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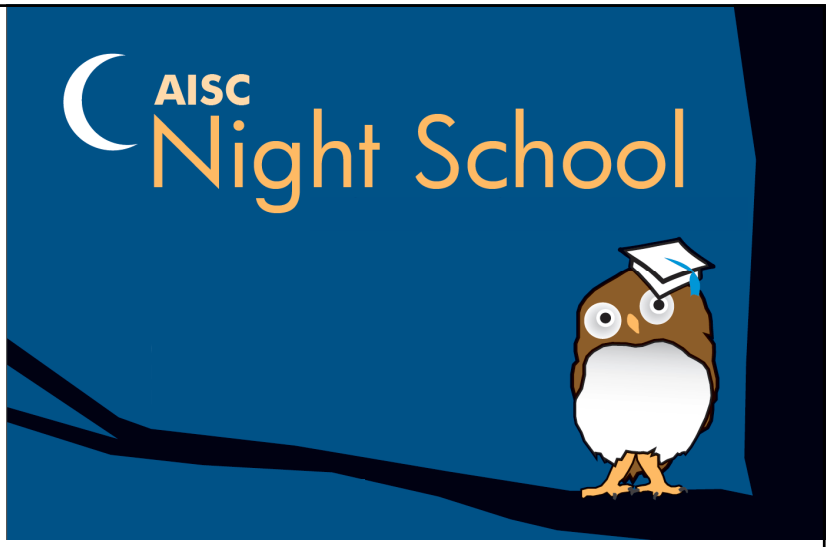

Welded Connections

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.

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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 CONECTION 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

10

WELDED CONECTION 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

11

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

12

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

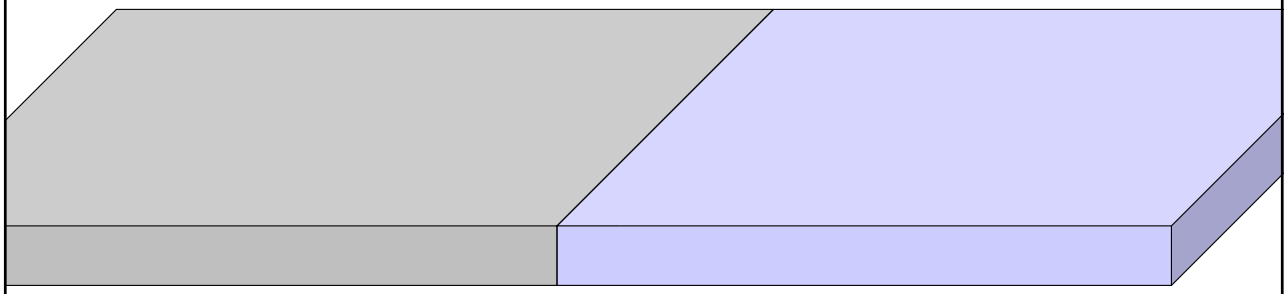
Outline

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

14

BUTT JOINTS

Butt Joint – same width, same thickness



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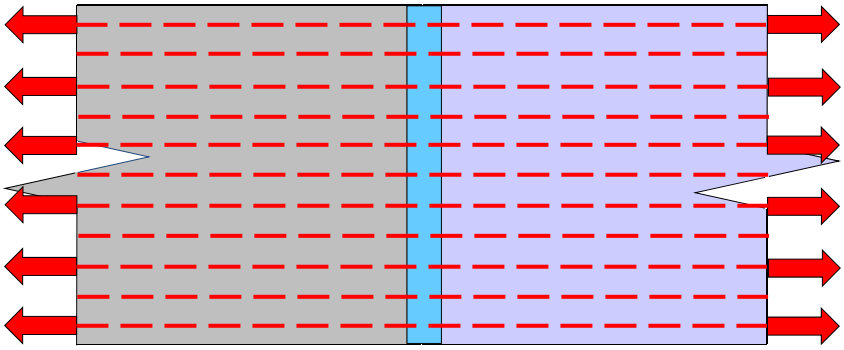
BUTT JOINTS

Butt Joint – same width, same thickness



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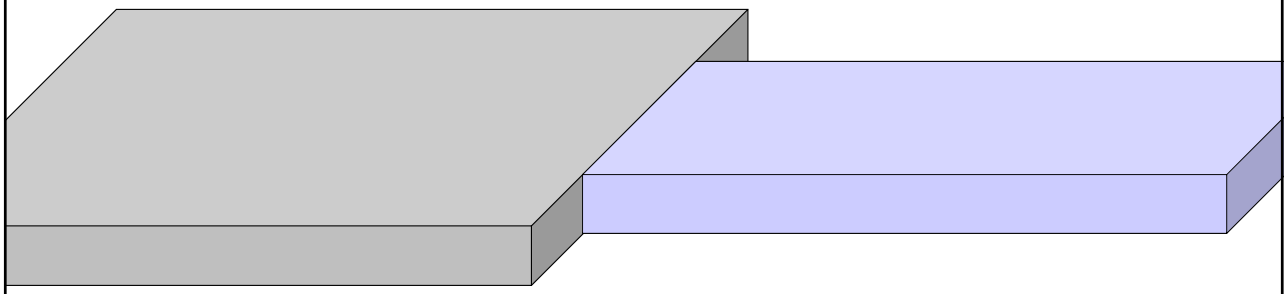
BUTT JOINTS

Butt Joint – different widths, same thickness



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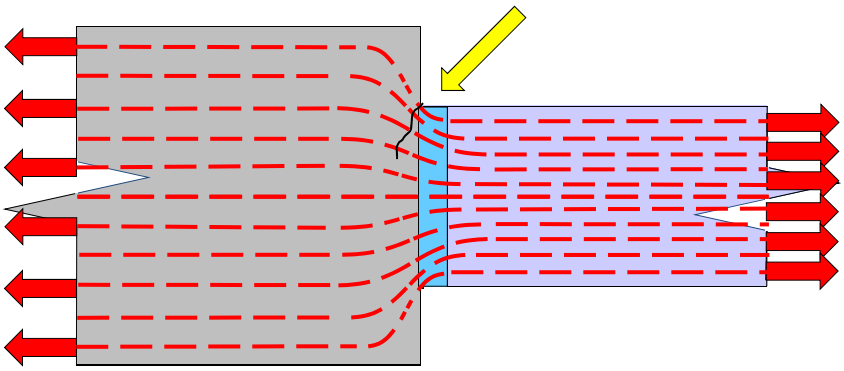
BUTT JOINTS

Butt Joint – different widths, same thickness



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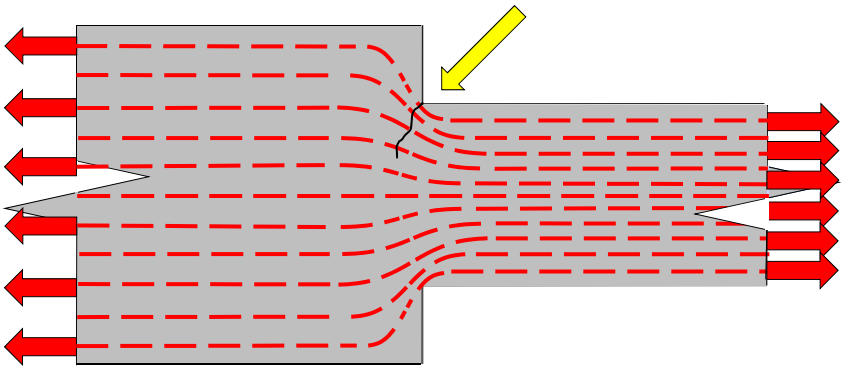
BUTT JOINTS

One piece of steel



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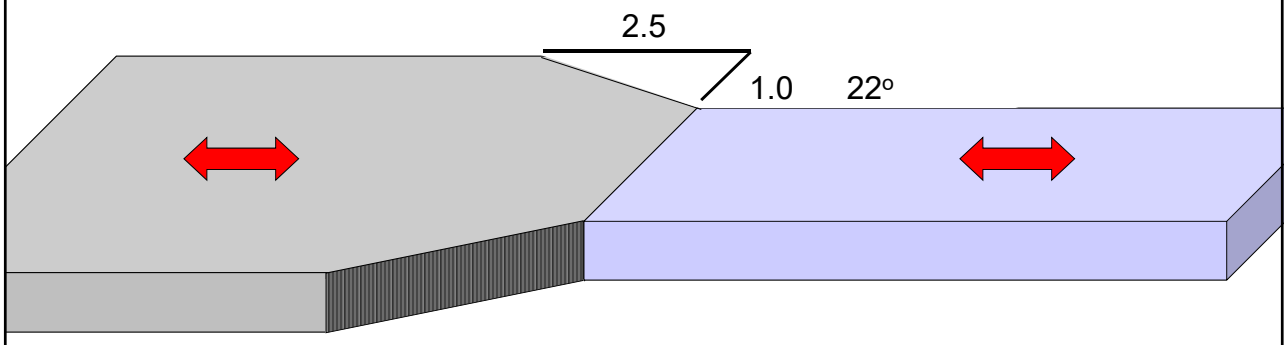
AWS D1.1: 2015 Structural Welding Code – Steel

Butt Joint – different widths

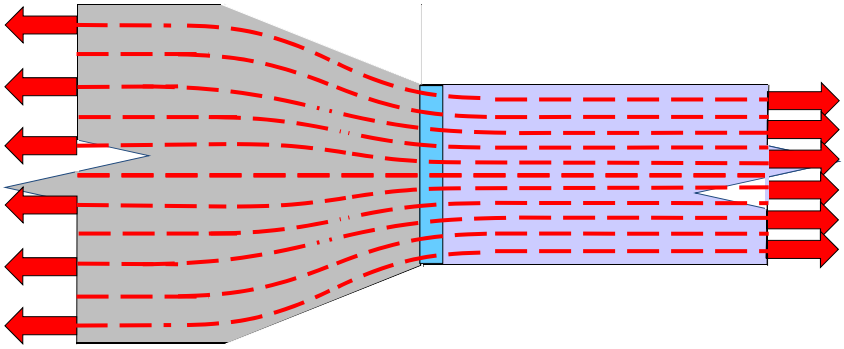


2.17.1.2 Provide transition for cyclically loaded members with width changes.

20

BUTT JOINTS

Butt Joint – different widths, same thickness



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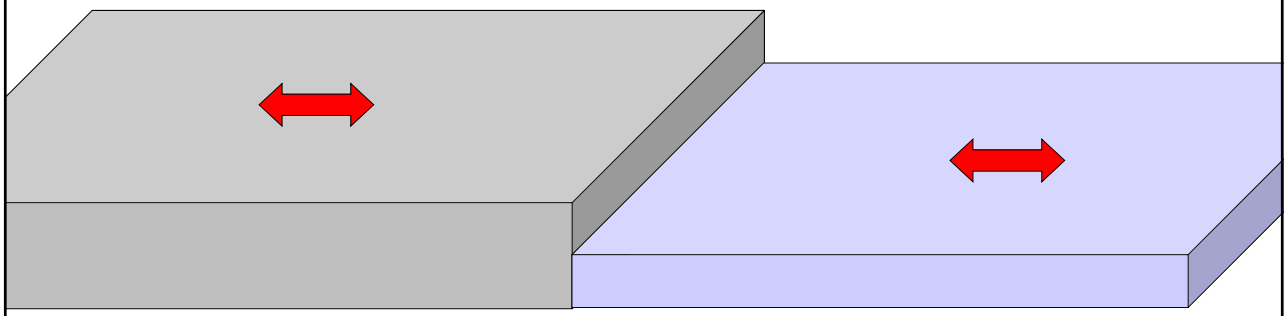
BUTT JOINTS

Butt Joint – different thicknesses



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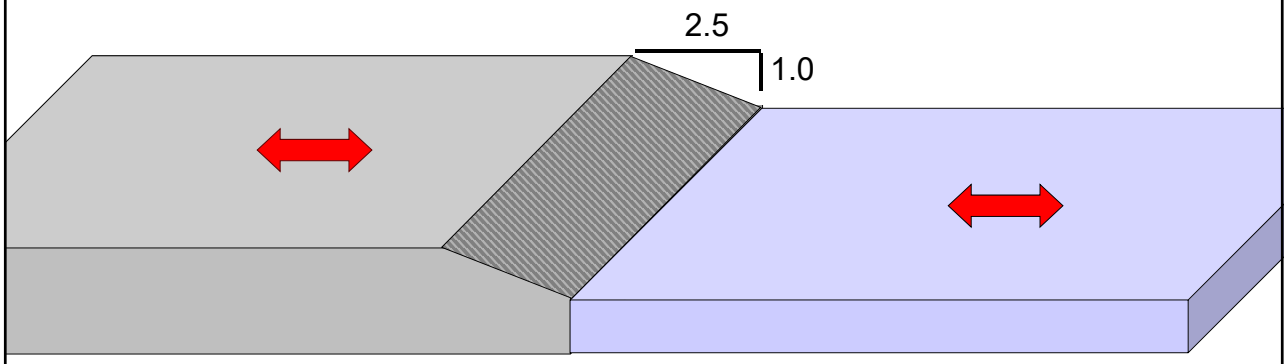
AWS D1.1: 2015 Structural Welding Code – Steel

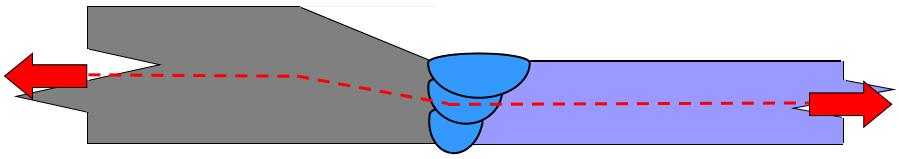
Butt Joint – different thicknesses



2.17.1.1 Provide transition for cyclically loaded members with thickness changes.

23

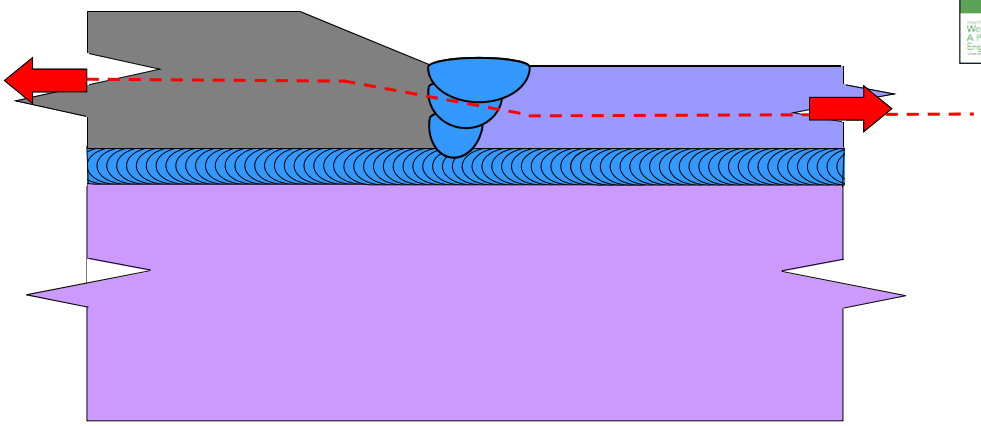
BUTT JOINTS



Secondary stresses due to eccentricity.

24

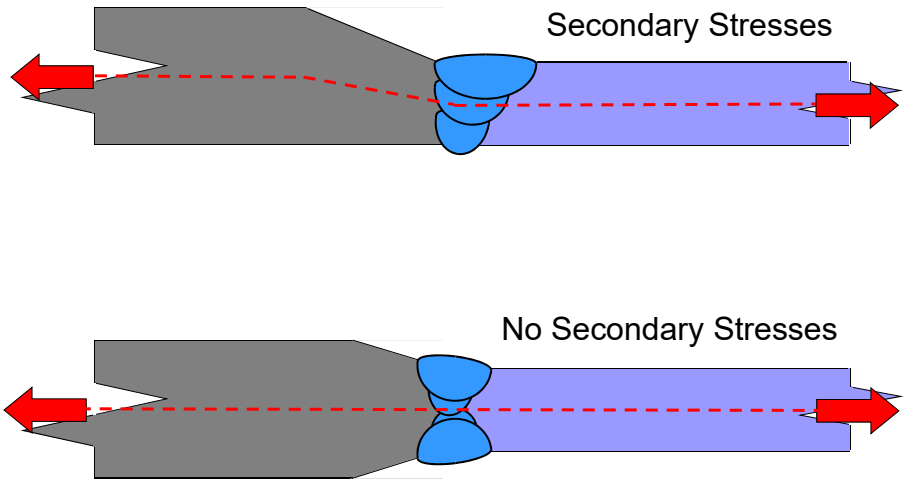
BUTT JOINTS



Web restricts rotation due to secondary stresses.

25

BUTT JOINTS



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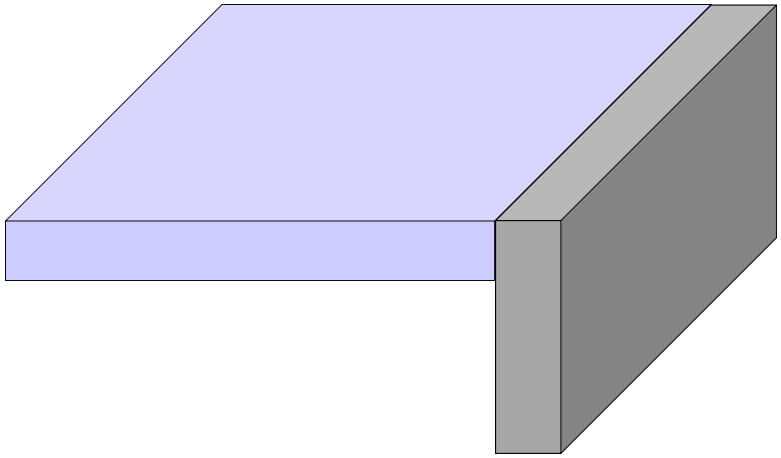
CORNER JOINTS



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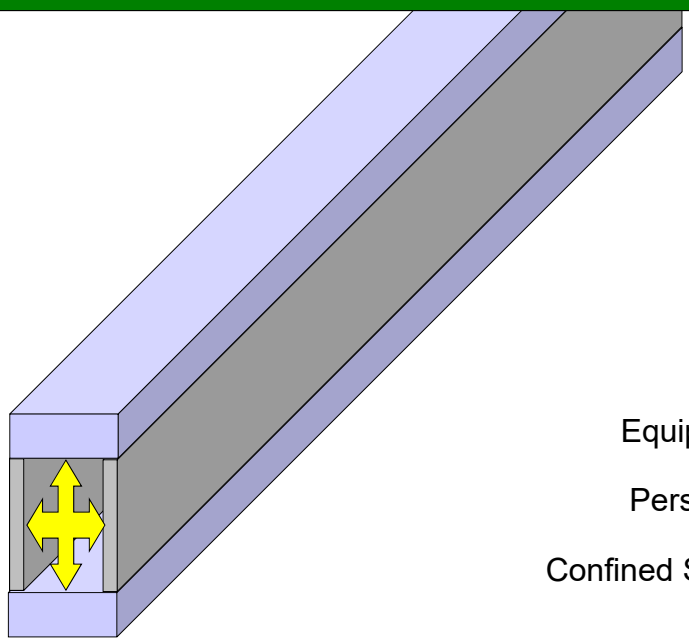
CORNER JOINTS



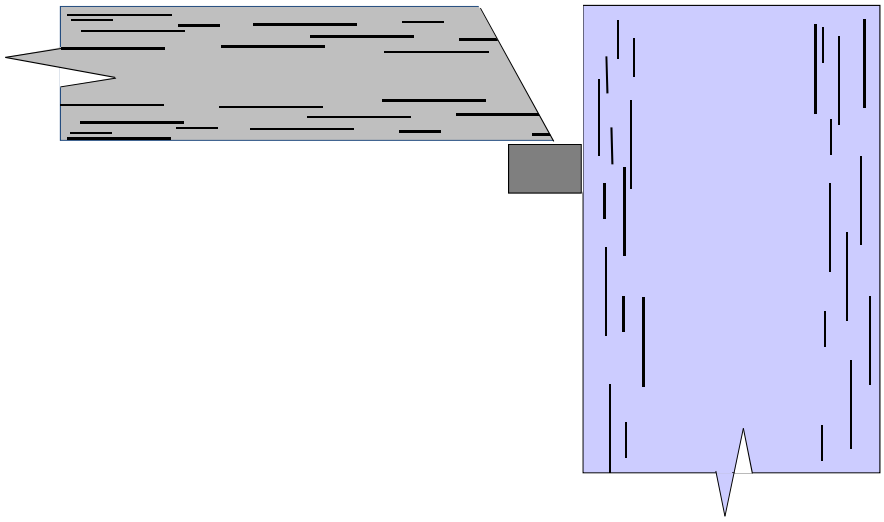
Equipment?

Personnel?

Confined Space?

28

CORNER JOINTS



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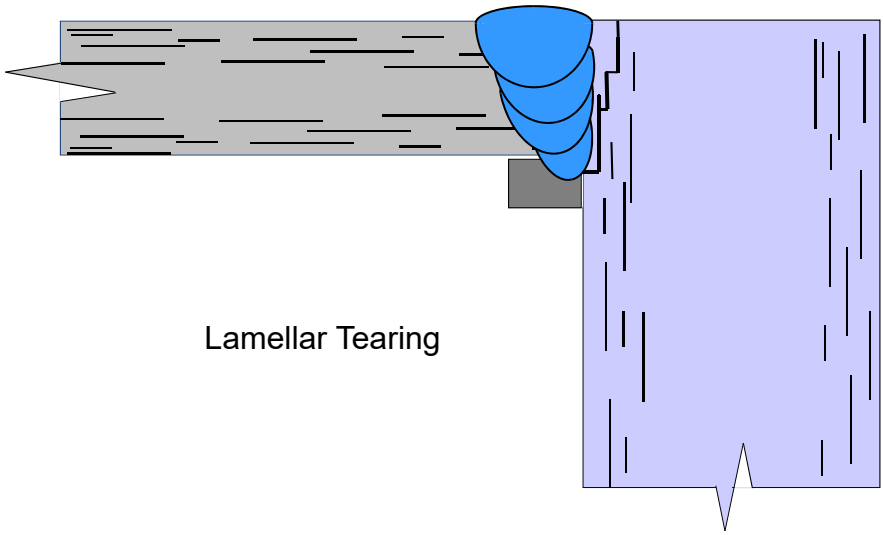
CORNER JOINTS



Lamellar Tearing

30

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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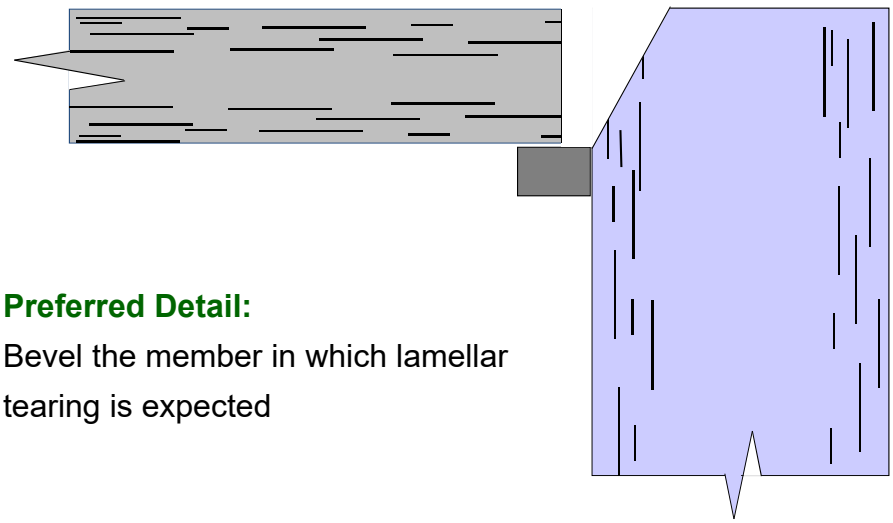
CORNER JOINTS

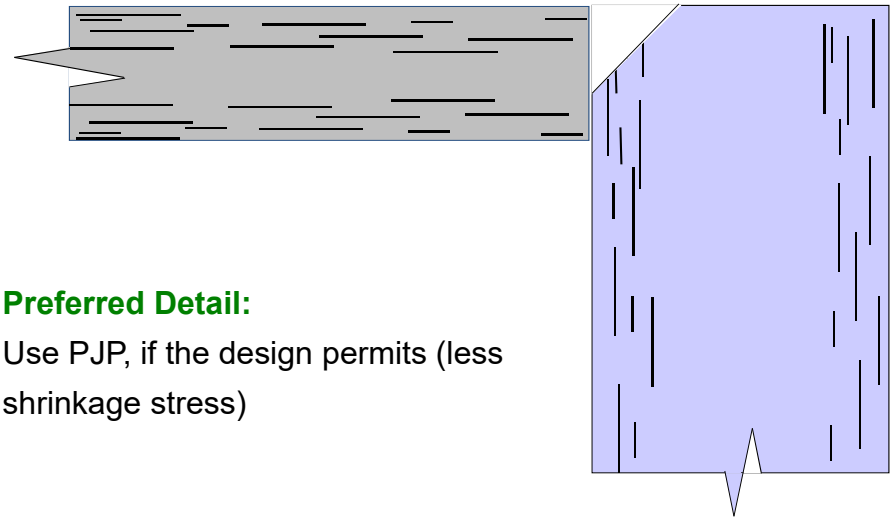


Preferred Detail:

Bevel the member in which lamellar tearing is expected

32

CORNER JOINTS



Preferred Detail:

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

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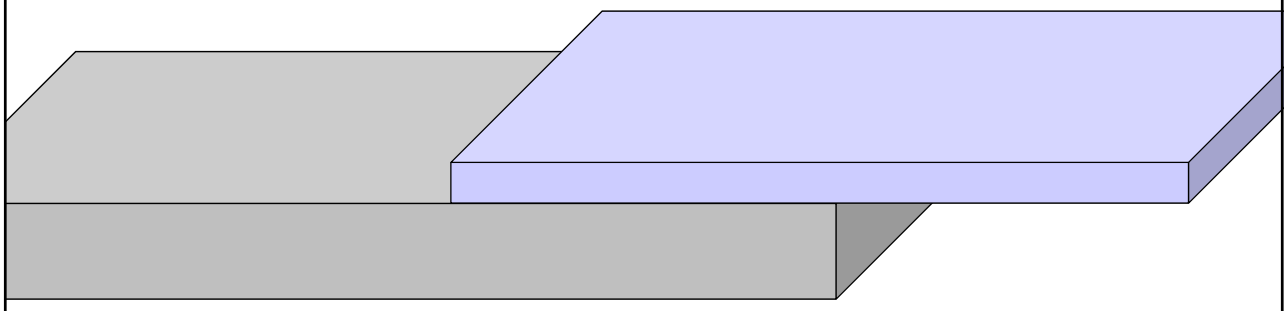
LAP JOINTS

Lap



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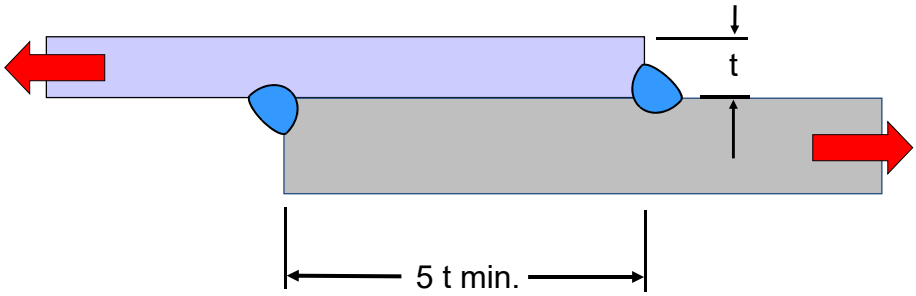
AISC 360-16 Specification J2.2b

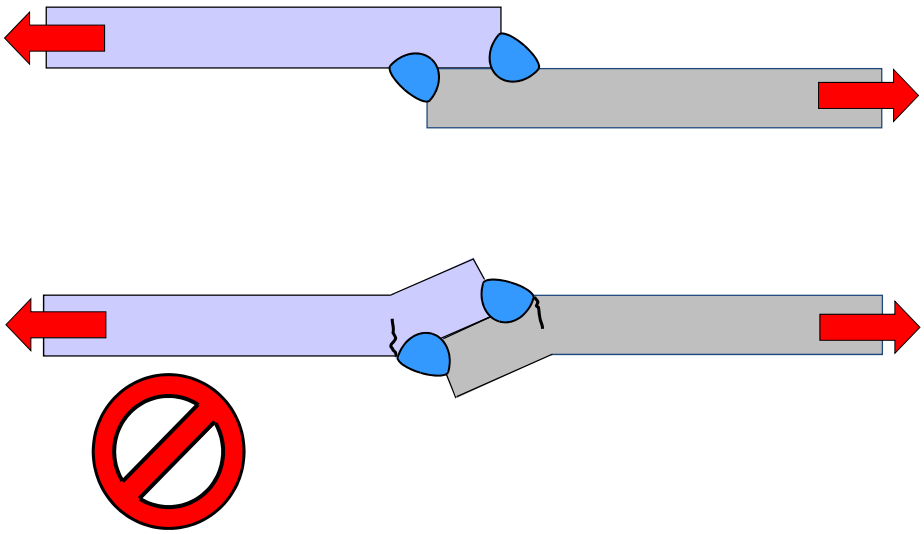
J2.2b(f)

(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).



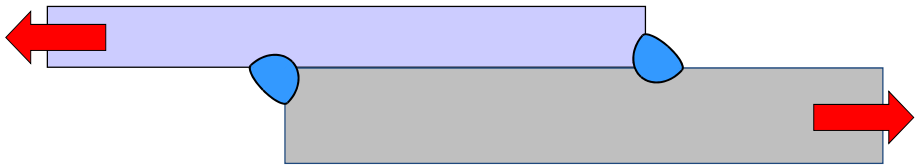
Also addressed in AWS D1.1:2015 clause 2.9.1.2

LAP JOINTS



AISC 360-16 Specification J2.2b

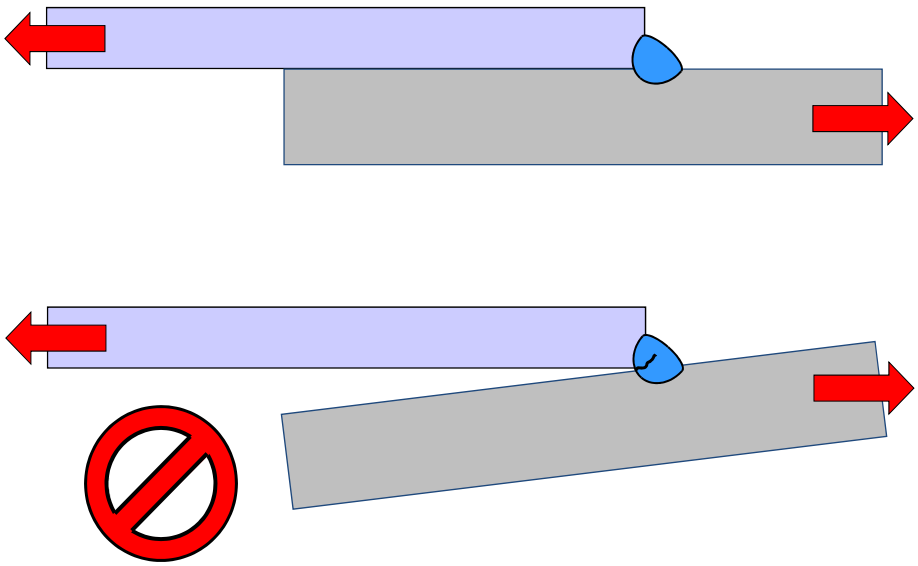
Lap Joints



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

LAP JOINTS



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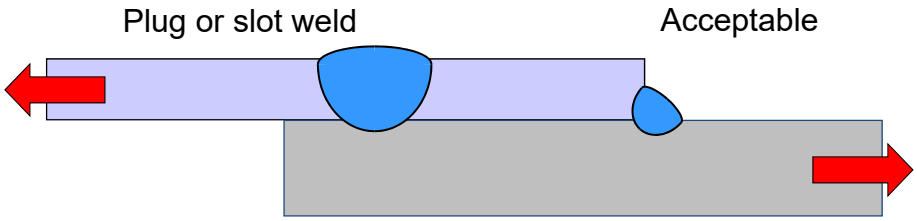
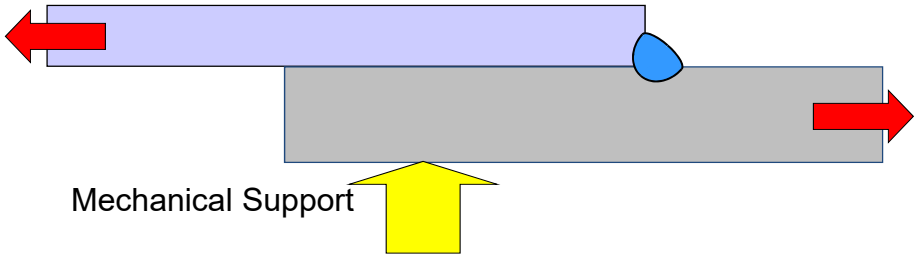
LAP JOINTS





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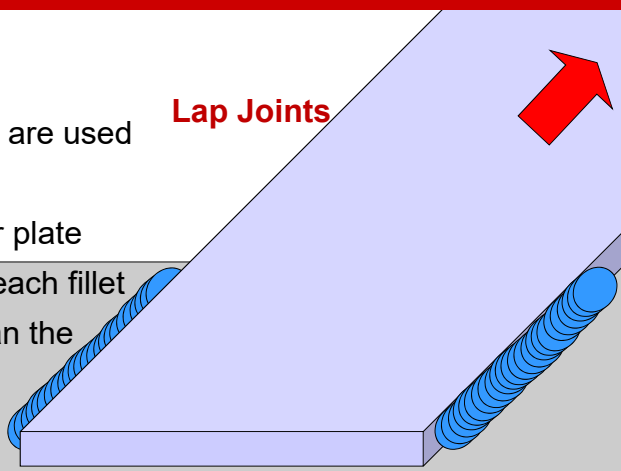
AWS D1.1:2015 clause 2.9.2

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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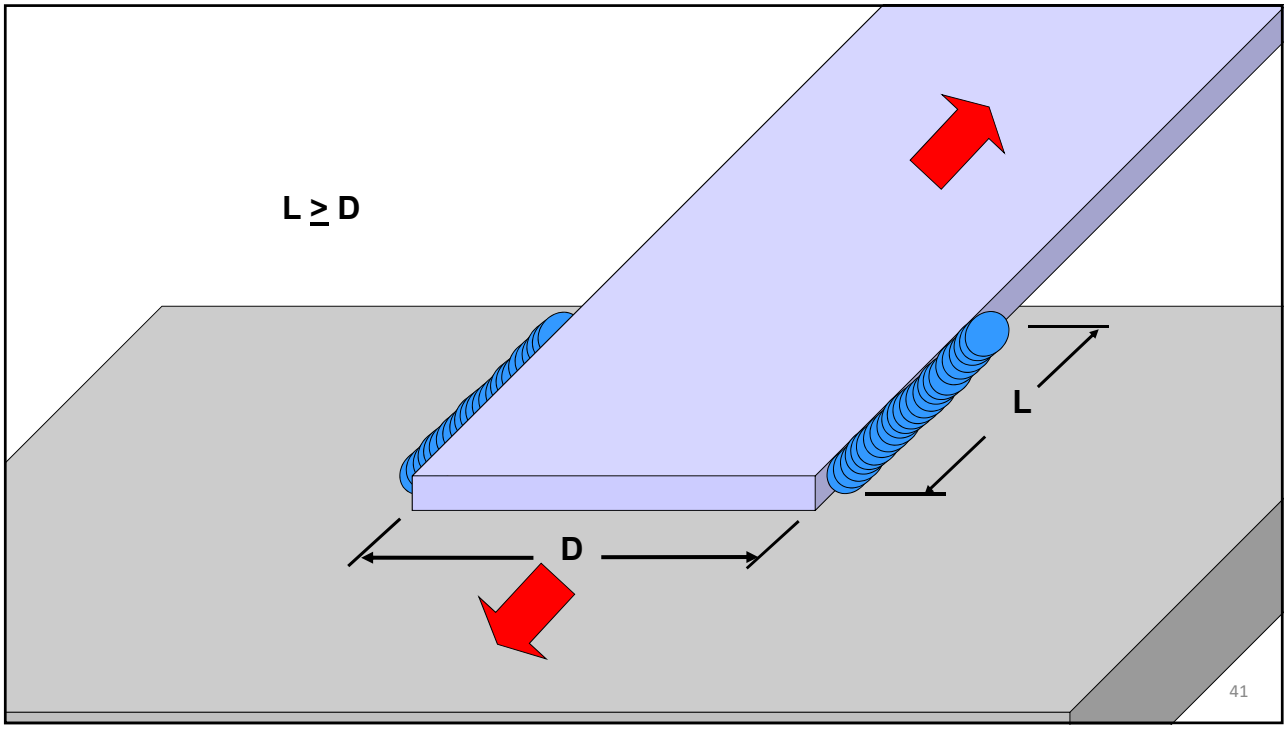

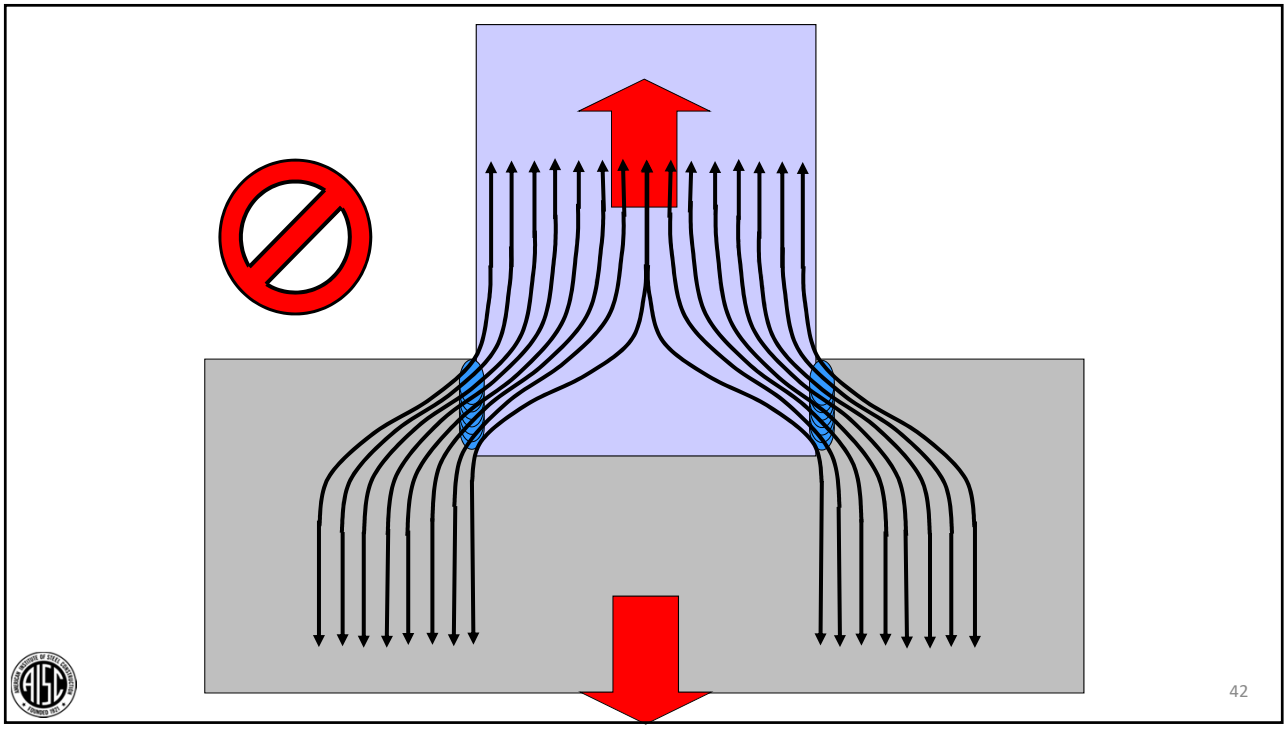

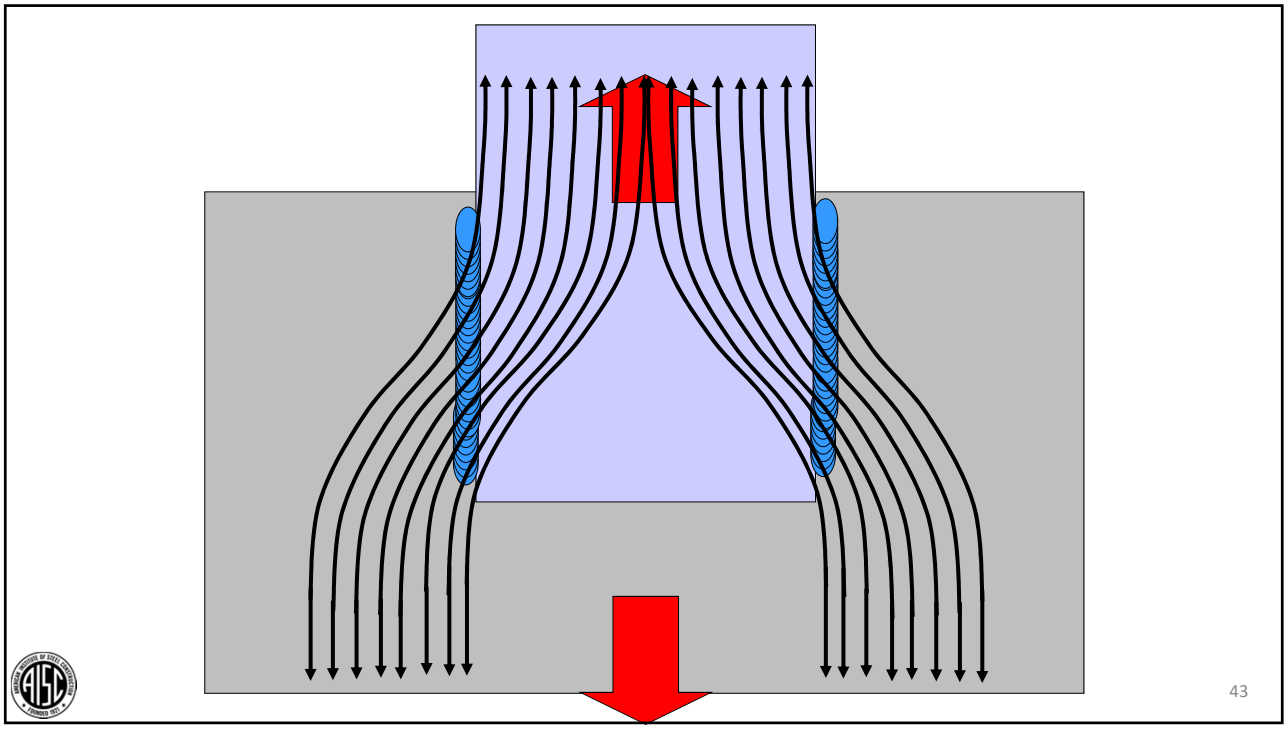

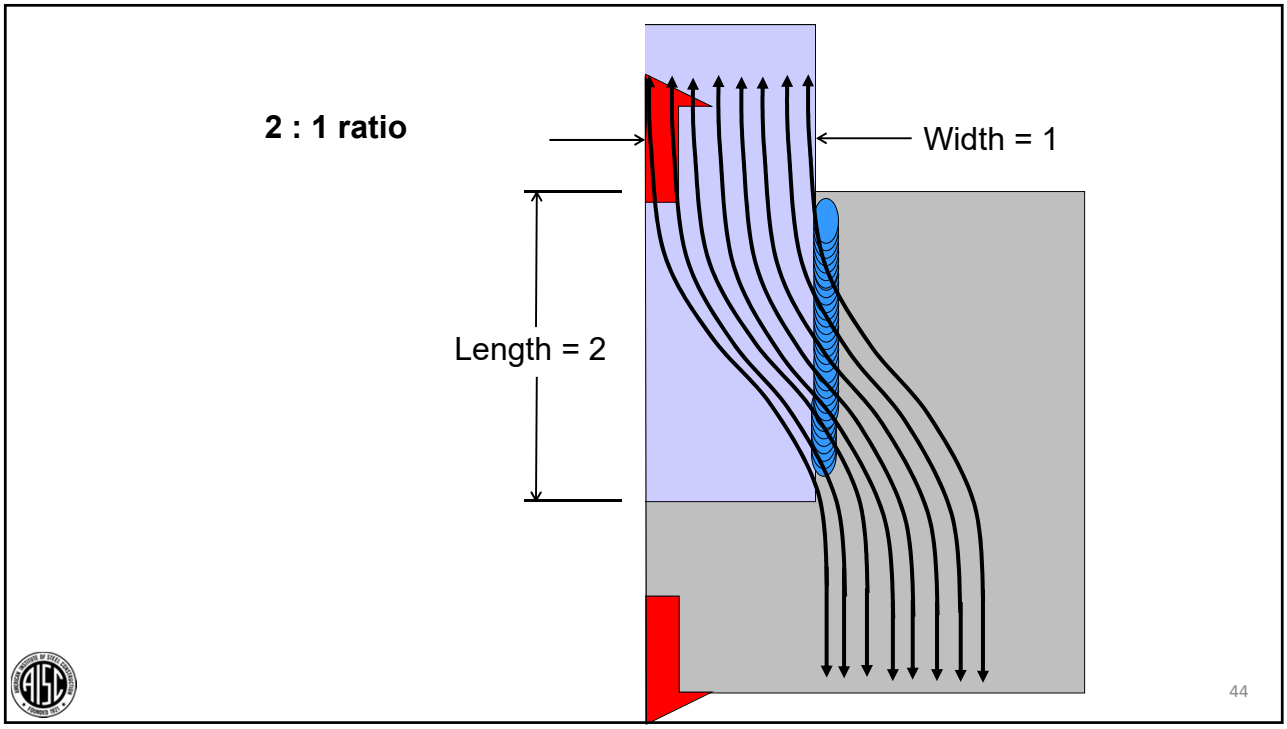

AISC 360-10 SPECIFICATION

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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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

$$A_e = A_n U \qquad \text{(D3-1)}$$

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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AISC 360-16 Specification for Structural Steel Buildings

TABLE D3.1

Shear Lag Factors for Conections to Tension Members

8 examples

6 welded examples

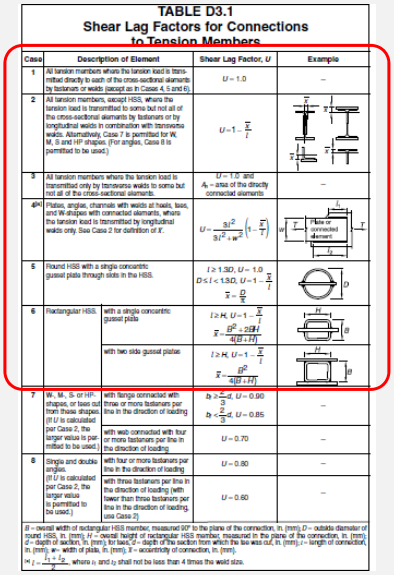
TABLE D3.1
Shear Lag Factors for Connections to Tension Members

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.		$U = 1.0$ and A_n = area of the directly connected elements	–
4[a]	Plates, angles, channels with welds at heels, toes, and W-shapes with connected elements, where the tension load is transmitted by longitudinal welds only. See Case 2 for definition of $\bar{x}$.		$U = \frac{3l^2}{3l^2 + w^2}\left(1 - \frac{\bar{x}}{l}\right)$	
5	Round HSS with a single concentric gusset plate through slots in the HSS.		$l \geq 1.3D$, $U = 1.0$ $D \leq l < 1.3D$, $U = 1 - \frac{\bar{x}}{l}$ $\bar{x} = \frac{D}{\pi}$	
6	Rectangular HSS.	with a single concentric gusset plate	$l \geq H$, $U = 1 - \frac{\bar{x}}{l}$ $\bar{x} = \frac{B^2 + 2BH}{4(B + H)}$	
		with two side gusset plates	$l \geq H$, $U = 1 - \frac{\bar{x}}{l}$ $\bar{x} = \frac{B^2}{4(B + H)}$	
7	W, M, S, or HP shapes, or tees cut 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	$b \geq \frac{2}{3}d$, $U = 0.90$ $b < \frac{2}{3}d$, $U = 0.85$	–
		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 fewer than three fasteners per line in the direction of loading, use Case 2)	$U = 0.60$	–

B = overall width of rectangular HSS member, measured 90° to the plane of the connection, in. (mm); D = outside diameter of round HSS, in. (mm); H = overall height of rectangular HSS member, measured in the plane of the connection, in. (mm); d = depth of section, in. (mm); for tees, d = depth of the section from which the tee was cut, in. (mm); l = length of connection, in. (mm); w = width of plate, in. (mm); $\bar{x}$ = eccentricity of connection, in. (mm)

[a] $l = \frac{l_1 + l_2}{2}$, where l_1 and l_2 shall not be less than 4 times the weld size.

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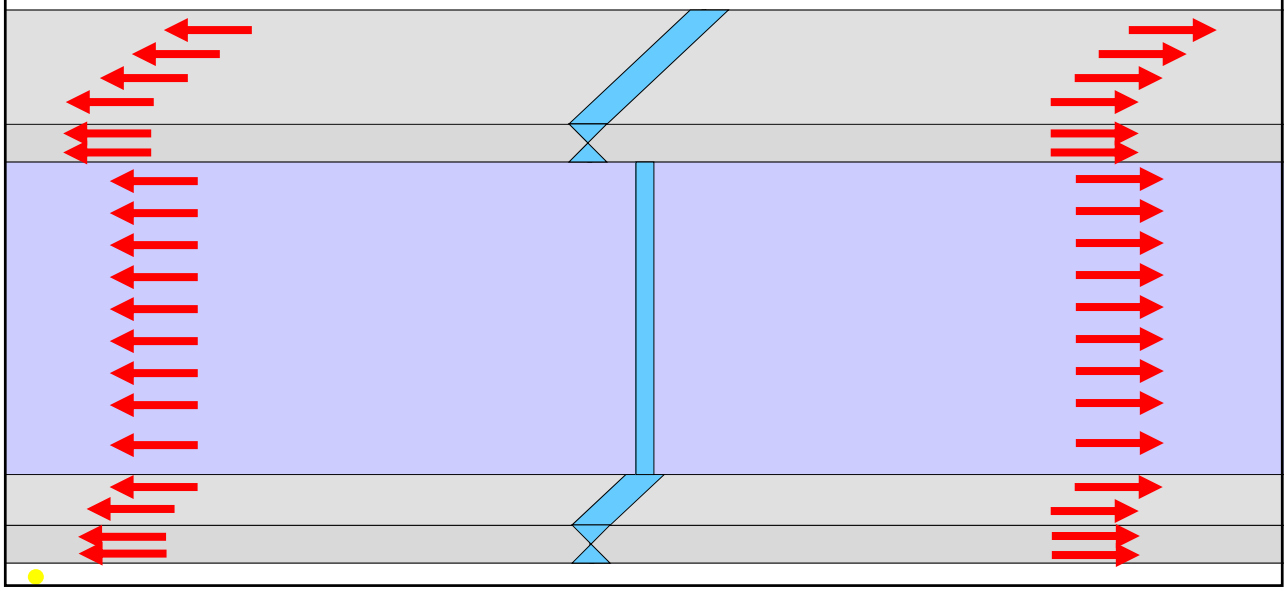
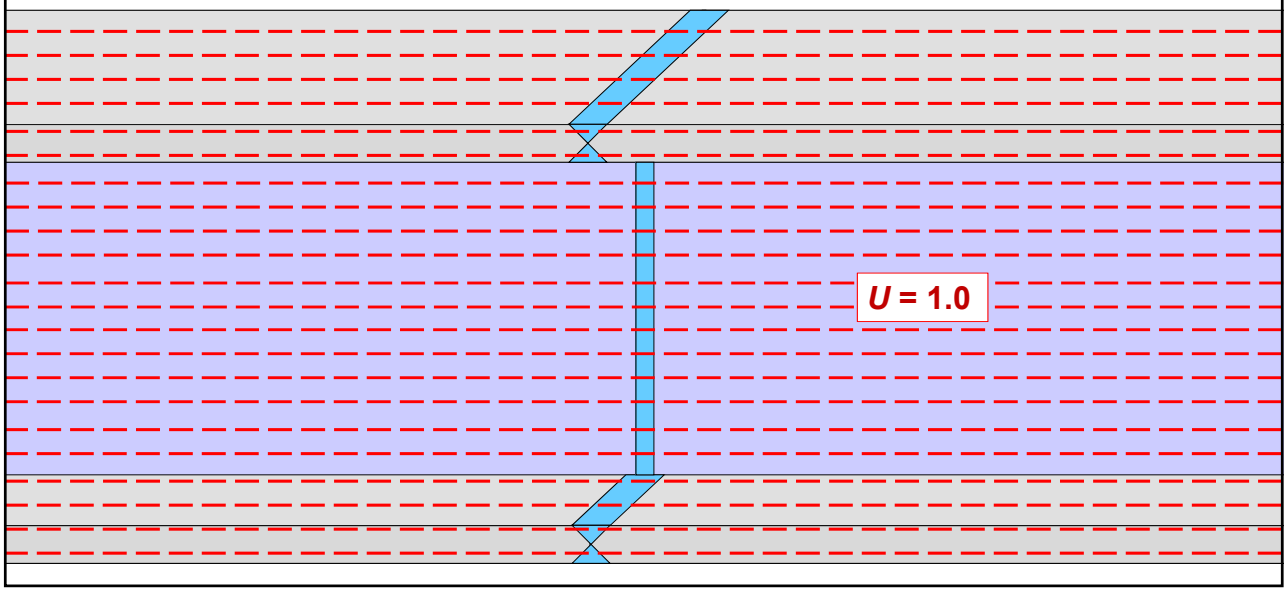
All tension members where the tension load is transmitted directly to each of the cross-sectional elements by fasteners or welds (except as in Cases 4, 5 and 6).



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).



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 $\bar{x}$.	$U = \frac{3l^2}{3l^2 + w^2}\left(1 - \frac{\bar{x}}{l}\right)$	l_1, w, T, Plate or connected element, T, l_2

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.

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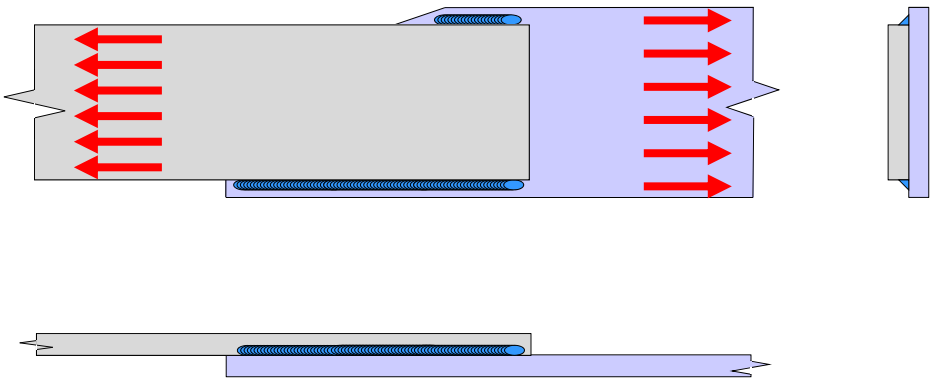
Plates, angles, channels with welds at heels, tees, and W-shapes with connected elements, where the tension load is transmitted by longitudinal welds only. See Case 2 for definition of $\bar{x}$.



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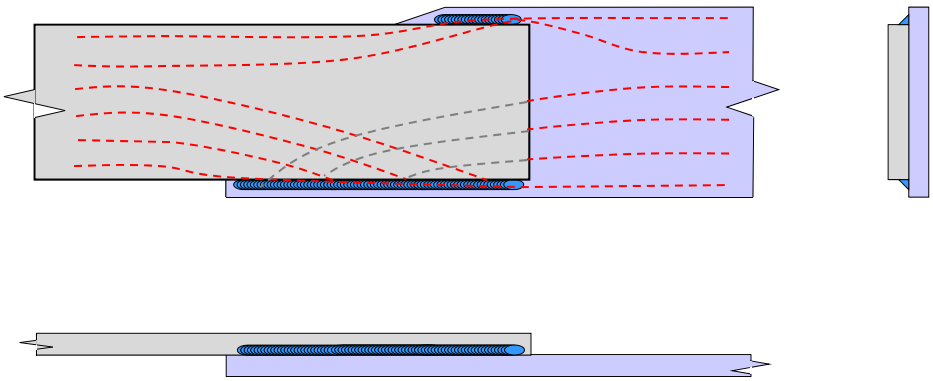
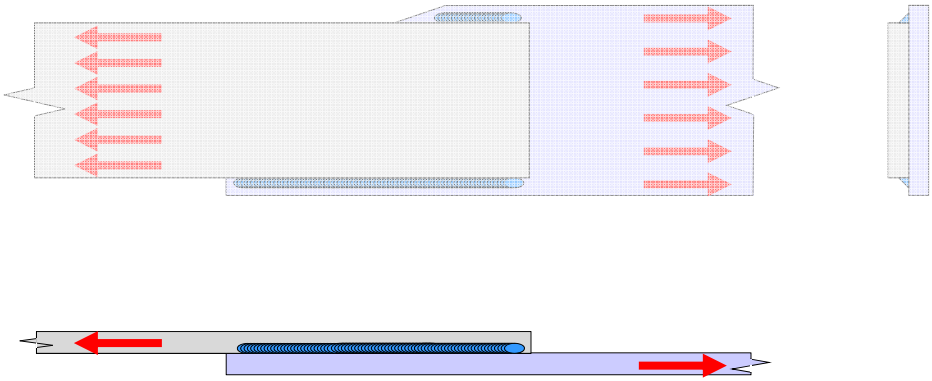
Plates, angles, channels with welds at heels, tees, and W-shapes with connected elements, where the tension load is transmitted by longitudinal welds only. See Case 2 for definition of $\bar{x}$.



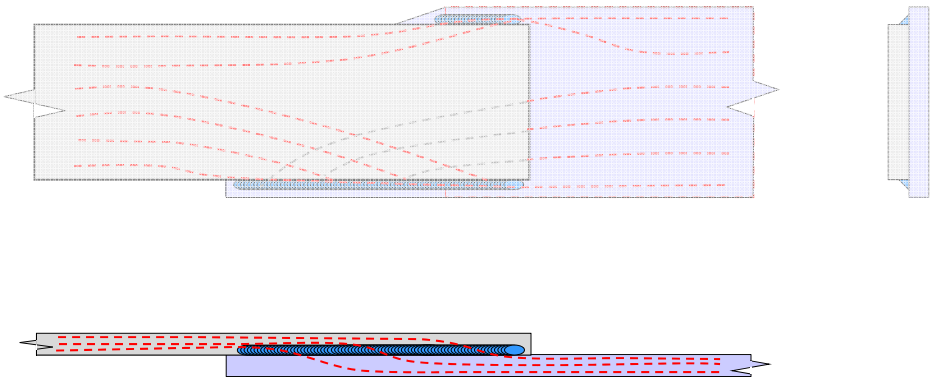
56

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 $\bar{x}$.



57

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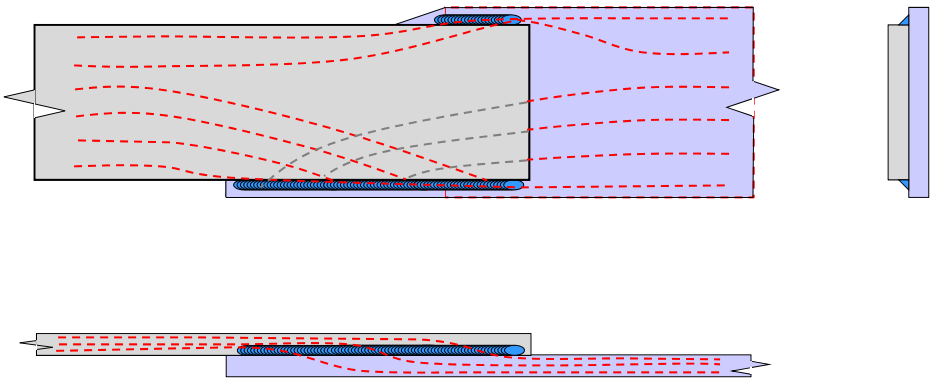
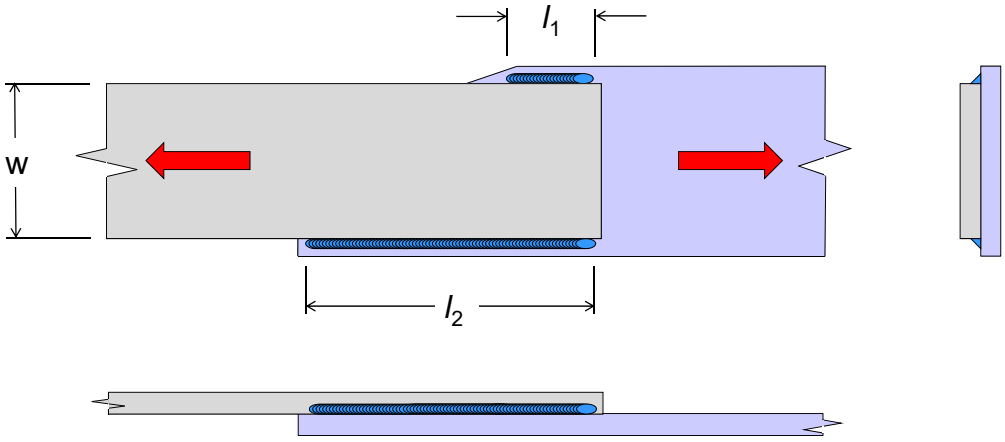
Plates, angles, channels with welds at heels, tees, and W-shapes with connected elements, where the tension load is transmitted not directly ~~by longitudinal welds only~~. See Case 2 for definition of x.



59

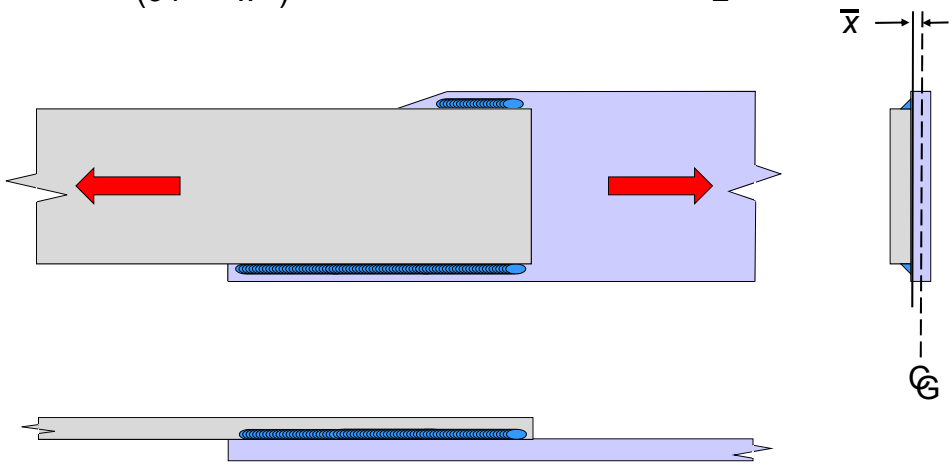
$$U = \frac{3\,l^2}{(3\,l^2 + w^2)}\left(1 - \frac{\bar{x}}{l}\right) \qquad l = \frac{l_1 + l_2}{2}$$



60

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

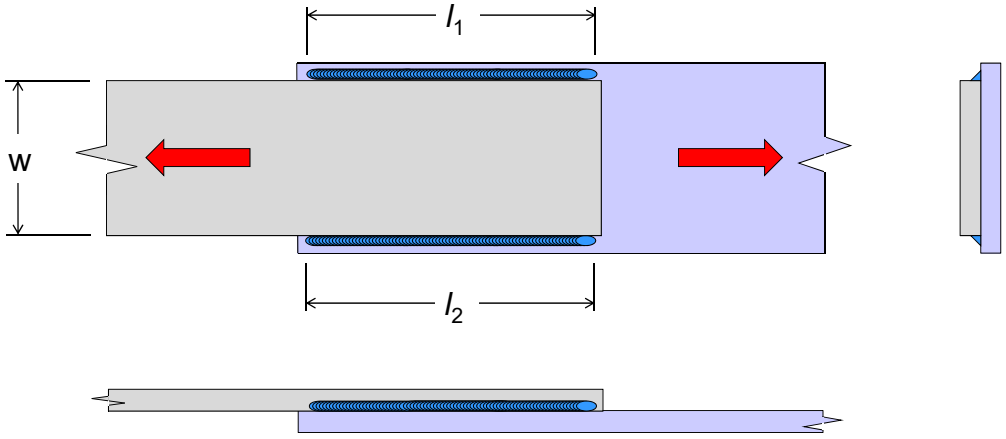
$$U = \frac{3\,l^2}{(3\,l^2 + w^2)}\left(1 - \frac{\bar{x}}{l}\right) \qquad l = \frac{l_1 + l_2}{2}$$



61

Let $l_1 = l_2$

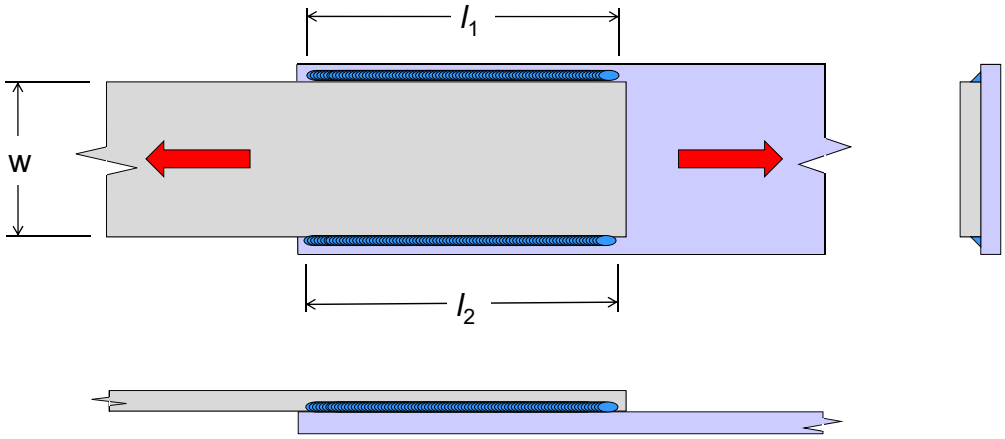
$$U = \frac{3\,l^2}{(3\,l^2 + w^2)}\left(1 - \frac{\bar{x}}{l}\right) \qquad l = \frac{l_1 + l_2}{2}$$



62

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

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



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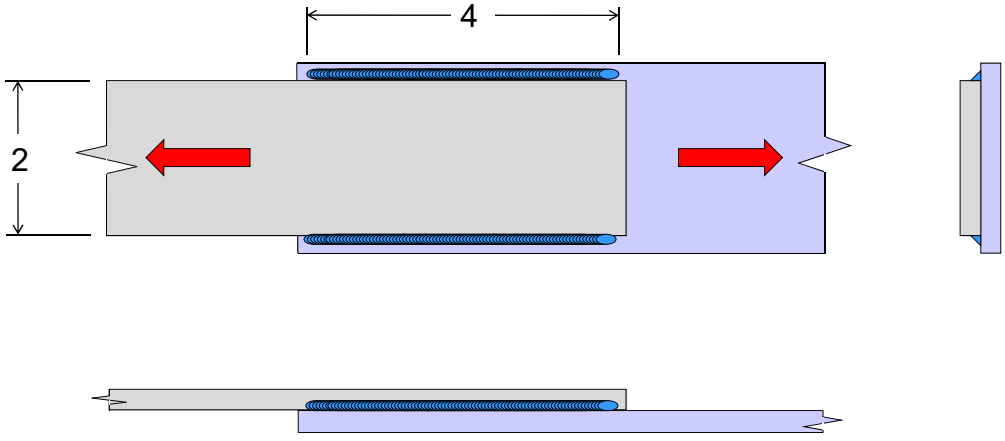
Let $l_1 = l_2 = 4$, w = 2, and $t = 1/2$

$U = 0.87$ $\quad U = \frac{3\,l^2}{(3\,l^2 + w^2)}\left(1 - \frac{\bar{x}}{l}\right) \qquad l = \frac{l_1 + l_2}{2}$

$\bar{x} = t/2 = 1/4$



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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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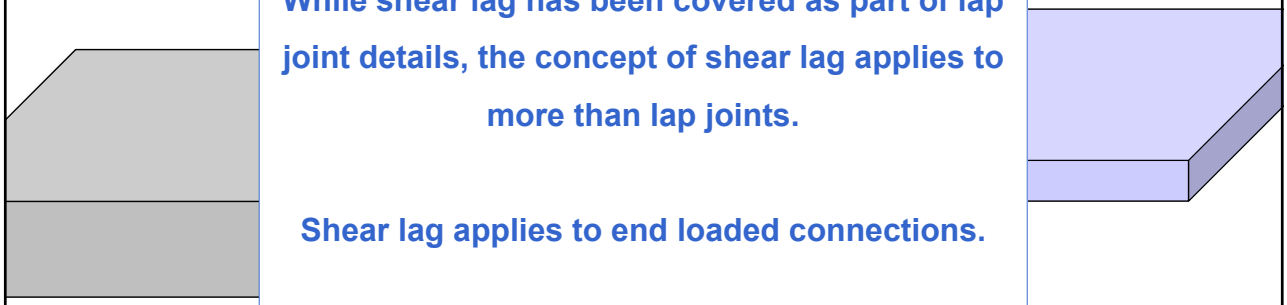
LAP JOINTS

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 doe 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.

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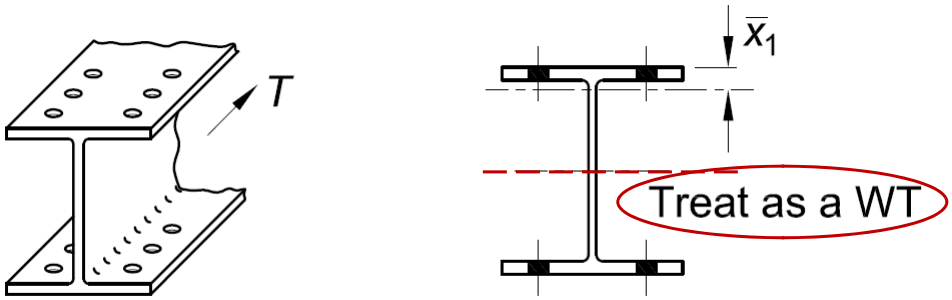
AISC 360-16 Specification for Structural Steel Buildings

Commentary Figure C-D3.1
Determination of $\bar{x}$ for U



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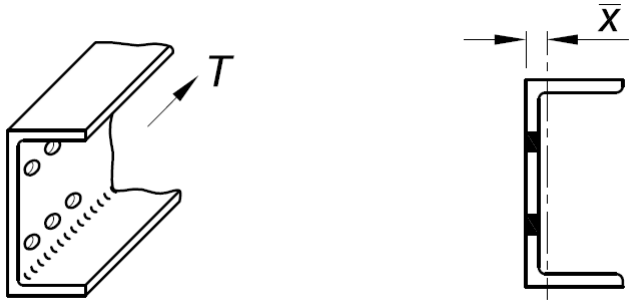
AISC 360-16 Specification for Structural Steel Buildings

Commentary Figure C-D3.1

Determination of $\bar{x}$ for U



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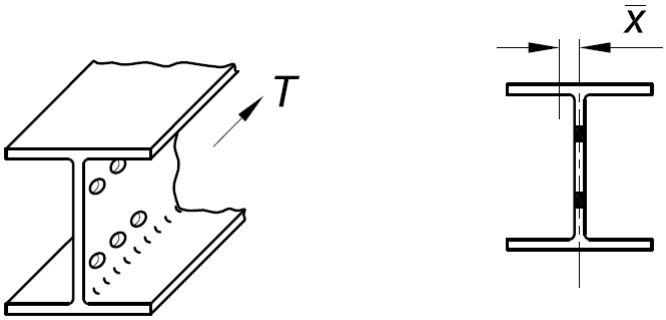
AISC 360-16 Specification for Structural Steel Buildings

Commentary Figure C-D3.1

Determination of $\bar{x}$ for U



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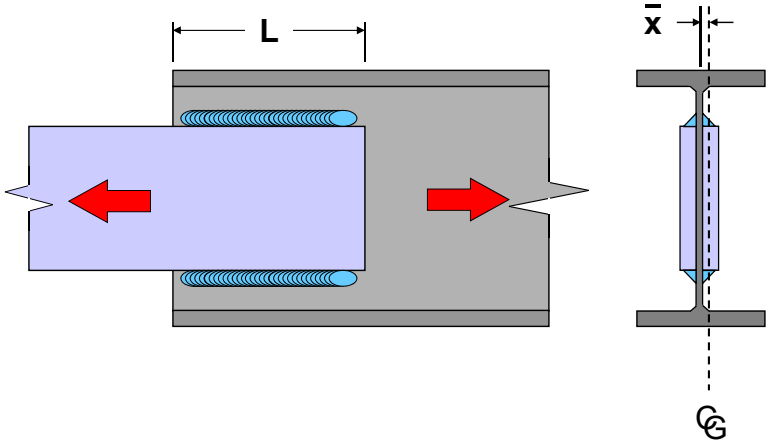
AISC 360-16 Specification for Structural Steel Buildings

TABLE D3.1

Shear Lag Factors for Connections to Tension Members



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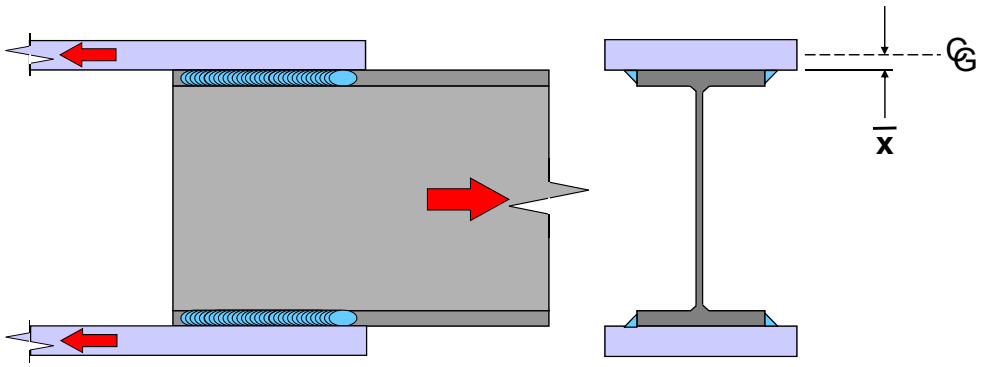
AISC 360-16 Specification for Structural Steel Buildings

TABLE D3.1

Shear Lag Factors for Connections to Tension Members



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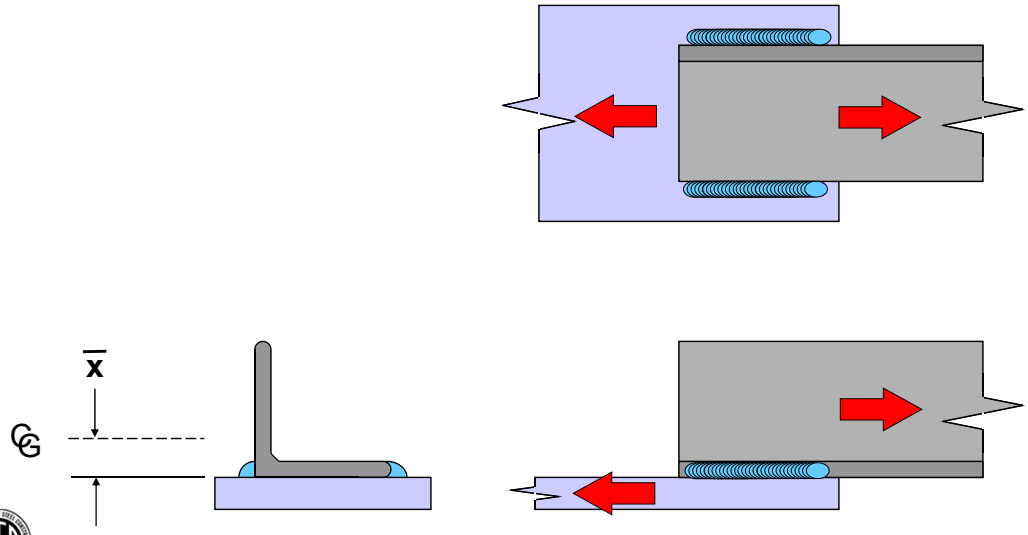
AISC 360-16 Specification for Structural Steel Buildings

TABLE D3.1

Shear Lag Factors for Connections to Tension Members



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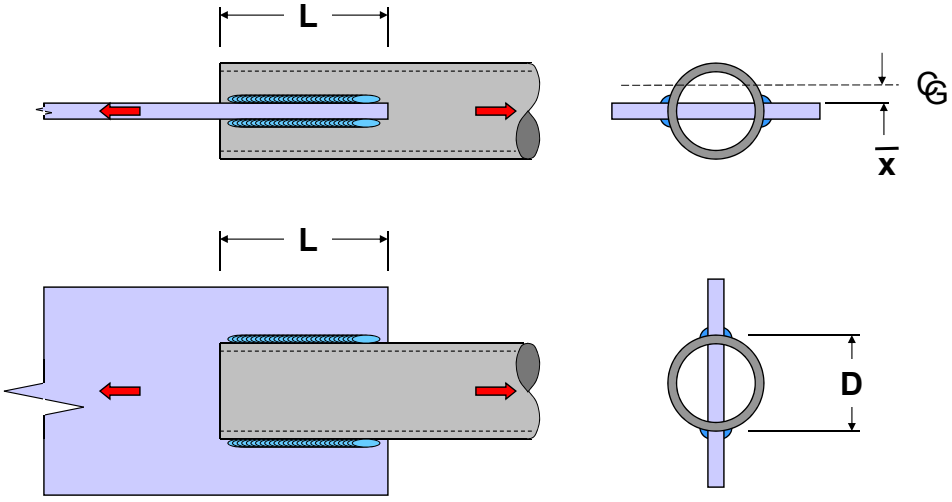
AISC 360-16 Specification for Structural Steel Buildings

TABLE D3.1

Shear Lag Factors for Connections to Tension Members



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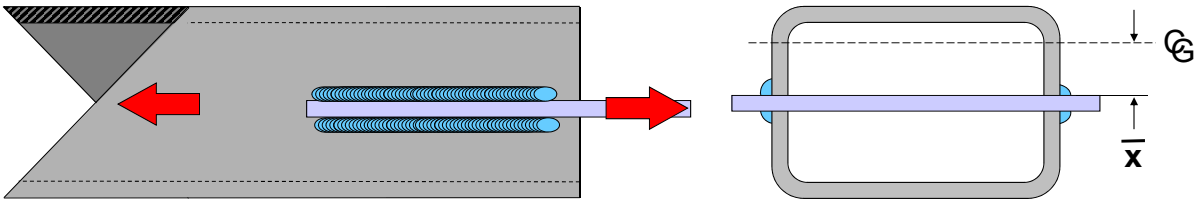
AISC 360-16 Specification for Structural Steel Buildings

TABLE D3.1

Shear Lag Factors for Connections to Tension Members



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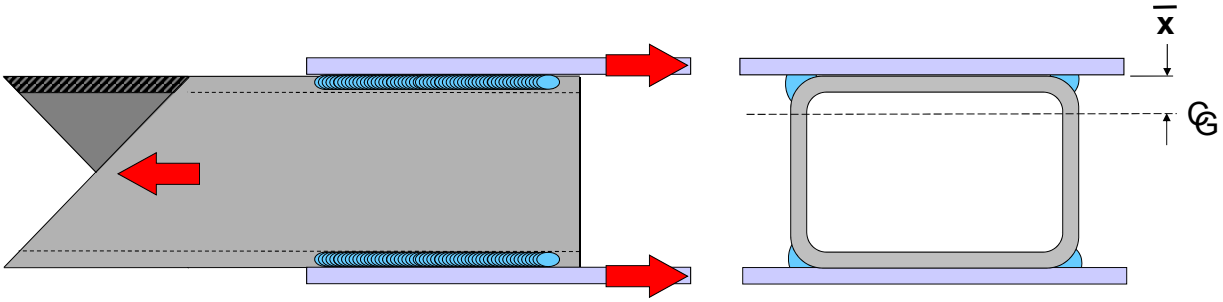
AISC 360-16 Specification for Structural Steel Buildings

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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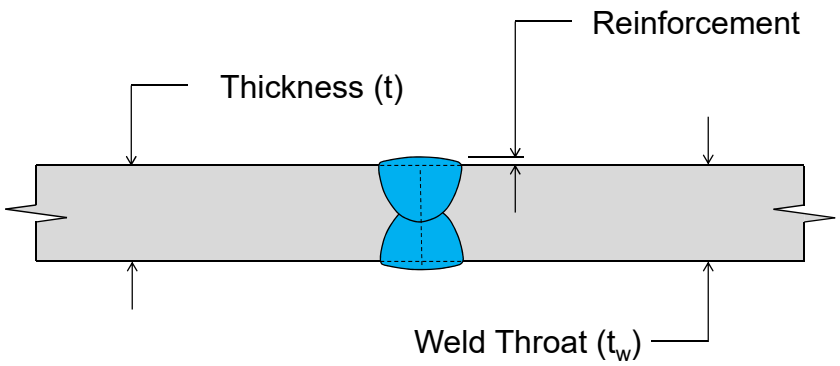
CJP GROOVE WELDS

Weld Throat Dimension (t_w)



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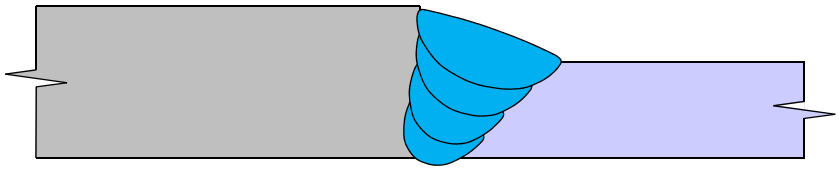
CJP GROOVE WELDS

Complete-Joint-Penetration Groove Weld (CJP)

Two thicknesses



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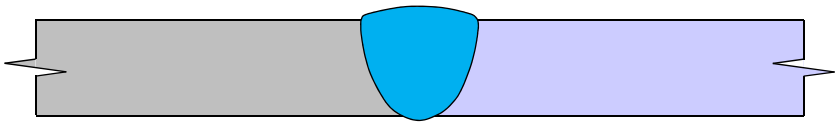
CJP GROOVE WELDS

Complete-Joint-Penetration Groove Weld (CJP)

Single sided

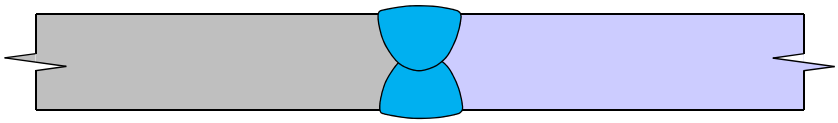


80

CJP GROOVE WELDS

Complete-Joint-Penetration Groove Weld (CJP)

Double sided



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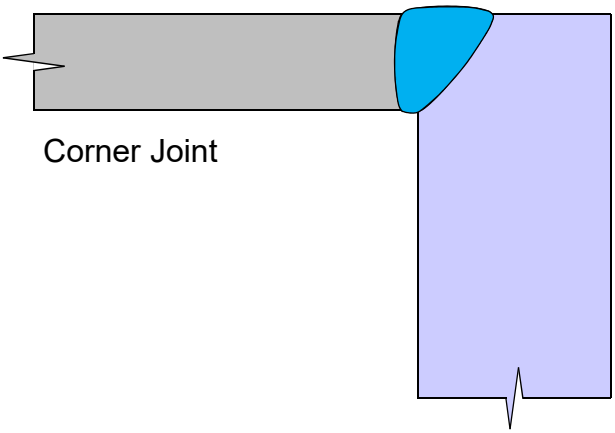
CJP GROOVE WELDS

Complete-Joint-Penetration Groove Weld (CJP)



Corner Joint

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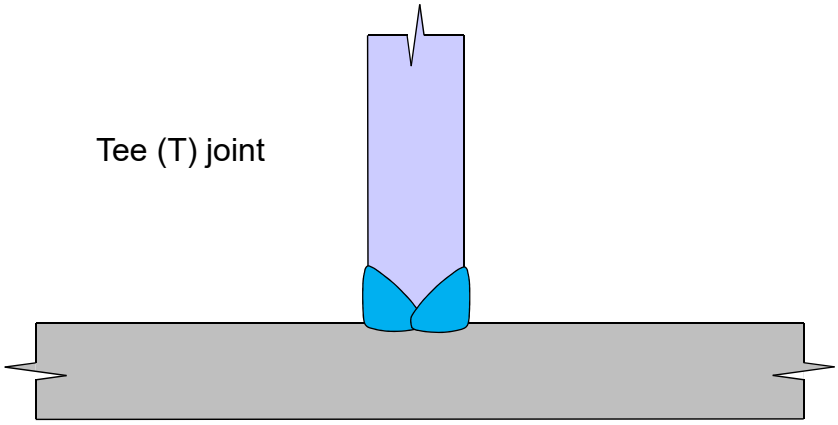
CJP GROOVE WELDS

Complete-Joint-Penetration Groove Weld (CJP)



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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

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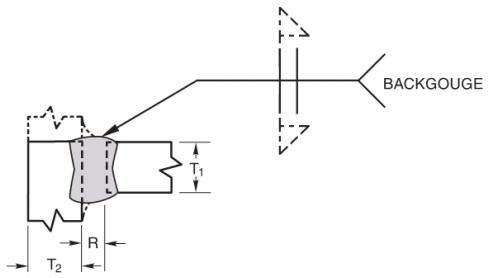
AWS D1.1: 2015 Structural Welding Code – Steel

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)	Tolerances: 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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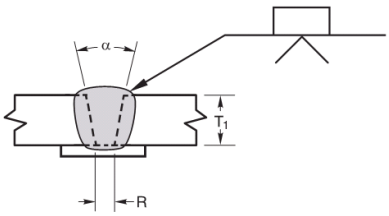
AWS D1.1: 2015 Structural Welding Code – Steel

Single V Groove Weld: CJP

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



Tolerances	
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°

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	B-U2a	U	—	R = 1/4	α = 45°	All	—	e, j
				R = 3/8	α = 30°	F, V, OH	—	e, j
				R = 1/2	α = 20°	F, V, OH	—	e, j
GMAW FCAW	B-U2a-GF	U	—	R = 3/16	α = 30°	F, V, OH	Required	a, j
				R = 3/8	α = 30°	F, V, OH	Not req.	a, j
				R = 1/4	α = 45°	F, V, OH	Not req.	a, j
SAW	B-L2a-S	2 max.	—	R = 1/4	α = 30°	F	—	j
SAW	B-U2-S	U	—	R = 5/8	α = 20°	F	—	j

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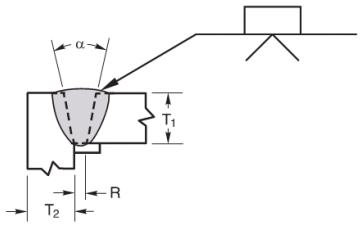
AWS D1.1: 2015 Structural Welding Code – Steel

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
α = +10°, –0°	+10°, –5°

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening	Groove Preparation: Groove Angle	Allowed Welding Positions	Gas Shielding for FCAW	Notes
SMAW	C-U2a	U	U	R = 1/4	α = 45°	All	—	e, j
				R = 3/8	α = 30°	F, V, OH	—	e, j
				R = 1/2	α = 20°	F, V, OH	—	e, j
GMAW FCAW	C-U2a-GF	U	U	R = 3/16	α = 30°	F, V, OH	Required	a
				R = 3/8	α = 30°	F, V, OH	Not req.	a, j
				R = 1/4	α = 45°	F, V, OH	Not req.	a, j
SAW	C-L2a-S	2 max.	U	R = 1/4	α = 30°	F	—	j
SAW	C-U2-S	U	U	R = 5/8	α = 20°	F	—	j

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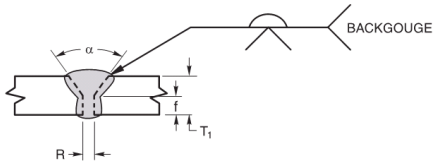
AWS D1.1: 2015 Structural Welding Code – Steel

Single V Groove Weld: CJP

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



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening, Root Face, Groove Angle	Tolerances: As Detailed (see 3.13.1)	Tolerances: As Fit-Up (see 3.13.1)	Allowed Welding Positions	Gas Shielding for FCAW	Notes
SMAW	B-U2	U	—	R = 0 to 1/8 f = 0 to 1/8 α = 60°	+1/16, –0 +1/16, –0 +10°, –0°	+1/16, –1/8 Not limited +10°, –5°	All	—	d, e, j
GMAW FCAW	B-U2-GF	U	—	R = 0 to 1/8 f = 0 to 1/8 α = 60°	+1/16, –0 +1/16, –0 +10°, –0°	+1/16, –1/8 Not limited +10°, –5°	All	Not required	a, d, j
SAW	B-L2c-S	Over 1/2 to 1	—	R = 0 f = 1/4 max. α = 60°	R = ±0 f = +0, –f α = +10°, –0°	+1/16, –0 ±1/16 +10°, –5°	F	—	d, j
		Over 1 to 1-1/2	—	R = 0 f = 1/2 max. α = 60°					
		Over 1-1/2 to 2	—	R = 0 f = 5/8 max. α = 60°					

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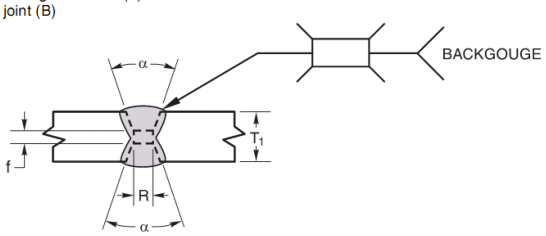
AWS D1.1: 2015 Structural Welding Code – Steel

Double V Groove Weld: CJP

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



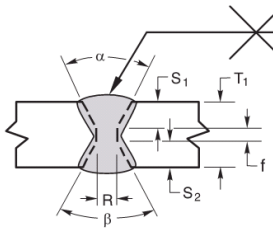
Spacer		Tolerances: As Detailed (see 3.13.1)	Tolerances: As Fit-Up (see 3.13.1)
		R = ±0	+1/4, –0
		f = ±0	+1/16, –0
		α = +10°, –0°	+10°, –5°
	SAW	±0	+1/16, –0
	SMAW	±0	+1/8, –0

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening	Groove Preparation: Root Face	Groove Preparation: Groove Angle	Allowed Welding Positions	Gas Shielding for FCAW	Notes
SMAW	B-U3a	U Spacer = 1/8 × R	—	R = 1/4	f = 0 to 1/8	α = 45°	All	—	d, e, h, j
				R = 3/8	f = 0 to 1/8	α = 30°	F, V, OH	—	
				R = 1/2	f = 0 to 1/8	α = 20°	F, V, OH	—	
SAW	B-U3a-S	U Spacer = 1/4 × R	—	R = 5/8	f = 0 to 1/4	α = 20°	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)



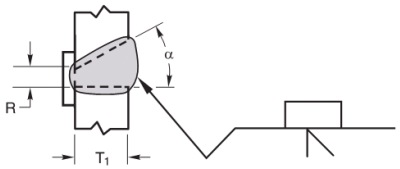
For B-U3c-S only		
T_1		S_1
Over	to	
2	2-1/2	1-3/8
2-1/2	3	1-3/4
3	3-5/8	2-1/8
3-5/8	4	2-3/8
4	4-3/4	2-3/4
4-3/4	5-1/2	3-1/4
5-1/2	6-1/4	3-3/4
For T_1 > 6-1/4 or $T_1 \le 2$ $S_1 = 2/3\ (T_1 - 1/4)$		

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening Root Face Groove Angle	Groove Preparation: Tolerances: As Detailed (see 3.13.1)	Groove Preparation: Tolerances: As Fit-Up (see 3.13.1)	Allowed Welding Positions	Gas Shielding for FCAW	Notes
SMAW	B-U3b	U	—	R = 0 to 1/8 f = 0 to 1/8 α = β = 60°	+1/16, –0 +1/16, –0 +10°, –0°	+1/16, –1/8 Not limited +10°, –5°	All	—	d, e, h, j
GMAW FCAW	B-U3-GF						All	Not required	a, d, h, j
SAW	B-U3c-S	U	—	R = 0 f = 1/4 min. α = β = 60°	+1/16, –0 +1/4, –0 +10°, –0°	+1/16, –0 +1/4, –0 +10°, –5°	F	—	d, h, j
				To find S_1 see table above: $S_2 = T_1 - (S_1 + f)$					

AWS D1.1: 2015 Structural Welding Code – Steel

Single Bevel Groove Weld: CJP

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



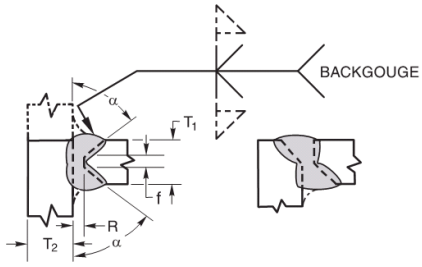
Tolerances	
As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)
R = +1/16, –0	+1/4, –1/16
α = +10°, –0°	+10°, –5°

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening	Groove Preparation: Groove Angle	Allowed Welding Positions	Gas Shielding for FCAW	Notes
SMAW	B-U4a	U	—	R = 1/4	α = 45°	All	—	c, e, j
				R = 3/8	α = 30°	All	—	c, e, j
GMAW FCAW	B-U4a-GF	U	—	R = 3/16	α = 30°	All	Required	a, c, j
				R = 1/4	α = 45°	All	Not req.	a, c, j
				R = 3/8	α = 30°	F, H	Not req.	a, c, j
SAW	B-U4a-S	U	—	R = 3/8	α = 30°	F	—	c, j
				R = 1/4	α = 45°			

AWS D1.1: 2015 Structural Welding Code – Steel

Double Bevel Groove Weld: CJP

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

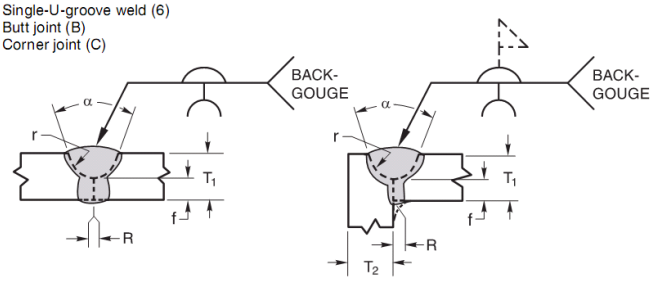


Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening, Root Face, Groove Angle	Groove Preparation: Tolerances: As Detailed (see 3.13.1)	Groove Preparation: Tolerances: As Fit-Up (see 3.13.1)	Allowed Welding Positions	Gas Shielding for FCAW	Notes
SMAW	TC-U5b	U	U	R = 0 to 1/8 f = 0 to 1/8 α = 45°	+1/16, –0 +1/16, –0 +10°, –0°	+1/16, –1/8 Not limited +10°, –5°	All	—	d, e, g, h, j, k
GMAW FCAW	TC-U5-GF	U	U				All	Not required	a, d, g, h, j, k
SAW	TC-U5-S	U	U	R = 0 f = 1/4 max. α = 60°	±0 +0, –3/16 +10°, –0°	+1/16, –0 ±1/16 +10°, –5°	F	—	d, g, h, j, k

AWS D1.1: 2015 Structural Welding Code – Steel

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
α = +10°, –0°	+10°, –5°
f = ±1/16	Not Limited
r = +1/8, –0	+1/8, –0

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening	Groove Preparation: Groove Angle	Groove Preparation: Root Face	Groove Preparation: Bevel Radius	Allowed Welding Positions	Gas Shielding for FCAW	Notes
SMAW	B-U6	U	—	R = 0 to 1/8	α = 45°	f = 1/8	r = 1/4	All	—	d, e, j
				R = 0 to 1/8	α = 20°	f = 1/8	r = 1/4	F, OH	—	d, e, j
	C-U6	U	U	R = 0 to 1/8	α = 45°	f = 1/8	r = 1/4	All	—	d, e, g, j
				R = 0 to 1/8	α = 20°	f = 1/8	r = 1/4	F, OH	—	d, e, g, j
GMAW FCAW	B-U6-GF	U	—	R = 0 to 1/8	α = 20°	f = 1/8	r = 1/4	All	Not req.	a, d, j
	C-U6-GF	U	U	R = 0 to 1/8	α = 20°	f = 1/8	r = 1/4	All	Not req.	a, d, g, j

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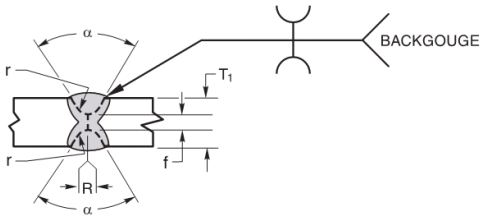
AWS D1.1: 2015 Structural Welding Code – Steel

Double U Groove Weld: CJP

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



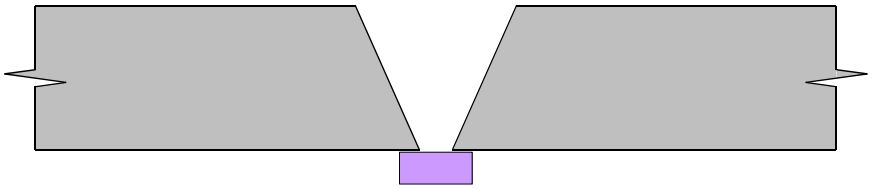
Tolerances	
As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)
For B-U7 and B-U7-GF	
R = +1/16, –0	+1/16, –1/8
α = +10°, –0°	+10°, –5°
f = +1/16, –0	Not Limited
r = +1/4, –0	±1/16
For B-U7-S	
R = +0	+1/16, –0
α = +10°, –0°	+10°, –5°
f = +0, –1/4	±1/16
r = +1/4, –0	±1/16

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening	Groove Preparation: Groove Angle	Groove Preparation: Root Face	Groove Preparation: Bevel Radius	Allowed Welding Positions	Gas Shielding for FCAW	Notes
SMAW	B-U7	U	—	R = 0 to 1/8	α = 45°	f = 1/8	r = 1/4	All	—	d, e, h, j
				R = 0 to 1/8	α = 20°	f = 1/8	r = 1/4	F, OH	—	d, e, h, j
GMAW FCAW	B-U7-GF	U	—	R = 0 to 1/8	α = 20°	f = 1/8	r = 1/4	All	Not required	a, d, j, h
SAW	B-U7-S	U	—	R = 0	α = 20°	f = 1/4 max.	r = 1/4	F	—	d, h, j

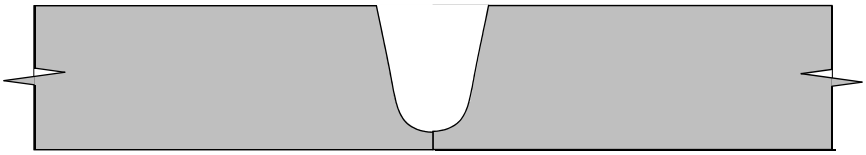
94

CJP GROOVE WELDS: V versus U

Single V: 1” plate, 45º included angle, 1/4” root opening



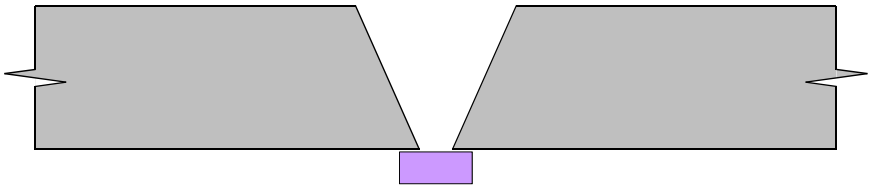
Single U: 1” plate, 20º included angle, 1/4” radius, 1/8” root face*



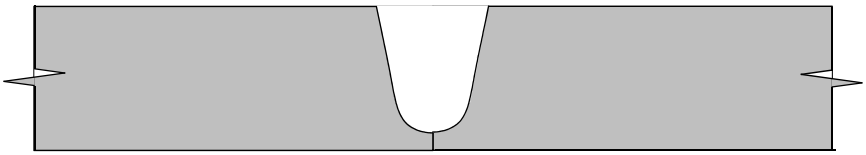
95

CJP GROOVE WELDS: V versus U

Single V: 1” plate, 45º included angle, 1/4” root opening



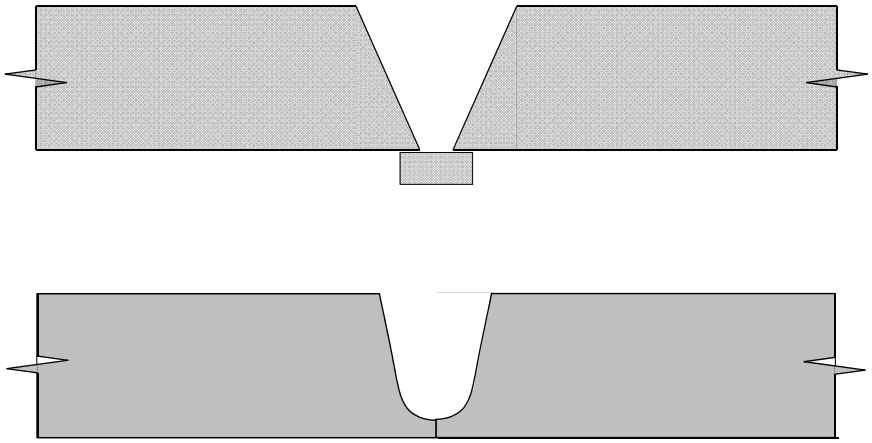
Single U: 1” plate, 20º included angle, 1/4” radius, 1/8” root face*



*plus backgouging

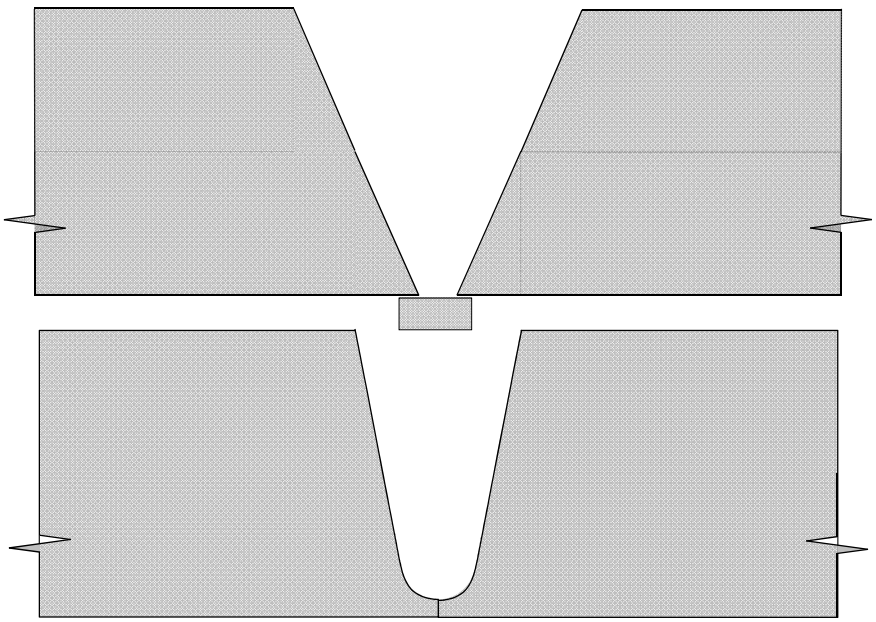
96

CJP GROOVE WELDS: V versus U



97

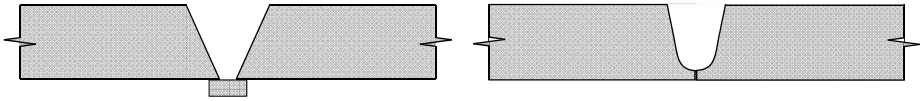
CJP GROOVE WELDS: V versus U



98

CJP GROOVE WELDS: V versus U

Advantages

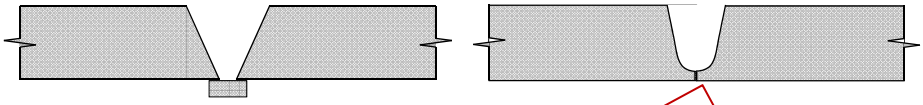


- Only two planar cuts
- All one-sided welding
- Accommodates variable root opening, included angles
- No backgouging required
- No machining, special gouging required
- Less weld metal in thicker materials; much less in thick material
- Easy to make root pass
- Grooves can be accurately machined
- Grooves 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, incl angles
- No ba ging required
- M chining, special gouging required
- L d metal in thicker aterials; 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

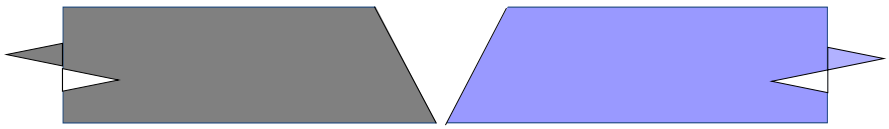
CJP GROOVE WELDS: SELECTION OF GROOVE TYPE

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.

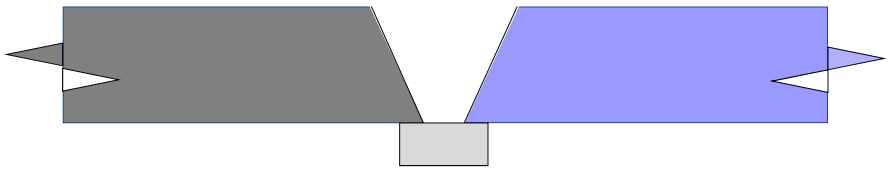
101

CJP GROOVE WELDS

Open Root



With Backing



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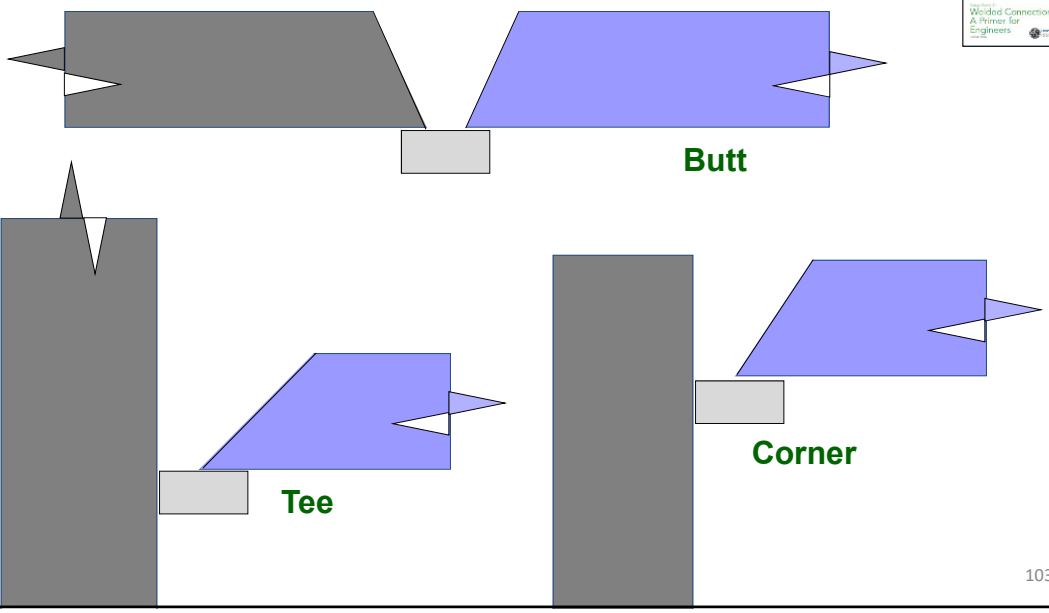
CJP GROOVE WELDS: BACKING



103

CJP GROOVE WELDS: BACKING

Backing materials for steel applications:

- Steel
- Copper
- Ceramic

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CJP GROOVE WELDS: BACKING

Steel backing:

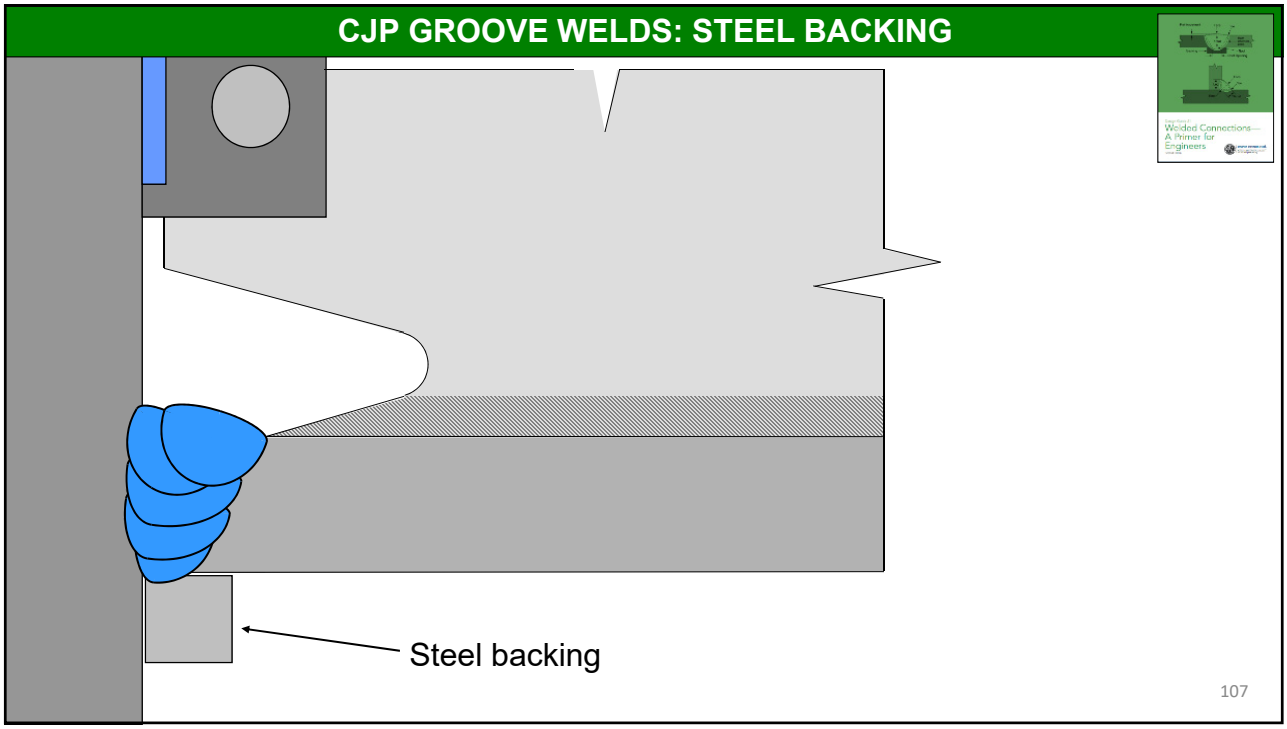
- Permanent (unless deliberately removed)
- May be called “fusible” backing
- Becomes part of the weldment
- May introduce notches (depending on the joint type and direction of loading)
- Removal is expensive
- Most common form of backing

105

CJP GROOVE WELDS: STEEL BACKING

106

CJP GROOVE WELDS: STEEL BACKING



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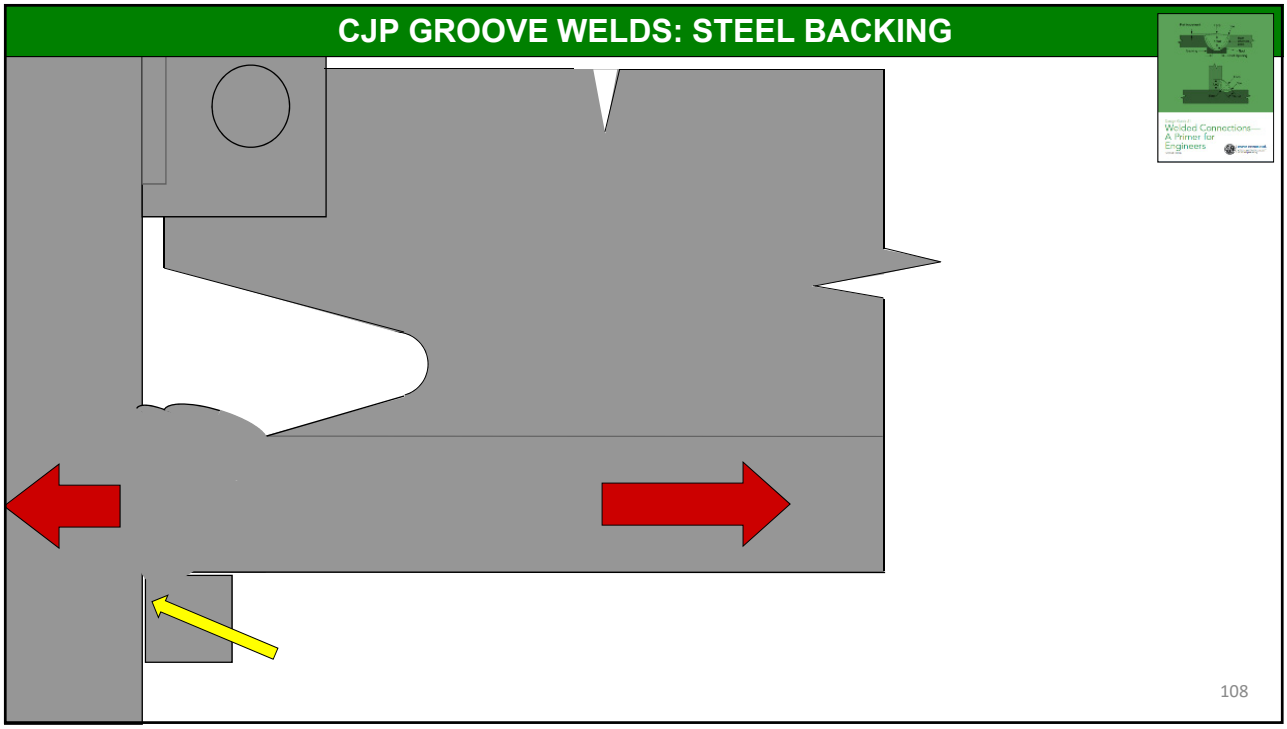
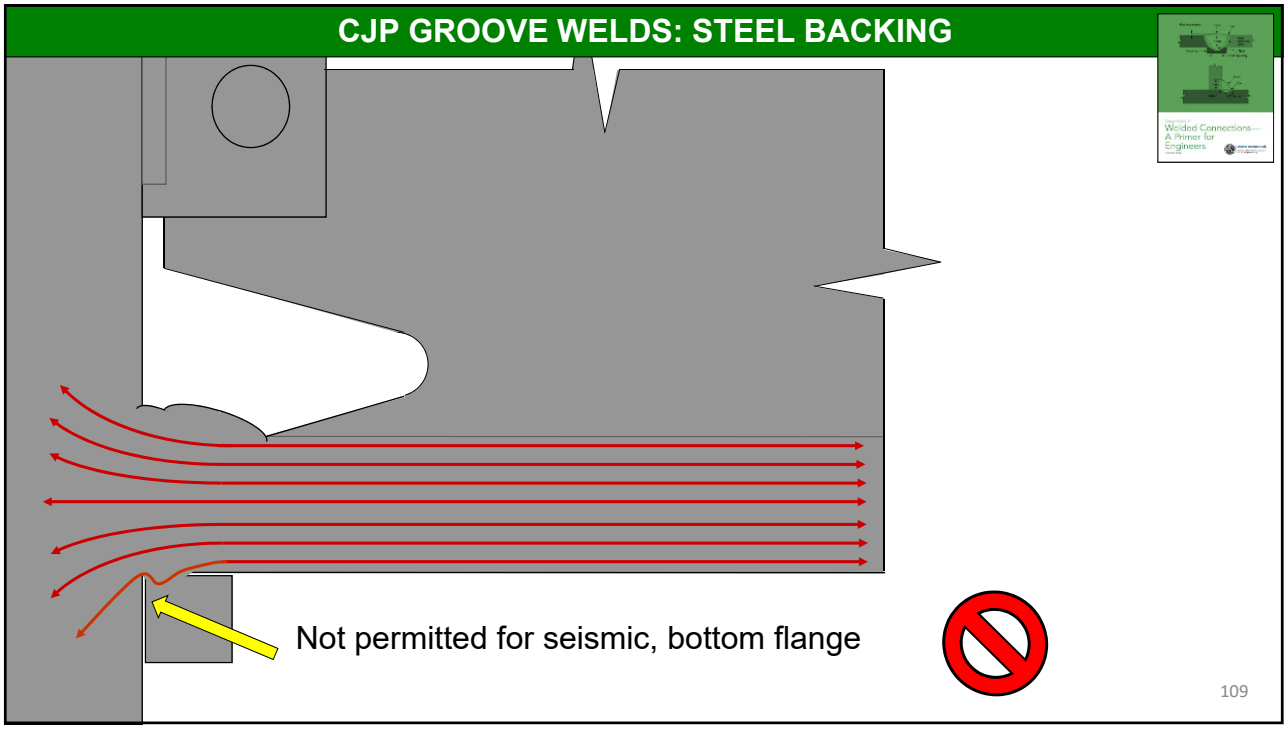
CJP GROOVE WELDS: STEEL BACKING



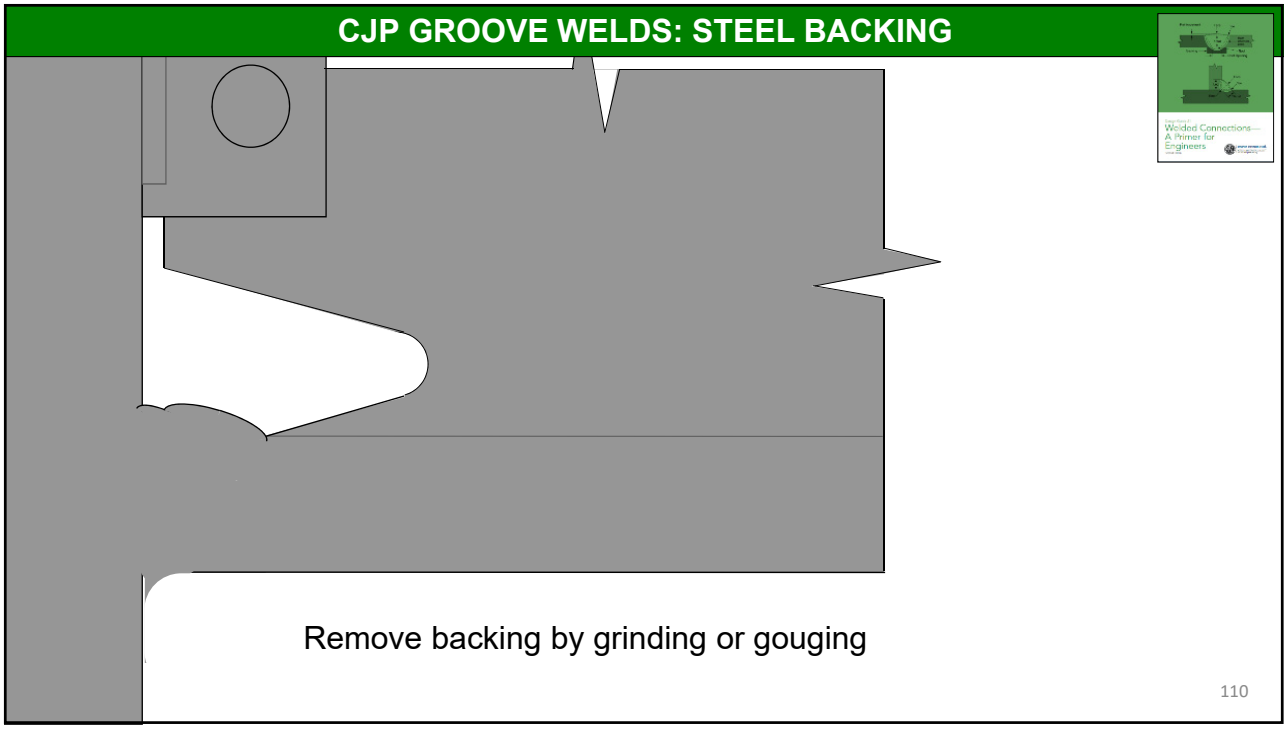
108

CJP GROOVE WELDS: STEEL BACKING



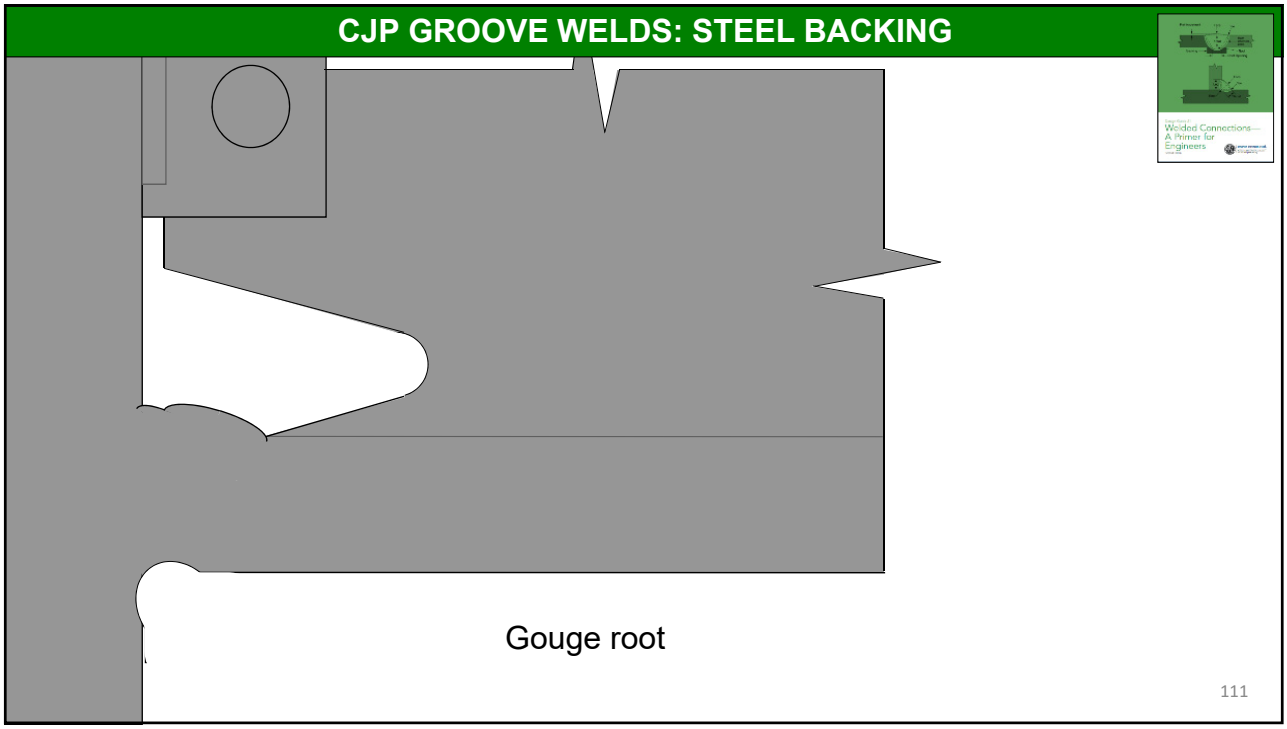
109

CJP GROOVE WELDS: STEEL BACKING



110

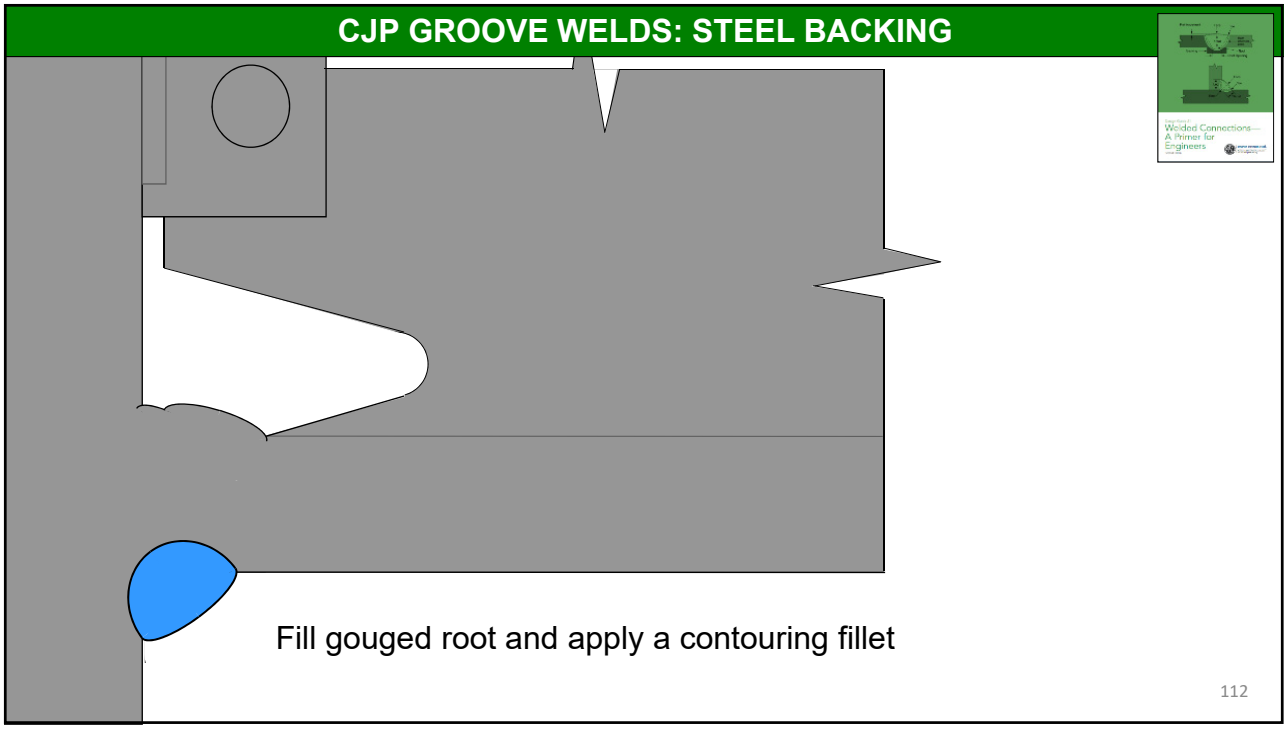
CJP GROOVE WELDS: STEEL BACKING



Gouge root

111

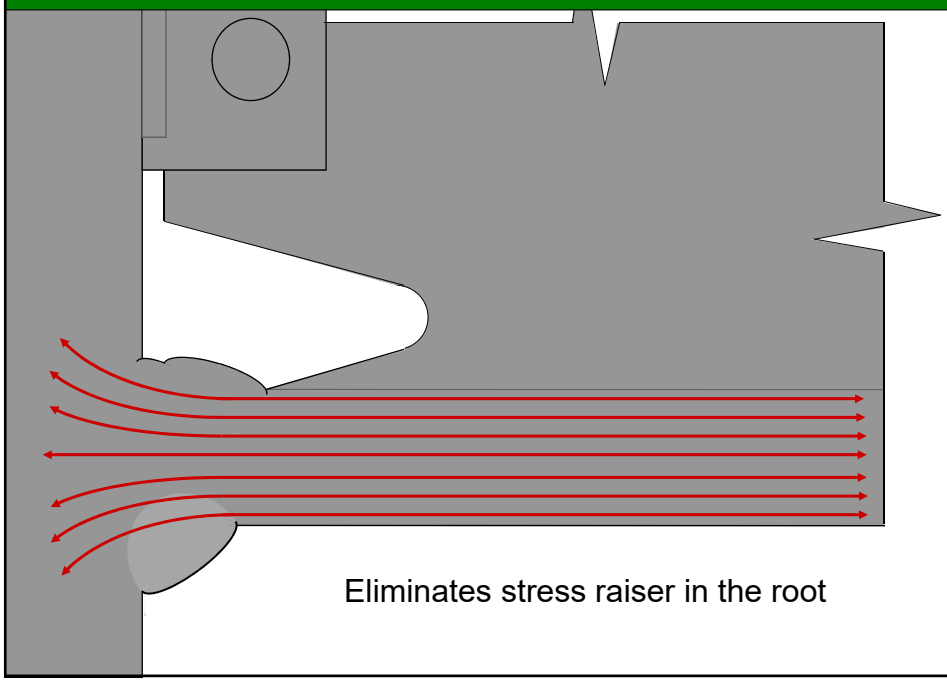
CJP GROOVE WELDS: STEEL BACKING



Fill gouged root and apply a contouring fillet

112

CJP GROOVE WELDS: STEEL BACKING



Eliminates stress raiser in the root

113

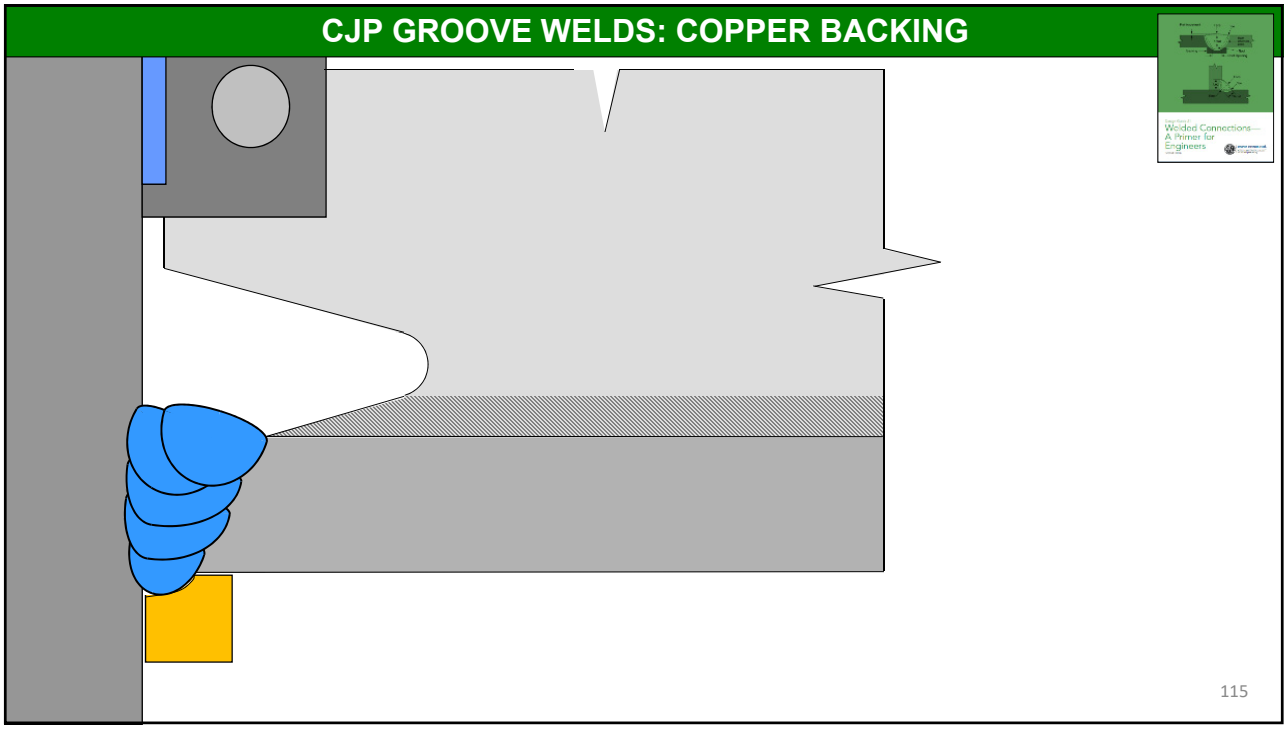
CJP GROOVE WELDS: BACKING

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)

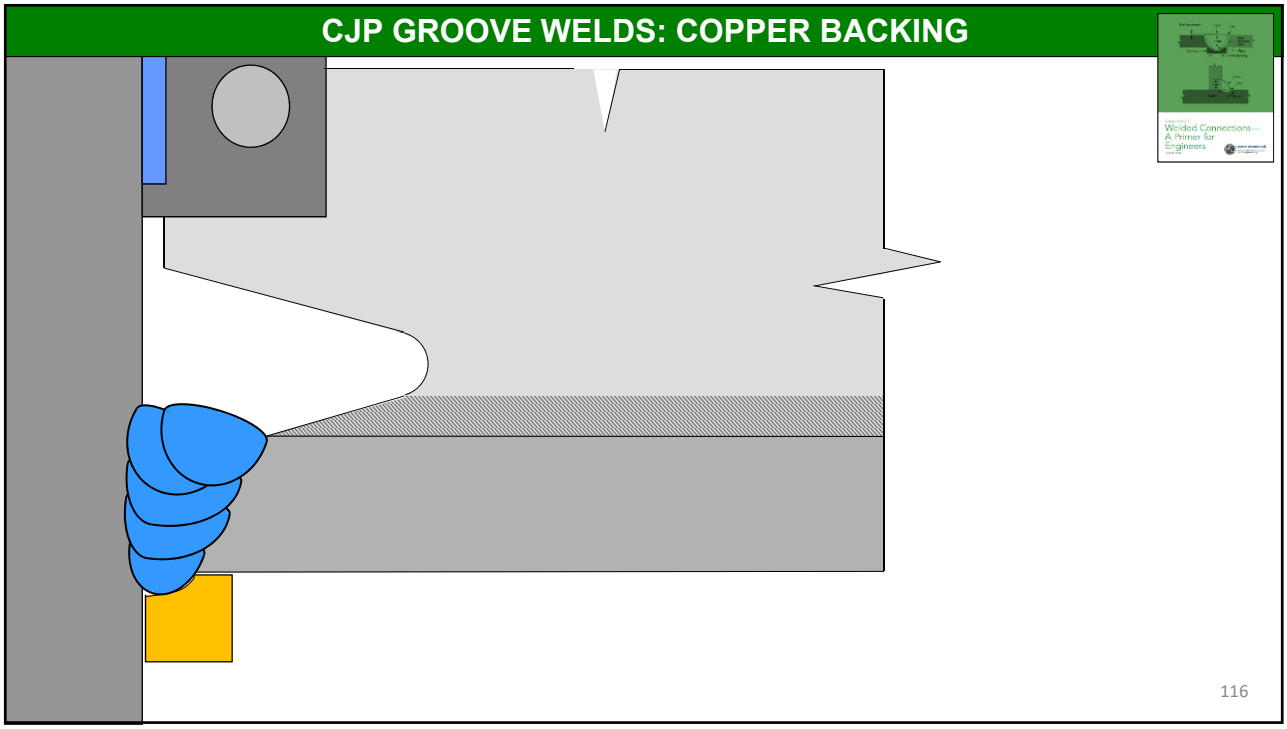
114

CJP GROOVE WELDS: COPPER BACKING



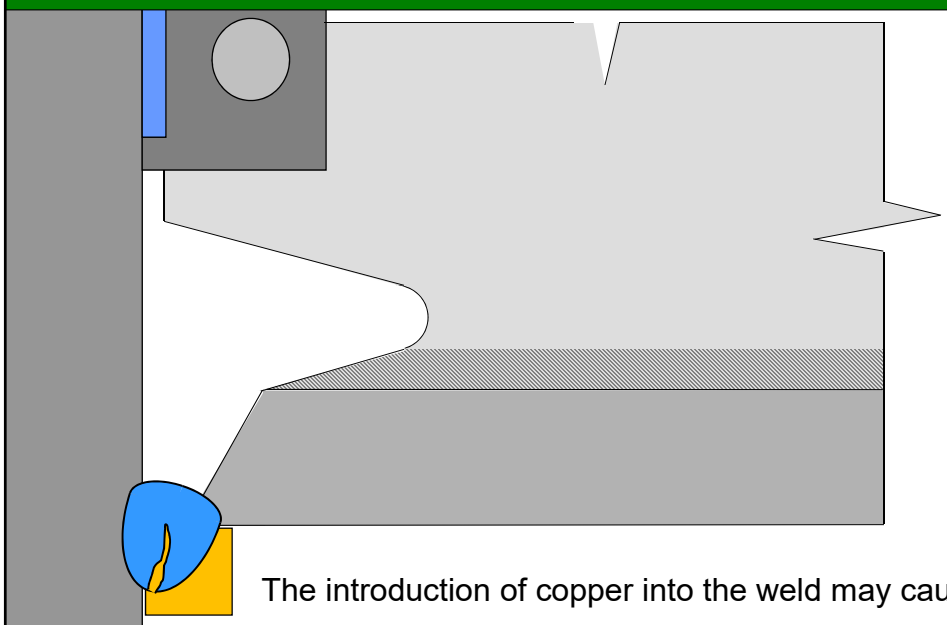
115

CJP GROOVE WELDS: COPPER BACKING



116

CJP GROOVE WELDS: COPPER BACKING



The introduction of copper into the weld may cause cracking.

117

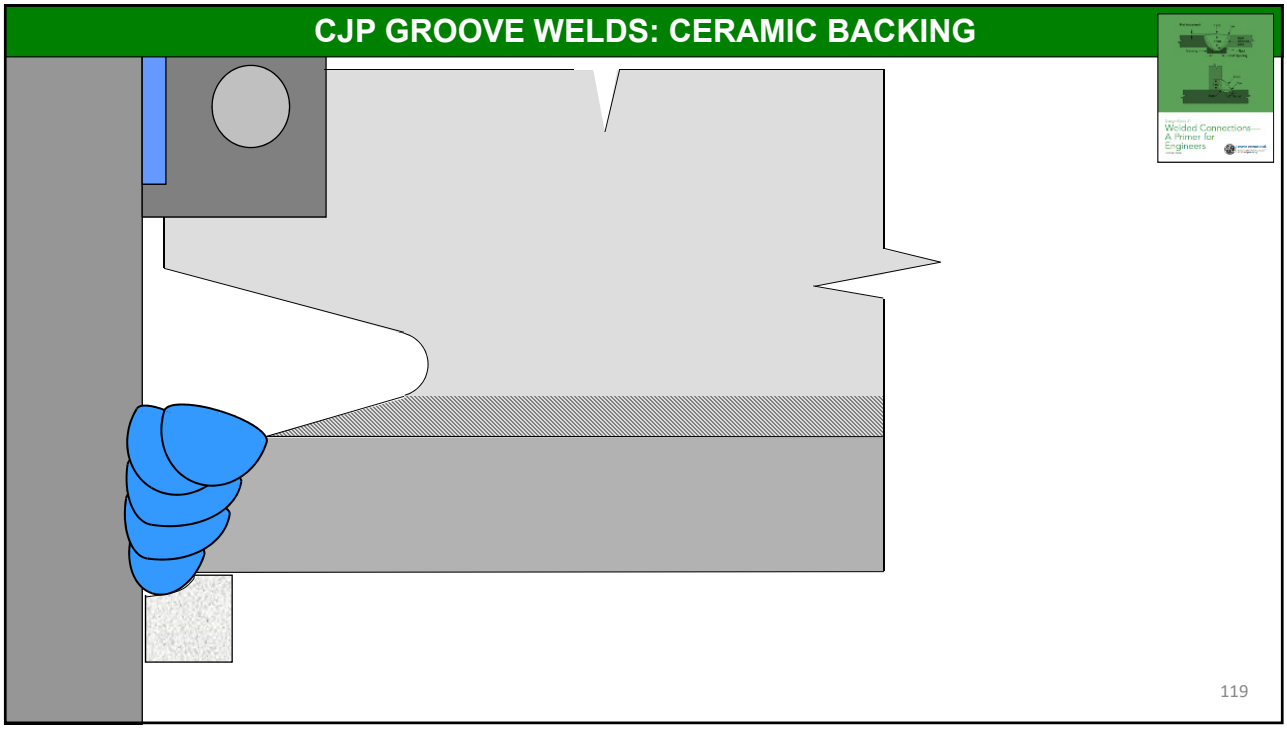
CJP GROOVE WELDS: BACKING

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)

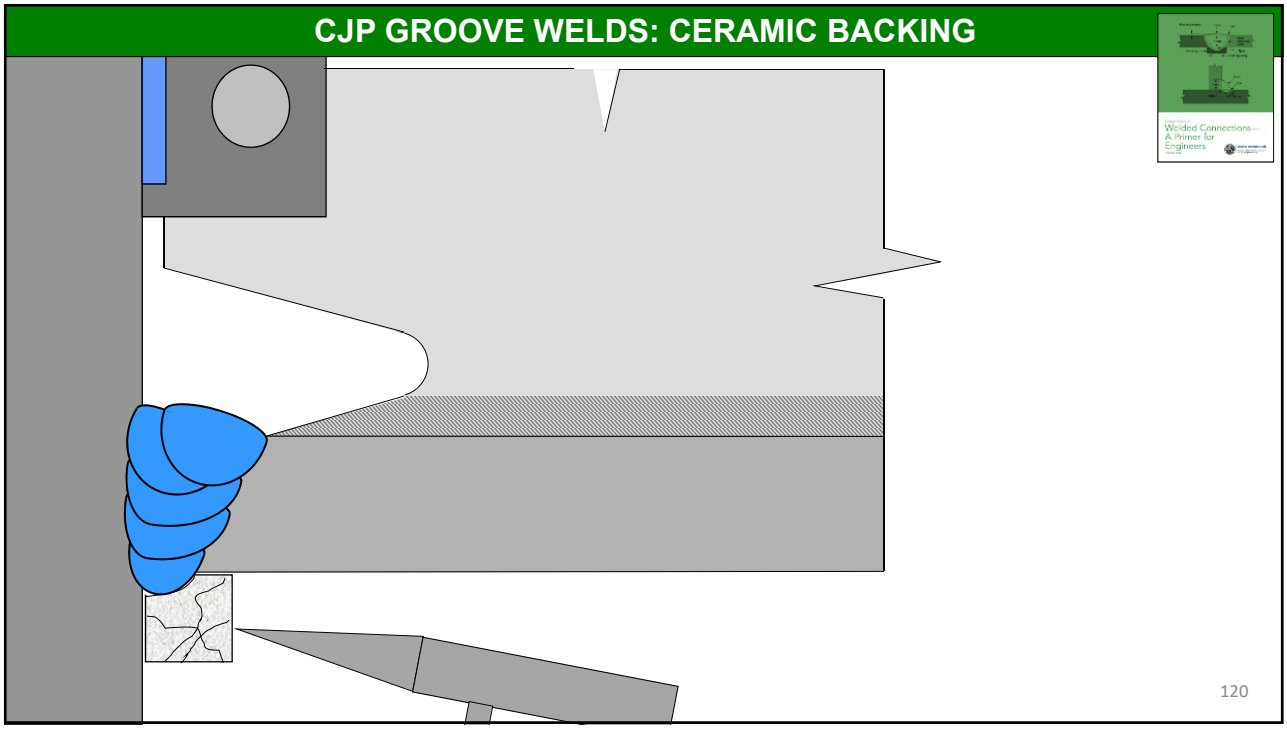
118

CJP GROOVE WELDS: CERAMIC BACKING



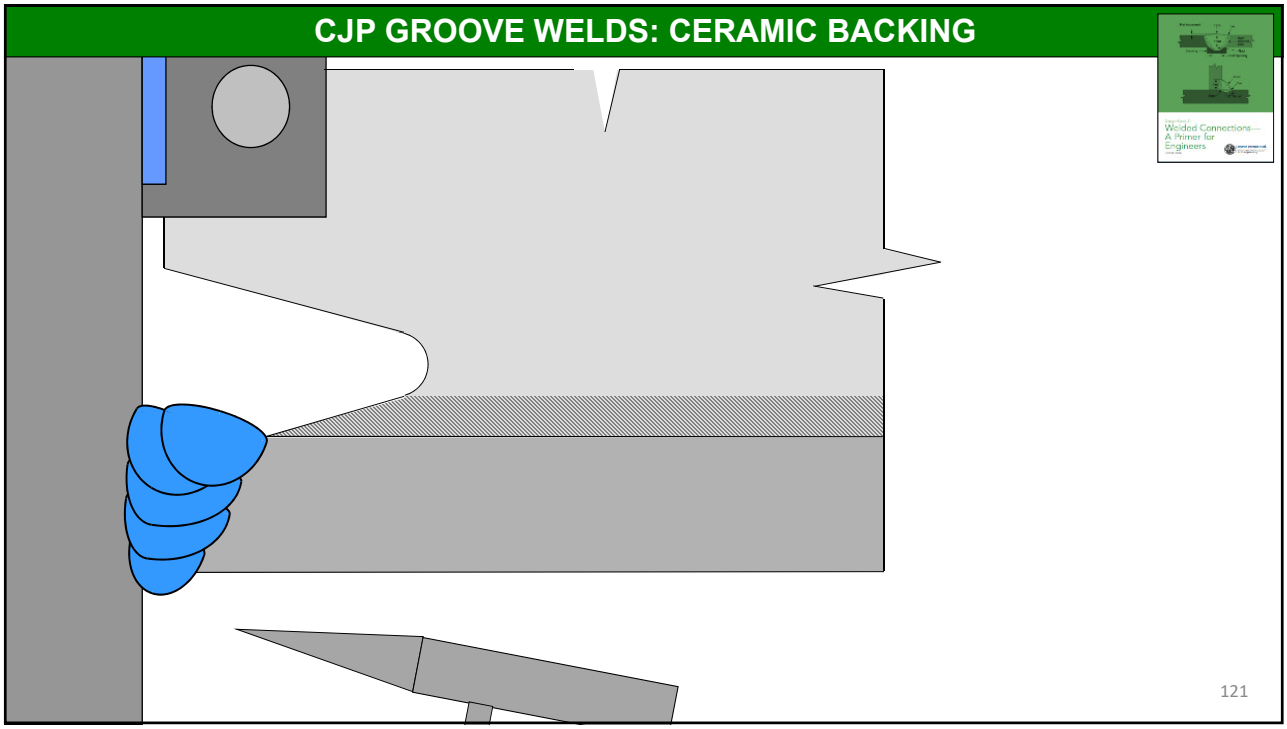
119

CJP GROOVE WELDS: CERAMIC BACKING



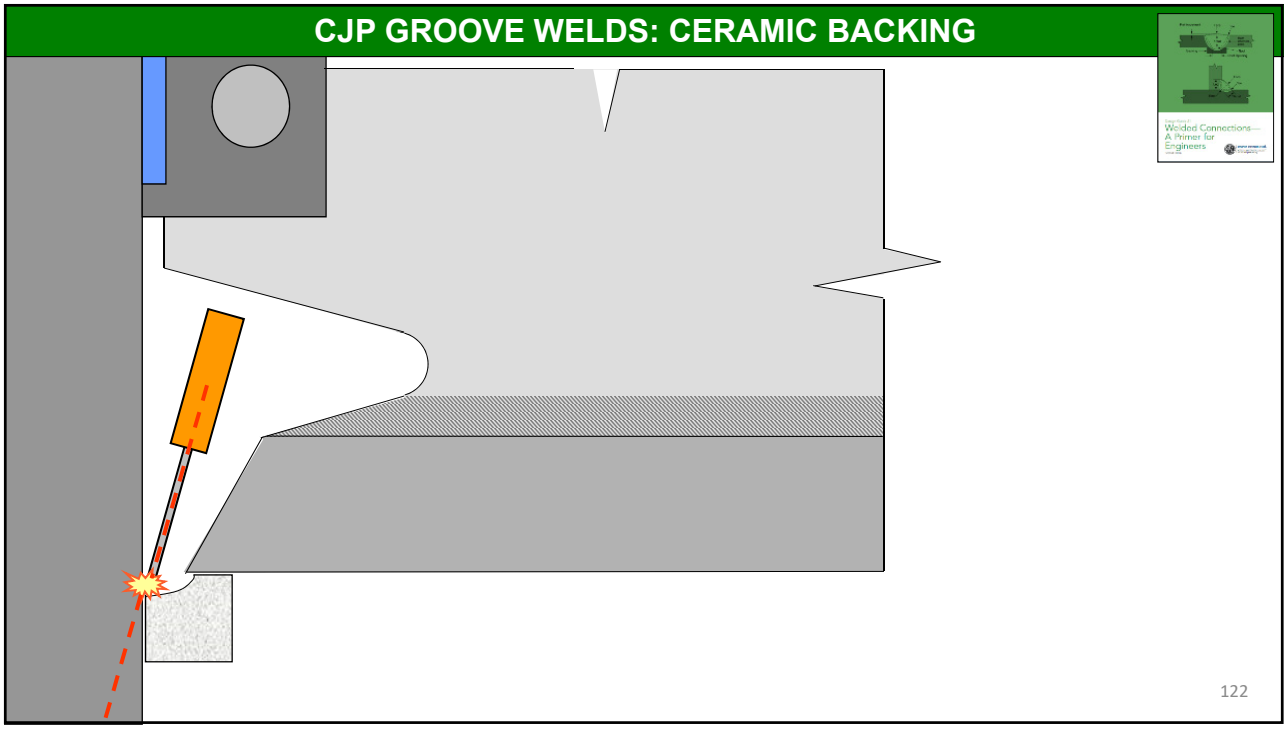
120

CJP GROOVE WELDS: CERAMIC BACKING



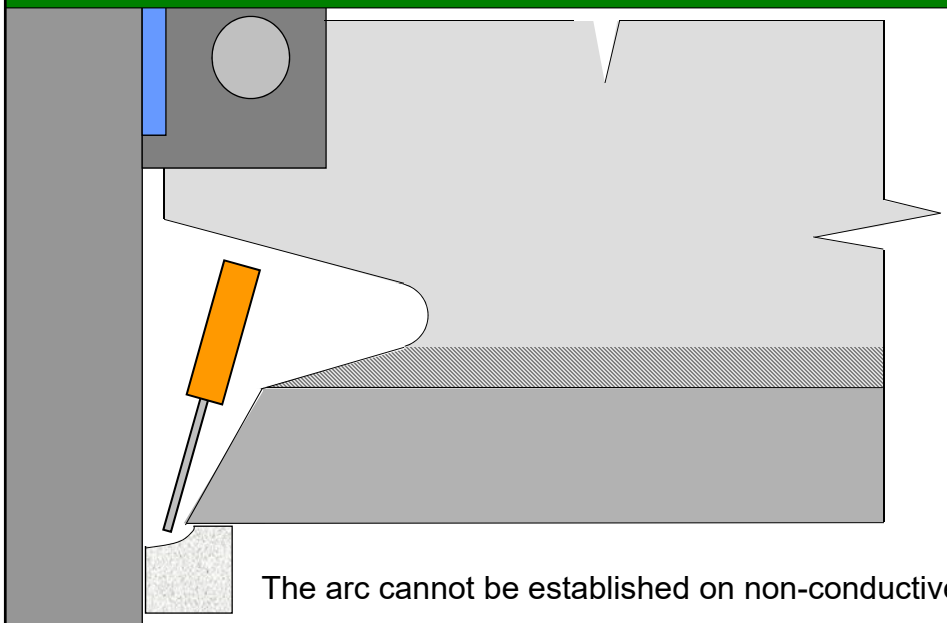
121

CJP GROOVE WELDS: CERAMIC BACKING



122

CJP GROOVE WELDS: CERAMIC BACKING



The arc cannot be established on non-conductive ceramic

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AWS D1.1: 2015 Structural Welding Code – Steel

CJP Groove Weld Types

Prequalified versus Qualified by Test

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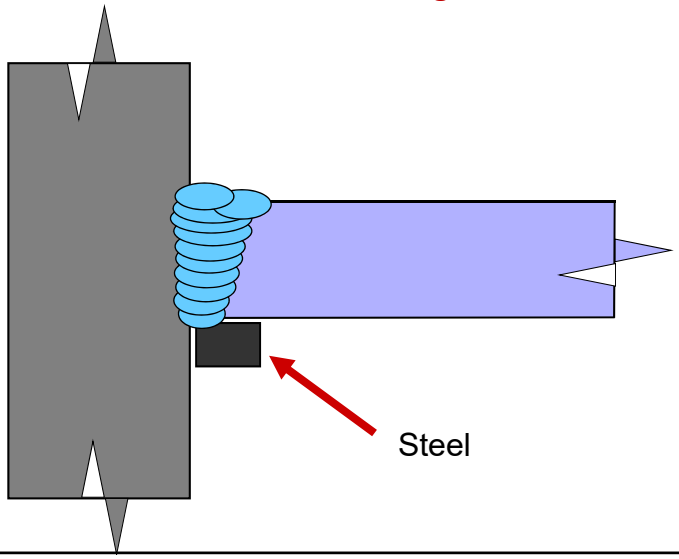
AWS D1.1:2015 Prequalified Joints

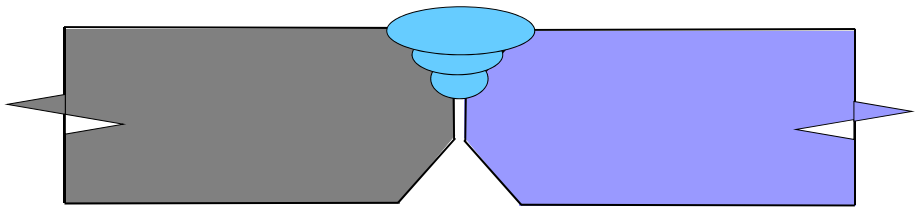
One sided, with steel backing



125

AWS D1.1:2015 Prequalified Joints

Two sided, with backgouging

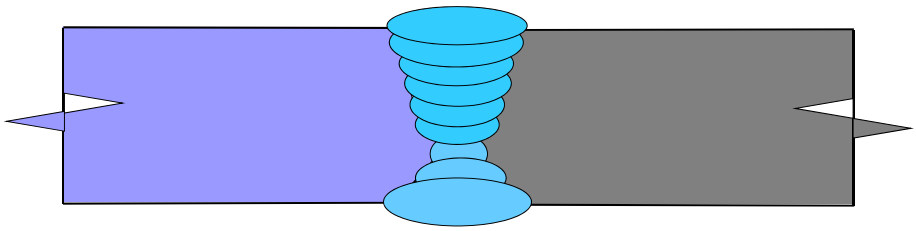


126

127

AWS D1.1:2015 Prequalified Joints

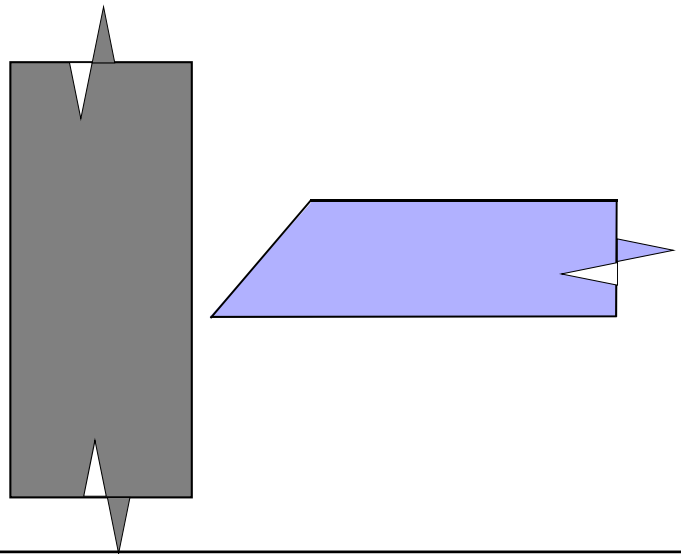
Two sided, with backgouging



128

AWS D1.1:2015 Prequalified Joints

One sided, open root



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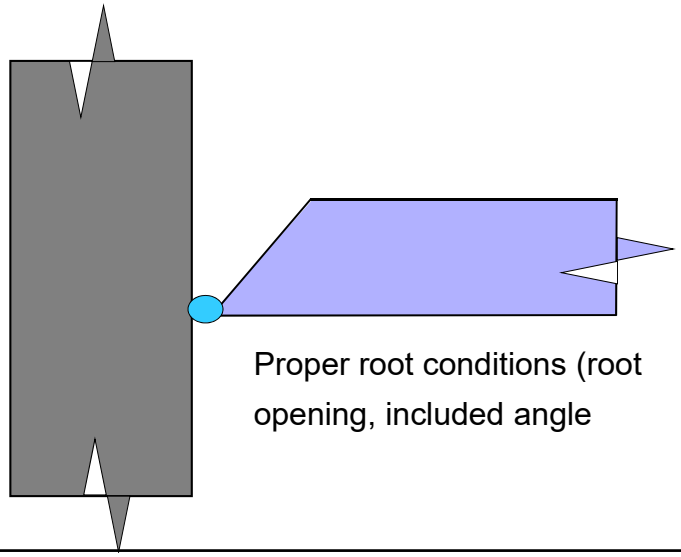
AWS D1.1:2015 Prequalified Joints

One sided, open root

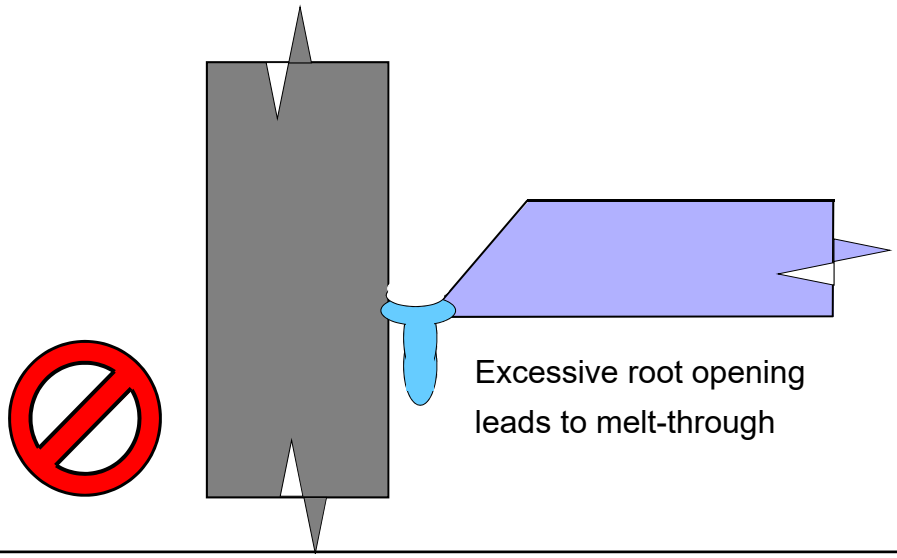


Proper root conditions (root opening, included angle

130

AWS D1.1:2015 Prequalified Joints

One sided, open root

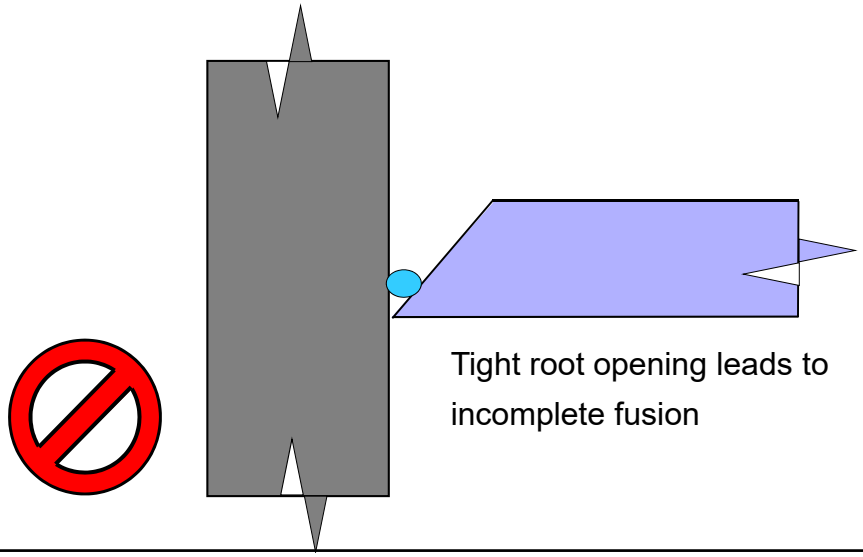


Excessive root opening leads to melt-through

131

AWS D1.1:2015 Prequalified Joints

One sided, open root

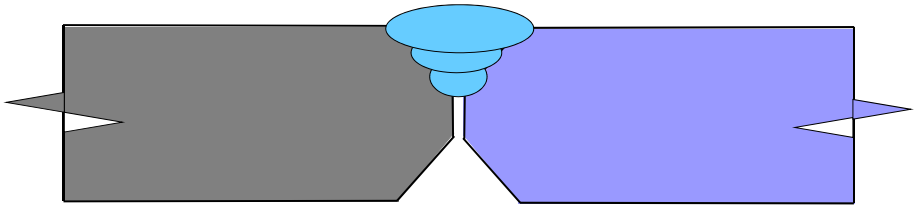


Tight root opening leads to incomplete fusion

132

AWS D1.1:2015 Prequalified Joints

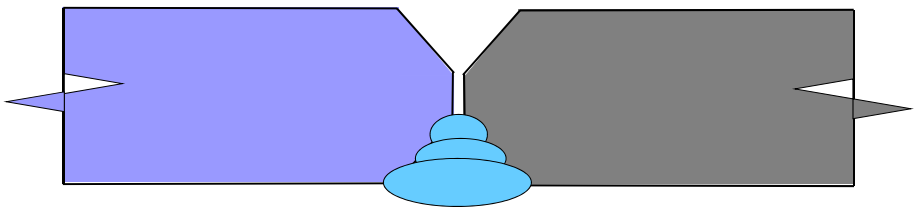
Two sided, without backgouging



133

AWS D1.1:2015 Prequalified Joints

Two sided, without backgouging



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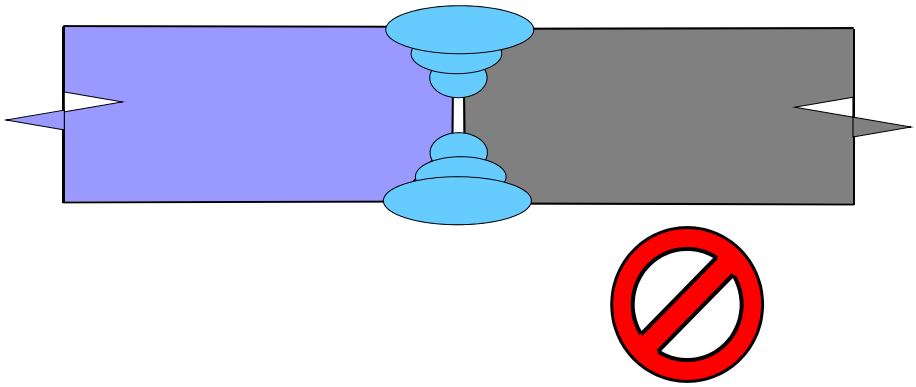
AWS D1.1:2015 Prequalified Joints

Two sided, without backgouging



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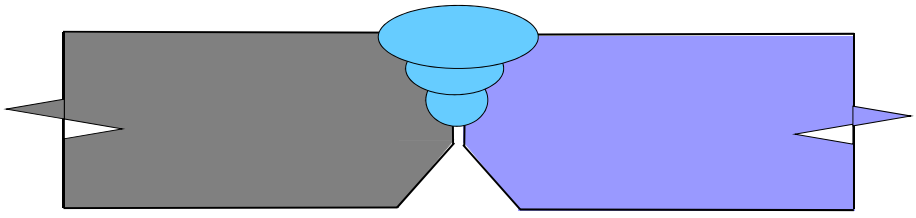
AWS D1.1:2015 Prequalified Joints

Two sided, without backgouging



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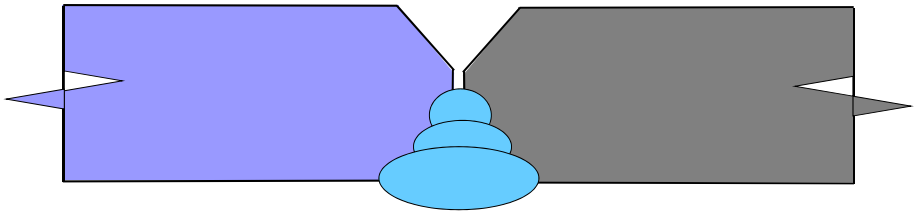
AWS D1.1:2015 Prequalified Joints

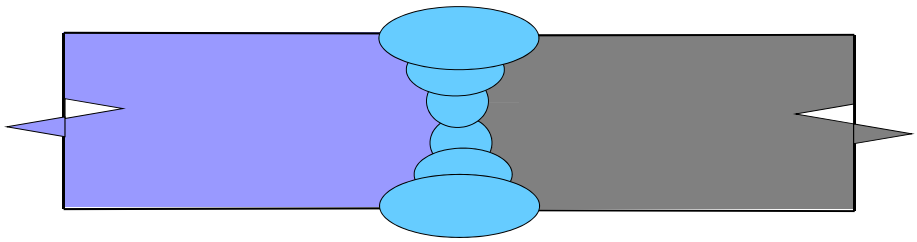
Two sided, without backgouging



137

AWS D1.1:2015 Prequalified Joints

Two sided, without backgouging



138

CJP GROOVE WELDS: BACKING

Backing materials for steel applications:

- Steel ← Prequalified by AWS D1.1
- Copper
- Ceramic

} Require qualification testing by AWS D1.1

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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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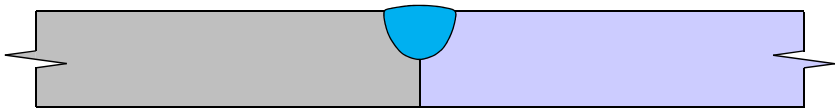
PJP GROOVE WELDS

Partial Joint Penetration Groove Weld (PJP)

Single sided PJP in butt joint

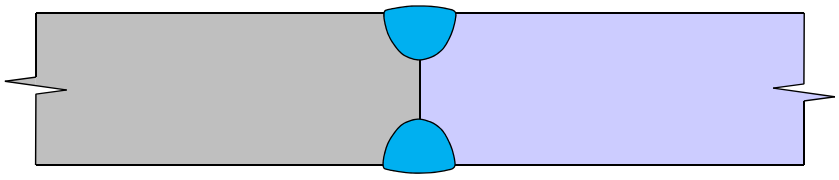


141

PJP GROOVE WELDS

Partial Joint Penetration Groove Weld (PJP)

Double sided PJP in butt joint

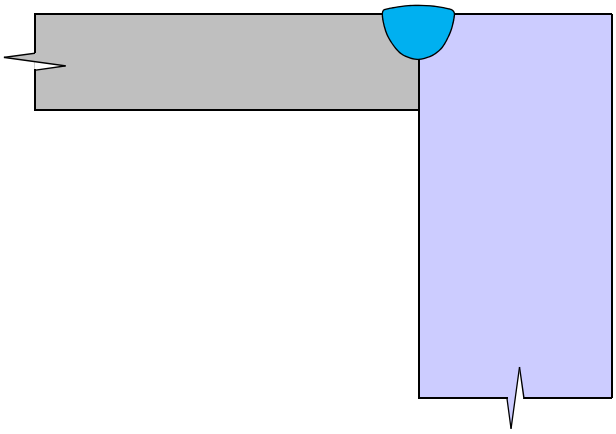


142

PJP GROOVE WELDS

Partial Joint Penetration Groove Weld (PJP)

Single sided PJP in corner joint

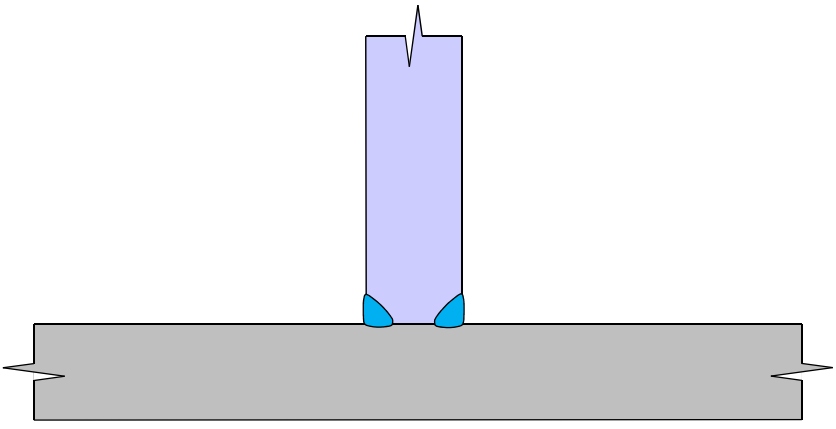


143

PJP GROOVE WELDS

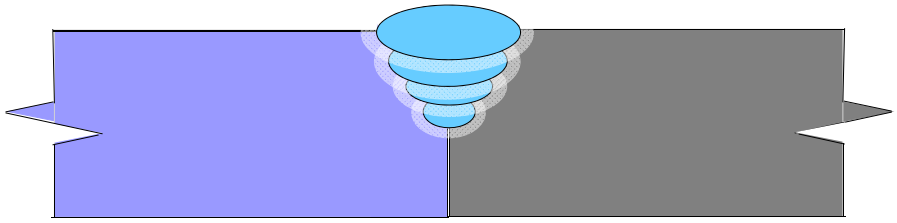
Partial Joint Penetration Groove Weld (PJP)

Double sided PJP in tee (T) joint



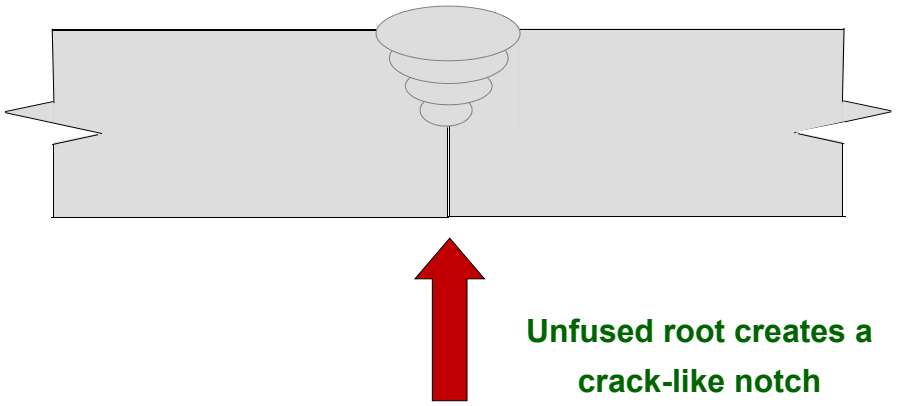
144

PJP GROOVE WELDS



145

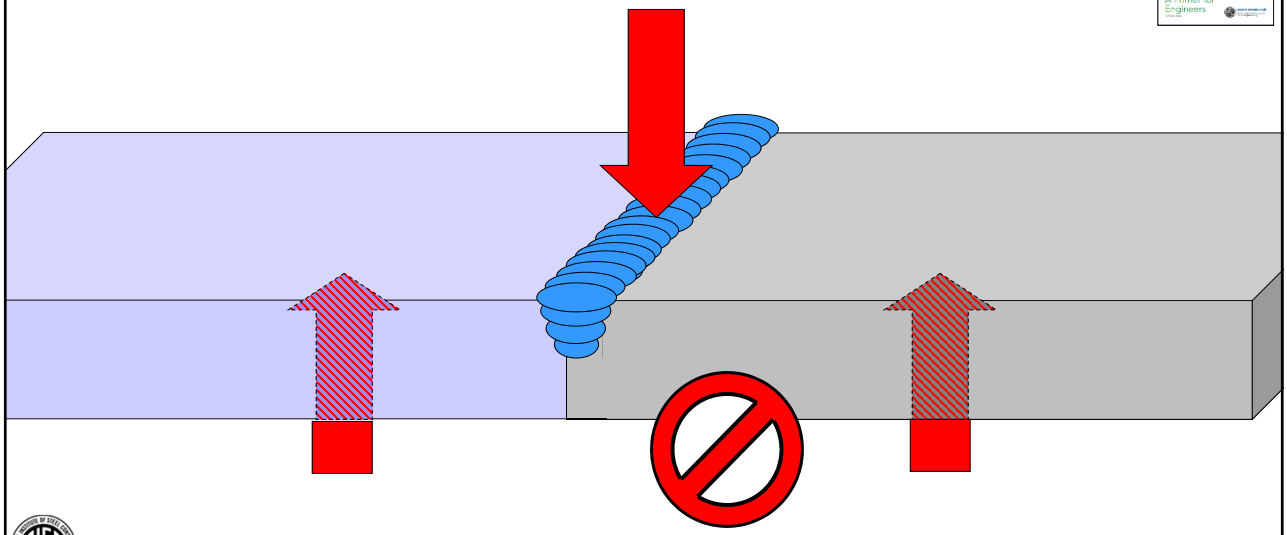
PJP GROOVE WELDS



146

PJP GROOVE WELDS

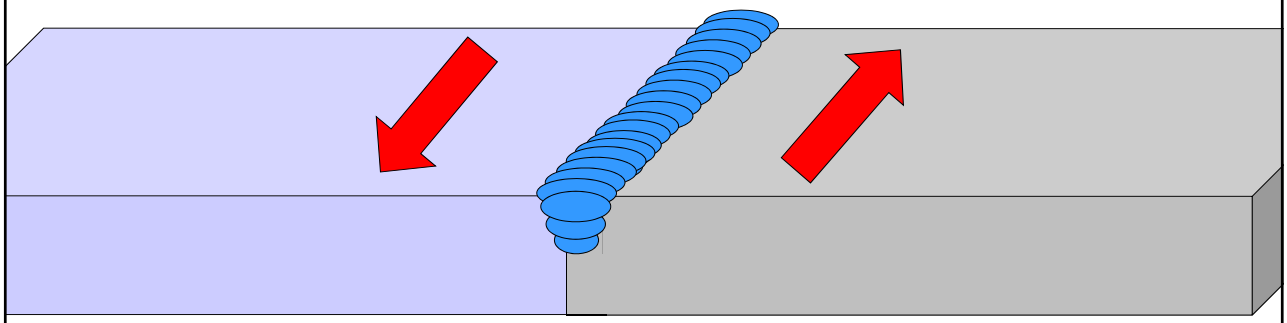
Unacceptable: straining about root



147

PJP GROOVE WELDS

Acceptable: no straining about root



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PJP GROOVE WELDS

General characteristics of PJP groove welds

- Throat < plate thickness
- Connection designer must determine throat

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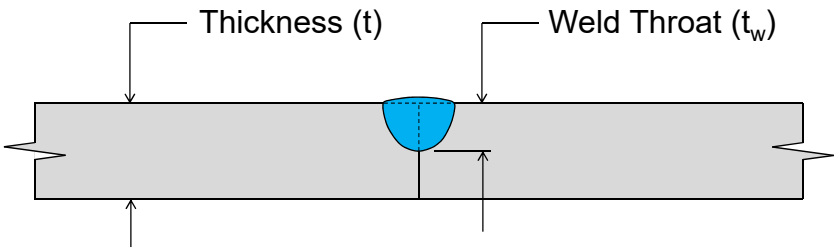
PJP GROOVE WELDS



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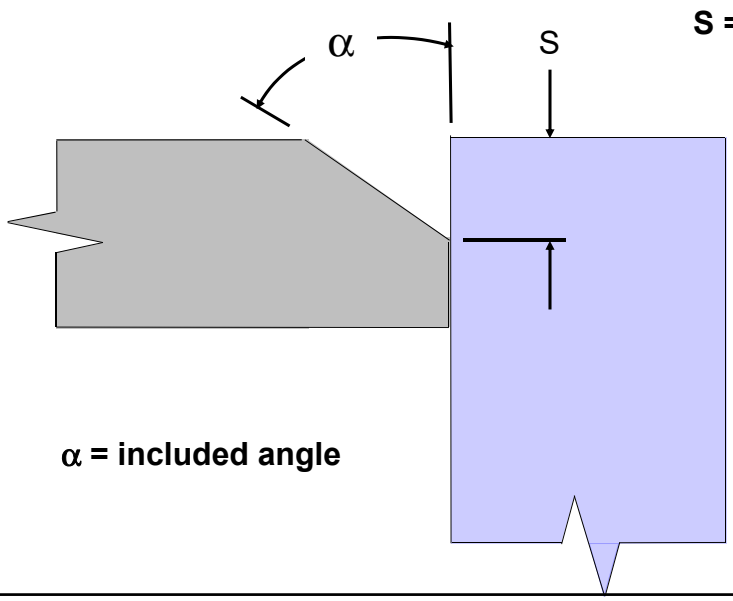
PJP GROOVE WELDS

General characteristics of PJP groove welds

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

151

PJP GROOVE WELDS



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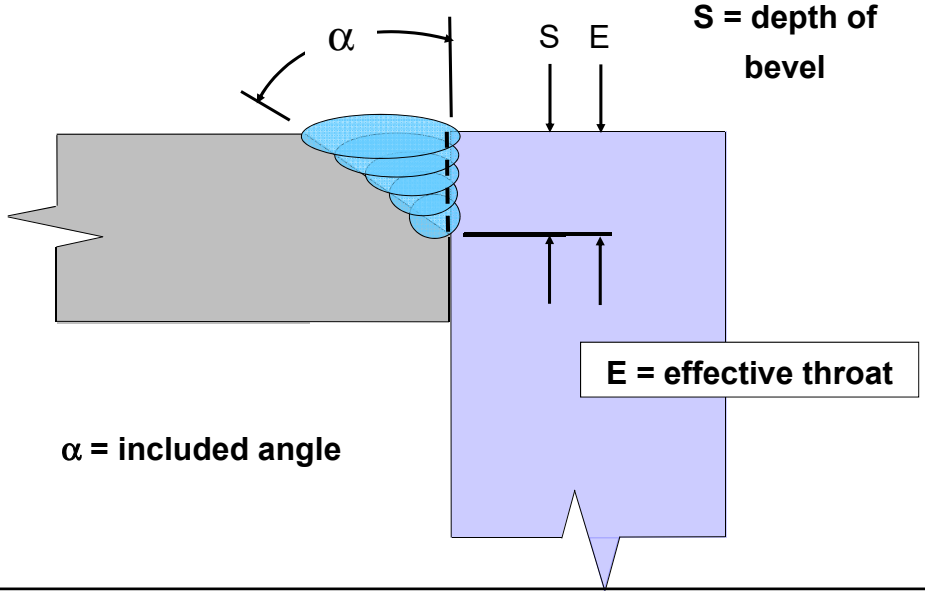
PJP GROOVE WELDS



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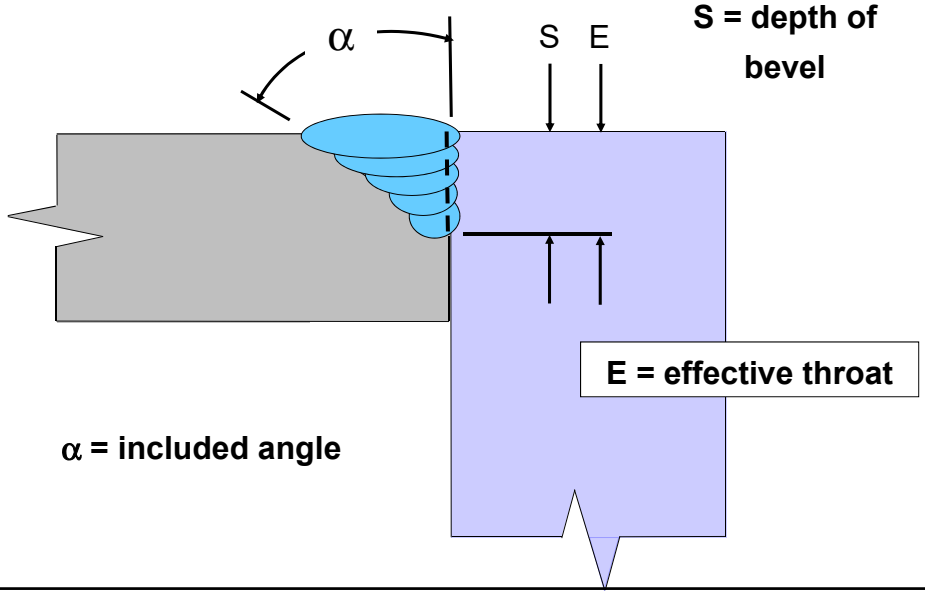
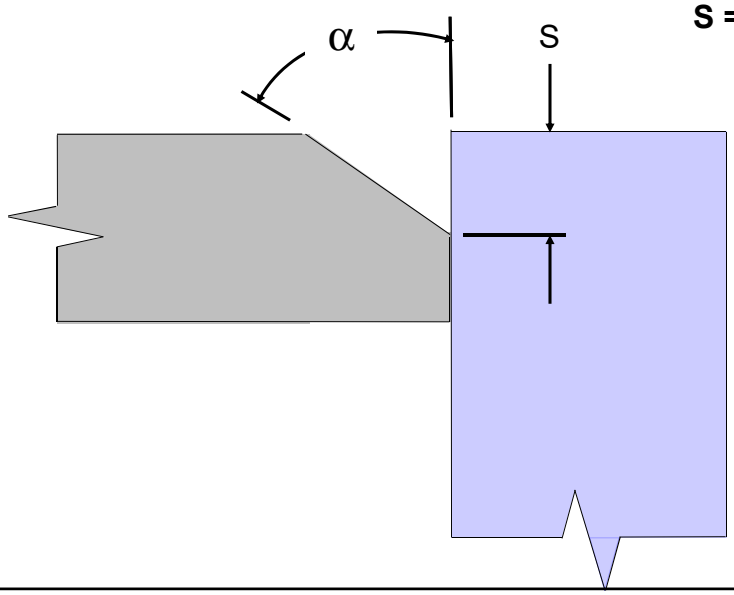
PJP GROOVE WELDS



154

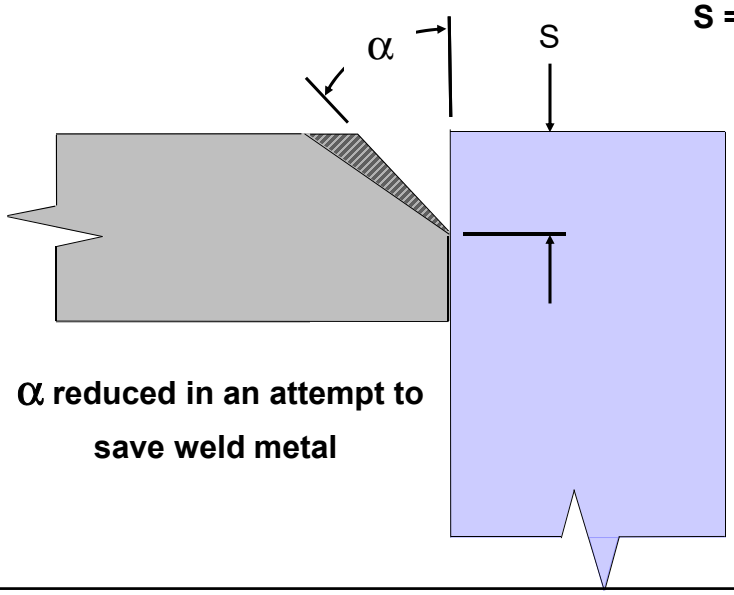
PJP GROOVE WELDS



S = depth of bevel

155

PJP GROOVE WELDS



S = depth of bevel

α reduced in an attempt to save weld metal

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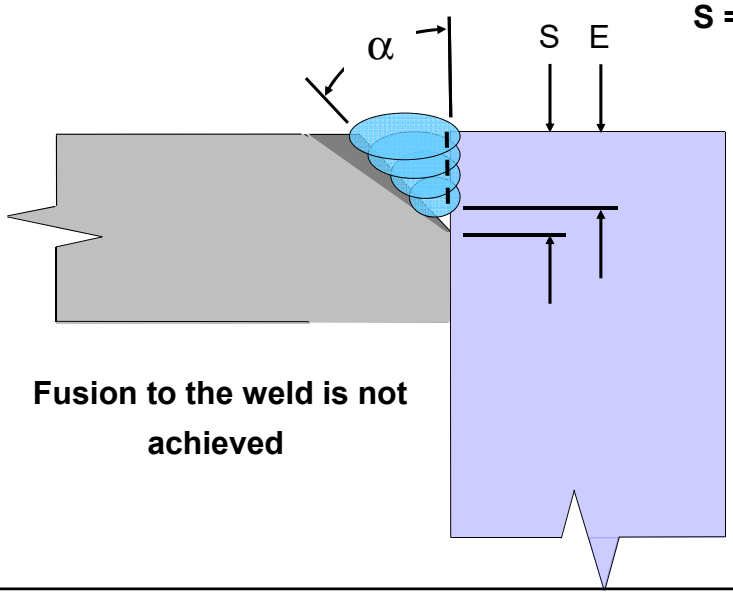
PJP GROOVE WELDS



S = depth of bevel

Fusion to the weld is not achieved

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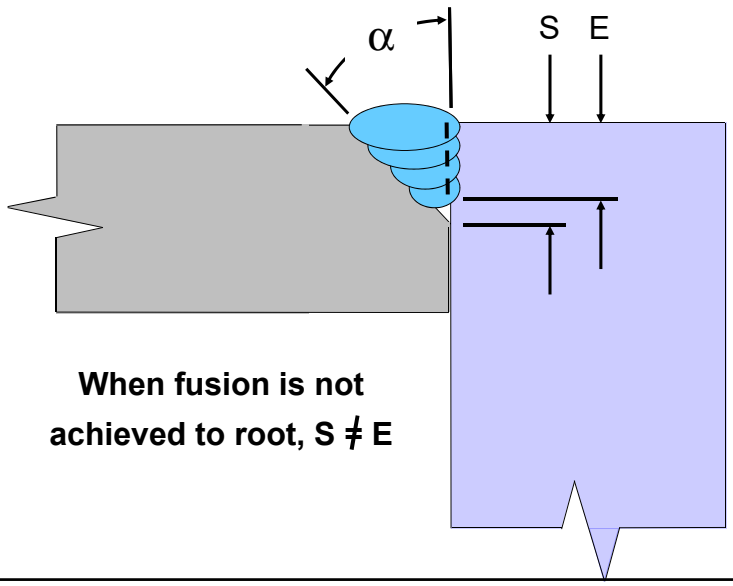
PJP GROOVE WELDS



When fusion is not achieved to root, S ≠ 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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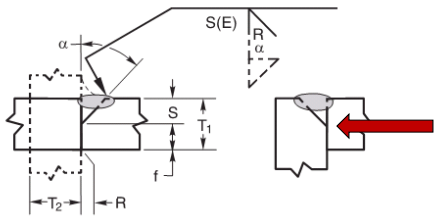
AWS D1.1: 2015 Structural Welding Code – Steel

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) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening Root Face Groove Angle	Groove Preparation: Tolerances As Detailed (see 3.12.3)	Groove Preparation: Tolerances As Fit-Up (see 3.12.3)	Allowed Welding Positions	Weld Size (E)	Notes
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	S	a, b, f, g, j, k
							V, OH	S–1/8	
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

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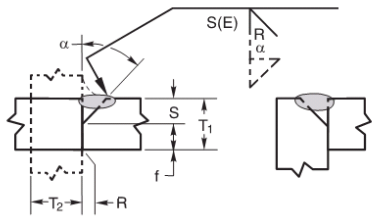
AWS D1.1: 2015 Structural Welding Code – Steel

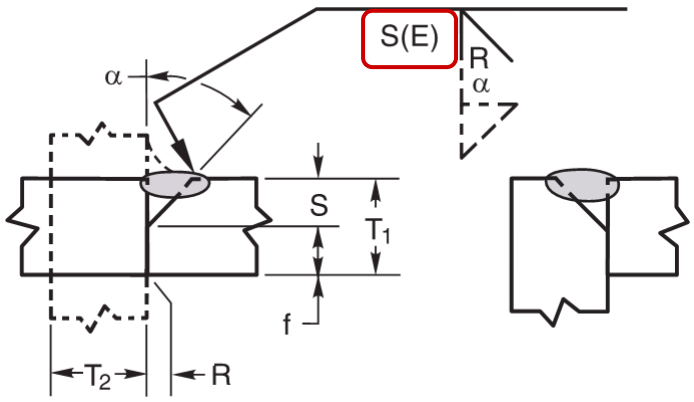
Figure 3.2

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



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening, Root Face, Groove Angle	Groove Preparation: Tolerances: As Detailed (see 3.12.3)	Groove Preparation: Tolerances: As Fit-Up (see 3.12.3)	Allowed Welding Positions	Weld Size (E)	Notes
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 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

AWS D1.1: 2015 Structural Welding Code – Steel



PJP GROOVE WELDS

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:

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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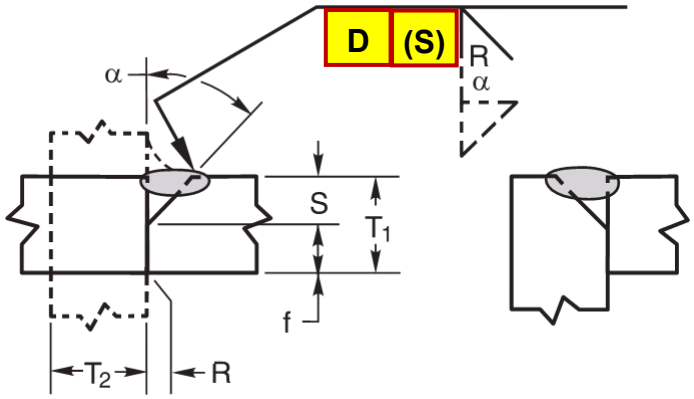
AWS D1.1: 2015 Structural Welding Code – Steel



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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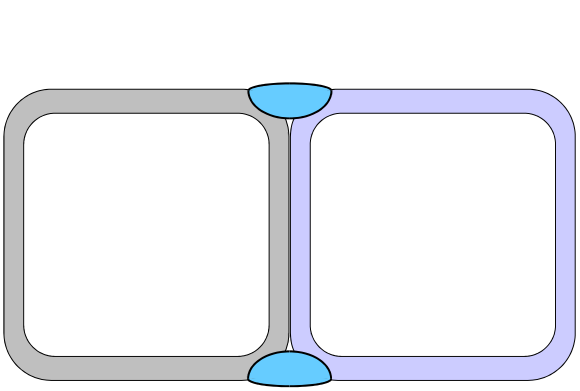
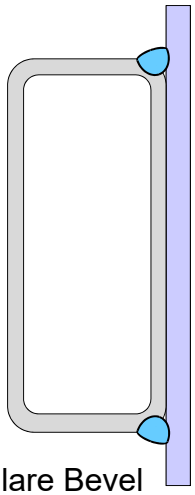
PJP GROOVE WELDS



Flare V



Flare Bevel

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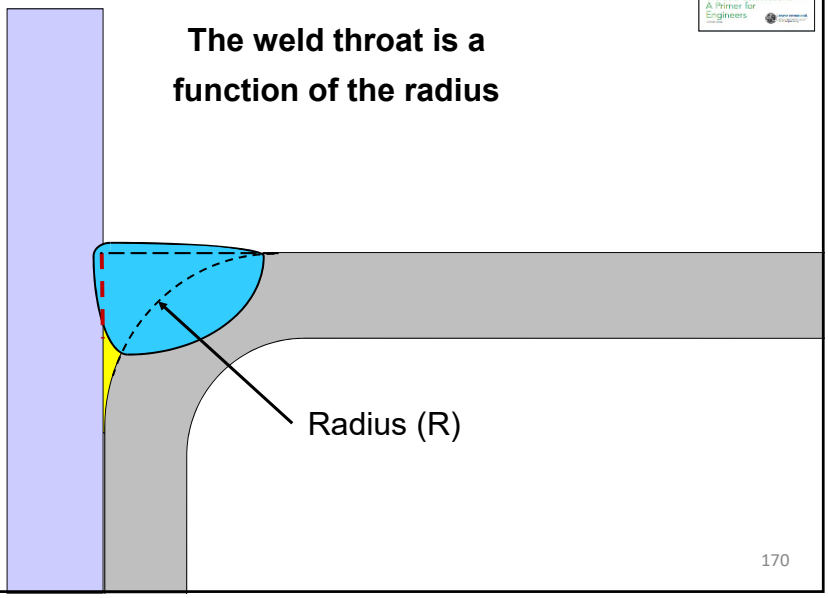
PJP GROOVE WELDS

The weld throat is a function of the radius



t_ω = (5/16) R
(illustrative only)

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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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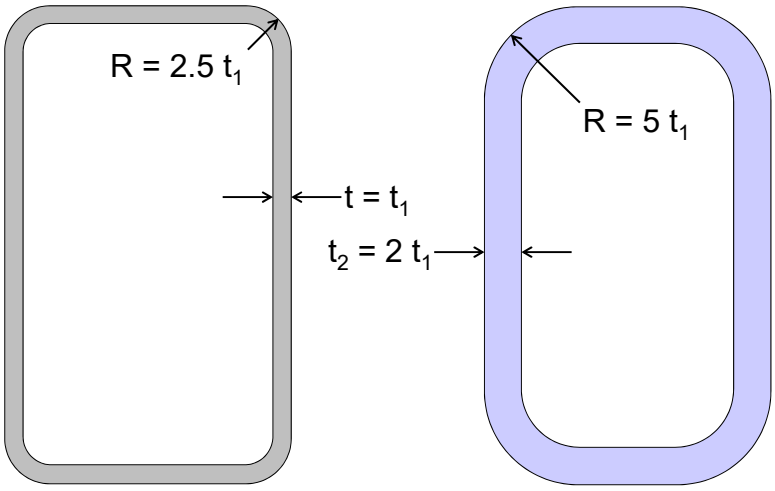
PJP GROOVE WELDS

ASTM limits: R ≤ 3t



Typical: R = 2.5 t

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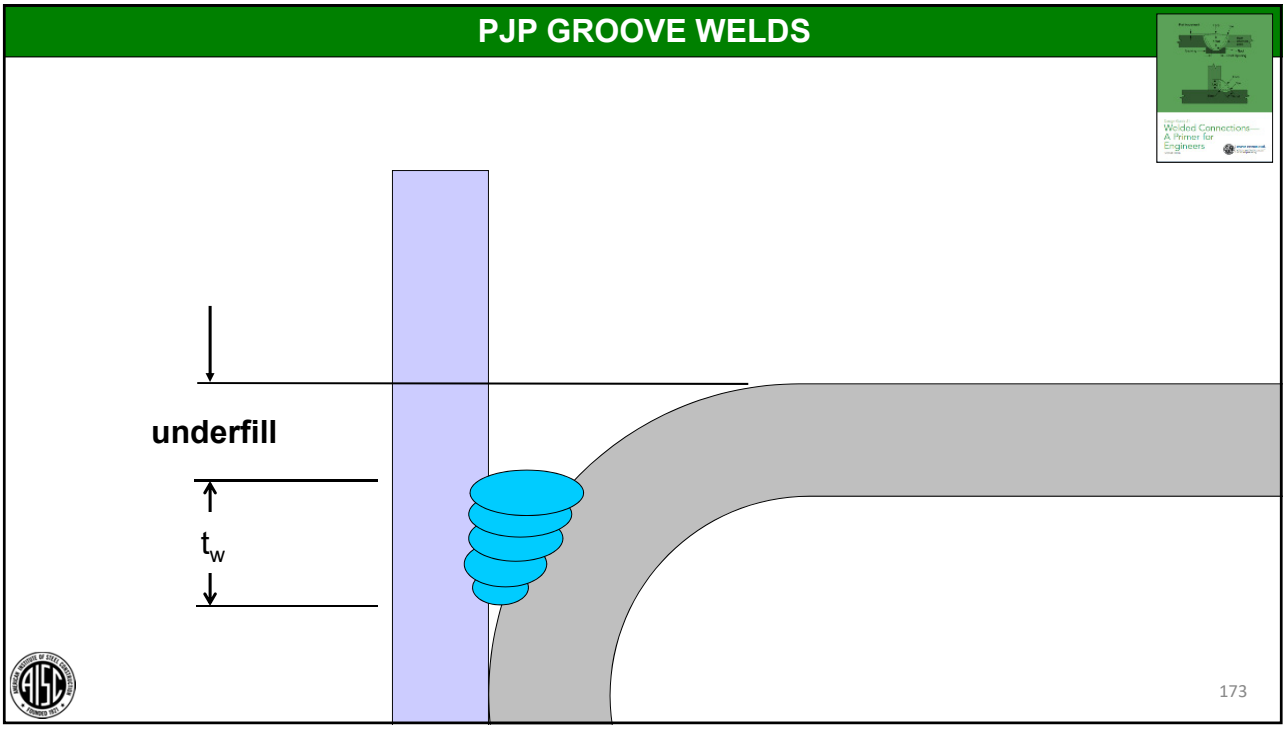
PJP GROOVE WELDS



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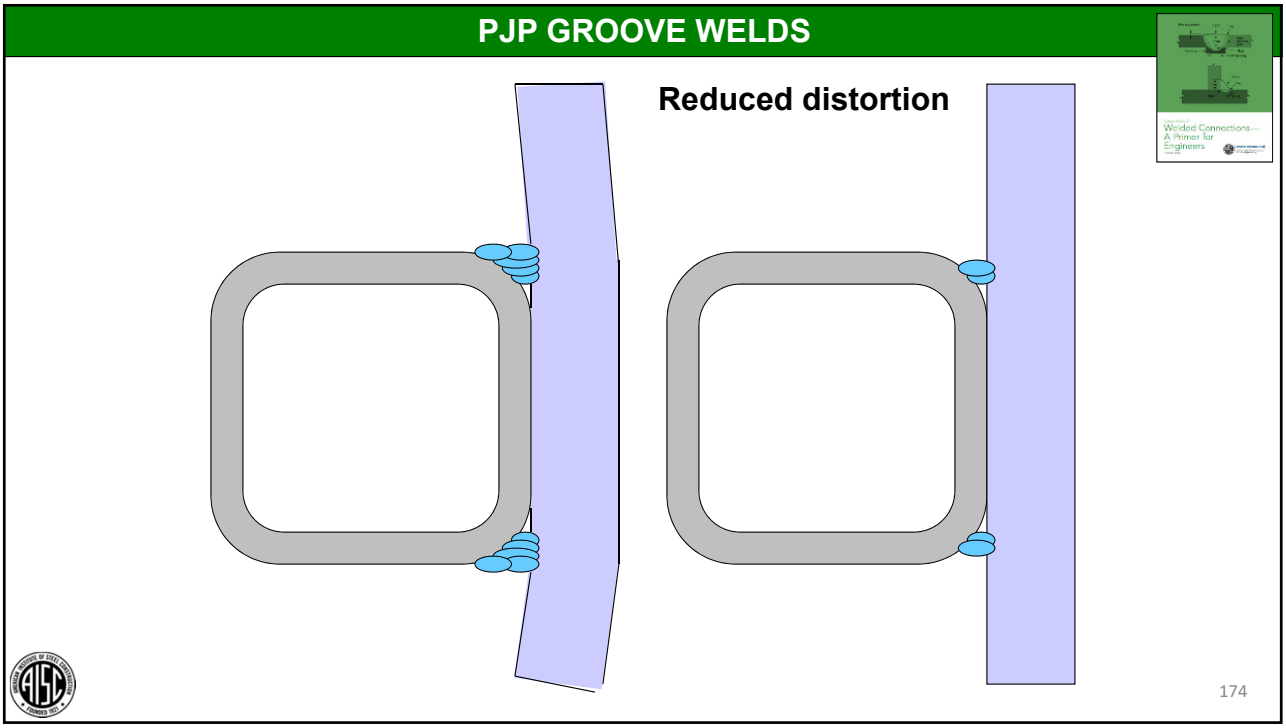
PJP GROOVE WELDS



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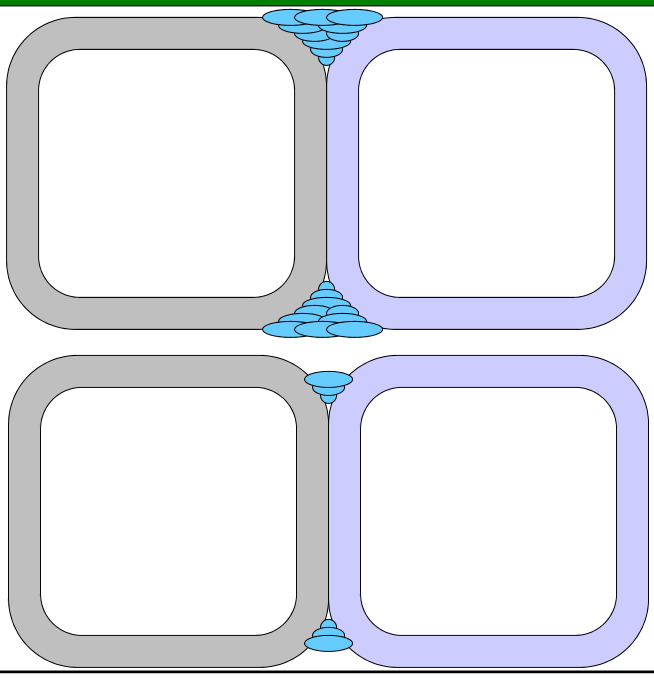
PJP GROOVE WELDS



Reduced cost

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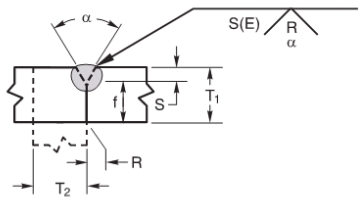
Single V Groove Weld: PJP

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



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening Root Face Groove Angle	Groove Preparation: Tolerances: As Detailed (see 3.12.3)	Groove Preparation: Tolerances: As Fit-Up (see 3.12.3)	Allowed Welding Positions	Weld Size (E)	Notes
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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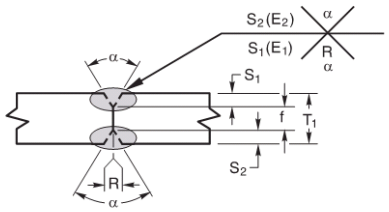
AWS D1.1: 2015 Structural Welding Code – Steel

Double V Groove Weld: PJP

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



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening Root Face Groove Angle	Groove Preparation: Tolerances: As Detailed (see 3.12.3)	Groove Preparation: Tolerances: As Fit-Up (see 3.12.3)	Allowed Welding Positions	Total Weld Size ($E_1 + E_2$)	Notes
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

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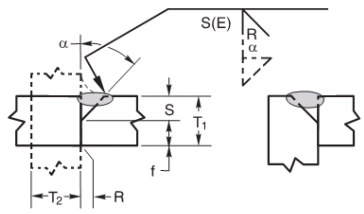
AWS D1.1: 2015 Structural Welding Code – Steel

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) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening Root Face Groove Angle	Groove Preparation: Tolerances: As Detailed (see 3.12.3)	Groove Preparation: Tolerances: As Fit-Up (see 3.12.3)	Allowed Welding Positions	Weld Size (E)	Notes
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 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

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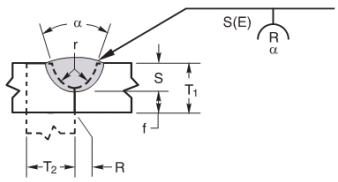
AWS D1.1: 2015 Structural Welding Code – Steel

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) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening Root Face Bevel Radius Groove Angle	Groove Preparation: Tolerances: As Detailed (see 3.12.3)	Groove Preparation: Tolerances: As Fit-Up (see 3.12.3)	Allowed Welding Positions	Weld Size (E)	Notes
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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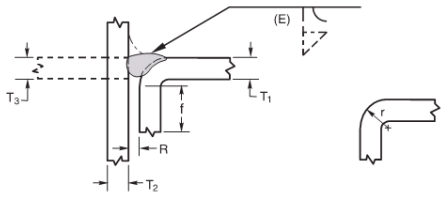
AWS D1.1: 2015 Structural Welding Code – Steel

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) T_1	Base Metal Thickness (U = unlimited) T_2	Base Metal Thickness (U = unlimited) T_3	Groove Preparation: Root Opening Root Face Bend Radius	Groove Preparation: Tolerances: As Detailed (see 3.12.3)	Groove Preparation: Tolerances: As Fit-Up (see 3.12.3)	Allowed Welding Positions	Weld Size (E)	Notes
SMAW FCAW-S	BTC-P10	3/16 min.	U	T_1 min.	R = 0 f = 3/16 min. r = $\frac{3T_1}{2}$ 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. 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	a, g, j, l, m
SAW	B-P10-S	1/2 min.	N/A	1/2 min.	R = 0 f = 1/2 min. r = $\frac{3T_1}{2}$ 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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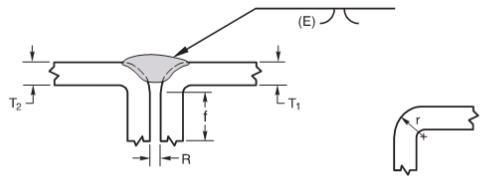
AWS D1.1: 2015 Structural Welding Code – Steel

Flare V Groove Weld: PJP

Flare-V-groove weld (11)
Butt joint (B)



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T_1	Base Metal Thickness (U = unlimited) T_2	Groove Preparation: Root Opening Root Face Bend Radius	Groove Preparation: Tolerances: As Detailed (see 3.12.3)	Groove Preparation: Tolerances: As Fit-Up (see 3.12.3)	Allowed Welding Positions	Weld Size (E)	Notes
SMAW FCAW-S	B-P11	3/16 min.	T_1 min.	R = 0 f = 3/16 min. 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. 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. 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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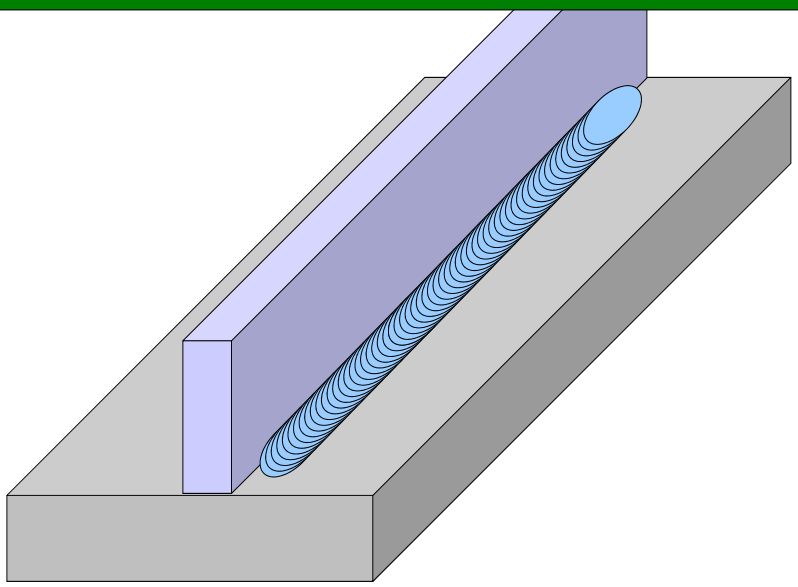
FILLET WELDS



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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 welds shall be the effective length multiplied by the effective throat. The effective throat of a fillet we 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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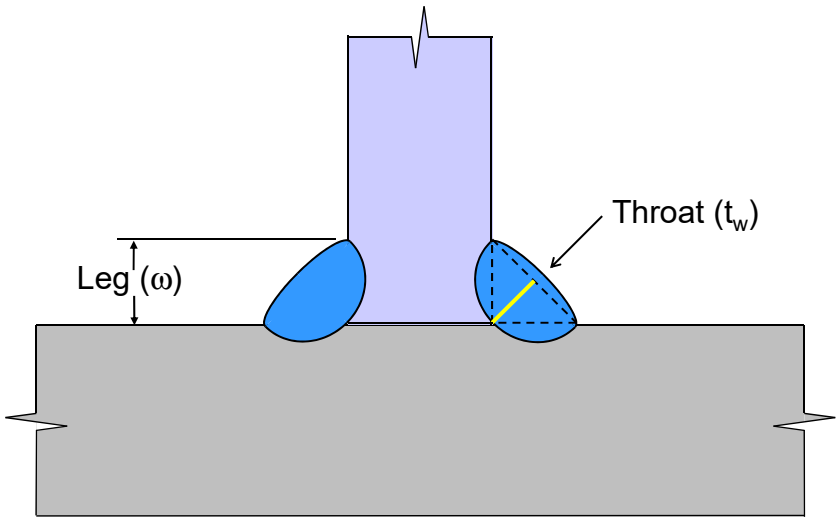
FILLET WELDS



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FILLET WELDS

Minimum sizes of fillet welds

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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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AISC 360-16 Specification for Structural Steel Buildings

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

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

Maximum sizes of fillet welds

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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:

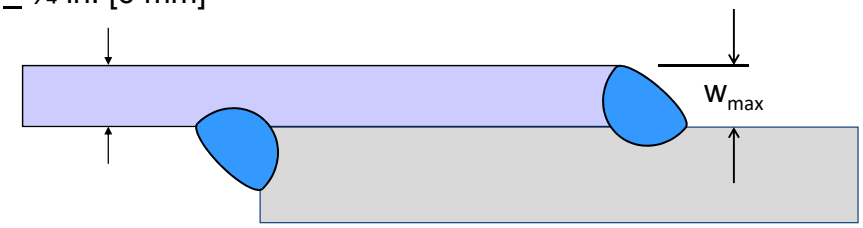
(1) Along edges of material less than 1/4 in. (6 mm) thick, not greater than the thickness of the material.

Also addressed in AWS D1.1:2015 clause 2.4.2.9

AISC 360-16 Specification for Structural Steel Buildings

Maximum Fillet Weld Size

$t \leq$ ¼ in. [6 mm]



(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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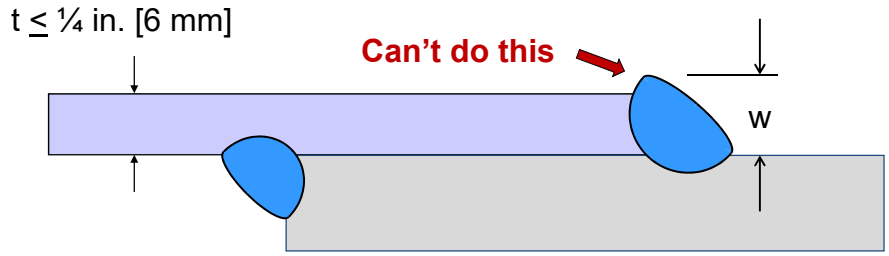
AISC 360-16 Specification for Structural Steel Buildings

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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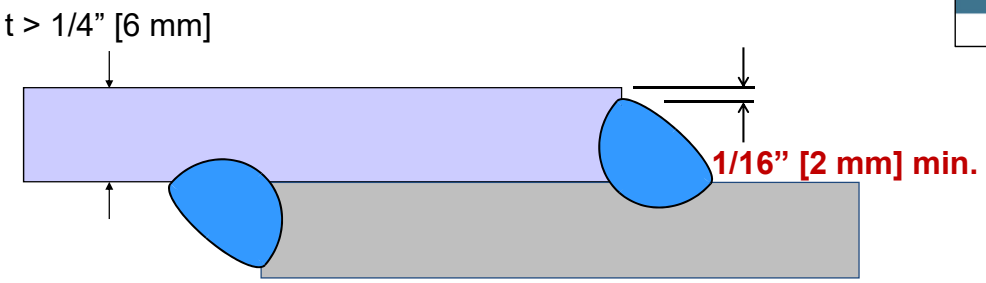
AISC 360-16 Specification for Structural Steel Buildings

Maximum Fillet Weld Size



(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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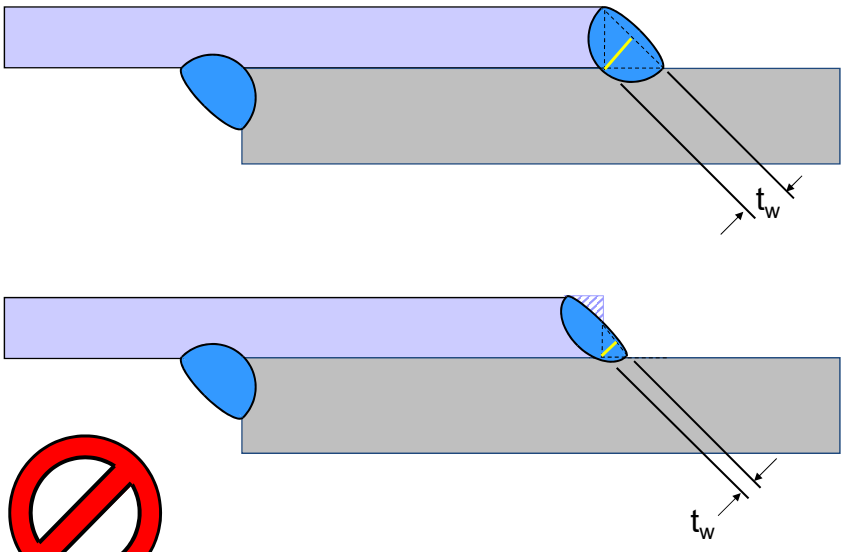
FILLET WELDS



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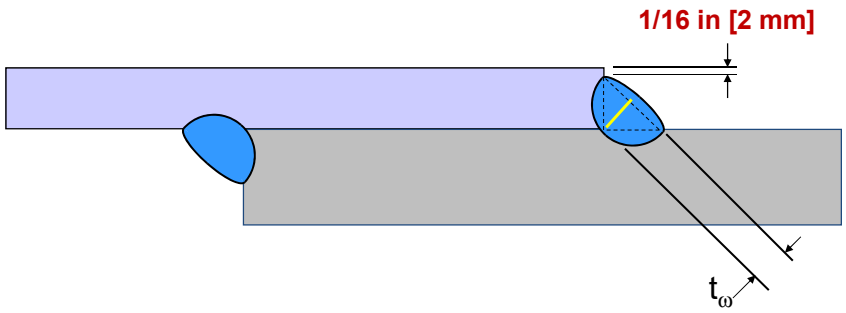
FILLET WELDS



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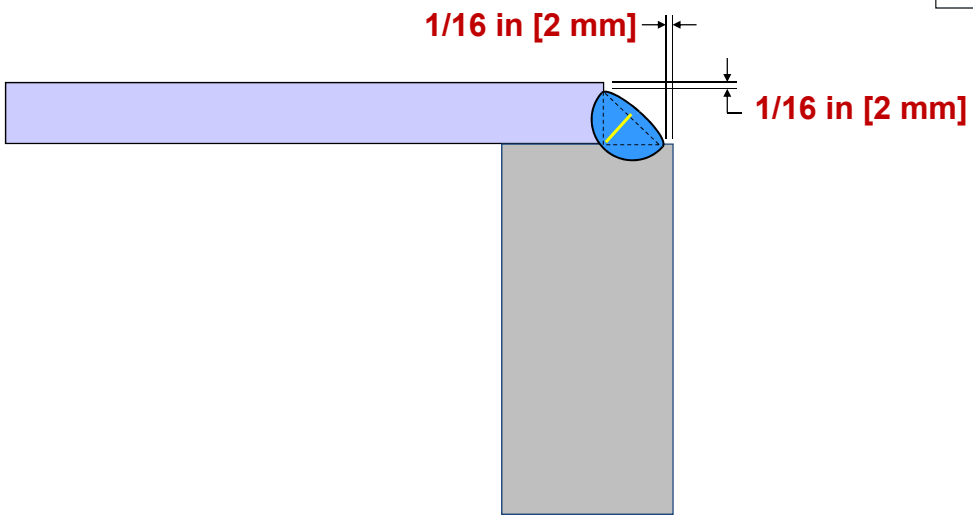
FILLET WELDS



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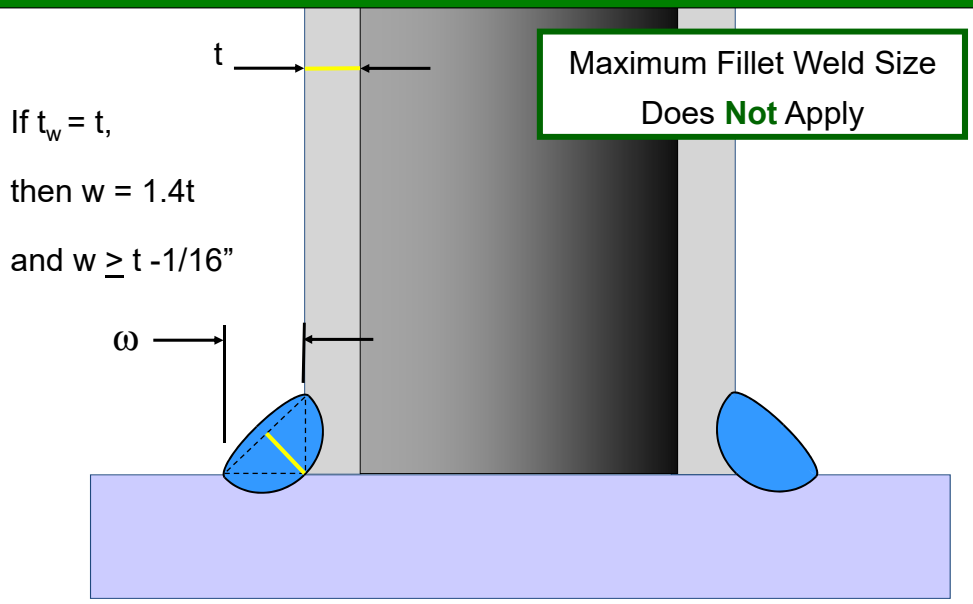
FILLET WELDS



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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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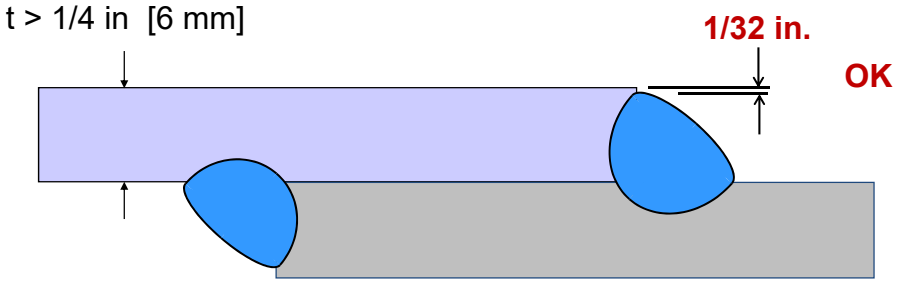
AISC 360-16 Specification for Structural Steel Buildings

Maximum Fillet Weld Size



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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FILLET WELDS

Minimum length of fillet welds

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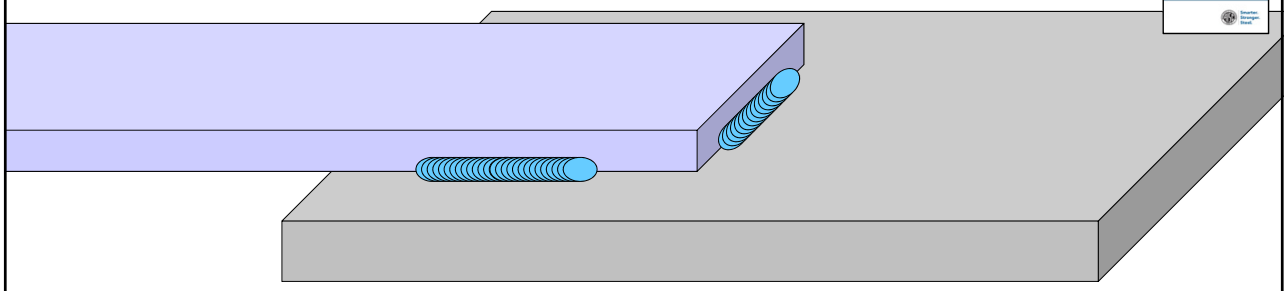
AISC 360-16 Specification 2.2b

Minimum Fillet Weld Length

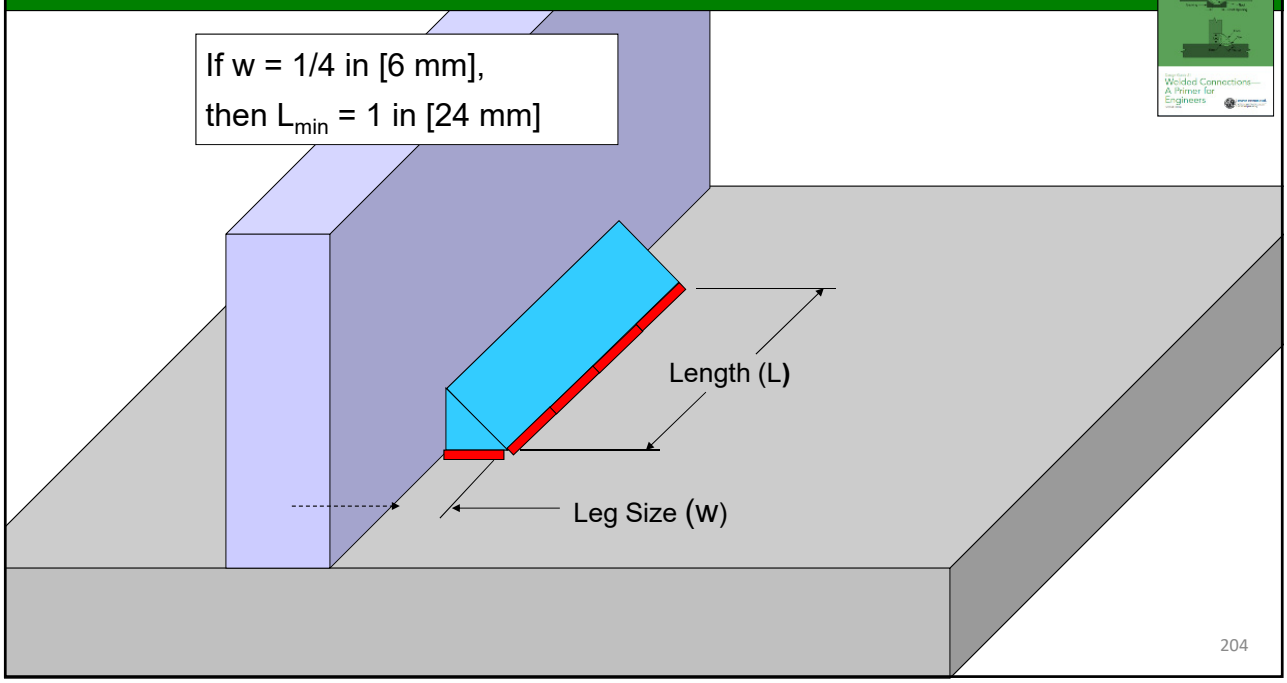


(c) The minimum effective length of fillet welds designed on the basis of strength shall be not less than four times the nominal weld size, or else the size of the weld shall be taken to exceed one-quarter of its length. For the effect of longitudinal fillet weld length in end connections upon the effective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

Also addressed in AWS D1.1:2015 clause 2.4.2.3

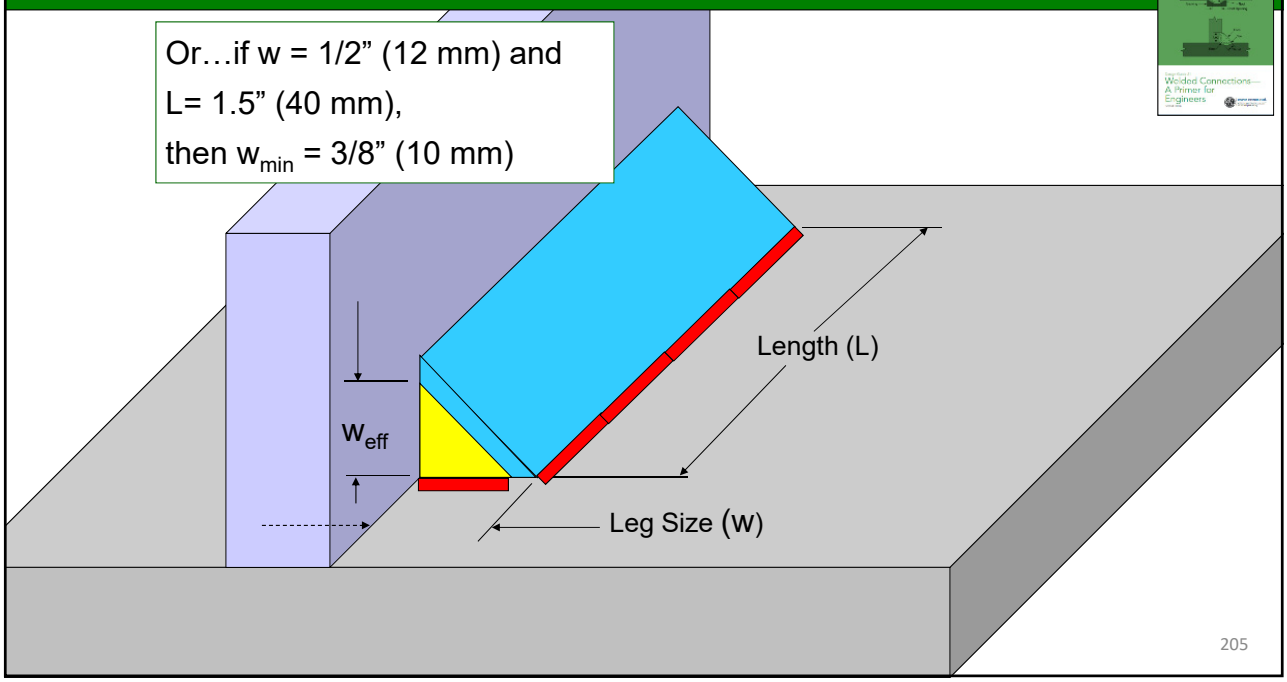
FILLET WELDS

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



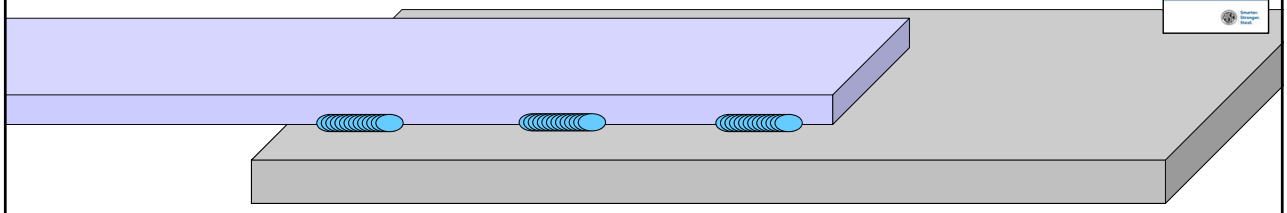
FILLET WELDS

Or…if w = 1/2” (12 mm) and
L= 1.5” (40 mm),
then w_{min} = 3/8” (10 mm)



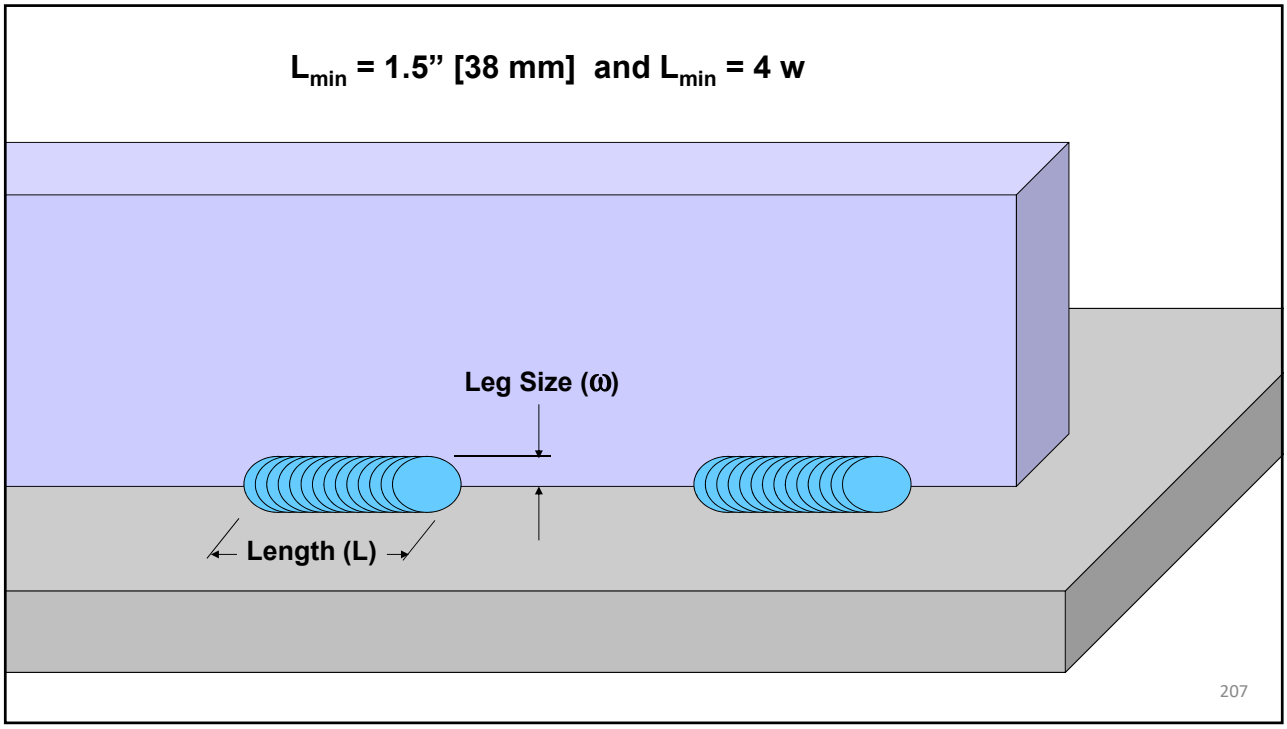
AISC 360-16 Specification 2.2b

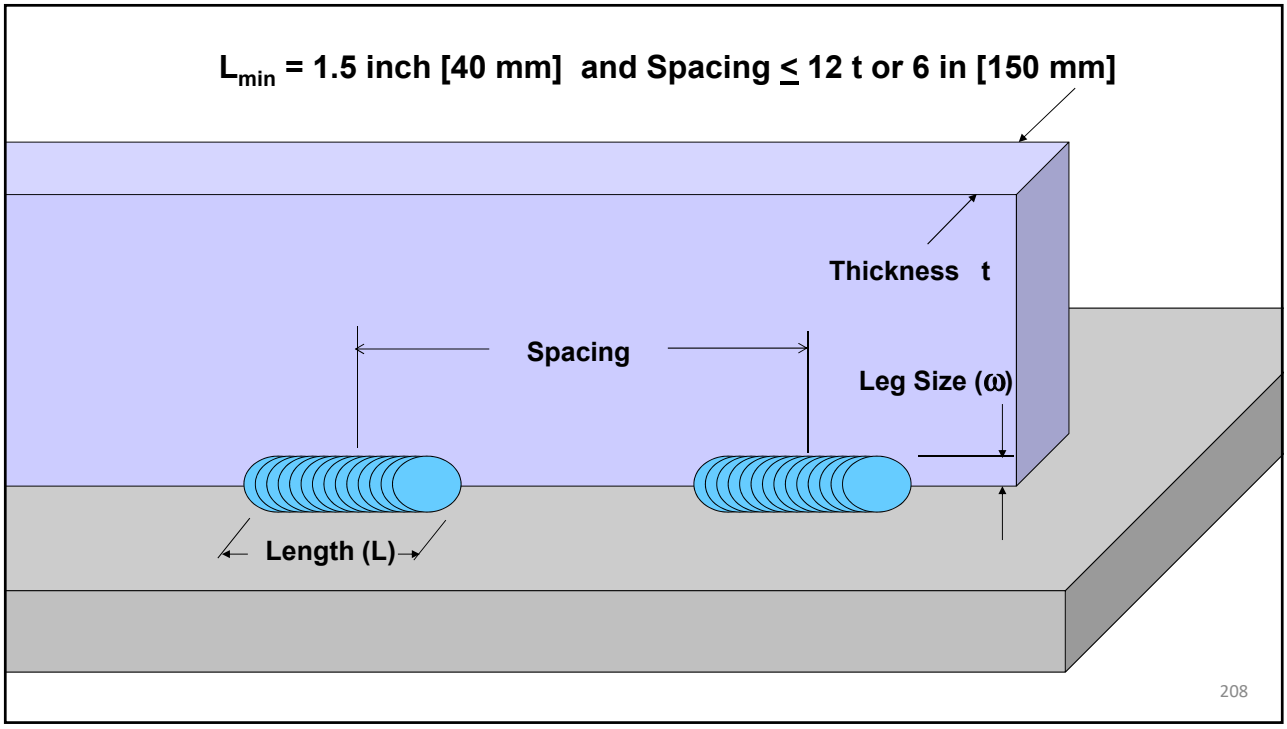
Intermittent Fillet Welds

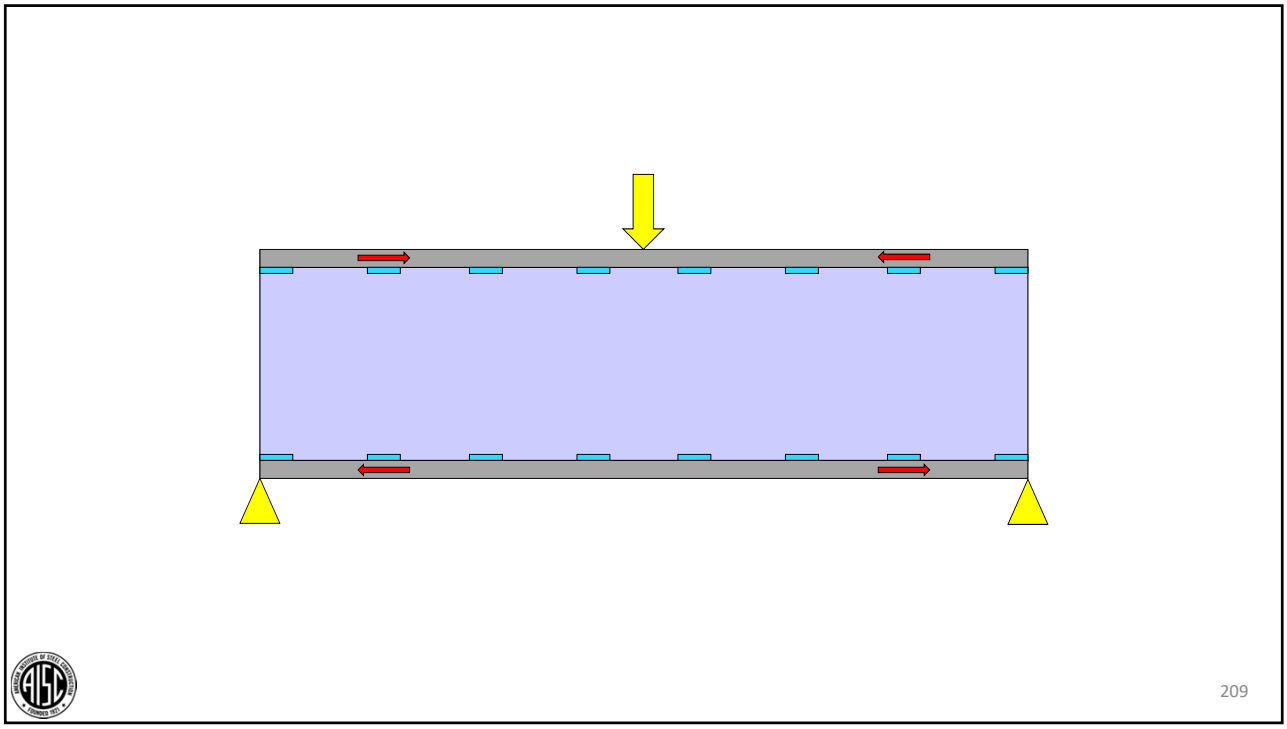


(e) Intermittent fillet welds are permitted to be used to transfer calculated stress across a joint or faying surfaces and to join components of built-up members. The length of any segment of intermittent fillet welding shall be not less than four times the weld size, with a minimum of 1-1/2 in. (38 mm).

Also addressed in AWS D1.1:2015 clause 2.4.2.4







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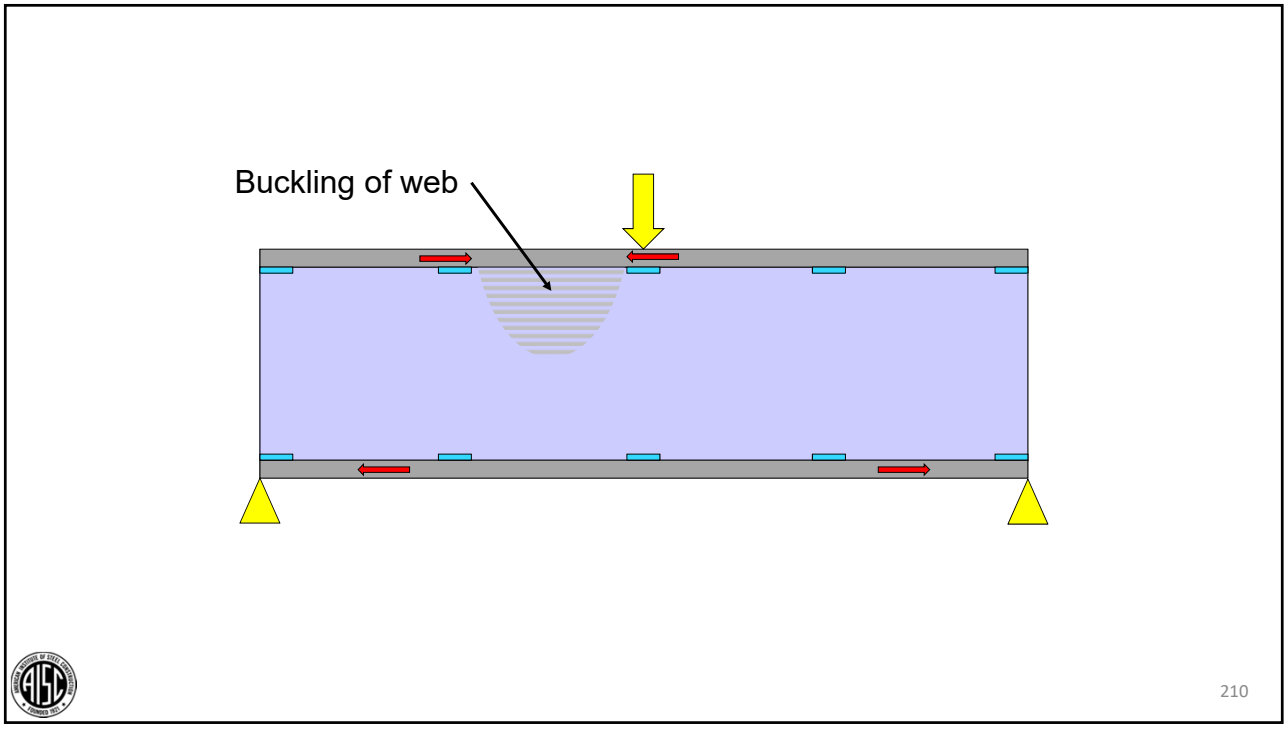

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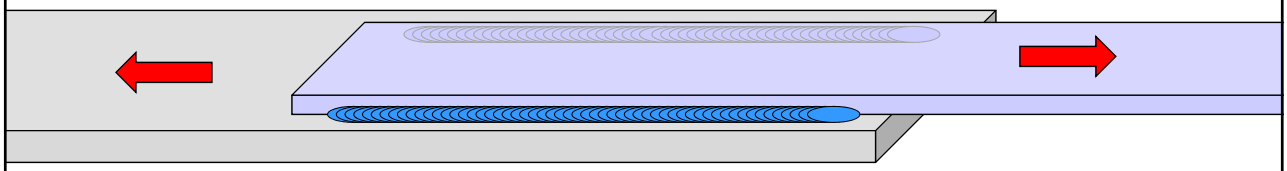
AISC 360-16 Specification 2.2b

Maximum length of end-loaded fillet welds



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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:

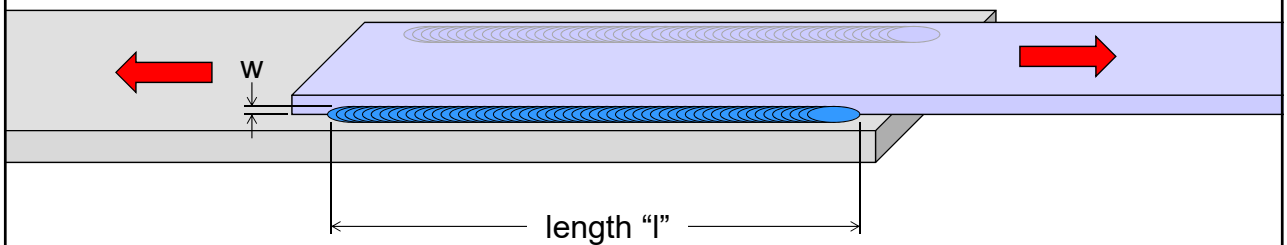
(1) For end-loaded fillet welds with a length up to 100 times the weld size, it is permitted to take the effective length equal to the actual length.

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 $l_{effective} = l_{actual}$



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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, b, 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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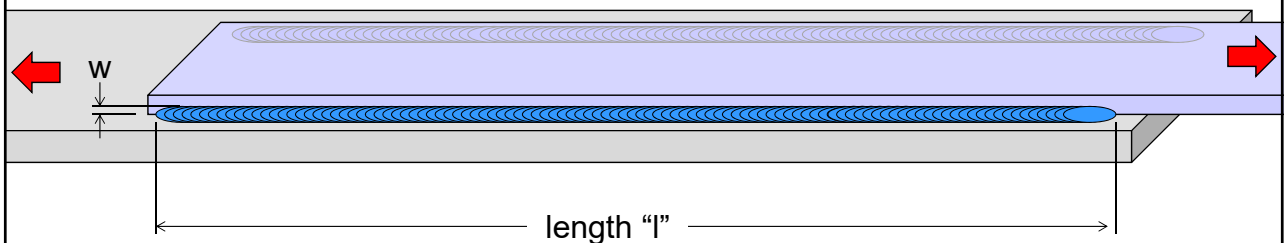
AISC 360-16 Specification for Structural Steel Buildings

Maximum length of end-loaded fillet welds

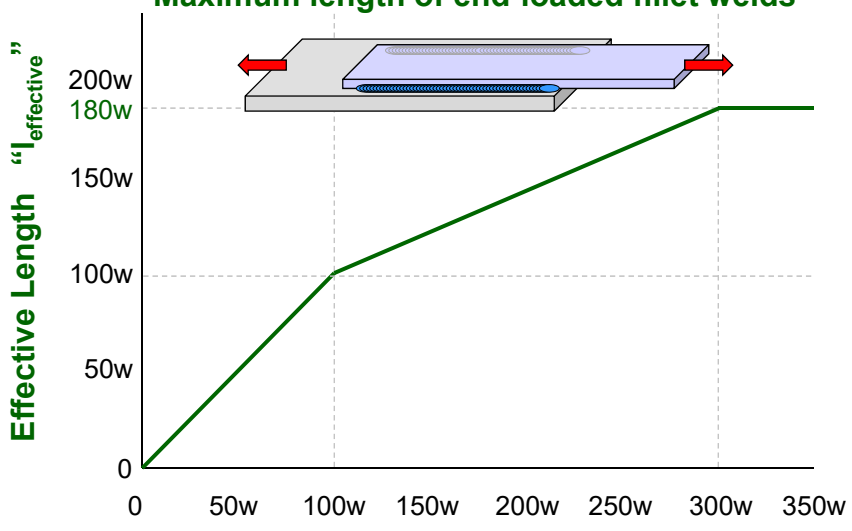
If length > 300 w, then $l_{effective}$ = 180 w



215

FILLET WELDS

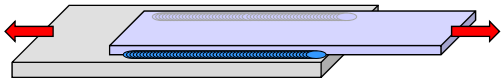
Maximum length of end-loaded fillet welds



216

FILLET WELDS

Maximum length of fillet welds

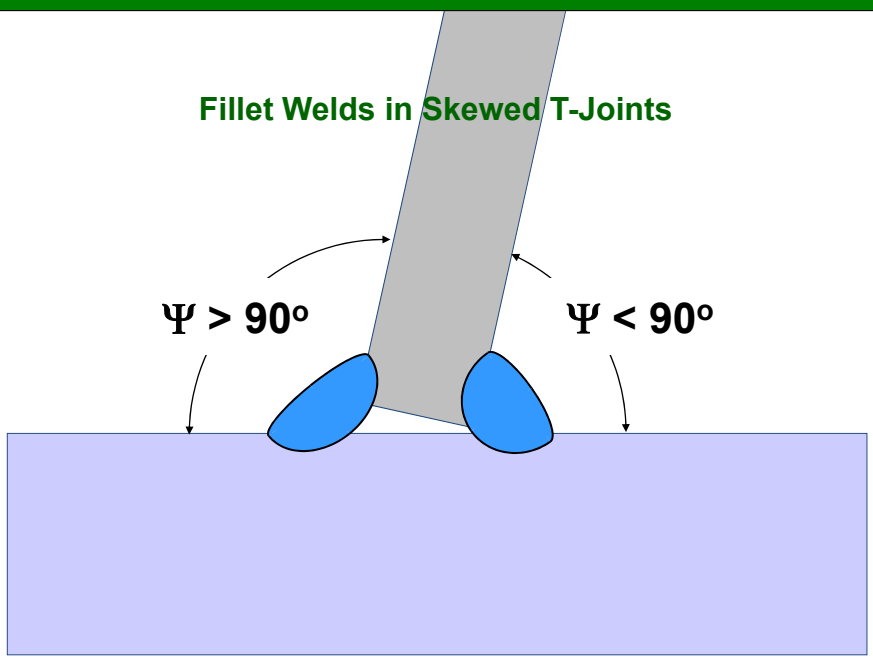


Weld Size w	100 w	180 w
3/16”	19”	34”
1/4”	25”	45”
5/16”	31”	56”
3/8”	38”	68”
1/2”	50”	90”
3/4”	75”	135”
1”	100”	180”

217

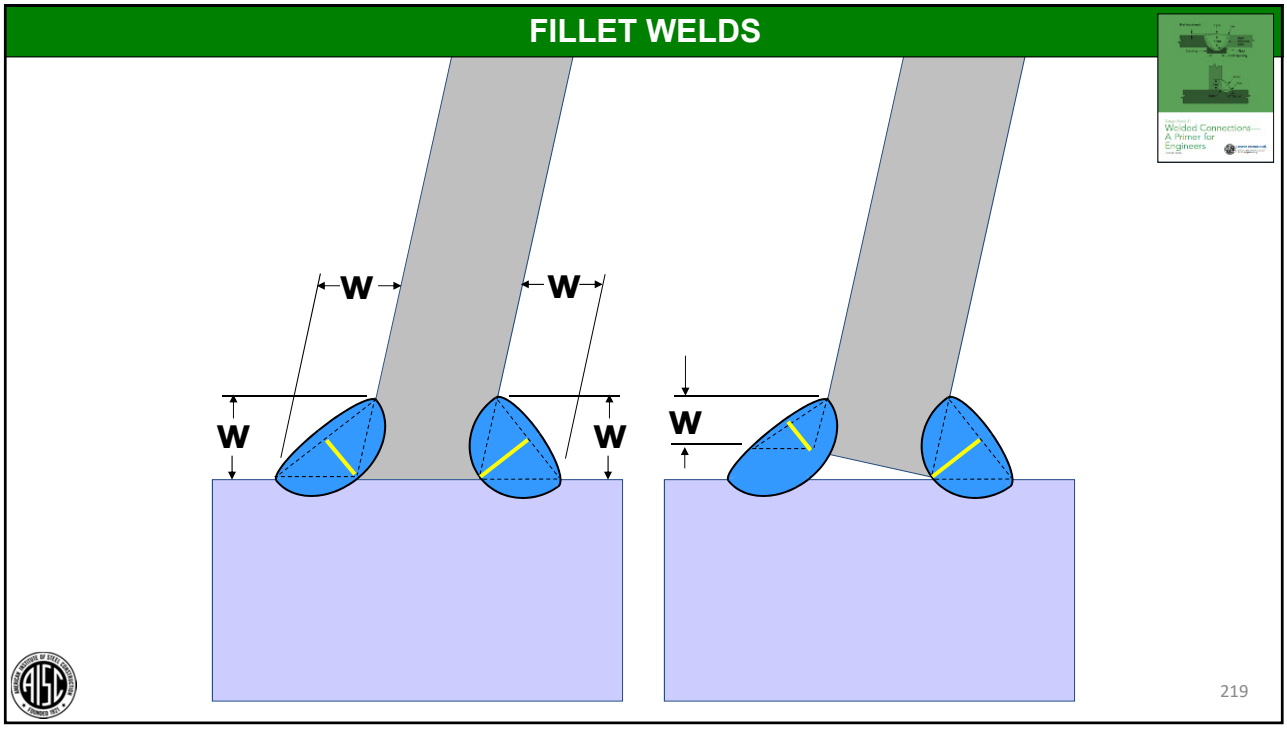
FILLET WELDS

Fillet Welds in Skewed T-Joints



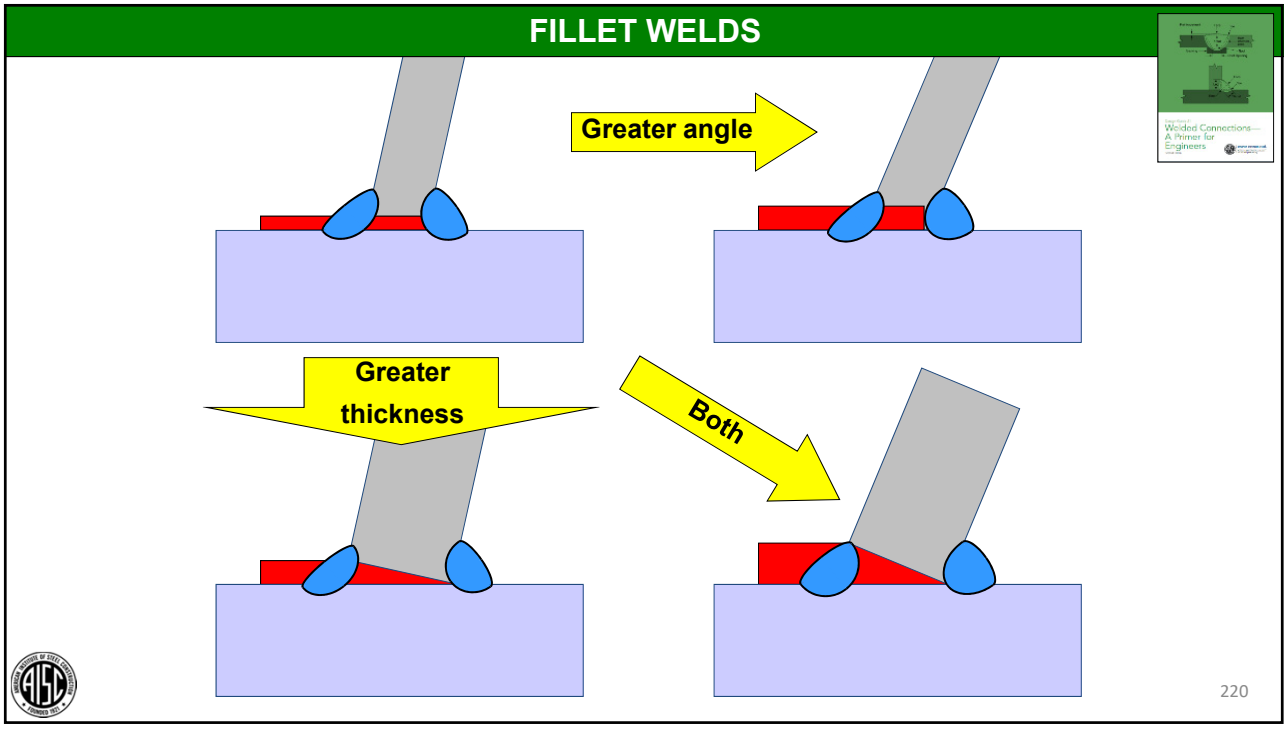
218

FILLET WELDS



219

FILLET WELDS



220

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.**

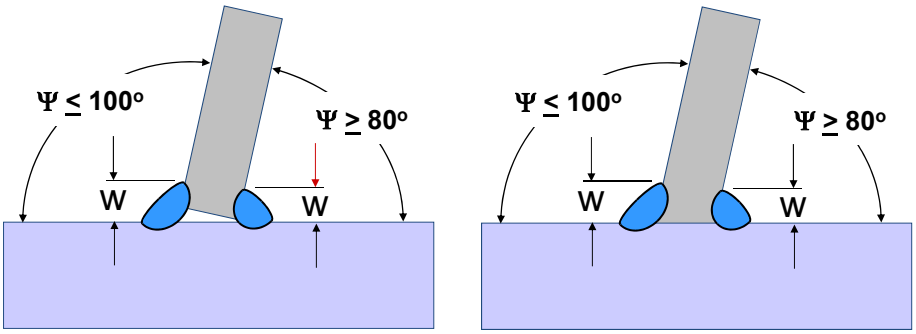
(2) For welds between parts with the surfaces meeting at an angle less than 80° or greater than 100°, the contract documents shall specify the effective throat.

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

221

AWS D1.1: 2015 Structural Welding Code – Steel

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



222

AWS D1.1: 2015 Structural Welding Code – Steel

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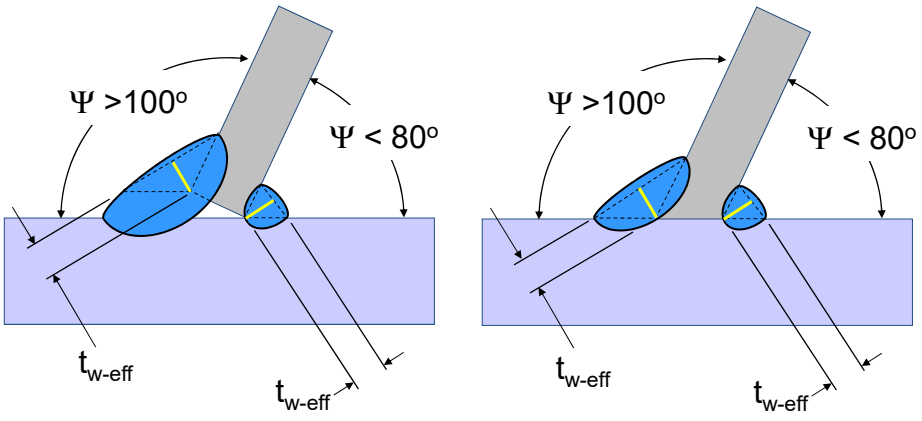
End returns and hold-backs for fillet welds, if required by design, shall be indicated on the contract documents.

223

AWS D1.1: 2015 Structural Welding Code – Steel

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

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



224

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 hall 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.

225

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 hall 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.

226

AWS D1.1: 2015 Structural Welding Code – Steel

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

	Position of Welding—V or OH			Position of Welding—H or F		
Dihedral Angle Ψ	Process	Z (in)	Z (mm)	Process	Z (in)	Z (mm)
60° > Ψ ≥ 45°	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° > Ψ ≥ 30°	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

227

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

	Position of Welding—V or OH			Position of Welding—H or F		
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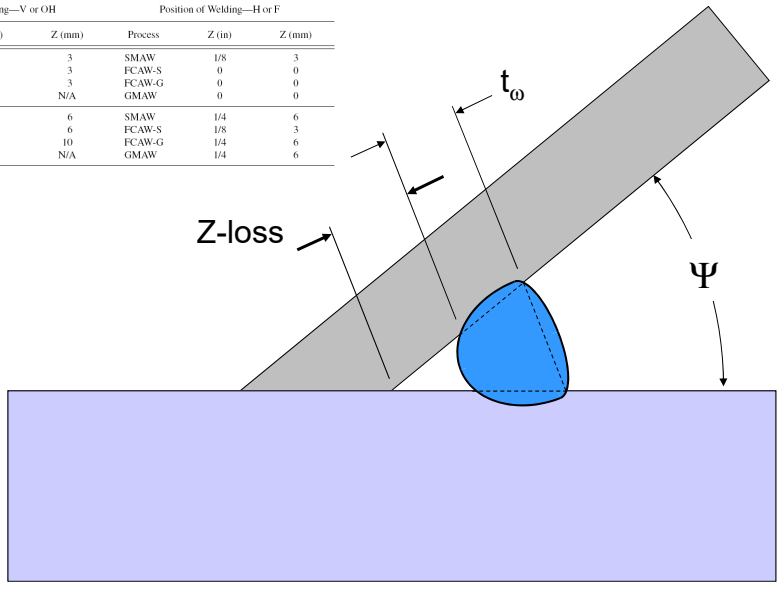
	FCAW-S	1/8	3	FCAW-S	0	0
	FCAW-G	1/8	3	FCAW-G	0	0
	GMAW	N/A	N/A	GMAW	0	0
45° > Ψ ≥ 30°	SMAW	1/4	6	SMAW	1/4	6
	FCAW-S	1/4	6	FCAW-S	1/8	3
	FCAW-G	3/8	10	FCAW-G	1/4	6
	GMAW	N/A	N/A	GMAW	1/4	6



228

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

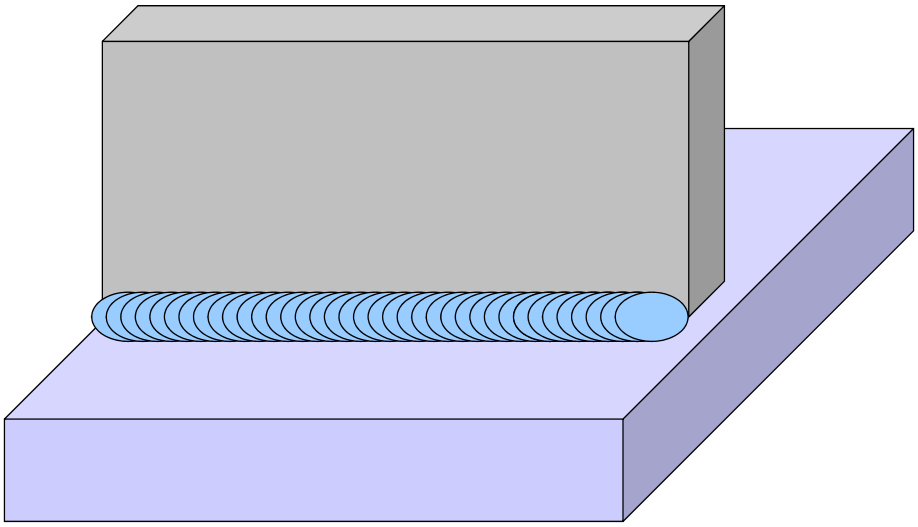
2.9.3.1 General.

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:

230

FILLET WELDS

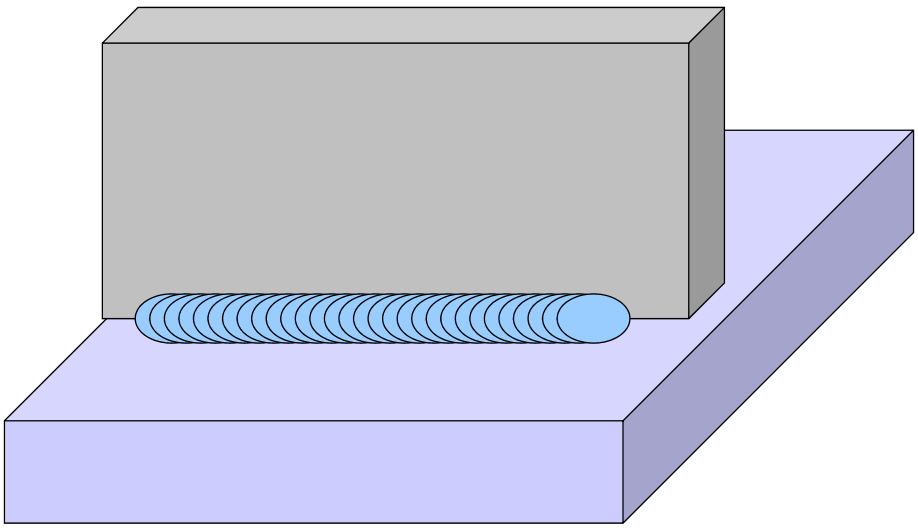
Extending to the End



231

FILLET WELDS

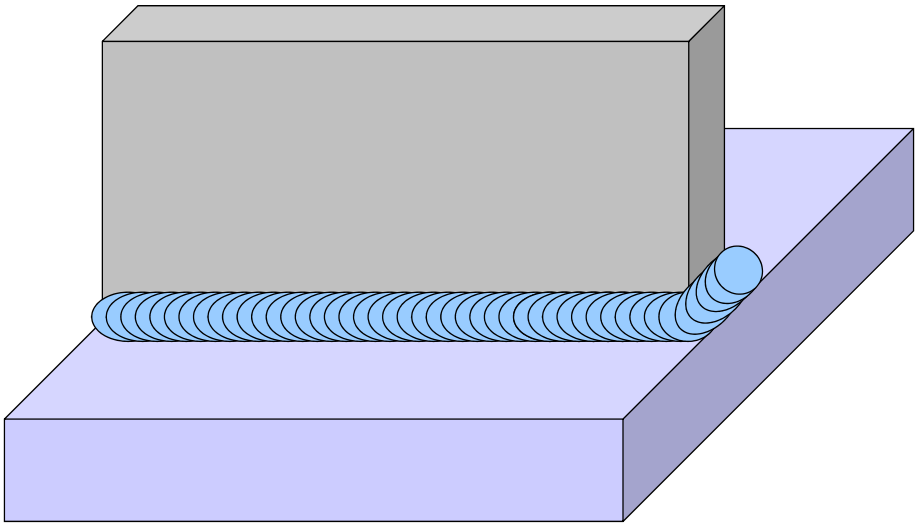
Stopped short



232

FILLET WELDS

End return (boxing)



233

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:**

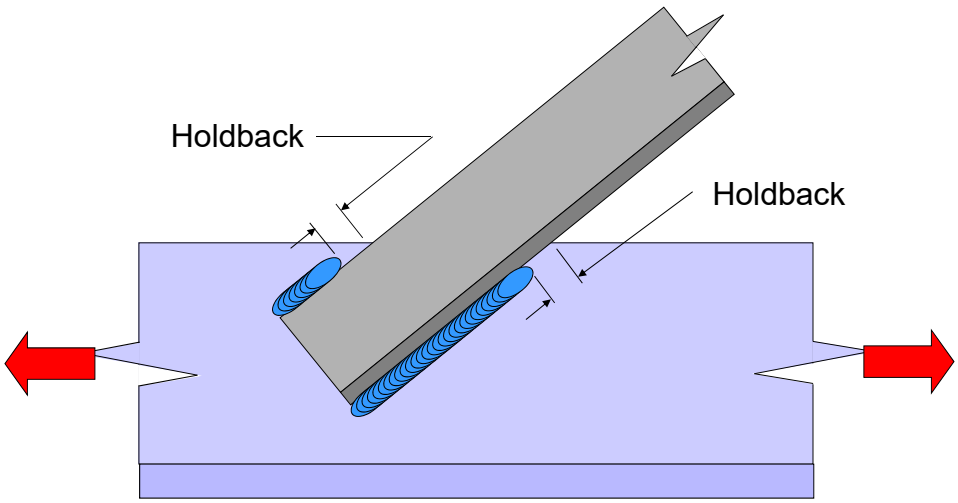
234

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).

235



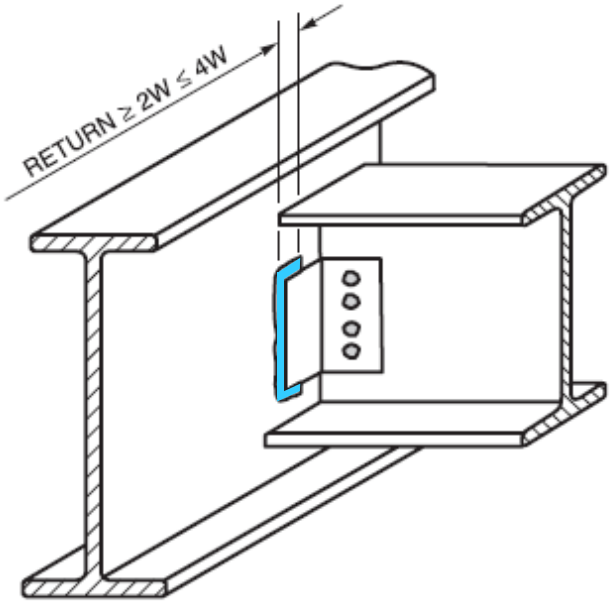
236

AWS D1.1: 2015 Structural Welding Code – Steel

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).

237



Note: W = nominal size of the weld.

238

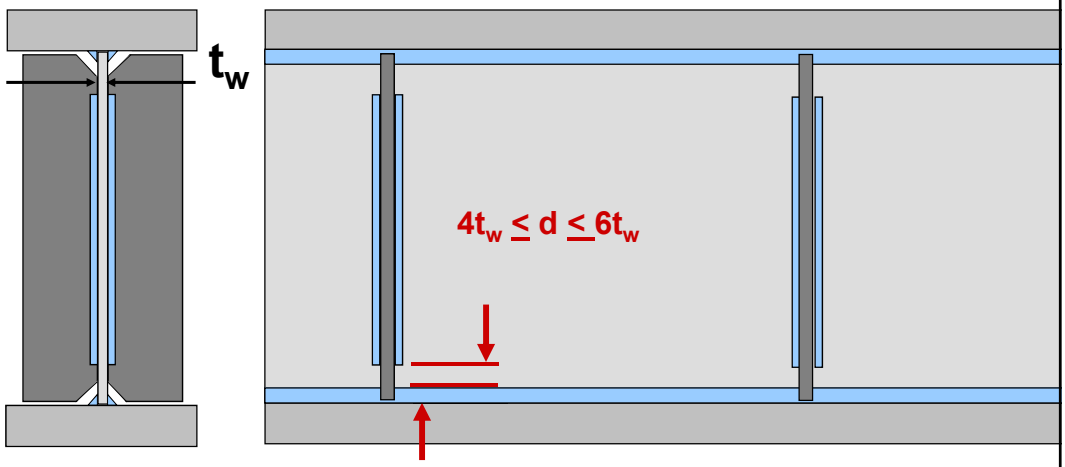
AWS D1.1: 2015 Structural Welding Code – Steel

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.

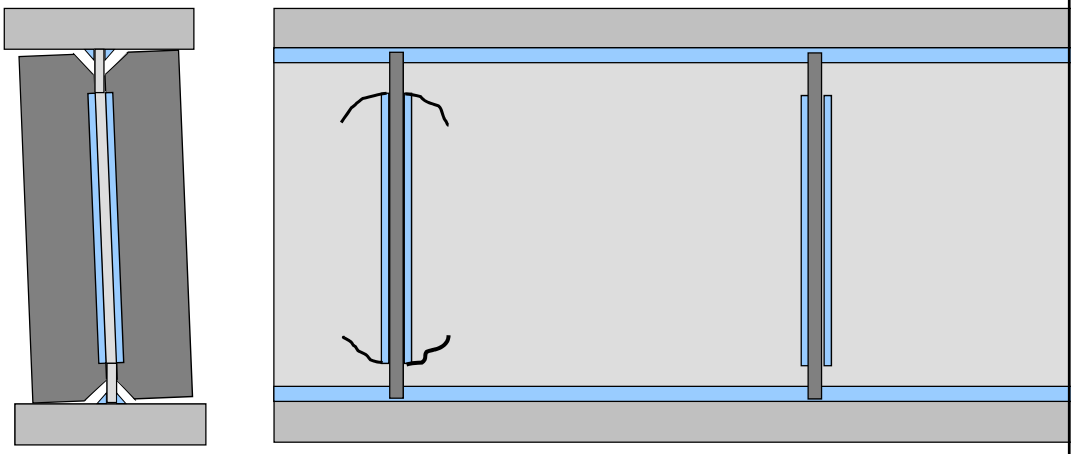
Per AISC 360-16 User Note: This applies when $t_w \leq$ ¾" (18 mm).

Exception to general practice



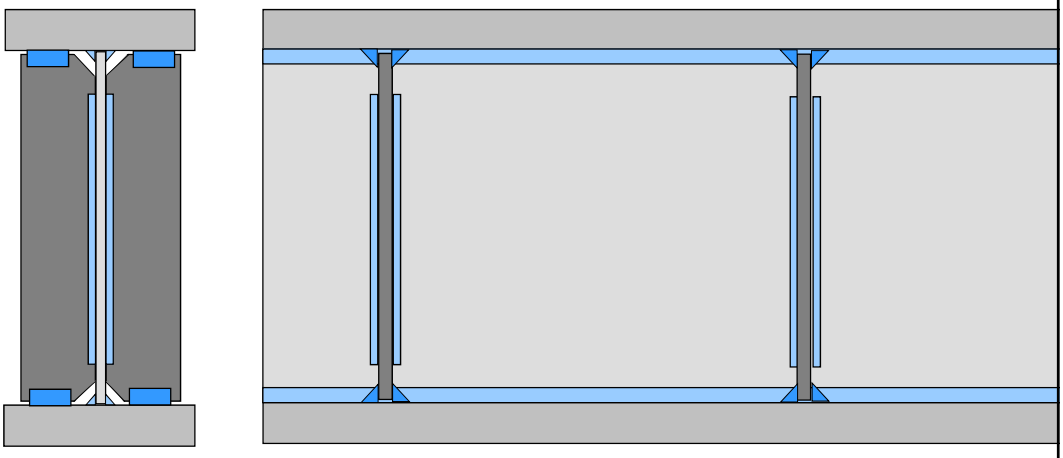
240

Cracking can occur in shipping



241

Does not apply when stiffeners are welded to flanges



242

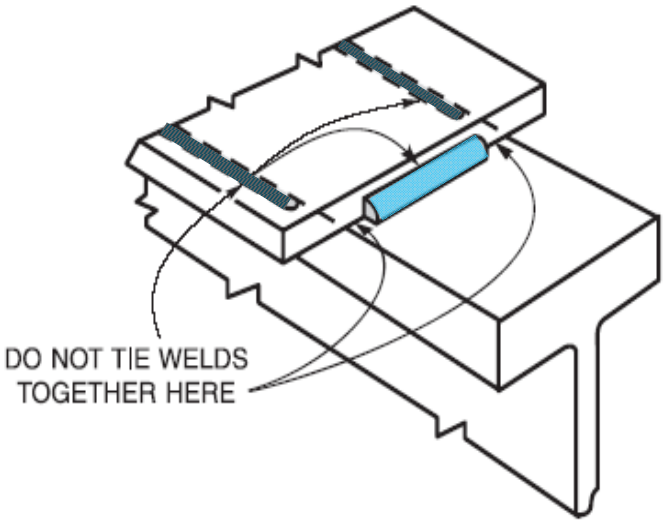
AWS D1.1: 2015 Structural Welding Code – Steel

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.

243



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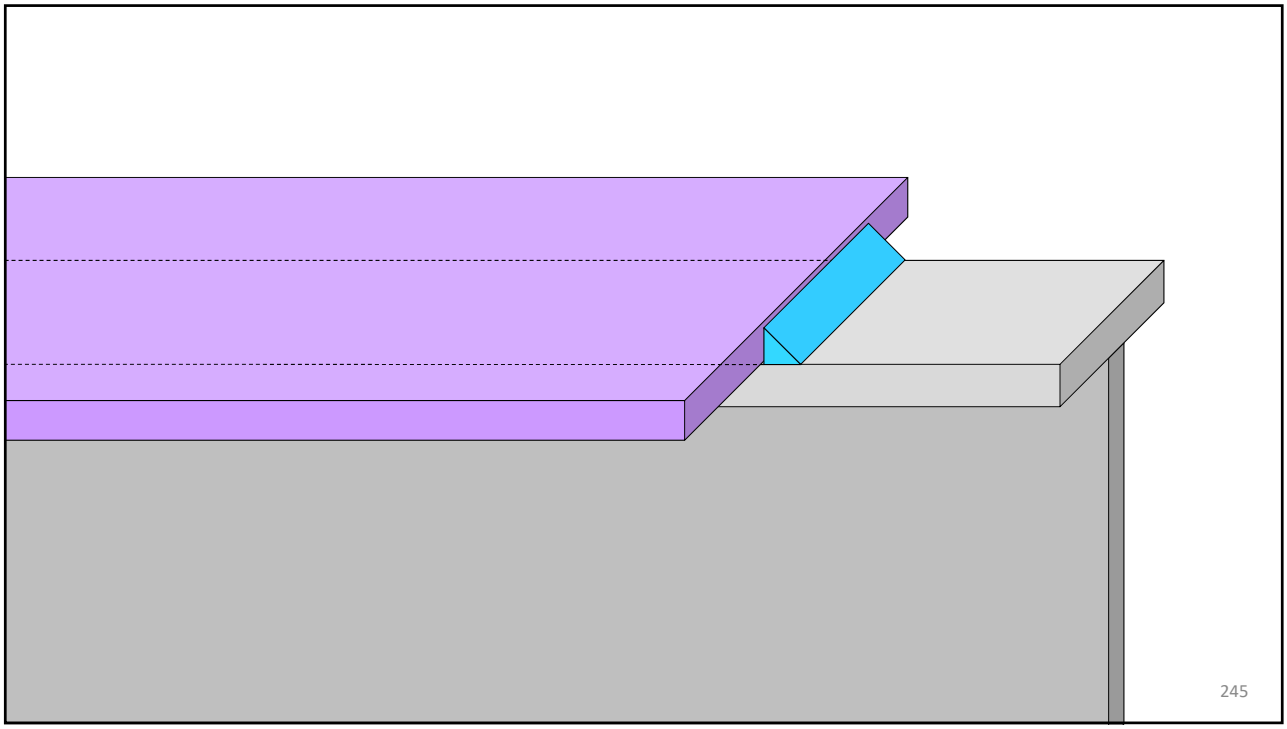

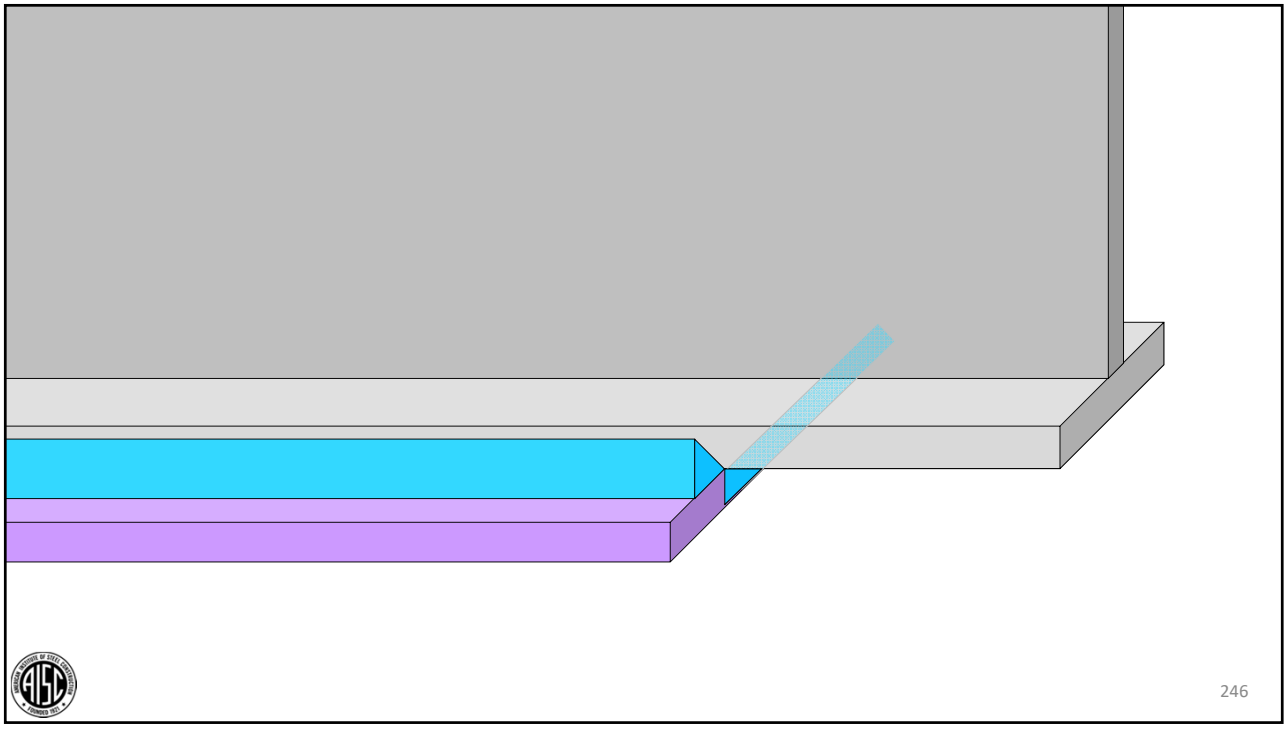

AISC 360-16 Specification for Structural Steel Buildings

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.

247

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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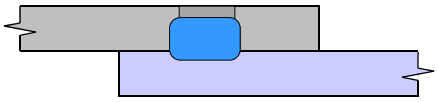
PLUG AND SLOT WELDS



- 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

250

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

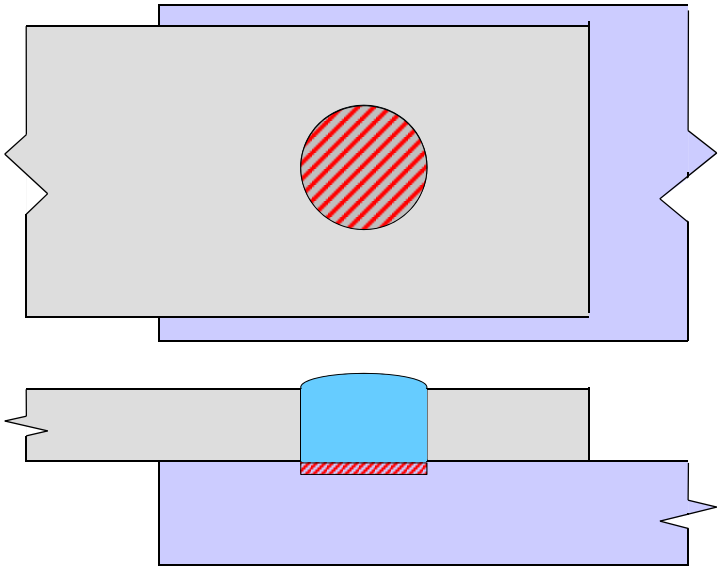
2.4.5.3 Effective Area.

The effective area shall be the nominal area of the hole or slot in the plane of the faying surface.

252

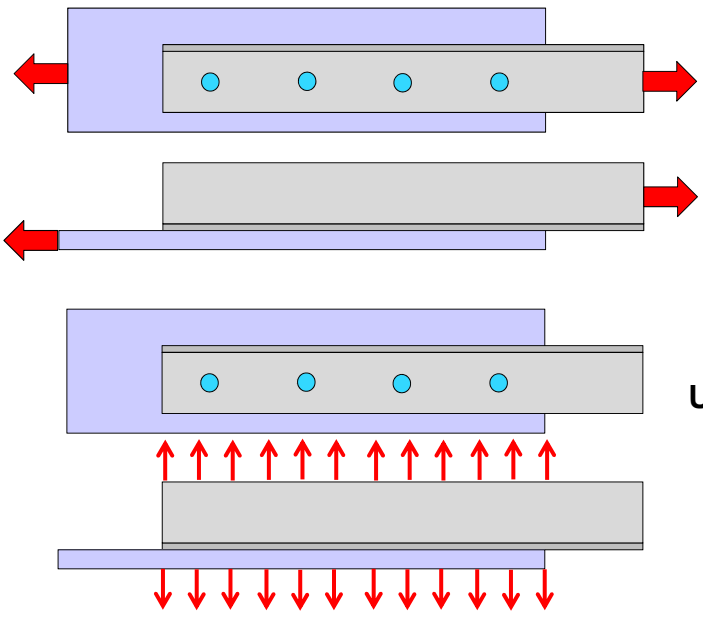
PLUG AND SLOT WELDS

Effective Area Area = $\pi d^2/4$



253

PLUG AND SLOT WELDS



254

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.

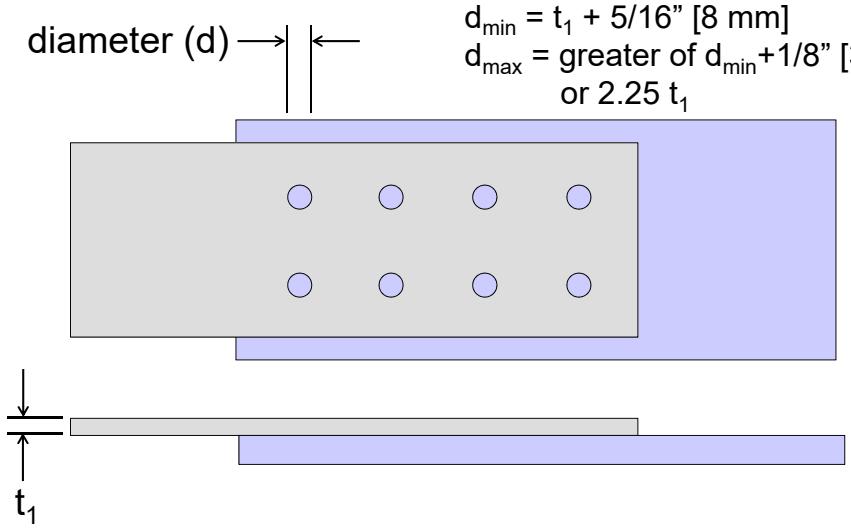
255

PLUG AND SLOT WELDS

Hole diameter (d)

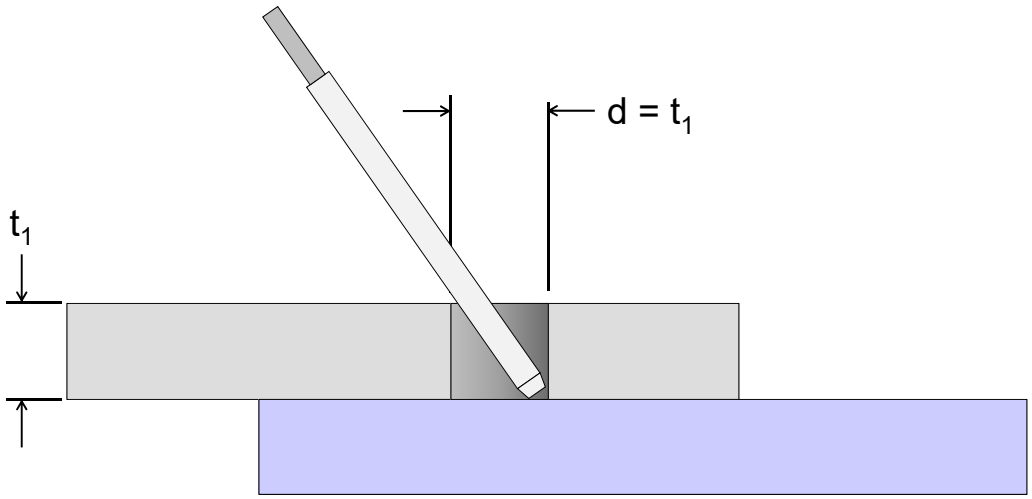
$d_{min} = t_1 + 5/16$" [8 mm]

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



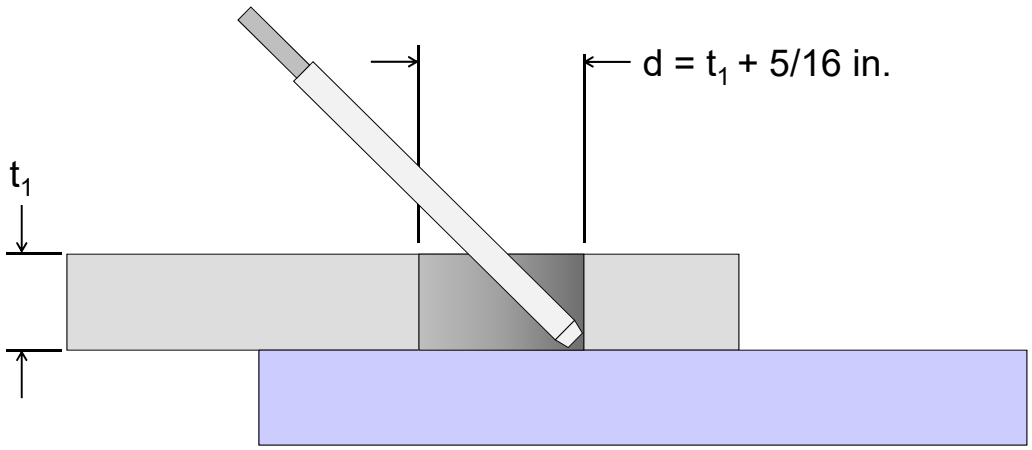
256

PLUG AND SLOT WELDS



257

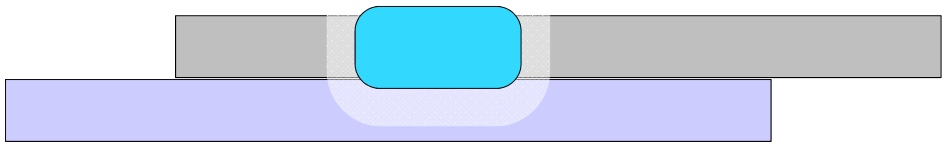
PLUG AND SLOT WELDS



258

PLUG AND SLOT WELDS

Prohibition on Quenched and Tempered Steels



259

WELDED CONNECTION DETAILS

Outline

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

260

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

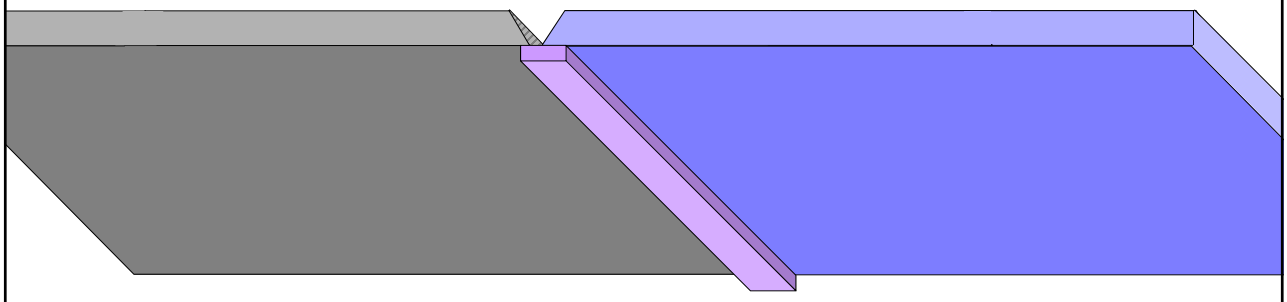
tack weld.

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

261

TACK WELDS

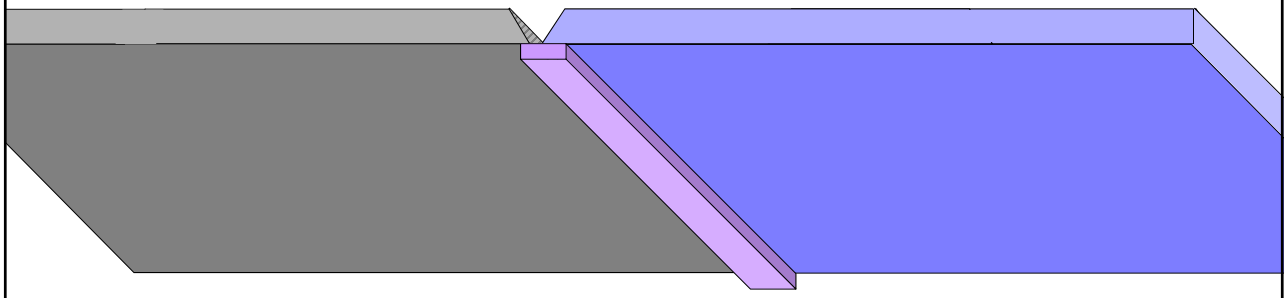
Tack welds attaching backing change stress distribution.



262

TACK WELDS

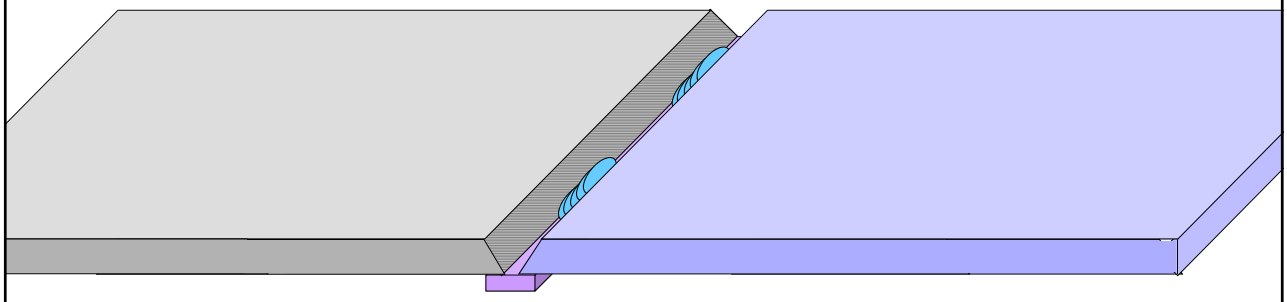
Tack welds attaching backing change stress distribution.



263

TACK WELDS

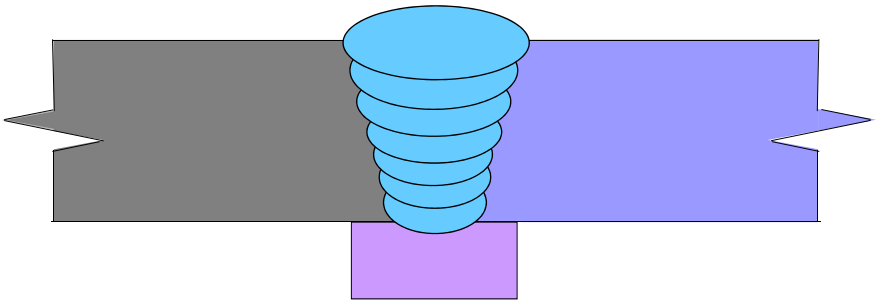
Tack welding in the joint



264

TACK WELDS

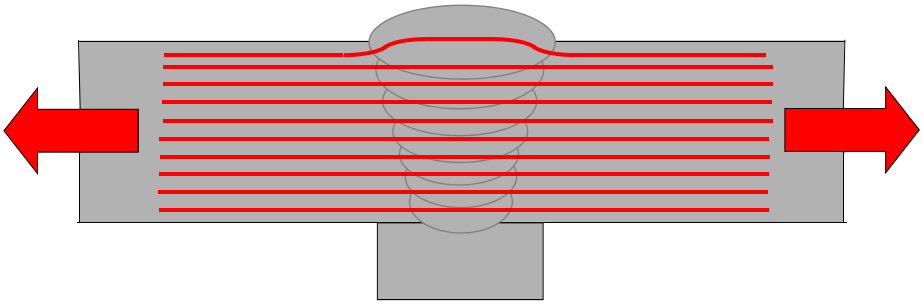
Tack welding in the joint



265

TACK WELDS

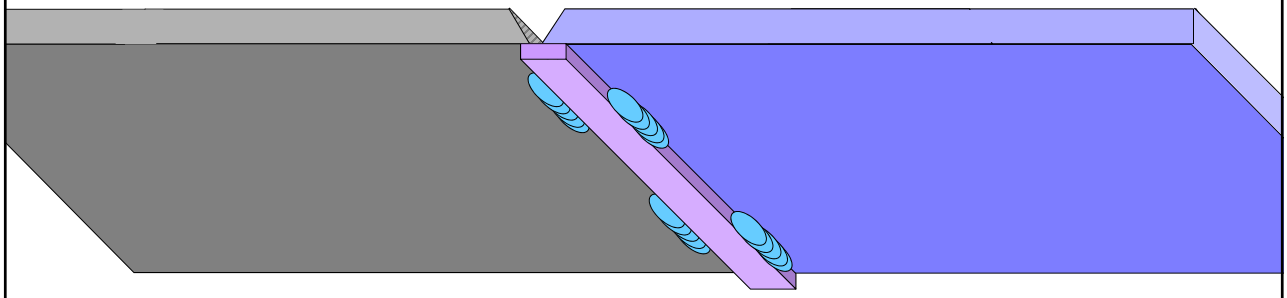
Tack welding in the joint



266

TACK WELDS

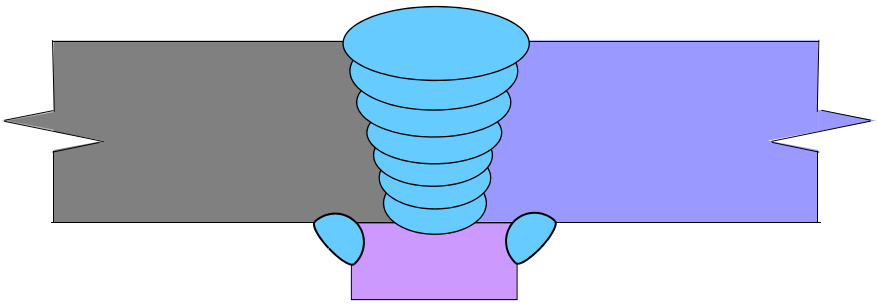
Tack welding outside the joint



267

TACK WELDS

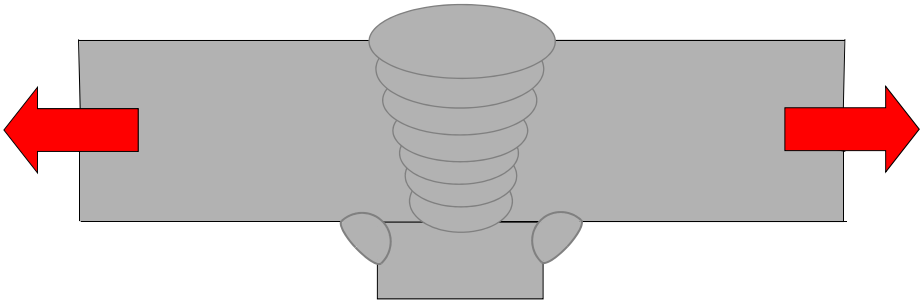
Tack welding outside the joint



268

TACK WELDS

Tack welding outside the joint



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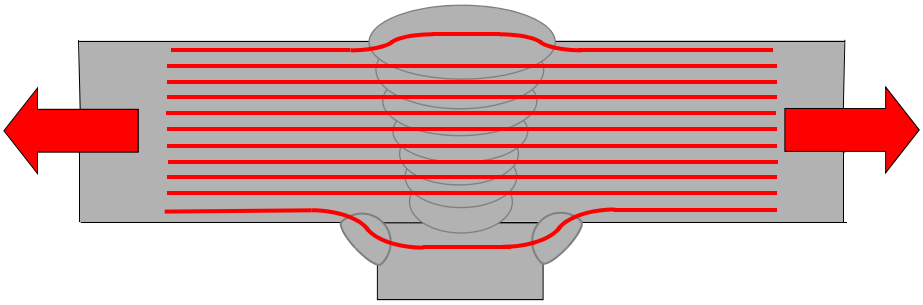
TACK WELDS

Tack welding outside the joint



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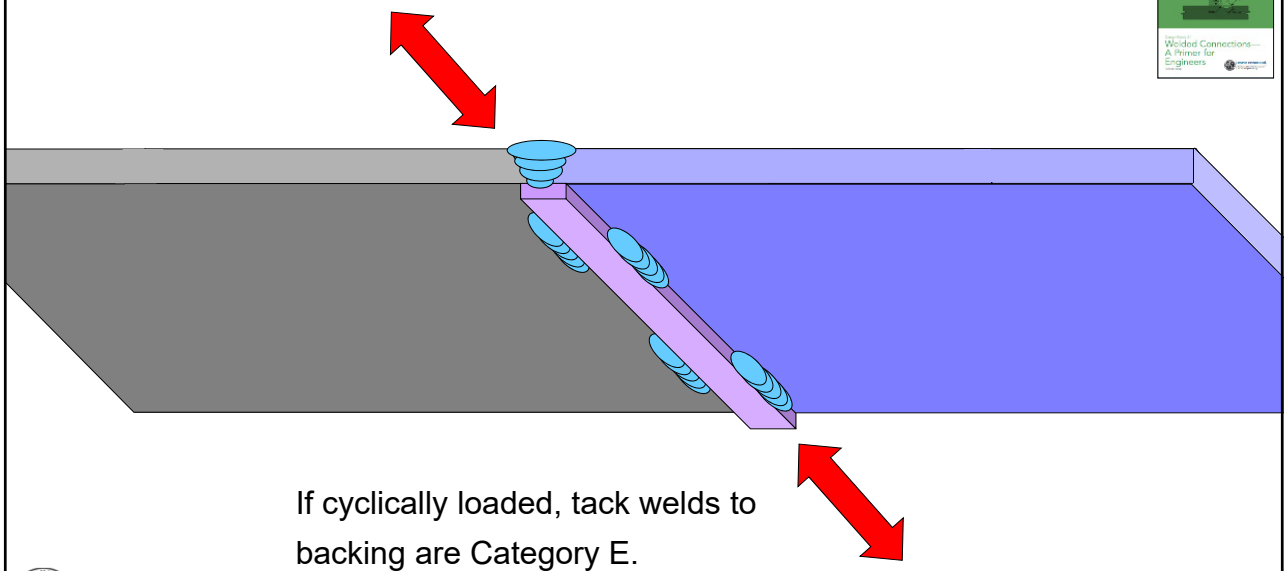
TACK WELDS

Tack welds on backing and fatigue

271

TACK WELDS



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

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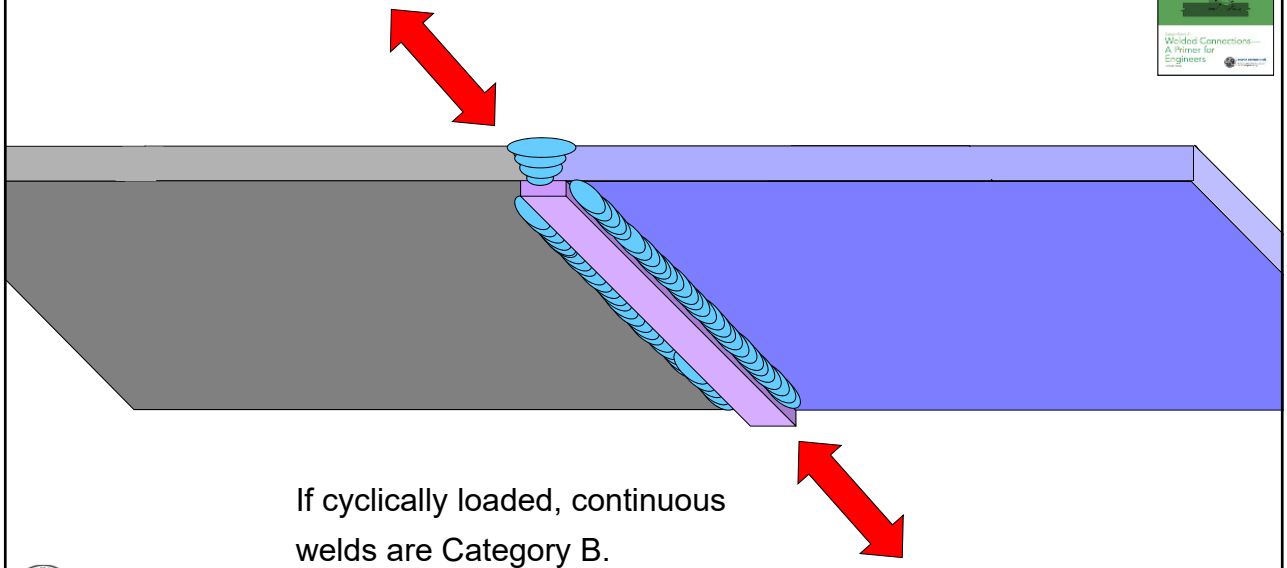
TACK WELDS



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

Allowable Strength of Welded Joints

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_{nBM} or F_{nw}) ksi (MPa)	Effective Area (A_{BM} or A_{we}) in.^{2} (mm^2)	Required Filler Metal Strength Level [a,b,c]
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.[d]
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	$\phi = 0.80$ $\Omega = 1.88$	$0.60F_{EXX}$	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	

AISC 360-16 Specification for Structural Steel Buildings

TABLE J2.5

Allowable Strength of Welded Joints

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_{nBM} or F_{nw}) ksi (MPa)	Effective Area (A_{BM} or A_{we}) in.^{2} (mm^2)	Required Filler Metal Strength Level [a,b,c]
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	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$[e]	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.				
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	

[a] For matching weld metal see AWS D1.1/D1.1M, Section 3.3.
[b] Filler metal with a strength level one strength level greater than matching is permitted.
[c] Filler metals with a strength level less than matching may be used for groove welds between the webs and flanges of built-up sections transferring 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.
[d] 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.

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_{nBM} or F_{nw}) ksi (MPa)	Effective Area (A_{BM} or A_{we}) 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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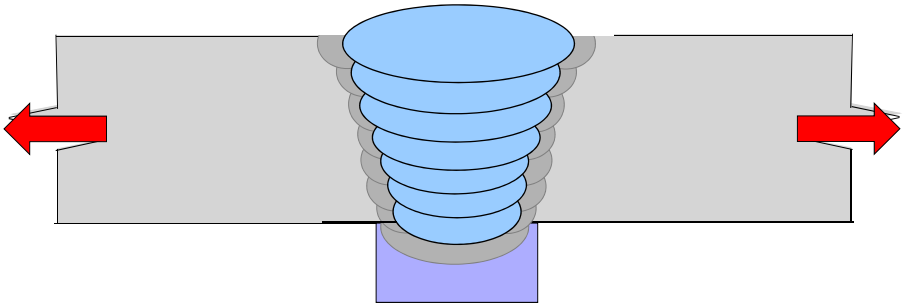
WELD METAL STRENGTH

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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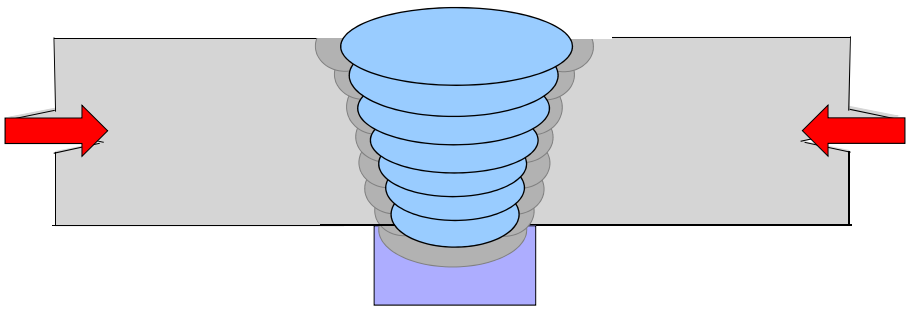
WELD METAL STRENGTH

CJP Groove Weld

Compression 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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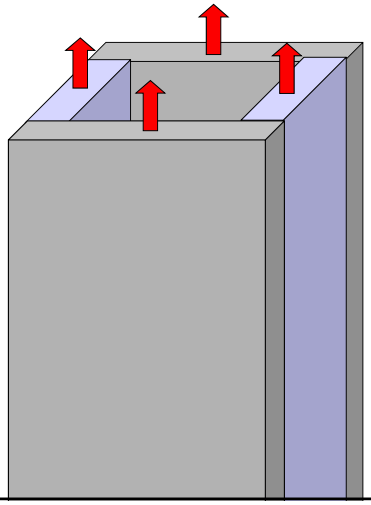
WELD METAL STRENGTH

CJP Groove Weld

Tension parallel to the weld axis



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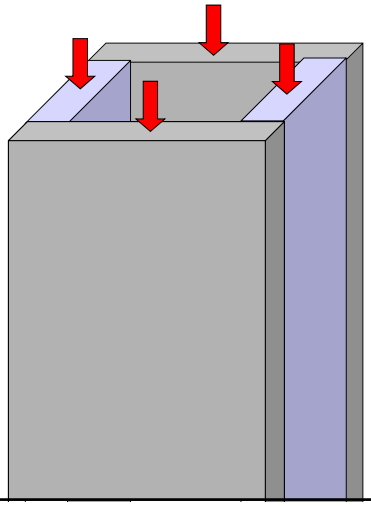
WELD METAL STRENGTH

CJP Groove Weld

Compression parallel 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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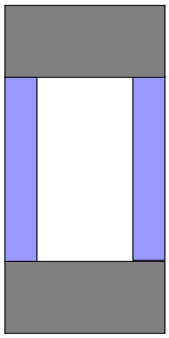
WELD METAL STRENGTH

CJP Groove Weld

Shear



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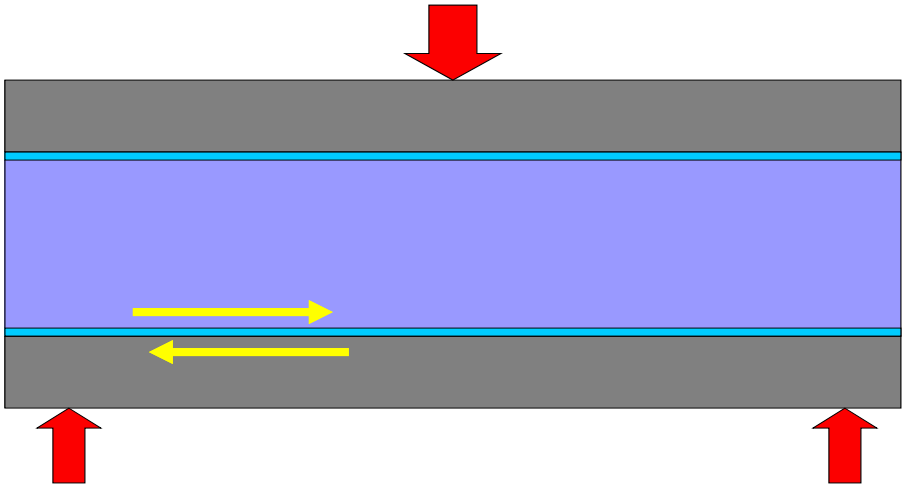
WELD METAL STRENGTH

CJP Groove Weld

Shear



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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	Filler metal with a strength level equal to or less than matching filler metal is permitted.
	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_{nBM} or F_{nw}) ksi (MPa)	Effective Area (A_{BM} or A_{we}) in.^{2} (mm^2)	Required Filler Metal Strength Level [M][N]
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.[O]
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	$\phi = 0.80$ $\Omega = 1.88$	$0.60F_{EXX}$	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	

AISC 360-16 Specification for Structural Steel Buildings

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_{nBM} or F_{nw}) ksi (MPa)	Effective Area (A_{BM} or A_{we}) in.^{2} (mm^2)	Required Filler Metal Strength Level [M][N]
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.[O]
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	$\phi = 0.80$ $\Omega = 1.88$	$0.60F_{EXX}$	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	

AISC 360-16 Specification for Structural Steel Buildings

Undermatching 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_{nBM} or F_{nw}) ksi (MPa)	Effective Area (A_{BM} or A_{we}) in.^{2} (mm^2)	Required Filler Metal Strength Level [M][N]
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.[O]
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	$\phi = 0.80$ $\Omega = 1.88$	$0.60F_{EXX}$	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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Undermatching is permitted.

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_{nBM} or F_{nw}) ksi (MPa)	Effective Area (A_{BM} or A_{we}) in.^{2} (mm^2)	Required Filler Metal Strength Level [M][N]
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	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$[M]	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.				
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	

[N] For matching weld metal see AWS D1.1/D1.1M, Section 3.3.
[O] Filler metal with a strength level one strength level greater than matching is permitted.
[P] Filler metals with a strength level less than matching may be used for groove welds between the webs and flanges of built-up sections transferring 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.
[Q] 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.

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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[a]	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 0.40 × yield strength of the base metal	
PJP Groove Welds		
Tension normal to the effective area	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
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	
Tension or compression parallel to axis of the weld[a]	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[d,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[a]	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 steels, see Table 3.1 and Table 4.9.
[c] Fillet welds and groove welds joining components of built-up 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 weld leg; 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 d (above) 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!

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- 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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- Password: Same as AISC website password.

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8-Session Registrants

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

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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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PDHs via recording

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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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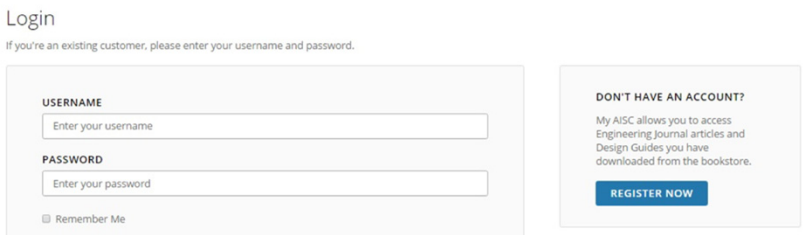

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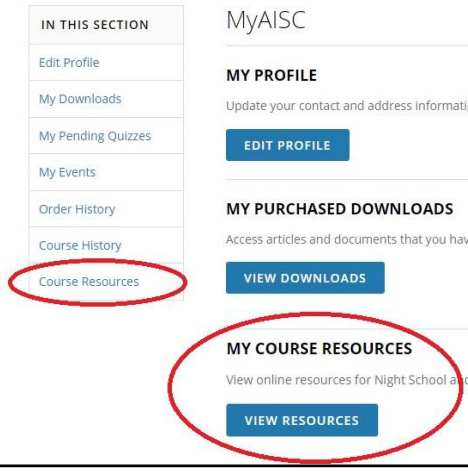

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Night School Resources

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

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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

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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.

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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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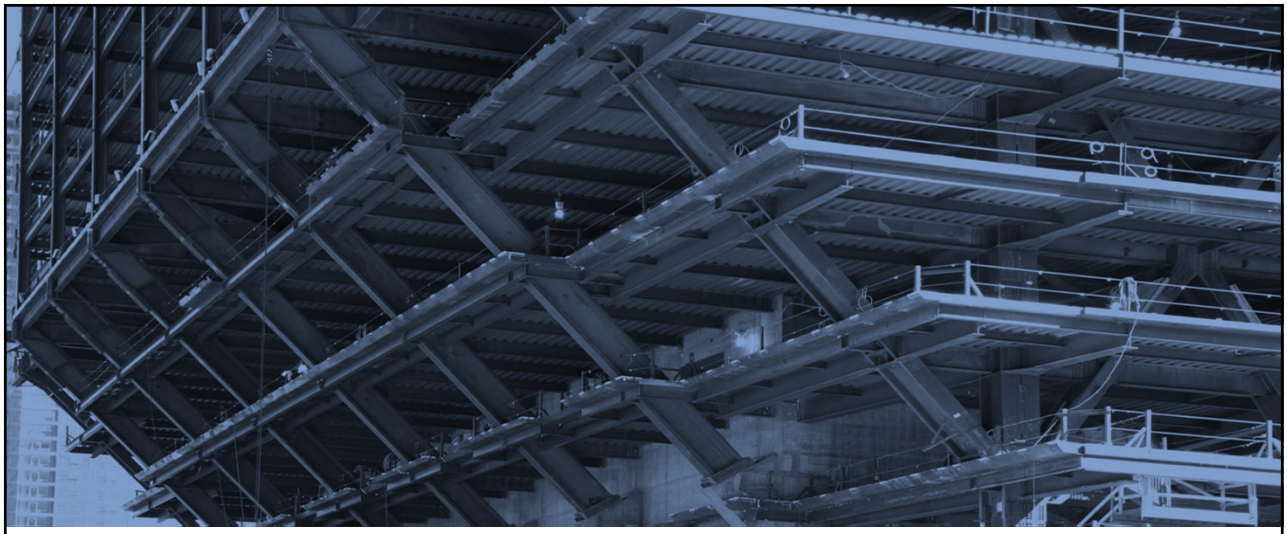

AISC | Thank you

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