There's always a solution in steel.

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Course Description

Welded Connections – The Good, the Bad, and the Ugly
December 3, 2015

It has been said that "the devil is in the details," and welded connections are no different. Subtle changes can affect the performance, quality, and cost of welded connections. Engineers, detailers, fabricators, and erectors will all benefit from this practical webinar that will present preferred practices for quality, dependable, cost-effective welded connections. Topics include:

- Details of butt, corner, and lap joints
- When and why width or thickness transitions are required in joints
- Details of groove welds, fillet welds, and plug welds
- Economy of PJP groove welds versus fillet welds
- The influence of left-in-place steel backing on statically, cyclically and seismically loaded connections
- Many other "details on details"

Learning Objectives

- Gain an understanding of principles that make for good welded connections
- Identify weld configurations that provide proper load path
- Identify weld geometries that do not induce undesirable loads such as stress raisers or bending on welds
- Determine simple, economical and safe welds for joints

There's always a solution in steel.

Welded Connections: The Good, The Bad, and The Ugly

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

structural STEEL

WELDED CONNECTIONS:

The Good, the Bad and the Ugly

9

What makes a

WELDED CONNECTION

Good, Bad or Ugly?

10

good

adjective \'gud\

: of high quality

: of somewhat high but not excellent quality

: correct or proper

11

bad

adjective \'bad\

: low or poor in quality

: not correct or proper

: not pleasant, pleasing, or enjoyable

12

ugly

adjective \’ə- gle\

: unpleasant to look at: not pretty or attractive

: unpleasant to hear

: offensive or disgusting

13

good

adjective \’gud\

: of high quality

: of somewhat high but not excellent quality

: correct or proper

14

What makes a

WELDED CONNECTION

correct or proper?

15

Principles of Connection Design

OUTLINE

PRINCIPLES OF WELDED CONNECTION DESIGN

- Twelve principles that make for **good** welded connections
- Examples of **good and bad** welded connections

UGLY WELDED CONNECTIONS

16

WELDED CONNECTIONS:

The Good, the Bad and the Ugly

17

Principles of Connection Design

1

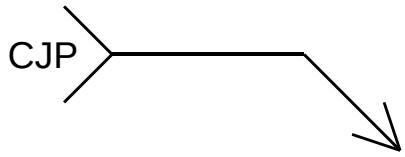
A correct and proper welded connection

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

Correct and proper = strong enough

(but not stronger than necessary)

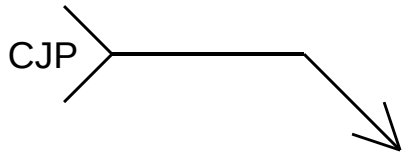
18



Official Definition:

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

19



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.

20

Principles of Connection Design

1

A correct and proper welded connection

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

21

Principles of Connection Design

2

A correct and proper welded connection

has a clear and direct load path.

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

Omer W. Blodgett

22

Principles of Connection Design

2

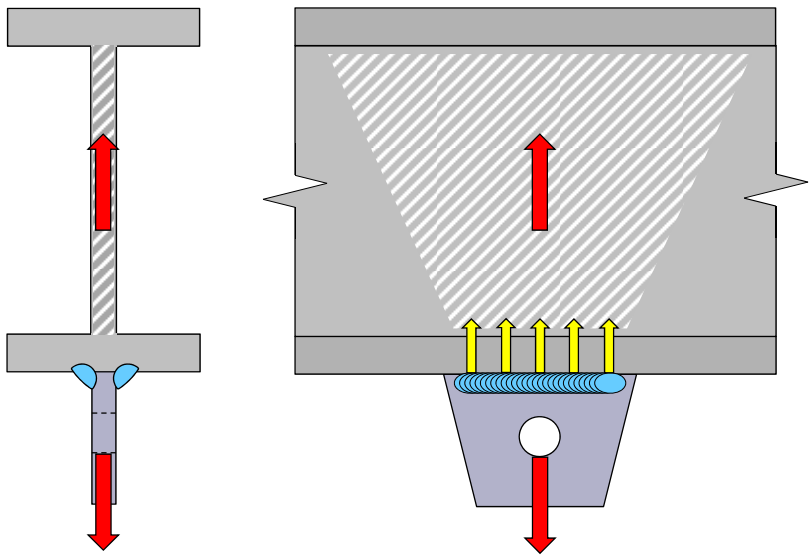
A correct and proper welded connection

has a clear and direct load path.

“The force goes to the stiff part.”

William “Bill” A. Milek

23



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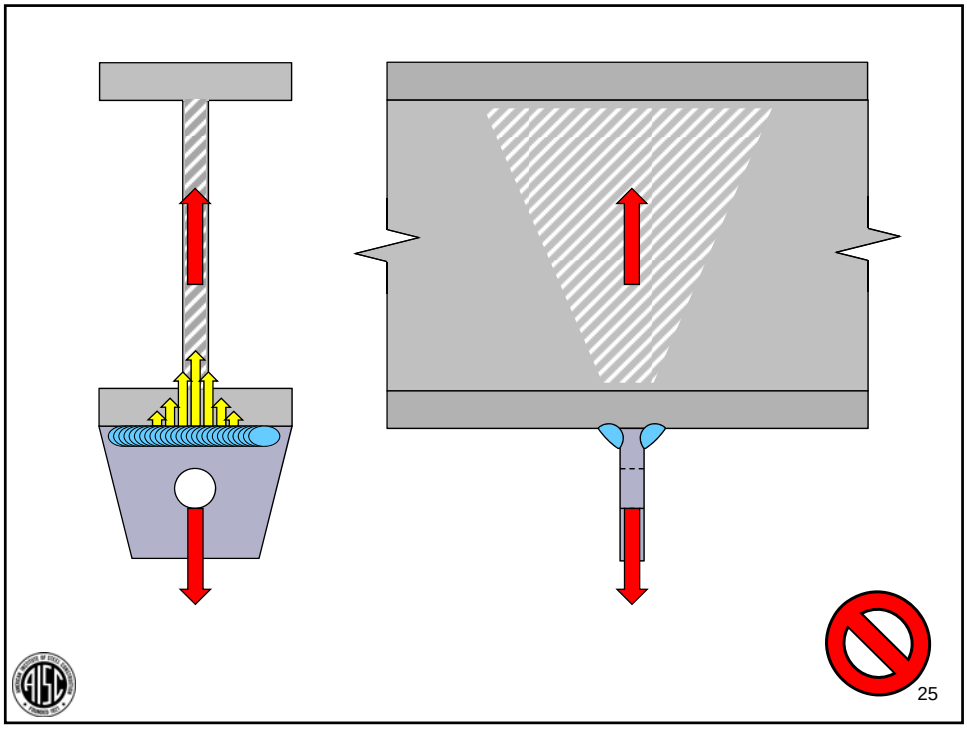
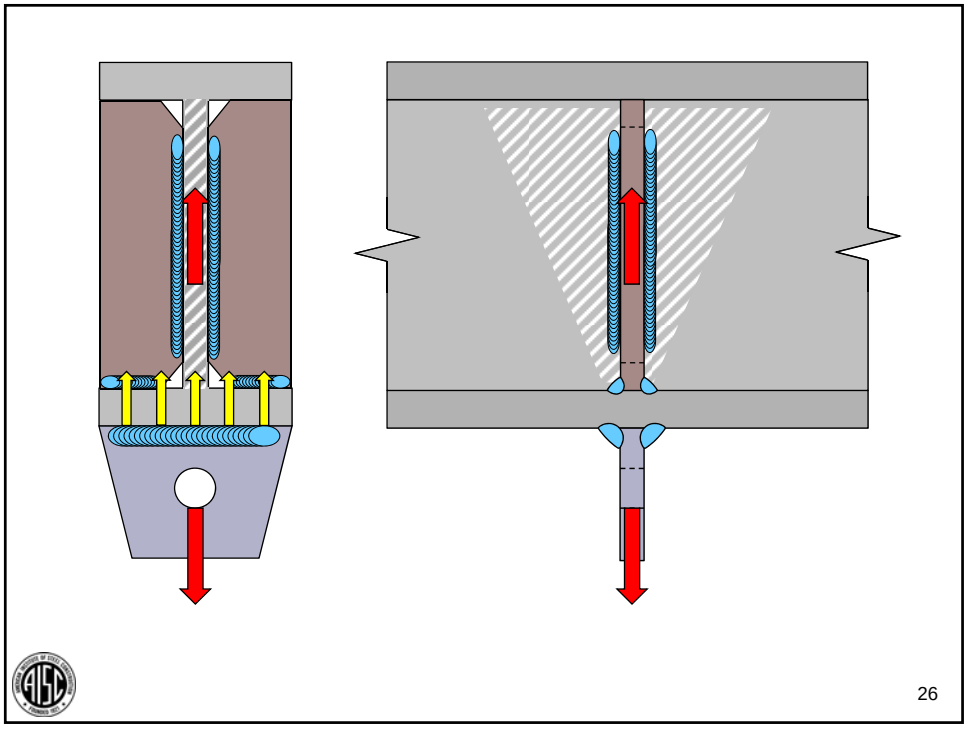
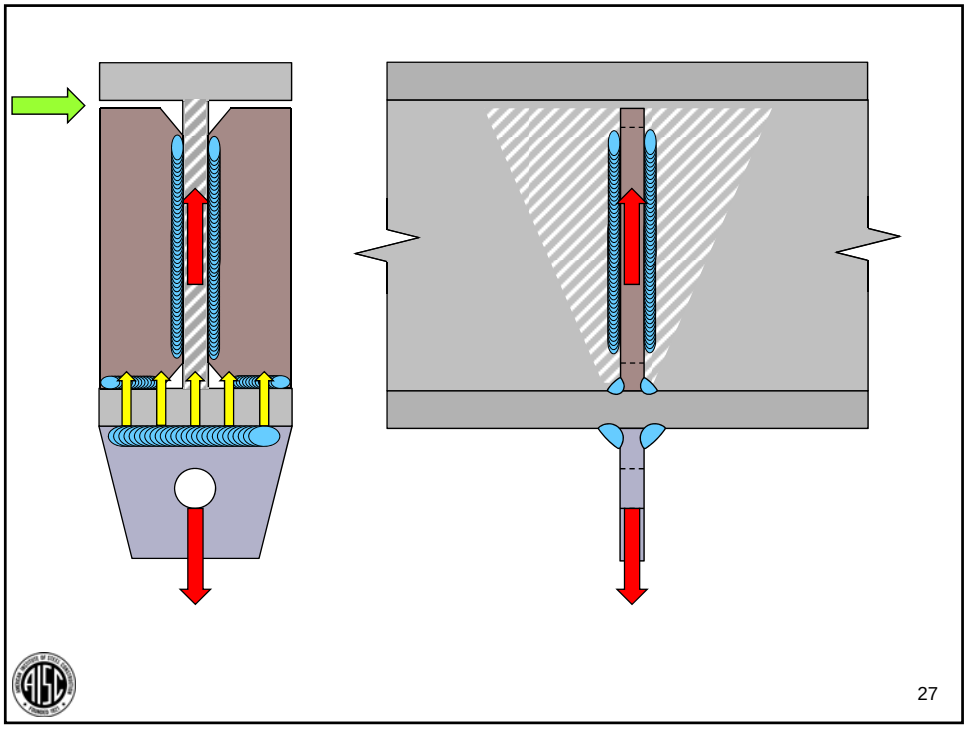
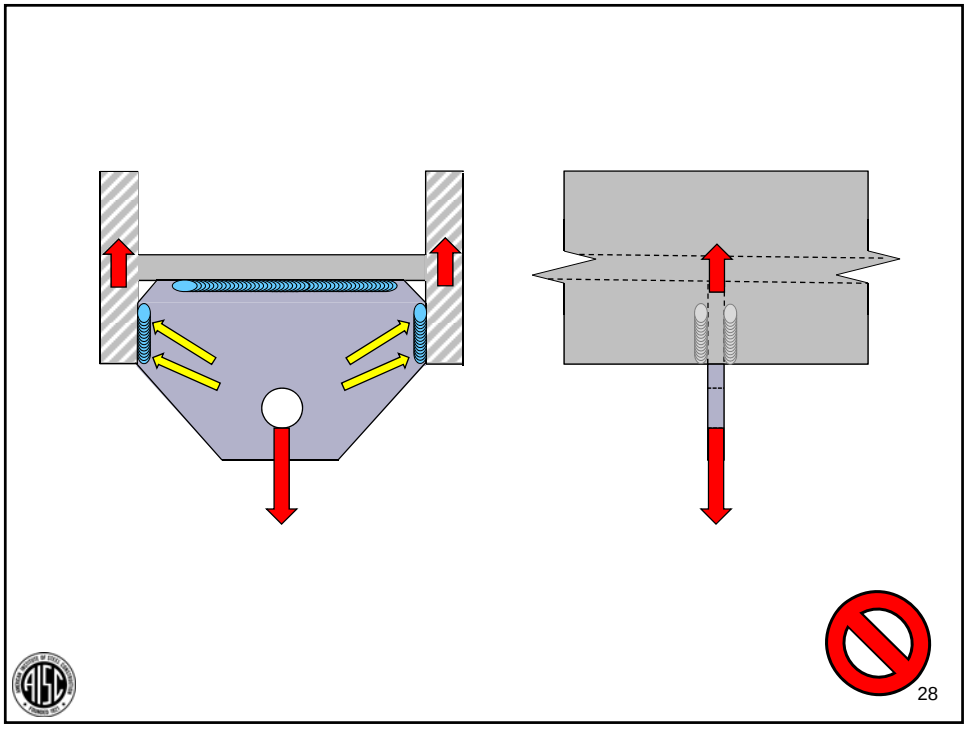
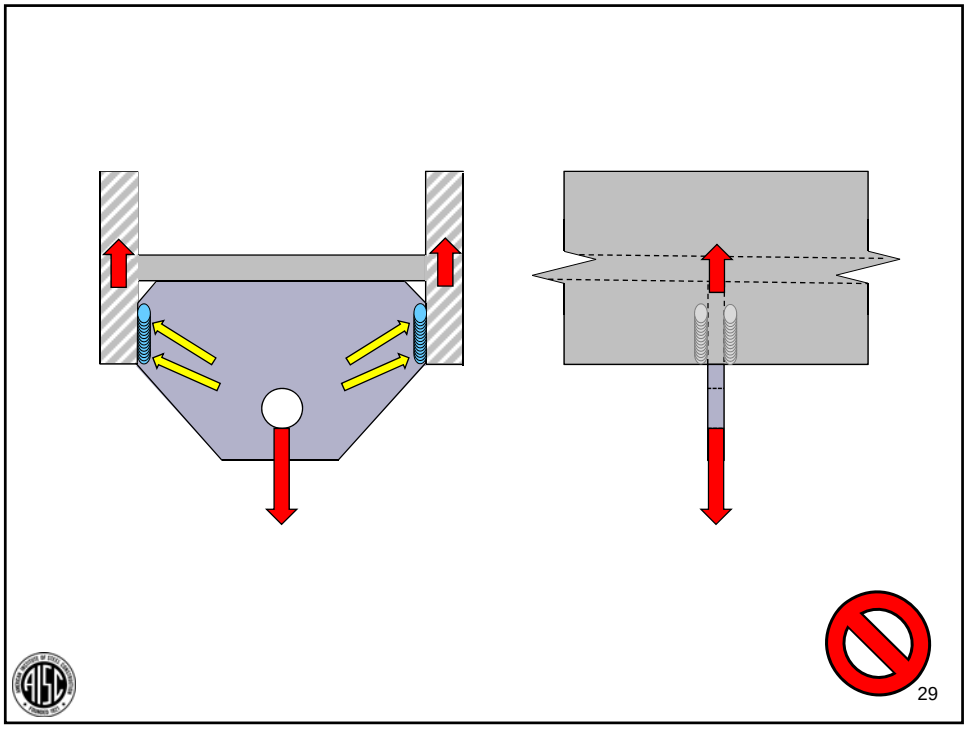
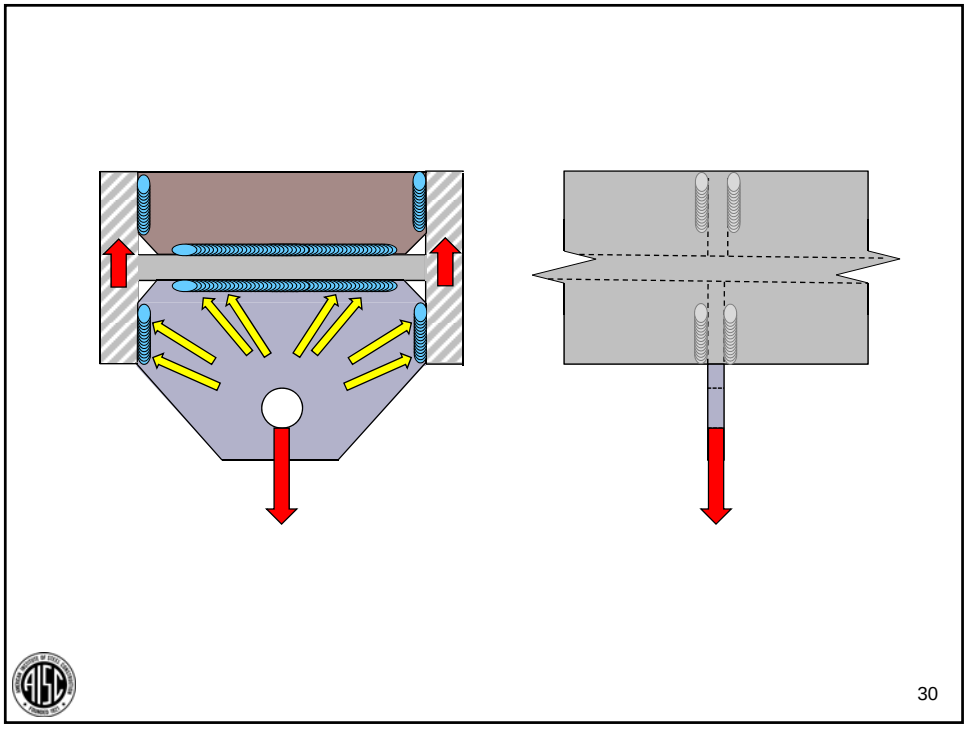


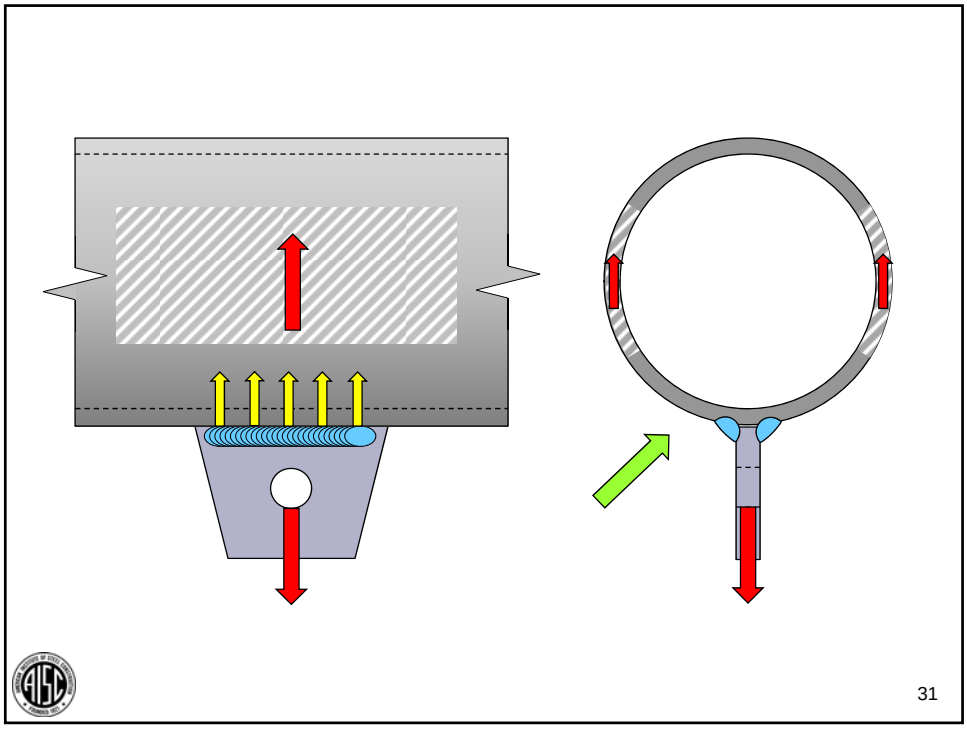


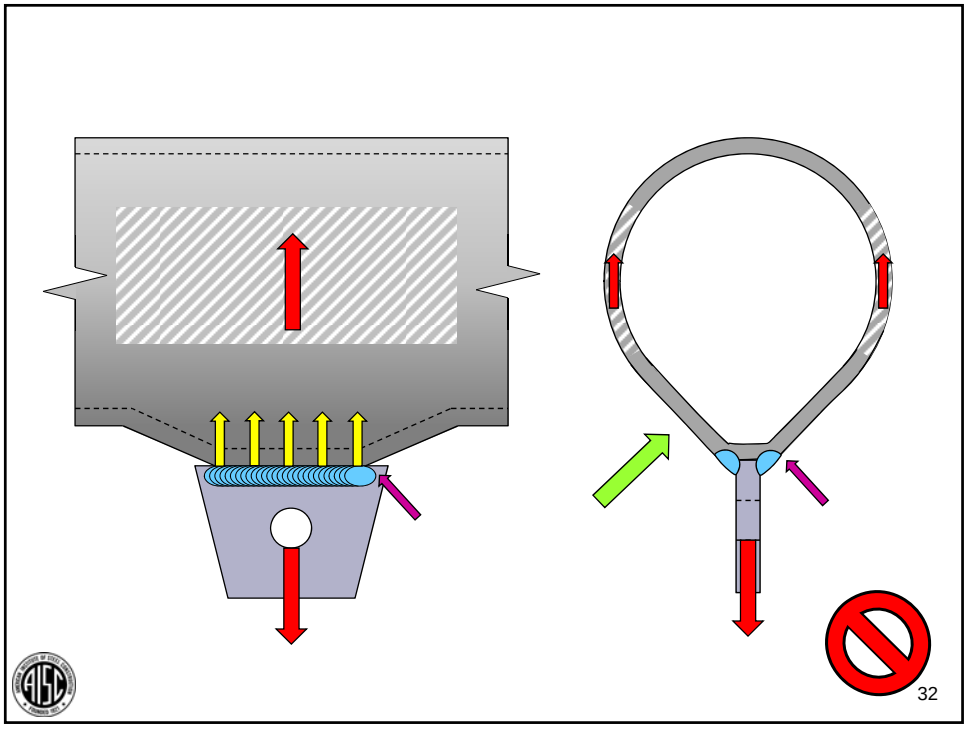


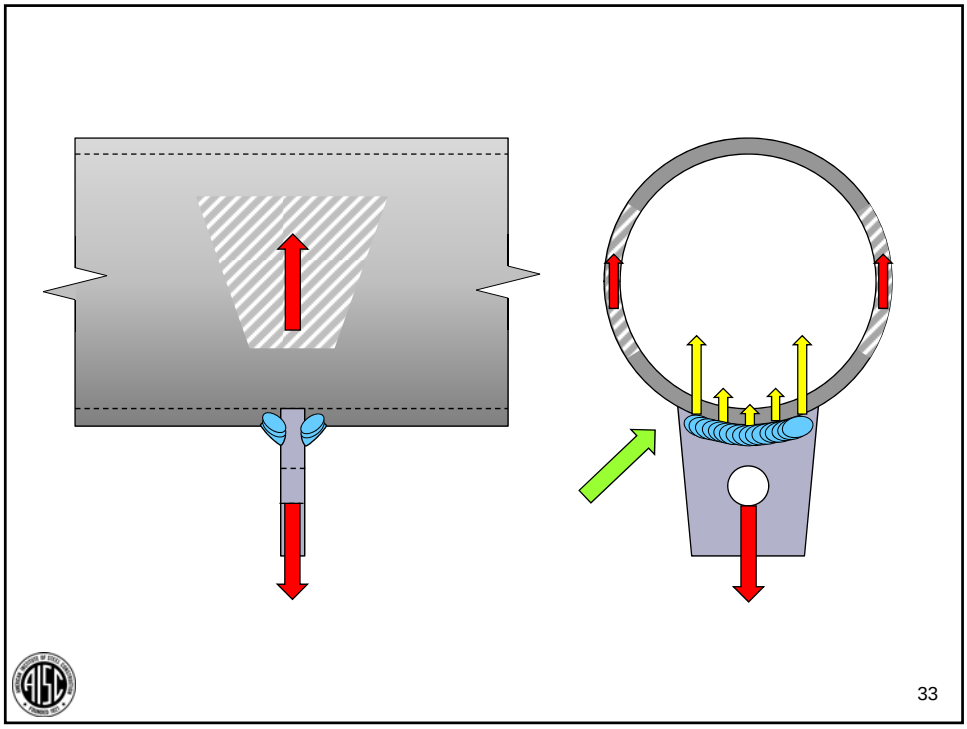


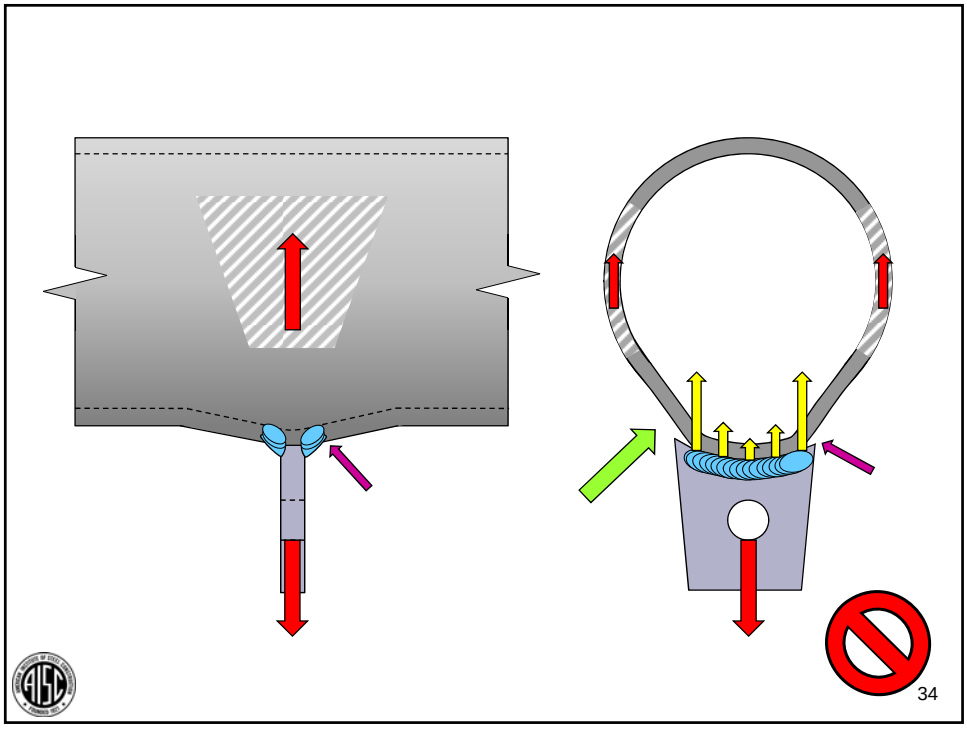


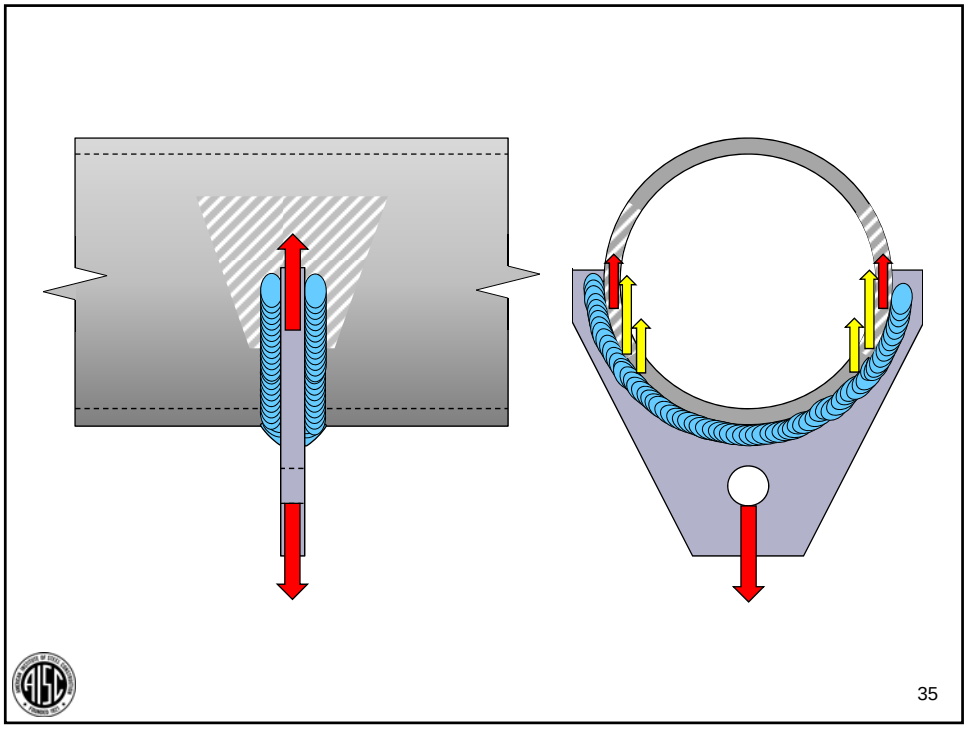


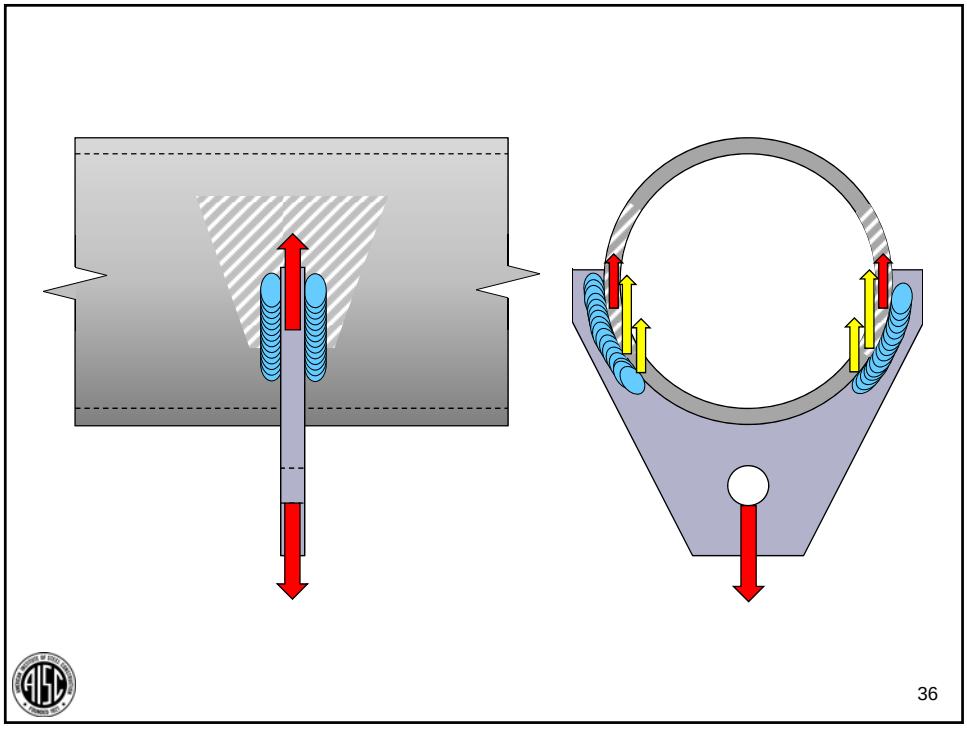


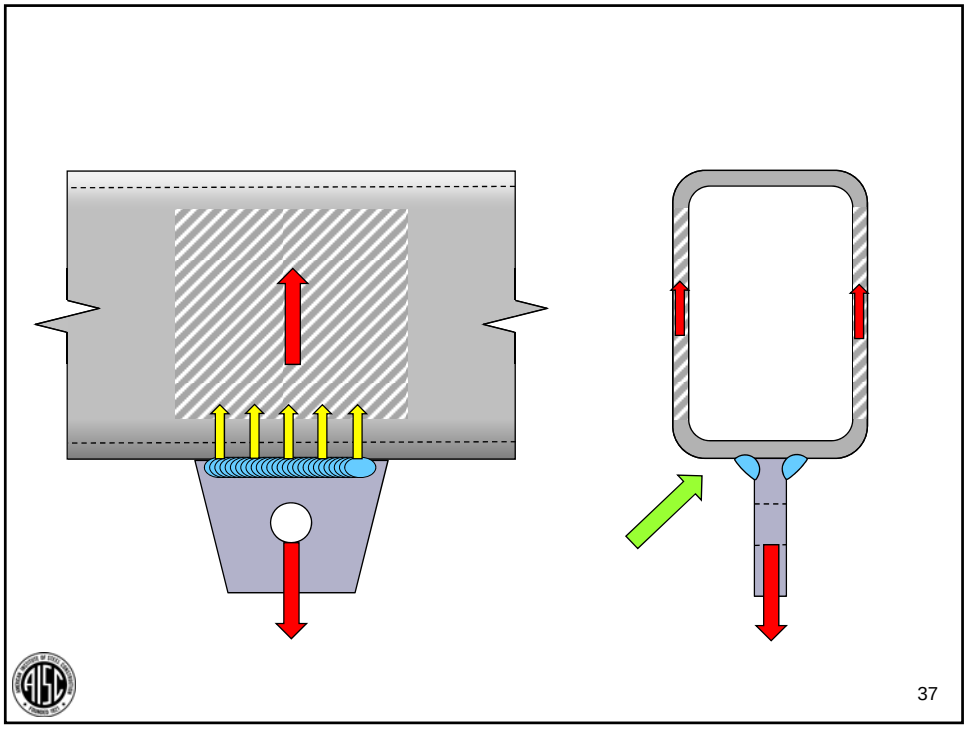


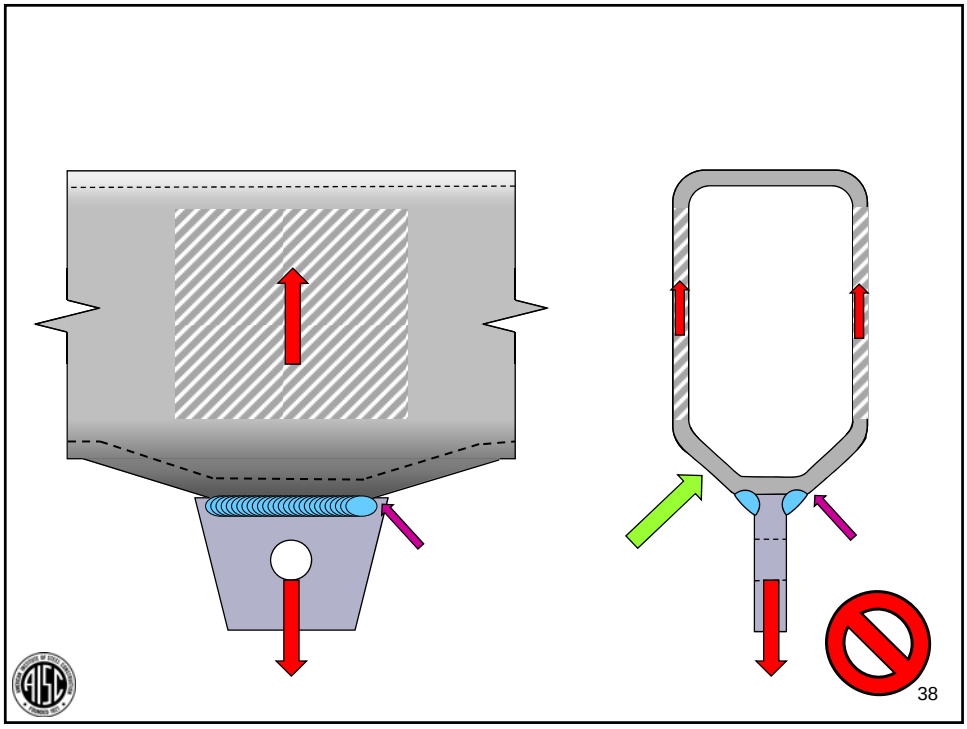


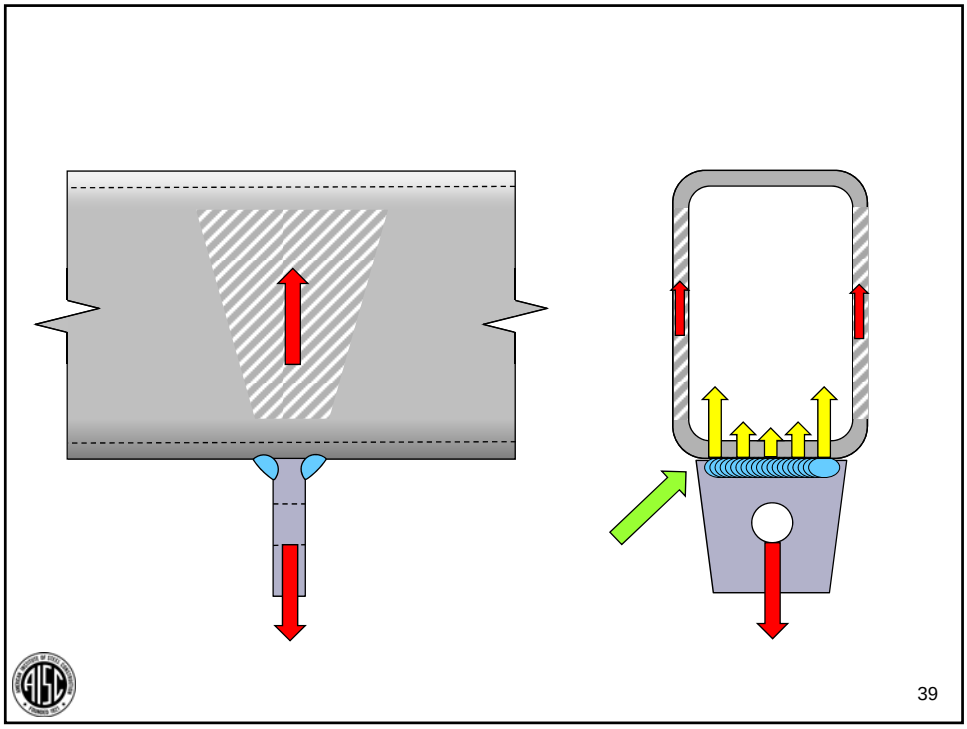


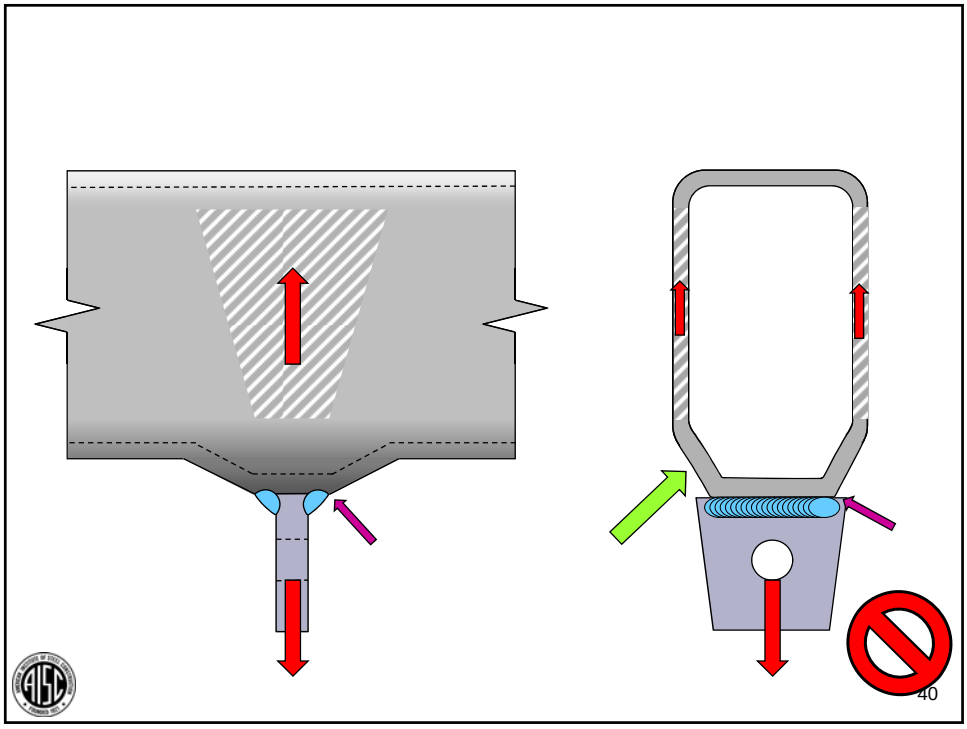


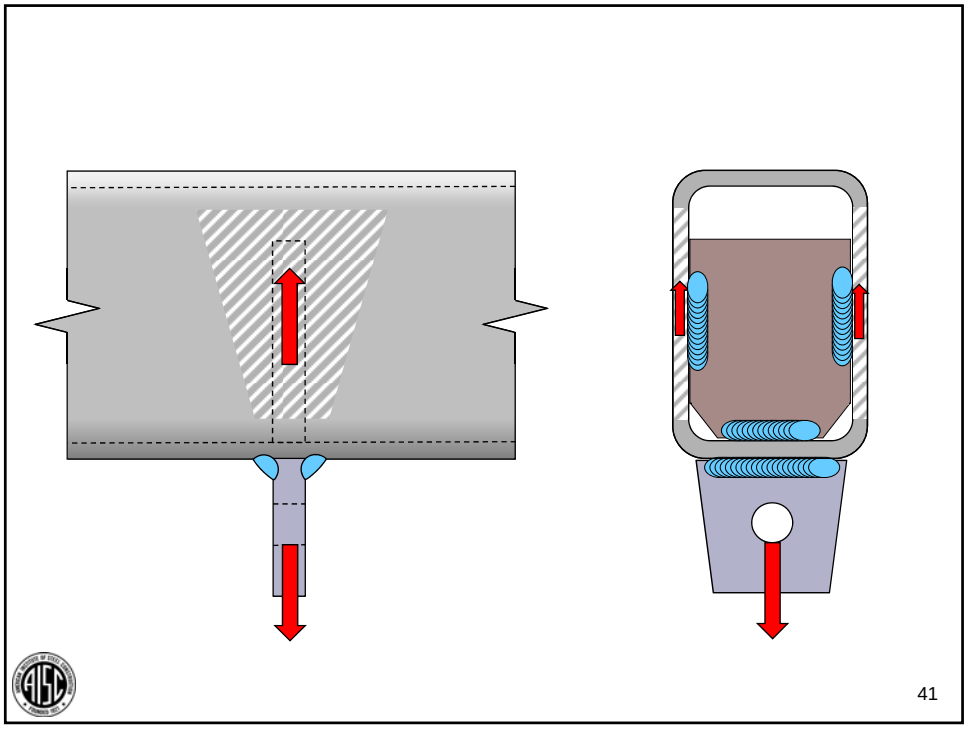


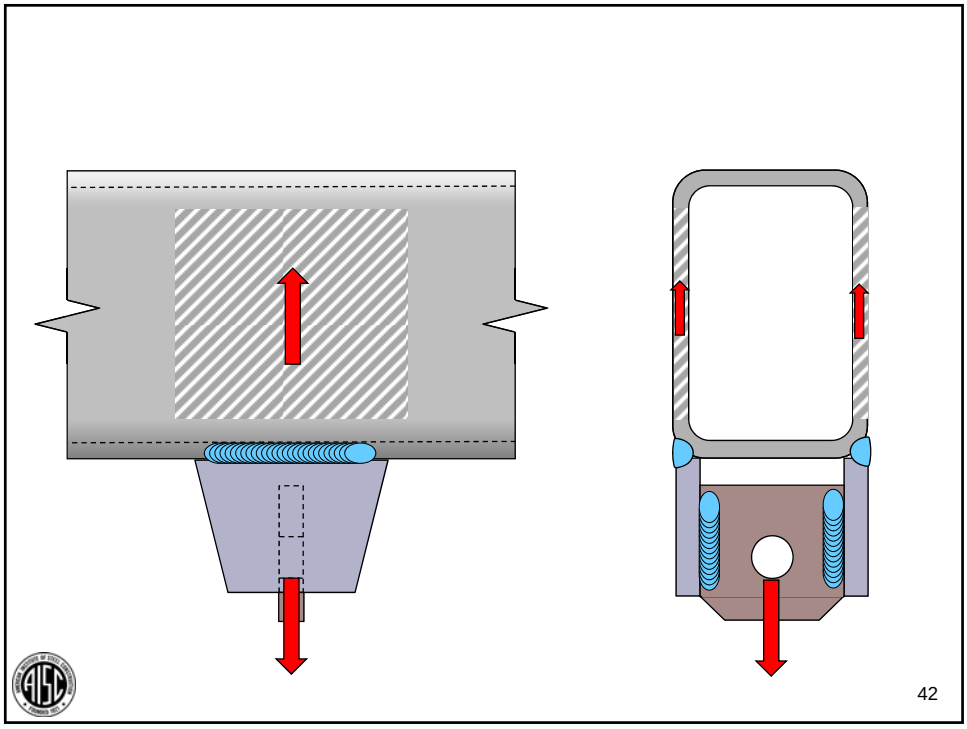


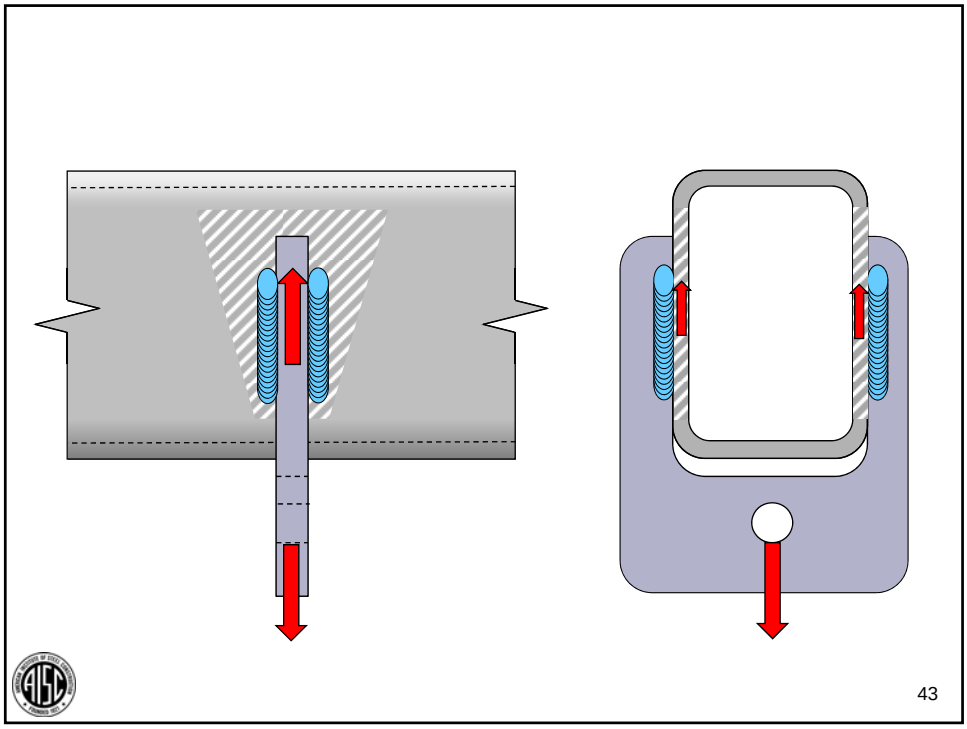












Principles of Connection Design

2

A correct and proper welded connection

has a clear and direct load path.

48

Principles of Connection Design

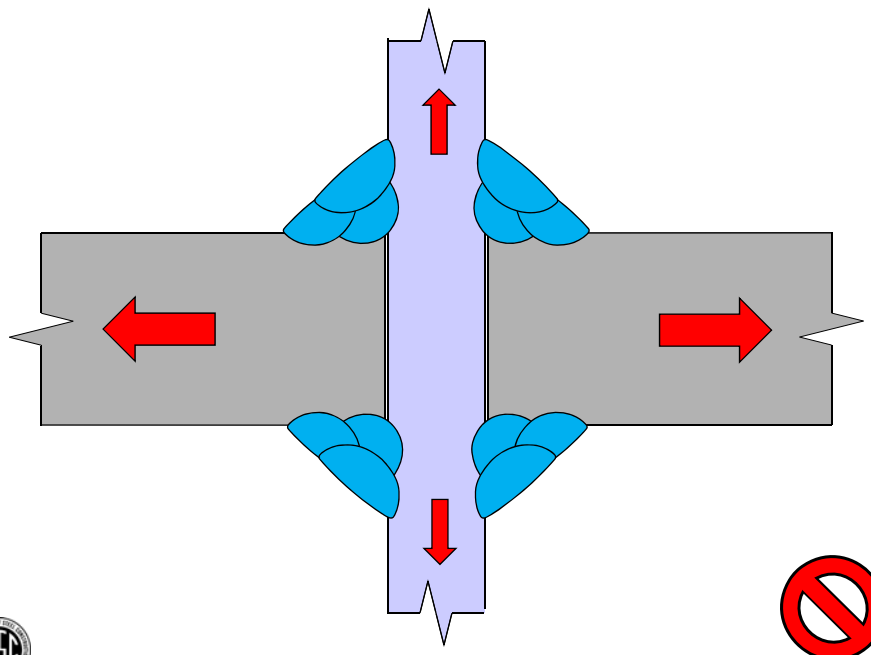
3

A correct and proper welded connection

places welds in regions of low stress.

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

49



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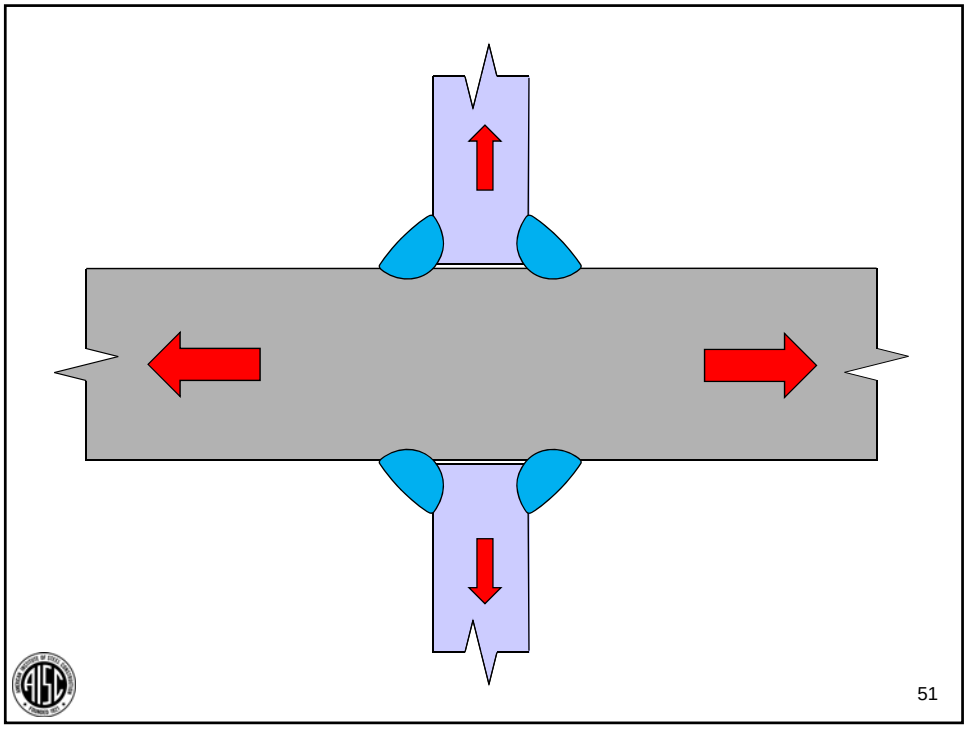
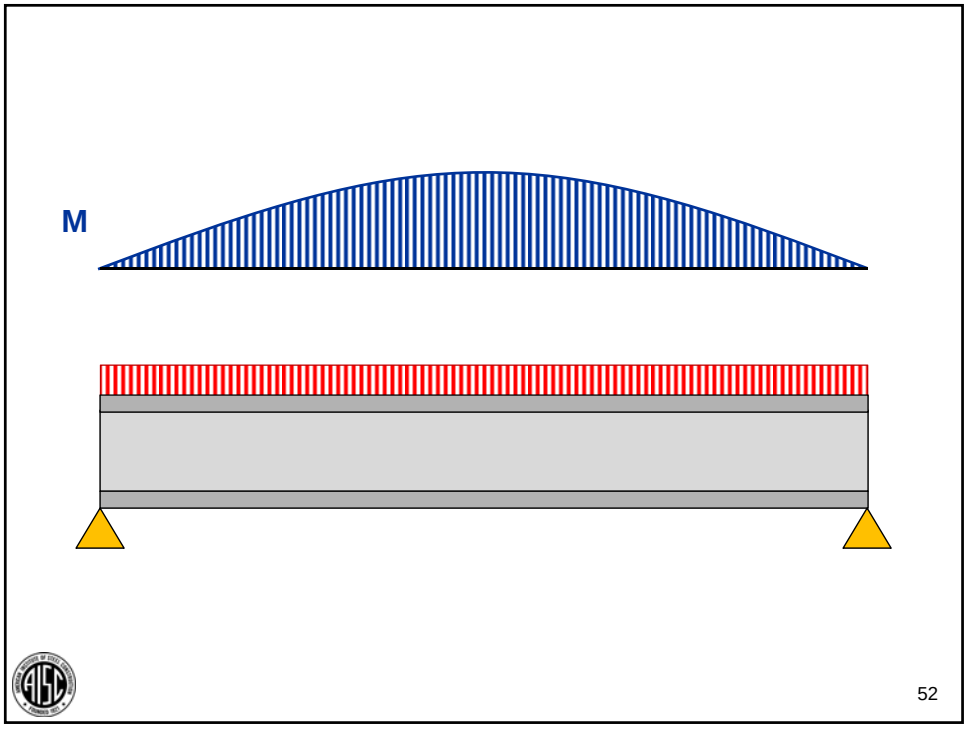
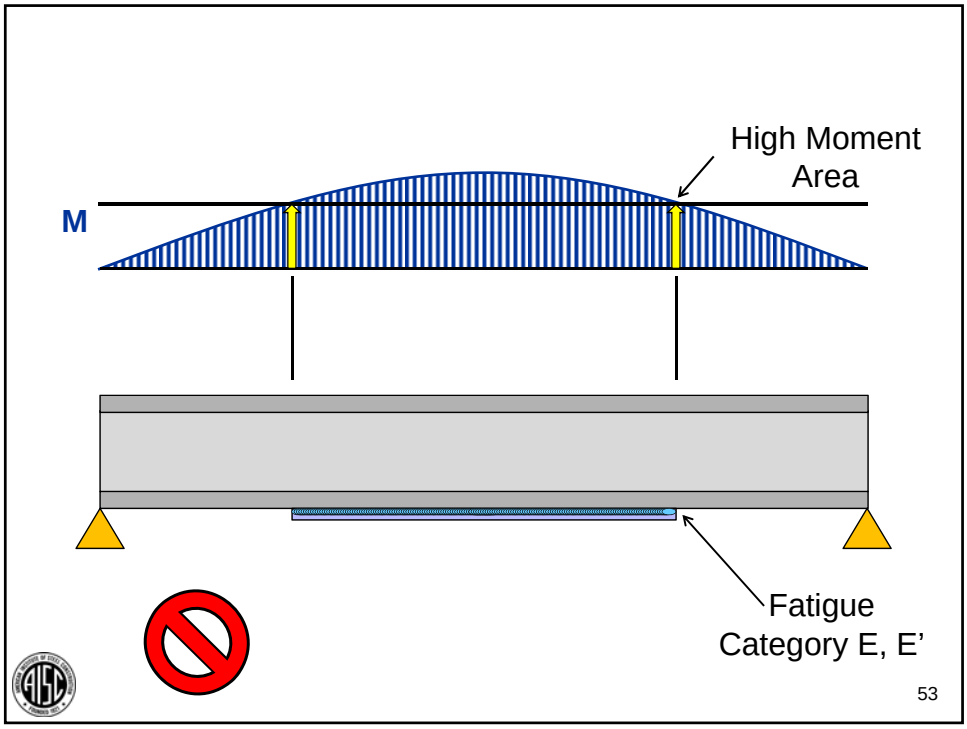
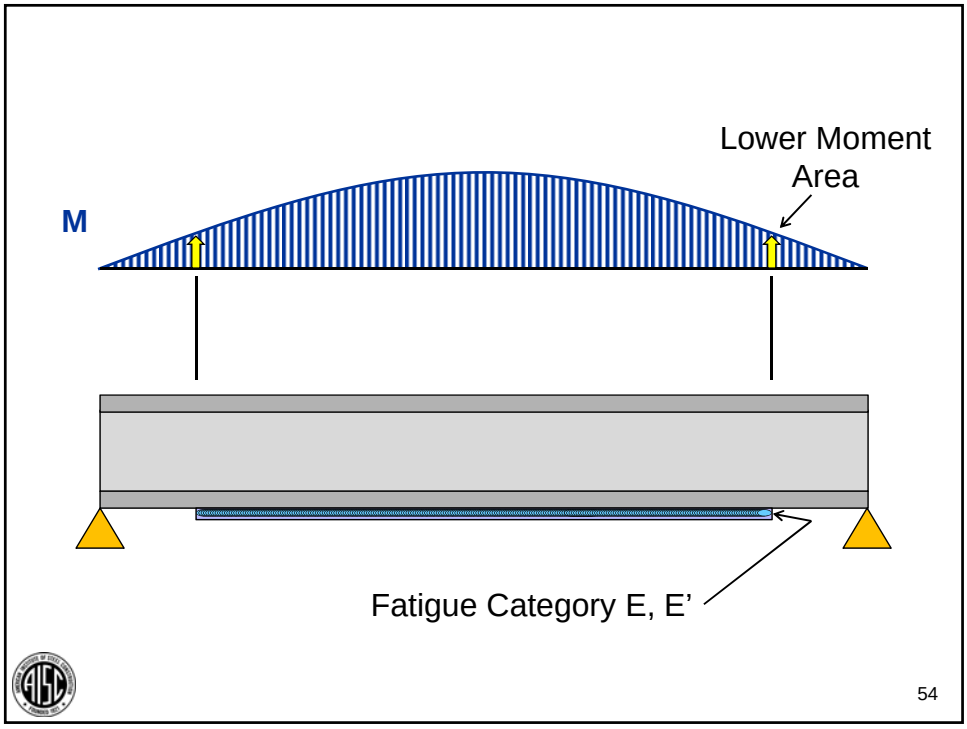








Principles of Connection Design

3

A correct and proper welded connection

places welds in regions of low stress.

55

Principles of Connection Design

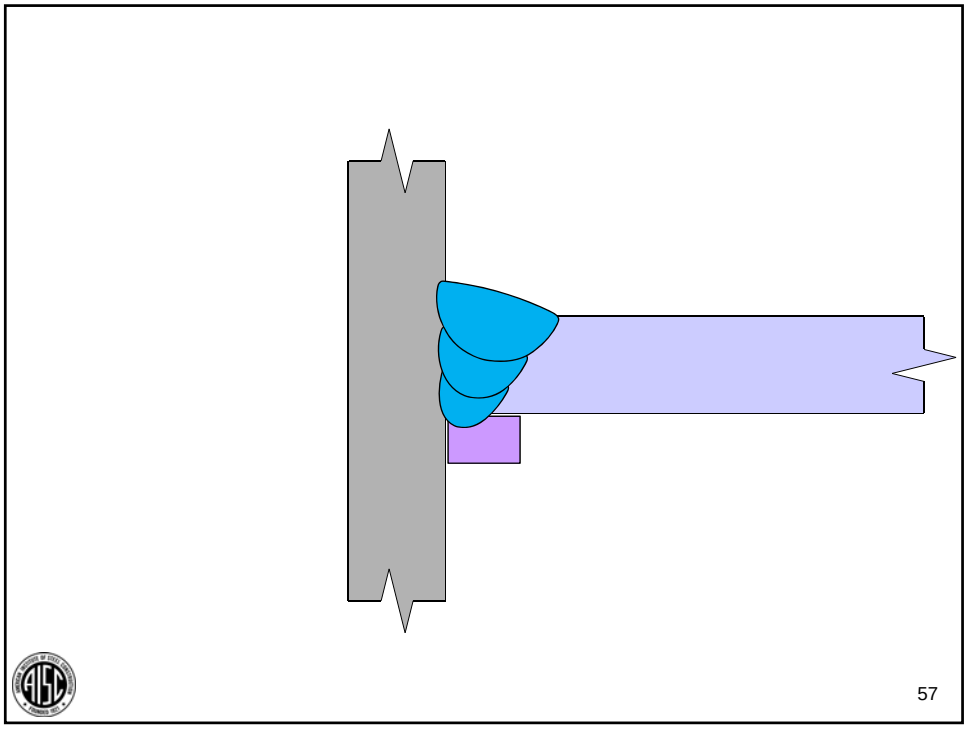
4

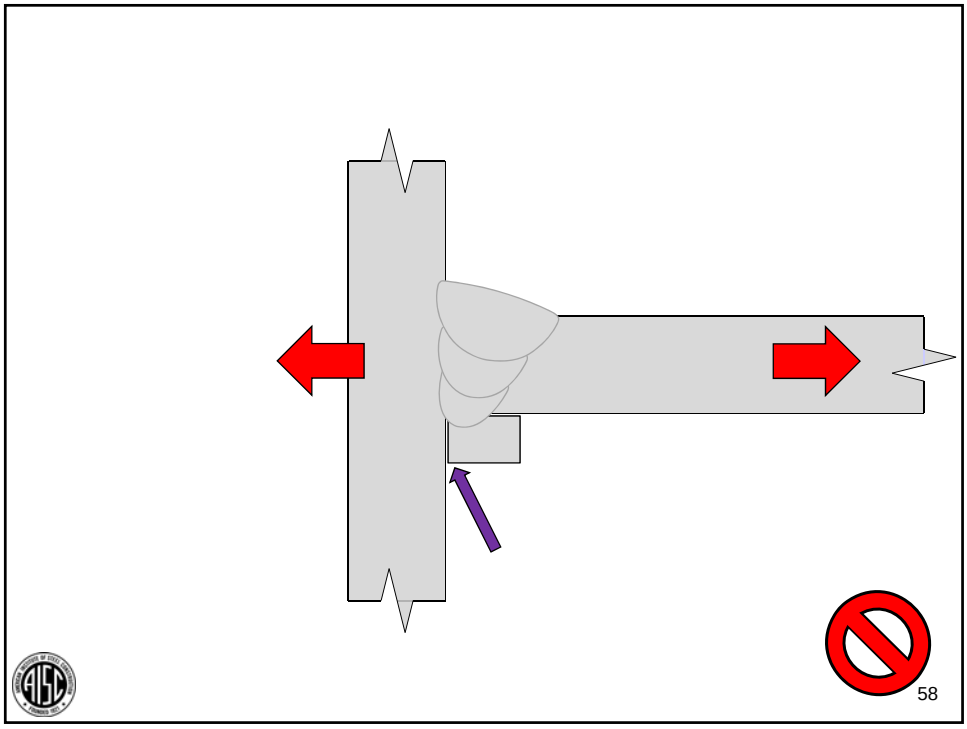
A correct and proper welded connection

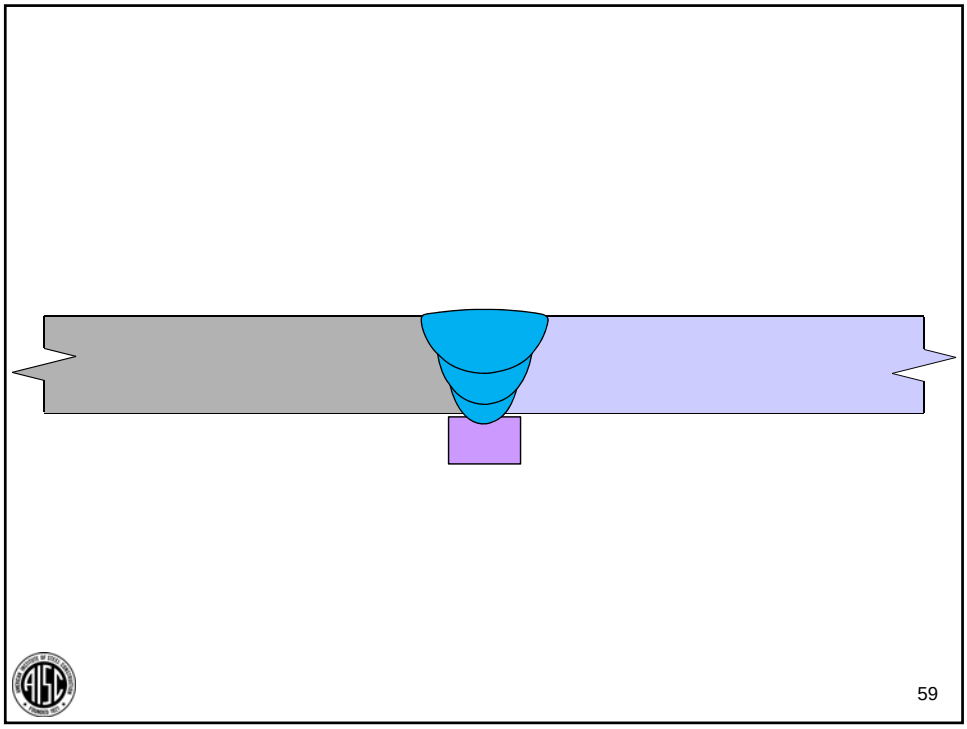
does not introduce stress raisers.

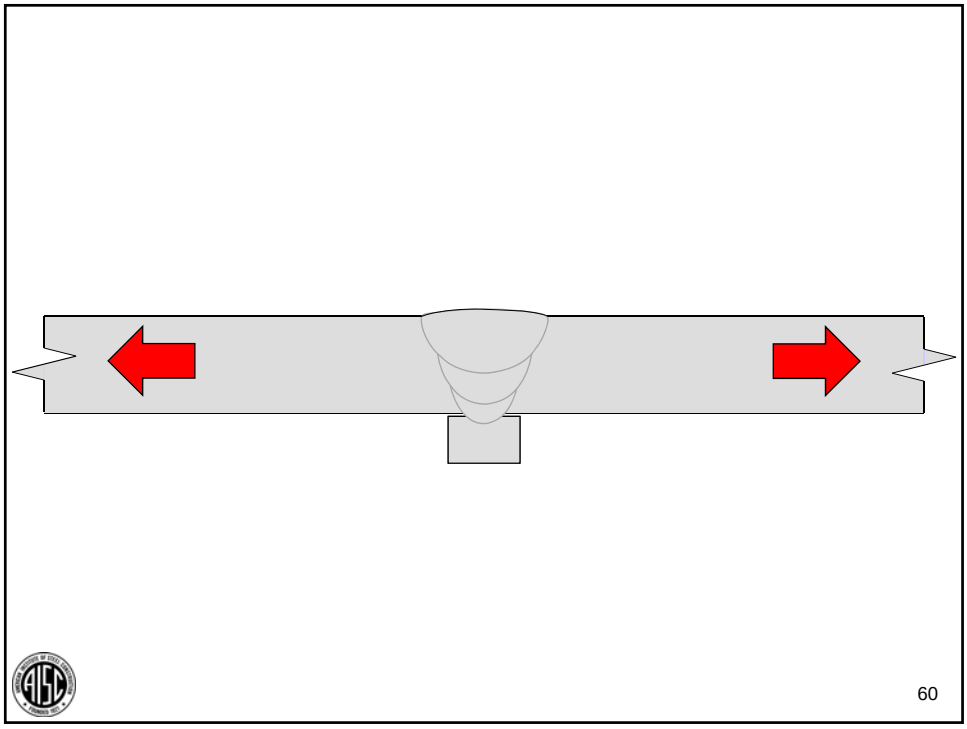
REMINDER:
Stress raisers are only stress raiser if there is a tensile stress component perpendicular to the stress raiser.

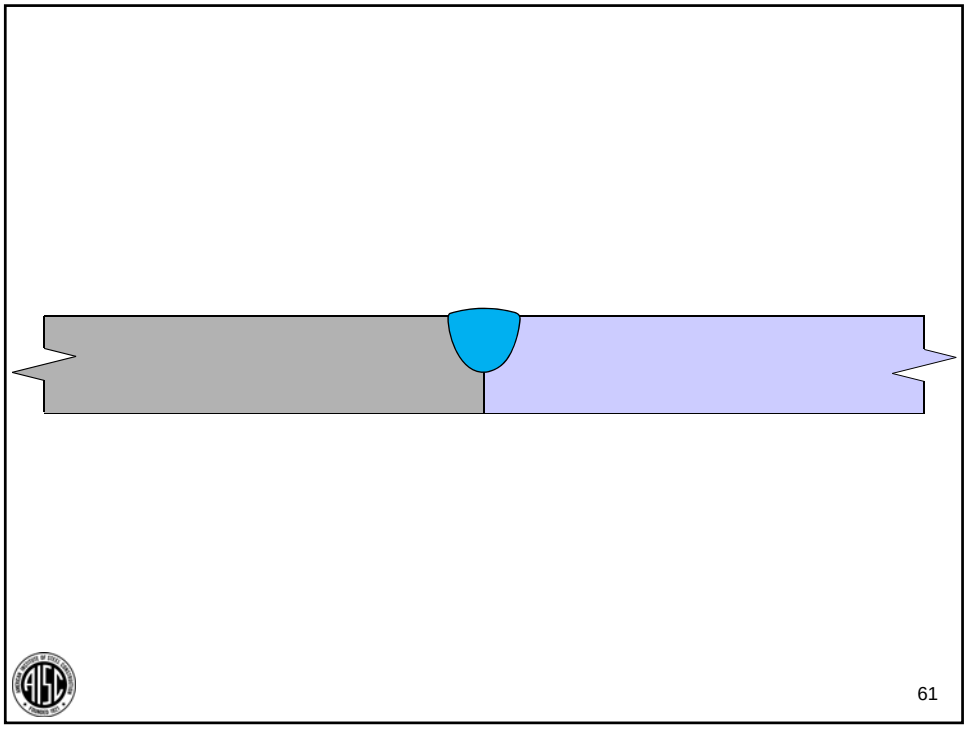
56

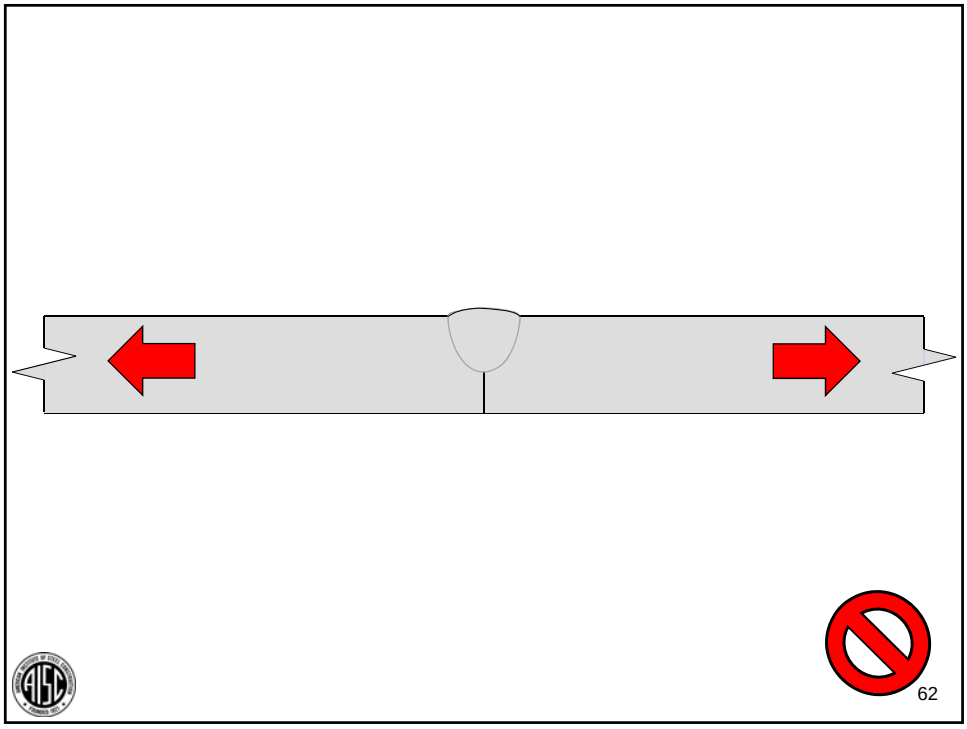


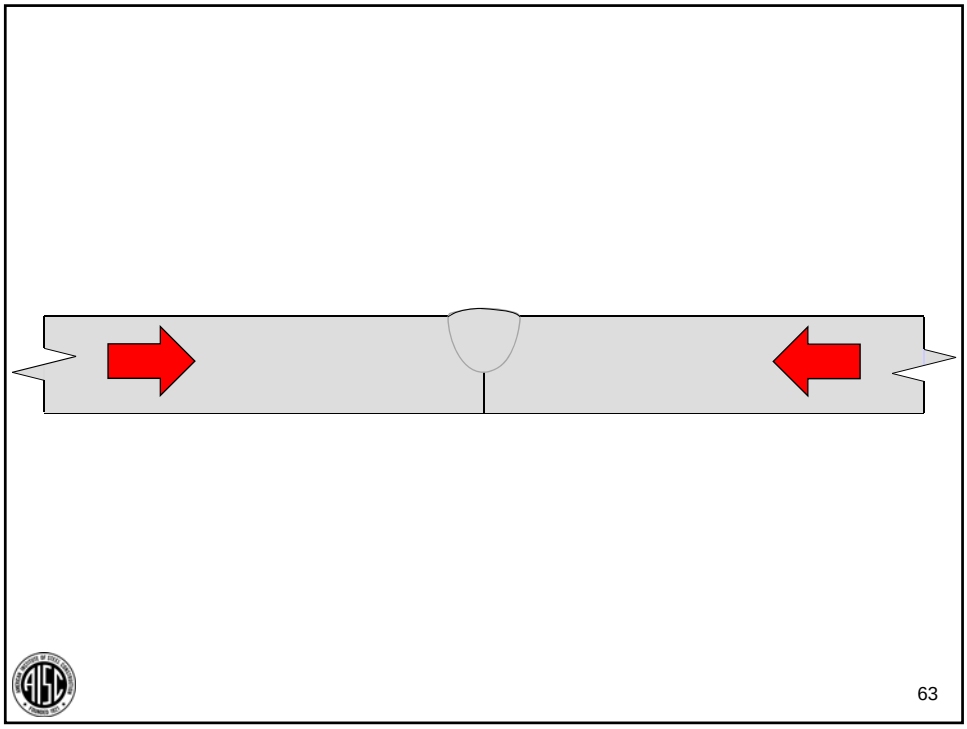


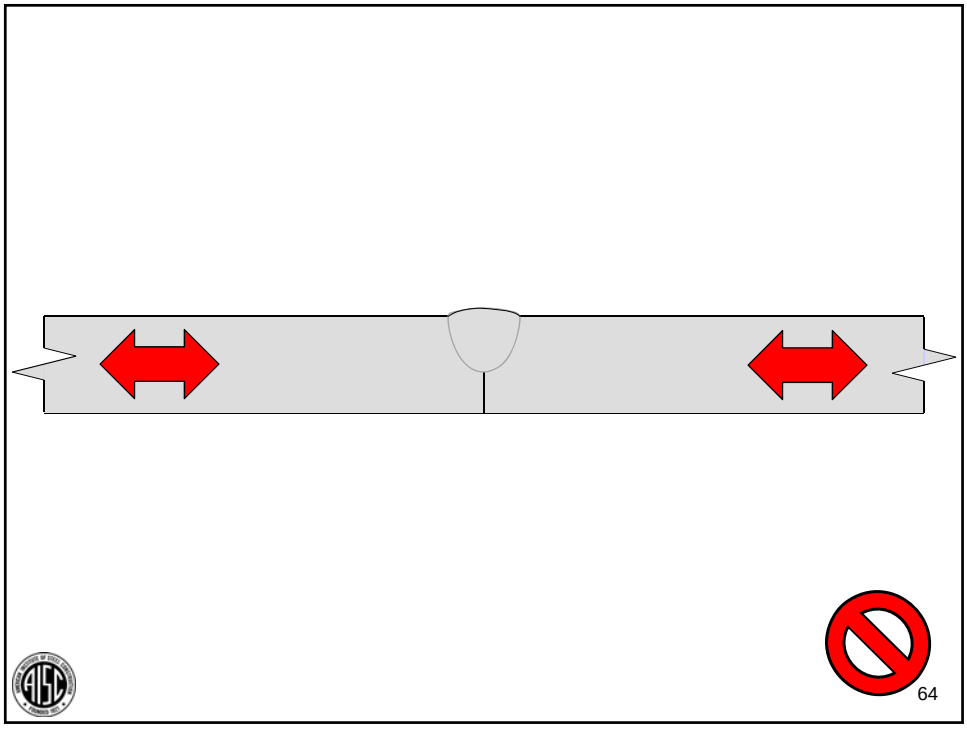


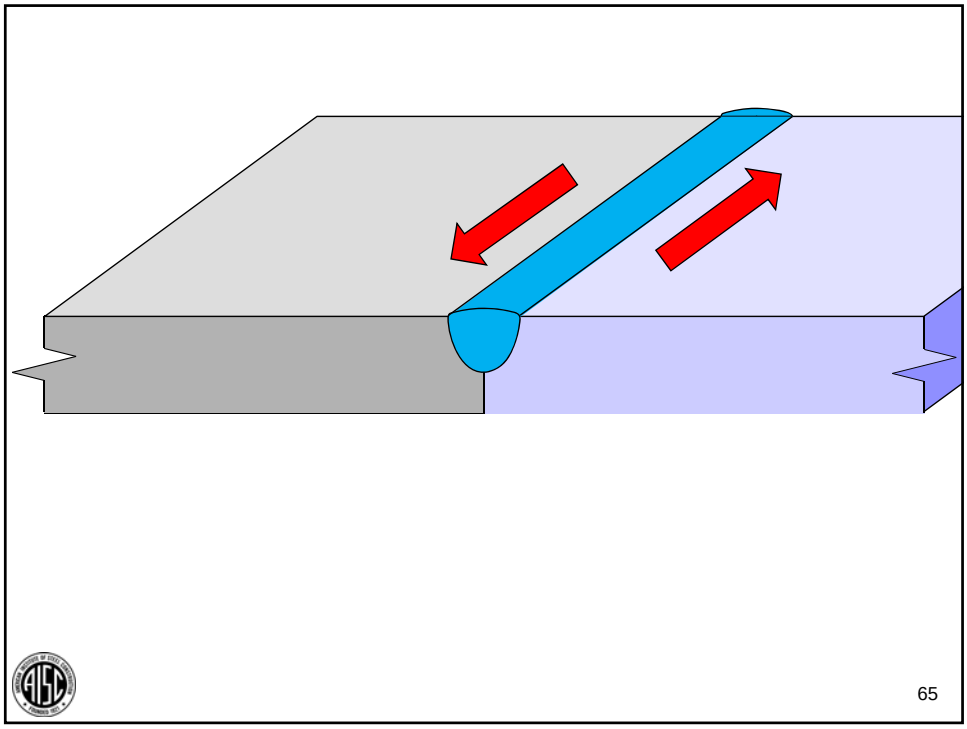


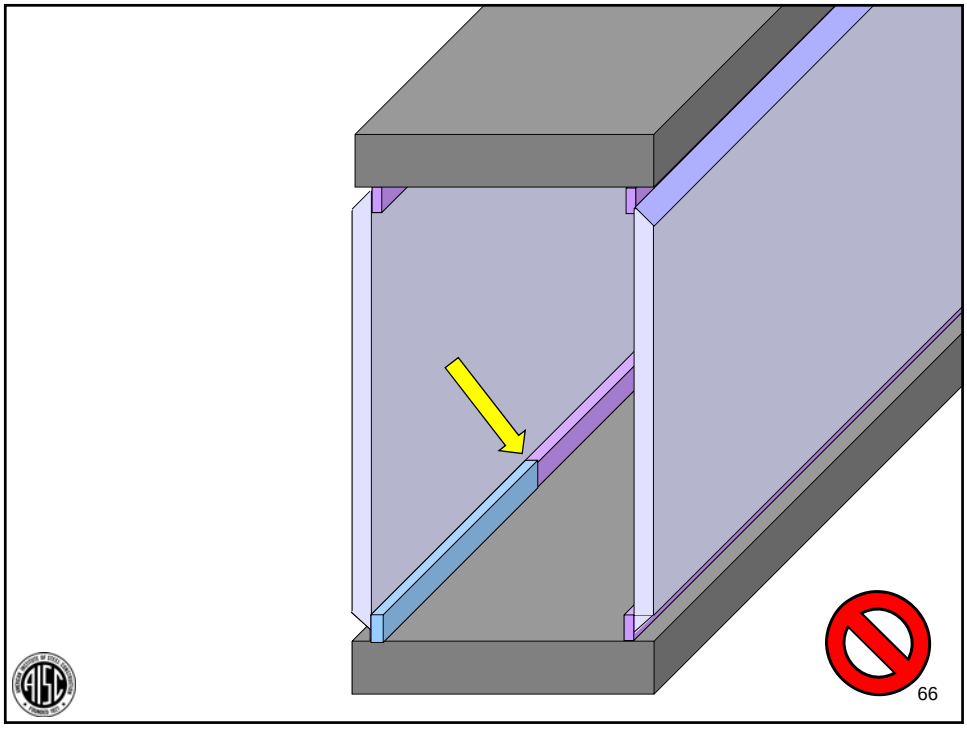


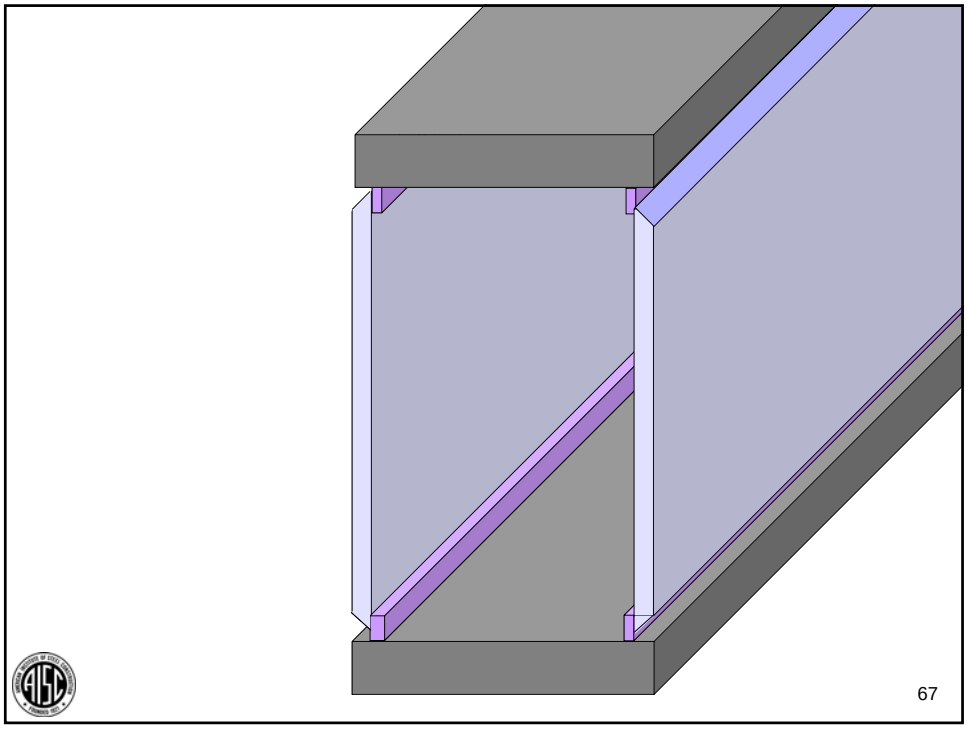












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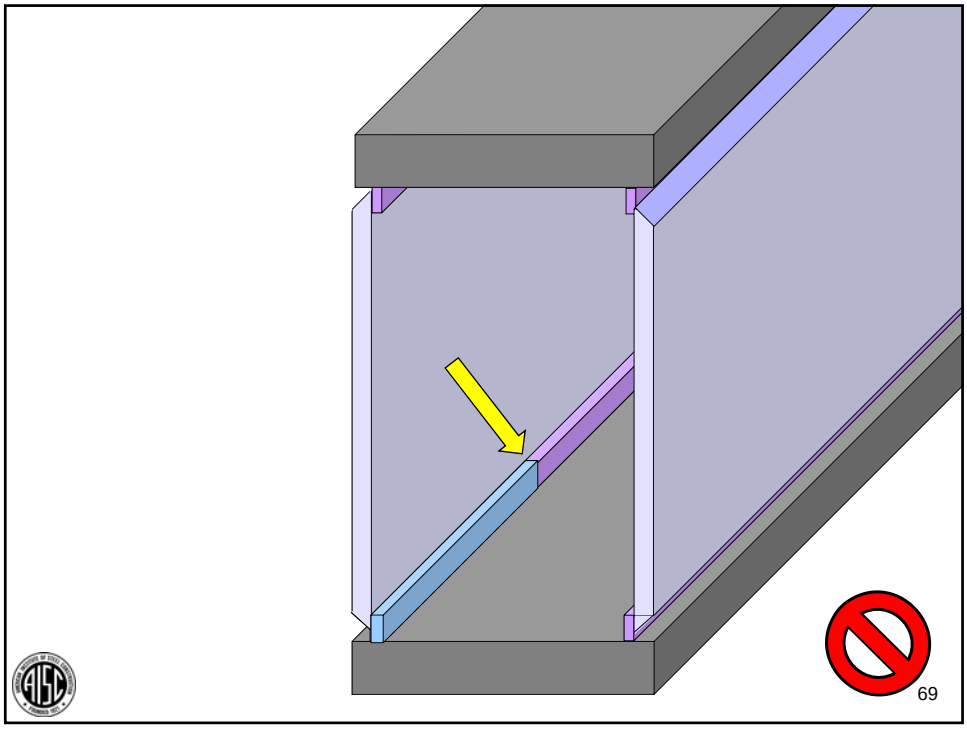
AWS D1.1:2010 Structural Welding Code--Steel

5.10.2 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 butt joints meeting all the requirements of Clause 5 of this code.

68



AWS D1.1:2010 Structural Welding Code--Steel

5.10.2 Full-Length Backing.

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70

AWS D1.1:2010 Structural Welding Code--Steel

5.10.2 Full-Length Backing (cont'd)

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:

71

Principles of Connection Design

4

A correct and proper welded connection

does not introduce stress raisers.

72

Principles of Connection Design

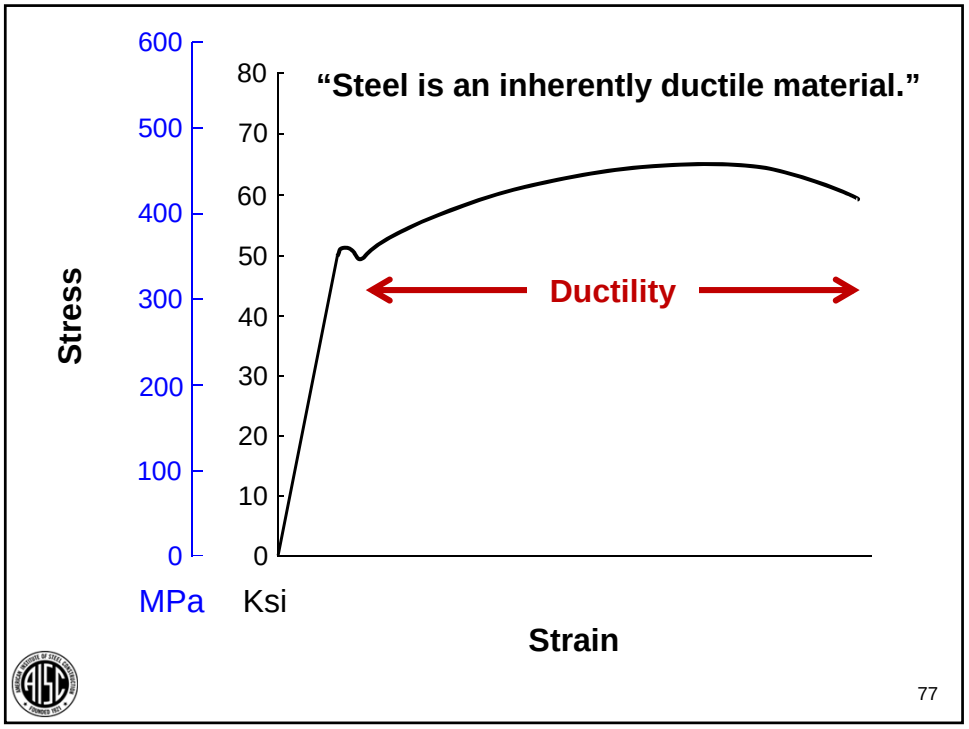
5

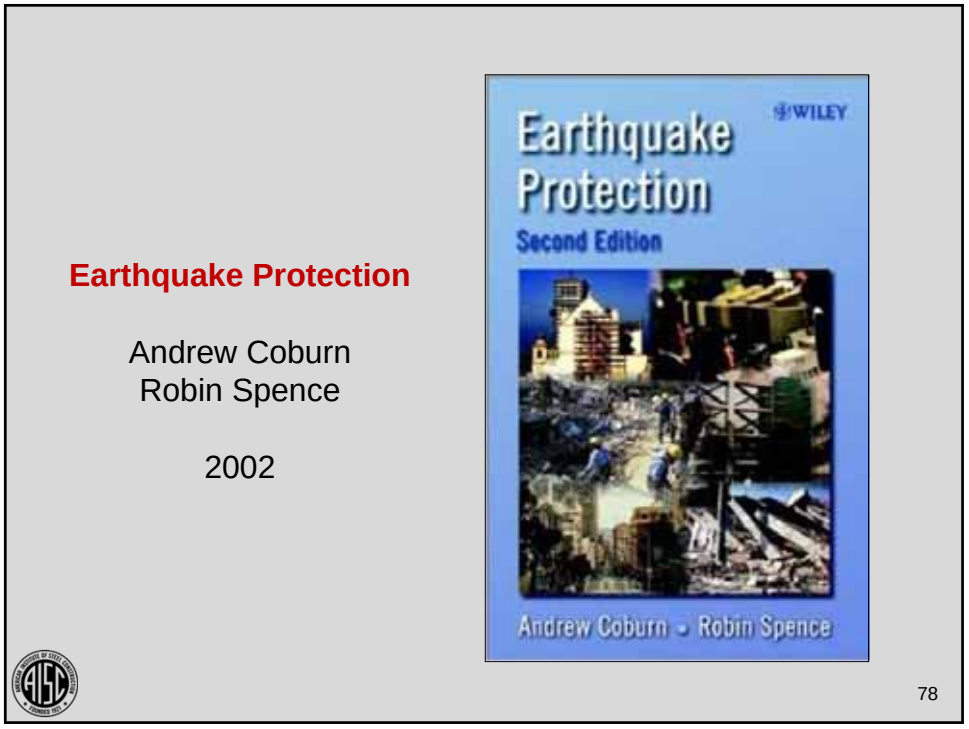
A correct and proper welded connection

is not constrained.

73

74





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)

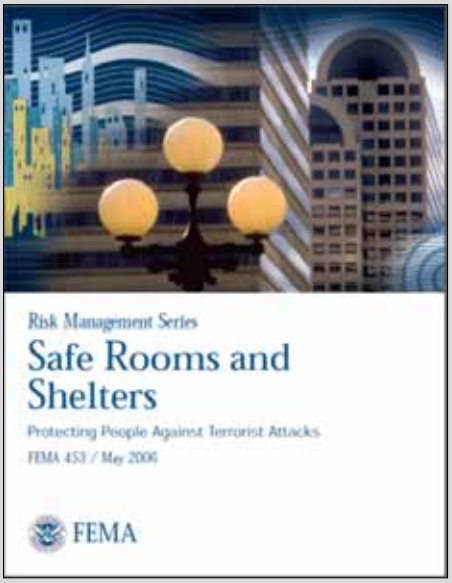
[16]Although welded joints can be a source of weakness and have resulted in some failures in recent earthquakes.

79

Safe Rooms and Shelters

Protecting People Against Terrorist Attacks

FEMA 453
May 2006



80

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

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.

81

US Army Corps of Engineers
Technical Instructions

Structural Design Criteria for Buildings

1999

82

d. Ductility. It is desirable, and required by code, that structures be ductile to avoid brittle failure mechanisms which could lead to an unexpected failure. Ductility is imperative for the design of earthquake resistant structures.

(1) Structural steel is an inherently ductile material. The ductility of steel structures is achieved by designing connections to avoid tearing or fracture and by ensuring an adequate path for loads to travel across the connection. Detailing for adequate stiffness and restraint of compressive braces, outstanding legs of members, compression flanges, etc. must be provided to avoid local and global instability by buckling of relatively slender steel members acting in compression. Deflections must be limited to prevent overall frame instability due to P-Δ effects. Steel bracing systems must be configured such that bracing forces can not distort columns in a manner that would amplify P-Δ effects Refer to TI 809-04 for additional information on acceptable and unacceptable bracing systems).

(2) Less ductile materials, such as concrete and unit-masonry, require steel

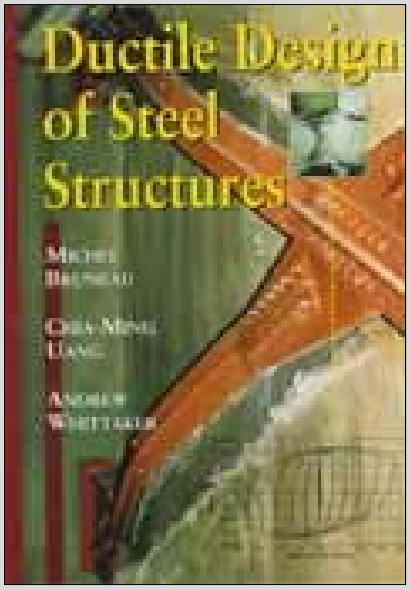
Structural steel in an inherently ductile material. The ductility of steel structures is achieved by designing connections to avoid tearing or fracture and by ensuring an adequate path for loads to travel across the connection.

83

Ductile Design of Steel Structures

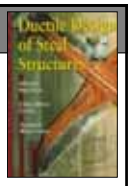
Bruneau
Uang
Whittaker

1998



84

Ductile Design of Steel Structures

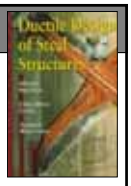


Preface

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

85

Ductile Design of Steel Structures

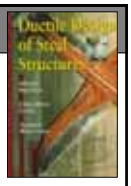


Chapter 1 Introduction

"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."

86

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."

87

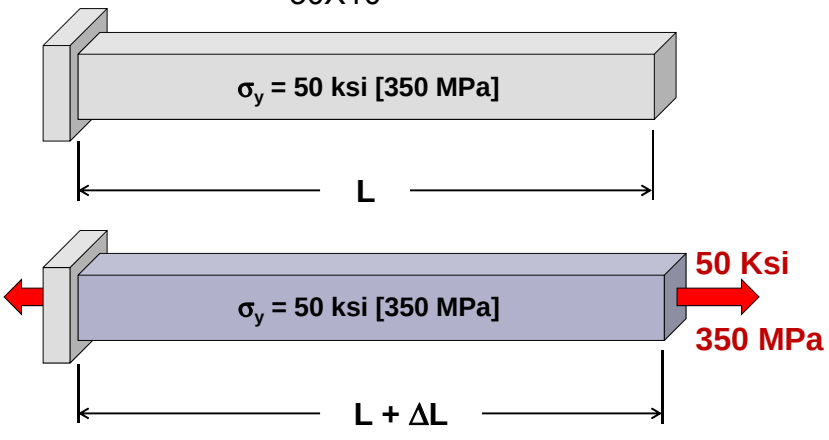
Fatigue and Fracture Control in Structures

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.

88

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

$$= \frac{50 \quad (10)}{30X10^{3}} = 0.017 \text{ in } [0.17\%]$$

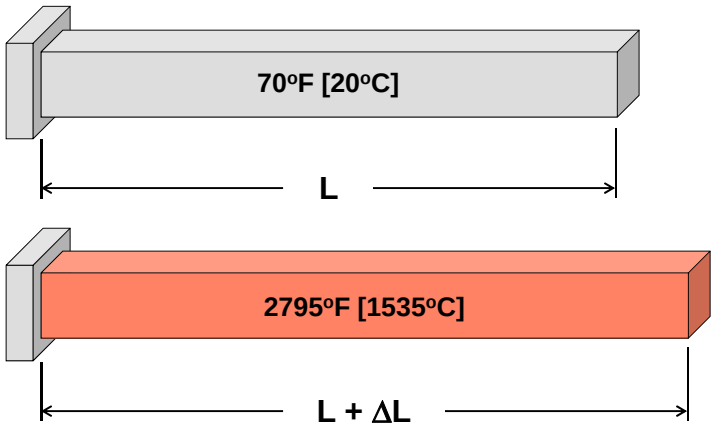


89

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

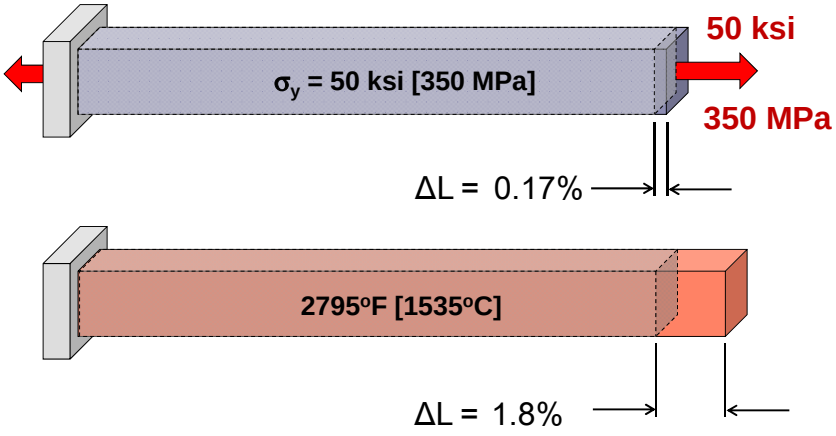
$$= 10 \ (2795 - 70) \ (6.6x10^{-6} \ )$$

$$= 0.18 \text{ in } [1.8\%]$$



90

Thermal expansion is approximately 10X yield elongation.



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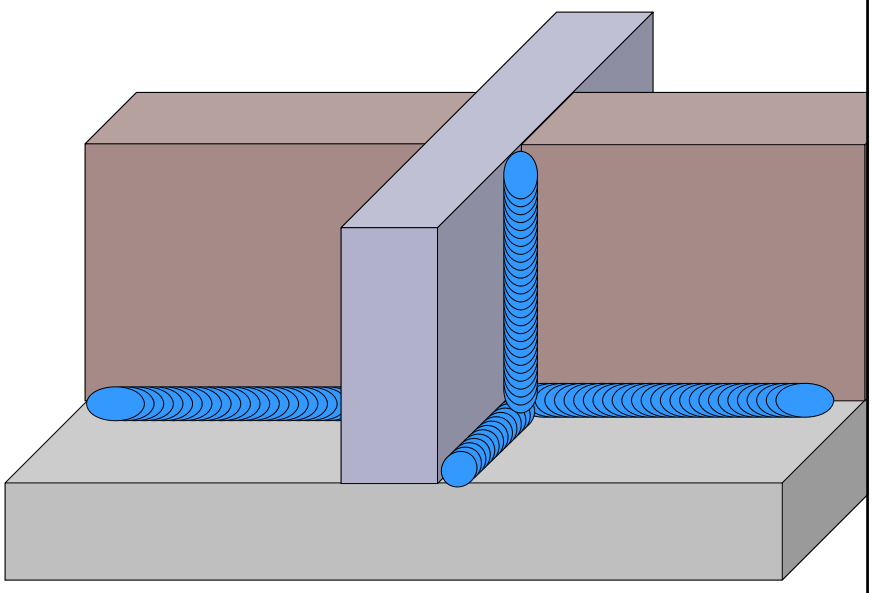
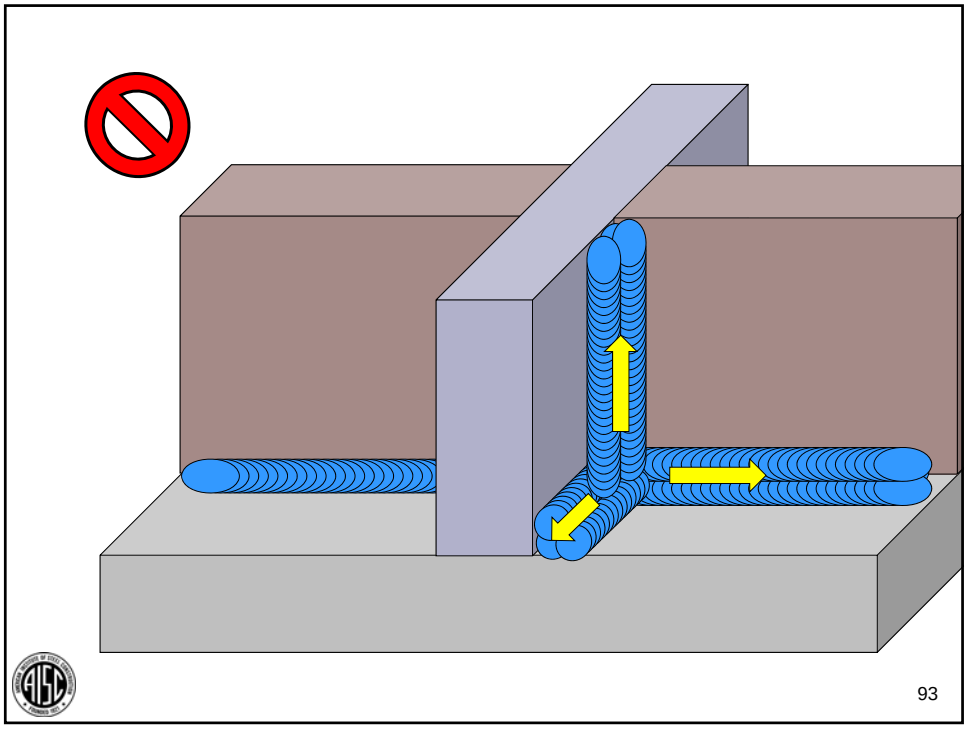
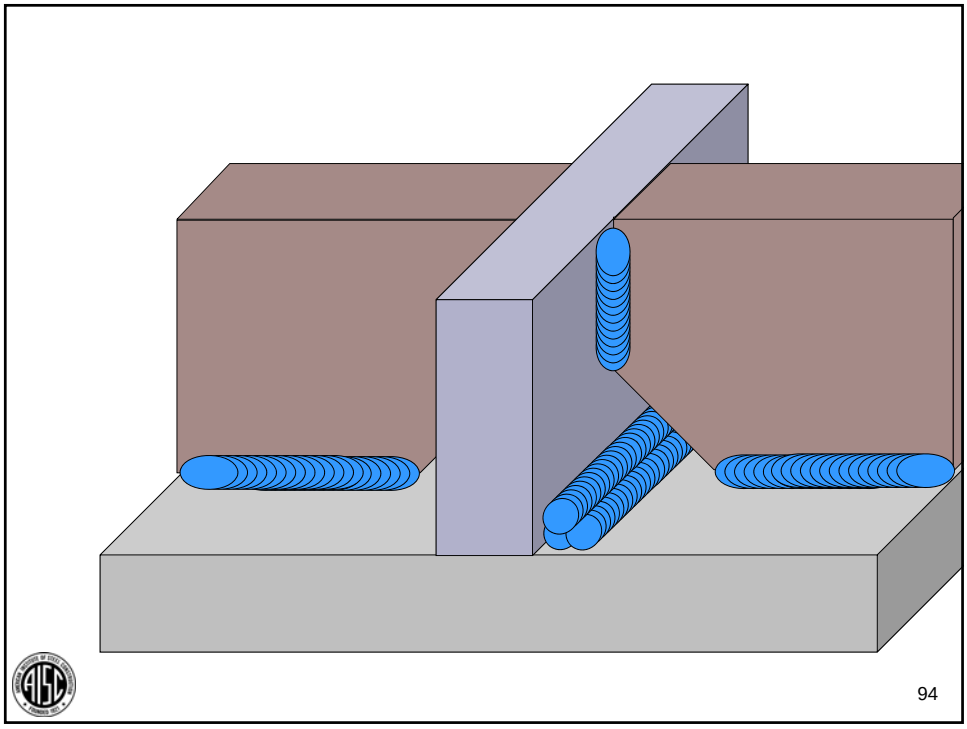
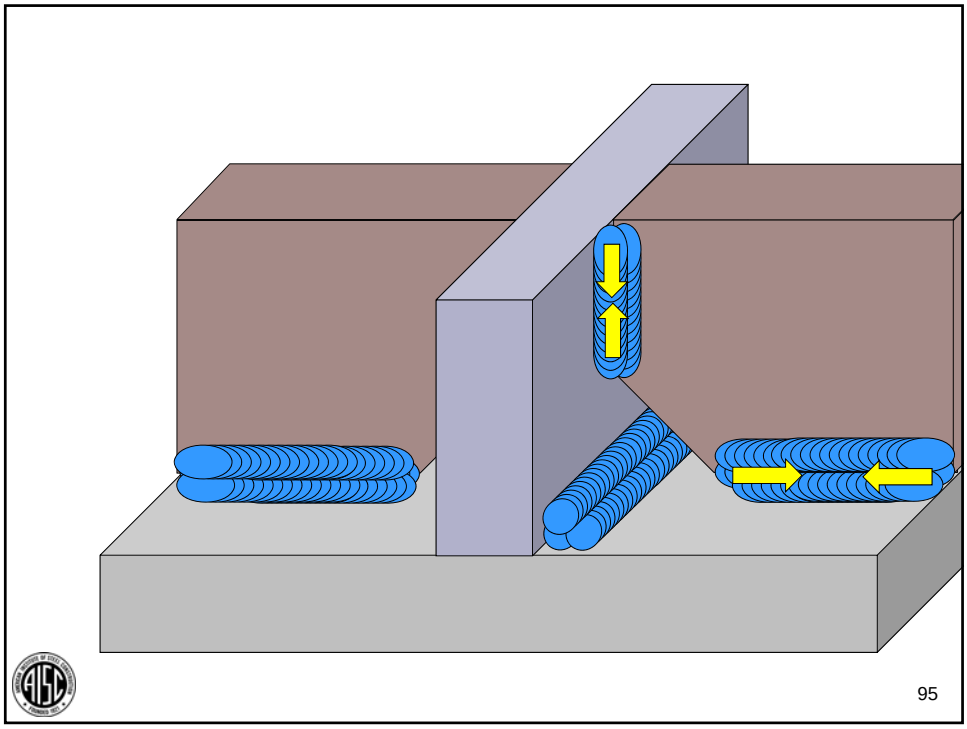


92







95

Principles of Connection Design

5

A correct and proper welded connection

is not constrained.

96

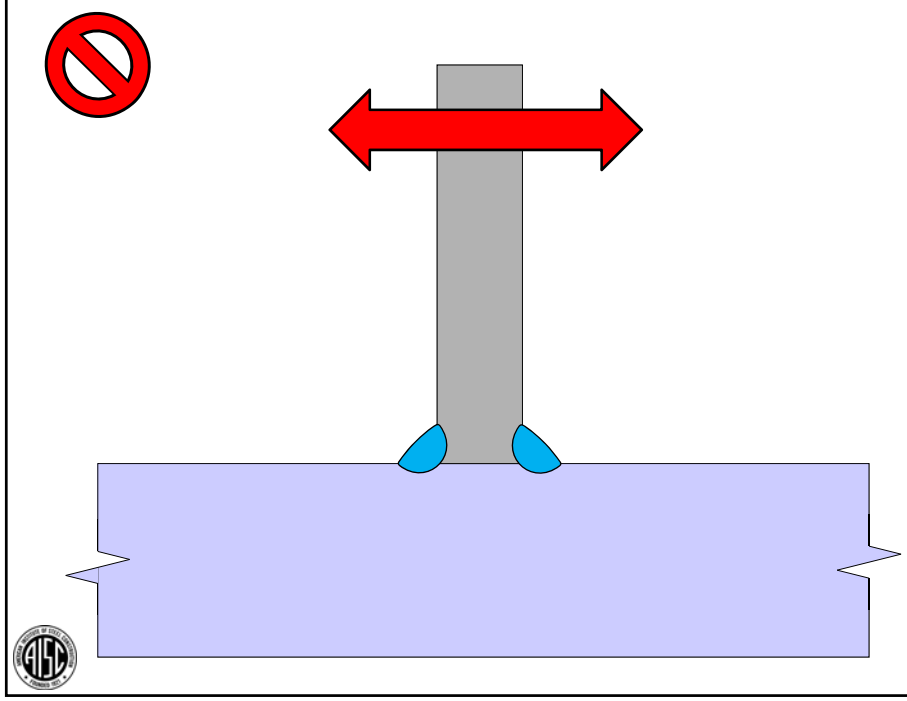
Principles of Connection Design

6

A correct and proper welded connection

does not subject the weld to bending.

97



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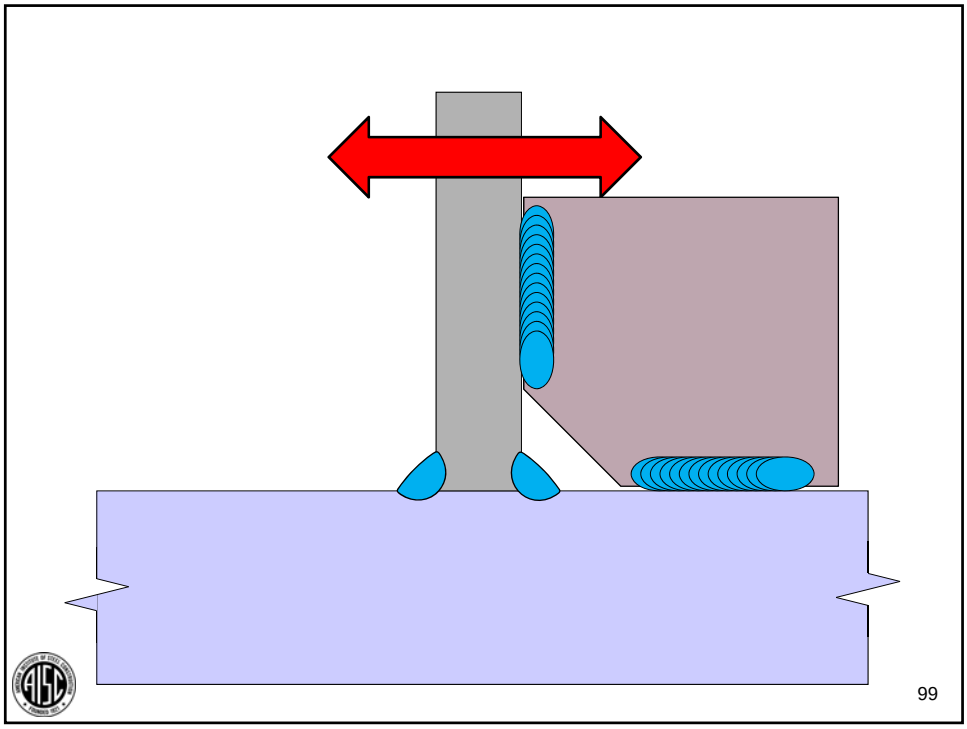
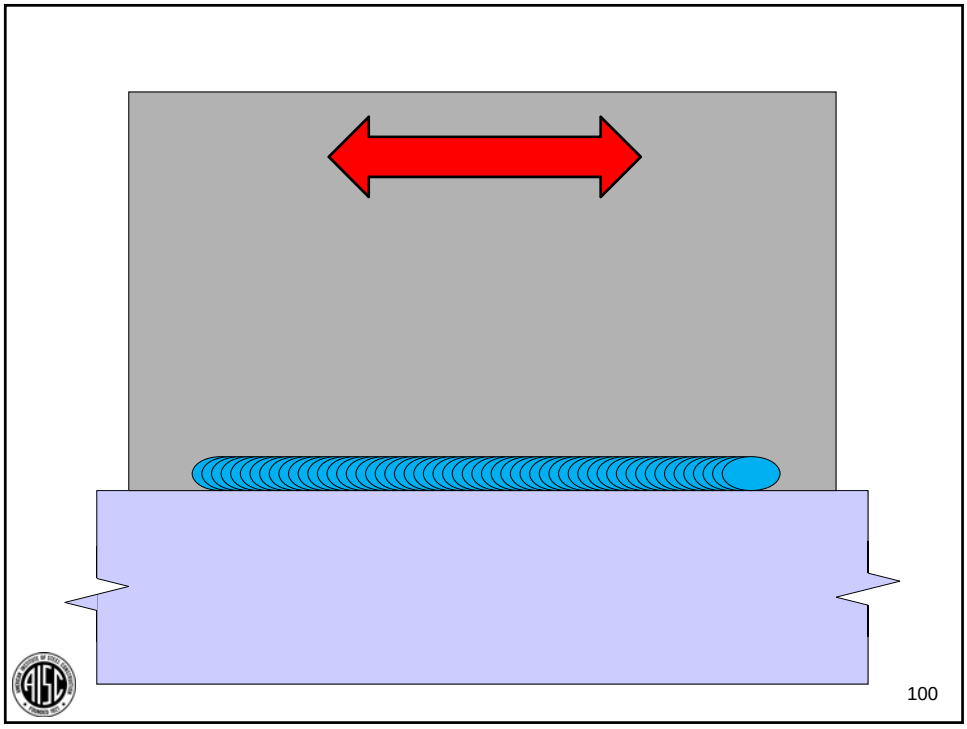




Principles of Connection Design

6

A correct and proper welded connection

does not subject the weld to bending.

101

Principles of Connection Design

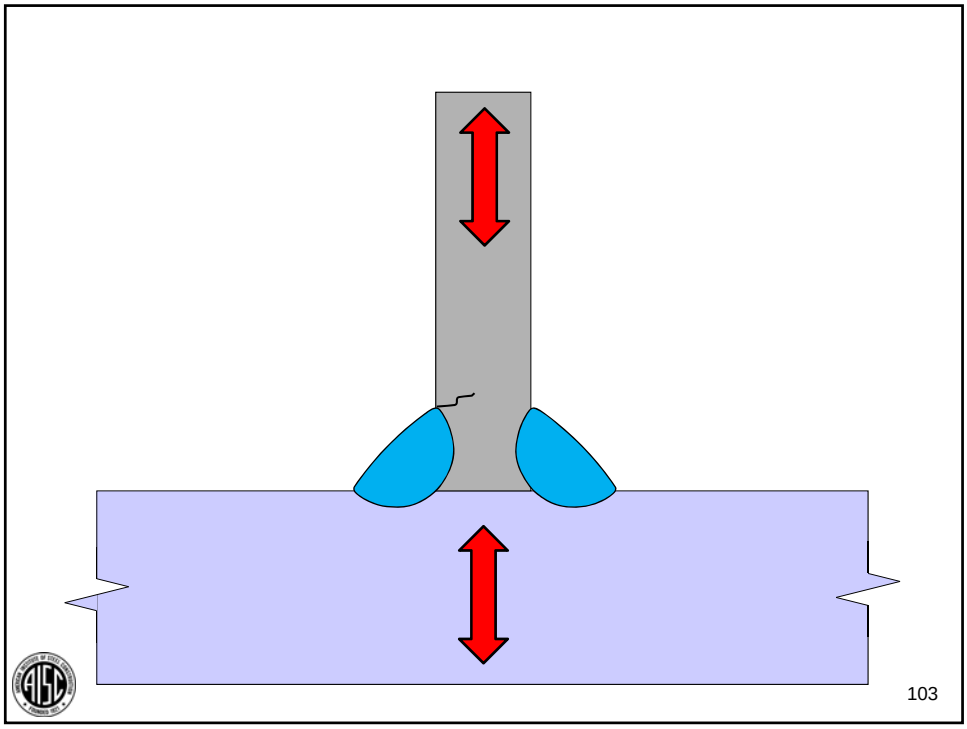
7

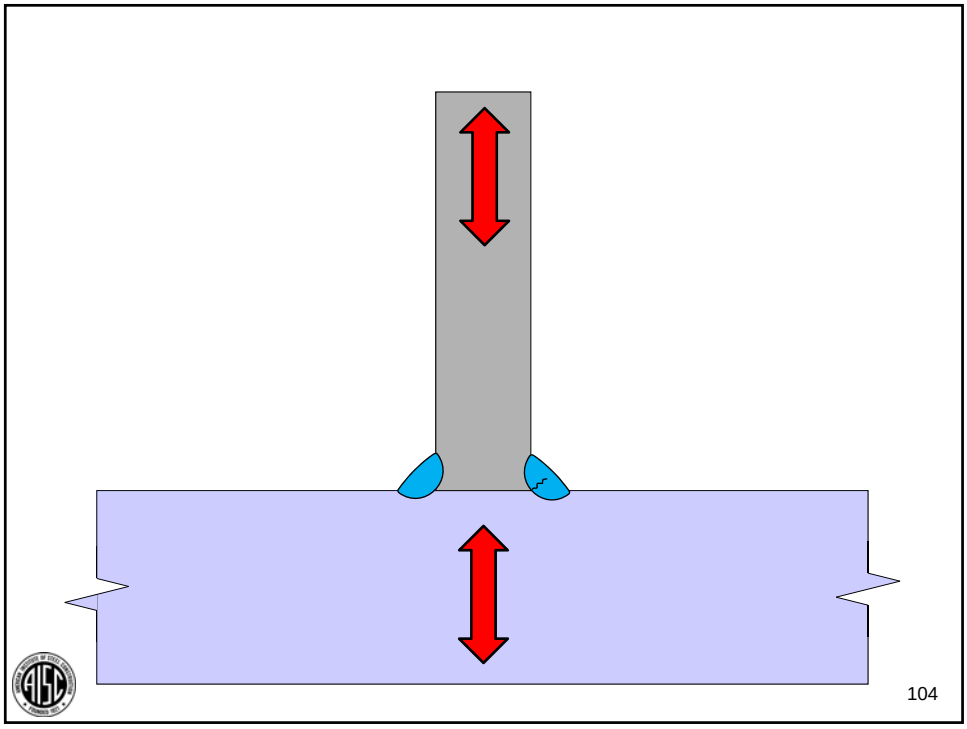
A correct and proper welded connection

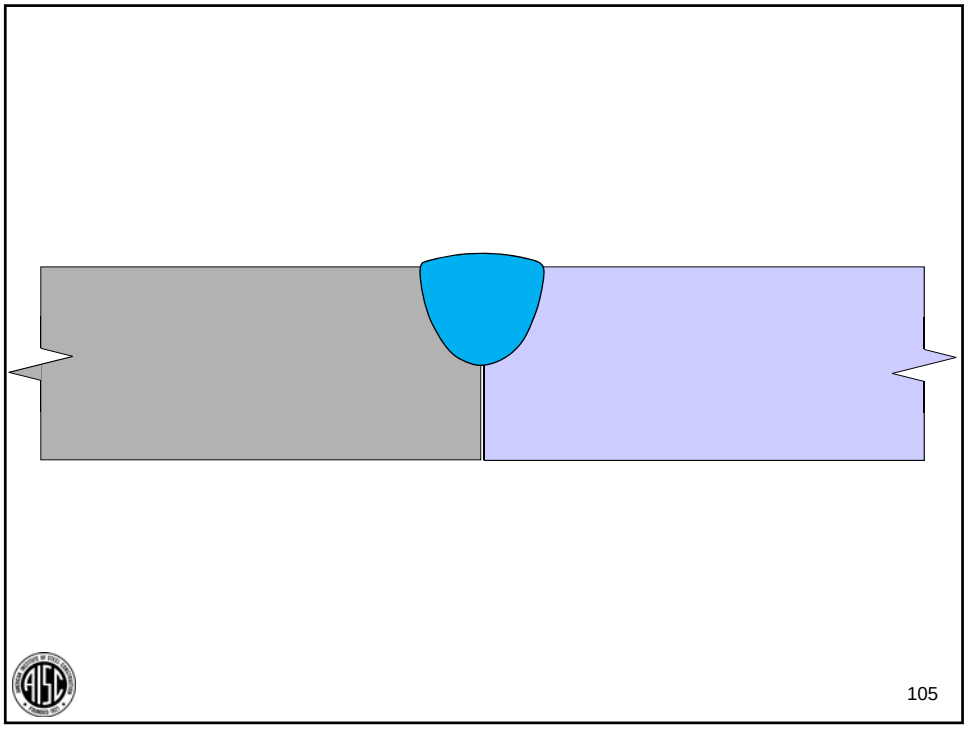
protects the toes and roots of the welds.

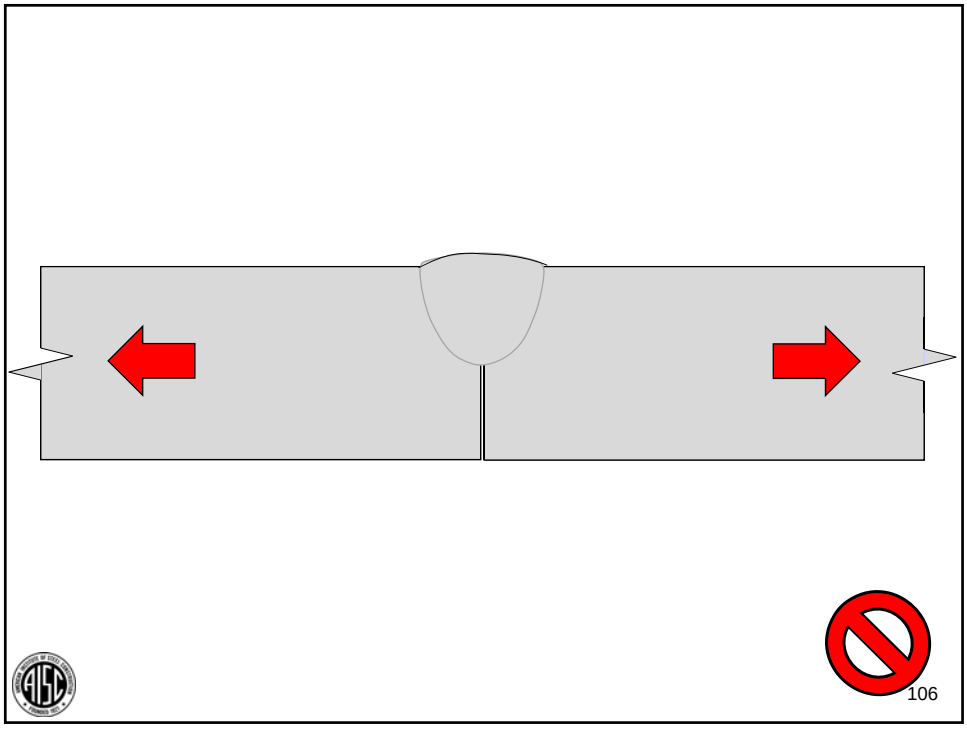
“Watch your toes
and
remember your roots.”

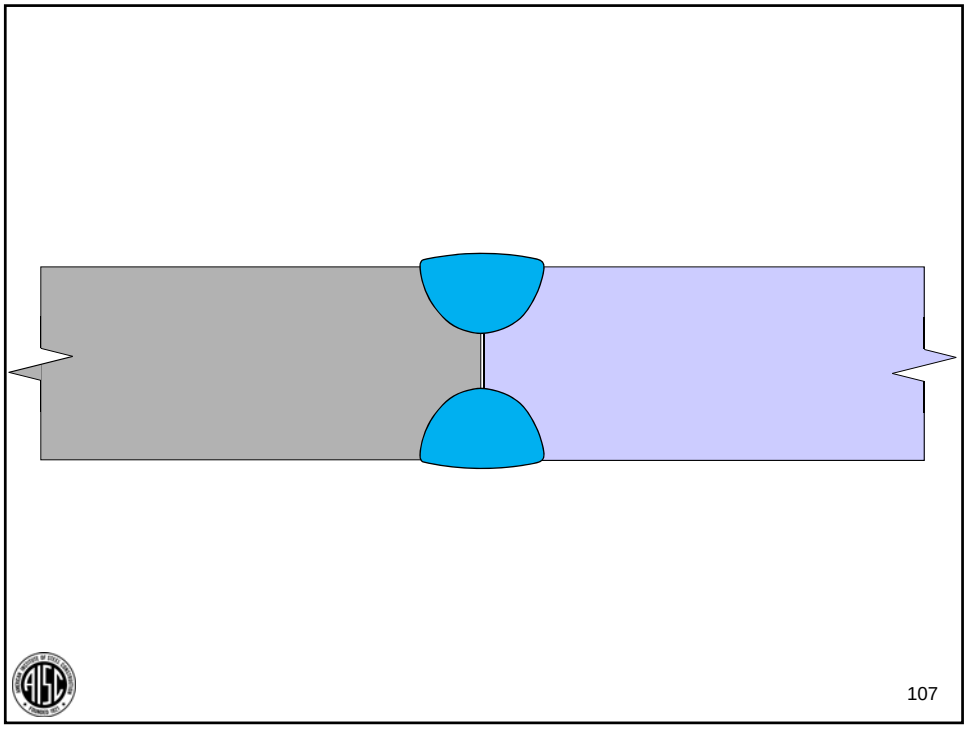
102

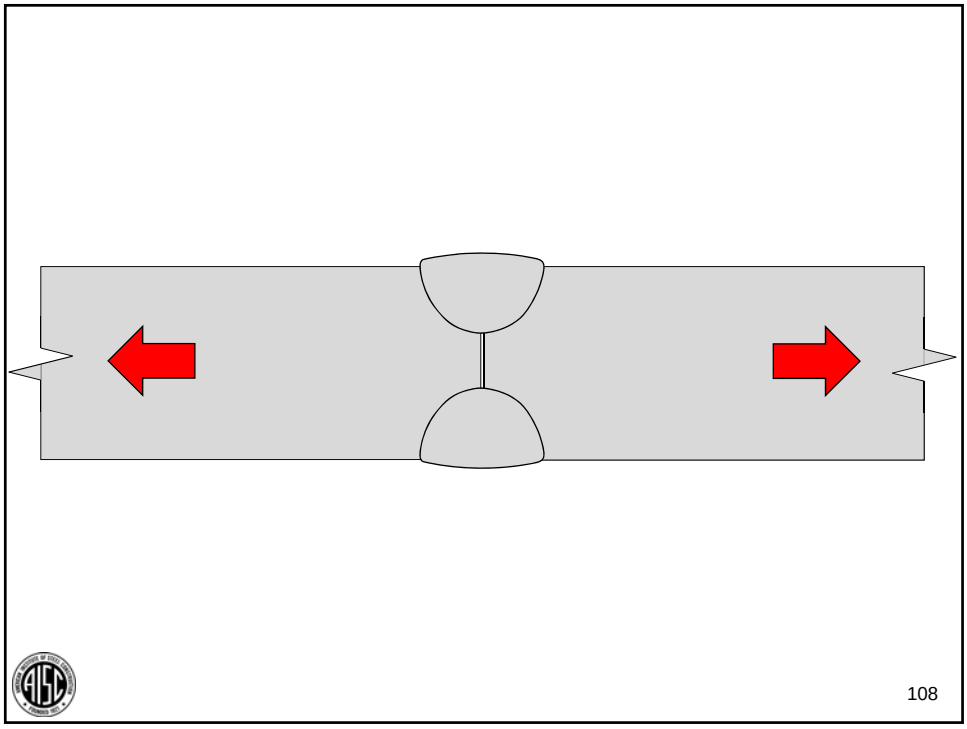












Principles of Connection Design

7

A correct and proper welded connection

protects the toes and roots of the welds.

109

Principles of Connection Design

8

A correct and proper welded connection

has a clearly defined throat.

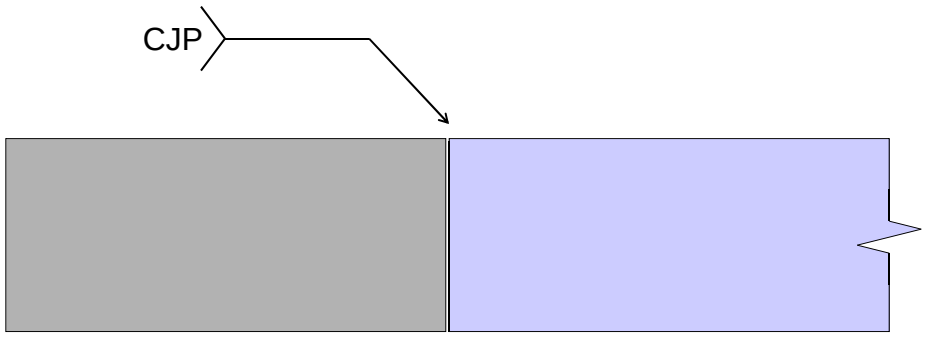
“A nothin’ weld ain’t worth nothin’ ”

110

nothin' weld:

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

111



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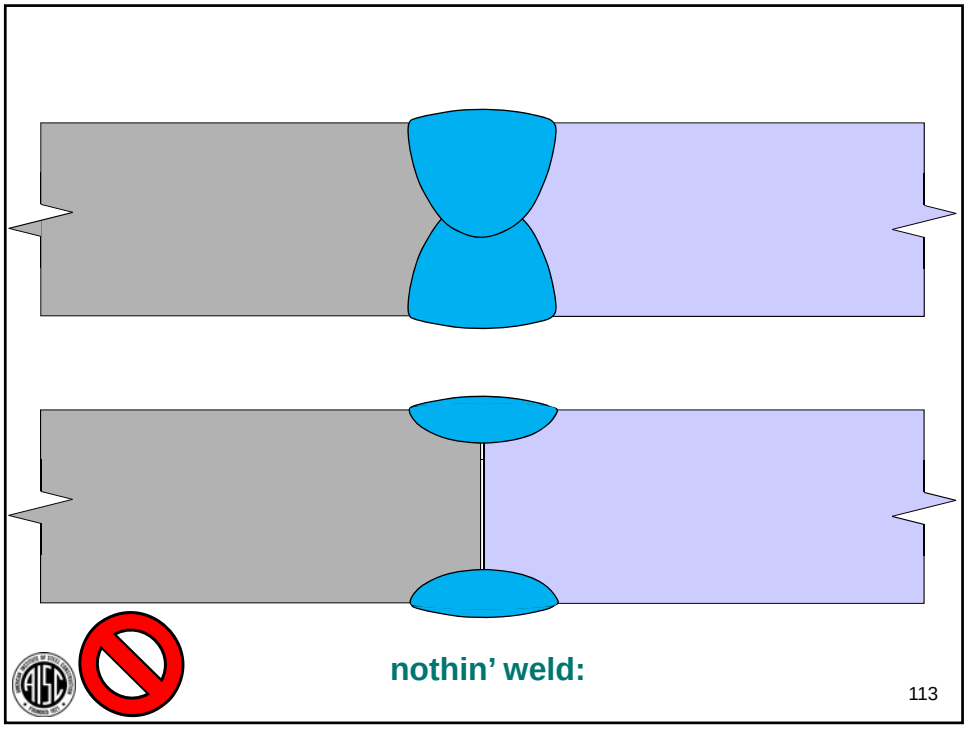
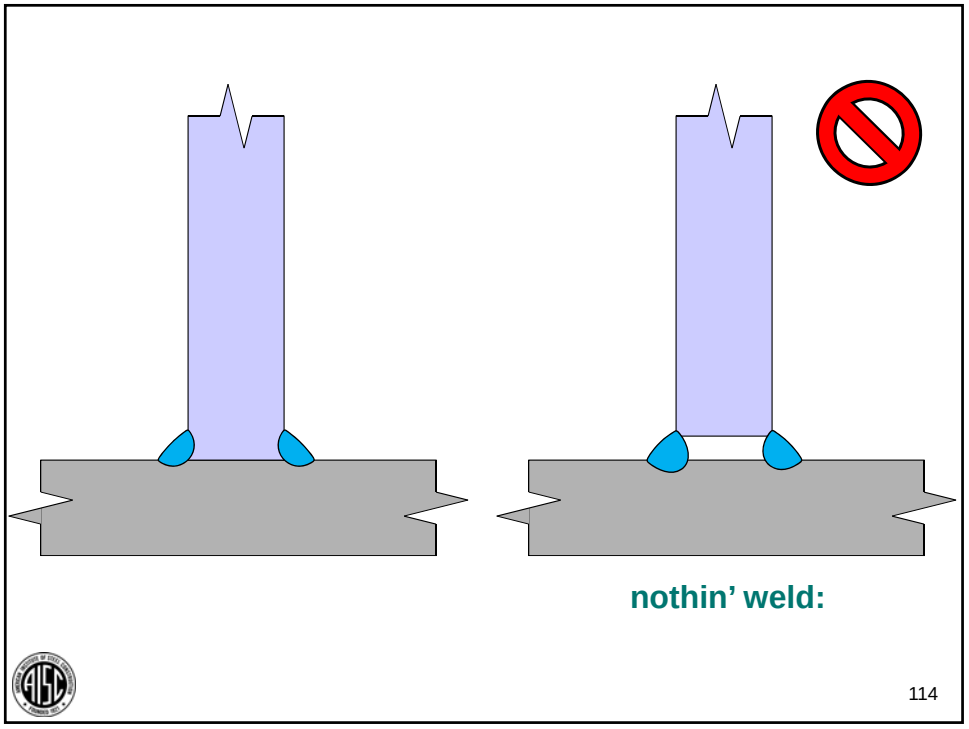




Principles of Connection Design

8

A correct and proper welded connection

has a clearly defined throat.

115

Principles of Connection Design

9

A correct and proper welded connection

recognizes material properties.

“Respect material properties.”

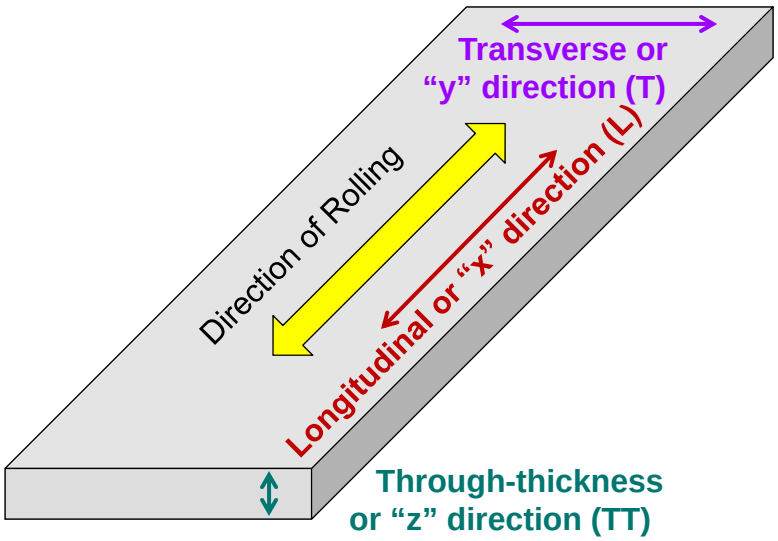
116

SAC Steel Project

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

Through-Thickness Properties of Structural Steels

117



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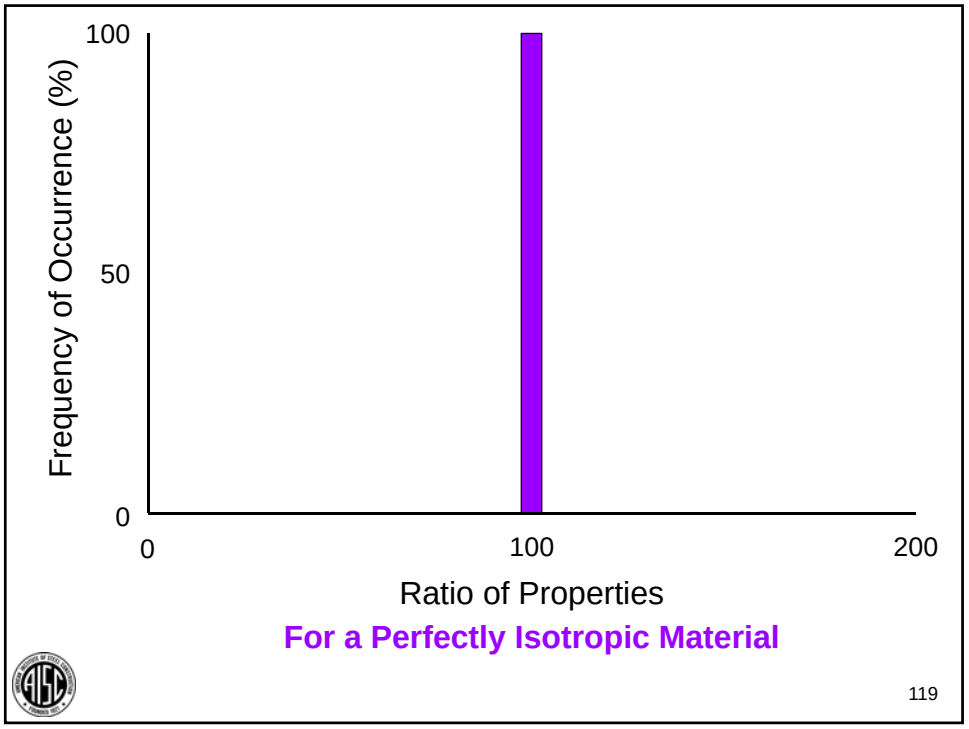
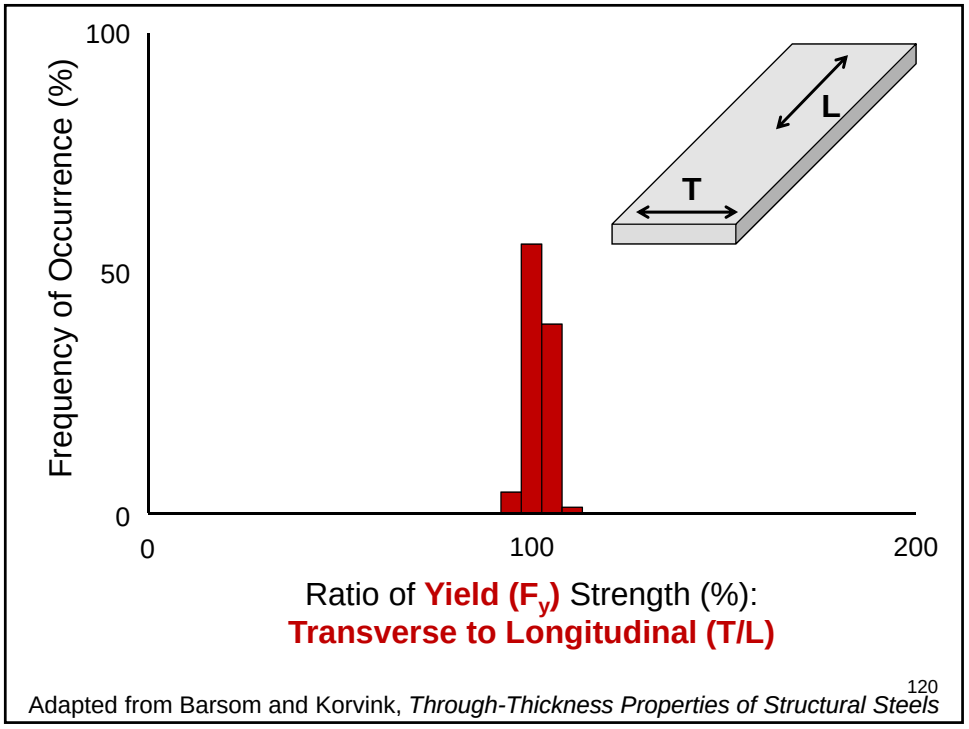
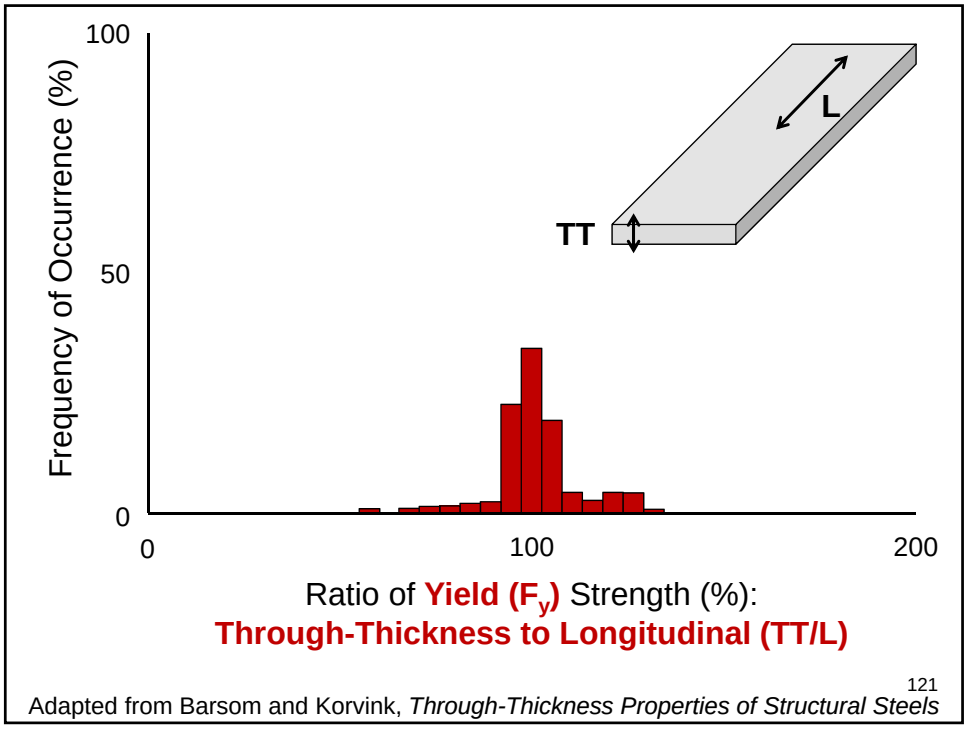
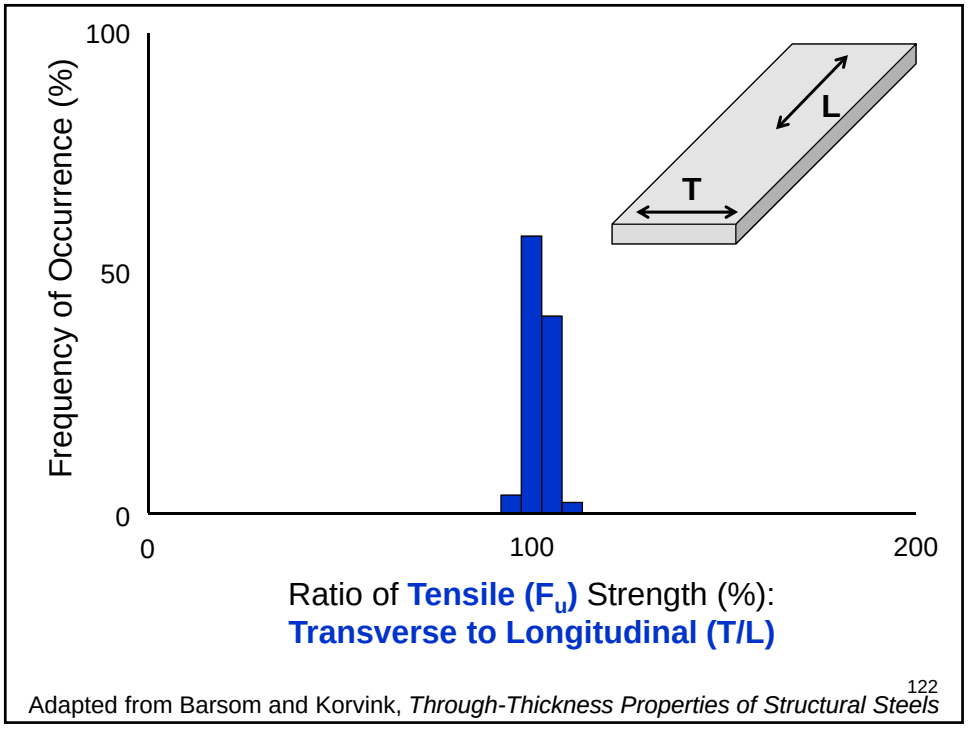


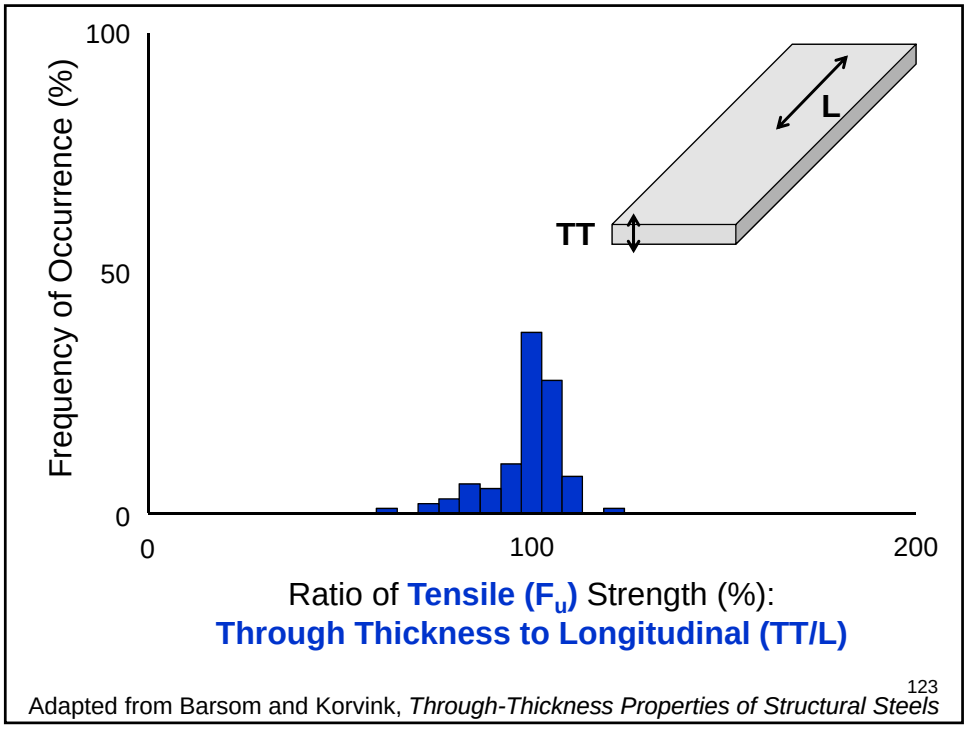




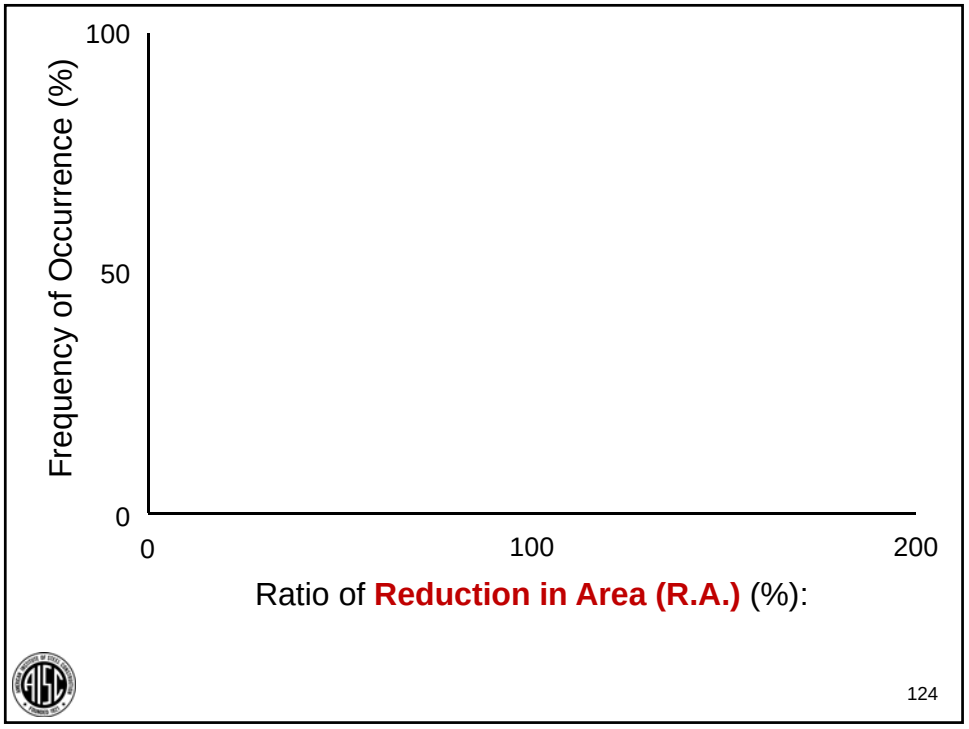
121
Adapted from Barsom and Korvink, *Through-Thickness Properties of Structural Steels*

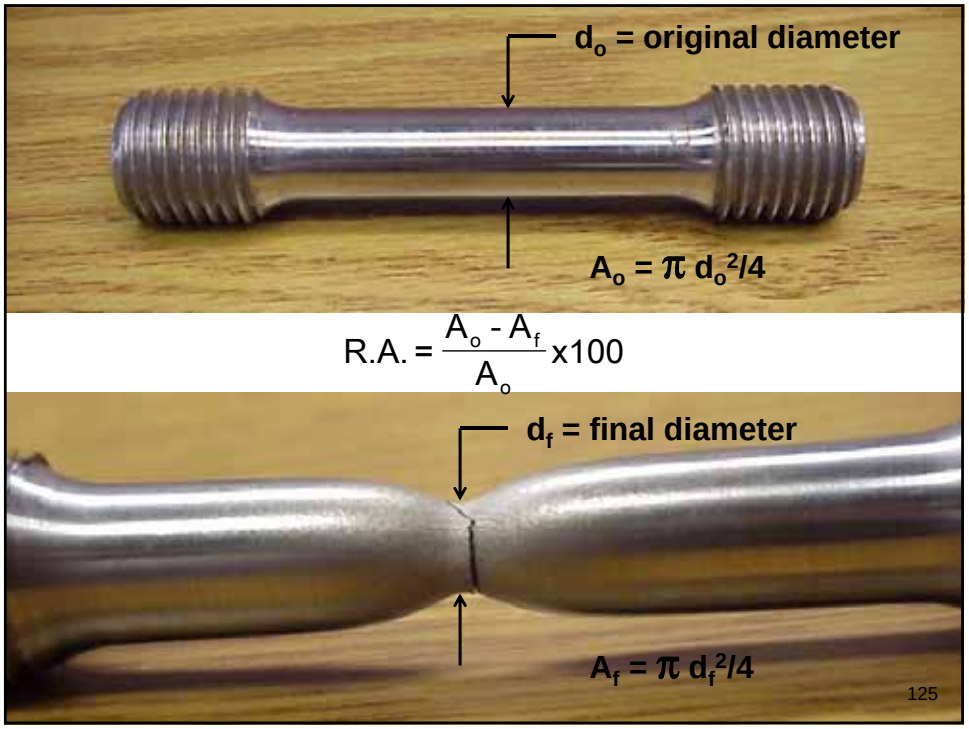


122
Adapted from Barsom and Korvink, *Through-Thickness Properties of Structural Steels*

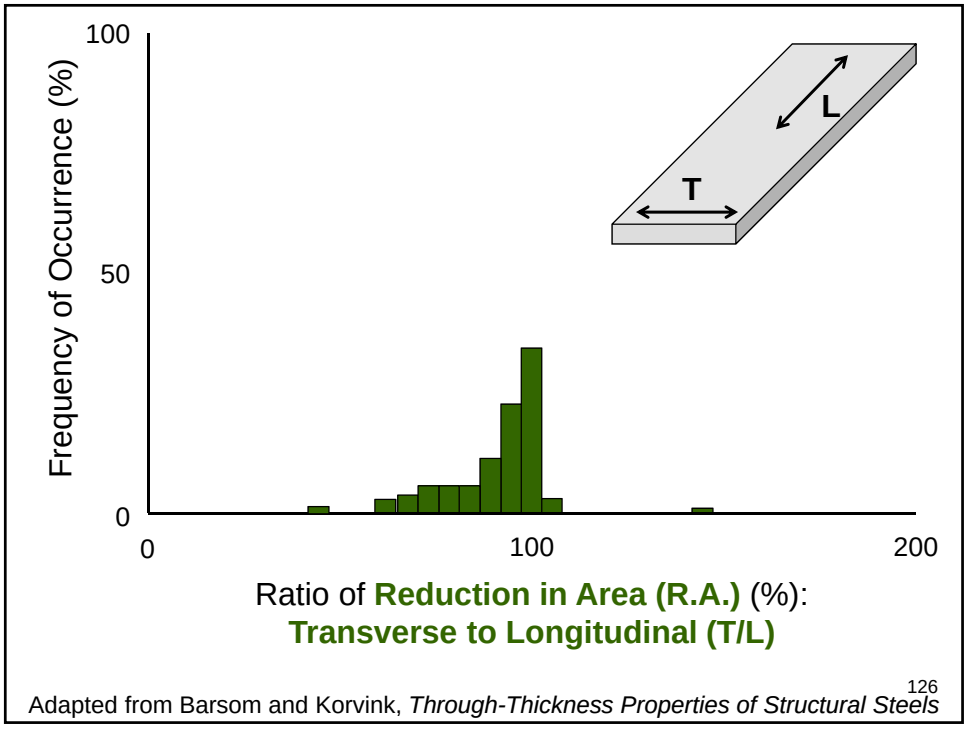


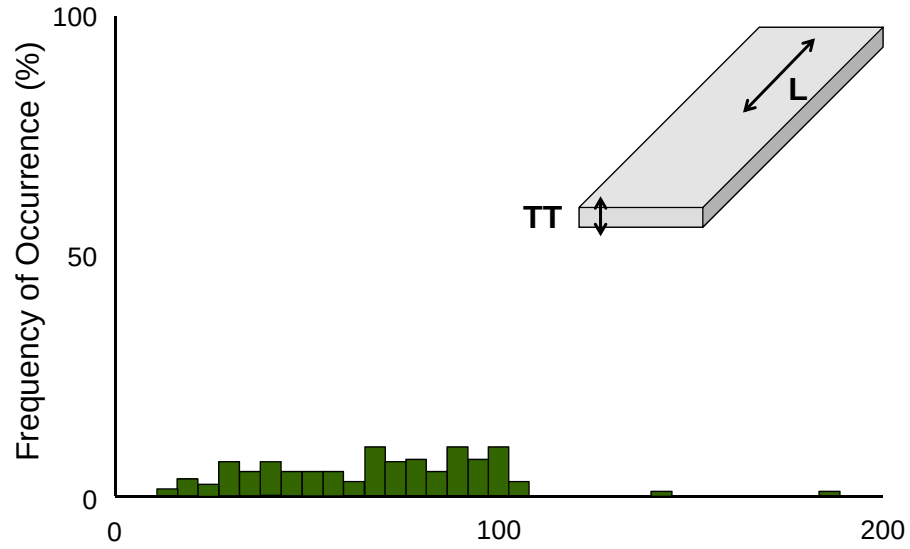
Adapted from Barsom and Korvink, *Through-Thickness Properties of Structural Steels*





$$R.A. = \frac{A_o - A_f}{A_o} x100$$





127

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

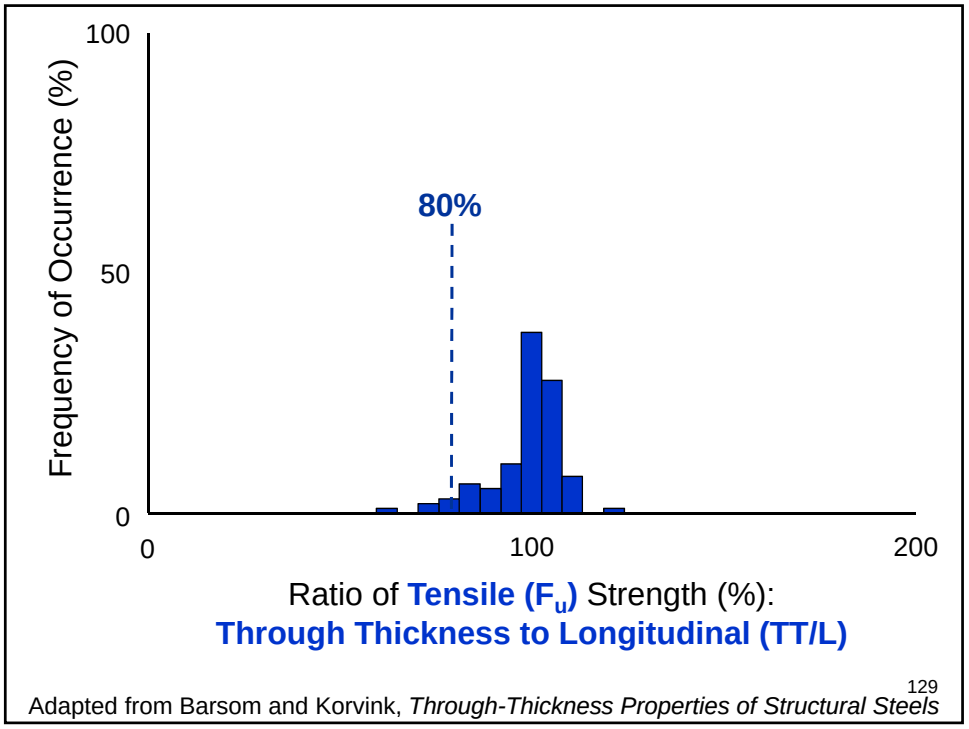
SAC Steel Project

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

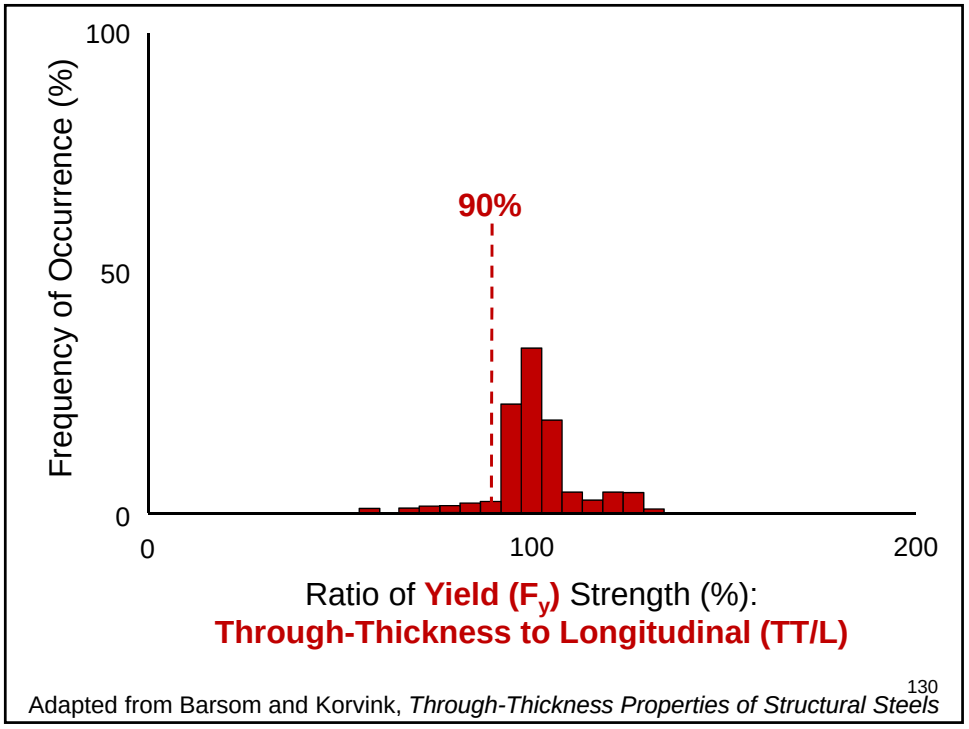
Through-Thickness Properties of Structural Steels

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 y the relationship **$F_y(TT) = 0.9\ F_y(L)$.**

128



129
Adapted from Barsom and Korvink, *Through-Thickness Properties of Structural Steels*



130
Adapted from Barsom and Korvink, *Through-Thickness Properties of Structural Steels*

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.**

131

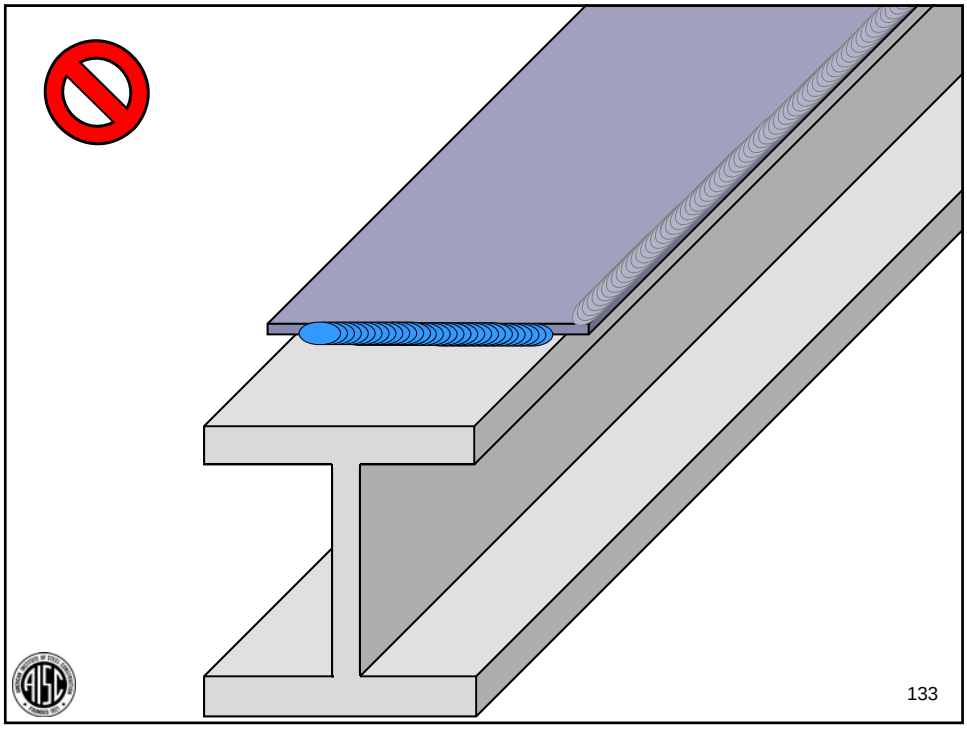
Principles of Connection Design

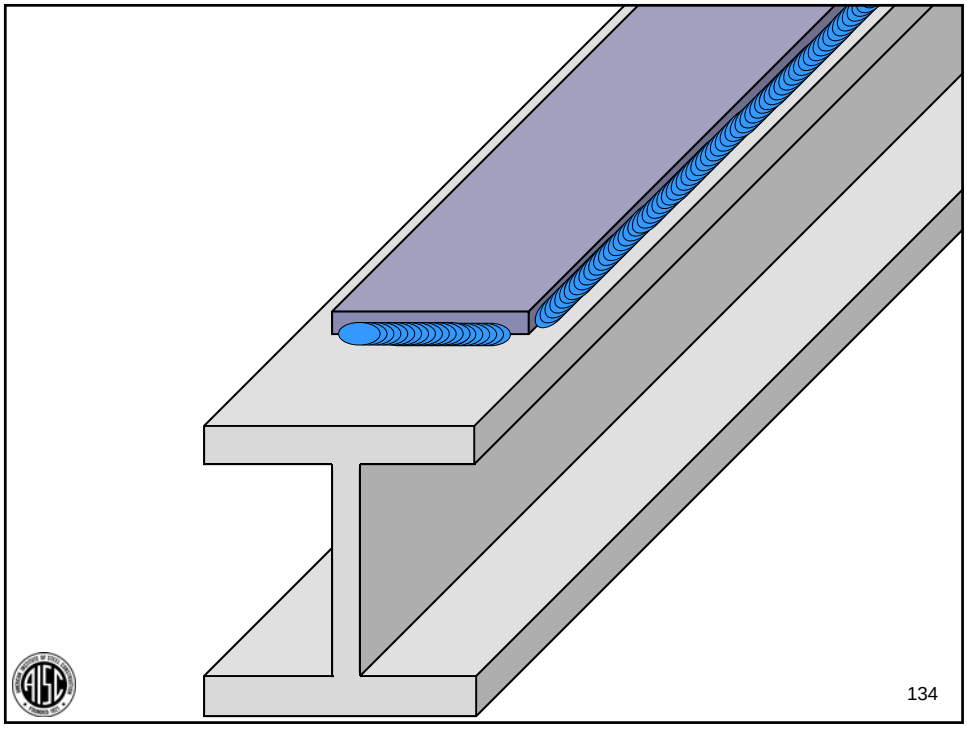
10

A correct and proper welded connection

is easy, economical, and safe to fabricate and erect.

132





Principles of Connection Design

10

A correct and proper welded connection

is easy, economical, and safe to fabricate and erect.

135

Principles of Connection Design

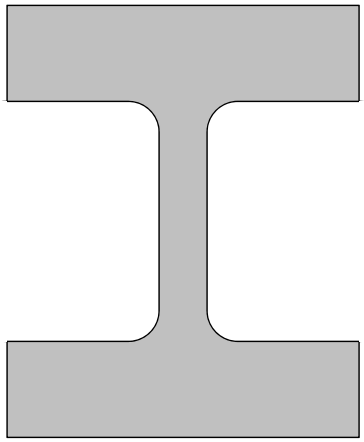
11

A correct and proper welded connection

recognizes commercial realities.

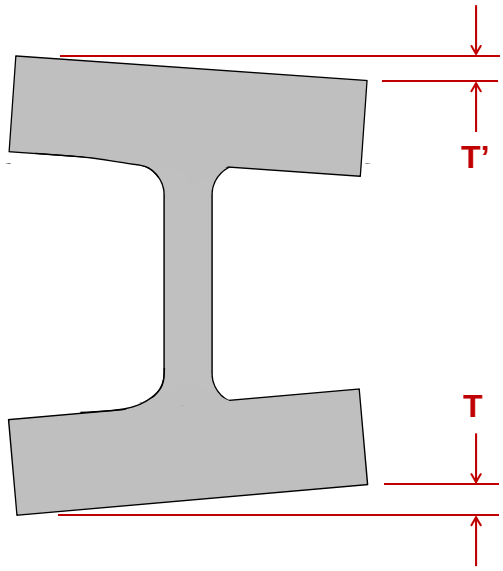
136

ASTM A6 Tolerances



137

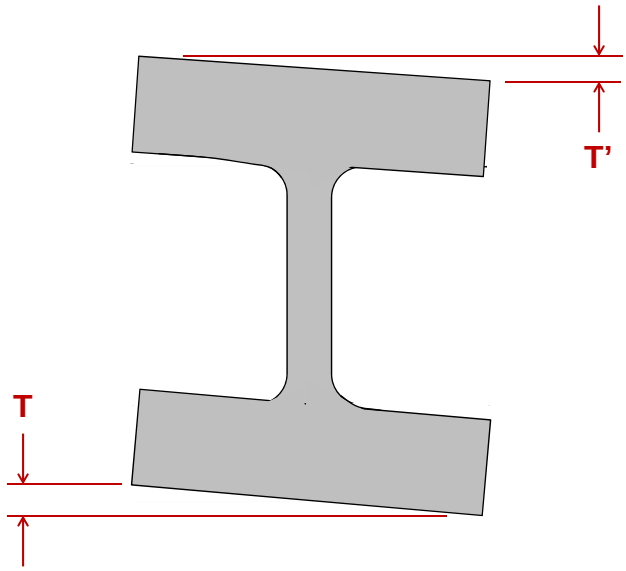
ASTM A6 Tolerances



For W over 12 in, **T + T' ≤ 5/16" [8 mm]**

138

ASTM A6 Tolerances

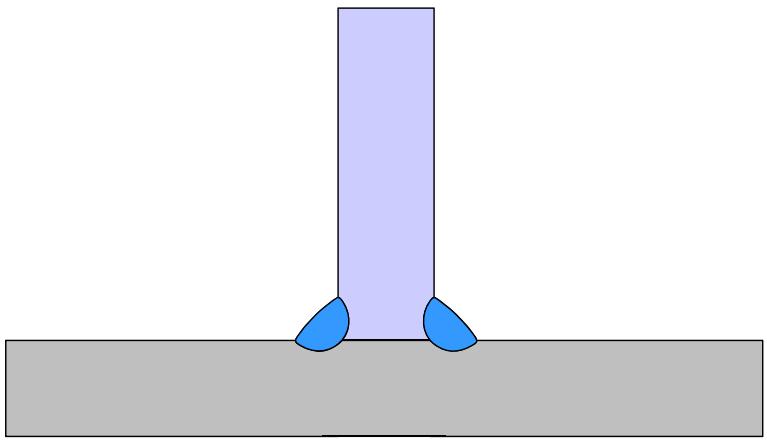


For W over 12 in, **T + T' ≤ 5/16" [8 mm]**

139

Distortion

Angular Distortion



140

AWS D1.1:2010 Structural Welding Code--Steel

Δ (in) ≤ W/100 or 1/ 4 in [6 mm], whichever it greater

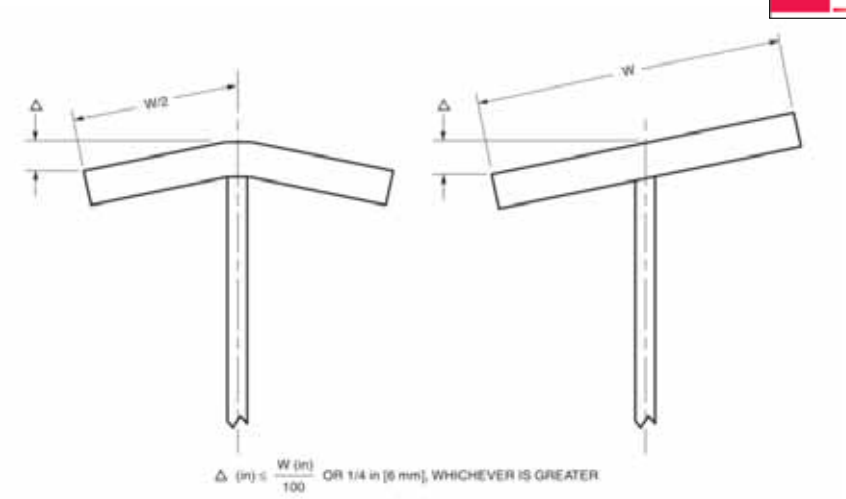
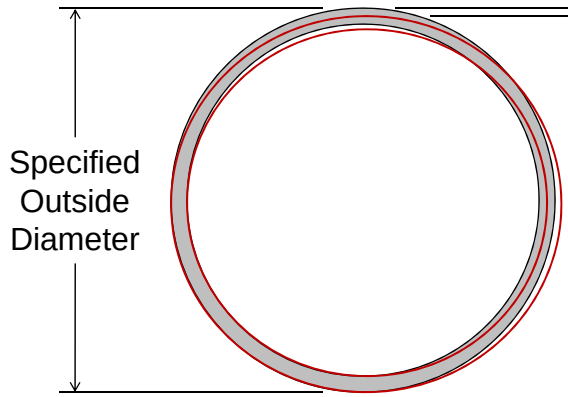


Figure C-5.7—Measurement of Flange Warpage and Tilt (see C-5.23.8)

141

ASTM A500 Tolerances

≤ ± 0.75% O.D.

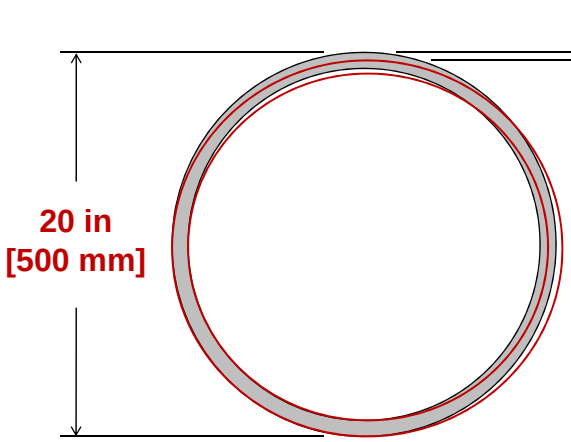


For outside diameters (O.D.) ≥ 2 in [50 mm]

142

ASTM A500 Tolerances

≤ ± 0.15 in [3.8 mm]



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

143

AWS D1.1:2010 Structural Welding Code--Steel

5.22.3.1 Girth Weld Alignment (Tubular).

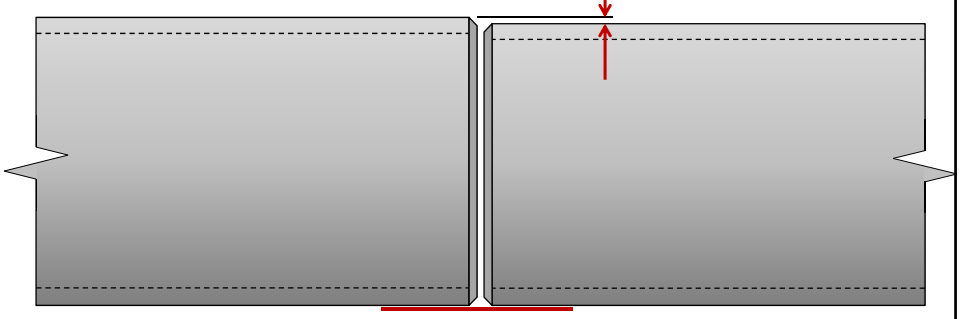
….Radial offset of abutting edges of girth weld seams **shall not exceed 0.2t** (where t is the thickness of the thinner member) and the maximum allowable shall be 1/4 in [6 mm], provided that any offset exceeding 1/8 in [3 mm] is welded from both sides…..

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

144

AWS D1.1 Tolerance
≤ ± 0.10 in [2.4 mm]

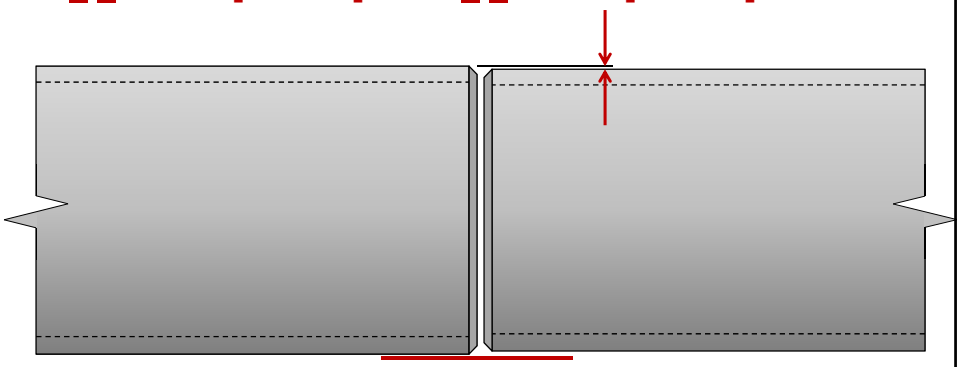
ASTM A500 Tolerance
≤ ± 0.15 in [3.8 mm]



145

AWS D1.1 Tolerance
≤ ± 0.10 in [2.4 mm]

ASTM A500 Tolerance
≤ ± 0.08 in [1.9 mm]



146

Principles of Connection Design

11

A correct and proper welded connection

recognizes commercial realities.

147

Principles of Connection Design

12

A correct and proper welded connection

is aesthetically pleasing.

Reminder:
"Beauty is in the eye of the beholder."

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

148

Principles of Connection Design

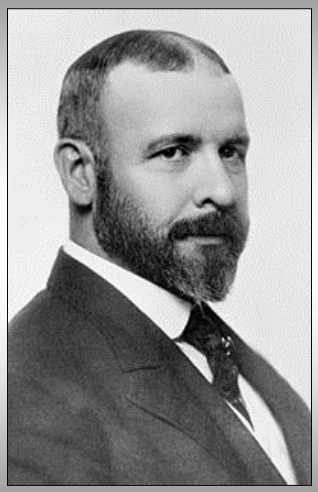
12

A correct and proper welded connection
is aesthetically pleasing.

“Form follows function.”

149

Architectural Philosophy



Form ever follows function.

Louis Henry Sullivan
Architect
1856 – 1924

150

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,

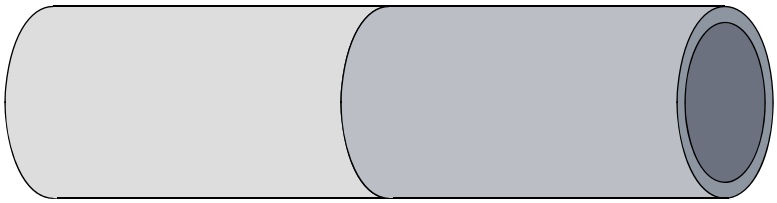
That form ever follows function. This is the law.

151

Ideal

152

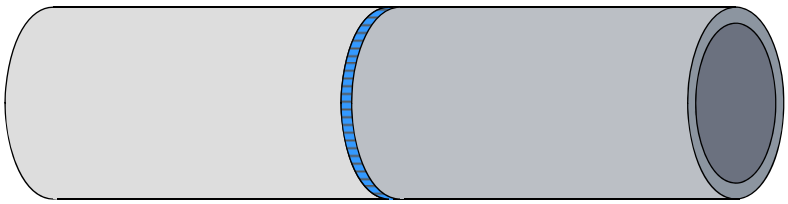
Reality



153

Pretty Close to Ideal

(at least in DKM's mind)



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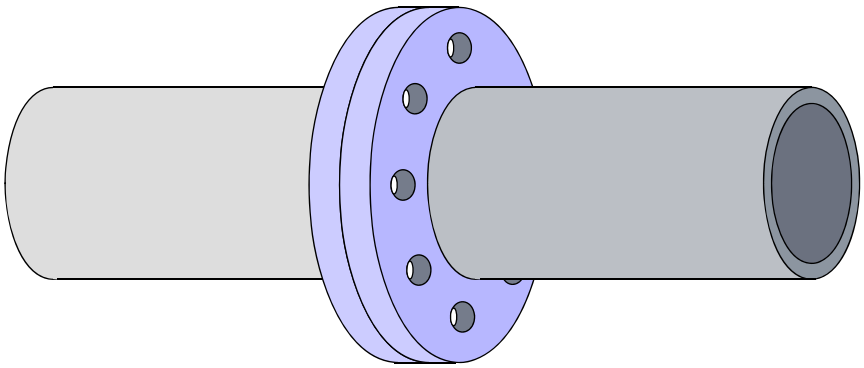
Not even close



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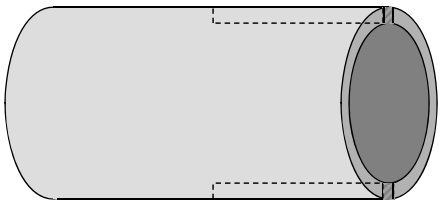
Not even close



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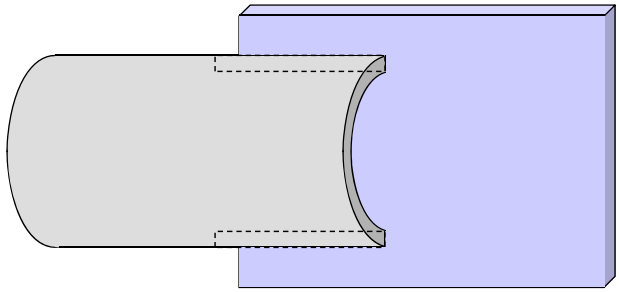
Not even close



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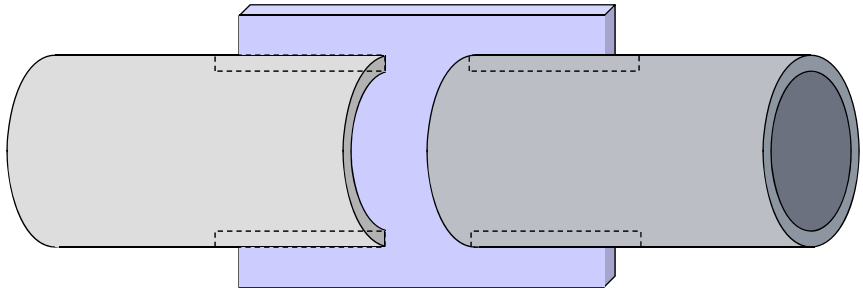
Not even close



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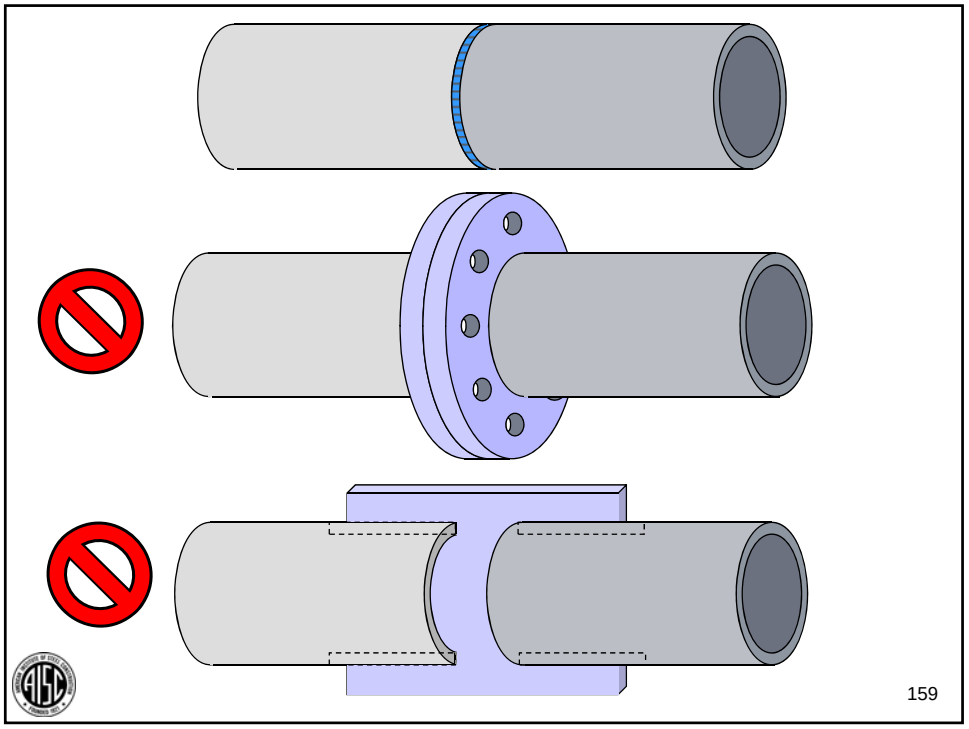


159

Principles of Connection Design

12

An aesthetically pleasing connection is:

welded, not bolted.

160

Principles of Connection Design

12

An aesthetically pleasing welded connection is:

directly welded.

- no gusset plates
- no flange plates

161

Principles of Connection Design

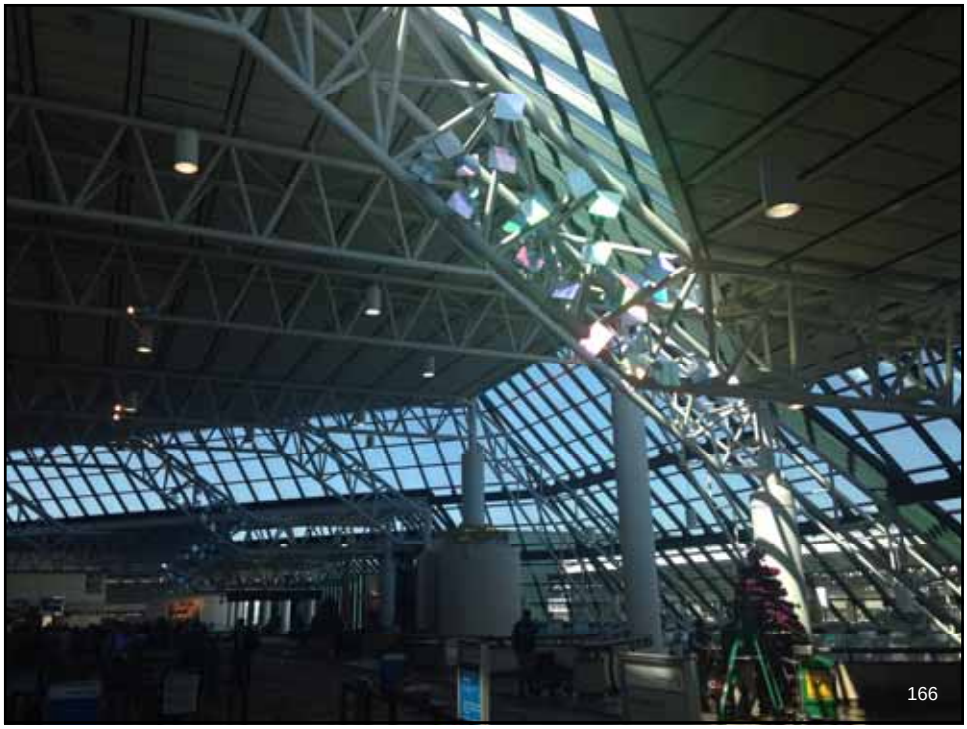
12

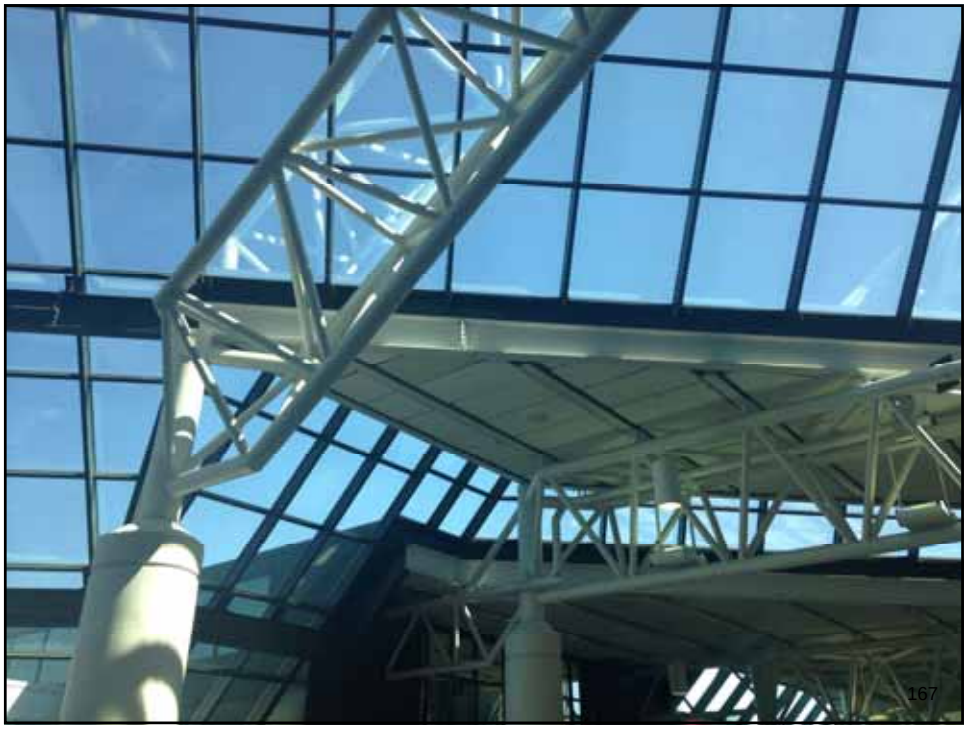
An aesthetically pleasing welded connection is:

left in the as-welded condition

- not ground

162





169


170

Modern Steel Construction
February 2015

Sylvie Boulanger
Collin Hughes


conference preview

WORKING WITH LARGE TRUSSES

What to keep in mind from design to erection

171

WORKING WITH LARGE TRUSSES

LARGE STEEL TRUSSES are continually being pushed to span further, support larger loads and be more aesthetically appealing. The challenge is to develop efficient, cost-effective and eye-catching designs through a collaborative effort between engineers, fabricators and erectors.

172

WORKING WITH LARGE TRUSSES

Splices. Some of the most critical items to collaborate on when working with large trusses are splice locations and types. The preferred number of splices (field or shop) on any truss is generally going to be zero. But as these are large trusses it is usually not feasible.

173

WORKING WITH LARGE TRUSSES

It is often the preference of steel fabricators to weld splices together in the shop, whereas erectors tend to prefer bolted splice connections. However, when handling large trusses with large loads it is often impractical, even impossible, to transfer the loads through a bolted connection, so field-welded connections must be used. Field welded splices should be avoided as much as possible, especially when the connection is difficult to reach.

174

Photo courtesy of Supermétal

175

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February 2015

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Collin Hughes

176

At the splice location, the top chords are hinged and the bottom chord is a hidden multi-bolted continuous joint (see image on previous page). The latter was initially specified as all site-welded, but the hidden "ugly" bolted connection, which was covered with a sleeve and field-finished, sped up construction and met aesthetic requirements. Initially proposed by the fabricator, the entire team adopted the solution. It optimized mobilization of site equipment—one tower crane and one mobile crane—and coordination with other trades such as deck and curtain wall.

Since the truss is triangulated, special arrangements were required to rotate the truss segments during fabrication, trans-

7

Principles of Connection Design

A correct and proper welded connection

1. is strong enough to transfer all the applied loads
2. has a clear and direct load path
3. places welds in regions of low stress
4. does not introduce stress raisers
5. is not constrained
6. does not subject the weld to bending
7. protects the toes and roots of the welds
8. has a clearly defined throat
9. recognizes material properties
10. is easy, economical, and safe to fabricate and erect
11. recognizes commercial realities
12. is aesthetically pleasing

178

WELDED CONNECTIONS:

The Good, the Bad and **the Ugly**

179

ugly

adjective \’ə- gle\

: unpleasant to look at: not pretty or attractive

: unpleasant to hear

: offensive or disgusting

180

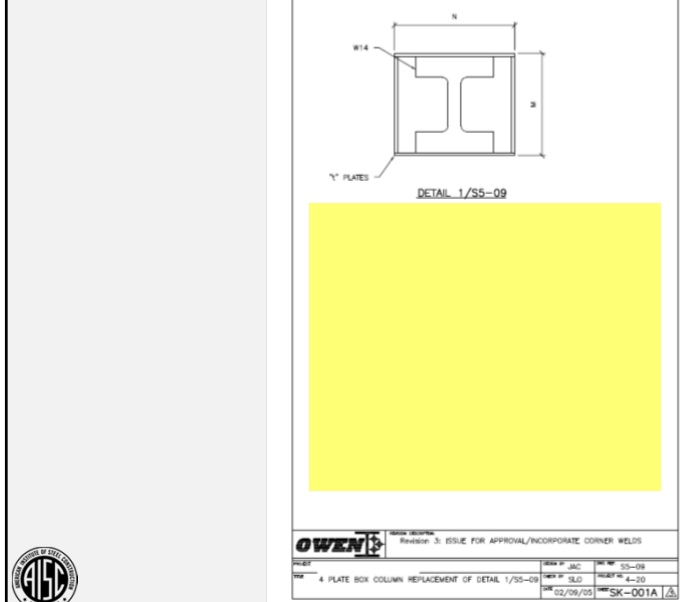
WELDED CONNECTIONS

that are offensive or disgusting

3 S's

Simple
Serious
Silly

181



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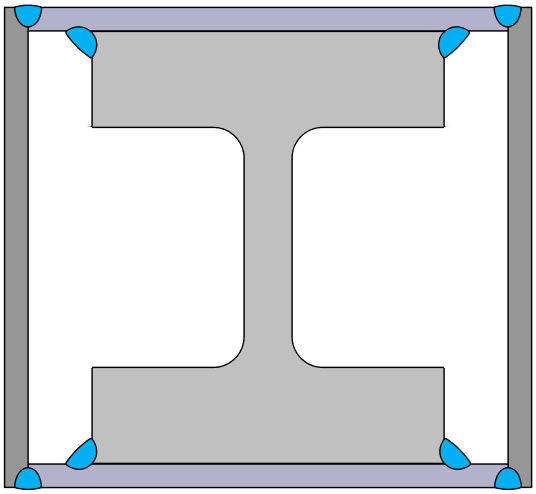

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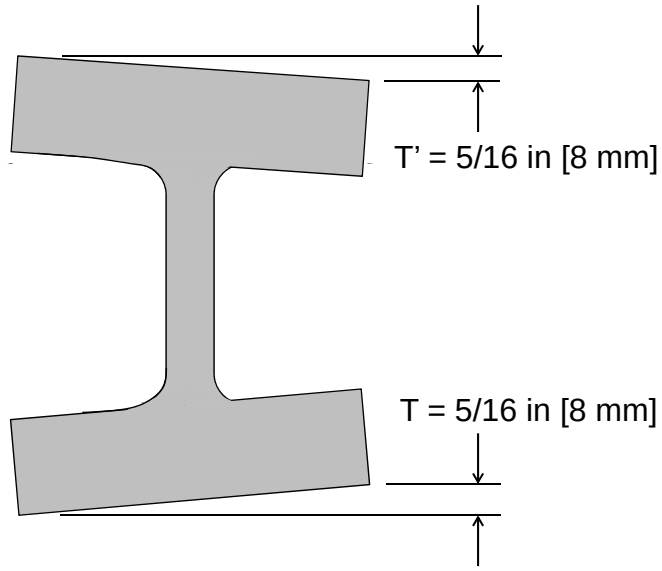
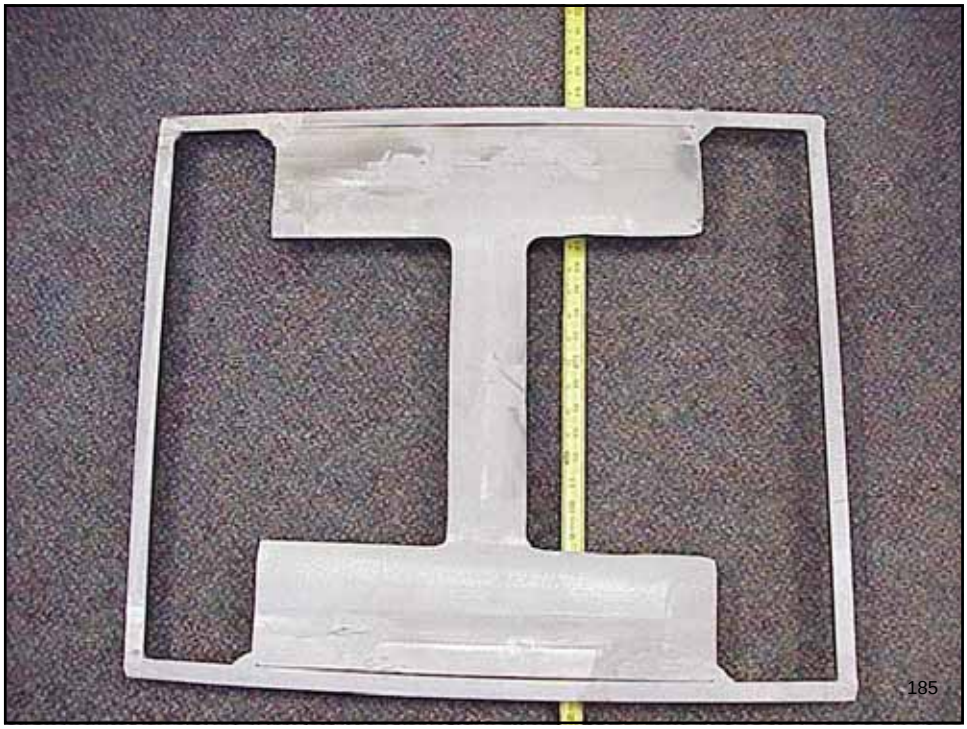
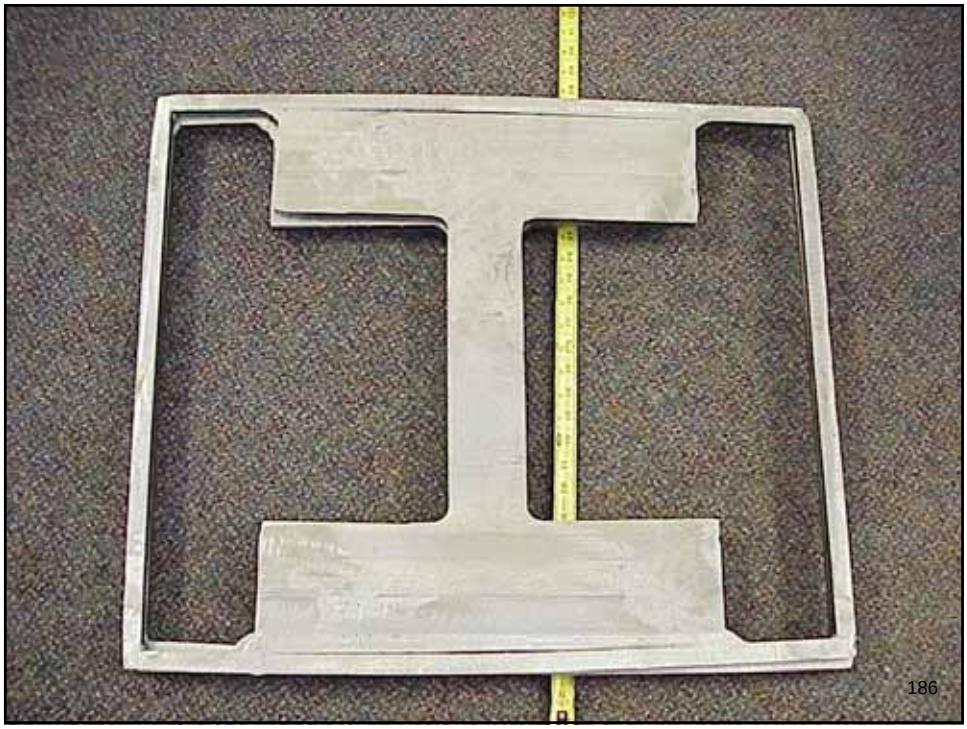
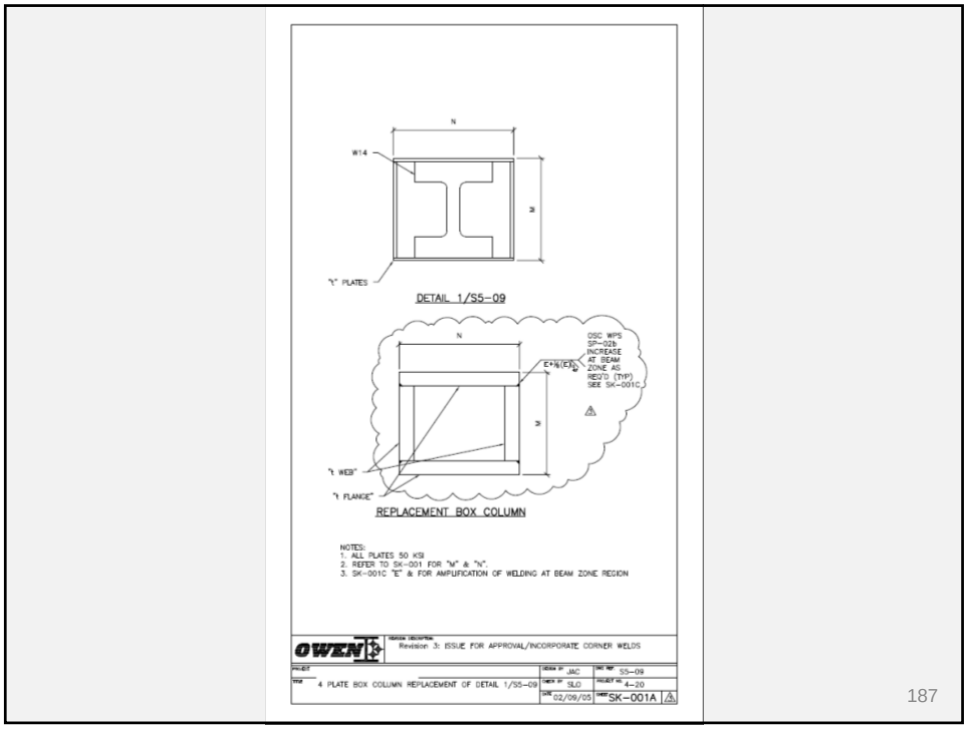


For W over 12 in

184







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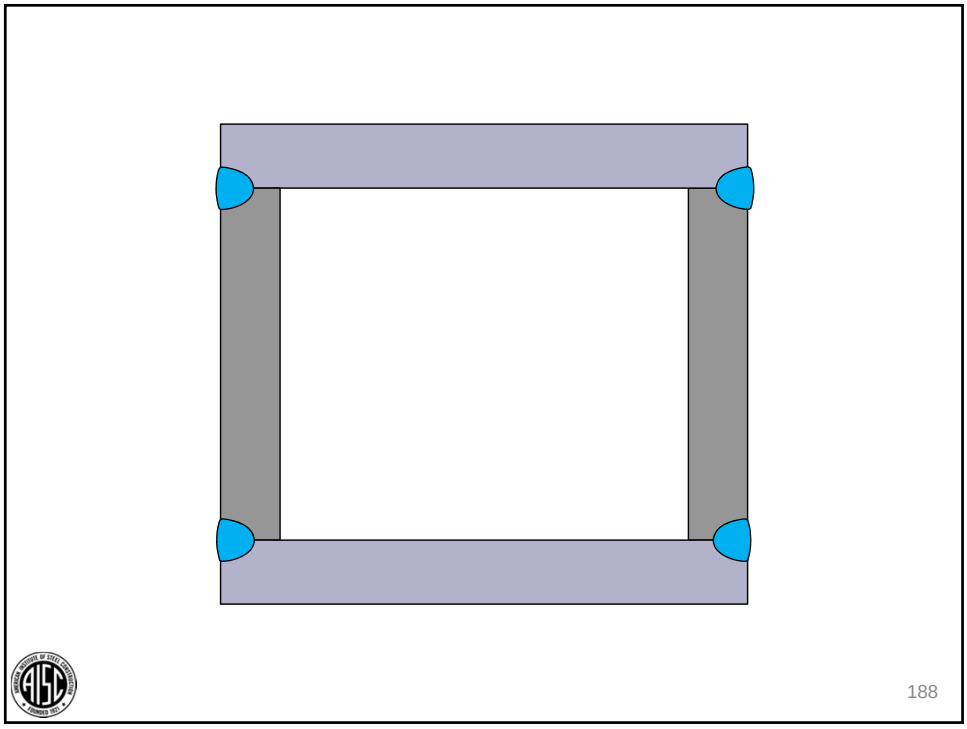
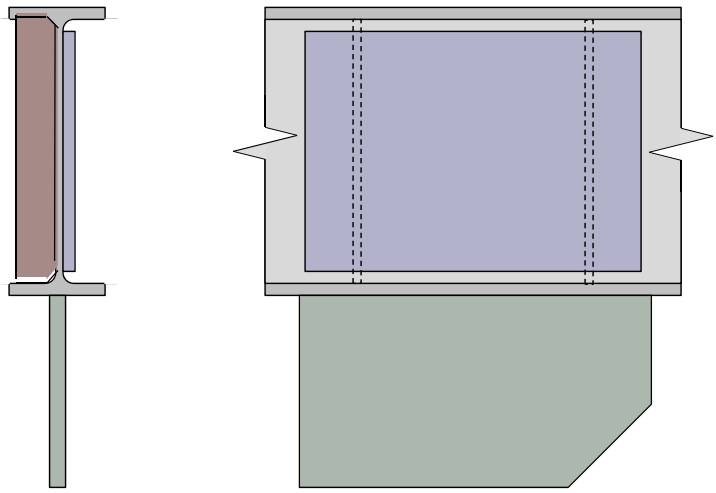
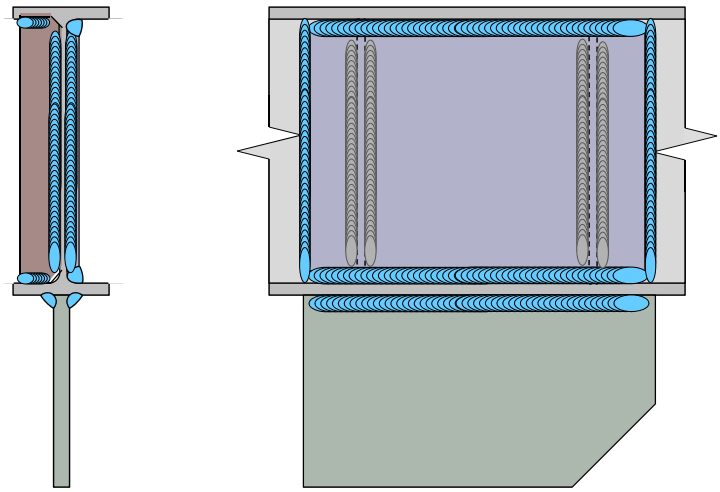

188

W30 X 90
t_w = 1/2 in, t_f = 5/8 in
1 in doubler on one side
1-1/2 in gusset



189

W30 X 90
t_w = 1/2 in, t_f = 5/8 in
1 in doubler on one side
1-1/2 in gusset



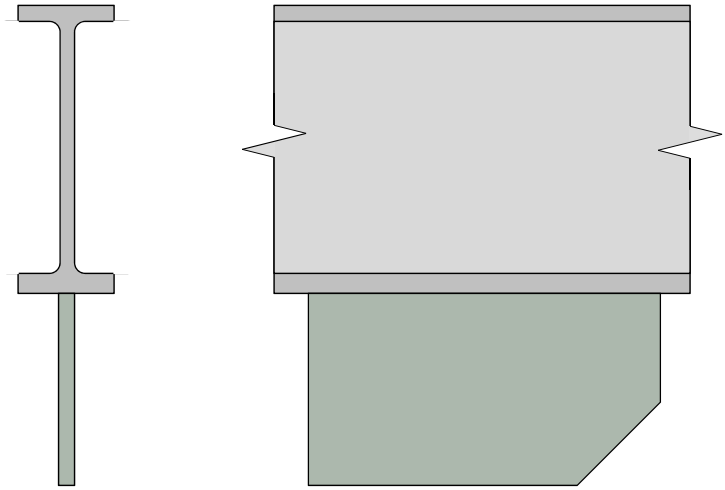
190

~~W30 X 90~~ → **Heavier**

~~t_w = 1/2 in, t_f = 5/8 in~~
~~1 in doubler on one side~~
1-1/2 in gusset

No Doubler

No Stiffeners



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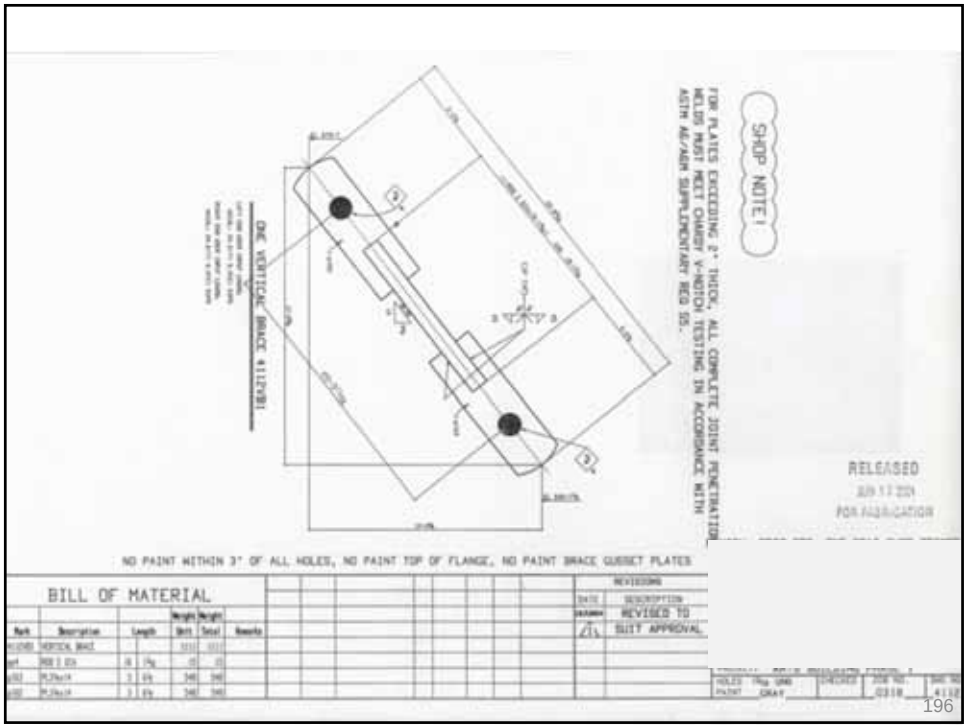

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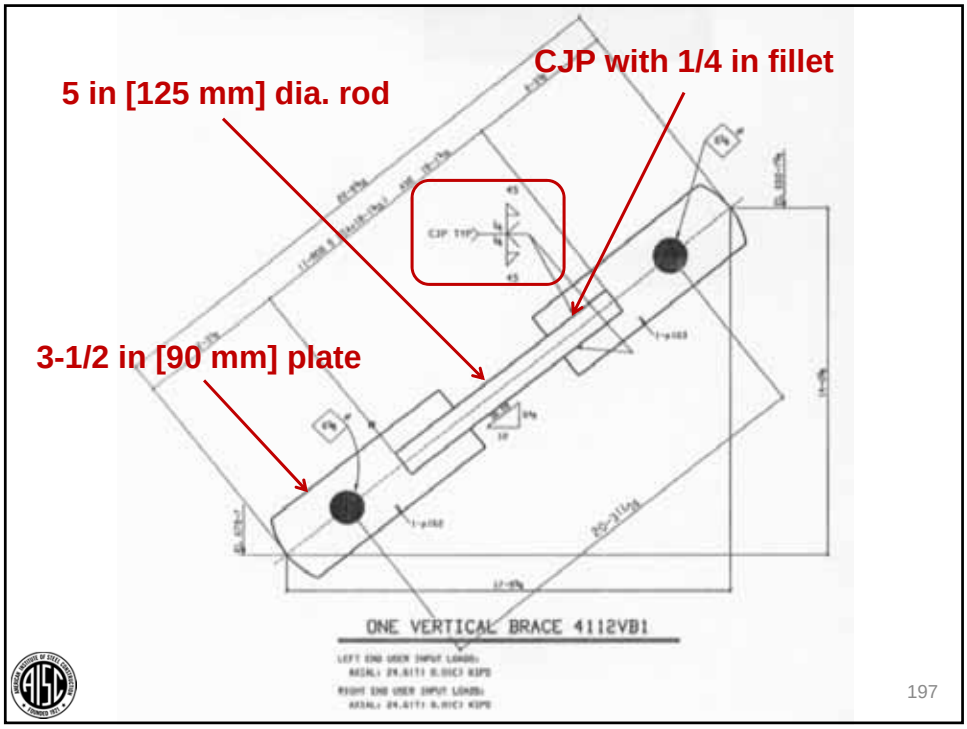
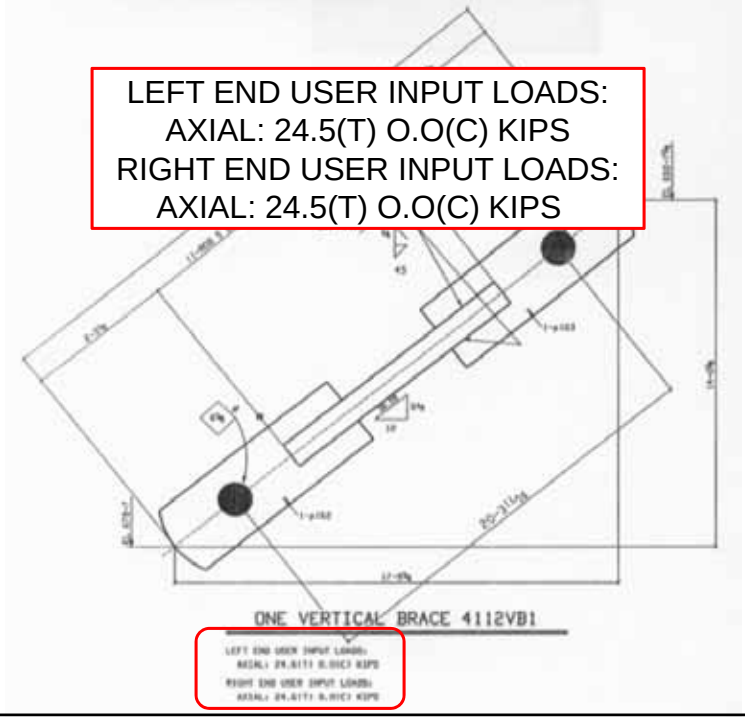


LEFT END USER INPUT LOADS:
AXIAL: 24.5(T) O.O(C) KIPS
RIGHT END USER INPUT LOADS:
AXIAL: 24.5(T) O.O(C) KIPS



203

LEFT END USER INPUT LOADS:
AXIAL: 24.5(T) O.O(C) KIPS
RIGHT END USER INPUT LOADS:
AXIAL: 24.5(T) O.O(C) KIPS

Rod:
F = 24.5/($5^2\pi$/4) = 1.25 ksi

CJP Welds:
F = 24.5/(2 X 3.5 X 15) = 0.23 ksi

Minimum Sized Fillet Welds :
F = 24.5/(4 X (5/16) X 0.707 X 15) = 1.84 ksi

Capacity of Minimum Sized Fillet Welds :
F = 4 X (5/16) X 0.707 X 15 X 0.30 X 70) = 278 kips

Load/Capacity of Minimum Sized Fillet Welds :
= 278 kips/24.5 kips = **11X**

204

CJP Weld Weight:

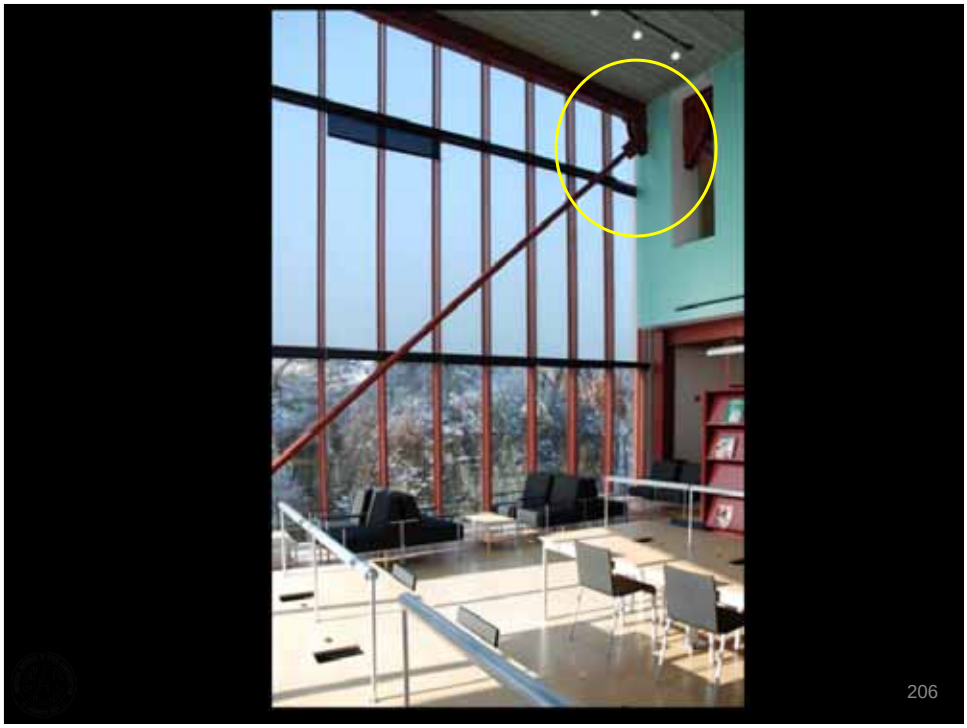
Volume = 4 at ($1.75^2/2$) X 15 = 91.8 in^3
Weight = 91.8 x 0.283 = 26.0 lbs

5/16 in Fillet Weld Weight:

Volume = 4 at ($(5/16)^2/2$) X 15 = 0.83 in^3
Weight = 0.83 x 0.283 = 0.032 lbs

Fillet weld option required 96.8% less weld metal!

205



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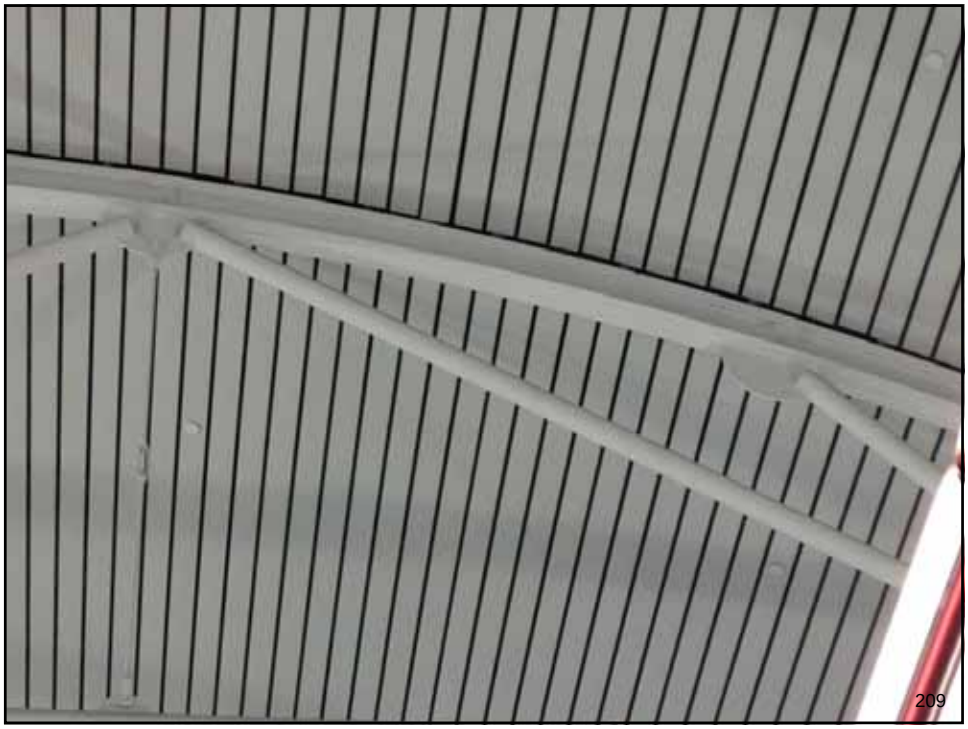

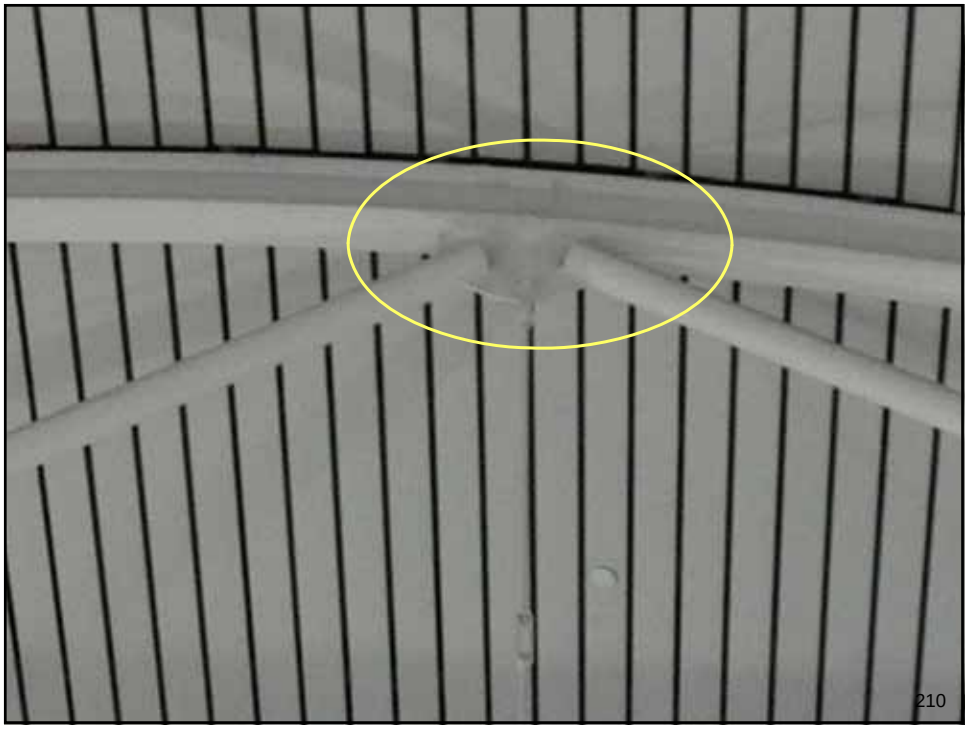

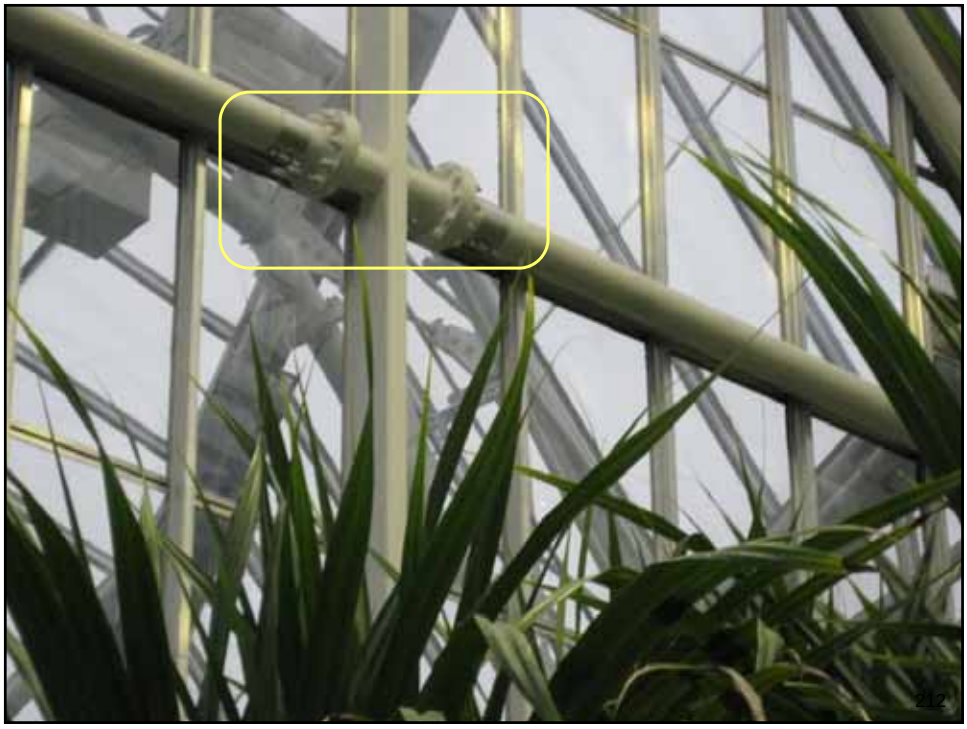

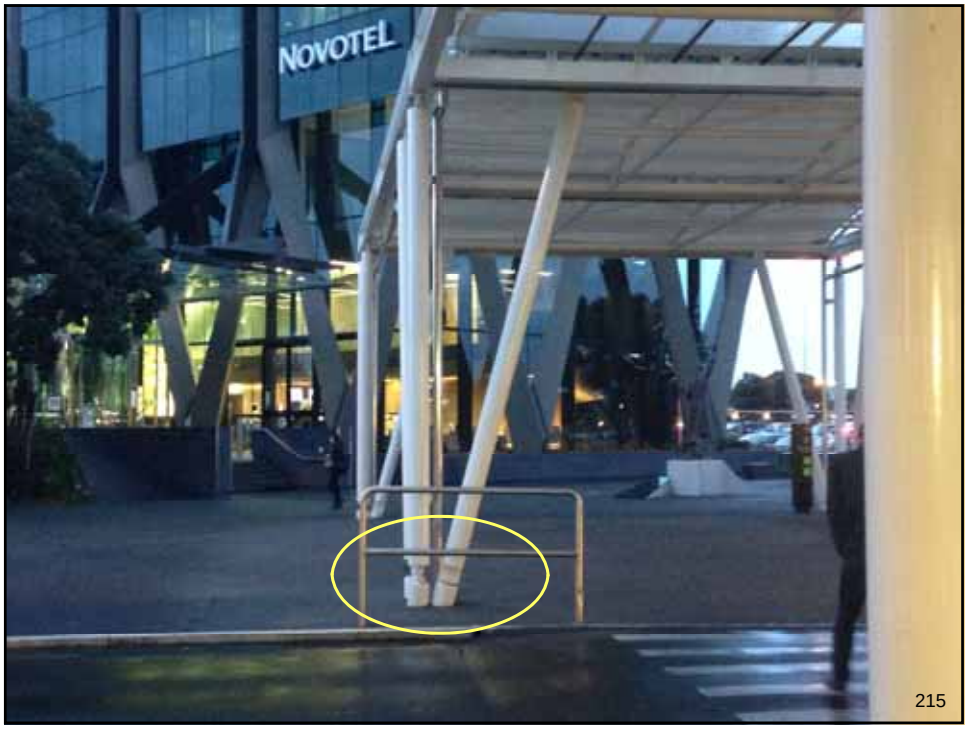

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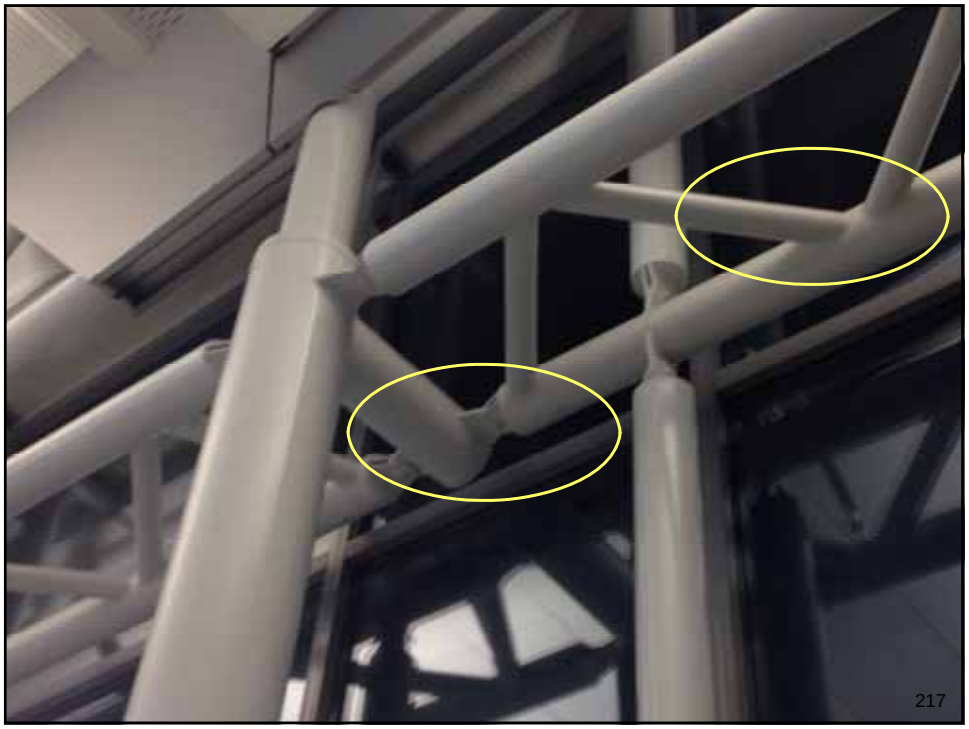
216



WELDED CONNECTIONS

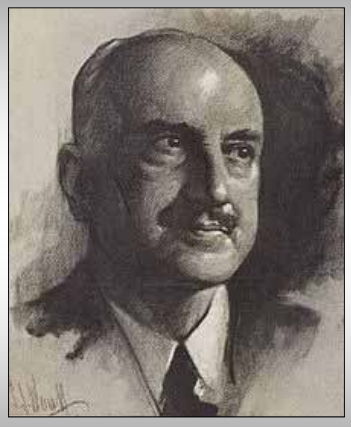
that are offensive or disgusting

3 S's

Simple
Serious
Silly

218

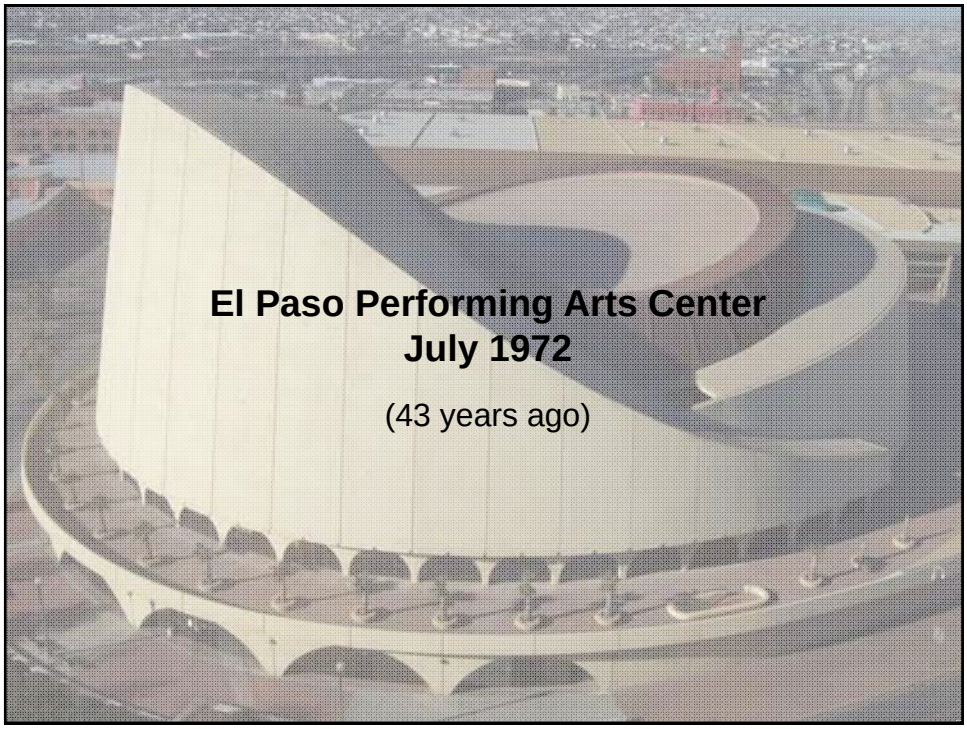
History

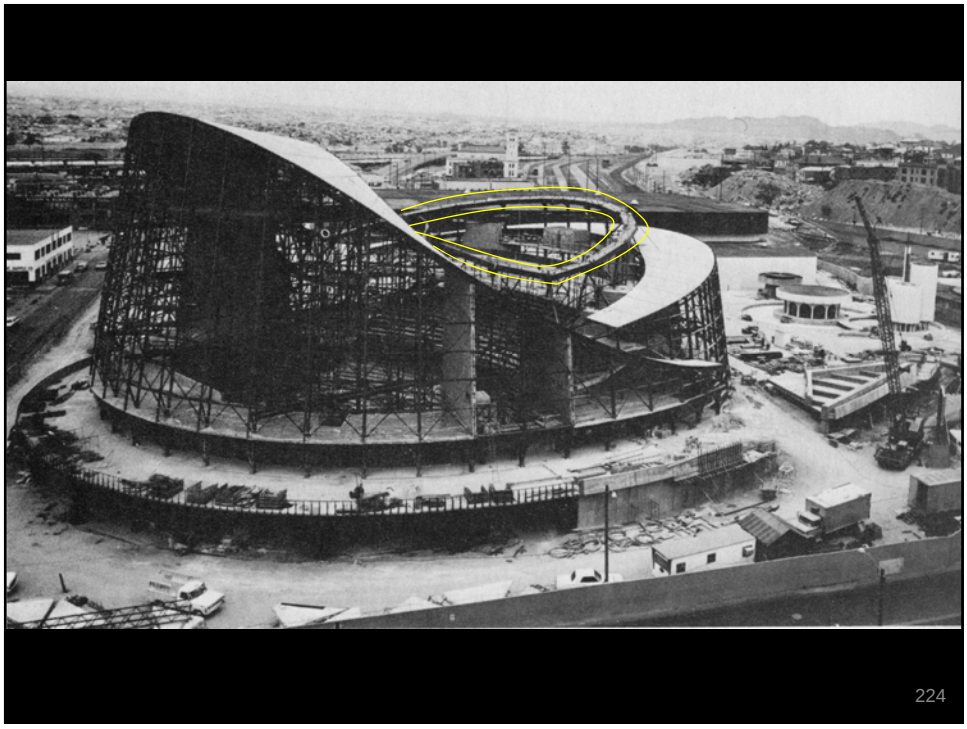


Those who cannot remember the past are condemned to repeat it.

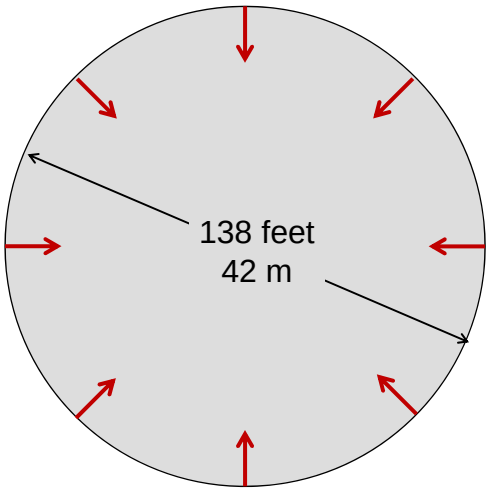
George Santayana
Philosopher, Essayist
1863 – 1952

219





Compression Ring



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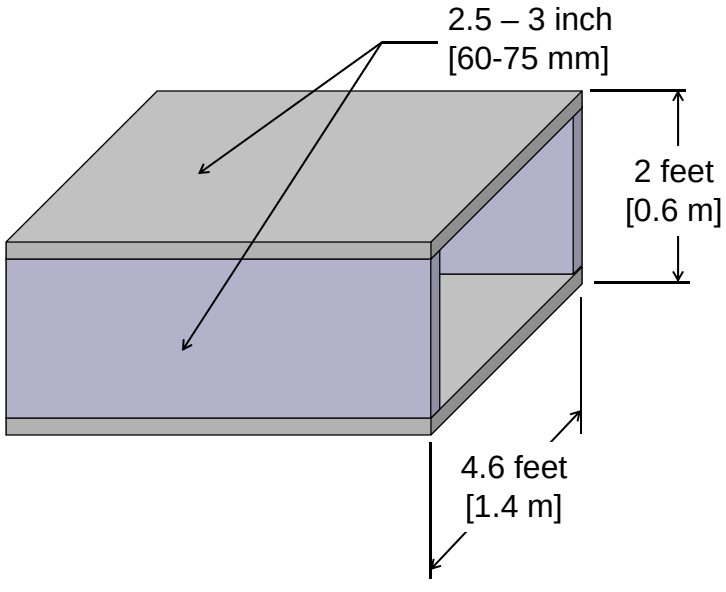

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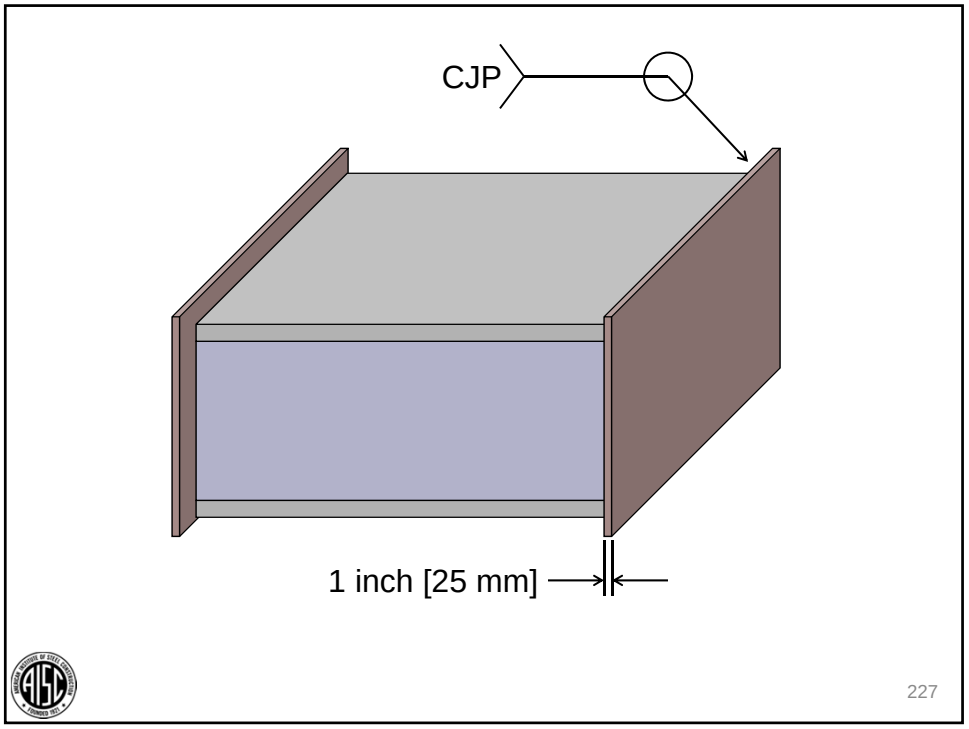
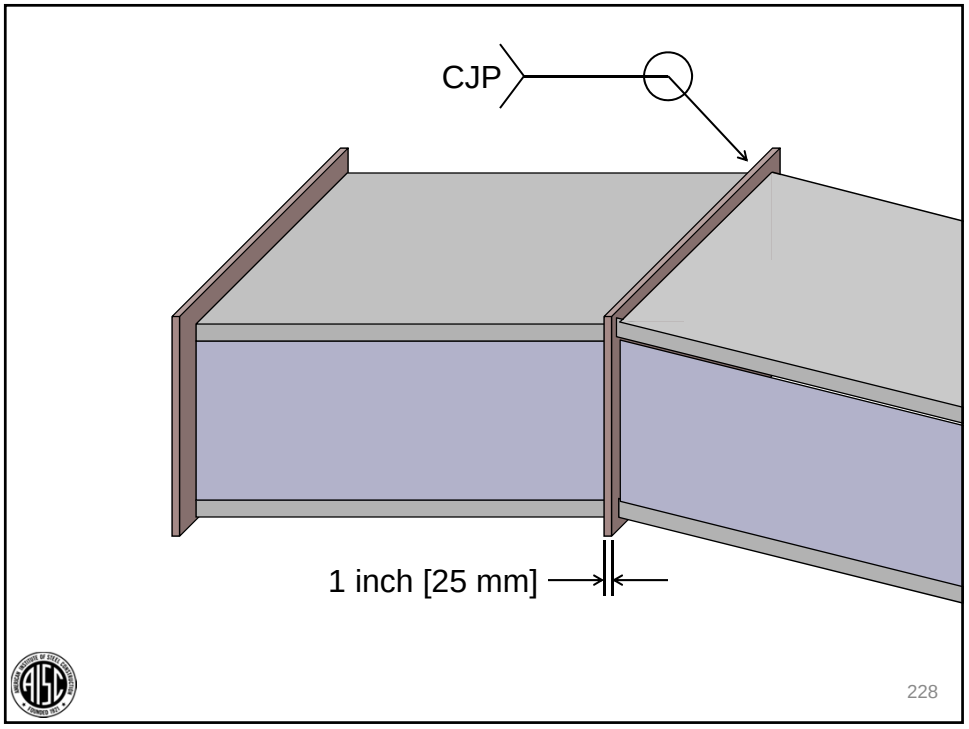
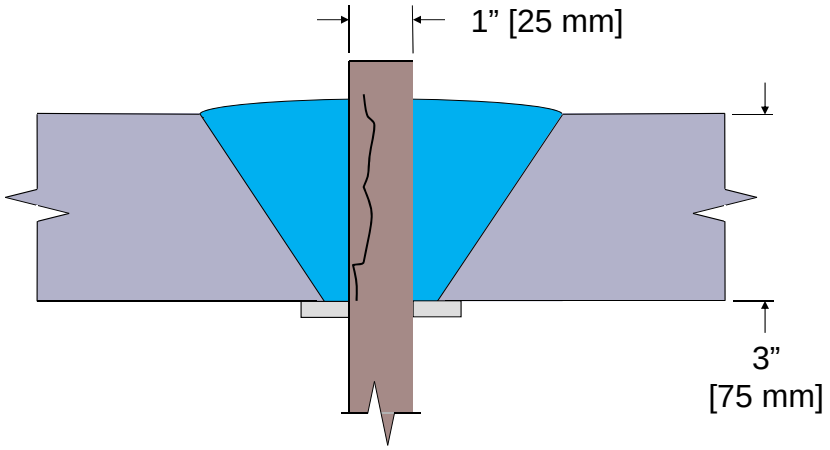




Lamellar Tearing



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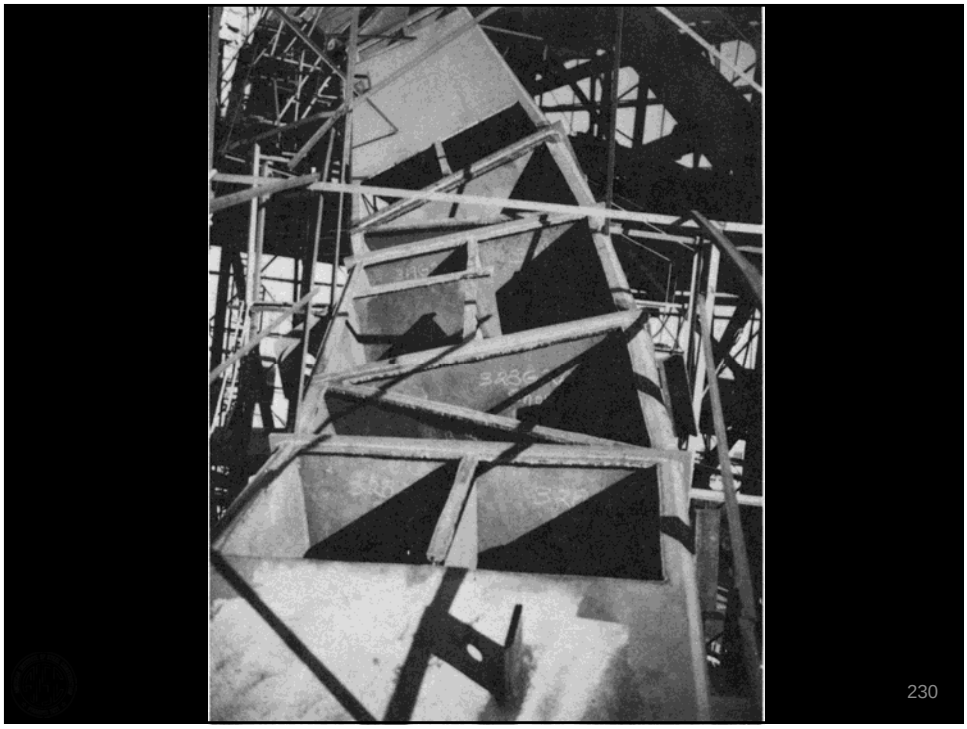

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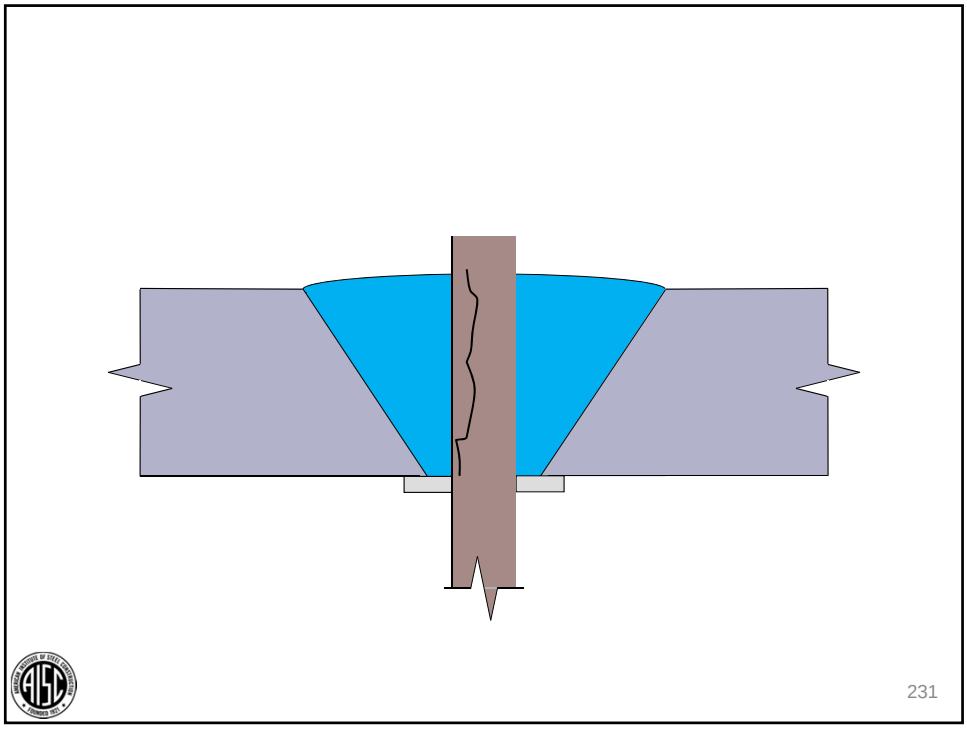
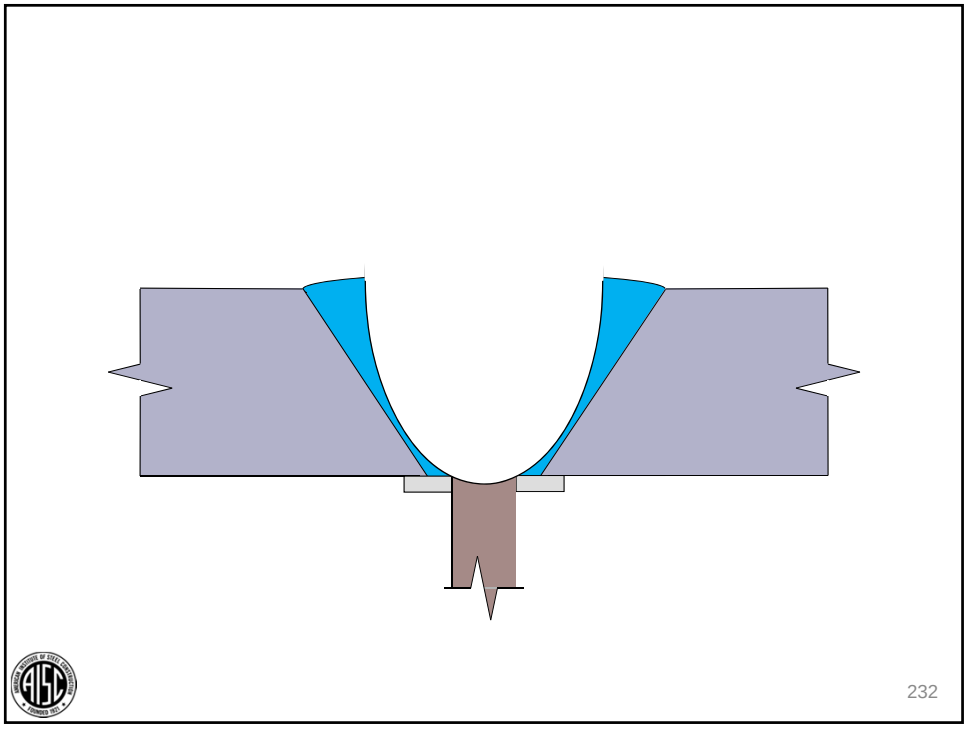
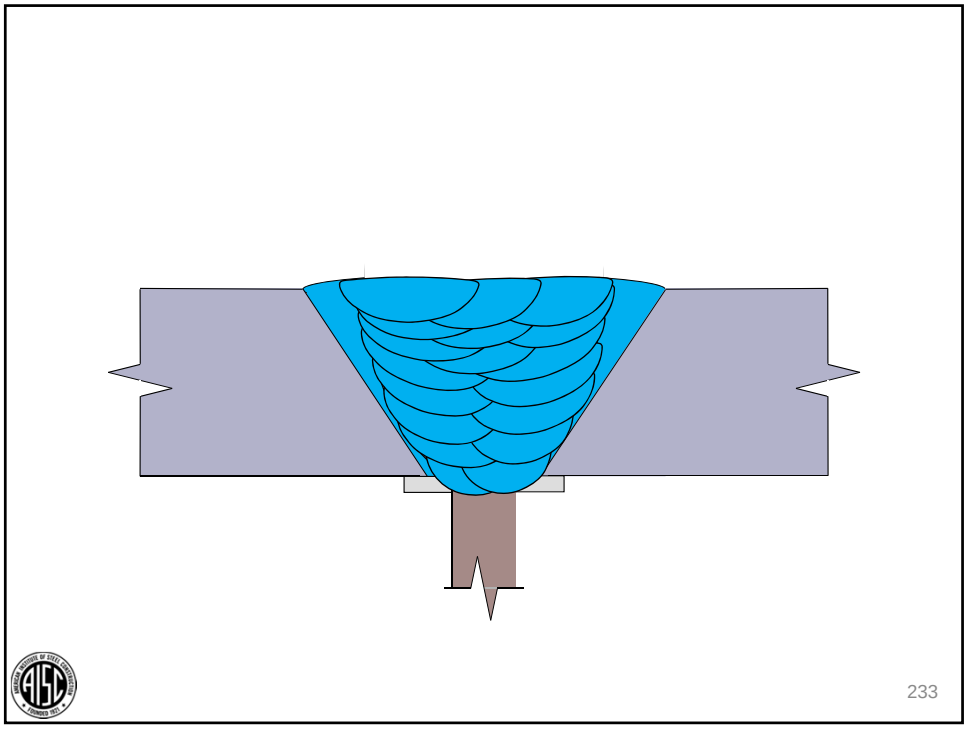
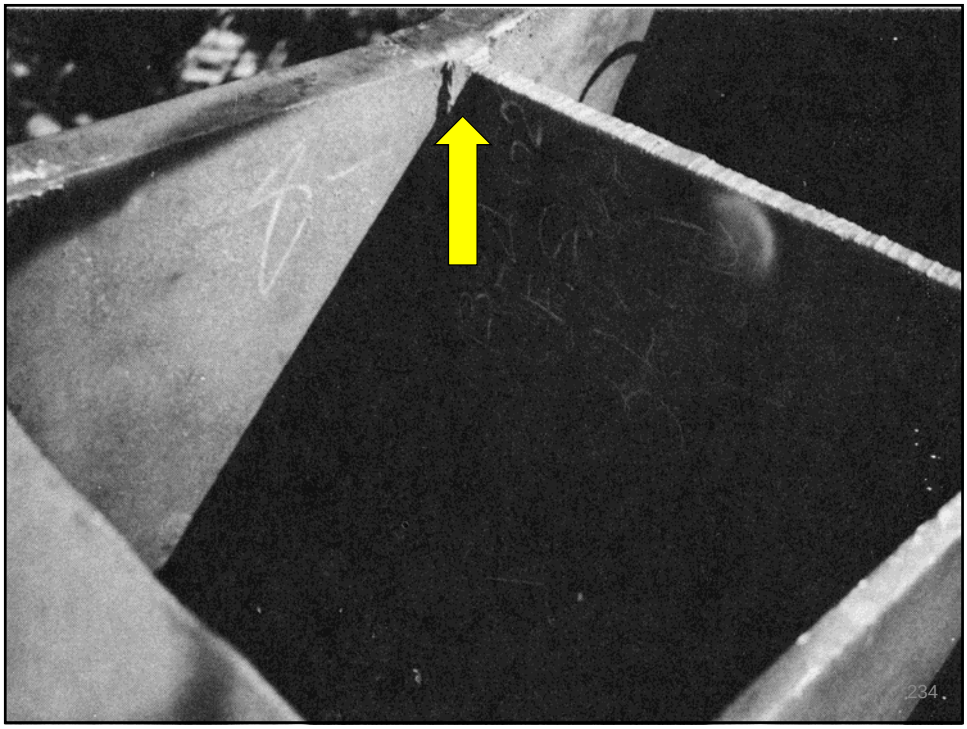








Principles of Connection Design

9

A correct and proper welded connection

recognizes material properties.

235

Principles of Connection Design

5

A correct and proper welded connection

is not constrained.

236

Principles of Connection Design

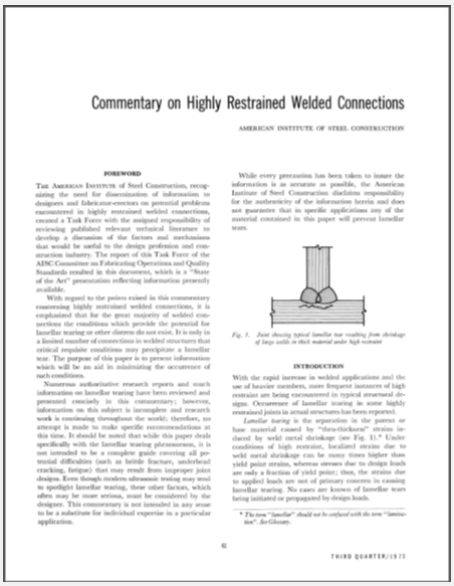
1

A correct and proper welded connection

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

237

Engineering Journal
Third Quarter 1973



Commentary on Highly Restrained Welded Connections

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

FOREWORD

THE AMERICAN INSTITUTE of Steel Construction, recognizing the need for dissemination of information to designers and fabricator-erectors on potential problems encountered in highly restrained welded connections, created a Task Force with the assigned responsibility of reviewing published relevant technical literature to develop a discussion of the factors and mechanisms that would be useful to the design profession and construction industry. The report of this Task Force of the AISC Committee on Fabricating Operations and Quality Standards resulted in this discussion, which is a "State of the Art" presentation reflecting information presently available.

With regard to the points raised in this commentary concerning highly restrained welded connections, it is emphasized that for the great majority of welded connections the conditions which provide the potential for lamellar tearing or other distress do not exist. It is only in a limited number of connections in welded structures that critical requisite conditions may precipitate a lamellar tear. The purpose of this paper is to present information which will be an aid in minimizing the occurrence of such conditions.

Numerous authoritative research reports and much information on lamellar tearing have been reviewed and presented concisely in this commentary; however, information on this subject is incomplete and research work is continuing throughout the world; therefore, no attempt is made to make specific recommendations at this time. It should be noted that while this paper deals specifically with the lamellar tearing phenomenon, it is not intended to be a complete guide covering all potential difficulties (such as brittle fracture, underbead cracking, fatigue) that may result from improper joint designs. Even though modern ultrasonic testing may tend to spotlight lamellar tearing, these other factors, which often may be more serious, must be considered by the designer. This commentary is not intended in any sense to be a substitute for individual expertise in a particular application.

While every precaution has been taken to insure the information is as accurate as possible, the American Institute of Steel Construction disclaims responsibility for the authenticity of the information herein and does not guarantee that its specific applications any of the material contained in this paper will prevent lamellar tears.

Fig. 1. Joint showing typical lamellar tear resulting from shrinkage of large welds in thick material under high restraint

INTRODUCTION

With the rapid increase in welded applications and the use of heavier members, more frequent instances of high restraint are being encountered in typical structural designs. Occurrences of lamellar tearing in some highly restrained joints in actual structures has been reported.

Lamellar tearing is the separation in the parent or base material caused by "through-thickness" strains induced by weld metal shrinkage (see Fig. 1).* Under conditions of high restraint, localized strains due to weld metal shrinkage can be many times higher than yield point strains, whereas stresses due to design loads are only a fraction of yield point; thus, the strains due to applied loads are not of primary concern in causing lamellar tearing. No cases are known of lamellar tears being initiated or propagated by design loads.

* The term "lamellar" should not be confused with the term "laminations". See Glossary.

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THIRD QUARTER/1973

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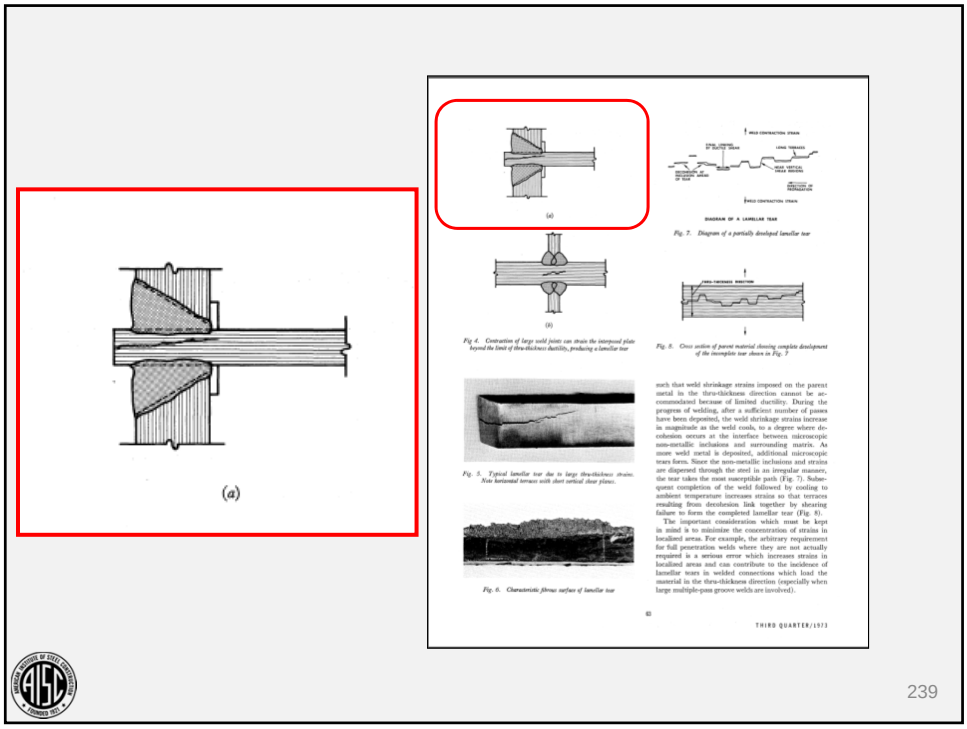
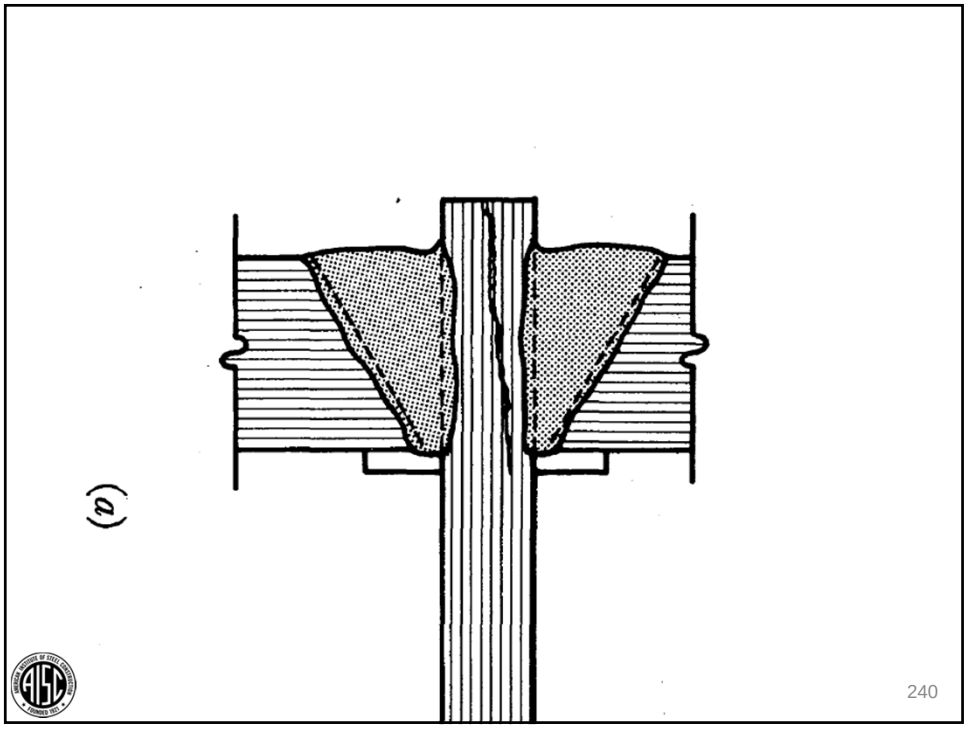
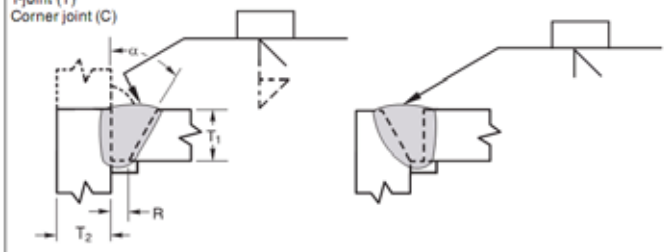




AWS D1.1:2010 Structural Welding Code--Steel

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



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

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

Prequalified Joint Details

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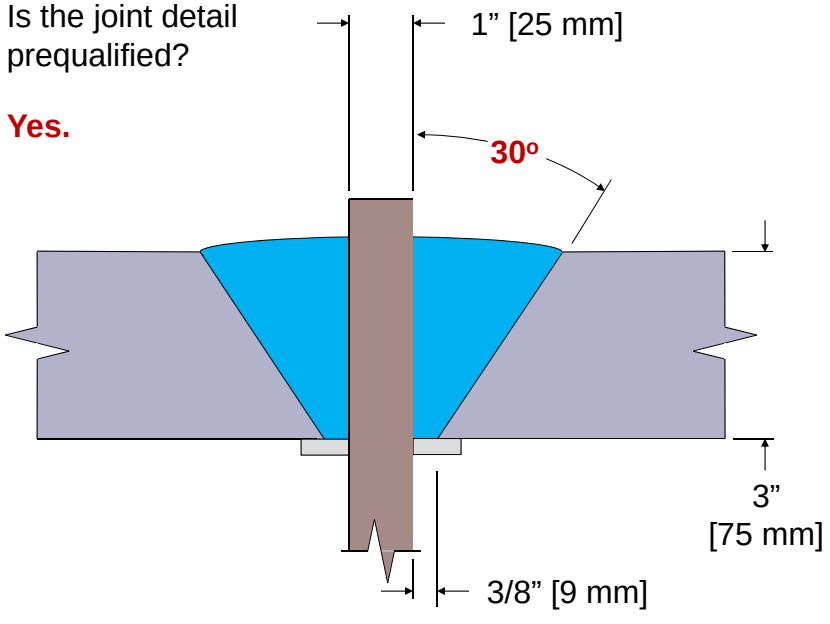
Is the joint detail prequalified?

Yes.



TC-U4a-GF

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AWS D1.1:2010 Structural Welding Code--Steel

1.4.1 Engineer's Responsibilities

The Engineer shall be responsible for the development of the contract documents that govern products or structural assemblies produced under this code. The Engineer may add to, delete from or otherwise modify, the requirements of this code to meet the requirements of a specific structure. All requirements that modify this code shall be incorporated into the contract documents. The Engineer shall determine the suitability of all joint details to be used in a welded structure.

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AWS D1.1:2010 Structural Welding Code--Steel

2.3.5.4 Prequalified Detail Dimensions

The joint details described in 3.12 (PJP) and 3.13 (CJP) have repeatedly demonstrated their adequacy in providing the conditions and clearances necessary for depositing and fusing sound weld metal to base metal. However, the use of these details shall not be interpreted as implying consideration of the effects of welding processes on base metal beyond the fusion boundary nor the suitability of the joint detail for a given application.

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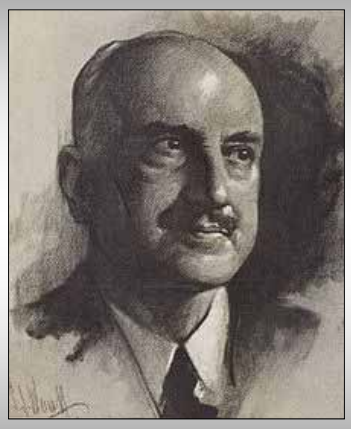
History



Those who cannot remember the past are condemned to repeat it.

George Santayana
Philosopher, Essayist
1863 – 1952

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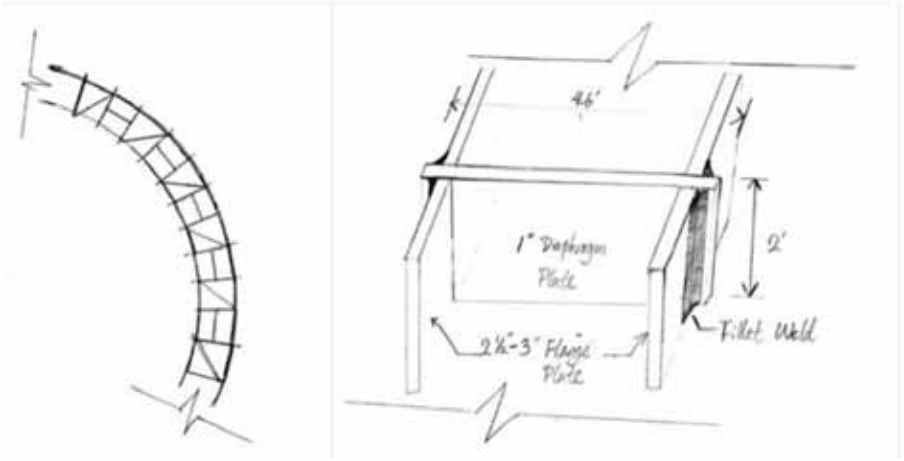
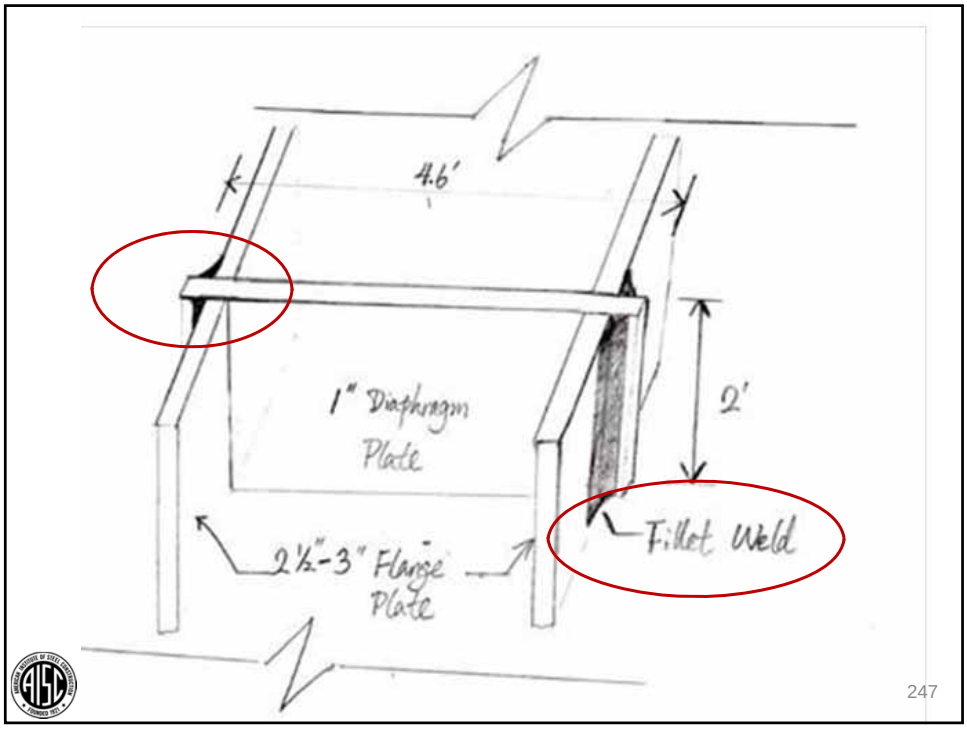
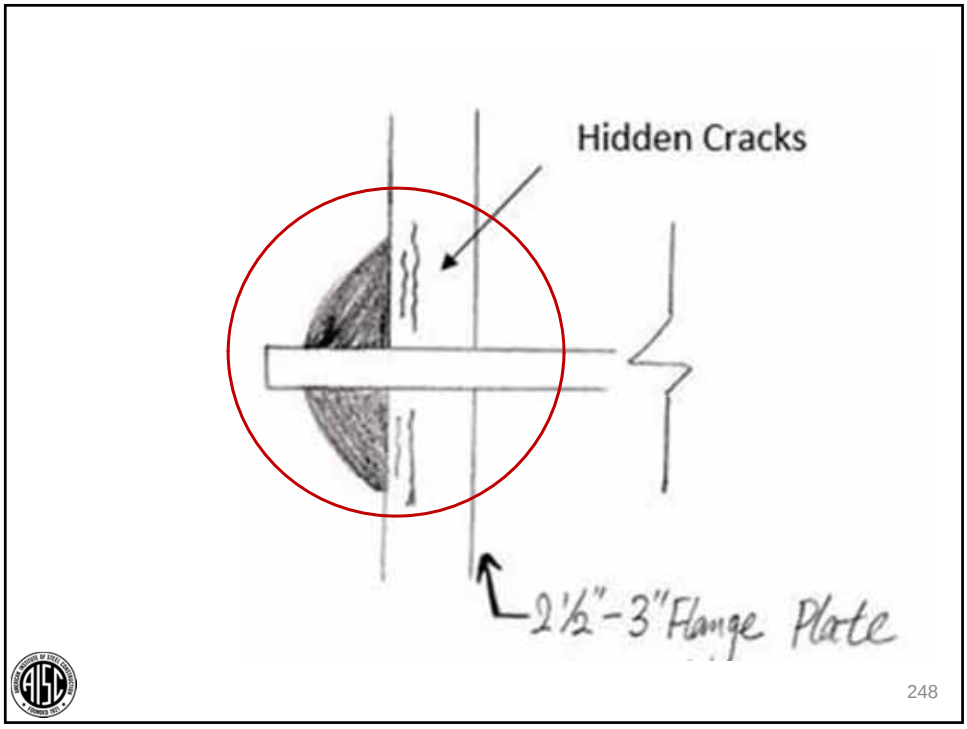
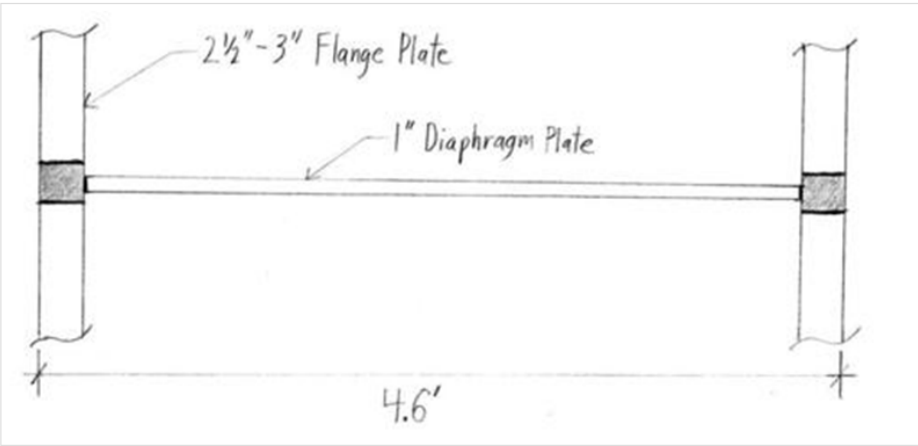


246







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Commentary on Highly Restrained Welded Connections

1. Select electrodes which deposit weld metal with the **lowest yield strength** adequate to carry design loads.
2. Design connections to **minimize accumulation and concentration of strains** resulting from weld metal contraction in localized areas.
3. Where possible, arrange connections so as to **avoid welded joints which induce thru-thickness strains** due to weld shrinkage.
4. Make connections with welds having the **minimum throat dimension** required to carry the stresses and having a **minimum practical volume of weld metal**.

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Commentary on Highly Restrained Welded Connections

5. Design corner joints with **proper consideration of edge preparation**.

6. Consideration of the **use of soft wire cushions** or other means to permit contraction of weld metal….

7. Whenever practical, **completely weld subassemblies** prior to final assembly of the connection.

8. **Do not arbitrarily use prequalified joints** without considering restraints provided by the complete connection assembly.

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Commentary on Highly Restrained Welded Connections

9. The **designer should fully research and utilize available experience** and knowledge on specific design details that might be potential sources of lamellar tearing.

10. **Do not use larger welds than are necessary** to transfer calculated forces.

11. **Do not specify stiffeners** when they are not required by design calculations.

12. Before making repairs to highly restrained connections, **determine whether the repair will be more detrimental** than the original cause for repair.

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Commentary on Highly Restrained Welded Connections

13. The **designer should selectively specify ultrasonic inspection** *after fabrication and/or erection* of those specific highly restrained welded connections critical to structural integrity that he considers to be subject to lamellar tearing.

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WELDED CONNECTIONS

that are offensive or disgusting

3 S's

Simple
Serious
Silly

255

Thank you, to all my friends who helped with examples.

Sylvie Boulanger, Supermétal
Joel Chandler, Owens Steel
Charlie Carter, AISC
Bob Disque, AISC (retired)
Jim Fisher, CSD
Larry Kloiber, LeJeune Steel
Ron Meng, Banker Steel
Bob Shaw, SSTC

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WELDED CONNECTIONS:

The Good, the Bad and the Ugly

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- Be on the lookout: Check your spam filter! Check your junk folder!
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