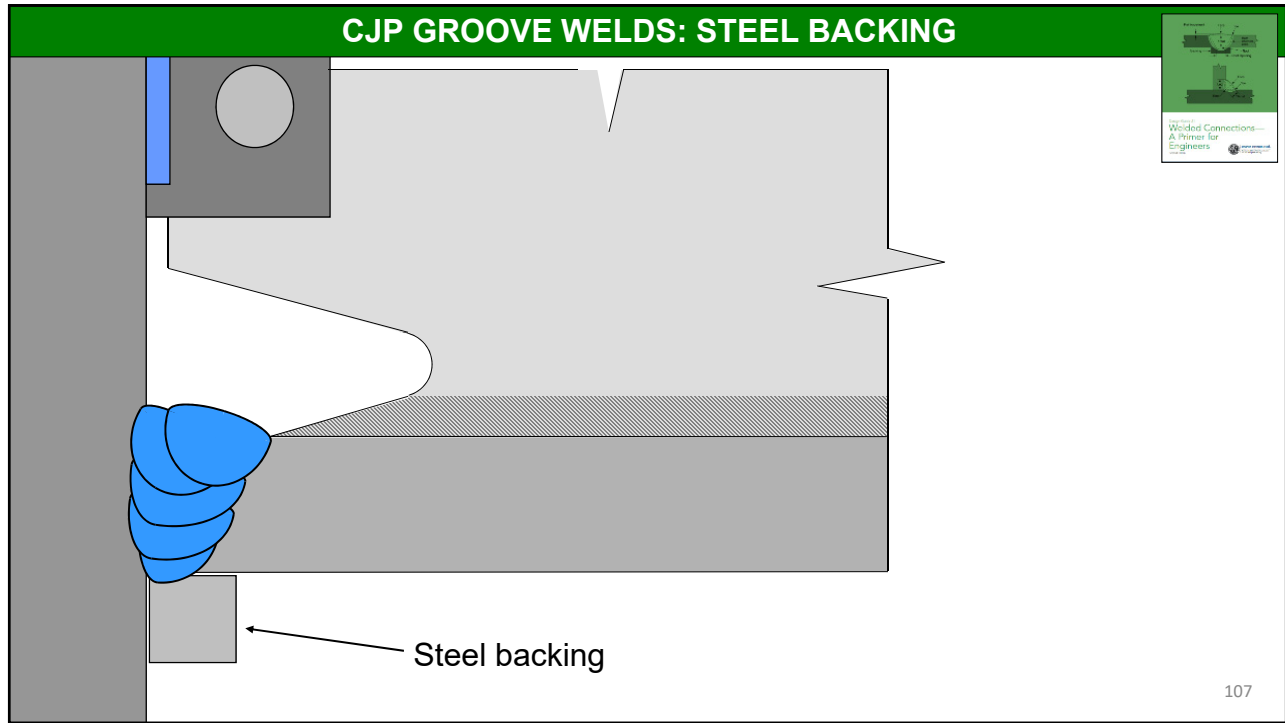


CJP GROOVE WELDS: STEEL BACKING



106





CJP GROOVE WELDS: STEEL BACKING

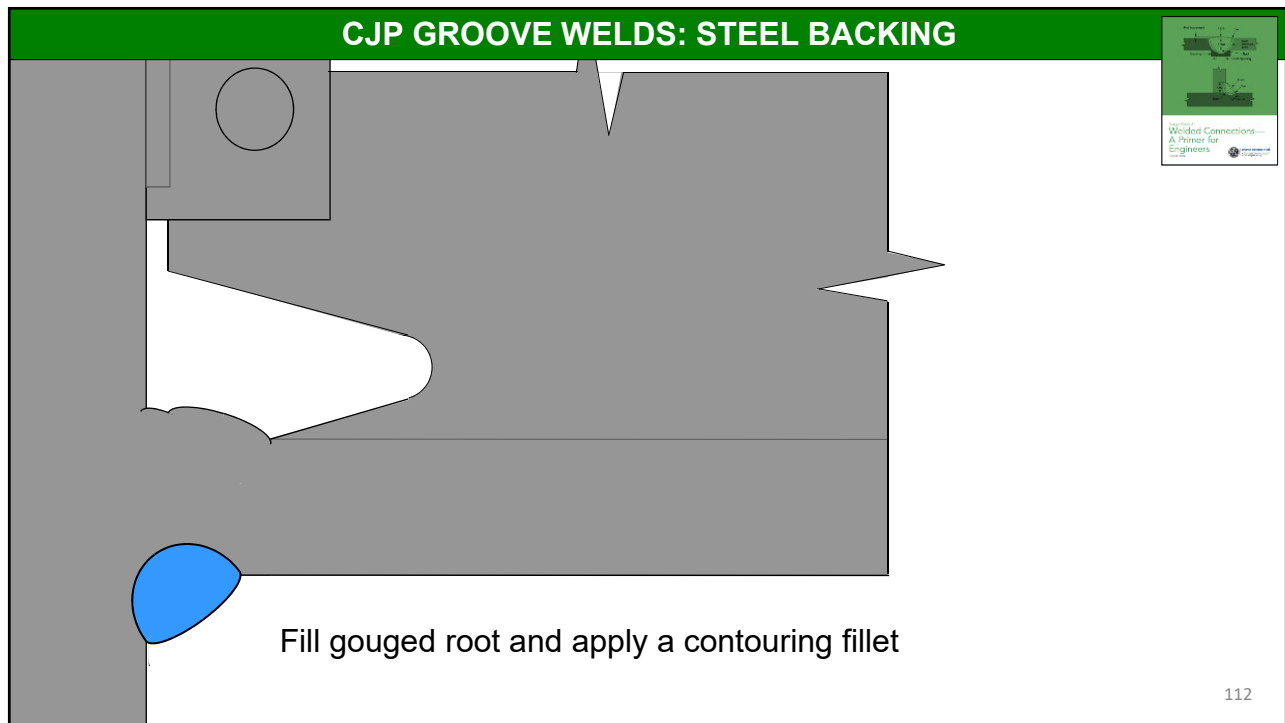
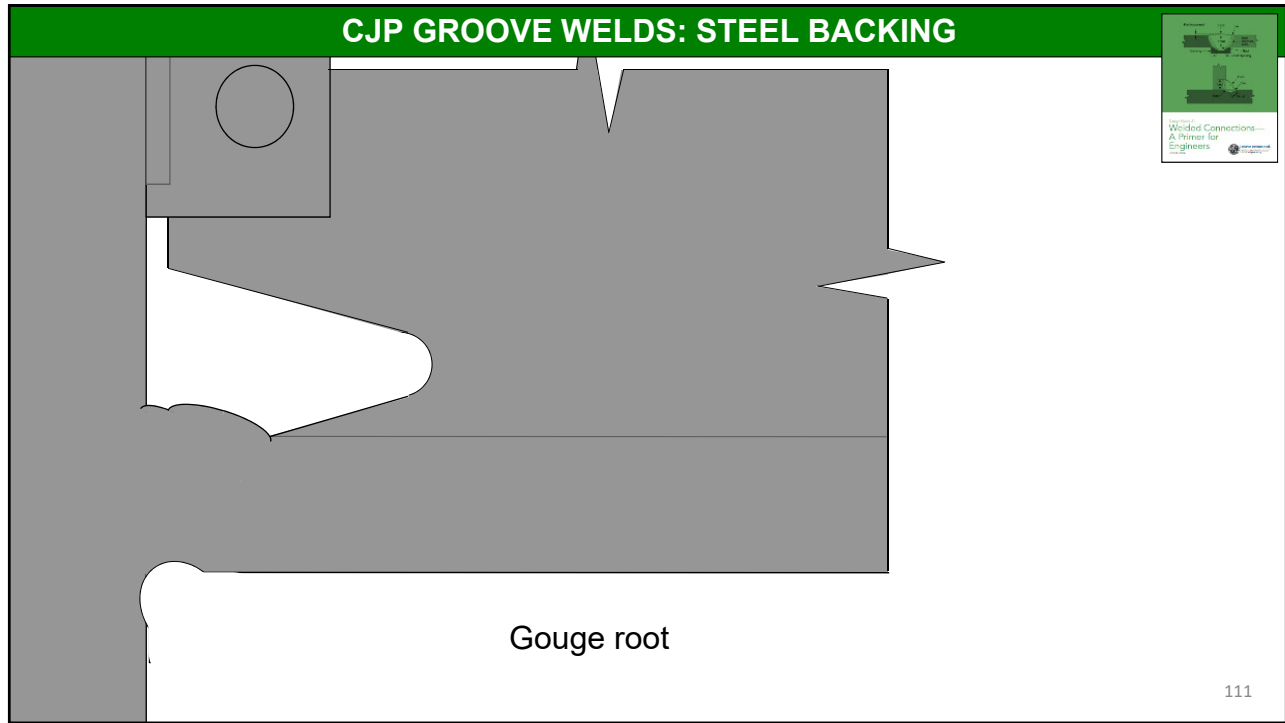
Not permitted for seismic, bottom flange

109

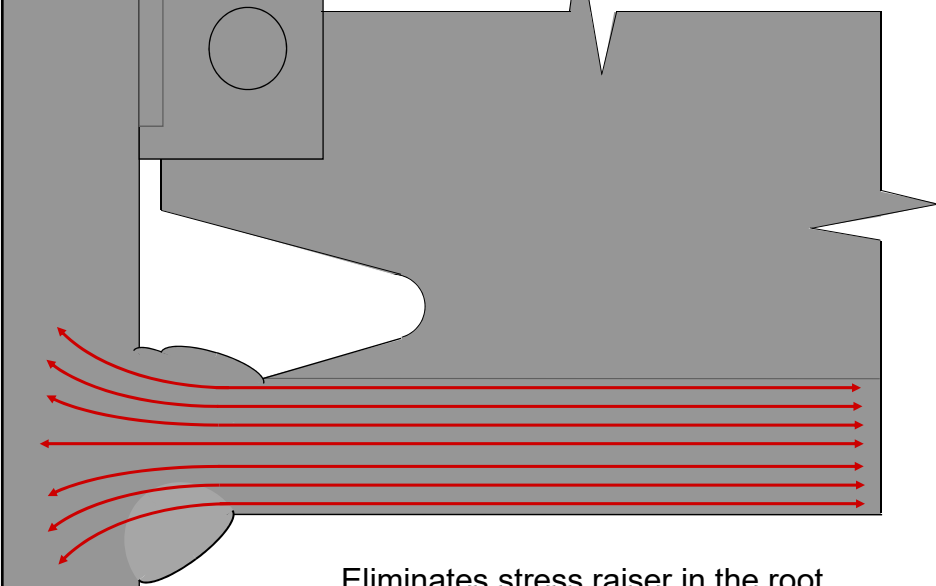
CJP GROOVE WELDS: STEEL BACKING

Remove backing by grinding or gouging

110



CJP GROOVE WELDS: STEEL BACKING



Eliminates stress raiser in the root

113

Welded Connections—
A Primer for
Engineers


CJP GROOVE WELDS: BACKING

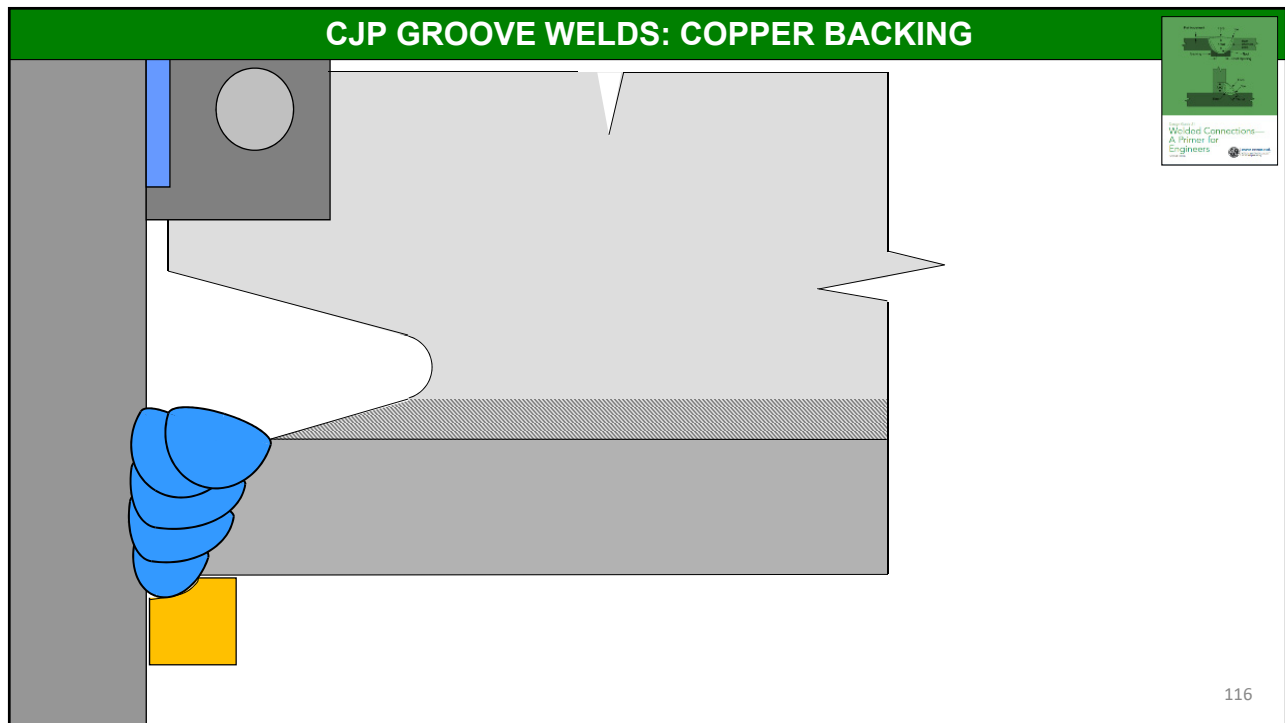
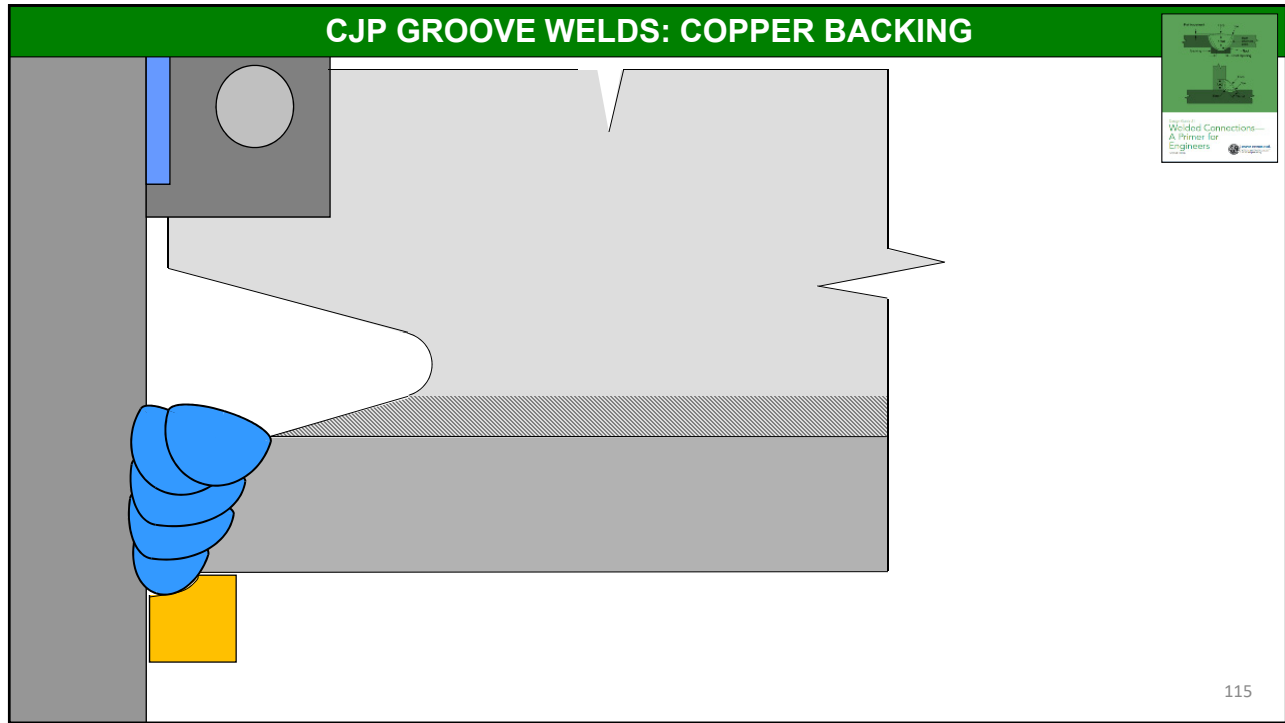
Copper backing:

- Nonfusible
- When properly used, can be easily removed and reused
- If melted, can add copper into the weld metal, which in turn can lead to solidification cracking
- WPSs must be qualified by test (i.e., are not prequalified)

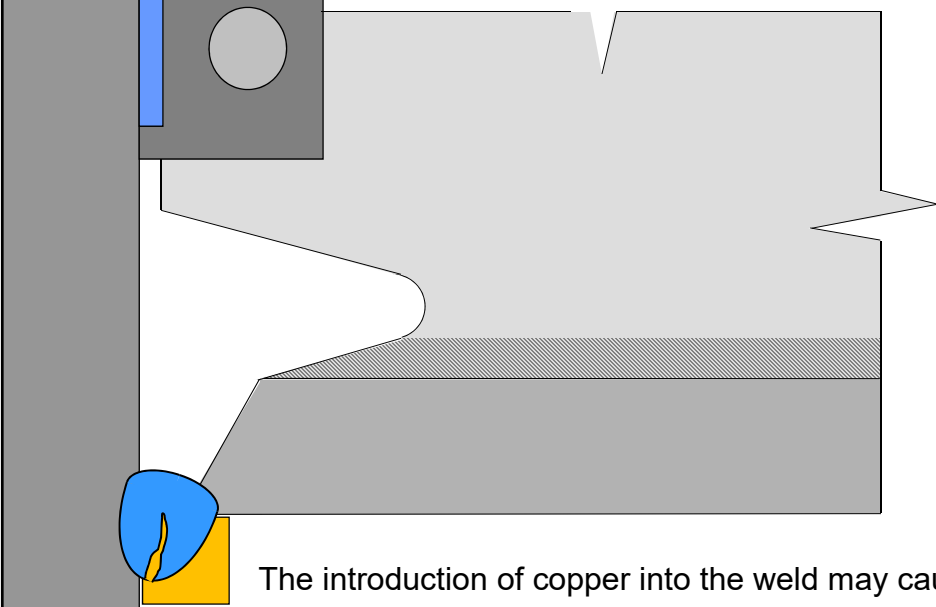
114

Welded Connections—
A Primer for
Engineers





CJP GROOVE WELDS: COPPER BACKING



The introduction of copper into the weld may cause cracking.


117

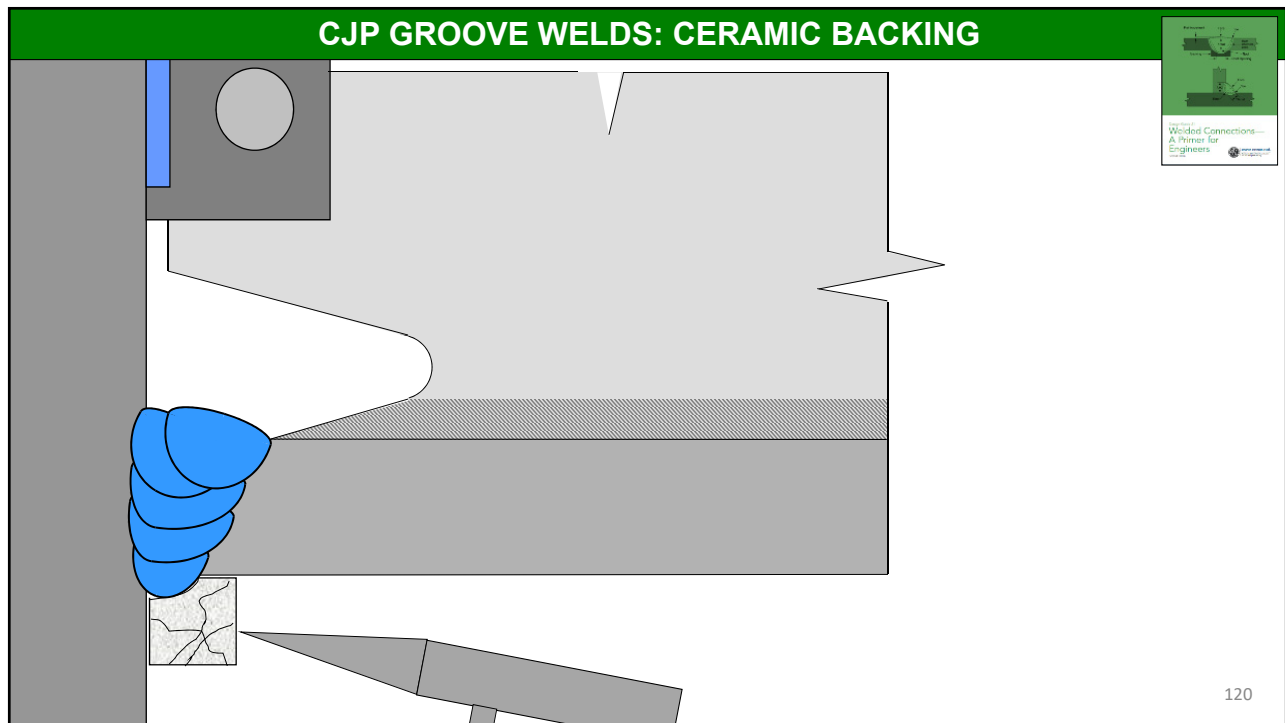
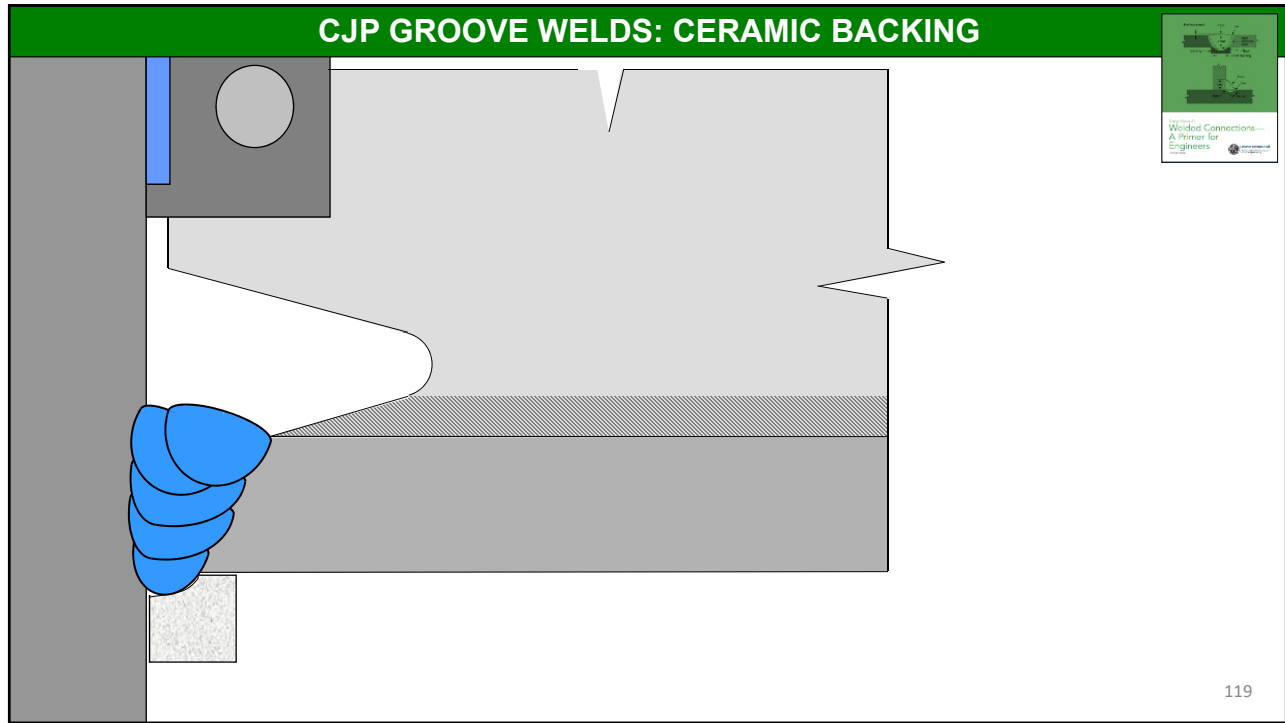
CJP GROOVE WELDS: BACKING

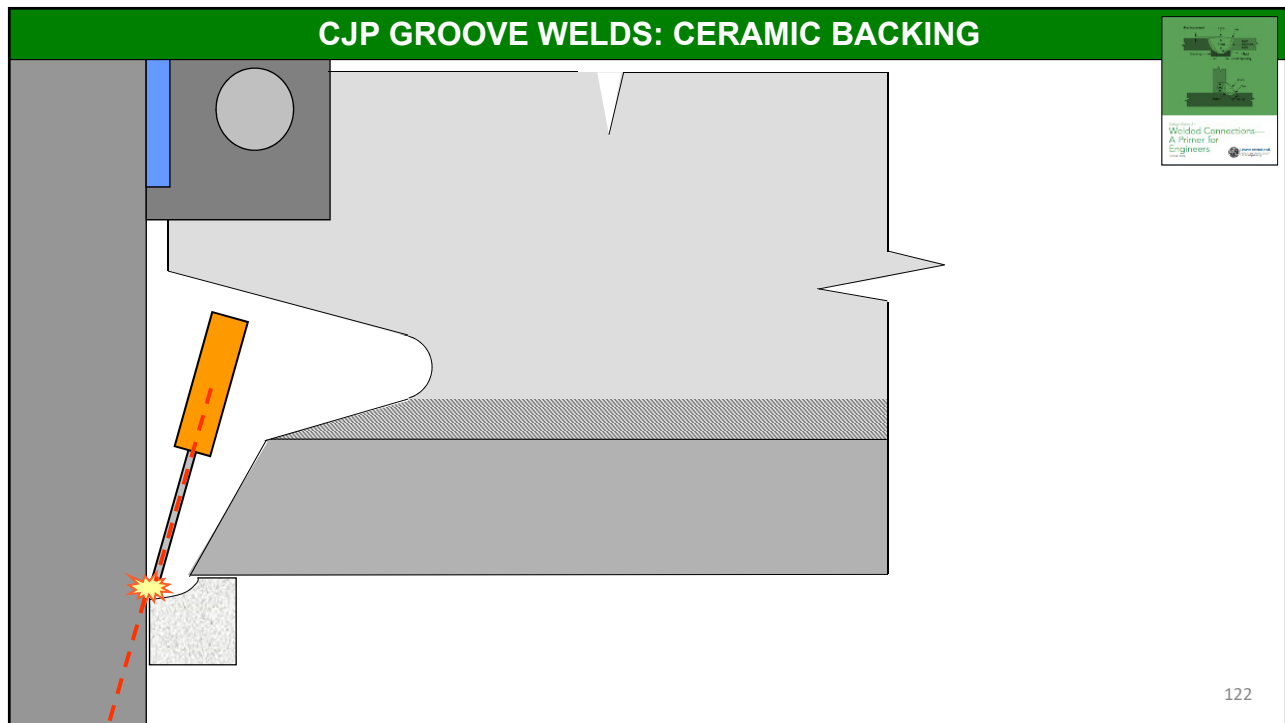
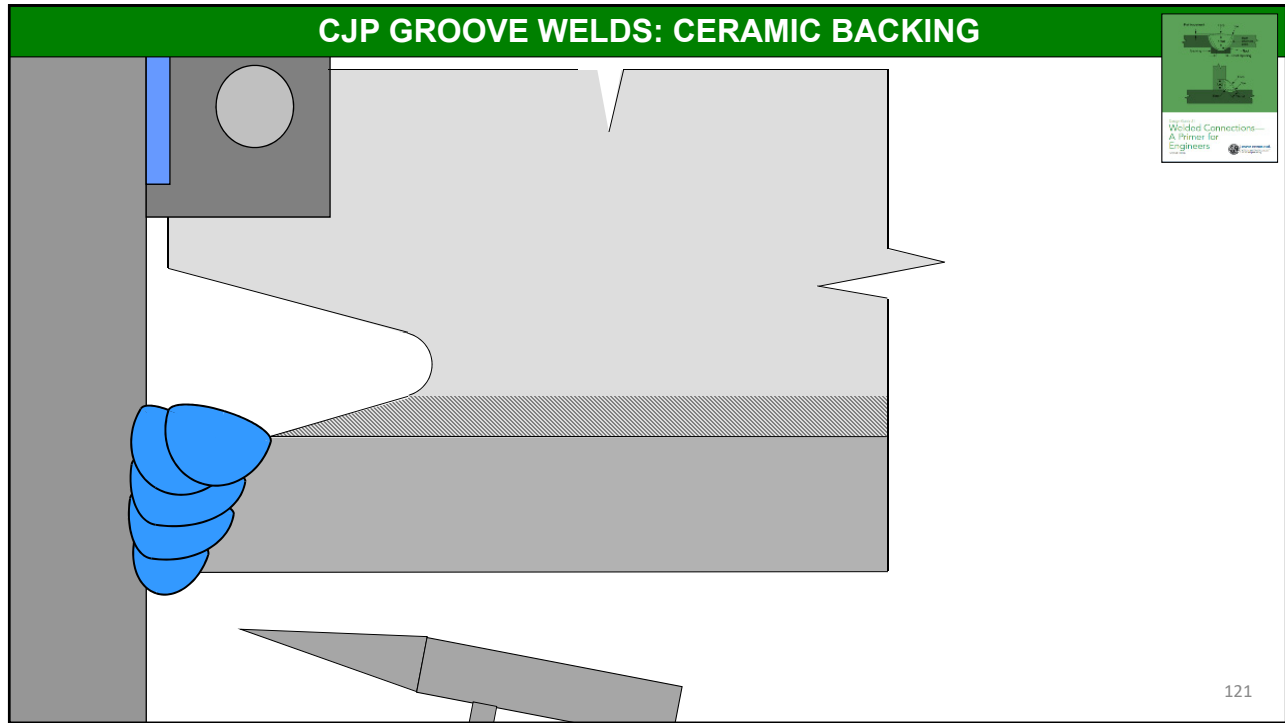
Ceramic backing:

- Nonfusible—easily removed
- Is not electrically conductive which can interfere with welding
- Ceramic is used one time; materials can be expensive
- WPSs must be qualified by test (i.e., are not prequalified)

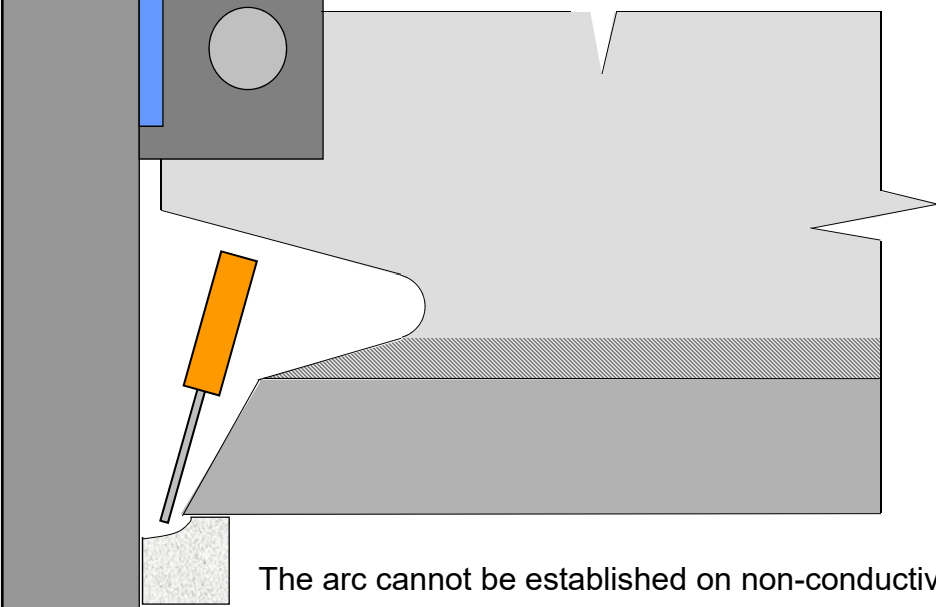
118








CJP GROOVE WELDS: CERAMIC BACKING



The arc cannot be established on non-conductive ceramic

123





AWS D1.1: 2015 Structural Welding Code – Steel

CJP Groove Weld Types

Prequalified versus Qualified by Test

124







AWS D1.1:2015 Prequalified Joints

One sided, with steel backing



Steel



125

AWS D1.1:2015 Prequalified Joints

Two sided, with backgouging



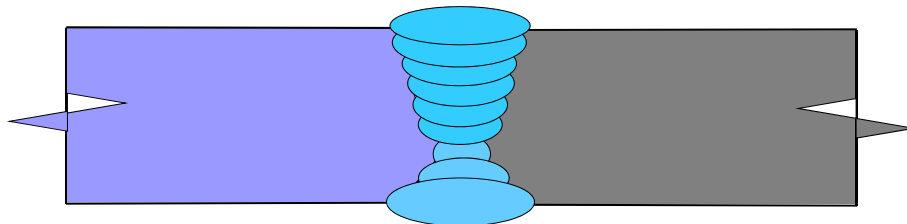
126



127

AWS D1.1:2015 Prequalified Joints

Two sided, with backgouging



128

AWS D1.1:2015 Prequalified Joints

One sided, open root

129

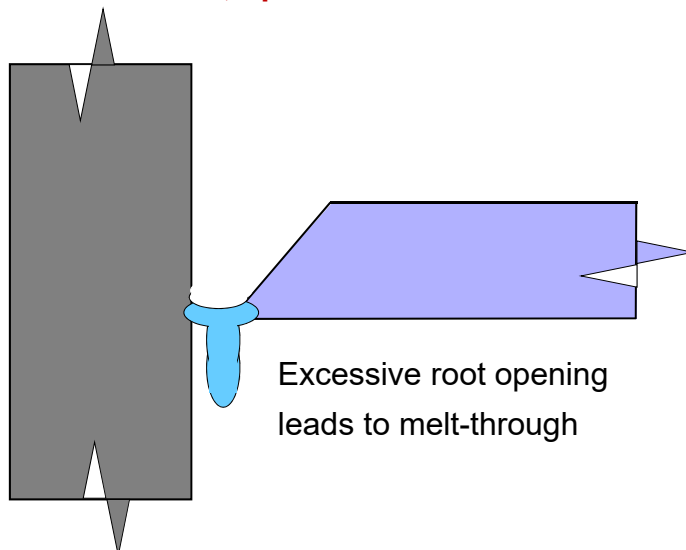
AWS D1.1:2015 Prequalified Joints

One sided, open root

Proper root conditions (root opening, included angle)




130

AWS D1.1:2015 Prequalified Joints



One sided, open root

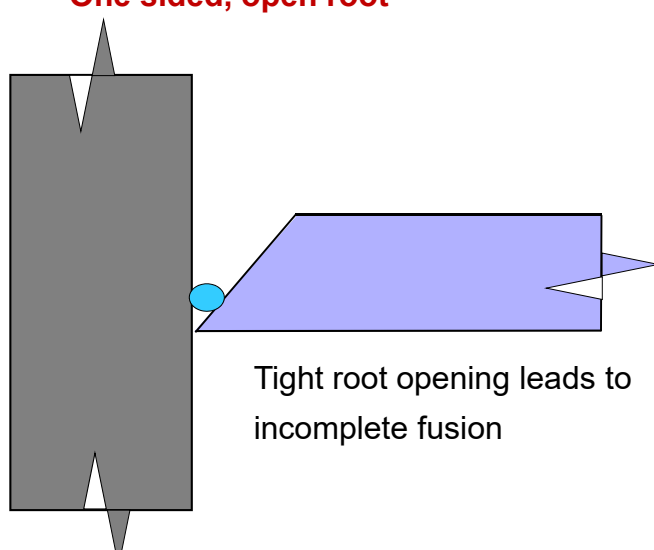
Excessive root opening leads to melt-through



131




Detailed description: This diagram illustrates a joint with a one-sided, open root. A grey vertical plate is on the left, and a blue horizontal plate is on the right. The root opening is significantly larger than the root face, and a blue liquid-like substance is shown dripping from the bottom of the joint, indicating melt-through. A red prohibition sign is placed to the left of the joint. The text 'One sided, open root' is at the top, and 'Excessive root opening leads to melt-through' is at the bottom right. The AISC logo is in the bottom left, and the AWS D1.1:2015 logo is in the top right. The slide number '131' is in the bottom right.

AWS D1.1:2015 Prequalified Joints



One sided, open root

Tight root opening leads to incomplete fusion

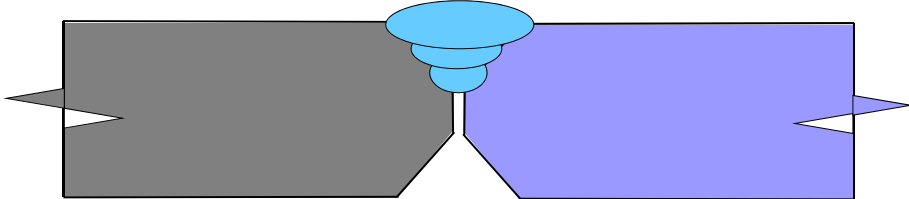



132

Detailed description: This diagram illustrates a joint with a one-sided, open root. A grey vertical plate is on the left, and a blue horizontal plate is on the right. The root opening is very narrow, and a small blue circle is shown at the bottom of the joint, indicating incomplete fusion. A red prohibition sign is placed to the left of the joint. The text 'One sided, open root' is at the top, and 'Tight root opening leads to incomplete fusion' is at the bottom right. The AISC logo is in the bottom left, and the AWS D1.1:2015 logo is in the top right. The slide number '132' is in the bottom right.

AWS D1.1:2015 Prequalified Joints

Two sided, without backgouging

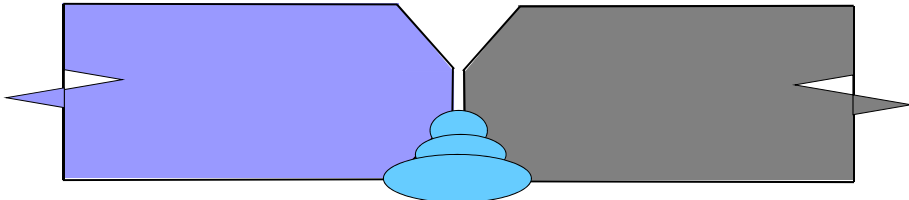





133

AWS D1.1:2015 Prequalified Joints

Two sided, without backgouging

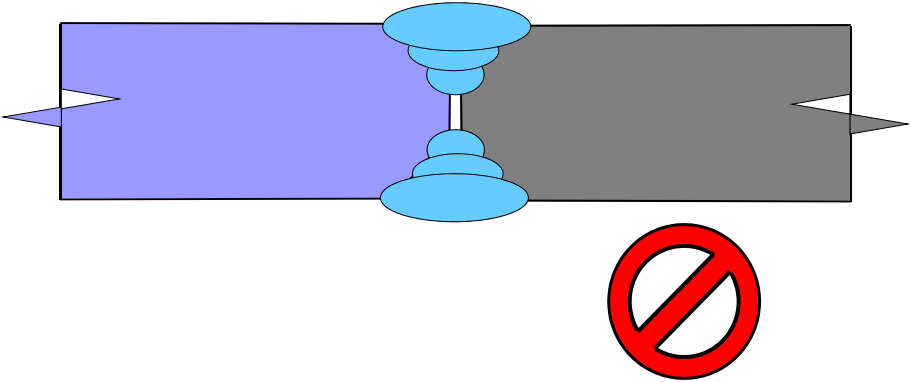






134

AWS D1.1:2015 Prequalified Joints

Two sided, without backgouging



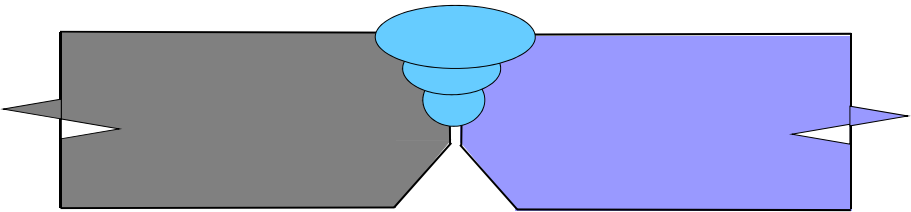
The diagram shows a butt joint between two plates, one light blue and one grey. The joint is welded from both sides, with blue weld metal visible on both the top and bottom surfaces. A red circle with a diagonal slash is placed below the joint, indicating that this configuration is not prequalified under AWS D1.1:2015. The plates have jagged ends on the left and right sides.





135

AWS D1.1:2015 Prequalified Joints

Two sided, without backgouging



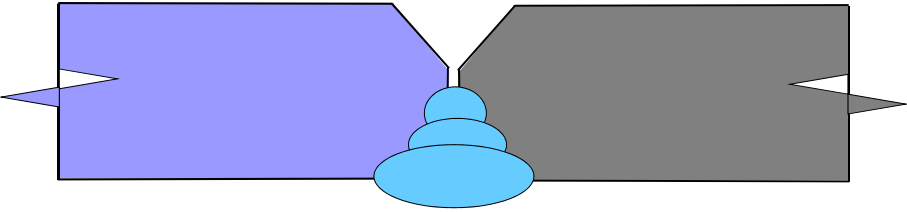
The diagram shows a butt joint between two plates, one grey and one light blue. The joint is welded from both sides, with blue weld metal visible on both the top and bottom surfaces. The plates are beveled at the joint to form a V-groove. The plates have jagged ends on the left and right sides.





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AWS D1.1:2015 Prequalified Joints

Two sided, without backgouging



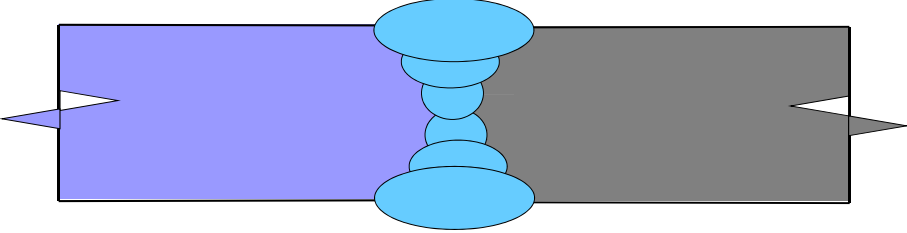






137

AWS D1.1:2015 Prequalified Joints

Two sided, without backgouging

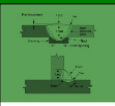







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CJP GROOVE WELDS: BACKING


Welded Connections—
A Primer for
Engineers

Backing materials for steel applications:

- Steel ← Prequalified by AWS D1.1
- Copper } Require qualification testing by AWS D1.1
- Ceramic }




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WELDED CONNECTION DETAILS


Outline

- Joints
- CJP Groove Welds
- • PJP Groove Welds
- Fillet Welds
- Plug and Slot Welds
- Tack Welds
- Weld Metal Strength



140

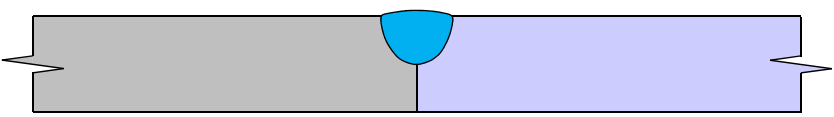
PJP GROOVE WELDS




Welded Connections—
A Primer for
Engineers


Partial Joint Penetration Groove Weld (PJP)

Single sided PJP in butt joint



141

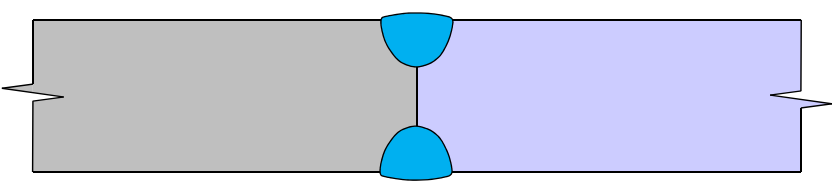
PJP GROOVE WELDS




Welded Connections—
A Primer for
Engineers

Partial Joint Penetration Groove Weld (PJP)

Double sided PJP in butt joint

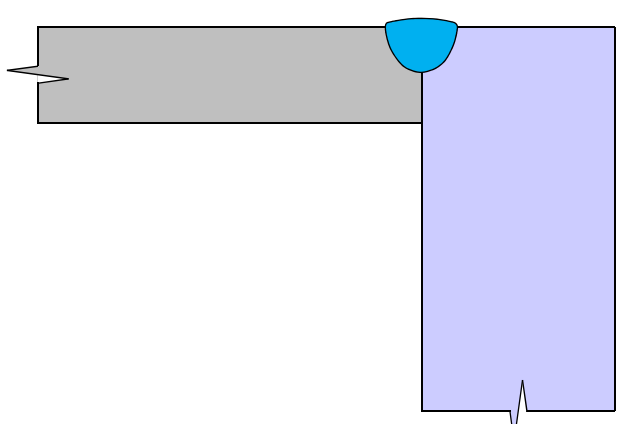


142


PJP GROOVE WELDS

Partial Joint Penetration Groove Weld (PJP)

Single sided PJP in corner joint



Welded Connections—
A Primer for
Engineers

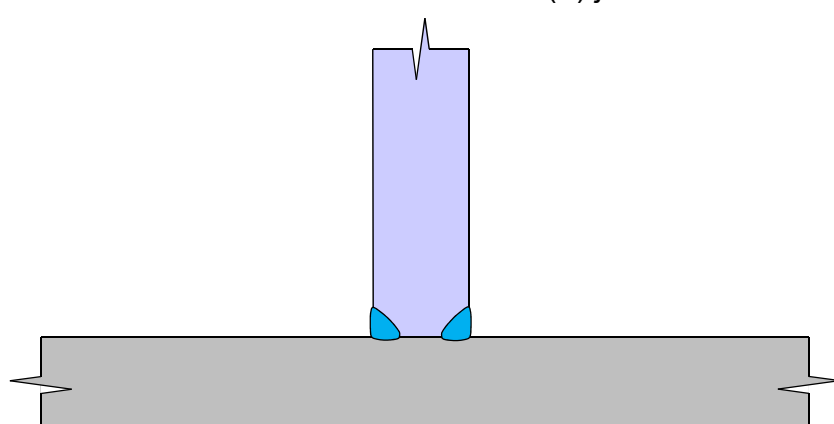


143


PJP GROOVE WELDS

Partial Joint Penetration Groove Weld (PJP)

Double sided PJP in tee (T) joint

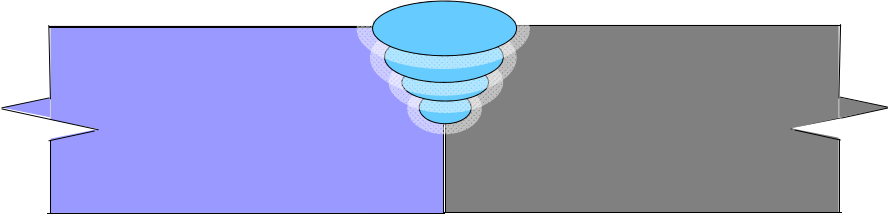


Welded Connections—
A Primer for
Engineers





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PJP GROOVE WELDS

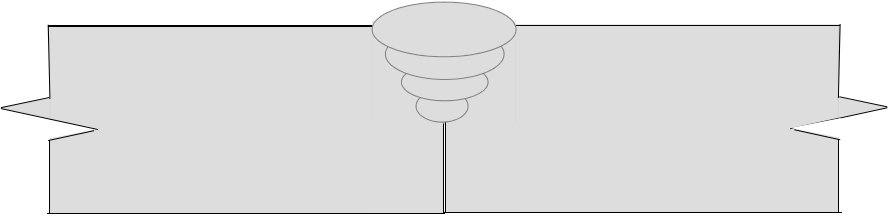


The diagram shows two steel plates, one purple and one grey, joined by a PJP groove weld. The weld is depicted with a blue, multi-layered, conical shape representing the fusion of the metal at the root. The root is fully fused, and the weld metal is shown as a solid, continuous structure.





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PJP GROOVE WELDS

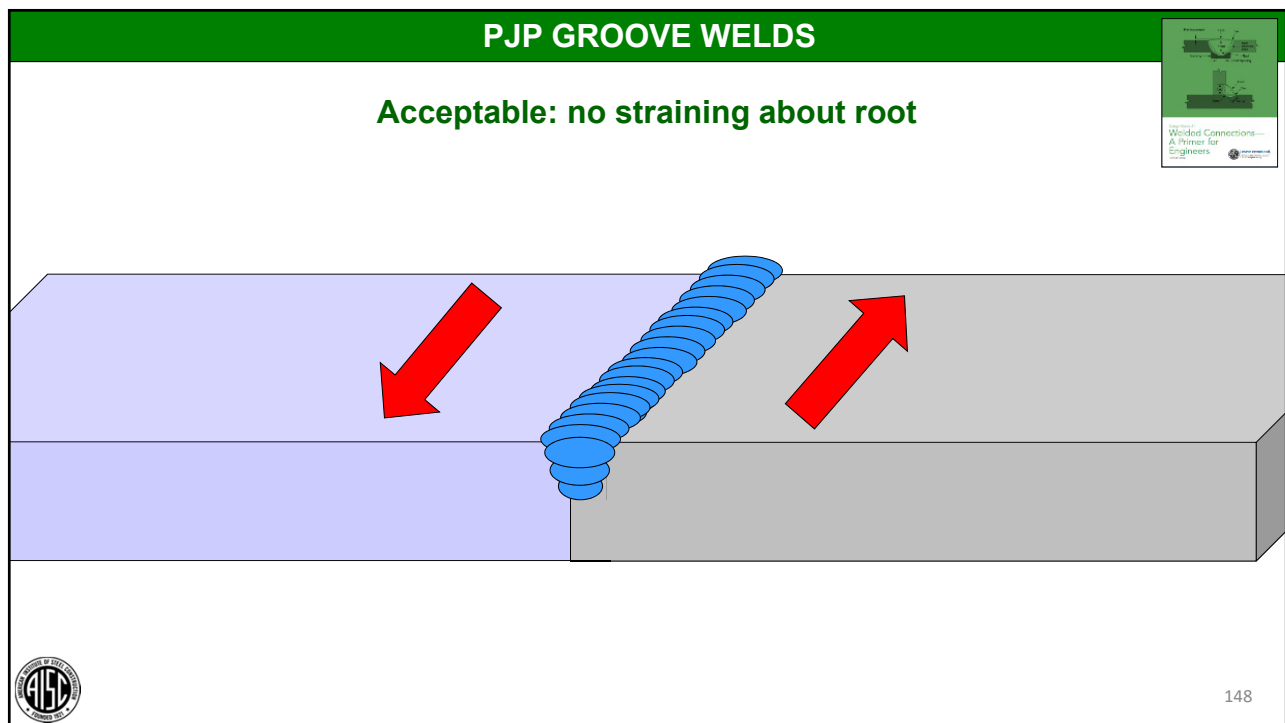
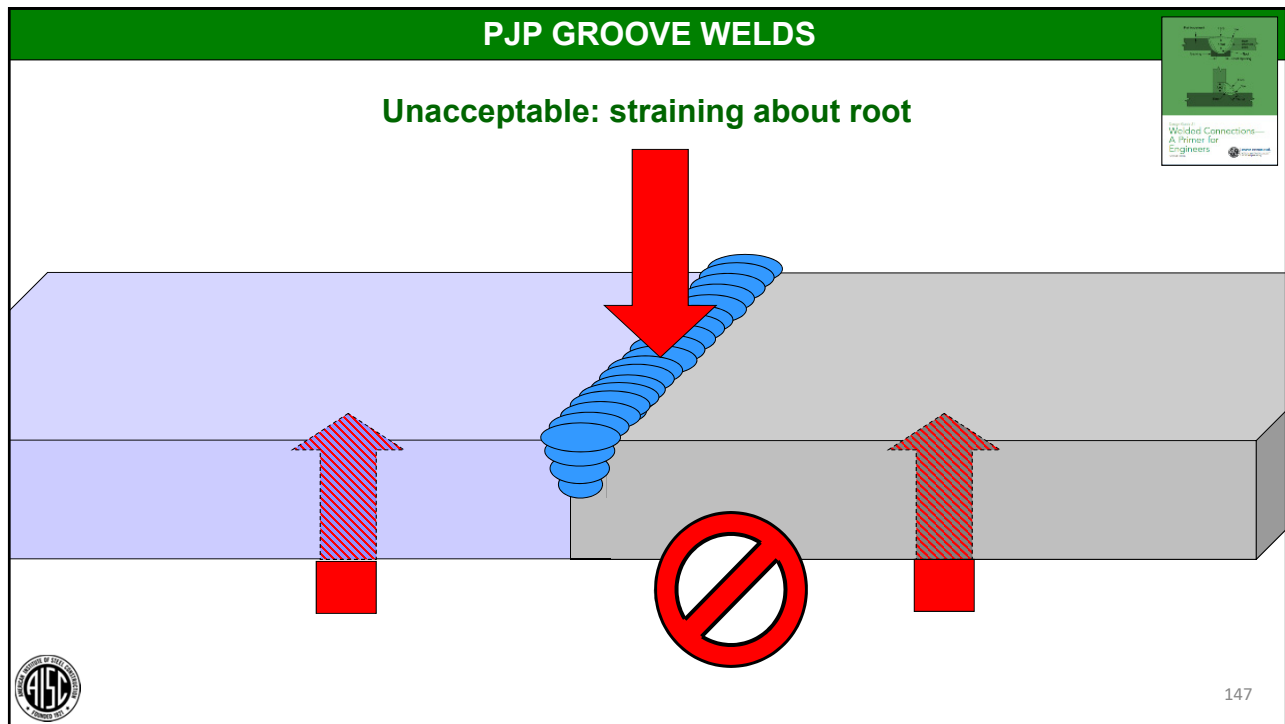


The diagram shows two steel plates, one purple and one grey, joined by a PJP groove weld. The weld is depicted with a grey, multi-layered, conical shape representing the fusion of the metal at the root. The root is unfused, creating a crack-like notch. A red arrow points to the unfused root.

**Unfused root creates a
crack-like notch**



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PJP GROOVE WELDS



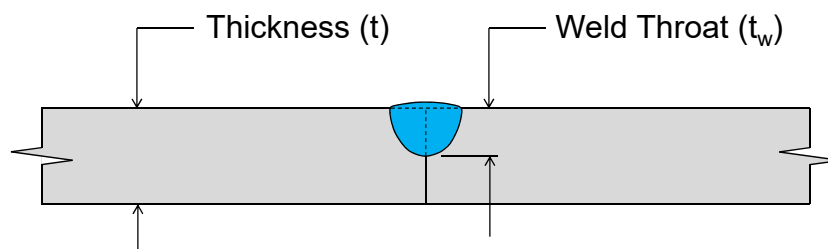
General characteristics of PJP groove welds

- Throat < plate thickness
- Connection designer must determine throat



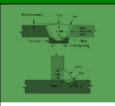
149

PJP GROOVE WELDS



150


PJP GROOVE WELDS



Welded Connections—
A Primer for
Engineers

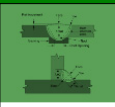
General characteristics of PJP groove welds

- Throat < plate thickness
- Connection designer must determine throat
- “E” dimension (effective throat)
- “S” dimension (depth of bevel)

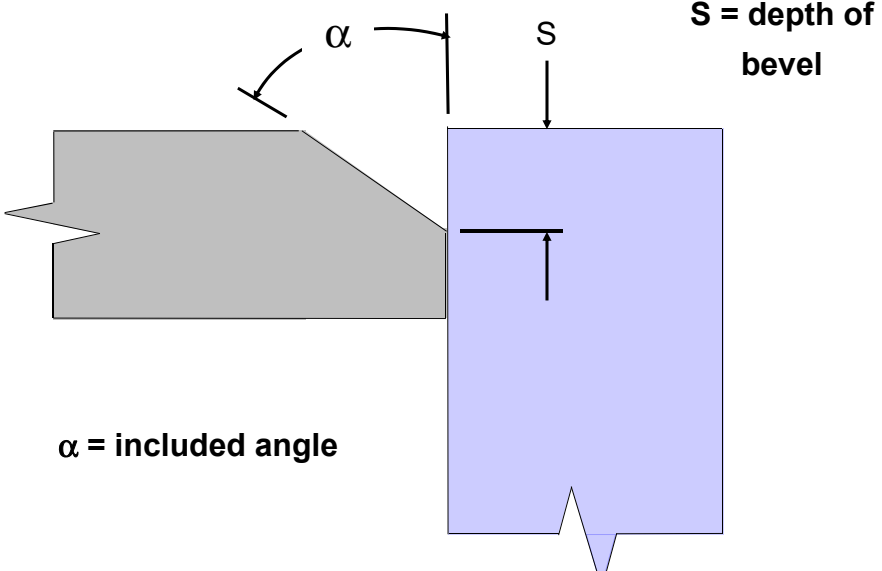


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PJP GROOVE WELDS




Welded Connections—
A Primer for
Engineers

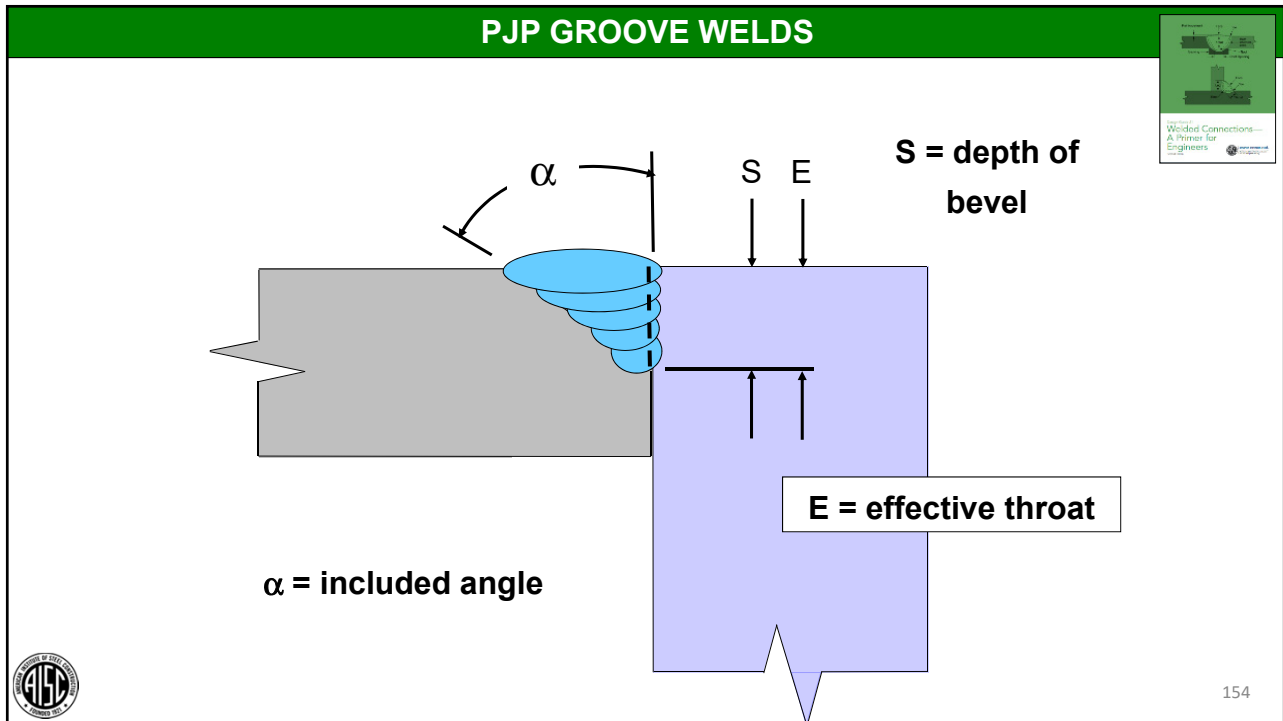
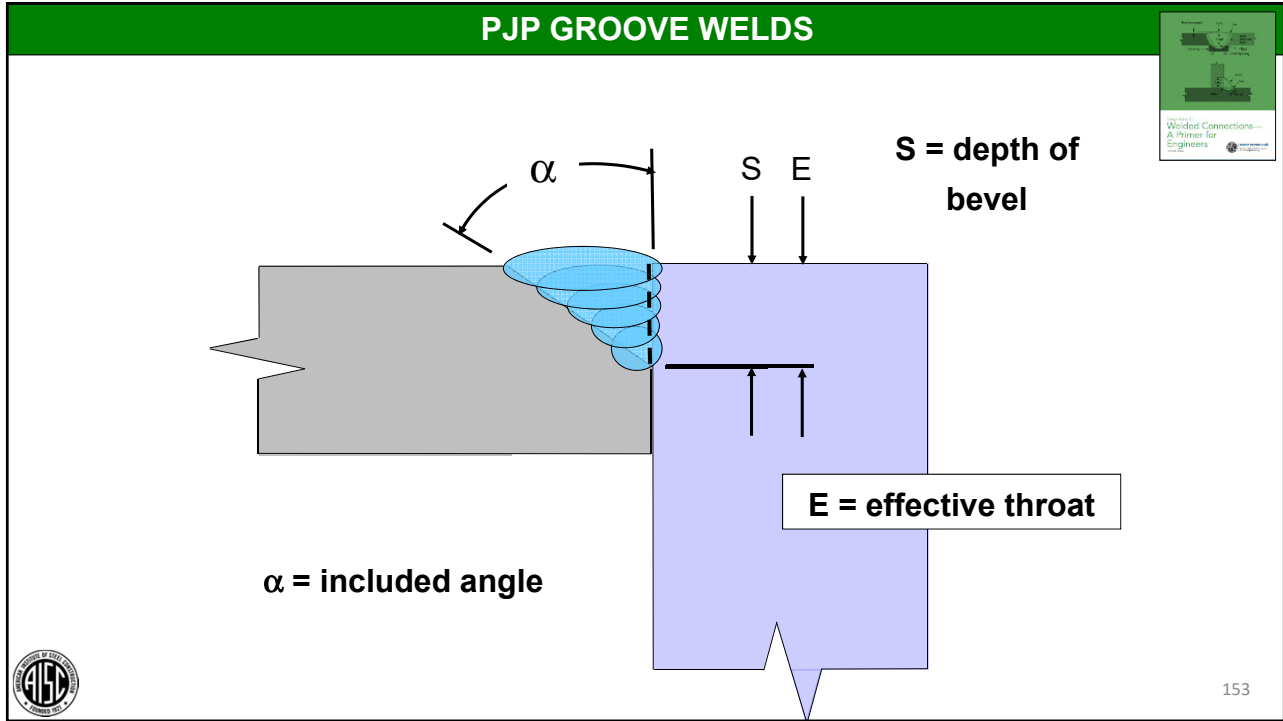


α = included angle

S = depth of bevel



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PJP GROOVE WELDS

α

S

S = depth of bevel



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Detailed description: This diagram illustrates a PJP groove weld. A grey plate on the left is beveled at a 45-degree angle, labeled with the Greek letter alpha (α). A blue plate on the right is shown with a groove cut into its top edge, with a depth labeled 'S'. The bevel of the grey plate fits into the groove of the blue plate. A horizontal line with an upward-pointing arrow indicates the weld line. The text 'S = depth of bevel' is positioned to the right of the diagram. The AISC logo is in the bottom left, and a thumbnail of the book cover is in the top right. The page number '155' is in the bottom right.



PJP GROOVE WELDS

α

S

S = depth of bevel

α reduced in an attempt to save weld metal



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Detailed description: This diagram illustrates a PJP groove weld where the bevel angle is reduced. A grey plate on the left has a bevel angle labeled with the Greek letter alpha (α), which is shown as a smaller angle than in the previous diagram. A blue plate on the right has a groove with depth 'S'. The bevel of the grey plate fits into the groove of the blue plate. A horizontal line with an upward-pointing arrow indicates the weld line. The text 'S = depth of bevel' is positioned to the right of the diagram. Below the grey plate, the text ' α reduced in an attempt to save weld metal' is written. The AISC logo is in the bottom left, and a thumbnail of the book cover is in the top right. The page number '156' is in the bottom right.

PJP GROOVE WELDS

The diagram shows a cross-section of a groove weld joint between a grey plate on the left and a blue plate on the right. The groove is filled with a blue weld metal. The angle of the groove is labeled α . The depth of the groove is labeled S and the depth of the weld metal is labeled E . A text box states "Fusion to the weld is not achieved". A legend indicates "S = depth of bevel".

S = depth of bevel

Fusion to the weld is not achieved





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PJP GROOVE WELDS

The diagram shows a cross-section of a groove weld joint between a grey plate on the left and a blue plate on the right. The groove is filled with a blue weld metal. The angle of the groove is labeled α . The depth of the groove is labeled S and the depth of the weld metal is labeled E . A text box states "When fusion is not achieved to root, $S \neq E$ ".

When fusion is not achieved to root, $S \neq E$



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AISC 360-16 Specification for Structural Steel Buildings

TABLE J2.1
Effective Throat of Partial-Joint-Penetration Groove Welds

Welding Process	Welding Position F (flat), H (horizontal), V (vertical), OH (overhead)	Groove Type (AWS D1.1/D1.1M, Figure 3.3)	Effective Throat
Shielded metal arc (SMAW)	All	J or U groove	depth of groove
Gas metal arc (GMAW) Flux cored arc (FCAW)		60° V	
Submerged arc (SAW)	F	J or U groove 60° bevel or V	
Gas metal arc (GMAW) Flux cored arc (FCAW)	F, H	45° bevel	depth of groove
Shielded metal arc (SMAW)	All	45° bevel	depth of groove minus 1/8 in. (3 mm)
Gas metal arc (GMAW) Flux cored arc (FCAW)	V, OH		

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AWS D1.1: 2015 Structural Welding Code – Steel

Figure 3.2

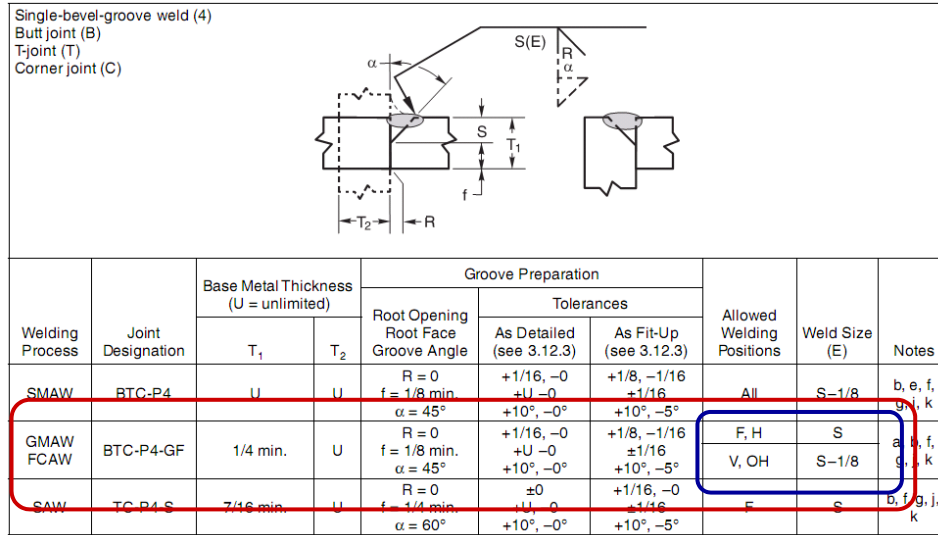
Single-bevel-groove weld (4)
 Butt joint (B)
 T-joint (T)
 Corner joint (C)

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 3.12.3)	As Fit-Up (see 3.12.3)			
SMAW	BTC-P4	U	U	R = 0 f = 1/8 min. α = 45°	+1/16, -0 +U -0 +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S-1/8	d, e, f, g, j, k
GMAW FCAW	BTC-P4-GF	1/4 min.	U	R = 0 f = 1/8 min. α = 45°	+1/16, -0 +U -0 +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	F, H V, OH	S S-1/8	a, b, f, g, j, k
SAW	TC-P4-S	7/16 min.	U	R = 0 f = 1/4 min. α = 60°	±0 +U, -0 +10°, -0°	+1/16, -0 ±1/16 +10°, -5°	F	S	b, f, g, j, k

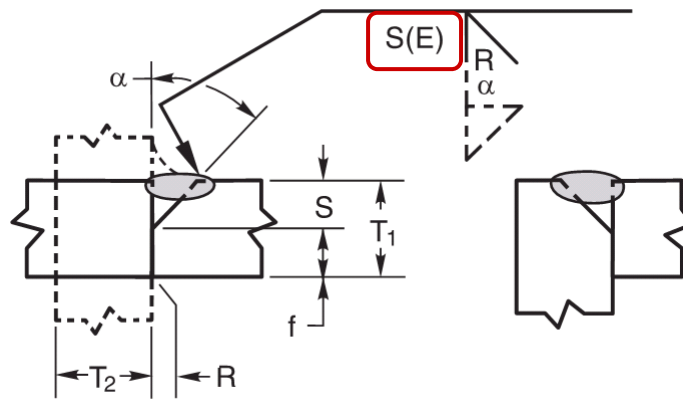
160

AWS D1.1: 2015 Structural Welding Code – Steel


Figure 3.2



AWS D1.1: 2015 Structural Welding Code – Steel




PJP GROOVE WELDS



Welded Connections—
A Primer for
Engineers

General characteristics of PJP groove welds


- Throat < plate thickness
- Connection designer must determine throat
- “E” dimension (effective throat)
- “S” dimension (depth of bevel)
- The Connection Designer (the **E**ngineer) specifies the **E** dimension
- The **S**hop (the detailer) determines the required **S** dimension



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AWS D1.1: 2015 Structural Welding Code – Steel

Coming in the future:



AWS D1.1: 2015
Structural Welding Code—
Steel

General characteristics of PJP groove welds


- Throat < plate thickness
- Connection designer must determine throat
- **S** dimension

Size

- **D** dimension


Depth

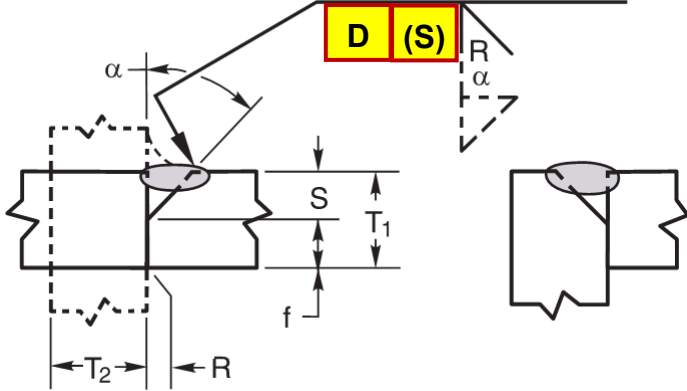
- The Connection Designer (the **E**ngineer) specifies the **E** dimension
- The **S**hop (the detailer) determines the required **S** dimension




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Note: the sequence on symbol doesn't change.


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PJP GROOVE WELDS



Minimum sizes of PJP groove welds

- AISC Table J2.3
- AWS D1.1 Table 3.5

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AISC 360-16 Specification for Structural Steel Buildings	
TABLE J2.3 Minimum Effective Throat of Partial-Joint-Penetration Groove Welds	
Material Thickness of Thinner Part Joined, in. (mm)	Minimum Effective Throat, ^[a] in. (mm)
To 1/4 (6) inclusive	1/8 (3)
Over 1/4 (6) to 1/2 (13)	3/16 (5)
Over 1/2 (13) to 3/4 (19)	1/4 (6)
Over 3/4 (19) to 1 1/2 (38)	5/16 (8)
Over 1 1/2 (38) to 2 1/4 (57)	3/8 (10)
Over 2 1/4 (57) to 6 (150)	1/2 (13)
Over 6 (150)	5/8 (16)


^[a] See Table J2.1.

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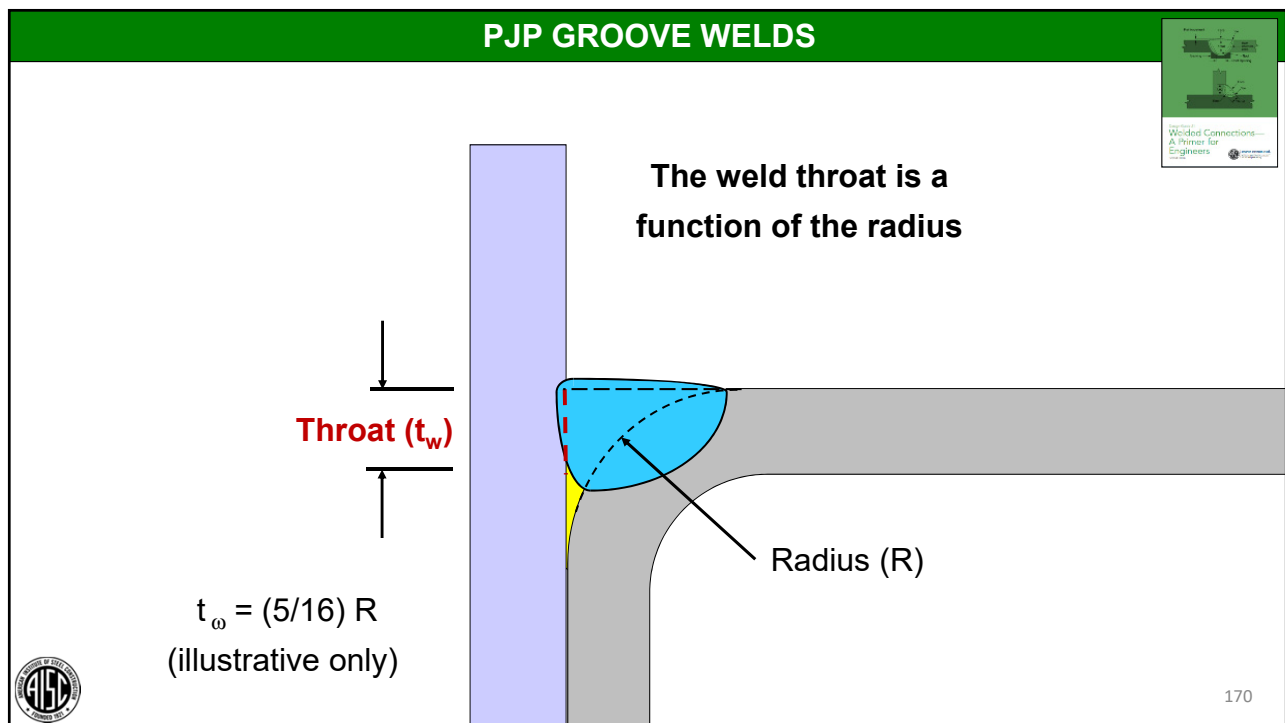
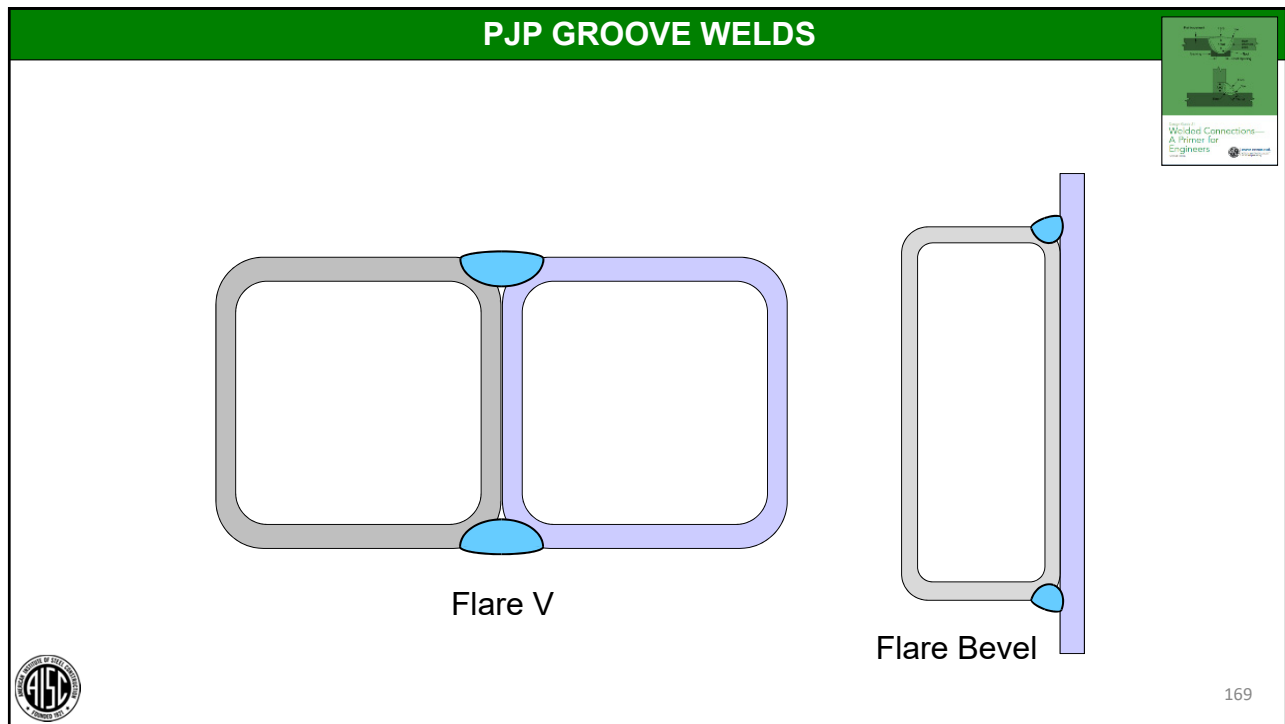
PJP GROOVE WELDS

Minimum sizes of PJP groove welds

- AISC Table J2.3
- AWS D1.1 Table 3.5
- Has nothing to do with design
- Deals with ensuring adequate heat input for fusion and fabrication-related cracking resistance
- Helps achieve some reasonable proportionality between plate thickness and weld size
- These are minimum weld sizes; larger welds can be used



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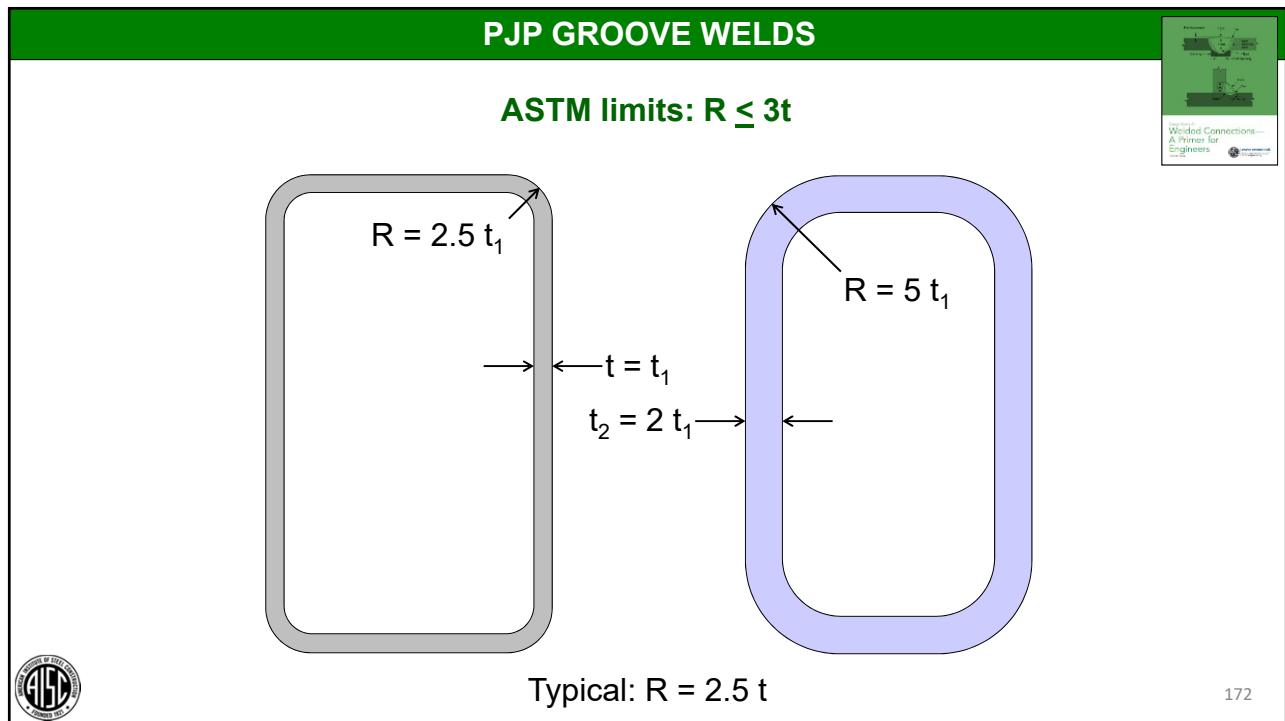


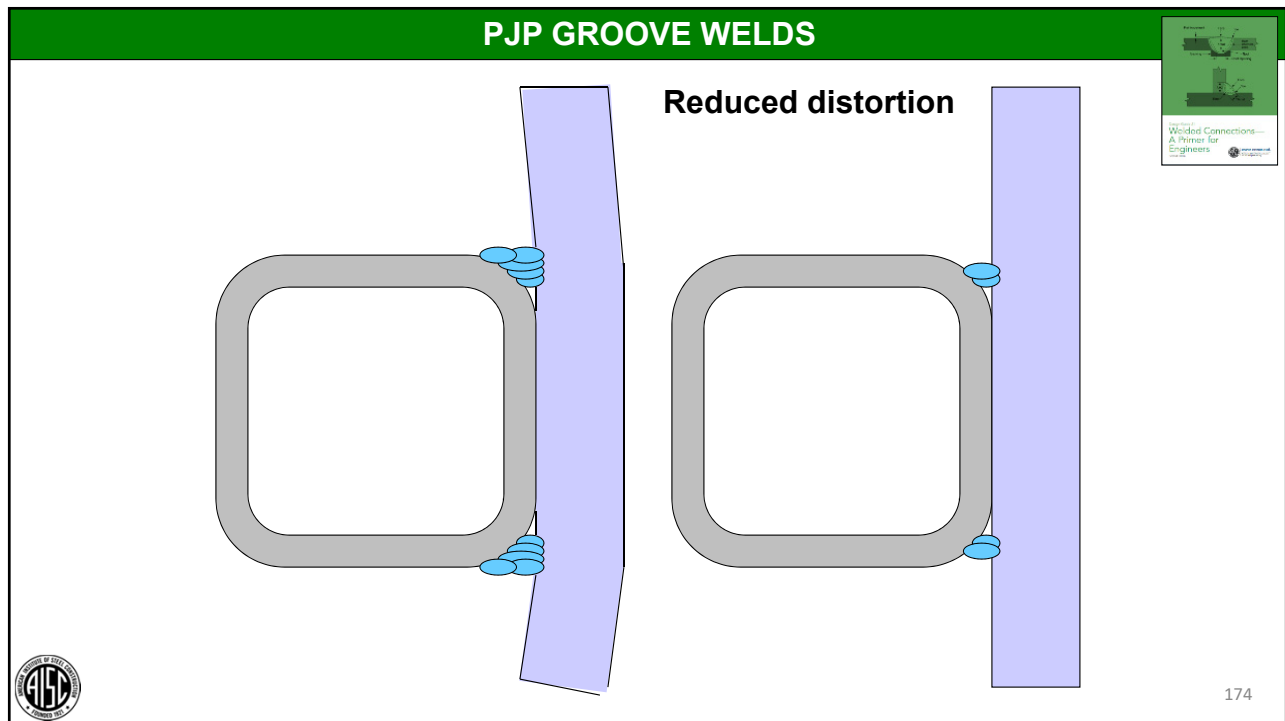
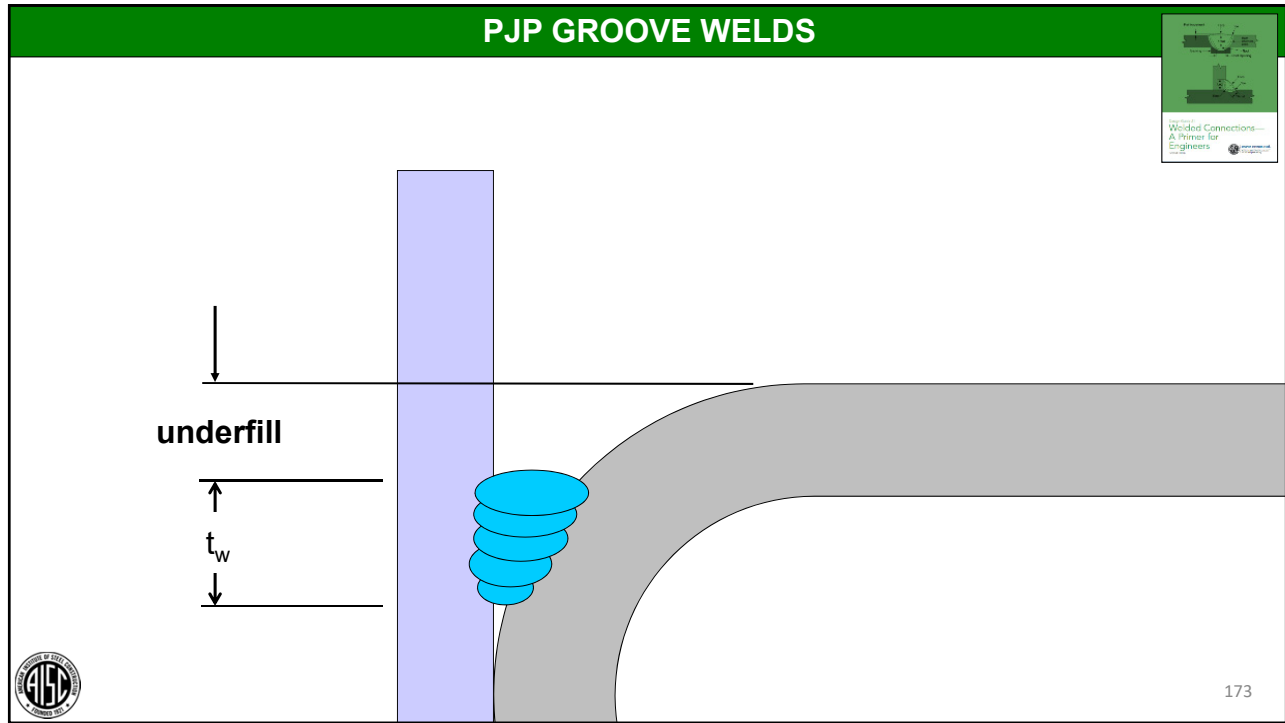
AISC 360-16 Specification for Structural Steel Buildings

TABLE J2.2
 Effective Throat of Flare Groove Welds

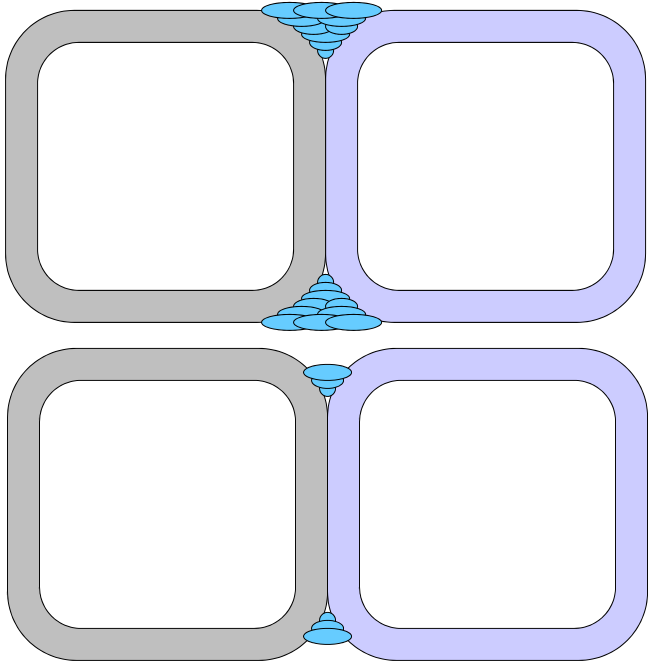
Welding Process	Flare-Bevel	Flare-Vee
SMAW FCAW-S	5/16 R	5/8 R
GMAW FCAW-G	5/8 R	3/4 R
SAW	5/16 R	1/2 R

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PJP GROOVE WELDS




Reduced cost



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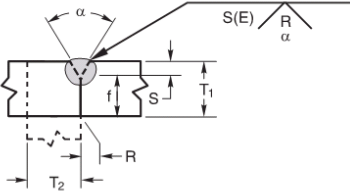
AWS D1.1: 2015 Structural Welding Code – Steel



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Single V Groove Weld: PJP

Single-V-groove weld (2)
 Butt joint (B)
 Corner joint (C)



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
				Root Opening Root Face Groove Angle	Tolerances				
		T ₁	T ₂		As Detailed (see 3.12.3)	As Fit-Up (see 3.12.3)			
SMAW	BC-P2	1/4 min.	U	R = 0 f = 1/32 min. α = 60°	+1/16, -0 +U, -0 +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S	b, e, f, j
GMAW FCAW	BC-P2-GF	1/4 min.	U	R = 0 f = 1/8 min. α = 60°	+1/16, -0 +U, -0 +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S	a, b, f, j
SAW	BC-P2-S	7/16 min.	U	R = 0 f = 1/4 min. α = 60°	±0 +U, -0 +10°, -0°	+1/16, -0 ±1/16 +10°, -5°	F	S	b, f, j

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Double V Groove Weld: PJP

Double-V-groove weld (3)
 Butt joint (B)

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Total Weld Size (E ₁ + E ₂)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 3.12.3)	As Fit-Up (see 3.12.3)			
SMAW	B-P3	1/2 min.	—	R = 0 f = 1/8 min. α = 60°	+1/16, -0 +U, -0 +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S ₁ + S ₂	e, f, i, j
GMAW FCAW	B-P3-GF	1/2 min.	—	R = 0 f = 1/8 min. α = 60°	+1/16, -0 +U, -0 +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S ₁ + S ₂	a, f, i, j
SAW	B-P3-S	3/4 min.	—	R = 0 f = 1/4 min. α = 60°	±0 +U, -0 +10°, -0°	+1/16, -0 ±1/16 +10°, -5°	F	S ₁ + S ₂	f, i, j



AWS D1.1: 2015 Structural Welding Code – Steel



Single Bevel Groove Weld: PJP

Single-bevel-groove weld (4)
 Butt joint (B)
 T-joint (T)
 Corner joint (C)

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 3.12.3)	As Fit-Up (see 3.12.3)			
SMAW	BTC-P4	U	U	R = 0 f = 1/8 min. α = 45°	+1/16, -0 +U -0 +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S-1/8	b, e, f, g, j, k
GMAW FCAW	BTC-P4-GF	1/4 min.	U	R = 0 f = 1/8 min. α = 45°	+1/16, -0 +U -0 +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	F, H V, OH	S	a, b, f, g, j, k
SAW	TC-P4-S	7/16 min.	U	R = 0 f = 1/4 min. α = 60°	±0 +U, -0 +10°, -0°	+1/16, -0 ±1/16 +10°, -5°	F	S	b, f, g, j, k



AWS D1.1: 2015 Structural Welding Code – Steel



Single U Groove Weld: PJP

Single-U-groove weld (6)
 Butt joint (B)
 Corner joint (C)

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening Root Face Bevel Radius Groove Angle	As Detailed (see 3.12.3)	As Fit-Up (see 3.12.3)			
SMAW	BC-P6	1/4 min.	U	R = 0 f = 1/32 min. r = 1/4 α = 45°	+1/16, -0 +U, -0 +1/4, -0 +10°, -0°	+1/8, -1/16 ±1/16 ±1/16 +10°, -5°	All	S	b, e, f, j
GMAW FCAW	BC-P6-GF	1/4 min.	U	R = 0 f = 1/8 min. r = 1/4 α = 20°	+1/16, -0 +U, -0 +1/4, -0 +10°, -0°	+1/8, -1/16 ±1/16 ±1/16 +10°, -5°	All	S	a, b, f, j
SAW	BC-P6-S	7/16 min.	U	R = 0 f = 1/4 min. r = 1/4 α = 20°	±0 +U, -0 +1/4, -0 +10°, -0°	+1/16, -0 ±1/16 ±1/16 +10°, -5°	F	S	b, f, j



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AWS D1.1: 2015 Structural Welding Code – Steel



Flare Bevel Groove Weld: PJP


Flare-bevel-groove weld (10)
 Butt joint (B)
 T-joint (T)
 Corner joint (C)

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)			Groove Preparation		Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	T ₃	Root Opening Root Face Bend Radius	Tolerances As Detailed (see 3.12.3) As Fit-Up (see 3.12.3)			
SMAW FCAW-S	BTC-P10	3/16 min.	U	T ₁ min.	R = 0 f = 3/16 min. 3T ₁ r = 1/2 min.	+1/16, -0 +U, -0 +U, -0	+1/8, -1/16 +U, -1/16 +U, -0	All	5/16 r e, g, j, l
GMAW FCAW-G	BTC-P10-GF	3/16 min.	U	T ₁ min.	R = 0 f = 3/16 min. 3T ₁ r = 1/2 min.	+1/16, -0 +U, -0 +U, -0	+1/8, -1/16 +U, -1/16 +U, -0	All	5/8 r a, g, j, l, m
SAW	B-P10-S	1/2 min.	N/A	1/2 min.	R = 0 f = 1/2 min. 3T ₁ r = 1/2 min.	±0 +U, -0 +U, -0	+1/16, -0 +U, -1/16 +U, -0	F	5/16 r g, j, l, m

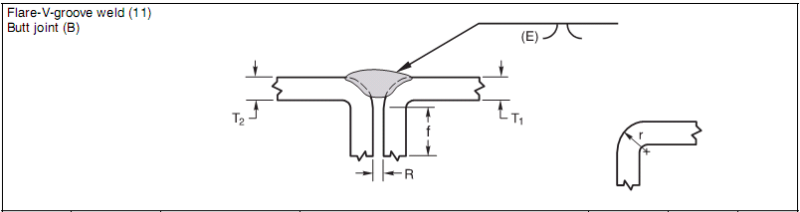


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AWS D1.1: 2015 Structural Welding Code – Steel



Flare V Groove Weld: PJP




Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening	Tolerances				
					Root Face	As Detailed (see 3.12.3)			
SMAW FCAW-S	B-P11	3/16 min.	T ₁ min.	R = 0 f = 3/16 min. 3T ₁ r = $\frac{3T_1}{2}$ min.	+1/16, -0 +U, -0 +U, -0	+1/8, -1/16 +U, -1/16 +U, -0	All	5/8 r	e, j, l, m, n
GMAW FCAW-G	B-P11-GF	3/16 min.	T ₁ min.	R = 0 f = 3/16 min. 3T ₁ r = $\frac{3T_1}{2}$ min.	+1/16, -0 +U, -0 +U, -0	+1/8, -1/16 +U, -1/16 +U, -0	All	3/4 r	a, j, l, m, n
SAW	B-P11-S	1/2 min.	T ₁ min.	R = 0 f = 1/2 min. 3T ₁ r = $\frac{3T_1}{2}$ min.	±0 +U, -0 +U, -0	+1/16, -0 +U, -1/16 +U, -0	F	1/2 r	j, l, m, n

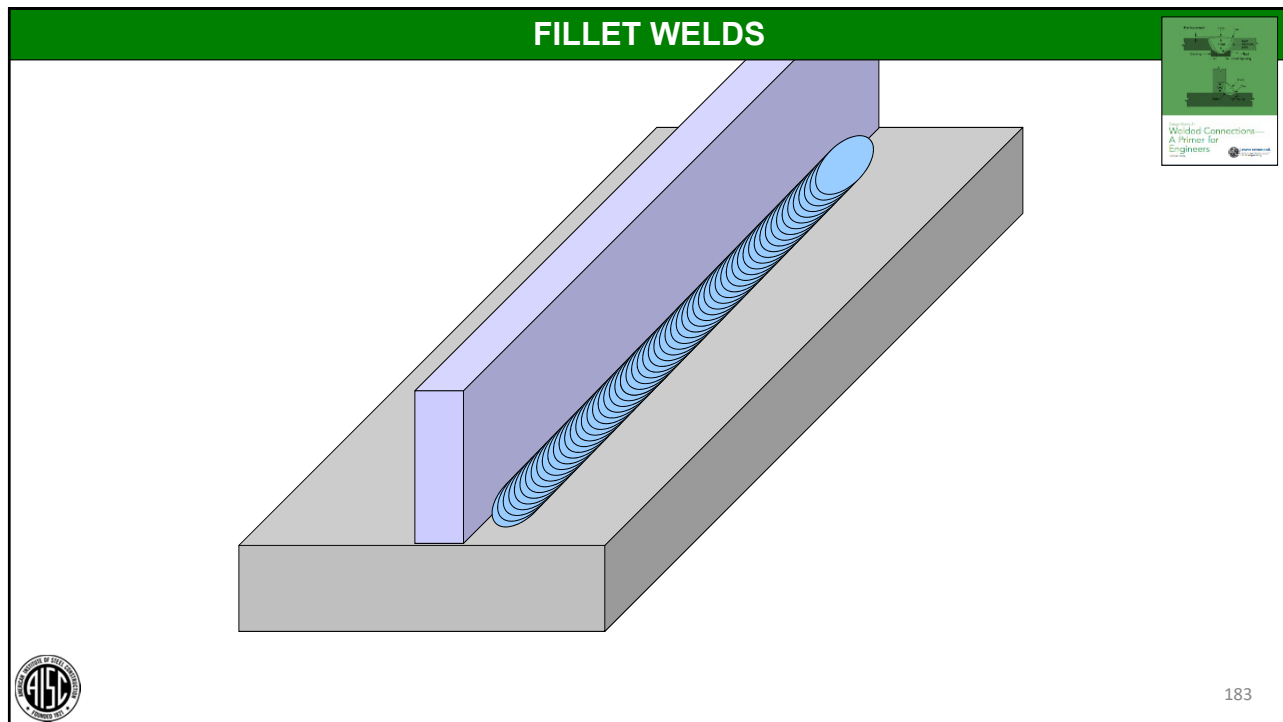

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WELDED CONNECTION DETAILS

Outline

- Joints
- CJP Groove Welds
- PJP Groove Welds
- ➔ • Fillet Welds
- Plug and Slot Welds
- Tack Welds
- Weld Metal Strength


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AISC 360-16 Specification for Structural Steel Buildings

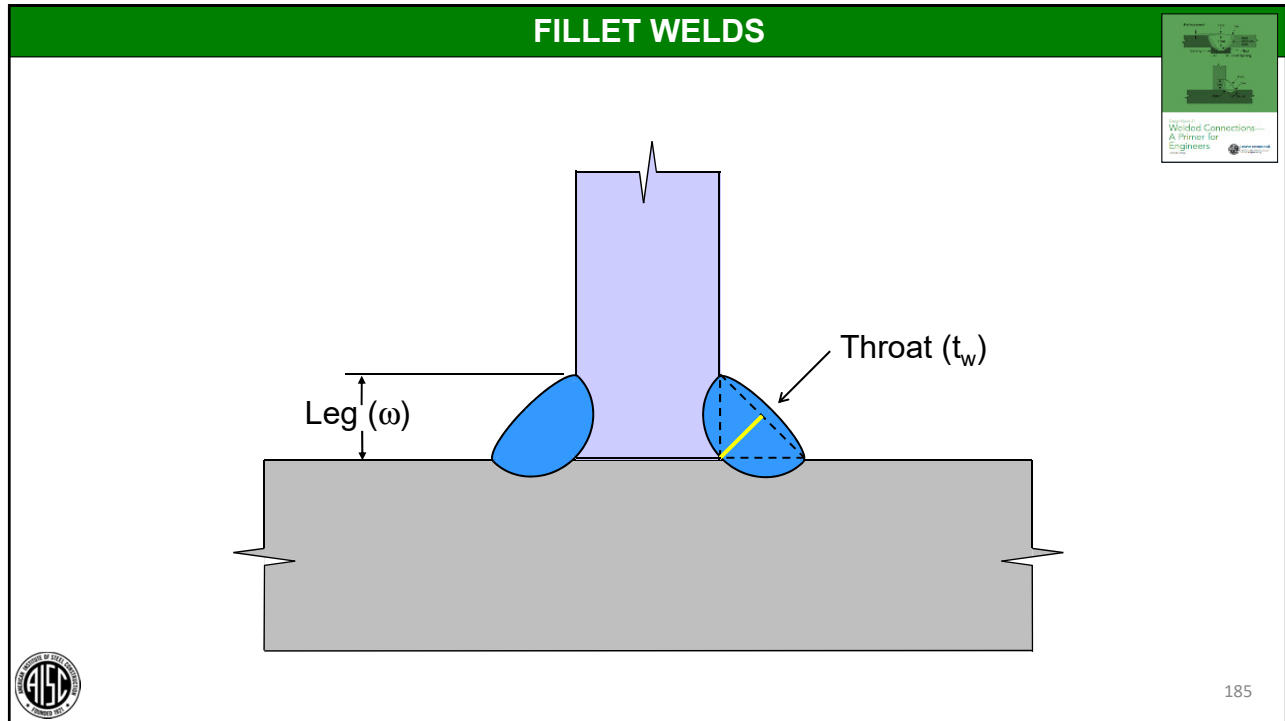
J2.2 Fillet Welds

2a. Effective Area


The effective area of a fillet weld shall be the effective length multiplied by the effective throat. **The effective throat of a fillet weld shall be the shortest distance from the root to the face of the diagrammatic weld.** An increase in effective throat is permitted if consistent penetration beyond the root of the diagrammatic weld is demonstrated using the projection process and procedure variables.



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AISC 360-16 Specification for Structural Steel Buildings




J2.2 Fillet Welds

2b. Limitations

Fillet welds shall meet the following limitations:

(a) The minimum size of fillet welds shall be not less than the size required to transmit calculated forces, nor the size as shown in Table J2.4.

These provisions do not apply to fillet weld reinforcements of PJP or CJP groove welds.


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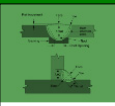


TABLE J2.4
 Minimum Size of Fillet Welds

Material Thickness of Thinner Part Joined, in. (mm)	Minimum Size of Fillet Weld, in. (mm)
To 1/4 (6), inclusive	1/8 (3)
Over 1/4 (6) to 1/2 (13)	3/16 (5)
Over 1/2 (13) to 3/4 (19)	1/4 (6)
Over 3/4 (19)	5/16 (8)


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FILLET WELDS



Welded Connections—
A Primer for
Engineers

Minimum sizes of fillet welds

- AISC Table J2.4
- AWS D1.1 Table 5.7
- Has nothing to do with design
- Deals with ensuring adequate heat input for fusion and fabrication-related cracking resistance
- Helps achieve some reasonable proportionality between plate thickness and weld size
- These are minimum weld sizes; larger welds can be used



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Fillet Welds



Welded Connections—
A Primer for
Engineers

Maximum sizes of fillet welds



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J2.2 Fillet Welds

2b. Limitations

Fillet welds shall meet the following limitations:

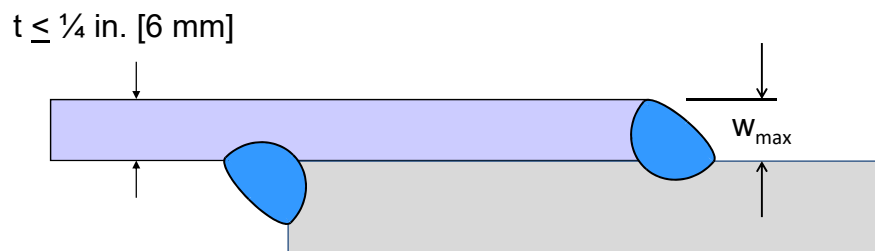
- (b) The maximum size of fillet welds of connected parts shall be:
 - (1) Along edges of material less than 1/4 in. (6 mm) thick, not greater than the thickness of the material.

Also addressed in AWS D1.1:2015 clause 2.4.2.9

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Maximum Fillet Weld Size

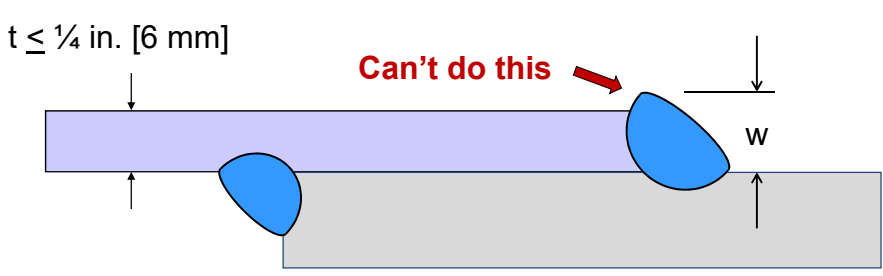


- (b) The maximum size of fillet welds of connected parts shall be:
 - (1) Along edges of material less than 1/4 in. (6 mm) thick, not greater than the thickness of the material.



AISC 360-16 Specification for Structural Steel Buildings

Maximum Fillet Weld Size



(b) The maximum size of fillet welds of connected parts shall be:

- (1) Along edges of material less than 1/4 in. (6 mm) thick, not greater than the thickness of the material.

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AISC 360-16 Specification for Structural Steel Buildings

J2.2 Fillet Welds

2b. Limitations


Fillet welds shall meet the following limitations:

(b) The maximum size of fillet welds of connected parts shall be:

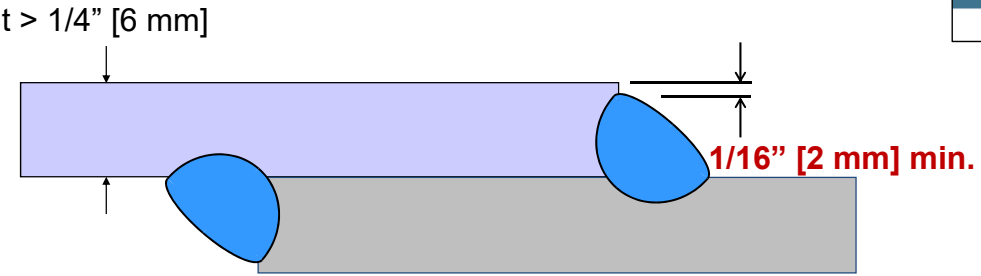
- (2) Along edges of material 1/4 in. (6 mm) or more in thickness; not greater than the thickness of the material minus 1/16 in. (2 mm), unless the weld is especially designed on the design drawing to be built out to obtain full-throat thickness. In the as-welded condition, the distance between the edge of the base metal and the toe of the weld is permitted to be less than 1/16 in. (2 mm), provided the weld size is clearly verifiable.

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Maximum Fillet Weld Size




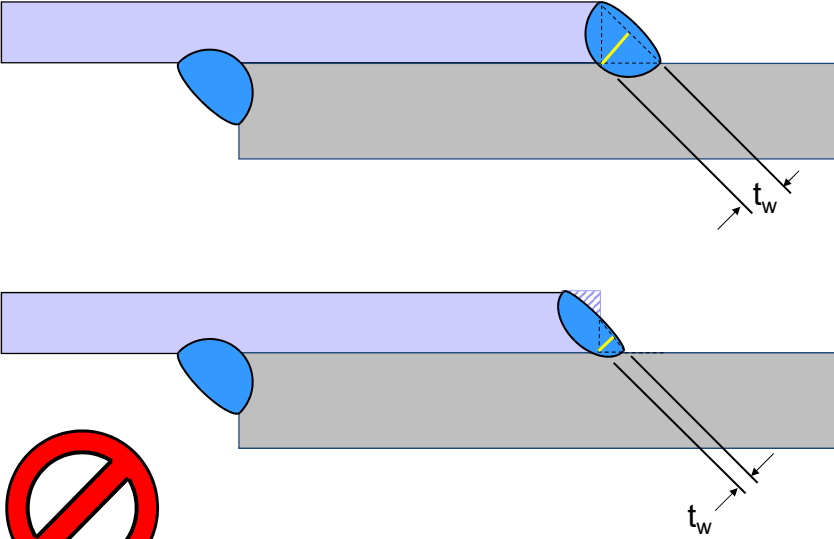
1/16" [2 mm] min.


(2) Along edges of material 1/4 in. (6 mm) or more in thickness; not greater than the thickness of the material minus 1/16 in. (2 mm), unless the weld is especially designed on the design drawing to be built out to obtain full-throat thickness.

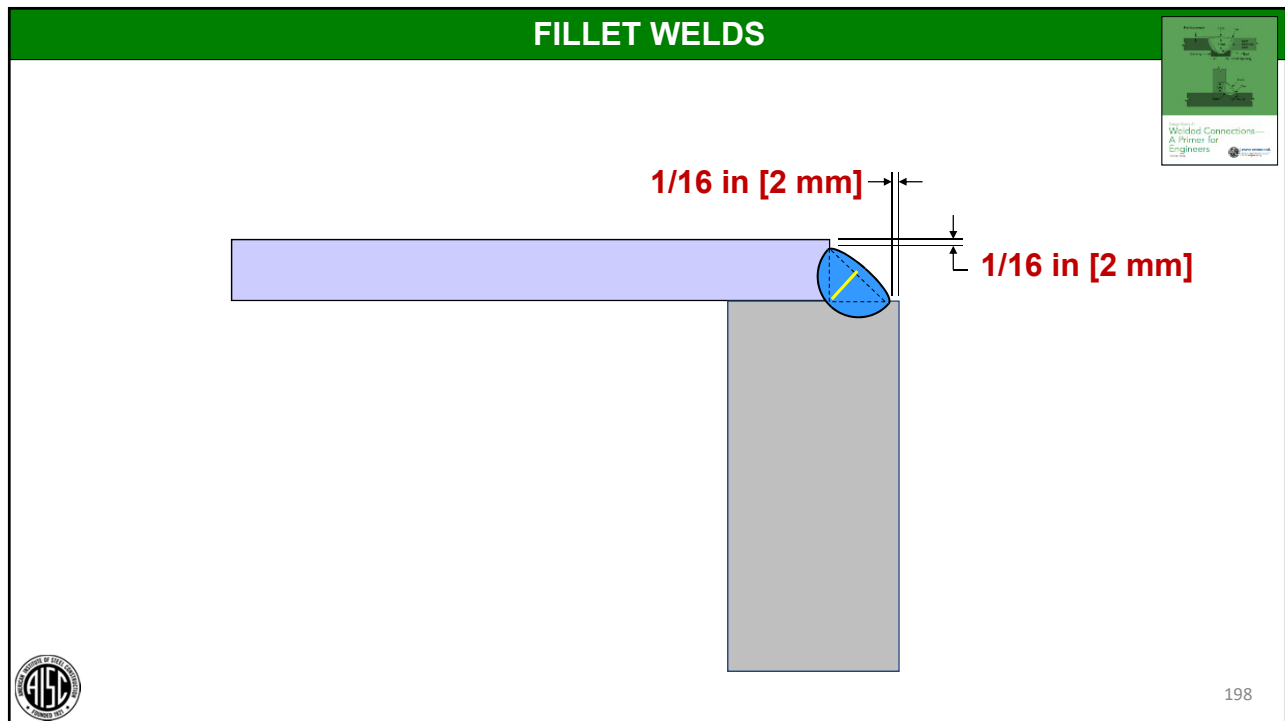
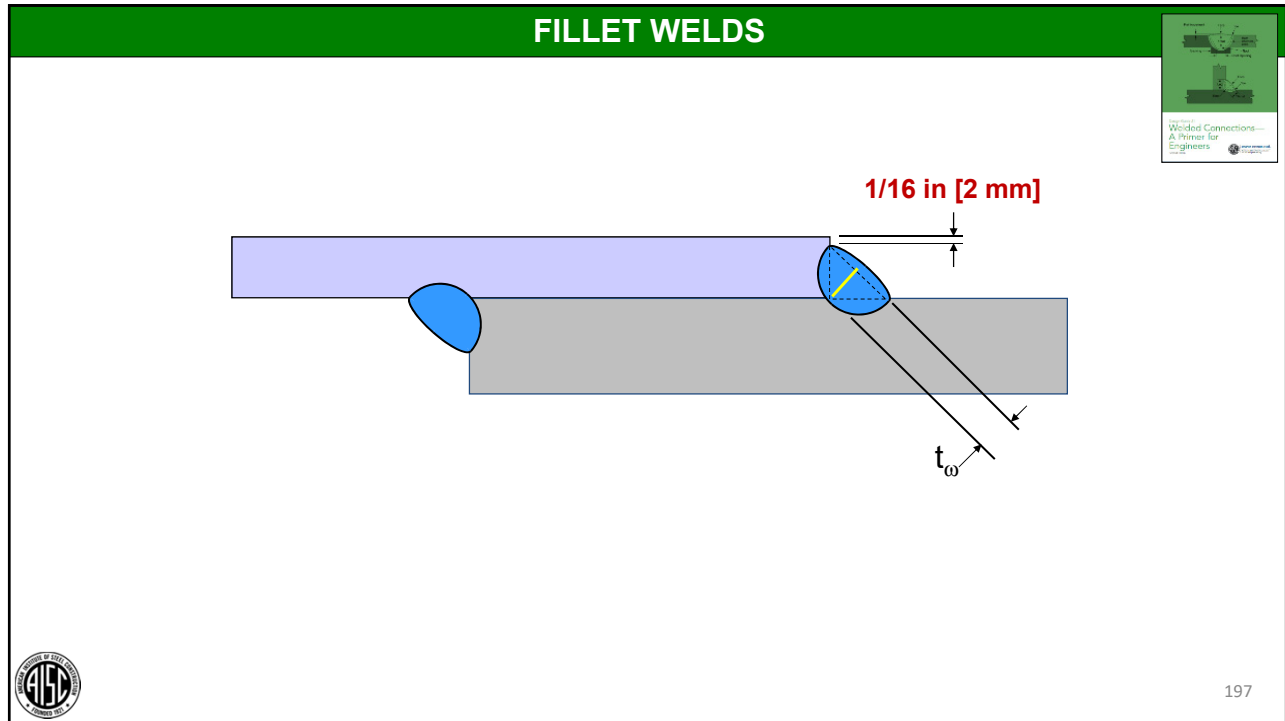
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FILLET WELDS





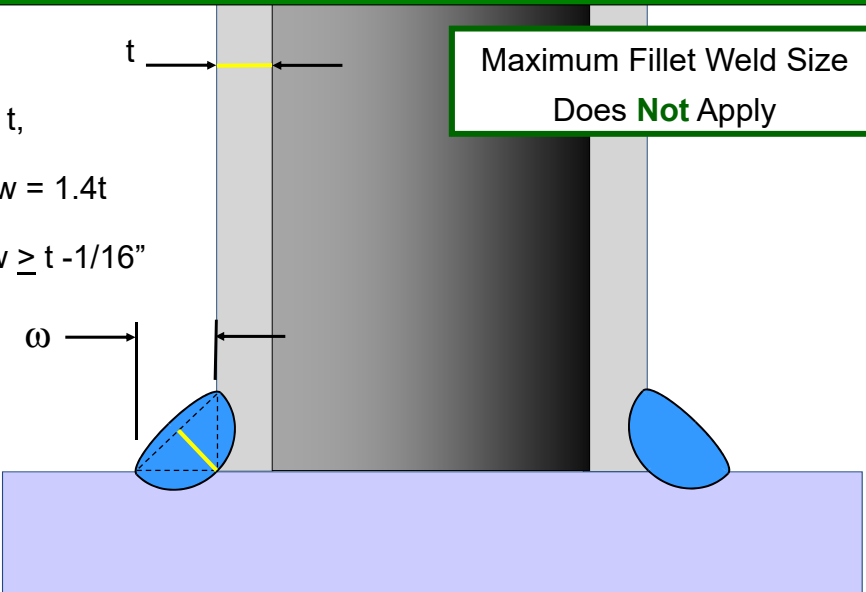
196



FILLET WELDS

If $t_w = t$,
then $w = 1.4t$
and $w \geq t - 1/16''$

**Maximum Fillet Weld Size
Does **Not** Apply**



The diagram shows a cross-section of a fillet weld joint. A vertical plate of thickness t is attached to a horizontal base plate. A fillet weld of size w is shown at the interface. A callout box states that the maximum fillet weld size does not apply. The AISC logo is in the bottom left, and the page number 199 is in the bottom right.

AISC 360-16 Specification for Structural Steel Buildings


J2.2 Fillet Welds

2b. Limitations

Fillet welds shall meet the following limitations:

(b) The maximum size of fillet welds of connected parts shall be:

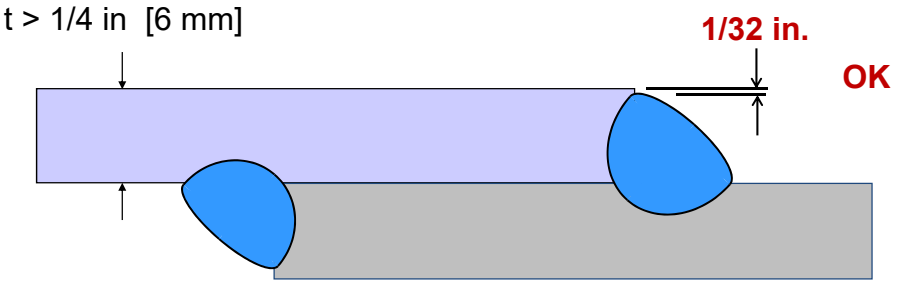
- (2) Along edges of material 1/4 in. (6 mm) or more in thickness; not greater than the thickness of the material minus 1/16 in. (2 mm), unless the weld is especially designed on the design drawing to be built out to obtain full-throat thickness. **In the as-welded condition, the distance between the edge of the base metal and the toe of the weld is permitted to be less than 1/16 in. (2 mm), provided the weld size is clearly verifiable.**



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AISC 360-16 Specification for Structural Steel Buildings

Maximum Fillet Weld Size





$t > 1/4 \text{ in [6 mm]}$

$1/32 \text{ in.}$

OK



In the as-welded condition, the distance between the edge of the base metal and the toe of the weld is permitted to be less than $1/16 \text{ in. (2 mm)}$, provided the weld size is clearly verifiable.



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FILLET WELDS

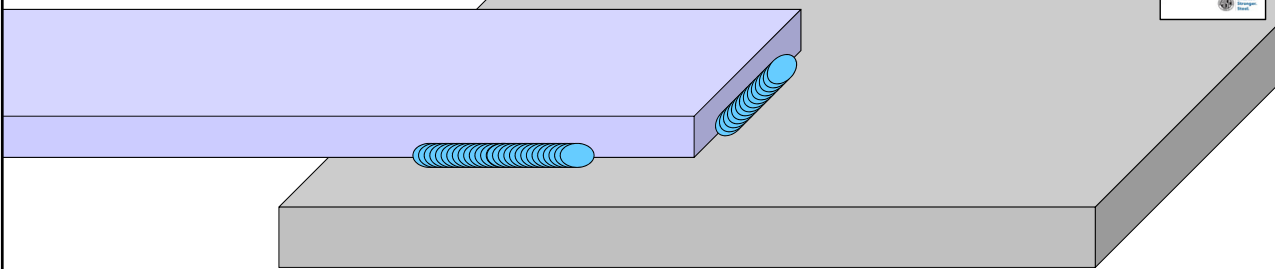
Minimum length of fillet welds



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AISC 360-16 Specification 2.2b

Minimum Fillet Weld Length



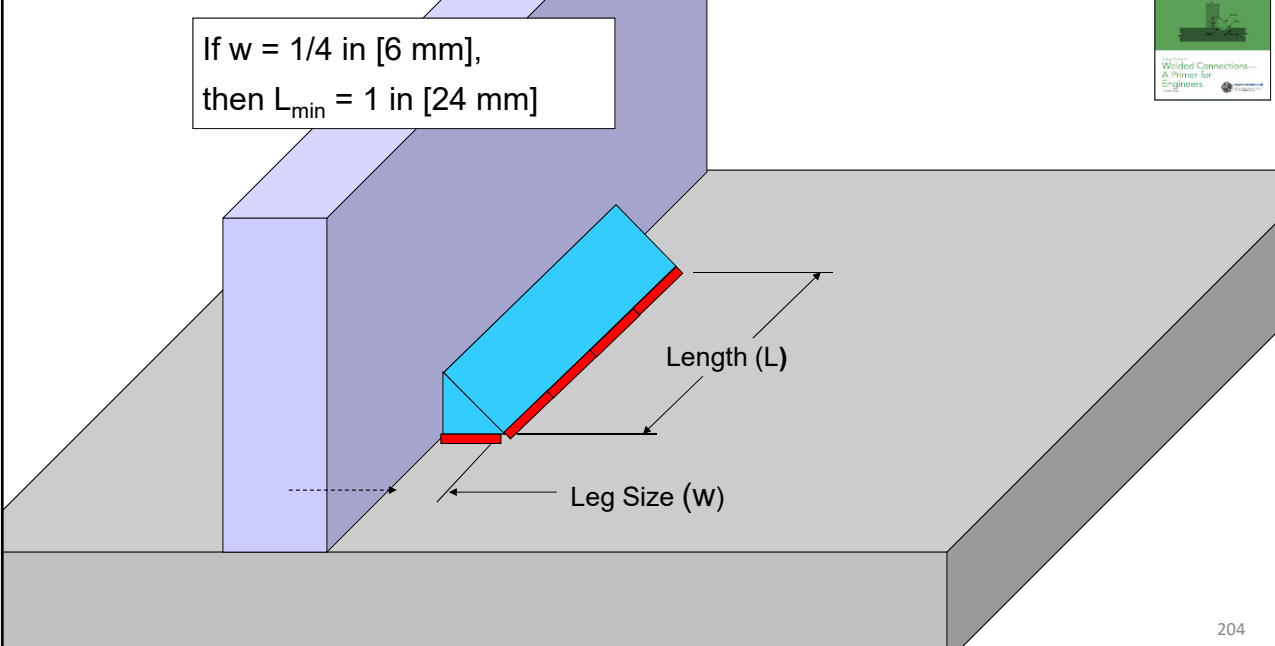
(c) The minimum effective length of fillet welds designed on the basis of strength shall be not less than four times the nominal weld size, or else the size of the weld shall be taken to exceed one-quarter of its length. For the effect of longitudinal fillet weld length in end connections upon the effective area of the connected member, see Section D3.

Also addressed in AWS D1.1:2015 clause 2.4.2.3

Specification for Structural Steel Buildings
American Institute of Steel Construction, Inc.

FILLET WELDS

If $w = 1/4$ in [6 mm],
then $L_{\min} = 1$ in [24 mm]

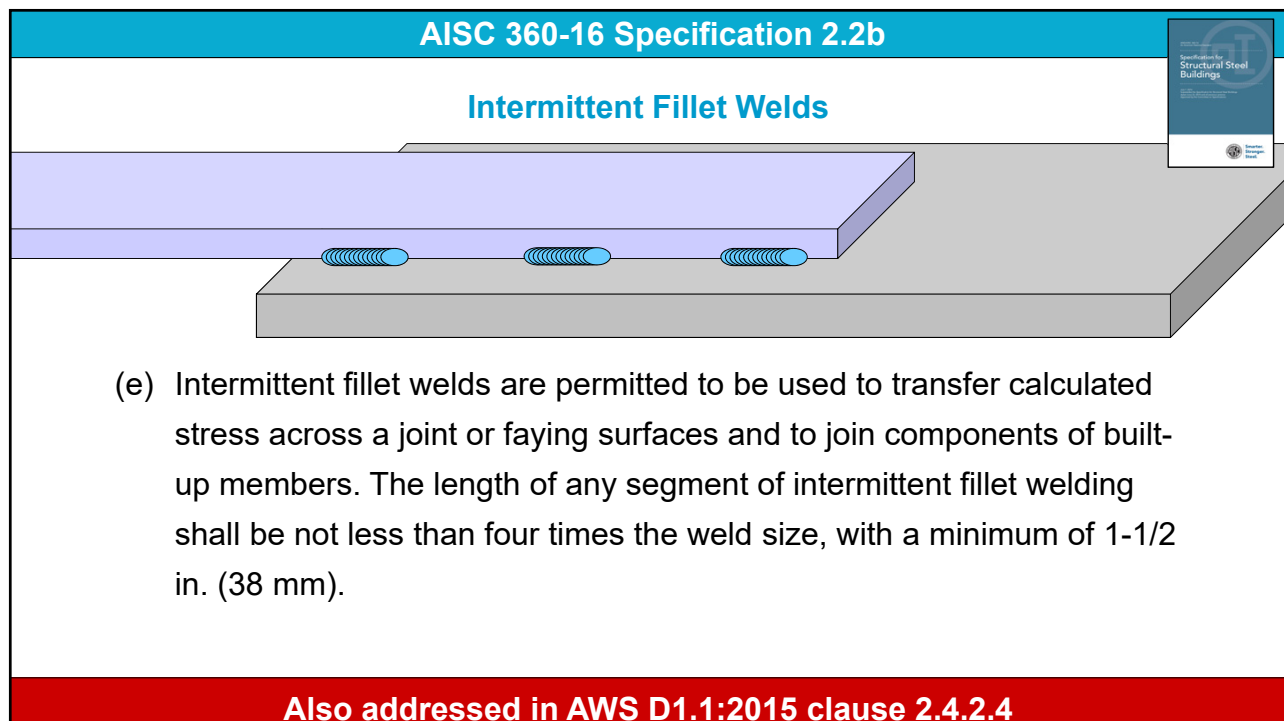
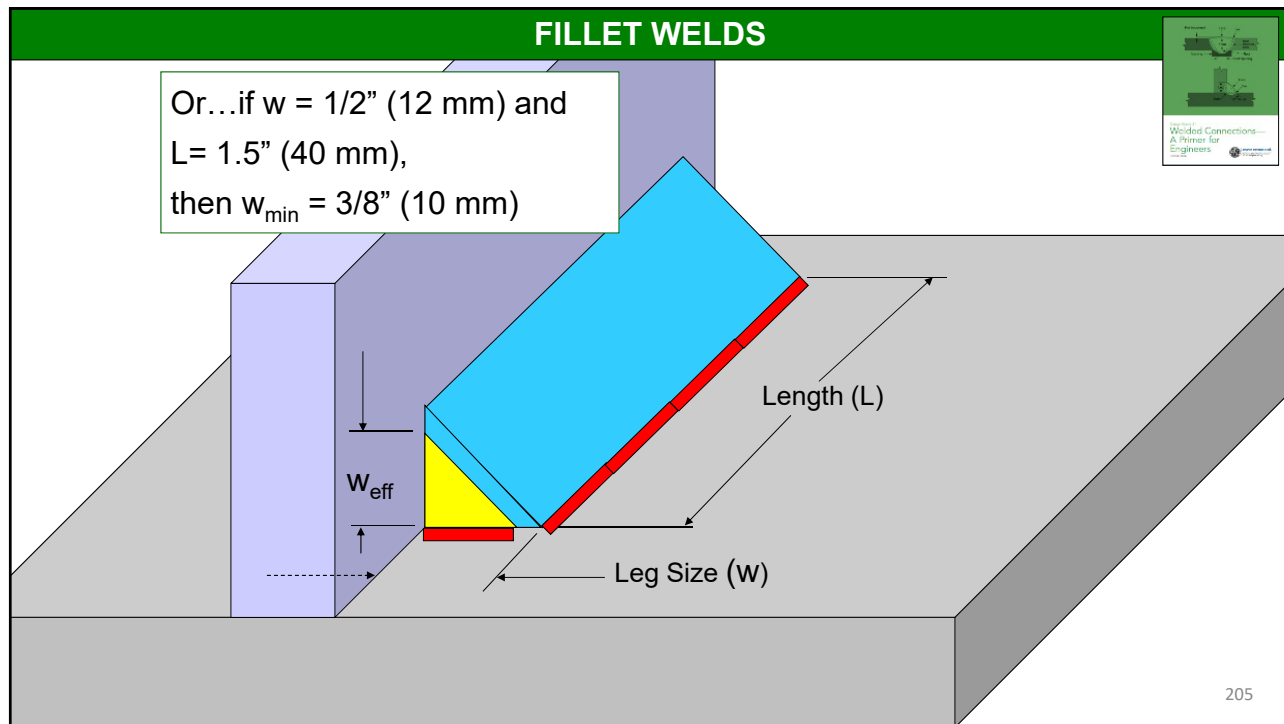


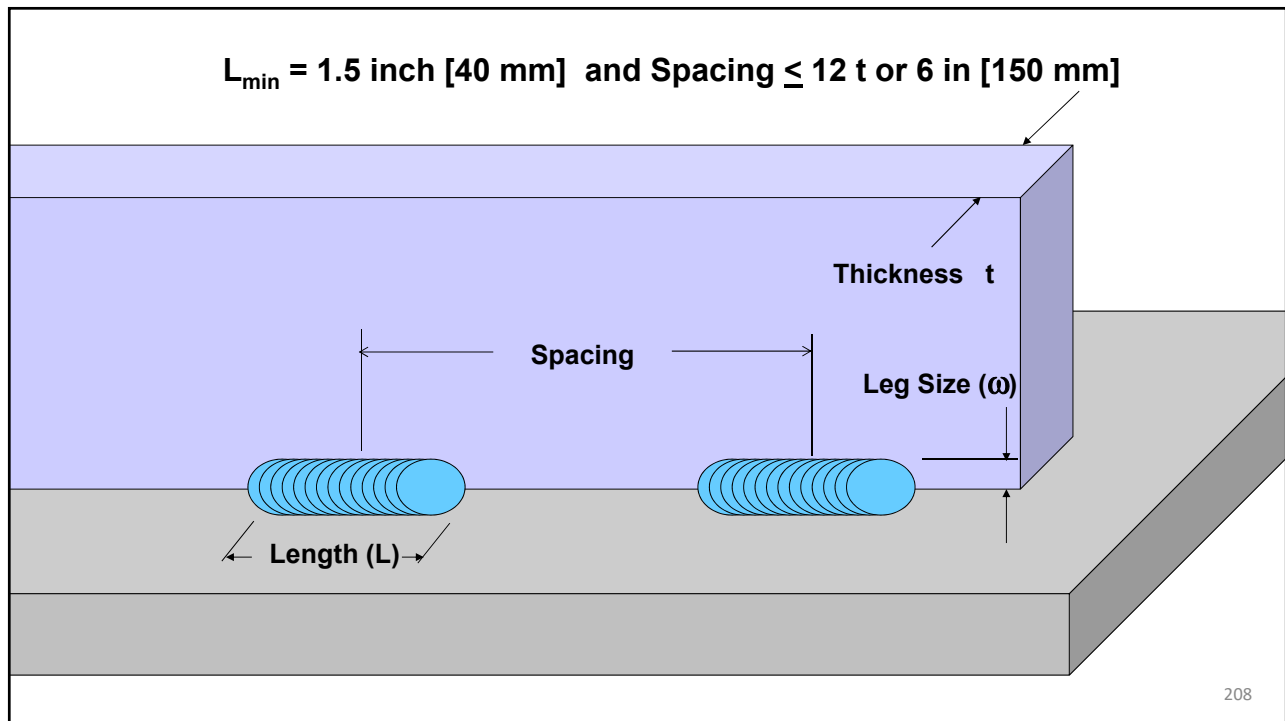
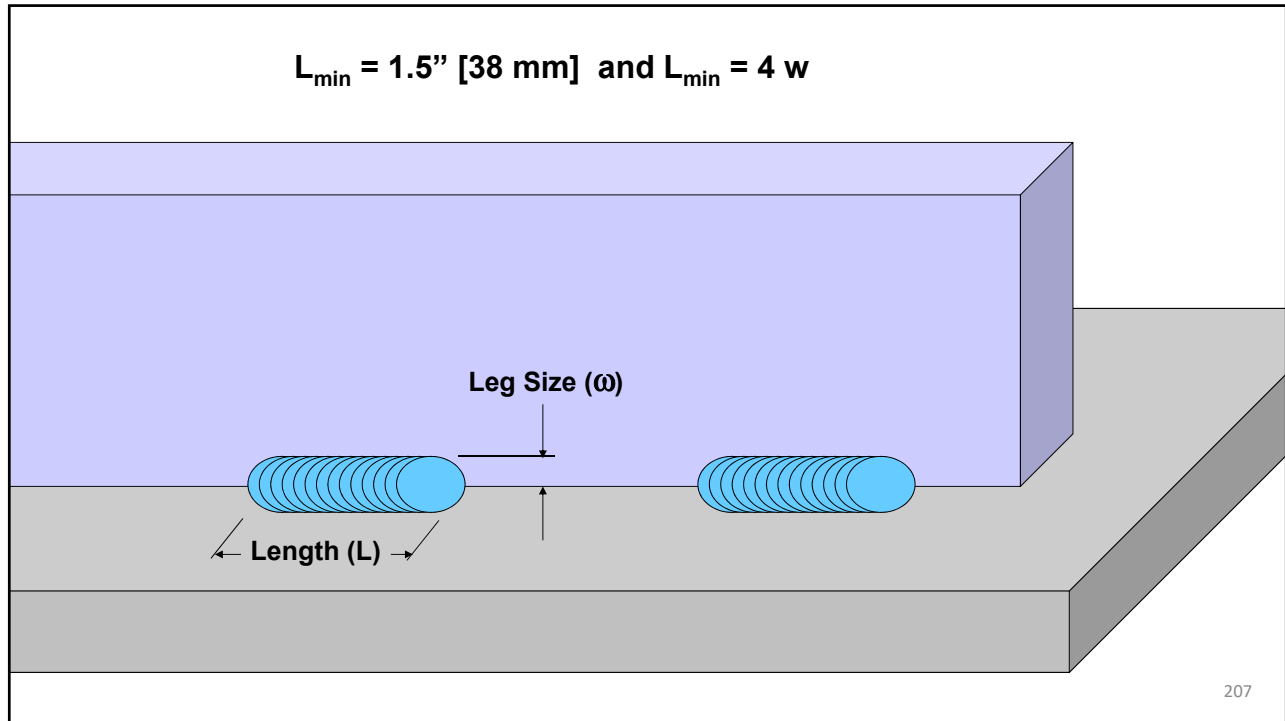
Length (L)

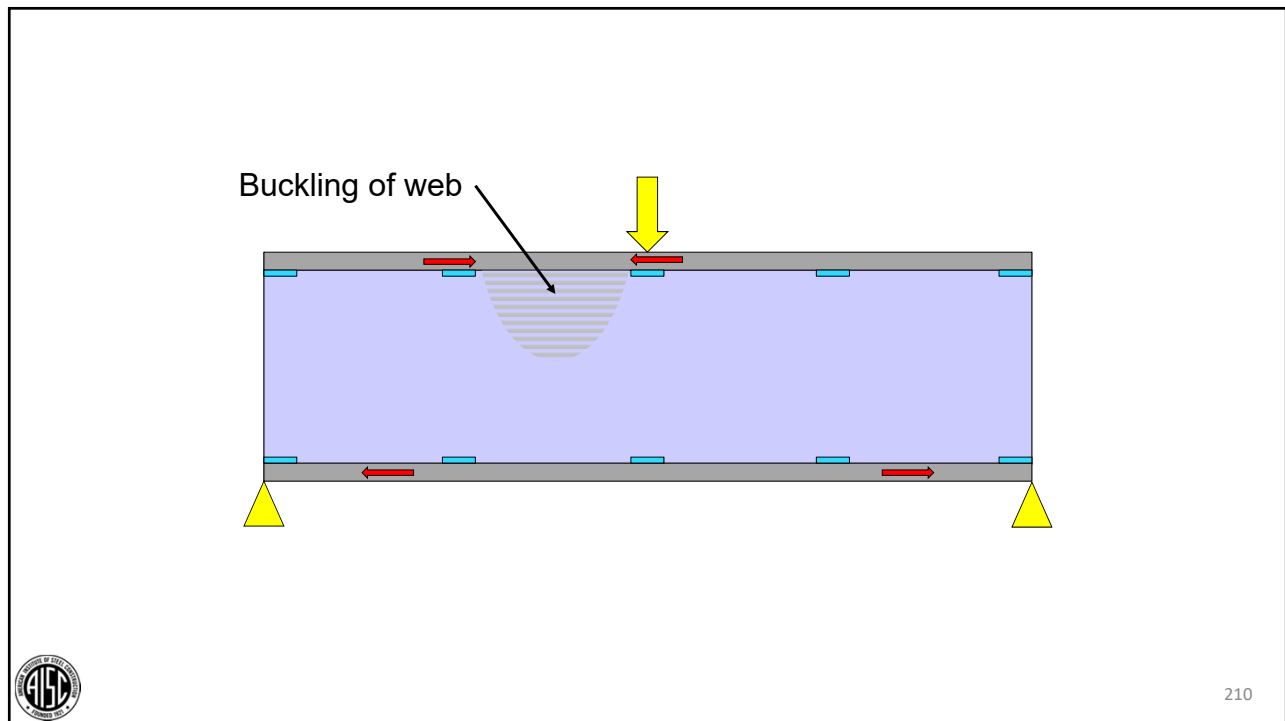
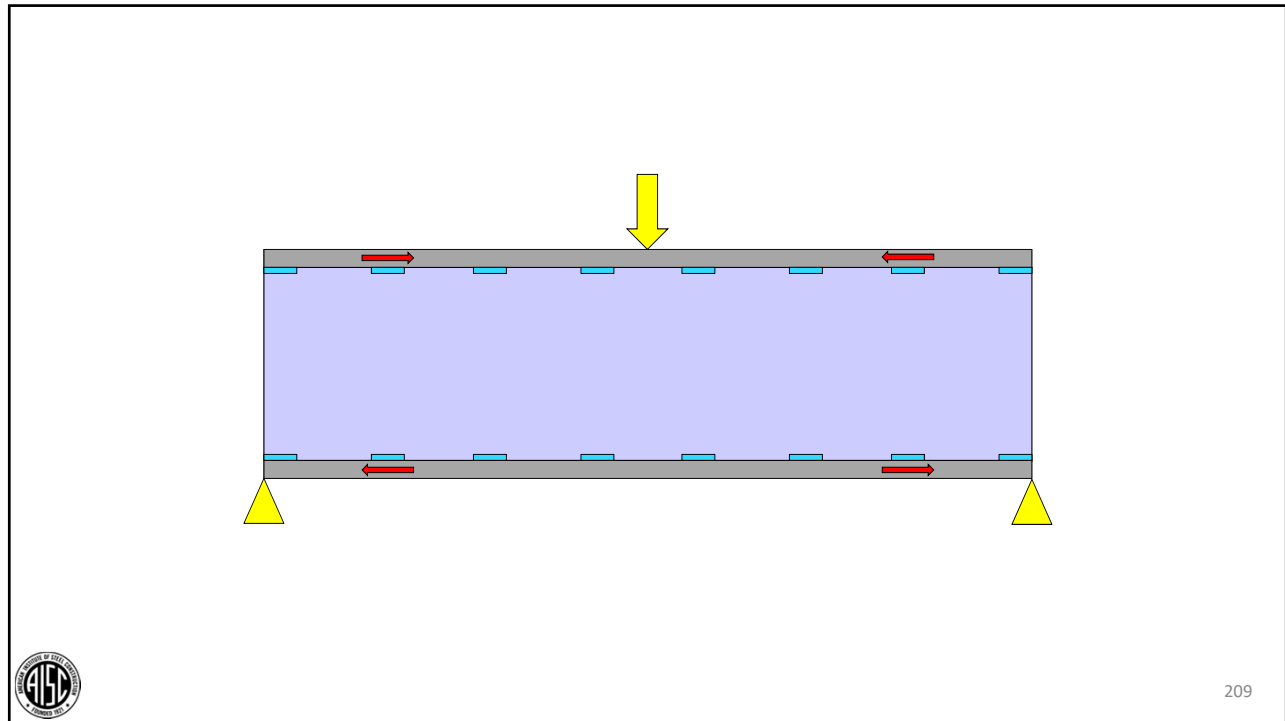
Leg Size (w)

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Welded Connections—A Primer for Engineers
American Institute of Steel Construction, Inc.

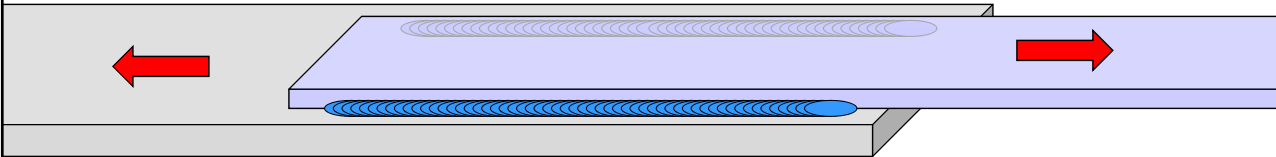







AISC 360-16 Specification 2.2b

Maximum length of end-loaded fillet welds



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American Institute of Steel Construction, Inc.

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AISC 360-16 Specification for Structural Steel Buildings


J2.2 Fillet Welds

2b. Limitations


(d) The effective length of fillet welds shall be determined as follows:

- (1) For end-loaded fillet welds with a length up to 100 times the weld size, it is permitted to take the effective length equal to the actual length.

Addressed in AWS D1.1:2015 clause 2.4.2.5

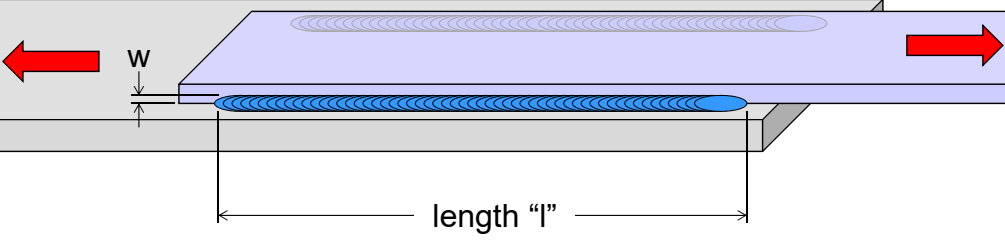



AISC 360-16 Specification 2.2b



Maximum length of end-loaded fillet welds


If length $\leq 100 w$, then $l_{\text{effective}} = l_{\text{actual}}$





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AISC 360-16 Specification for Structural Steel Buildings



J2.2 Fillet Welds

2b. Limitations

(d) The effective length of fillet welds shall be determined as follows:


(2) When the length of the end-loaded fillet weld exceeds 100 times the weld size, the effective length shall be determined by multiplying the actual length by the reduction factor, β , determined as follows:

$$\beta = 1.2 - 0.002(l/w) < 1.0$$

where

l = actual length of the end-loaded weld, in. (mm)

w = size of weld leg, in. (mm)




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AISC 360-16 Specification for Structural Steel Buildings

Maximum length of end-loaded fillet welds

If length $> 300 w$, then $l_{\text{effective}} = 180 w$

length "l"




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FILLET WELDS

Maximum length of end-loaded fillet welds

Effective Length "l_{effective}"

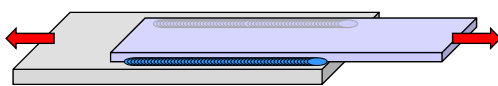
Actual Length "l_{actual}"




216

FILLET WELDS

Maximum length of fillet welds

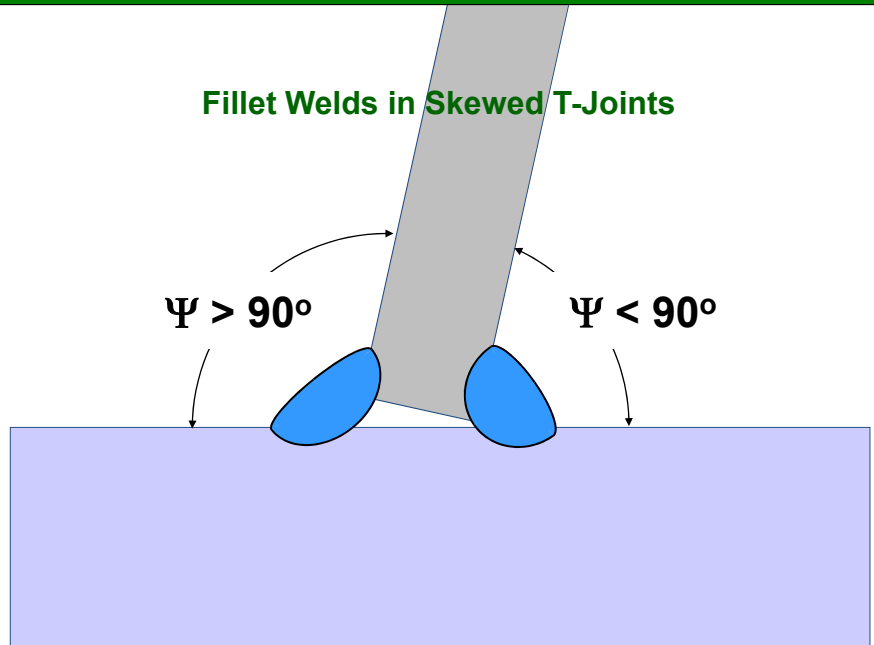



Weld Size w	$100 w$	$180 w$
3/16"	19"	34"
1/4"	25"	45"
5/16"	31"	56"
3/8"	38"	68"
1/2"	50"	90"
3/4"	75"	135"
1"	100"	180"

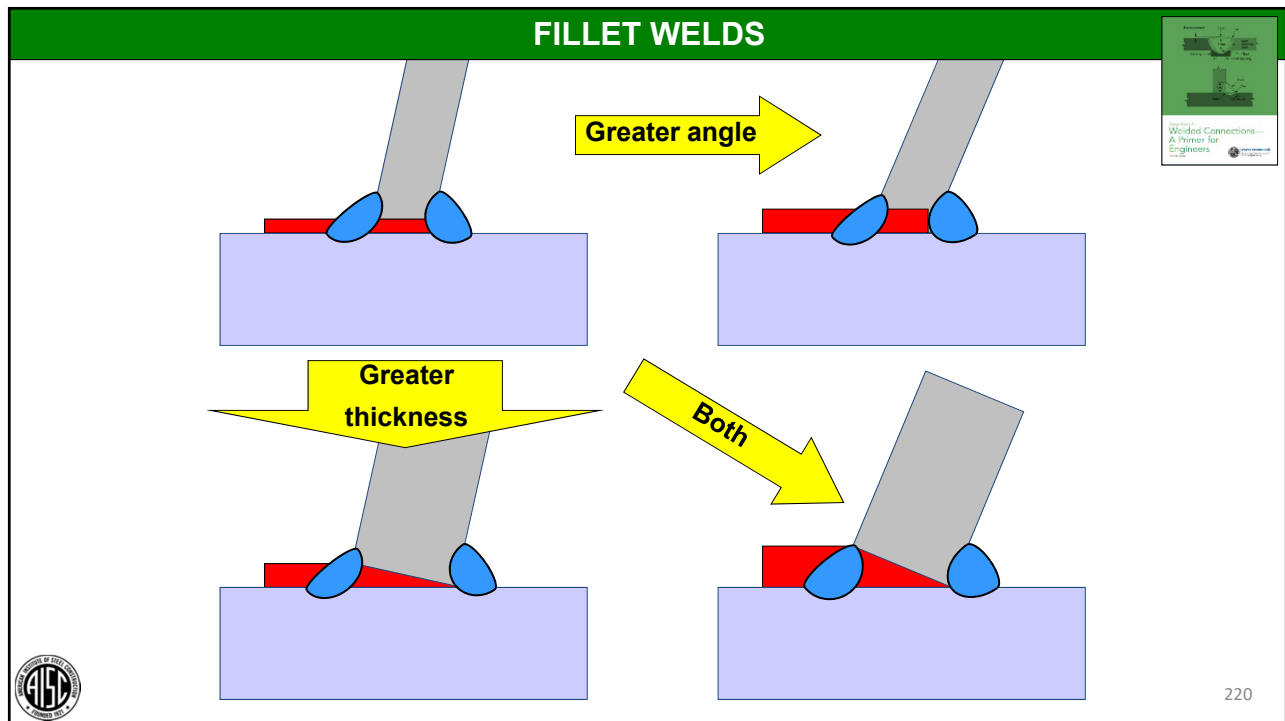
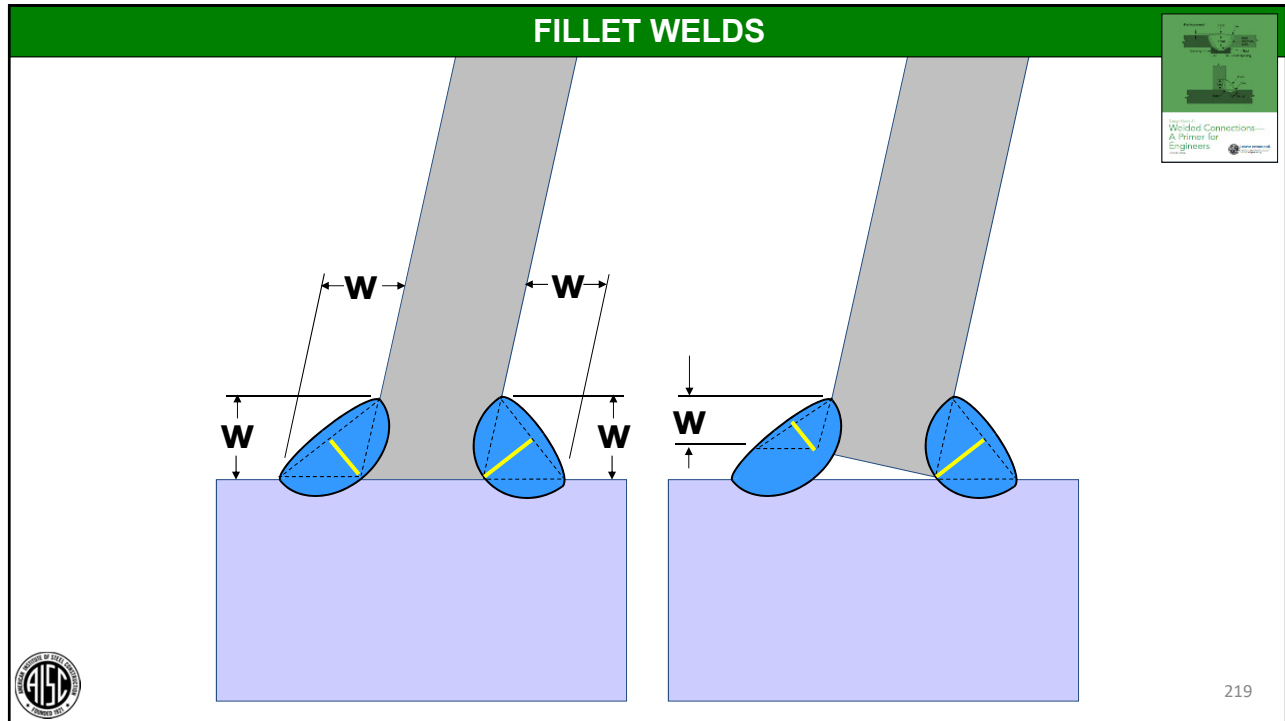

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FILLET WELDS

Fillet Welds in Skewed T-Joints




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AWS D1.1: 2015 Structural Welding Code – Steel



2.3.4 Weld Size and Length

Contract design drawings shall specify the effective weld length and, for PJP groove welds, the required weld size “(E).”

For fillet welds and skewed T-joints, the following shall be provided on the **contract documents**.

- (1) For fillet welds between parts with surfaces meeting at an angle between 80° and 100° , **contract documents shall specify the fillet weld leg size.**
- (2) For welds between parts with the surfaces meeting at an angle less than 80° or greater than 100° , the contract documents shall specify the effective throat.

End returns and hold-backs for fillet welds, if required by design, shall be indicated on the contract documents.

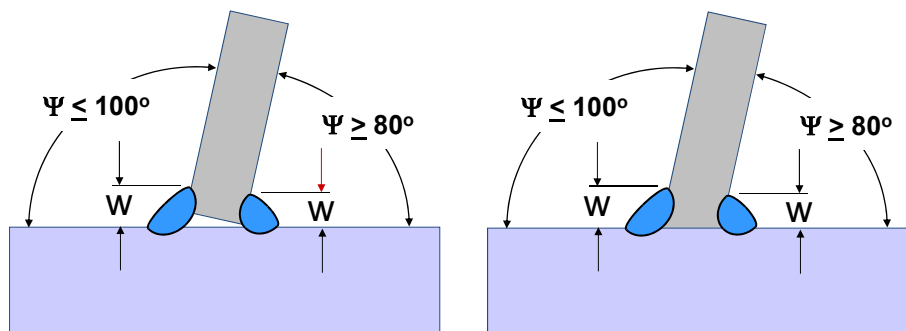


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AWS D1.1: 2015 Structural Welding Code – Steel



Specify **fillet weld leg size (w)** within these limits:
 $80^\circ \leq \Psi \leq 100^\circ$



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AWS D1.1: 2015 Structural Welding Code – Steel



2.3.4 Weld Size and Length.

Contract design drawings shall specify the effective weld length and, for PJP groove welds, the required weld size “(E).”

For fillet welds and skewed T-joints, the following shall be provided on the **contract documents**.

- (1) For fillet welds between parts with surfaces meeting at an angle between 80° and 100° , contract documents shall specify the fillet weld leg size.
- (2) For welds between parts with the surfaces meeting at an angle less than 80° or greater than 100° , the **contract documents shall specify the effective throat**.

End returns and hold-backs for fillet welds, if required by design, shall be indicated on the contract documents.



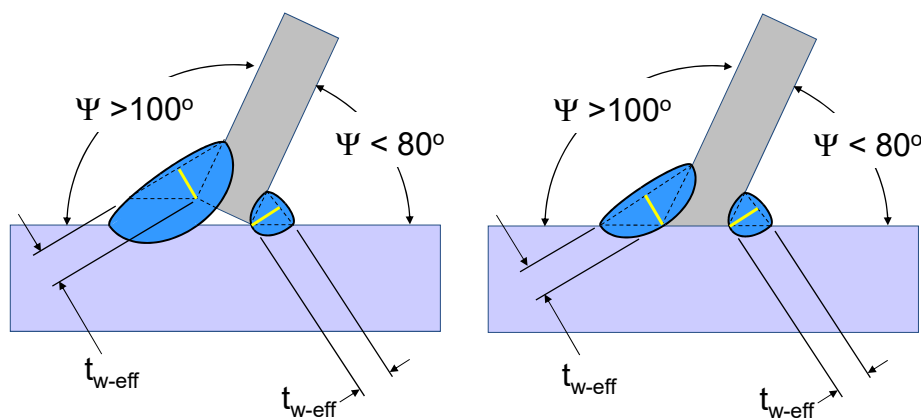
223

AWS D1.1: 2015 Structural Welding Code – Steel



Specify **effective throat** ($t_{w\text{-eff}}$) within these limits:

for $\Psi > 100^\circ$ and $\Psi < 80^\circ$



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AWS D1.1: 2015 Structural Welding Code – Steel



2.3.5.2 Fillet Welds and Welds in Skewed T-Joints.

The following shall be provided on the **shop drawings**:

- (1) For fillet welds between parts with surfaces meeting at an angle between 80° and 100° , **shop drawings** shall specify the fillet weld leg size,
- (2) For welds between parts with surfaces meeting at an angle less than 80° or greater than 100° , the shop drawings shall show the detailed arrangement of welds and required leg size to account for effects of joint geometry and, where appropriate, the Z-loss reduction for the process to be used and the angle,
- (3) End returns and hold-backs.



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AWS D1.1: 2015 Structural Welding Code – Steel



2.3.5.2 Fillet Welds and Welds in Skewed T-Joints.

The following shall be provided on the **shop drawings**:

- (1) For fillet welds between parts with surfaces meeting at an angle between 80° and 100° , shop drawings shall specify the fillet weld leg size,
- (2) For welds between parts with surfaces meeting at an angle less than 80° or greater than 100° , the **shop drawings shall show the detailed arrangement of welds** and required leg size to account for effects of joint geometry and, where appropriate, the Z-loss reduction for the process to be used and the angle,
- (3) End returns and hold-backs.




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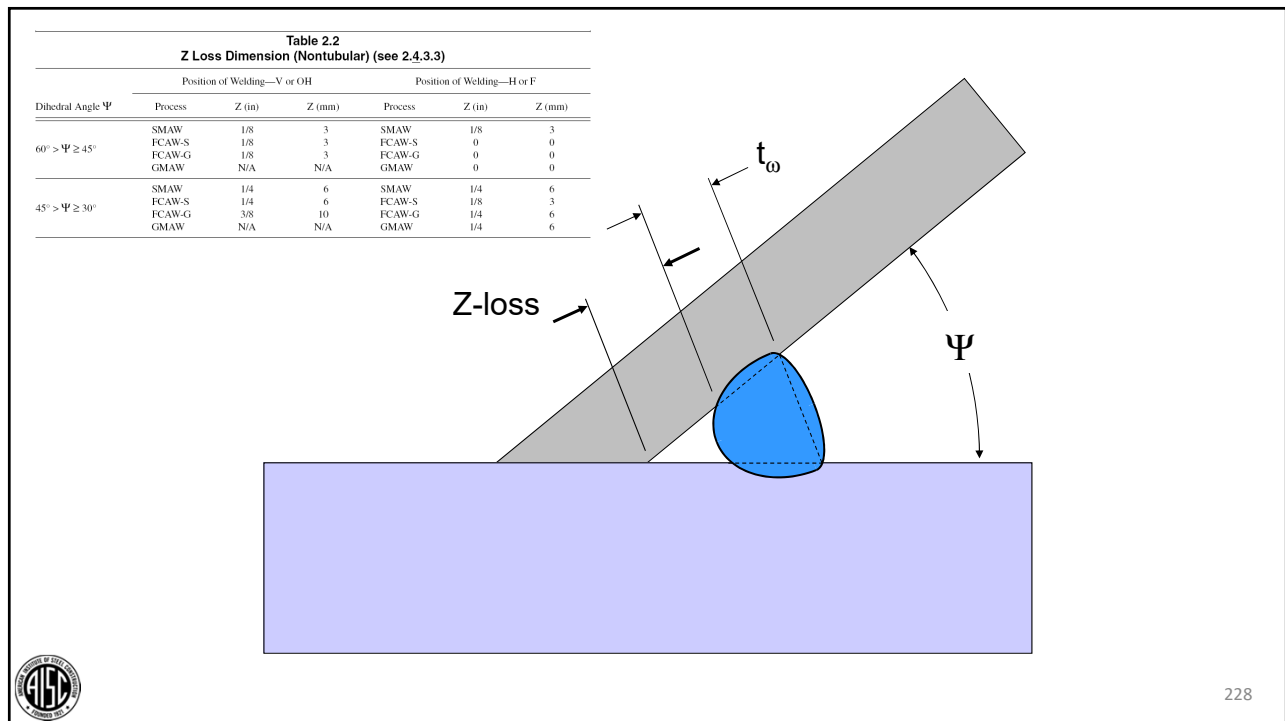
AWS D1.1: 2015 Structural Welding Code – Steel

AWS D1.1: 2015
 Structural Welding Code – Steel

**Table 2.2
 Z Loss Dimension (Nontubular) (see 2.4.3.3)**

Dihedral Angle Ψ	Position of Welding—V or OH			Position of Welding—H or F		
	Process	Z (in)	Z (mm)	Process	Z (in)	Z (mm)
$60^\circ > \Psi \geq 45^\circ$	SMAW	1/8	3	SMAW	1/8	3
	FCAW-S	1/8	3	FCAW-S	0	0
	FCAW-G	1/8	3	FCAW-G	0	0
	GMAW	N/A	N/A	GMAW	0	0
$45^\circ > \Psi \geq 30^\circ$	SMAW	1/4	6	SMAW	1/4	6
	FCAW-S	1/4	6	FCAW-S	1/8	3
	FCAW-G	3/8	10	FCAW-G	1/4	6
	GMAW	N/A	N/A	GMAW	1/4	6


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FILLET WELDS



Fillet weld termination

- AISC J2.2b User Note
- AWS D1.1:2015 clause 2.9.3



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AWS D1.1: 2015 Structural Welding Code – Steel



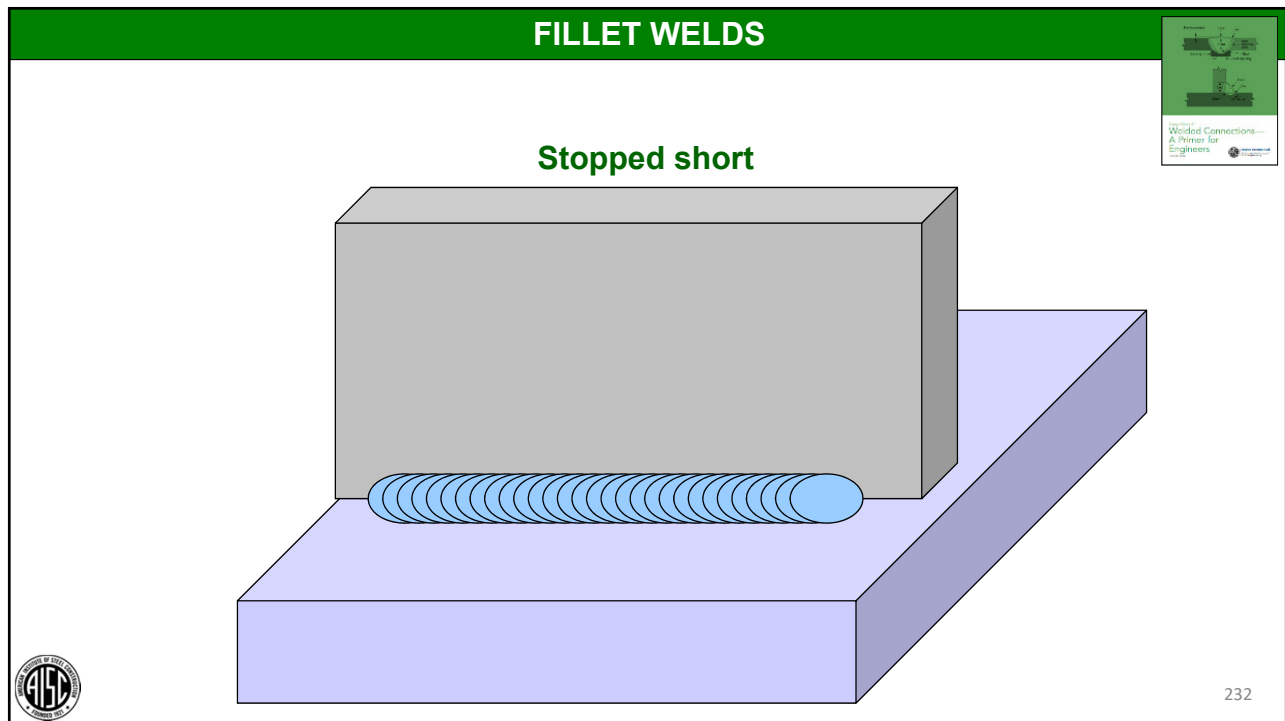
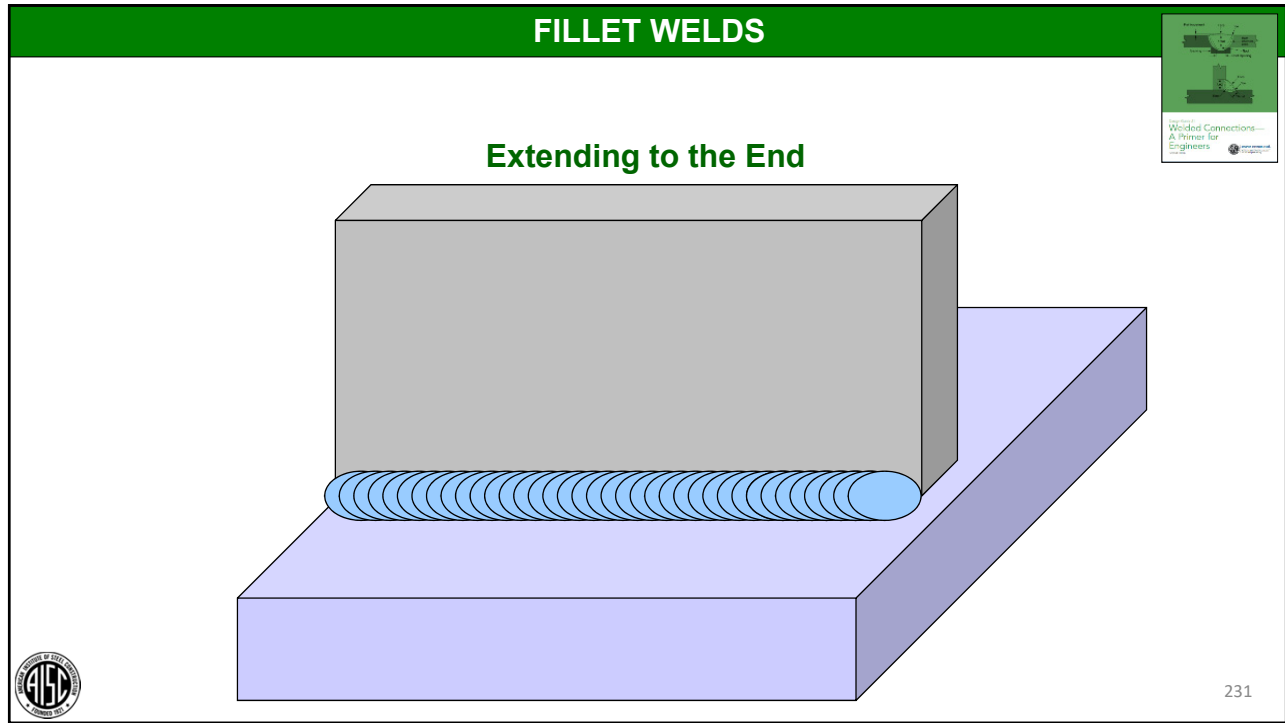
2.9.3 Fillet Weld Terminations

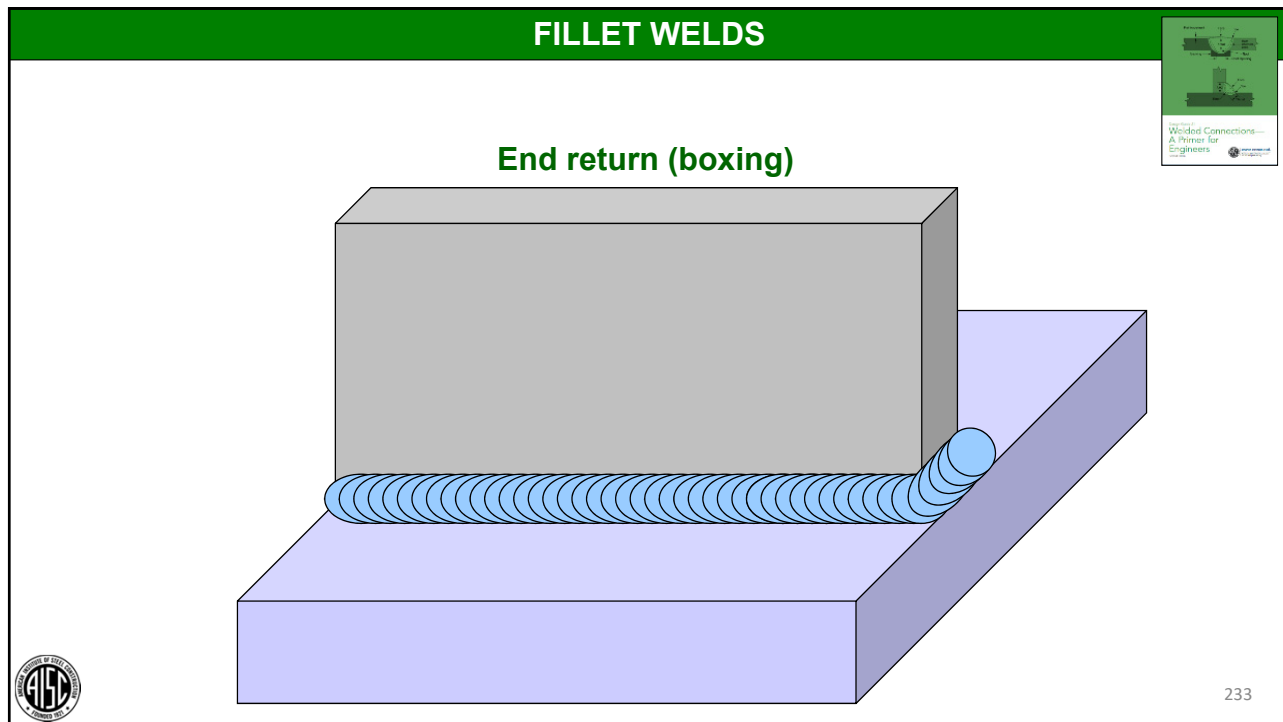
2.9.3.1 General.

Fillet weld terminations may extend to the ends or sides of parts or may be stopped short or may have end returns except as limited by the following cases:



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AWS D1.1: 2015 Structural Welding Code – Steel

2.9.3 Fillet Weld Terminations

2.9.3.1 General.

Fillet weld terminations may extend to the ends or sides of parts or may be stopped short or may have end returns **except as limited by the following cases:**



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AWS D1.1: 2015 Structural Welding Code – Steel

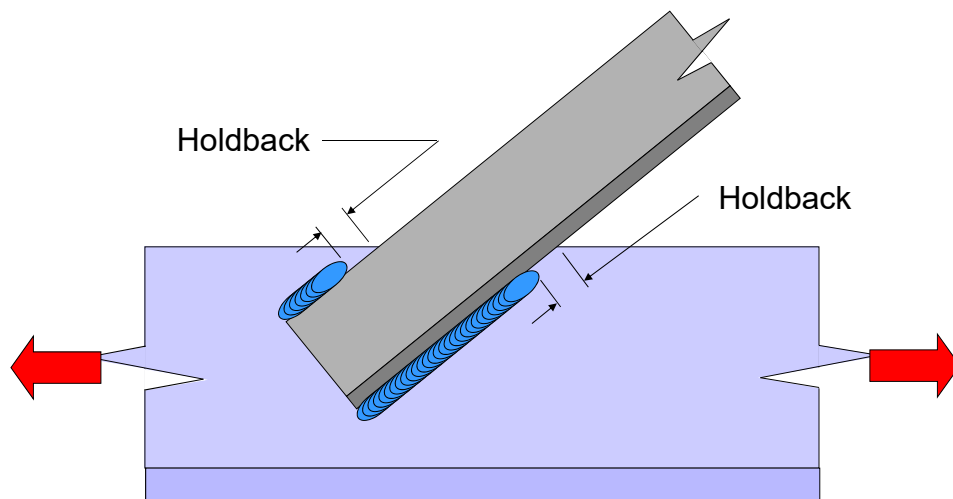


2.9.3.2 Lap Joints Subject to Tension.

In lap joints in which one part extends beyond the edge or side of a part subject to calculated tensile stress, fillet welds shall terminate not less than the size of the weld from the start of the extension (see Figure 2.6).



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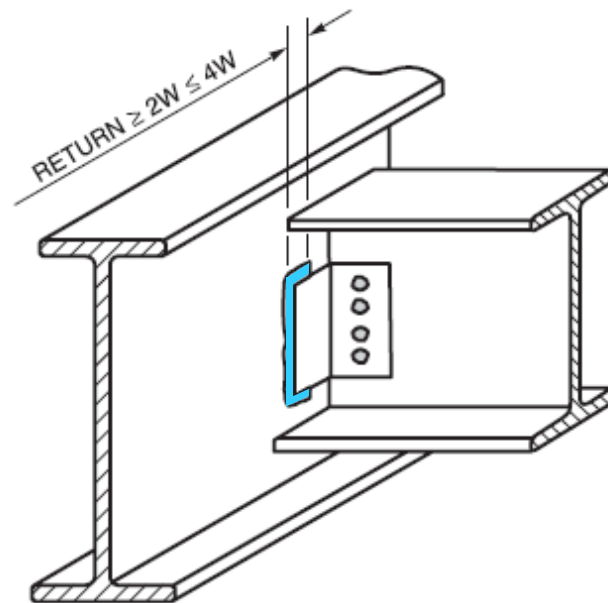


2.9.3.3 Maximum End Return Length.

Welded joints shall be arranged to allow the flexibility assumed in the connection design. If the outstanding legs of connection base metal are attached with end returned welds, the length of the end return shall not exceed four times the nominal size of the weld (see Figure 2.7 for examples of flexible connections).



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Note: W = nominal size of the weld.



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AWS D1.1: 2015 Structural Welding Code – Steel

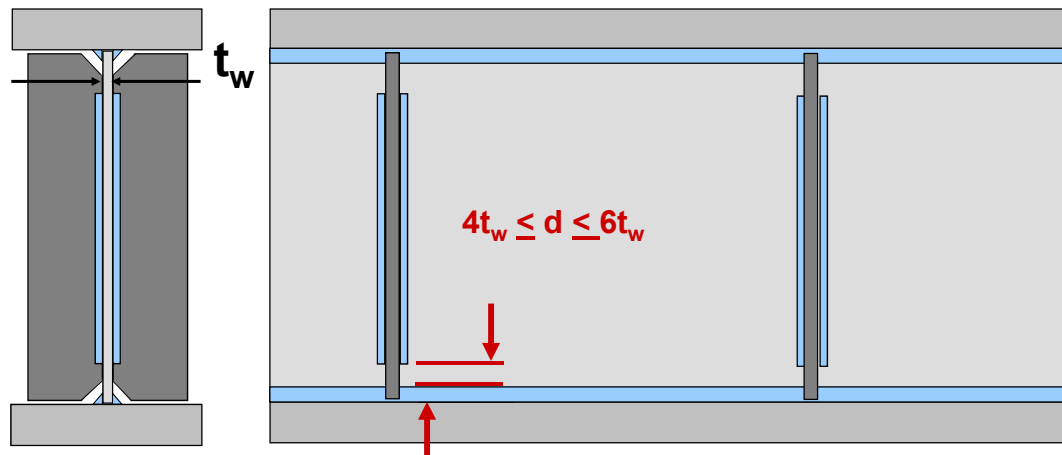


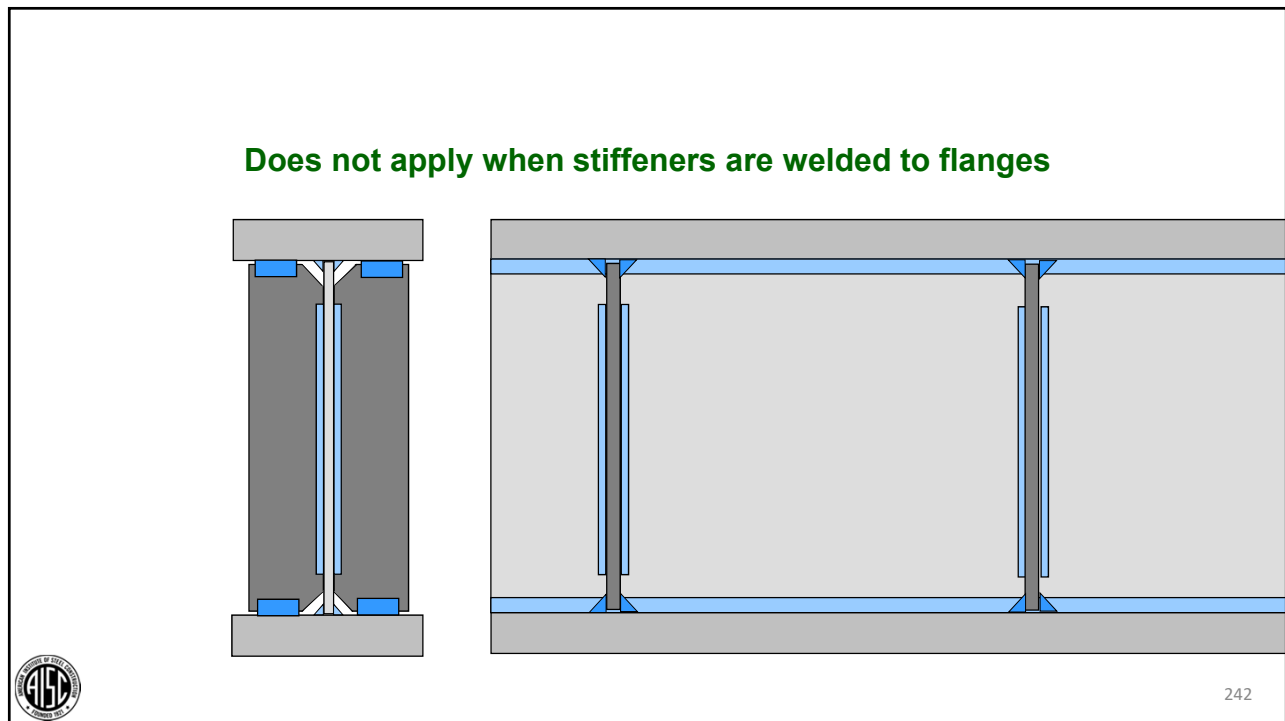
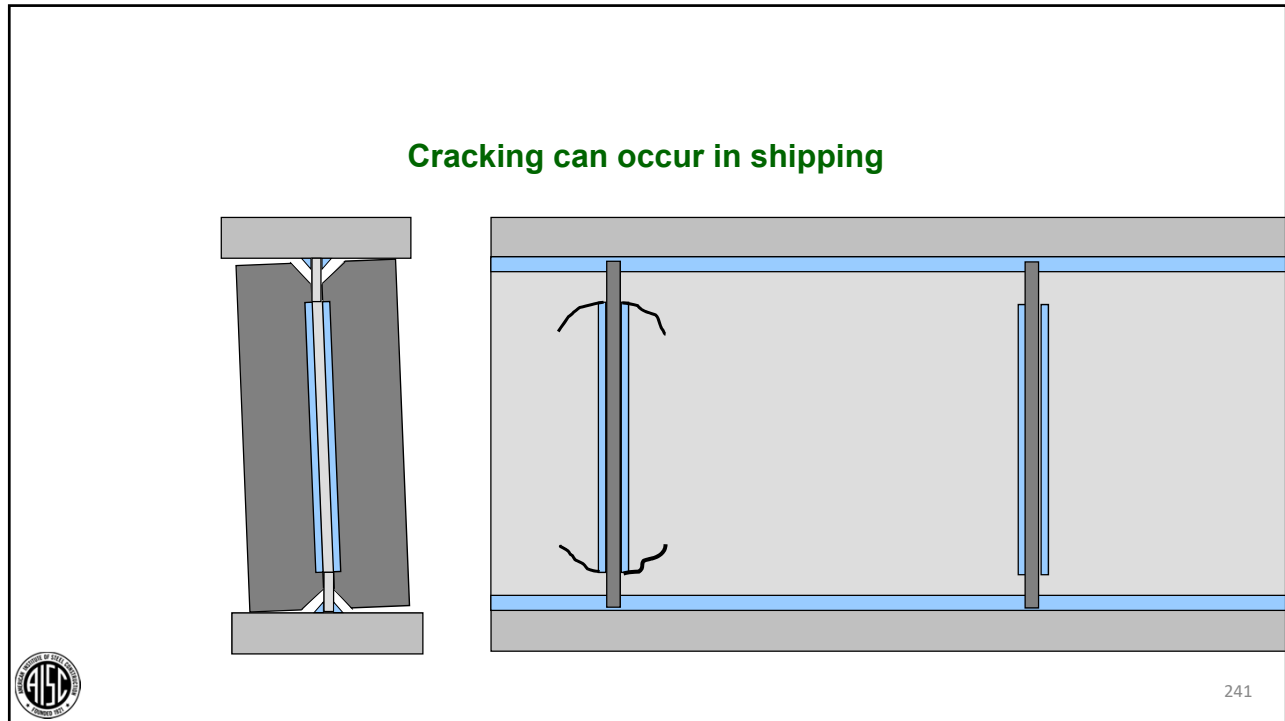
2.9.3.4 Transverse Stiffener Welds.

Except where the ends of stiffeners are welded to the flange, fillet welds joining transverse stiffeners to girder webs shall start or terminate not less than four times nor more than six times the thickness of the web from the web toe of the web-to-flange welds.

Per AISC 360-16 User Note: This applies when $t_w \leq \frac{3}{4}''$ (18 mm).

Exception to general practice





AWS D1.1: 2015 Structural Welding Code – Steel



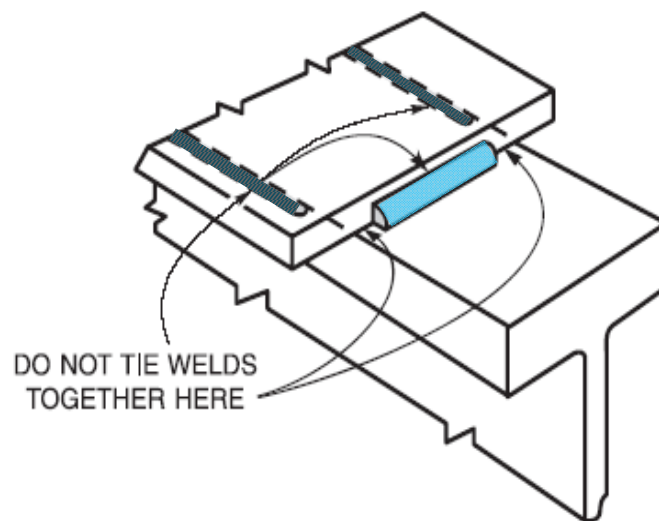
2.9.3.5 Opposite Sides of a Common Plane.

Fillet welds on the opposite sides of a common plane shall be interrupted at the corner common to both welds (see Figure 2.8), except as follows:

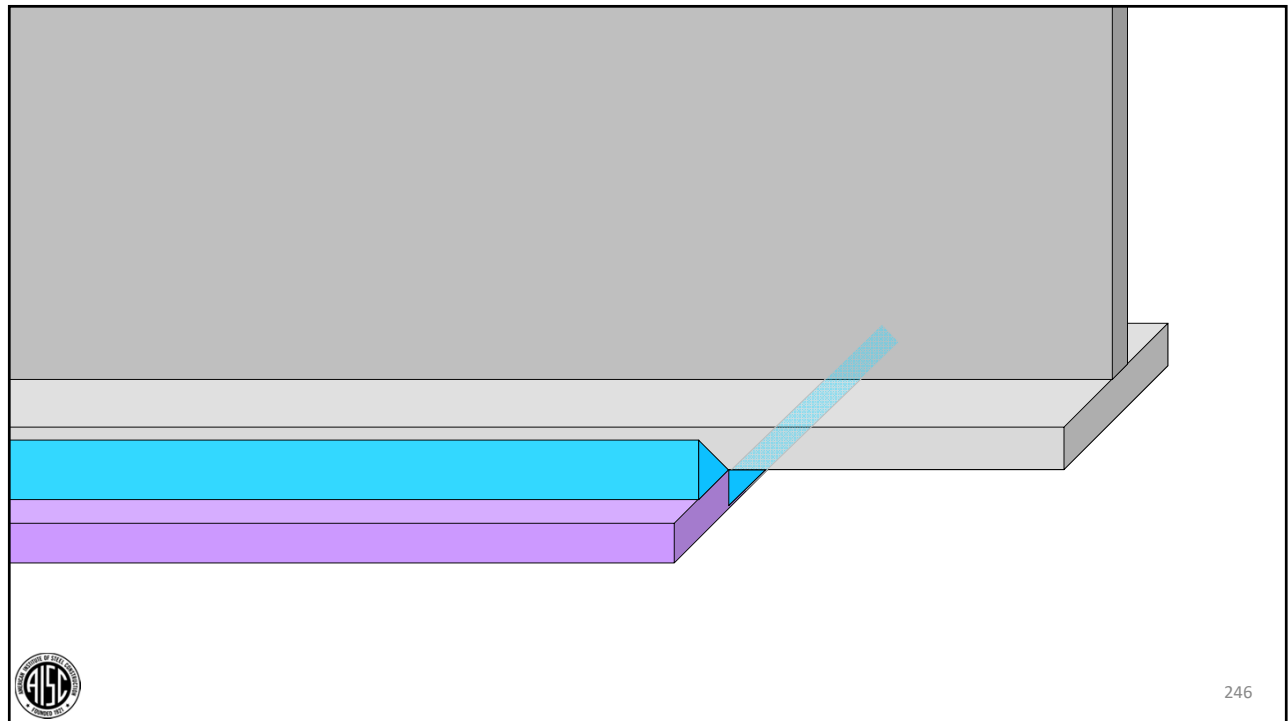
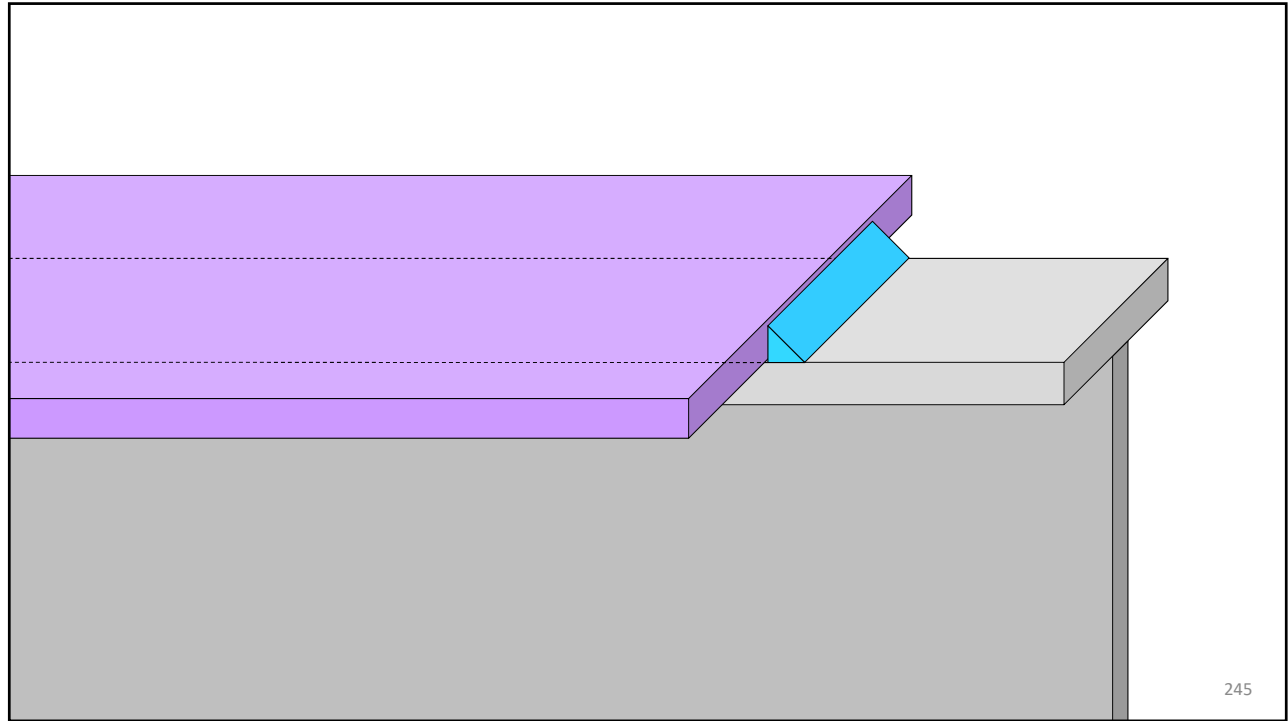
When joints are required to be sealed, or when a continuous weld is needed for other reasons, the contract documents shall specify where these welds are required to be continuous.



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AISC 360-16 Specification for Structural Steel Buildings



J2.2 Fillet Welds

2b. Limitations

- (g) Fillet weld terminations should be detailed in a manner that does not result in a notch in the base metal subject to applied tension loads. Components shall not be connected by welds where the weld would prevent the deformation required to provide assumed design conditions.

User Note: Fillet weld terminations be detailed in a manner that does not result in a notch in the base metal transverse to applied tension loads that can occur as a result of normal fabrication. An accepted practice to avoid notches in base metal is to stop fillet welds short of the edge of the base metal by a length approximately equal to the size of the weld. In most welds, the effect of stopping short can be neglected in strength calculations.



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AWS D1.1: 2015 Structural Welding Code – Steel



2.3.4 Weld Size and Length.

Contract design drawings shall specify the effective weld length....

End returns and hold-backs for fillet welds, if required by design, shall be indicated on the contract documents.



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WELDED CONNECTION DETAILS

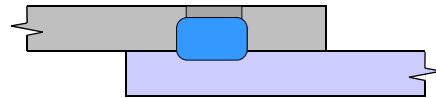
Outline

- Joints
- CJP Groove Welds
- PJP Groove Welds
- Fillet Welds
- ➔ • Plug and Slot Welds
- Tack Welds
- Weld Metal Strength



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PLUG AND SLOT WELDS





- Used in lap joints
- Usually used with other welds
- Not good for cyclically loaded structures
- Intended to transmit shear (not tension)
- Implications for tab-and-slot construction
- Restricted in quenched and tempered steels



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AWS D1.1: 2015 Structural Welding Code – Steel		
		
Table 2.3 Allowable Stresses (see 2.6.4 and 2.16.1)		
Type of Applied Stress	Allowable Stress	Required Filler Metal Strength Level
Plug and Slot Welds		
Shear parallel to the faying surface on the effective area ^f	0.30 × classification tensile strength of filler metal	Filler metal with a strength level equal to or less than matching filler metal may be used
Shear parallel to the faying surfaces on the effective area^f.		
		
251		

AWS D1.1: 2015 Structural Welding Code – Steel	
	
2.4.5 Plug and Slot Welds	
2.4.5.3 Effective Area.	
The effective area shall be the nominal area of the hole or slot in the plane of the faying surface.	
	
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PLUG AND SLOT WELDS

Effective Area

Area = $\pi d^2/4$

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PLUG AND SLOT WELDS

Acceptable

Unacceptable


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AWS D1.1: 2015 Structural Welding Code – Steel




2.4.5.1 Diameter and Width Limitations.

The minimum diameter of the hole or the width of slot in which a plug or slot weld is to be deposited shall be no less than the thickness of the part in which it is made plus 5/16 in [8 mm]. The maximum diameter of the hole or width of slot shall not exceed the minimum diameter plus 1/8 in [3mm] or 2-1/4 time the thickness of the part, whichever is greater.


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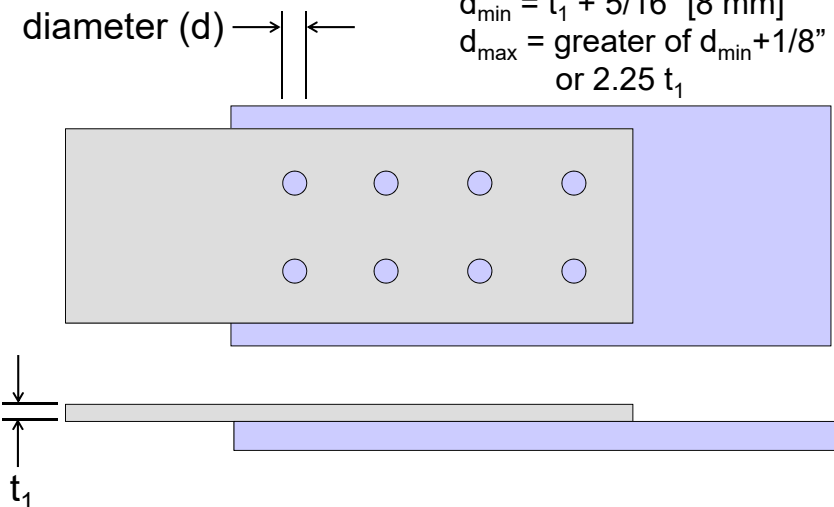
PLUG AND SLOT WELDS




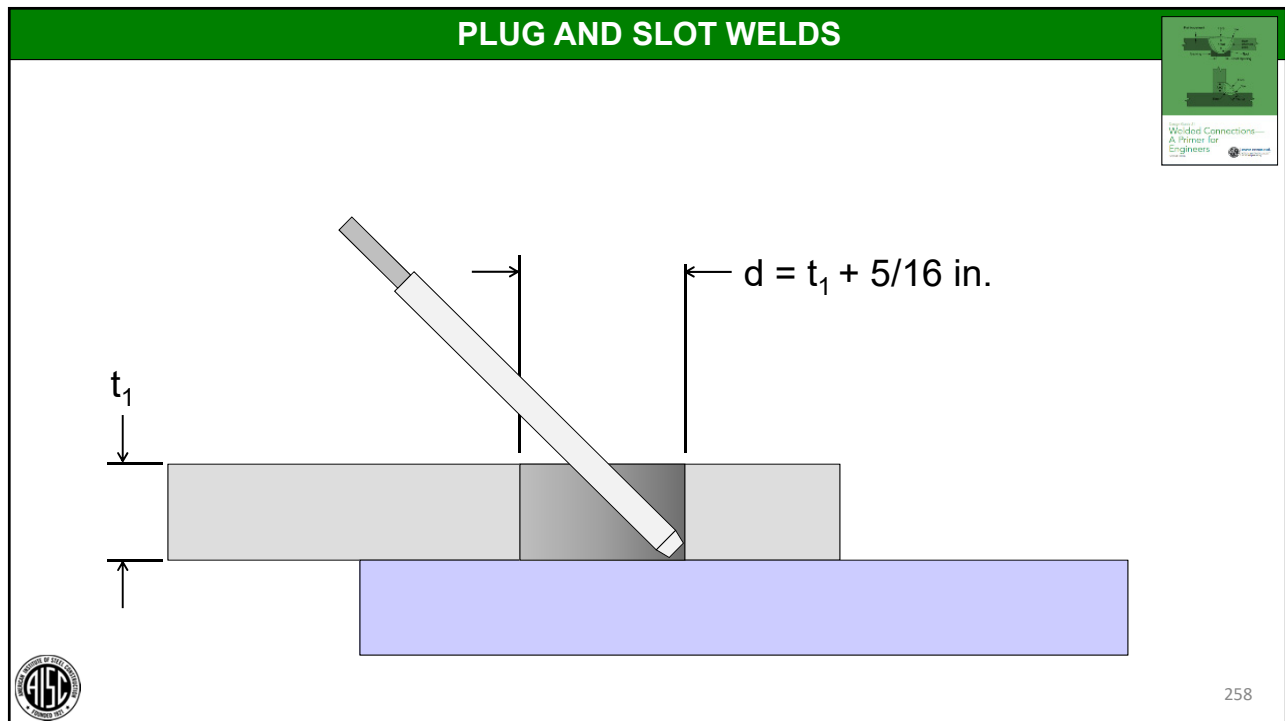
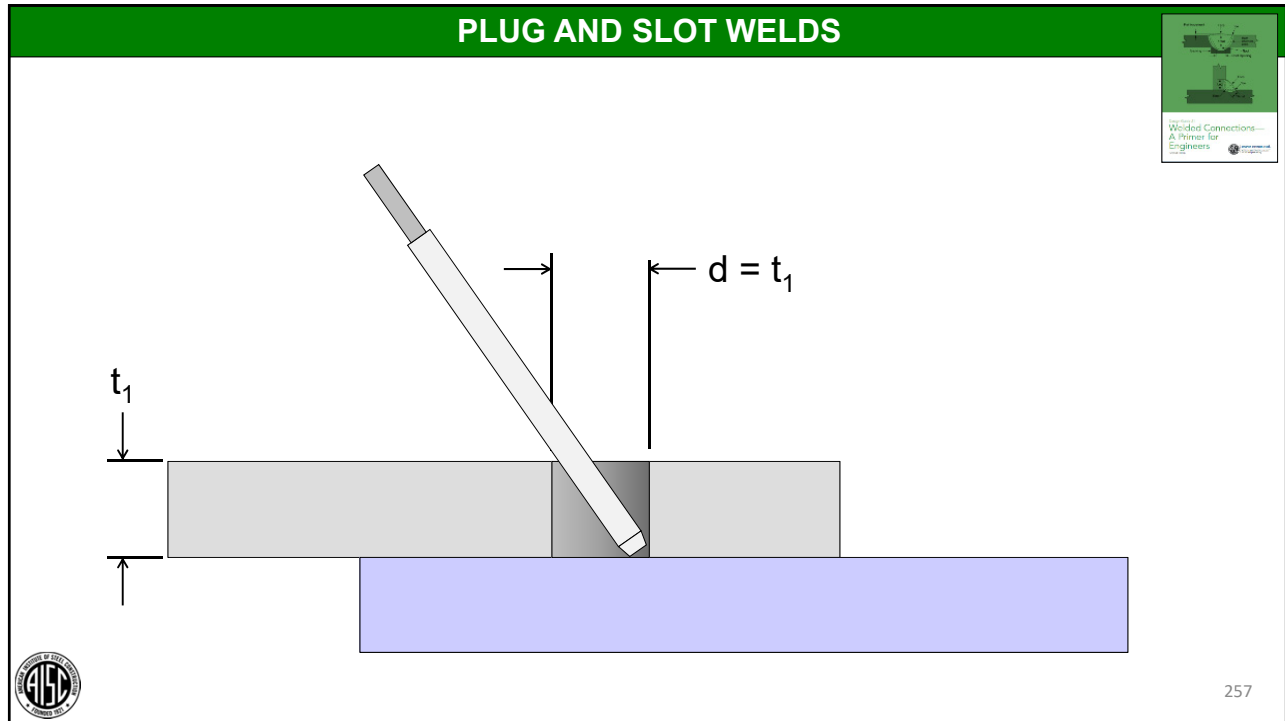
Hole diameter (d)

$$d_{\min} = t_1 + 5/16" [8 \text{ mm}]$$

$$d_{\max} = \text{greater of } d_{\min} + 1/8" [3\text{mm}] \text{ or } 2.25 t_1$$



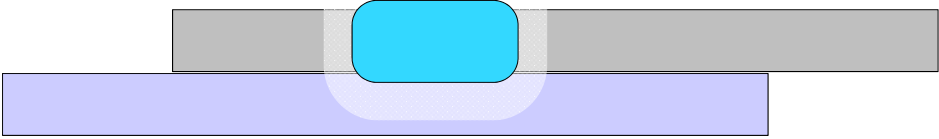



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PLUG AND SLOT WELDS

Prohibition on Quenched and Tempered Steels




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WELDED CONNECTION DETAILS

Outline

- Joints
- CJP Groove Welds
- PJP Groove Welds
- Fillet Welds
- Plug and Slot Welds
- ➔ • Tack Welds
- Weld Metal Strength





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AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0-2010)

tack weld.



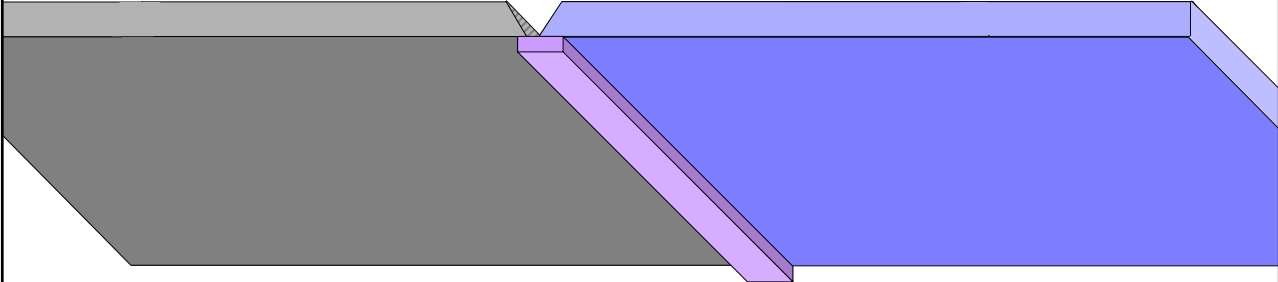
A weld made to hold parts of a weldment in proper alignment until the final welds are made.



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TACK WELDS

Tack welds attaching backing change stress distribution.




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TACK WELDS

Tack welds attaching backing change stress distribution.

Welded Connections—
A Primer for
Engineers




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TACK WELDS

Tack welding in the joint

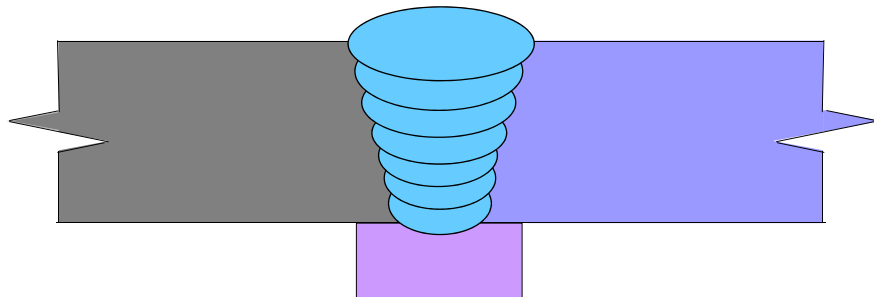
Welded Connections—
A Primer for
Engineers





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TACK WELDS

Tack welding in the joint



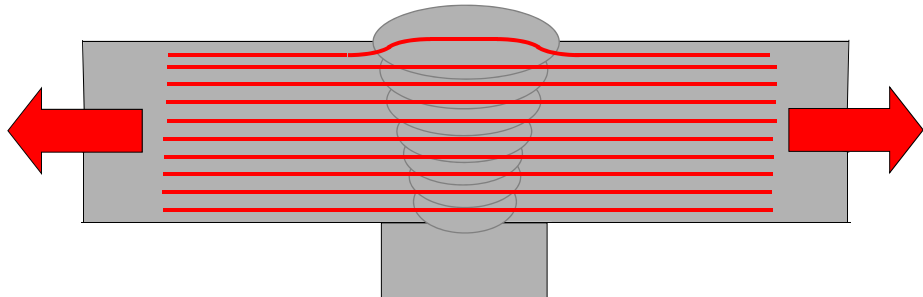
The diagram shows a cross-section of a steel joint. A central vertical purple rectangular element is positioned between two horizontal plates: a grey one on the left and a blue one on the right. Five blue, semi-circular weld ripples are shown vertically along the top surface of the purple element, representing tack welds. The horizontal plates have jagged ends on both sides, indicating they are part of a larger assembly.





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TACK WELDS

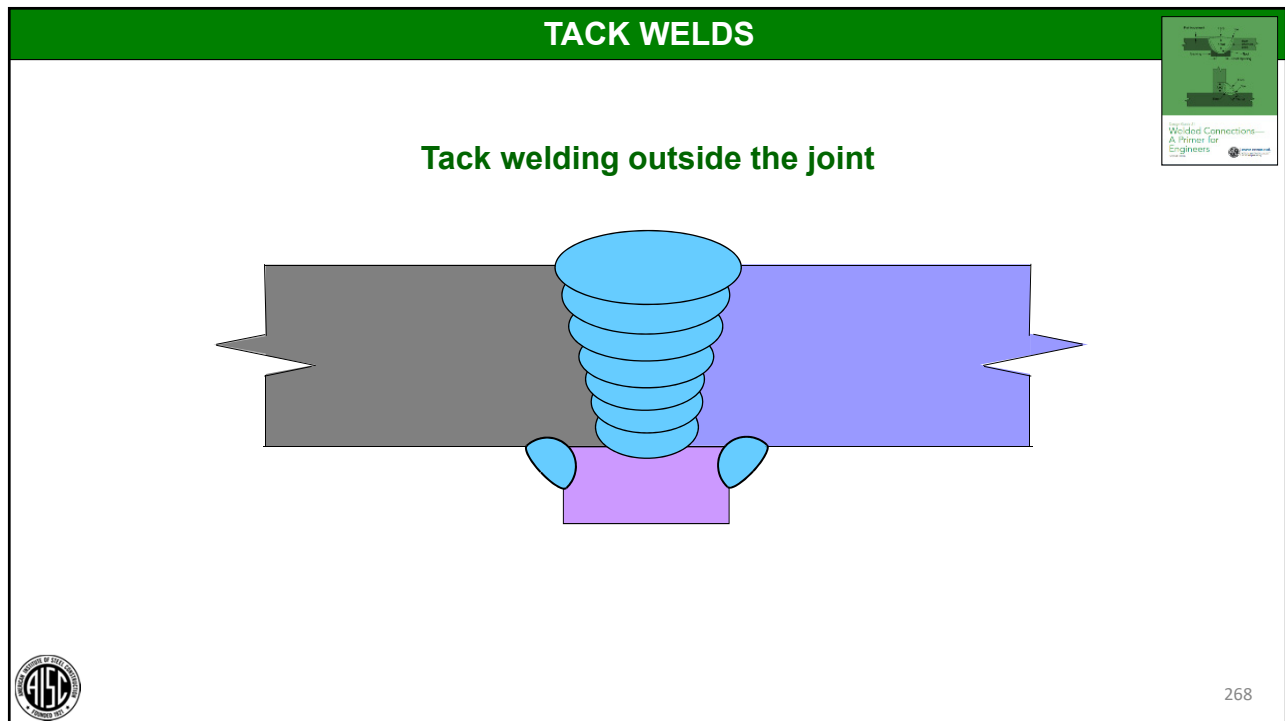
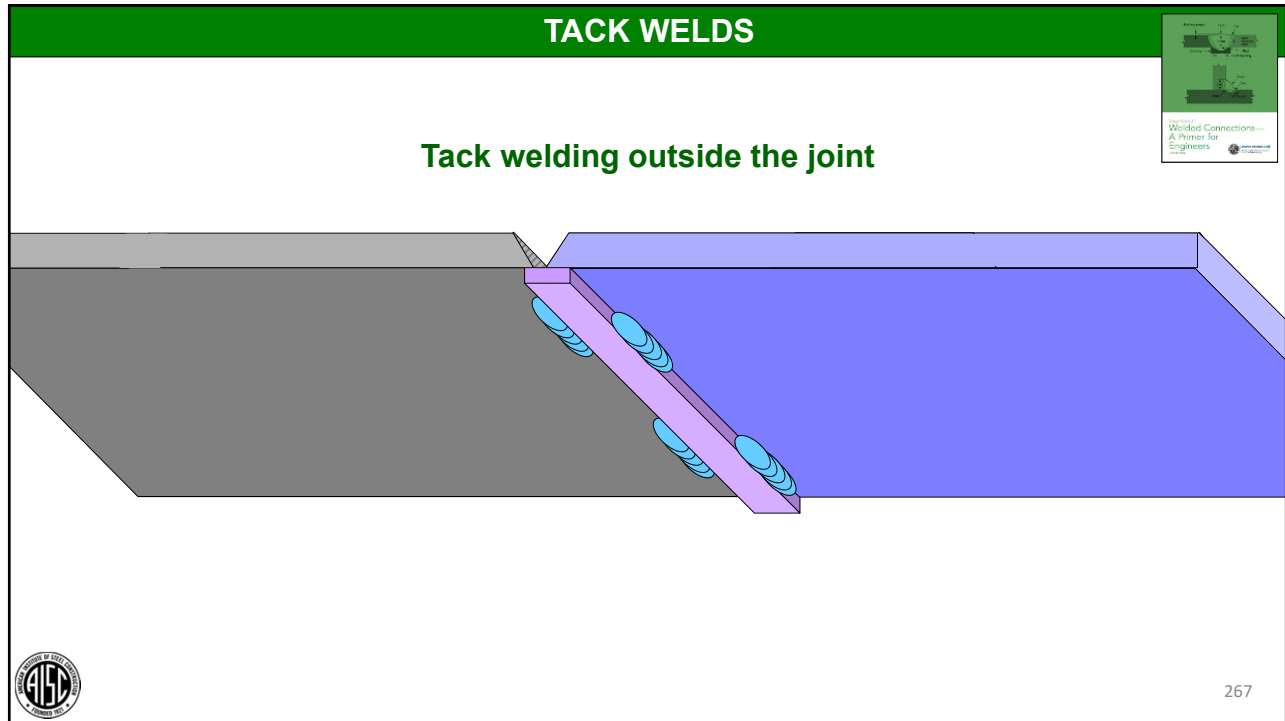
Tack welding in the joint



The diagram shows a cross-section of a steel joint, similar to the one above. A central vertical grey rectangular element is positioned between two horizontal plates, both of which are grey. Five horizontal red lines are drawn across the joint, representing tack welds. A red arrow points to the left from the left plate, and another red arrow points to the right from the right plate, indicating the direction of applied force. The welds are shown as slightly curved, suggesting they are under stress.

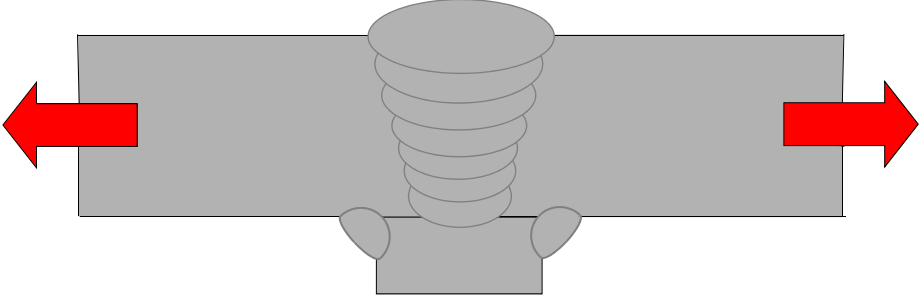


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TACK WELDS

Tack welding outside the joint



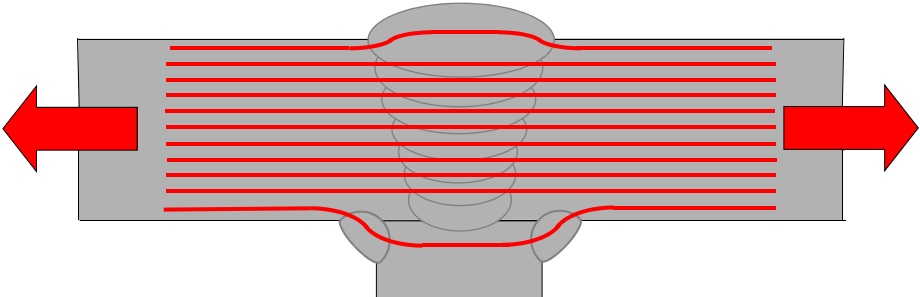
The diagram shows a bolted connection between two steel plates. A central bolt with a nut and washer is shown. Two red arrows point outwards from the plates, indicating tension. The plates are shown with a slight gap between them, and the bolt is positioned in the center. The text 'Tack welding outside the joint' is written above the diagram.





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TACK WELDS

Tack welding outside the joint



The diagram shows a bolted connection between two steel plates. A central bolt with a nut and washer is shown. Two red arrows point outwards from the plates, indicating tension. The plates are shown with a slight gap between them, and the bolt is positioned in the center. The text 'Tack welding outside the joint' is written above the diagram.



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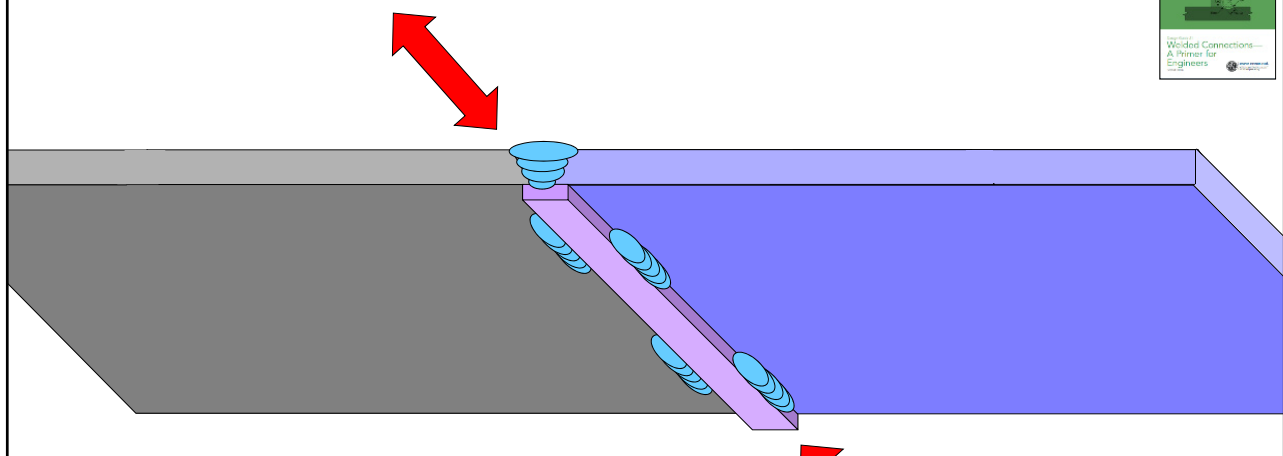
TACK WELDS

Tack welds on backing and fatigue




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TACK WELDS

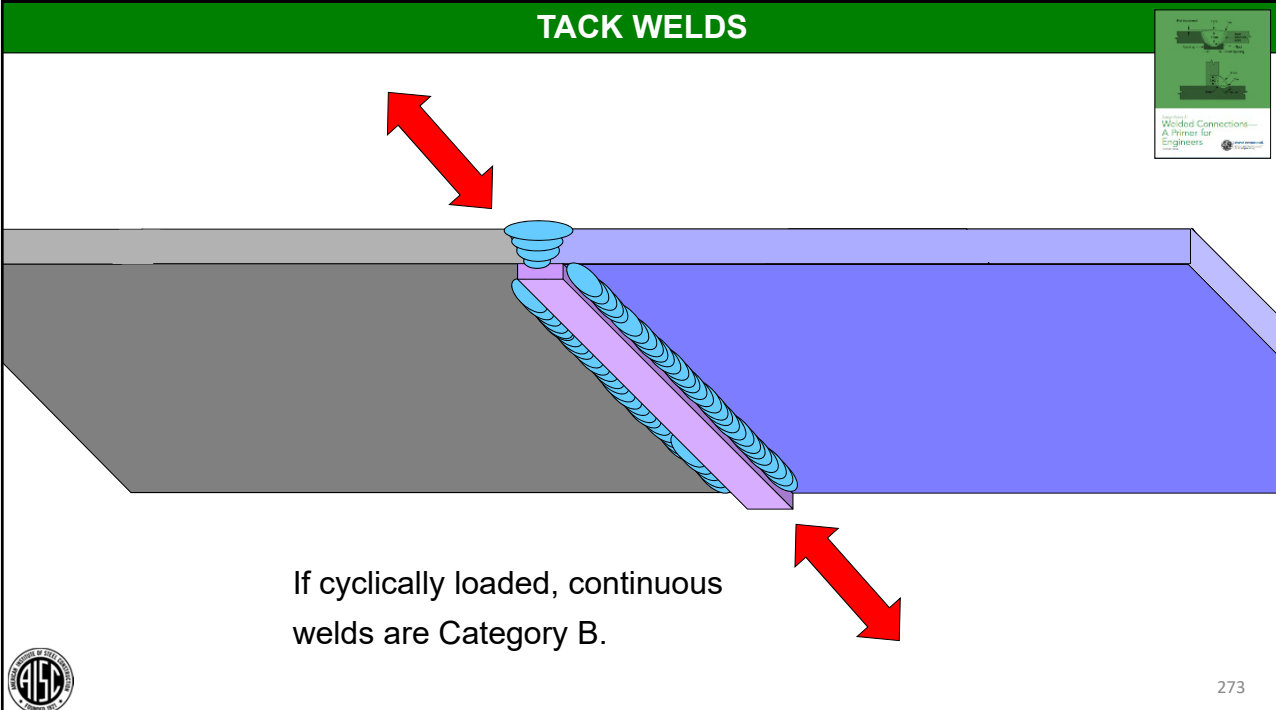


If cyclically loaded, tack welds to backing are Category E.





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TACK WELDS



If cyclically loaded, continuous welds are Category B.

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AWS D1.1: 2015 Structural Welding Code – Steel



5.17 Tack Welds and Construction Aid Welds

5.17.1 General Requirements

- (1) Tack welds and construction aid welds shall be made with a qualified or prequalified WPS and by qualified personnel.
- (2) Tack welds that are not incorporated in final welds, and construction aid welds that are not removed, shall meet visual inspection requirements before a member is accepted.

Make tack weld like other welds

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AWS D1.1: 2015 Structural Welding Code – Steel



5.17 Tack Welds and Construction Aid Welds

5.17.2 Exclusions.

Tack welds and construction aid welds are permitted except that:

- (1) In tension zones of cyclically loaded structures, there shall be no tack welds not incorporated into the final weld except as permitted by 2.17.2, nor construction aid welds. Locations more than $1/6$ of the depth of the web from tension flanges of beams or girders are considered outside the tension zone.



Be careful with tack weld when loading is cyclic and seismic

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AWS D1.1: 2015 Structural Welding Code – Steel



5.17 Tack Welds and Construction Aid Welds

5.17.2 Exclusions.

Tack welds and construction aid welds are permitted except that:

- (2) On members made of quenched and tempered steel with specified yield strength greater than 70 ksi [485 MPa], tack welds outside the final weld and construction aid welds shall require the approval of the Engineer.



Be careful with tack weld when steel is Q&T

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WELDED CONNECTION DETAILS

Outline

- Joints
- CJP Groove Welds
- PJP Groove Welds
- Fillet Welds
- Plug and Slot Welds
- Tack Welds
- ➔ • Weld Metal Strength



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WELD METAL STRENGTH

- Matching
- Undermatching
- Overmatching



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WELD METAL STRENGTH



Matching Strength

- Only required for CJP in tension
- OK for all welds
- Usually used for groove welds
- Compares minimum specified tensile strength values
(F_y/F_u ratios = different)



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WELD METAL STRENGTH



Undermatching Strength

- Typical applications are fillets, PJPs on higher strength steel
- More fabrication crack resistant



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AISC 360-16 Specification for Structural Steel Buildings					
TABLE J2.5 Available Strength of Welded Joints, ksi (MPa)					
Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_u or F_w) ksi (MPa)	Effective Area (A_{fu} or A_{we}) in ² (mm ²)	Required Filler Metal Strength Level ^{MN}
COMPLETE JOINT PENETRATION GROOVE WELDS					
Tension Normal to weld axis	Strength of the joint is controlled by the base metal			Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.	
Compression Normal to weld axis	Strength of the joint is controlled by the base metal			Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.	
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.			Filler metal with a strength level equal to or less than matching filler metal is permitted.	
Shear	Strength of the joint is controlled by the base metal			Matching filler metal shall be used ²¹	
PARTIAL JOINT PENETRATION GROOVE WELDS INCLUDING FLARE V-GROOVE AND FLARE BEVEL GROOVE WELDS					
Tension Normal to weld axis	Base	$\phi = 0.75$ $\Omega = 2.00$	F_u	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.90$ $\Omega = 1.88$	$0.60F_{uX}$	See J2.1a	
Compression Column to base plate and column splices designed per Section J1.4(1)	Compressive stress need not be considered in design of welds joining the parts.				
Compression Connections of members designed to bear other than columns as described in Section J1.4(2)	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4	
	Weld	$\phi = 0.90$ $\Omega = 1.88$	$0.60F_{uX}$	See J2.1a	
Compression Connections not finished-to-bear	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4	
	Weld	$\phi = 0.90$ $\Omega = 1.88$	$0.90F_{uX}$	See J2.1a	
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.				
Shear	Base	Governed by J4			
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{uX}$	See J2.1a	

TABLE J2.5
 Allowable Strength of Welded Joints



AISC 360-16 Specification for Structural Steel Buildings					
TABLE J2.5 (continued) Available Strength of Welded Joints, ksi (MPa)					
Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_u or F_w) ksi (MPa)	Effective Area (A_{fu} or A_{we}) in ² (mm ²)	Required Filler Metal Strength Level ^{MN}
FILLET WELDS INCLUDING FILLETS IN HOLES AND SLOTS AND SKEWED T-JOINTS					
Shear	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{uX}$ ²¹	See J2.2a	
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.				
FILLS AND SLOT WELDS					
Shear Parallel to laying surface on the surface on the effective area	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{uX}$	See J2.3a	

²¹ For matching filler metal see AWS D1.1/D1.1M, Section 3.3.
²² Filler metal with a strength level one strength level greater than matching is permitted.
²³ Filler metals with a strength level less than matching may be used for groove welds between the webs and flanges of built-up sections transmitting shear loads, or in applications where high restraint is a concern. In these applications, the weld joint shall be detailed and the weld shall be designed using the thickness of the material as the effective throat, where $\phi = 0.80$, $\Omega = 1.88$ and $0.60F_{uX}$ is the nominal strength.
²⁴ Alternatively, the provisions of Section J2.4(a) are permitted provided the deformation compatibility of the various weld statements is considered. Sections J2.4(b) and (c) are special applications of Section J2.4(a) that provide for deformation compatibility.

TABLE J2.5
 Allowable Strength of Welded Joints



AISC 360-16 Specification for Structural Steel Buildings					
TABLE J2.5 Available Strength of Welded Joints, ksi (MPa)					
Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_{tBM} or F_{tW}) ksi (MPa)	Effective Area (A_{tBM} or A_{tW}) in. ² (mm ²)	Required Filler Metal Strength Level [a][b]
COMPLETE-JOINT-PENETRATION GROOVE WELDS					
Tension Normal to weld axis	Strength of the joint is controlled by the base metal			Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.	
Compression Normal to weld axis	Strength of the joint is controlled by the base metal			Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.	
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.			Filler metal with a strength level equal to or less than matching filler metal is permitted.	
Shear	Strength of the joint is controlled by the base metal			Matching filler metal shall be used. ^[c]	



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AISC 360-16 Specification for Structural Steel Buildings		
Complete-Joint-Penetration Groove Welds		
COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal	Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[c]

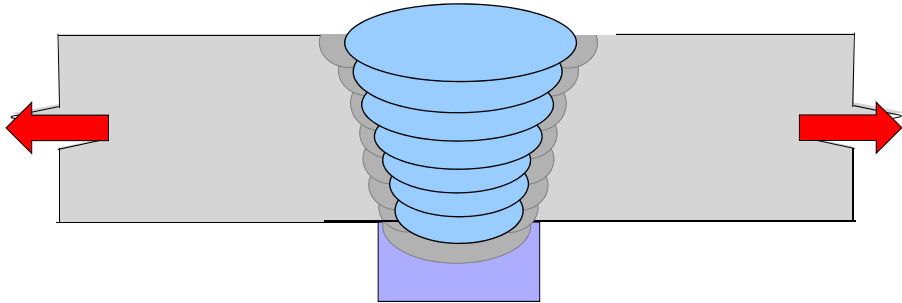



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WELD METAL STRENGTH

CJP Groove Weld

Tension normal (perpendicular) to the weld axis








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AISC 360-16 Specification for Structural Steel Buildings

Complete-Joint-Penetration Groove Welds



COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal	Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[c]

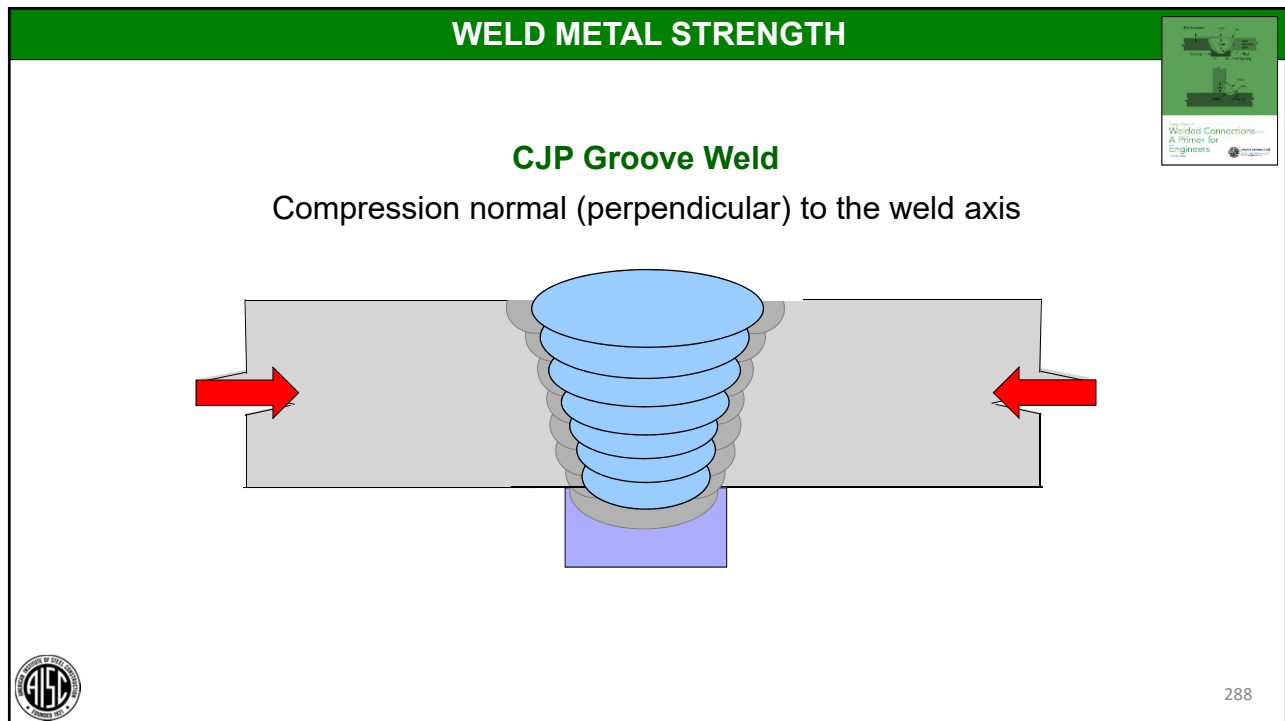

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AISC 360-16 Specification for Structural Steel Buildings

Complete-Joint-Penetration Groove Welds

COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal	Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^(c)

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AISC 360-16 Specification for Structural Steel Buildings		
Complete-Joint-Penetration Groove Welds		
COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal	Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[c]



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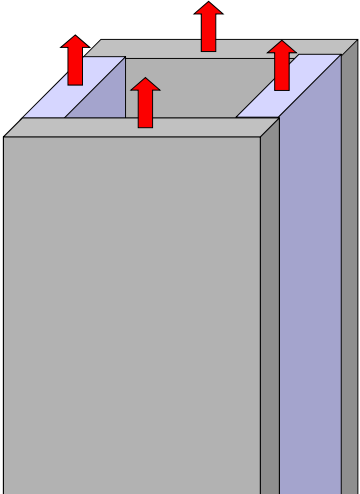
AISC 360-16 Specification for Structural Steel Buildings		
Complete-Joint-Penetration Groove Welds		
COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal	Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[c]




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WELD METAL STRENGTH


CJP Groove Weld
Tension parallel to the weld axis



The diagram shows a 3D perspective view of a CJP Groove Weld. A vertical grey rectangular block is shown with a groove cut into its top surface. The groove is filled with a grey weld metal. Four red arrows point upwards from the top surface of the block, indicating tension applied parallel to the weld axis.

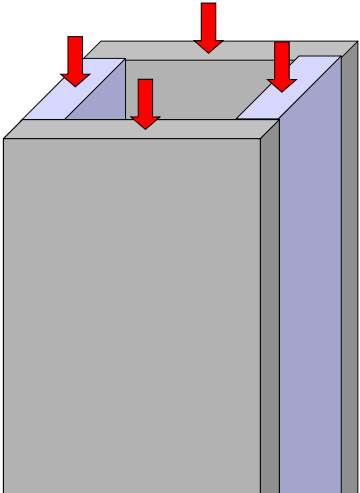

Welded Connections—
A Primer for
Engineers

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WELD METAL STRENGTH


CJP Groove Weld
Compression parallel to the weld axis



The diagram shows a 3D perspective view of a CJP Groove Weld. A vertical grey rectangular block is shown with a groove cut into its top surface. The groove is filled with a grey weld metal. Four red arrows point downwards from the top surface of the block, indicating compression applied parallel to the weld axis.


Welded Connections—
A Primer for
Engineers

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AISC 360-16 Specification for Structural Steel Buildings		
Complete-Joint-Penetration Groove Welds		
COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal	Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[c]

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AISC 360-16 Specification for Structural Steel Buildings		
Complete-Joint-Penetration Groove Welds		
COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal	Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[c]



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WELD METAL STRENGTH

CJP Groove Weld
Shear



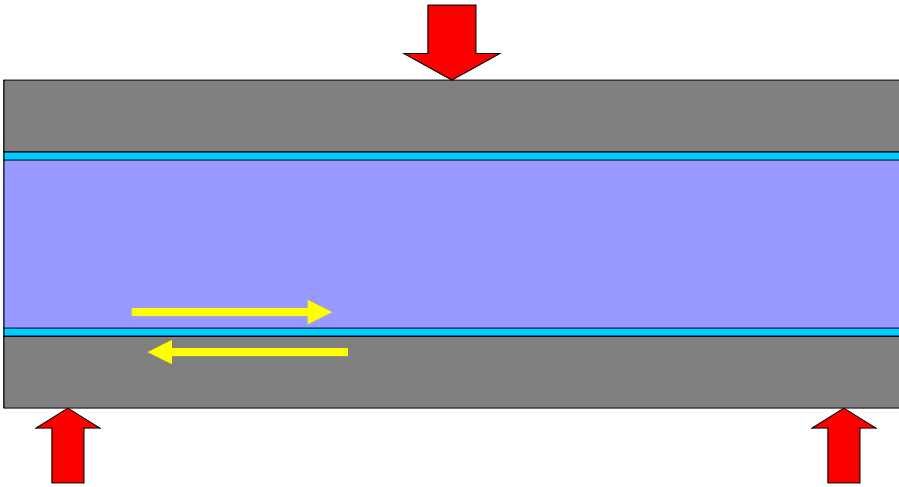
The diagram shows a vertical cross-section of a CJP Groove Weld. It consists of two grey rectangular plates, one on top and one on bottom, which are joined by a central vertical groove. The groove is filled with a blue material representing the weld metal. The entire assembly is shown in a simple, schematic style.



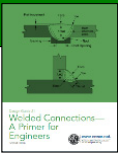

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WELD METAL STRENGTH

CJP Groove Weld
Shear




The diagram shows a horizontal cross-section of a CJP Groove Weld. It consists of two grey rectangular plates, one on top and one on bottom, which are joined by a central horizontal groove. The groove is filled with a blue material representing the weld metal. A large red arrow points downwards from the top plate, and two red arrows point upwards from the bottom plate. Two yellow arrows point horizontally in opposite directions (one to the right, one to the left) within the blue weld metal, indicating the direction of shear stress.




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AISC 360-16 Specification for Structural Steel Buildings




Complete-Joint-Penetration Groove Welds

COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal	Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[c]



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AISC 360-16 Specification for Structural Steel Buildings



Partial-Joint-Penetration Groove Welds

PARTIAL-JOINT-PENETRATION GROOVE WELDS INCLUDING FLARE V-GROOVE AND FLARE BEVEL GROOVE WELDS				
Tension Normal to weld axis	Base	$\phi = 0.75$ $\Omega = 2.00$	F_u	See J4
	Weld	$\phi = 0.80$ $\Omega = 1.88$	$0.60F_{EXX}$	See J2.1a
Compression Column to base plate and column splices designed per Section J1.4(1)	Compressive stress need not be considered in design of welds joining the parts.			
Compression Connections of members designed to bear other than columns as described in Section J1.4(2)	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4
	Weld	$\phi = 0.80$ $\Omega = 1.88$	$0.60F_{EXX}$	See J2.1a
Compression Connections not finished-to-bear	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4
	Weld	$\phi = 0.80$ $\Omega = 1.88$	$0.90F_{EXX}$	See J2.1a
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.			
Shear	Base	Governed by J4		
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$	See J2.1a


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AISC 360-16 Specification for Structural Steel Buildings

Fillet Welds

FILLET WELDS INCLUDING FILLETS IN HOLES AND SLOTS AND SKEWED T-JOINTS					
Shear	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}^{(d)}$	See J2.2a	
Tension or compression Parallel to weld axis		Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.			

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AISC 360-16 Specification for Structural Steel Buildings

Plug and Slot Welds

PLUG AND SLOT WELDS					
Shear Parallel to faying surface on the surface on the effective area	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$	See J2.3a	


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AISC 360-16 Specification for Structural Steel Buildings




Matching filler metal required.

TABLE J2.5 Available Strength of Welded Joints, ksi (MPa)					
Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_u or F_w) ksi (MPa)	Effective Area ($A_{e,w}$ or $A_{e,m}$) in ² (mm ²)	Required Filler Metal Strength Level MIN
COMPLETE JOINT PENETRATION GROOVE WELDS					
Tension Normal to weld axis	Strength of the joint is controlled by the base metal			Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.	
Compression Normal to weld axis	Strength of the joint is controlled by the base metal			Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.	
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.			Filler metal with a strength level equal to or less than matching filler metal is permitted.	
Shear	Strength of the joint is controlled by the base metal			Matching filler metal shall be used. ²	
PARTIAL JOINT PENETRATION GROOVE WELDS INCLUDING FLARE V-GROOVE AND FLARE BEVEL GROOVE WELDS					
Tension Normal to weld axis	Base	$\phi = 0.75$ $\Omega = 2.00$	F_u	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Weld	$\phi = 0.90$ $\Omega = 1.88$	$0.60F_{2XX}$	See J2.1a		
Compression Column to base plate and column splices designed per Section J1.4(1)	Compressive stress need not be considered in design of welds joining the parts.				
Compression Connections of members designed to bear other than columns as described in Section J1.4(2)	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Weld	$\phi = 0.90$ $\Omega = 1.88$	$0.60F_{2XX}$	See J2.1a		
Compression Connections not finished-to-bear	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Weld	$\phi = 0.90$ $\Omega = 1.88$	$0.90F_{2XX}$	See J2.1a		
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.				
Shear	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{2XX}$	See J2.1a		




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One strength level less than matching is permitted.


TABLE J2.5 Available Strength of Welded Joints, ksi (MPa)					
Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_u or F_w) ksi (MPa)	Effective Area ($A_{e,w}$ or $A_{e,m}$) in ² (mm ²)	Required Filler Metal Strength Level MIN
COMPLETE JOINT PENETRATION GROOVE WELDS					
Tension Normal to weld axis	Strength of the joint is controlled by the base metal			Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.	
Compression Normal to weld axis	Strength of the joint is controlled by the base metal			Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.	
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.			Filler metal with a strength level equal to or less than matching filler metal is permitted.	
Shear	Strength of the joint is controlled by the base metal			Matching filler metal shall be used. ²	
PARTIAL JOINT PENETRATION GROOVE WELDS INCLUDING FLARE V-GROOVE AND FLARE BEVEL GROOVE WELDS					
Tension Normal to weld axis	Base	$\phi = 0.75$ $\Omega = 2.00$	F_u	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Weld	$\phi = 0.90$ $\Omega = 1.88$	$0.60F_{2XX}$	See J2.1a		
Compression Column to base plate and column splices designed per Section J1.4(1)	Compressive stress need not be considered in design of welds joining the parts.				
Compression Connections of members designed to bear other than columns as described in Section J1.4(2)	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Weld	$\phi = 0.90$ $\Omega = 1.88$	$0.60F_{2XX}$	See J2.1a		
Compression Connections not finished-to-bear	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Weld	$\phi = 0.90$ $\Omega = 1.88$	$0.90F_{2XX}$	See J2.1a		
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.				
Shear	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{2XX}$	See J2.1a		




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Undermatching is permitted.







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Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_{EW} or F_{EW}) ksi (MPa)	Effective Area (A_{EW} or A_{EW}) in. ² (mm ²)	Required Filler Metal Strength Level ^{MN}
COMPLETE JOINT PENETRATION GROOVE WELDS					
Tension Normal to weld axis			Strength of the joint is controlled by the base metal		Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis			Strength of the joint is controlled by the base metal		Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression Parallel to weld axis			Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.		Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear			Strength of the joint is controlled by the base metal		Matching filler metal shall be used ²¹
PARTIAL JOINT PENETRATION GROOVE WELDS INCLUDING FLARE V-GROOVE AND FLARE BEVEL GROOVE WELDS					
Tension Normal to weld axis	Base	$\phi = 0.75$ $\Omega = 2.00$	F_u	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.90$ $\Omega = 1.98$	$0.60F_{EXX}$	See J2.1a	
Compression Column to base plate and column splices designed per Section J1.4(1)			Compressive stress need not be considered in design of welds joining the parts.		
Compression Connections of members designed to bear other than columns as described in Section J1.4(2)	Base	$\phi = 0.90$ $\Omega = 1.97$	F_y	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.90$ $\Omega = 1.98$	$0.60F_{EXX}$	See J2.1a	
Compression Connections not finished-to-bear	Base	$\phi = 0.90$ $\Omega = 1.97$	F_y	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.90$ $\Omega = 1.98$	$0.90F_{EXX}$	See J2.1a	
Tension or compression Parallel to weld axis			Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.		
Shear	Base		Governed by J4		
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$	See J2.1a	

AISC 360-16 Specification for Structural Steel Buildings

Undermatching is permitted.





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Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_{EW} or F_{EW}) ksi (MPa)	Effective Area (A_{EW} or A_{EW}) in. ² (mm ²)	Required Filler Metal Strength Level ^{MN}
FILLET WELDS INCLUDING FILLETS IN HOLES AND SLOTS AND SKEWED T-JOINTS					
Shear	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$ ²¹	See J2.2a	
Tension or compression Parallel to weld axis			Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.		
FILLS AND SLOT WELDS					
Shear Parallel to laying surface on the surface on the effective area	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$	See J2.3a	

²¹ For matching weld metal see AWS D1.1/D1.1M, Section 3.3.
²² Filler metal with a strength level one strength level greater than matching is permitted.
²³ Filler metal with a strength level less than matching may be used for groove welds between the webs and flanges of built-up sections transmitting shear loads, or in applications where high restraint is a concern. In these applications, the weld joint shall be detailed and the weld shall be designed using the thickness of the material as the effective throat, where $\phi = 0.80$, $\Omega = 1.88$ and $0.60F_{EXX}$ is the nominal strength.
²⁴ Alternatively, the provisions of Section J2.4(a) are permitted provided the deformation compatibility of the various weld elements is considered. Sections J2.4(b) and (c) are special applications of Section J2.4(a) that provide for deformation compatibility.

AWS D1.1: 2015 Structural Welding Code – Steel



Table 2.3

Table 2.3 Allowable Stresses (see 2.6.4 and 2.16.1)		
Type of Applied Stress	Allowable Stress	Required Filler Metal Strength Level
CJP Groove Welds		
Tension normal to the effective area ^a	Same as base metal	Matching filler metal shall be used ^b
Compression normal to effective area	Same as base metal	Filler metal with a strength level equal to or one classification (10 ksi [70 MPa]) less than matching filler metal may be used.
Tension or compression parallel to axis of the weld ^d	Not a welded joint design consideration	Filler metal with a strength level equal to or less than matching filler metal may be used
Shear on effective area	0.30 × classification tensile strength of filler metal except shear on the base metal shall not exceed 0.60 × yield strength of the base metal	
PJP Groove Welds		
Tension normal to the effective area	0.30 × classification tensile strength of filler metal	
Compression normal to effective area of weld in joints designed to bear	0.90 × classification tensile strength of filler metal, but not more than 0.90 × yield strength of the connected base metal	
Compression normal to effective area of weld in joints not designed to bear	0.75 × classification tensile strength of filler metal	Filler metal with a strength level equal to or less than matching filler metal may be used
Tension or compression parallel to axis of the weld ^d	Not a welded joint design consideration	
Shear parallel to axis of effective area	0.30 × classification tensile strength of filler metal except shear on the base metal shall not exceed 0.40 × yield strength of the base metal	
Fillet Welds		
Shear on effective area or weld	0.30 × classification tensile strength of filler metal except that the base metal net section shear area stress shall not exceed 0.40 × yield strength of the base metal ^e	Filler metal with a strength level equal to or less than matching filler metal may be used
Tension or compression parallel to axis of the weld ^d	Not a welded joint design consideration	
Plug and Slot Welds		
Shear parallel to the faying surface on the effective area ^f	0.30 × classification tensile strength of filler metal	Filler metal with a strength level equal to or less than matching filler metal may be used.

^a For definitions of effective areas, see 2.4.
^b For matching filler metal to base metal strength for code approved metals, see Table 3.1 and Table 4.9.
^c Fillet welds and groove welds joining components of full-size members are allowed to be designed without regard to the tension and compression stresses in the connected components parallel to the weld axis although the area of the weld normal to the weld axis may be included in the cross-sectional area of the member.
^d The limitation on stress in the base metal to 0.40 × yield point of base metal does not apply to stress on the diagrammatic welding; however, a check shall be made to assure that the strength of the connection is not limited by the thickness of the base metal on the net area around the connection, particularly in the case of a pair of fillet welds on opposite sides of a plate element.
^e Alternatively, see 2.6.4.2, 2.6.4.3, and 2.6.4.4. Note if laborer applies.
^f The strength of the connection shall also be limited by the tear-out load capacity of the thinner base metal on the perimeter area around the connection.



WELDED CONNECTION DETAILS

Outline

- Joints
- CJP Groove Welds
- PJP Groove Welds
- Fillet Welds
- Plug and Slot Welds
- Tack Welds
- Weld Metal Strength



Thank you!

AISC | Questions?



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Individual Session Registrants

PDH Certificates

- You will receive an email on how to report attendance from: registration@aisc.org.
- Be on the lookout: Check your spam filter! Check your junk folder!
- Completely fill out online form. Don't forget to check the boxes next to each attendee's name!



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Individual Session Registrants

PDH Certificates

- Reporting site (URL will be provided in the forthcoming email).
- Username: Same as AISC website username.
- Password: Same as AISC website password.



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8-Session Registrants

PDH Certificates

One certificate will be issued at the conclusion of all 8 sessions.



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8-Session Registrants

Access to the quiz

Information for accessing the quiz will be emailed to you by Thursday. It will contain a link to access the quiz. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

Quiz and attendance records

Posted Thursday mornings. www.aisc.org/nightschool -- Click on Current Course Details.

Reasons for quiz

- EEU – You must take all quizzes and the final exam to receive EEU.
- PDHs – If you watch a recorded session, you must pass quiz for PDHs.
- REINFORCEMENT – Reinforce what you learn tonight. Get more out of the course.

Note: If you attend the live presentation, you do not have to take the quizzes to receive PDHs



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8-Session Registrants

Access to the recording

Information for accessing the recording will be emailed to you by Thursday. The recording will be available for four weeks. (For 8-session registrants only.) EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

PDHs via recording

If you watch a recorded session, you must take *and pass* the quiz for PDHs.



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Night School Resources

Find all your handouts, quizzes and quiz scores, recording access, and attendance information all in one place!



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Night School Resources

Go to www.aisc.org and sign in.



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8-Session Registrants

Night School Resources

EDUCATION PUBLICATIONS NASCC: THE STEEL CONFERENCE STEEL SOLUTIONS CENTER AWARDS AND COMPETITIONS TECHNICAL RESOURCES

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Course Resources

Event	Start Date
NS 13 8-Session Package-Night School 13 - Design of Industrial Buildings	1/30/2017 7:00:00 PM
NS 14 8-Session Package-Night School 14 - Fundamentals of Stability	6/5/2017 7:00:00 PM



8-Session Registrants

Night School Resources



Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	View Passcode: NS13DSN	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	Handouts	Available 02/08/2017 5pm EST	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	Handouts	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	Handouts	Available 03/01/2017 5pm EST	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girder Design and Frame Analysis	3/6/2017 7:00:00 PM	Handouts	Available 03/08/2017 5pm EST	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	Handouts	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Bldg Bracing Dsn	3/27/2017 7:00:00 PM	Handouts	Available 03/29/2017 5pm EST	Available 03/29/2017 5pm EST	Pending



8-Session Registrants

Night School Resources

- Weekly “quiz and recording” email.
- Weekly updates of the master quiz and attendance record, found at www.aisc.org/nightschool21. Scroll down to Quiz and Attendance records.
 - Updated on Thursday mornings.



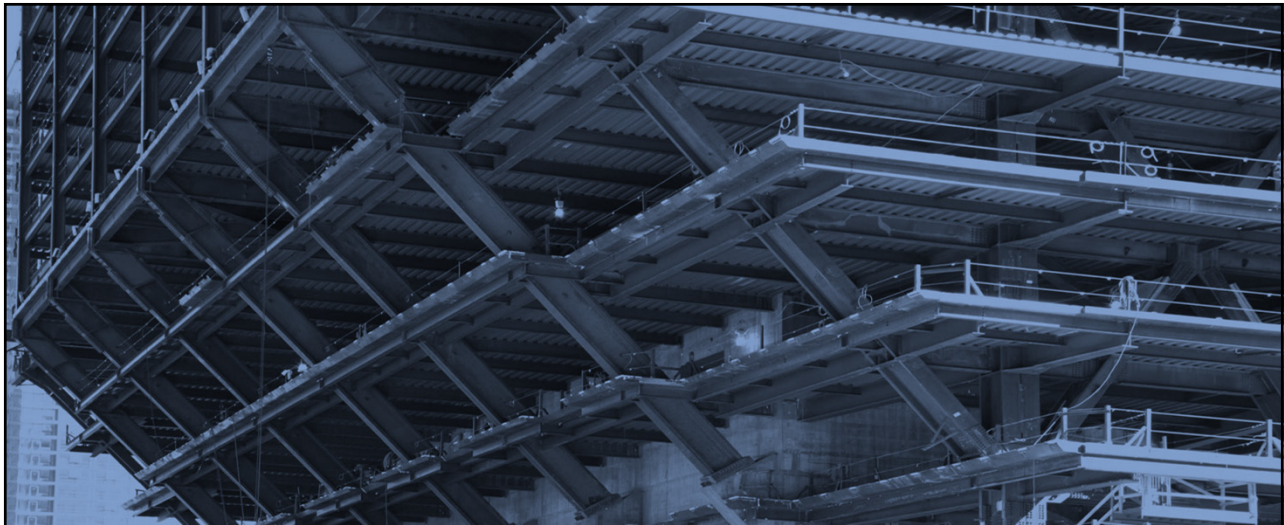
8-Session Registrants

Night School Resources

- Webinar connection information
 - Reminder email sent out Tuesday mornings
- Links to handouts also found here



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