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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

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Course Description

Part 3: Special Welding Applications and Field Fixes

July 13, 2017

This session covers atypical welding applications for buildings. The session presents practical, straightforward solutions to challenging situations including: extending anchor bolts, welding on coated steels, welding AESS, welding on existing structures, welding heavy sections, welding under high restraint, field welding and heat shrinking.

Learning Objectives

- Name four weldability concerns with extending anchor rods.
- Describe tolerance issues that may affect welded connections in AESS structures.
- Identify welded HSS connections where member configurations could prevent proper welding, inspection or assembly.
- Identify situations where rolled heavy shapes in welded connections may perform poorly.

There's always a solution in steel.

Welded Connections

Part 3: Special Welding Applications and Field Fixes
July 13, 2017

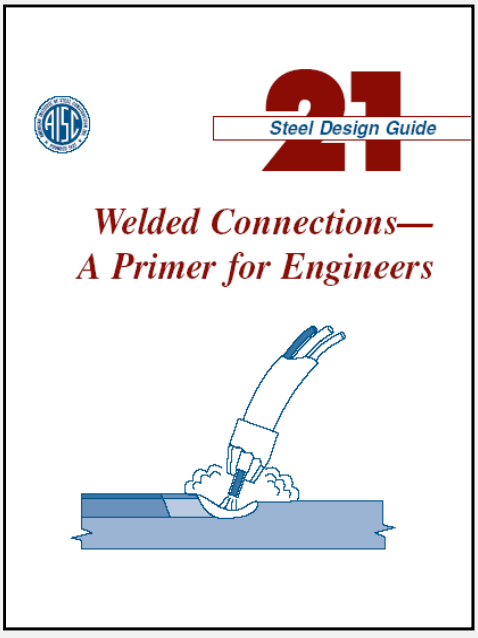
Presented by
Duane Miller, Sc.D., P.E.
Manager of Engineering Services and Welding Design Consultant at The Lincoln Electric Company
Cleveland, OH

structural STEEL

Special Welding Applications and Field Fixes

Chapter 12

Special Welding Applications

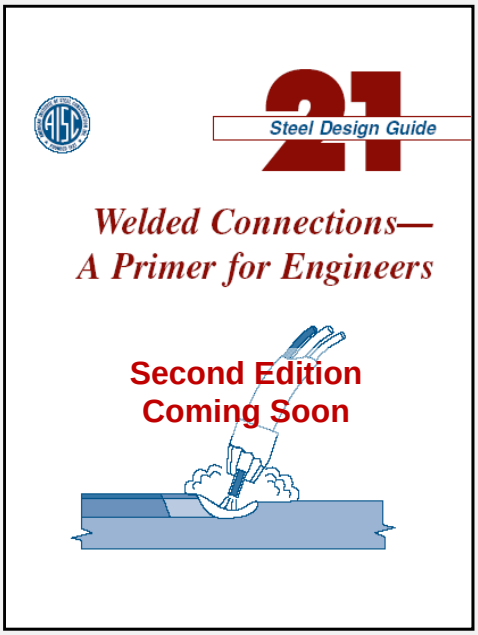


Chapter 14

Special Welding Applications

Chapter 15

Problems and Fixes



14. SPECIAL WELDING APPLICATIONS

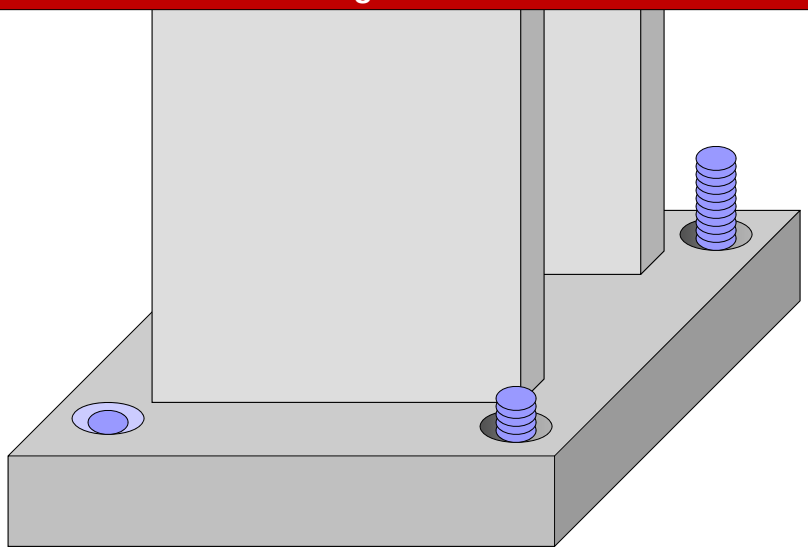
15 PROBLEMS AND FIXES

15.1 Repairs to Base Metal
15.2 Repairs to Cut Edges
15.3 Butt Joint Alignment
15.4 Out-of-tolerance Weld Joints
15.5 Fixing Members That Are Cut Short
15.6 Repair of Mislocated Holes
15.7 Use of Plug Welds In Lieu Of Bolts
15.8 Repairs to Welds
15.9 Heat Shrinking of Q&T Steel
15.10 Unspecified Welds
15.11 Welds Made Without Inspection
15.12 Welding on Anchor Rods
15.13 Welding Anchor Rod to Base Plates
15.14 Removing and Reinstalling Column Base Plates
15.15 Repairing Lamellar Tears

Special Welding Applications and Field Fixes

- Welding on Anchor Rods
- Welding on Heavy Sections (“Jumbo Shapes”)
- Welding HSS
- Welding AESS
- Field Welding
- Welding on Existing Structures
- Combining Welds and Bolts

Special Welding Applications and Field Fixes: Extending Anchor Rods



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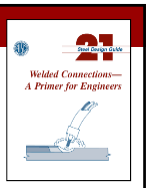
Design Guide 21: Welded Connections



12. Special Welding Applications

12.1 WELDING ON ANCHOR RODS

12.1.1 General

Before any welding on anchor rods is considered, the rod's composition must be considered, as addressed in detail in Section 4.3.4 of this Guide. This point cannot be overstressed; material with unknown or poor weldability simply should not be welded upon until appropriate testing and analysis has been performed.

12.1.2 Extending Anchor Rods

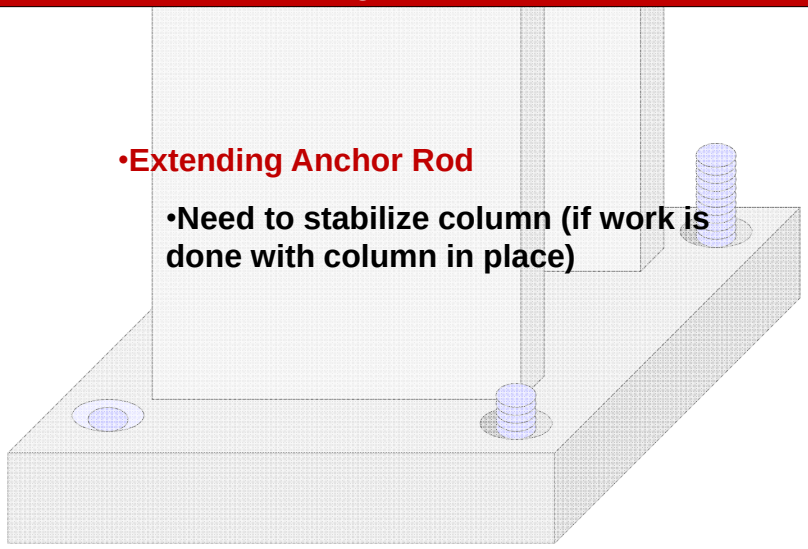
When an anchor rod is set too deep, there may be an inadequate length of thread available for proper engagement of the nut. In extreme conditions, the end of the anchor rod may be below the top surface of the base plate. Possible solutions that involve welding are often offered, but such approaches must be carefully evaluated.

Even when a weldable anchor rod is involved, several commonly proposed corrective concepts are problematic. For example, if the rod is very short, some may be tempted to use a plug weld in the base plate to weld on to the end of the

A connection detail has been developed to address some of the problematic aspects associated with anchor rod extension (Fisher and Kloiber, 2006). The weld joint involved is a double-sided horizontal bevel groove weld. The extension rod is prepared by applying two bevels that form a chisel-like configuration (not a pencil point) as shown in Figure 12–1. A ring or washer is made from steel with a known weldability, and of a thickness great enough that welds will not melt through it. The top surface of the ring is positioned so that it is flush with the too-short rod. The ring acts as a weld tab, allowing the arc starts and stops to be placed outside of the width of the anchor rod. As with prequalified double-sided welds, the root region of the first weld pass should be backgouged before the second side is welded. When the welding is complete, the ring can be removed by grinding or other methods and finally, the weld can be ground flush around the perimeter.

Welding is typically performed with SMAW using electrodes with low-hydrogen coatings. The strength of the electrode must be selected to match the strength of the anchor rod used. Depending on the rod composition, preheat may

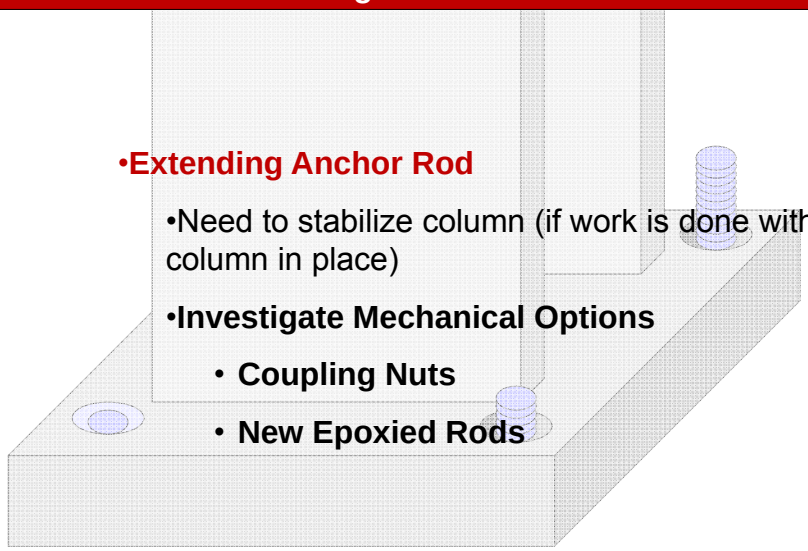
Special Welding Applications and Field Fixes: Extending Anchor Rods



- **Extending Anchor Rod**
  - **Need to stabilize column (if work is done with column in place)**

17

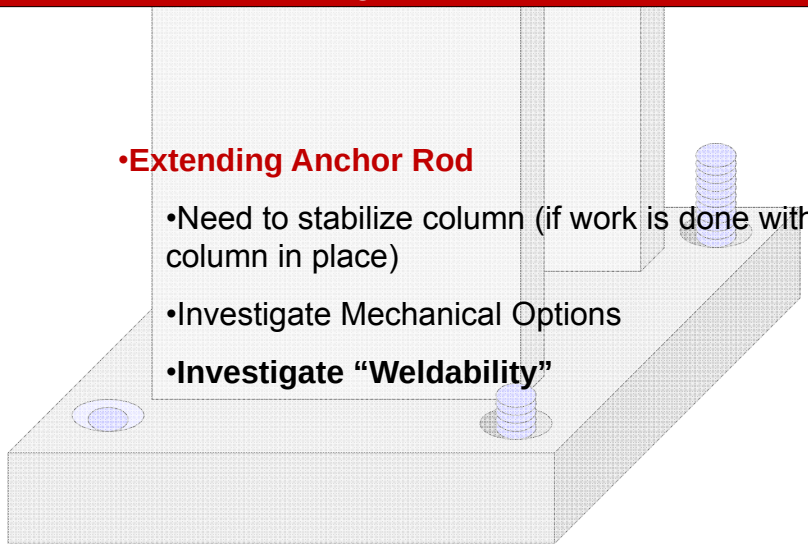
Special Welding Applications and Field Fixes: Extending Anchor Rods



- **Extending Anchor Rod**
  - Need to stabilize column (if work is done with column in place)
  - **Investigate Mechanical Options**
    - **Coupling Nuts**
    - **New Epoxied Rods**

18

Special Welding Applications and Field Fixes: Extending Anchor Rods



- **Extending Anchor Rod**
  - Need to stabilize column (if work is done with column in place)
  - Investigate Mechanical Options
  - **Investigate "Weldability"**

19

Weldability

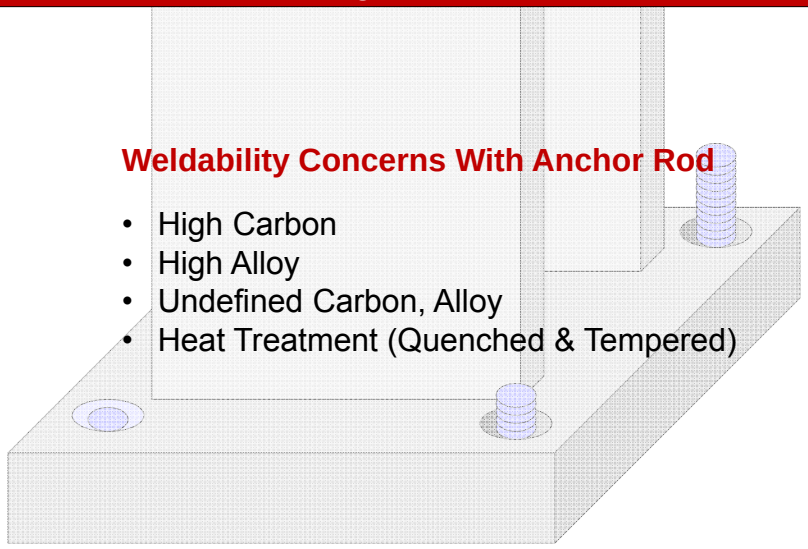
- Based on composition
- Driven by carbon content
- Compounded by alloy content
- Related to "hardenability"
- "Hot cracking" concerns as well (S, P, others)

Weldability: How easily can the material be welded

NOT can the material be welded

20

Special Welding Applications and Field Fixes: Extending Anchor Rods

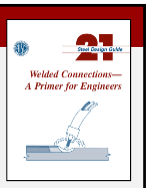


Weldability Concerns With Anchor Rod

- High Carbon
- High Alloy
- Undefined Carbon, Alloy
- Heat Treatment (Quenched & Tempered)

21

Design Guide 21: Welded Connections



Metallurgical Issues

4.5 Welding Nonstructural Steels

4.5.1 Anchor Rods

ASTM A307

ASTM A325

ASTM A354

ASTM A449

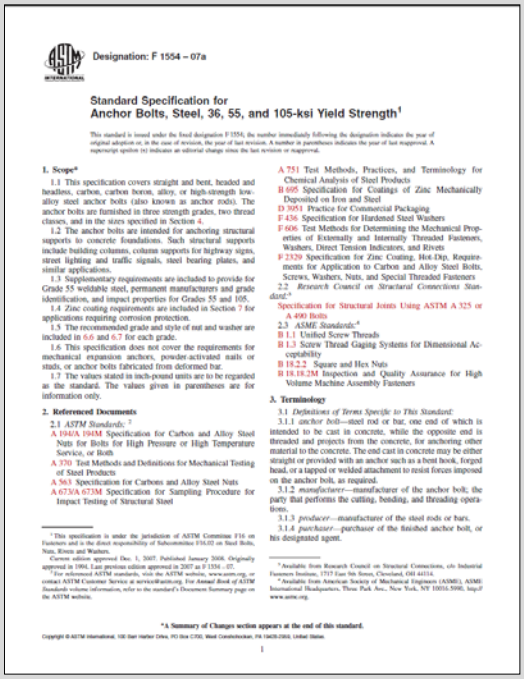
ASTM A675

➡ ASTM F1554

22

ASTM A1554-07a

Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength



Designation: F 1554 – 07a

Standard Specification for
Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength[1]

This standard is issued under the fixed designation F 1554; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers straight and bent, headed and headless, carbon, carbon boron, alloy, or high-strength low-alloy steel anchor bolts (also known as anchor rods). The anchor bolts are furnished in three strength grades, two thread classes, and in the sizes specified in Section 4.

1.2 The anchor bolts are intended for anchoring structural supports to concrete foundations. Such structural supports include building columns, column supports for highway signs, street lighting and traffic signals, steel bearing plates, and similar applications.

1.3 Supplementary requirements are included to provide for Grade 55 weldable steel, permanent manufacturers and grade identification, and impact properties for Grades 55 and 105.

1.4 Zinc coating requirements are included in Section 7 for applications requiring corrosion protection.

1.5 The recommended grade and style of nut and washer are included in 6.6 and 6.7 for each grade.

1.6 This specification does not cover the requirements for mechanical expansion anchors, powder-activated nails or studs, or anchor bolts fabricated from deformed bar.

1.7 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 563 Specification for Carbons and Alloy Steel Nuts

A 673/A 673M Specification for Sampling Procedure for Impact Testing of Structural Steel

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

D 3951 Practice for Commercial Packaging

F 436 Specification for Hardened Steel Washers

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets

F 2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

2.2 *Research Council on Structural Connections Standard:* [3]

Specification for Structural Joints Using ASTM A 325 or A 490 Bolts

2.3 *ASME Standards:* [4]

B 1.1 Unified Screw Threads

B 1.3 Screw Thread Gaging Systems for Dimensional Acceptability

B 18.2.2 Square and Hex Nuts

B 18.18.2M Inspection and Quality Assurance for High Volume Machine Assembly Fasteners

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *anchor bolt*—steel rod or bar, one end of which is intended to be cast in concrete, while the opposite end is threaded and projects from the concrete, for anchoring other material to the concrete. The end cast in concrete may be either straight or provided with an anchor such as a bent hook, forged head, or a tapped or welded attachment to resist forces imposed on the anchor bolt, as required.

3.1.2 *manufacturer*—manufacturer of the anchor bolt; the party that performs the cutting, bending, and threading operations.

3.1.3 *producer*—manufacturer of the steel rods or bars.

3.1.4 *purchaser*—purchaser of the finished anchor bolt, or his designated agent.

[1] This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets and Washers.

Current edition approved Dec. 1, 2007. Published January 2008. Originally approved in 1994. Last previous edition approved in 2007 as F 1554 – 07.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Research Council on Structural Connections, c/o Industrial Fasteners Institute, 1717 East 9th Street, Cleveland, OH 44114.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

* A Summary of Changes section appears at the end of this standard.

ASTM A1554-07a

Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

Three Grades

4. Classification

4.1 The anchor bolts are furnished in three grades denoting minimum yield strength and two classes denoting thread class as follows:

Grade	Tensile Strength, ksi (MPa)	Description Yield Strength, min, ksi (MPa)	Size Range, in. (mm)
36[A]	58–80 (400–558)	36 (248)	¼ –4 (6.4–102)
55	75–95 (517–655)	55 (380)	¼ –4 (6.4–102)
105	125–150 (862–1034)	105 (724)	¼ –3 (6.4–76)

Class	
1A	anchor bolts with Class 1A threads
2A	anchor bolts with Class 2A threads

[A] When Grade 36 is specified, a weldable Grade 55 may be furnished at the supplier's option.

ASTM A1554-07a

Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

4.2 Weldable steel for Grade 55 is provided for in Supplementary Requirement SI.

25

ASTM A1554-07a

Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

Substitution option: weldable Grade 55 for Grade 36

4. Classification

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26

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Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

Permitted Options	
Ordered	**Delivered**
Grade 36	Grade 36
	Grade 55 S1
Grade 55	Grade 55
	Grade 55 S1
Grade 55 S1	Grade 55 S1
Grade 105	Grade 105

27

ASTM A1554-07a

Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

Permitted Options	
Ordered	**Delivered**
Grade 36	Grade 36
	Grade 55 S1
Grade 55	Grade 55
	Grade 55 S1
Grade 55 S1	Grade 55 S1
Grade 105	Grade 105

Four Types to be Considered

28

ASTM A1554-07a

Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

Grade 36

TABLE 1 Chemical Requirements for Grade 36

Element	Diameter, in. (mm)		
	To ¾ (20), incl	Over ¾ to 1½ (20 to 40), incl	Over 1½ to 4 (40 to 100), incl
Carbon, max, %			
Heat	0.26	27	0.28
Product	0.29	0	0.31
Manganese, %			
Heat	[A]	0–0.90	0.60–0.90
Product		0.54–0.98	0.54–0.98
Phosphorus, max, %			
Heat		0.04	0.04
Product		0.05	0.05
Sulfur, max, %			
Heat	0.05	0.05	0.05
Product	0.06	0.06	0.06
Copper, min, % (when specified)			
Heat	0.20	0.20	0.20
Product	0.18	0.18	0.18

[A] Optional with the manufacturer but shall be compatible with weldable steel.

Similar to A36

29

ASTM A1554-07a

Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

Grade 55

Grade 105

TABLE 2 Chemical Requirements for Grades 55 and 105

Element	Composition, %	
	Heat Analysis	Product Analysis
Phosphorous, max	0.040	0.048
Sulfur, max	0.050	0.058
Copper, min (when Cu is specified)	0.20	0.18

No controls on carbon or alloy content

30

ASTM A1554-07a

Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

Grade 55 S1

S1. Grade 55 Bars and Anchor Bolts

S1.1 The material described in this section is intended for welding. This supplemental section, by chemical composition restrictions and by a carbon equivalent formula, provides assurance of weldability.

S1.2 Welding technique is of fundamental importance when bolts produced to this supplementary section are welded. It is assumed that suitable welding procedures for the steel being welded and the intended service will be selected.

31

ASTM A1554-97a

Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

Grade 55 S1

S1.5 *Chemical Composition:*

S1.5.1 Steel shall conform to the following limitations:

	Heat Analysis	Product Analysis
Carbon, max, %	0.30	0.33
Manganese, max, %	1.35	1.41
Phosphorus, max, %	0.040	0.048
Sulfur, max, %	0.050	0.058
Silicon, max, %	0.50	0.55

Cold Cracking Controls

Hot Cracking Controls

32

Grade 55 S1

ASTM A1554-97a

Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

S1.5.2 *Carbon Equivalent*—In addition to the requirements specified in S1.5.1, the analysis shall be such as to provide a carbon equivalent (CE) meeting the following requirements:

S1.5.2.1 For alloy or low-alloy steel, the carbon equivalent shall not exceed 0.45 % when calculated as follows:

$$CE = \%\,C + \frac{\%\,Mn}{6} + \frac{\%\,Cu}{40} + \frac{\%\,Ni}{20} + \frac{\%\,Cr}{10} - \frac{\%\,Mo}{50} - \frac{\%\,V}{10}$$

S1.5.2.2 For carbon steel, the carbon equivalent shall not exceed 0.40 % when calculated as follows:

$$CE = \%\,C + \frac{\%\,Mn}{4}$$

33

Grade 36

- Chemistry is similar to that of ASTM A36
- Deviation on Mn permitted only for smaller rods
- If Grade 55 is substituted, only weldable (S1) material may be used

Weldability should be good.

34

Grade 55

- The only chemistry control is on S, P (and Cu, when Cu is specified)
- No weldability promises

Weldability should be investigated on a case-by-case basis.

35

Grade 55 S1

- Chemistry is similar to that of ASTM A36
- Carbon equivalency limits
- "The material described in this section is intended for welding."
- "This supplemental section...provides assurance of weldability."

Weldability should be good.

36

Grade 105

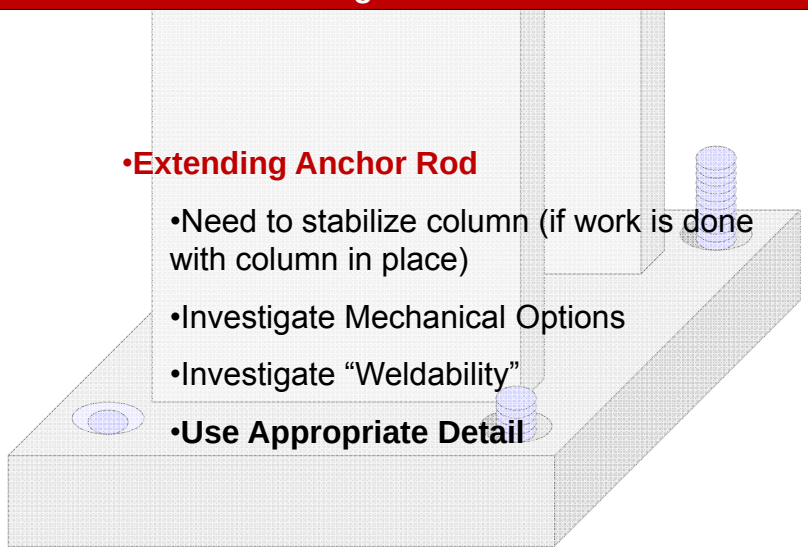
- The only chemistry control is on S, P (and Cu, when Cu is specified)
- No weldability promises
- High strength (105 ksi yield)
- May be quenched and tempered

Weldability is likely to be poor.

Caveat: poor weldability does not mean unweldable.

37

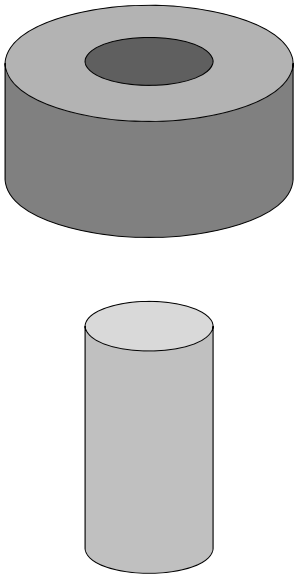
Special Welding Applications and Field Fixes: Extending Anchor Rods



- **Extending Anchor Rod**
  - Need to stabilize column (if work is done with column in place)
  - Investigate Mechanical Options
  - Investigate "Weldability"
  - **Use Appropriate Detail**

38

Cut “donut” from weldable steel—same ID as OD of rod.



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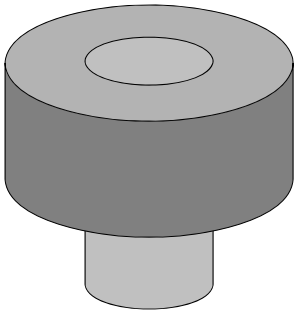
“Donut” acts as weld tab and shelf bar.



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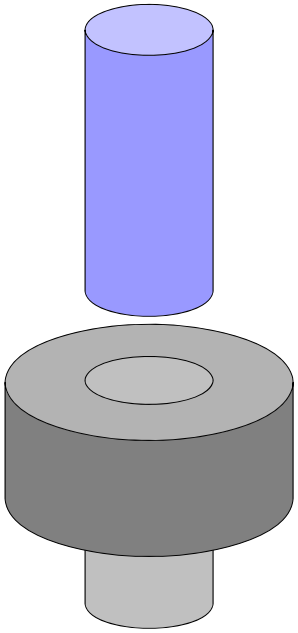
Use weldable steel for the extension.



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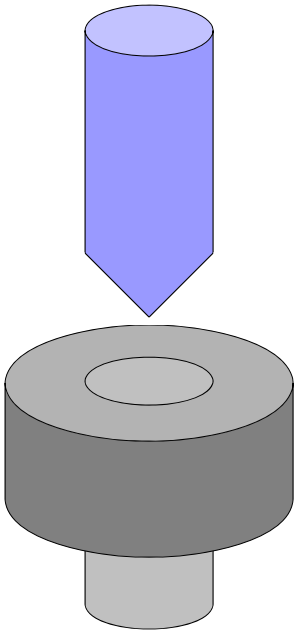
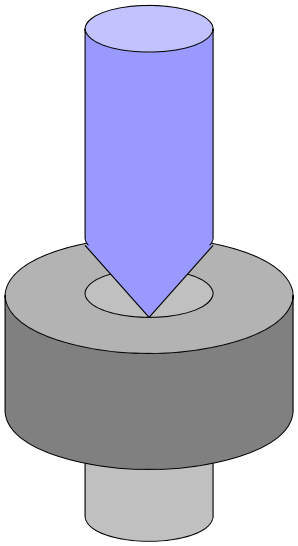
Grind extension to a chisel point (not pencil point).



42

Assemble



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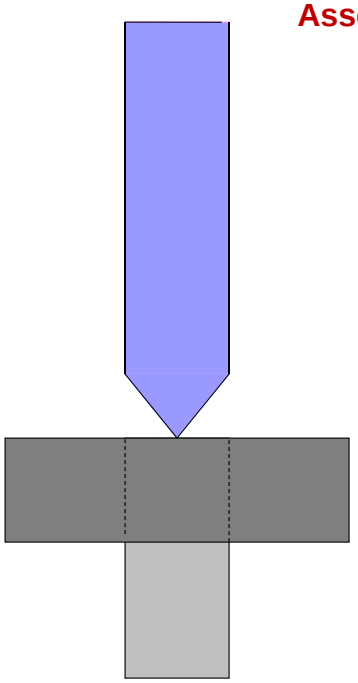

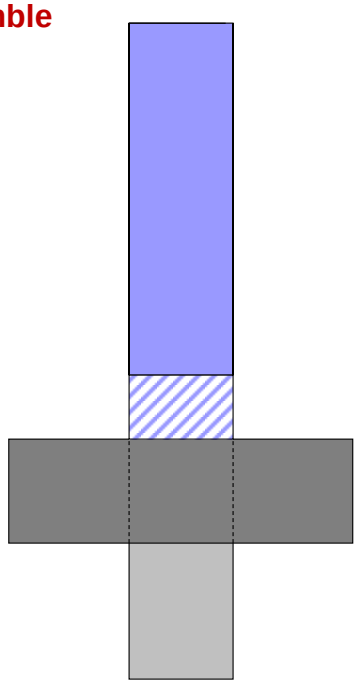

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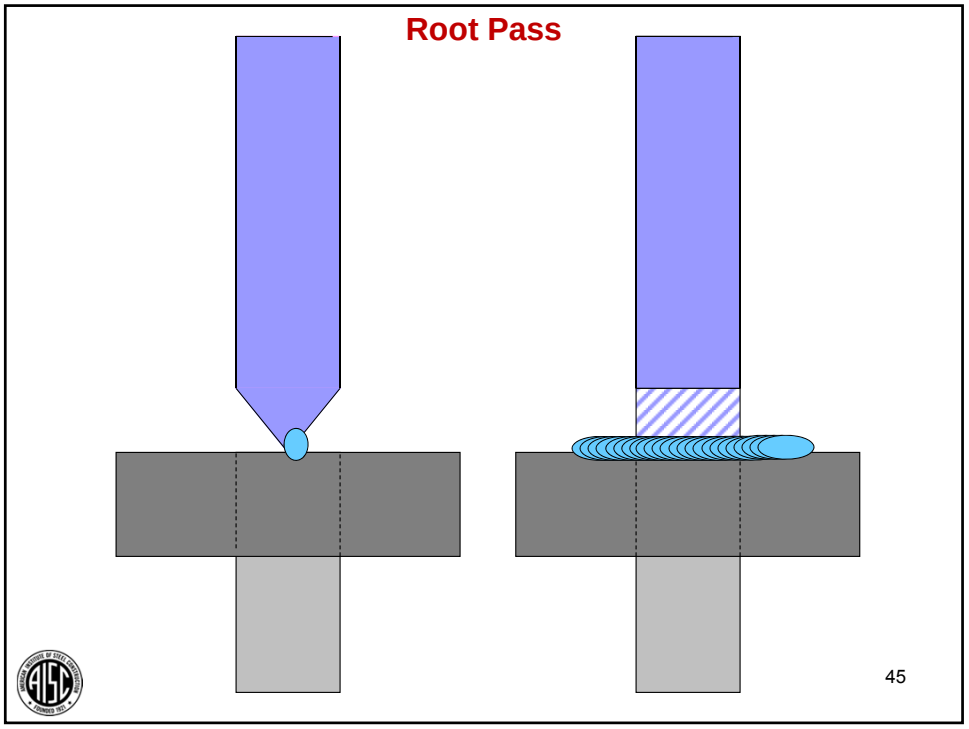

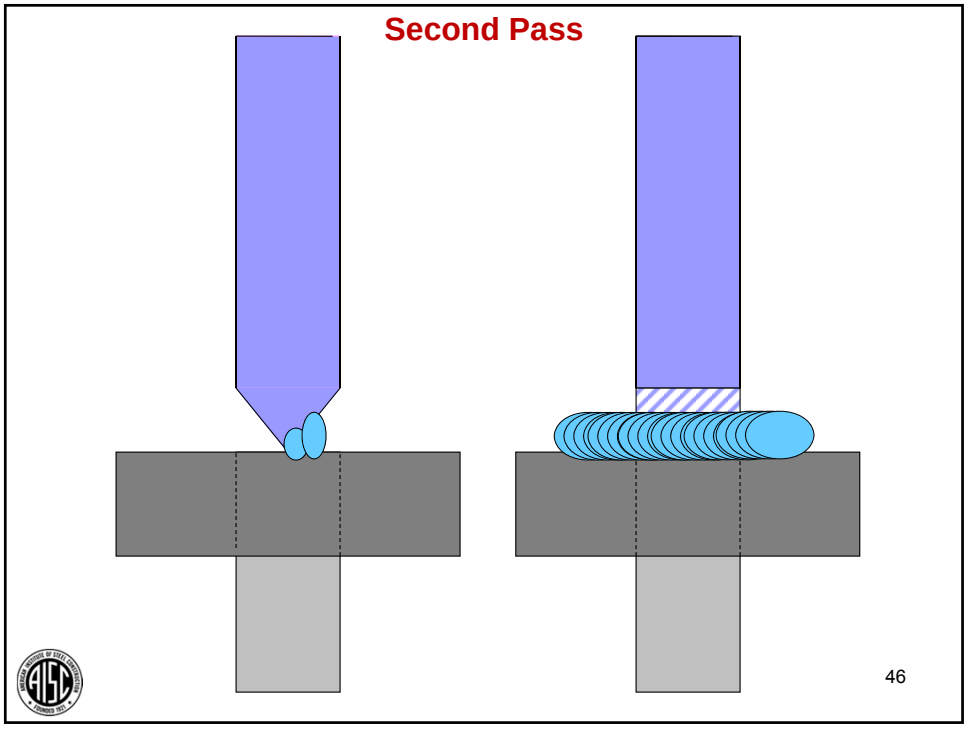

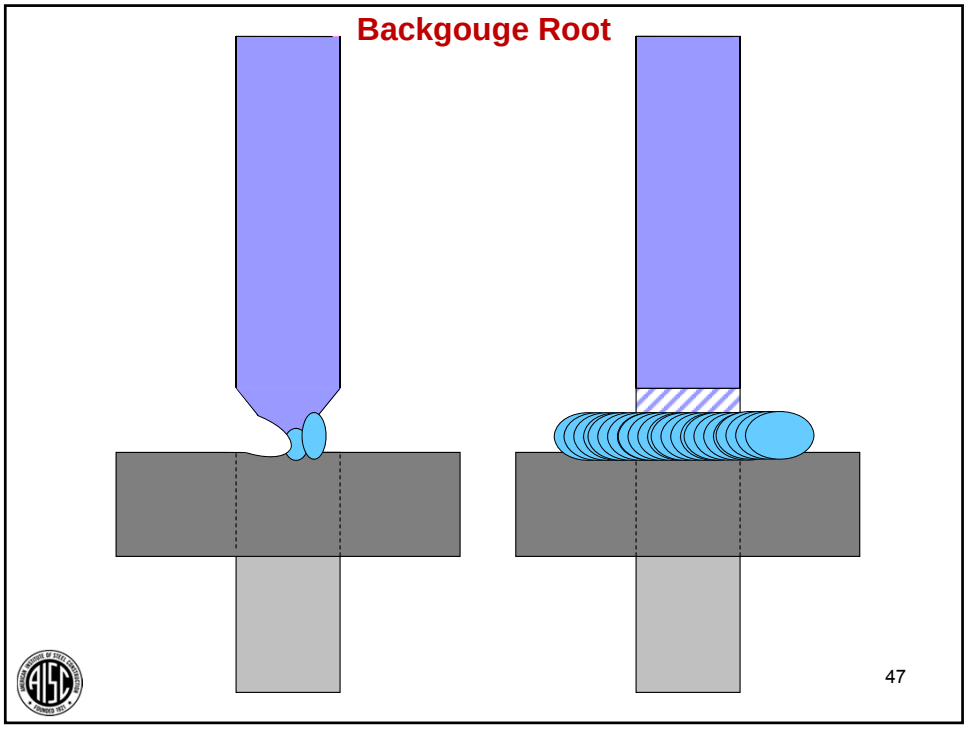

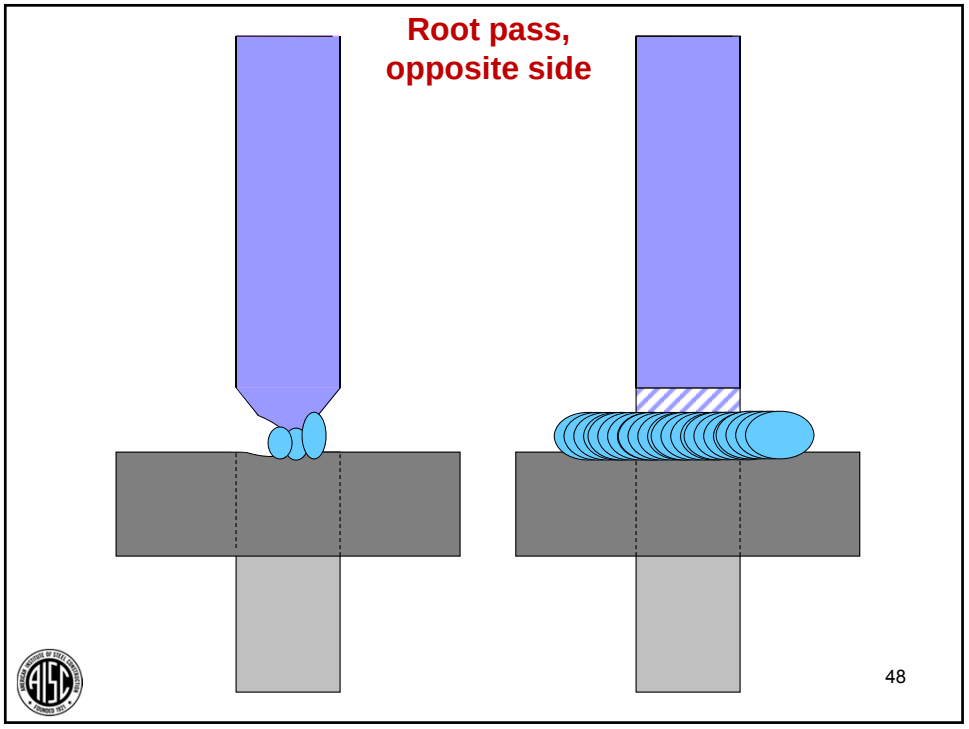

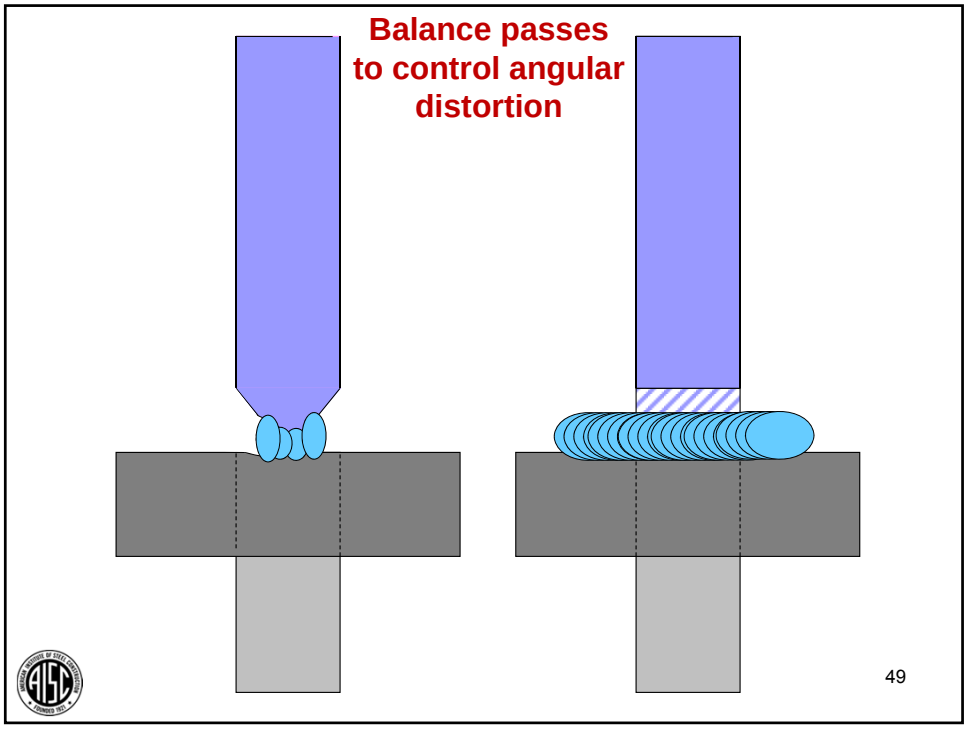

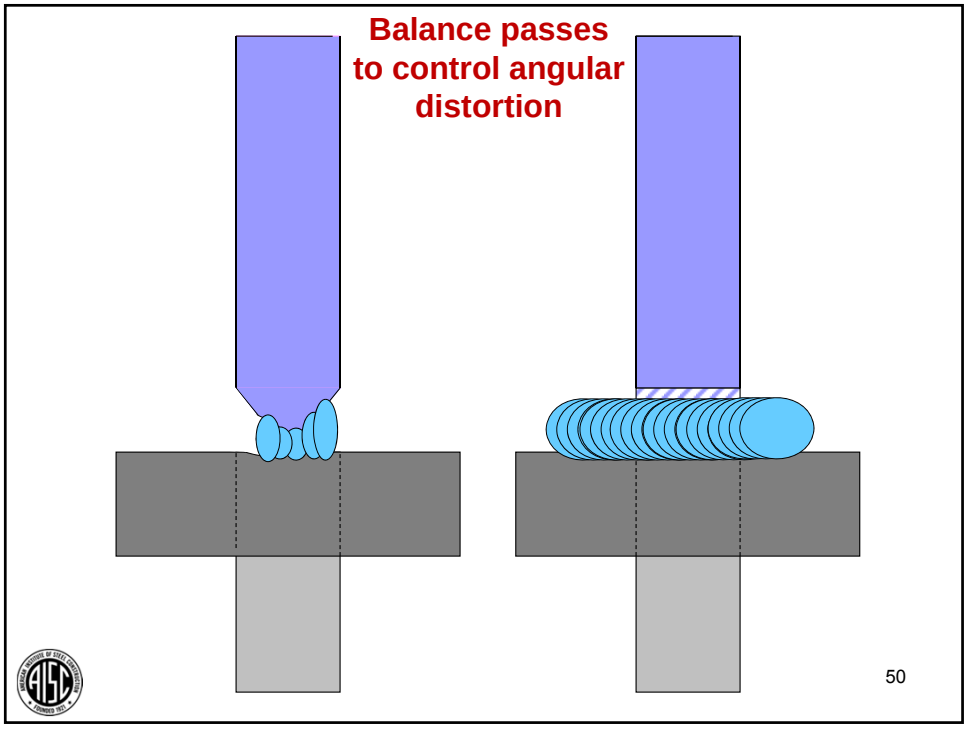

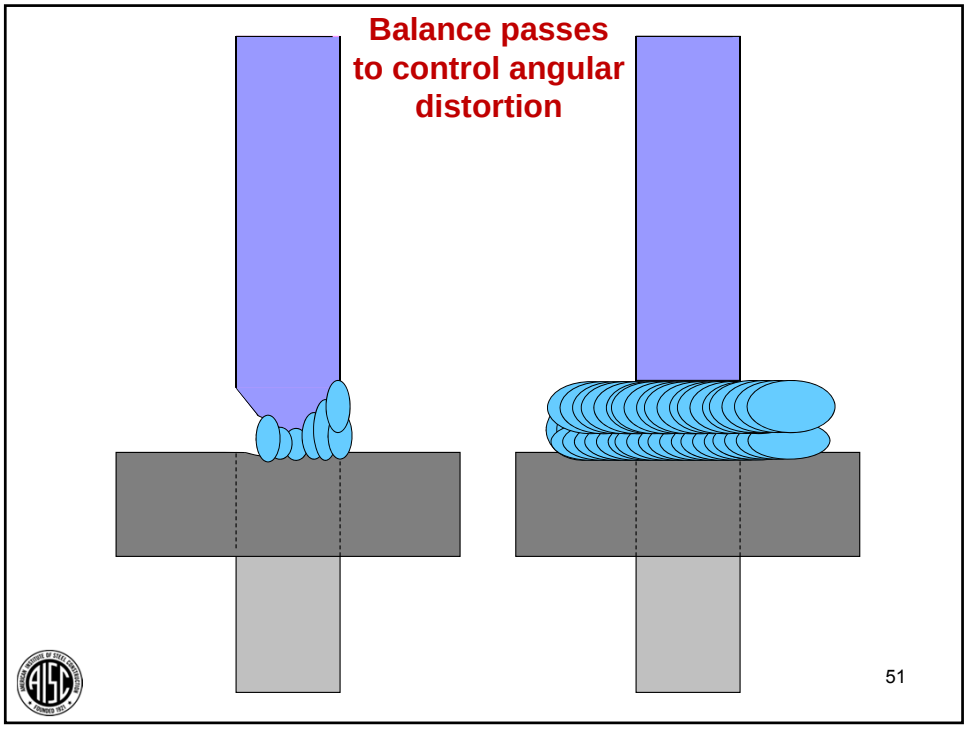

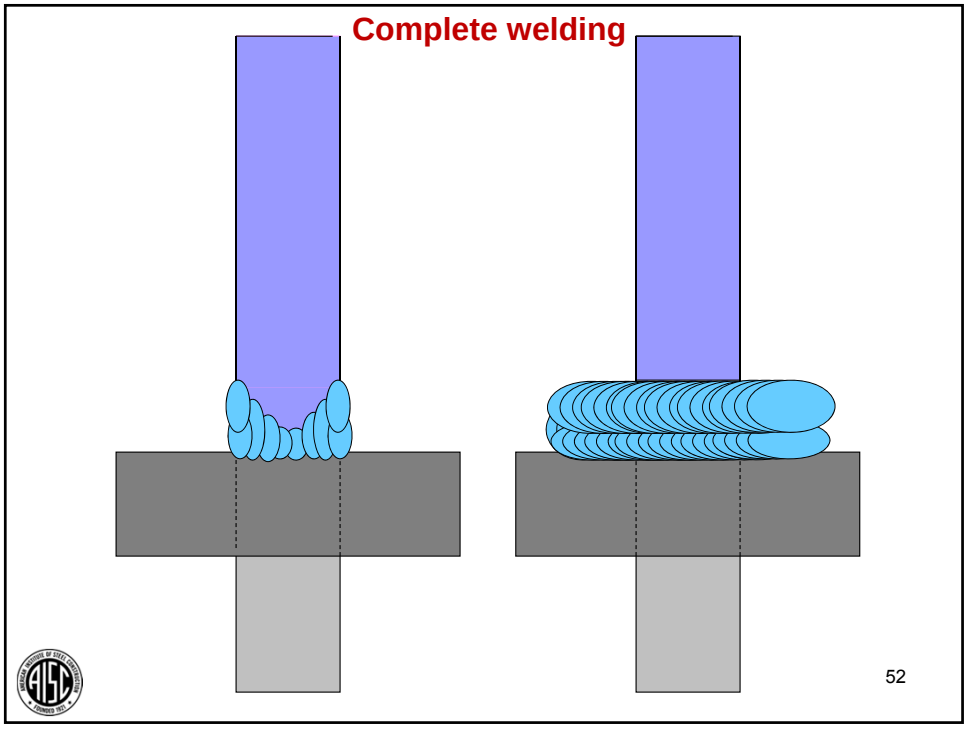

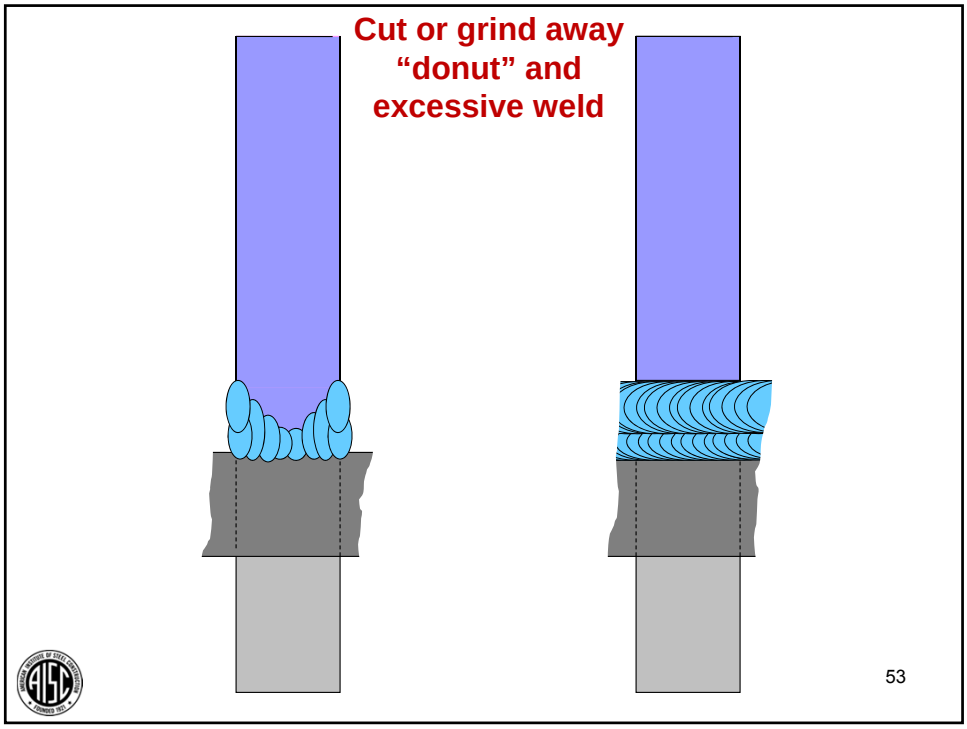

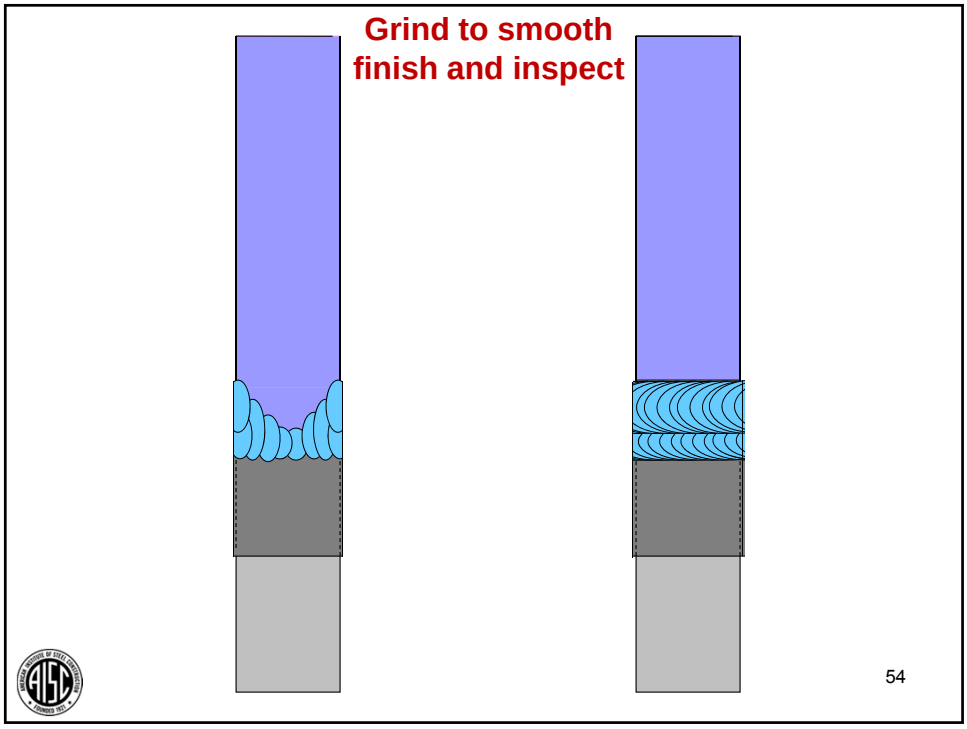

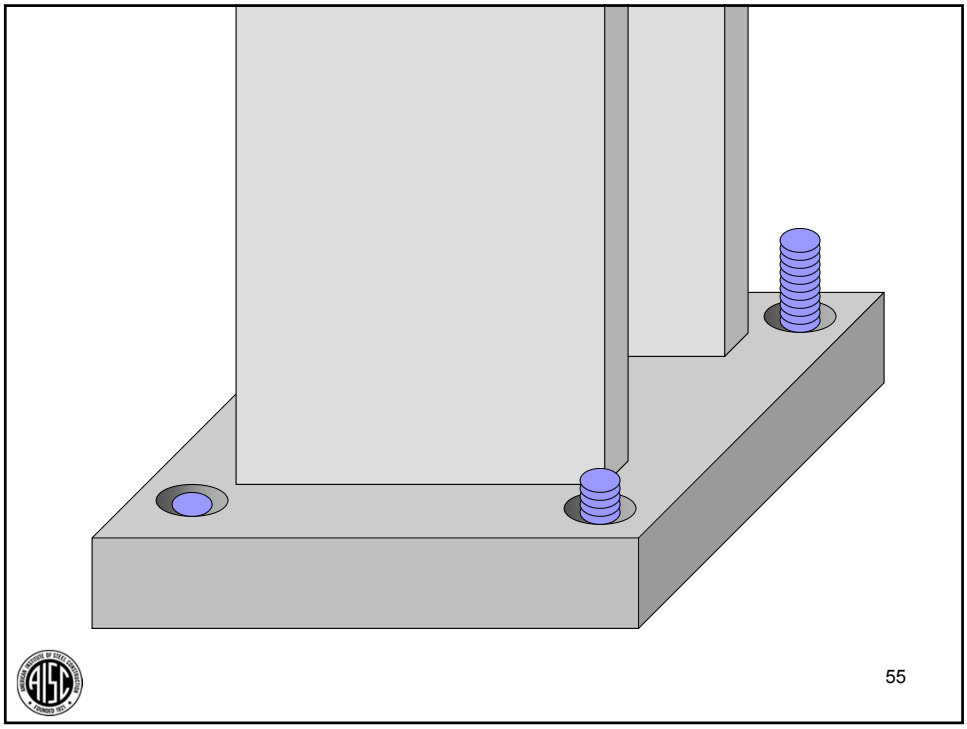

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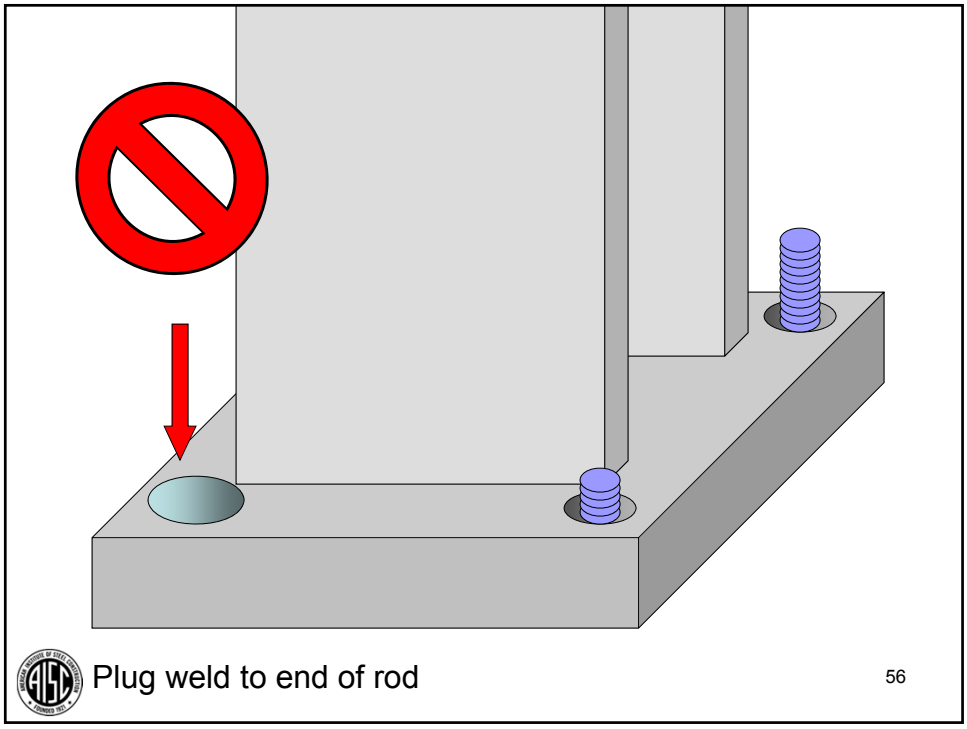
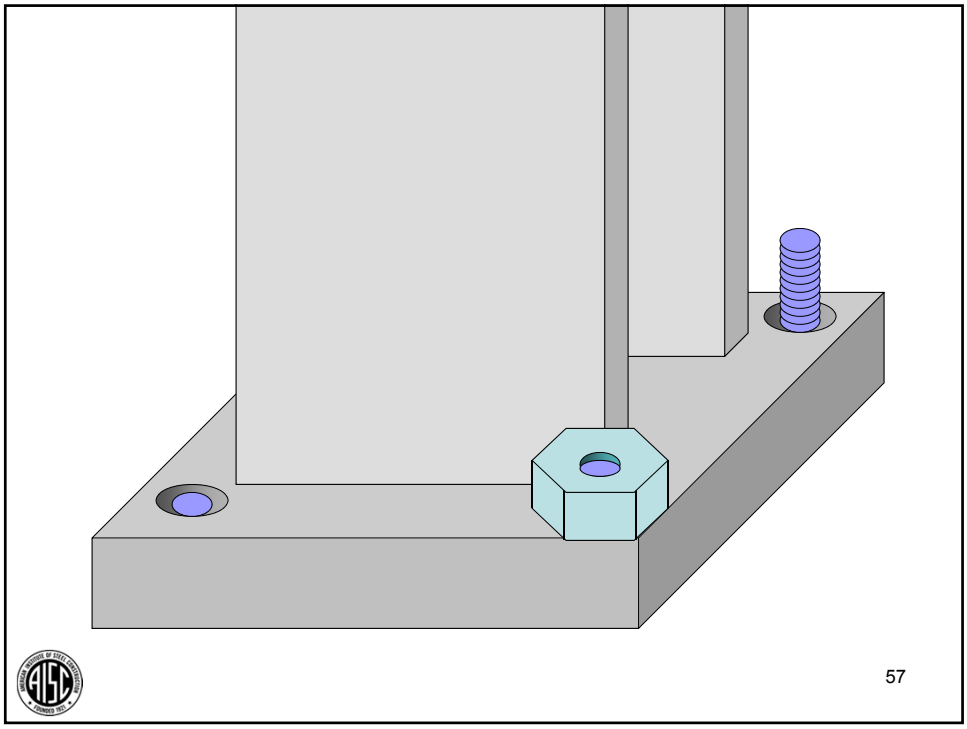
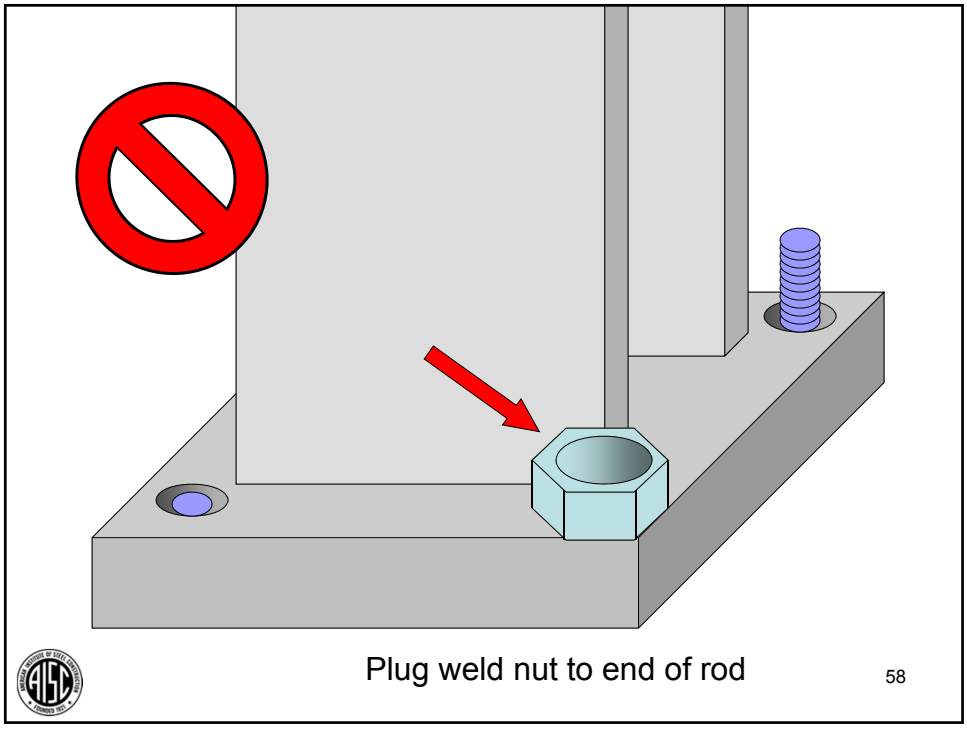


Plug weld to end of rod

56



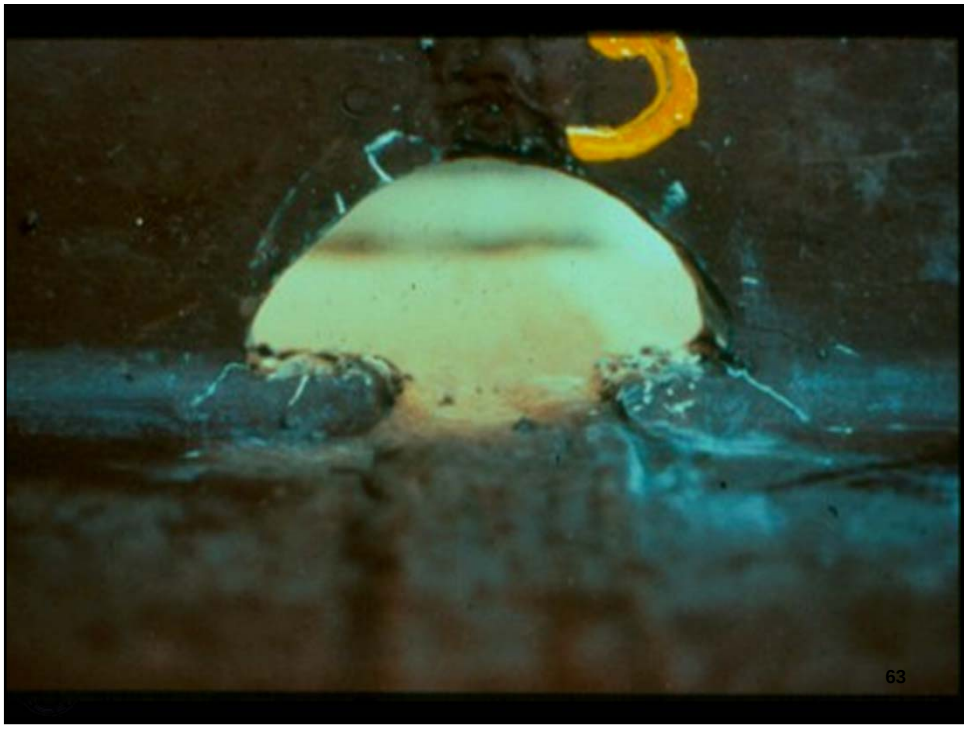


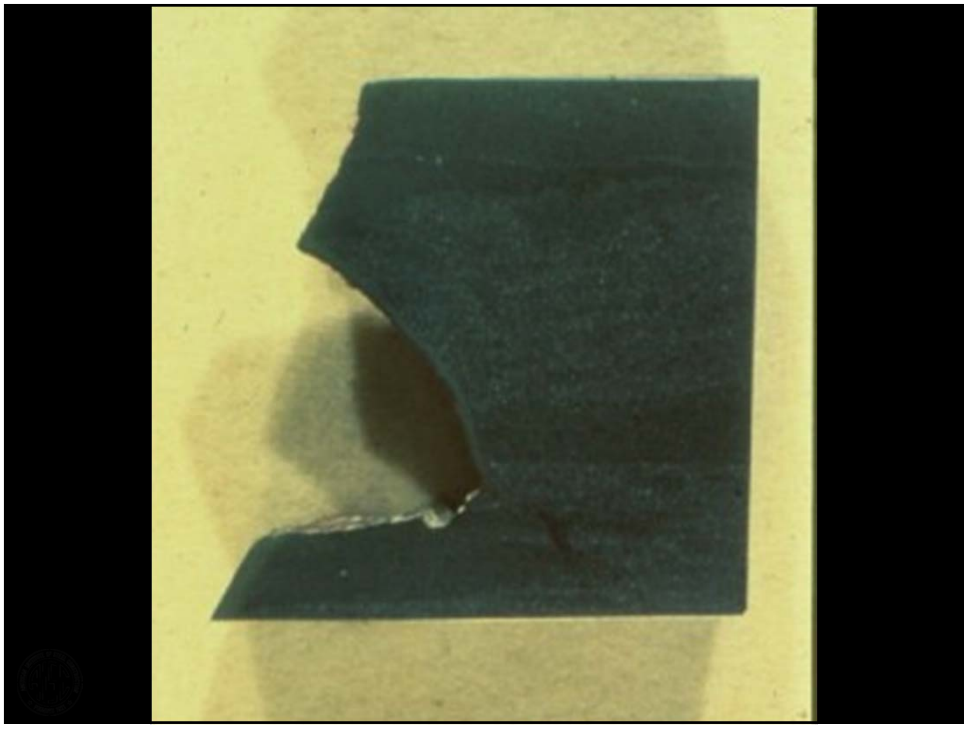
Special Welding Applications and Field Fixes

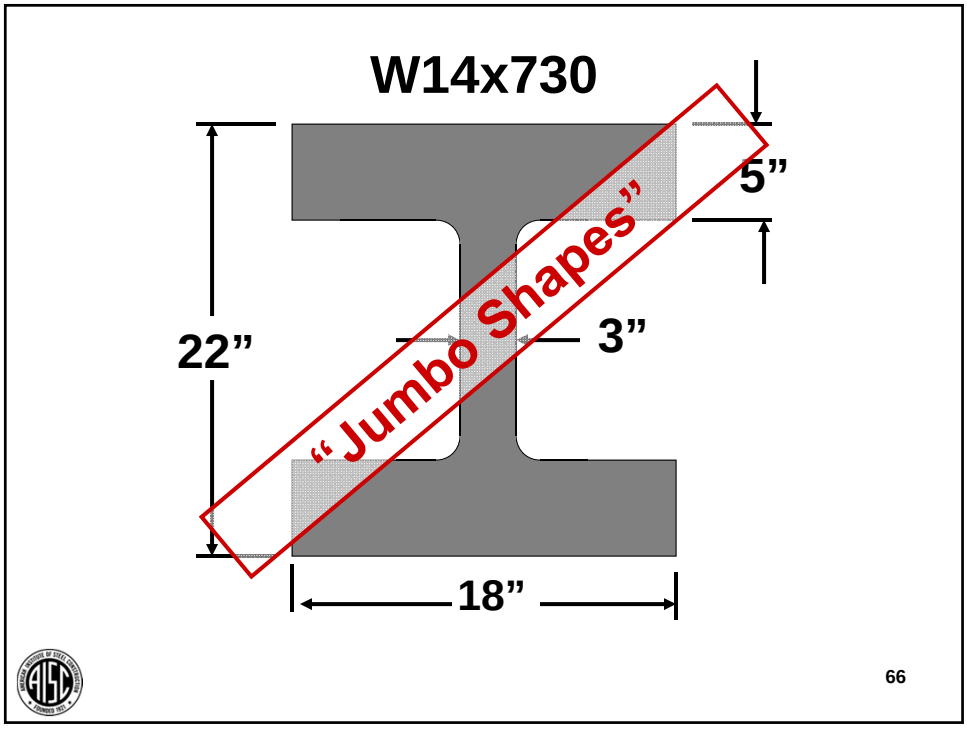
- Welding on Anchor Rods
- Welding on Heavy Sections (“Jumbo Shapes”)
- Welding HSS
- Welding AESS
- Field Welding
- Welding on Existing Structures
- Combining Welds and Bolts

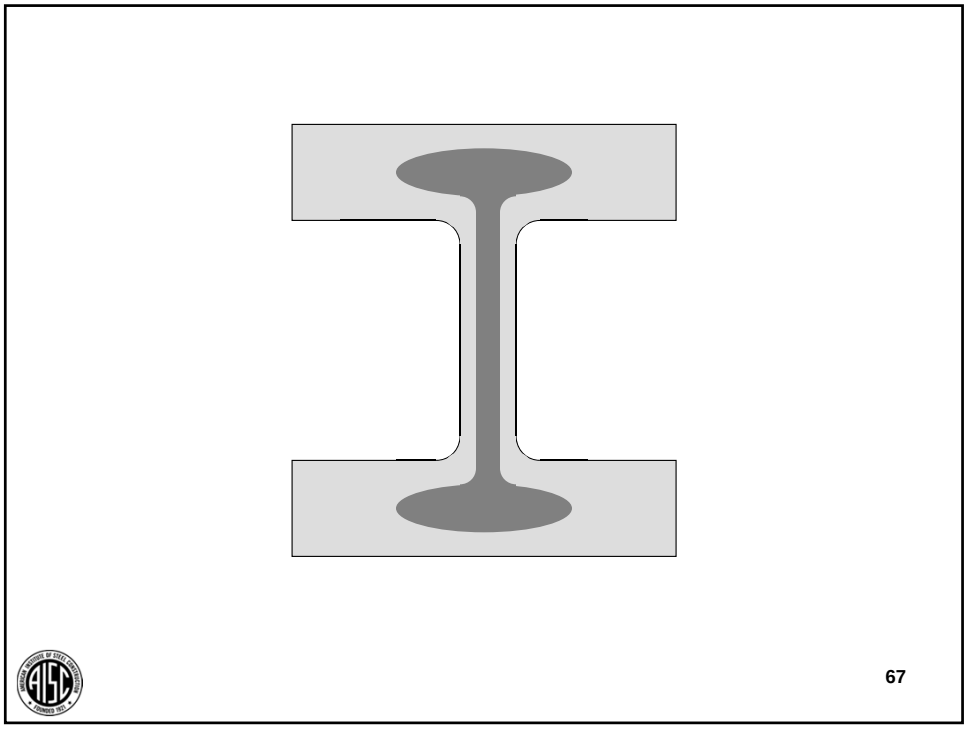
59

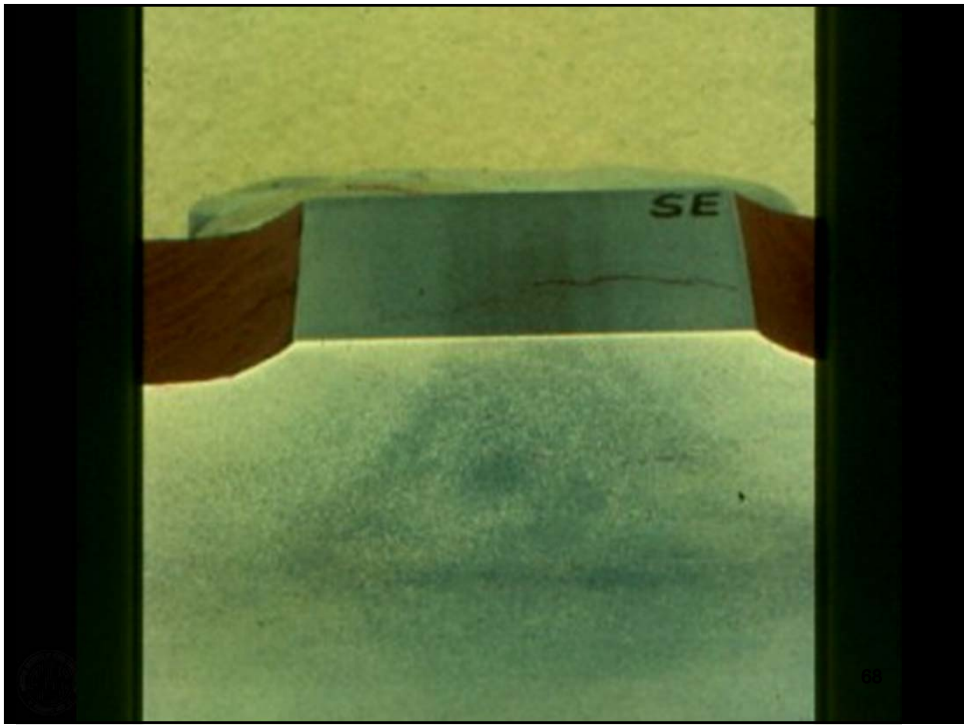
60











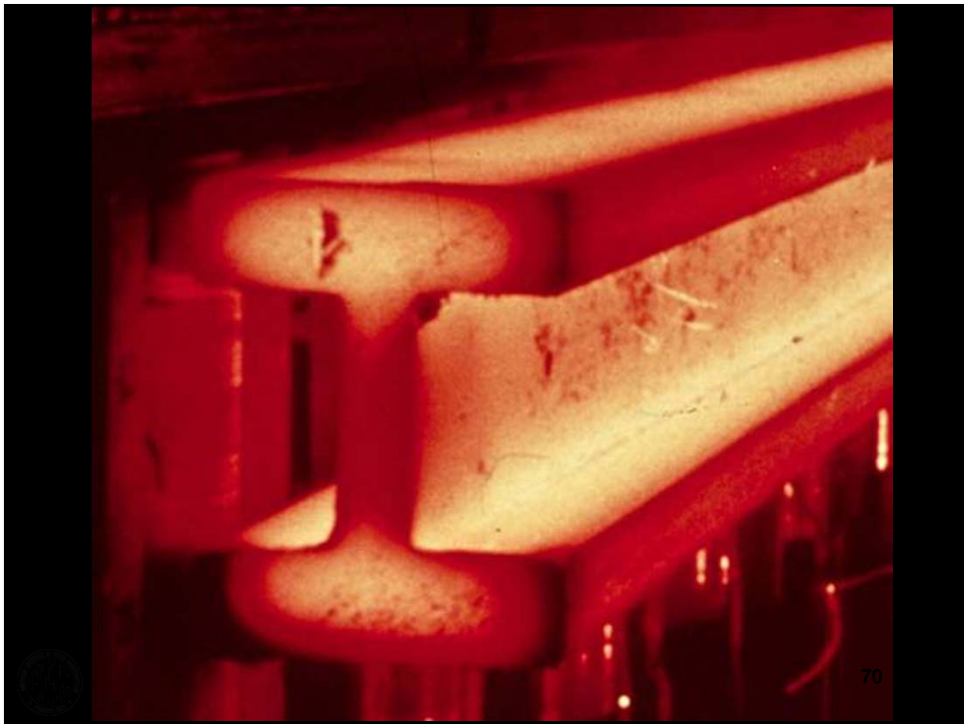
AISC 360-10 SPECIFICATION

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.

69



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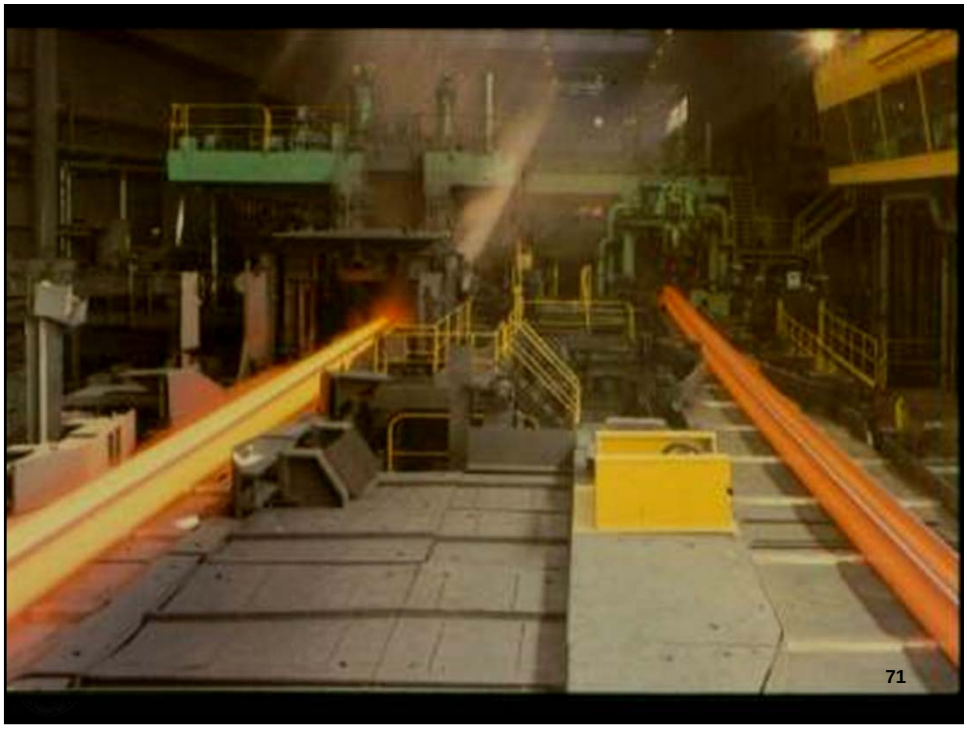
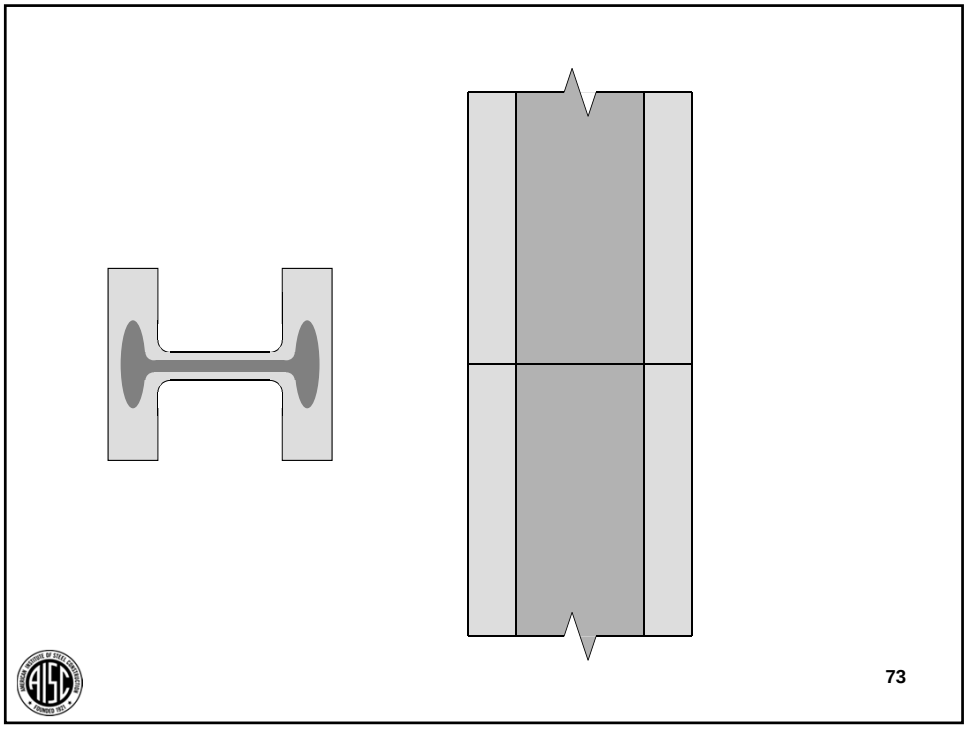


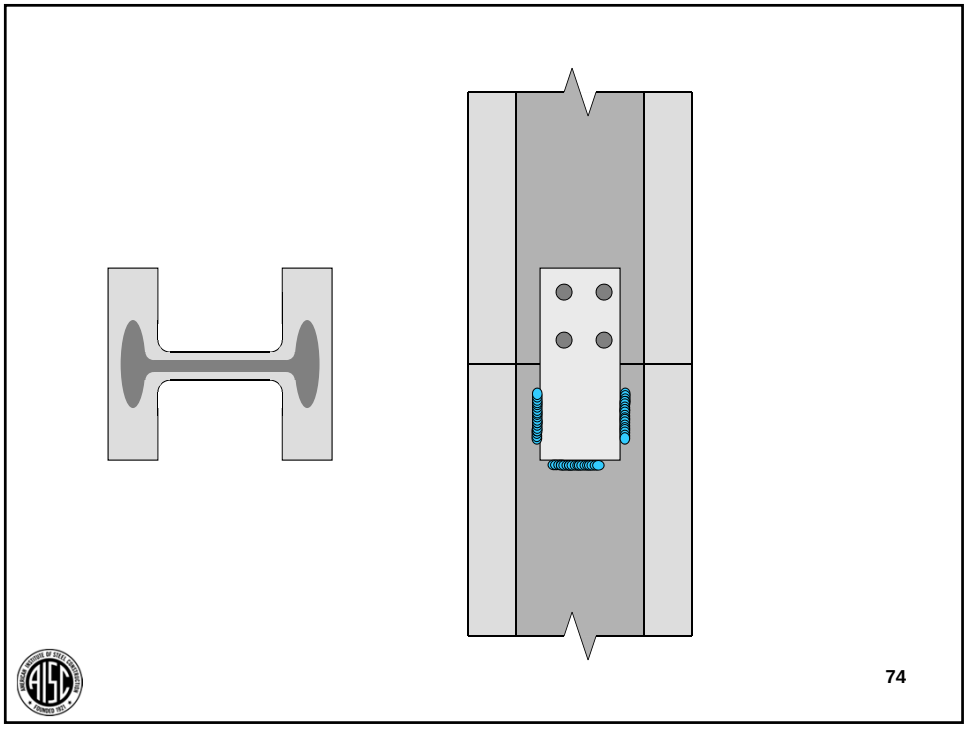
AISC 360-10 SPECIFICATION

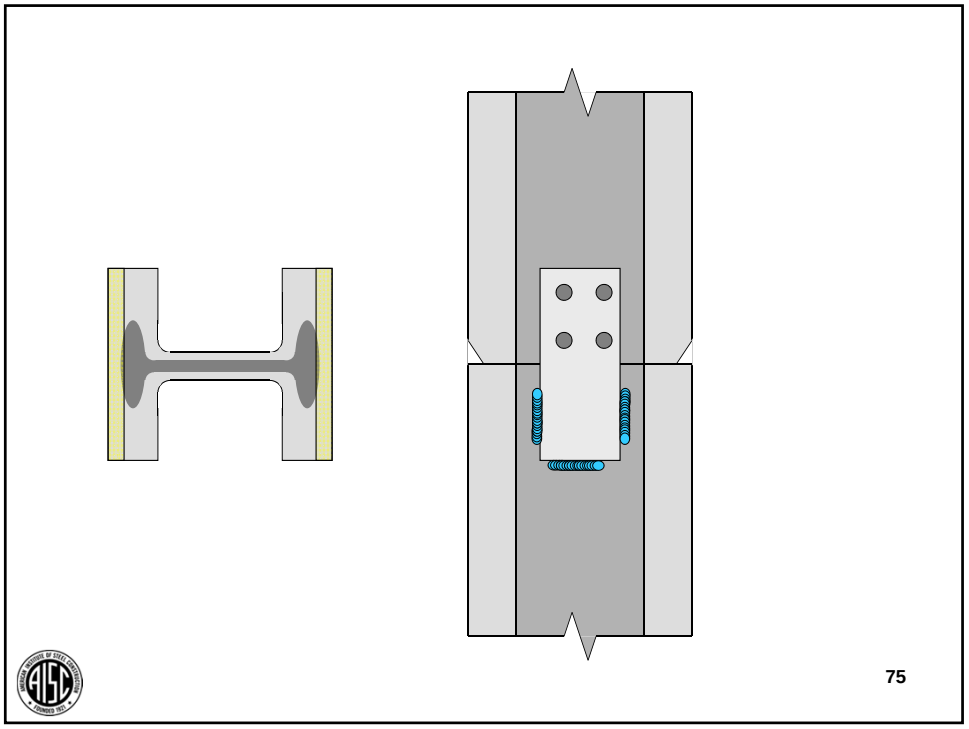
Commentary A3.1c

This characteristic is not detrimental to suitability for compression members or for nonwelded 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.

72







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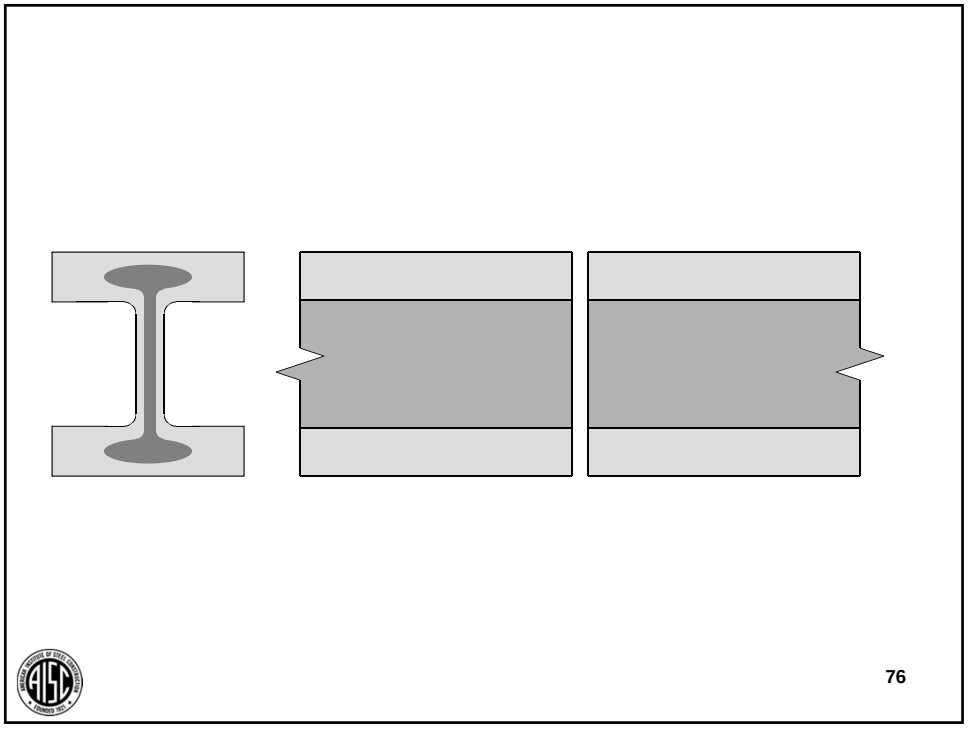

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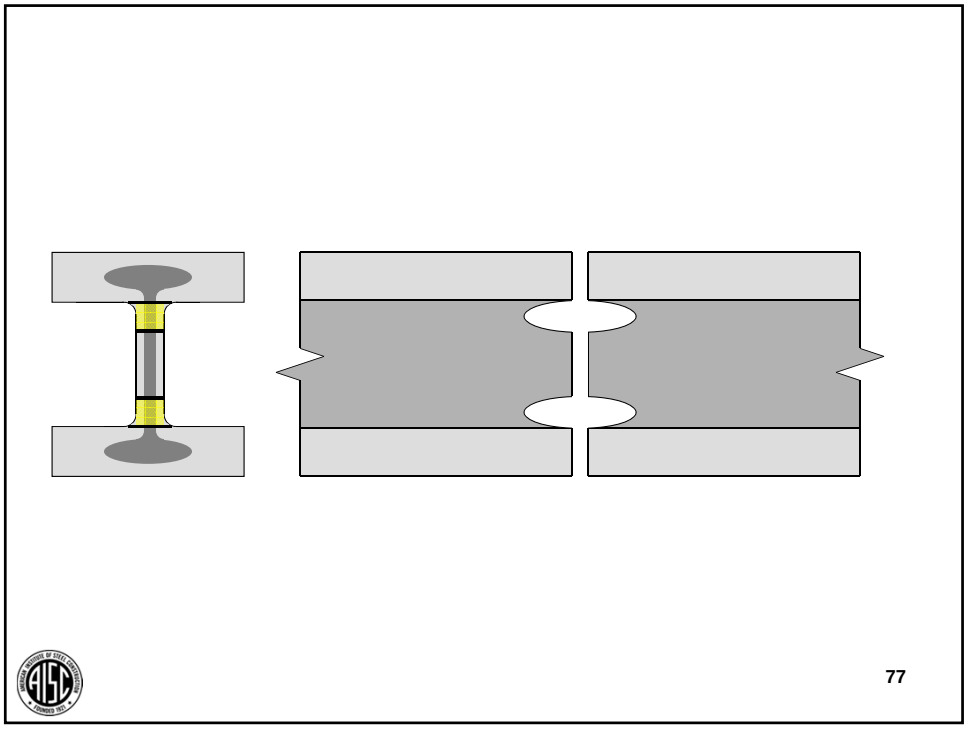

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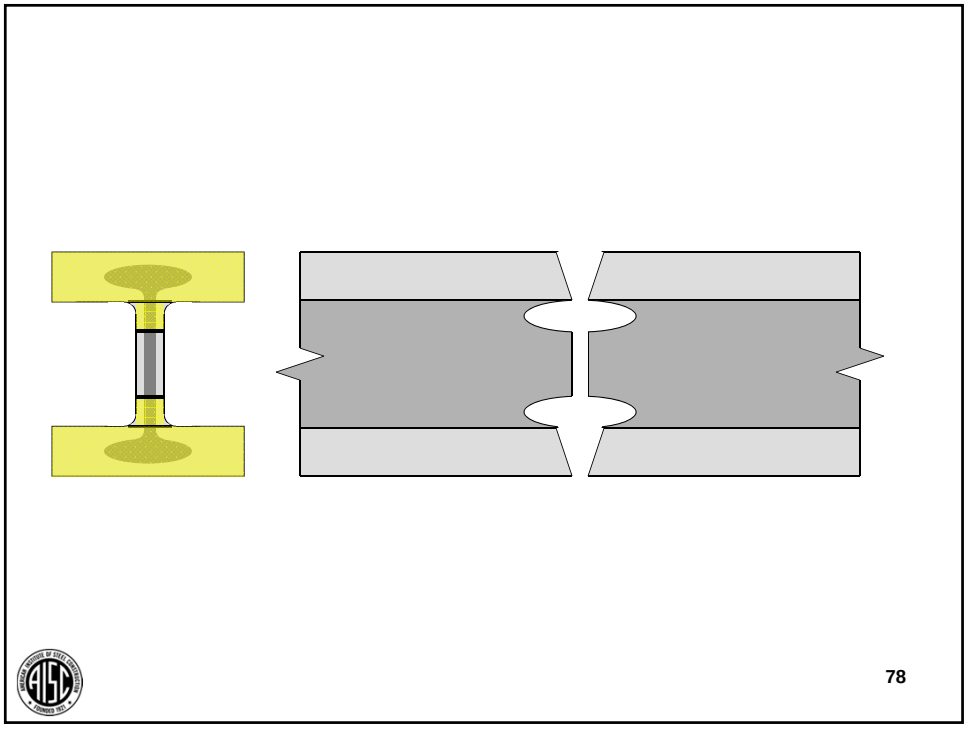

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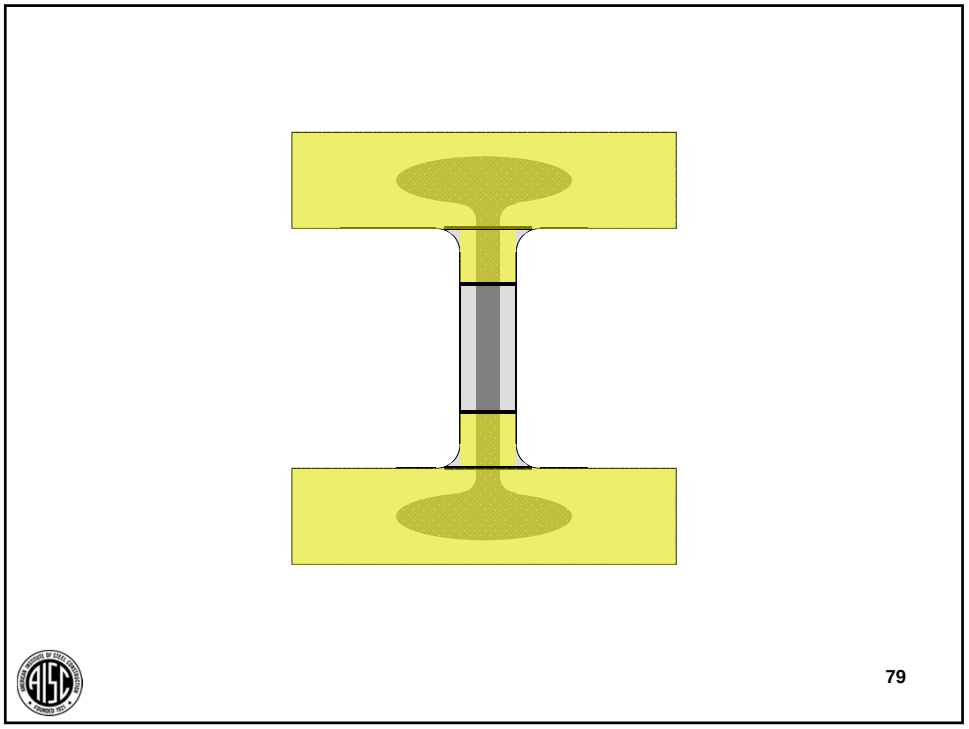

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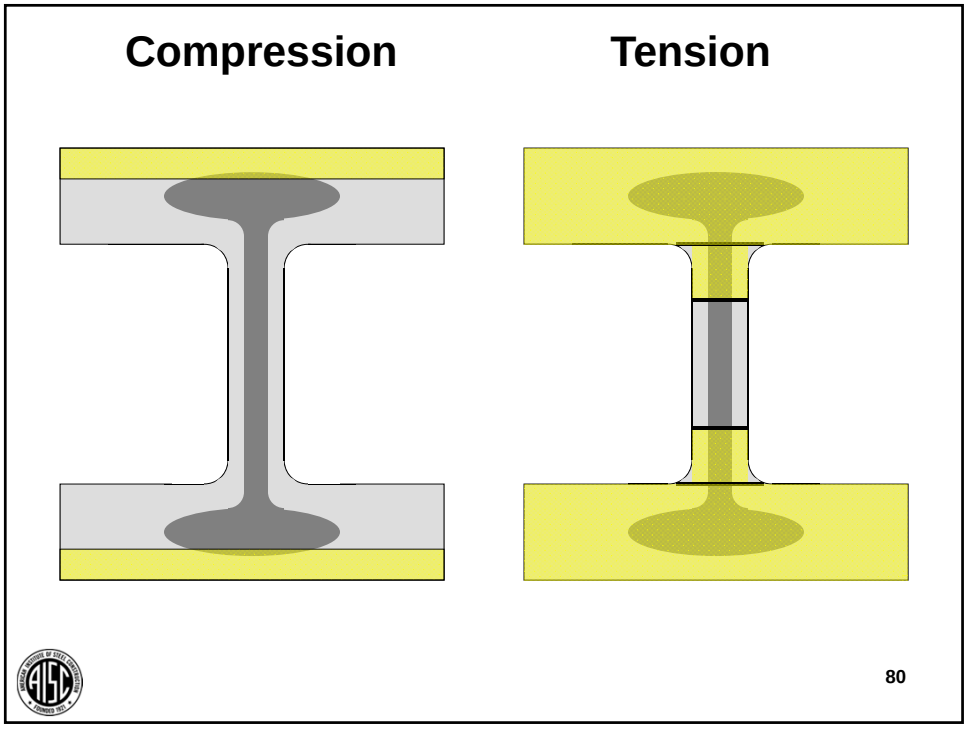

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AISC 360-10 SPECIFICATION

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.

81

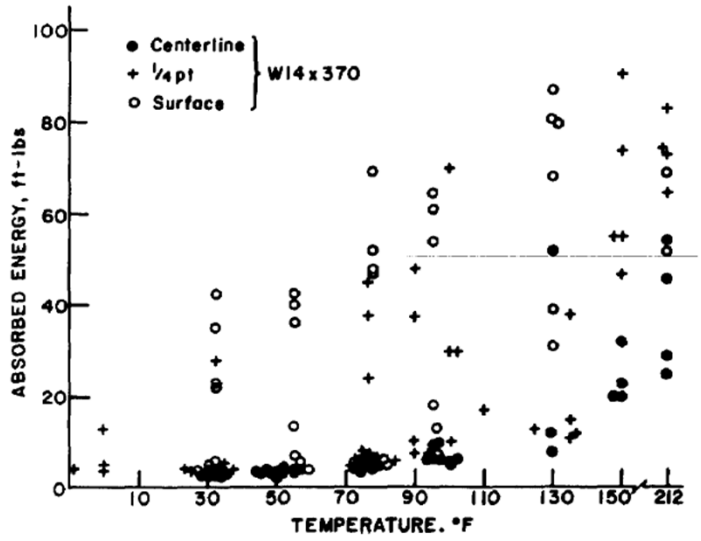
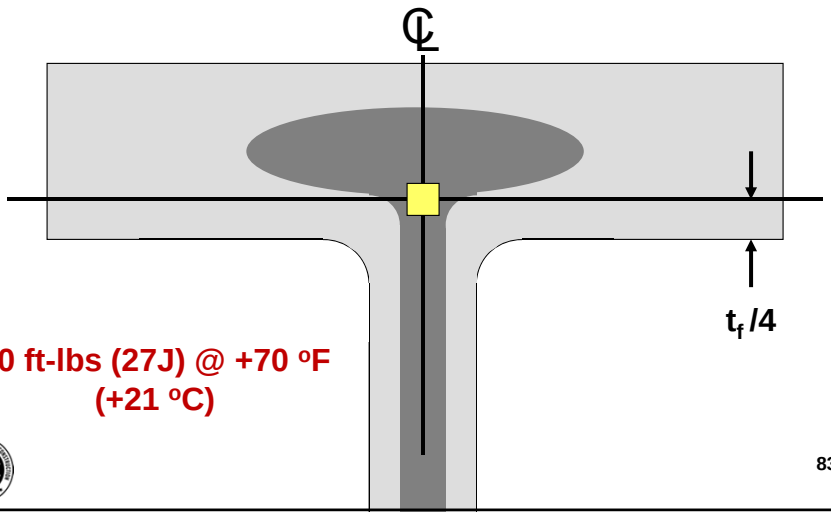


Fig. 15. Charpy V-Notch test results for W14 × 370 section—Supplier A

82

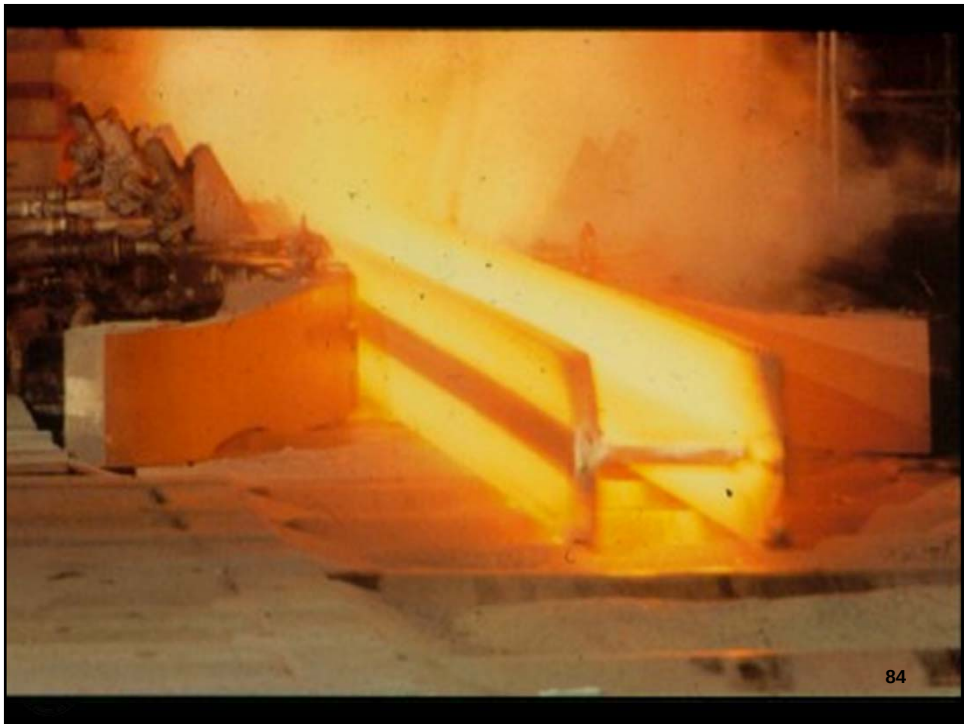
AISC 360-10 SPECIFICATION

ASTM A6, Supplementary Requirement S30 *Charpy V-Notch Impact Tests for Structural Shapes—Alternate Core Location*



20 ft-lbs (27J) @ +70 ºF (+21 ºC)

83



84

AISC 360-10 SPECIFICATION

ASTM A6, Supplementary Requirement S5 *Charpy V-Notch Impact Test*

20 ft-lbs (27J) @ +70 ºF (+21 ºC)

85

AISC 360-10 SPECIFICATION

J2.6 Filler Metal Requirements

20 ft-lbs (27J) @ +40 ºF (+4 ºC)

86

AISC 360-10 SPECIFICATION

Commentary A3.1c

To minimize the potential for fracture, the notch toughness requirement of Section A3.1c must be used in conjunction with good design and fabrication procedures.

87

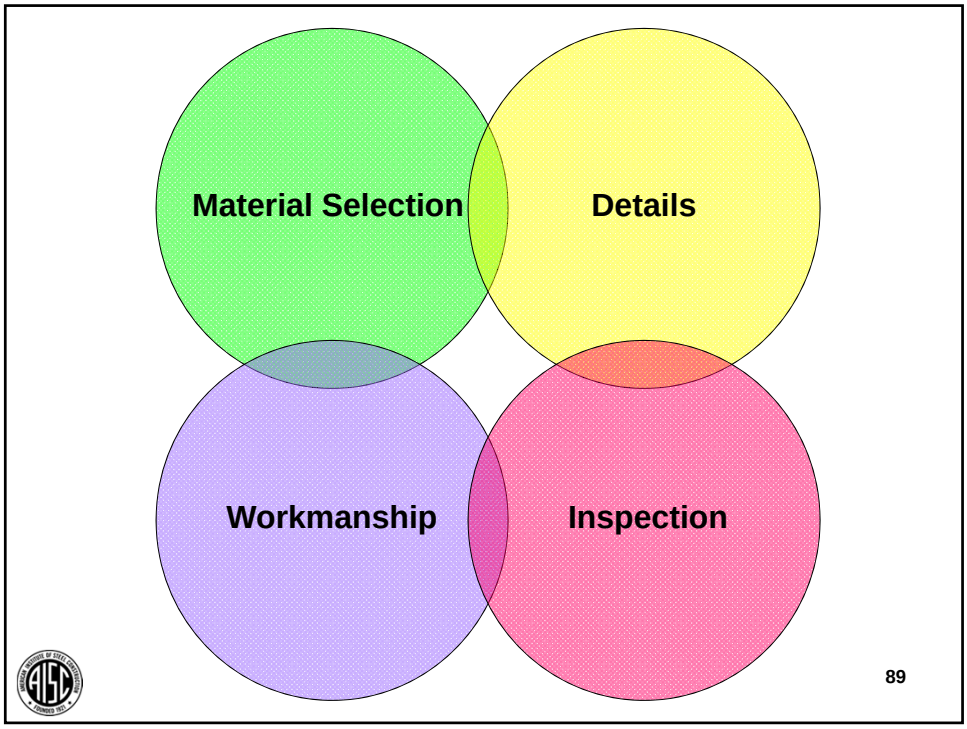
AISC 360-10 SPECIFICATION

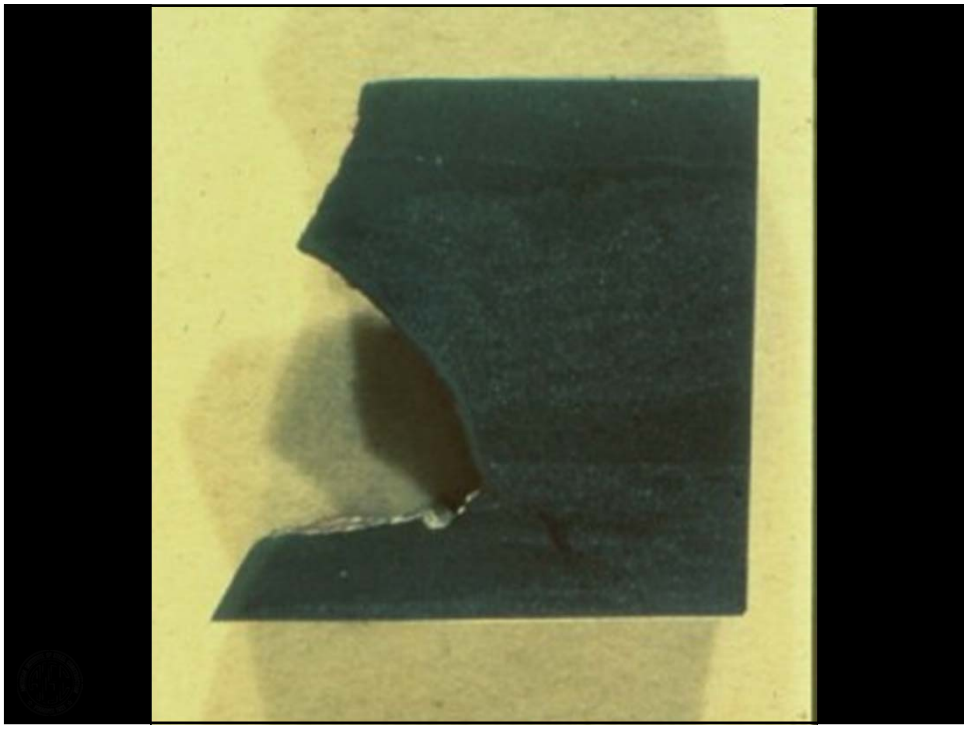
Commentary A3.1a

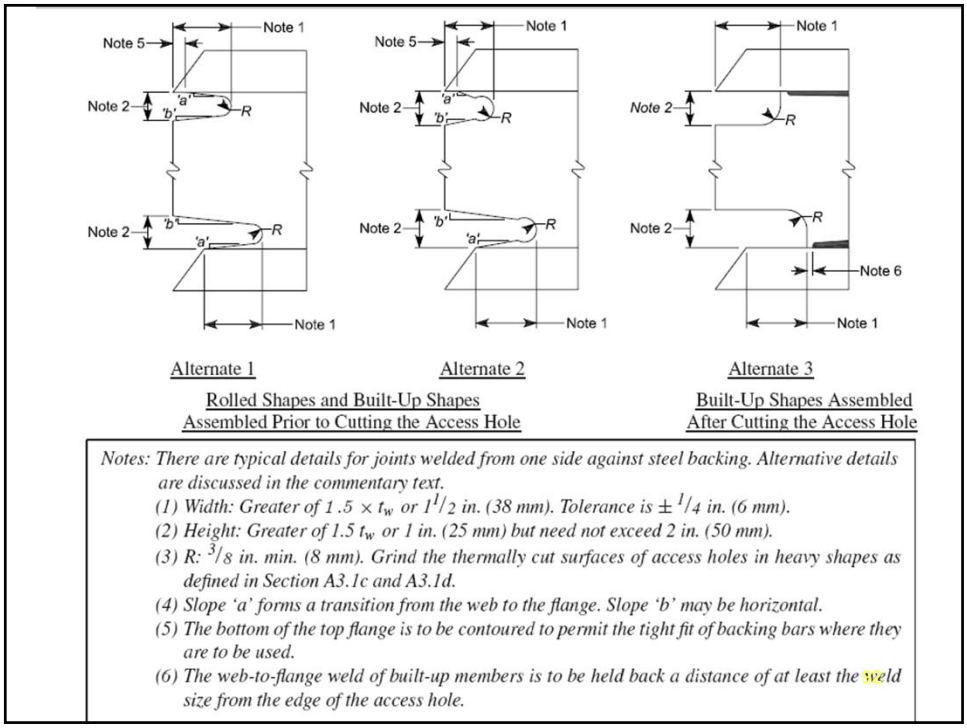
ASTM Designations

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.

88







Alternate 1 — Rolled Shapes and Built-Up Shapes Assembled Prior to Cutting the Access Hole

Alternate 2 — Rolled Shapes and Built-Up Shapes Assembled Prior to Cutting the Access Hole

Alternate 3 — Built-Up Shapes Assembled After Cutting the Access Hole

Notes: There are typical details for joints welded from one side against steel backing. Alternative details are discussed in the commentary text.

(1) Width: Greater of 1.5 × t_w or $1^1/_2$ in. (38 mm). Tolerance is $\pm\,^1/_4$ in. (6 mm).

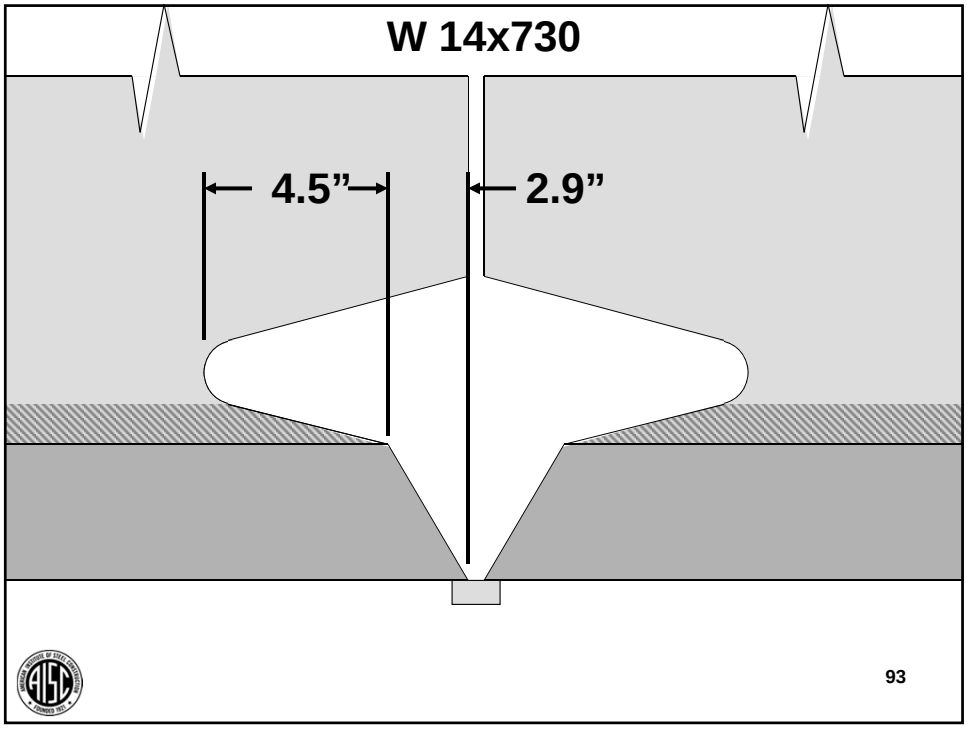
(2) Height: Greater of 1.5 t_w or 1 in. (25 mm) but need not exceed 2 in. (50 mm).

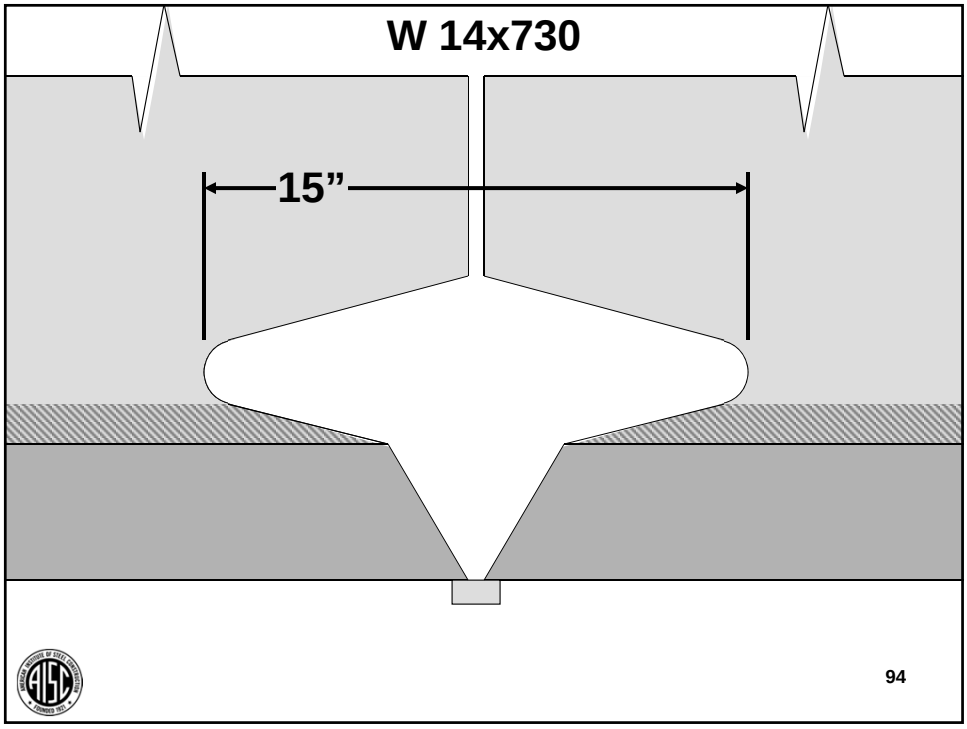
(3) R: $^3/_8$ in. min. (8 mm). Grind the thermally cut surfaces of access holes in heavy shapes as defined in Section A3.1c and A3.1d.

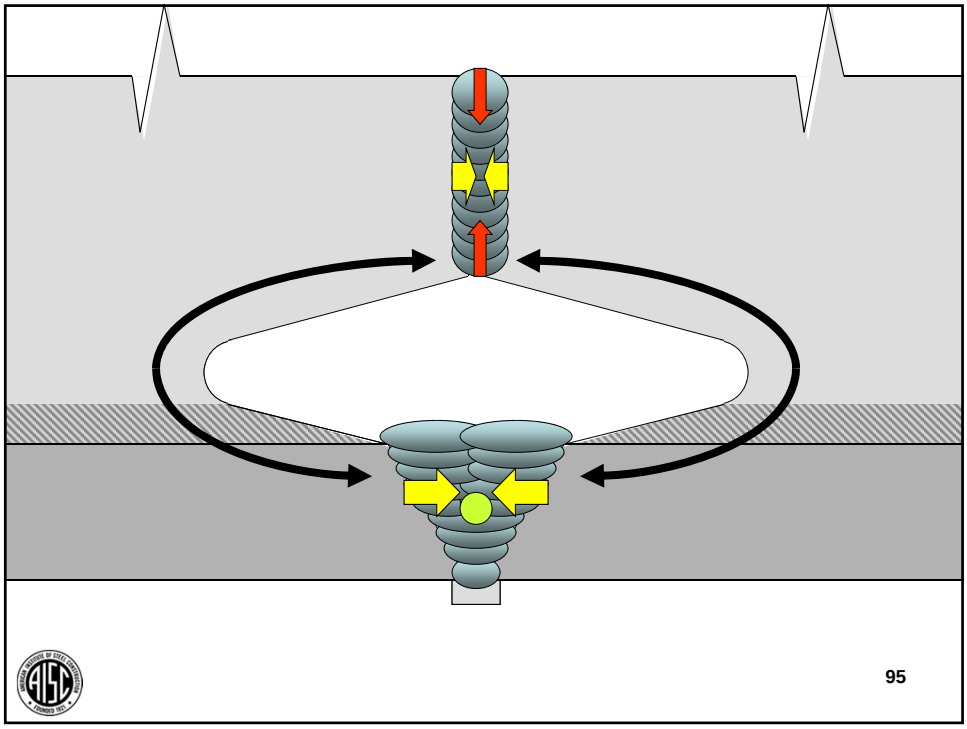
(4) Slope 'a' forms a transition from the web to the flange. Slope 'b' may be horizontal.

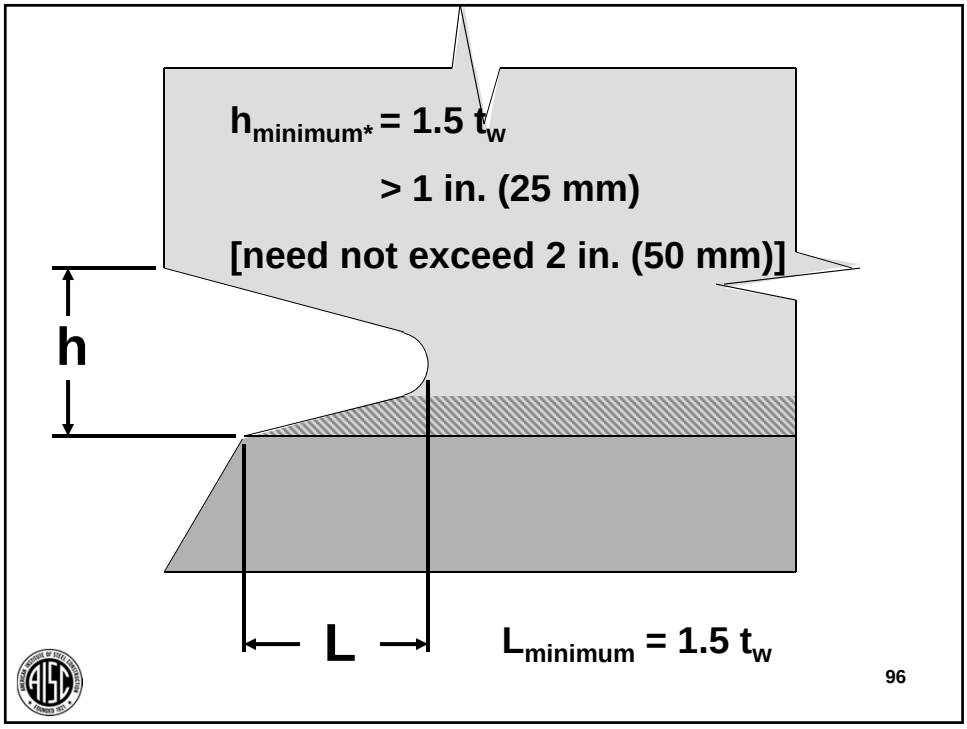
(5) The bottom of the top flange is to be contoured to permit the tight fit of backing bars where they are to be used.

(6) The web-to-flange weld of built-up members is to be held back a distance of at least the weld size from the edge of the access hole.









AISC 360-10 SPECIFICATION

M2.2 Thermal Cutting

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

98

AISC 360-10 SPECIFICATION

M2.2 Thermal Cutting

The thermally cut surface of access holes in ASTM A6/6M 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.

99

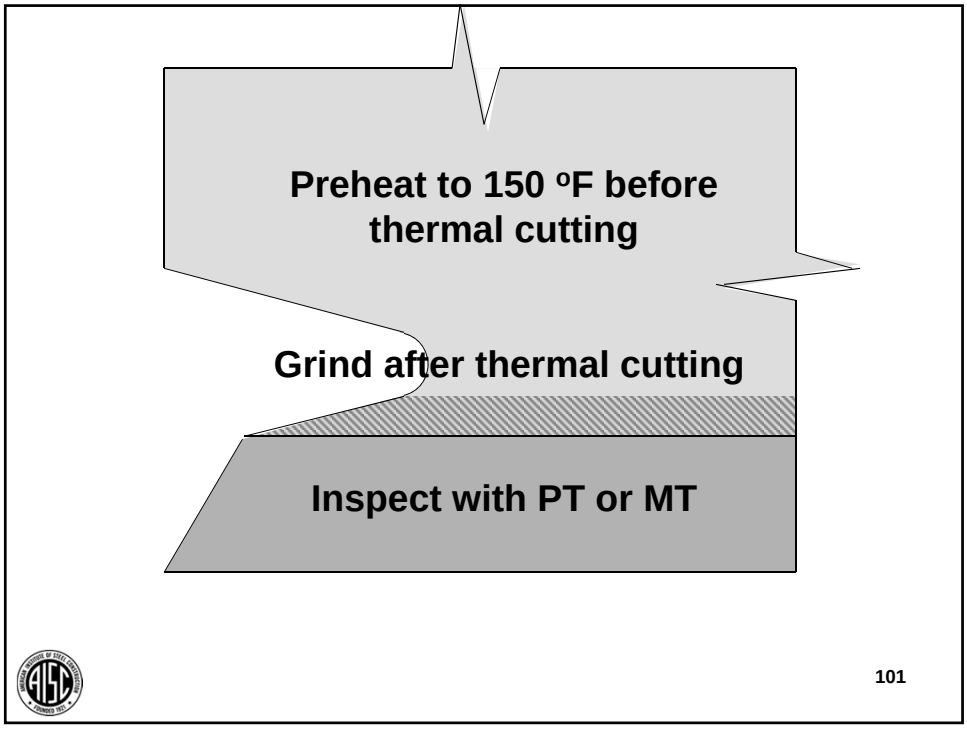
AISC 360-10 SPECIFICATION

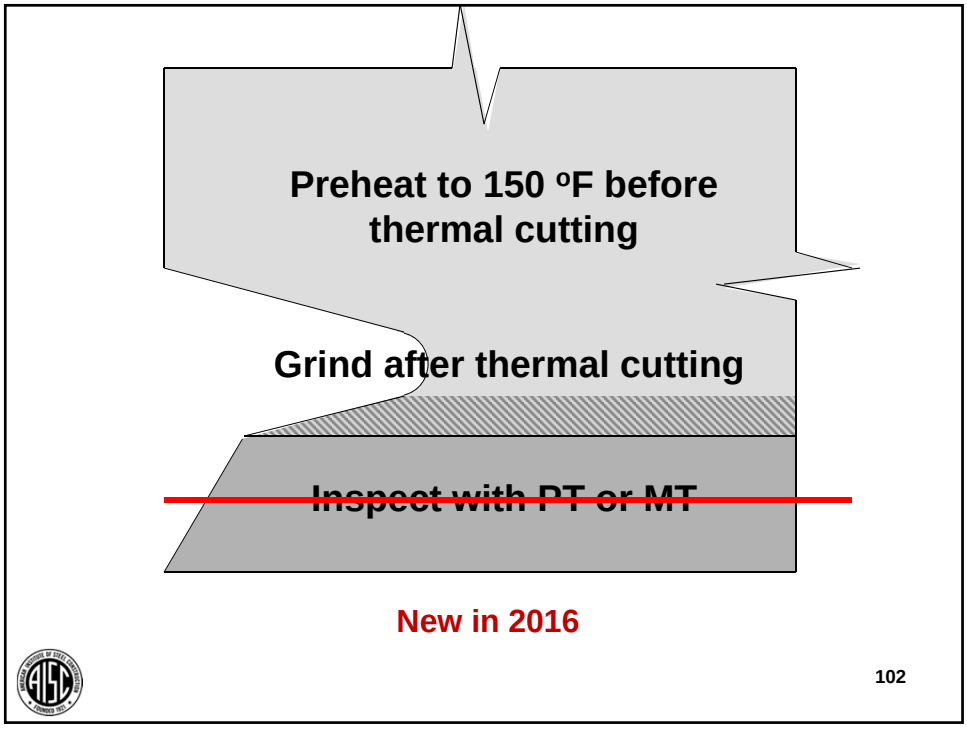
N5.5 Nondestructive Testing of Welded Joints

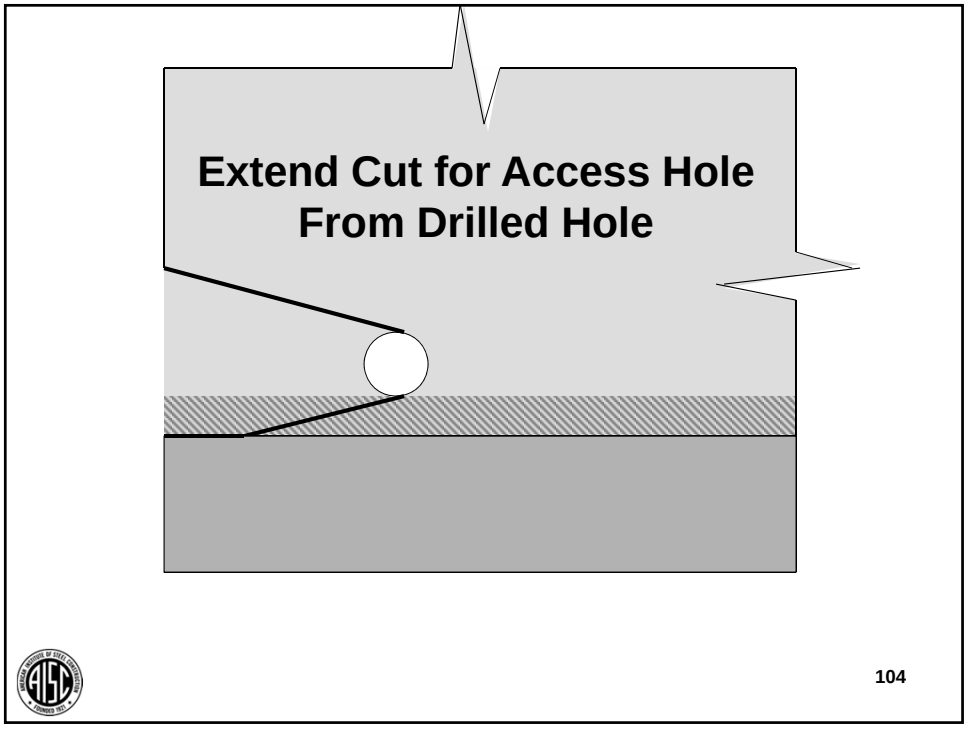
5c Access Hole NDT

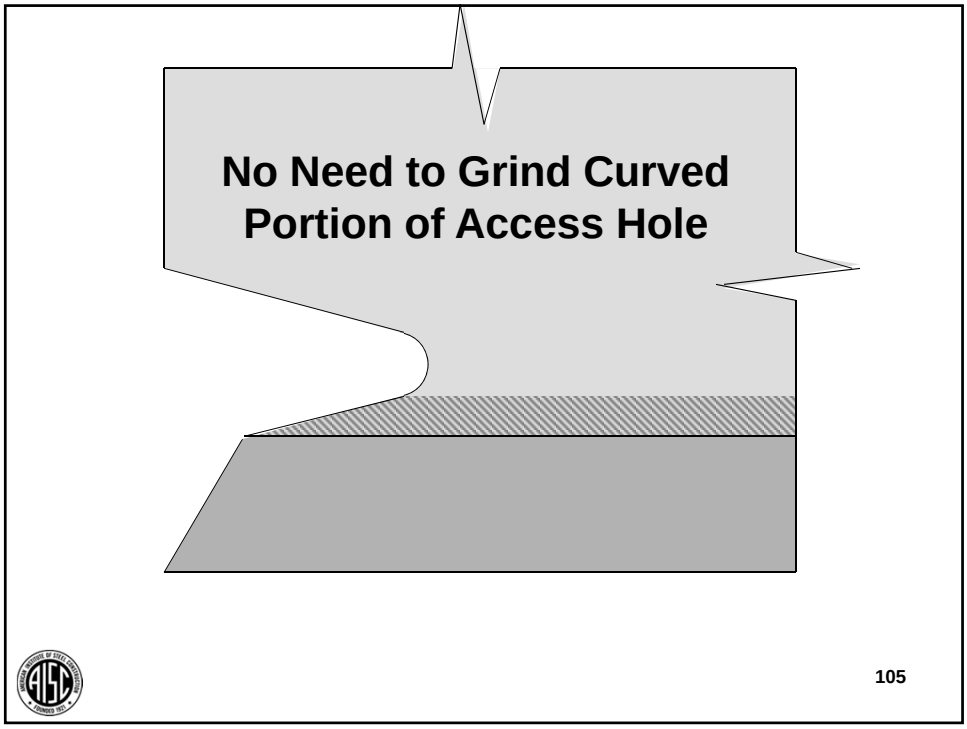
Thermally cut surfaces of access holes shall be tested by QA using MT or PT, when the flange thickness exceeds 2 in. (50 mm) for rolled shapes, or when the web thickness exceeds 2 in. (50 mm) for built-up shapes.

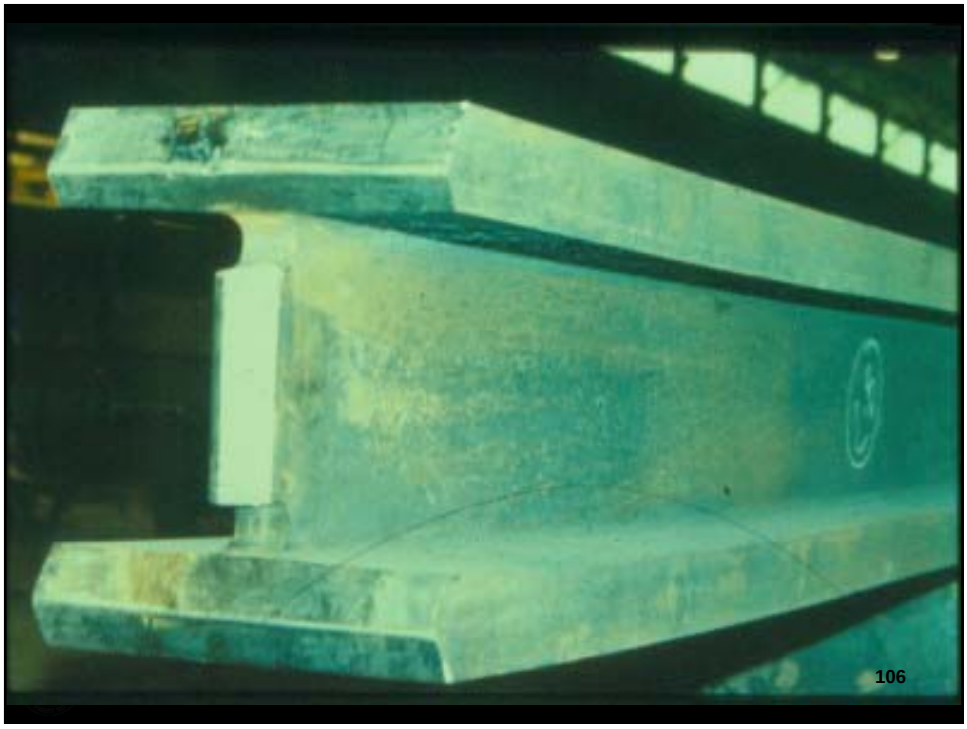
100











AWS D1.1:2015 Structural Welding Code--Steel

5.20.6 Temperature Limitations

In making welding under conditions of severe external shrinkage restraint, once the welding has started, the joint shall not be allowed to cool below the minimum specified preheat until the joint has been completed or sufficient weld has been deposited to ensure freedom from cracking.

107

AISC 360-10 SPECIFICATION

Commentary C-J1.5

When splicing hot-rolled shapes with flange thicknesses exceeding 2 in. (50 mm) or heavy welded built-up members, these potentially harmful weld shrinkage strains can be avoided by using bolted splices, fillet-welded lap splices, or splices that combine a welded and bolted detail (see Figure C-J1.1).

108

AISC 360-10 SPECIFICATION

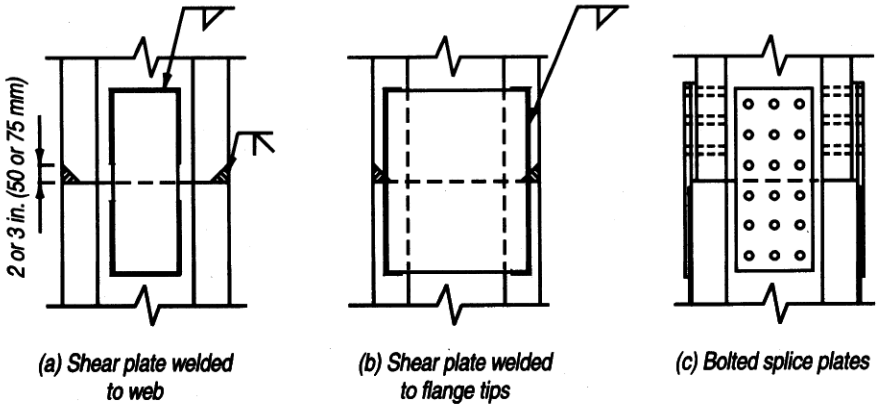
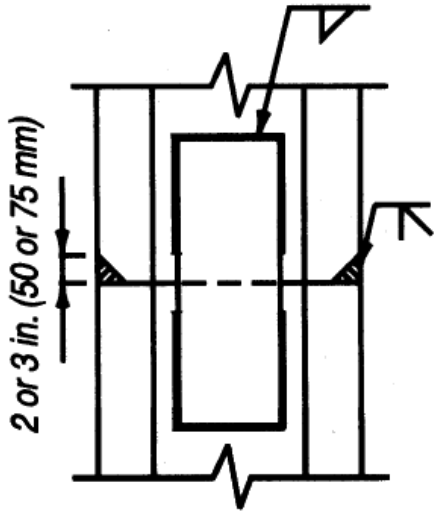


Fig. C-J1.1. Alternative splices that minimize weld restraint tensile stresses.

109

AISC 360-10 SPECIFICATION



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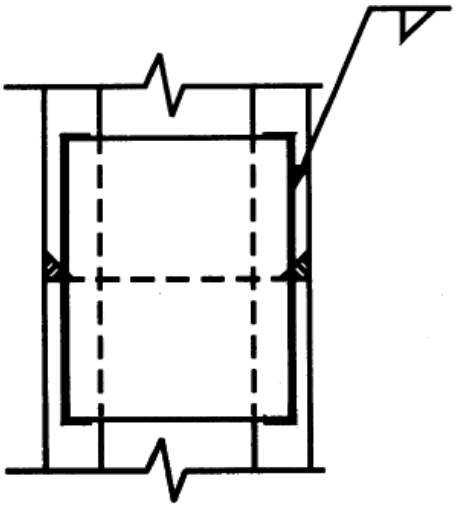
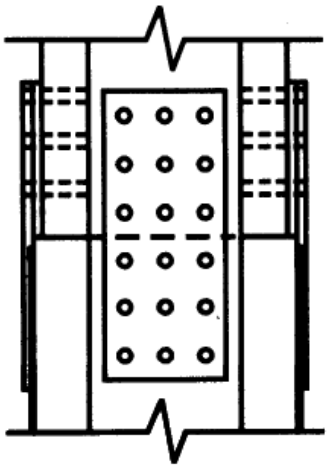
AISC 360-10 SPECIFICATION



(b) Shear plate welded to flange tips

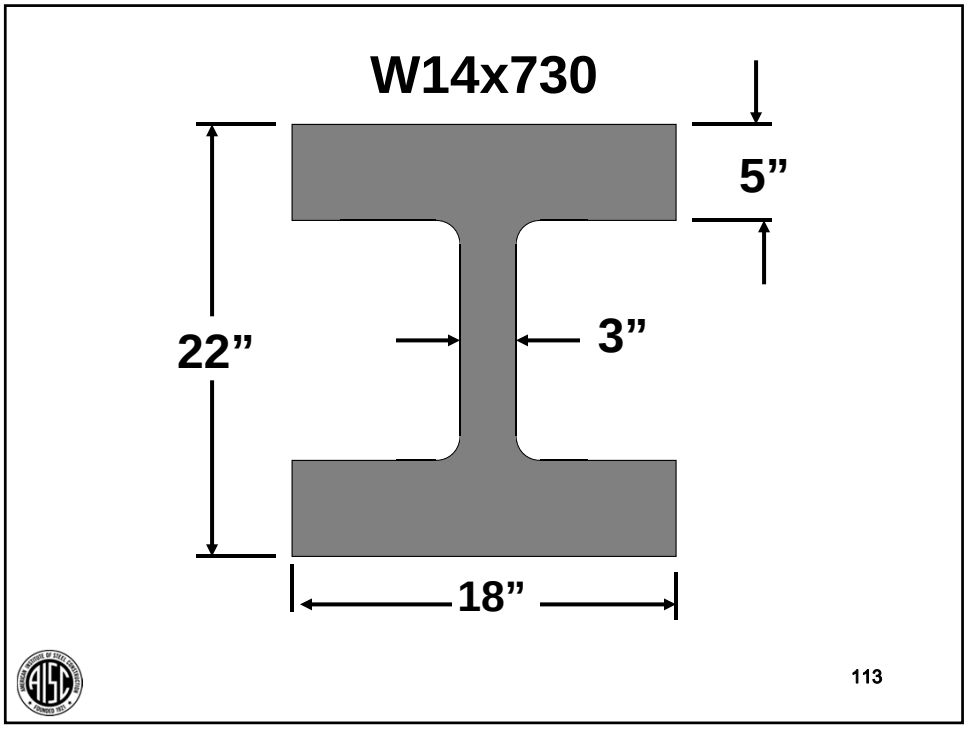
111

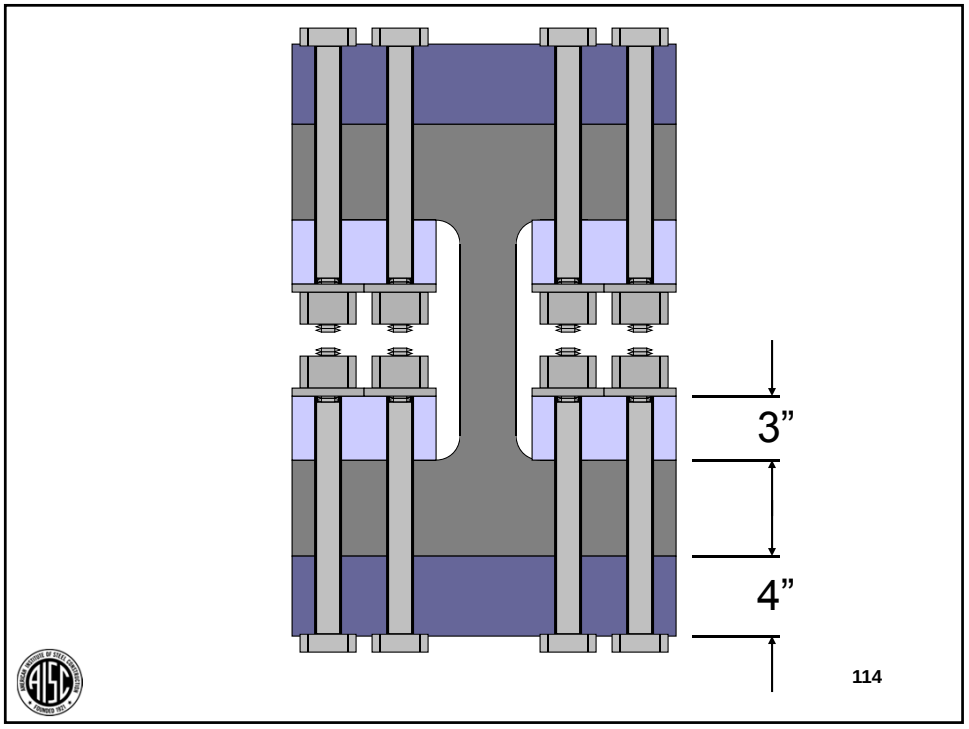
AISC 360-10 SPECIFICATION

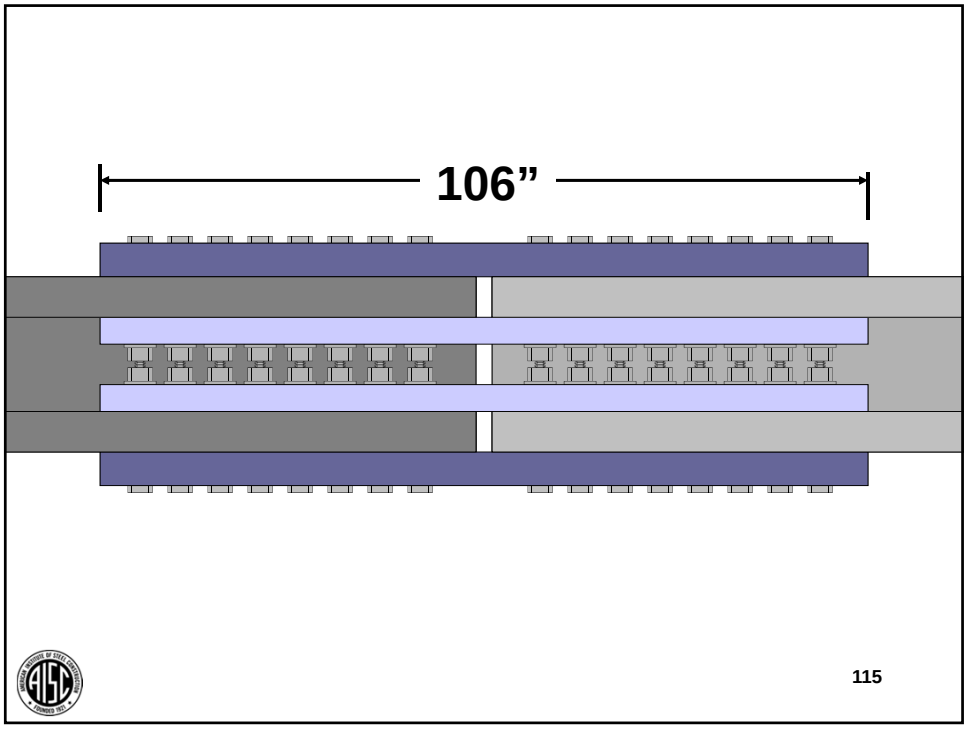


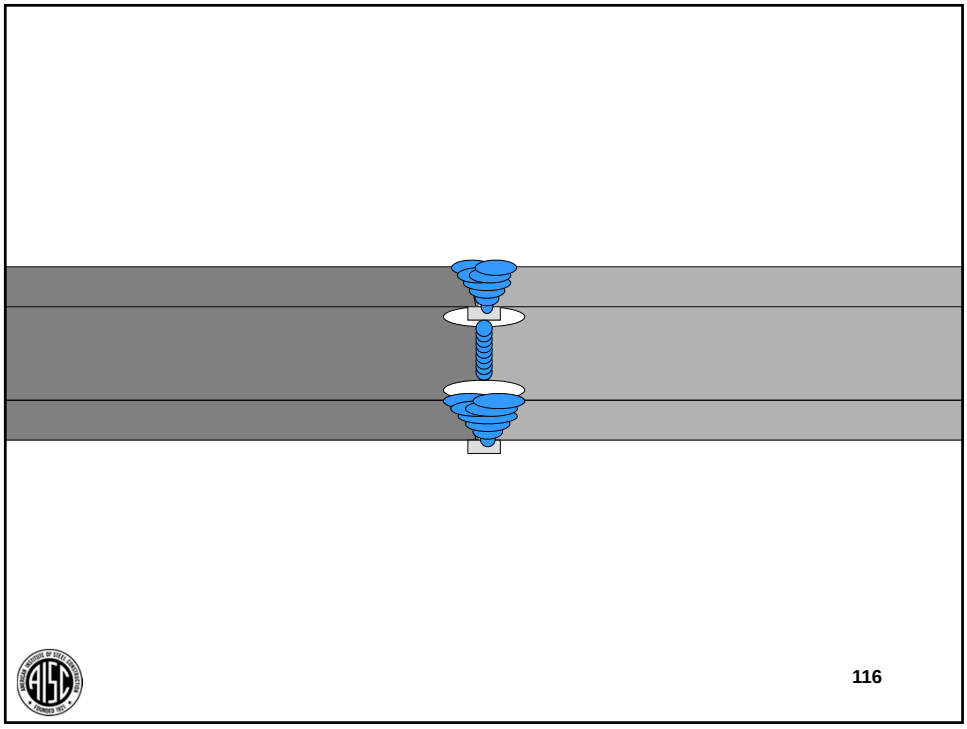
(c) Bolted splice plates

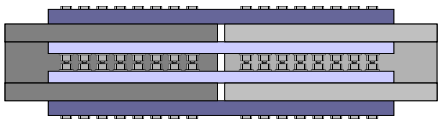
112

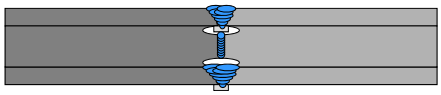








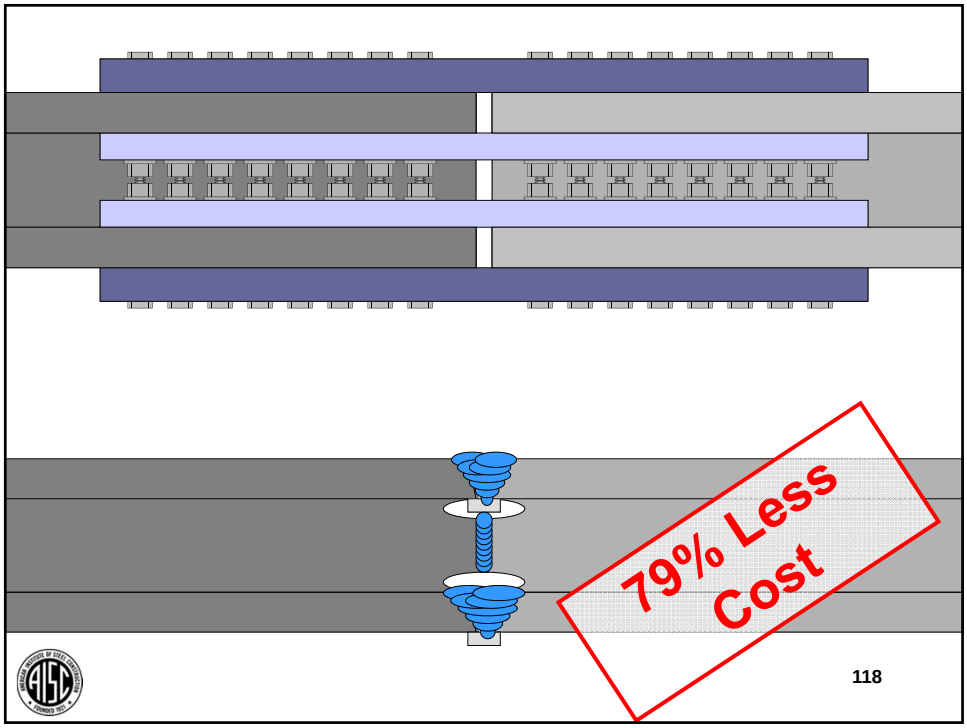




	Bolted Detail		Welded Detail	
Labor	84.3 hr	$4974	28.6 hr	$1687
Steel	6900#	$3312	-	-
Bolts	128	$1314	-	-
Electrode	-	-	70#	$88
Flux	-	-	140#	$164
Total	-	$9600	-	$1939

Costs last updated in 2010.

117



118

Non-column Application of Wide-Flange Shapes

Barsom

"Such fractures can be avoided only when the material, the design, and the fabrication, inspection and erection practices are properly defined and implemented for the particular structure."

119

Non-column Application of Wide-Flange Shapes

Barsom

"Although higher fracture toughness would have been desirable, it would not have prevented the fracture of the tension cord member of the roof truss of the Orlando Civic Center because large fabrication cracks were formed along the perimeter of the thermal cut surfaces of many weld access holes."

120

Non-column Application of Wide-Flange Shapes

Barsom

"Also, because specifications present minimum requirements, the need for additional requirements must be investigated for new and unproven designs, for the use of new materials, for the use of common materials in new and unique applications, and for any other nontraditional situation."

121

Special Welding Applications and Field Fixes

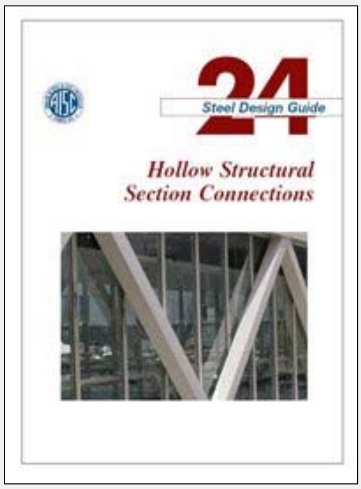
- Welding on Anchor Rods
- Welding on Heavy Sections ("Jumbo Shapes")
- Welding HSS
- Welding AESS
- Field Welding
- Welding on Existing Structures
- Combining Welds and Bolts

122

Special Welding Applications and Field Fixes: Welding HSS

Design Guide 24

Jeffrey Packer, Ph.D., D.Sc., P.Eng.
Donald Sherman, Ph.D., P.E.
Maura Lecce, Ph.D



123

Special Welding Applications and Field Fixes: Welding HSS

HSS Limit States

Typically not limited by the weld.

Connection may dictate the member size

Interaction between member designer and connection designer

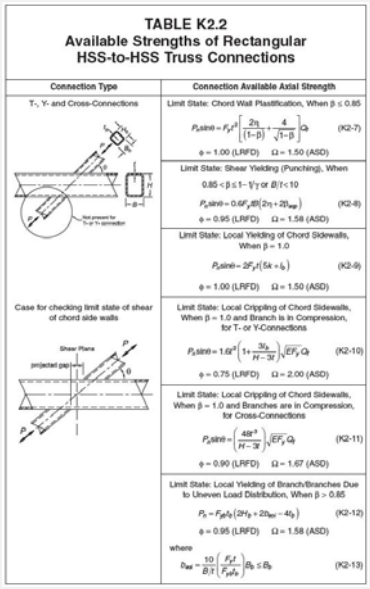
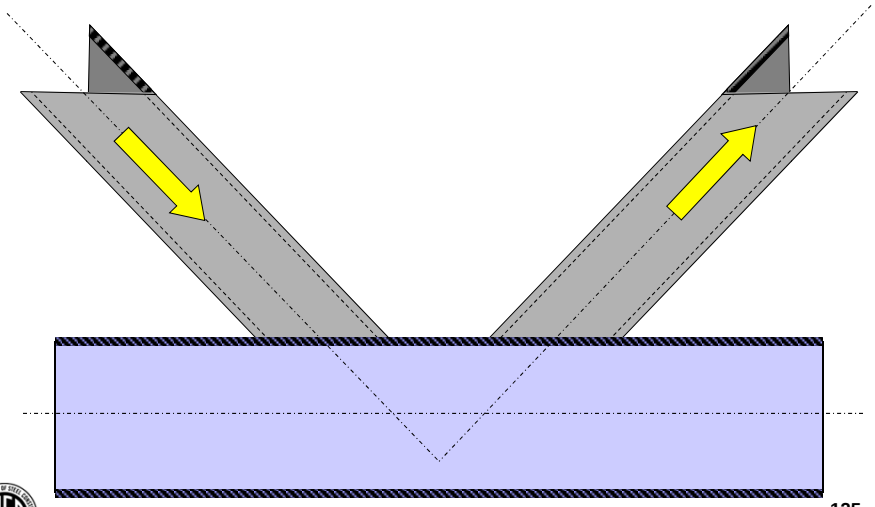


TABLE K2.2
Available Strengths of Rectangular HSS-to-HSS Truss Connections

Connection Type	Connection Available Axial Strength
T-, Y- and Cross-Connections	Limit State: Chord Wall Plastification, When $\beta \le 0.85$ $P_n \sin\theta = F_y t^2 \left[\frac{2\eta}{(1-\beta)} + \frac{4}{\sqrt{1-\beta}}\right] Q_f$ (K2-7) $\phi = 1.00$ (LRFD) $\Omega = 1.50$ (ASD)
	Limit State: Shear Yielding (Punching), When $0.85 < \beta \le 1-1/\gamma$ or $B/t < 10$ $P_n \sin\theta = 0.6 F_y t B (2\eta + 2\beta_{eff})$ (K2-8) $\phi = 0.95$ (LRFD) $\Omega = 1.58$ (ASD)
	Limit State: Local Yielding of Chord Sidewalls, When $\beta = 1.0$ $P_n \sin\theta = 2F_y t (5k + l_b)$ (K2-9) $\phi = 1.00$ (LRFD) $\Omega = 1.50$ (ASD)
Case for checking limit state of shear of chord side walls	Limit State: Local Crippling of Chord Sidewalls, When $\beta = 1.0$ and Branch is in Compression, for T- or Y-Connections $P_n \sin\theta = 1.6 t^2 \left(1 + \frac{3l_b}{H-3t}\right) \sqrt{EF_y} Q_f$ (K2-10) $\phi = 0.75$ (LRFD) $\Omega = 2.00$ (ASD)
	Limit State: Local Crippling of Chord Sidewalls, When $\beta = 1.0$ and Branches are in Compression, for Cross-Connections $P_n \sin\theta = \left(\frac{48t^3}{H-3t}\right) \sqrt{EF_y} Q_f$ (K2-11) $\phi = 0.90$ (LRFD) $\Omega = 1.67$ (ASD)
	Limit State: Local Yielding of Branch/Branches Due to Uneven Load Distribution, When $\beta > 0.85$ $P_n = F_{yb} t_b (2H_b + 2b_{be} - 4t_b)$ (K2-12) $\phi = 0.95$ (LRFD) $\Omega = 1.58$ (ASD) where $b_{be} = \frac{10}{B/t}\left(\frac{F_y t}{F_{yb} t_b}\right) B_b \le B_b$ (K2-13)

Limit States for Tubular Connections

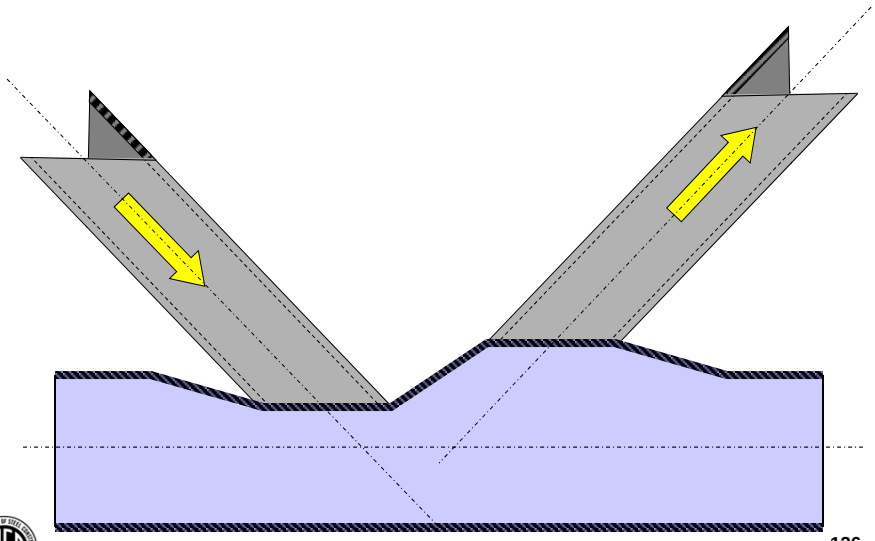
Sectional view



125

Limit States for Tubular Connections

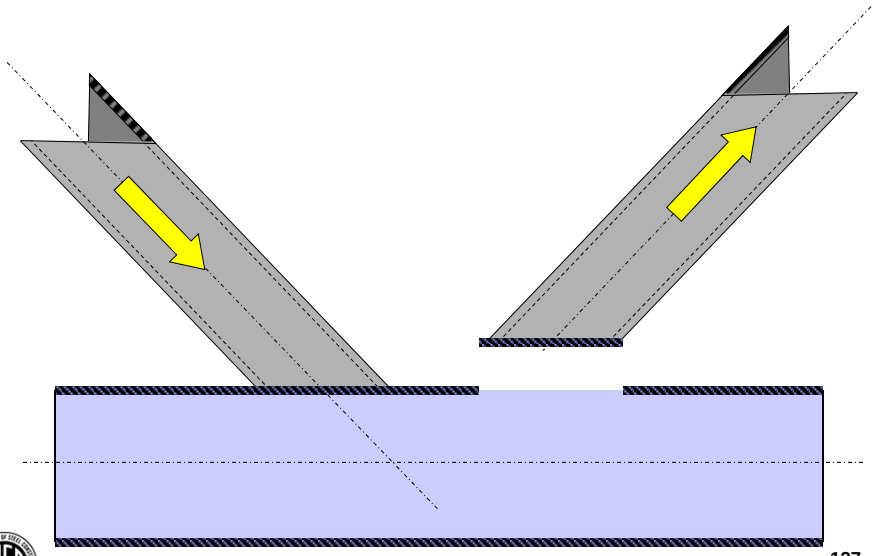
Plastification of the chord wall



126

Limit States for Tubular Connections

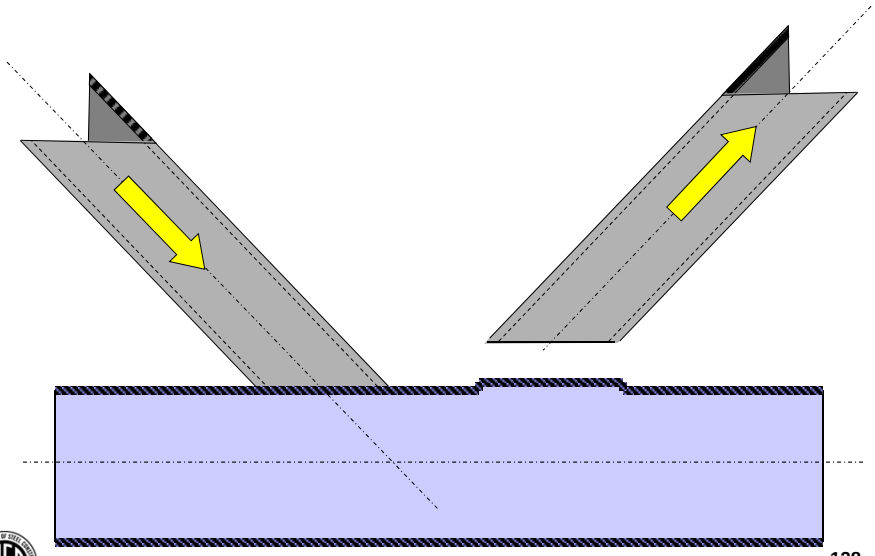
Punching shear rupture of the chord face



127

Limit States for Tubular Connections

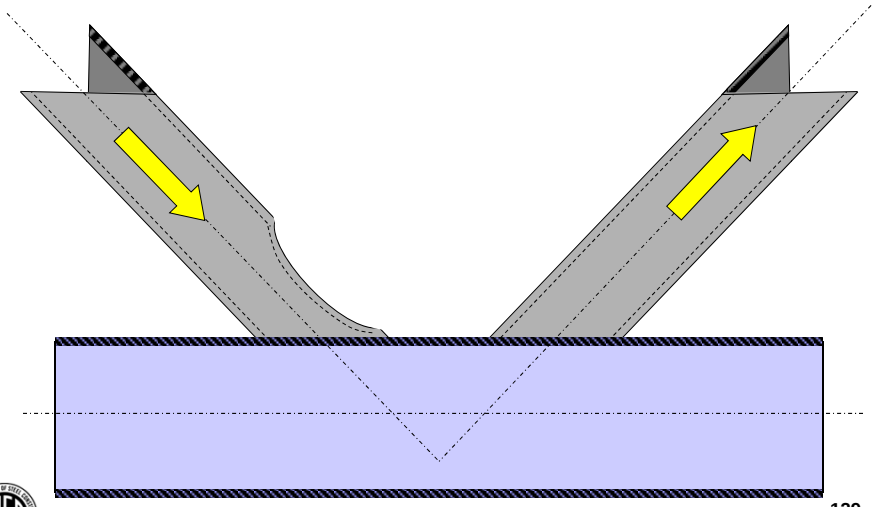
Tension rupture of the branch member



128

Limit States for Tubular Connections

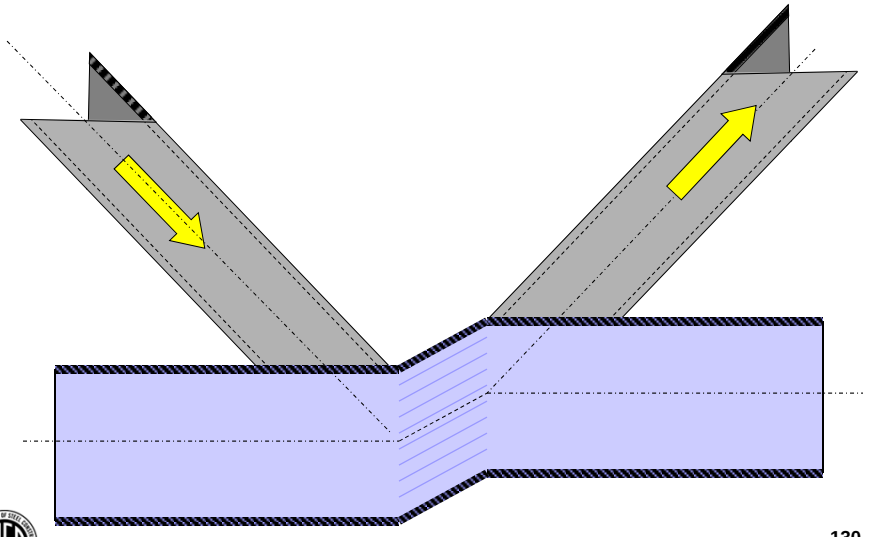
Local buckling of the branch member



129

Limit States for Tubular Connections

Overall shear yielding of the chord

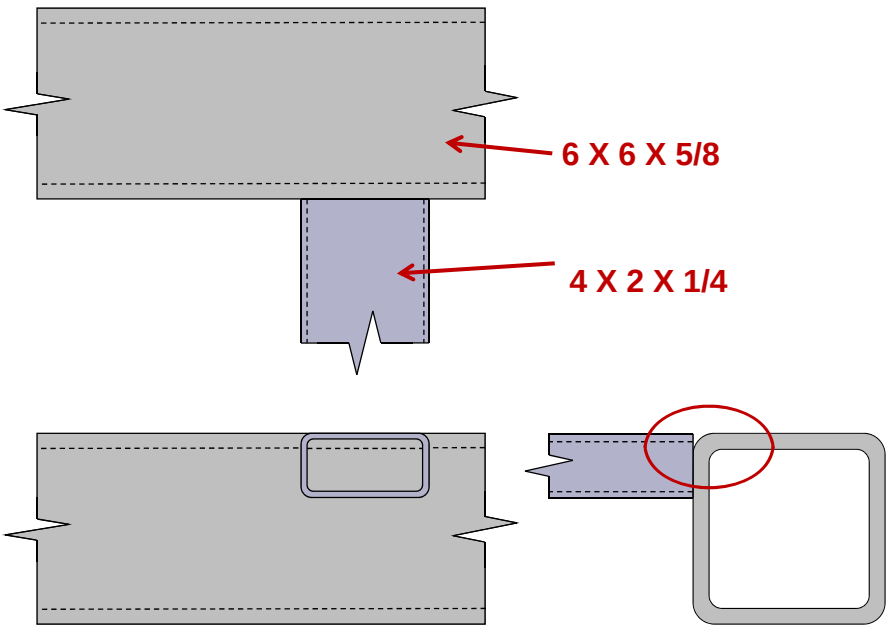


130

Special Welding Applications and Field Fixes: Welding HSS

Overall Configuration

131



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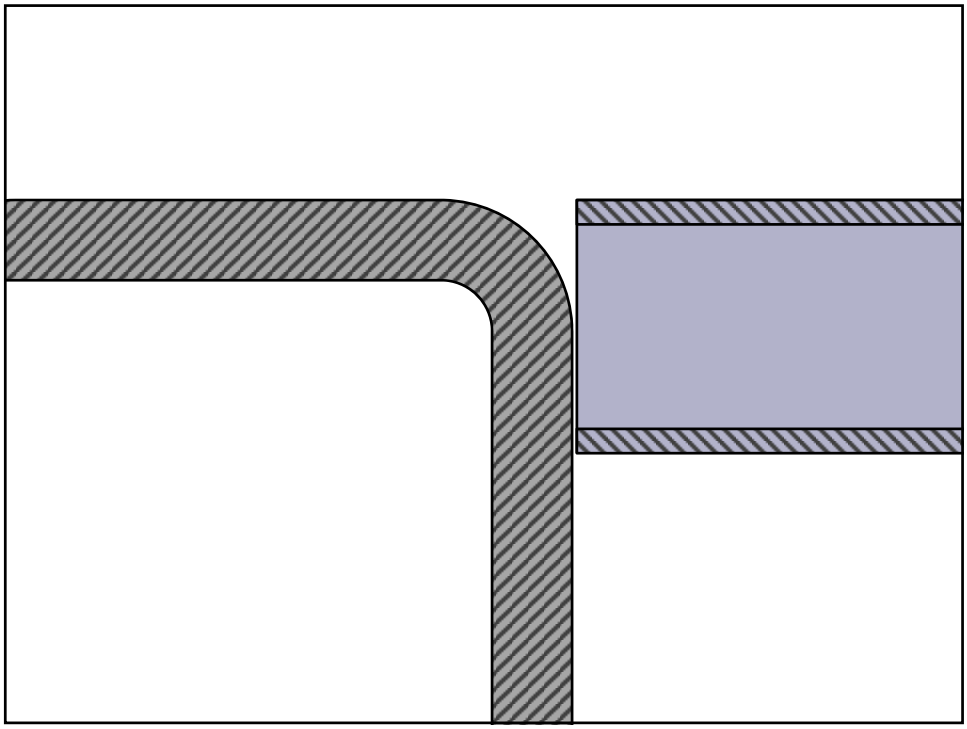
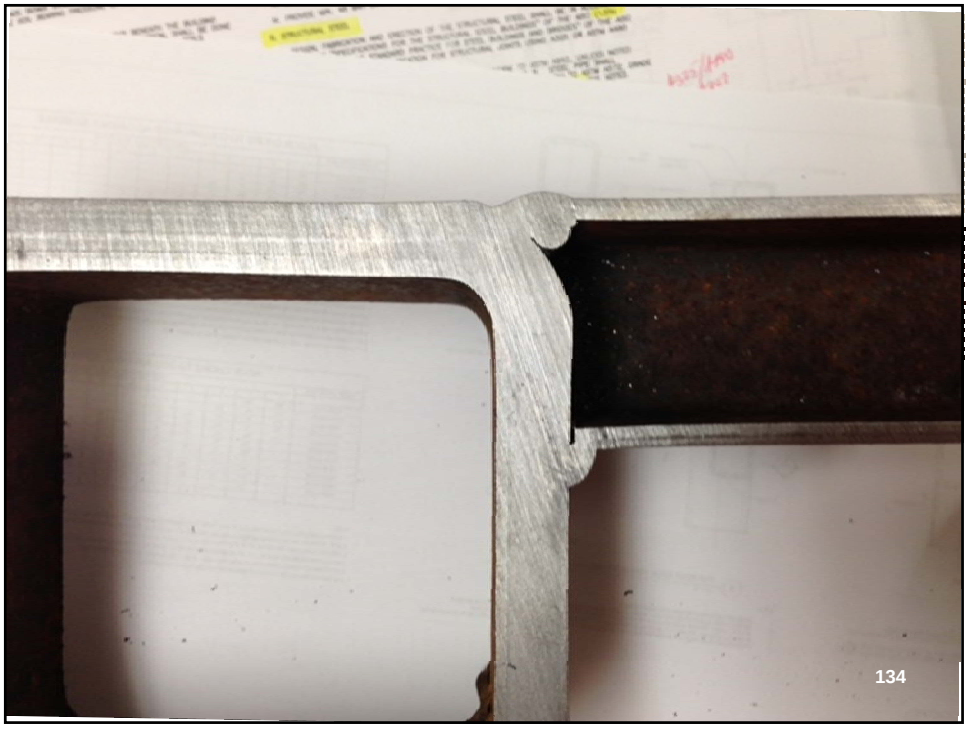
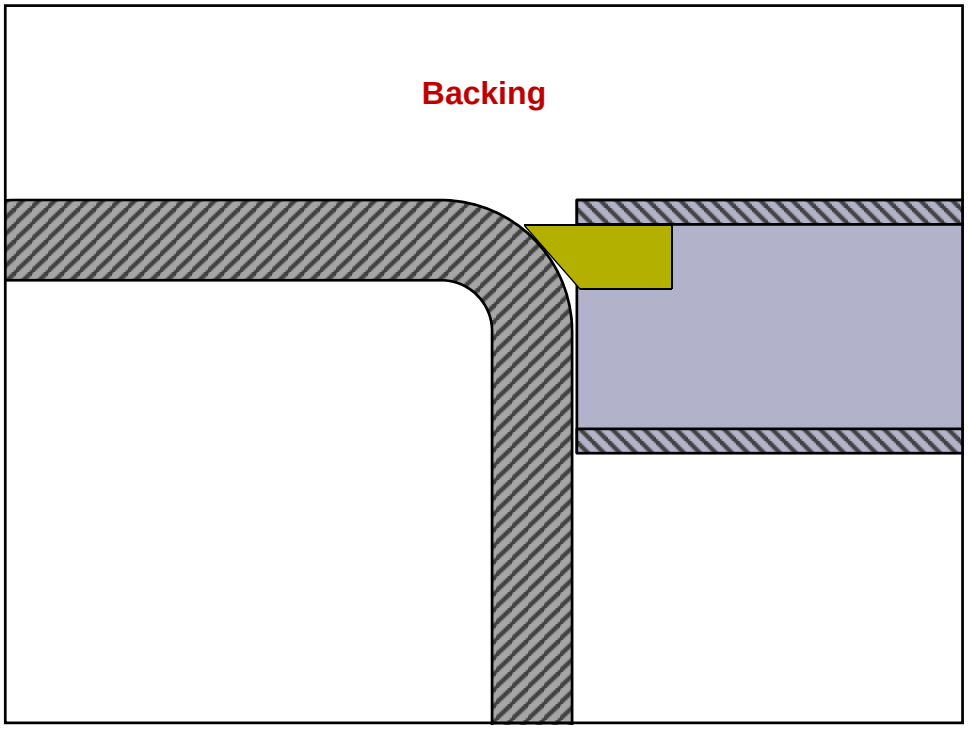
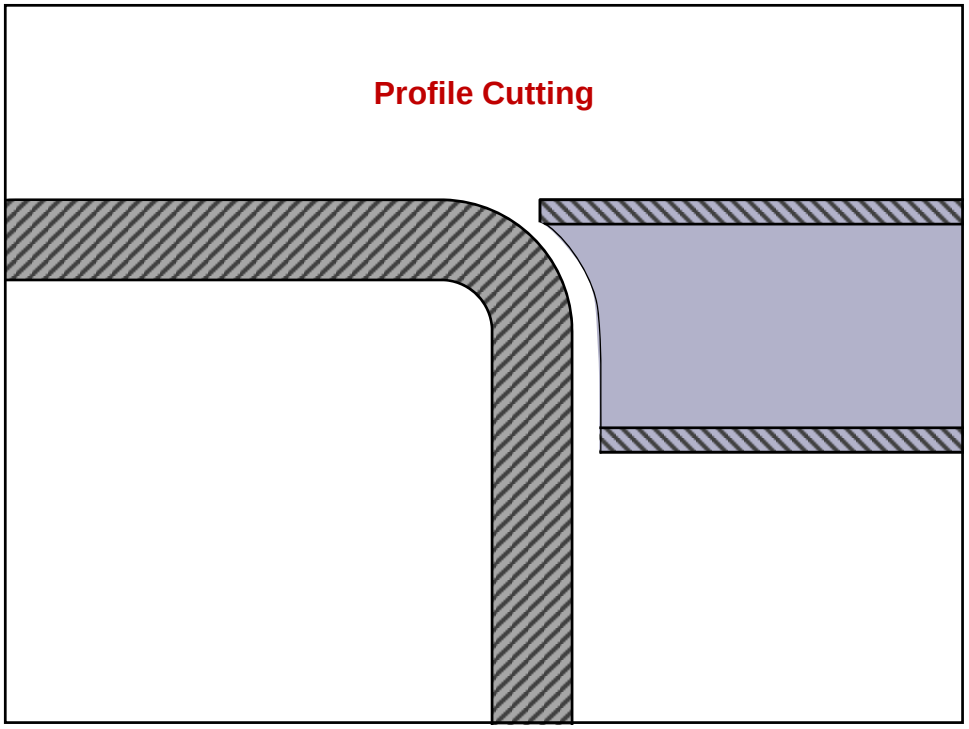
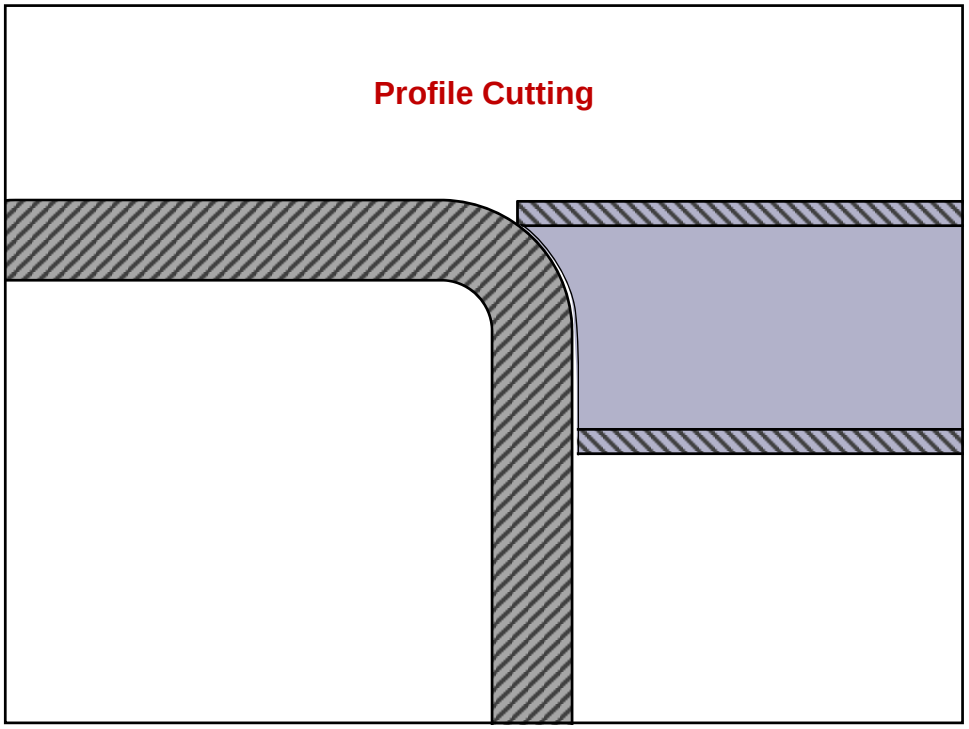
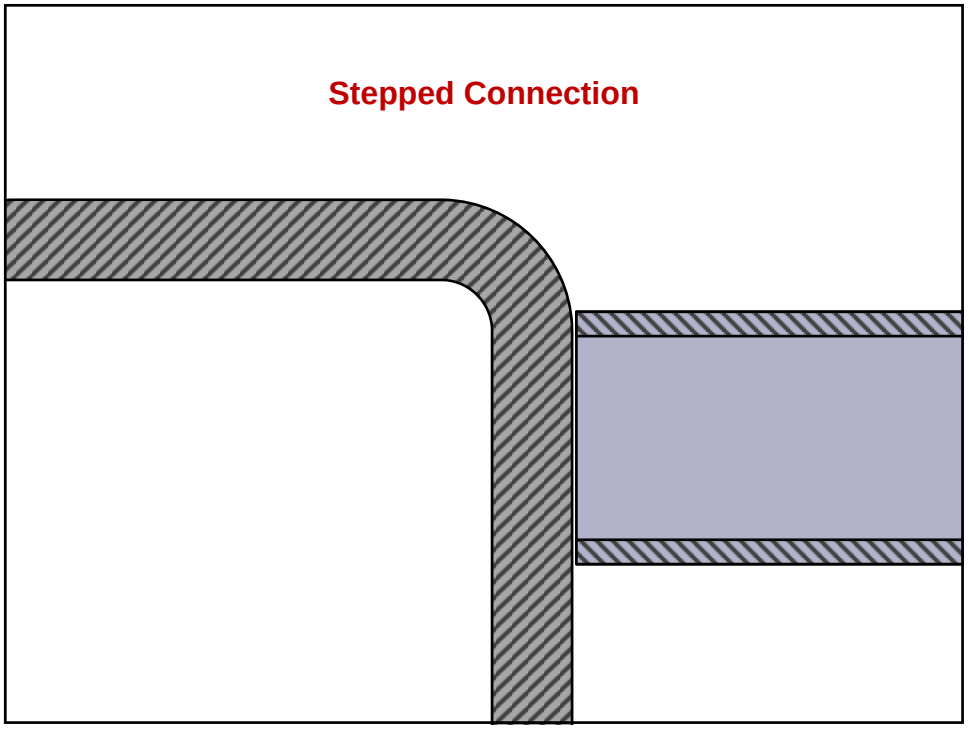


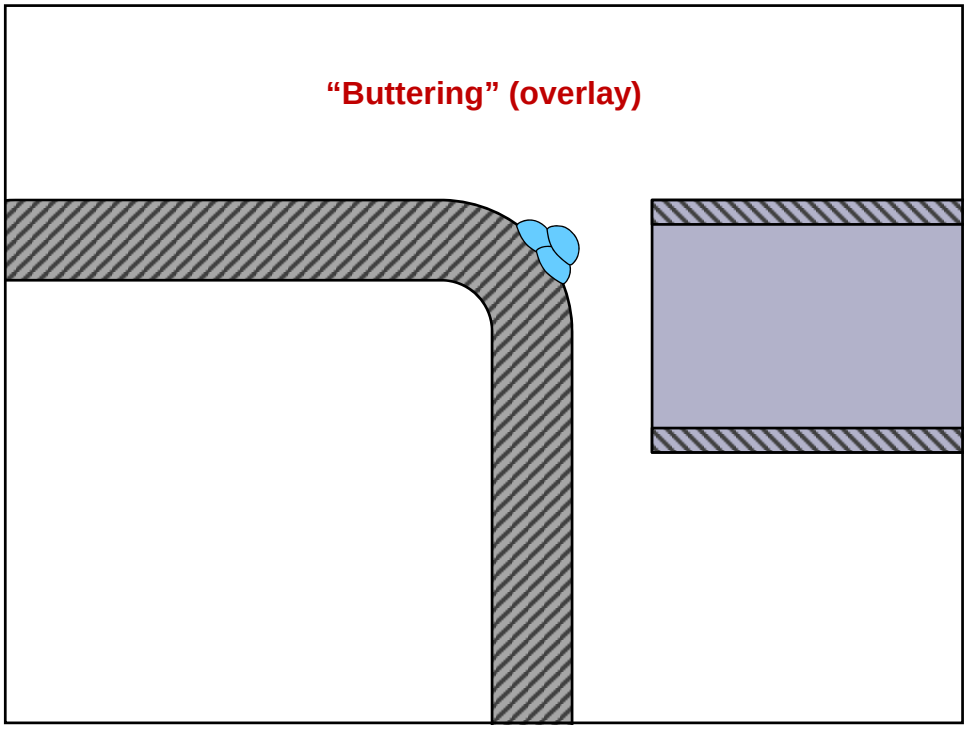


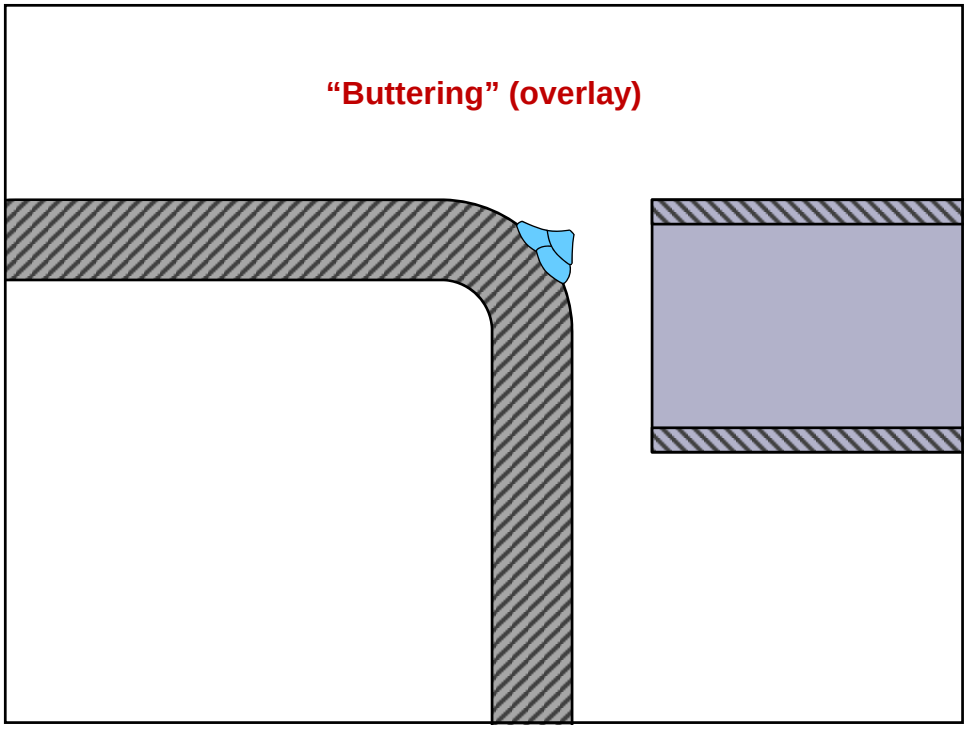


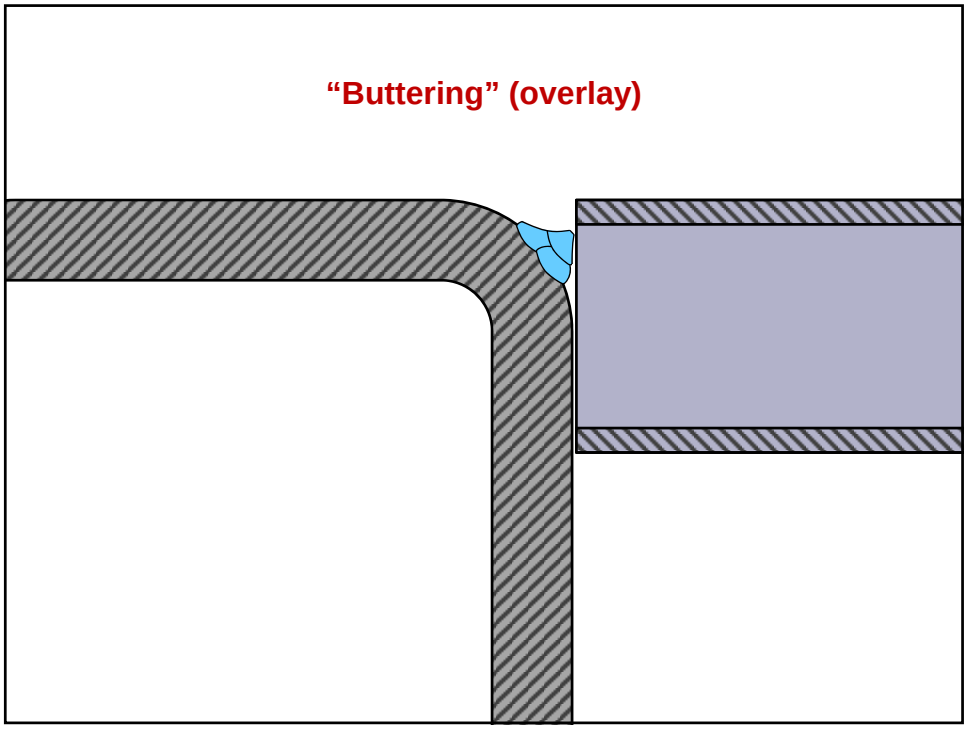


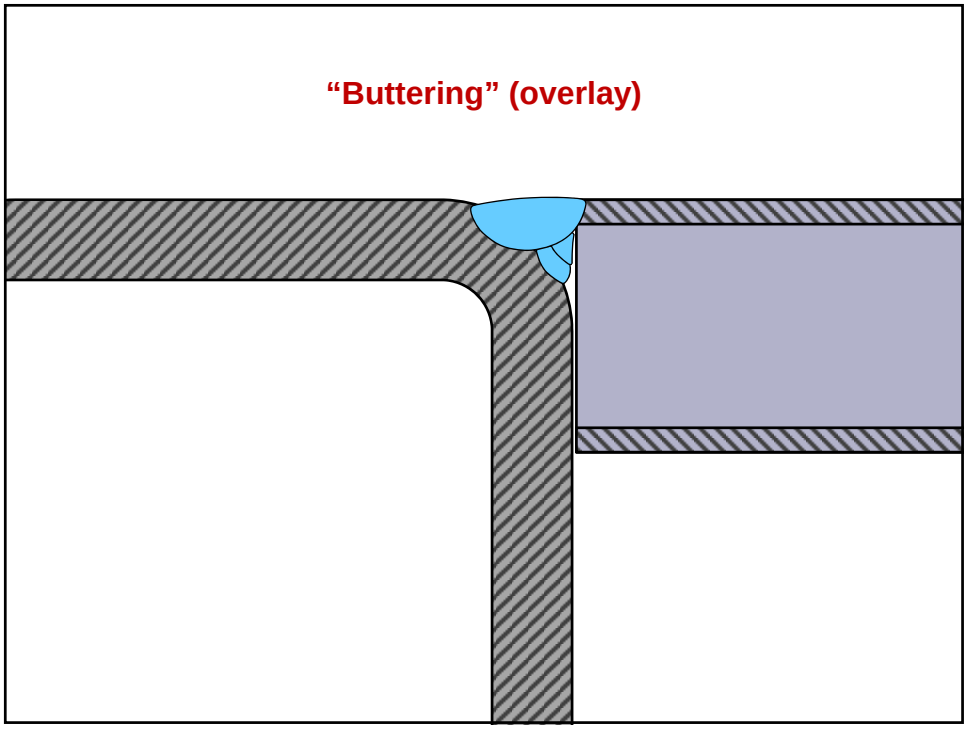


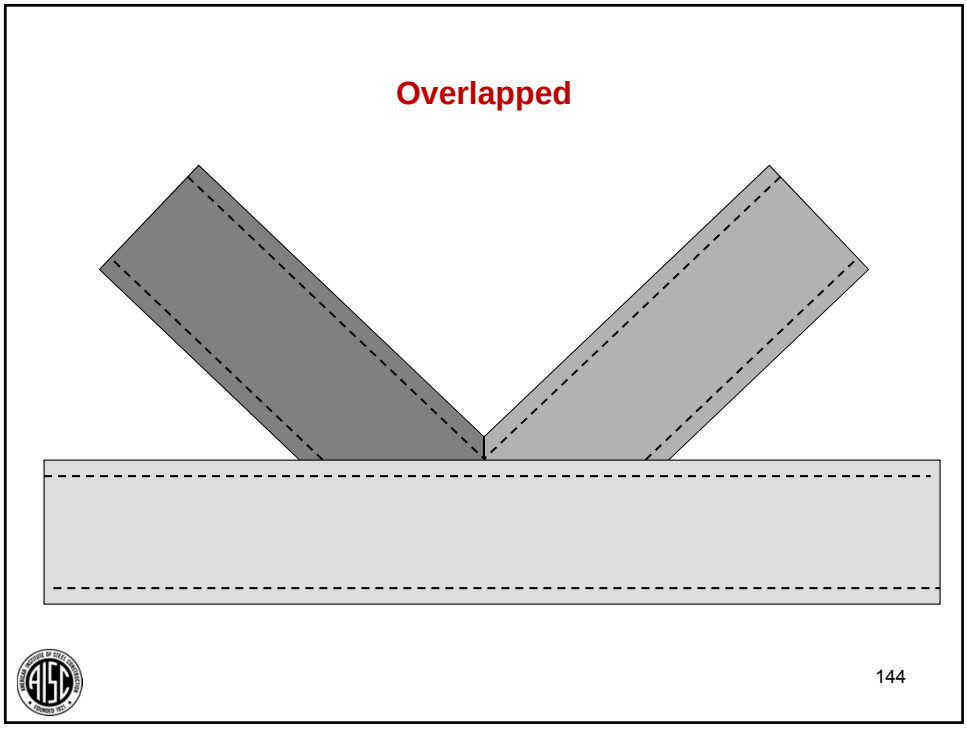


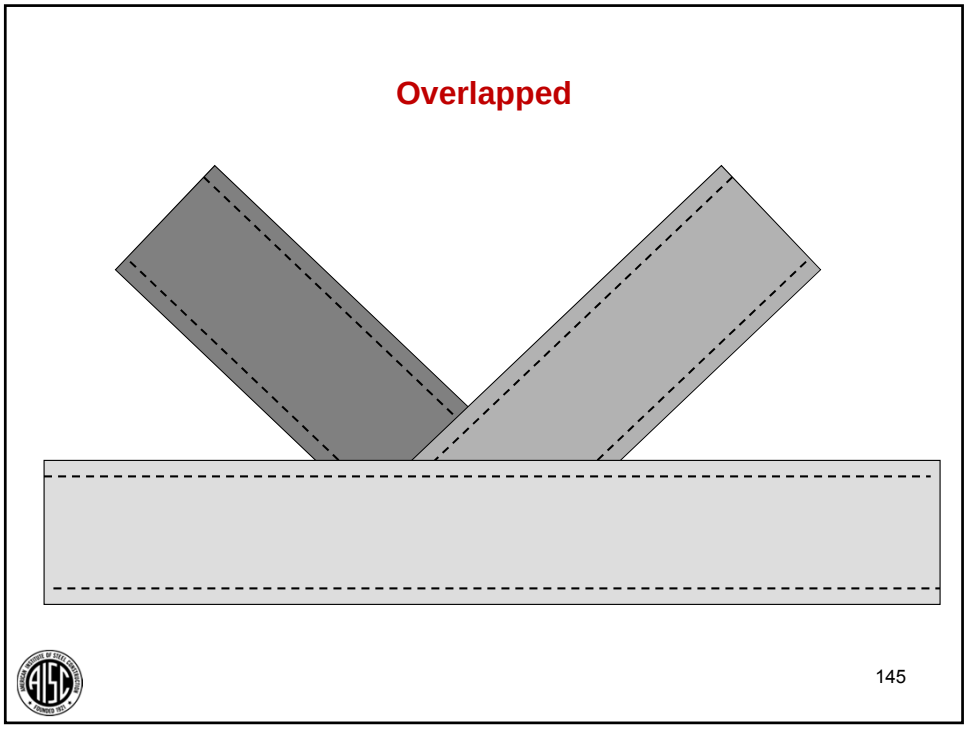


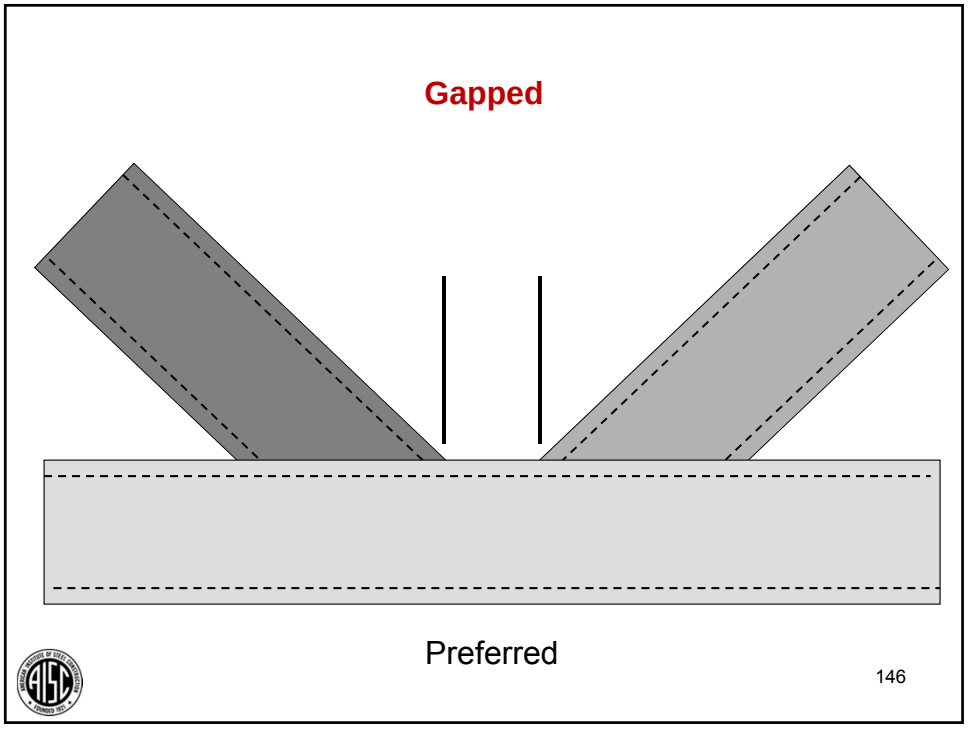




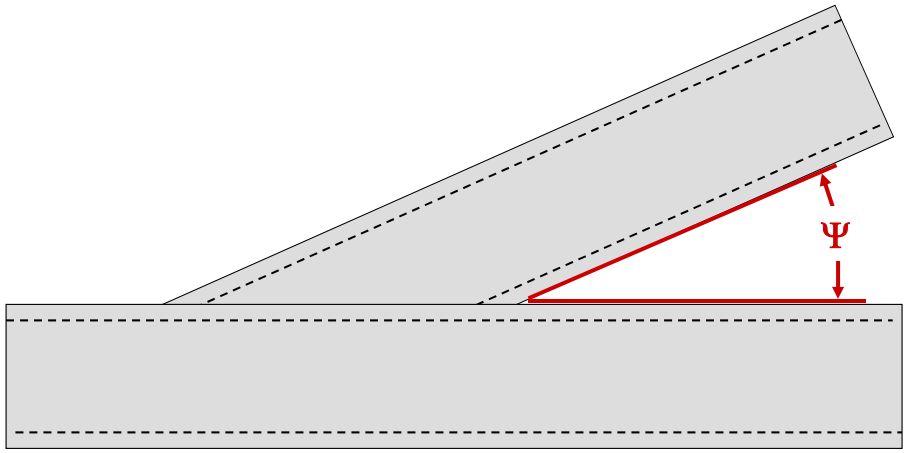








Provide Access for Welding and Inspection



Ψ = 30° minimum

147

Special Welding Applications and Field Fixes: Welding HSS

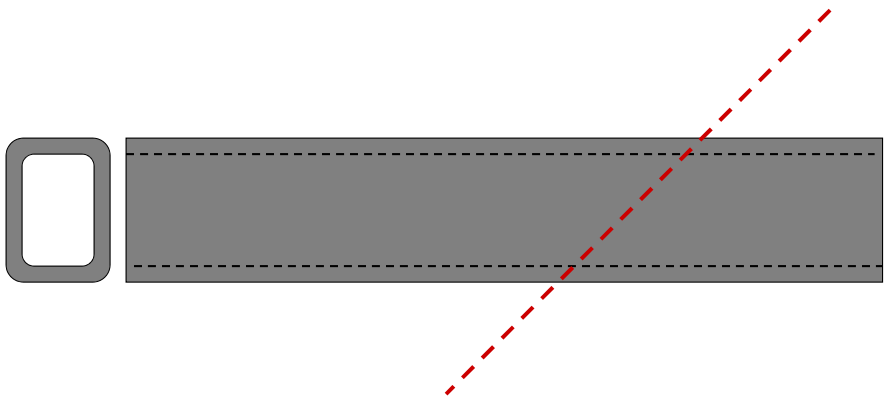
Cutting and Fitting

148

Square and Rectangular HSS

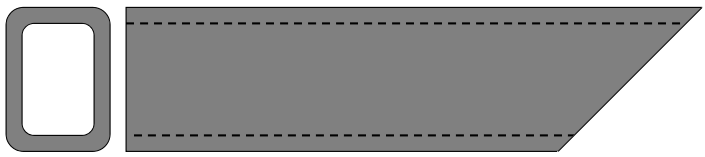
149

Square and Rectangular HSS



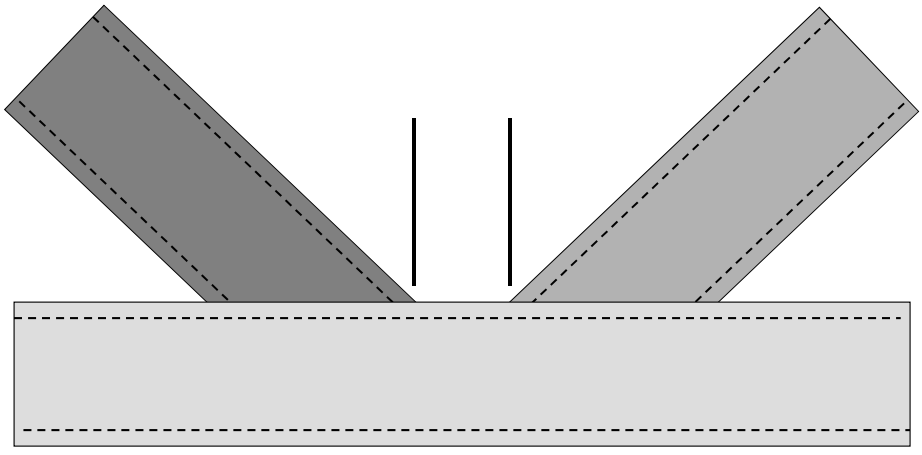
150

Square and Rectangular HSS



151

Square and Rectangular HSS Gapped



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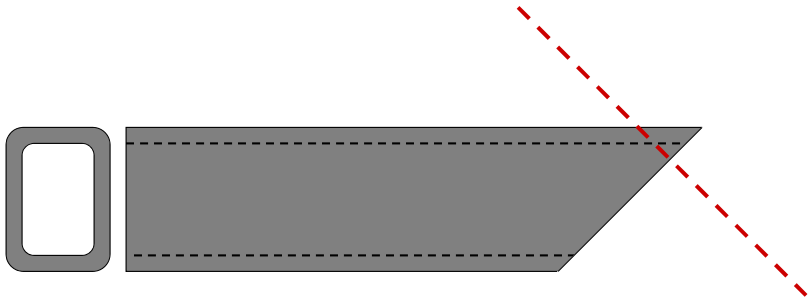
Square and Rectangular HSS



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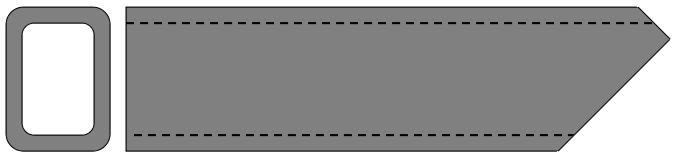
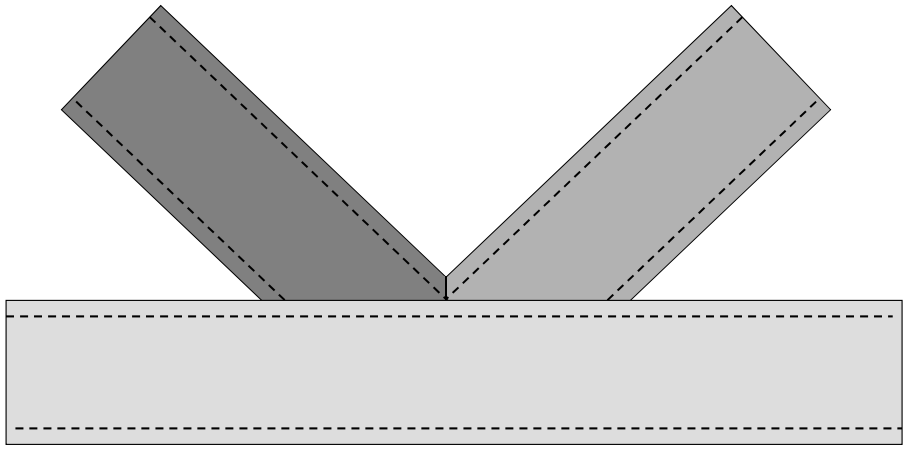
Square and Rectangular HSS



154

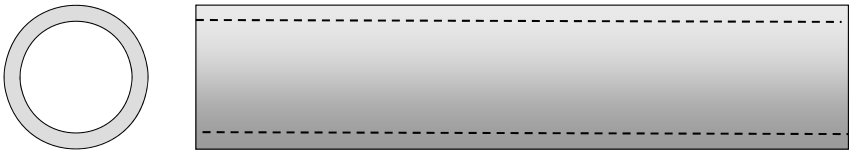
Square and Rectangular HSS Overlapped



All possible with saw cuts

155

Round HSS



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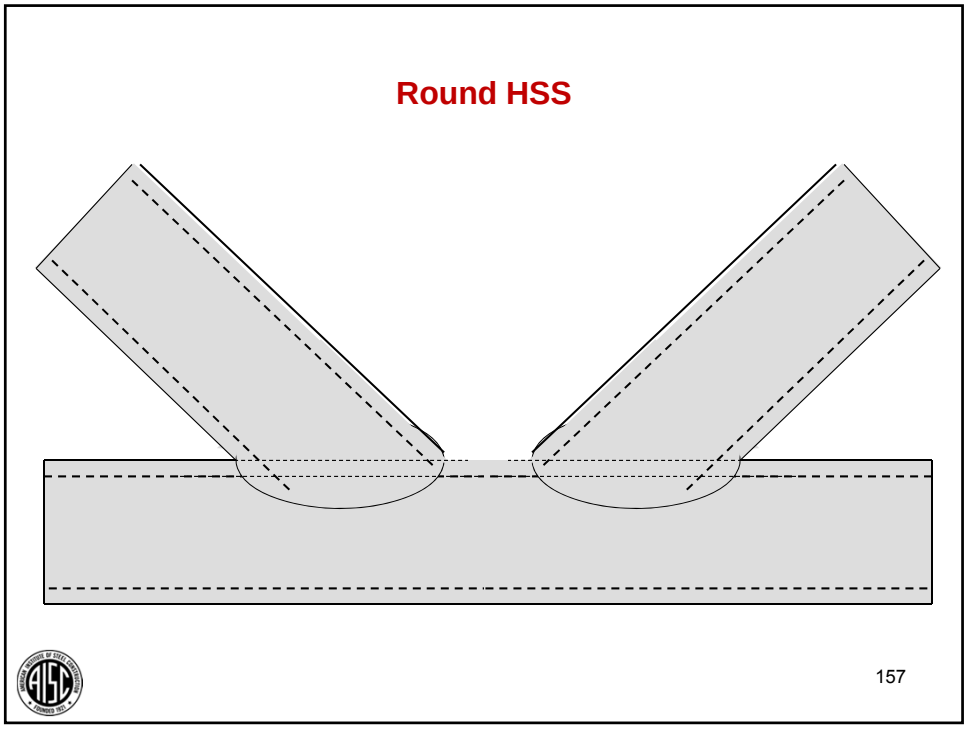
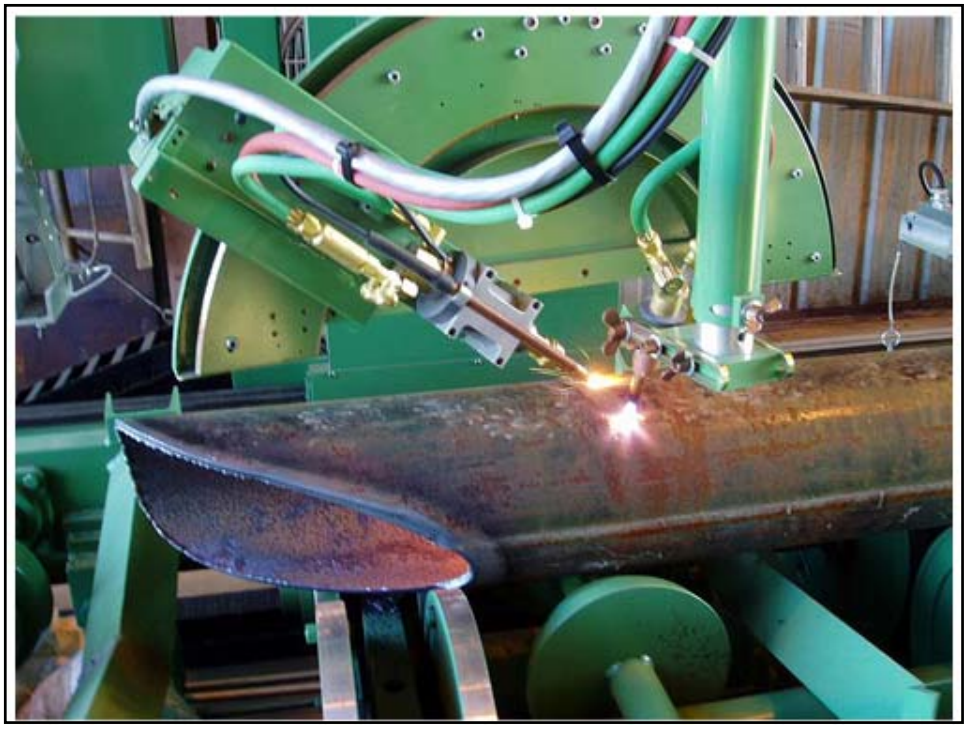
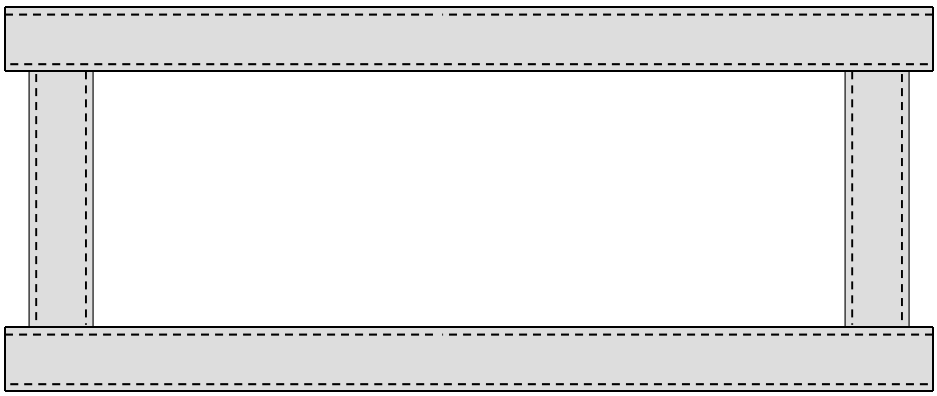




Square and Rectangular HSS



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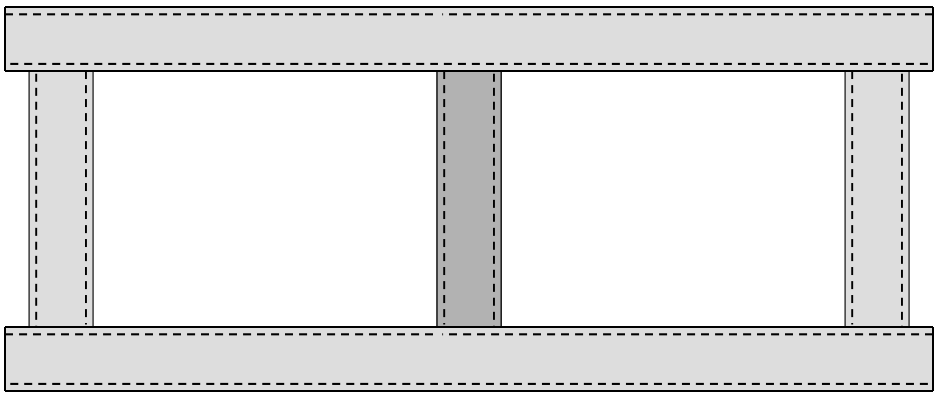
Square and Rectangular HSS



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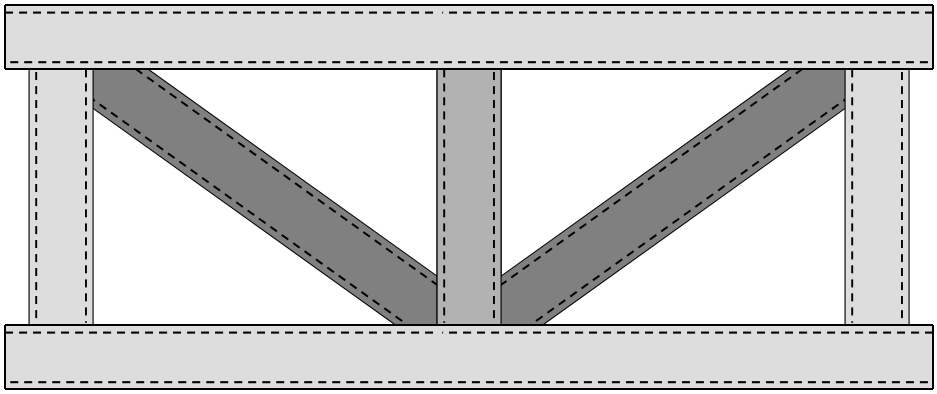
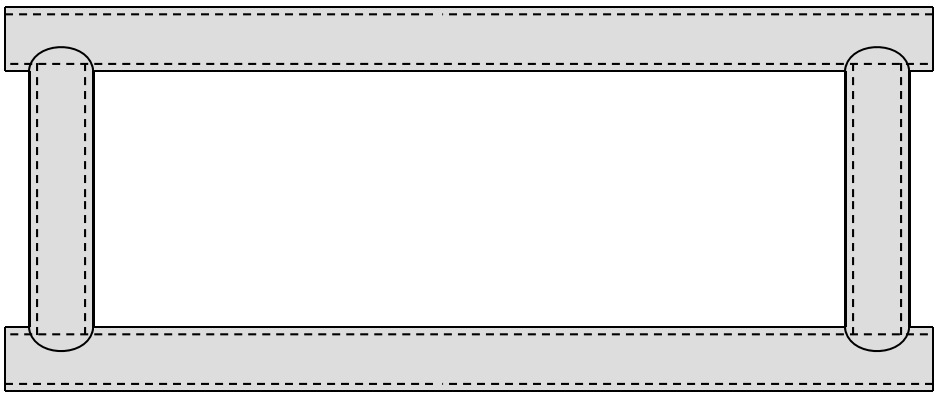
Square and Rectangular HSS



161

Round HSS



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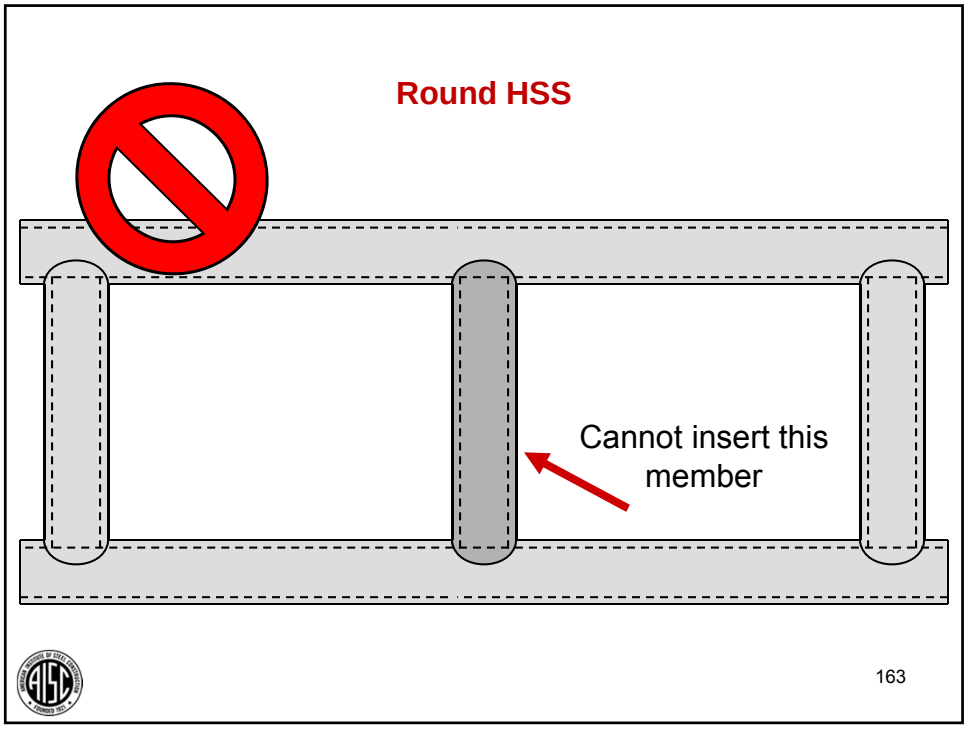
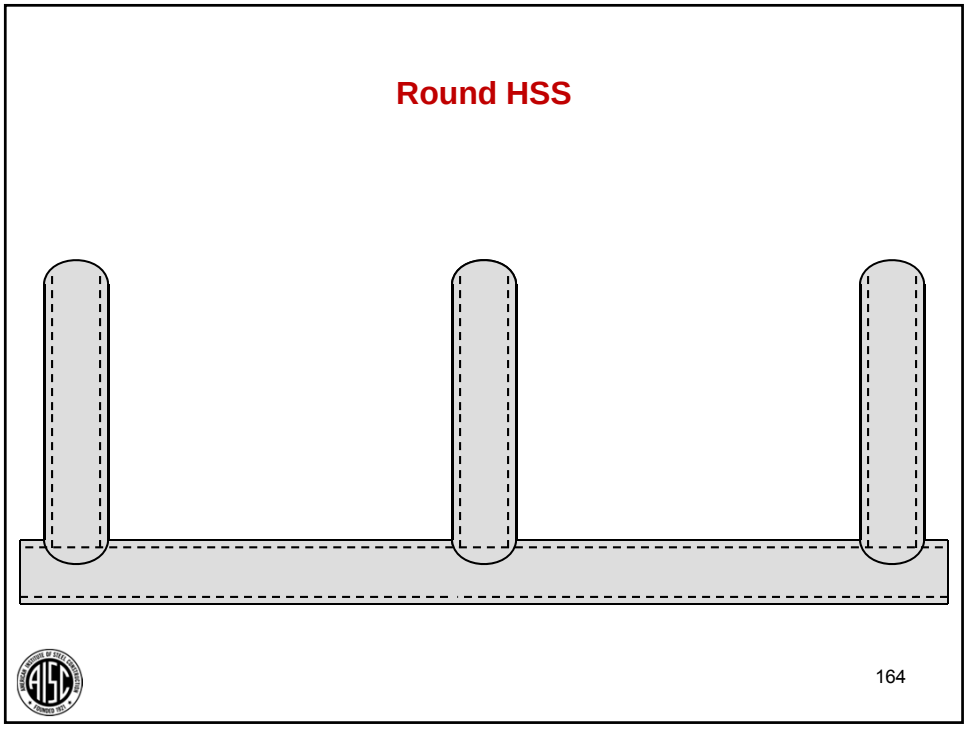
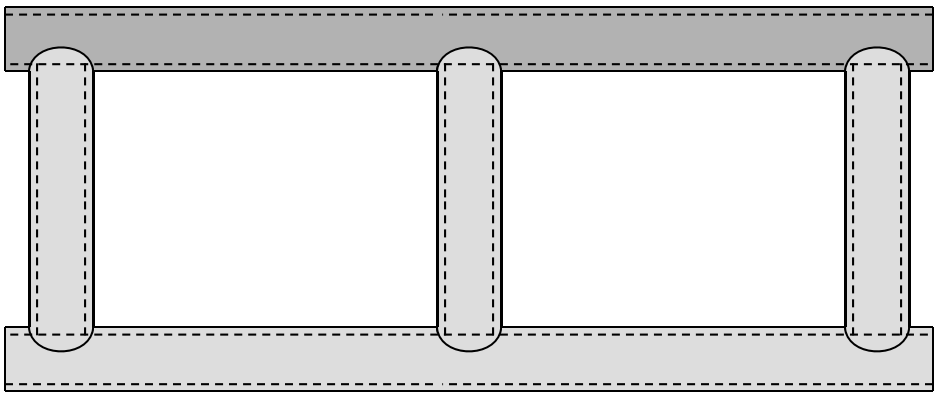




Round HSS



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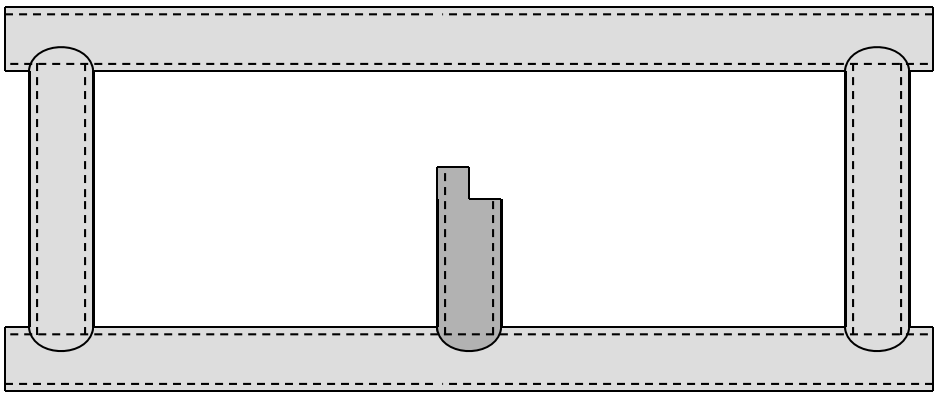
Round HSS



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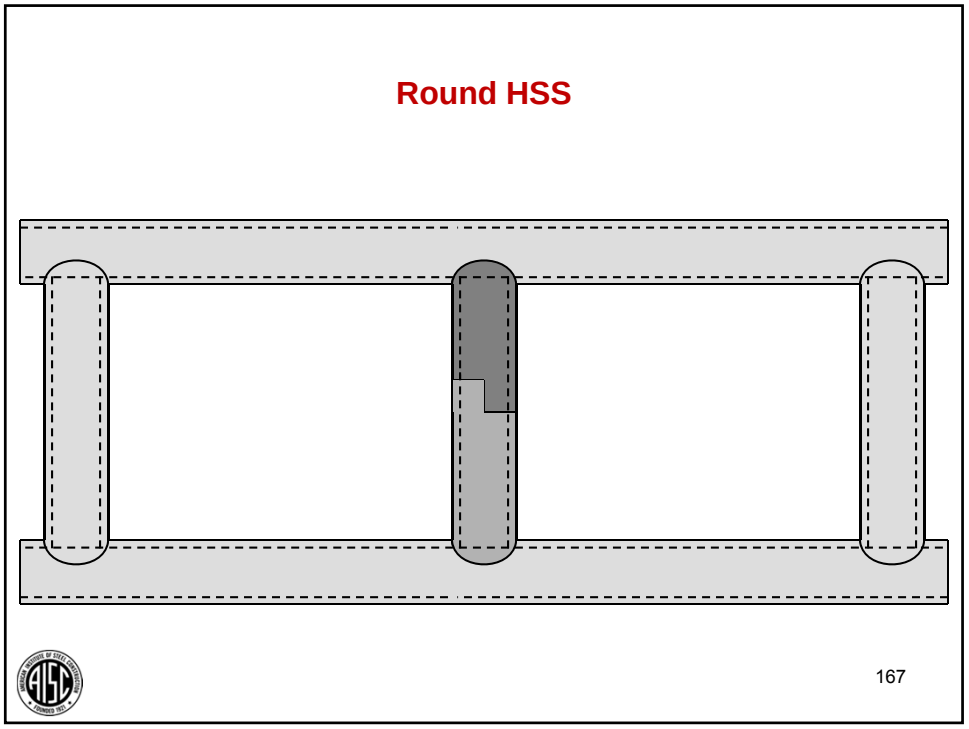
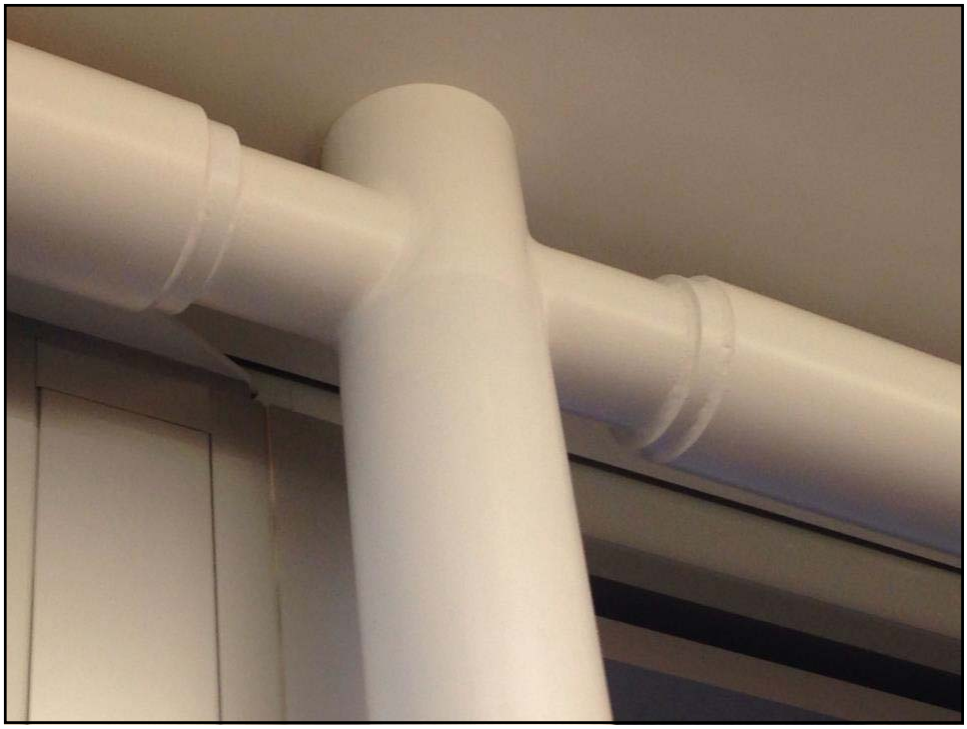
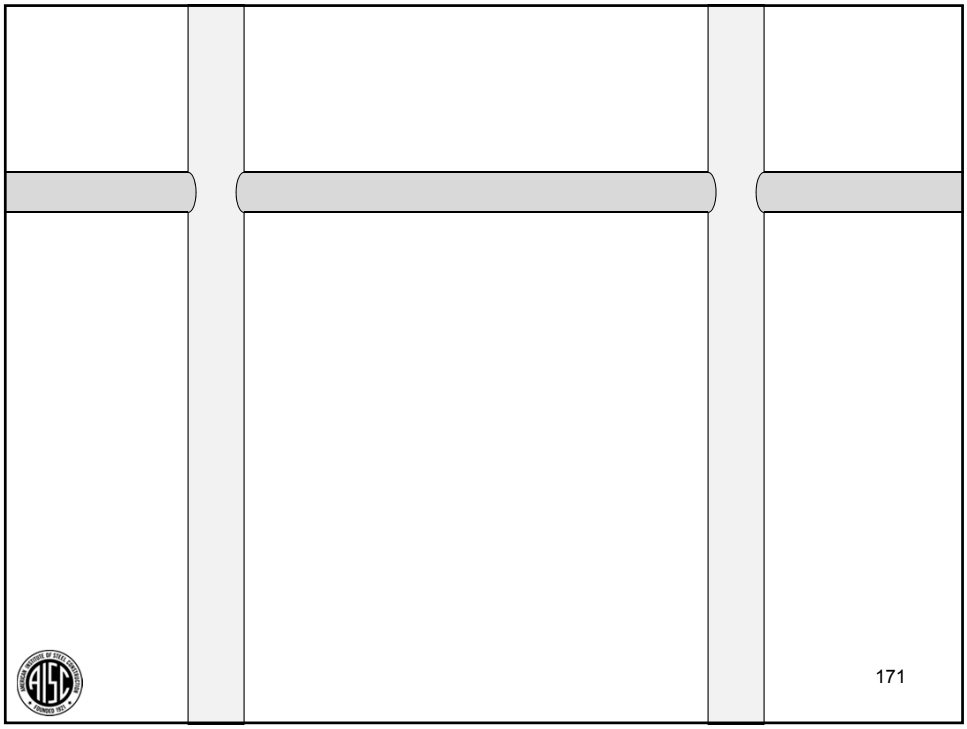
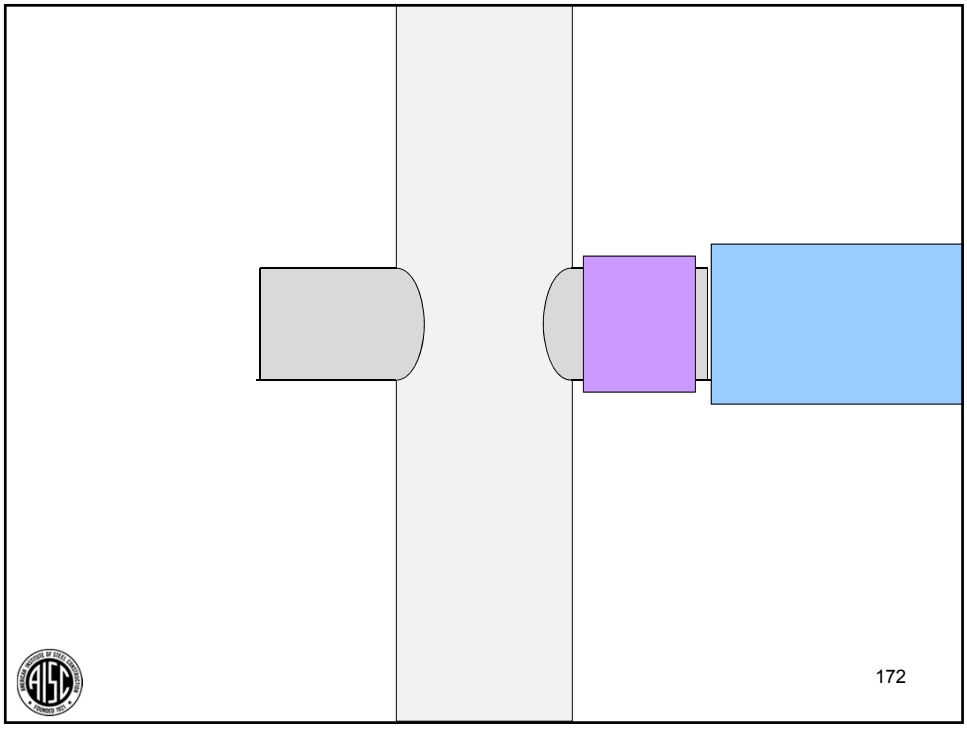
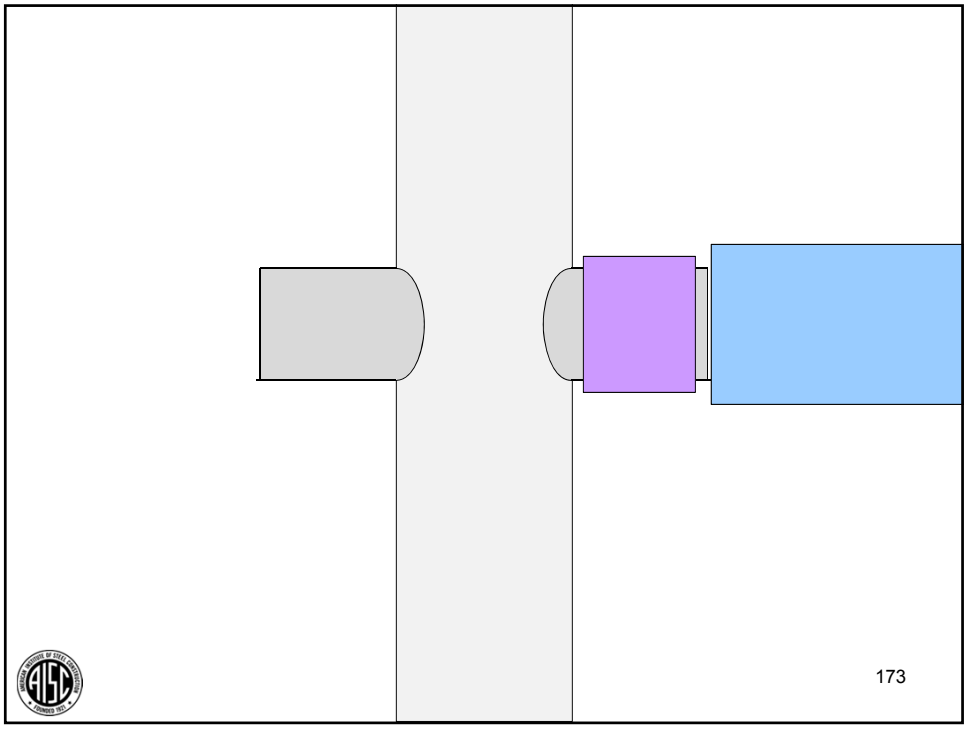


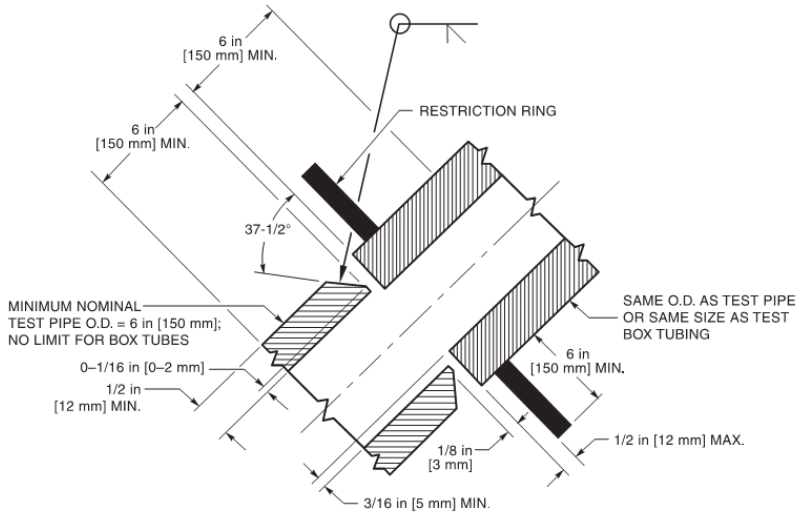








AWS D1.1 6GR Welder Qualification Test

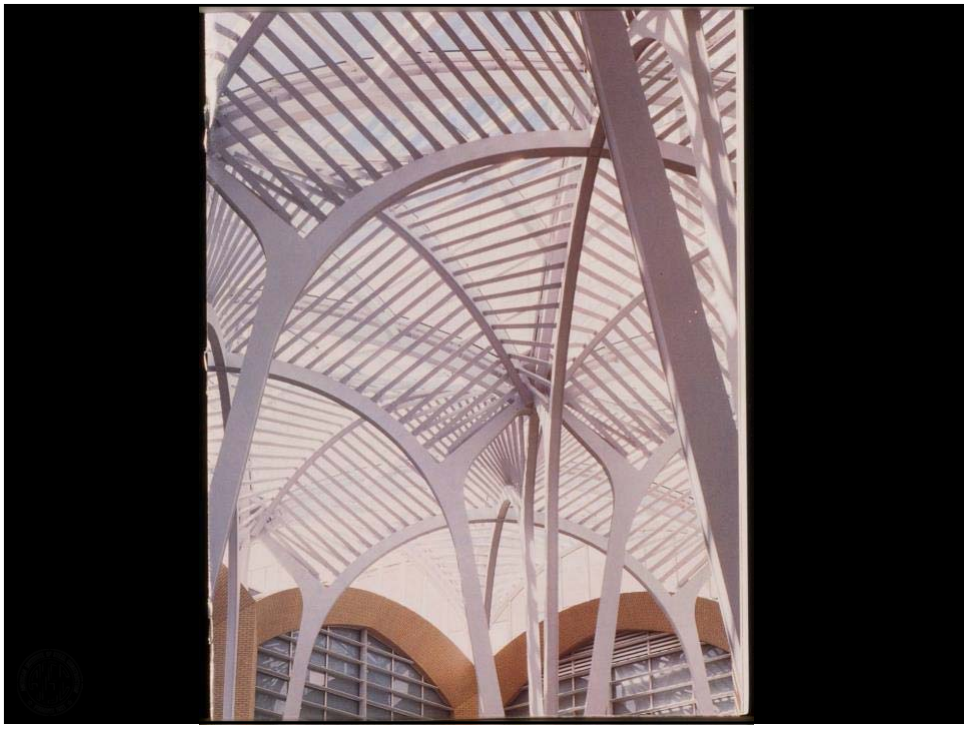


175

Special Welding Applications and Field Fixes

- Welding on Anchor Rods
- Welding on Heavy Sections (“Jumbo Shapes”)
- Welding HSS
- Welding AESS
- Field Welding
- Welding on Existing Structures
- Combining Welds and Bolts

176



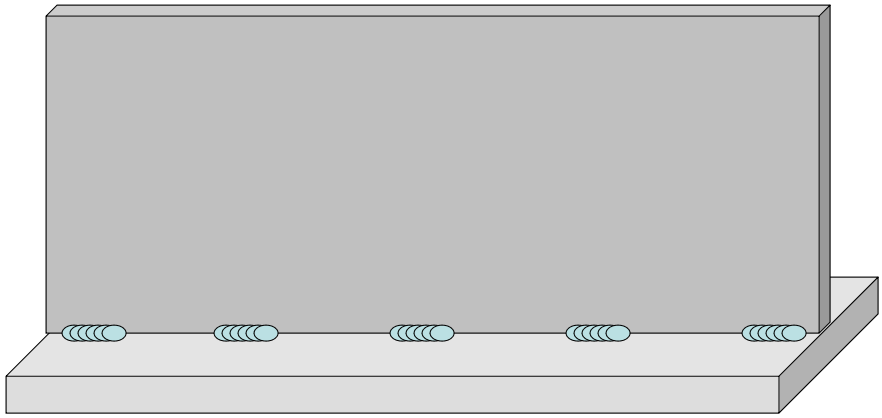
Special Welding Applications and Field Fixes
Welding AESS

- How pretty is pretty?
- Use of mock ups (samples)
- Tolerances
- Potential code conflicts

183

Special Welding Applications and Field Fixes
Welding AESS

Required for strength

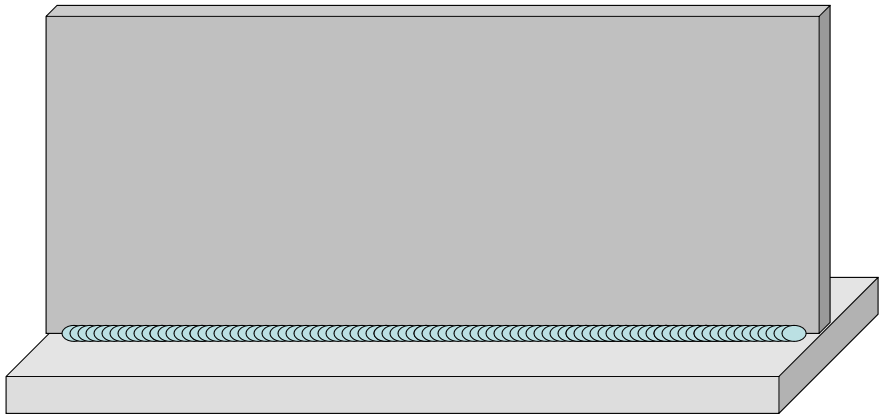


184

Special Welding Applications and Field Fixes
Welding AESS

Required for AESS

Higher cost, more distortion

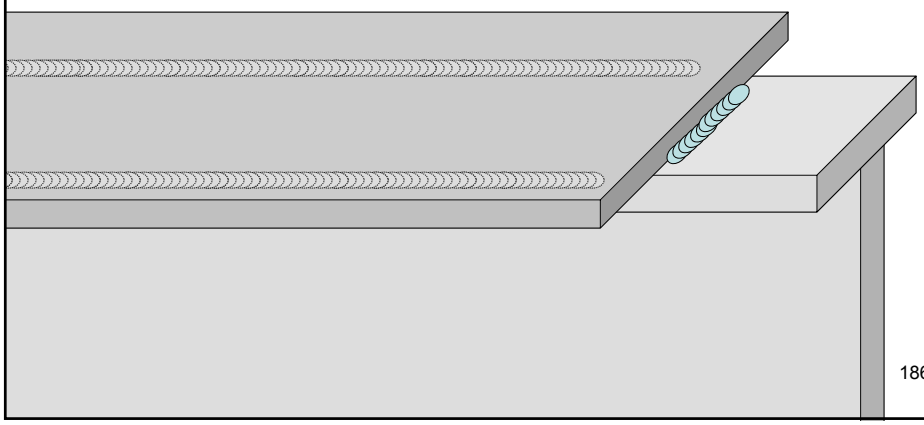


185

Special Welding Applications and Field Fixes
Welding AESS

Code requires interruption of welds at corners*

*Some relief in AWS D1.1:2015, and AISC 360-16

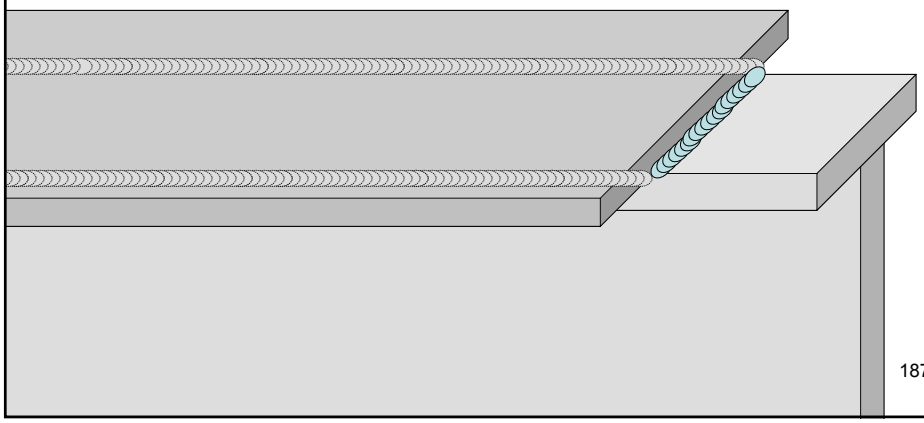


186

Special Welding Applications and Field Fixes
Welding AESS

AESS may require sealed joints

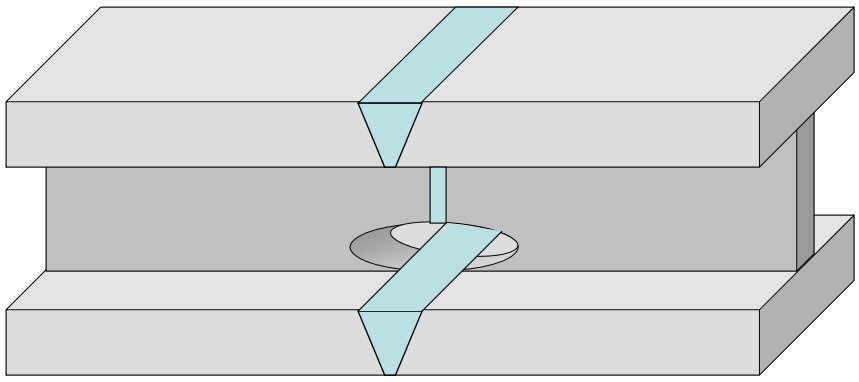
Workmanship concerns, Inspection issues



187

Special Welding Applications and Field Fixes
Welding AESS

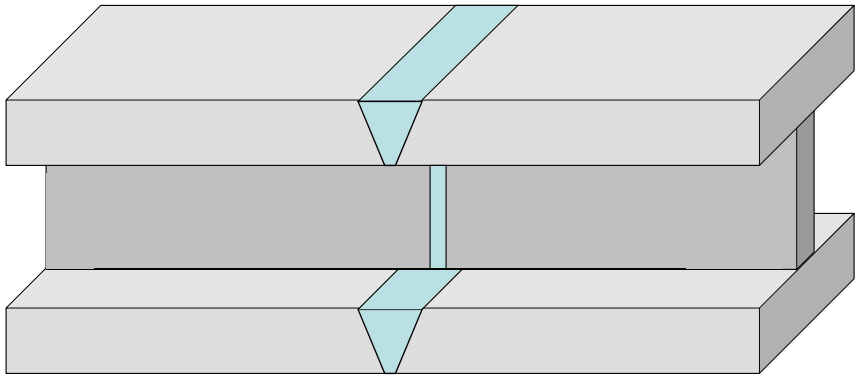
Code required weld access holes



188

Special Welding Applications and Field Fixes
Welding AESS

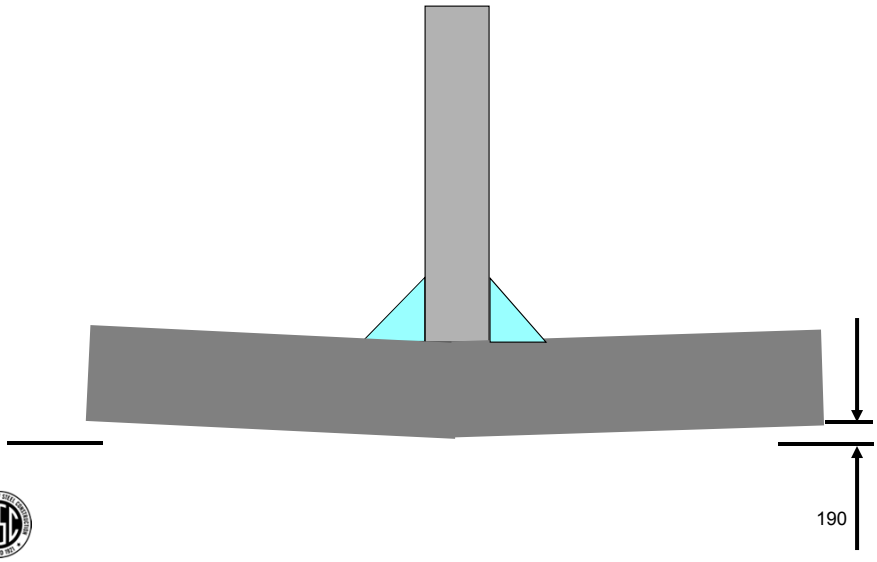
AESS may prohibit weld access holes



189

Special Welding Applications and Field Fixes
Welding AESS

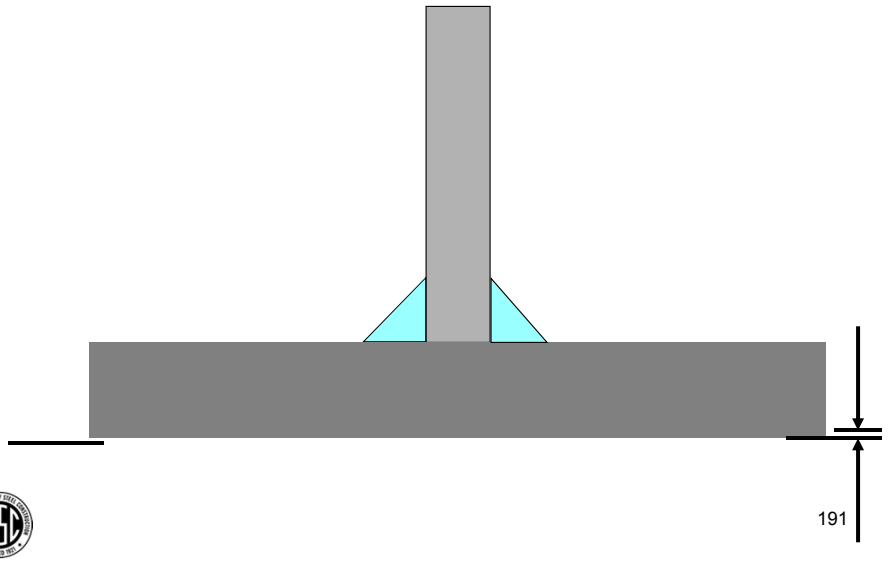
AWS D1.1 acceptable distortion



190

Special Welding Applications and Field Fixes
Welding AESS

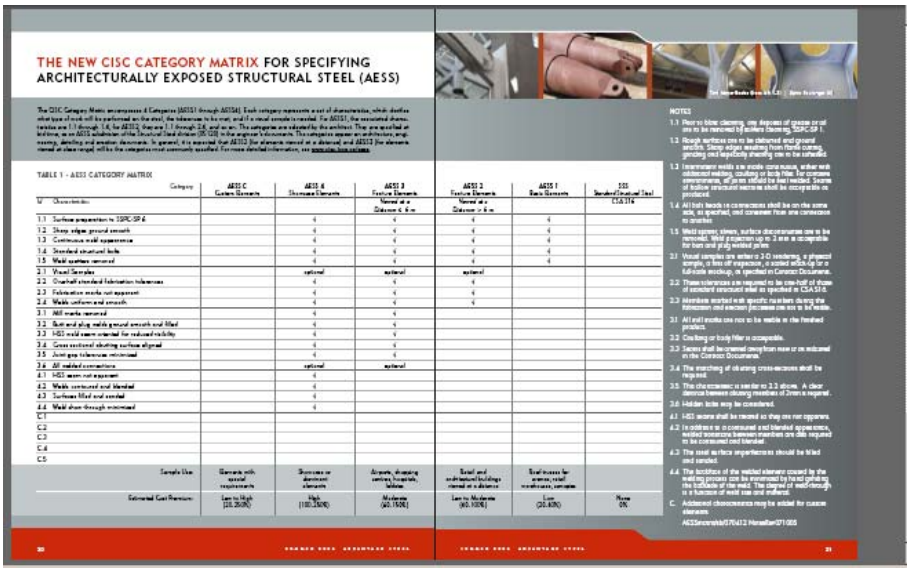
AESS may limit permissible distortion



191

http://www.cisc-icca.ca/docs/aess/ASteel31_AESS.pdf

THE CANADIAN MATRIX:
A CATEGORY APPROACH FOR SPECIFYING AESS



THE NEW CISC CATEGORY MATRIX FOR SPECIFYING ARCHITECTURALLY EXPOSED STRUCTURAL STEEL (AESS)

194

TABLE 1 - AESS CATEGORY MATRIX

Id	Characteristics	Category: AESS C Custom Elements	AESS 4 Showcase Elements	AESS 3 Feature Elements Viewed at a Distance ≤ 6 m	AESS Feature El Viewed Distance
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	optional	optior
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 filled and sanded		√		
4.4	Weld show-through minimized		√		
C.1					
C.2					

195

Special Welding Applications and Field Fixes
Welding AESS

NEW

AISC 303-16
Code of Standard Practice

196

Table 10.1. AESS Category Matrix

Category	AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS
Characteristics 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	optional	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 filled and sanded		√				
4.4 Weld show-through minimized		√				
C.1						
C.2						
C.3						
C.4						
C.5						
Sample Use:	Elements with special requirements to be defined in	Showcase or dominant elements	Airports, shopping centers, hospitals, lobbies	Retail and architectural buildings viewed at a distance	Roof trusses for arenas, retail warehouses, canopies	
Estimated Cost Premium:	Low to High (20-250%)	High (100-250%)	Moderate (60-150%)	Low to Moderate (40-100%)	Low (20-60%)	None 0%

Special Welding Applications and Field Fixes

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198

Special Welding Applications and Field Fixes
Field Welding

- Shop versus field welding: primarily an issue of cost.
- Some environmental issues (wind, rain, cold)
- Out-of-position welding
- Primary issue: managerial

199

Special Welding Applications and Field Fixes
Field Welding

Myths

- Can't get quality welds out-of-position
- Can't get quality in the field
- No codes govern field work
- Field welders aren't "certified" (i.e., qualified)
- There is no QC inspection in the field
- There is no audit program for field erectors

202

American Institute of Steel Construction, Inc.

is proud to recognize

ABC Erectors, Inc.

Any City, USA

for successfully meeting the quality certification requirements for

Advanced Certified Steel Erector

Roger E. Ferch

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Certification valid through May 2006

Special Welding Applications and Field Fixes

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204

Special Welding Applications and Field Fixes
Welding on Existing Structures

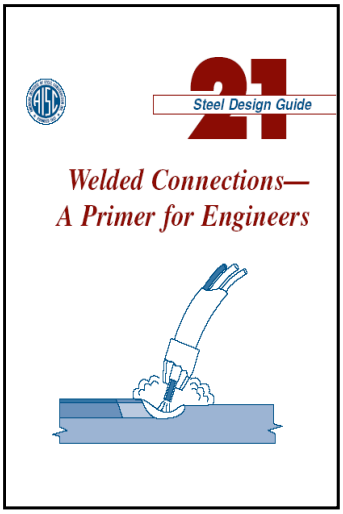
- Historic steels
- Welding on members under load
- Fire
- Cold worked steel/strain aged steel
- Comprehensive plans

205

Chapter 4 Metallurgical Issues

Historic (Obsolete) Steels

- ASTM A9
- ASTM A7
- ASTM A373
- ASTM A242



206

Special Welding Applications and Field Fixes
Welding on Existing Structures

Historic steels

- Check weldability, especially for riveted structures
- Rule of thumb (not 100% reliable):
  If steel was produced after WWII, steel will likely have acceptable weldability
- Weldability of steel does not decrease with time
- Steel does corrode with time

207

Special Welding Applications and Field Fixes
Welding on Existing Structures

- Historic steels
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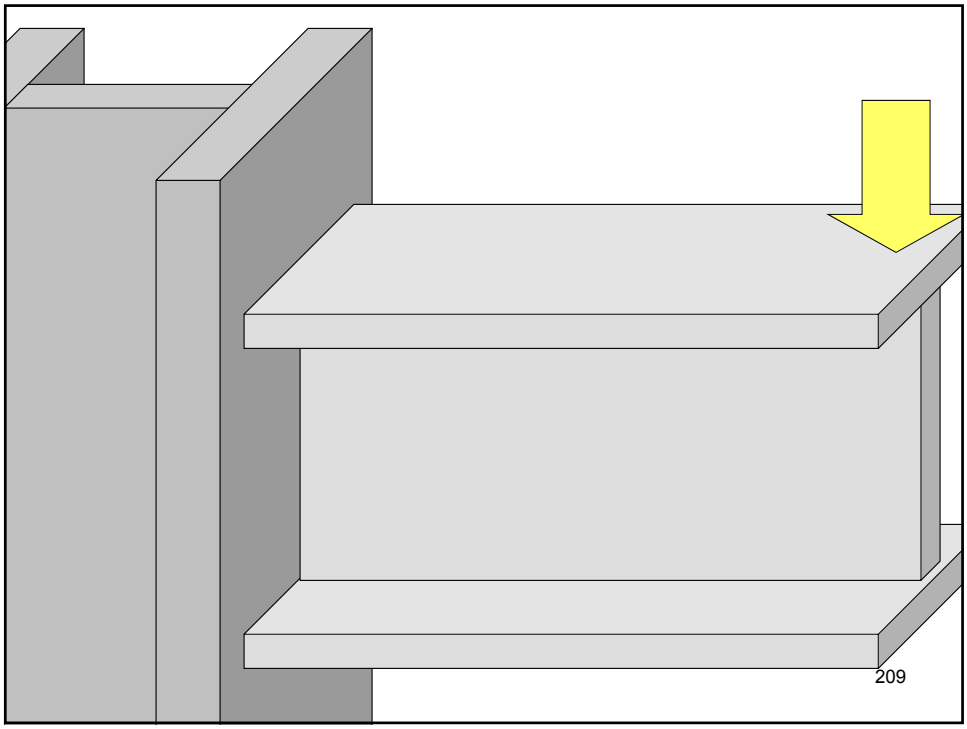
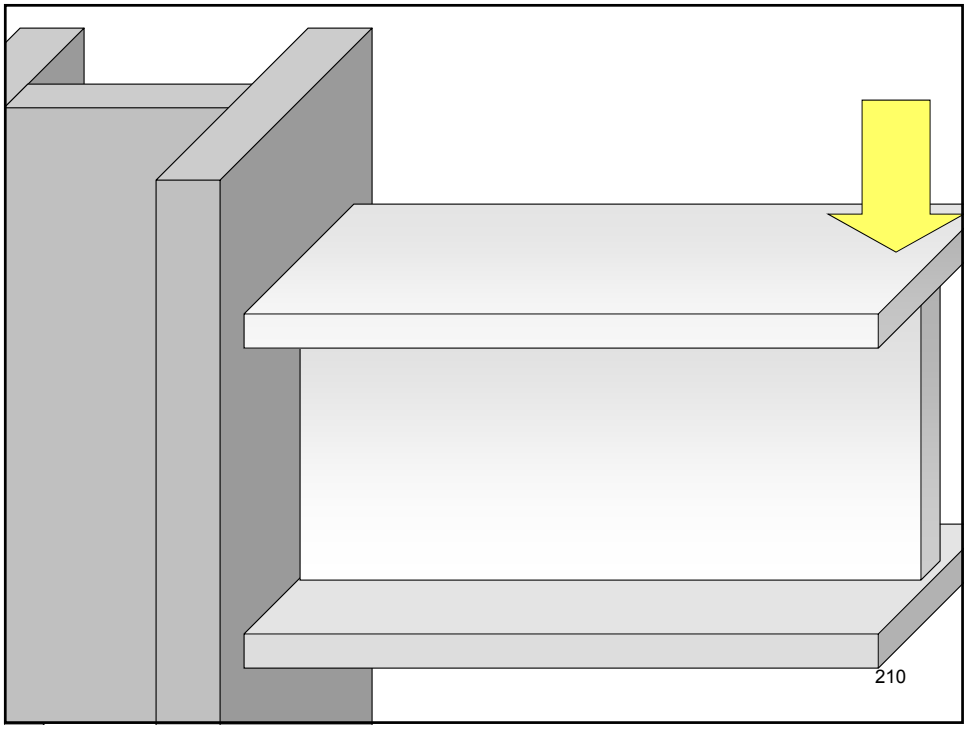
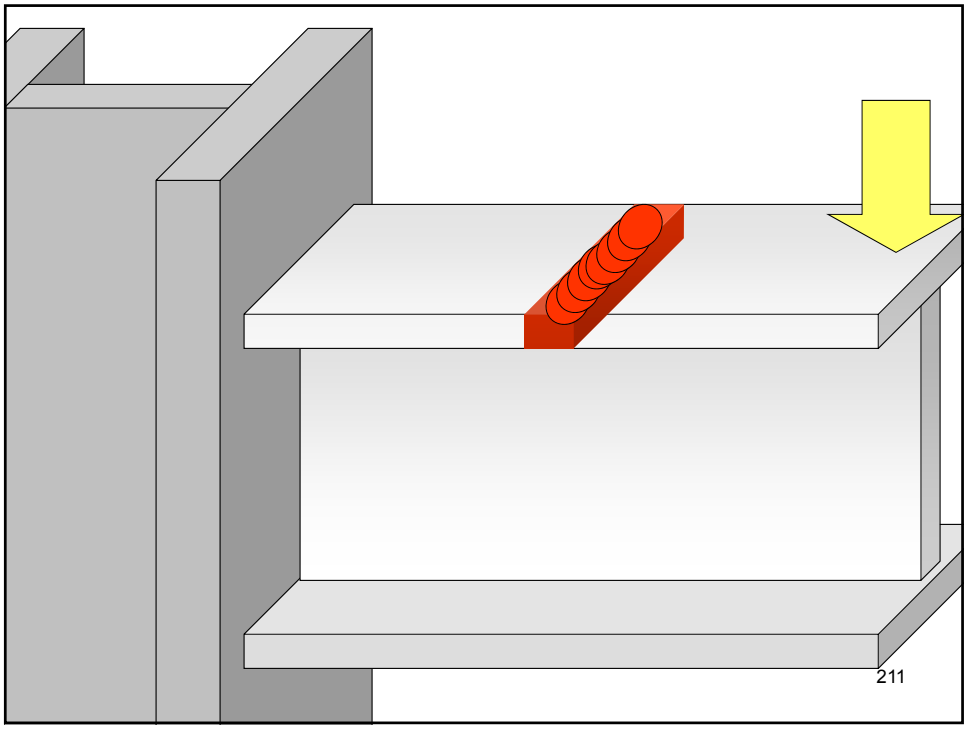
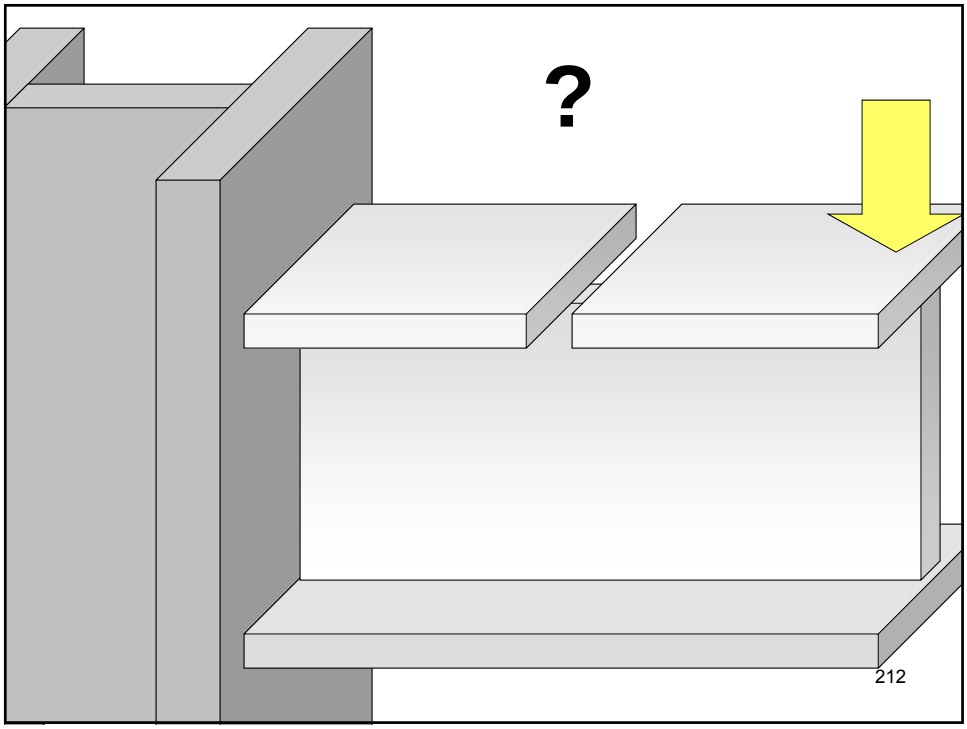
- Cold worked steel/strain aged steel
- Comprehensive plans

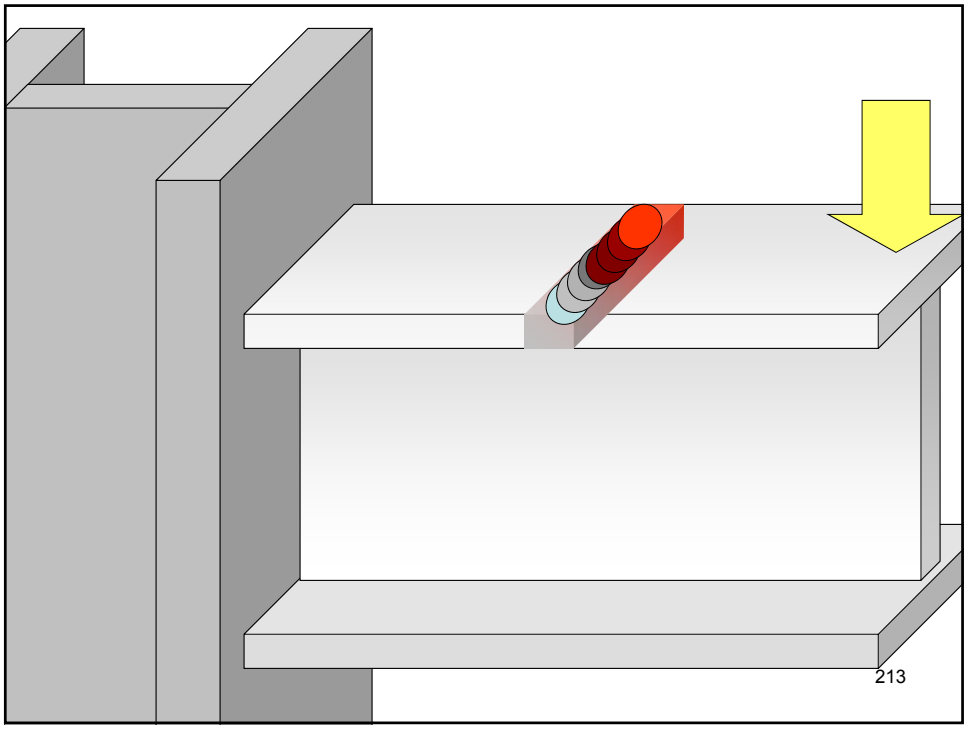
208

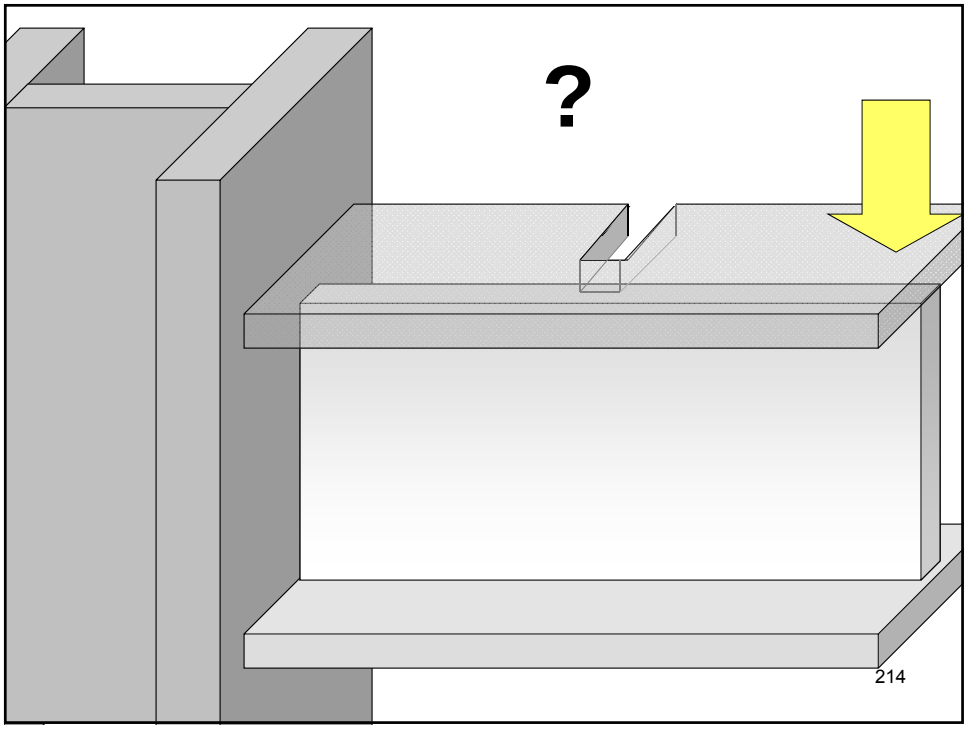


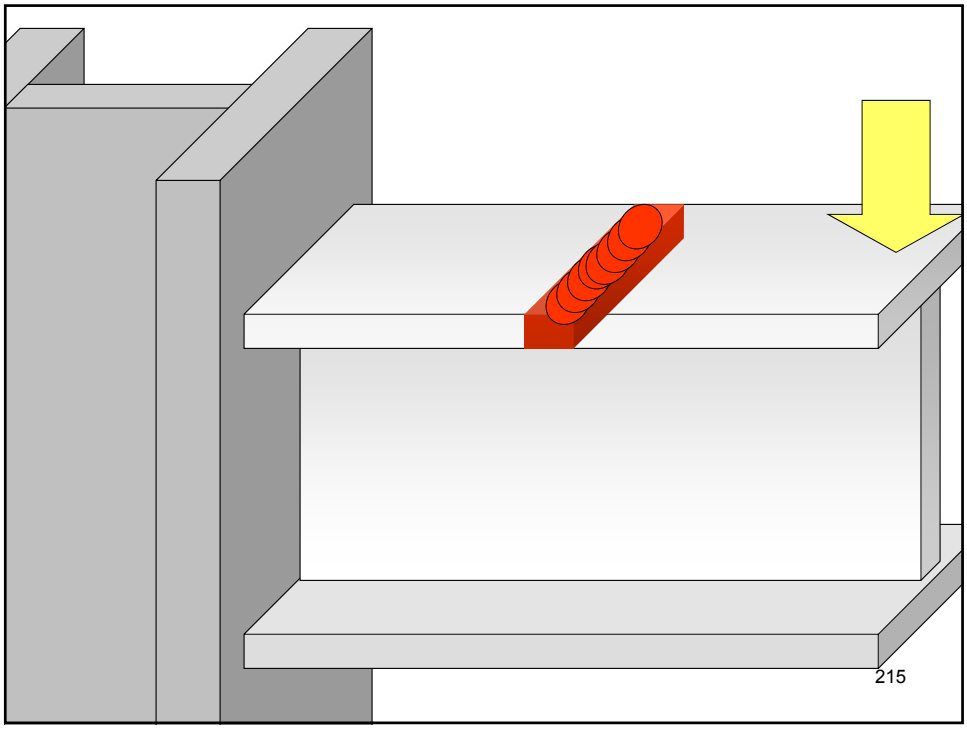


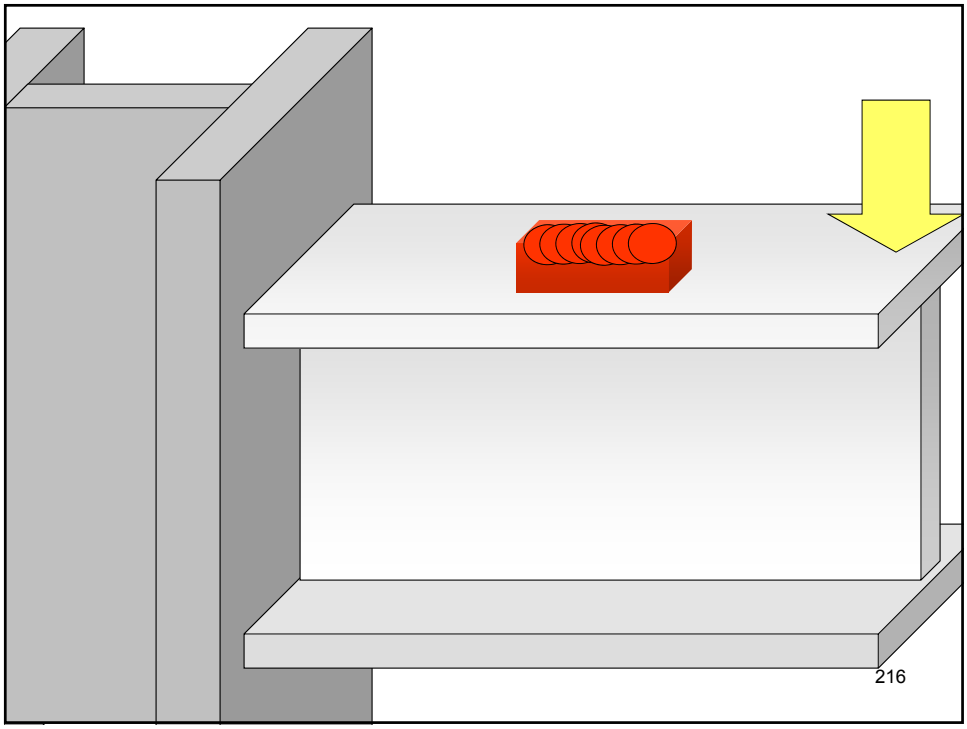


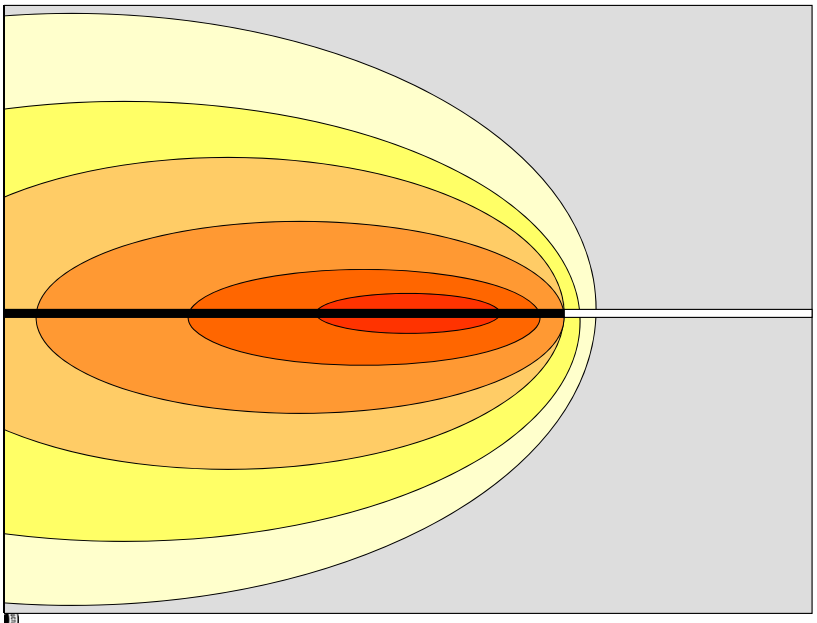












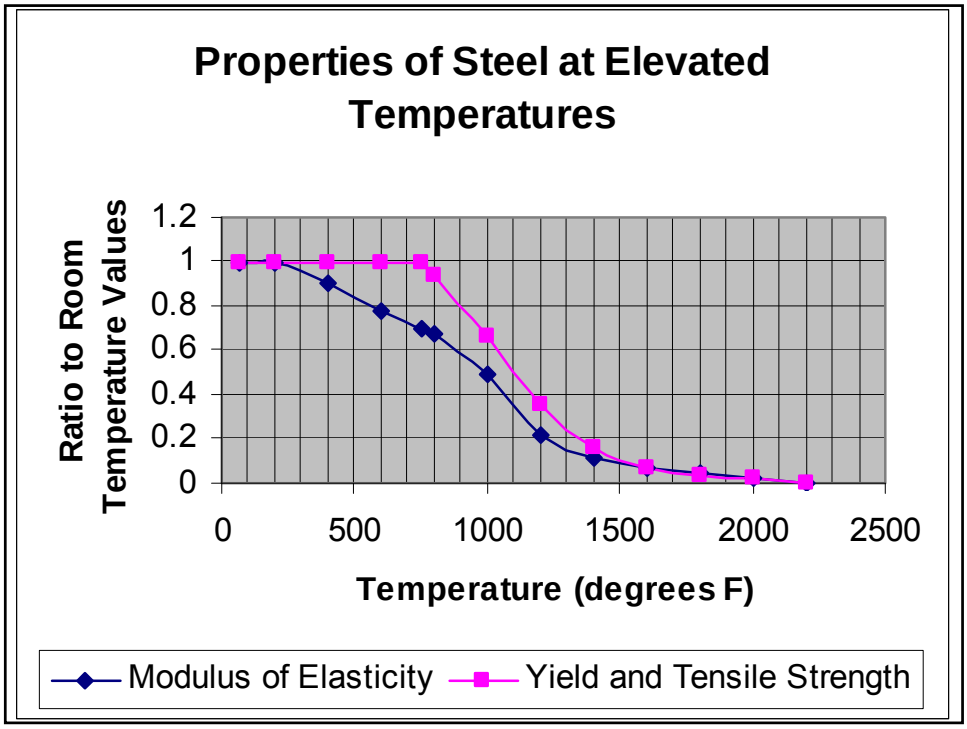
217

Table A-4.2.1
Properties of Steel at Elevated Temperatures

Steel Tempreature (°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.

218

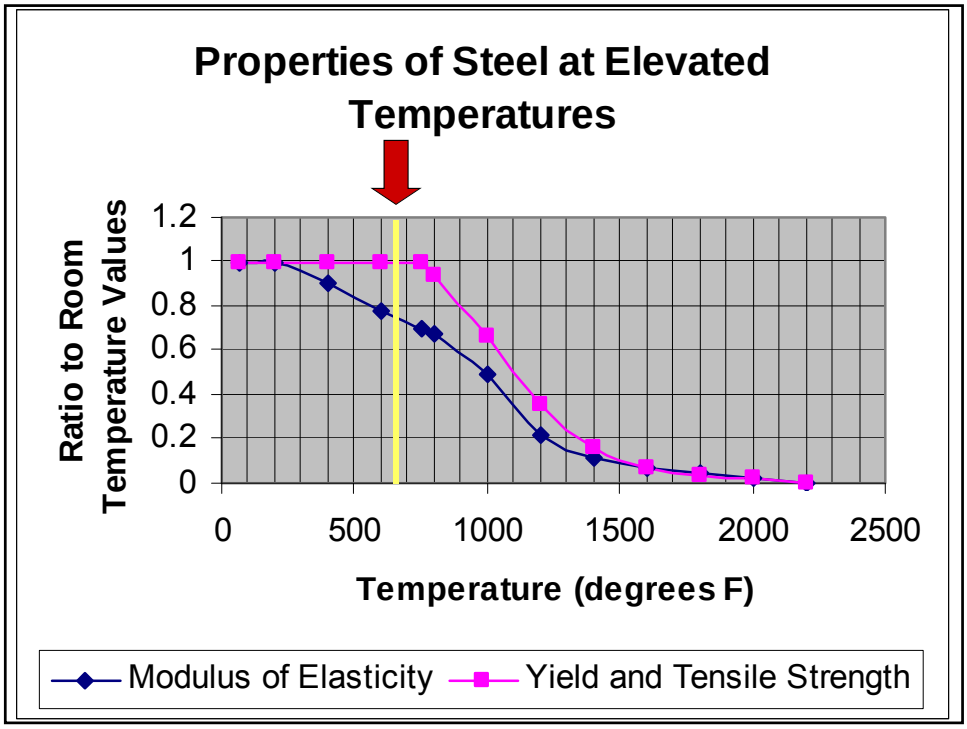


Special Welding Applications and Field Fixes
Welding on Existing Structures

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

220



Special Welding Applications and Field Fixes
Welding on Existing Structures

- Historic steels
- Welding on members under load
- Fire
- Cold worked steel/strain aged steel
- Comprehensive plans

222

Special Welding Applications and Field Fixes
Welding on Existing Structures

Fire

- Unlike new steel frames, existing structures may have many combustibles in the area.
- Unlike new construction, working on existing structures often involves cutting torches—big concern.
- Unintended welding work lead ("ground") paths

223

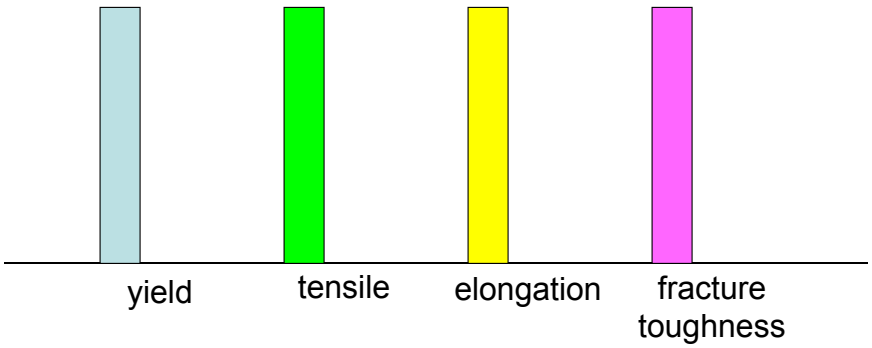
Special Welding Applications and Field Fixes
Welding on Existing Structures

- Historic steels
- Welding on members under load
- Fire
- Cold worked steel/strain aged steel
- Comprehensive plans

224

Special Welding Applications and Field Fixes
Welding on Existing Structures

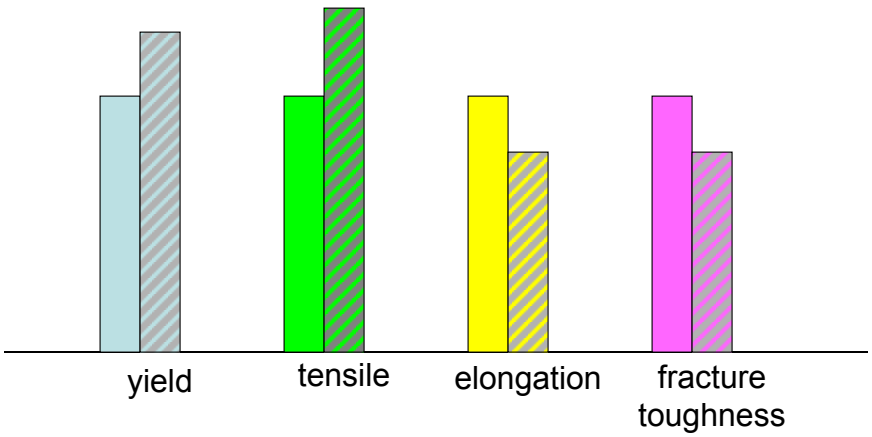
Hot rolled steel



225

Special Welding Applications and Field Fixes
Welding on Existing Structures

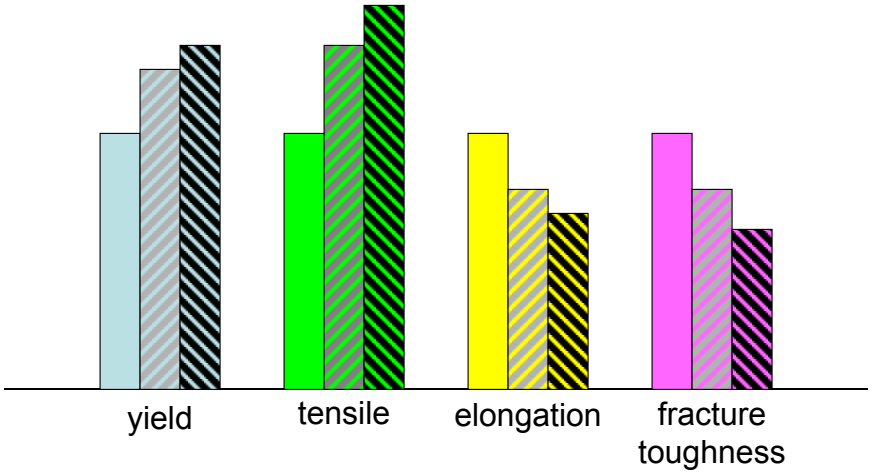
Cold worked



226

Special Welding Applications and Field Fixes
Welding on Existing Structures

Cold worked plus strain aged



227

Special Welding Applications and Field Fixes
Welding on Existing Structures

Strain aging

- Occurs when steel is heated to 400-700 ^{o}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)

228

Special Welding Applications and Field Fixes
Welding on Existing Structures

Strain aging: practical implications

- Cold worked steel will be higher in strength, lower in ductility and toughness, and less forgiving.
- Take extra precautions to eliminate cracks and other stress raisers before welding.

229

Special Welding Applications and Field Fixes

- Welding on Anchor Rods
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230

Special Welding Applications and Field Fixes
Combining Welds and Bolts

- Normally, connections are initially designed to be all welded, or all bolted.
- Retrofit work often necessitates more capacity from connections; adding welds to riveted or bolted connections is often an attractive solution.
- Changes in plans for projects under construction may require additional capacity for bolted connections, and welds may offer an attractive solution.

231

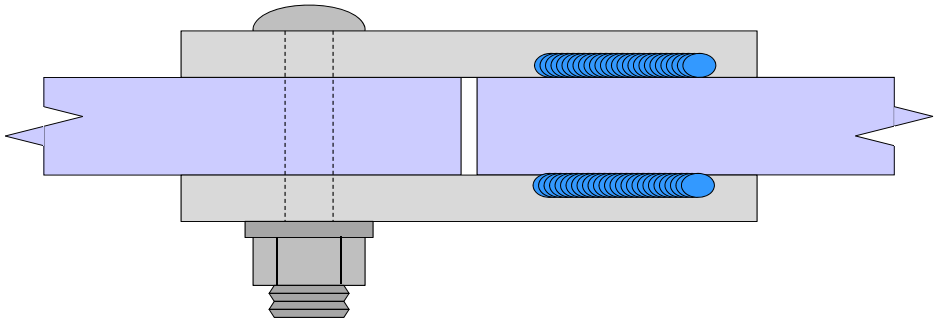
Special Welding Applications and Field Fixes
Combining Welds and Bolts

The “rules” seem to constantly change.

232

Special Welding Applications and Field Fixes
Combining Welds and Bolts

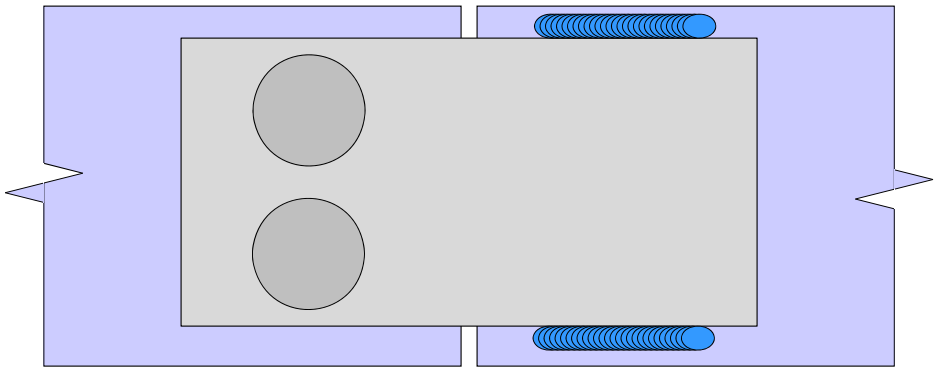
What is not of concern:



233

Special Welding Applications and Field Fixes
Combining Welds and Bolts

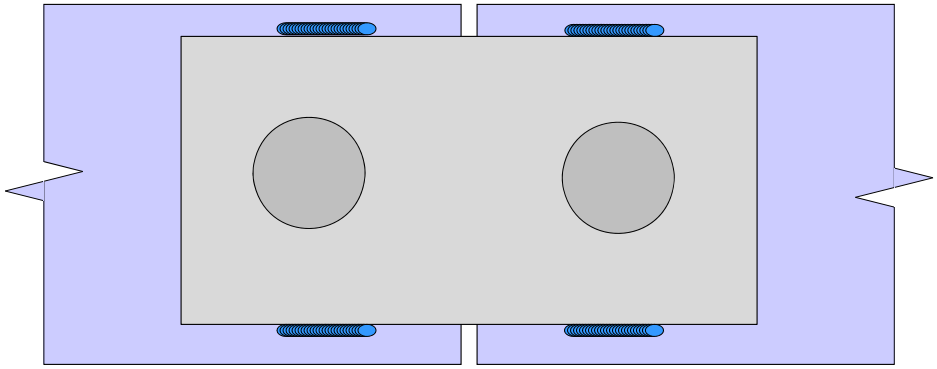
What is not of concern:



234

Special Welding Applications and Field Fixes
Combining Welds and Bolts

What is of concern:



235

AISC 360-16

J1.8. Bolts in Combination with Welds

Bolts shall not be considered as sharing the load in combination with welds, except in the design of shear connections on a common faying surface where strain compatibility between the bolts and welds is considered.

236

AISC 360-16

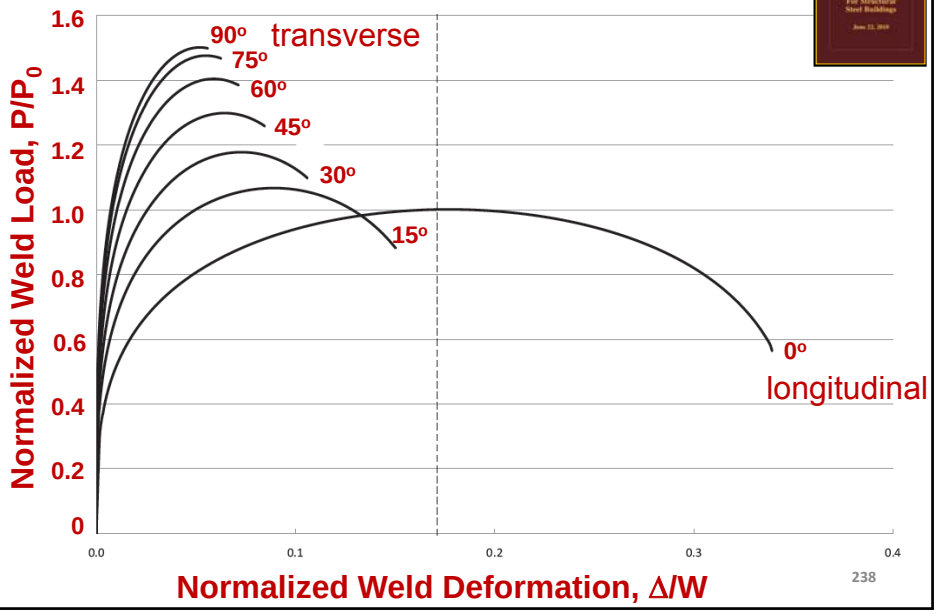
J1.8. Bolts in Combination with Welds (cont'd)

It is permitted to determine the available strength, ΦRn and Rn/Ω, as applicable, of a joint combining the strengths of high-strength bolts and longitudinal fillet welds as the sum of (1) the nominal slip resistance, Rn, for bolts as defined in Equation J3-4 according to the requirements of a slip critical connection and (2) the nominal weld strength, Rn, as defined in Section J2.4, when the following apply:

237

AISC 360-10 SPECIFICATION

Figure C-J2.13



238

AISC 360-16

J1.9. Welded Alterations to Structures With Existing Rivets or Bolts

In making welded alterations to structures, existing rivets and high-strength bolts in standard or short-slotted holes transverse to the direction of load, tightened to the requirements of slip-critical connections are permitted to be utilized for resisting loads present at the time of alteration and the welding need only provide the additional required strength.

239

AISC 360-16

J1.9. Welded Alterations to Structures With Existing Rivets or Bolts (cont'd)

The weld available strength shall provide the additional required strength, but not less than 25% of the required strength of the connection.

240

Special Welding Applications and Field Fixes

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241

Special Welding Applications and Field Fixes

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PDH Certificates

Within 2 business days…

- 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!

Individual Webinar Registrants
PDH Certificates

Within 2 business days…

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

3-Session Package Registrants
PDH Certificates

One certificate will be issued at the conclusion of all 3 sessions.

3-Session Package Registrants
Quizzes

Within two days, you will receive access to the quiz for this webinar. Quizzes are due three weeks after the live session.

Reasons for quiz:
PROFESSIONAL DEVELOPMENT HOURS – If you watch a recorded session you must take quiz for PDHs.
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3-Session Package Registrants
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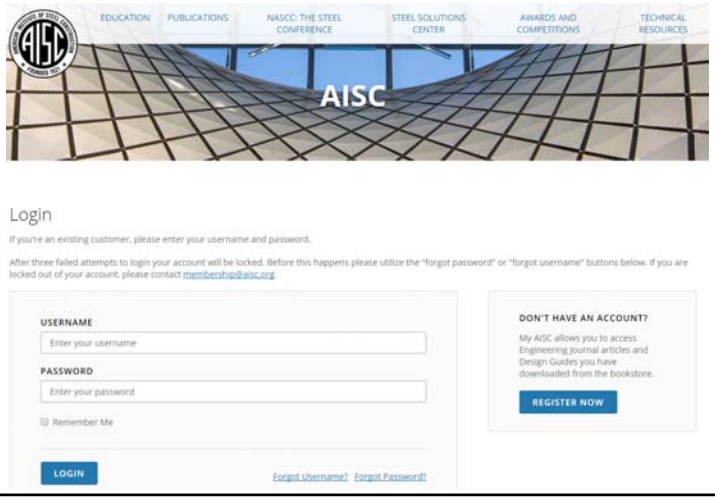
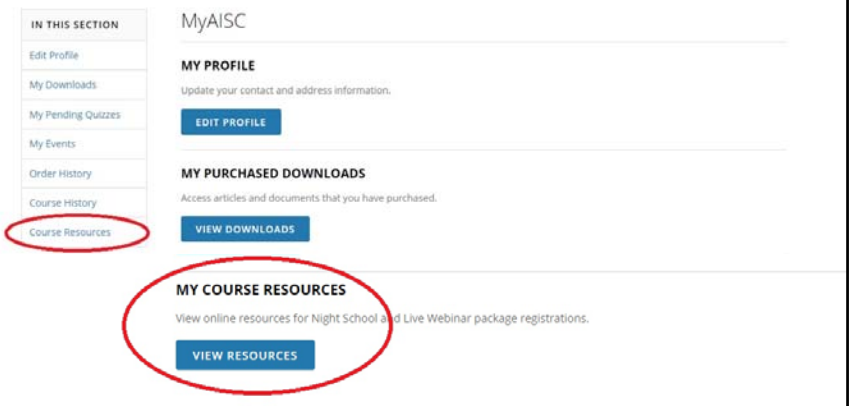
Find all your handouts, quizzes, quiz scores, recording access, and attendance records in one place!

3-Session Package Registrants
Course Resources

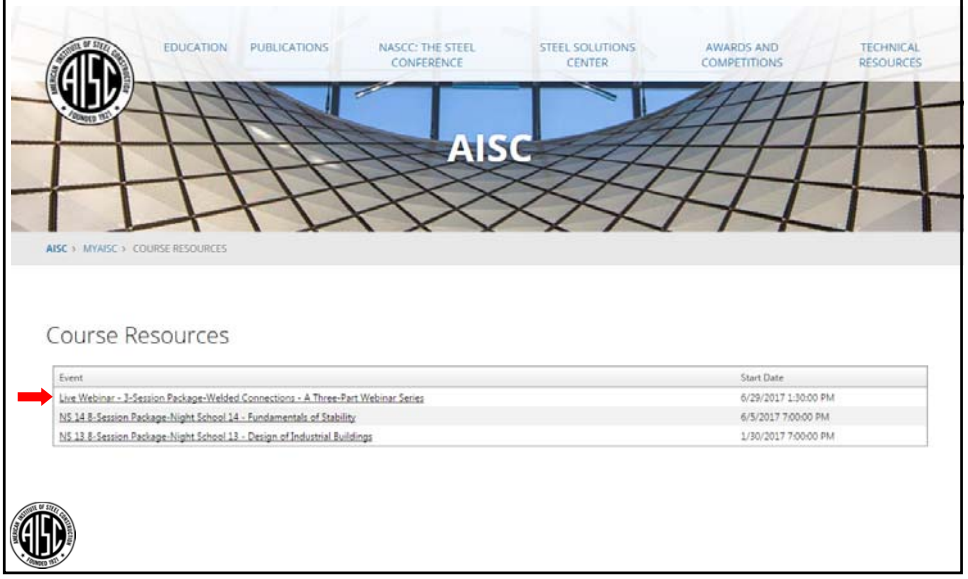
Go to www.aisc.org and sign in.



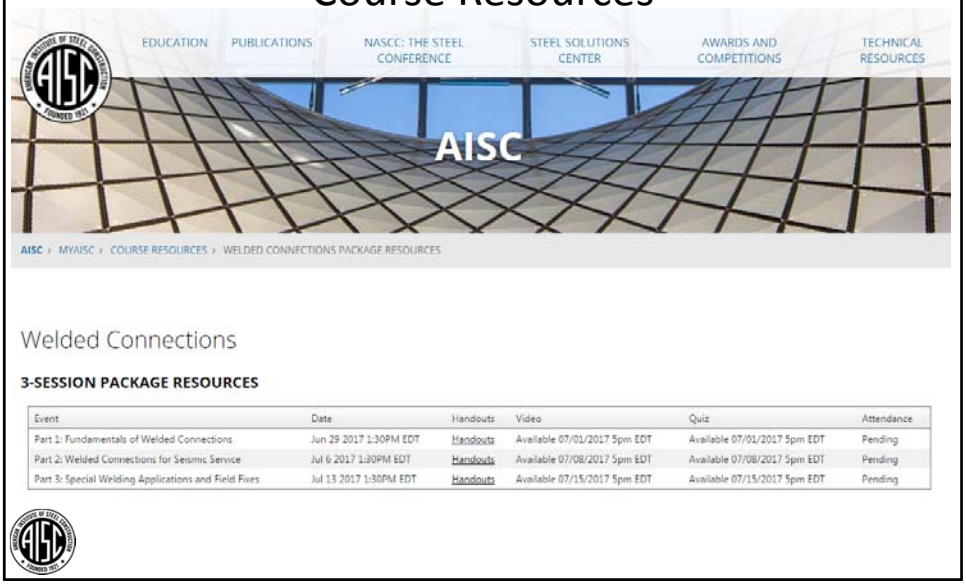
3-Session Package Registrants
Course Resources



3-Session Package Registrants
Course Resources



3-Session Package Registrants
Course Resources



3-Session Package Registrants

Quiz and Recording Email Notification

Within two days, you will receive an email notification regarding access to the quiz and recording for this session. The email will include links to the quiz and recording.

EMAIL COMES FROM WEBINARS@AISC.ORG

All Registrants

Connection Information and Handouts

Webinar connection information:

- Can be found in your confirmation/registration receipt
- Reminder sent out Wednesday afternoon

Link to handouts also found here

There's always a solution in steel.

Thank You

Please give us your feedback!
Survey at conclusion of webinar.