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Night School



Welded Connections
A Primer for Engineers



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Course Description

21.2 Principles of Welded Connections October 15, 2019

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.





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 21 Course Schedule

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



Night School 21 Welded Connections -- A Primer for Engineers

Session 2: Principles of Welded Connections
October 15, 2019



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



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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




Welded Connections—
A Primer for
Engineers

A correct and proper welded connection


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

1

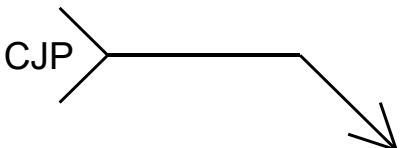
Correct and proper = strong enough
(but not stronger than necessary)

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PRINCIPLES OF WELDED CONNECTIONS




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CJP 

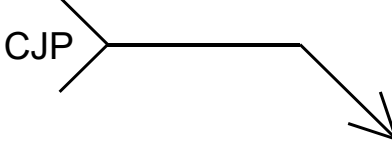
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Official Definition:
A groove weld in which weld metal extends through the joint thickness.

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PRINCIPLES OF WELDED CONNECTIONS




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

14

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




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

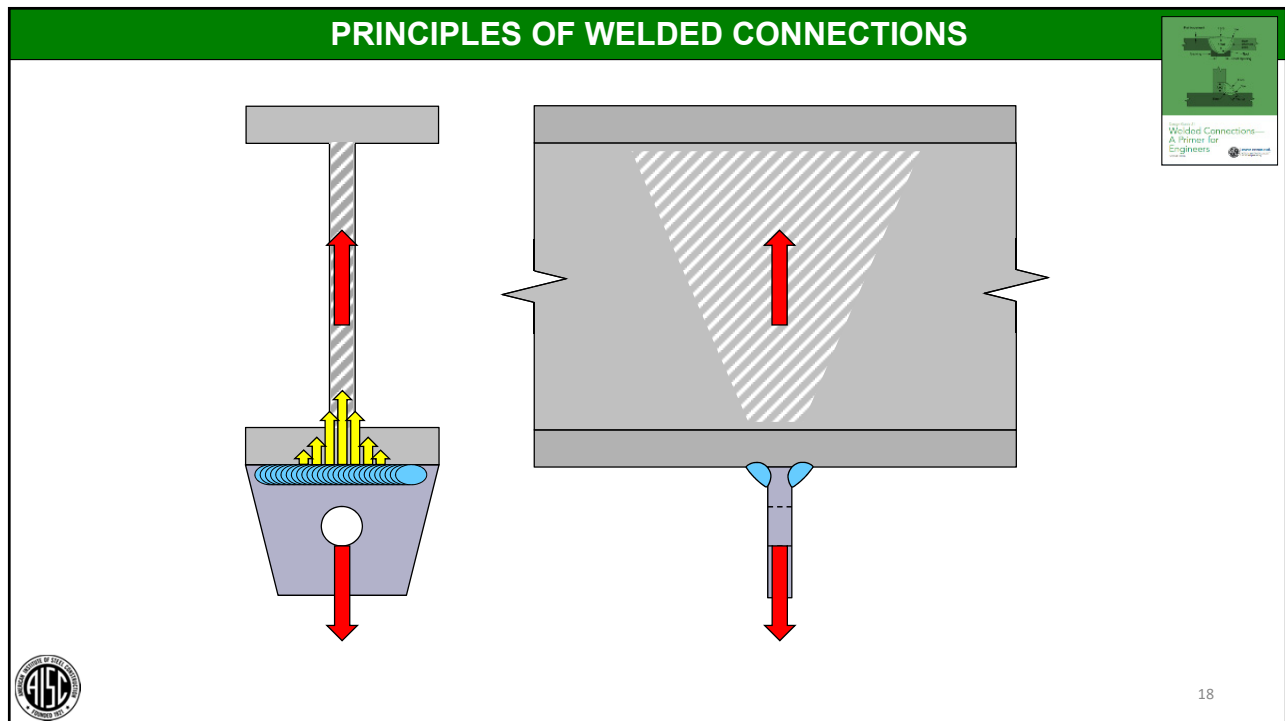
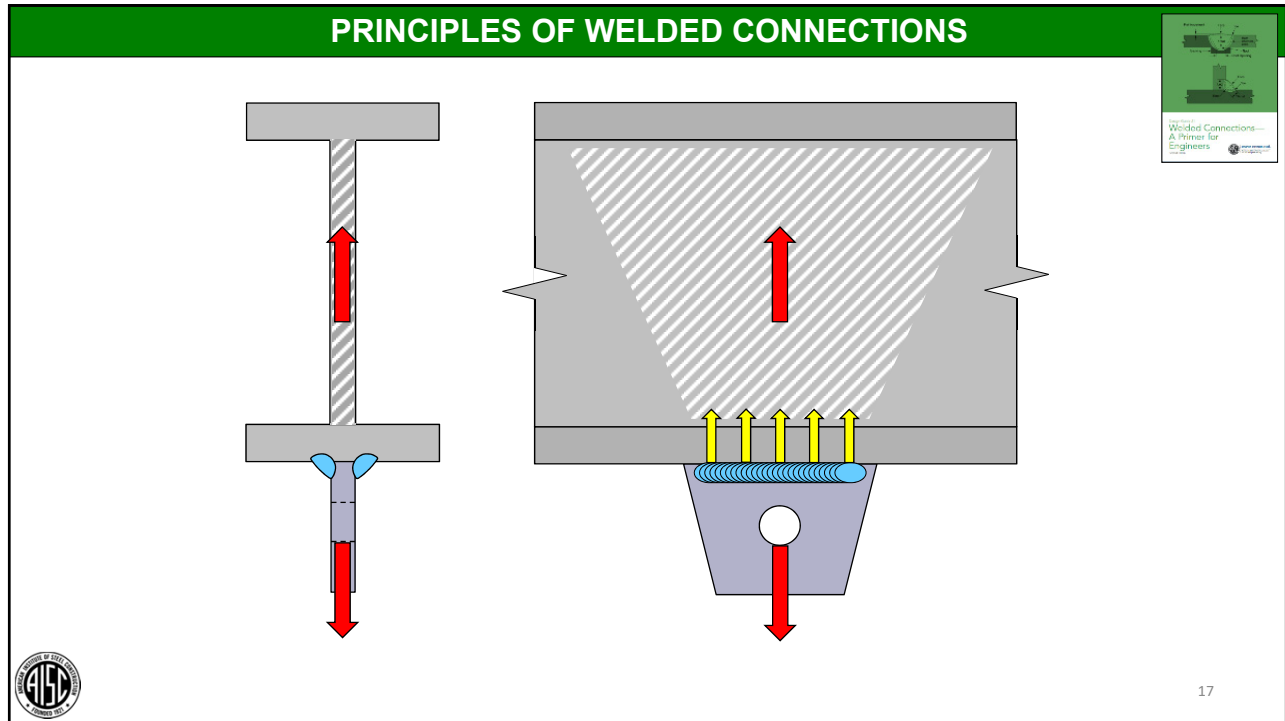
2

“The force goes to the stiff part.”

William “Bill” A. Milek



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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates a welded connection under two different loading conditions. On the left, a vertical member is shown in shear, with a green arrow pointing right and a red arrow pointing down. The welds are shown in blue, and the member is shaded brown. On the right, the same member is shown under tension, with a red arrow pointing down. The member is shaded grey, and the welds are shown in blue. A small inset in the top right corner shows a thumbnail of the presentation slide.

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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates a welded connection under two different loading conditions. On the left, a vertical member is shown under tension, with a red arrow pointing down. The member is shaded grey, and the welds are shown in blue. On the right, the same member is shown under shear, with a red arrow pointing up. The member is shaded grey, and the welds are shown in blue. A red prohibition sign is located in the bottom right corner. A small inset in the top right corner shows a thumbnail of the presentation slide.

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PRINCIPLES OF WELDED CONNECTIONS



The diagram illustrates a welded connection between a top flange and a bottom chord. On the left, a cross-sectional view shows a top flange with a central hole and two vertical stiffeners. A downward red arrow indicates tension, while two upward red arrows indicate shear. Yellow arrows show the shear flow path through the welds. On the right, a side view shows the top flange and chord with a central vertical weld. A downward red arrow indicates tension, and an upward red arrow indicates shear.



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PRINCIPLES OF WELDED CONNECTIONS


The diagram illustrates a welded connection between a top flange and a bottom chord. On the left, a cross-sectional view shows a top flange with a central hole and two vertical stiffeners. A downward red arrow indicates tension, while two upward red arrows indicate shear. Yellow arrows show the shear flow path through the welds. On the right, a side view shows the top flange and chord with a central vertical weld. A downward red arrow indicates tension, and an upward red arrow indicates shear.



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PRINCIPLES OF WELDED CONNECTIONS


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PRINCIPLES OF WELDED CONNECTIONS


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A Primer for
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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 illustrates two types of welded connections under tension. On the left, a vertical member is attached to a horizontal plate using a fillet weld. A red arrow points down from the member, and another red arrow points up from the weld. On the right, a circular member is attached to a trapezoidal base using a groove weld. A red arrow points down from the base, and two red arrows point up from the weld. Yellow arrows indicate the direction of the weld metal.

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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates two types of welded connections under tension. On the left, a vertical member is attached to a horizontal plate using a fillet weld. A red arrow points down from the member, and another red arrow points up from the weld. On the right, a circular member is attached to a trapezoidal base using a groove weld. A red arrow points down from the base, and two red arrows point up from the weld. Yellow arrows indicate the direction of the weld metal.


 

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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates a proper welded connection. On the left, a cross-section of a column base plate is shown with a shear plate welded to its bottom flange. Four vertical welds connect the shear plate to the column flange. A red arrow points upwards from the column, and another red arrow points downwards from the shear plate. On the right, a side view of a beam is shown welded to the shear plate with two vertical welds. Red arrows indicate tension in the beam, and a green arrow indicates the beam's shear force.

Welded Connections—
A Primer for
Engineers




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PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates an improper welded connection. On the left, a cross-section of a column base plate is shown with a shear plate welded to its bottom flange. Two diagonal welds connect the shear plate to the column flange. A red arrow points upwards from the column, and another red arrow points downwards from the shear plate. On the right, a side view of a beam is shown welded to the shear plate with two diagonal welds. Red arrows indicate tension in the beam, and a green arrow indicates the beam's shear force. A red prohibition sign is placed next to the beam welds.



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PRINCIPLES OF WELDED CONNECTIONS



The diagram illustrates a proper welded connection. On the left, a cross-section shows a top plate with a hatched triangular area representing the weld metal. A red arrow points upwards from the center of this area, and another red arrow points downwards from the bottom of the plate. On the right, a perspective view shows a top plate being pulled upwards by a green arrow. The bottom plate is pulled downwards by a red arrow. The weld is shown as a blue wavy line. Yellow arrows point upwards from the weld, and red arrows point upwards from the top plate's vertical edges, indicating that the weld and the top plate are effectively acting as a single unit.



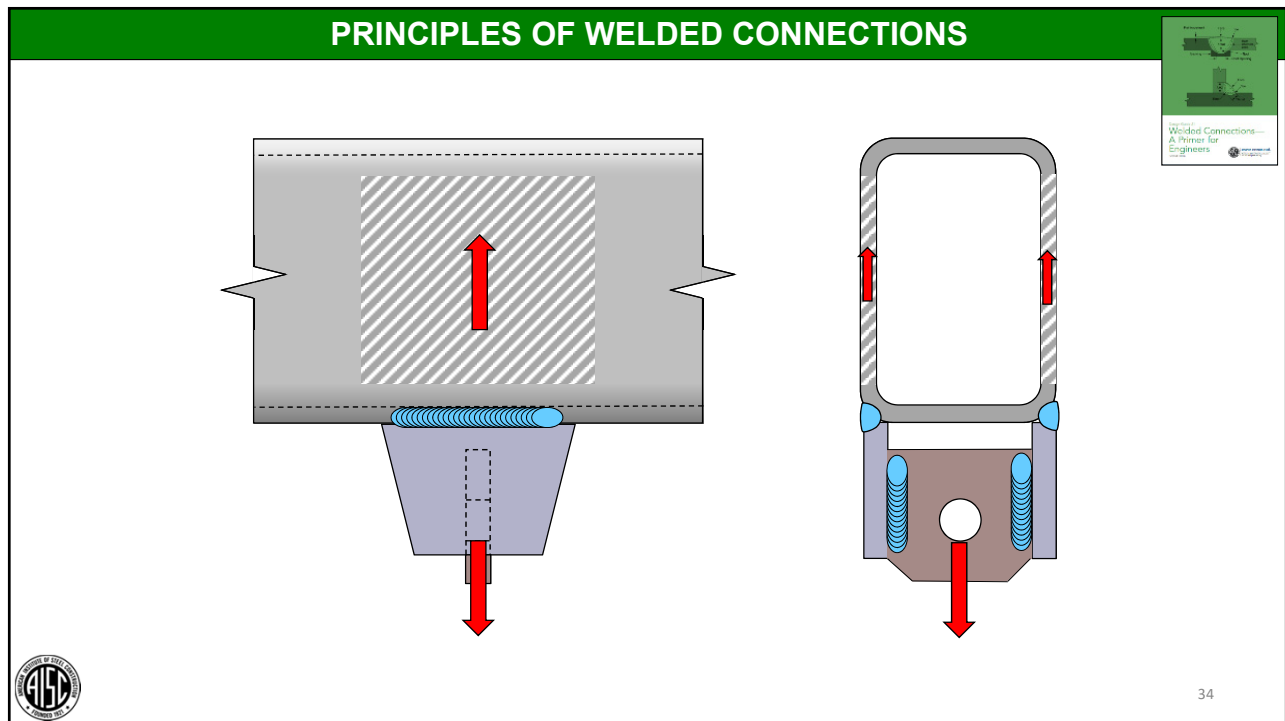
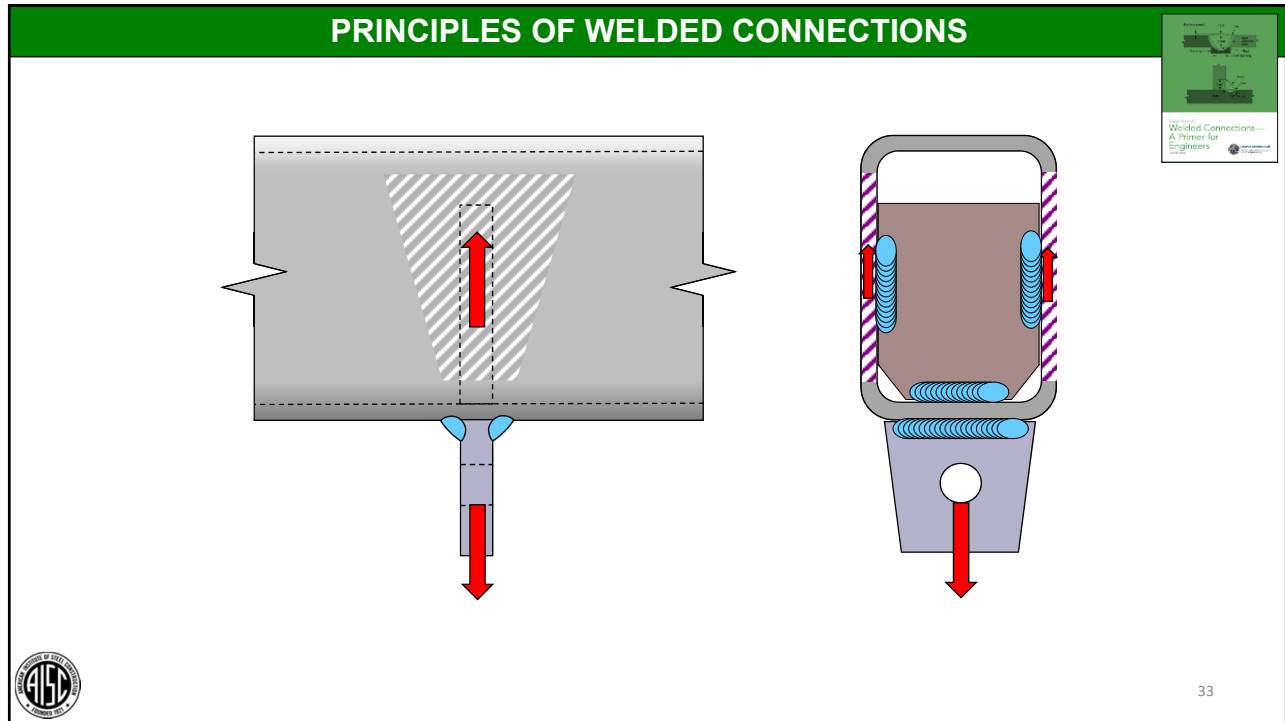
31

PRINCIPLES OF WELDED CONNECTIONS

The diagram illustrates an improper welded connection. On the left, a cross-section shows a top plate with a hatched triangular area representing the weld metal. A red arrow points upwards from the center of this area, and another red arrow points downwards from the bottom of the plate. On the right, a perspective view shows a top plate being pulled upwards by a green arrow. The bottom plate is pulled downwards by a red arrow. The weld is shown as a blue wavy line. A purple arrow points to the top plate's vertical edge, and another purple arrow points to the weld. A red circle with a diagonal slash (a prohibition sign) is placed next to the bottom plate, indicating that the force is not being transferred through the weld but through the top plate.



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PRINCIPLES OF WELDED CONNECTIONS

The left diagram shows a cross-section of a beam-to-column connection. A vertical beam is attached to a horizontal column. A shear plate is positioned between the beam and the column, with welds on both sides. A red arrow points upwards from the beam, and another red arrow points downwards from the column. The right diagram shows a similar connection but with a different weld configuration, possibly a moment-resisting connection. A red arrow points downwards from the column. In the top right corner, there is a small thumbnail of the presentation slide with the title 'Welded Connections – A Primer for Engineers' and the AISC logo. In the bottom left corner, there is the AISC logo. In the bottom right corner, the number '35' is displayed.









PRINCIPLES OF WELDED CONNECTIONS

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


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.



2

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PRINCIPLES OF WELDED CONNECTIONS



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


3


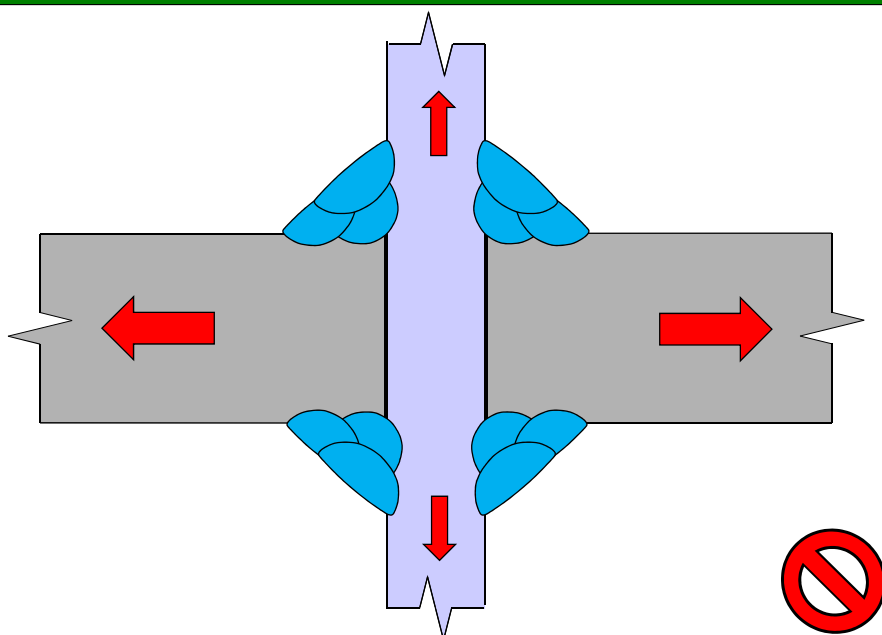
Corollary:
When possible, pass major loads through steel, not through welds



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PRINCIPLES OF WELDED CONNECTIONS






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PRINCIPLES OF WELDED CONNECTIONS


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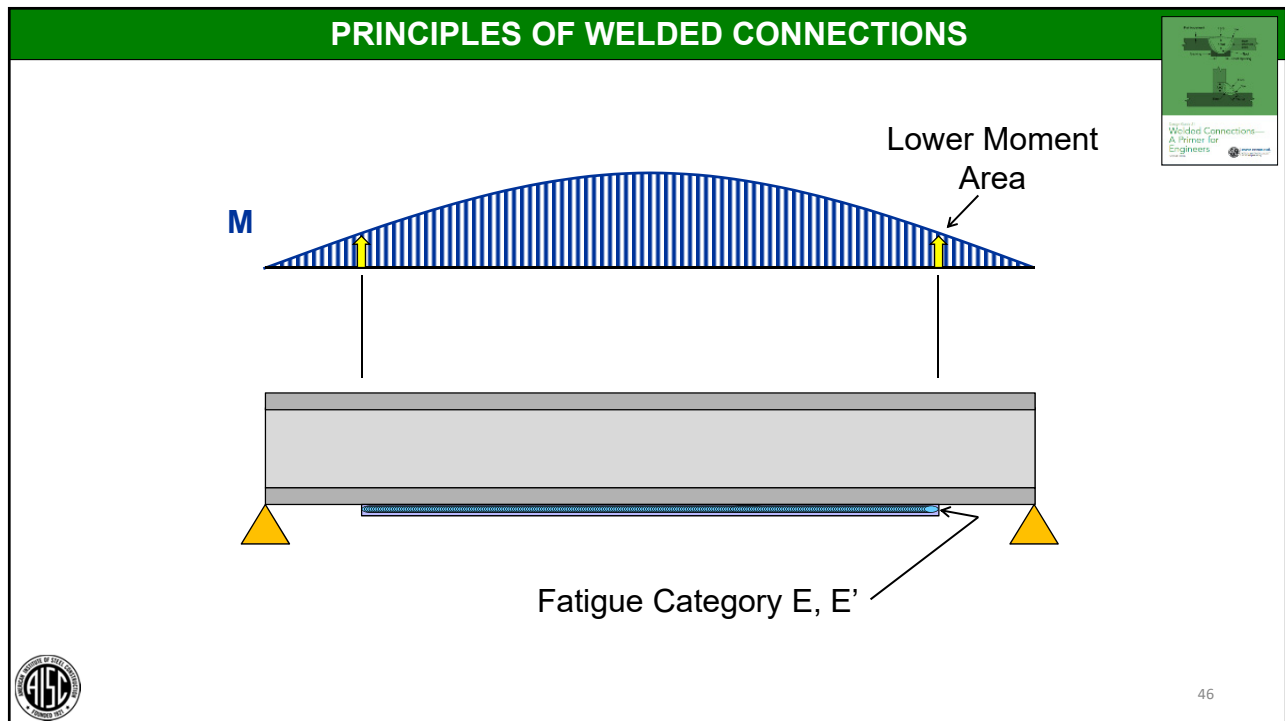
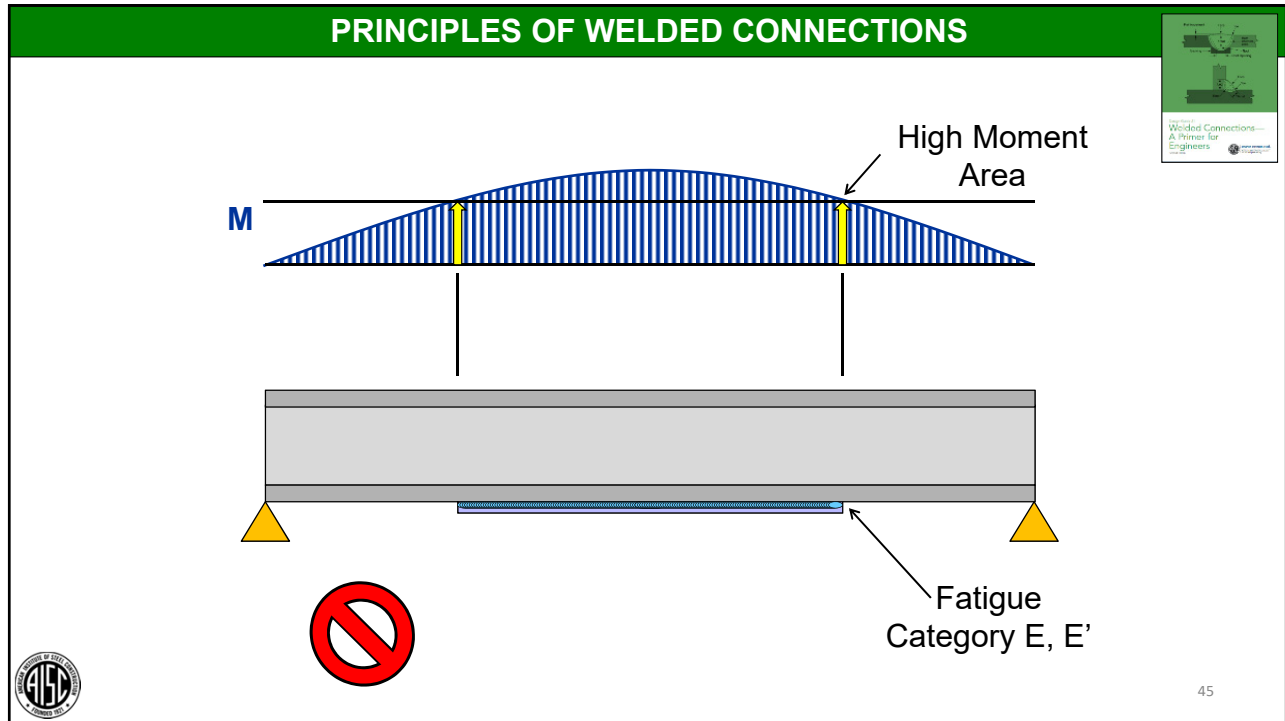
43

PRINCIPLES OF WELDED CONNECTIONS

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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

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

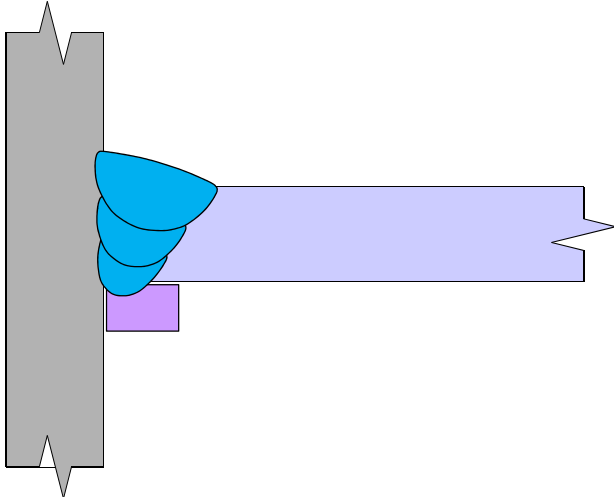
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REMINDER:
Stress raisers are only stress raiser if there is a tensile stress component perpendicular to the stress raiser.



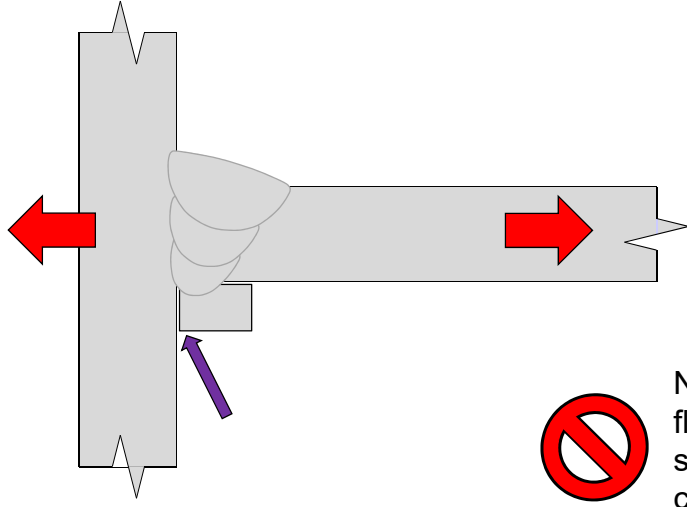
48

PRINCIPLES OF WELDED CONNECTIONS



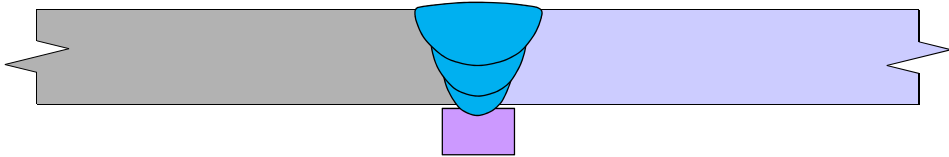
The diagram illustrates a welded connection between a vertical column and a horizontal beam. The column is shown in grey with a jagged top and bottom edge. The beam is shown in light blue. A top flange connection is shown with three blue curved welds. A purple rectangular gusset plate is attached to the bottom flange of the beam. In the top right corner, there is a small thumbnail image of the book cover and the text "Welded Connections—A Primer for Engineers". In the bottom left corner is the AISC logo. In the bottom right corner is the number "49".

PRINCIPLES OF WELDED CONNECTIONS





The diagram illustrates a welded connection between a vertical column and a horizontal beam, similar to the one above. The column and beam are shown in grey. A top flange connection is shown with three grey curved welds. A purple rectangular gusset plate is attached to the bottom flange of the beam. Red arrows point left from the column and right from the beam, indicating seismic moment. A red prohibition sign (a red circle with a diagonal line) is placed over the gusset plate. To the right of the sign, the text reads "Not for bottom flange of high seismic moment connections". In the top right corner, there is a small thumbnail image of the book cover and the text "Welded Connections—A Primer for Engineers". In the bottom left corner is the AISC logo. In the bottom right corner is the number "50".

PRINCIPLES OF WELDED CONNECTIONS

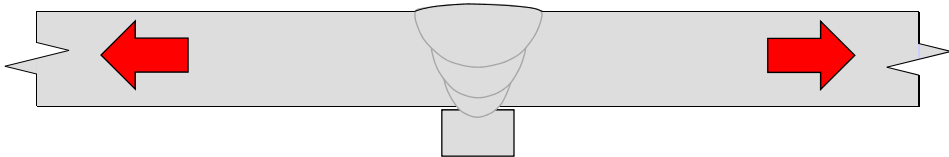


The diagram shows a horizontal beam with a central section highlighted in light blue. This section is connected to a vertical column below it. The beam is shown in two colors: grey on the left and light blue on the right. A purple rectangular block is positioned directly below the beam's center, representing the column. The connection is a full-penetration butt weld, with the weld metal shown in a darker blue. The beam ends are jagged, indicating it is part of a larger structure.

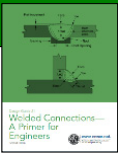



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PRINCIPLES OF WELDED CONNECTIONS

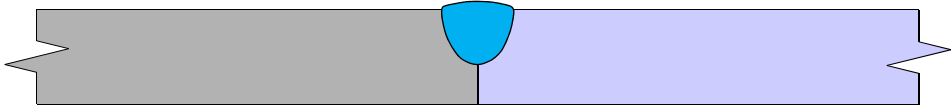


The diagram shows a horizontal beam with a central section highlighted in light grey. This section is connected to a vertical column below it. The beam is shown in two colors: light grey on the left and light blue on the right. A grey rectangular block is positioned directly below the beam's center, representing the column. The connection is a full-penetration butt weld, with the weld metal shown in a darker grey. Two red arrows point outwards from the center of the beam, indicating shear forces. The beam ends are jagged, indicating it is part of a larger structure.





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PRINCIPLES OF WELDED CONNECTIONS

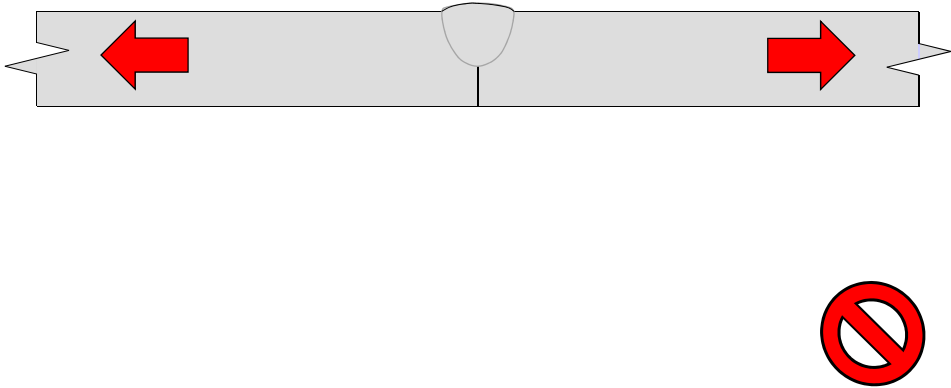


The diagram shows two horizontal steel plates, one gray on the left and one light blue on the right, joined at their ends. A blue semi-circular weld bead is shown at the center of the joint, representing a proper butt joint weld.

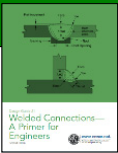



53

PRINCIPLES OF WELDED CONNECTIONS

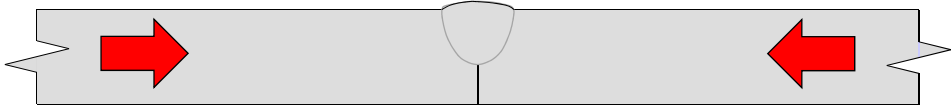


The diagram shows two horizontal steel plates, both gray, joined at their ends. Two red arrows point outwards from the joint, indicating tension. A red prohibition sign (a circle with a diagonal slash) is located in the bottom right corner, indicating that this configuration is incorrect or prohibited.





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PRINCIPLES OF WELDED CONNECTIONS

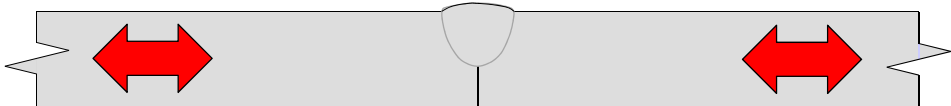


The diagram shows a horizontal steel beam with a central weld. Two red arrows point towards each other from the ends of the beam, indicating shear force. The weld is shown as a semi-circular shape on the top surface of the beam.





55

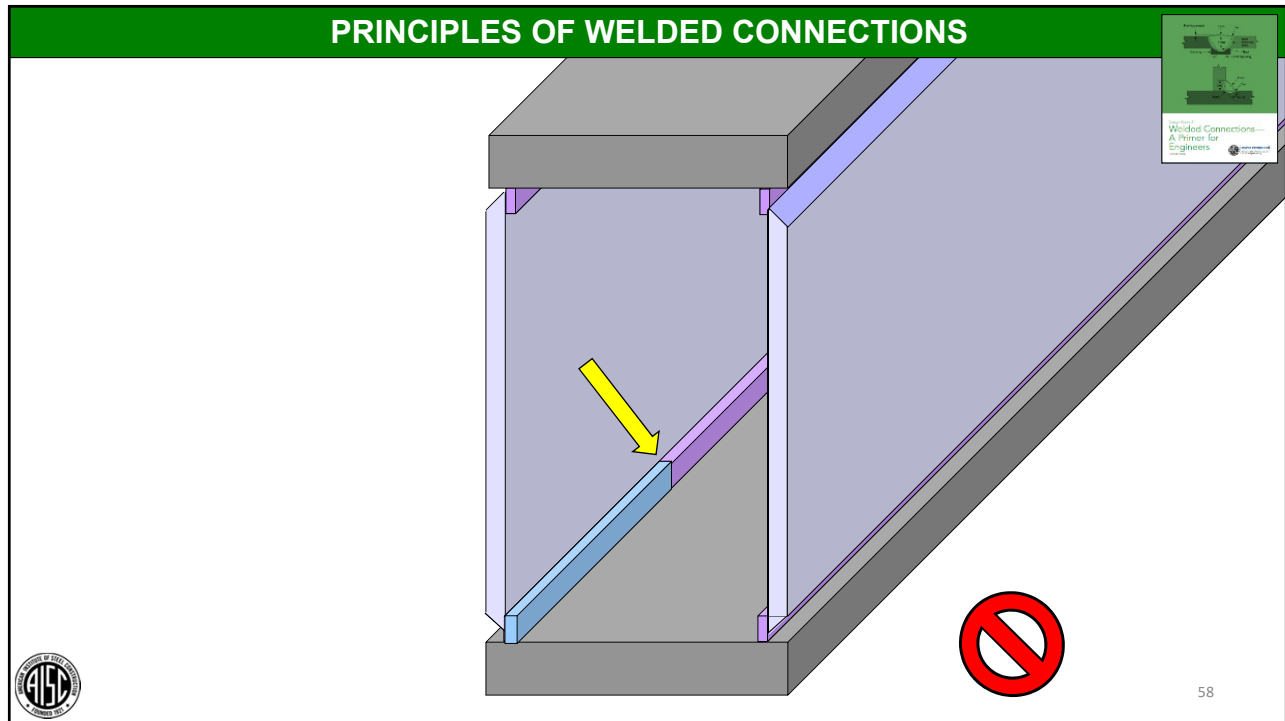
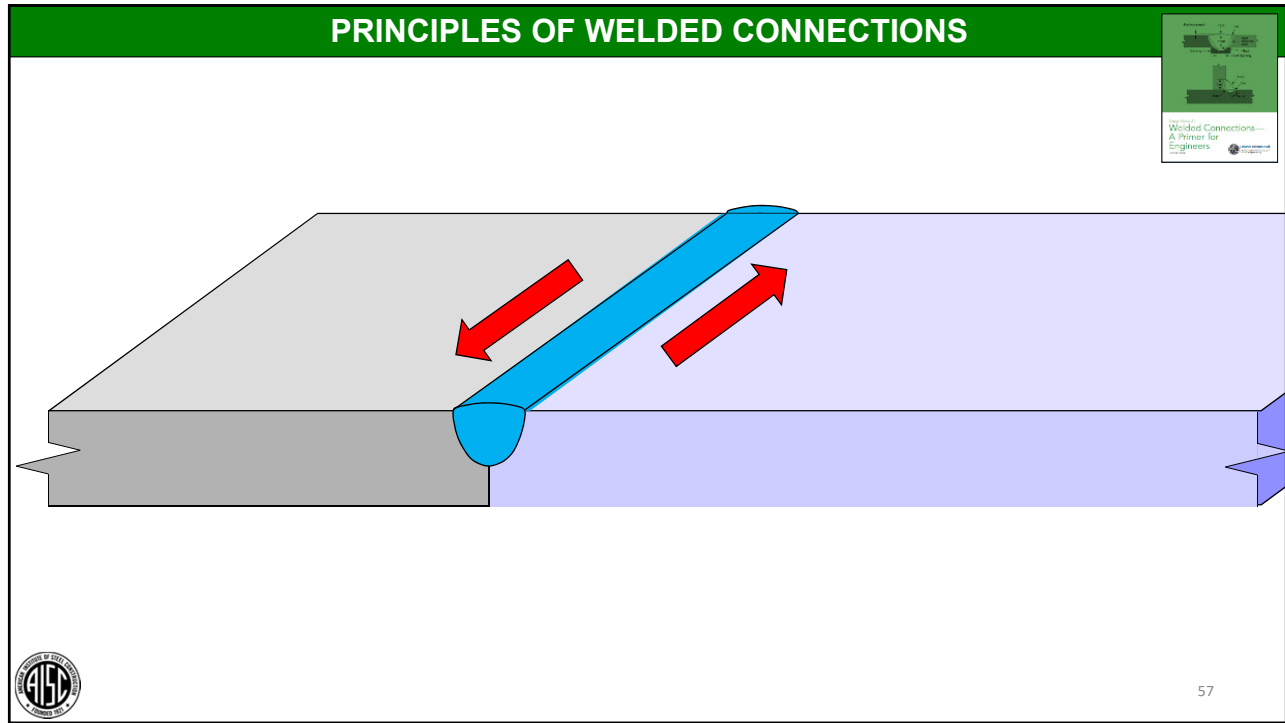
PRINCIPLES OF WELDED CONNECTIONS

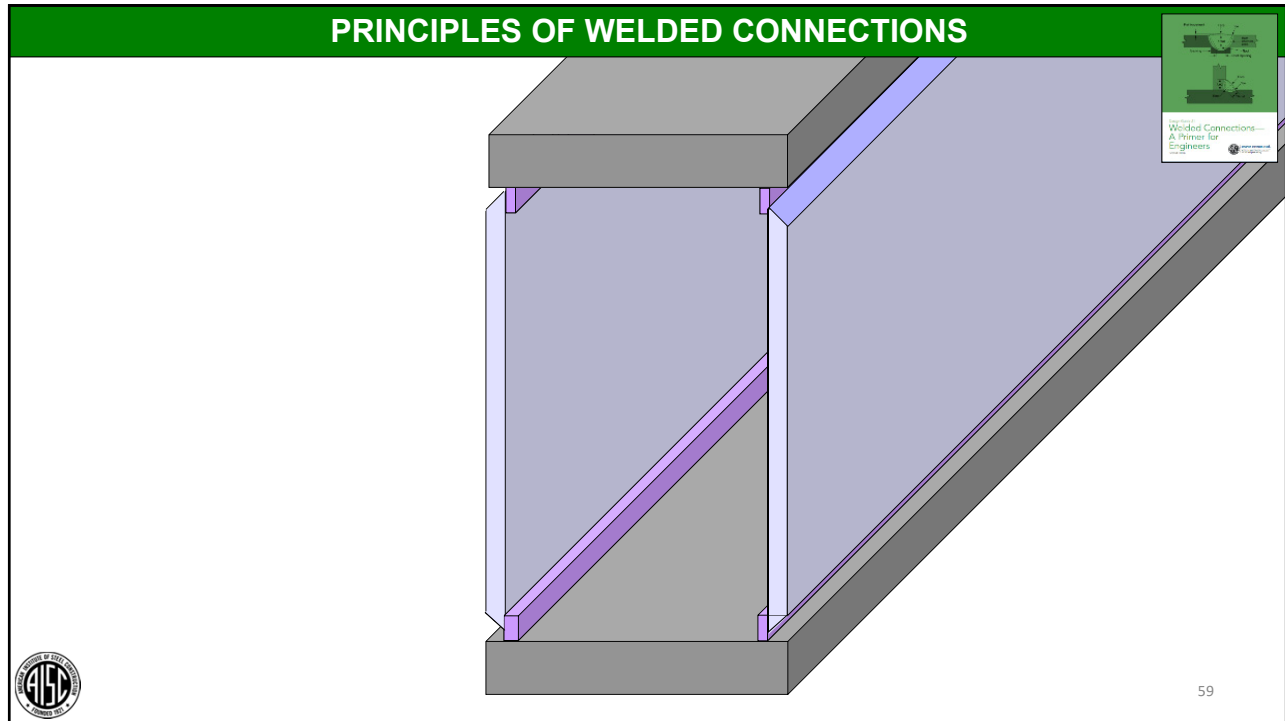


The diagram shows a horizontal steel beam with a central weld. Two red double-headed arrows are positioned on the beam, one on each side of the weld, indicating tension force. The weld is shown as a semi-circular shape on the top surface of the beam.



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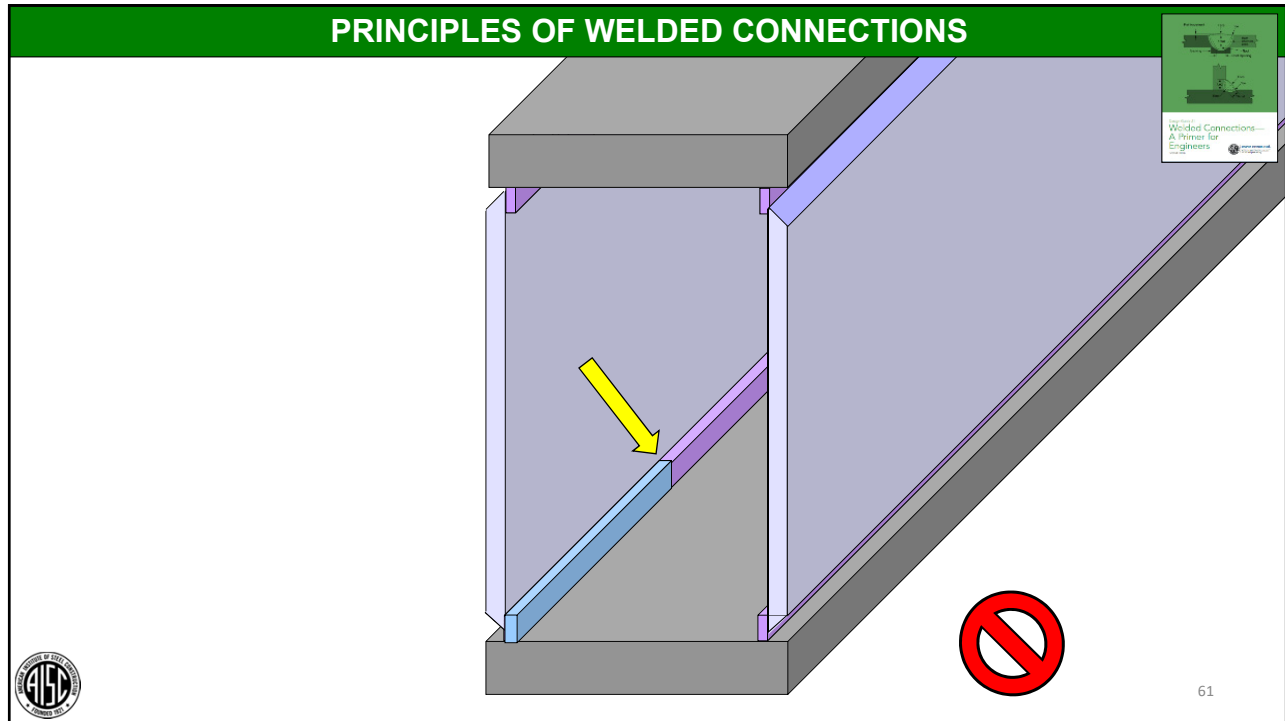


AWS D1.1: 2015 Structural Welding Code – Steel

9.23.1 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: 2015 Structural Welding Code – Steel

9.23.1 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.



The AISC logo is in the bottom left. The number 62 is in the bottom right.

AWS D1.1: 2015 Structural Welding Code – Steel



9.23.1 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.**

4





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PRINCIPLES OF WELDED CONNECTIONS

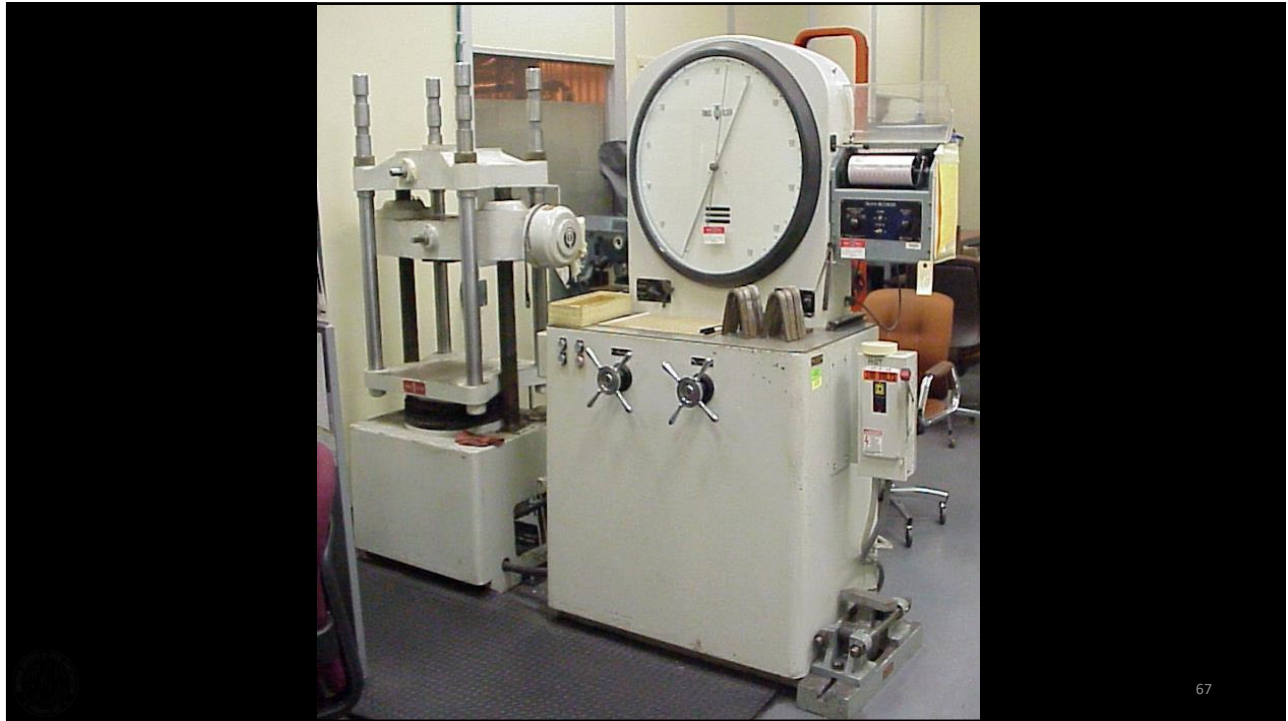
**A correct and proper welded connection
is not constrained.**

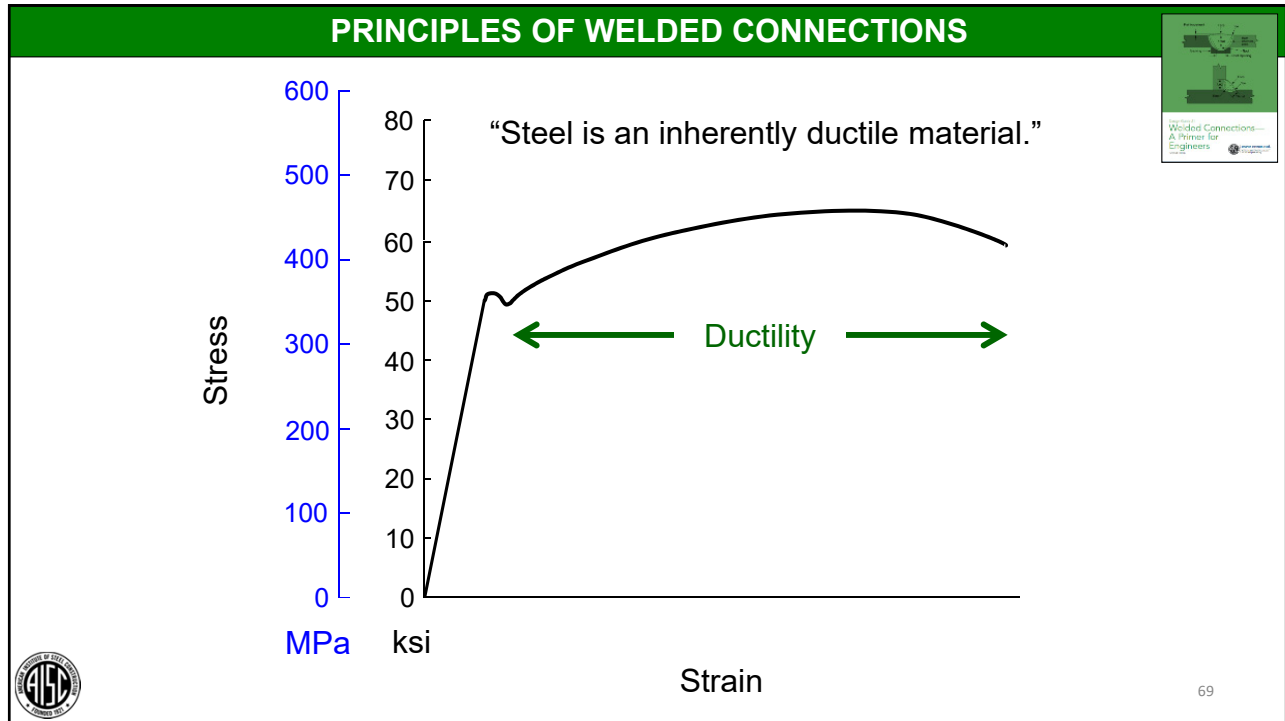
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Earthquake Protection

Andrew Coburn
Robin Spence

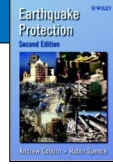
2002

The book cover features a blue background with the title 'Earthquake Protection' in large white letters, 'Second Edition' below it, and the Wiley logo in the top right. The central image shows a city in ruins after an earthquake, with workers in blue and yellow safety gear amidst the debris. The authors' names, Andrew Coburn and Robin Spence, are listed at the bottom of the cover.

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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.



Safe Rooms and Shelters

Protecting People Against
Terrorist Attacks

FEMA 453
May 2006



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 are

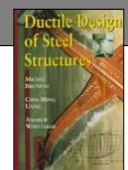
Steel in an inherently ductile material that is capable of sustaining large deformations; however, the every efficient thin-flanged sections make the conventional frame construction vulnerable to localized damage.

detailed to tie into the concrete slabs.



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Ductile Design of Steel Structures



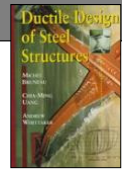
Preface

“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

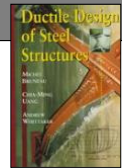
“However, there are many situations in which an explicit approach to the design of ductile steel structures is necessary because the inherent material ductility alone is not sufficient to provide the desired ultimate performance.”

•



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Ductile Design of Steel Structures



Chapter 1 Introduction

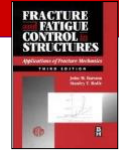
“To achieve this ductile response, one must recognize and avoid conditions that may lead to brittle failures and adopt appropriate design strategies to allow for stable and reliable hysteretic energy-dissipation mechanisms. This sort of thinking is relatively new in structural engineering.”

• •



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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.

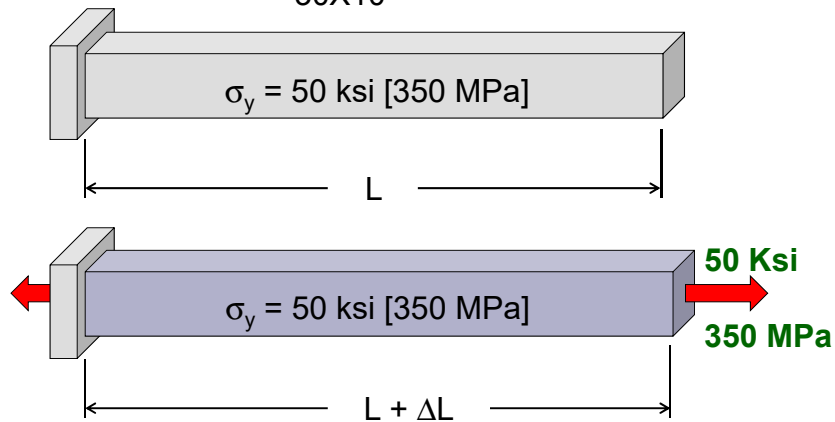


PRINCIPLES OF WELDED CONNECTIONS



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

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



PRINCIPLES OF WELDED CONNECTIONS

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

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

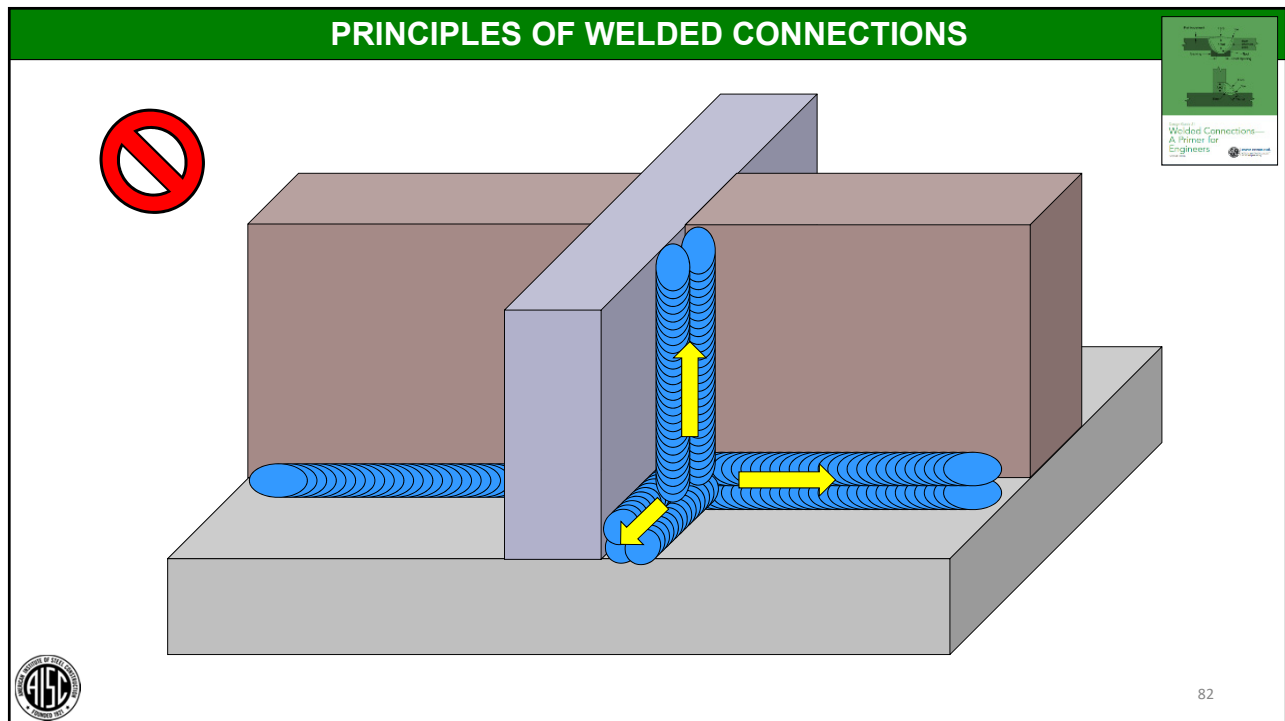
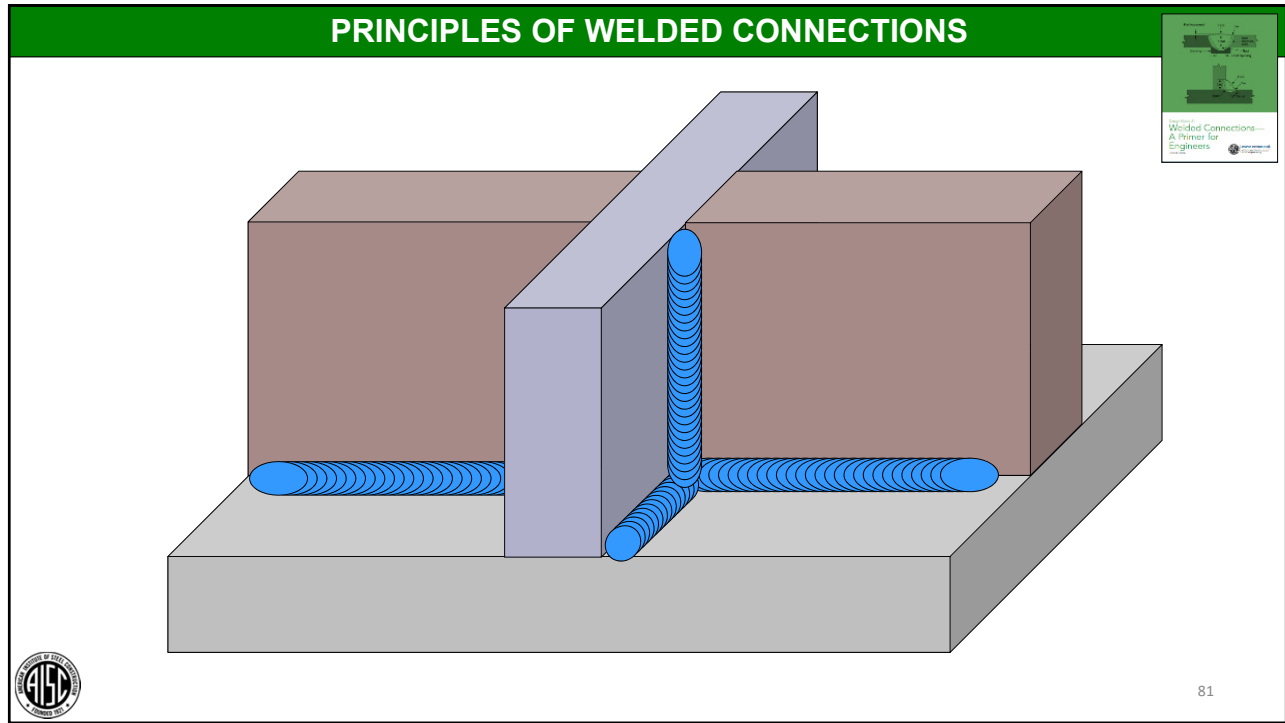
$$= 0.18 \text{ in [18 \%]}$$

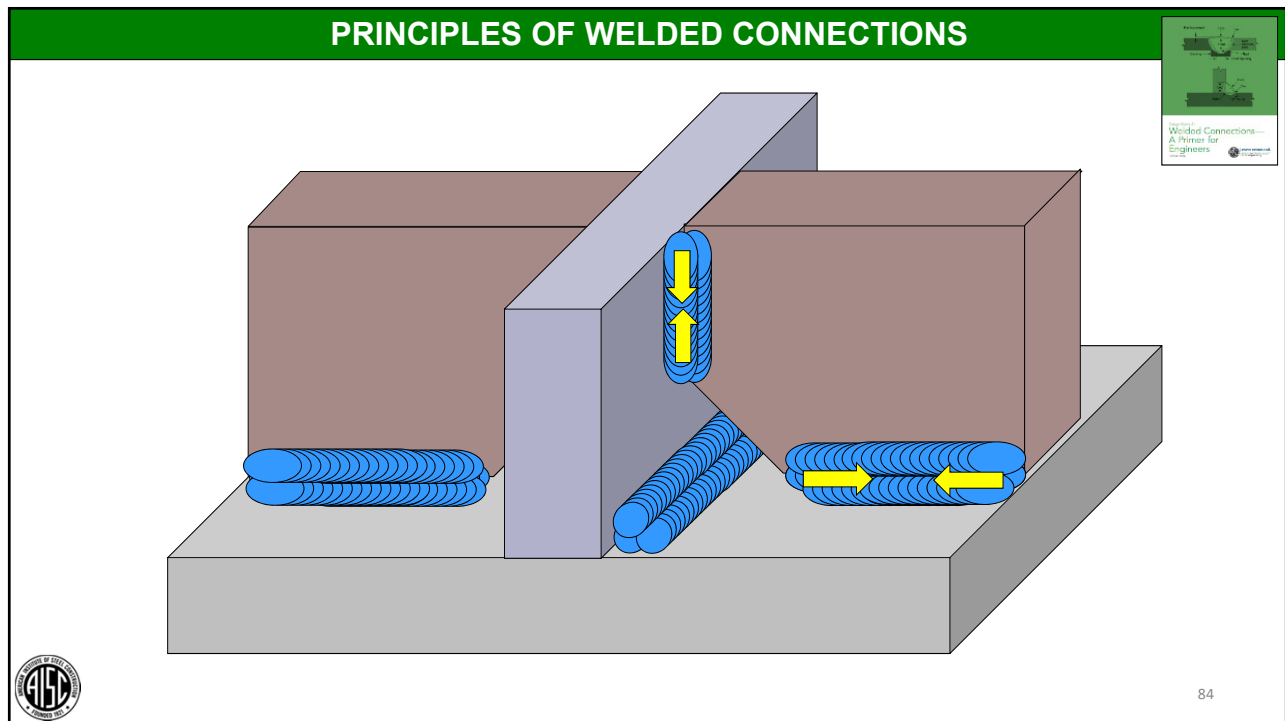
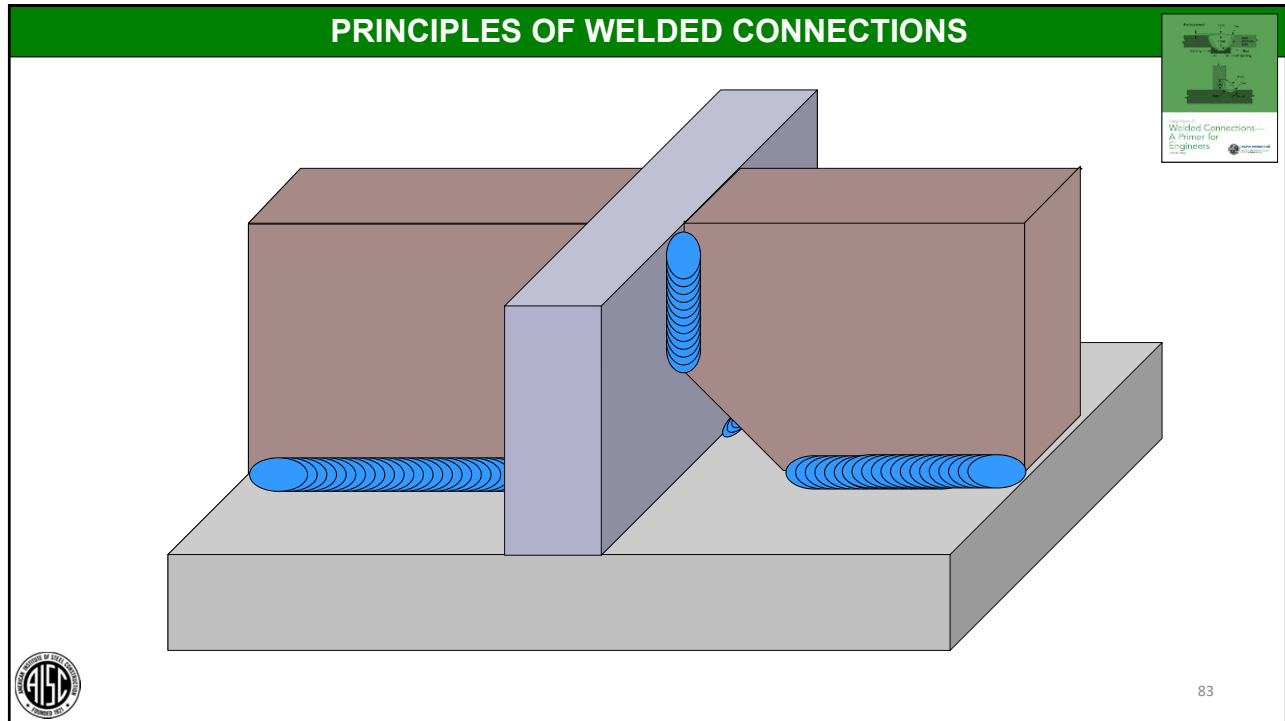
79

PRINCIPLES OF WELDED CONNECTIONS

Thermal expansion is approximately 10X yield elongation.

80







PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection is not constrained.

5





85

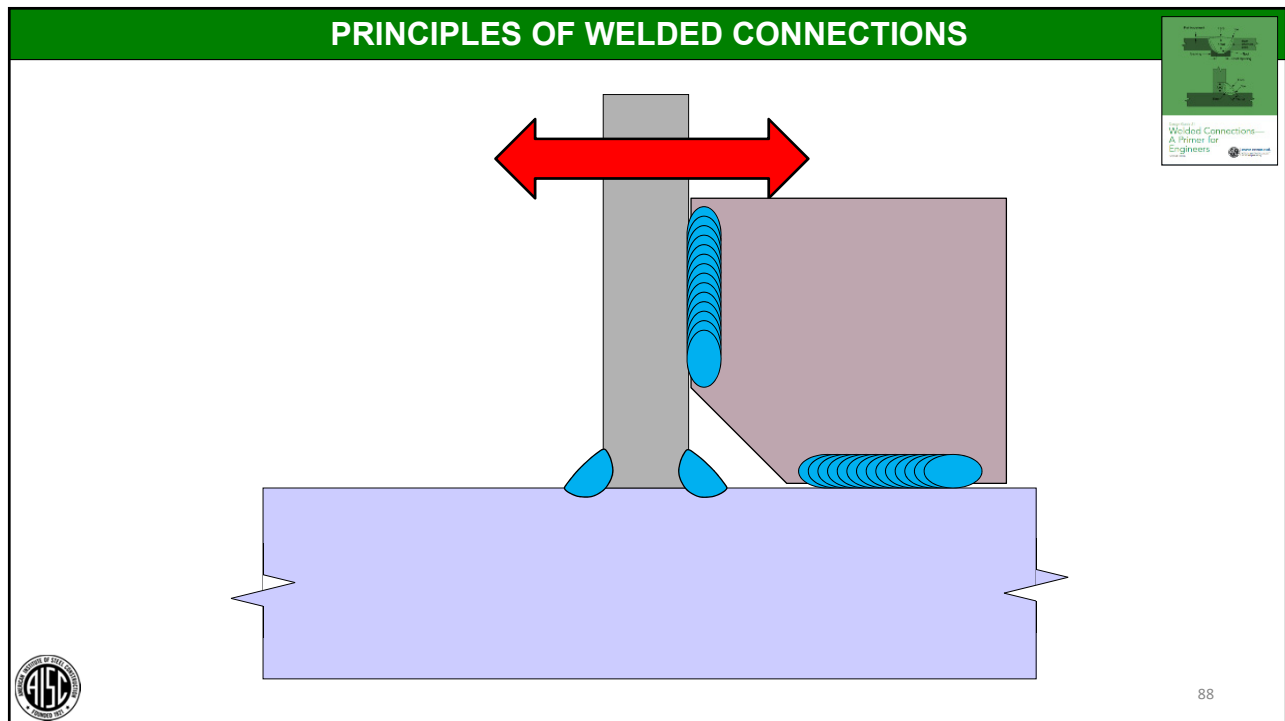
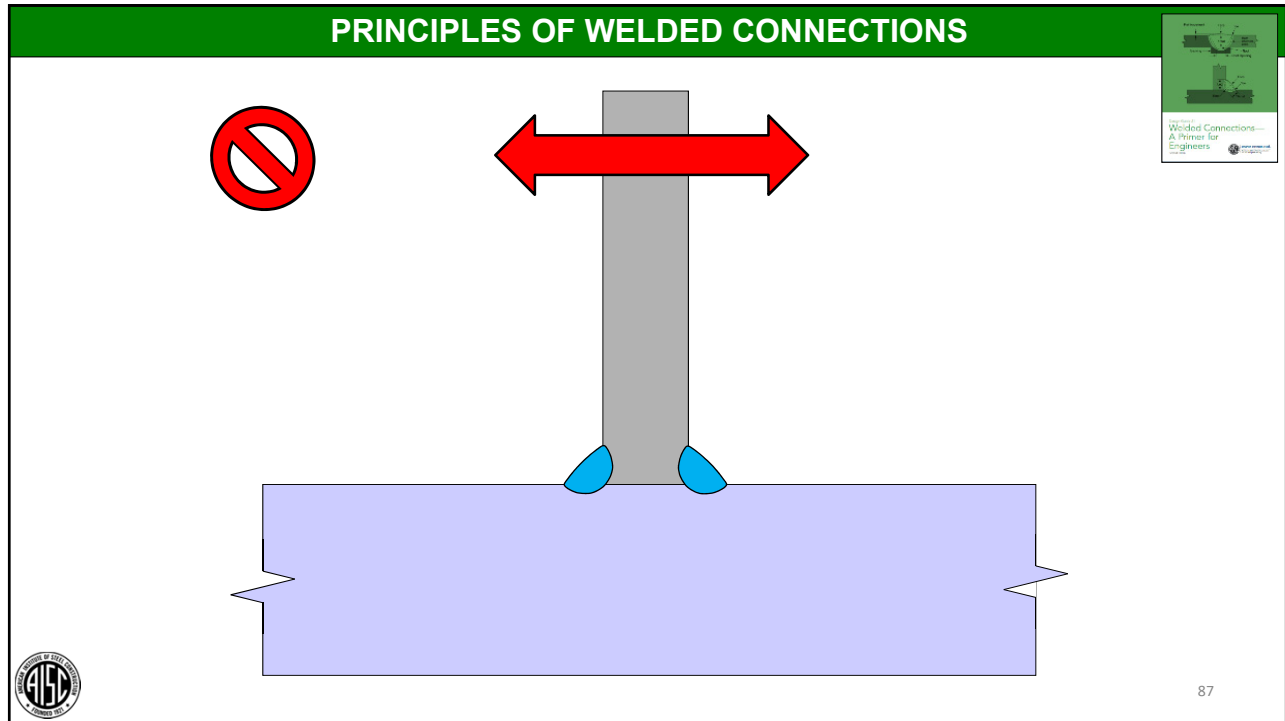
PRINCIPLES OF WELDED CONNECTIONS

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

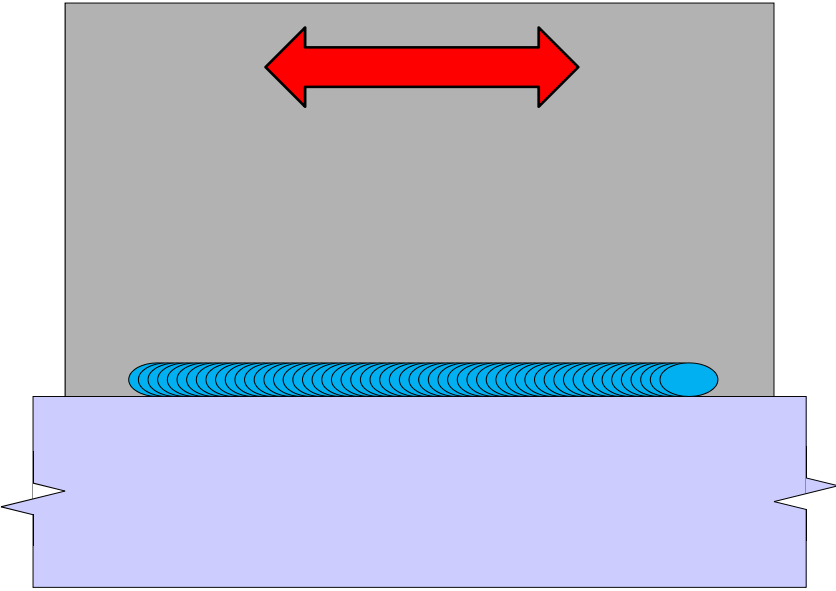
6





86



PRINCIPLES OF WELDED CONNECTIONS



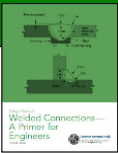

The diagram illustrates a welded connection between a grey upper plate and a purple lower base plate. A blue weld line is shown at the interface. A red double-headed arrow is positioned above the weld, indicating that the connection is subjected to bending about the root of the weld. The base plate has jagged ends, suggesting it is part of a larger assembly.



89

PRINCIPLES OF WELDED CONNECTIONS

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





90

PRINCIPLES OF WELDED CONNECTIONS

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



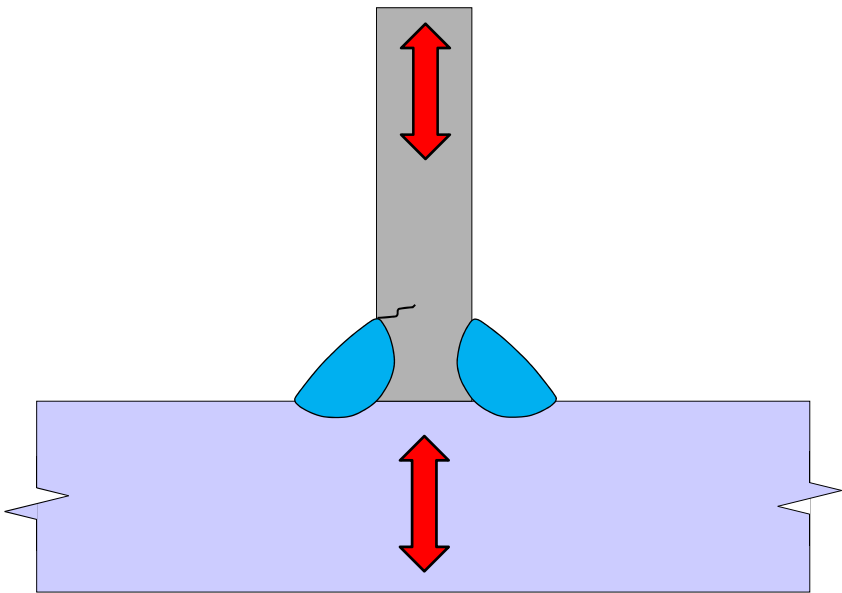
7

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

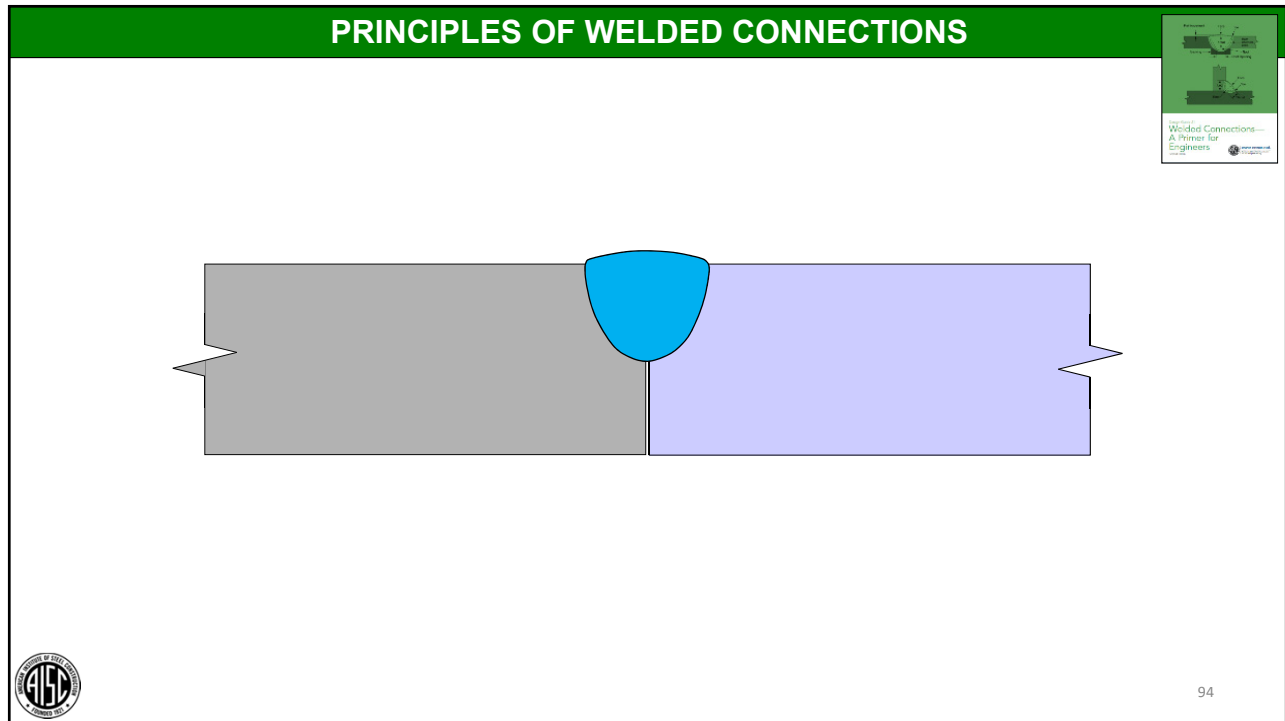
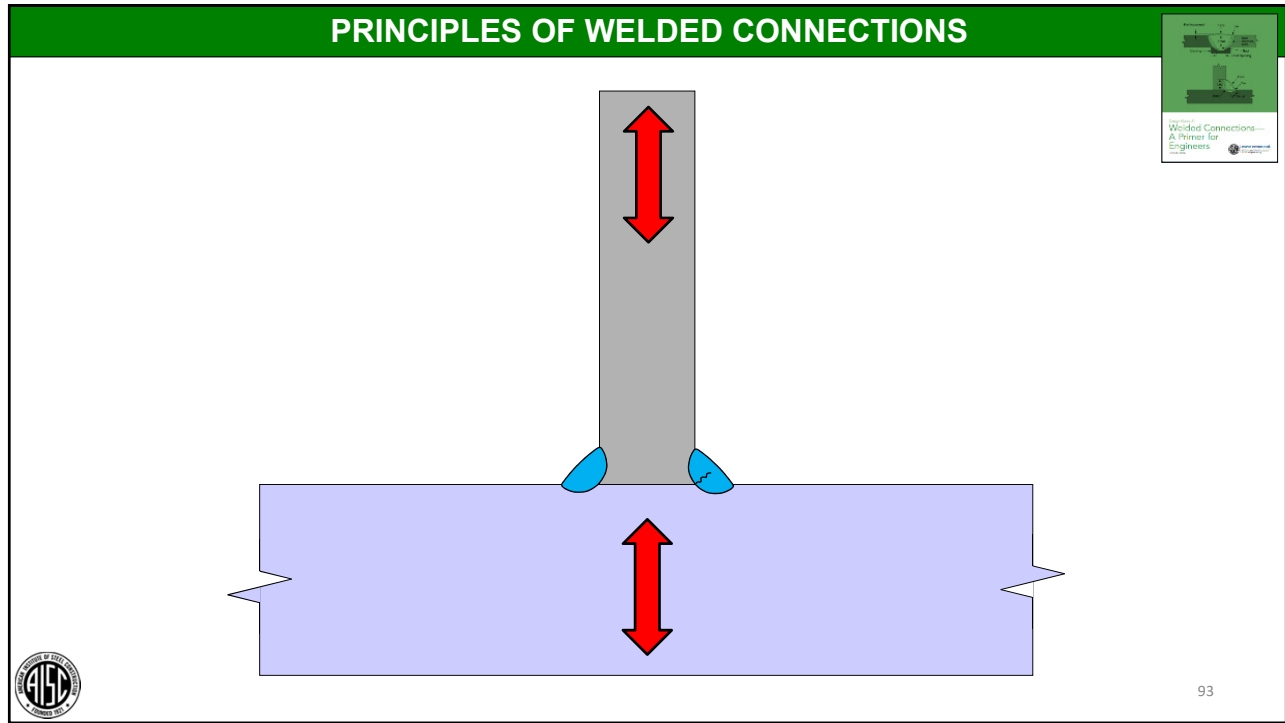


91

PRINCIPLES OF WELDED CONNECTIONS





92



PRINCIPLES OF WELDED CONNECTIONS

The diagram shows a horizontal butt joint between two steel plates. A single V-groove weld is shown in the center. Two red arrows point outwards from the joint, indicating tension. A red prohibition sign (a circle with a diagonal slash) is located in the bottom right corner of the slide.



Welded Connections—
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PRINCIPLES OF WELDED CONNECTIONS

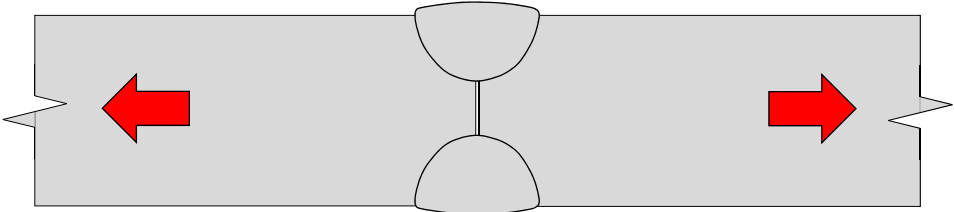
The diagram shows a horizontal butt joint between two steel plates. The left plate is grey and the right plate is light blue. A double V-groove weld is shown in the center, with two blue semi-circular weld profiles. The plates have jagged ends on the left and right sides.


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PRINCIPLES OF WELDED CONNECTIONS



The diagram shows a horizontal rectangular steel plate with a central vertical weld joint. Two red arrows point outwards from the center, indicating tension forces. The weld joint is depicted with two semi-circular weld profiles meeting at a central vertical line. The plate has jagged ends on both sides, suggesting it is part of a larger structure.

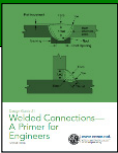



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PRINCIPLES OF WELDED CONNECTIONS


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

7



98


PRINCIPLES OF WELDED CONNECTIONS



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


8

“A nothin’ weld ain’t worth nothin’ ”




99

PRINCIPLES OF WELDED CONNECTIONS



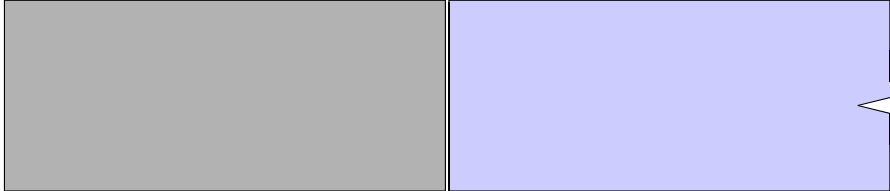
nothin’ weld:
A weld that looks like what you wanted, but it ain’t.




100

PRINCIPLES OF WELDED CONNECTIONS


CJP



The diagram shows two rectangular plates, one gray on the left and one light blue on the right, joined at their center. A vertical line with a break symbol at the top and bottom indicates the joint. An arrow labeled 'CJP' points to this joint line.

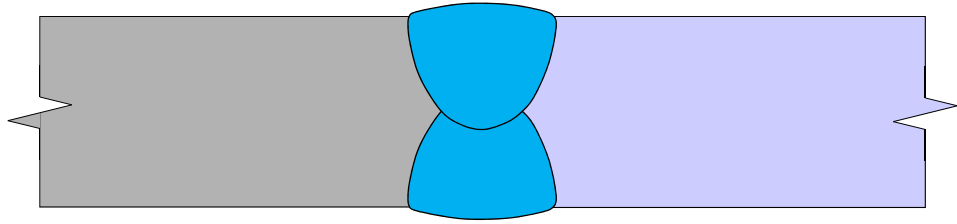


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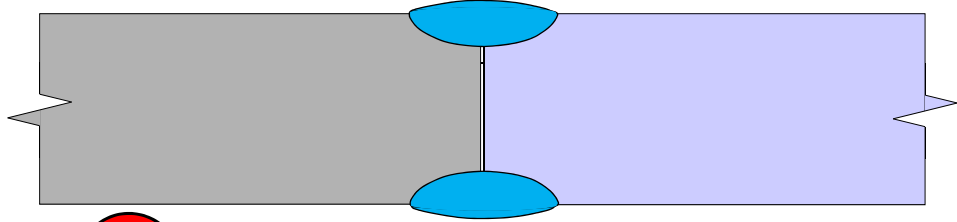


101


PRINCIPLES OF WELDED CONNECTIONS




The diagram shows two rectangular plates, one gray on the left and one light blue on the right, joined at their center. The joint is a double V-groove weld, with blue weld metal filling the V-shaped gaps on both the top and bottom surfaces.




The diagram shows two rectangular plates, one gray on the left and one light blue on the right, joined at their center. There is a visible gap between the plates at the joint, and the weld metal is shown as two separate blue shapes on the top and bottom surfaces, not connecting the plates.



nothin' weld:

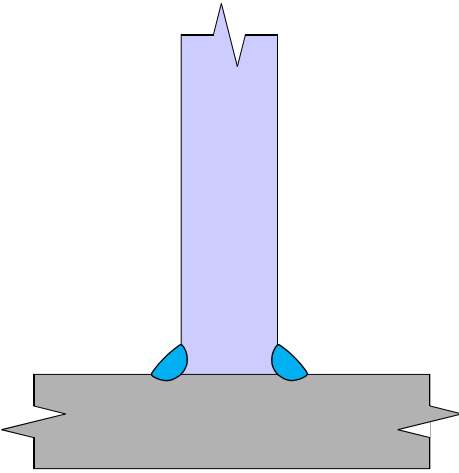


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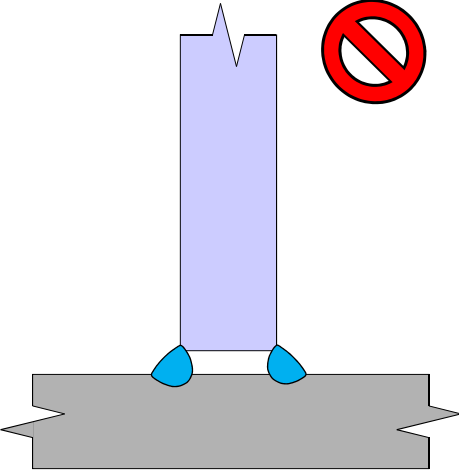


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PRINCIPLES OF WELDED CONNECTIONS




A vertical purple steel member is shown welded to a horizontal grey base plate. The welds are represented by blue teardrop shapes. The throat of the connection is clearly defined and sharp.



A vertical purple steel member is shown welded to a horizontal grey base plate. There is a visible gap between the member and the base plate. A red circle with a diagonal slash is placed to the right of the member. Below the diagram, the text "nothin' weld:" is written in green.




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PRINCIPLES OF WELDED CONNECTIONS


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



8



Welded Connections—
A Primer for
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PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection recognizes material properties.


9

“Respect material properties.”



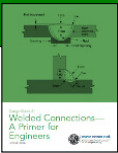

105

PRINCIPLES OF WELDED CONNECTIONS

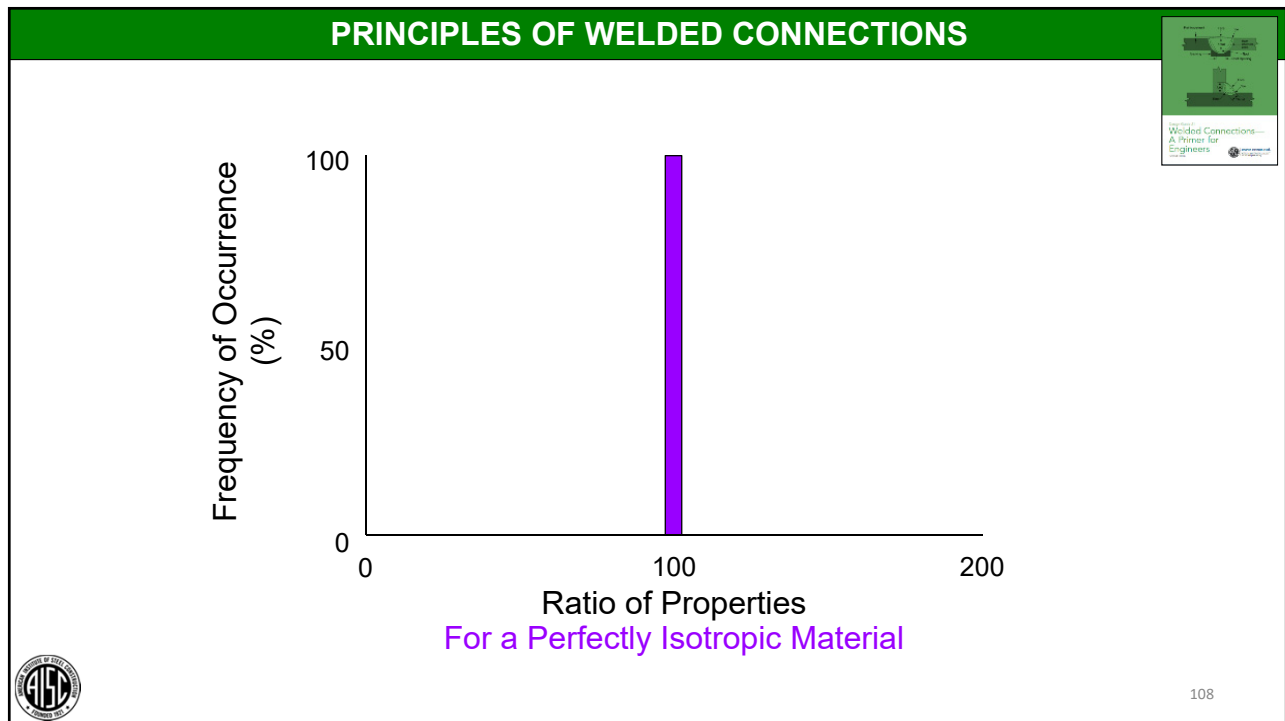
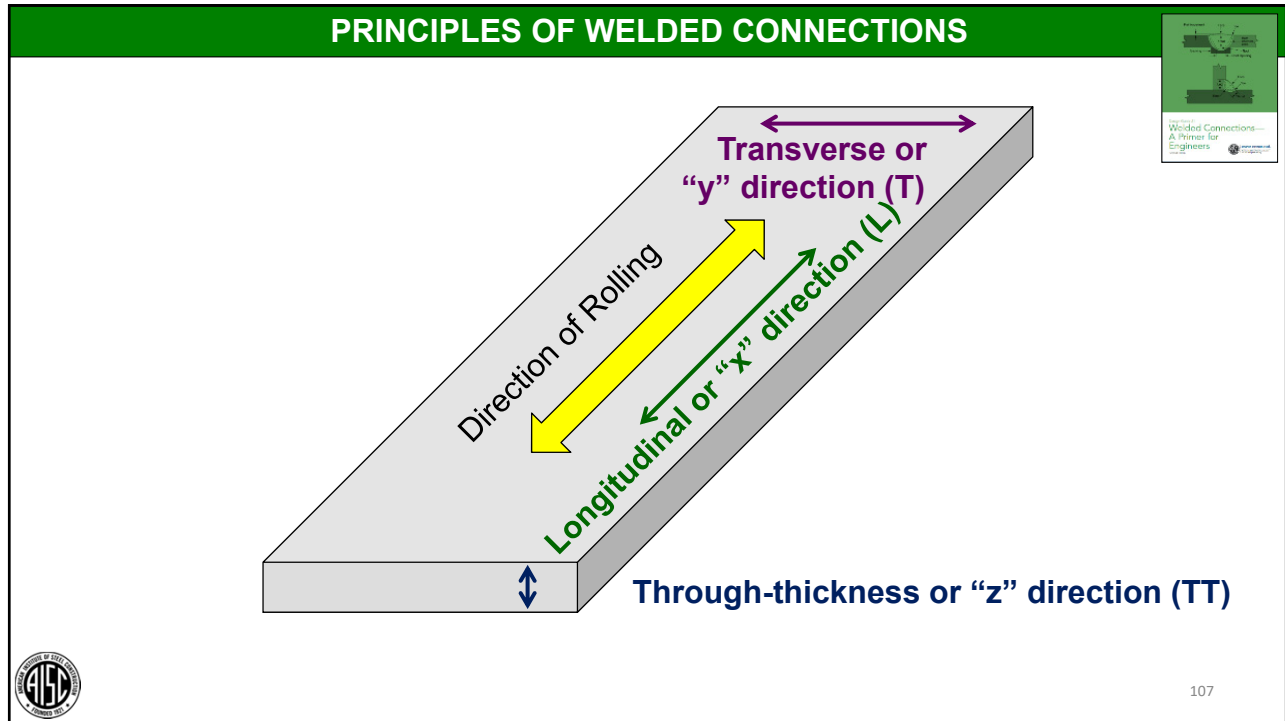


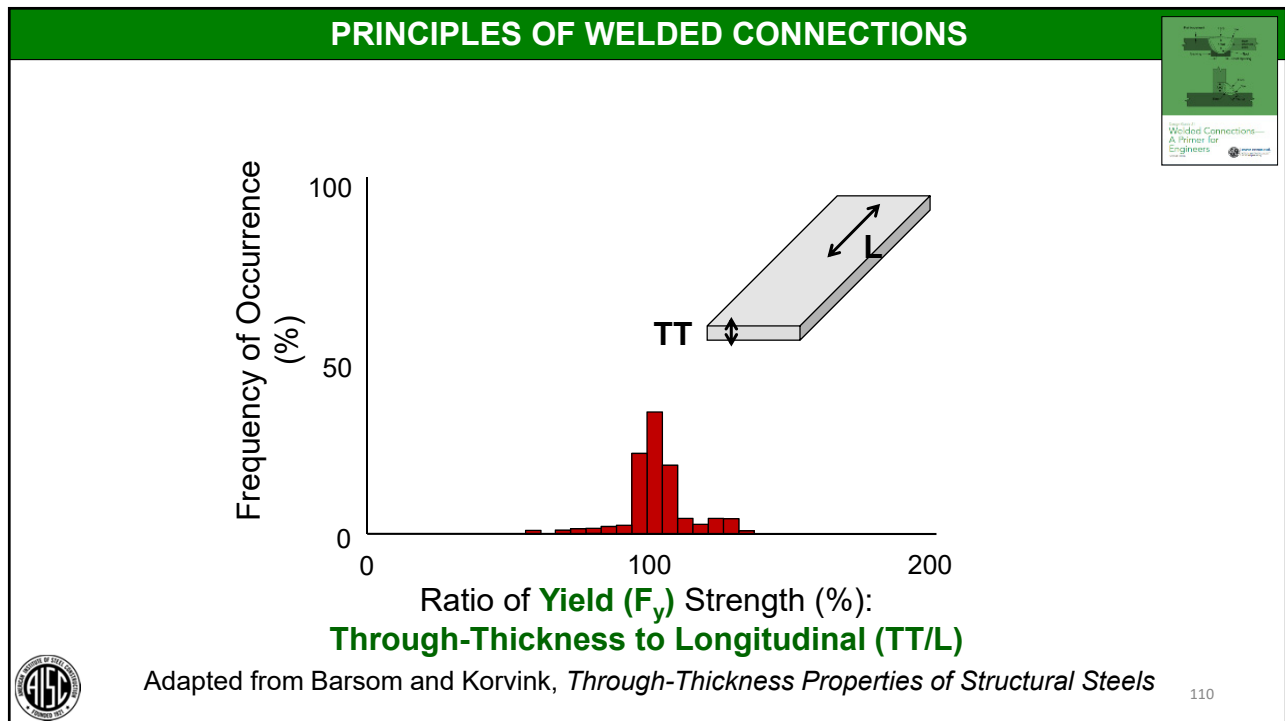
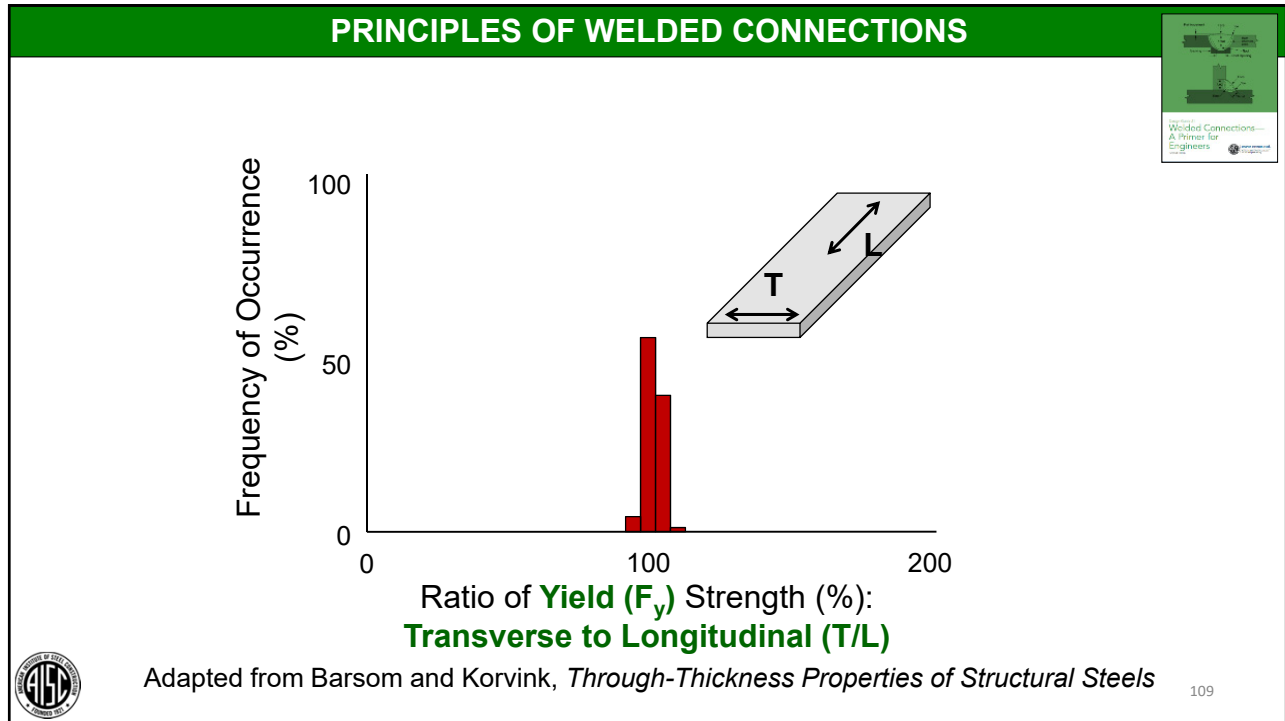
Report No. SAC/BD-97/01 Barsom and Korvink

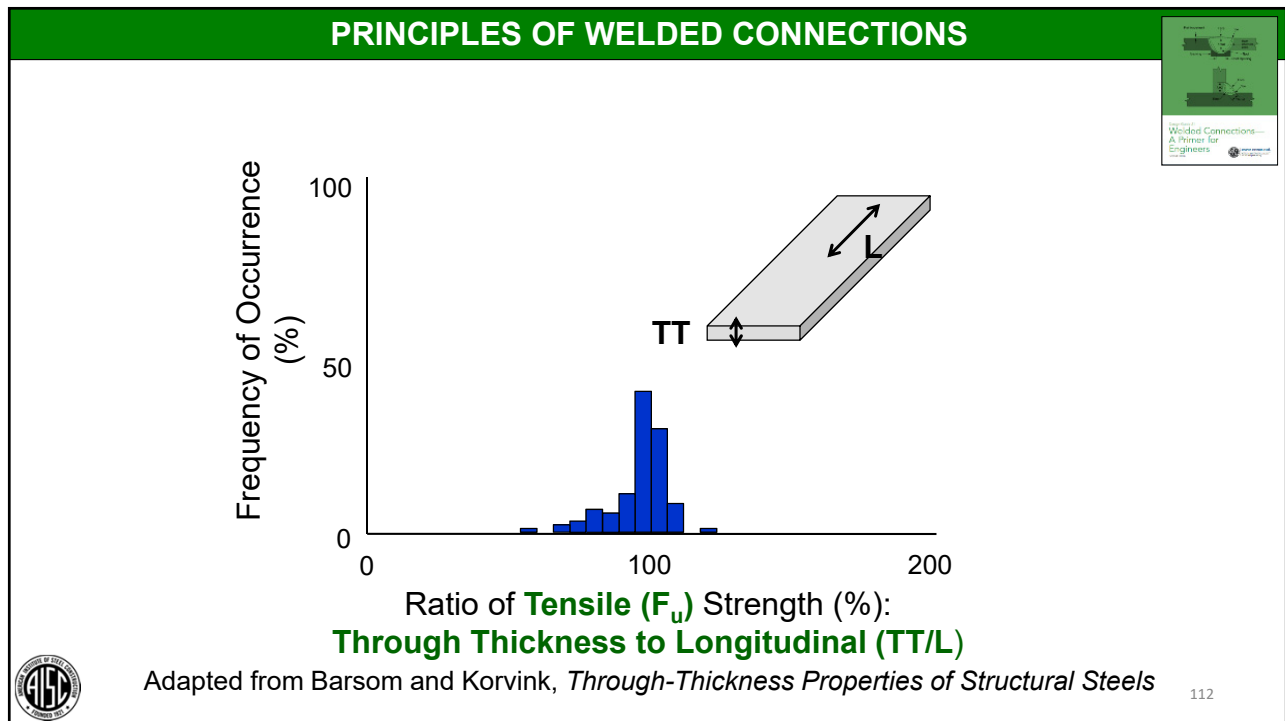
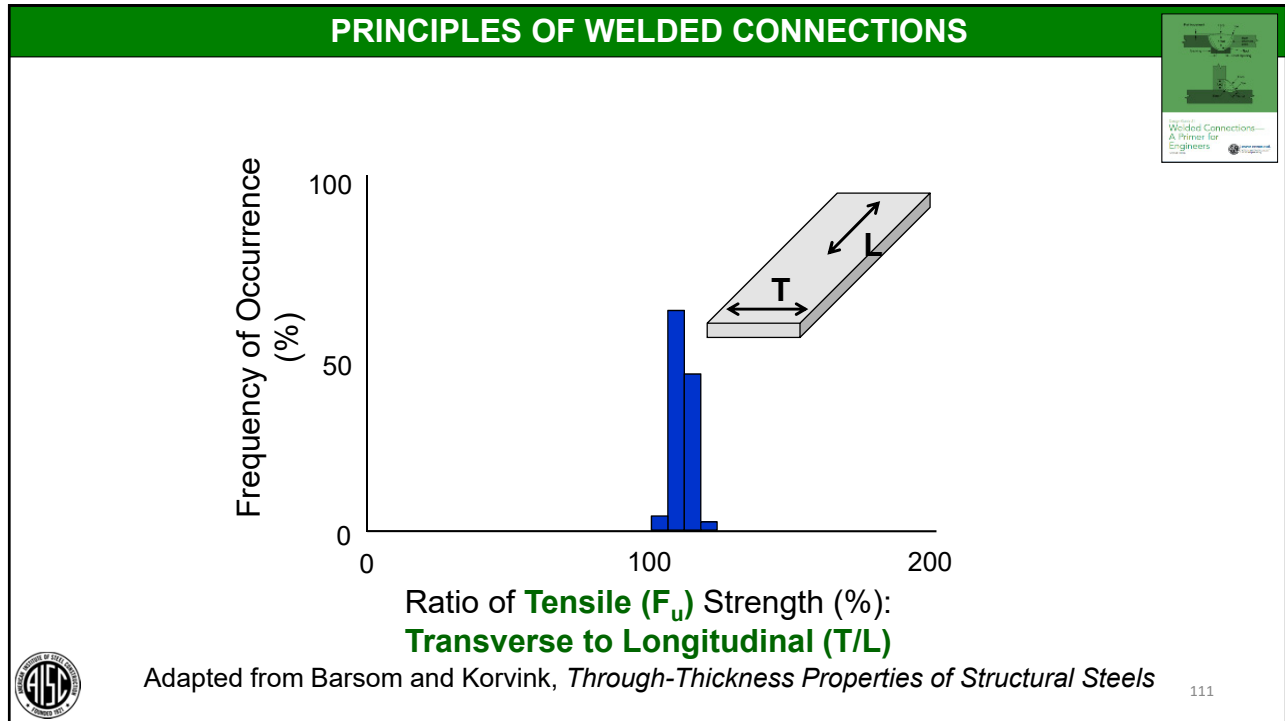
**Through-Thickness Properties
of Structural Steels**

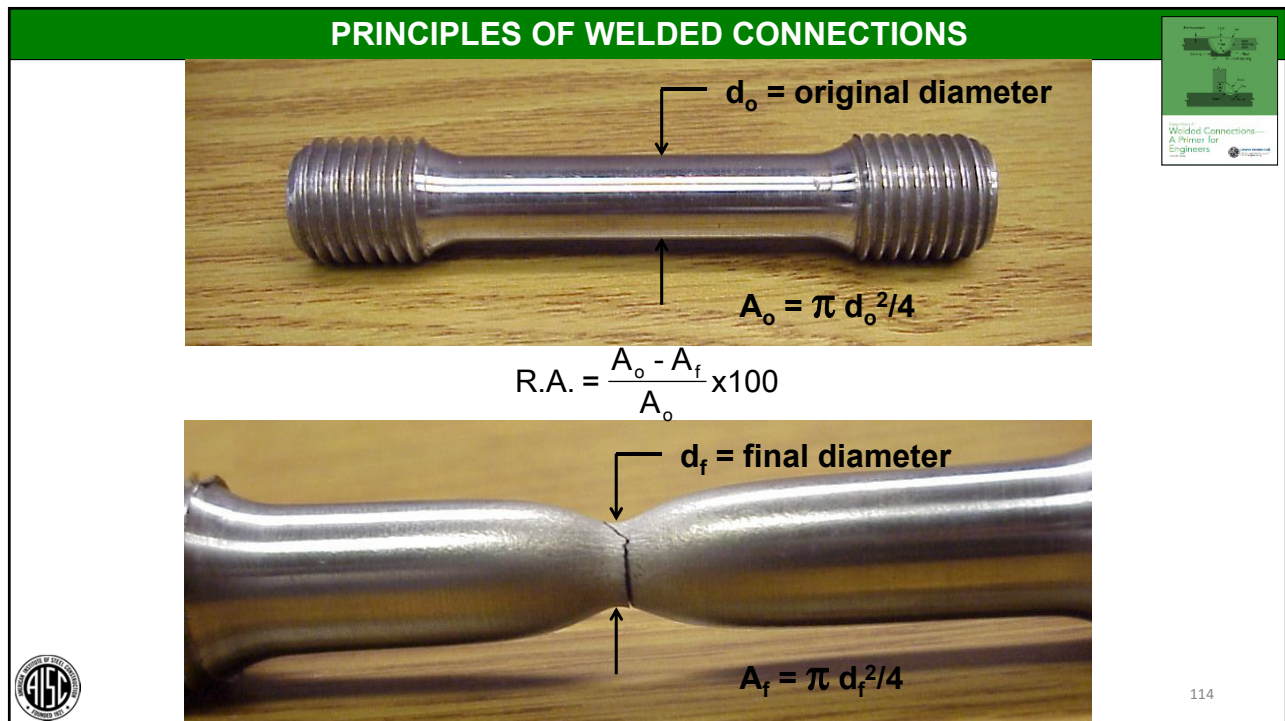
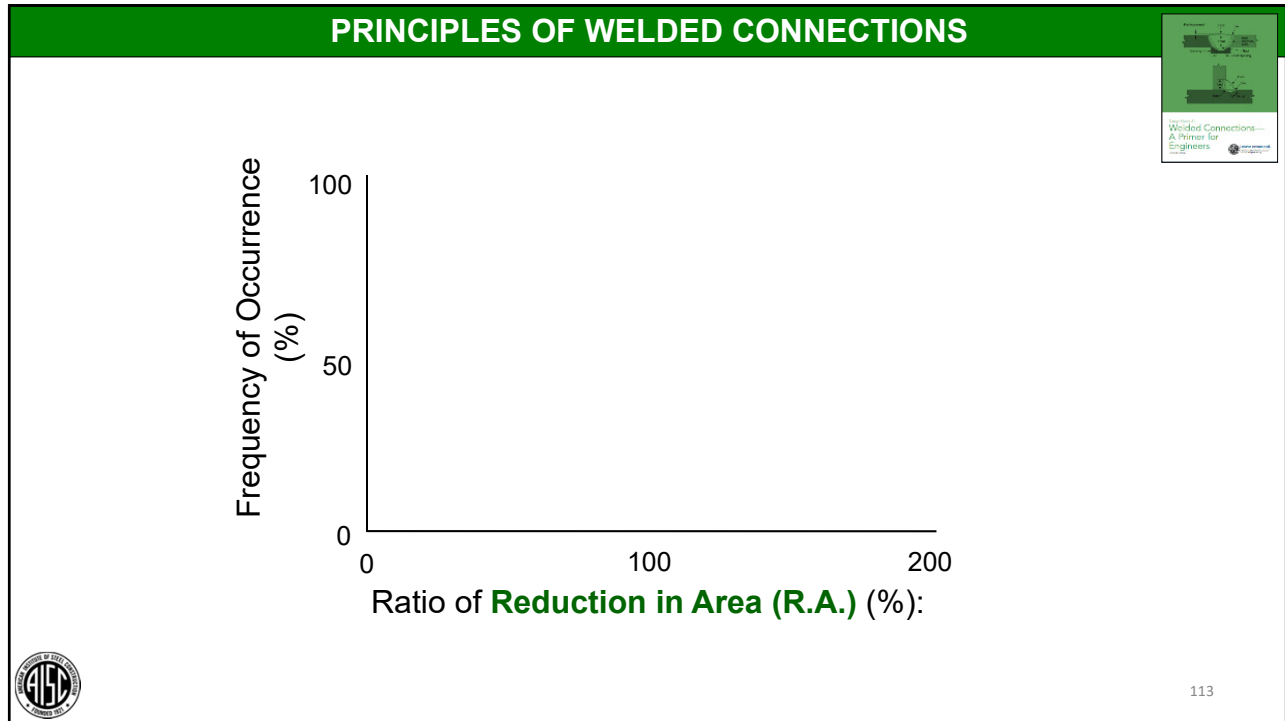


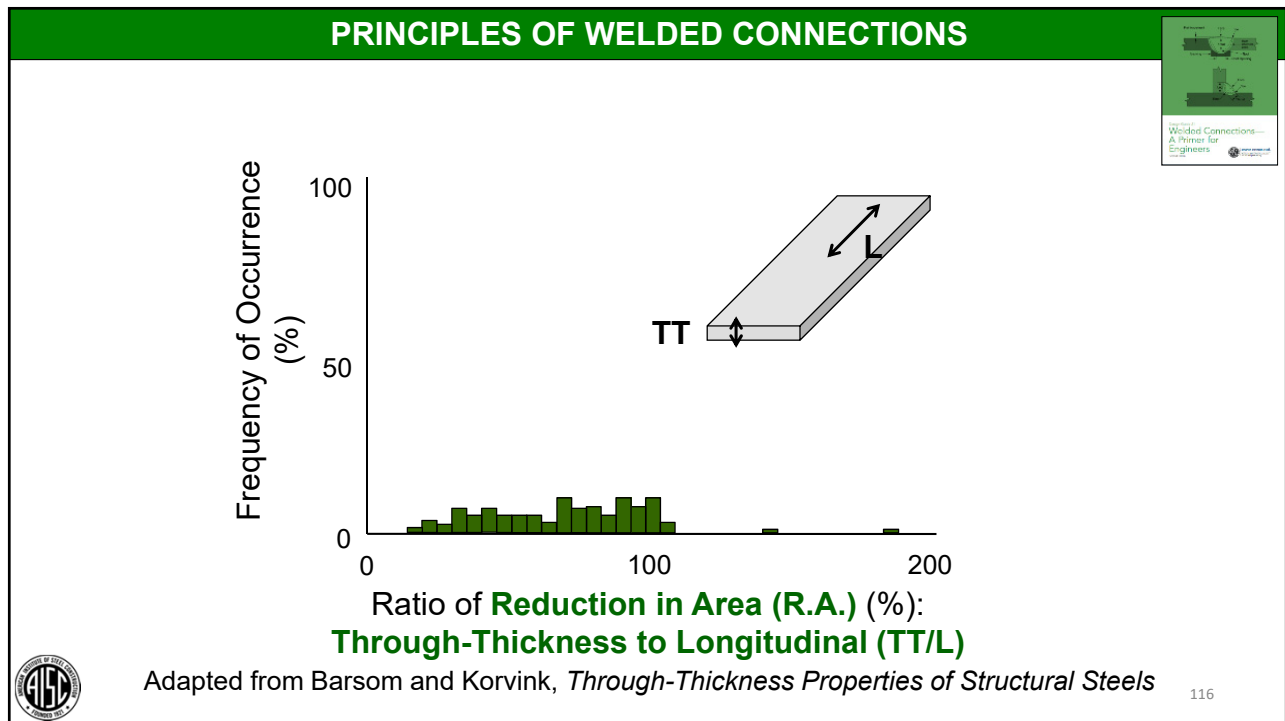
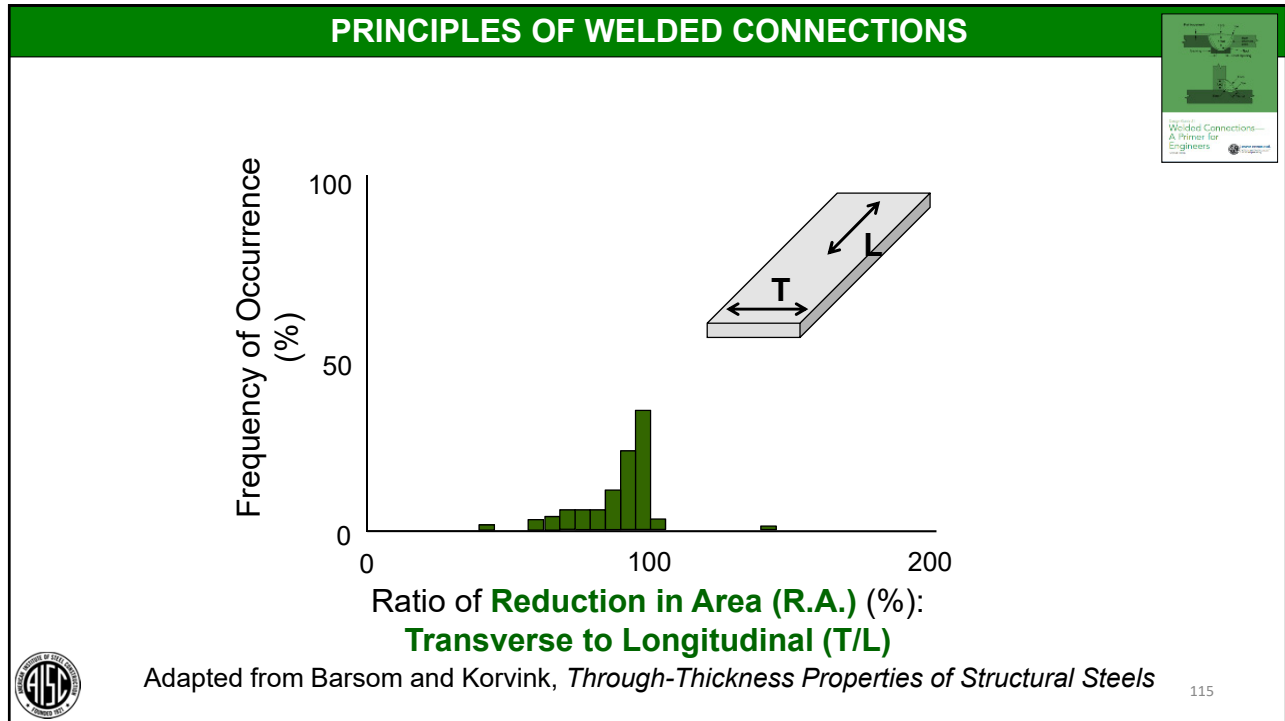
106













PRINCIPLES OF WELDED CONNECTIONS



SAC
Steel Project

Report No. SAC/BD-97/01


Barsom and Korvink



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A Primer for
Engineers

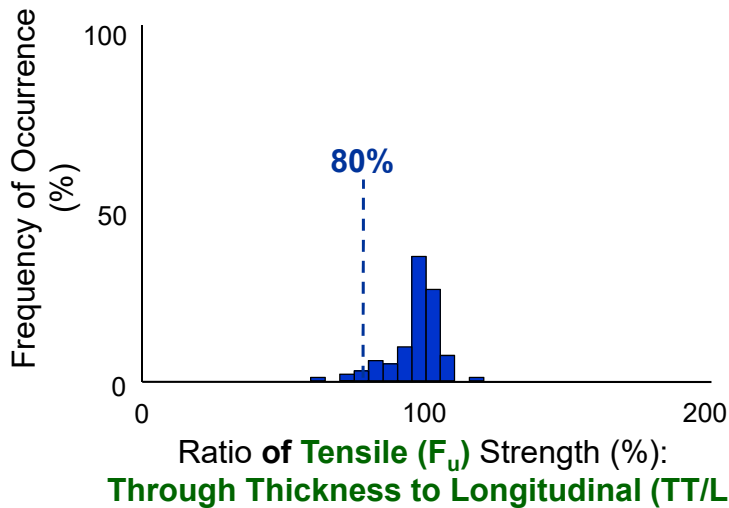
**Through-Thickness Properties
of Structural Steels**

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




Frequency of Occurrence (%)

Ratio of Tensile (F_u) Strength (%):
Through Thickness to Longitudinal (TT/L)

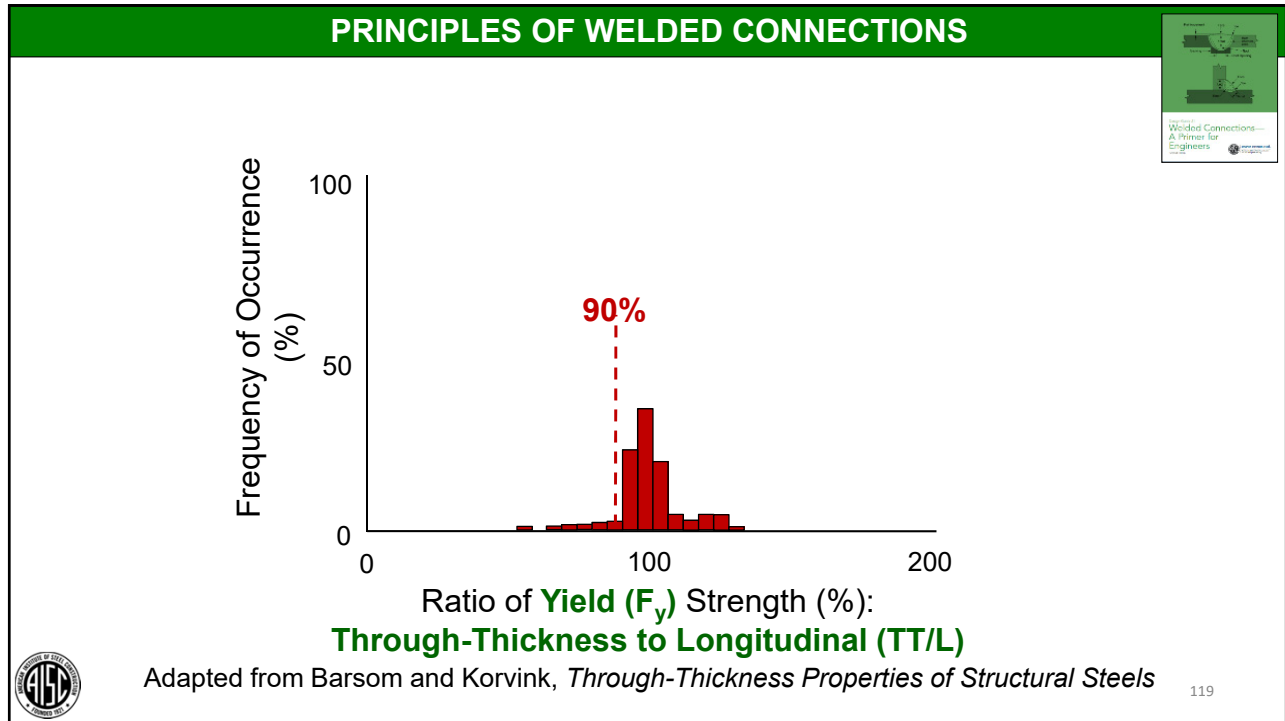


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Adapted from Barsom and Korvink, *Through-Thickness Properties of Structural Steels*



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PRINCIPLES OF WELDED CONNECTIONS

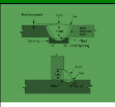


SAC
Steel Project


Report No. SAC/BD-97/01

Barsom and Korvink

**Through-Thickness Properties
of Structural Steels**


Welded Connections—
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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.**





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PRINCIPLES OF WELDED CONNECTIONS

A correct and proper welded connection recognizes material properties.

9





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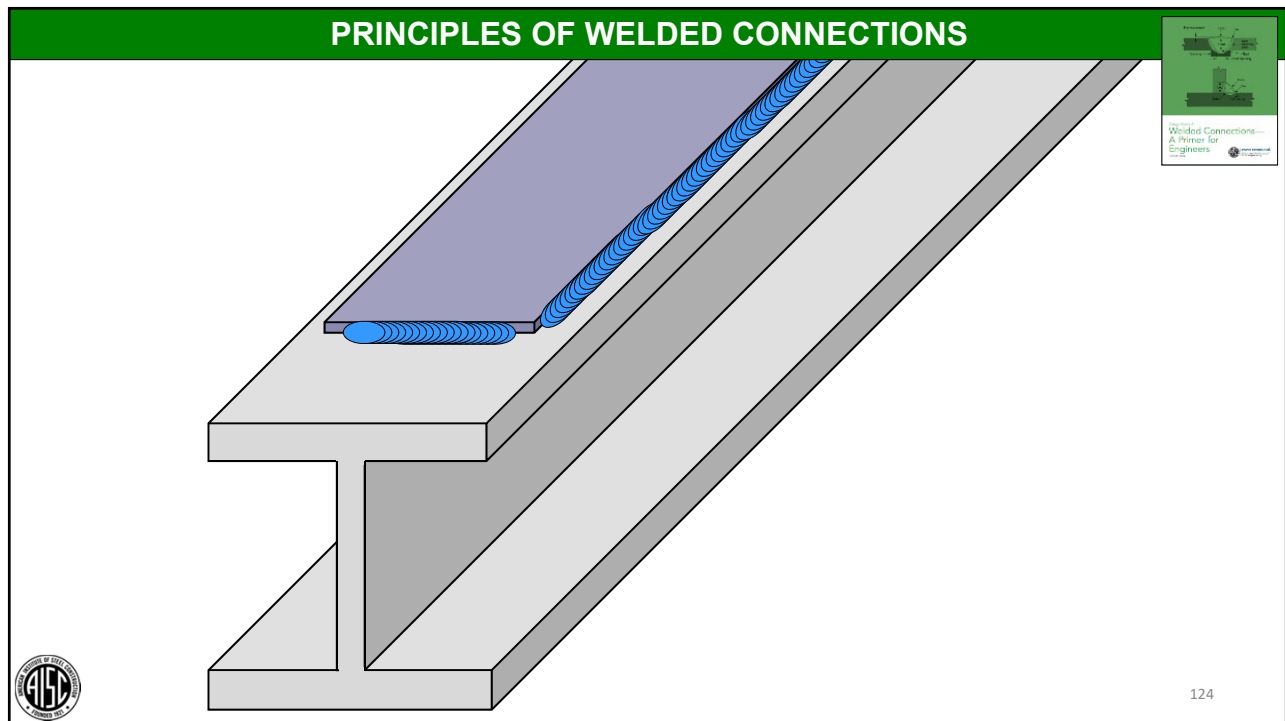
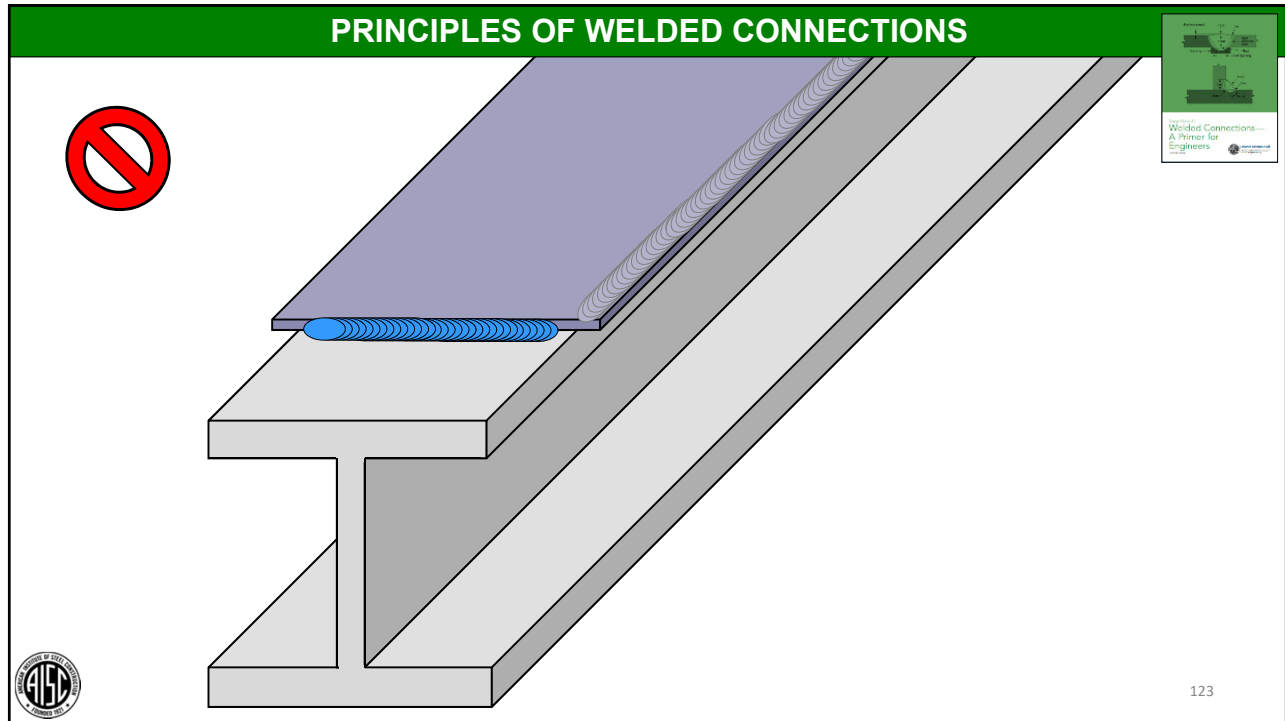
PRINCIPLES OF WELDED CONNECTIONS

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

10





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PRINCIPLES OF WELDED CONNECTIONS

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

10





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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





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PRINCIPLES OF WELDED CONNECTIONS


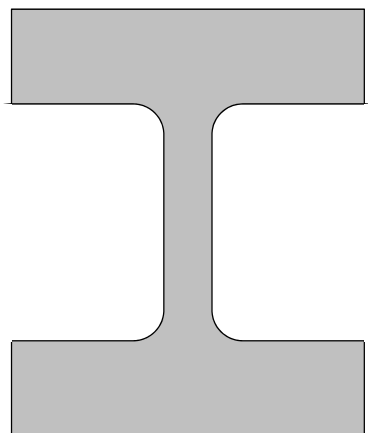
A correct and proper welded connection recognizes commercial realities.

12



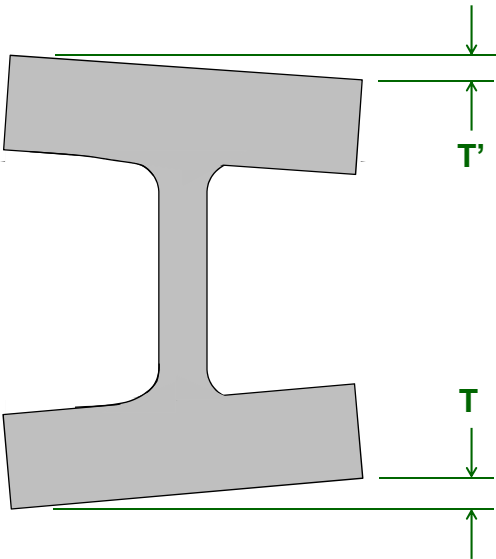
129

ASTM A6 Tolerances




130

ASTM A6 Tolerances



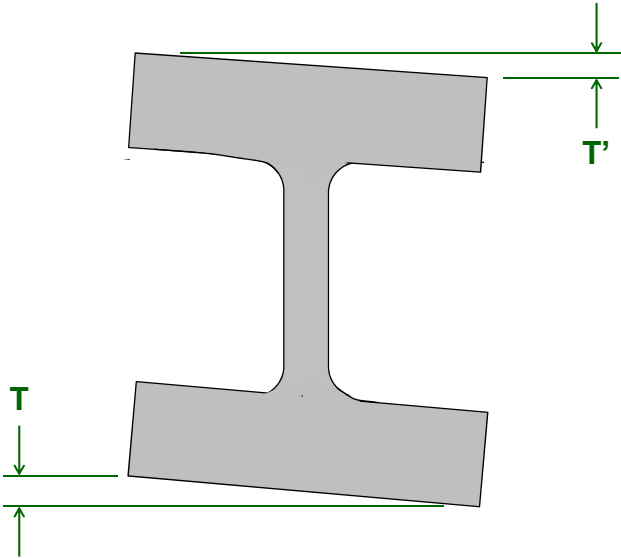
The diagram shows a cross-section of an I-beam. On the right side, a vertical double-headed arrow labeled T' indicates the tolerance for the top flange's thickness. On the left side, a vertical double-headed arrow labeled T indicates the tolerance for the bottom flange's thickness. Horizontal lines extend from the ends of these arrows to the flange surfaces.

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




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ASTM A6 Tolerances



The diagram shows a cross-section of an I-beam. On the right side, a vertical double-headed arrow labeled T' indicates the tolerance for the top flange's thickness. On the left side, a vertical double-headed arrow labeled T indicates the tolerance for the bottom flange's thickness. Horizontal lines extend from the ends of these arrows to the flange surfaces.

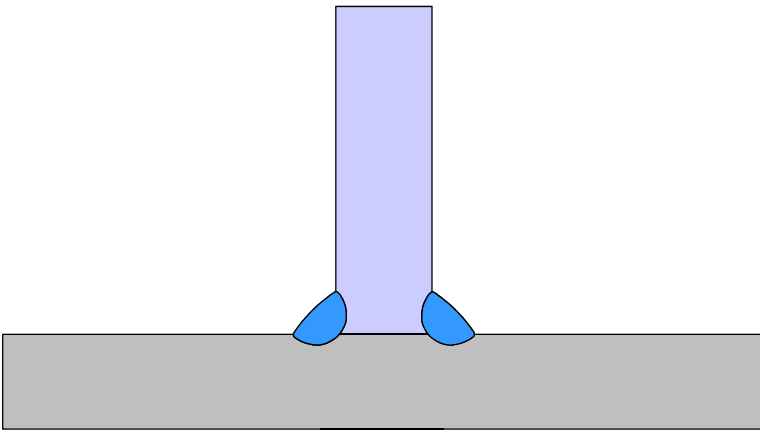
For W over 12 in, $T + T' \leq 5/16''$ [8 mm]




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PRINCIPLES OF WELDED CONNECTIONS

Angular Distortion





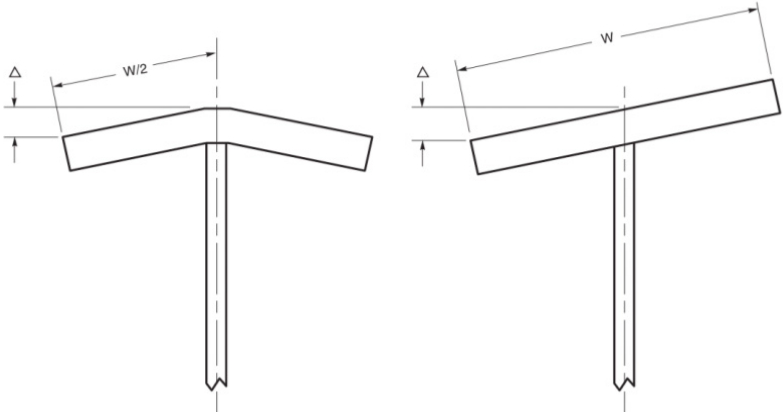
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AWS D1.1: 2015 Structural Welding Code – Steel

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

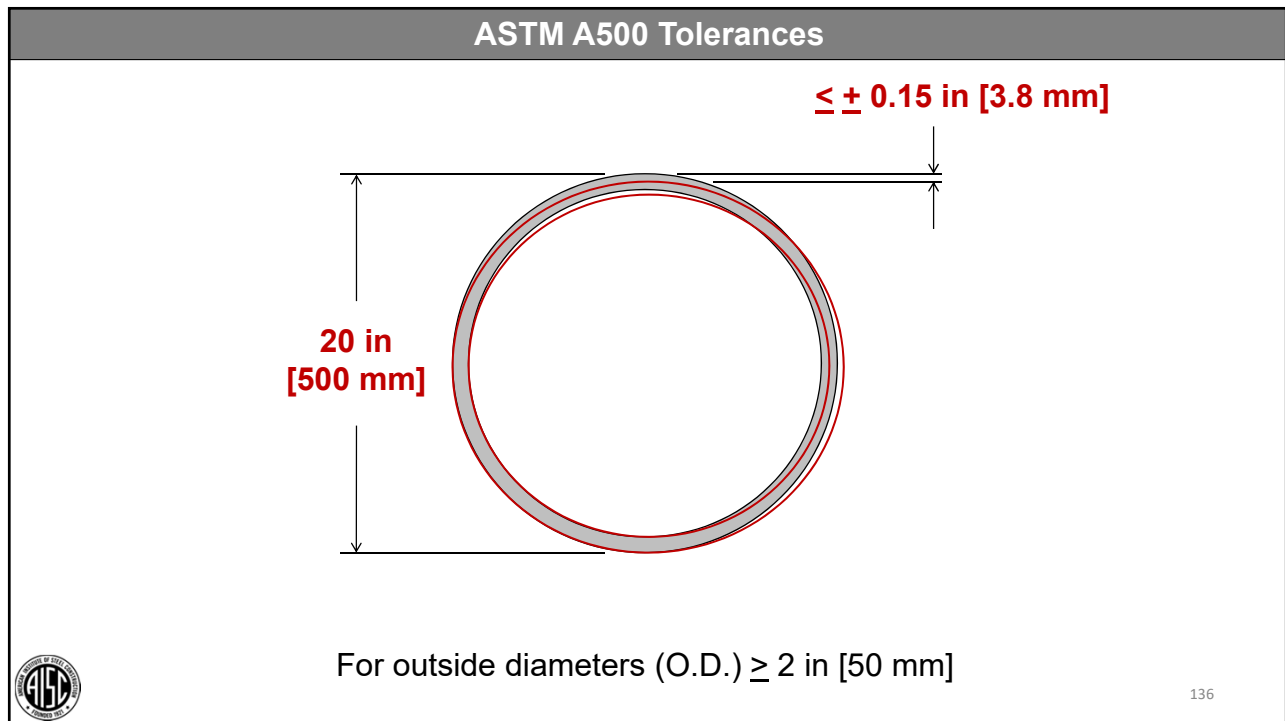
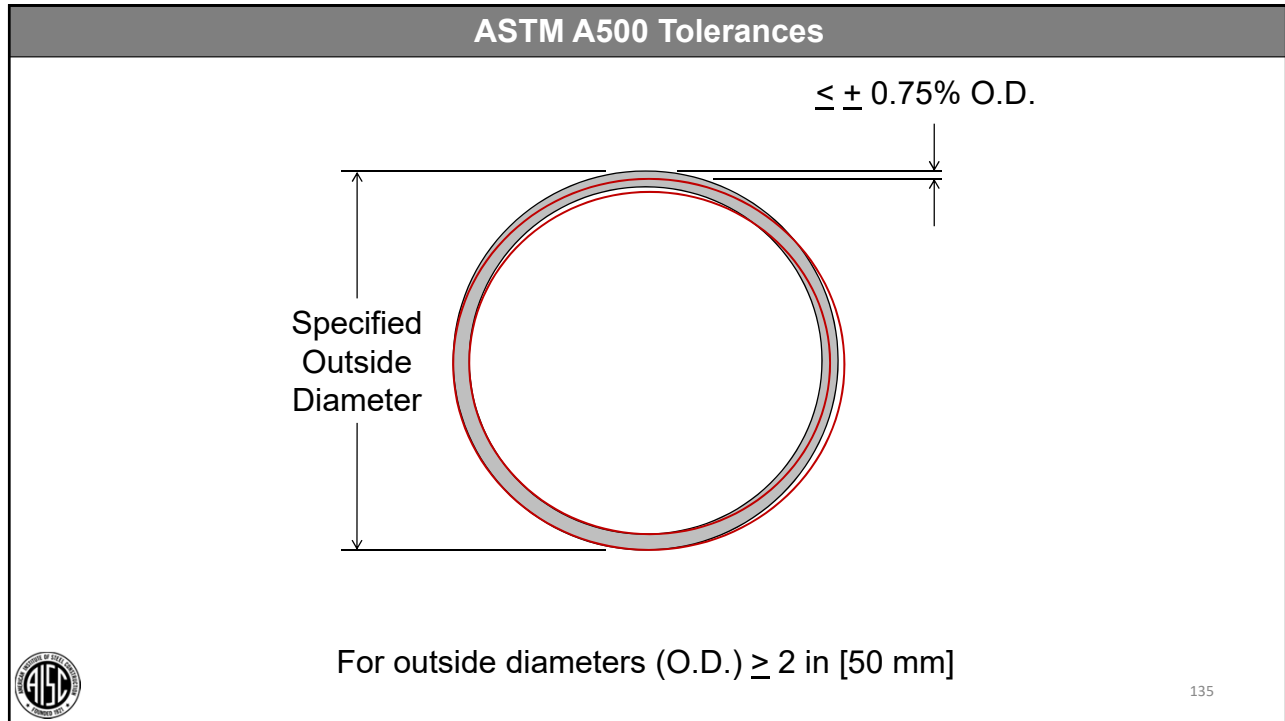
Figure C-5.7—Measurement of Flange Warpage and Tilt (see C-5.23.8)



AWS D1.1: 2015
Structural Welding Code—
Steel



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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]



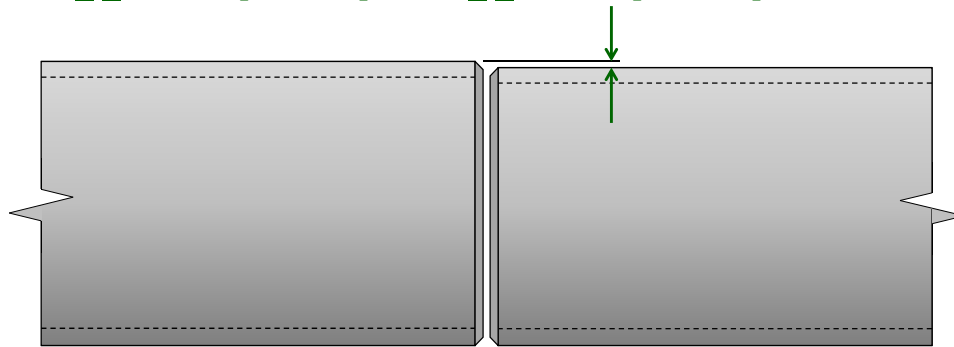
137

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]

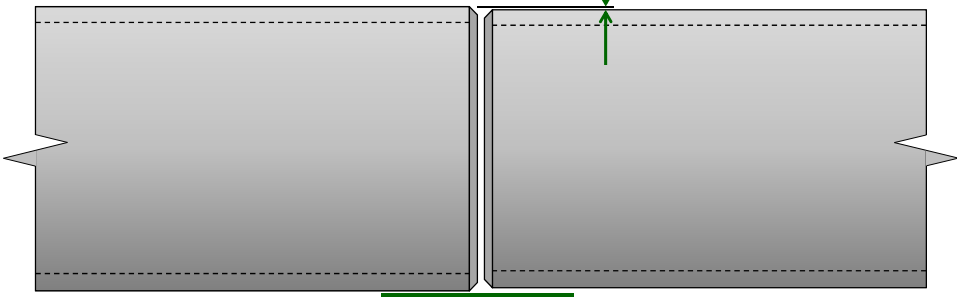


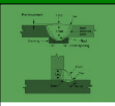
138

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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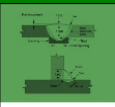


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PRINCIPLES OF WELDED CONNECTIONS

**A correct and proper welded connection
recognizes commercial realities.**

12




Welded Connections—
A Primer for
Engineers



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PRINCIPLES OF WELDED CONNECTIONS




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

13


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




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

“Form follows function.”



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PRINCIPLES OF WELDED CONNECTIONS



Architectural Philosophy

Form ever follows function.

**Louis Henry Sullivan
Architect
1856-1924**

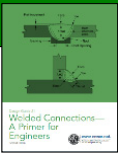



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PRINCIPLES OF WELDED CONNECTIONS

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.





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PRINCIPLES OF WELDED CONNECTIONS

Ideal



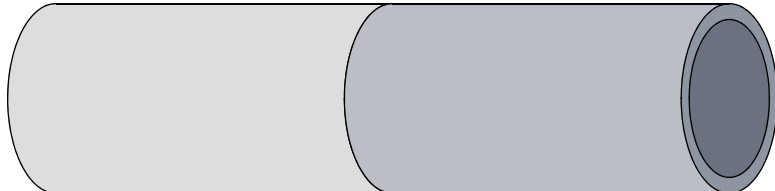
The diagram illustrates an ideal welded connection between two cylindrical members. The transition from the larger diameter section on the left to the smaller diameter section on the right is smooth and continuous, with no visible weld lines or abrupt changes in geometry. The entire assembly is shaded in a uniform light gray.



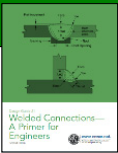

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PRINCIPLES OF WELDED CONNECTIONS

Reality



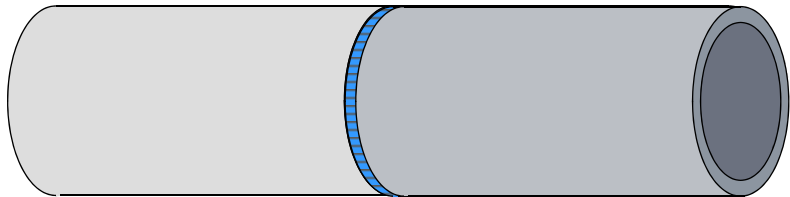
The diagram illustrates a realistic welded connection between two cylindrical members. A distinct vertical weld line is visible, separating the two sections. The transition is not smooth, and the two sections are shaded in slightly different tones of gray, indicating a change in material or geometry at the joint.





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PRINCIPLES OF WELDED CONNECTIONS

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



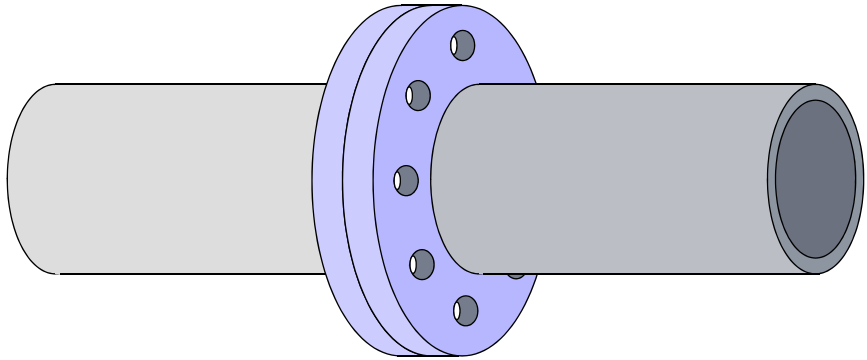
The diagram shows two cylindrical pipe sections joined by a butt-welded joint. The weld is represented by a blue, textured ring around the circumference of the pipes. The pipes are shaded in light gray, and the joint is shown in a perspective view.



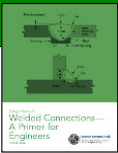

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PRINCIPLES OF WELDED CONNECTIONS

Not even close



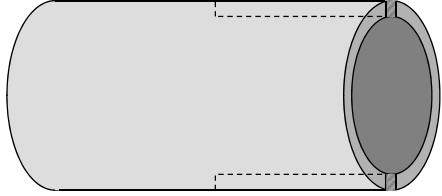
The diagram shows two cylindrical pipe sections joined by a flange-welded joint. A blue flange with six bolt holes is positioned between the two pipes, which are shaded in light gray. The flange is shown in a perspective view.





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PRINCIPLES OF WELDED CONNECTIONS

Not even close



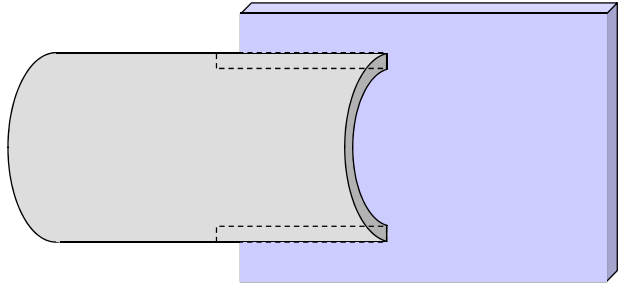
The diagram shows a grey cylindrical pipe with a rounded end on the left and a flat end on the right. A dashed line indicates the pipe's internal structure. At the flat end, there is a small gap between the pipe's outer surface and an implied inner surface, illustrating a poor fit.





149

PRINCIPLES OF WELDED CONNECTIONS

Not even close



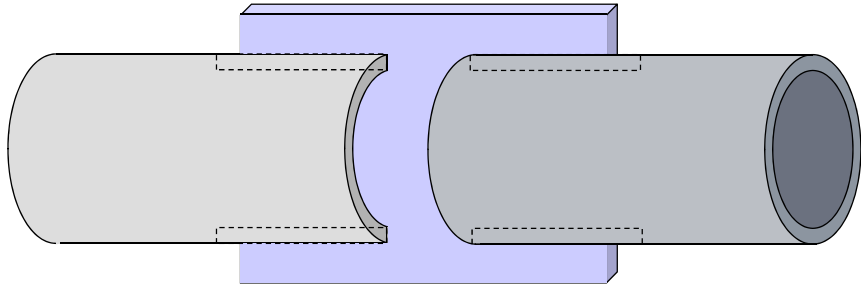
The diagram shows a grey cylindrical pipe with a rounded end on the left and a flat end on the right. A dashed line indicates the pipe's internal structure. The pipe is positioned next to a light blue rectangular block. There is a significant gap between the pipe's end and the block, illustrating a poor fit.





150

PRINCIPLES OF WELDED CONNECTIONS

Not even close

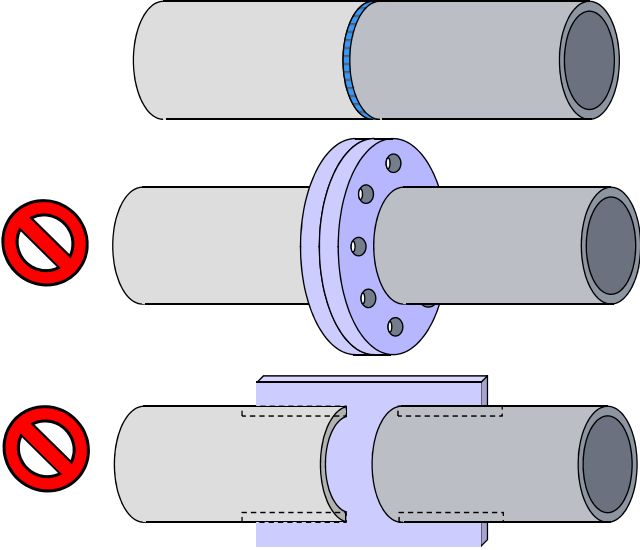


The diagram shows two horizontal pipes, one on the left and one on the right, both with a light gray finish. They are positioned such that there is a significant gap between them. A light blue T-shaped component is positioned behind the pipes, with its vertical stem between them. Dashed lines indicate the intended weld locations on the pipes. The text "Not even close" is centered above the pipes.





151

PRINCIPLES OF WELDED CONNECTIONS




The diagram illustrates three incorrect methods for connecting pipes:

- The top diagram shows two pipes joined by a single circumferential weld. A red prohibition sign is to its left.
- The middle diagram shows two pipes connected by a blue flange with six bolts. A red prohibition sign is to its left.
- The bottom diagram shows two pipes with a gap between them, similar to the slide above, but with a light blue T-shaped component behind them. A red prohibition sign is to its left.



152

PRINCIPLES OF WELDED CONNECTIONS




An aesthetically pleasing connection is:
welded, not bolted.




153

PRINCIPLES OF WELDED CONNECTIONS



An aesthetically pleasing welded connection is:
directly welded.

- no gusset plates
- no flange plates





154

PRINCIPLES OF WELDED CONNECTIONS

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

13





155

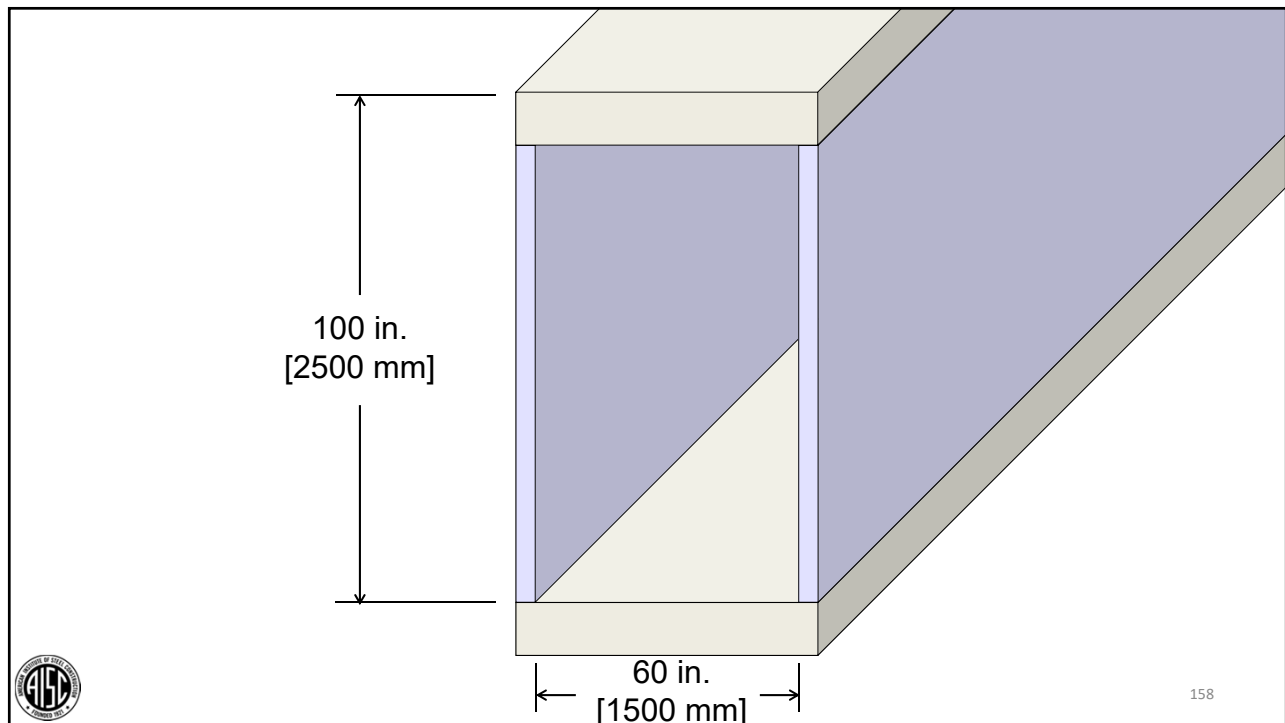
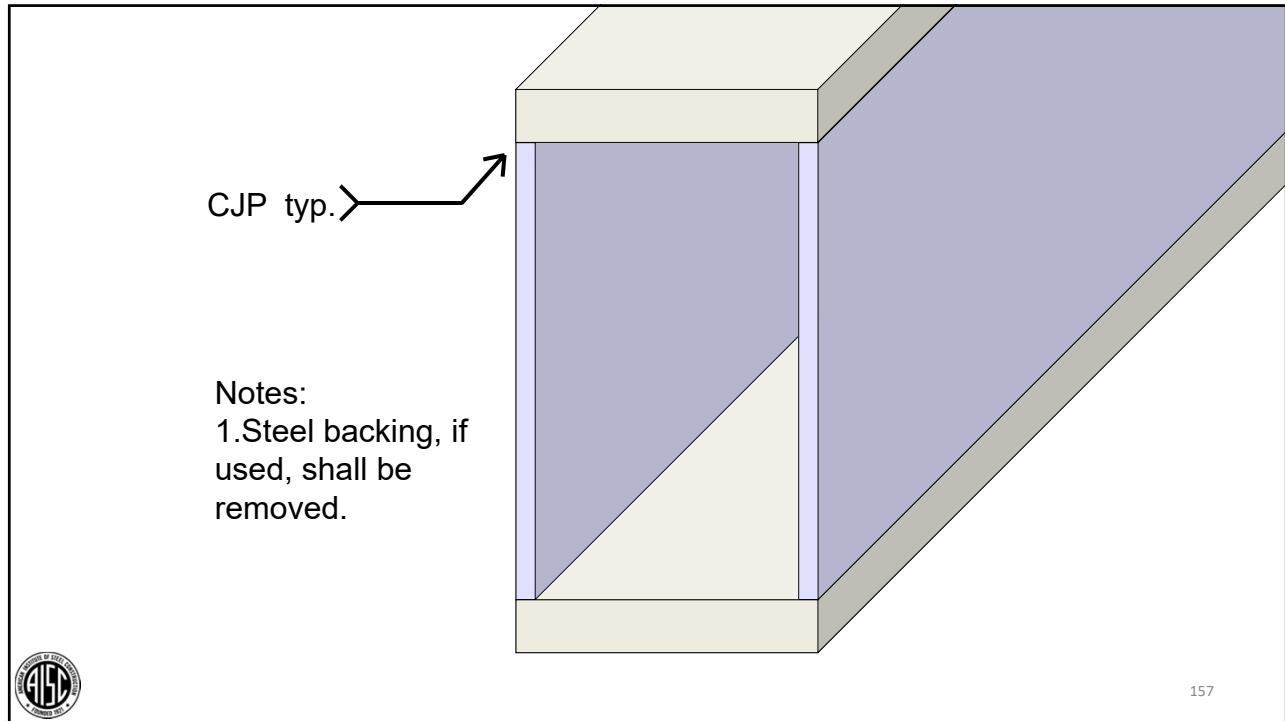
PRINCIPLES OF WELDED CONNECTIONS

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

14




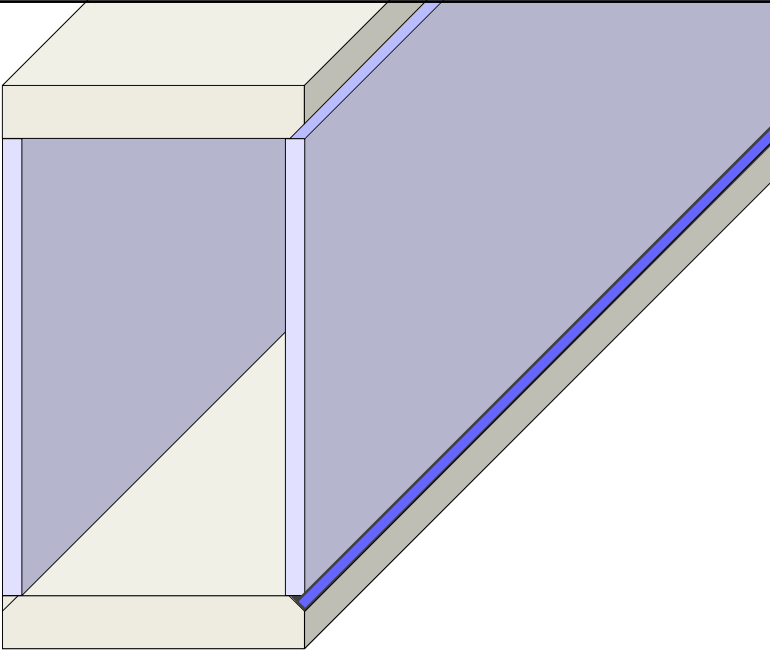
156



Ideal
(if design permits)

- PJP groove welds
- NDT inspection?
- Category B'


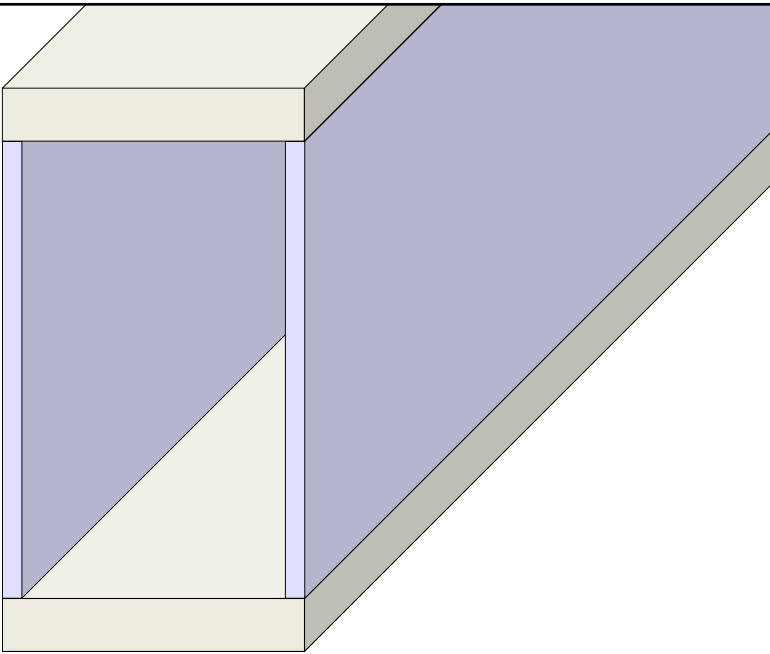
Note: PJP detail permits beveling of flange, to mitigate lamellar tearing tendencies.



159

Options

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

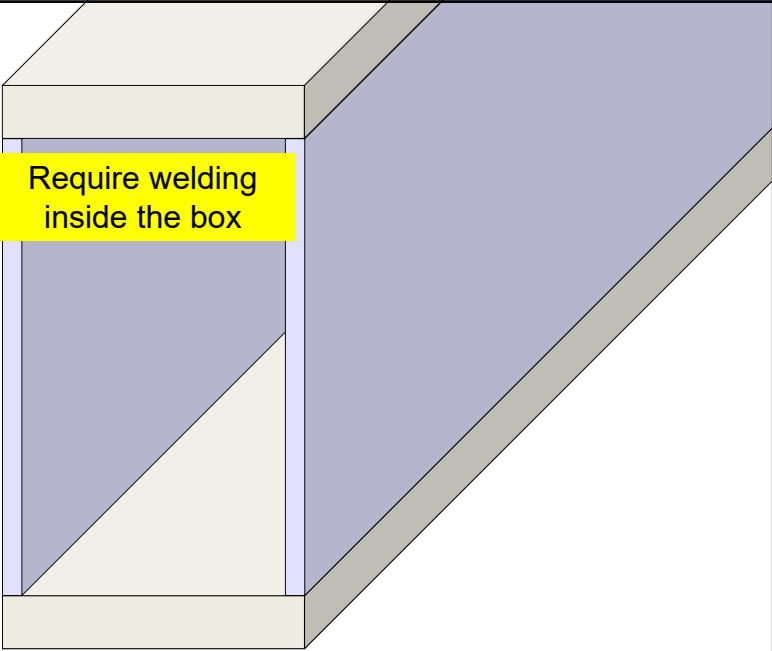



160

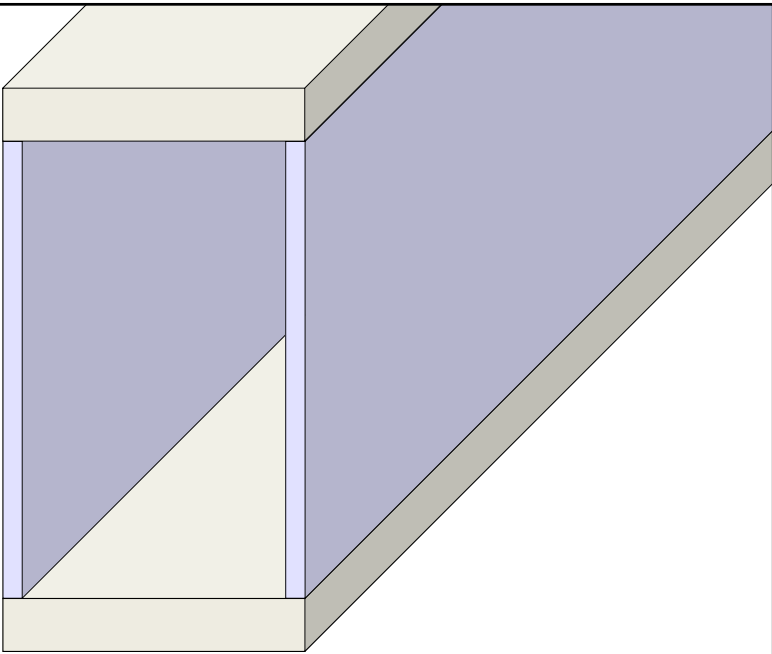
Options

- 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')

Require welding inside the box




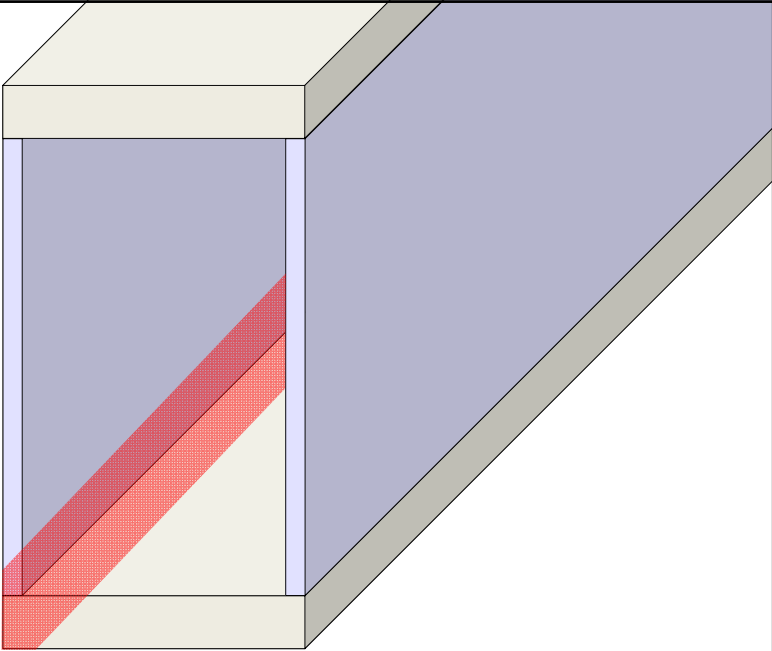
 161



100 in.
[2500 mm]


60 in.
[1500 mm]

 162



CJP typ. →

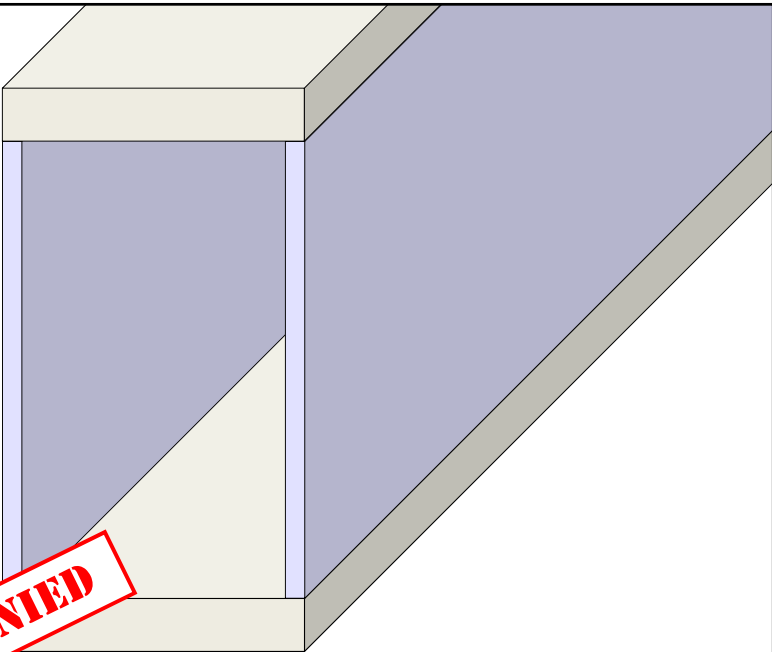
Notes:
1. Steel backing, if used, shall be removed.
2. Minimum preheat for flange steel is 325°F [160°C]




163

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')



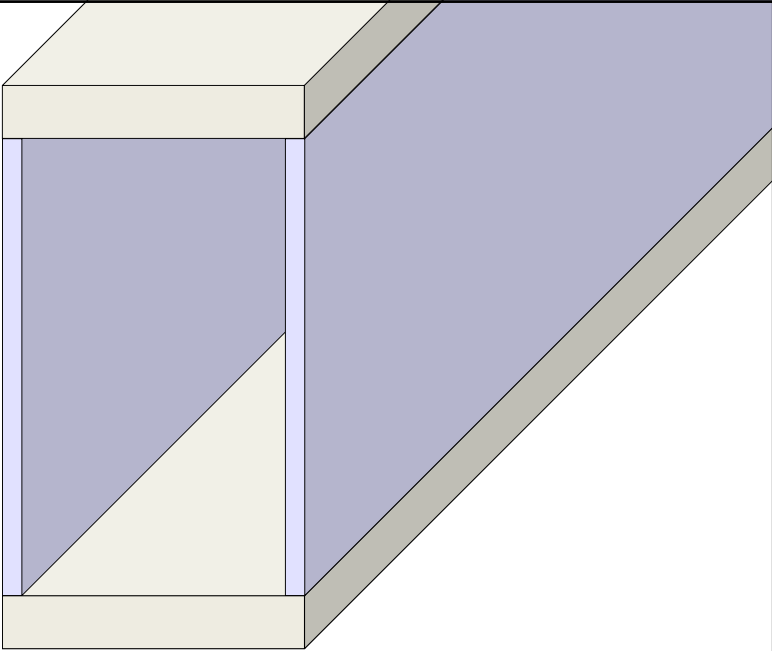
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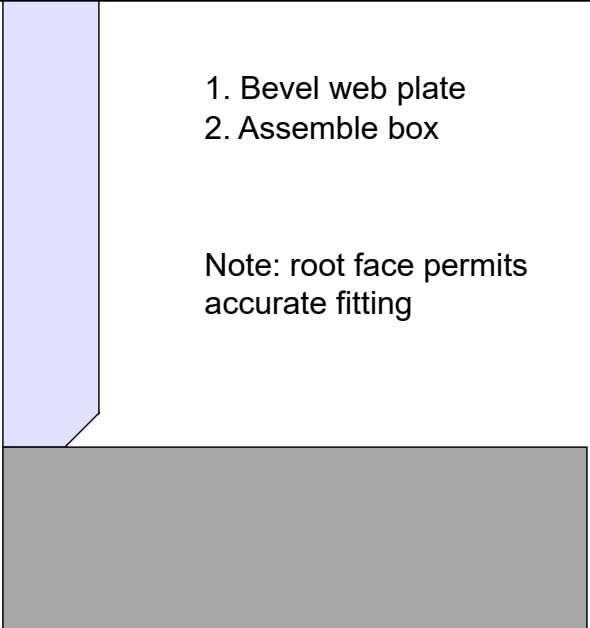
164

Actual

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




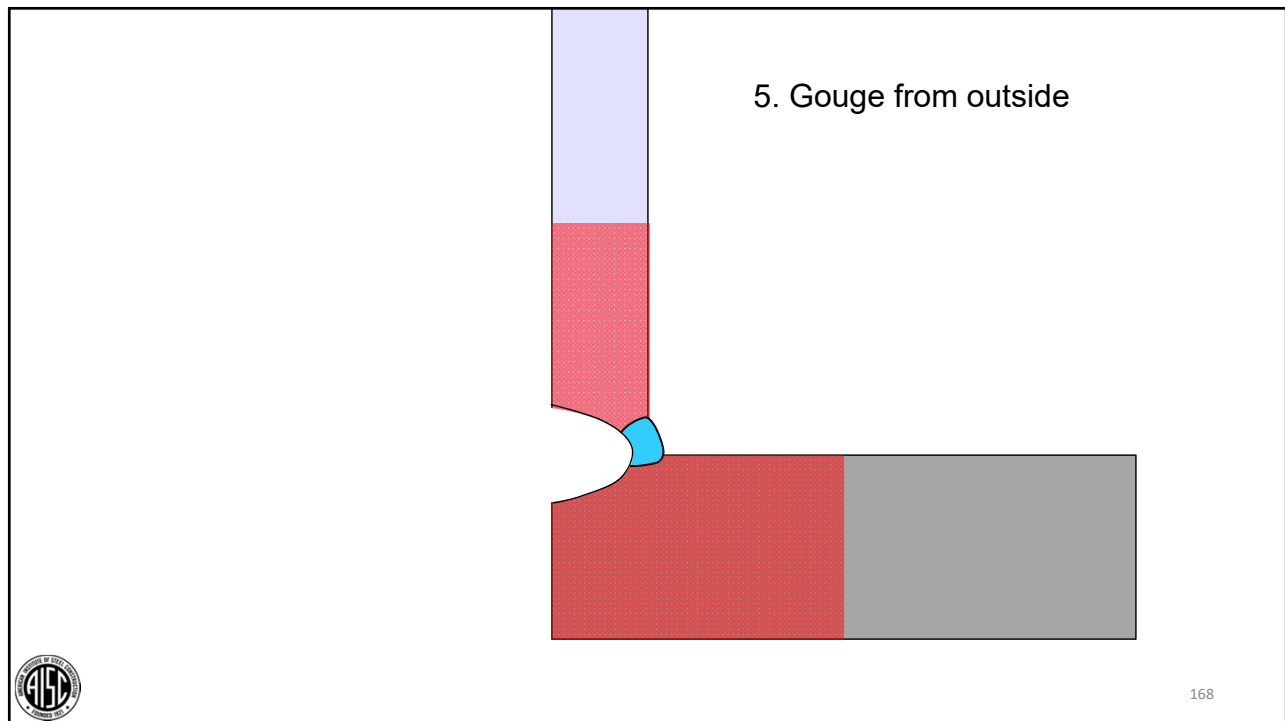
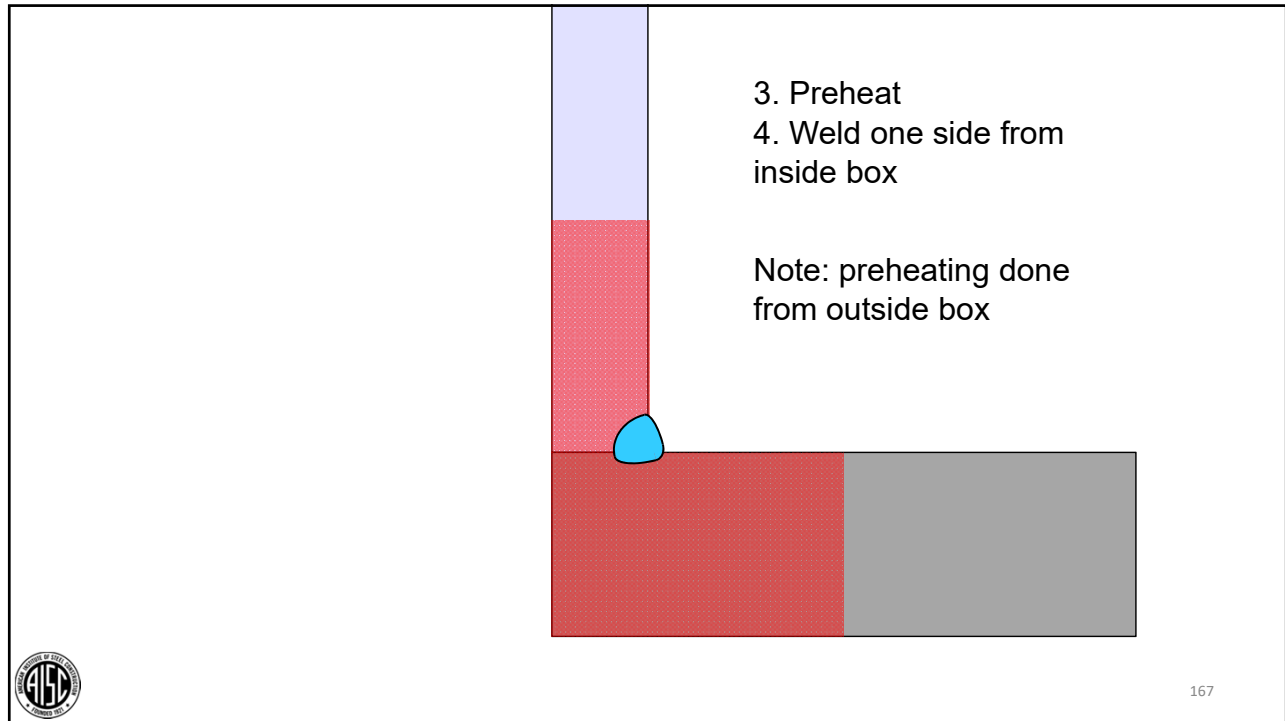
 165

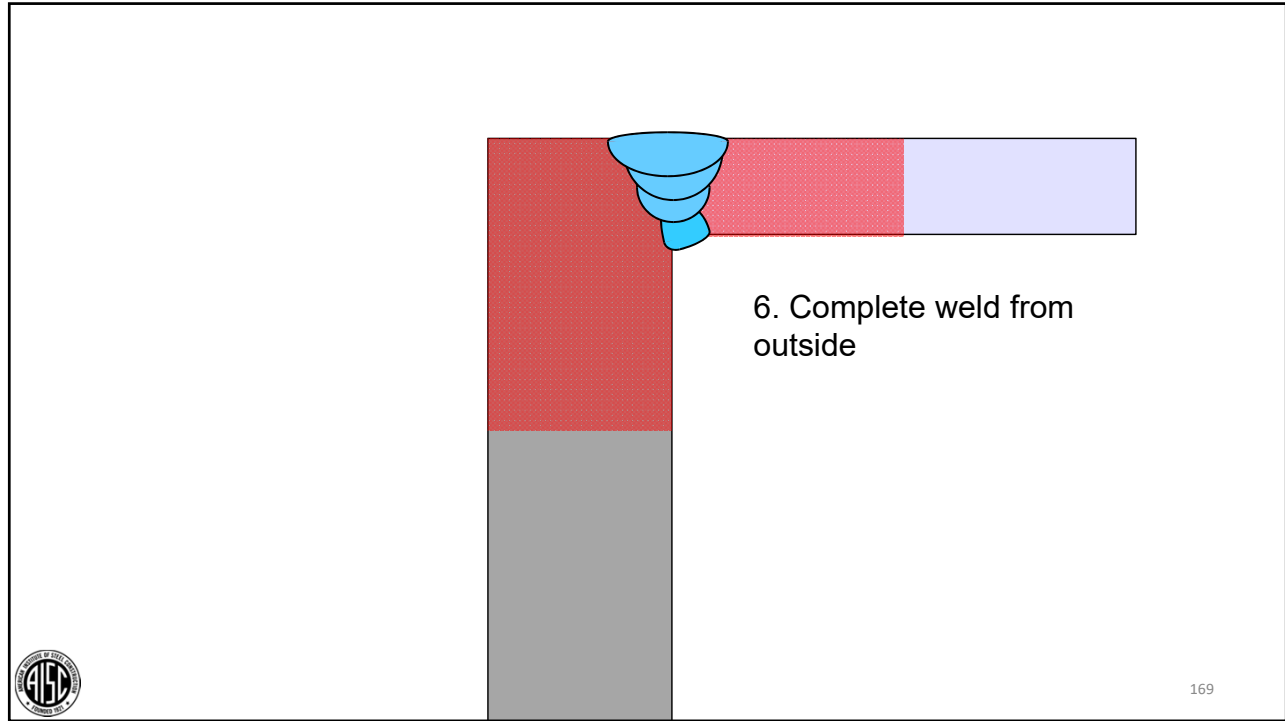


1. Bevel web plate
2. Assemble box

Note: root face permits accurate fitting

 166


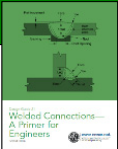




PRINCIPLES OF WELDED CONNECTIONS


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

14




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PRINCIPLES OF WELDED CONNECTIONS



14 Principles of Welded Connection Design


What makes a welded connection correct or proper?



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Thank you!

AISC | Questions?



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Stronger.
Steel.**

Individual Session Registrants

PDH Certificates

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



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Individual Session Registrants

PDH Certificates

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



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8-Session Registrants

PDH Certificates

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



8-Session Registrants

Access to the quiz

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

Quiz and attendance records

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

Reasons for quiz

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

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



8-Session Registrants

Access to the recording

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

PDHs via recording

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



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8-Session Registrants

Night School Resources

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



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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"/>	
<p><input type="checkbox"/> Remember Me</p>	



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8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.

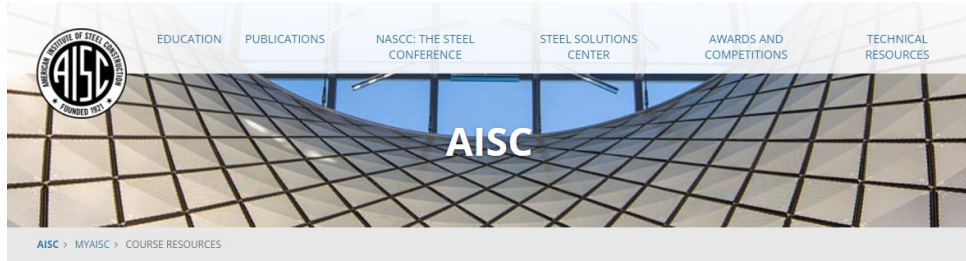
<p>IN THIS SECTION</p> <ul style="list-style-type: none">Edit ProfileMy DownloadsMy Pending QuizzesMy EventsOrder HistoryCourse HistoryCourse Resources	<p>MyAISC</p> <hr/> <p>MY PROFILE</p> <p>Update your contact and address information.</p> <p>EDIT PROFILE</p> <hr/> <p>MY PURCHASED DOWNLOADS</p> <p>Access articles and documents that you have purchased.</p> <p>VIEW DOWNLOADS</p> <hr/> <p>MY COURSE RESOURCES</p> <p>View online resources for Night School and Live Webinar package registrations.</p> <p>VIEW RESOURCES</p>
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8-Session Registrants

Night School Resources



Course Resources

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



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 Dgn	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/nightschool21. Scroll down to Quiz and Attendance records.
 - Updated on Thursday mornings.



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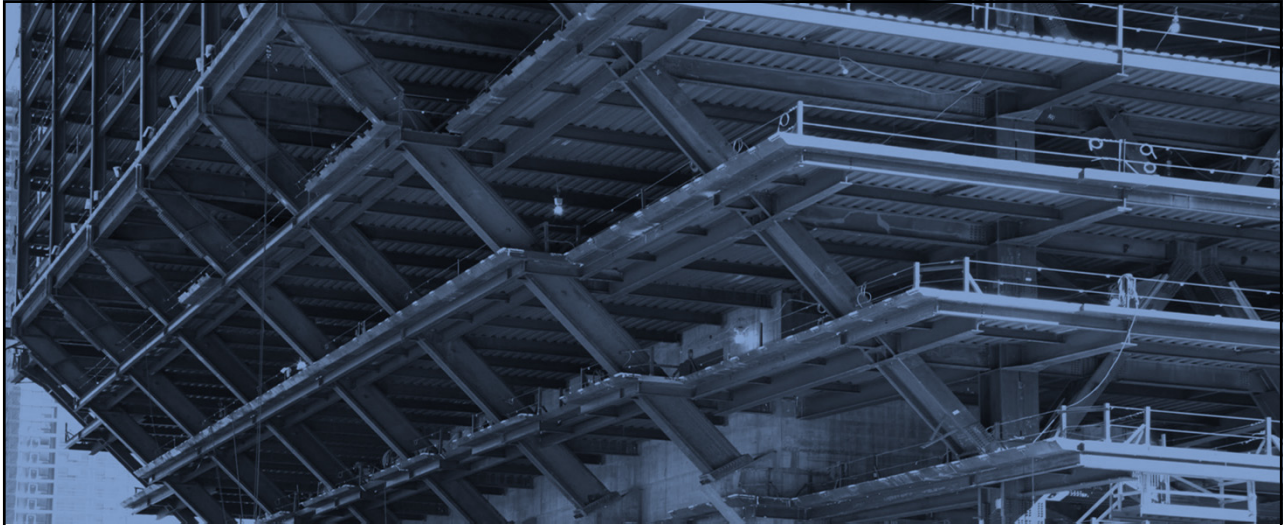
8-Session Registrants

Night School Resources

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



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AISC | Thank you



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