



**Night School 27:
Fundamentals of
Welding and Bolting**

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AISC Night School



Session 3 – Special Welding Applications
October 18, 2021 | Duane K. Miller




**Smarter.
Stronger.
Steel.**

AISC Night School

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AISC Night School

Course Description

**Special Welding Applications
October 18, 2021**


This session covers atypical welding applications for buildings. The live webinar presents practical, straightforward solutions to challenging situations including: welding of steel headed stud anchors, welding on coated steels, welding AESS, welding on existing structures, welding heavy sections, welding under high restraint, field welding, heat shrinking, cold temperature applications and more.




AISC Night School

Learning Objectives


1. Describe tolerance issues that may affect welded connections in AESS structures.
2. Identify welded HSS connections where member configurations could prevent proper welding, inspection or assembly.
3. List considerations for welded connections on rolled heavy shapes.
4. List consideration for welded connections in cold temperature applications.




Night School 27: Fundamentals of Welding and Bolting




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Night School 27: Fundamentals of Welding and Bolting
 Welding Part 3: Special Welding Applications
 October 18, 2021
 Duane K. Miller, PE, ScD, The Lincoln Electric Company







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SPECIAL WELDING APPLICATIONS

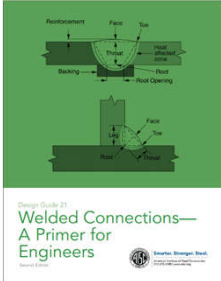



10

AISC Design Guide 21, 2nd Edition

Welded Connections—
 A Primer for Engineers

Chapter 14 Special Welding Applications




11

SPECIAL WELDING APPLICATIONS

Chapter 14 Special Welding Applications



- 14.1 Welding of Steel Headed Stud Anchors
- 14.2 Welding on Galvanized Steels
- 14.3 Welding on Primed and Painted Steel
- 14.4 Welding on Heavy Shapes
- 14.5 Welding on Highly Restrained Members
- 14.6 Welding HSS




12

SPECIAL WELDING APPLICATIONS



- 14.7 Welding AESS
- 14.8 Shop Versus Field Welding
- 14.9 Welding on Existing Structures
- 14.10 Welds and Mechanical Fasteners
- 14.11 Welding on Members to be Hot-Dip Galvanized
- 14.12 Cold Temperature Applications
- 14.13 Deck Welding



13

SPECIAL WELDING APPLICATIONS

- 14.14 Welding on In-Place Embed Plates
- 14.15 Heat Shrinking
- 14.16 Buttering



14

SPECIAL WELDING APPLICATIONS

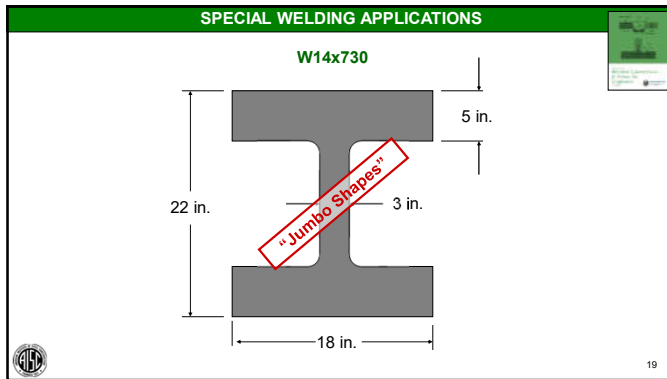
Today's Webinar

- ➔ 14.4 Welding on Heavy Shapes
- 14.6 Welding HSS
- 14.7 Welding AESS
- 14.8 Shop Versus Field Welding
- 14.9 Welding on Existing Structures
- 14.12 Cold Temperature Applications
- 14.15 Heat Shrinking
- 14.16 Buttering



15





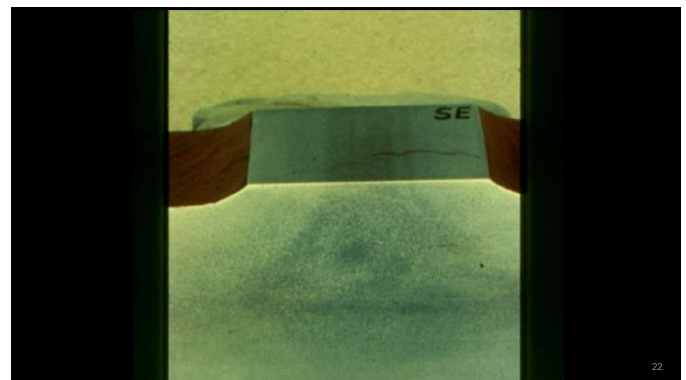
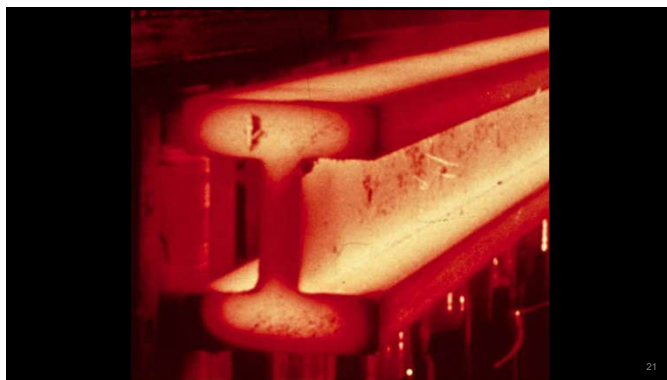
AISC 360-16 SPECIFICATION

Commentary A3

1c. Rolled Heavy Shapes

The web-to-flange intersection and the web center of heavy hot-rolled shapes, as well as the interior portions of heavy plates, may contain a more coarse grain structure and/or lower notch toughness material than other areas of these products.

Segregation Reduced Rolling Slower Cooling



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Commentary A3

1c. Rolled Heavy Shapes

This characteristic is not detrimental to suitability for compression members or for non-welded members. However, when heavy cross sections are joined by splices or connections using complete-joint-penetration groove welds that extend through the coarser and/or low notch-tough interior portions, tensile strains induced by welding may result in cracking.

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Commentary A3

1a. ASTM Designations

Rolled Steel is anisotropic, especially insofar as ductility is concerned; therefore, weld contraction strain in the region of highly restrained welded connections may exceed the strength of the material if special attention is not given to material selection, details, workmanship and inspection.

Material Details Workmanship Inspection

AISC 360-16 Specification for Structural Steel Buildings

Material

CHAPTER A
GENERAL PROVISIONS

A3. MATERIAL

1c. Rolled Heavy Shapes

ASTM A6/A6M hot-rolled shapes with a flange thickness exceeding 2 in. (50 mm) are considered to be rolled heavy shapes. Rolled heavy shapes used as members subject to primary (computed) tensile forces due to tension or flexure and spliced or connected using complete-joint-penetration groove welds that fuse through the thickness of the flange or the flange and the web, shall be specified as follows. The structural design documents shall require that such shapes be supplied with Charpy V-notch (CVN) impact test results in

25

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Material

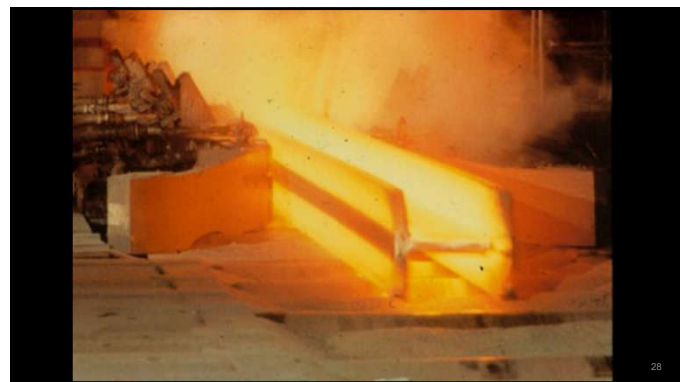
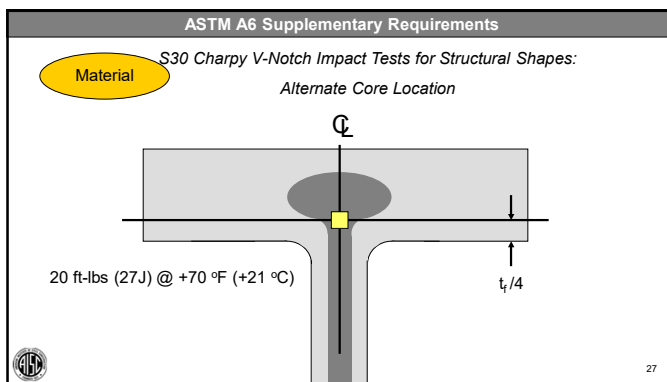
CHAPTER A
GENERAL PROVISIONS

A3. MATERIAL

1c. Rolled Heavy Shapes (cont'd)

The structural design documents shall require that such shapes be supplied with Charpy V-notch (CVN) impact test results in accordance with ASTM A6/A6M, Supplementary Requirement S30, Charpy V-Notch Impact Test for Structural Shapes—Alternate Core Location. The impact test shall meet a minimum average value of 20 ft-lb (27 J) absorbed energy at a maximum temperature of +70°F (+21°C).

26



AISC 360-16 Specification for Structural Steel Buildings

Material

CHAPTER A
GENERAL PROVISIONS

A3 MATERIAL

1d. Built-Up Heavy Shapes

Built-up cross sections consisting of plates with a thickness exceeding 2 in. (50 mm) are considered built-up heavy shapes. Built-up heavy shapes used as members subject to primary (computed) tensile forces due to tension or flexure and spliced or connected to other members using complete-joint-penetration groove welds that fuse through the thickness of the plates, shall be specified as follows. The structural design documents shall require that the steel be supplied with Charpy V-notch impact test results in accordance with ASTM A6/A6M.

29

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Material

CHAPTER A
GENERAL PROVISIONS

A3 MATERIAL

1d. Built-Up Heavy Shapes (cont'd)

The structural design documents shall require that the steel be supplied with Charpy V-notch impact test results in accordance with ASTM A6/A6M, Supplementary Requirement S5, Charpy V-Notch Impact Test. The impact test shall be conducted in accordance with ASTM A673/A673M, Frequency P, and shall meet a minimum average value of 20 ft-lb (27 J) absorbed energy at a maximum temperature of +70°F (+21°C).

30

ASTM A6 Supplementary Requirements

Material S5 Charpy V-Notch Impact Test

20 ft-lbs (27 J) @ +70 °F (+21 °C)

For built-up cross sections

31

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Material CHAPTER J
 DESIGN OF CONNECTIONS

J2. 6. Filler Metal Requirements

Filler metal with a specified minimum Charpy V-notch toughness of 20 ft-lb (27 J) at 40°F (4°C) or lower shall be used in the following joints:

- (a) CJP groove welded T- and corner joints with steel backing left in place, subject to tension normal to the effective area, unless the joints are designed using the nominal strength and resistance factor or safety factor, as applicable, for a PJP groove weld
- (b) CJP groove welded splices subject to tension normal to the effective area in heavy sections, as defined in Sections A3.1c and A3.1d

32

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Material J2.6 Filler Metal Requirements

20 ft-lbs (27 J) @ +40 °F (+4 °C)

33

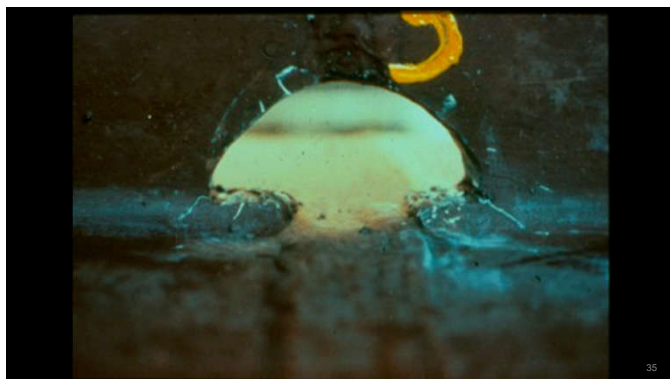
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Commentary A3

1c. Rolled Heavy Shapes

To minimize the potential for fracture, the notch toughness requirements of Section A3.1c must be used in conjunction with good design and fabrication procedures. Specific requirements are given in Sections J1.5, J1.6, J2.6 and J2.7.

34



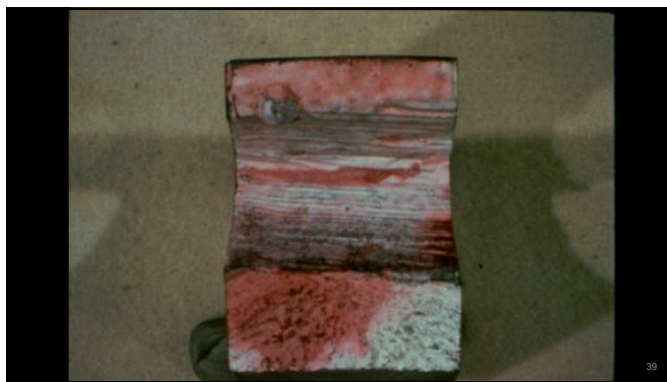
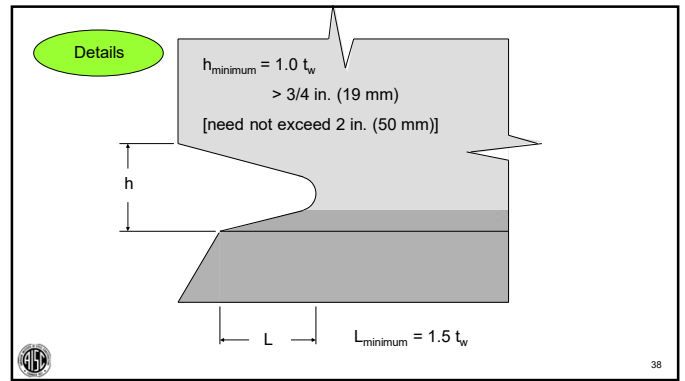
AISC 360-16 Specification for Structural Steel Buildings

**CHAPTER J
 DESIGN OF CONNECTIONS**

J1.6. Weld Access Holes

Weld access holes shall meet the following requirements:

- (a) All weld access holes required to facilitate welding operations shall be detailed to provide room for weld backing as needed.
- (b) The access hole shall have a length from the toe of the weld preparation not less than 1-1/2 times the thickness of the material in which the hole is made, nor less than 1-1/2 in. (38 mm).
- (c) The access hole shall have a height not less than the thickness of the material with the access hole, nor less than 3/4 in. (19 mm), nor does it need to...



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**CHAPTER M
 FABRICATION AND ERECTION**

Workmanship

M2.2. Thermal Cutting

For beam copes and weld access holes in which the curved part of the access hole is thermally cut in ASTM A6/A6M hot-rolled shapes with a flange thickness exceeding 2 in. (50 mm) and welded built-up shapes with material thickness greater than 2 in. (50 mm), a preheat temperature of not less than 150°F (66°C) shall be applied prior to thermal cutting. The thermally cut surface of access holes in ASTM A6/A6M hot-rolled shapes with a flange thickness exceeding 2 in. (50 mm) and built-up shapes with a material thickness greater than 2 in. (50 mm) shall be ground.

AWS D1.1:2020 STRUCTURAL WELDING CODE

Table 5.8
**Prequalified Minimum
 Preheat/Interpass Temperatures**

A B C D E F	Steel Specification	Welding Process	Thickness of Thick Part or Root of Bevel		Preheat and Interpass Temperature (see 5.7)
			in.	mm	
I	ASTM A36	Shielded Metal Arc	1/8 to 3/4	3 to 20	0°
	ASTM A572	Shielded Metal Arc	1/8 to 3/4	3 to 20	0°
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	ASTM A572	Shielded Metal Arc	1/8 to 3/4	3 to 20	0°
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	ASTM A572	Shielded Metal Arc	1/8 to 3/4	3 to 20	0°
	ASTM A572	Shielded Metal Arc	1/8 to 3/4	3 to 20	0°
B	ASTM A1008 HSLAS-F	Shielded Metal Arc	1/8 to 3/4	3 to 20	0°
	ASTM A1008 HSLAS-F	Shielded Metal Arc	1/8 to 3/4	3 to 20	0°
	ASTM A1008 HSLAS-F	Shielded Metal Arc	1/8 to 3/4	3 to 20	0°
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AWS D1.1:2020 STRUCTURAL WELDING CODE


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	ASTM A572	Shielded Metal Arc	1/8 to 3/4	3 to 20	0°
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	ASTM A1008 HSLAS-F	Shielded Metal Arc	1/8 to 3/4	3 to 20	0°
	ASTM A1008 HSLAS-F	Shielded Metal Arc	1/8 to 3/4	3 to 20	0°
	ASTM A1008 HSLAS-F	Shielded Metal Arc	1/8 to 3/4	3 to 20	0°

AISC 360-16 Specification for Structural Steel Buildings

Inspection Commentary J1

J1.5. Splices in Heavy Sections

Previous editions of this Specification required magnetic particle or dye-penetrant inspection of thermally cut weld access holes for splices in heavy sections. This requirement was deliberately removed as anecdotal evidence suggested this inspection was not necessary because cracks from thermal cutting rarely occurred when the other Specification requirements were met. The previously prescribed magnetic particle testing or penetrant testing was replaced with a requirement for visual inspection of weld access holes after welding (see Table N5.4-3).




43

SPECIAL WELDING APPLICATIONS

Welding Heavy Sections: Summary

- Material notch toughness requirements (≥ 2 in [50 mm])
- Weld access hole geometry
- Preheat for thermal cutting, grinding
- MT and PT no longer required, but good visual needed
- Preheat for welding
- Follow other "good practices" for welding on highly restrained members

Material
Details
Workmanship
Inspection



44

SPECIAL WELDING APPLICATIONS

Today's Webinar

- 14.4 Welding on Heavy Shapes
- ➔ 14.6 Welding HSS
- 14.7 Welding AESS
- 14.8 Shop Versus Field Welding
- 14.9 Welding on Existing Structures
- 14.12 Cold Temperature Applications
- 14.15 Heat Shrinking
- 14.16 Buttering



45

SPECIAL WELDING APPLICATIONS

14.6 Welding HSS

- ➔ Connections and HSS member size
- Overall configuration
- Cutting and preparing HSS

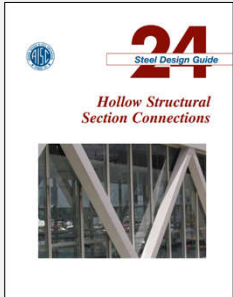



46

Design Guide 24

Hollow Structural Section Connections

by
 Packer, Sherman, Lecce


47

Design Guide 24 Hollow Structural Section Connections

**Chapter 1
 Introduction**

"Connections usually have been the challenging aspect for the designer of structures that involve HSS...Note that, in many cases, the local strength of the HSS at the connection is an integral part—and perhaps a limitation—of the design."

HSS member size may need to be increased to accommodate connection design.




48

Design Guide 24 Hollow Structural Section Connections

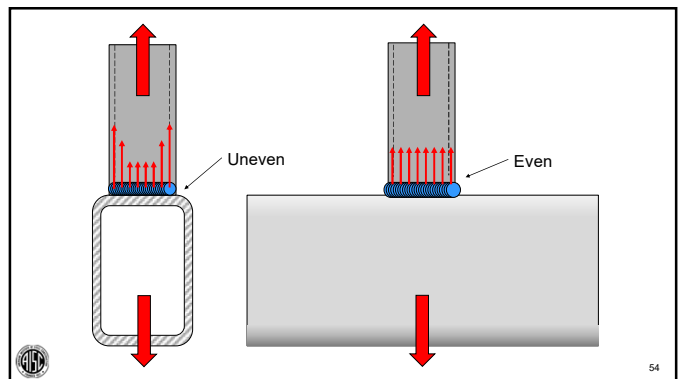
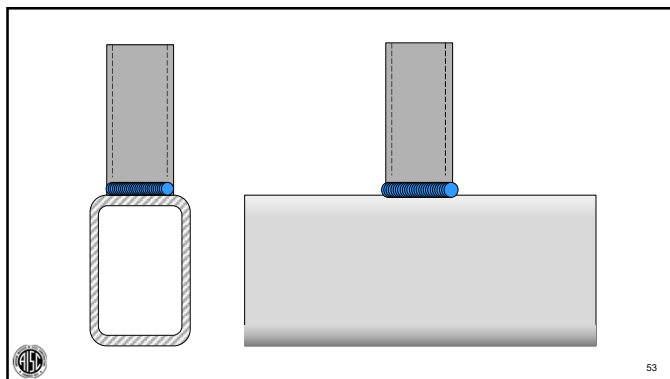
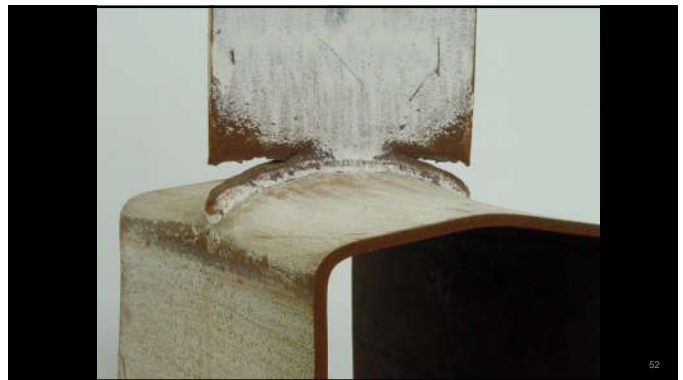
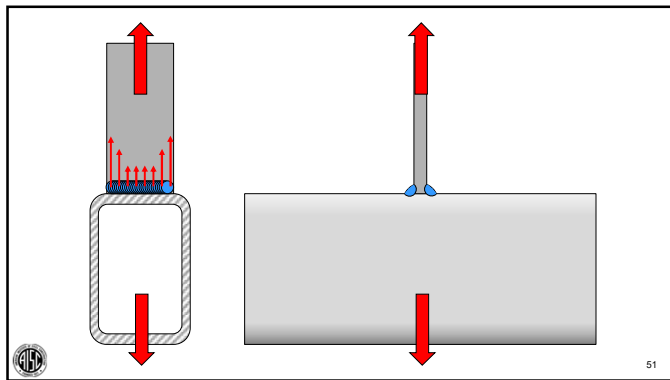
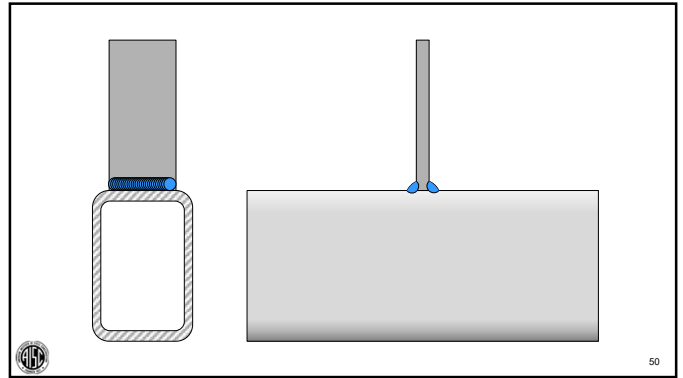
Chapter 2
Welding

2.4 EFFECTIVE WELD LENGTH

Due to the variation in flexural stiffness of the wall across the width of a rectangular HSS, a force transmitted through a weld is often not uniformly distributed. This can be accounted for in design using an effective weld length approach. This reduced effective length applies both to the weld and to the force in the connected element.



49



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TABLE K2.1

Available Strength of Plate-to-Round HSS Connections

Connection Type	Connection Available Strength	Plate Bending
Transverse Plate T- and Cross-Connections 	Limit State: HSS Local Yielding $R_n = F_y A_g$ $\phi = 0.90$ (LRFD) $\Omega = 1.67$ (ASD)	$M_n = 0.55 F_y A_g$ (K2-1a)
Longitudinal Plate T-, Y- and Cross-Connections 	Limit State: HSS Plasticization $R_n = 1.5 F_y A_g$ $\phi = 0.90$ (LRFD) $\Omega = 1.67$ (ASD)	$M_n = 0.8 F_y A_g$ (K2-2b)

Parameters

$\phi = 1$ for HSS connecting surface in tension
 $\phi = 1.0 - 0.22(1 + \lambda)$ for HSS connecting surface in compression (K2-2)

$\lambda = \frac{L}{r} \sqrt{\frac{F_y}{E}}$ (K2-4)

where F_y and M_n are determined on the side of the joint that has the lower compression stress. F_y and M_n refer to required strengths in the HSS. F_y is for LRFD, and F_y for ASD. $M_n = M_n$ for LRFD, and M_n for ASD.

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Longitudinal Plate T-, Y- and Cross-Connections

Limit State: HSS Plasticization		
Plate Axial Load	In-Plane	Out-of-Plane
$R_n \sin(\theta) = 5.5 F_y t^2 \left(1 + 0.25 \frac{b}{D} \right) \phi$ (K2-2a)	$M_n = 0.8 F_y A_g$ (K2-2b)	-
$\phi = 0.90$ (LRFD) $\Omega = 1.67$ (ASD)		

AISC 360:16 Specification for Structural Steel Buildings

TABLE K5.1

Effective Weld Properties for Connection to Rectangular HSS

Connection Type	Effective Weld Properties
Transverse Plate T- and Cross-Connections under Plate Axial Load 	$l_e = 2B_e$ (K5-4)

AISC 360:16 Specification for Structural Steel Buildings

Effective Weld Properties for Connection to Rectangular HSS

Connection Type	Weld Properties
Transverse Plate T- and Cross-Connections under Plate Axial Load 	<div style="border: 1px solid red; padding: 2px; display: inline-block;">Effective Weld Properties</div> $l_e = 2B_e$ (K5-4)

where l_e = total effective weld length for welds on both sides of the transverse plate

SPECIAL WELDING APPLICATIONS

14.6 Welding HSS

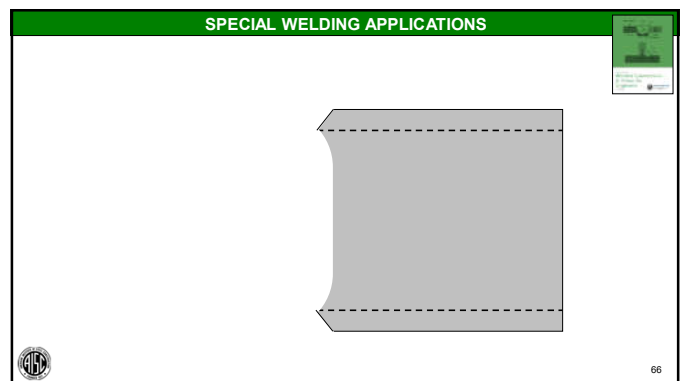
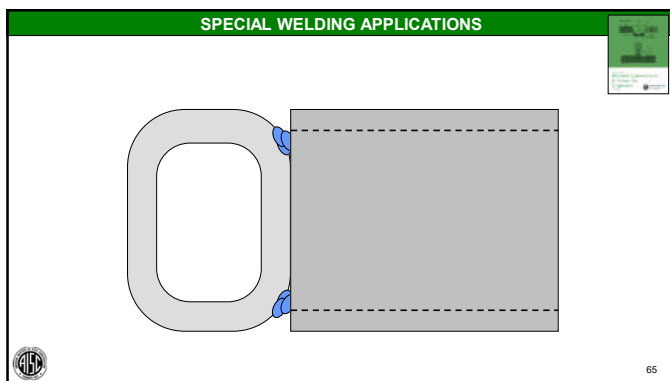
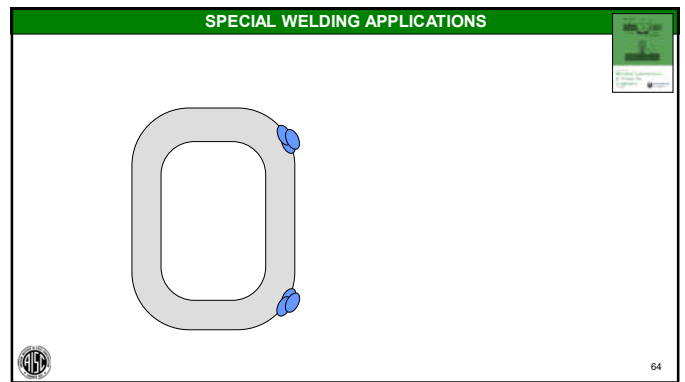
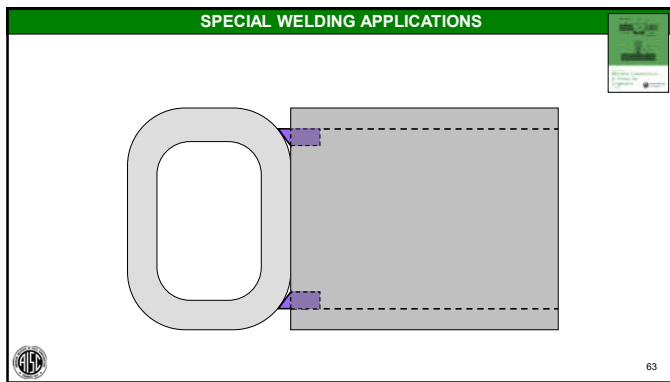
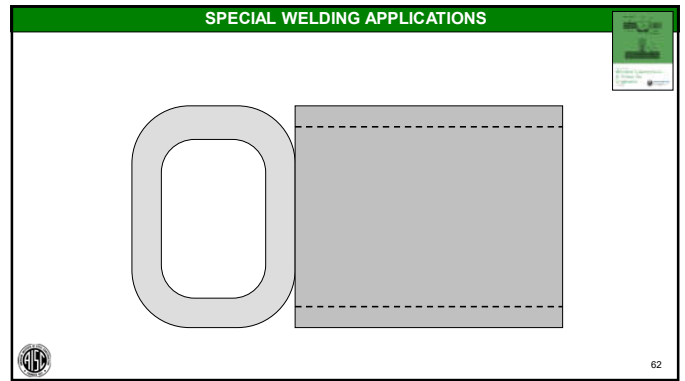
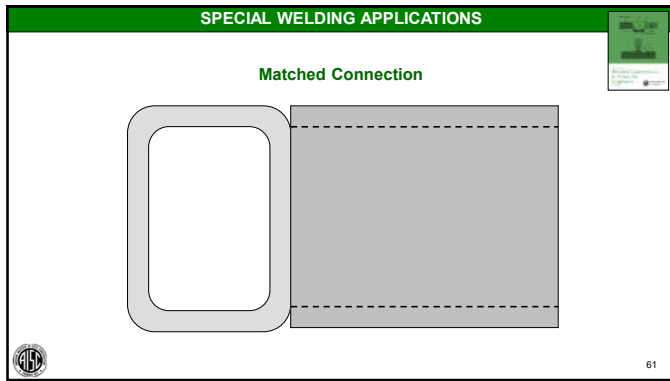
- Connections and HSS member size
- ➔ Overall configuration
- Cutting and preparing HSS

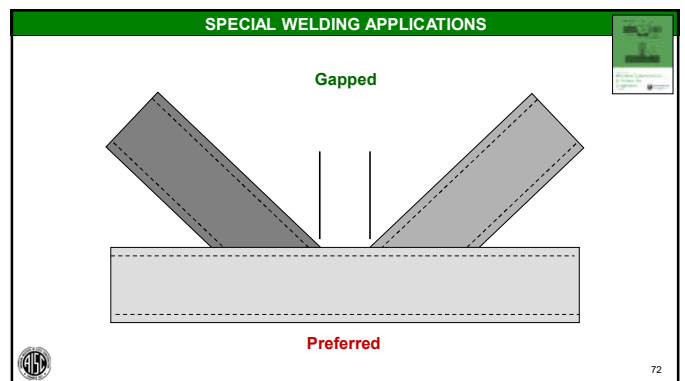
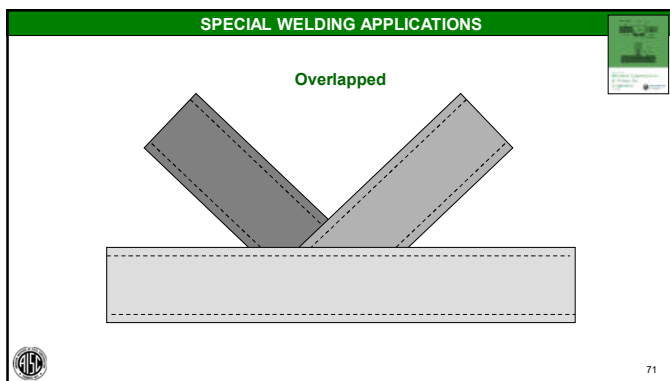
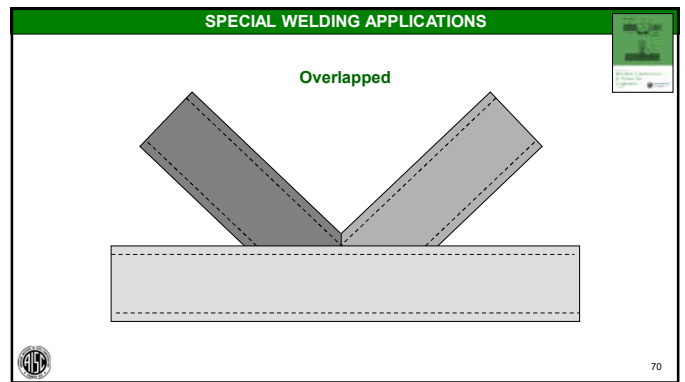
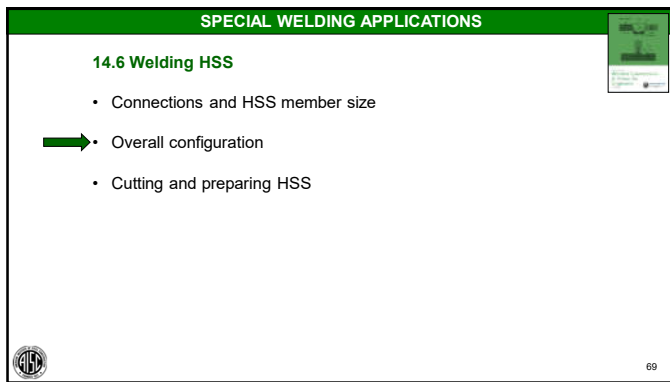
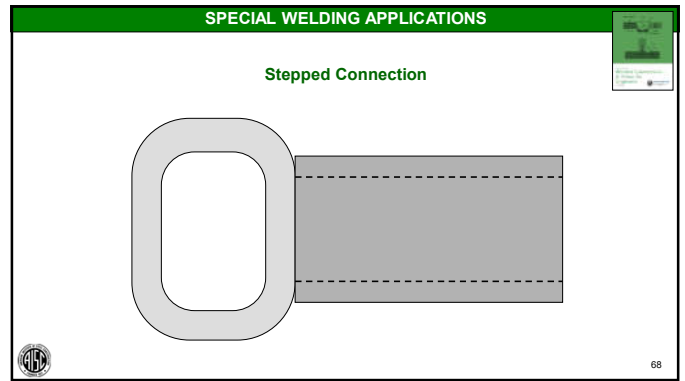
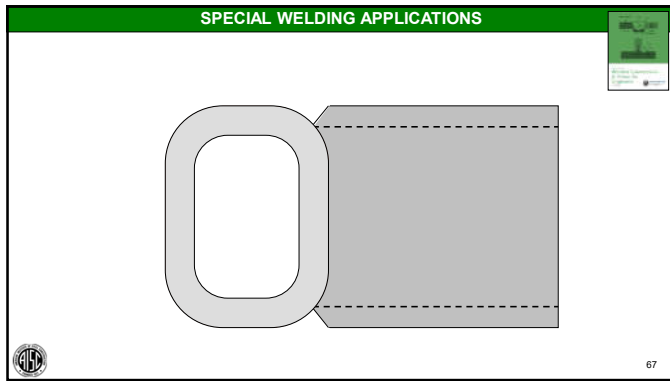
SPECIAL WELDING APPLICATIONS

Rectangular

Round

Rectangular is nearly always easier to fabricate





SPECIAL WELDING APPLICATIONS

Provide Access for Welding and Inspection

- Can the welder see the puddle?
- Can the inspector see the weld?

$\Psi = 30^\circ$ minimum

73

SPECIAL WELDING APPLICATIONS

14.6 Welding HSS

- Connections and HSS member size
- Overall configuration
- ➔ • Cutting and preparing HSS

74

SPECIAL WELDING APPLICATIONS

Box HSS

75

SPECIAL WELDING APPLICATIONS

Box HSS

76

SPECIAL WELDING APPLICATIONS

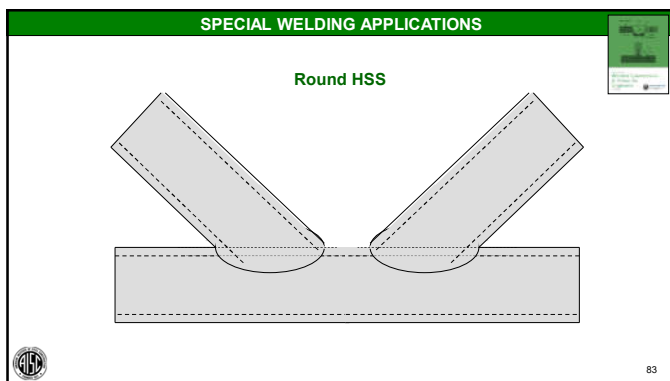
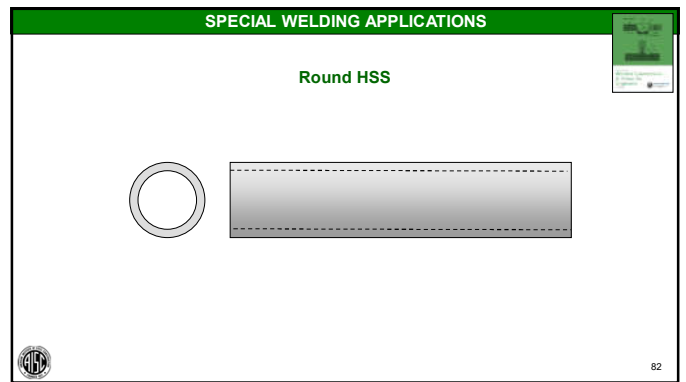
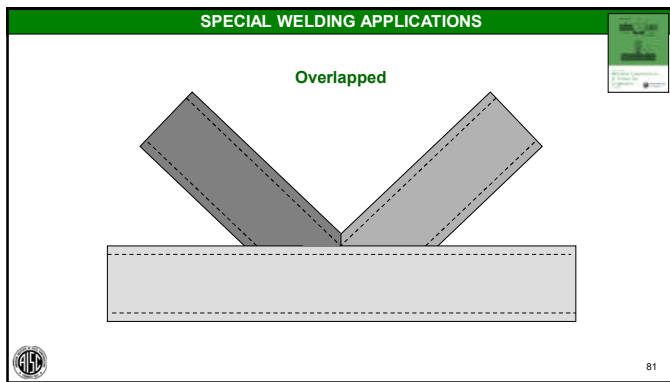
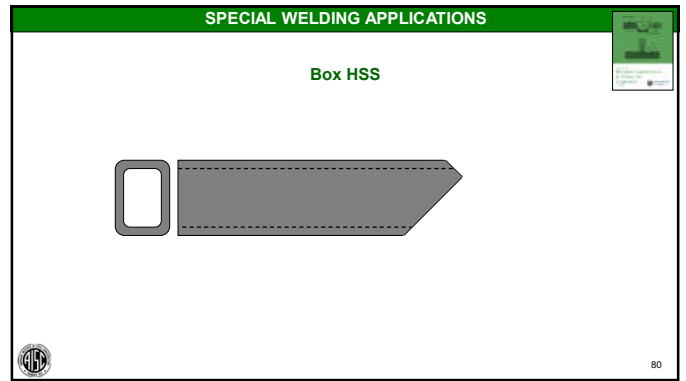
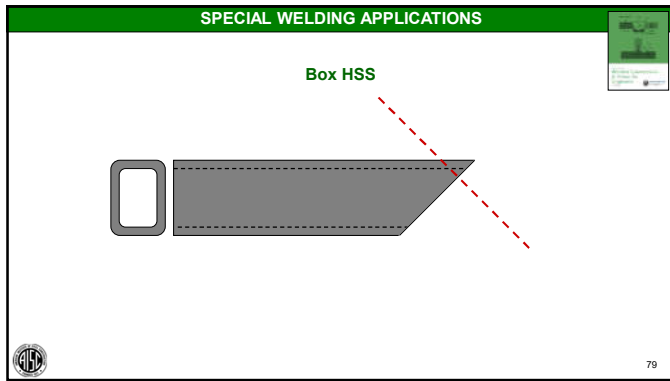
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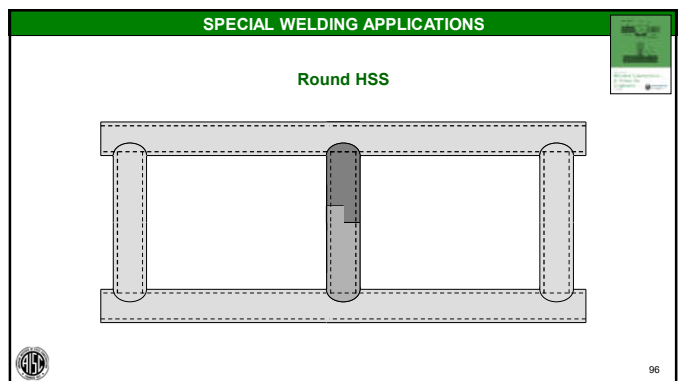
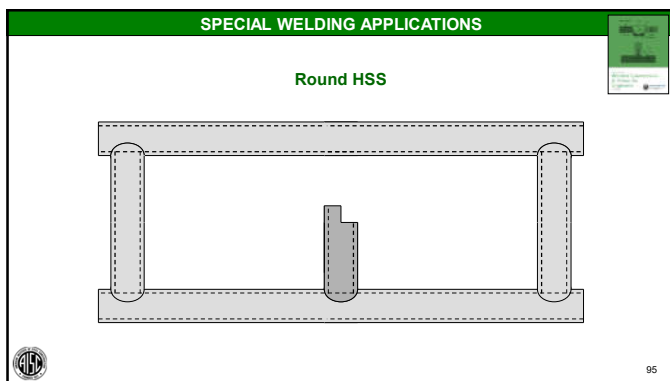
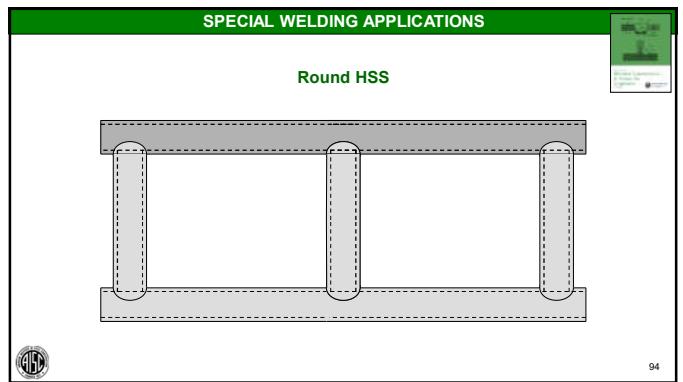
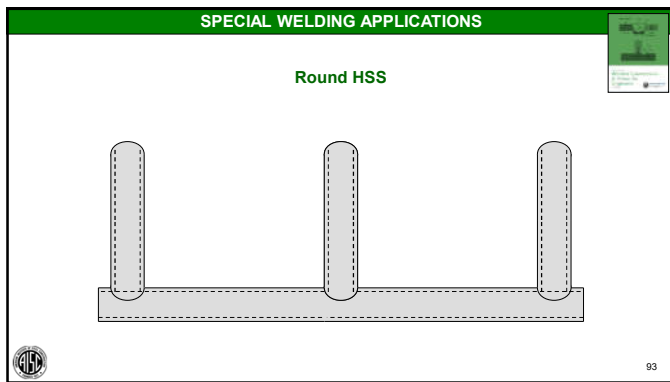
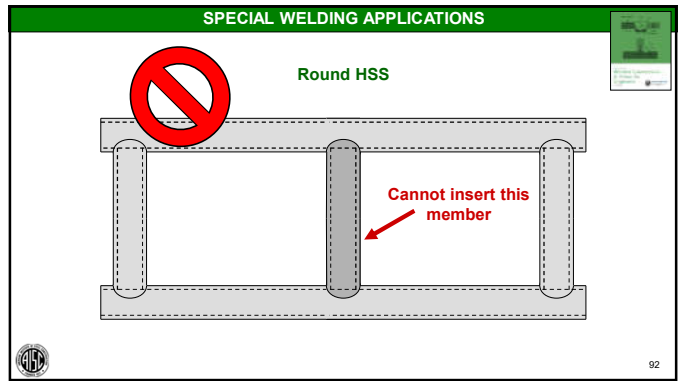
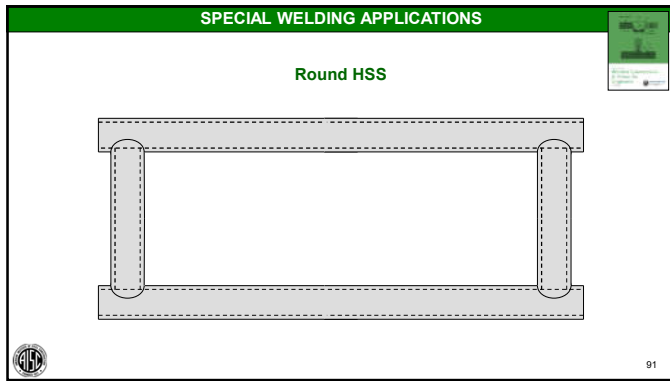
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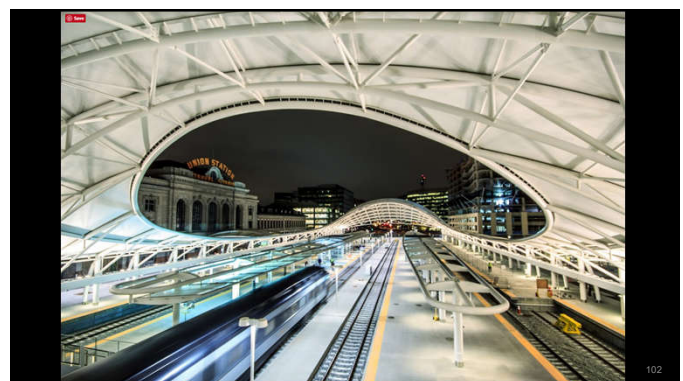
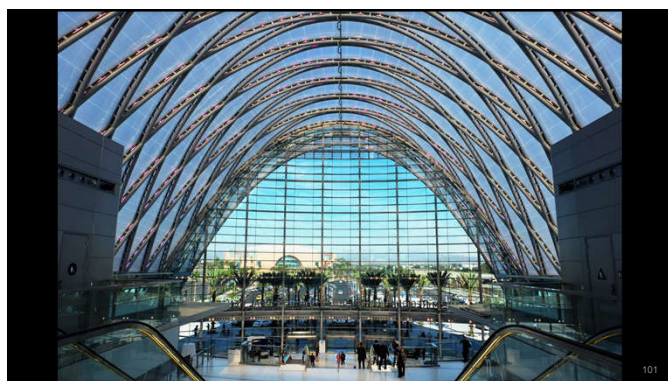
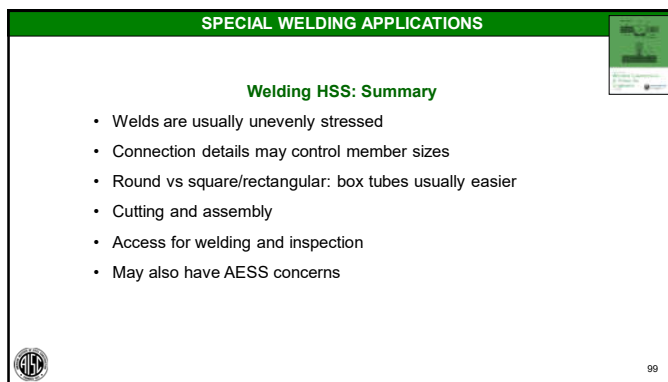
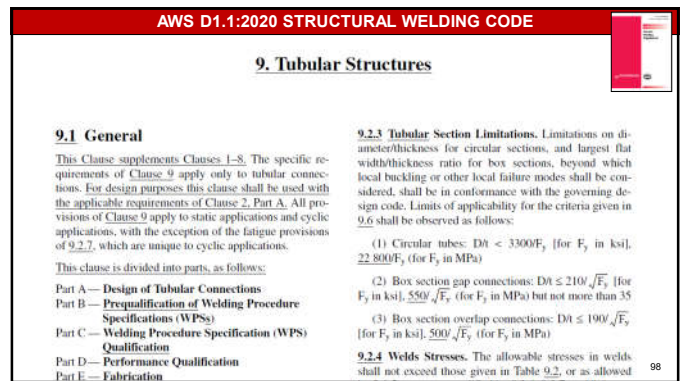
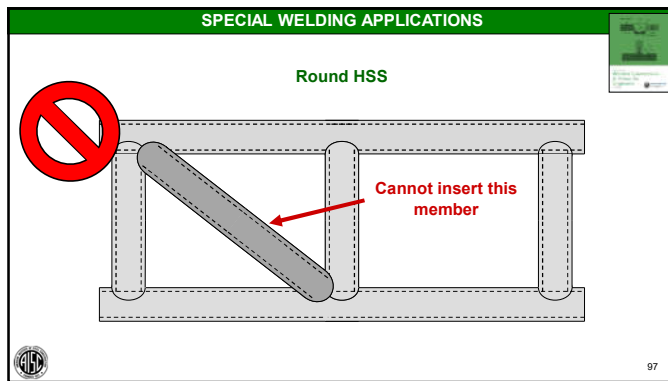
SPECIAL WELDING APPLICATIONS

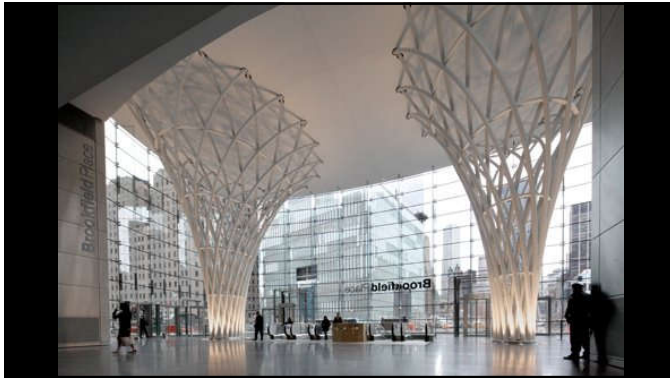
Gapped

78









SPECIAL WELDING APPLICATIONS

Welding AESS

- ➔ Defining "pretty"
- Use of Mock-ups
- Technical issues
- Note requirements on drawings

105

AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges

AISC 303-16

Code of Standard Practice for Steel Buildings and Bridges

Section 10.
 Architecturally Exposed Structural Steel

Category	AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS
Characteristics	Custom Elements	Showcase Elements	Feature Elements in close view	Feature Elements not in close view	Basic Elements	Standard Structural Steel
M						
1.1		*	*	*	*	*
1.2		*	*	*	*	*
1.3		*	*	*	*	*
1.4		*	*	*	*	*
1.5		*	*	*	*	*
2.1		*	*	optional		
2.2		*	*	*	*	*
2.3		*	*	*	*	*
2.4		*	*	*	*	*
3.1		*	*	*	*	*
3.2		*	*	*	*	*
3.3		*	*	*	*	*
3.4		*	*	*	*	*
3.5		*	*	*	*	*
3.6		optional	optional			
4.1		*	*	*	*	*
4.2		*	*	*	*	*
4.3		*	*	*	*	*
4.4		*	*	*	*	*
C.1						
C.2						
C.3						
C.4						
C.5						

106

AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges

**TABLE 10.1
AESS Category Matrix**

Category	AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS
Characteristics	Custom Elements	Showcase Elements	Feature Elements in close view	Feature Elements not in close view	Basic Elements	Standard Structural Steel
M						
1.1		*	*	*	*	*
1.2		*	*	*	*	*
1.3		*	*	*	*	*
1.4		*	*	*	*	*
1.5		*	*	*	*	*
2.1		*	*	optional		
2.2		*	*	*	*	*
2.3		*	*	*	*	*
2.4		*	*	*	*	*
3.1		*	*	*	*	*
3.2		*	*	*	*	*
3.3		*	*	*	*	*
3.4		*	*	*	*	*
3.5		*	*	*	*	*
3.6		optional	optional			
4.1		*	*	*	*	*
4.2		*	*	*	*	*
4.3		*	*	*	*	*
4.4		*	*	*	*	*
C.1						
C.2						
C.3						
C.4						
C.5						

107

AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges

**TABLE 10.1
AESS Category Matrix**

Category	AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS	
Id	Characteristics	Custom Elements	Showcase Elements	Feature Elements in close view	Feature Elements not in close view	Basic Elements	Standard Structural Steel
1.1	Surface preparation to SSPC-SP 6		*	*	*	*	
1.2	Sharp edges ground smooth		*	*	*	*	
1.3	Continuous weld appearance		*	*	*	*	
1.4	Standard structural bolts		*	*	*	*	
1.5	Weld spatters removed		*	*	*	*	
2.1	Visual samples		*	*	optional		
2.2	One-half standard fabrication tolerances		*	*	*	*	
2.3	Fabrication marks not apparent		*	*	*	*	
2.4	Welds uniform and smooth		*	*	*	*	

108

AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges

**TABLE 10.1
 AESS Category Matrix**

Category	AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS
Id	Custom Elements	Showcase Elements	Feature Elements in close view	Feature Elements not in close view	Basic Elements	Standard Structural Steel
1.1 Surface preparation to SSPC-SP 6		*	*	*	*	*
1.2 Sharp edges ground smooth		*	*	*	*	*
1.3 Continuous weld appearance		*	*	*	*	*
1.4 Standard structural bolts		*	*	*	*	*
1.5 Weld spatters removed		*	*	*	*	*
2.1 Visual samples		*	*	*	optional	
2.2 One-half standard fabrication tolerances		*	*	*	*	
2.3 Fabrication marks not apparent		*	*	*	*	
2.4 Welds uniform and smooth		*	*	*	*	

109

AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges

1.1 Surface preparation to SSPC-SP 6	*	*	*	*
1.2 Sharp edges ground smooth	*	*	*	*
1.3 Continuous weld appearance	*	*	*	*
1.4 Standard structural bolts	*	*	*	*
1.5 Weld spatters removed	*	*	*	*
2.1 Visual samples	*	*	*	optional
2.2 One-half standard fabrication tolerances	*	*	*	*
2.3 Fabrication marks not apparent	*	*	*	*
2.4 Welds uniform and smooth	*	*	*	*
3.1 Mill marks removed	*	*	*	*
3.2 Butt and plug welds ground smooth and filled	*	*	*	*
3.3 HSS weld seam oriented for reduced visibility	*	*	*	*
3.4 Cross sectional abutting surface aligned	*	*	*	*
3.5 Joint gap tolerances minimized	*	*	*	*
3.6 All welded connections	optional	optional		
4.1 HSS seam not apparent	*	*	*	*
4.2 Welds contoured and blended	*	*	*	*
4.3 Surfaces filed and sanded	*	*	*	*
4.4 Weld show-through minimized	*	*	*	*

Many welding-related issues

110



SPECIAL WELDING APPLICATIONS

Welding AESS

- Defining "pretty"
- Use of Mock-ups
- Technical issues
- Note requirements on drawings

113

AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges

1.1 Surface preparation to SSPC-SP 6	*	*	*	*
1.2 Sharp edges ground smooth	*	*	*	*
1.3 Continuous weld appearance	*	*	*	*
1.4 Standard structural bolts	*	*	*	*
1.5 Weld spatters removed	*	*	*	*
2.1 Visual samples	*	*	*	optional
2.2 One-half standard fabrication tolerances	*	*	*	*
2.3 Fabrication marks not apparent	*	*	*	*
2.4 Welds uniform and smooth	*	*	*	*
3.1 Mill marks removed	*	*	*	*
3.2 Butt and plug welds ground smooth and filled	*	*	*	*
3.3 HSS weld seam oriented for reduced visibility	*	*	*	*
3.4 Cross sectional abutting surface aligned	*	*	*	*
3.5 Joint gap tolerances minimized	*	*	*	*
3.6 All welded connections	optional	optional		
4.1 HSS seam not apparent	*	*	*	*
4.2 Welds contoured and blended	*	*	*	*
4.3 Surfaces filed and sanded	*	*	*	*
4.4 Weld show-through minimized	*	*	*	*


Mock-ups

114

AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges

SECTION 10. ARCHITECTURALLY EXPOSED STRUCTURAL STEEL

10.1.2. A mock-up shall be required for AESS 3, 4 and C. If a mock-up is to be used in other AESS categories, it shall be specified in the *contract documents*. When required, the nature and extent of the mock-up shall be specified in the *contract documents*. Alternatively, when a mock-up is not practical, the first piece of an element or *connection* can be used to determine acceptability.




115

AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges

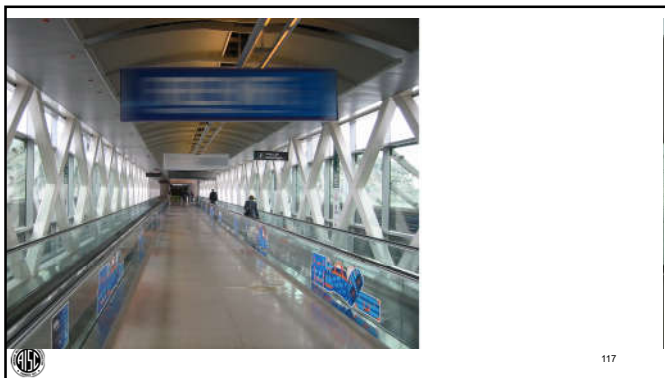
SECTION 10. ARCHITECTURALLY EXPOSED STRUCTURAL STEEL

Commentary:
 Generally, a mock-up is produced and approved in the shop and subsequently placed in the field. The acceptability of the mock-up can be affected by many factors, including distance of view, lighting and finishing. The expectations for the location and conditions of the mock-up at time of approval should be defined in the *contract documents*.

Suggestion: View mock-up at the same distance as the viewer will be from the final welded connection in service.




116



SPECIAL WELDING APPLICATIONS

Welding AESS


- Defining "pretty"
- Use of Mock-ups
- ➔ • Technical issues
- Note requirements on drawings



118

SPECIAL WELDING APPLICATIONS

Sufficient for strength




119

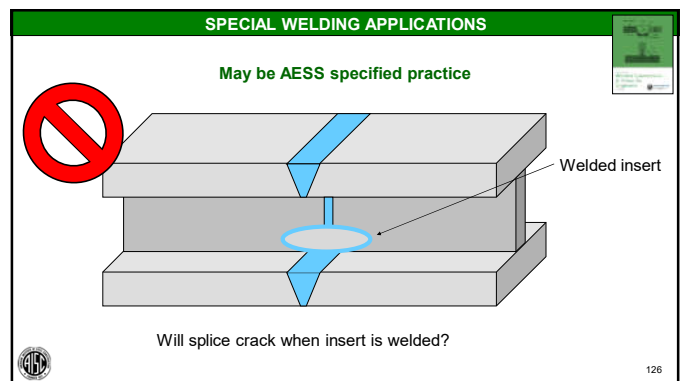
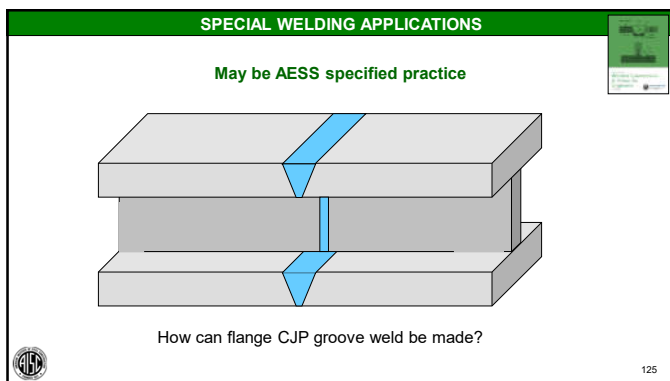
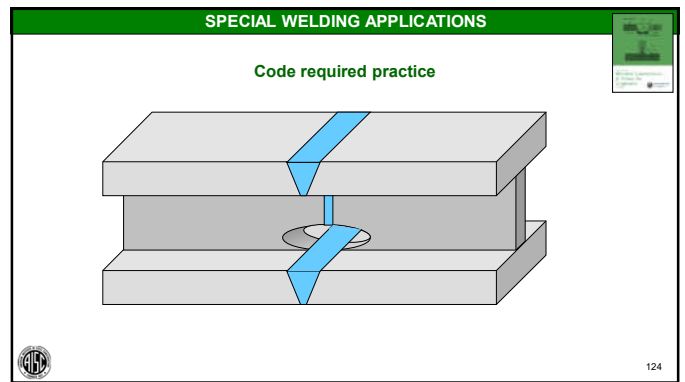
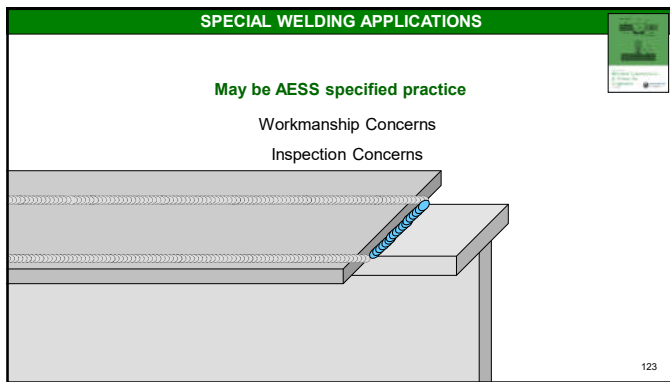
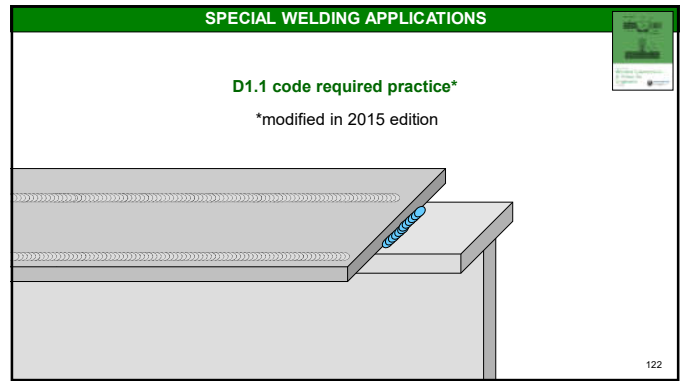
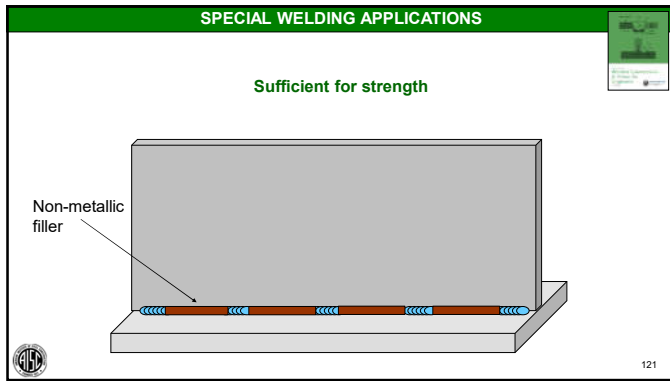
SPECIAL WELDING APPLICATIONS

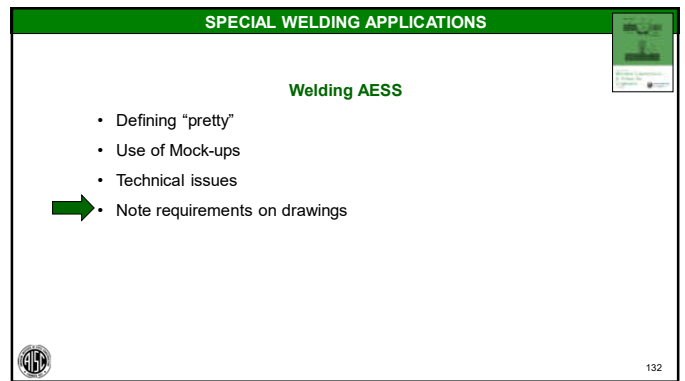
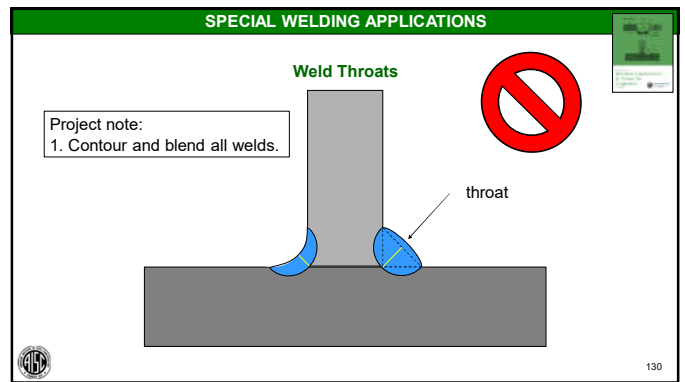
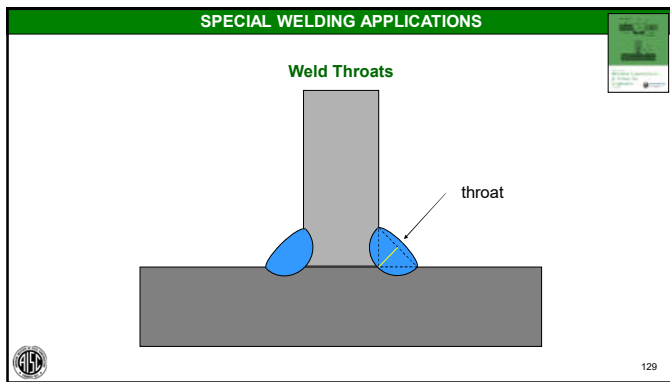
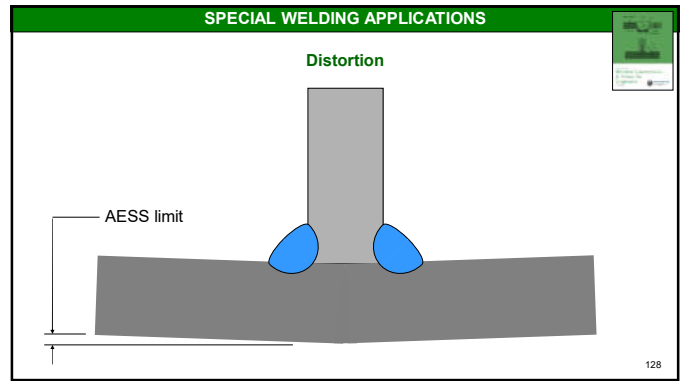
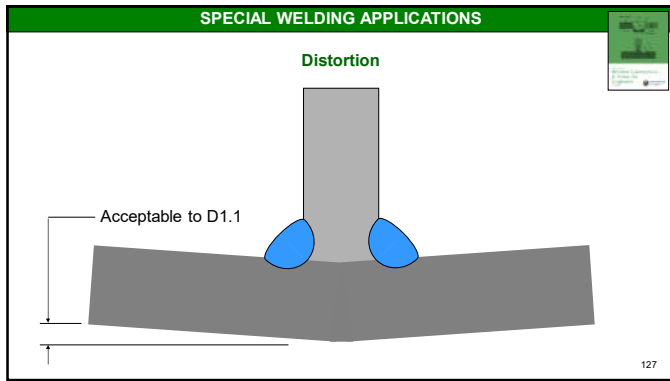
May be required for AESS

Cost
 Distortion



120






SPECIAL WELDING APPLICATIONS

Welding AESS: Summary

- Defining "pretty"; use AISC 303 Section 10
- Mock-ups are often critical; view from an appropriate distance
- Define all expectations; some requirements may conflict with code requirements



133

SPECIAL WELDING APPLICATIONS

Today's Webinar

- 14.4 Welding on Heavy Shapes
- 14.6 Welding HSS
- 14.7 Welding AESS
- ➔ 14.8 Shop Versus Field Welding
- 14.9 Welding on Existing Structures
- 14.12 Cold Temperature Applications
- 14.15 Heat Shrinking
- 14.16 Buttering




134



SPECIAL WELDING APPLICATIONS

Shop versus Field Welding


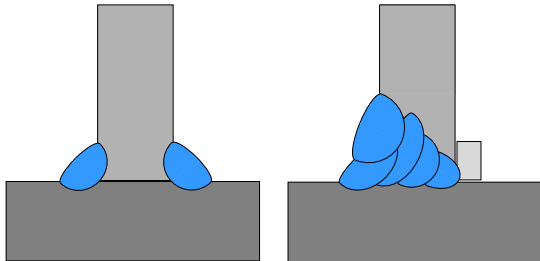
- Primarily an issue of cost
- Some environmental issues (cold, wind, rain, etc.)
- Out-of-position welding may be needed



136

SPECIAL WELDING APPLICATIONS

Usually Preferred




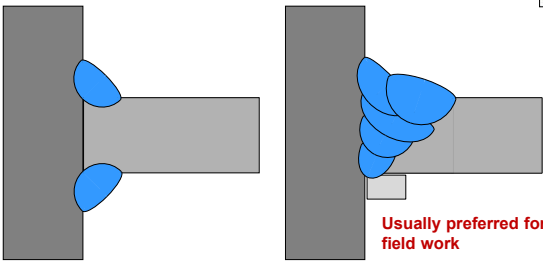
137

SPECIAL WELDING APPLICATIONS

Requires overhead welding

All flat welding

Usually preferred for field work




138

SPECIAL WELDING APPLICATIONS

Shop versus Field Welding

- Primarily an issue of cost
- Some environmental issues (cold, wind, rain, etc.)
- Out-of-position welding may be needed
- Easier to control projects in a shop environment



139

SPECIAL WELDING APPLICATIONS

Myths

- You can't get quality welds out-of-position




140

AWS D1.1:2015 STRUCTURAL WELDING CODE

**Table 4.12
 Welding Personnel Performance Essential Variable Changes
 Requiring Requalification (see 4.19)**

Essential Variable Changes to WPQR Requiring Requalification	Welding Personnel		
	Welders ^b	Welding Operators ^{b,c}	Tack Welders
(1) To a process not qualified (GMAW-S is considered a separate process)	X	X	X
(2) To an SMAW electrode with an F-number (see Table 4.13) higher than the WPQR electrode F-number	X		X
➔ (3) To a position not qualified	X	X	X
(4) To a diameter or thickness not qualified	X	X	
(5) To a vertical welding progression not qualified (uphill or downhill)	X		
(6) The omission of backing (if used in the WPQR test)	X	X	
(7) To multiple electrodes (if a single electrode was used in the WPQR test) but not vice versa		X ^a	




141

SPECIAL WELDING APPLICATIONS

Myths

- You can't get quality welds out-of-position
- You can't get quality in the field




142



SPECIAL WELDING APPLICATIONS

Myths

- You can't get quality welds out-of-position
- You can't get quality in the field
- Codes do not apply to field welding



144

AWS D1.1:2020 Structural Welding Code--Steel

7. Fabrication

7.1 Scope

This clause contains requirements for the **fabrication and erection of welded assemblies and structures** produced by any process applicable under this code (see 5.5 and 6.15) related to:

- (1) Materials
- (2) Processes and WPSs
- (3) Weld Details
- (4) Weld Quality and Repairs
- (5) Member Dimensional Tolerances

SPECIAL WELDING APPLICATIONS

Myths

- You can't get quality welds out-of-position
- You can't get quality in the field
- Codes do not apply to field welding
- Field welders are not "certified" (qualified)

AWS D1.1:2020 Structural Welding Code--Steel

6. Qualification

6.2.2.2 Qualification Responsibility

Each manufacturer or Contractor shall be responsible for the qualification of welders, welding operators and tack welders, whether the qualification is conducted by the manufacturer, Contractor, or an independent testing agency.

SPECIAL WELDING APPLICATIONS

Myths

- You can't get quality welds out-of-position
- You can't get quality in the field
- Codes do not apply to field welding
- Field welders are not "certified" (qualified)
- WPSs are not used in the field

AISC 360-16 Specification for Structural Steel Buildings

CHAPTER N

QUALITY CONTROL AND QUALITY ASSURANCE

TABLE N5.4-1
Inspection Tasks Prior to Welding

Inspection Tasks Prior to Welding	QC	QA
Welder qualification records and continuity records	P	O
WPS available	P	P
Manufacturer certifications for welding consumables available	P	P
Material identification (type/grade)	O	O
Welder identification system ^(a)	O	O
Fit-up of groove welds (including joint geometry)		
• Joint preparations		
• Dimensions (alignment, root opening, root face, bevel)		
• Cleanliness (condition of steel surfaces)		
• Tacking (tack weld quality and location)		
• Backing type and fit (if applicable)		
Fit-up of CJP groove welds of HSS T, Y, and K-joints without backing (including joint geometry)		
• Joint preparations		
• Dimensions (alignment, root opening, root face, bevel)		
• Cleanliness (condition of steel surfaces)		
• Tacking (tack weld quality and location)		
Composition and finish of access holes	O	O
Fit-up of fillet welds		
• Dimensions (alignment, gaps at root)		
• Cleanliness (condition of steel surfaces)		
• Tacking (tack weld quality and location)		
Check welding equipment	O	-

^(a) The fabricator or welder, as applicable, shall maintain a system by which a welder who has welded a joint or member can be verified. Entries O, P, and QA shall be the first three letters.

AISC 360-16 Specification for Structural Steel Buildings


TABLE N5.4-1
Inspection Tasks Prior to Welding

Inspection Tasks Prior to Welding	QC	QA
Welder qualification records and continuity records	P	O
WPS available	P	P
Manufacturer certifications for welding consumables available	P	P
Material identification (type/grade)	O	O
Welder identification system ^(a)	O	O
Fit-up of groove welds (including joint geometry)		
• Joint preparations		
• Dimensions (alignment, root opening, root face, bevel)		
• Cleanliness (condition of steel surfaces)		
• Tacking (tack weld quality and location)		
• Backing type and fit (if applicable)		

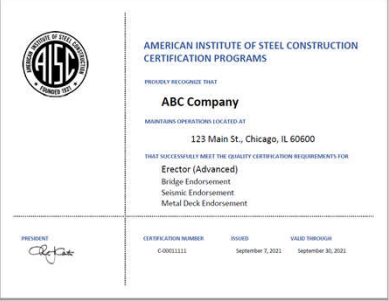

SPECIAL WELDING APPLICATIONS

Myths

- You can't get quality welds out-of-position
- You can't get quality in the field
- Codes do not apply to field welding
- Field welders are not "certified" (qualified)
- WPSs are not used in the field
- There is no audit program for field contractors



151



AMERICAN INSTITUTE OF STEEL CONSTRUCTION
CERTIFICATION PROGRAMS

PROUDLY RECOGNIZE THAT

ABC Company

MANUFACTURING OPERATIONS LOCATED AT

123 Main St., Chicago, IL 60600

THAT SUCCESSFULLY MEET THE QUALITY CERTIFICATION REQUIREMENTS FOR

Erector (Advanced)
Bridge Endorsement
Seismic Endorsement
Metal Deck Endorsement

PRESIDENT: [Signature]

CERTIFICATION NUMBER: C00011111


ISSUED: September 7, 2021

VALID THROUGH: September 30, 2022

SPECIAL WELDING APPLICATIONS

Myths

- You can't get quality welds out-of-position
- You can't get quality in the field
- Codes do not apply to field welding
- Field welders are not "certified" (qualified)
- WPSs are not used in the field
- There is no audit program for field contractors
- There are no contractor-supplied inspectors for field work



153


AISC 360-16 Specification for Structural Steel Buildings

CHAPTER N

QUALITY CONTROL AND QUALITY ASSURANCE

N2. FABRICATOR AND ERECTOR QUALITY CONTROL PROGRAM

The **fabricator and erector** shall establish, maintain and implement QC procedures to ensure that their work is performed in accordance with this Specification and the construction documents.




154

SPECIAL WELDING APPLICATIONS

Shop vs Field Welding: Summary

- There are some legitimate differences/concerns
- Shop operations generally preferred due to lower costs
- Mature codes control field welding
- Field contractor certification programs exist
- Inspection requirements have been made clearer in Chapter N




155

SPECIAL WELDING APPLICATIONS

Today's Webinar

- 14.4 Welding on Heavy Shapes
- 14.6 Welding HSS
- 14.7 Welding AESS
- 14.8 Shop Versus Field Welding
- ➔ 14.9 Welding on Existing Structures
- 14.12 Cold Temperature Applications
- 14.15 Heat Shrinking
- 14.16 Buttering





156

SPECIAL WELDING APPLICATIONS

14.9 Welding on Existing Structures


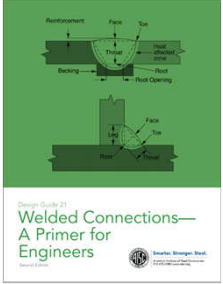
- Historic steels
- Welding under load
- Fire
- Cold working / strain aging



157

AISC Design Guide 21
Chapter 4 Metallurgical Issues

- Historic (obsolete) steels
 - ASTM A9
 - ASTM A7
 - ASTM A373
 - ASTM A242
- Check weldability of steel (especially if riveted)





158

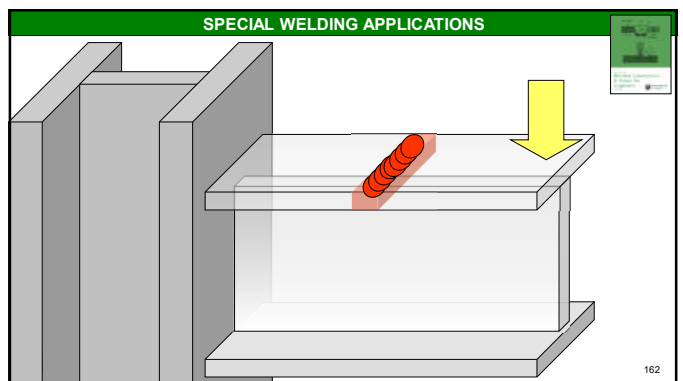
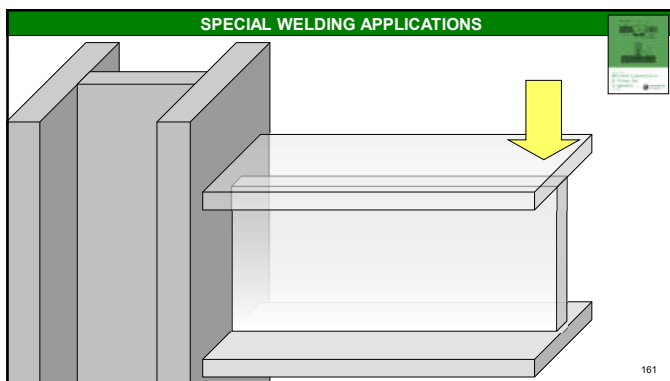
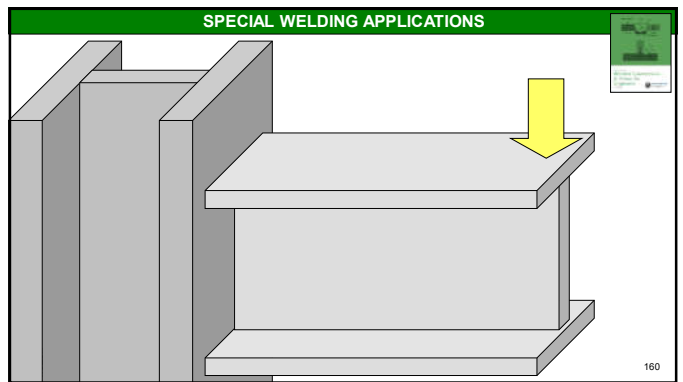
SPECIAL WELDING APPLICATIONS

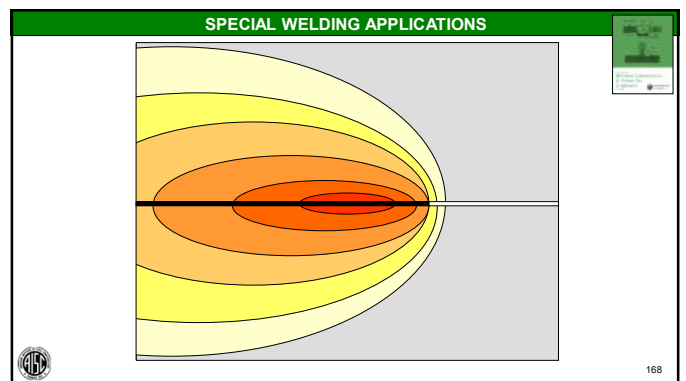
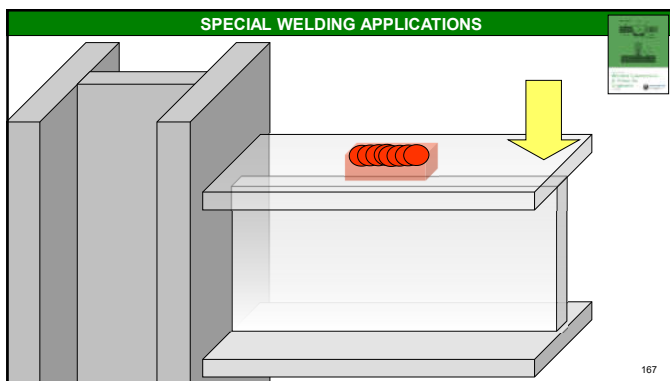
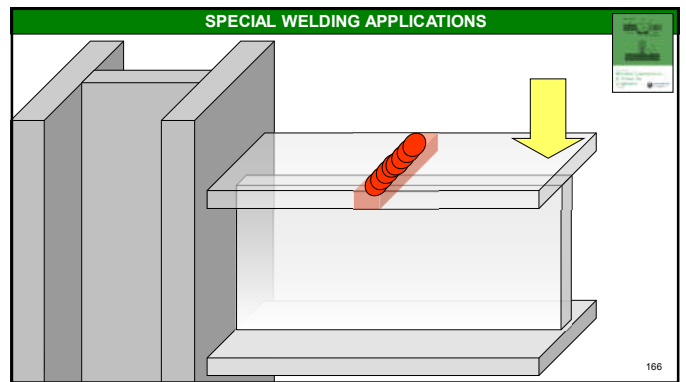
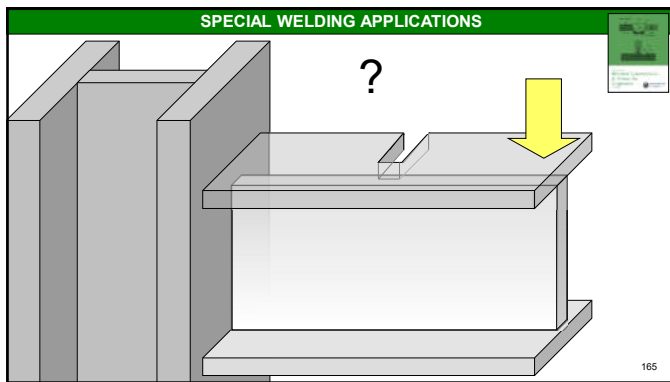
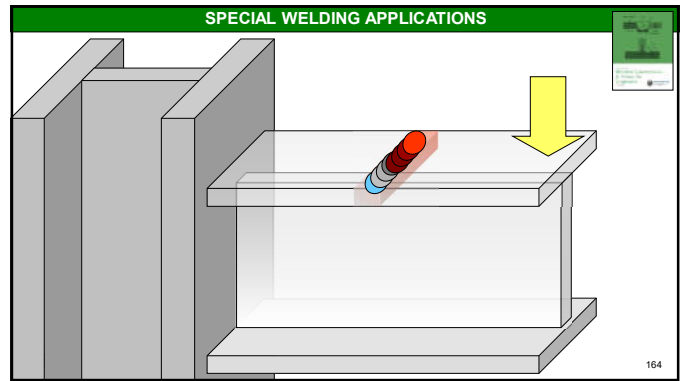
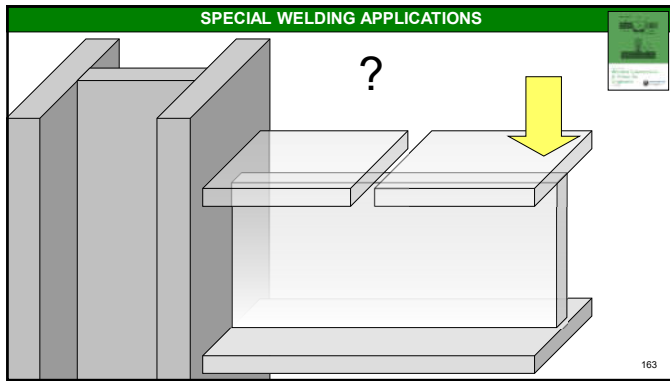
14.9 Welding on Existing Structures

- Historic steels
- Welding under load
- Fire
- Cold working / strain aging



159



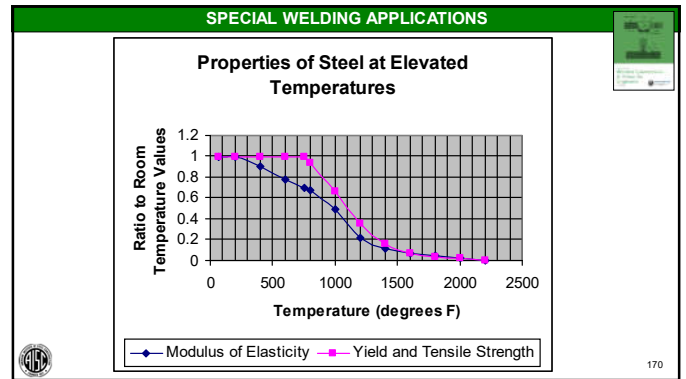


AISC 360-16 Specification for Structural Steel Buildings

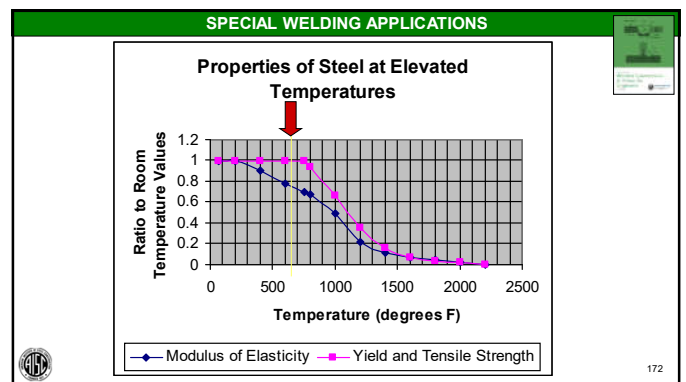
**Table A-4.2.1
 Properties of Steel at Elevated Temperatures**

Steel Temperature (°F) [°C]	$k_E = E_m / E$	$k_Y = F_{ym} / F_Y$	$k_U = F_{um} / F_Y$
68 [20]	*	*	*
200 [93]	1.00	*	*
400 [204]	0.90	*	*
600 [316]	0.78	*	*
750 [399]	0.70	1.00	1.00
800 [427]	0.67	0.94	0.94
1000 [538]	0.49	0.66	0.66
1200 [649]	0.22	0.35	0.35
1400 [760]	0.11	0.16	0.16
1600 [871]	0.07	0.07	0.07
1800 [982]	0.05	0.04	0.04
2000 [1093]	0.02	0.02	0.02
2200 [1204]	0.00	0.00	0.00

*Use ambient properties.



- SPECIAL WELDING APPLICATIONS**
- Welding on members under load**
- The amount of material at temperatures >650 °F is negligible (Blodgett)
 - Only a very small percentage of the cross section experiences reduced properties (Tide)
 - The impact of the weld orientation (longitudinal versus transverse) is typically inconsequential (Ricker)
 - Each situation should be checked




- SPECIAL WELDING APPLICATIONS**
- 14.9 Welding on Existing Structures**
- Historic steels
 - Welding under load
 - ➔ • Fire
 - Cold working / strain aging

- SPECIAL WELDING APPLICATIONS**
- Welding on Existing Structures**
- General precaution: Fire!
 - From combustibles
 - From unintended work circuits
 - Thermal cutting is typically >> problem than welding

SPECIAL WELDING APPLICATIONS

14.9 Welding on Existing Structures

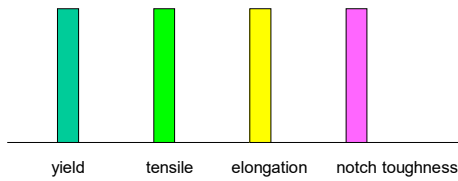
- Historic steels
- Welding under load
- Fire
- ➔ • Cold working / strain aging




175

SPECIAL WELDING APPLICATIONS

As received hot rolled steel



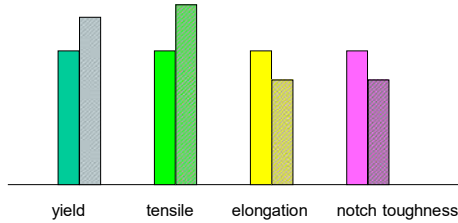
yield tensile elongation notch toughness




176

SPECIAL WELDING APPLICATIONS

Effects of cold working



yield tensile elongation notch toughness




177

SPECIAL WELDING APPLICATIONS

Strain Aging

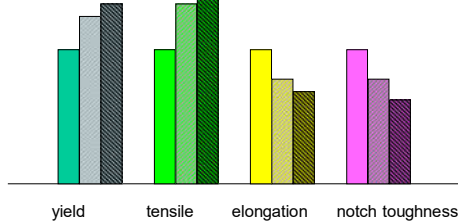
- Occurs when steel is heated to 400-700 °F
- Yield, tensile increase
- Ductility, notch toughness decrease
- Aggravated by presence of “free” nitrogen
- Stress relief helps, but...
 - Typically impractical
 - Depending on alloy, may experience cracking (Cr, Mo, V, B)




178

SPECIAL WELDING APPLICATIONS

Effects of strain aging



yield tensile elongation notch toughness



179

SPECIAL WELDING APPLICATIONS

Welding on plastically deformed members

- Reduced notch toughness
 - Make sure material is crack and notch free
- Reduced ductility
 - Minimize practices that increase ductility demand




180

AWS D1.1:2020 STRUCTURAL WELDING CODE

11. Strengthening and Repair of Existing Structures

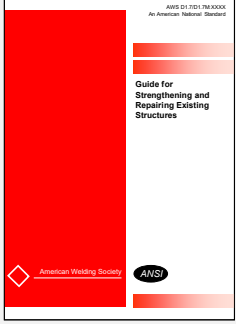

11.1 Scope

Strengthening or repair of an existing structure shall consist of modifications to meet design requirements, specified by the Engineer. This clause includes requirements for a comprehensive plan for the work, including design, workmanship, inspection, and documentation. The use of fatigue life enhancement methods is also described.



181

AWS D1.7
Guide for Strengthening and Repairing Existing Structures





182

SPECIAL WELDING APPLICATIONS

Welding on Existing Structures: Summary

- May involve historic steel: see DG 21 Chapter 4
- Welding on members under load: Caution
- Fire potential: sparks, resistance heating: Caution
- Welding on cold worked steel: local reduced ductility



183

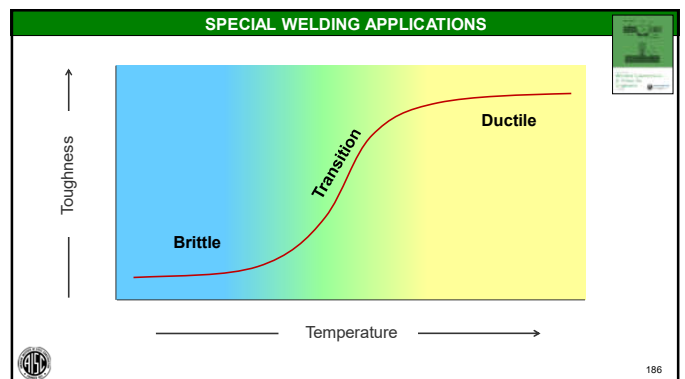
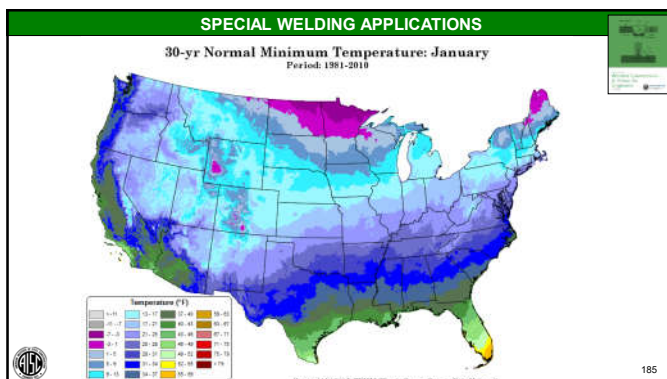
SPECIAL WELDING APPLICATIONS

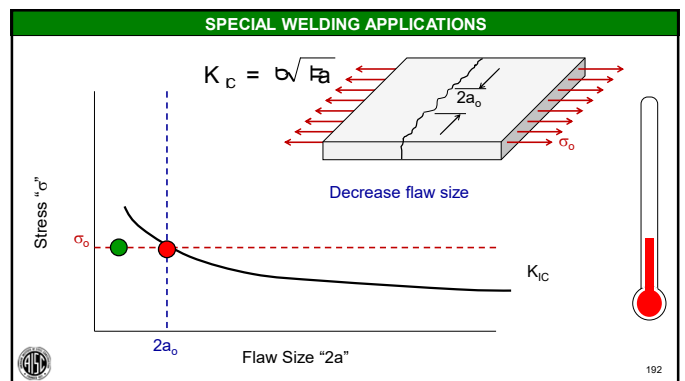
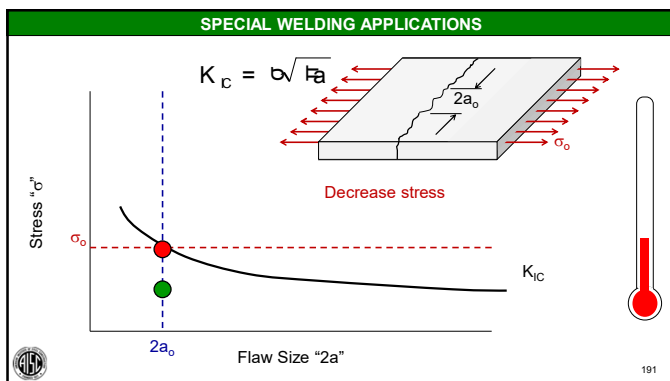
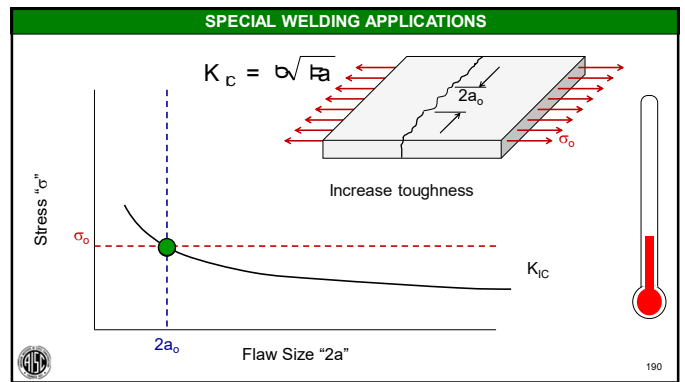
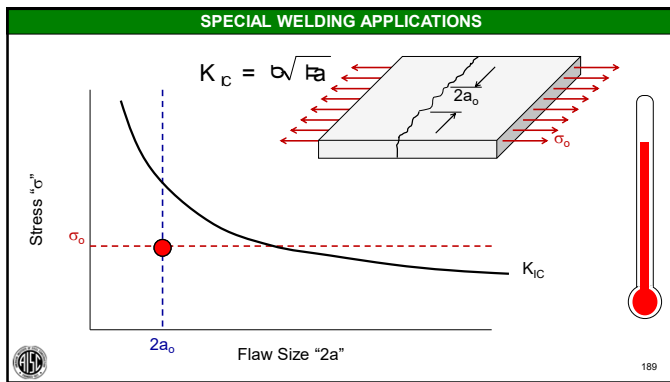
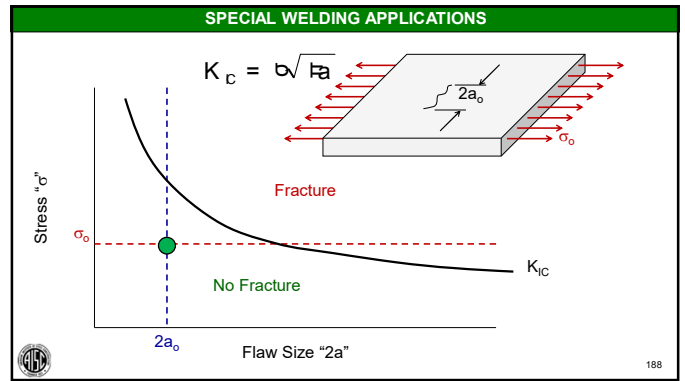
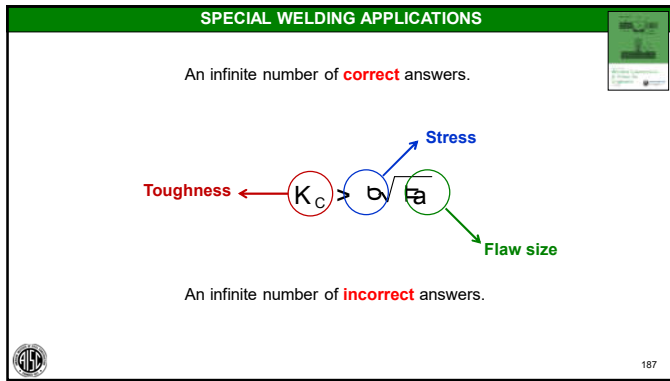
Today's Webinar

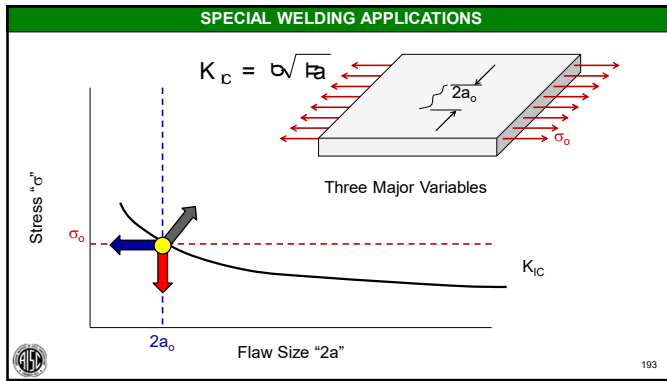
- 14.4 Welding on Heavy Shapes
- 14.6 Welding HSS
- 14.7 Welding AESS
- 14.8 Shop Versus Field Welding
- 14.9 Welding on Existing Structures
- ➔ 14.12 Cold Temperature Applications
- 14.15 Heat Shrinking
- 14.16 Buttering



184







AISC 360-16 Specification for Structural Steel Buildings

Commentary A3. MATERIAL

1a. ASTM Designations

"For especially demanding service conditions such as structures exposed to low temperatures, particularly those with impact loading, the specification of steels with superior notch toughness may be warranted."

$K_{IC} > \sigma \sqrt{Fa}$

194

AISC 360-16 Specification for Structural Steel Buildings

Commentary A3. MATERIAL

1a. ASTM Designations

"Good workmanship and good design details incorporating joint geometry that avoids severe stress concentrations are generally the most effective means of providing fracture-resistant construction."

$K_{IC} > \sigma \sqrt{Fa}$

195

SPECIAL WELDING APPLICATIONS

Cold Temperature Applications: Summary

Material Details Workmanship Inspection

For "good design details" and joint geometries that "avoid severe stress concentrations", consider Appendix 3 Design for Fatigue.

196

SPECIAL WELDING APPLICATIONS

Today's Webinar

- 14.4 Welding on Heavy Shapes
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- 14.16 Buttering

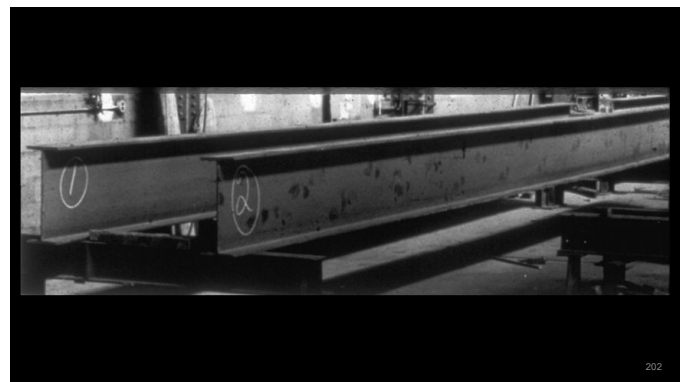
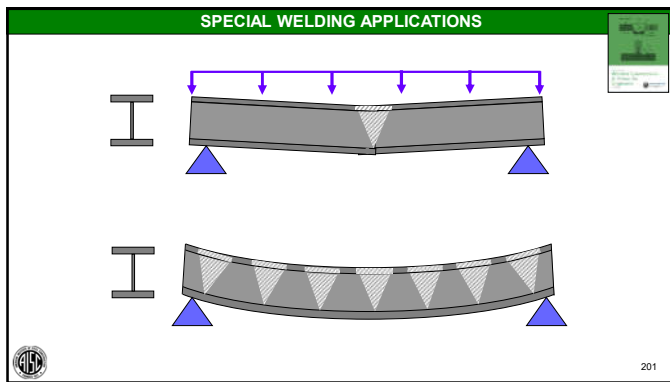
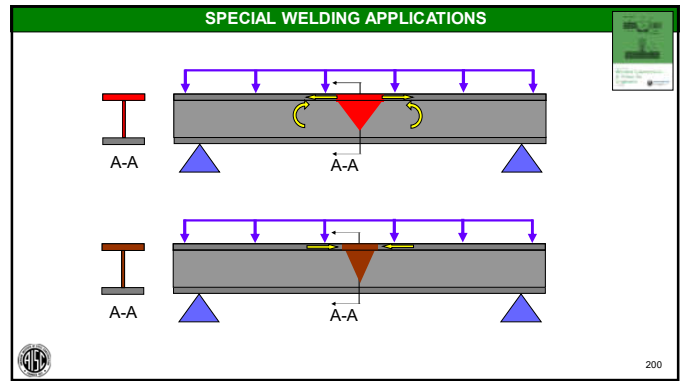
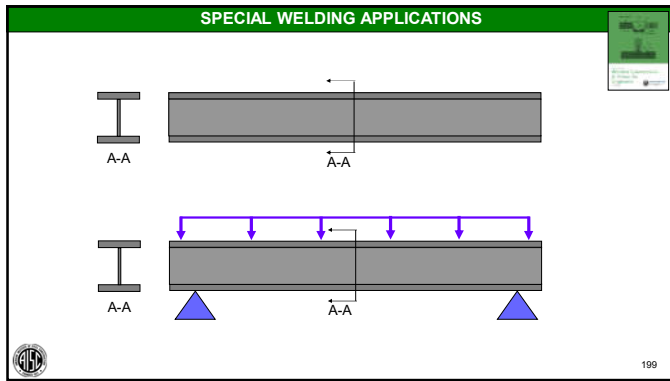
197

SPECIAL WELDING APPLICATIONS

Heat Shrinking

- Used to curve straight steel
- Used to straighten bent steel
- Used to correct for distortion
- Also known as "heat straightening"


198



SPECIAL WELDING APPLICATIONS

Heat Shrinking

- 1200 °F temperature limit for hot rolled steels
- 1100 °F temperature limit for quenched and tempered steels
- New limits for QST steels
- Pre-stress of up to 50% of room temperature yield (Avent)




205

AWS D1.1:2020 STRUCTURAL WELDING CODE

7.25.2 Localized Heat Repair Temperature Limitations.

Members distorted by welding shall be straightened by mechanical means or by application of a limited amount of localized heat. The temperature of heated areas as measured by approved methods shall not exceed 1100°F [600°C] for quenched and tempered steel nor 1200°F [650°C] for other steels. The part to be heated for straightening shall be substantially free of stress and from external forces, except those stresses resulting from the mechanical straightening method used in conjunction with the application of heat.




206

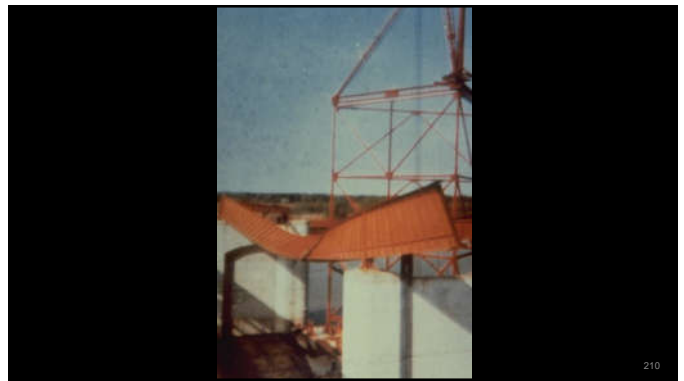
SPECIAL WELDING APPLICATIONS

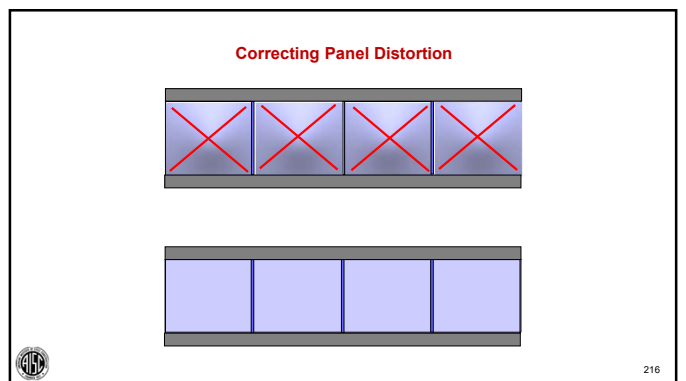
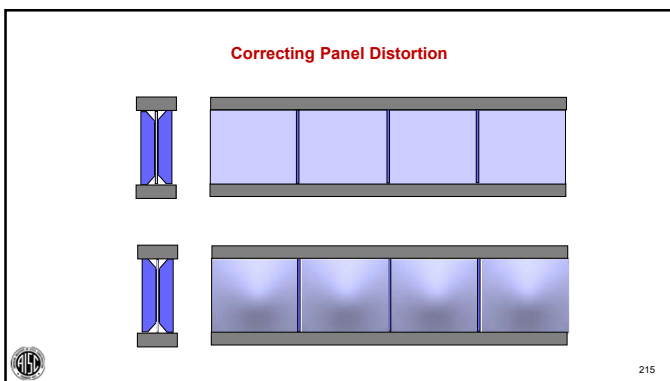
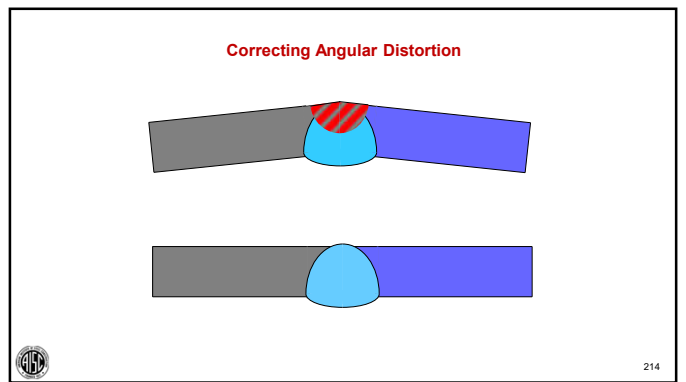
Heat Shrinking

- For new steel being curved
 - No change in modulus of elasticity (E)
 - Slight increase in yield and tensile strength
 - 10-25% increase in ductility
- For bent steel being straightened
 - Yield strength increases 10%
 - Tensile strength increases 4-6%



207






SPECIAL WELDING APPLICATIONS

Heat Shrinking: Summary

- Used for shaping and straightening steel
- Code limits on temperatures
- Material is not damaged if properly done



217

SPECIAL WELDING APPLICATIONS

Today's Webinar

- 14.4 Welding on Heavy Shapes
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- 14.7 Welding AESS
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- 14.9 Welding on Existing Structures
- 14.12 Cold Temperature Applications
- 14.15 Heat Shrinking
- ➔ 14.16 Buttering



218

SPECIAL WELDING APPLICATIONS

BUTTERING





219

AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2020)

buttering

A surfacing variation primarily use to provide metallurgically compatible weld metal for the subsequent completion of the weld.

See also buildup, cladding, and hardfacing.

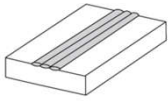


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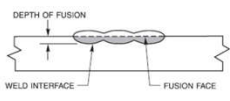
AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2020)

surfacing weld


A weld applied to a surface, as opposed to making a joint, to obtain desired properties or dimensions. See Figures B15(C) and B30(C).



(C) SURFACING WELD
Figure B15(C)



(C) SURFACING WELD
Figure B30(C)




221

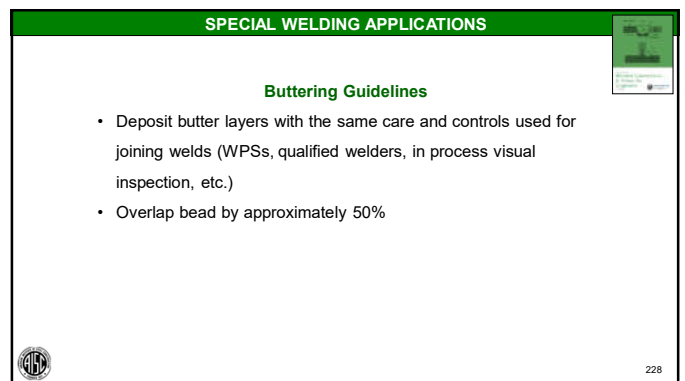
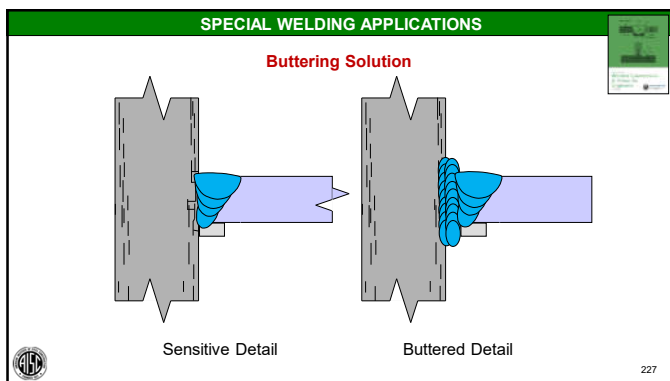
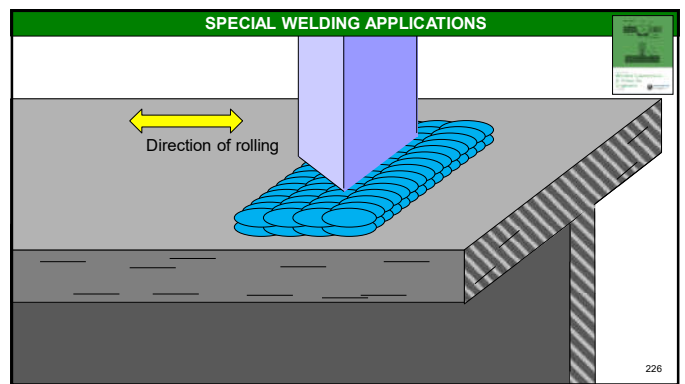
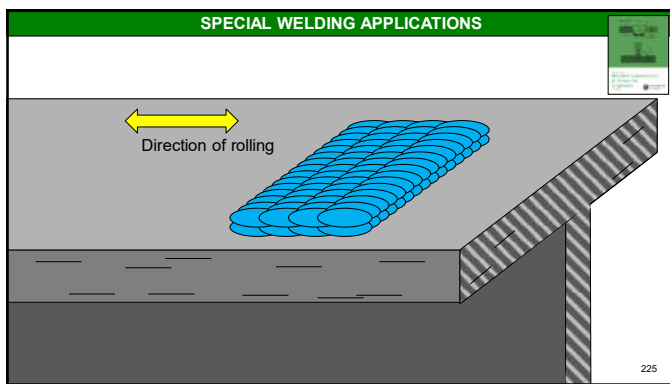
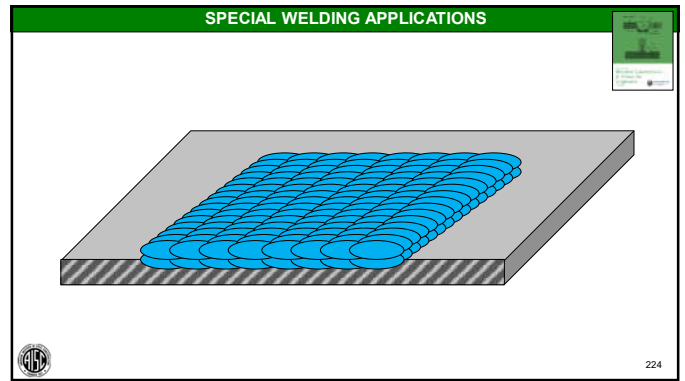
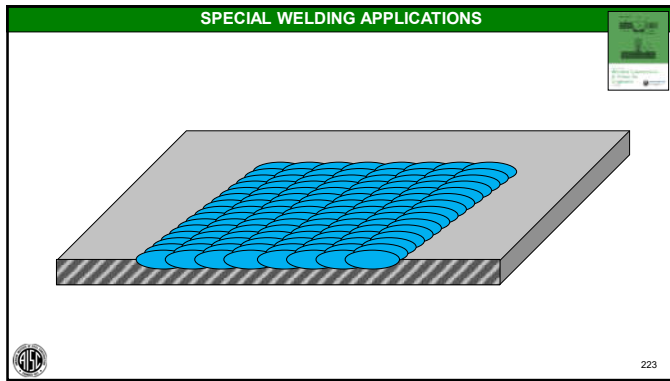
SPECIAL WELDING APPLICATIONS

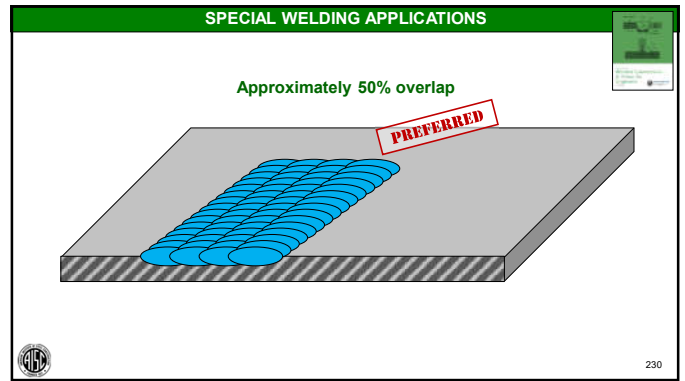
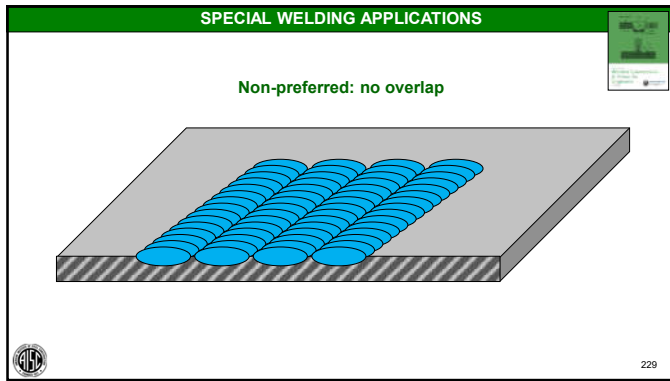
Buttering is used to:

- Mitigate lamellar tearing tendencies
- Build up the faces of groove weld joint cavities where root openings are excessive
- Restore material from steel that was damaged by corrosion
- Enable welding on "hard to weld" steels



222





SPECIAL WELDING APPLICATIONS

Buttering Guidelines

- Deposit butter layers with the same care and controls used for joining welds (WPSs. Qualified welders, in process visual inspection, etc.)
- Overlap bead by approximately 50%.
- If NDT of the weld to be made to the butter layer is required, the butter layer should also receive NDT.

231

This slide contains the title 'SPECIAL WELDING APPLICATIONS' at the top, followed by the section header 'Buttering Guidelines'. Below the header is a bulleted list of three guidelines. The AISC logo is in the bottom left corner, and the number 231 is in the bottom right corner.

SPECIAL WELDING APPLICATIONS

Buttering: Summary

- Build up out-of-tolerance joints
- One method to mitigate lamellar tearing
- Buttering procedures should be consistent with the applicable code, including final quality requirements

232

This slide contains the title 'SPECIAL WELDING APPLICATIONS' at the top, followed by the section header 'Buttering: Summary'. Below the header is a bulleted list of three summary points. The AISC logo is in the bottom left corner, and the number 232 is in the bottom right corner.

SPECIAL WELDING APPLICATIONS

Today's Webinar

- 14.4 Welding on Heavy Shapes
- 14.6 Welding HSS
- 14.7 Welding AESS
- 14.8 Shop Versus Field Welding
- 14.9 Welding on Existing Structures
- 14.12 Cold Temperature Applications
- 14.15 Heat Shrinking
- 14.16 Buttering

233

This slide contains the title 'SPECIAL WELDING APPLICATIONS' at the top, followed by the section header 'Today's Webinar'. Below the header is a list of seven webinar topics. The AISC logo is in the bottom left corner, and the number 233 is in the bottom right corner.

SPECIAL WELDING APPLICATIONS

234

This slide contains the title 'SPECIAL WELDING APPLICATIONS' at the top. The AISC logo is in the bottom left corner, and the number 234 is in the bottom right corner.

Thank you!

AISC | Questions



Individual Session Registrants

PDH Certificates

- All WFH individuals associated with a group registration will be issued a certificate.
- All individuals attending at your connection: you will receive an email on how to report their 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!

8-Session Registrants

PDH Certificates

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

8-Session Registrants

Access to the quiz

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

Quiz and attendance records

Posted Friday 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

8-Session Registrants

Access to the recording

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

PDHs via recording

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

8-Session Registrants

Night School Resources

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

8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.

8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.

8-Session Registrants

Night School Resources

Course	Start/End
My 8-Session Design Night School 27 - Design of Industrial Buildings	10/18/21 - 10/18/21 AM
My 8-Session Design Night School 27 - Fundamentals of Bolting	10/18/21 - 10/18/21 AM

8-Session Registrants

Night School Resources

Event	Date	Materials	Video	Quiz	Attendance
NS13 - Design Office	10/18/21 10:00 AM	09/02/20	0/00	Pass	Participate
NS13 - Structural Connections	10/18/21 10:00 AM	09/02/20	0/00	Scale 80	Participate
NS13 - Lateral Load Systems and Details	10/18/21 10:00 AM	09/02/20	Available 10/18/2017 10:00 EST	Available 10/18/2017 10:00 EST	Participate
NS13 - Moment-Resisting Frames	10/18/21 10:00 AM	09/02/20	Available 10/18/2017 10:00 EST	Available 10/18/2017 10:00 EST	Participate
NS13 - Core-Drift Design and Frame Analysis	10/18/21 10:00 AM	09/02/20	Available 10/18/2017 10:00 EST	Available 10/18/2017 10:00 EST	Participate
NS13 - Frame Member and Connection Design	10/18/21 10:00 AM	09/02/20	Available 10/18/2017 10:00 EST	Available 10/18/2017 10:00 EST	Participate
NS13 - Transfer Core-Drift Longitudinal Strip Beams	10/18/21 10:00 AM	09/02/20	Available 10/18/2017 10:00 EST	Available 10/18/2017 10:00 EST	Participate
NS13 - Building Envelope and Building Design	10/18/21 10:00 AM	09/02/20	Available 10/18/2017 10:00 EST	Available 10/18/2017 10:00 EST	Participate

8-Session Registrants

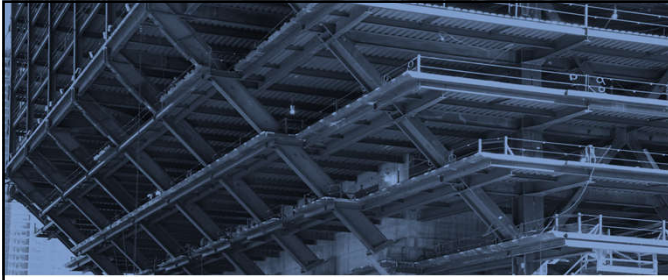
Night School Resources

- Weekly “quiz and recording” email.
- Weekly updates of the master quiz and attendance record, found at www.aisc.org/nightschool27. Scroll down to Quiz and Attendance records.
 - Updated on Friday mornings.

8-Session Registrants

Night School Resources

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



AISC | Thank you

