

Night School 27: Fundamentals of Welding and Bolting

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**AISC**
Night School



Session 2 – Principles of Welded Connections

October 4, 2021 | Curtis Decker



**Smarter.
Stronger.
Steel.**

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Course Description

NS27.2 – Welding Part 2 Principles of Welded Connections October 4, 2021

Following the right principles can lead to better welded connections and better projects. In this session, 14 principles of welded connection design will be presented. The principles are discussed and then illustrated with examples of connections that comply and do not comply with the concepts.



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Learning Objectives

- Identify welded connection details that allow force to enter into the section that lies parallel.
- Identify when additional members are needed in a welded connection due to force changing direction.
- Identify situations where welds undergo bending.
- Identify preferred weld details to avoid material failures such as lamellar tearing.



Night School 27: Fundamentals of Welding and Bolting



Curtis L. Decker, PhD, PE,
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The Lincoln Electric
Company



Chad Larson, LeJeune
Bolt Company



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Night School 27: Fundamentals of Welding and Bolting


Welding Part 2: Principles of Welded Connections
October 4, 2021

Curtis L. Decker, PhD, PE, SE, The Lincoln Electric Company




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PRINCIPLES OF WELDED CONNECTIONS




14 Principles of Welded Connection Design

What makes a welded connection correct or proper?



PRINCIPLES OF WELDED CONNECTIONS




A correct and proper welded connection

is strong enough to transfer all the applied loads through the connection.


Correct and proper = strong enough
(but not stronger than necessary)

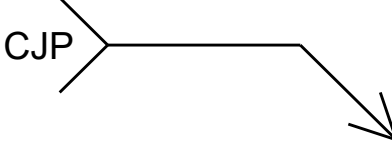
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PRINCIPLES OF WELDED CONNECTIONS



Welded Connections—
A Primer for
Engineers




CJP

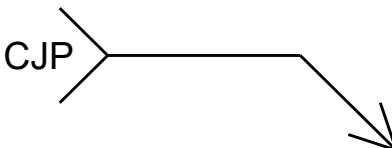
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Official Definition:
A groove weld in which weld metal extends through the joint thickness.

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PRINCIPLES OF WELDED CONNECTIONS


Welded Connections—
A Primer for
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CJP

1

Unofficial Definitions:



- A weld specified J.I.C. (just in case)
- A weld specified when loads are unknown.
- A weld specified for really important connections.
- A weld specified when NDT is desired.
- A weld specified when no one wants to calculate weld size.

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PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection
is strong enough to transfer all the applied loads
through the connection.

1



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PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection
has a clear and direct load path.

2


“Provide a path so a transverse force can enter that part of the member (section) that lies parallel to the force.”

Omer W. Blodgett



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PRINCIPLES OF WELDED CONNECTIONS




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**A correct and proper welded connection
has a clear and direct load path.**


2

“The force goes to the stiff part.”

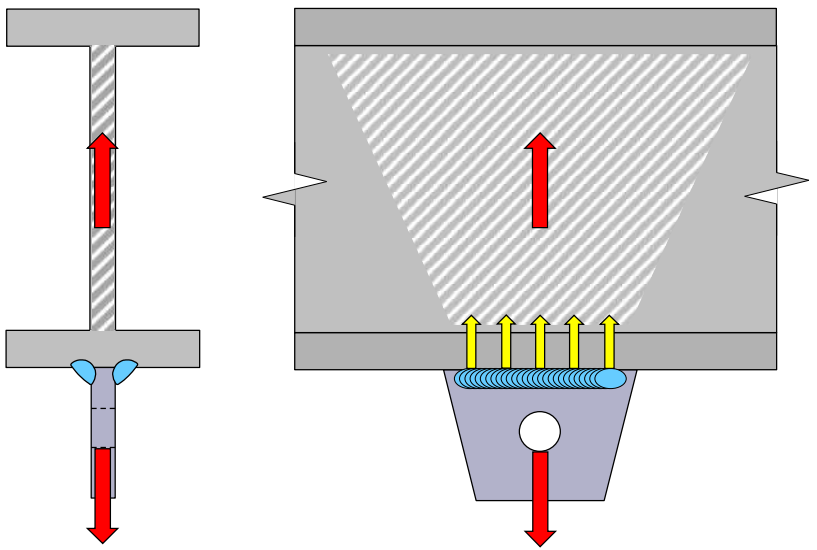
William “Bill” A. Milek


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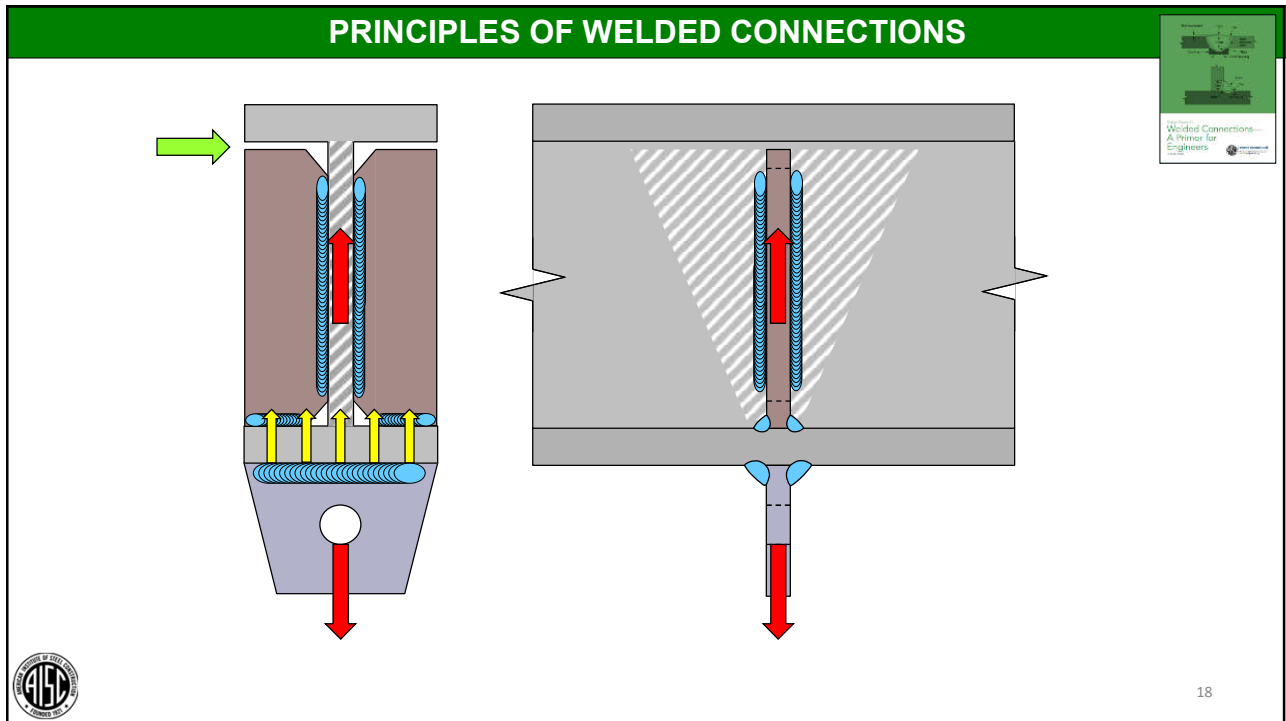
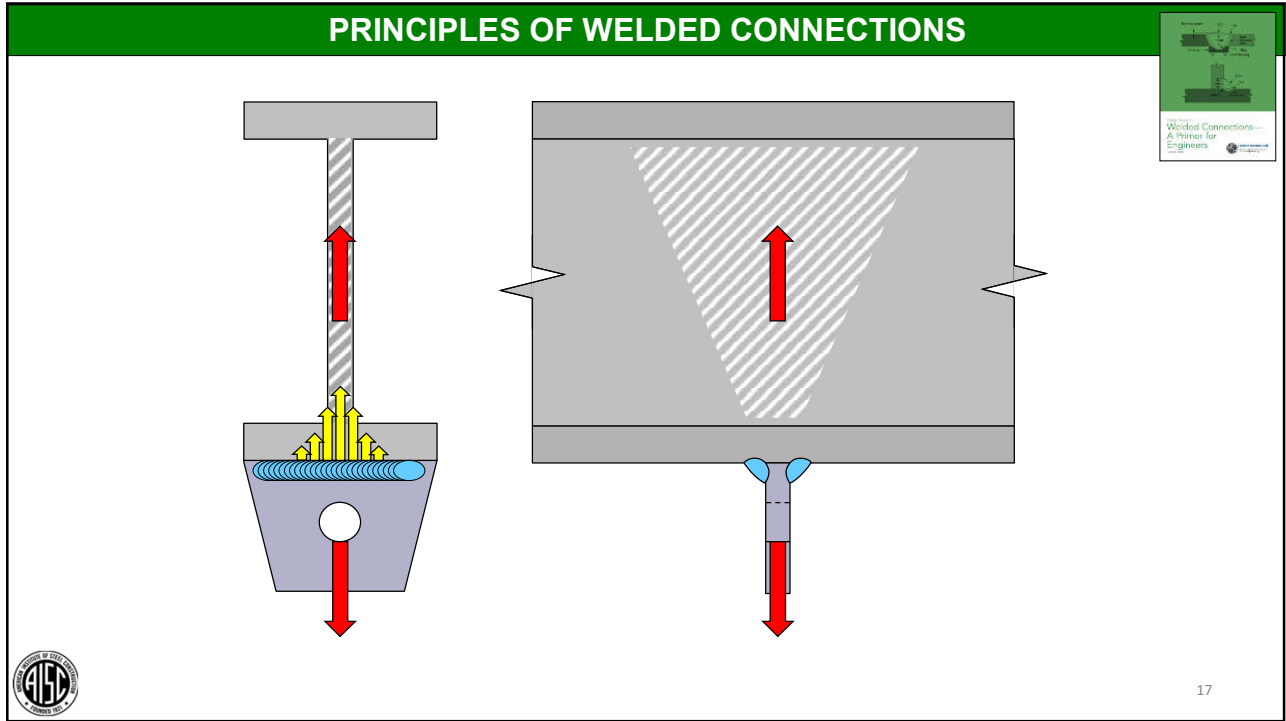
PRINCIPLES OF WELDED CONNECTIONS



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Engineers



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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates the principles of welded connections under tension and shear. On the left, a cross-section of a beam-to-column connection is shown. The top flange is welded to the column flange. Red arrows indicate tension in the top flange, and yellow arrows indicate shear in the web. On the right, a similar connection is shown, but with a red arrow indicating tension in the column web. A red prohibition sign is shown below the right diagram, indicating that this configuration is not recommended.

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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates the principles of welded connections under tension and shear. On the left, a cross-section of a beam-to-column connection is shown. The top flange is welded to the column flange. Red arrows indicate tension in the top flange, and yellow arrows indicate shear in the web. On the right, a similar connection is shown, but with a red arrow indicating tension in the column web.


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Engineers

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PRINCIPLES OF WELDED CONNECTIONS


The diagram illustrates a welded connection between a top flange and a bottom web. On the left, a cross-sectional view shows the top flange being pulled up (red arrow) and the bottom web being pulled down (red arrow). Yellow arrows indicate shear forces acting on the weld. On the right, a side view shows the connection under a downward load (red arrow). A small inset in the top right corner shows a book cover titled "Welded Connections—A Primer for Engineers".



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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates a welded connection between a top flange and a bottom web. On the left, a cross-sectional view shows the top flange being pulled up (red arrow) and the bottom web being pulled down (red arrow). Yellow arrows indicate shear forces acting on the weld. On the right, a side view shows the connection under a downward load (red arrow). A green arrow points to the weld area. A small inset in the top right corner shows a book cover titled "Welded Connections—A Primer for Engineers".




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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates a welded connection under tension and shear. On the left, a cross-section shows a plate with a weld to a gusset plate. A red arrow points up from the plate, and a red arrow points down from the gusset plate. Yellow arrows point up from the weld, and a purple arrow points right from the gusset plate. On the right, a circular ring is shown with a vertical stem. Red arrows point inward from the ring to the stem, and a red arrow points down from the stem. Green arrows point left and right from the stem, and a purple arrow points right from the stem. A red prohibition sign is next to the stem.

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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates a welded connection under tension and shear. On the left, a cross-section shows a plate with a weld to a gusset plate. A red arrow points up from the plate, and a red arrow points down from the gusset plate. On the right, a circular ring is shown with a vertical stem. Yellow arrows point up from the stem, and a red arrow points down from the stem. Green arrows point left and right from the stem.

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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates two scenarios for a T-joint connection. On the left, a cross-section shows a vertical member being welded to a horizontal member. A red arrow points upwards from the top of the vertical member, and a purple arrow points to the fillet weld. On the right, a similar joint is shown but with a red arrow pointing downwards from the bottom of the vertical member. A green arrow points to the gap between the two members, and a red prohibition sign is placed next to it, indicating this is an incorrect and unsafe practice.

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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates two scenarios for a T-joint connection. On the left, a cross-section shows a vertical member being welded to a horizontal member. A red arrow points upwards from the top of the vertical member, and a purple arrow points to the weld. On the right, a similar joint is shown but with a red arrow pointing downwards from the bottom of the vertical member, and a purple arrow points to the weld.

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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates two types of welded connections. On the left, a V-groove butt joint is shown in cross-section. A red arrow points upwards from the joint, and another red arrow points downwards from the bottom of the joint. On the right, a circular gusset plate is shown in cross-section. A red arrow points downwards from the bottom of the gusset plate. The gusset plate is welded to a larger structure, with blue welds and yellow arrows indicating the direction of force or movement.

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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates two types of welded connections. On the left, a rectangular gusset plate is shown in cross-section. A red arrow points upwards from the joint, and another red arrow points downwards from the bottom of the gusset plate. On the right, a lap joint is shown in cross-section. A red arrow points downwards from the bottom of the joint, and a green arrow points upwards from the side of the joint.

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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates a fillet weld connection. On the left, a cross-section shows a vertical plate with a hatched rectangular area representing a weld. A red arrow points upwards from the center of the weld, and another red arrow points downwards from the bottom of the plate. A purple arrow points to the right at the bottom corner of the plate. On the right, a perspective view shows a vertical plate with a hatched rectangular area. Red arrows point upwards from the top corners and downwards from the bottom corners. A green arrow points to the left from the bottom-left corner. A purple arrow points to the right at the bottom corner. A red circle with a diagonal slash is positioned to the right of the plate, indicating a failure mode.

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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates a groove weld connection. On the left, a cross-section shows a vertical plate with a hatched triangular area representing a weld. A red arrow points upwards from the center of the weld, and another red arrow points downwards from the bottom of the plate. A purple arrow points to the right at the bottom corner of the plate. On the right, a perspective view shows a vertical plate with a hatched triangular area. Red arrows point upwards from the top corners and downwards from the bottom corners. A green arrow points to the left from the bottom-left corner. A purple arrow points to the right at the bottom corner. Yellow arrows point upwards from the bottom edge of the plate.

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PRINCIPLES OF WELDED CONNECTIONS

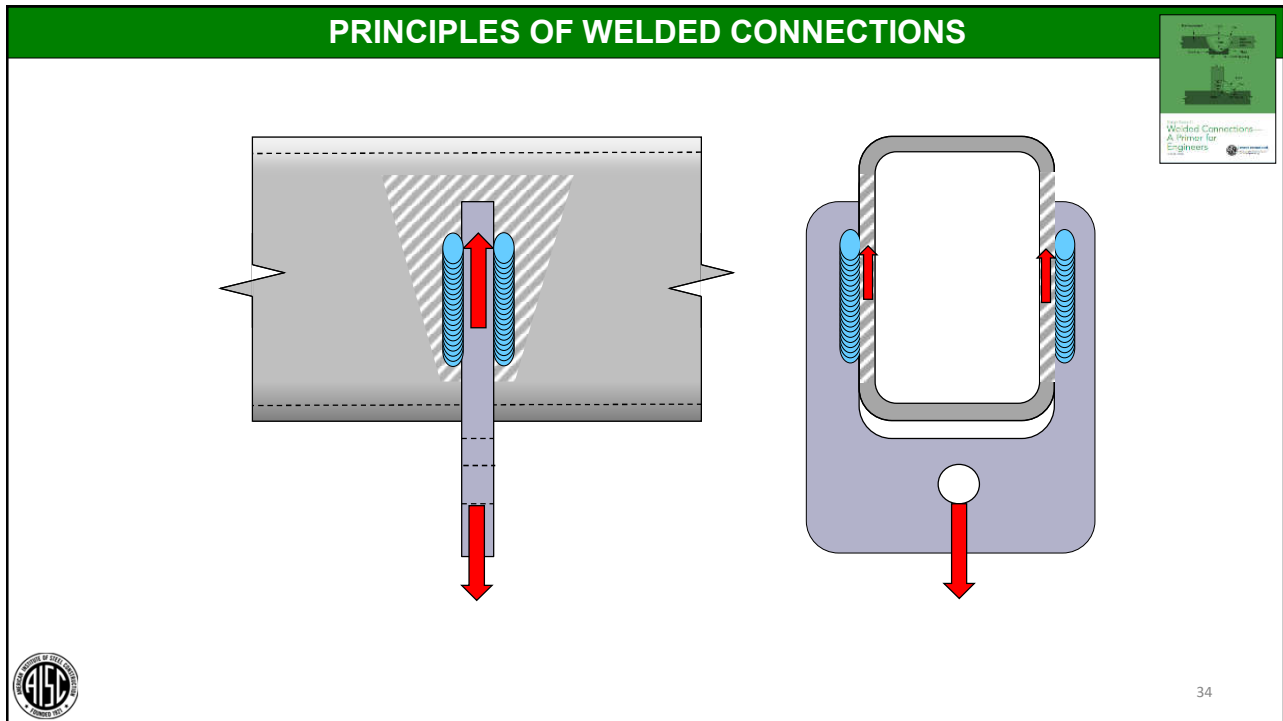
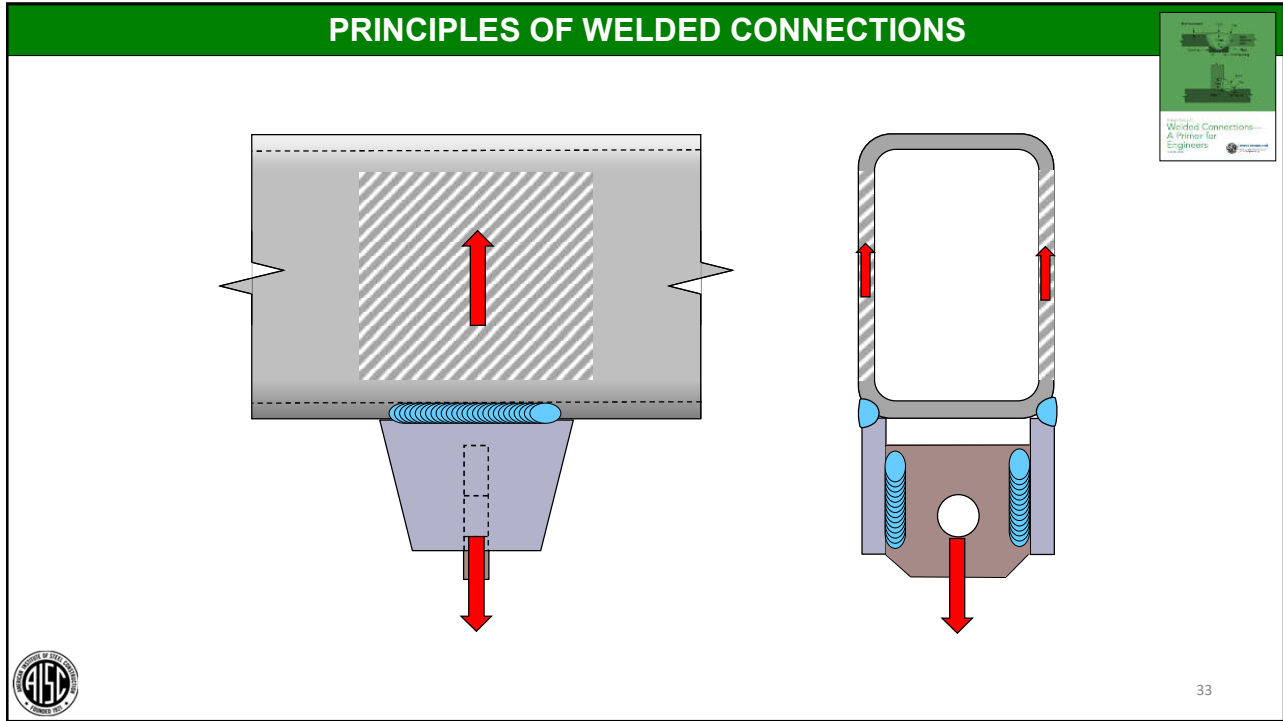
The diagram illustrates the principles of welded connections. On the left, a cross-section of a T-joint is shown with a weld. A red arrow points upwards from the stem, and another red arrow points downwards from the flange. A purple arrow points to the weld. On the right, a side view of a channel section welded to a plate is shown. Red arrows indicate tension in the channel walls, a green arrow indicates shear in the weld, and a red prohibition sign indicates a failure mode. A small inset in the top right corner shows a book cover titled "Welded Connections—A Primer for Engineers".

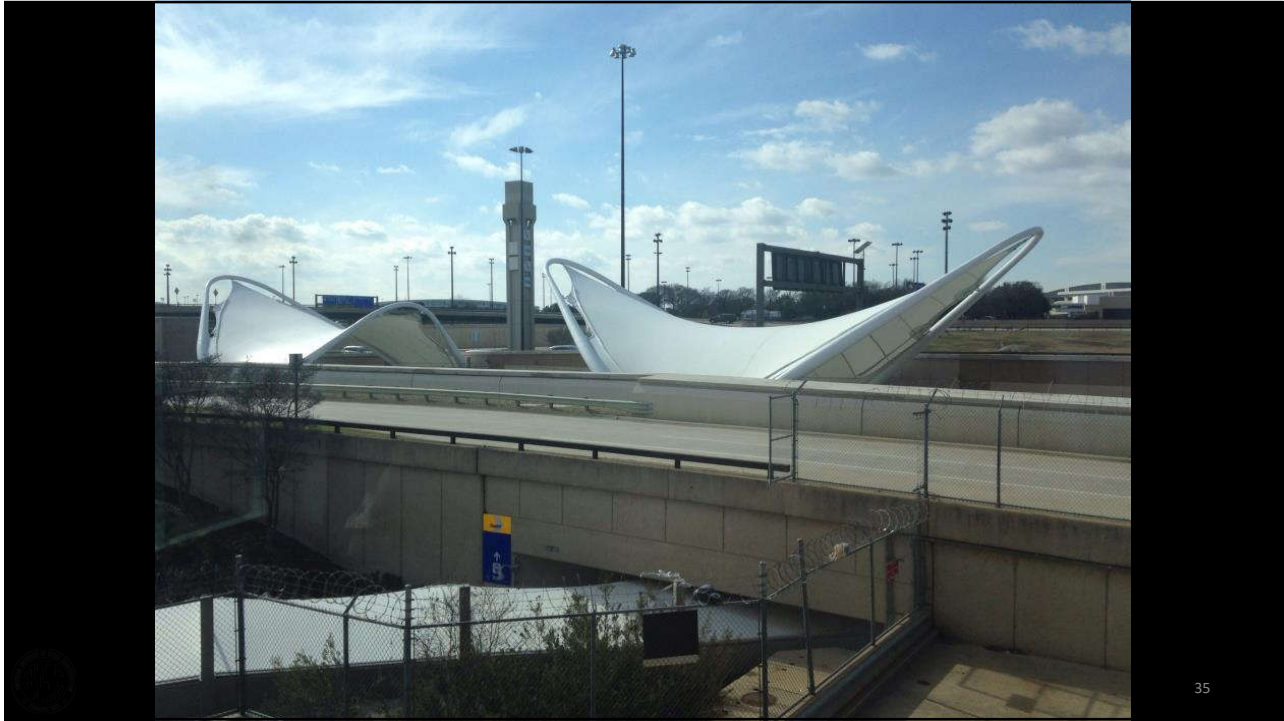
31

PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates the principles of welded connections. On the left, a cross-section of a T-joint is shown with a weld. A red arrow points upwards from the stem, and another red arrow points downwards from the flange. A purple arrow points to the weld. On the right, a side view of a channel section welded to a plate is shown. Red arrows indicate tension in the channel walls, and blue arrows indicate shear in the weld. A small inset in the top right corner shows a book cover titled "Welded Connections—A Primer for Engineers".

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PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection has a clear and direct load path. **2**

Note regarding HSS: the examples cited are to illustrate the load path concept. HSS connections can be successfully made in accordance with AISC 360 Chapter K through the use of design principles that consider the unique challenges of HSS.





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PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection places welds in regions of low stress. **3**


Corollary:
When possible, pass major loads through steel, not through welds



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PRINCIPLES OF WELDED CONNECTIONS


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PRINCIPLES OF WELDED CONNECTIONS


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PRINCIPLES OF WELDED CONNECTIONS

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PRINCIPLES OF WELDED CONNECTIONS

Lower Moment Area

Fatigue Category E, E'




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PRINCIPLES OF WELDED CONNECTIONS


A correct and proper welded connection places welds in regions of low stress.

3



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PRINCIPLES OF WELDED CONNECTIONS




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Engineers


**A correct and proper welded connection
does not introduce stress raisers.**

4

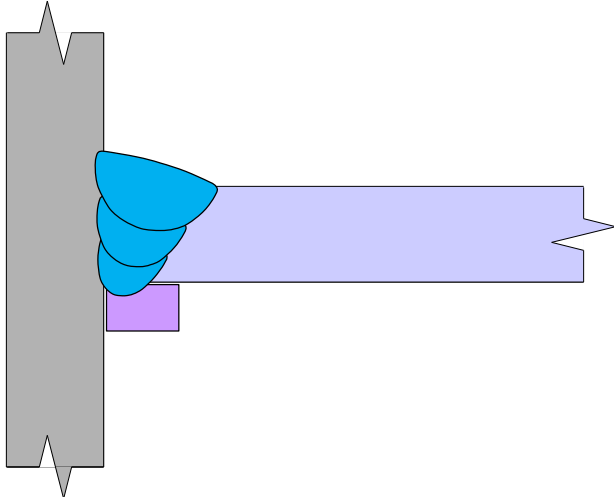
REMINDER:
Stress raisers are only stress raiser if there is a tensile stress component
perpendicular to the stress raiser.


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PRINCIPLES OF WELDED CONNECTIONS

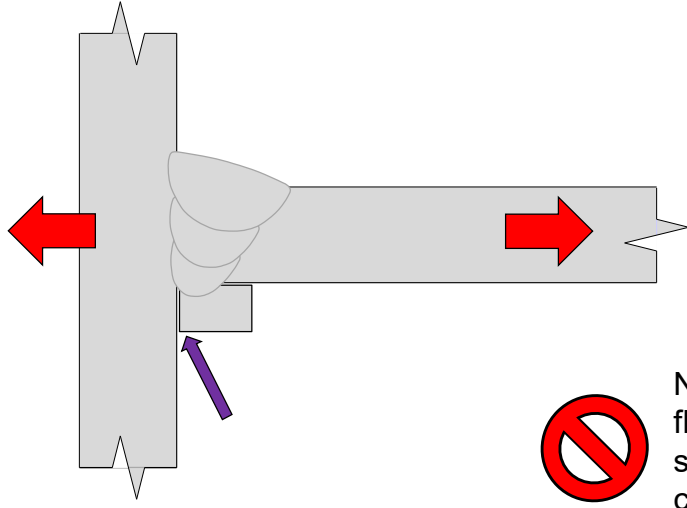


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PRINCIPLES OF WELDED CONNECTIONS



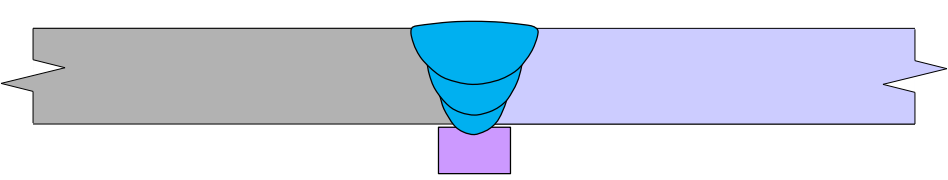


Not for bottom flange of high seismic moment connections



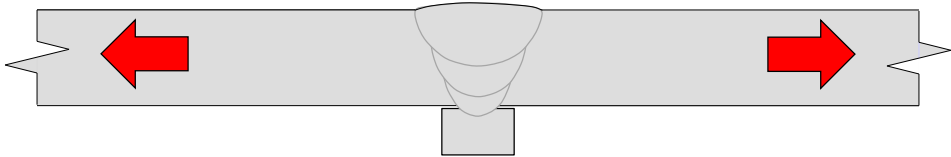
49

PRINCIPLES OF WELDED CONNECTIONS





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PRINCIPLES OF WELDED CONNECTIONS

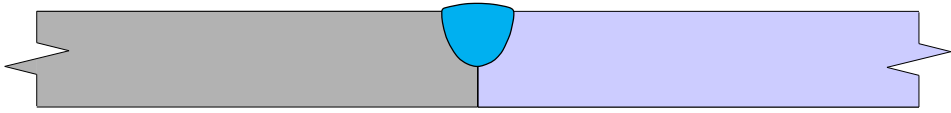


The diagram shows a horizontal steel beam with a central butt joint. Two red arrows point outwards from the joint, indicating tension. A weld is shown as a semi-circular shape on top of the joint, with a rectangular base underneath. The beam has jagged ends on both sides.





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PRINCIPLES OF WELDED CONNECTIONS

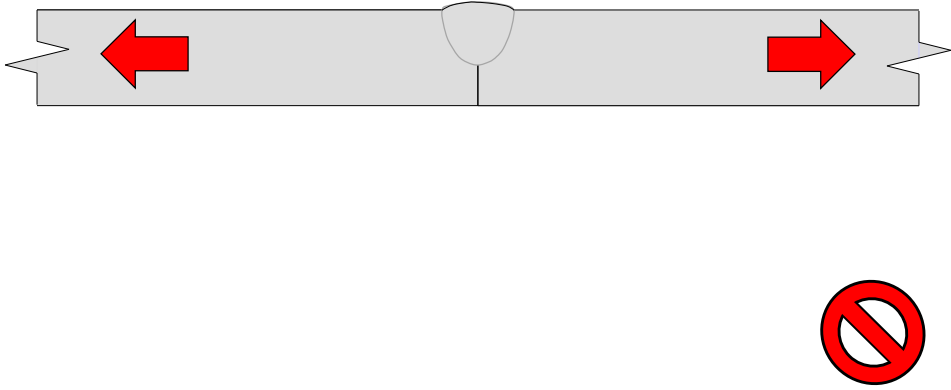



The diagram shows a horizontal steel beam with a central butt joint. The left half of the beam is shaded grey and the right half is shaded light blue. A blue semi-circular weld is shown on top of the joint. The beam has jagged ends on both sides.




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PRINCIPLES OF WELDED CONNECTIONS

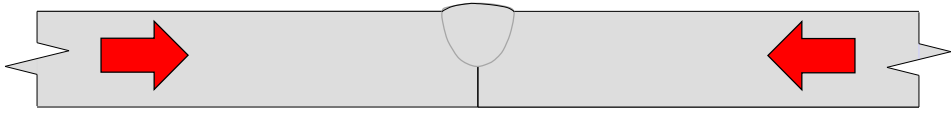




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PRINCIPLES OF WELDED CONNECTIONS

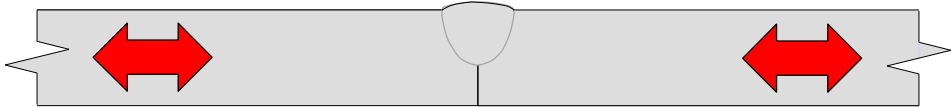



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PRINCIPLES OF WELDED CONNECTIONS

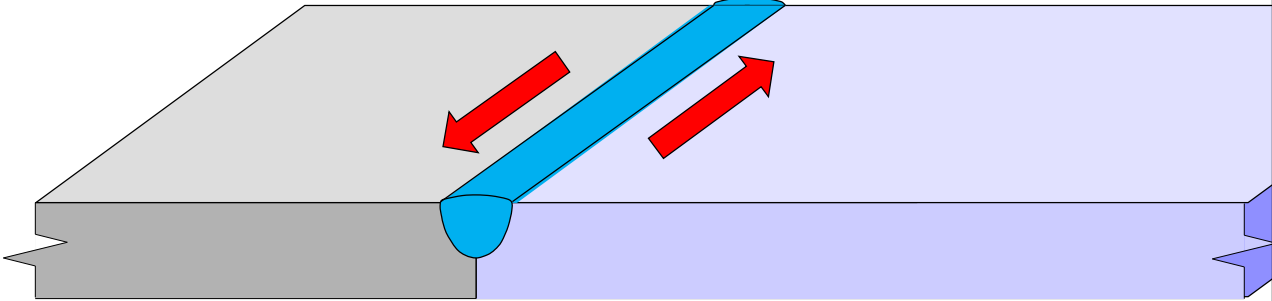


The diagram shows a horizontal butt joint between two steel plates. Two red double-headed arrows point outwards from the joint, indicating tensile force. A weld bead is shown in the center of the joint. A red circle with a diagonal slash is positioned in the bottom right corner, indicating that this type of connection is not recommended.





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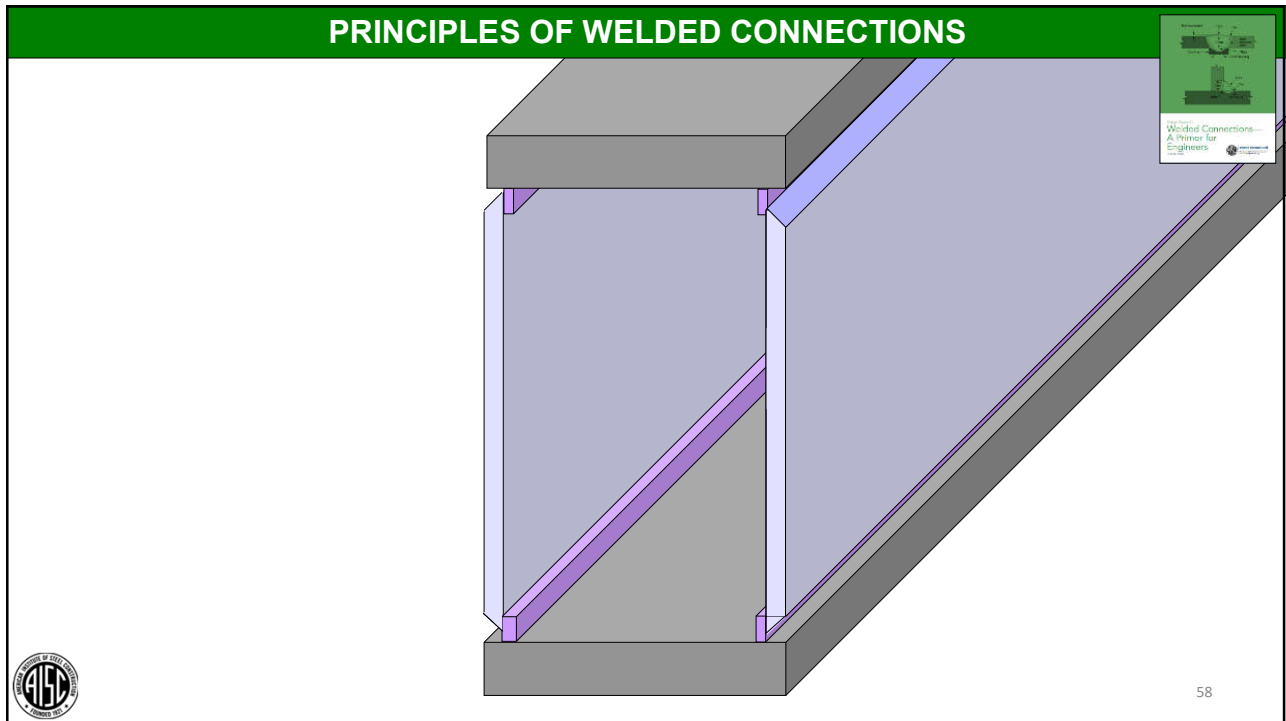
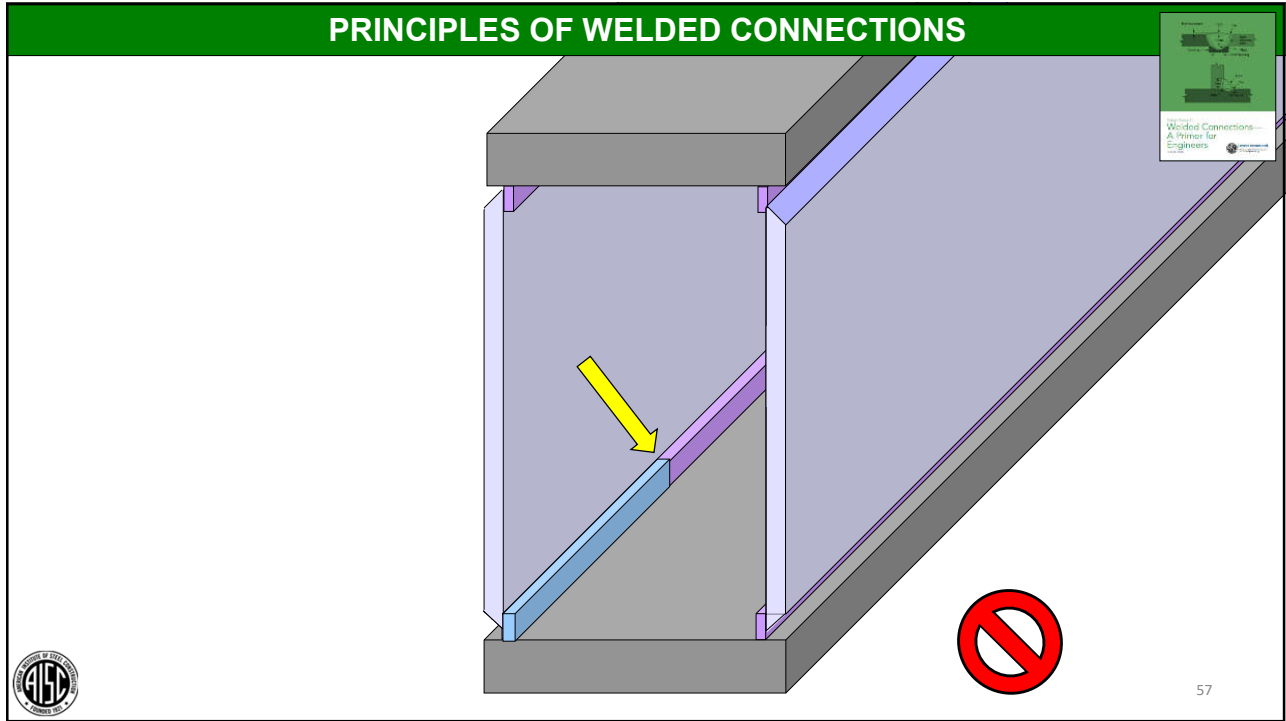
PRINCIPLES OF WELDED CONNECTIONS



The diagram shows a lap joint where two steel plates overlap. A blue weld bead is applied to the top surface of the overlapping section. Two red double-headed arrows point outwards from the joint, indicating tensile force. A blue arrow points along the length of the weld bead, indicating the direction of the weld.



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AWS D1.1: 2020 Structural Welding Code – Steel



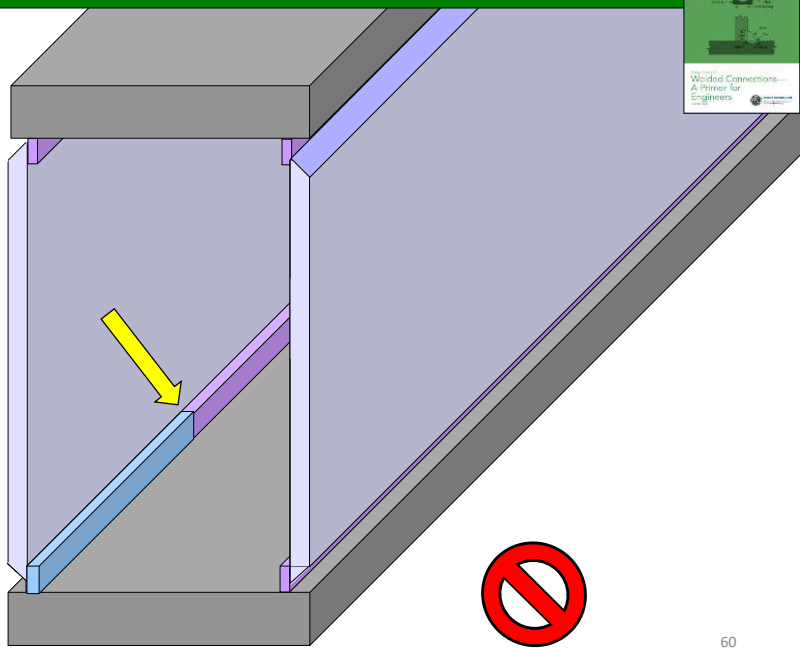
7.9.1.2 Full-Length Backing.

Except as permitted below, steel backing shall be made continuous for the full length of the weld. All joints in the steel backing shall be CJP groove weld joints meeting all the requirements of Clause 7 of this code.



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PRINCIPLES OF WELDED CONNECTIONS



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AWS D1.1: 2020 Structural Welding Code – Steel



7.9.1.2 Full-Length Backing.

Except as permitted below, steel backing shall be made continuous for the full length of the weld. All joints in the steel backing shall be CJP groove weld joints meeting all the requirements of Clause 5 of this code.



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AWS D1.1: 2020 Structural Welding Code – Steel



7.9.1.2 Full-Length Backing.

For statically loaded applications, backing for welds to the ends of closed sections, such as hollow structural sections (HSS), are permitted to be made from one or two pieces with unspliced discontinuities where all of the following conditions are met:





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PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection does not introduce stress raisers.

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PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection is not constrained.

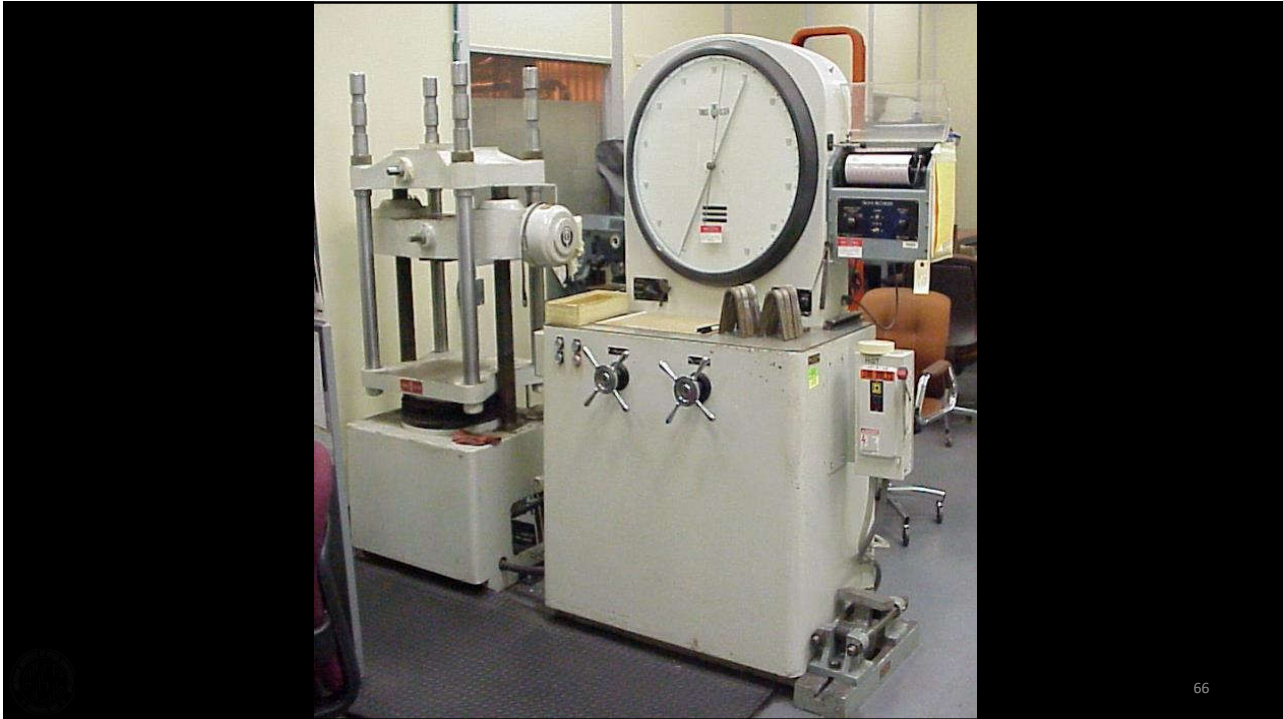
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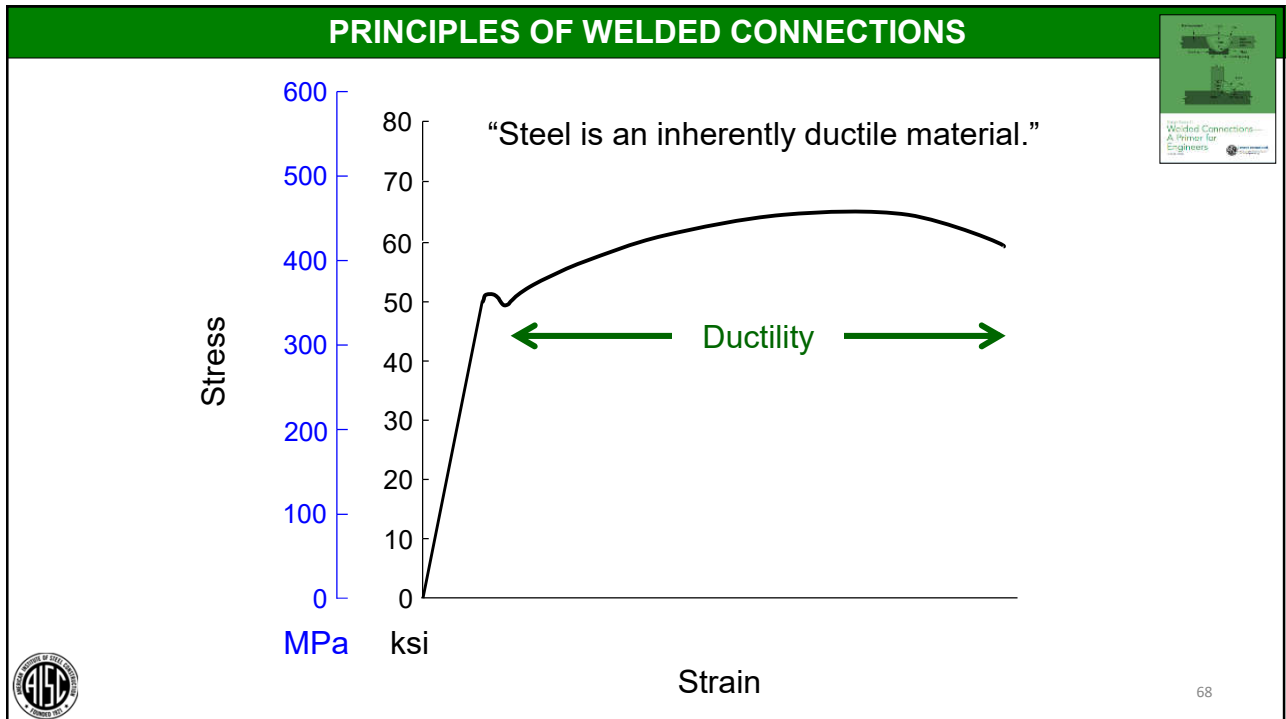
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66



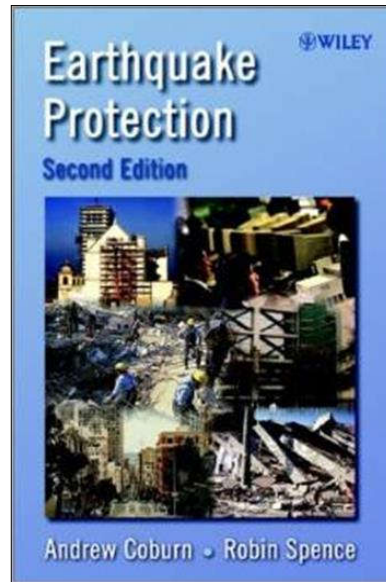
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Earthquake Protection

Andrew Coburn
Robin Spence

2002



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EARTHQUAKE PROTECTION

dictated by questions of availability and cost. The essential material requirements for earthquake-resistant structures are strength and ductility, and these properties are closely interrelated. *Ductility* refers to the ability of a material to deform after its maximum strength has been reached, without losing its ability to carry load. Structures made from materials which have this property can survive short-term accidental overloads because, rather than breaking, they can deform during the overload and absorb a large amount of energy without losing strength, instead of simply breaking. Steel is an inherently ductile material, and is thus very suitable for building in earthquake areas.¹⁶ California and Japan make extensive use of steel in large buildings of all types. Concrete and all types of masonry, without reinforcement, are brittle materials, but by means of embedment of steel

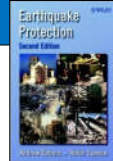
¹⁴ There are a wide variety of techniques which have been discussed by Key (1988) and Hansen and Soong (2001).

¹⁵ Soong and Spencer (2000).

¹⁶ Although welded joints can be a source of weakness and have resulted in some failures in recent earthquakes.

Steel is an inherently ductile material, and is thus very suitable for building in earthquake areas.¹⁶

¹⁶ Although welded joints can be a source of weakness and have resulted in some failures in recent earthquakes.


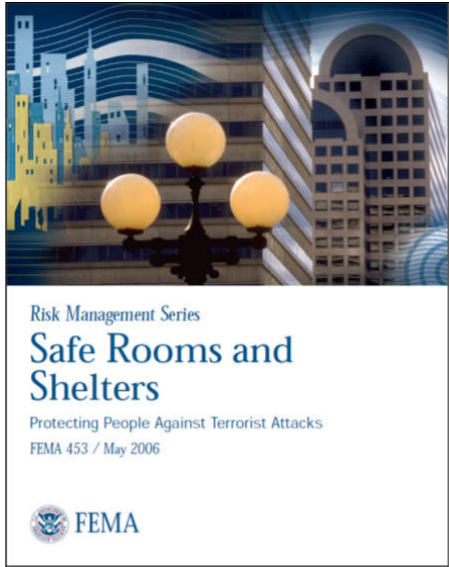


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Safe Rooms and Shelters

Protecting People Against
Terrorist Attacks

FEMA 453
May 2006





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SAFE ROOMS AND SHELTERS

Steelwork is generally better suited to resist relatively low intensity, but long duration effects of large stand-off explosions. **Steel is an inherently ductile material** that is capable of sustaining large deformations; however, the very efficient thin-flanged sections make the conventional frame construction vulnerable to localized damage. Complex stress combinations and concentrations may occur that cause localized distress and prevent the section from developing its ultimate strength. Steel buildings may experience significant rebound and must therefore be designed to support significant reversals of loading. Concrete filled tube sections or

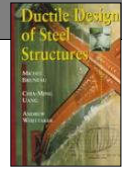
Steel in an inherently ductile material that is capable of sustaining large deformations; however, the every efficient thin-flanged sections make the conventional frame construction vulnerable to localized damage.

detailed to tie into the concrete slabs.



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Ductile Design of Steel Structures



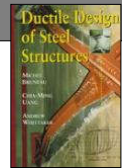
Preface

“Many practicing engineers have wrongly believed for years that the ductile nature of the structural steel material directly translates into inherently ductile structures.”



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Ductile Design of Steel Structures



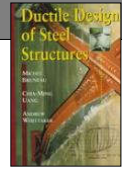
Chapter 1 Introduction

“However, there are many situations in which an explicit approach to the design of ductile steel structures is necessary because the inherent material ductility alone is not sufficient to provide the desired ultimate performance.”



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Ductile Design of Steel Structures



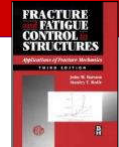
Chapter 1 Introduction

“To achieve this ductile response, one must recognize and avoid conditions that may lead to brittle failures and adopt appropriate design strategies to allow for stable and reliable hysteretic energy-dissipation mechanisms. This sort of thinking is relatively new in structural engineering.”



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Fatigue and Fracture Control in Structures



Most structural materials exhibit considerable strain (deformation) before reaching the tensile or ultimate strength....However, under conditions of low temperature, rapid loading and/or high constraint (e.g., when the principle stresses σ_1 , σ_2 , and σ_3 are essentially equal), even ductile materials may not exhibit any deformation before fracture.




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PRINCIPLES OF WELDED CONNECTIONS

$$\Delta L = \frac{PL}{AE} = \frac{\sigma L}{E}$$

$$= \frac{50 \times 10}{30 \times 10^3} = 0.017 \text{ in [1.7\%]}$$



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PRINCIPLES OF WELDED CONNECTIONS

$$\Delta L = L (\Delta t)(C_{exp})$$

$$= 10 (2795 - 70)(6.6 \times 10^{-6})$$

$$= 0.18 \text{ in [18 \%]}$$


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PRINCIPLES OF WELDED CONNECTIONS

Thermal expansion is approximately 10X yield elongation.

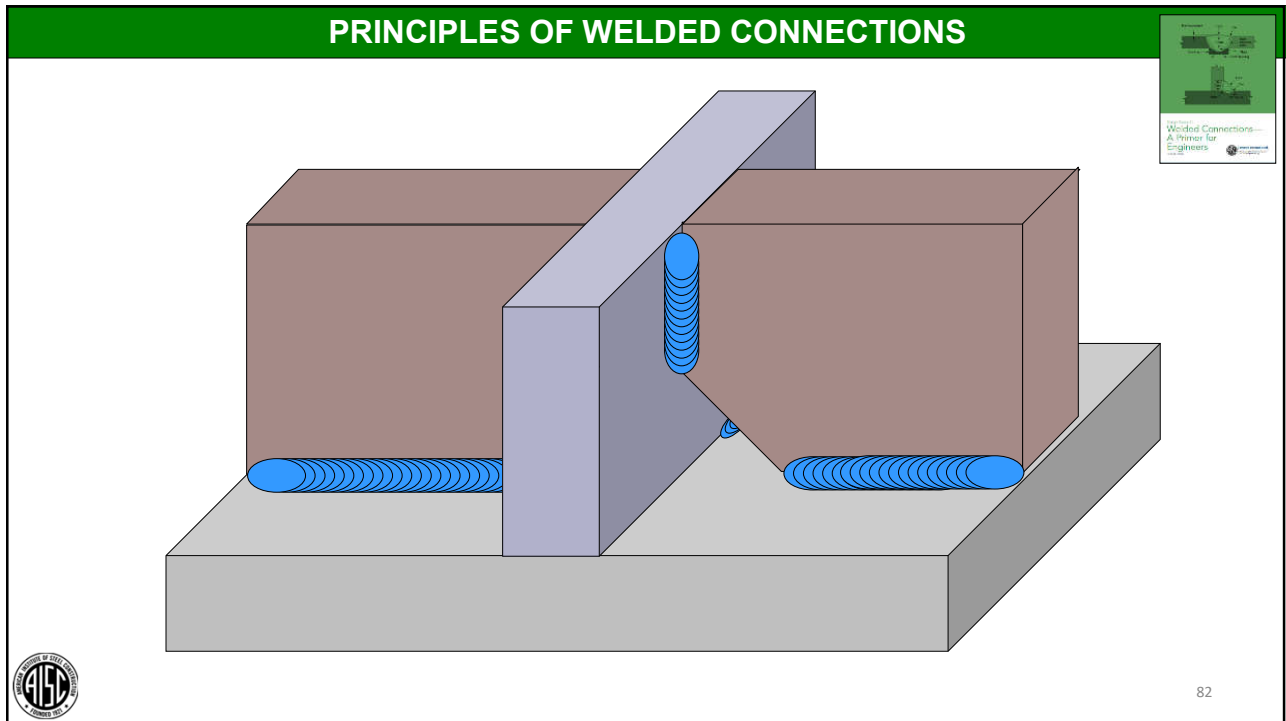
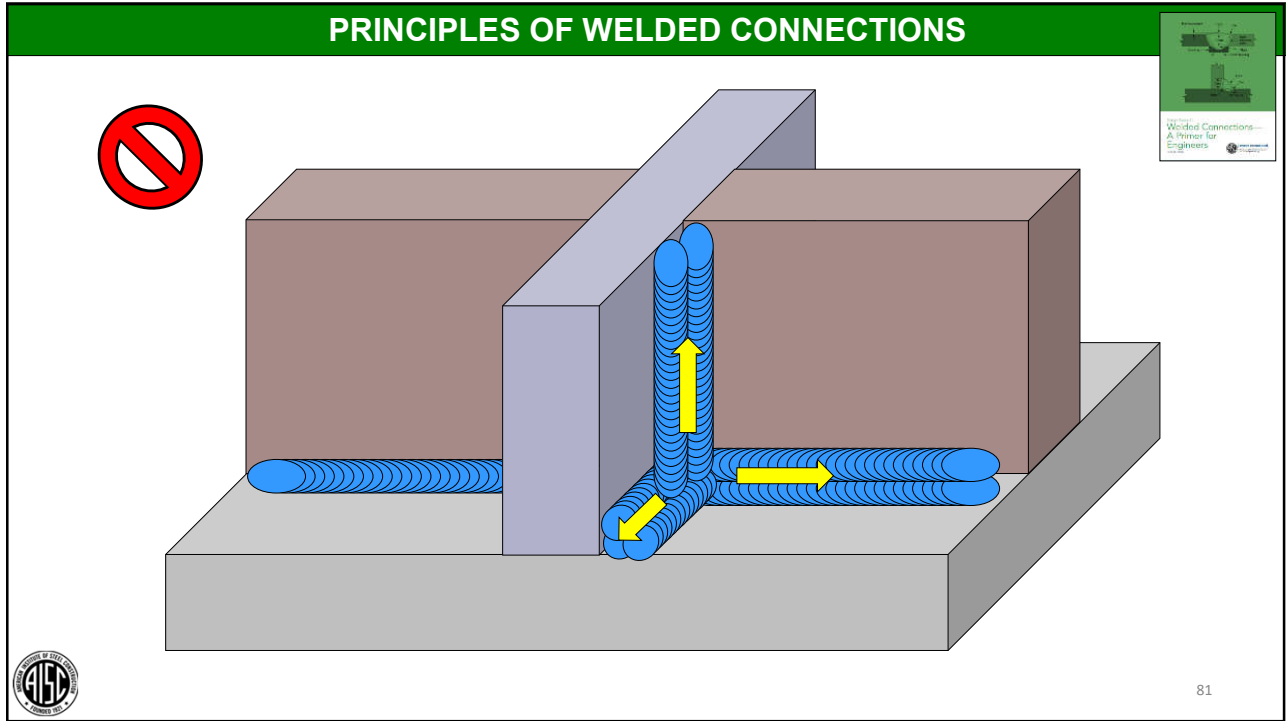
The diagram illustrates the relationship between yield strength, yield elongation, and thermal expansion. The top part shows a steel bar under a yield stress $\sigma_y = 50 \text{ ksi} [350 \text{ MPa}]$, with a yield elongation of $\epsilon = [1.7\%]$. The bottom part shows a steel bar heated to $2795^\circ\text{F} [1535^\circ\text{C}]$, with a thermal expansion of $\epsilon = [18\%]$. The thermal expansion is approximately 10 times the yield elongation.

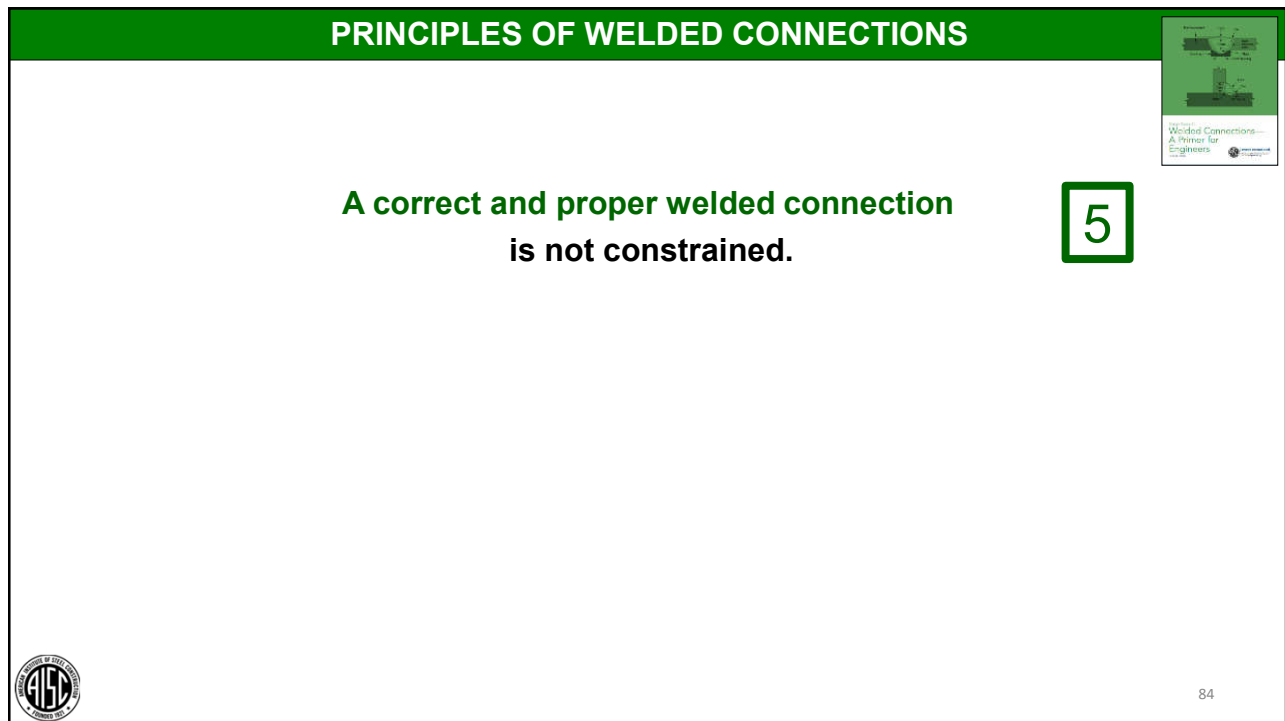
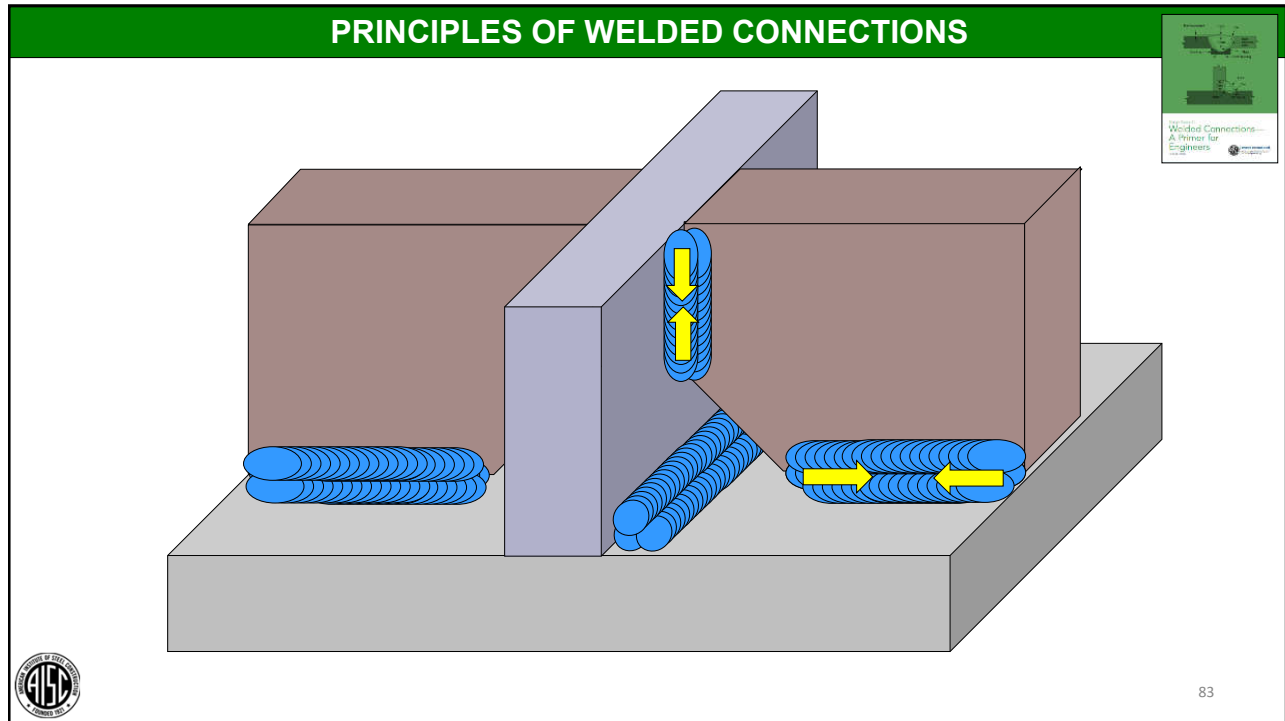
79

PRINCIPLES OF WELDED CONNECTIONS

The diagram shows a 3D perspective view of a welded connection. A vertical column is connected to a horizontal beam by a fillet weld. The weld is shown as a blue, textured surface. The column and beam are shown in a light blue color, and the surrounding structure is shown in a light gray color.



80







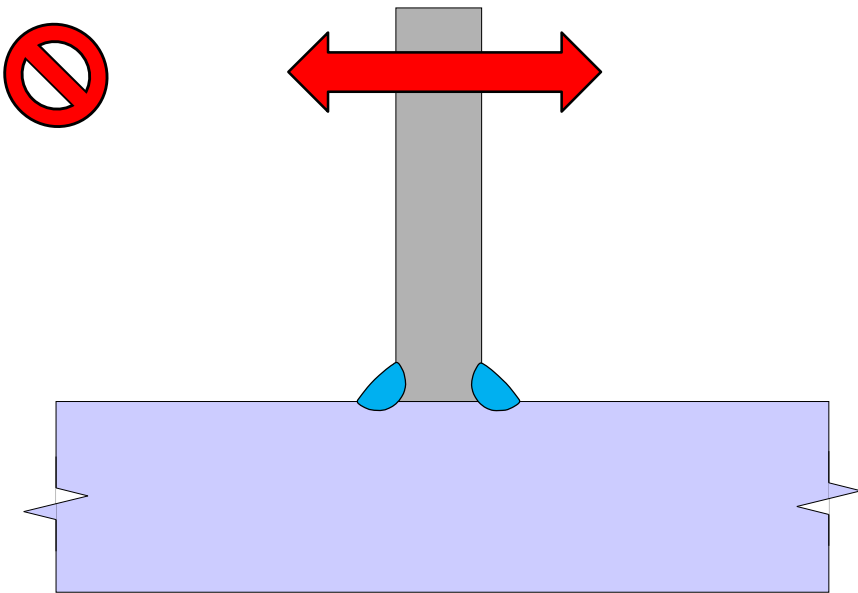
PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection does not subject the weld to bending about the root. **6**

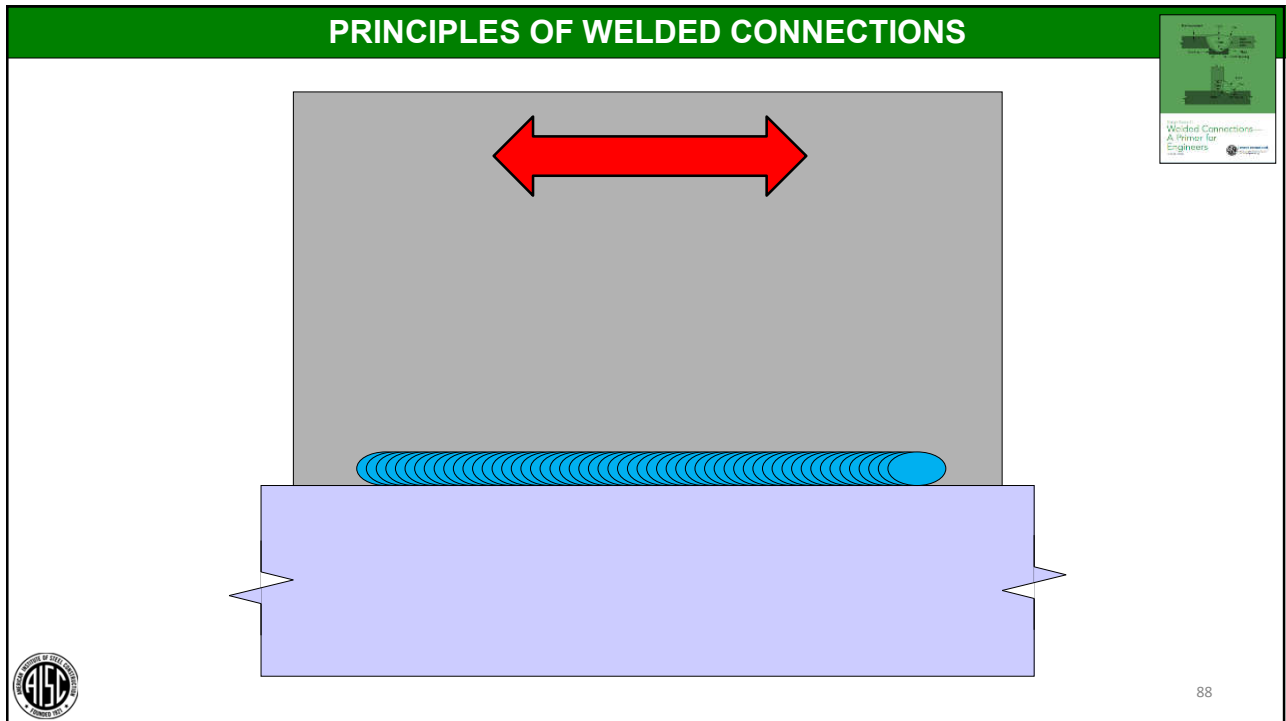
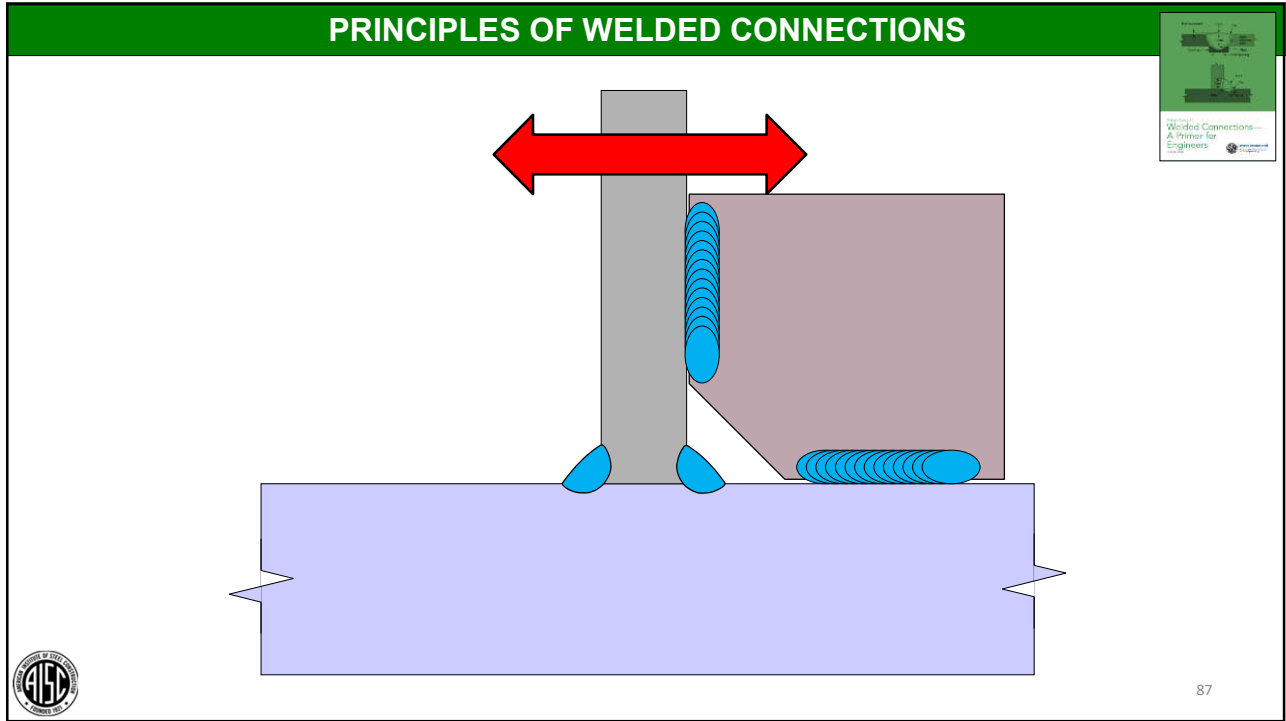


85


PRINCIPLES OF WELDED CONNECTIONS




86



PRINCIPLES OF WELDED CONNECTIONS




A correct and proper welded connection does not subject the weld to bending about the root. **6**




89

PRINCIPLES OF WELDED CONNECTIONS

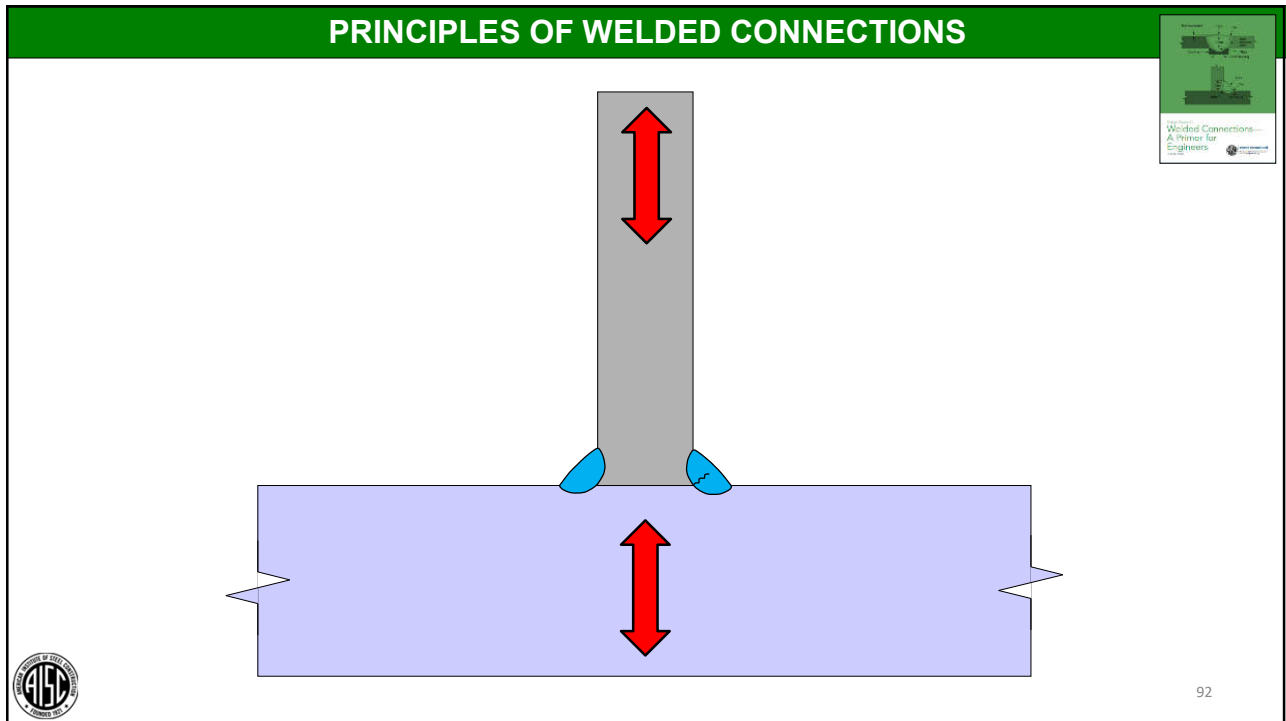
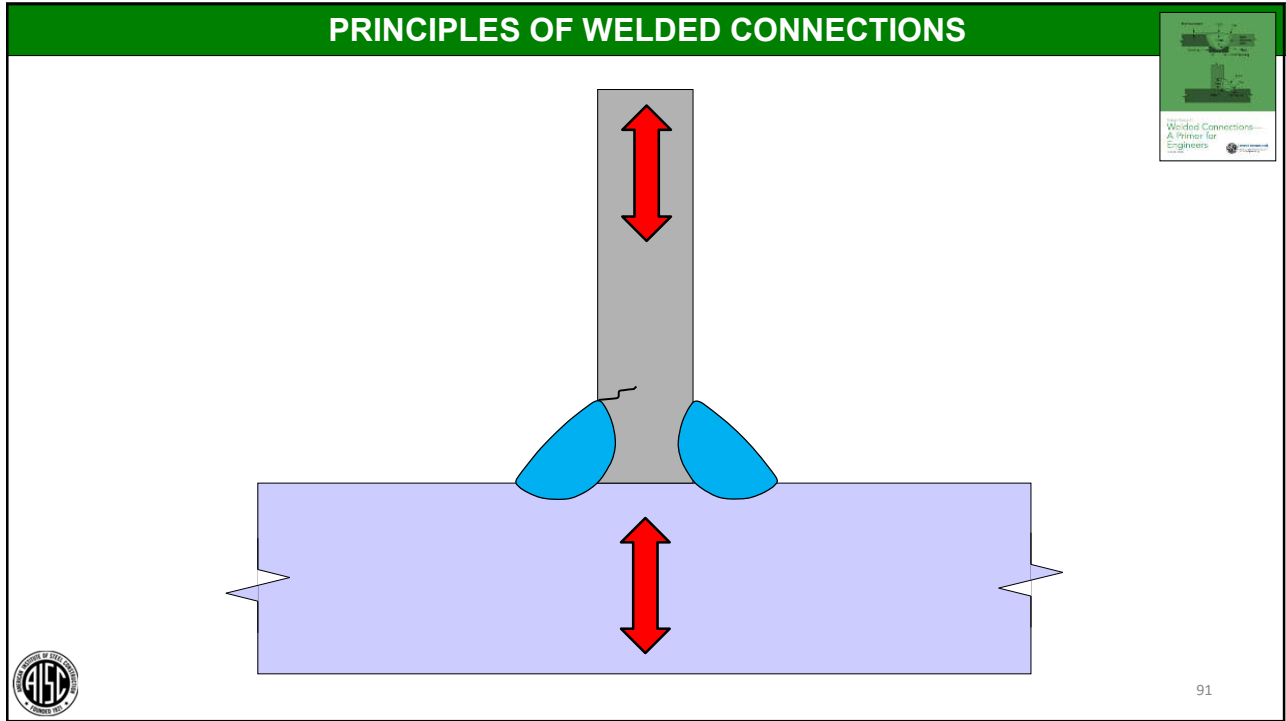


A correct and proper welded connection protects the toes and roots of the welds. **7**

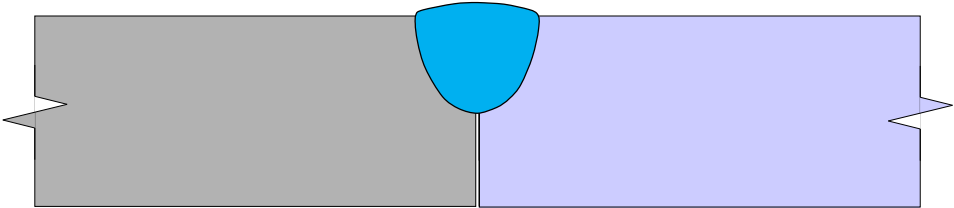
**“Watch your toes
and
remember your roots.”**





90



PRINCIPLES OF WELDED CONNECTIONS

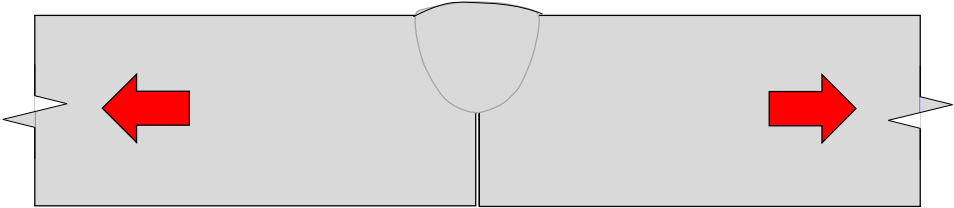


The diagram shows two rectangular plates, one gray and one light blue, joined by a central weld. The weld is depicted as a blue, semi-circular shape with a vertical line extending downwards from its center, representing the weld root. The plates have jagged ends on the left and right sides, indicating they are part of a larger structure.





93

PRINCIPLES OF WELDED CONNECTIONS

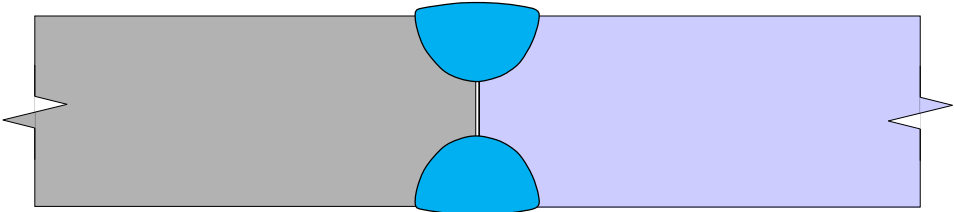



The diagram shows two rectangular plates, both gray, joined by a central weld. The weld is depicted as a gray, semi-circular shape with a vertical line extending downwards from its center. Two red arrows point outwards from the plates, one to the left and one to the right, representing tensile forces. The plates have jagged ends on the left and right sides.




94

PRINCIPLES OF WELDED CONNECTIONS

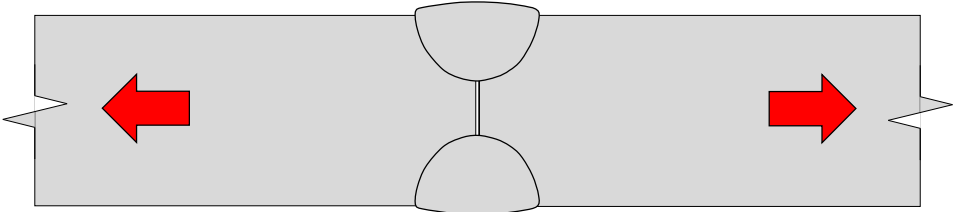




Welded Connections—
A Primer for
Engineers




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PRINCIPLES OF WELDED CONNECTIONS




Welded Connections—
A Primer for
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PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection protects the toes and roots of the welds.

7





97

PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection has a clearly defined throat.

8



“A nothin’ weld ain’t worth nothin’ ”



98

PRINCIPLES OF WELDED CONNECTIONS



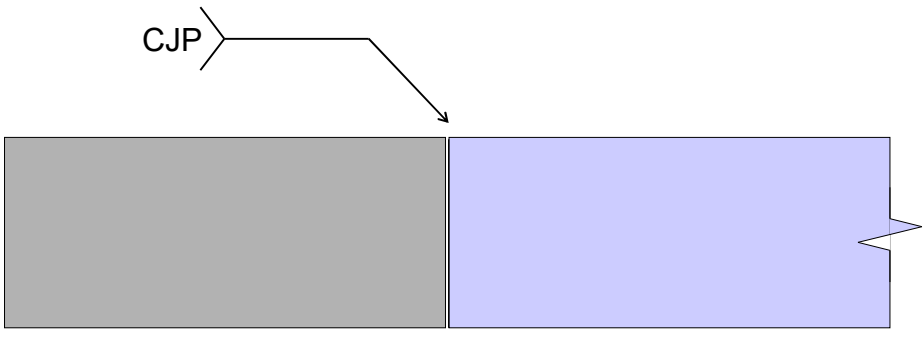
nothin' weld:
A weld that looks like what you wanted, but it ain't.



99

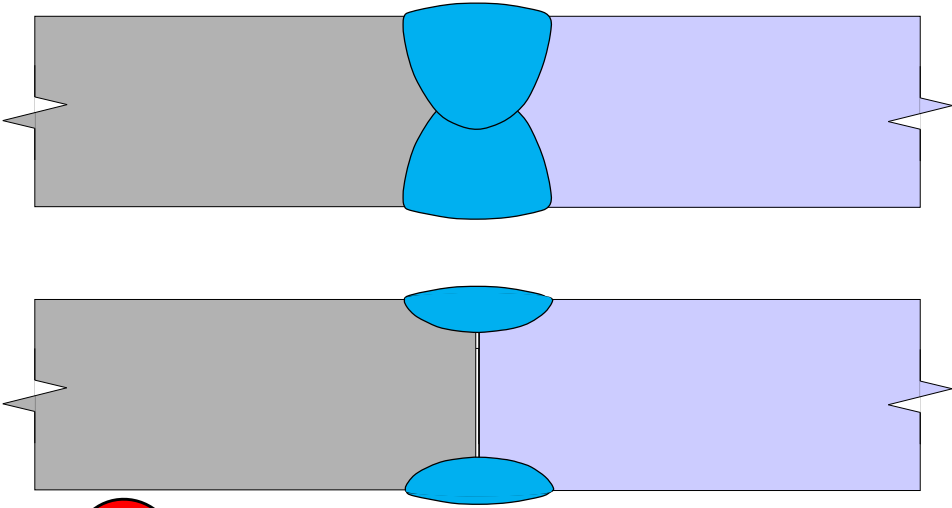
PRINCIPLES OF WELDED CONNECTIONS

CJP





100

PRINCIPLES OF WELDED CONNECTIONS

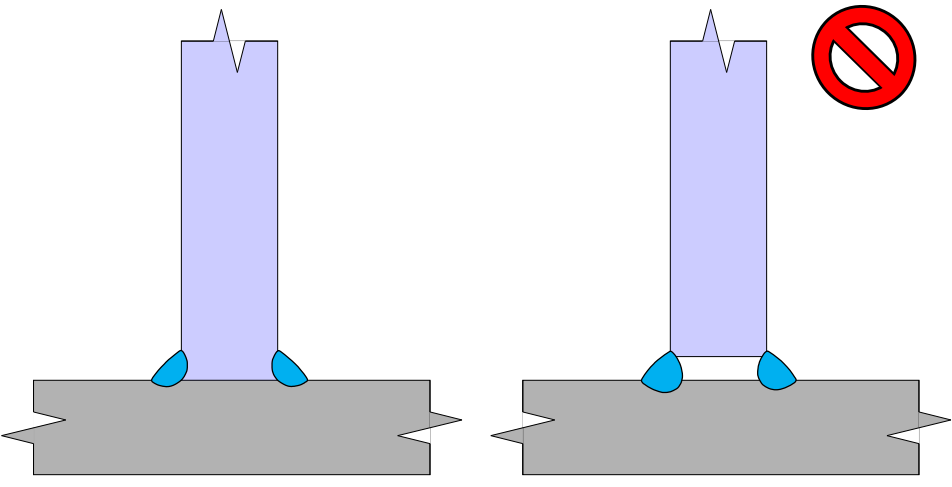


nothin' weld:



101




PRINCIPLES OF WELDED CONNECTIONS



nothin' weld:




102



PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection has a clearly defined throat.

8





103

PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection recognizes material properties.


9

“Respect material properties.”



104


PRINCIPLES OF WELDED CONNECTIONS




SAC
Steel Project

Report No. SAC/BD-97/01 Barsom and Korvink

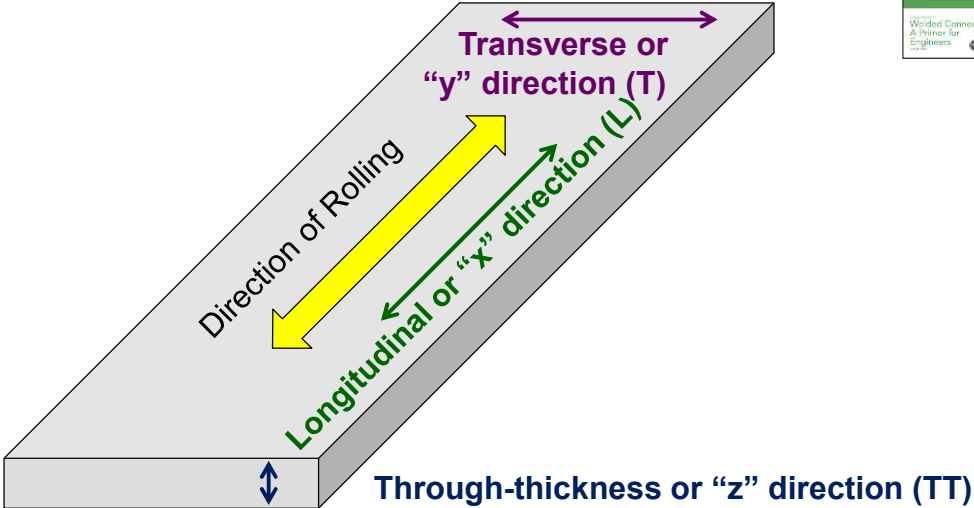
**Through-Thickness Properties
of Structural Steels**



Welded Connections—
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105

PRINCIPLES OF WELDED CONNECTIONS




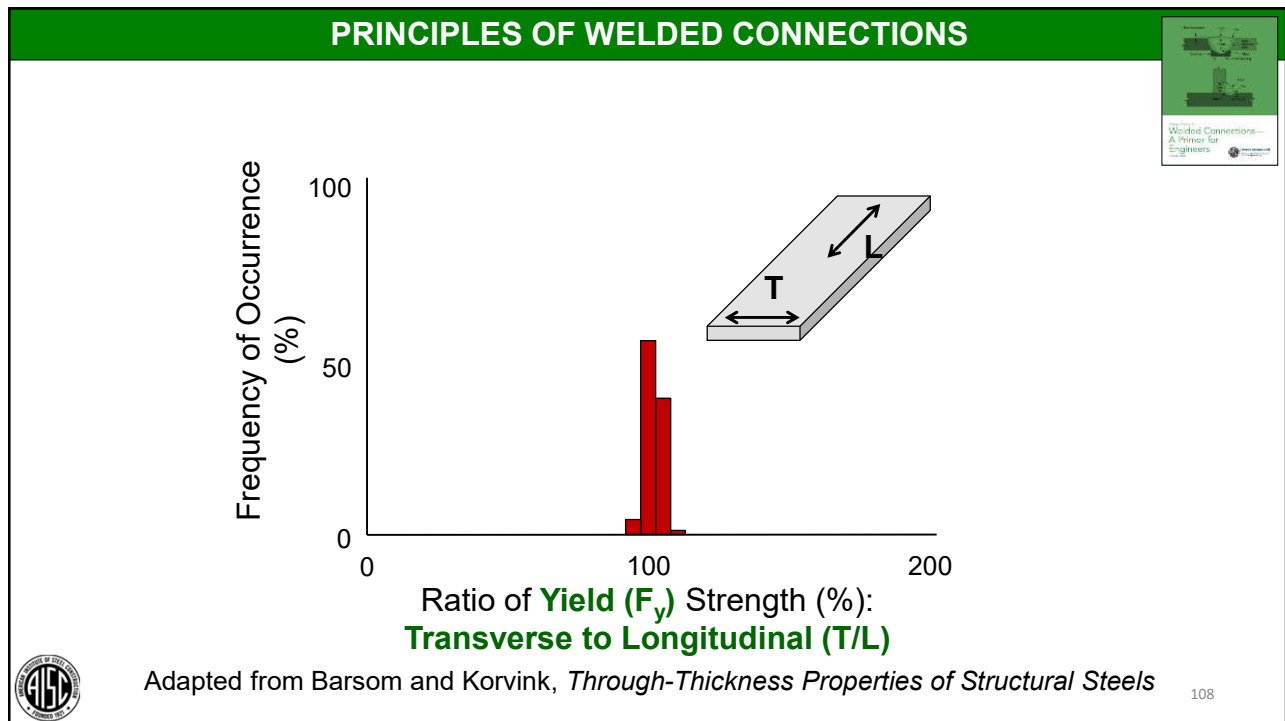
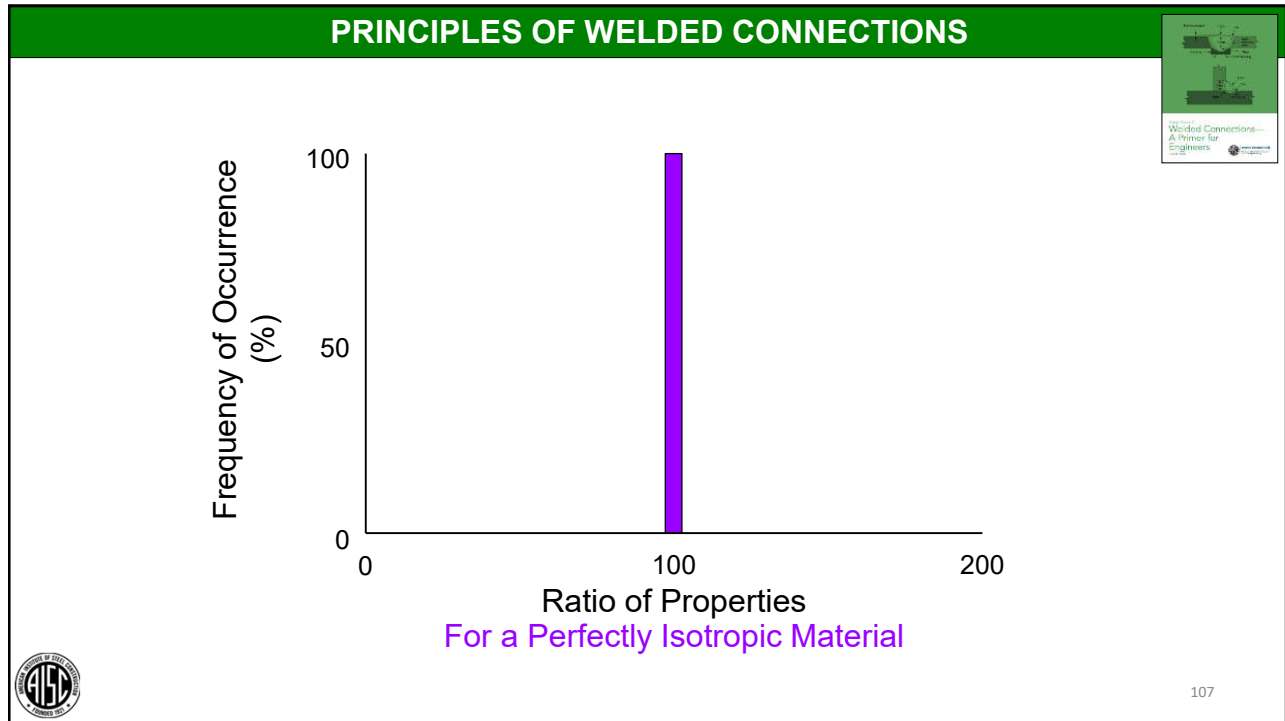
Transverse or
"y" direction (T)

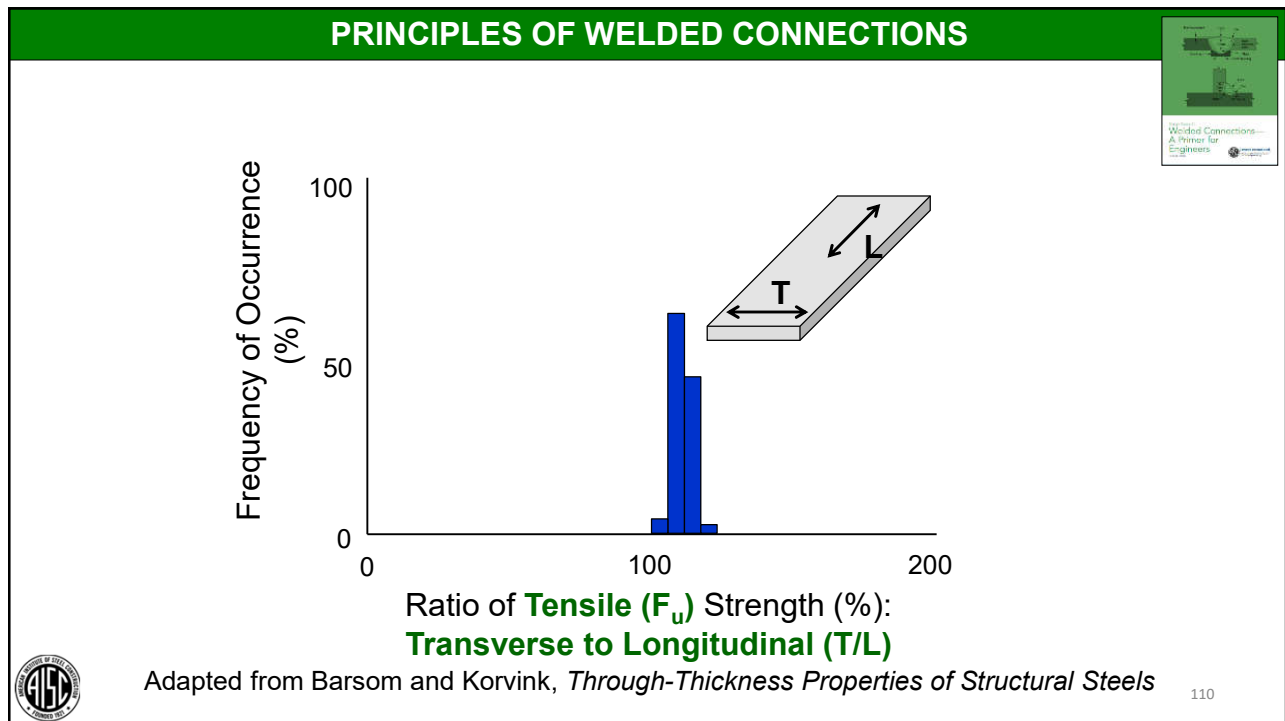
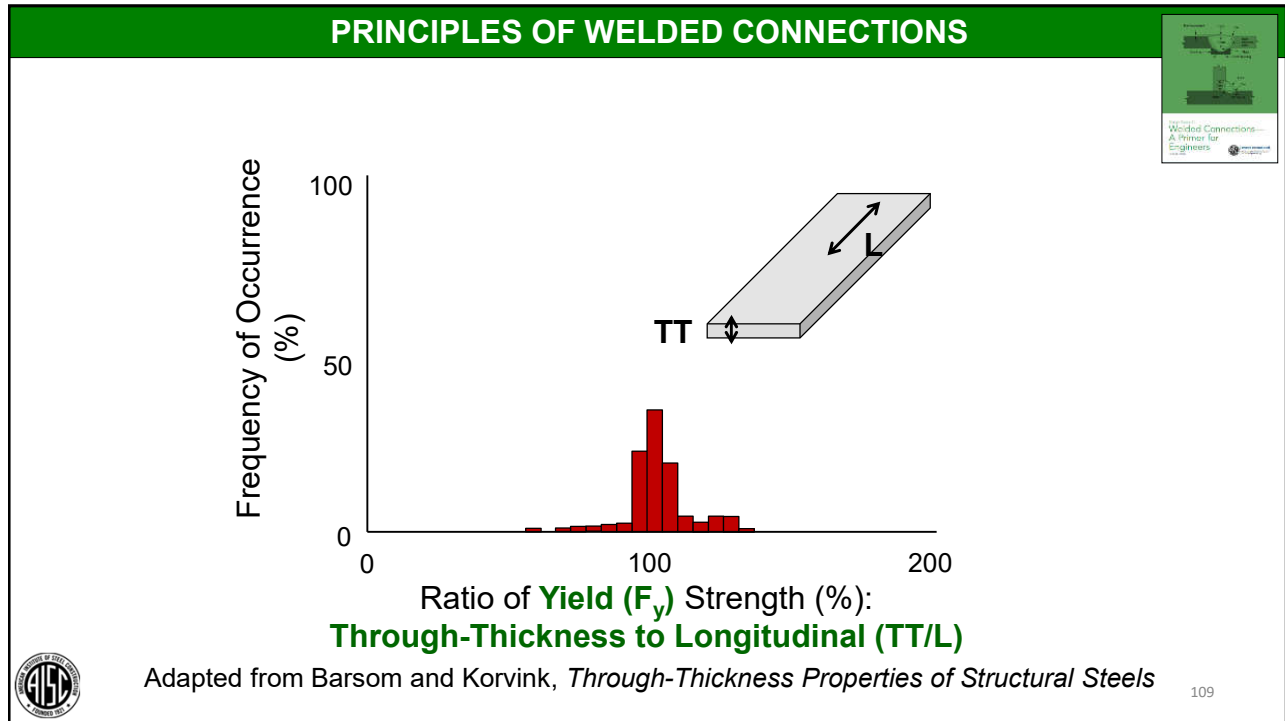
Direction of Rolling

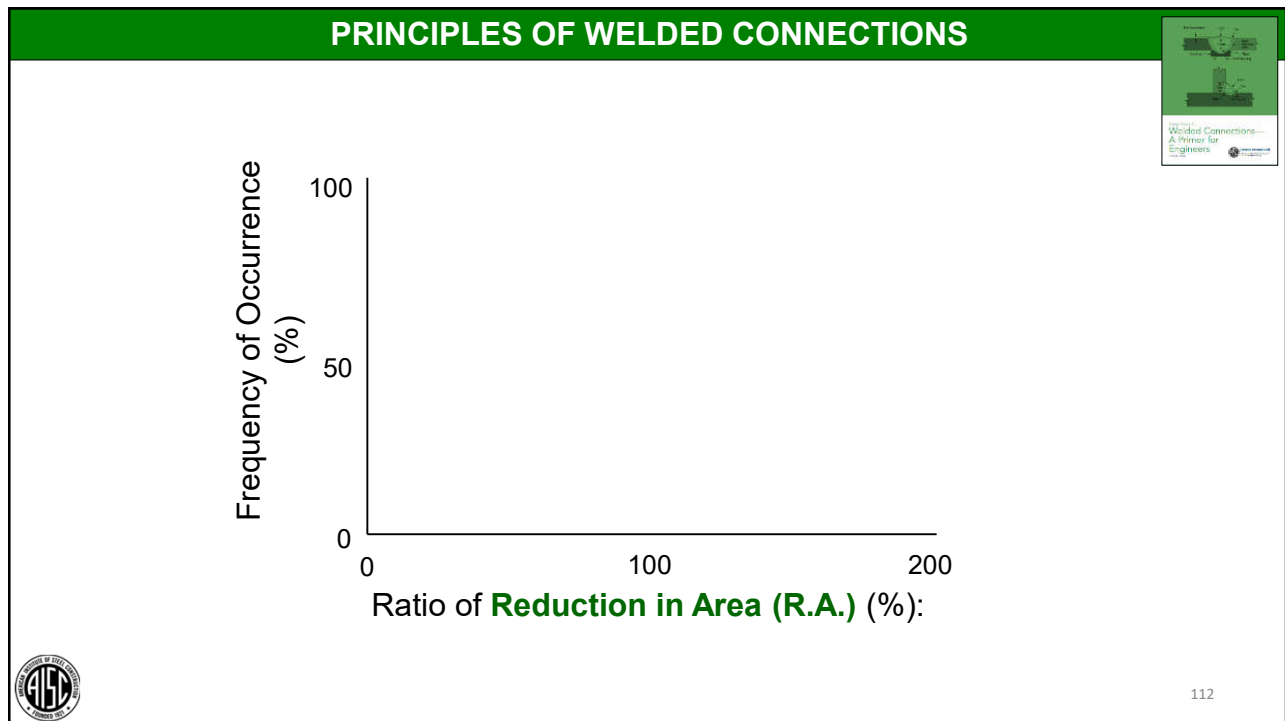
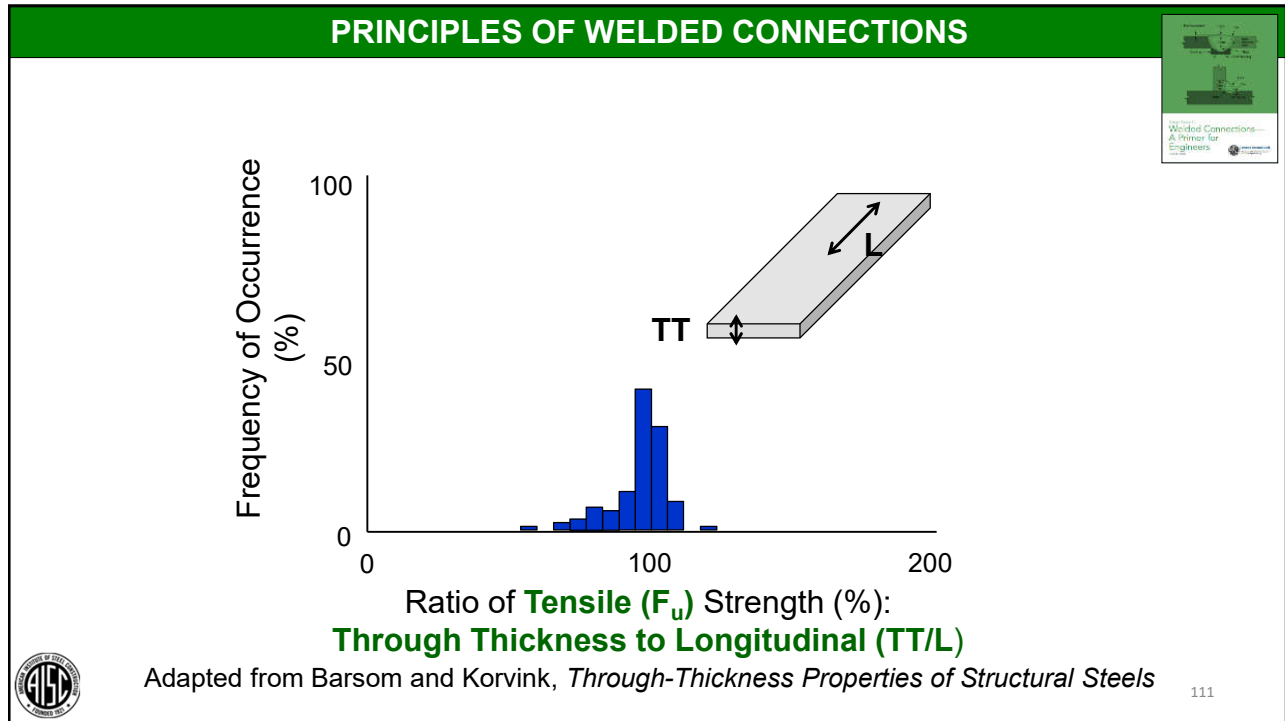
Longitudinal or "x" direction (L)

Through-thickness or "z" direction (TT)


106

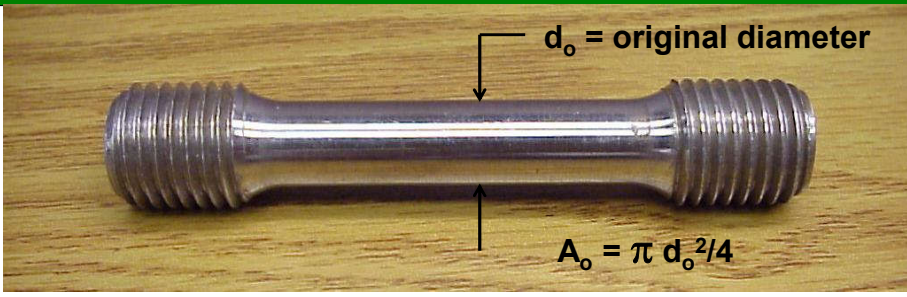






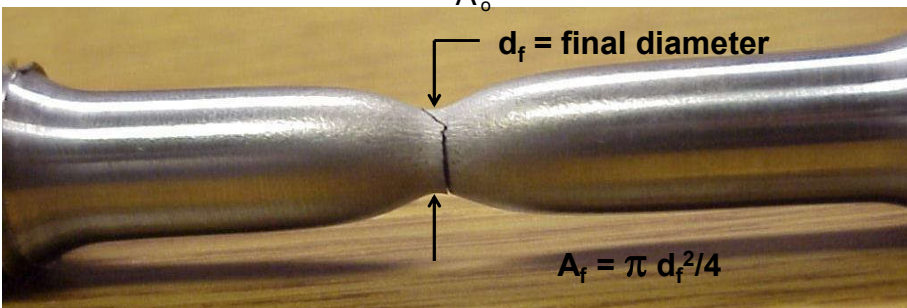
PRINCIPLES OF WELDED CONNECTIONS






$d_o = \text{original diameter}$

$A_o = \pi d_o^2 / 4$

$$R.A. = \frac{A_o - A_f}{A_o} \times 100$$



$d_f = \text{final diameter}$

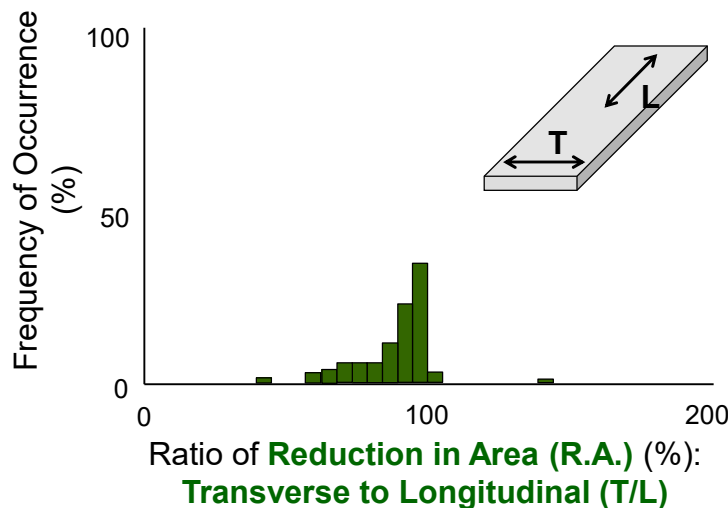
$A_f = \pi d_f^2 / 4$



113

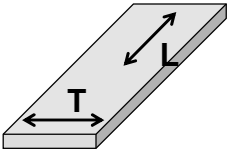
PRINCIPLES OF WELDED CONNECTIONS






Frequency of Occurrence (%)

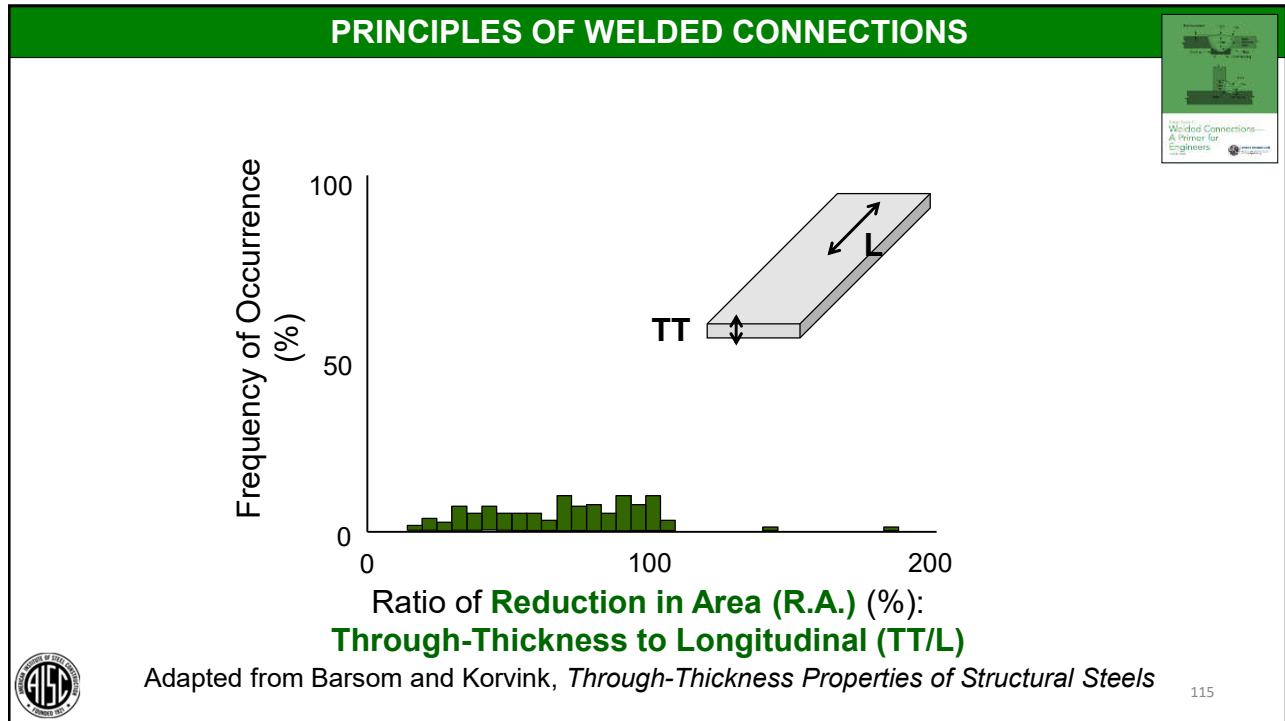
Ratio of **Reduction in Area (R.A.) (%)**:
Transverse to Longitudinal (T/L)






Adapted from Barsom and Korvink, *Through-Thickness Properties of Structural Steels*

114




PRINCIPLES OF WELDED CONNECTIONS



Report No. SAC/BD-97/01

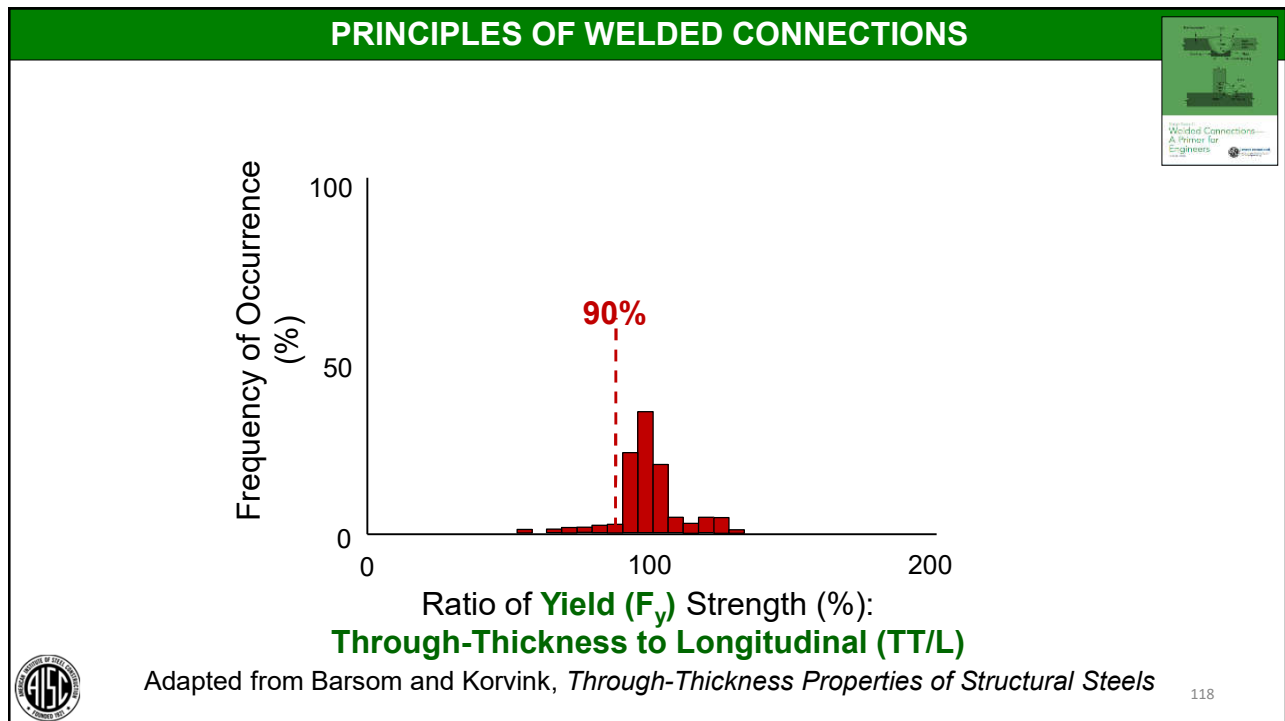
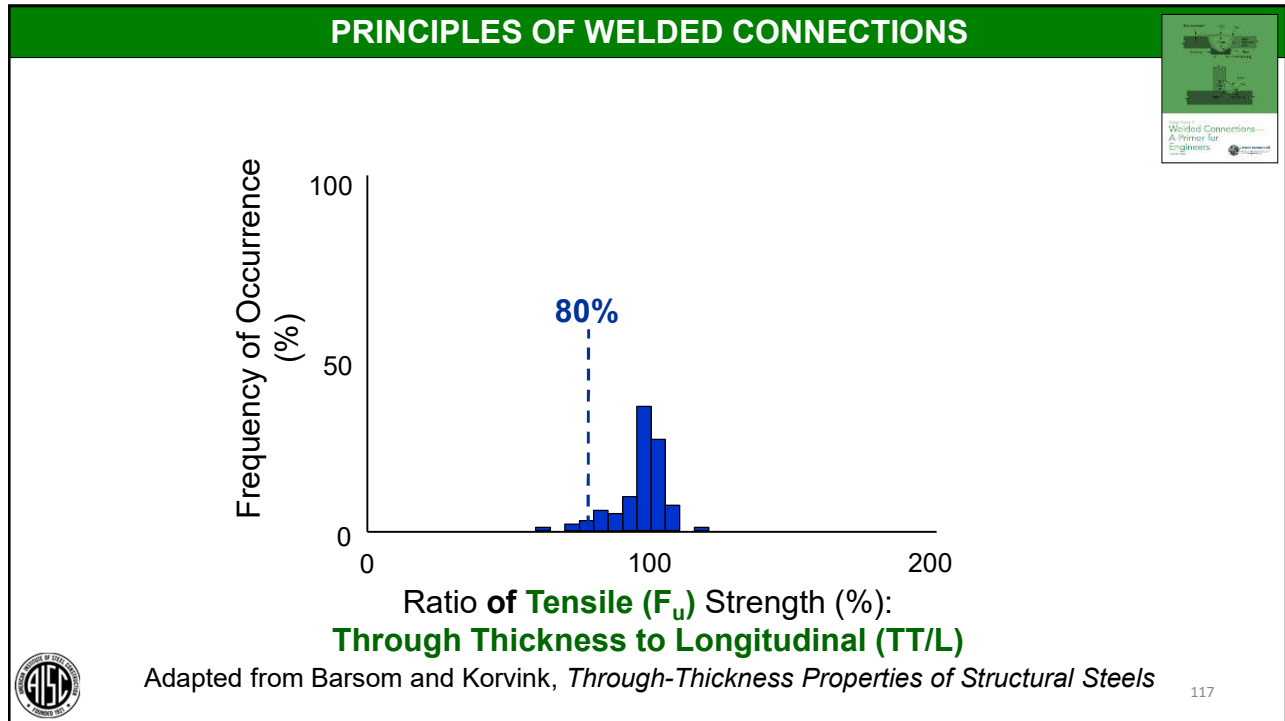
Barsom and Korvink

**Through-Thickness Properties
of Structural Steels**




A conservative through-thickness ultimate strength value can be derived from the longitudinal values and is give by the relationship of $F_u(TT) = 0.8 F_u(L)$. Similarly, a conservative through thickness tensile yield strength value can be derived from the longitudinal values and is given by the relationship $F_y(TT) = 0.9 F_y(L)$.

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PRINCIPLES OF WELDED CONNECTIONS



Report No. SAC/BD-97/01 Barsom and Korvink

**Through-Thickness Properties
of Structural Steels**

Generally, a minimum twenty percent (**20%**) reduction-of-area value has been used as a good measure of lamellar tearing resistance^{7,12}. However, lamellar tearing behavior of steel products is determined by a complex interaction among factors related to **material properties, detailing, welding procedure, fabrication and design.**





119

PRINCIPLES OF WELDED CONNECTIONS

**A correct and proper welded connection
recognizes material properties.**

9





120

PRINCIPLES OF WELDED CONNECTIONS

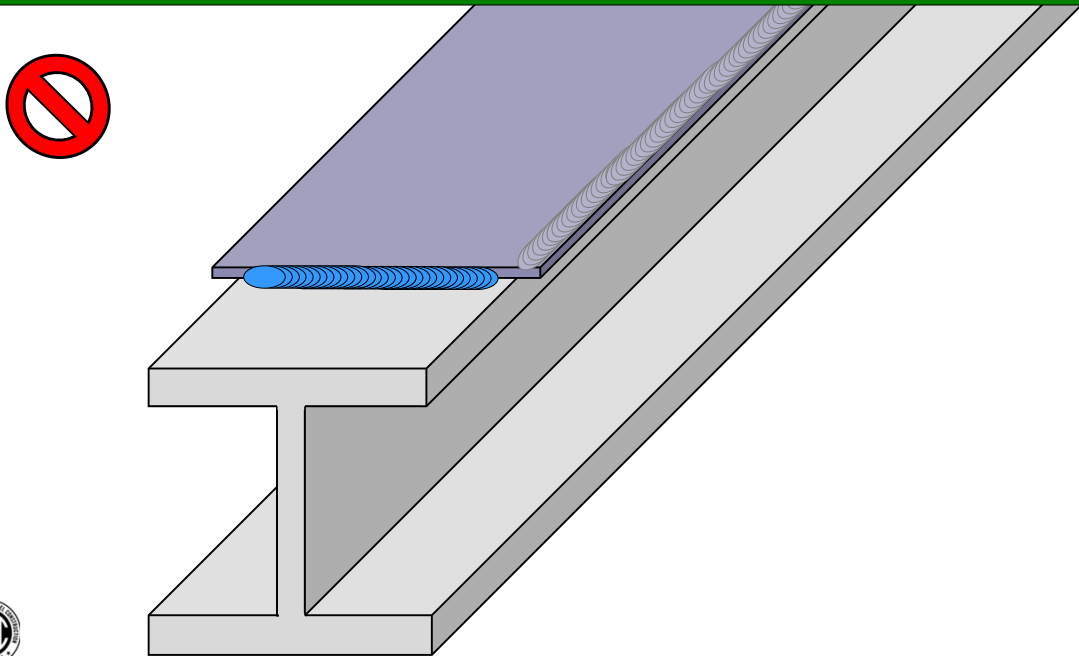
**A correct and proper welded connection
is easy and economical to fabricate and erect.**



10



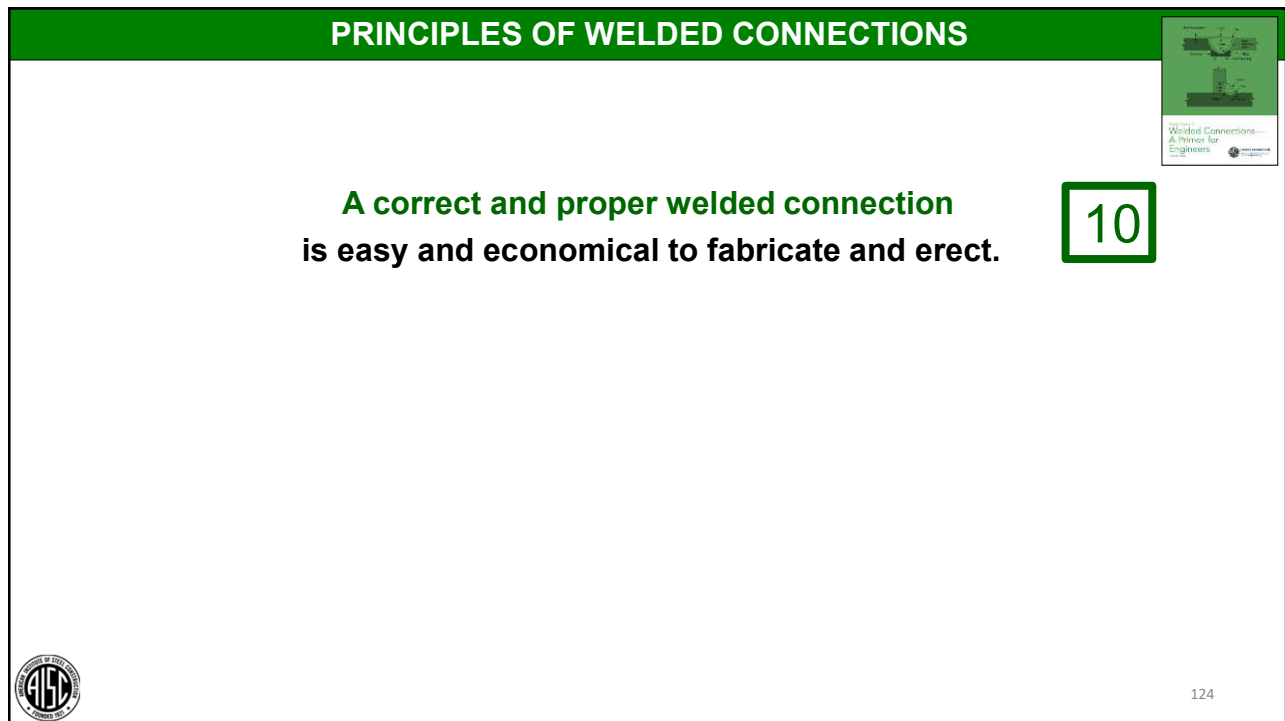
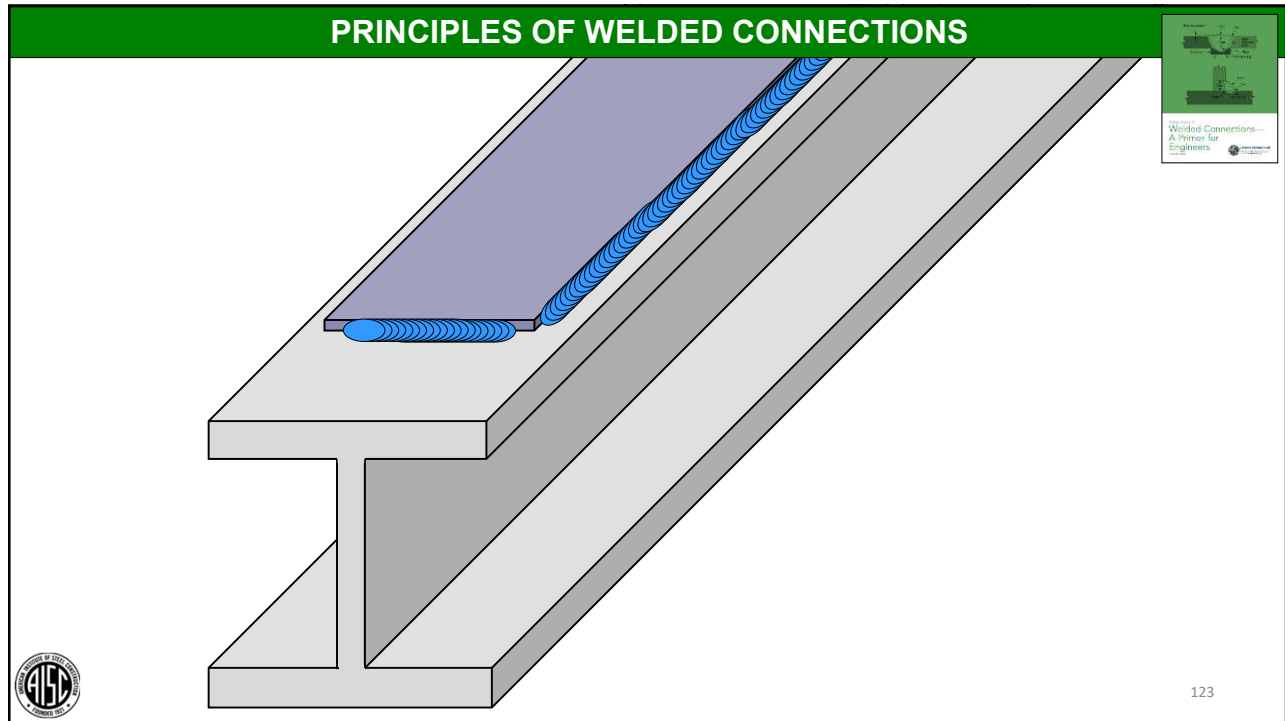
121

PRINCIPLES OF WELDED CONNECTIONS







122




PRINCIPLES OF WELDED CONNECTIONS

**A correct and proper welded connection
is easily inspected.**


11

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PRINCIPLES OF WELDED CONNECTIONS





The issue of inspection should be considered when details are specified. Inspection includes both **visual inspection as well as nondestructive testing.** On complex assemblies, subsequent welding operations may preclude inspection of previously deposited welds. For such assemblies, **hold points may need to be established.** **Left-in-place steel backing can complicate the interpretation of NDT results.**

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PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection is easily inspected.

11





127

PRINCIPLES OF WELDED CONNECTIONS

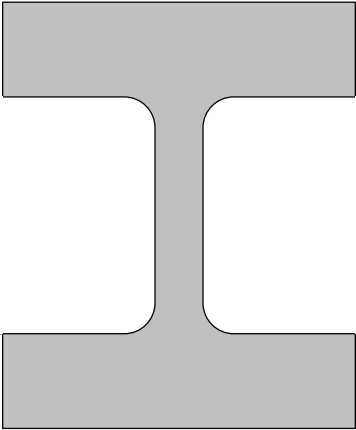
A correct and proper welded connection recognizes commercial realities.

12




128

ASTM A6 Tolerances

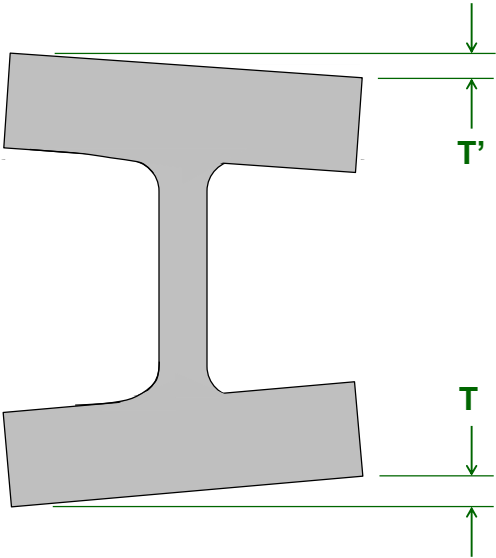


The diagram shows a standard I-beam cross-section with a uniform top flange and bottom flange, and a central web. The top and bottom flanges are parallel to each other.




129

ASTM A6 Tolerances



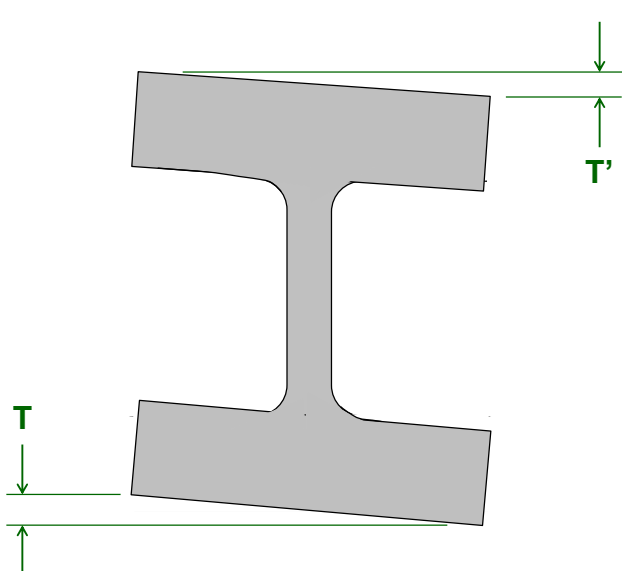
The diagram shows an I-beam cross-section where the top flange is twisted downwards and the bottom flange is twisted upwards. Green dimension lines with arrows indicate the maximum vertical displacement of the flange edges from their original parallel positions. The top displacement is labeled T' and the bottom displacement is labeled T .

For W over 12 in, $T + T' \leq 5/16''$ [8 mm]




130

ASTM A6 Tolerances



The diagram shows a grey I-beam with two green dimension lines. The top flange has a downward-pointing arrow labeled 'T' and an upward-pointing arrow labeled 'T'' indicating the tolerance range. The bottom flange has a downward-pointing arrow labeled 'T' and an upward-pointing arrow labeled 'T'' indicating the tolerance range.

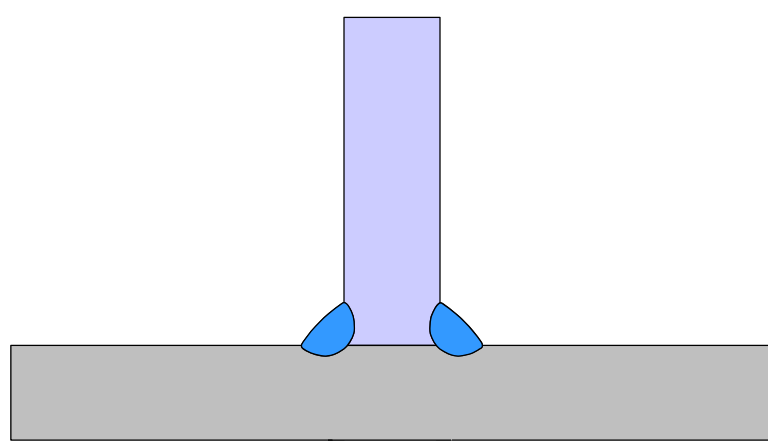
For W over 12 in, $T + T' \leq 5/16''$ [8 mm]




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PRINCIPLES OF WELDED CONNECTIONS


Angular Distortion



The diagram shows a blue I-beam welded to a grey plate. The welds are shown in blue. The I-beam is tilted, illustrating angular distortion.



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AWS D1.1: 2015 Structural Welding Code – Steel

Δ (in) \leq W/100 or 1/4 in [6 mm], whichever is greater

Δ (in) $\leq \frac{W \text{ (in)}}{100}$ OR 1/4 in [6 mm], WHICHEVER IS GREATER

Figure C-5.7—Measurement of Flange Warpage and Tilt (see C-5.23.8)

133

ASTM A500 Tolerances

$\leq \pm 0.75\%$ O.D.

Specified
Outside
Diameter

For outside diameters (O.D.) \geq 2 in [50 mm]


134

ASTM A500 Tolerances

20 in [500 mm]


$\leq \pm 0.15$ in [3.8 mm]

For outside diameters (O.D.) ≥ 2 in [50 mm]



135


AWS D1.1: 2015 Structural Welding Code – Steel



9.24.1 Girth Weld Alignment (Tubular).

...Radial offset of abutting edges of girth weld seams **shall not exceed $0.2t$** (where t is the thickness of the thinner member) and the maximum allowable shall be $1/4$ in [6 mm], provided that any offset exceeding $1/8$ in [3 mm] is welded from both sides.....

Let $t = 1/2$ in [12 mm], then $0.2t = 0.10$ in [2.4 mm]





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PRINCIPLES OF WELDED CONNECTIONS

AWS D1.1 Tolerance
 $\leq \pm 0.10$ in [2.4 mm]

ASTM A500 Tolerance
 $\leq \pm 0.15$ in [3.8 mm]


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PRINCIPLES OF WELDED CONNECTIONS

AWS D1.1 Tolerance
 $\leq \pm 0.10$ in [2.4 mm]


ASTM A500 Tolerance
 $\leq \pm 0.08$ in [1.9 mm]


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PRINCIPLES OF WELDED CONNECTIONS




A correct and proper welded connection recognizes commercial realities.

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PRINCIPLES OF WELDED CONNECTIONS




A correct and proper welded connection is aesthetically pleasing.

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Reminder:
“Beauty is in the eye of the beholder.”

Reminder 2:
Sometimes, pretty doesn’t really matter.



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PRINCIPLES OF WELDED CONNECTIONS



**Welded Connections—
A Primer for
Engineers**


**A correct and proper welded connection
is aesthetically pleasing.**

“Form follows function.”




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PRINCIPLES OF WELDED CONNECTIONS




**Welded Connections—
A Primer for
Engineers**



Architectural Philosophy

Form ever follows function.

**Louis Henry Sullivan
Architect
1856-1924**



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PRINCIPLES OF WELDED CONNECTIONS



Louis Henry Sullivan

It is the pervading law of all things organic and inorganic,
Of all things physical and metaphysical,
Of all things human, and all things super-human,
Of all true manifestations of the head,
Of the heart, of the soul,
That the life is recognizable in its expression,
That form ever follows function. This is the law.



PRINCIPLES OF WELDED CONNECTIONS

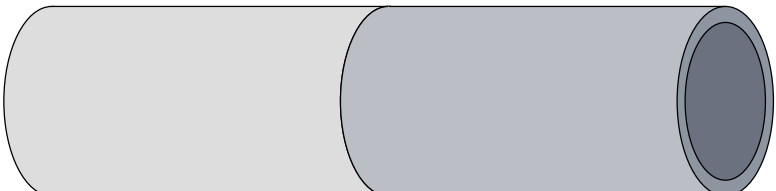


Ideal





PRINCIPLES OF WELDED CONNECTIONS

Reality



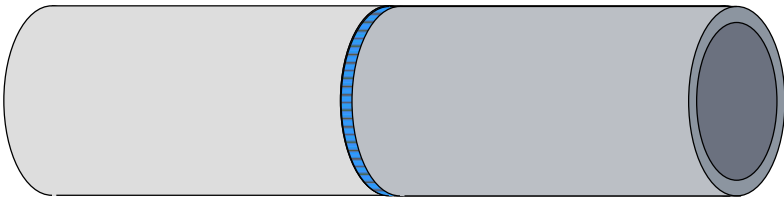
The diagram shows two cylindrical pipe sections joined together. The joint is a simple butt weld with a visible weld bead on the exterior surface. The pipes are shaded in a light gray color.





145

PRINCIPLES OF WELDED CONNECTIONS

Pretty Close to Ideal
(at least in DKM's mind)



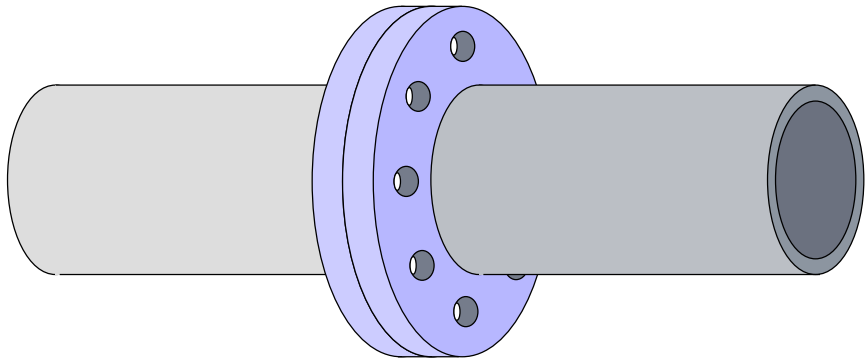
The diagram shows two cylindrical pipe sections joined together. The joint is a butt weld with a blue hatched area representing the weld metal. The pipes are shaded in a light gray color.





146

PRINCIPLES OF WELDED CONNECTIONS

Not even close



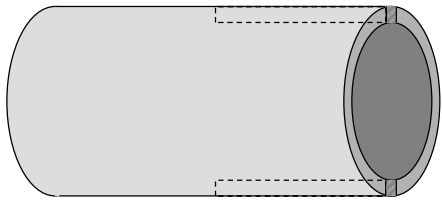

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PRINCIPLES OF WELDED CONNECTIONS

Not even close



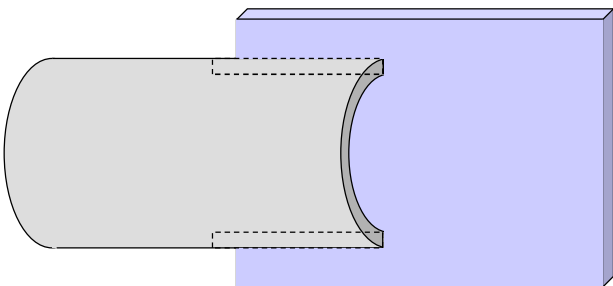

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148

PRINCIPLES OF WELDED CONNECTIONS

Not even close



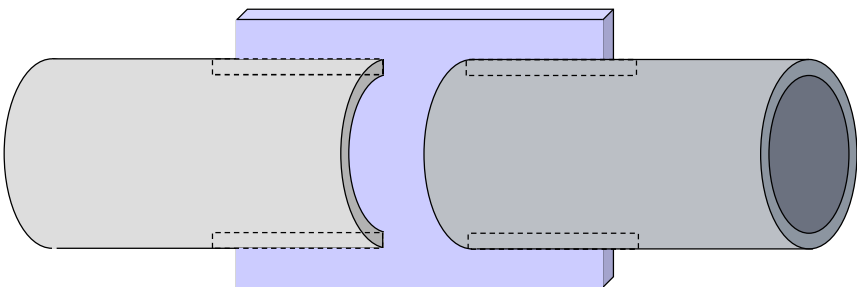
The diagram shows a grey cylindrical pipe on the left and a light blue rectangular plate on the right. The pipe's end is positioned to the left of the plate's edge, with a dashed line indicating the intended contact point. The text "Not even close" is centered above the pipe.





149

PRINCIPLES OF WELDED CONNECTIONS

Not even close

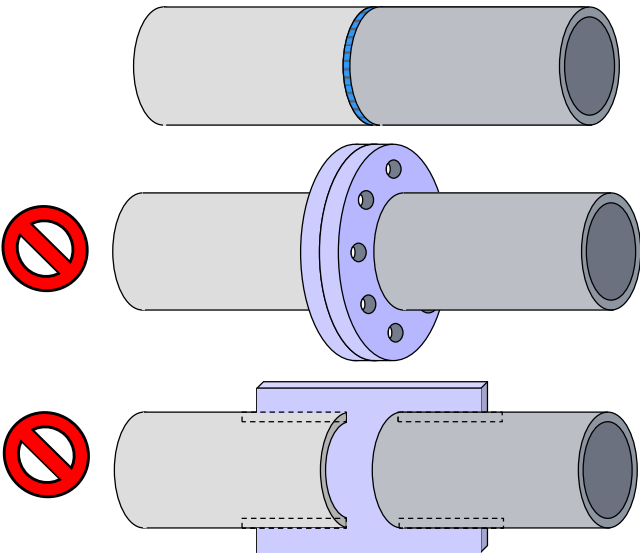


The diagram shows two grey cylindrical pipes on either side of a light blue rectangular plate. The pipe on the left is positioned to the left of the plate's edge, and the pipe on the right is positioned to the right of the plate's edge. Dashed lines indicate the intended contact points. The text "Not even close" is centered above the pipes.




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PRINCIPLES OF WELDED CONNECTIONS



Welded Connections—
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Engineers




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PRINCIPLES OF WELDED CONNECTIONS


**An aesthetically pleasing connection is:
welded, not bolted.**

Welded Connections—
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Engineers





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PRINCIPLES OF WELDED CONNECTIONS




An aesthetically pleasing welded connection is:

- directly welded.
- no gusset plates
- no flange plates





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PRINCIPLES OF WELDED CONNECTIONS



A correct and proper welded connection is aesthetically pleasing.

13




154


PRINCIPLES OF WELDED CONNECTIONS

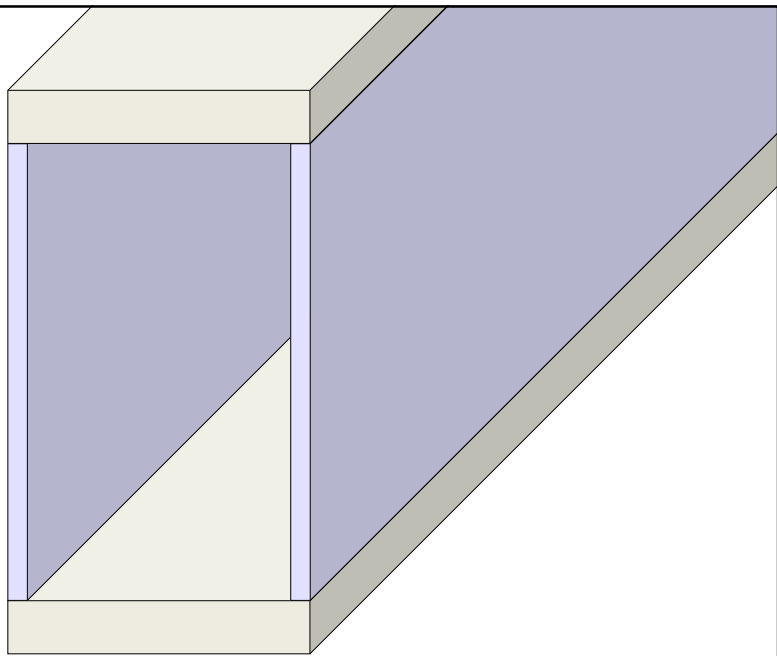
**A correct and proper welded connection
can be made safely.**

14




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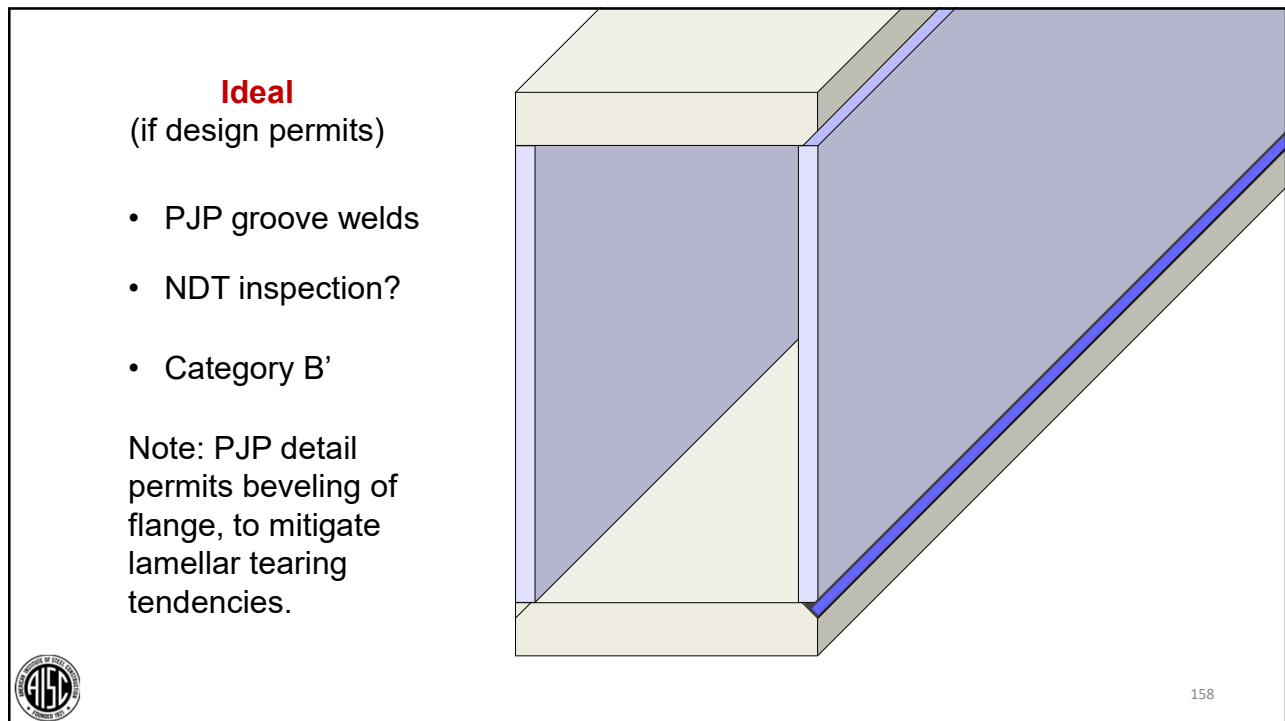
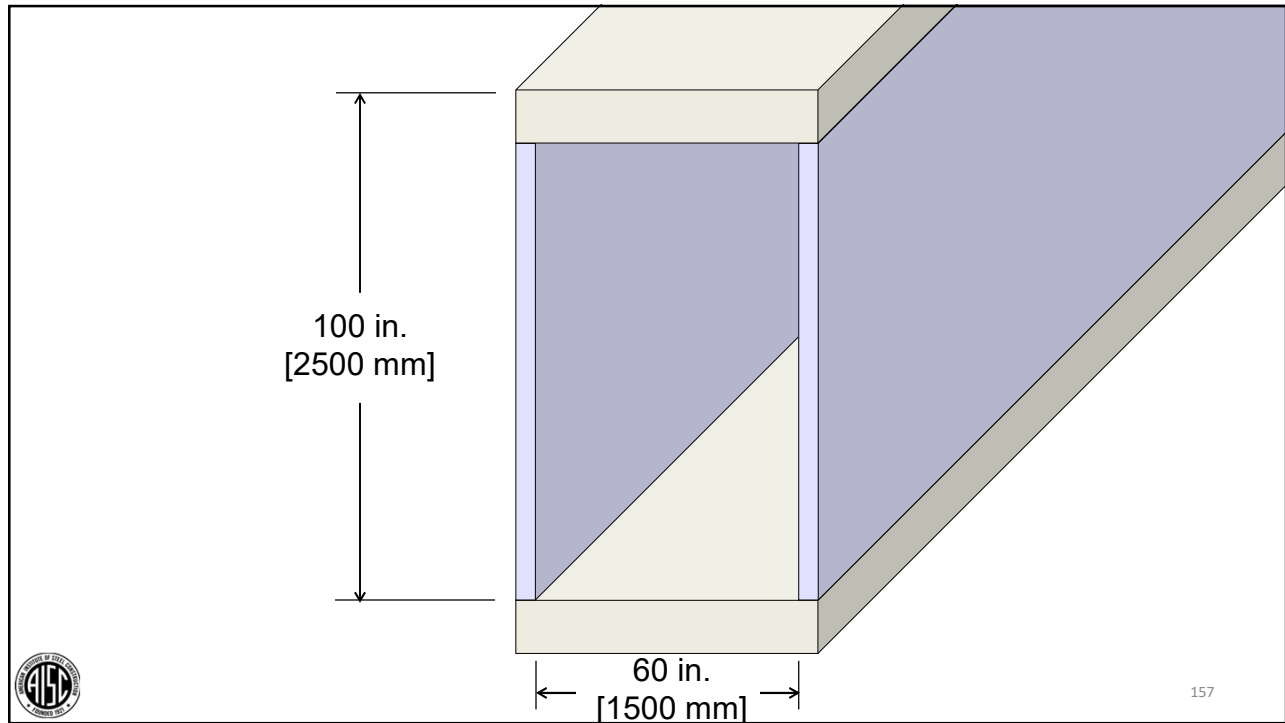
155



CJP typ. →

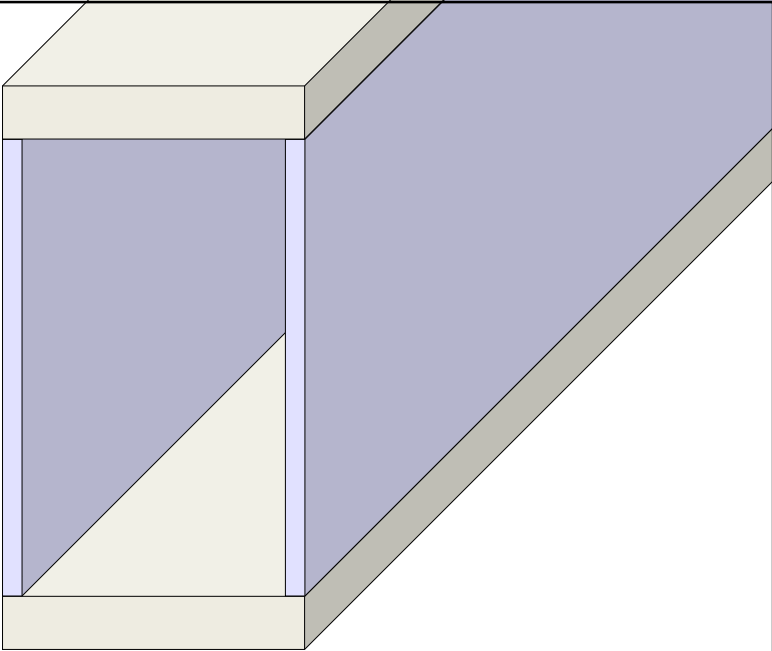
Notes:
1. Steel backing, if
used, shall be
removed.

156




Options

- Doubled sided CJP
- Single sided CJP with backing, then remove backing
- Non-prequalified CJP detail (open root, copper, ceramic)
- Challenge detail: use steel backing (but category B')



The diagram shows a 3D perspective of a corner joint. Two plates meet at a 90-degree angle. A light-colored backing is visible behind the joint, supporting the weld. The weld is shown as a dark grey line along the corner. The plates are colored in shades of blue and grey.

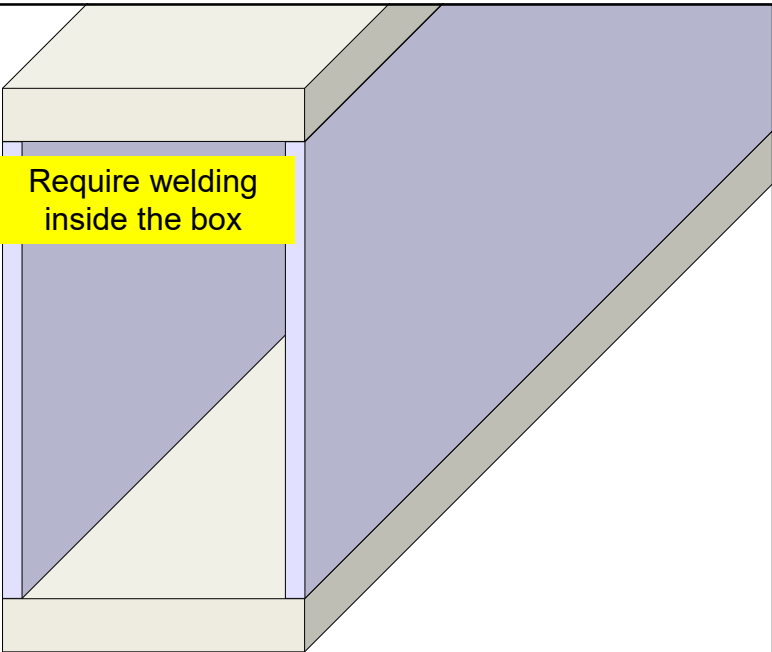


159


Options

- Doubled sided CJP
- Single sided CJP with backing, then remove backing
- Non-prequalified CJP detail (open root, copper, ceramic)
- Challenge detail: use steel backing (but category B')

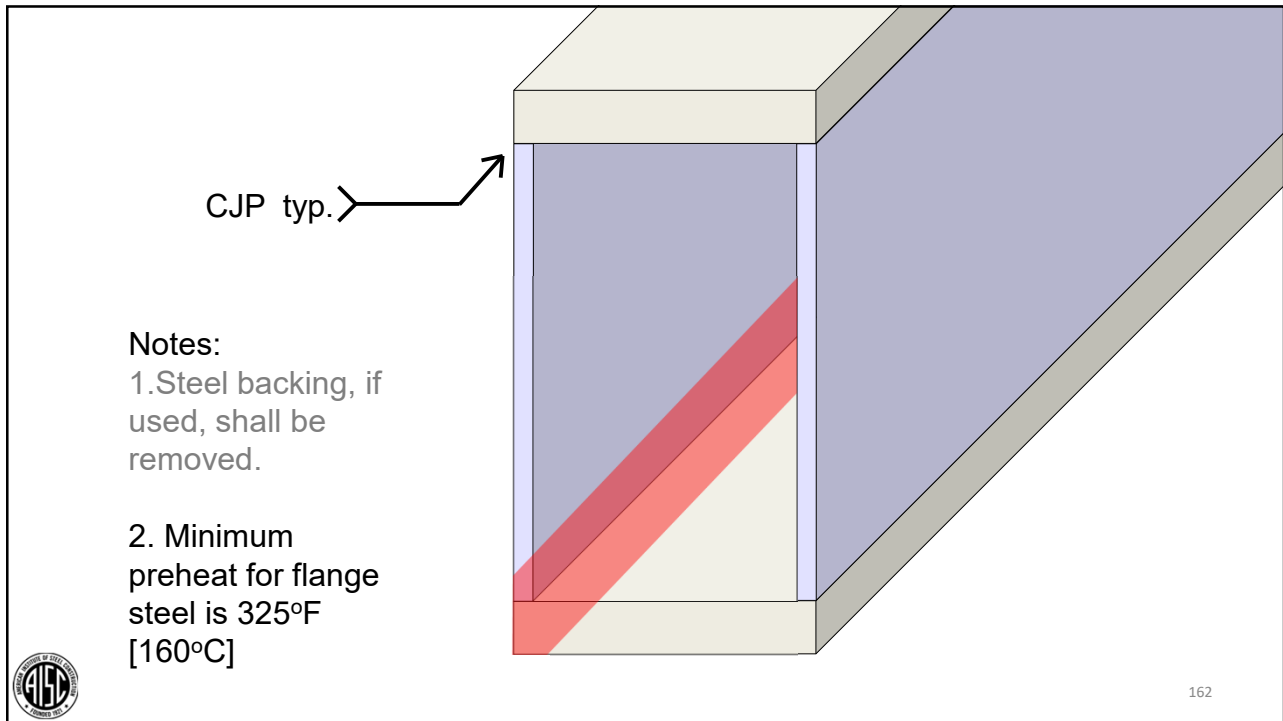
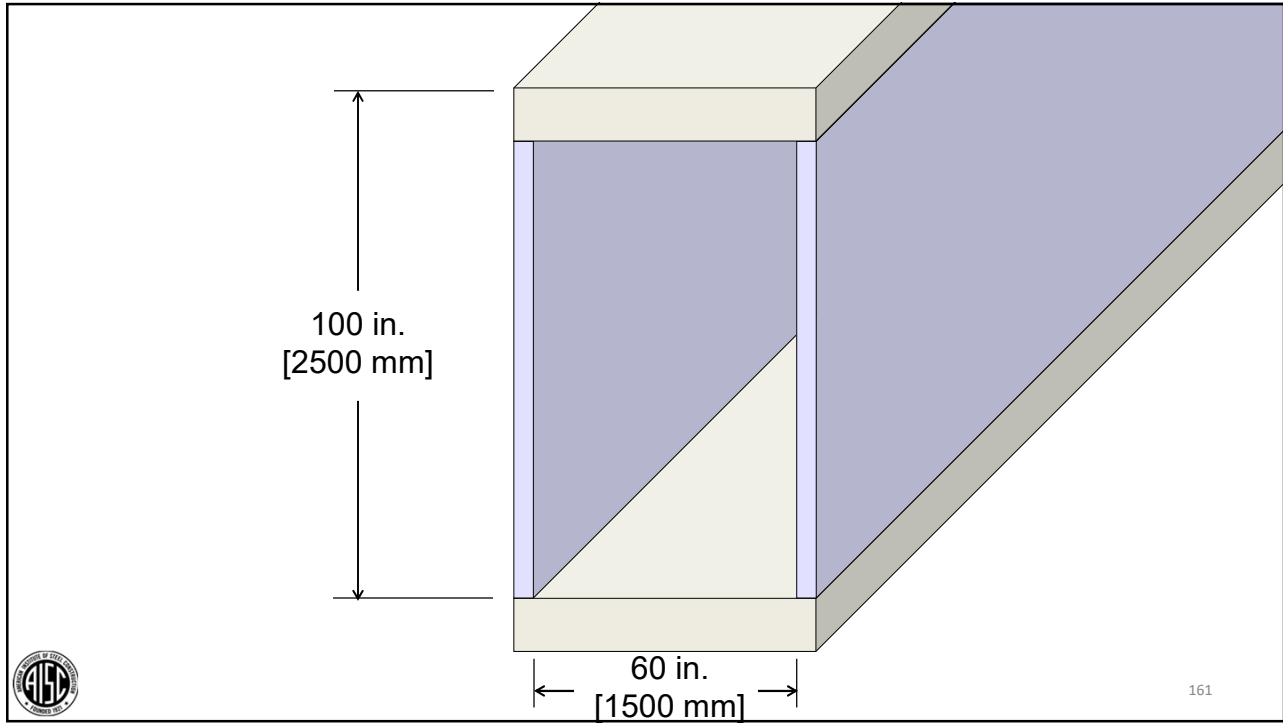
Require welding inside the box



The diagram is identical to the one on slide 159, showing a 3D perspective of a corner joint with backing. A yellow callout box with the text "Require welding inside the box" is positioned over the joint area.

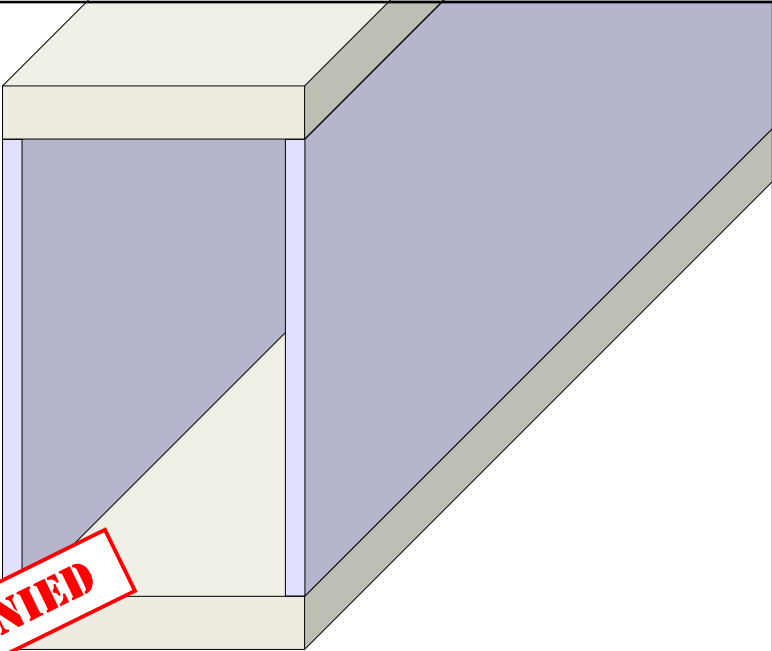


160




Options

- Doubled sided CJP
- Single sided CJP with backing, then remove backing
- Non-prequalified CJP detail (open root, copper, ceramic)
- Challenge detail: use steel backing (but category B')

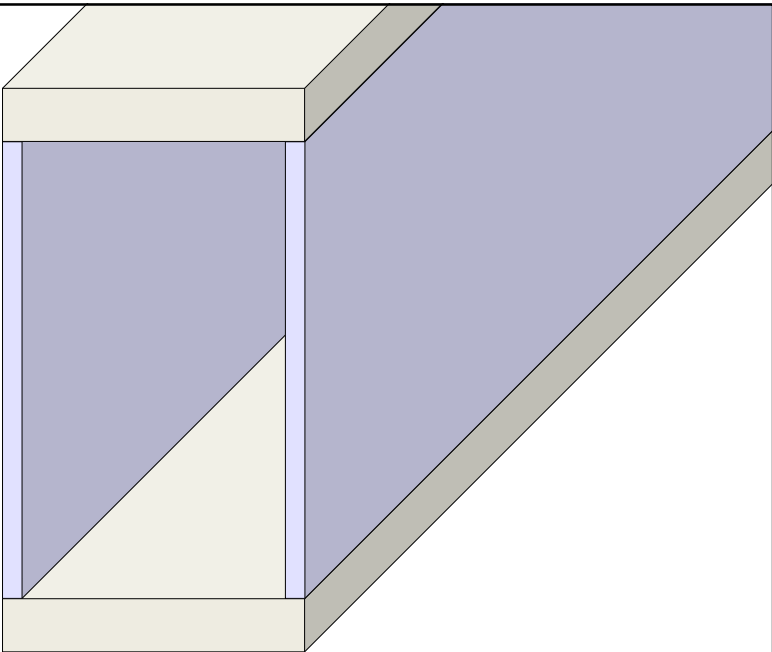


The diagram shows a 3D cutaway of a double-sided CJP weld joint. The top and bottom plates are light gray, and the vertical plates are blue. A red stamp with the word "DENIED" is placed over the bottom edge of the joint.


 163

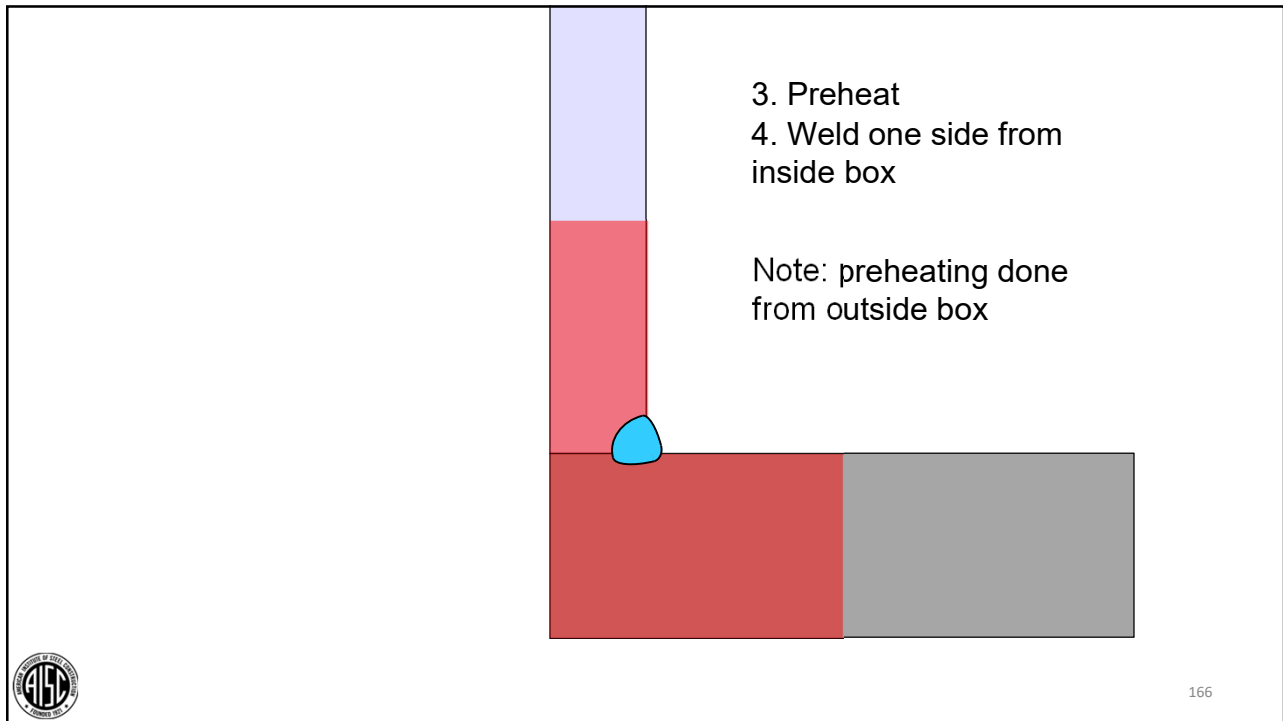
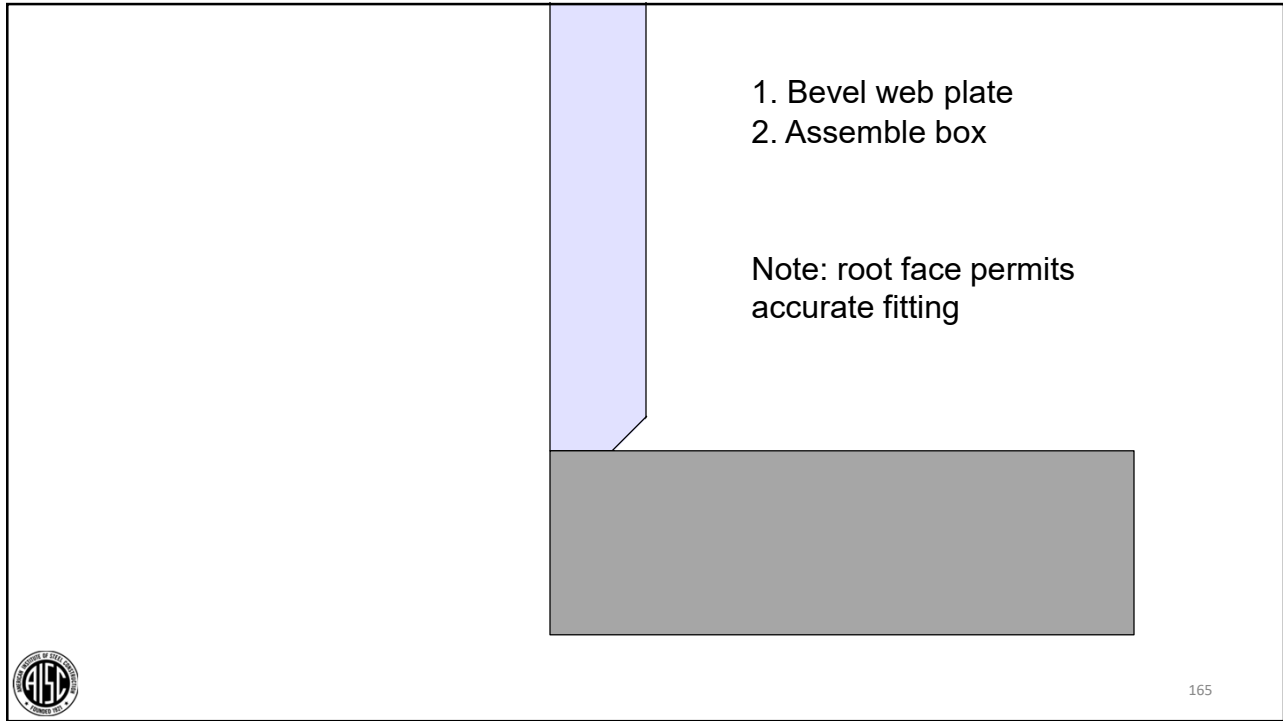
Actual

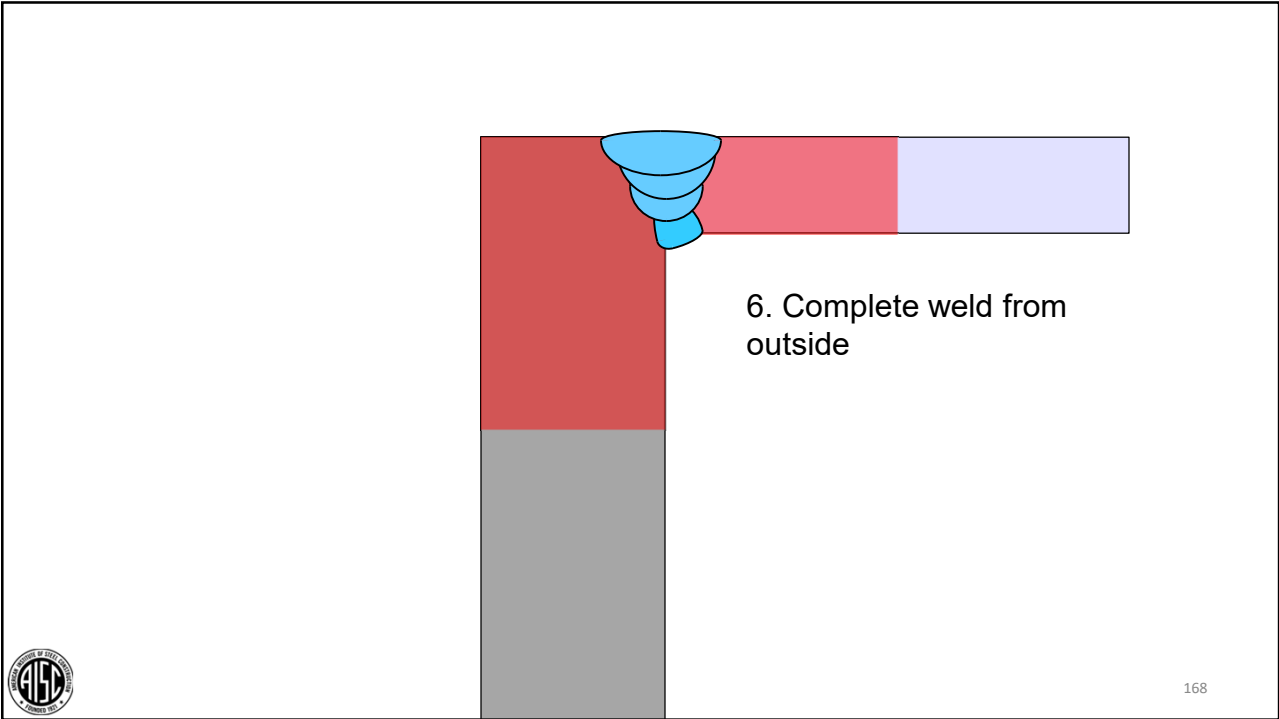
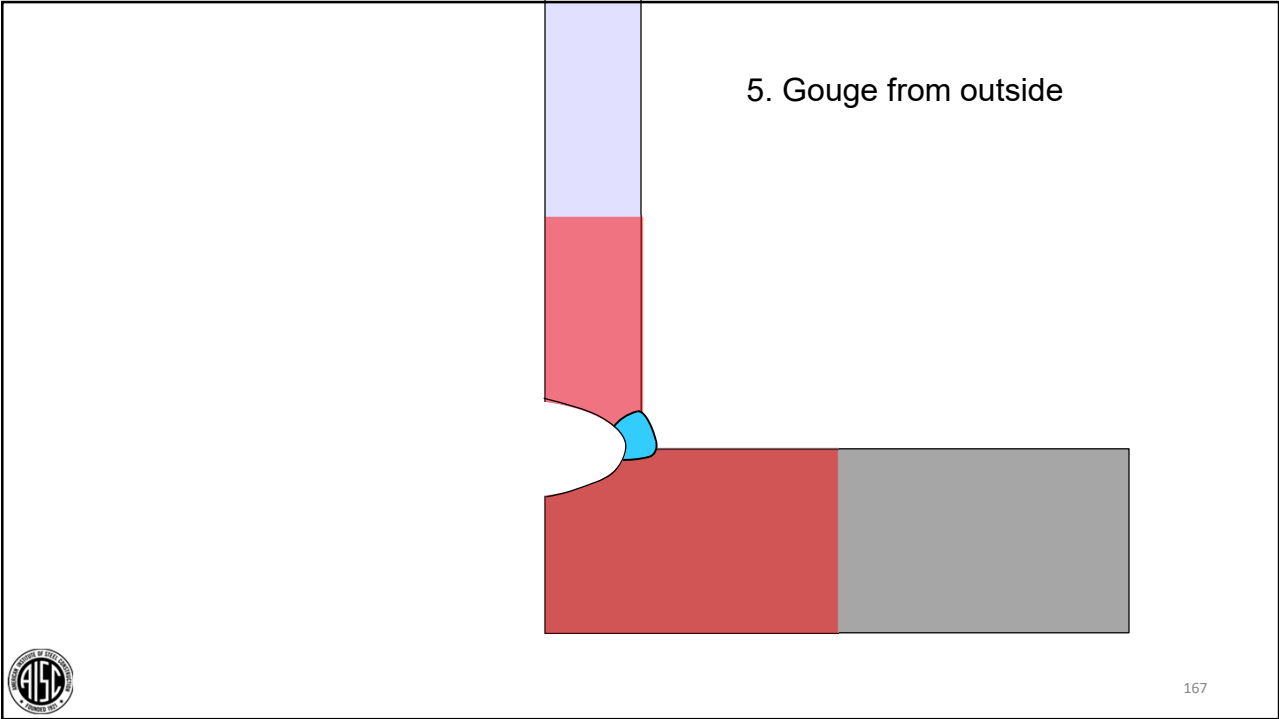
- Doubled sided CJP
- Special safety precautions (heat, access, ventilation)
- Single bevel, gouge from outside
- No lamellar tearing, despite compromised detail



The diagram shows a 3D cutaway of a double-sided CJP weld joint. The top and bottom plates are light gray, and the vertical plates are blue. The bottom edge of the joint has a single bevel.

 164







PRINCIPLES OF WELDED CONNECTIONS

**A correct and proper welded connection
can be made safely.**

14





169

PRINCIPLES OF WELDED CONNECTIONS

14 Principles of Welded Connection Design

What makes a welded connection correct or proper?



170

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.



Login

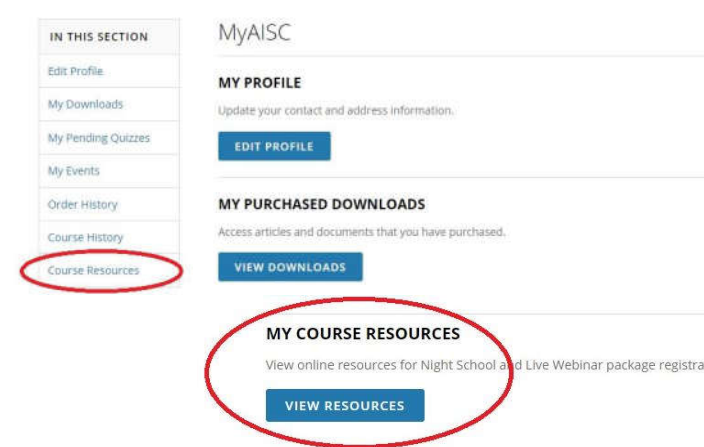
If you're an existing customer, please enter your username and password.

<p>USERNAME</p> <input type="text" value="Enter your username"/>	<p>DON'T HAVE AN ACCOUNT?</p> <p>My AISC allows you to access Engineering Journal articles and Design Guides you have downloaded from the bookstore.</p> <p>REGISTER NOW</p>
<p>PASSWORD</p> <input type="text" value="Enter your password"/>	
<input type="checkbox"/> Remember Me	

8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.



8-Session Registrants

Night School Resources



Course Resources

Event	Start Date
NS 33 8-Session Package-Night School 33 - Design of Industrial Buildings	1/30/2017 7:00:00 PM
NS 34 8-Session Package-Night School 34 - Fundamentals of Stability	6/5/2017 7:00:00 PM



8-Session Registrants

Night School Resources



Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	View Passcode: NS13DSN	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	Handouts	Available 02/08/2017 5pm EST	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	Handouts	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	Handouts	Available 03/01/2017 5pm EST	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girder Design and Frame Analysis	3/6/2017 7:00:00 PM	Handouts	Available 03/08/2017 5pm EST	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	Handouts	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Bldg Bracing Dsn	3/27/2017 7:00:00 PM	Handouts	Available 03/29/2017 5pm EST	Available 03/29/2017 5pm EST	Pending
NS13 - Building Envelope and Bracing Design	4/3/2017 7:00:00 PM	Handouts	Available 04/05/2017 5pm EST	Available 04/05/2017 5pm EST	Pending

8-Session Registrants

Night School Resources

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

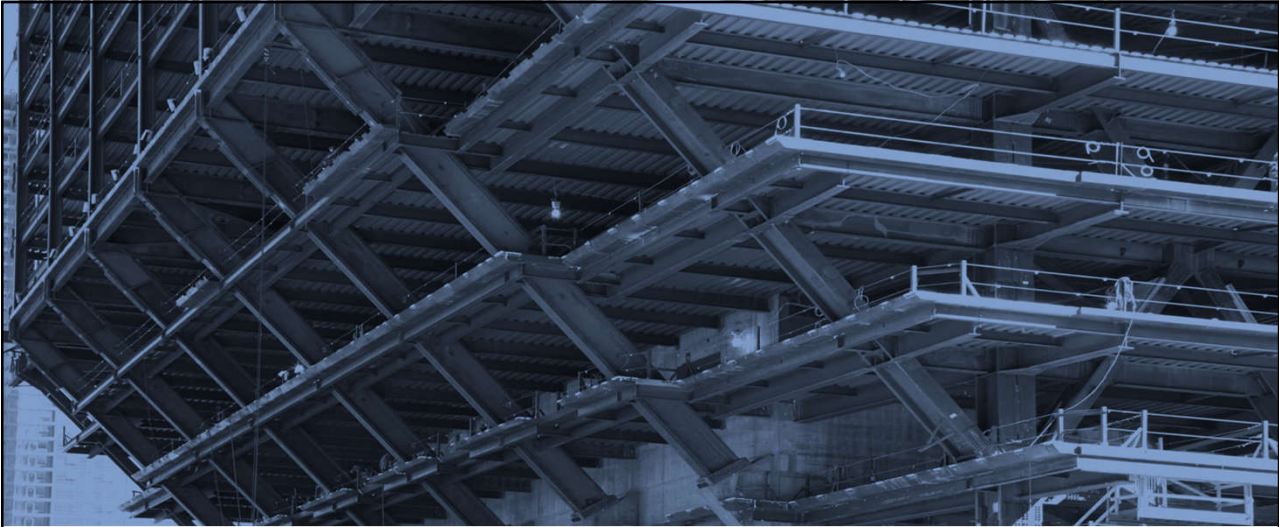


8-Session Registrants

Night School Resources

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





AISC | Thank you

