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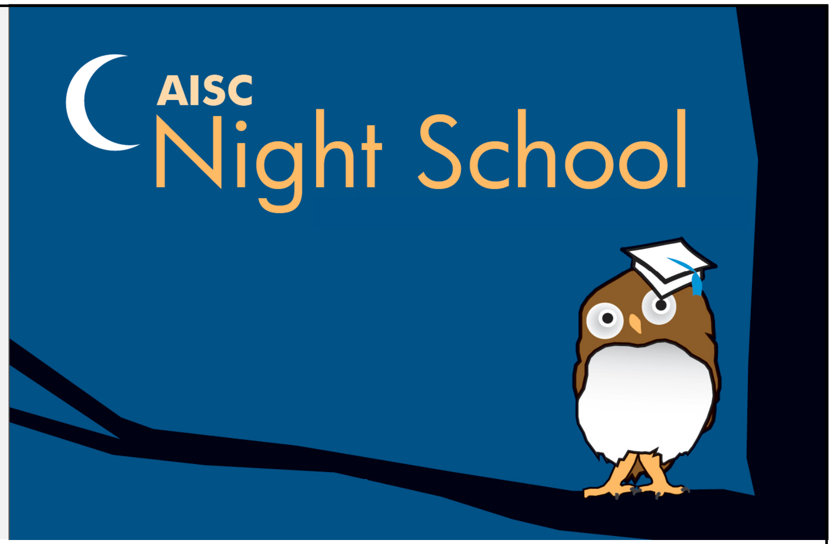

Welded Connections

A Primer for Engineers

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Course Description

21.5 Fatigue of Welded Connections
November 19, 2019

This session is specifically geared to toward Engineers and Contractors involved with bridge construction, but is equally applicable to individuals involved with the design and fabrication of crane girders and supports, and other weldments subject to cyclic loading. The basic concepts behind fatigue-resistant steel structures are considered, explaining the interrelated variables of stress range, connection geometry and the expected life of the welded connection. The role of dead load stress versus live load stress are discussed, as are the variable of weld quality and steel strength. Using AISC 360 Appendix 3, weld geometries are considered in detail with a practical focus on how to increase the fatigue resistance of welded connections.

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Learning Objectives

- Describe the provisions included in Appendix 3 of the 2016 AISC Specification for Structural Steel Buildings.
- Describe the concepts behind the fatigue design requirements.
- List the categories of connection details and predictive models.
- List the fatigue design requirements for welded connections.

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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

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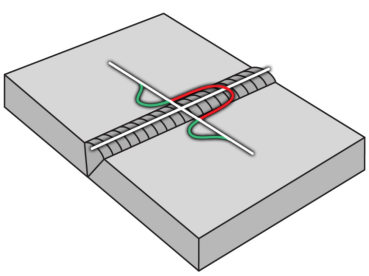
Night School 21
Welded Connections --
A Primer for Engineers

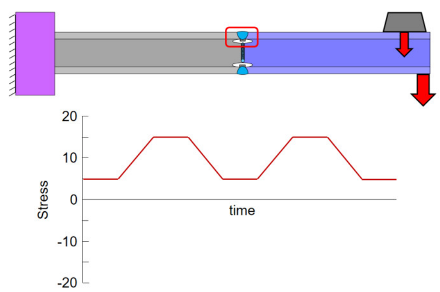
Session 5: Fatigue of Welded Connections
November 19, 2019

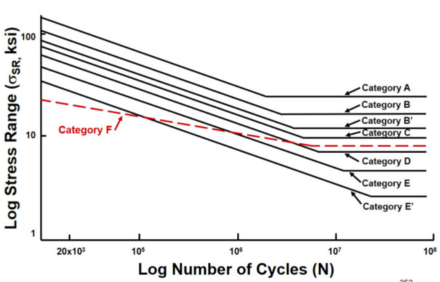
Duane K. Miller, PE, ScD
Manager of Engineering Services and Welding Design Consultant
LINCOLN ELECTRIC

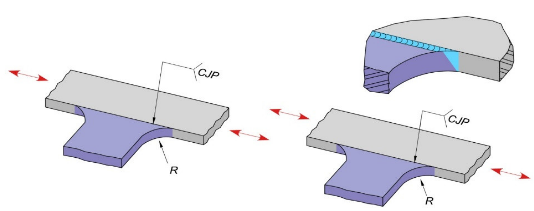
Smarter. Stronger. Steel.

FATIGUE OF WELDED CONNECTIONS









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FATIGUE CONSIDERATIONS

Chapter 12: Fatigue Considerations

12.1 Introduction

12.1 Stress Range

12.3 Connection Geometry

12.4 Computations

12.5 Inspection Issues

12.6 Special Fabrication and Erection Requirements

12.7 Limitations to the Appendix 3 Methodology

11

FATIGUE OF WELDED CONNECTIONS

Learning Objectives

Understanding Basics of Fatigue

Understanding the Role of the Stress Range

Understanding the Different Detail Categories

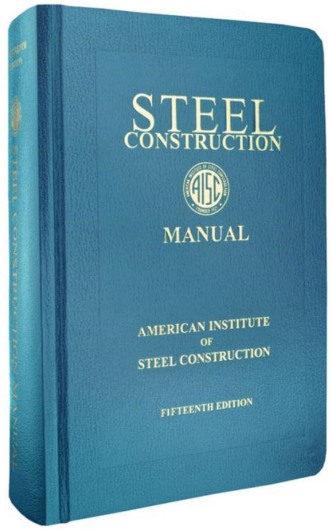
Learn How to Choose Weld Type and Geometry for Fatigue Applications

12

AISC 360-16 Specification for Structural Steel Buildings

AISC 360-16

Specification for Structural Steel Buildings



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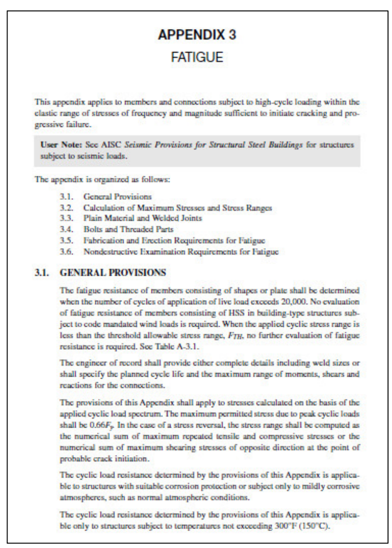
AISC 360-16 Specification for Structural Steel Buildings

Appendix 3

Fatigue



APPENDIX 3

FATIGUE

This appendix applies to members and connections subject to high-cycle loading within the elastic range of stresses of frequency and magnitude sufficient to initiate cracking and progressive failure.

User Note: See AISC *Seismic Provisions for Structural Steel Buildings* for structures subject to seismic loads.

The appendix is organized as follows:

3.1. General Provisions
3.2. Calculation of Maximum Stresses and Stress Ranges
3.3. Plain Material and Welded Joints
3.4. Bolts and Threaded Parts
3.5. Fabrication and Erection Requirements for Fatigue
3.6. Nondestructive Examination Requirements for Fatigue

3.1. GENERAL PROVISIONS

The fatigue resistance of members consisting of shapes or plate shall be determined when the number of cycles of application of live load exceeds 20,000. No evaluation of fatigue resistance of members consisting of HSS in building-type structures subject to code mandated wind loads is required. When the applied cyclic stress range is less than the threshold allowable stress range, F_{TH}, no further evaluation of fatigue resistance is required. See Table A-3.1.

The engineer of record shall provide either complete details including weld sizes or shall specify the planned cycle life and the maximum range of moments, shears and reactions for the connections.

The provisions of this Appendix shall apply to stresses calculated on the basis of the applied cyclic load spectrum. The maximum permitted stress due to peak cyclic loads shall be $0.66F_y$. In the case of a stress reversal, the stress range shall be computed as the numerical sum of maximum repeated tensile and compressive stresses or the numerical sum of maximum shearing stresses of opposite direction at the point of probable crack initiation.

The cyclic load resistance determined by the provisions of this Appendix is applicable to structures with suitable corrosion protection or subject only to mildly corrosive atmospheres, such as normal atmospheric conditions.

The cyclic load resistance determined by the provisions of this Appendix is applicable only to structures subject to temperatures not exceeding 300°F (150°C).

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FATIGUE OF WELDED CONNECTIONS

Outline

1. Background and Theory
2. Design Model
3. Details Associated with the Model
4. Summary

FATIGUE OF WELDED CONNECTIONS

Outline

1. Background and Theory
   - Definition
   - Causation
   - Variables Affecting Fatigue

FATIGUE CONSIDERATIONS

What is fatigue?

21

AISC 360-16 Specification for Structural Steel Buildings

GLOSSARY

Fatigue.

Limit state of crack initiation and growth resulting from repeated application of live loads.

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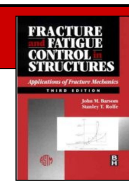
Fracture and Fatigue Control in Structures



"Fatigue is the process of cumulative damage in a benign environment that is caused by repeated fluctuating loads and, in the presence of an aggressive environment, is known as corrosion fatigue."

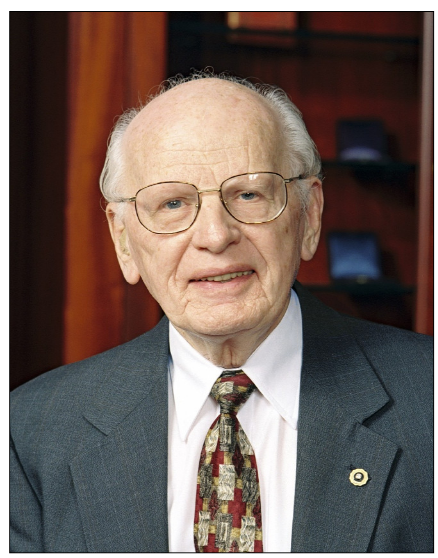
Barsom and Rolfe

23

Fatigue

Fatigue is the result of repeated plastic deformation.

Omer W. Blodgett

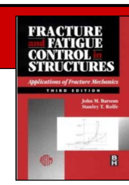


FATIGUE CONSIDERATIONS

What causes fatigue?

25

Fracture and Fatigue Control in Structures



"Fatigue damage of components subjected to normally elastic stress fluctuations occurs at regions of stress (strain) raisers where the localized stress exceeds the yield stress of the material. After a certain number of load fluctuations, the accumulated damage causes the initiation and subsequent propagation of a crack, or cracks, in the plastically damaged regions."

Barsom and Rolfe

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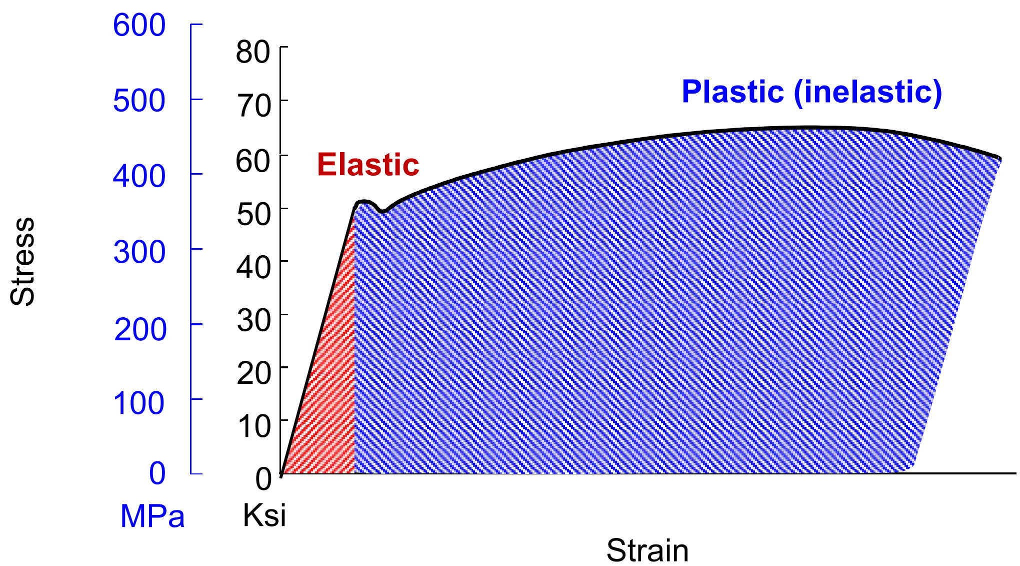
FATIGUE CONSIDERATIONS



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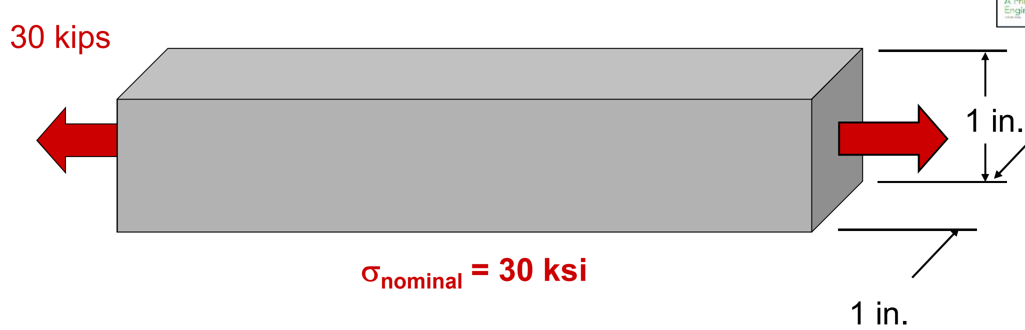
FATIGUE CONSIDERATIONS



$$\text{Stress}, \sigma = \frac{P}{A} = \frac{30\ \text{kips}}{1\ \text{in}^2} = 30\ \text{ksi}$$

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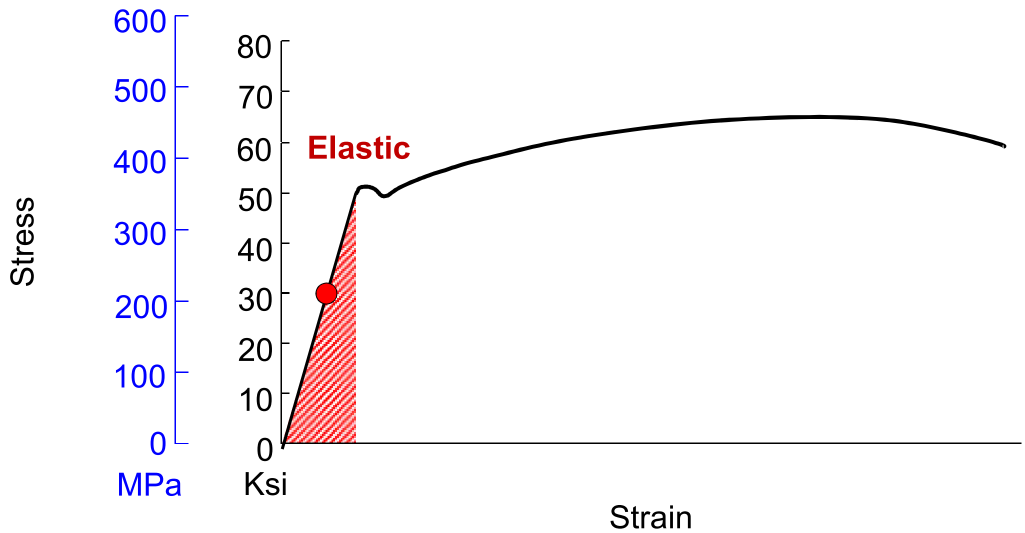
FATIGUE CONSIDERATIONS



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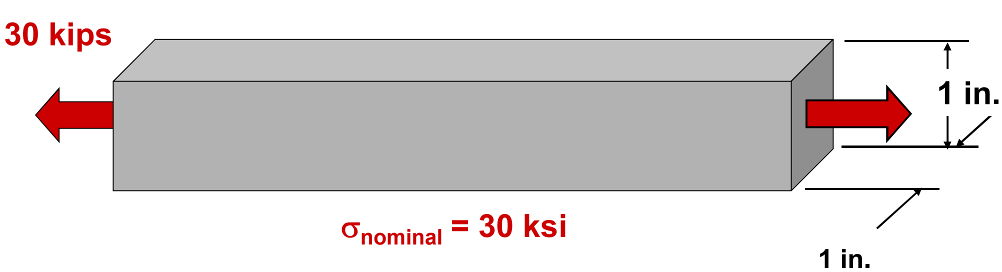
FATIGUE CONSIDERATIONS

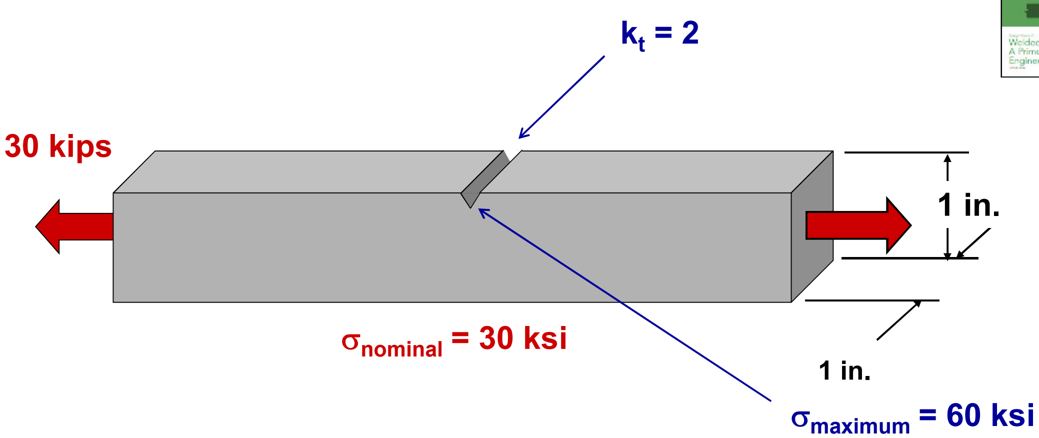
Stress Concentrator (k_t)



$$k_t = \frac{\sigma_{maximum}}{\sigma_{nominal}} \qquad \sigma_{maximum} = k_t \cdot \sigma_{nominal}$$

30

FATIGUE CONSIDERATIONS



$$k_t = 2 = \frac{\sigma_{maximum}}{\sigma_{nominal}} = \frac{\sigma_{maximum}}{30\ ksi} \qquad \sigma_{maximum} = 60\ ksi$$

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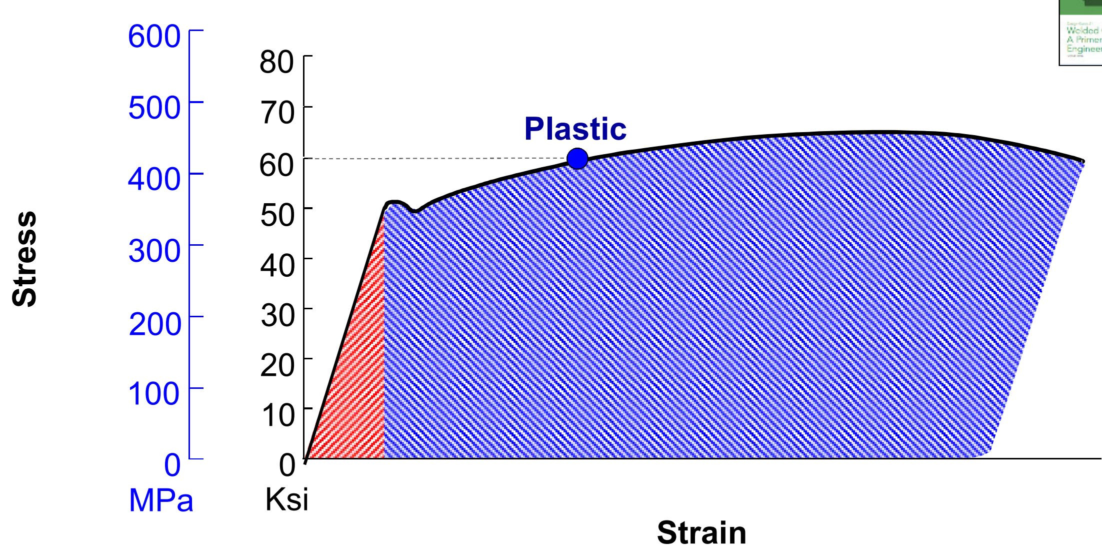
FATIGUE CONSIDERATIONS



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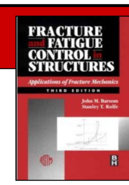
Fracture and Fatigue Control in Structures



"Welding technology is complex and fabrication by welding encompasses characteristics that should be understood to different levels by the design engineer, the fabricator, and the welder. Some of these characteristics pertinent to the present discussion are residual stresses, imperfections, and stress concentrations."

Barsom and Rolfe

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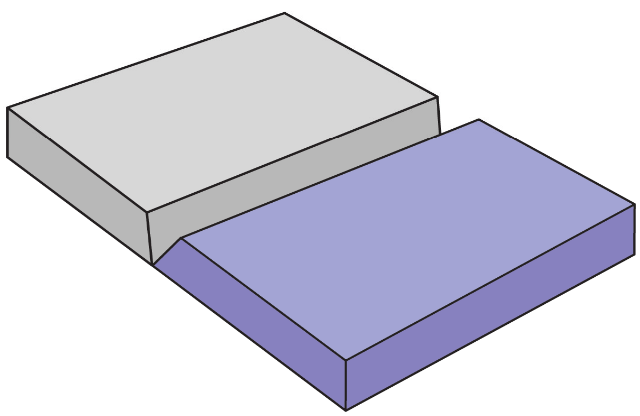
FATIGUE CONSIDERATIONS

Residual Stresses



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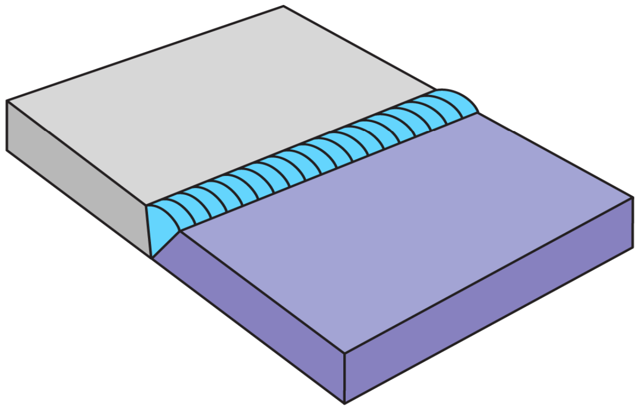
FATIGUE CONSIDERATIONS

Residual Stresses



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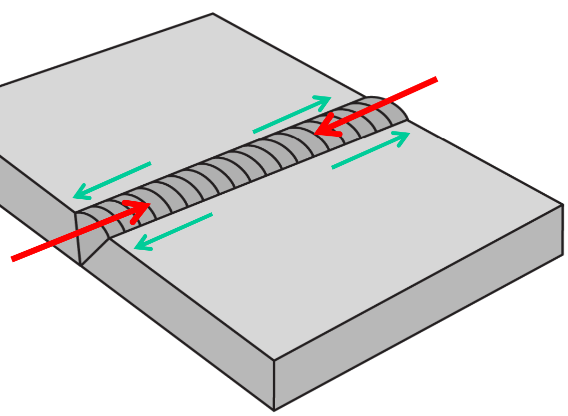
FATIGUE CONSIDERATIONS

Residual Stresses



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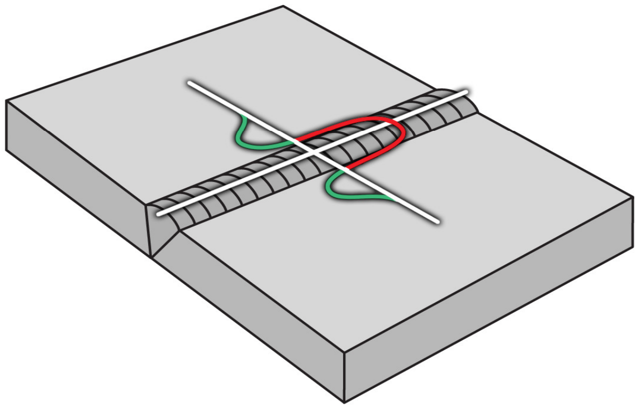
FATIGUE CONSIDERATIONS

Residual Stresses



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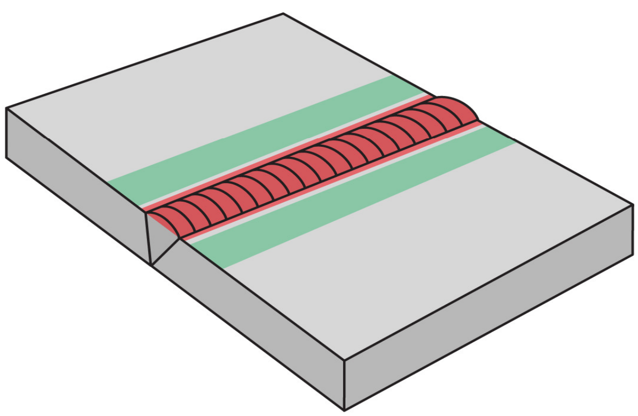
FATIGUE CONSIDERATIONS

Residual Stresses



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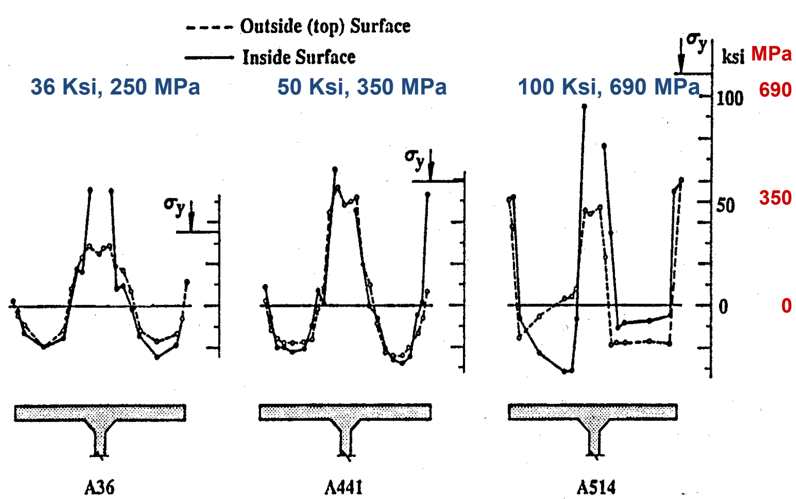
FATIGUE CONSIDERATIONS

Residual Stresses



From "Economical and Fatigue Resistant Steel Bridge Details, National Highway Institute Course No. 13049

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Fracture and Fatigue Control in Structures

"Welding technology is complex and fabrication by welding encompasses characteristics that should be understood to different levels by the design engineer, the fabricator, and the welder. Some of these characteristics pertinent to the present discussion are residual stresses, imperfections, and stress concentrations."

Barsom and Rolfe

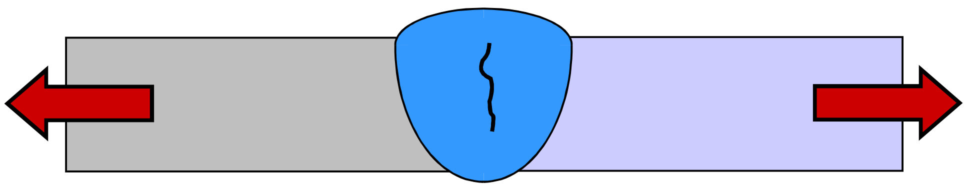
40

FATIGUE CONSIDERATIONS

Imperfections

Crack in Weld

(almost always a defect)



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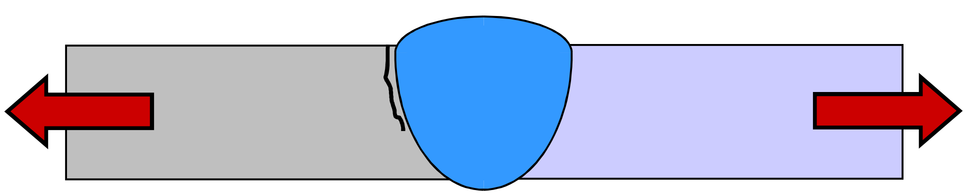
FATIGUE CONSIDERATIONS

Imperfections

Crack in Heat Affected Zone (HAZ)

(almost always a defect)



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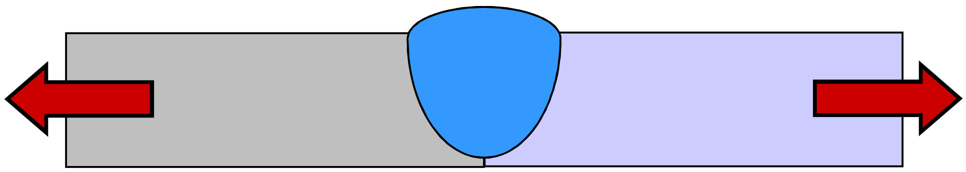
FATIGUE CONSIDERATIONS

Imperfections

Incomplete Joint Penetration in CJP

(almost always a defect)



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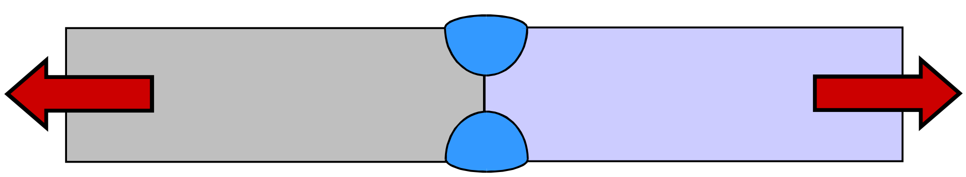
FATIGUE CONSIDERATIONS

Imperfections

Incomplete Joint Penetration in CJP

(almost always a defect)



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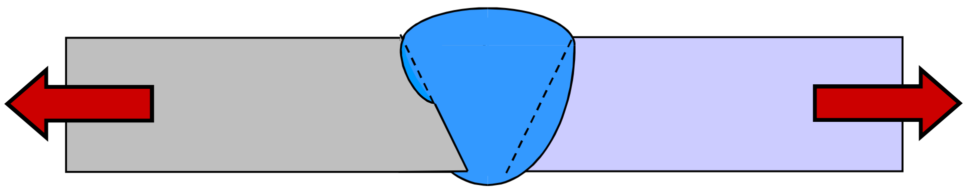
FATIGUE CONSIDERATIONS

Imperfections

Incomplete Fusion

(almost always a defect)



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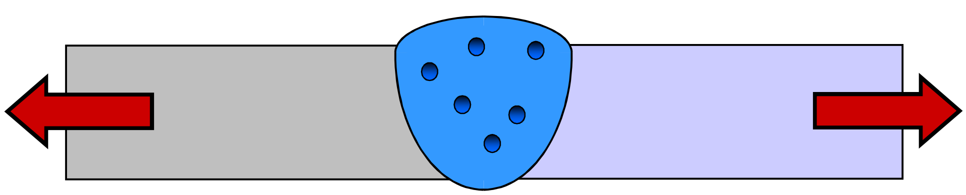
FATIGUE CONSIDERATIONS

Imperfections

Porosity



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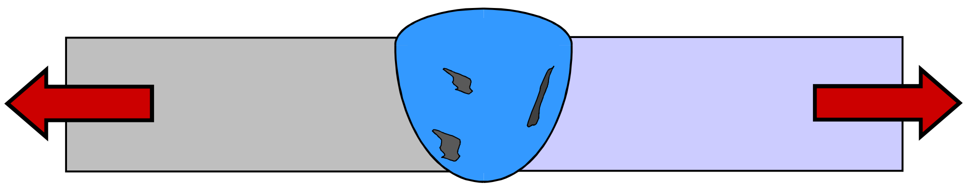
FATIGUE CONSIDERATIONS

Imperfections

Slag Inclusions



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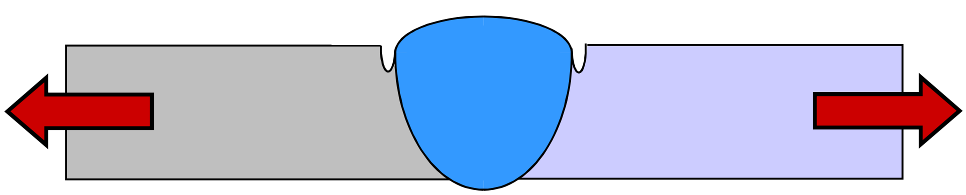
FATIGUE CONSIDERATIONS

Imperfections

Undercut



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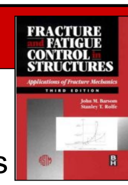
Fracture and Fatigue Control in Structures



"Welding technology is complex and fabrication by welding encompasses characteristics that should be understood to different levels by the design engineer, the fabricator, and the welder. Some of these characteristics pertinent to the present discussion are residual stresses, imperfections, and stress concentrations."

Barsom and Rolfe

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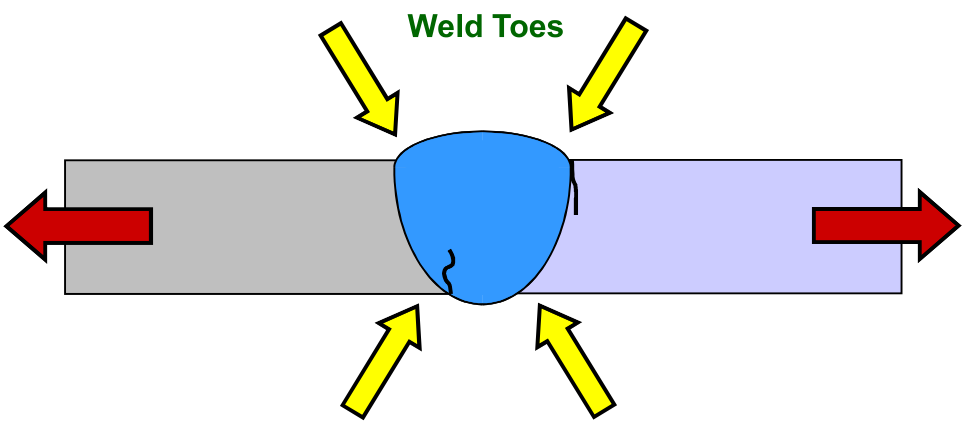
FATIGUE CONSIDERATIONS

Stress Concentrations



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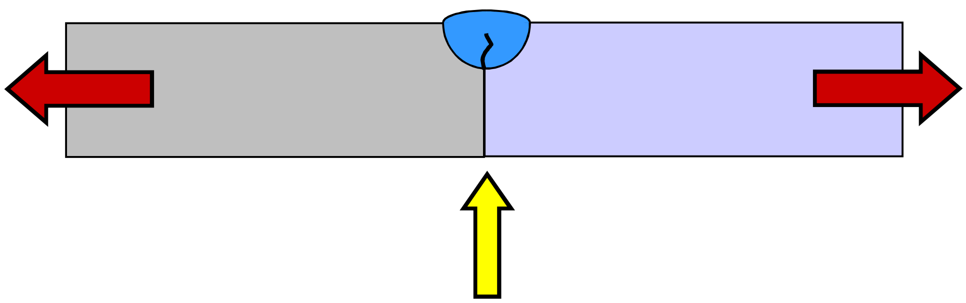
FATIGUE CONSIDERATIONS

Stress Concentrations

Unfused Root of Single Sided PJP Groove Weld



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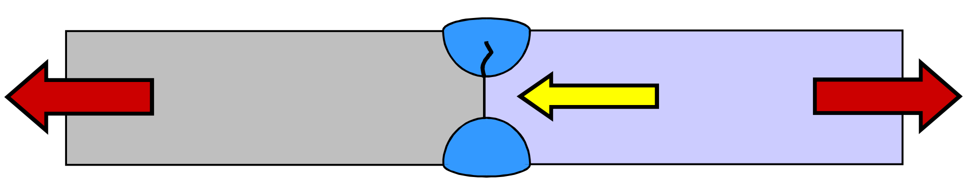
FATIGUE CONSIDERATIONS

Stress Concentrations

Unfused Root of Double Sided PJP Groove Weld



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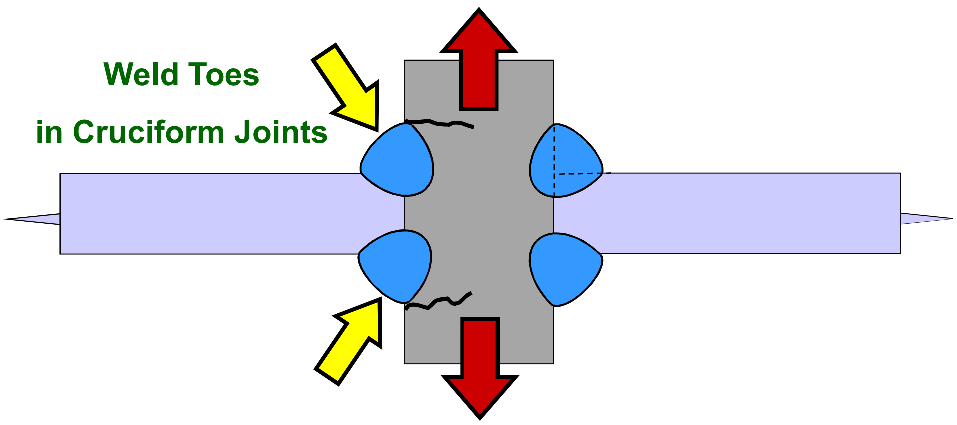
FATIGUE CONSIDERATIONS

Stress Concentrations



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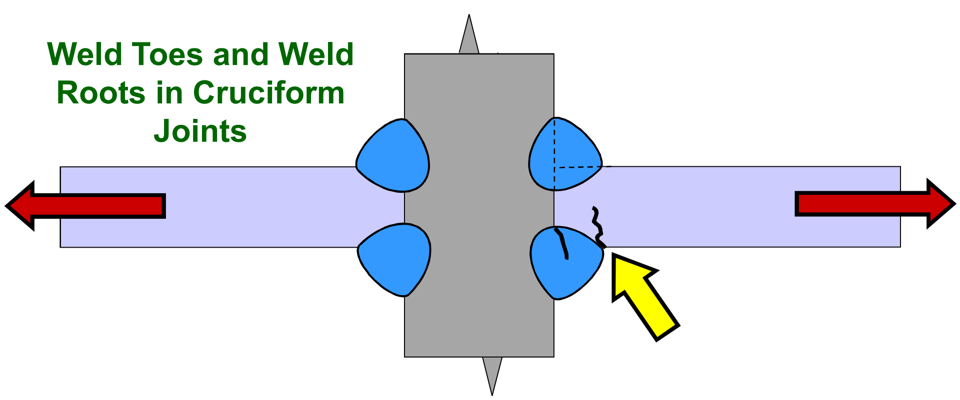
FATIGUE CONSIDERATIONS

Stress Concentrations



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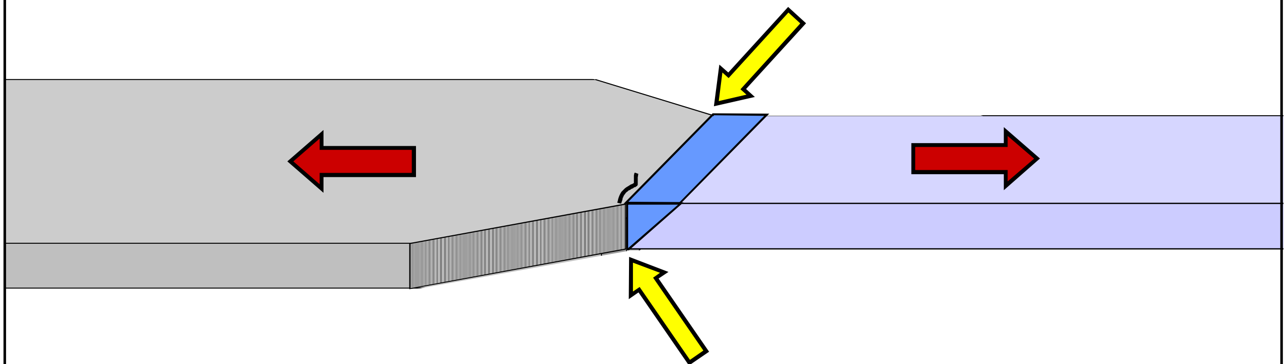
FATIGUE CONSIDERATIONS

Stress Concentrations

Width Transitions in Butt Joints



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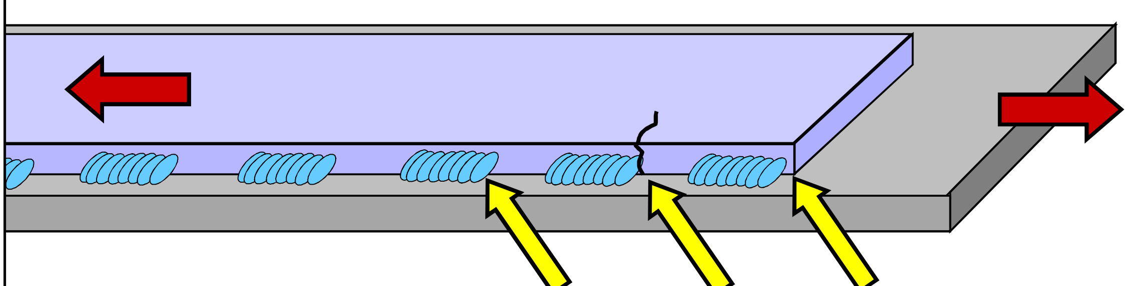
FATIGUE CONSIDERATIONS

Stress Concentrations

Ends of Intermittent Fillet Welds



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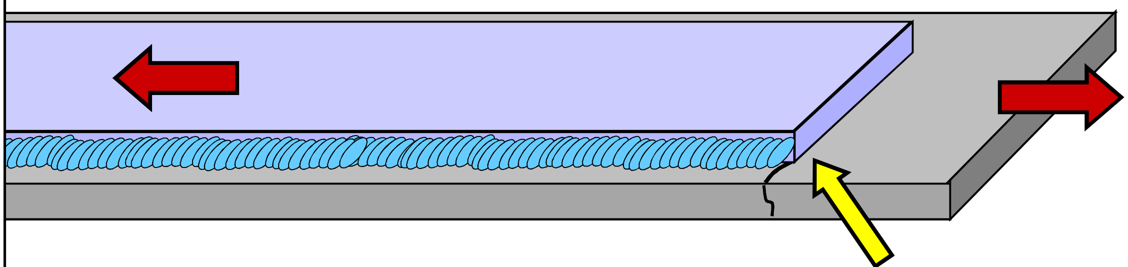
FATIGUE CONSIDERATIONS

Stress Concentrations

Ends of Continuous Fillet Welds at Partial Length Cover Plates



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AISC 360-16 Specification for Structural Steel Buildings

APPENDIX 3 COMMENTARY

3.1. GENERAL PROVISIONS

Extensive test programs using full-size specimens, substantiated by theoretical stress analysis, have confirmed the following general conclusions (Fisher et al., 1970; Fisher et al., 1974):

(1) Stress range and notch severity are the dominant stress variables for welded details and beams.

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FATIGUE CONSIDERATIONS

Stress Range

$$F_{SR} = F_{MAX} - F_{MIN}$$

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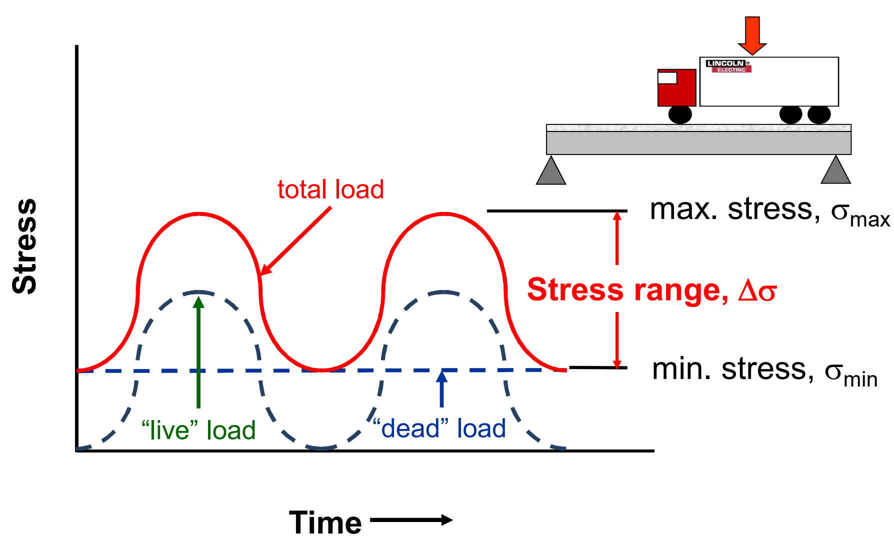
FATIGUE CONSIDERATIONS



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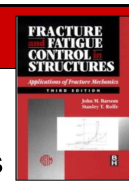
Fracture and Fatigue Control in Structures



“Welding technology is complex and fabrication by welding encompasses characteristics that should be understood to different levels by the design engineer, the fabricator, and the welder. Some of these characteristics pertinent to the present discussion are residual stresses, imperfections, and stress concentrations.”

Barsom and Rolfe

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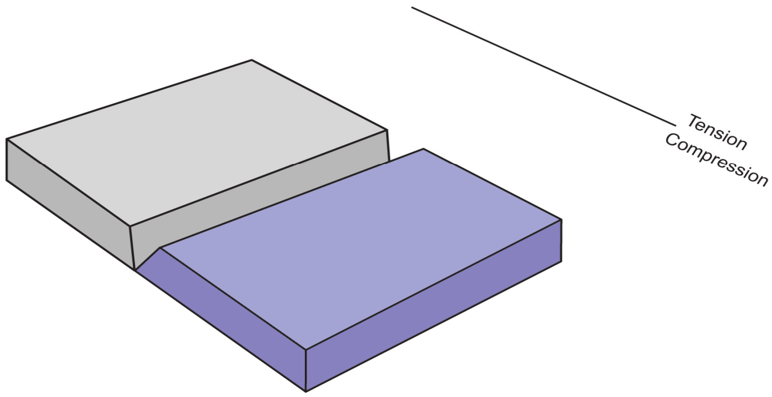
FATIGUE CONSIDERATIONS

Residual Stresses: Before Welding



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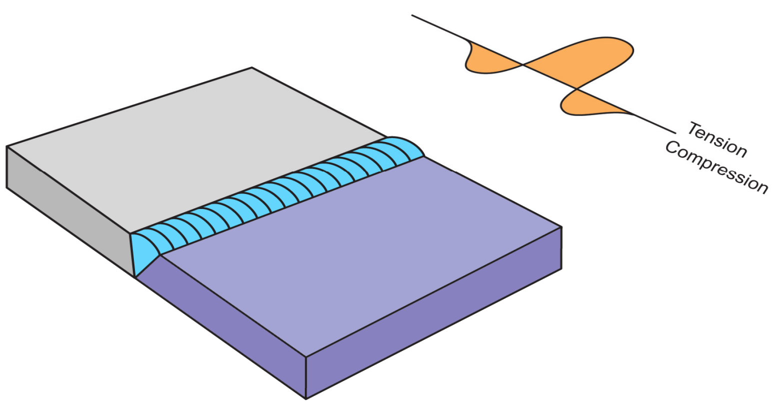
FATIGUE CONSIDERATIONS

Residual Stresses: After Welding



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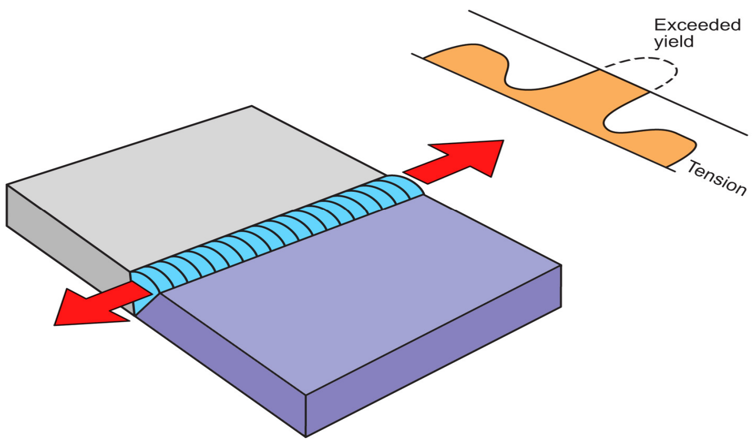
FATIGUE CONSIDERATIONS

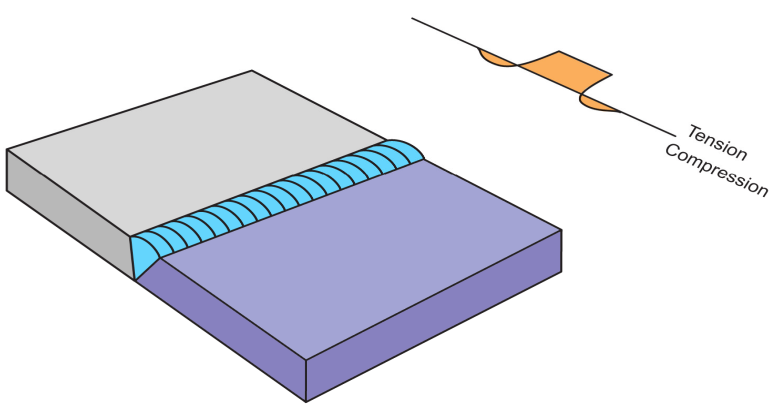
Stresses: Residual and Applied



65

FATIGUE CONSIDERATIONS

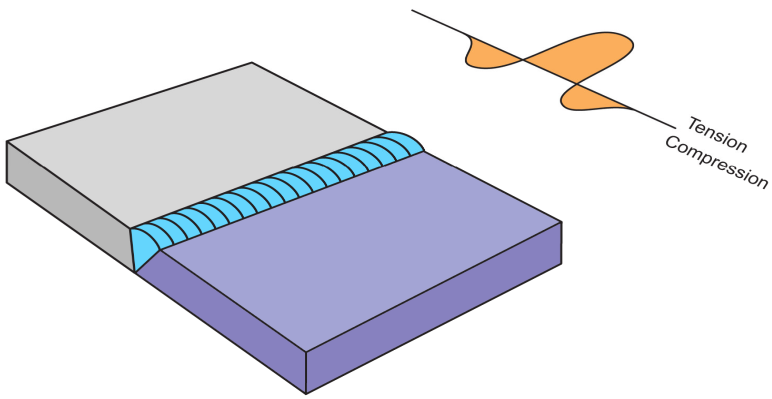
Residual Stresses: After Tensile Loading



66

FATIGUE CONSIDERATIONS

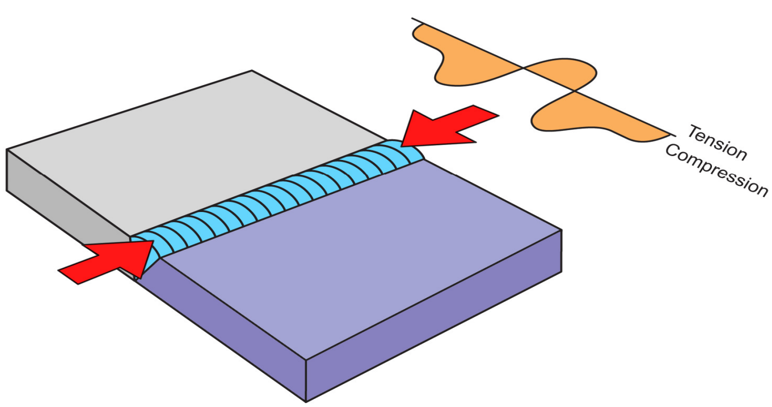
Residual Stresses: After Welding



67

FATIGUE CONSIDERATIONS

Stresses: Residual and Applied



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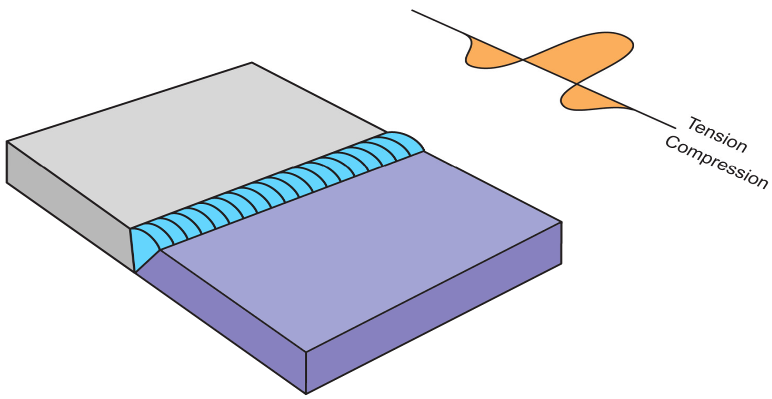
FATIGUE CONSIDERATIONS

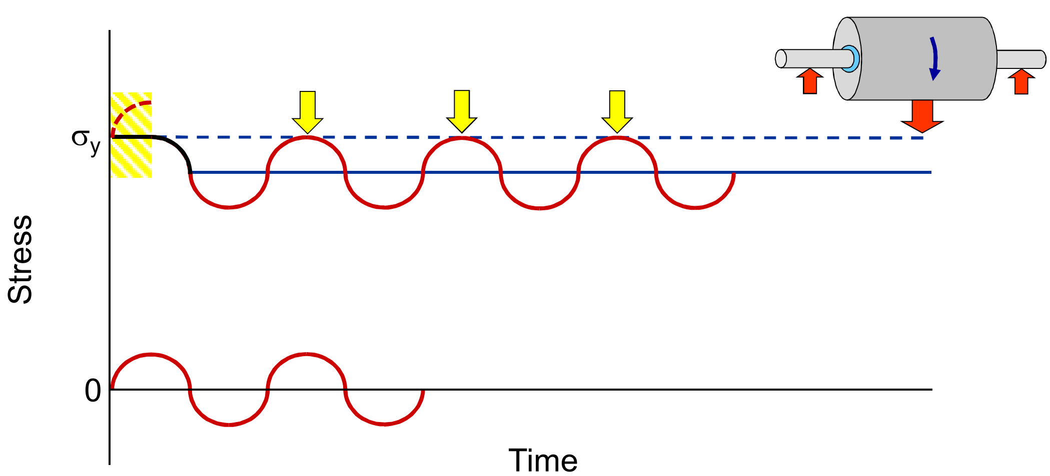
Residual Stresses: After Compressive Loading



69

FATIGUE CONSIDERATIONS

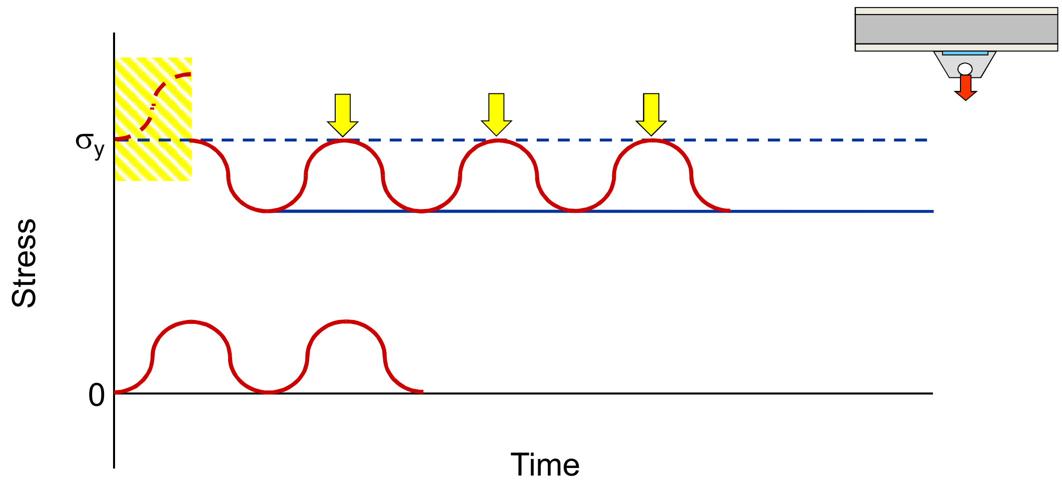
Complete Reversal



70

FATIGUE CONSIDERATIONS

Zero to Full Tensile



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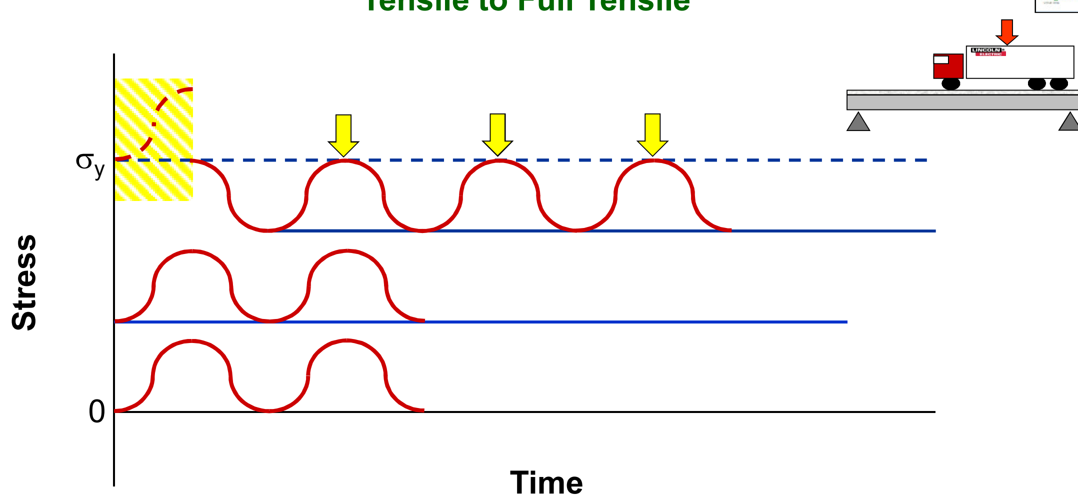
FATIGUE CONSIDERATIONS

Tensile to Full Tensile



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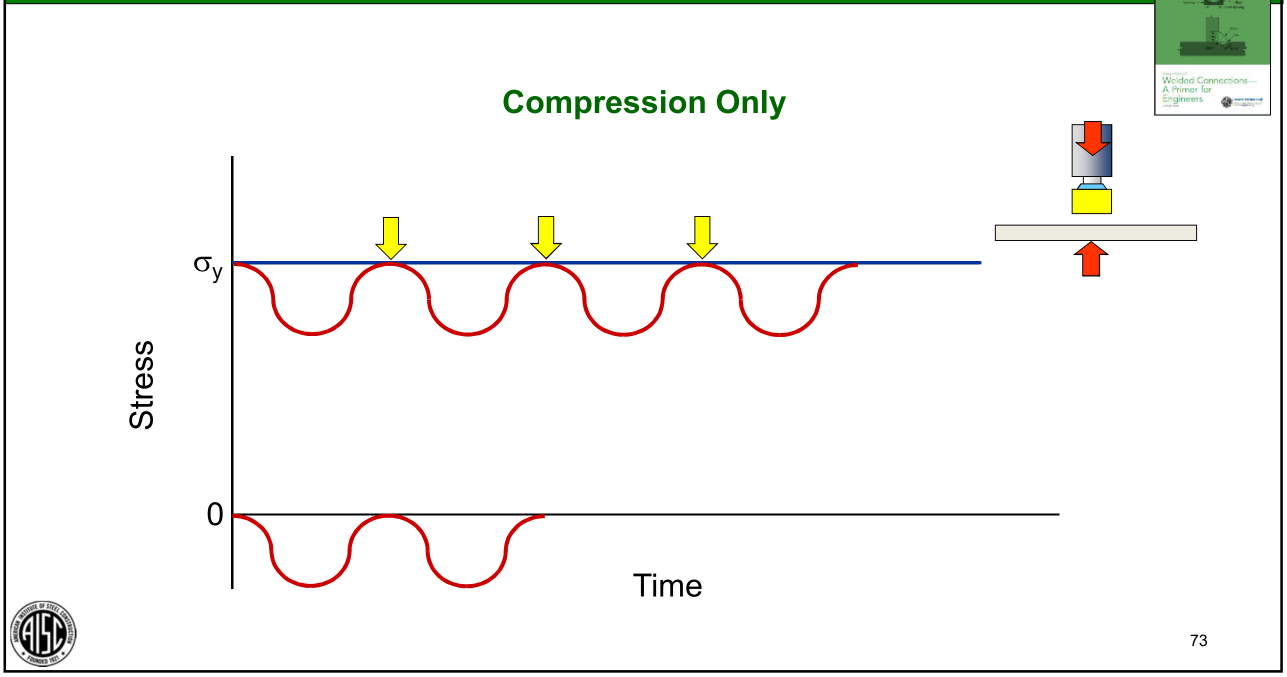
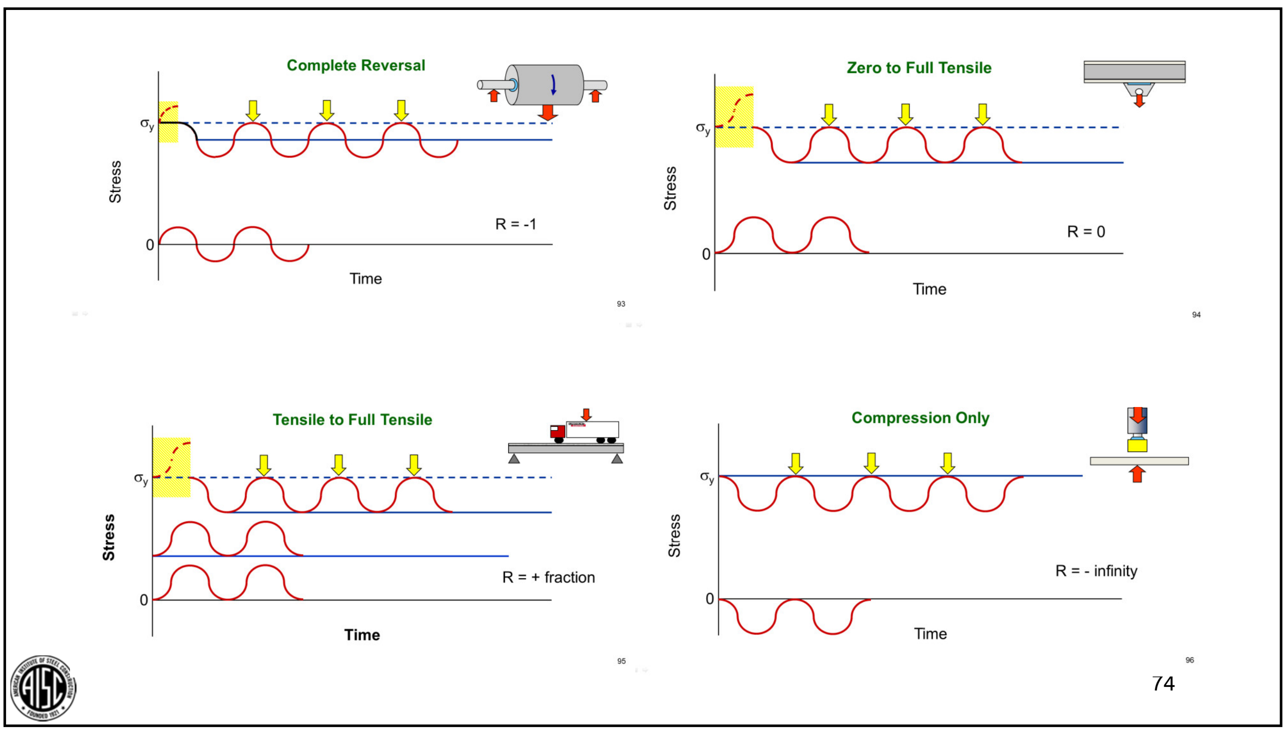
FATIGUE CONSIDERATIONS





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APPENDIX 3 COMMENTARY

3.1. GENERAL PROVISIONS

Extensive test programs using full-size specimens, substantiated by theoretical stress analysis, have confirmed the following general conclusions (Fisher et al., 1970; Fisher et al., 1974):

(1) Stress range and notch severity are the dominant stress variables for welded details and beams.

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APPENDIX 3 COMMENTARY

3.1. GENERAL PROVISIONS (cont'd)

2) Other variables such as minimum stress, mean stress and maximum stresses are not significant for design purposes.

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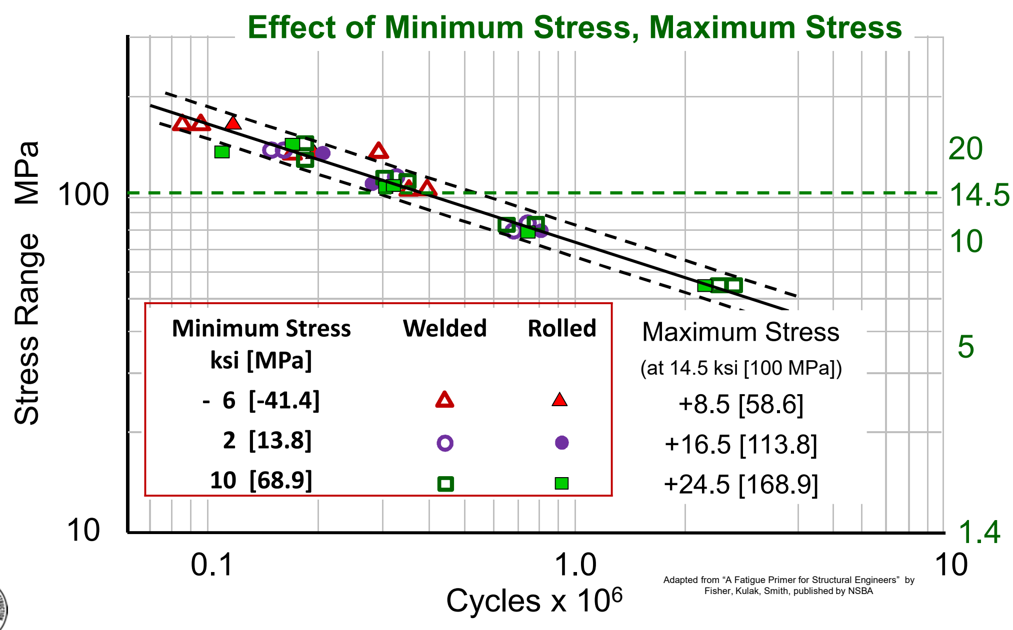
FATIGUE CONSIDERATIONS



Adapted from "A Fatigue Primer for Structural Engineers" by Fisher, Kulak, Smith, published by NSBA

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APPENDIX 3 COMMENTARY

3.1. GENERAL PROVISIONS (cont'd)

3) Structural steels with a specified minimum yield stress of 36 to 100 ksi (250 to 690 MPa) do not exhibit significantly different fatigue strengths for given welded details fabricated in the same manner.

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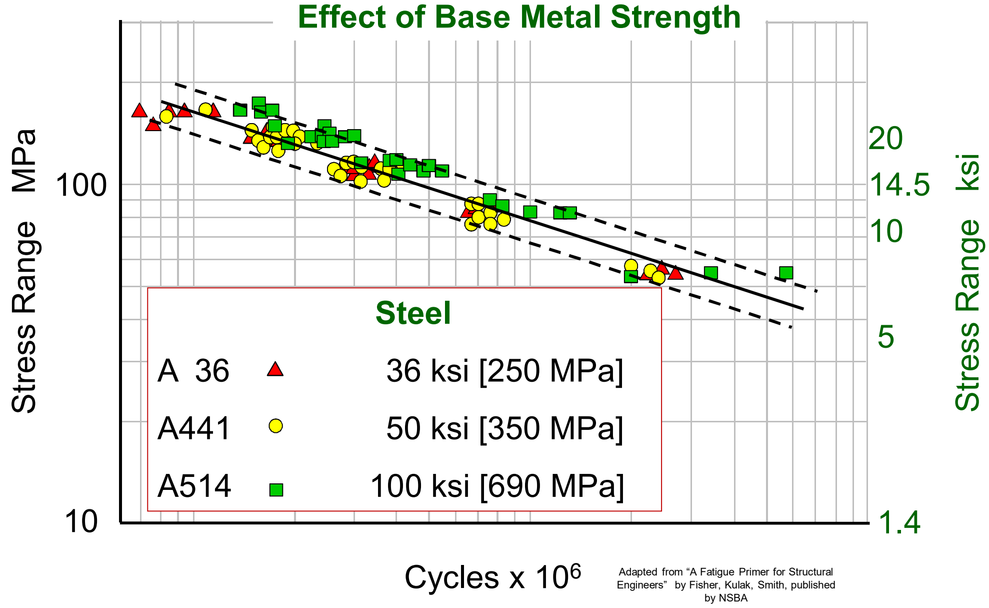
FATIGUE CONSIDERATIONS



Adapted from "A Fatigue Primer for Structural Engineers" by Fisher, Kulak, Smith, published by NSBA

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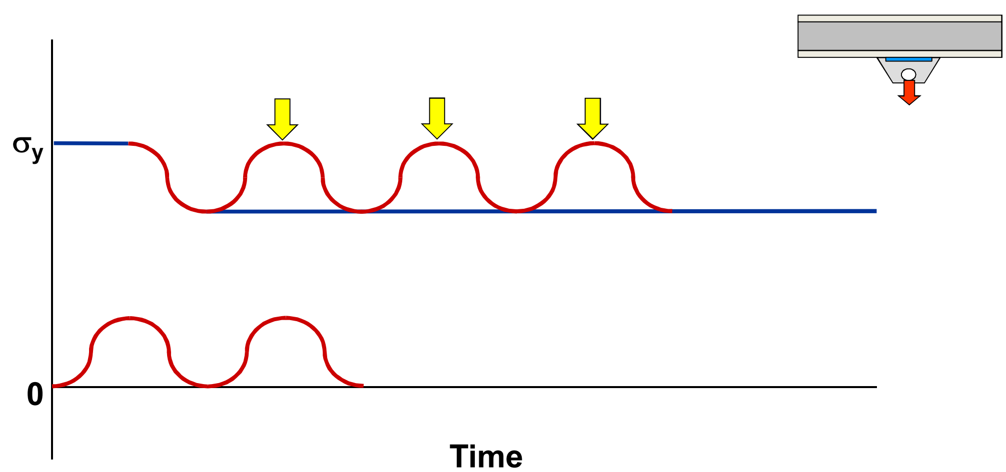
FATIGUE CONSIDERATIONS

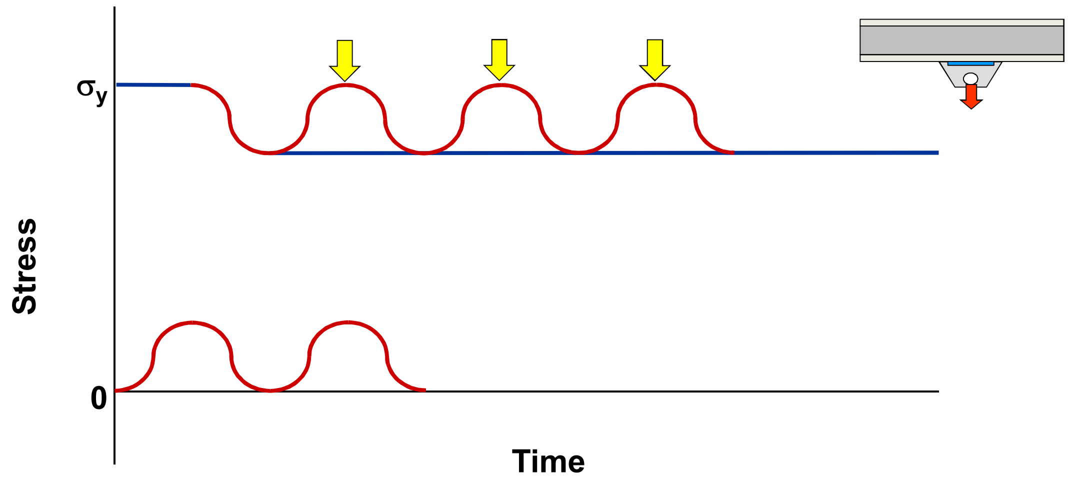
Lower Yield Steel



80

FATIGUE CONSIDERATIONS

Higher Yield Steel



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FATIGUE OF WELDED CONNECTIONS

Outline

1. Background and Theory
2. Design Model
3. Details Associated with the Model
4. Summary

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FATIGUE OF WELDED CONNECTIONS

Outline

1. Background and Theory
2. Design Model
   - Fatigue Testing
   - Categories of Connection Details
   - Predictive Model
   - Special Categories: C' and C''

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FATIGUE CONSIDERATIONS

Fatigue Testing

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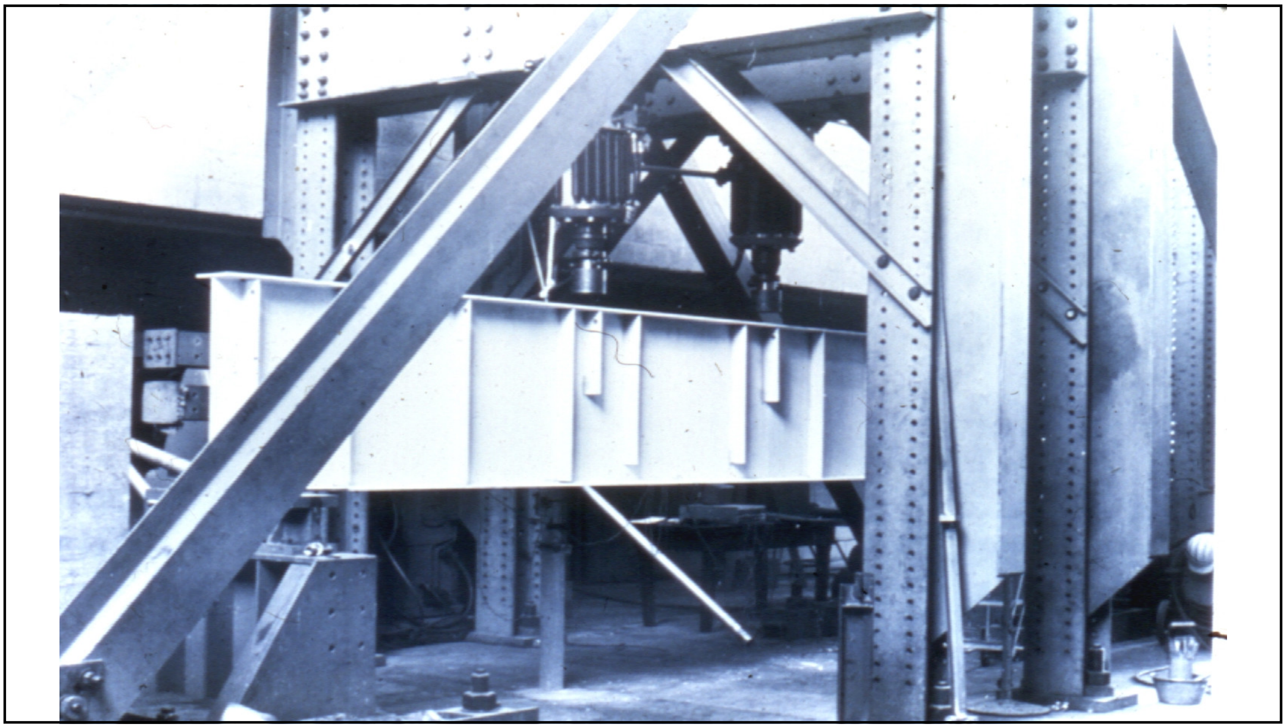

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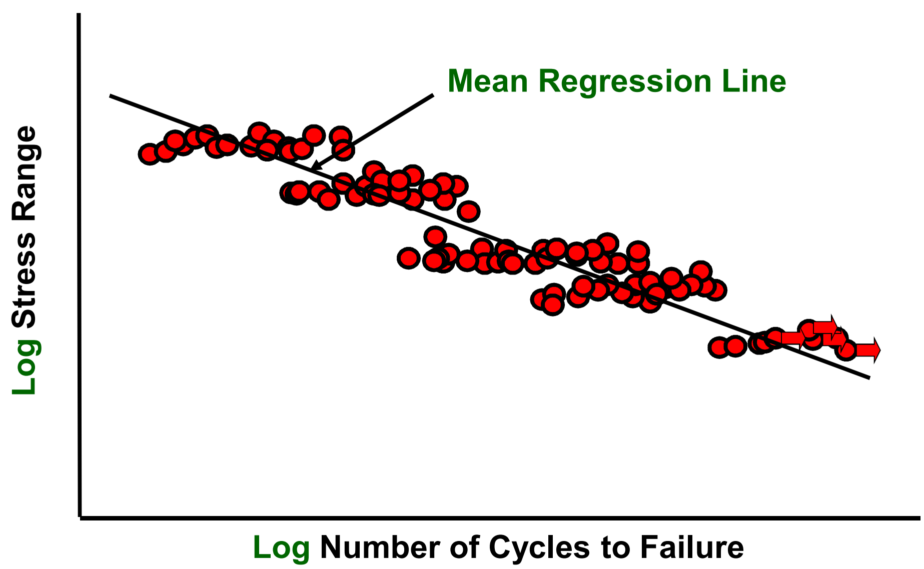

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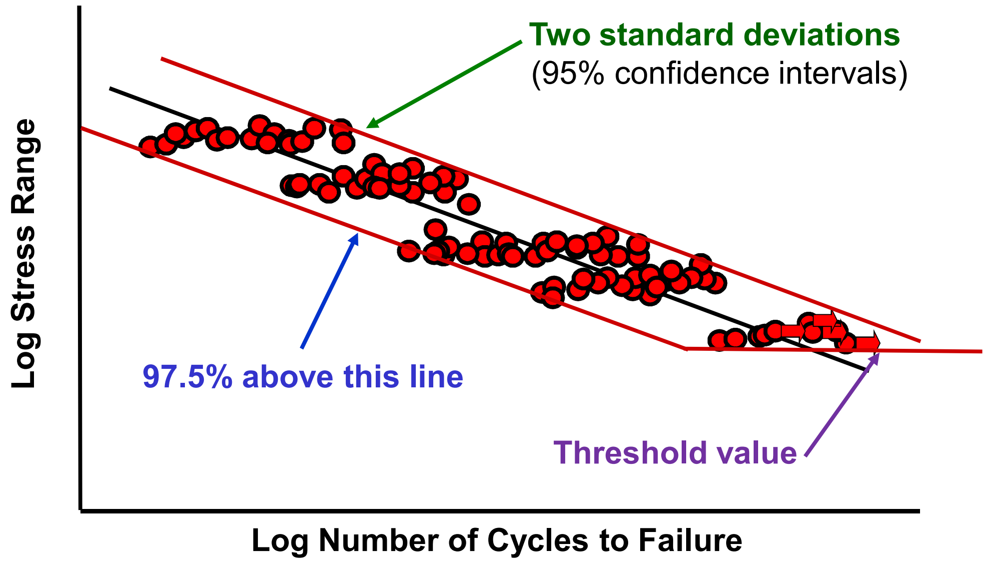
FATIGUE CONSIDERATIONS



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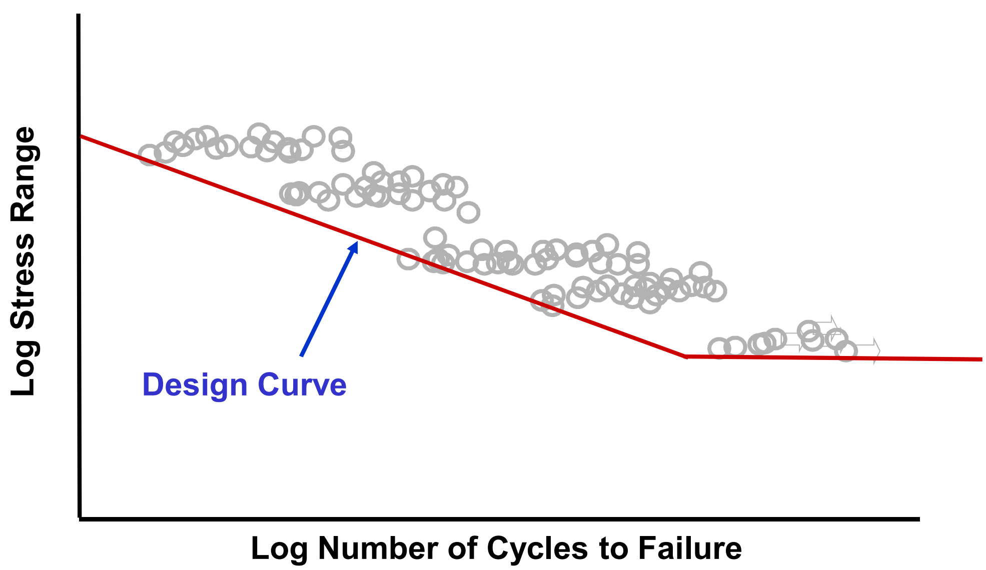
FATIGUE CONSIDERATIONS



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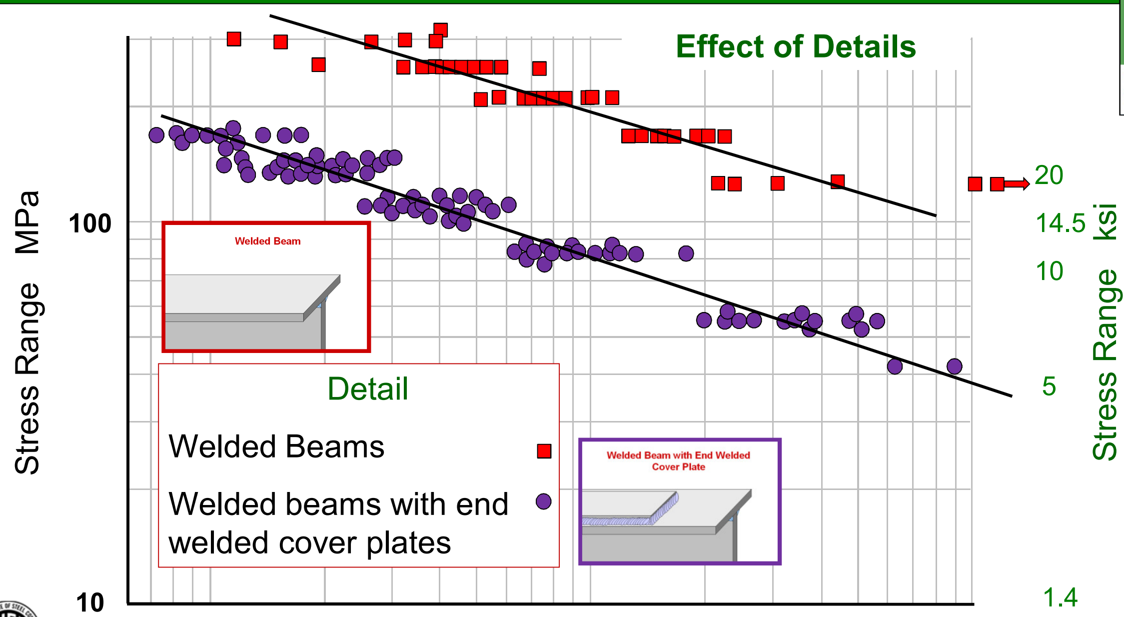
FATIGUE CONSIDERATIONS



Adapted from "A Fatigue Primer for Structural Engineers" by Fisher, Kulak, Smith, published by NSBA

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FATIGUE CONSIDERATIONS

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FATIGUE CONSIDERATIONS

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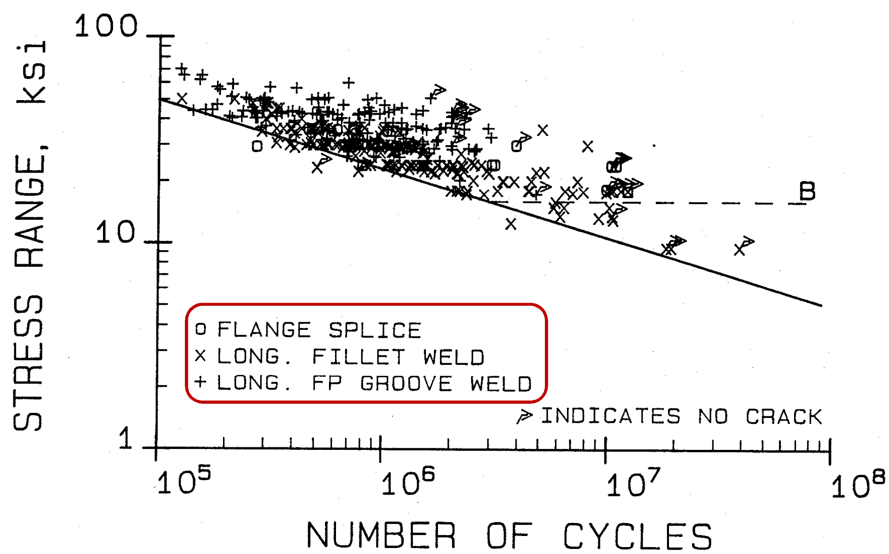
FATIGUE CONSIDERATIONS

Category B Details



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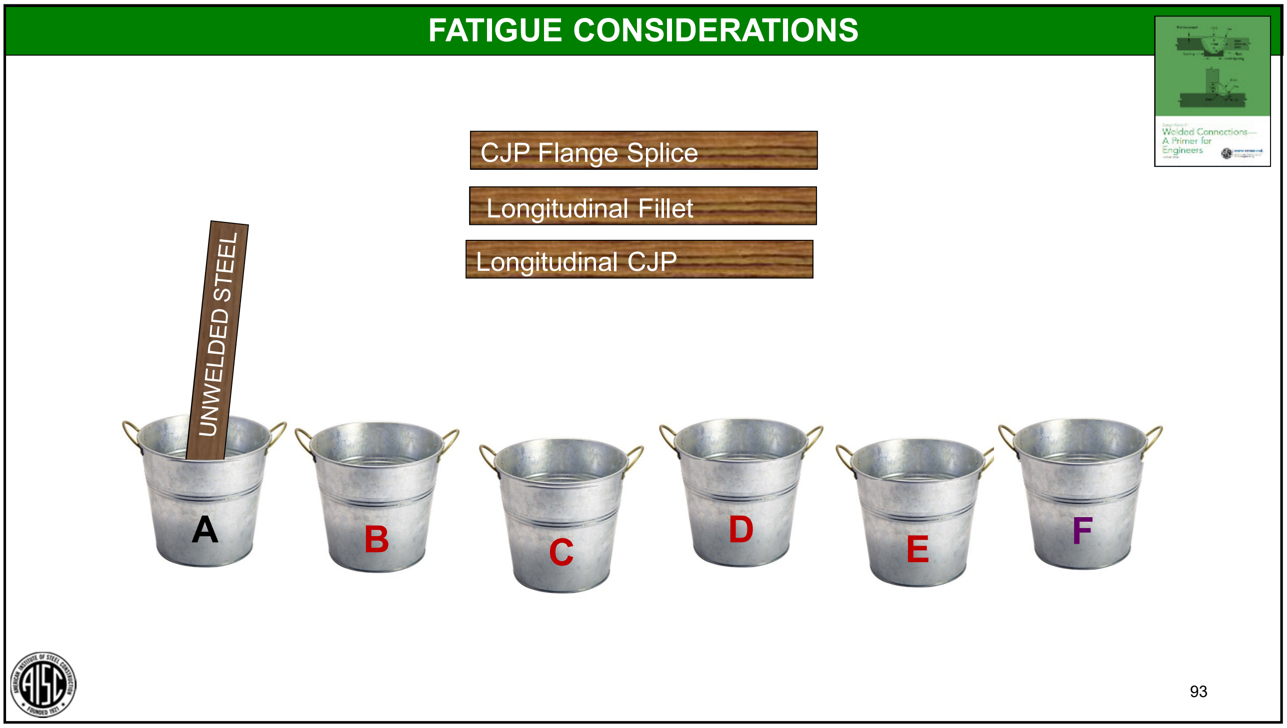
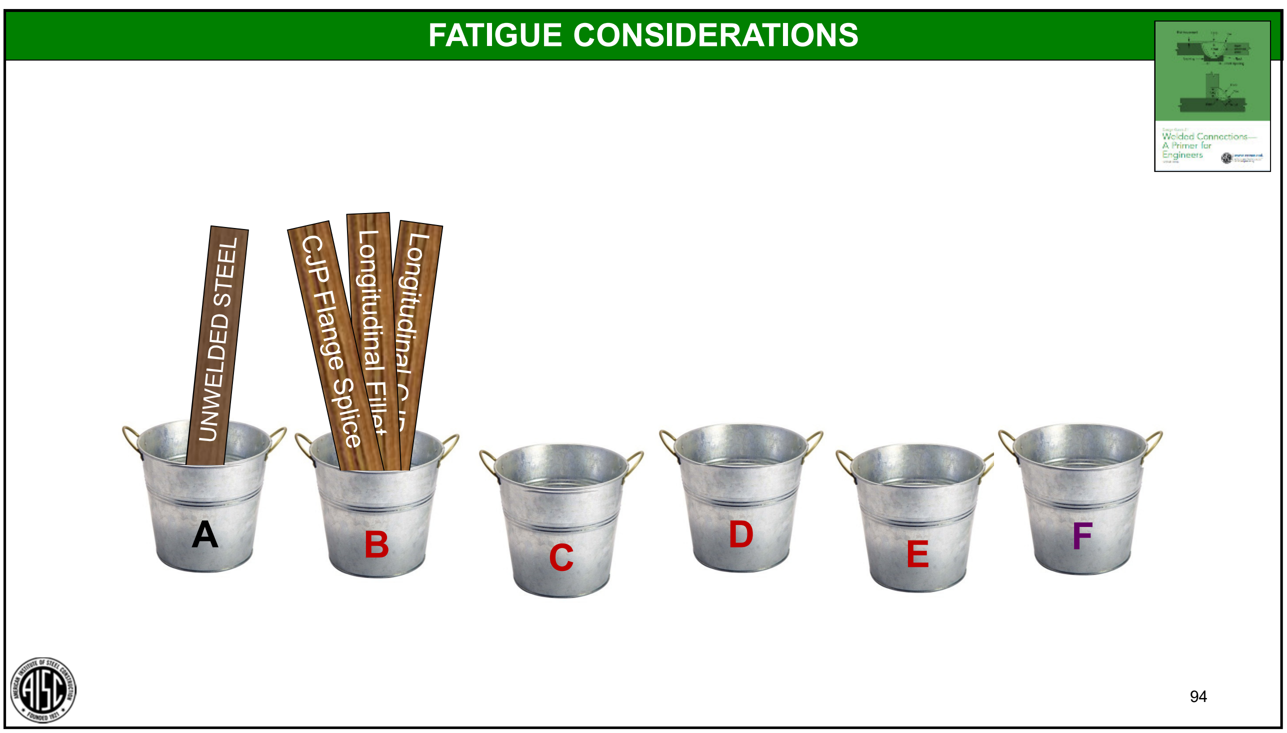
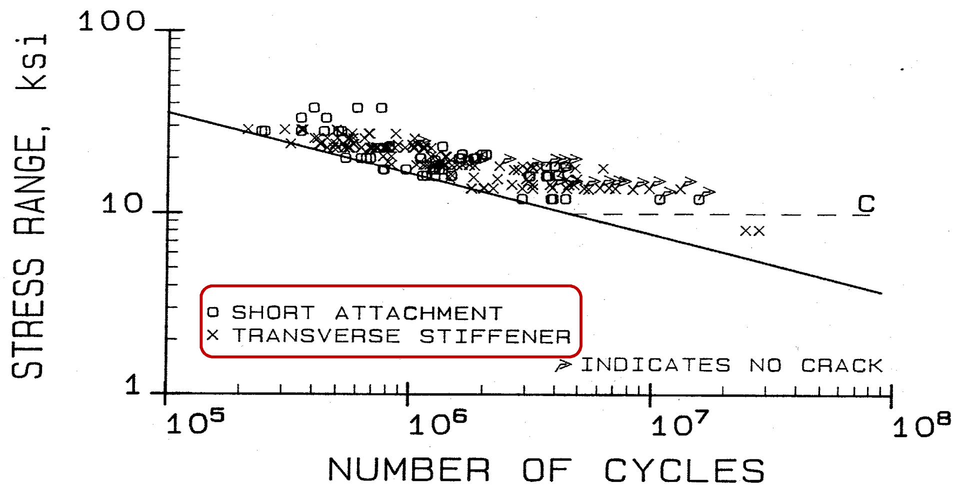

FATIGUE CONSIDERATIONS
CJP Flange Splice
Longitudinal Fillet
Longitudinal CJP
UNWELDED STEEL
A
B
C
D
E
F
93


FATIGUE CONSIDERATIONS
UNWELDED STEEL
CJP Flange Splice
Longitudinal Fill
Longitudinal
A
B
C
D
E
F
94

FATIGUE CONSIDERATIONS

Category C Details



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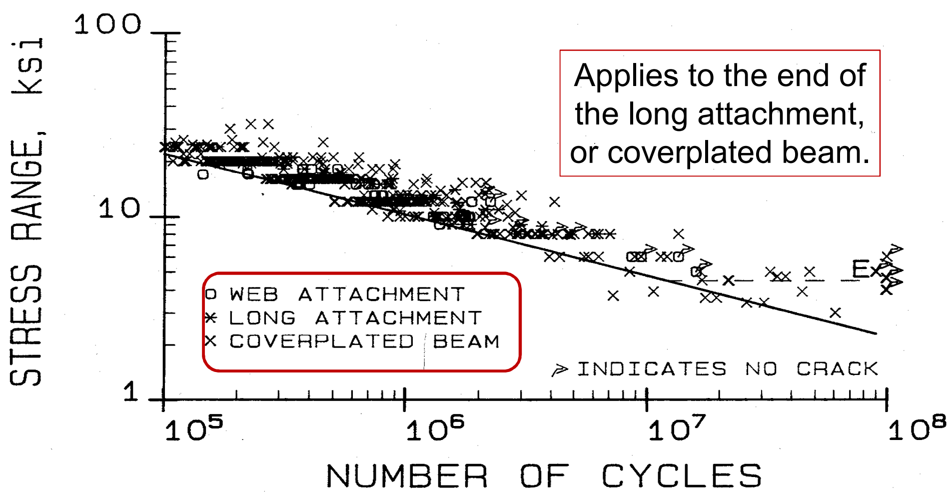
FATIGUE CONSIDERATIONS

Category E Details



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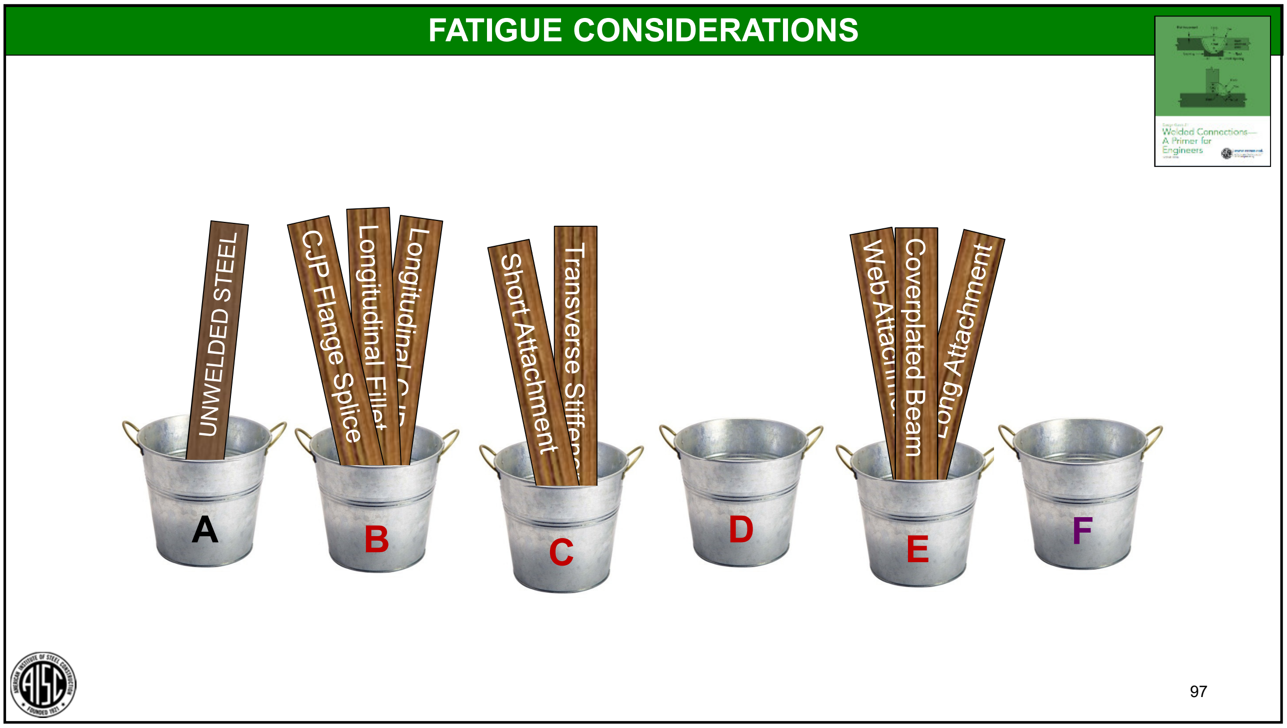
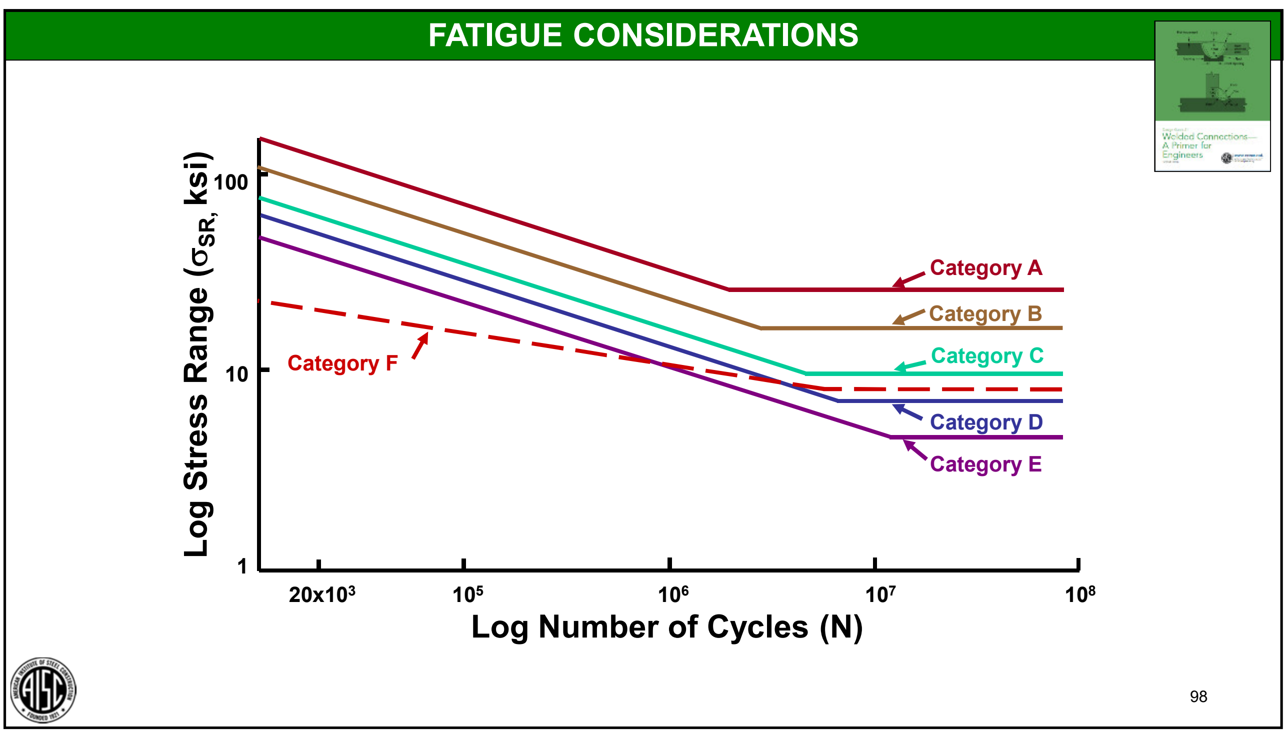
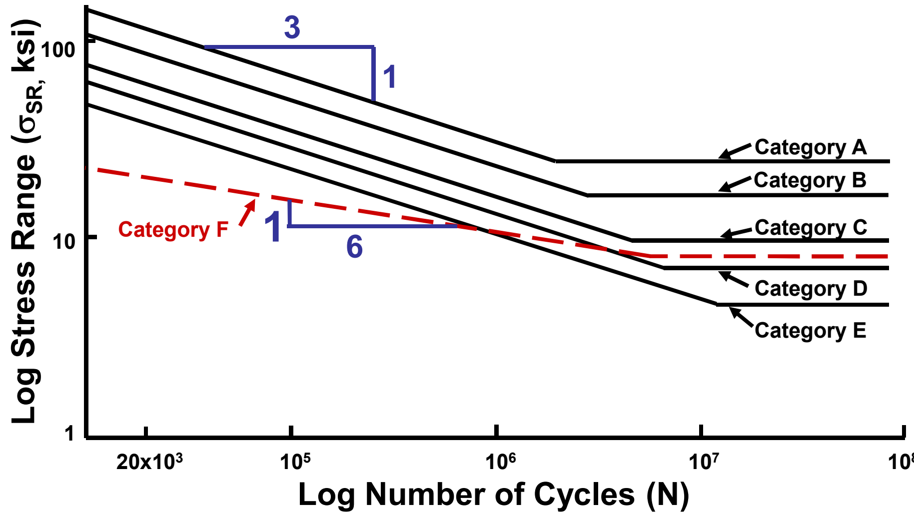

FATIGUE CONSIDERATIONS
UNWELDED STEEL
CJP Flange Splice
Short Attachment
Coverplated Beam
Long Attachment
A
B
C
D
E
F
97


FATIGUE CONSIDERATIONS
Log Stress Range (σ_{SR}, ksi)
100
10
1
Category A
Category B
Category C
Category D
Category E
Category F
20x10³
10⁵
10⁶
10⁷
10⁸
Log Number of Cycles (N)
98

FATIGUE CONSIDERATIONS



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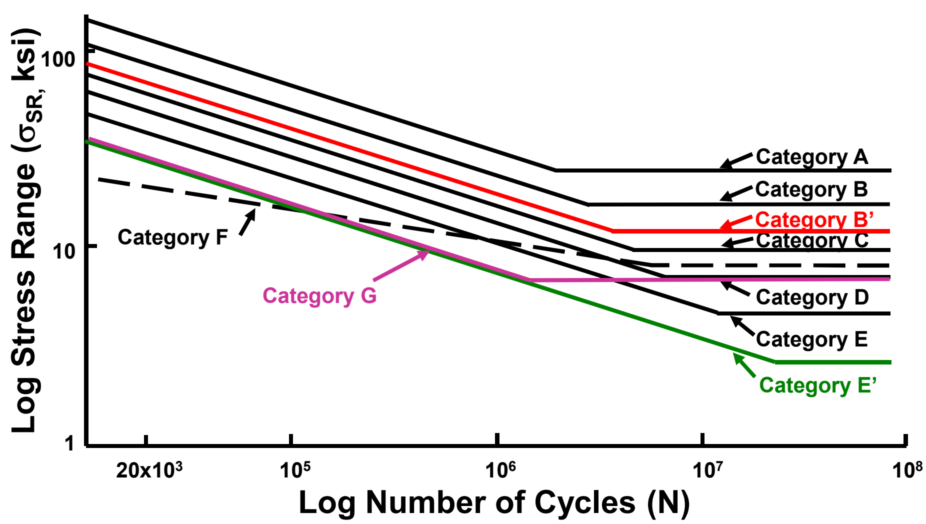
FATIGUE CONSIDERATIONS



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APPENDIX 3 COMMENTARY

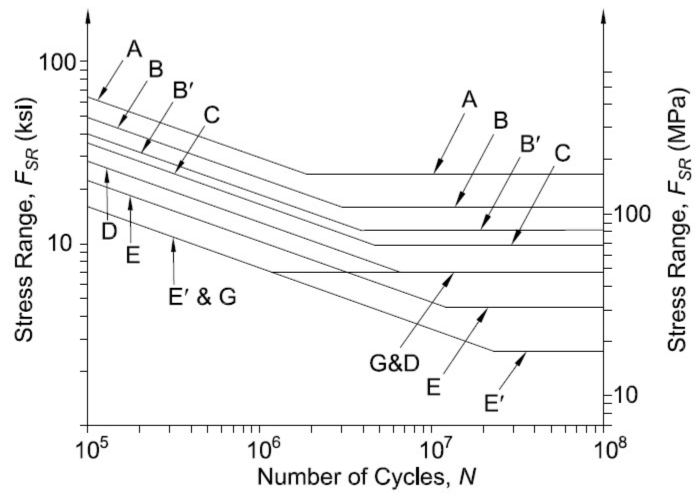

Fig. C-A-3.1. Fatigue resistance curves.

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FATIGUE CONSIDERATIONS

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APPENDIX 3 FATIGUE

3.3. PLAIN MATERIAL AND WELDED JOINTS

In plain material and welded joints, the range of stress due to the applied cyclic loads shall not exceed the allowable stress range computed as follows.

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(a) For stress categories A, B, B′, C, D, E and E′ the allowable stress range, F_{SR}, shall be determined by Equation A-3-1 or A-3-1M, as follows:

$$\boxed{F_{SR} = 1{,}000\left(\frac{C_f}{n_{SR}}\right)^{0.333} \geq F_{TH}} \qquad \text{(A-3-1)}$$

$$F_{SR} = 6900\left(\frac{C_f}{n_{SR}}\right)^{0.333} \geq F_{TH} \qquad \text{(S.I.)} \quad \text{(A-3-1M)}$$

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where

C_f = constant from Table A-3.1 for the fatigue category

F_{SR} = allowable stress range, ksi (MPa)

F_{TH} = threshold allowable stress range, maximum stress range for indefinite design life from Table A-3.1, ksi (MPa)

n_{SR} = number of stress range fluctuations in design life

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AISC 360-16 Specification for Structural Steel Buildings

(a) For stress categories A, B, B′, C, D, E and E′ the allowable stress range, F_{SR}, shall be determined by Equation A-3-1 or A-3-1M, as follows:

$$F_{SR} = 1{,}000\left(\frac{C_f}{n_{SR}}\right)^{\boxed{0.333}} \geq F_{TH} \qquad \text{(A-3-1)}$$

$$F_{SR} = 6900\left(\frac{C_f}{n_{SR}}\right)^{0.333} \geq F_{TH} \qquad \text{(S.I.)} \quad \text{(A-3-1M)}$$

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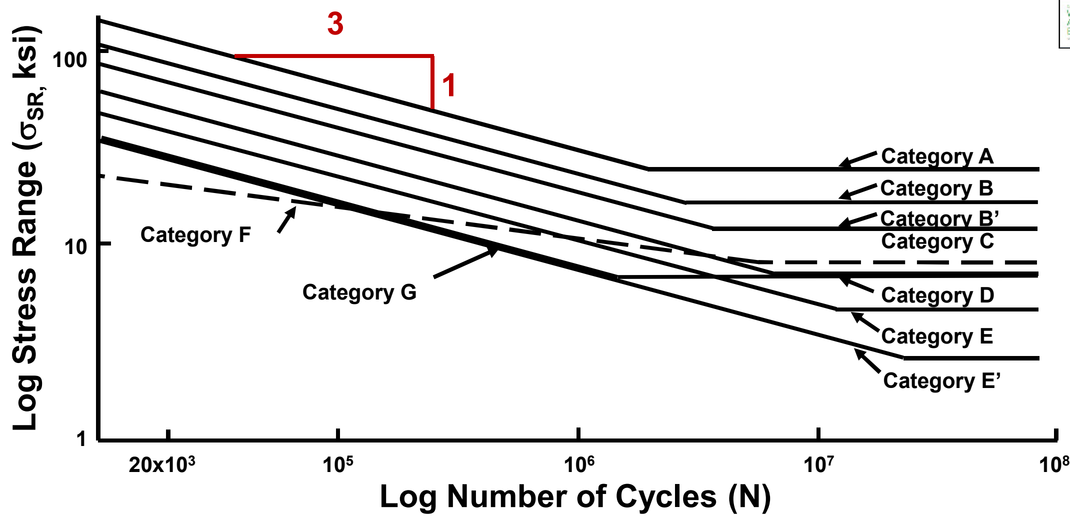
FATIGUE CONSIDERATIONS



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(b) For stress category F, the allowable stress range, F_{SR}, shall be determined by Equation A-3-2 or A-3-2M, as follows:

$$F_{SR} = 100\left(\frac{1.5}{n_{SR}}\right)^{\boxed{0.167}} \geq 8 \text{ ksi} \qquad \text{(A-3.2)}$$

$$F_{SR} = 690\left(\frac{1.5}{n_{SR}}\right)^{0.167} \geq 55 \text{ MPa} \qquad \text{(S.I.) (A-3.2M)}$$

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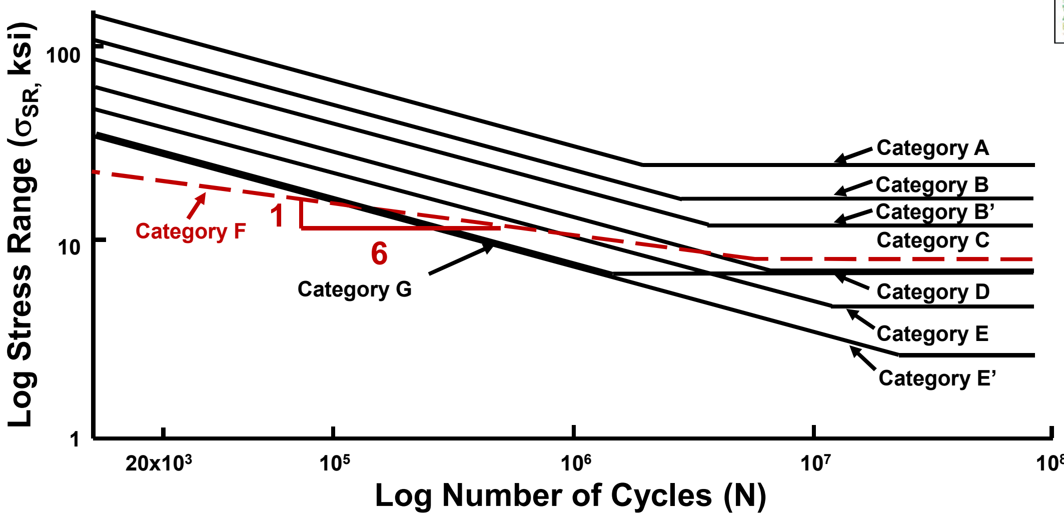
FATIGUE CONSIDERATIONS



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(c) For tension-loaded plate elements connected at their end by cruciform, T or corner details with partial joint-penetration (PJP) groove welds transverse to the direction of stress, with or without reinforcing or contouring fillet welds, or if joined with only fillet welds, the allowable stress range on the cross section of the tension-loaded plate element shall be determined as the lesser of the following:

To be discussed later.

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(a) For stress categories A, B, B′, C, D, E and E′ the allowable stress range, F_{SR}, shall be determined by Equation A-3-1 or A-3-1M, as follows:

$$F_{SR} = 1{,}000 \left(\frac{\boxed{C_f}}{n_{SR}} \right)^{0.333} \geq F_{TH} \qquad \text{(A-3-1)}$$

$$F_{SR} = 6900 \left(\frac{C_f}{n_{SR}} \right)^{0.333} \geq F_{TH} \qquad \text{(S.I.)} \quad \text{(A-3-1M)}$$

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TABLE A-3.1
Fatigue Design Parameters

Description	Stress Category	Constant C_f	Threshold F_{TH}, ksi (MPa)	Potential Crack Initiation Point
SECTION 1—PLAIN MATERIAL AWAY FROM ANY WELDING				
1.1 Base metal, except noncoated weathering steel, with as-rolled or cleaned surfaces; flame-cut edges with surface roughness value of 1,000 μin. (25 μm) or less, but without reentrant corners	A	25	24 (165)	Away from all welds or structural connections

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AISC 360-16 Specification for Structural Steel Buildings

16.1-202 FATIGUE DESIGN PARAMETERS [Table A-3.1.

TABLE A-3.1
Fatigue Design Parameters

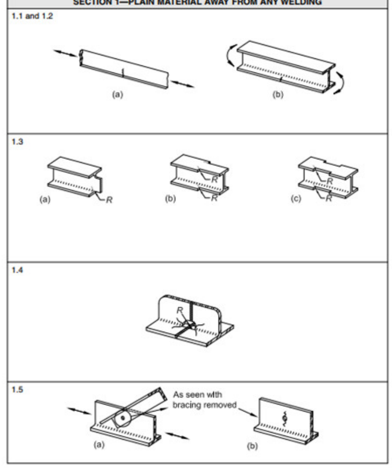
Description	Stress Category	Constant C_f	Threshold F_{TH}, ksi (MPa)	Potential Crack Initiation Point
SECTION 1—PLAIN MATERIAL AWAY FROM ANY WELDING				
1.1 Base metal, except noncoated weathering steel, with as-rolled or cleaned surfaces; flame-cut edges with surface roughness value of 1,000 μin. (25 μm) or less, but without reentrant corners	A	25	24 (165)	Away from all welds or structural connections
1.2 Noncoated weathering steel base metal with as-rolled or cleaned surfaces; flame-cut edges with surface roughness value of 1,000 μin. (25 μm) or less, but without reentrant corners	B	12	16 (110)	Away from all welds or structural connections
1.3 Member with reentrant corners at copes, cuts, block-outs or other geometrical discontinuities, except weld access holes				At any external edge or at hole perimeter
$R \geq 1$ in. (25 mm), with radius, R, formed by predrilling, subpunching and reaming or thermally cut and ground to a bright metal surface	C	4.4	10 (69)	
$R \geq 3/8$ in. (10 mm) and the radius, R, need not be ground to a bright metal surface	E′	0.39	2.6 (18)	
1.4 Rolled cross sections with weld access holes made to requirements of Section J1.6				At reentrant corner of weld access hole
Access hole $R \geq 1$ in. (25 mm) with radius, R, formed by predrilling, subpunching and reaming or thermally cut and ground to a bright metal surface	C	4.4	10 (69)	
Access hole $R \geq 3/8$ in. (10 mm) and the radius, R, need not be ground to a bright metal surface	E′	0.39	2.6 (18)	
1.5 Members with drilled or reamed holes				In net section originating at side of the hole
Holes containing pretensioned bolts	C	4.4	10 (69)	
Open holes without bolts	D	2.2	7 (48)	

Table A-3.1.] FATIGUE DESIGN PARAMETERS 16.1-203

TABLE A-3.1 (continued)
Fatigue Design Parameters

Illustrative Typical Examples

SECTION 1—PLAIN MATERIAL AWAY FROM ANY WELDING



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16.1-202 FATIGUE DESIGN PARAMETERS [Table A-3.1.

TABLE A-3.1
Fatigue Design Parameters

16.1-204 FATIGUE DESIGN PARAMETERS [Table A-3.1.

TABLE A-3.1 (continued)
Fatigue Design Parameters

Description	Stress Category	Constant C_f	Threshold F_{TH}, ksi (MPa)	Potential Crack Initiation Point
SECTION 2—CONNECTED MATERIAL IN MECHANICALLY FASTENED JOINTS				
2.1 Gross area of base metal in lap joints connected by high-strength bolts in joints satisfying all requirements for slip-critical connections	B	12	16 (110)	Through gross section near hole
[illegible] basis of bearing resistance, but fabricated and installed to all requirements for slip-critical connections	[illegible]	[illegible]	[illegible]	[illegible] of hole
2.3 Base metal at the net section of riveted joints	C	4.4	10 (69)	In net section originating at side of hole
2.4 Base metal at net section of eyebar head or pin plate	E	1.1	4.5 (31)	In net section originating at side of hole

SECTION 1—PLAIN MATERIAL AWAY FROM ANY WELDING

SECTION 2-CONNECTED MATERIAL IN MECHANICALLY FASTENED JOINTS

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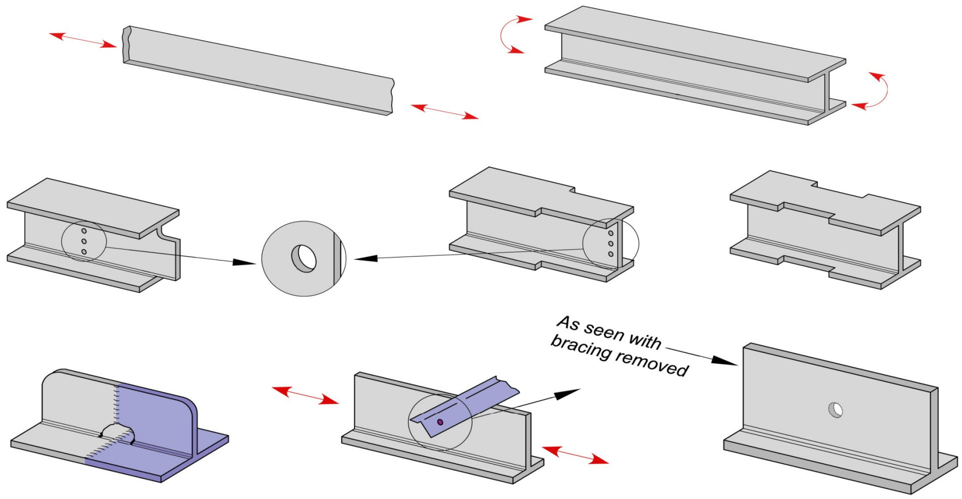
AISC 360-16 Specification for Structural Steel Buildings

Section 1: Plain Material Away From any Welding



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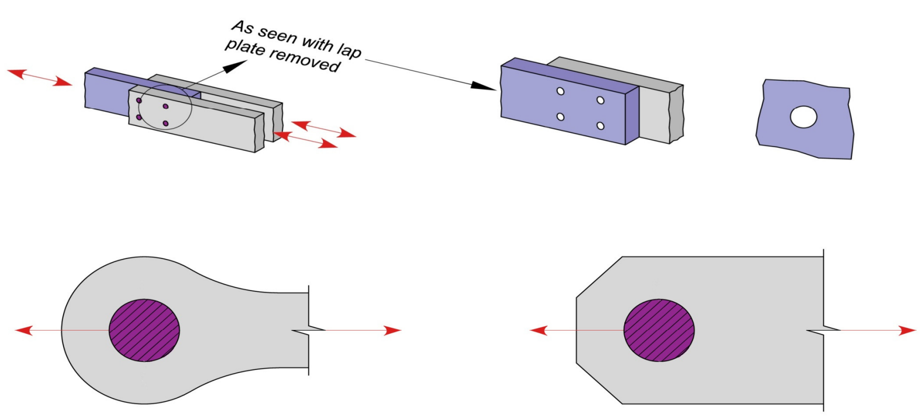
AISC 360-16 Specification for Structural Steel Buildings

Section 2: Connected Material in Mechanically Fastened Joints



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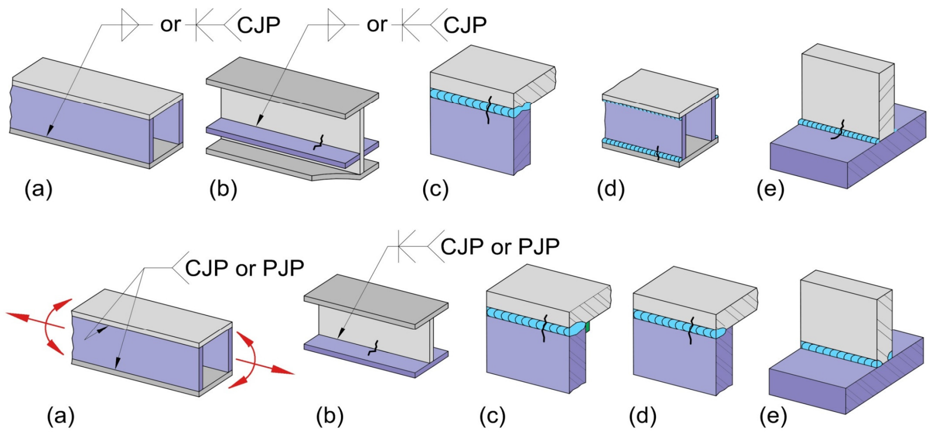
Section 3: Welded Joints Joining Components of Built-Up Members



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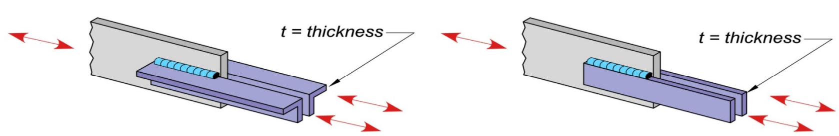
Section 4: Longitudinal Fillet Welded End Connections



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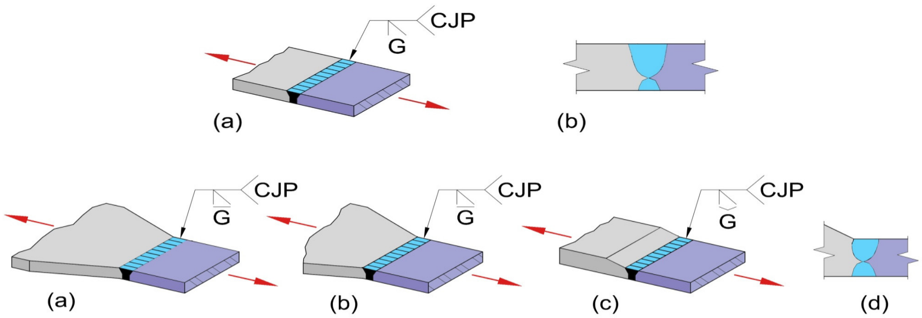
Section 5: Welded Joints Transverse to Direction of Stress



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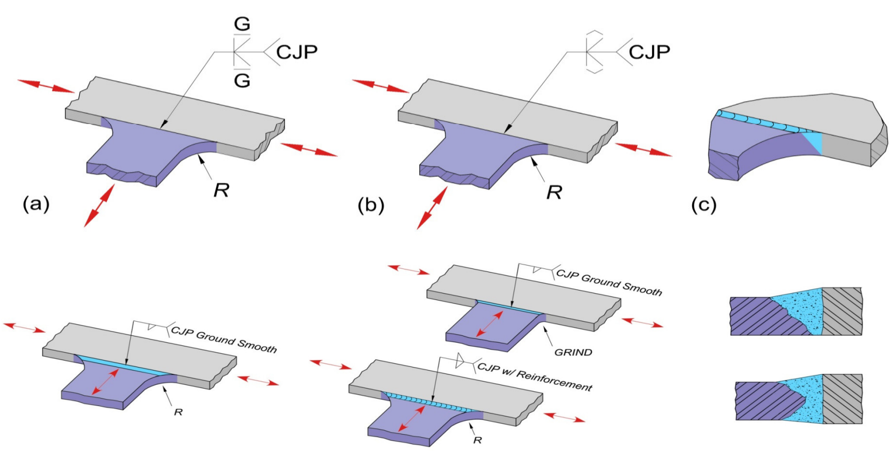
Section 6: Base Metal at Welded Transverse Member Connections



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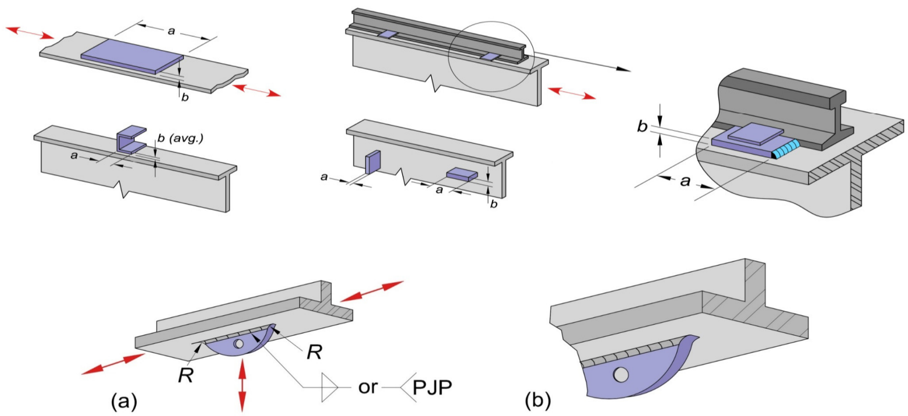
Section 7: Base Metal at Short Attachments[a]



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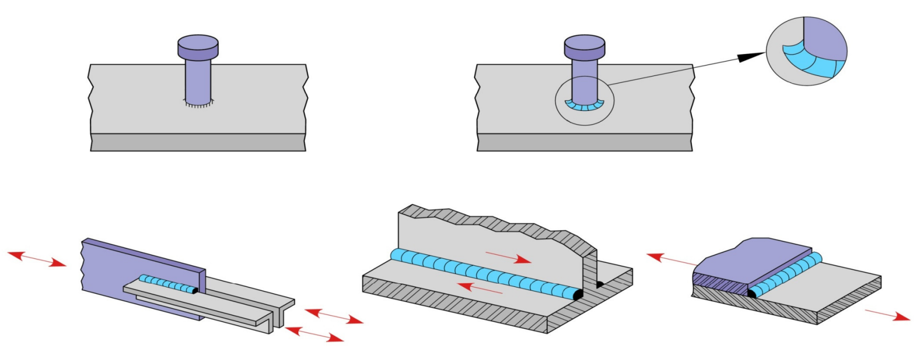
Section 8: Miscellaneous



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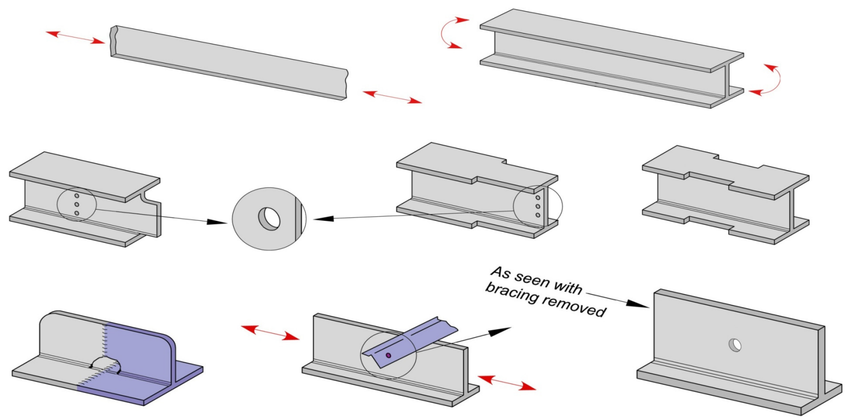
Section 1: Plain Material Away from any Welding



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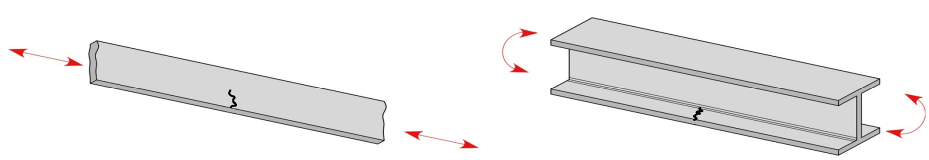
AISC 360-16 Specification for Structural Steel Buildings

Section 1: Plain Material Away from any Welding

A

1.1



Description: Base metal, except noncoated weathering steel, with as-rolled or cleaned surface; flame-cut edges with surface roughness value of 1,000 μin. (25 μm) or less, but without reentrant corners

Potential Crack Initiation Point: Away from all welds or structural connections

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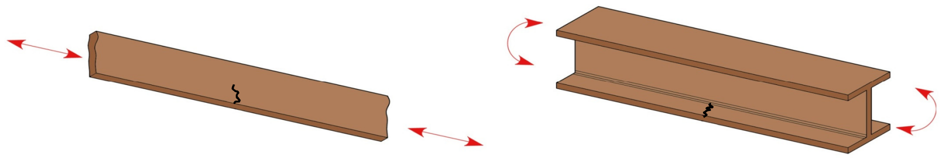
Section 1: Plain Material Away from any Welding

B

1.2



Description: Noncoated weathering steel base metal with as-rolled or cleaned surface; flame-cut edges with surface roughness value of 1,000 μin. (25 μm) or less, but without re-entrant corners

Potential Crack Initiation Point: Away from all welds or structural connections

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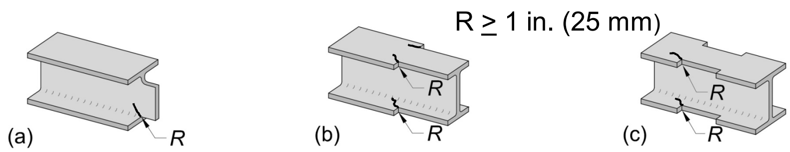
AISC 360-16 Specification for Structural Steel Buildings

Section 1: Plain Material Away from any Welding

C

1.3



Description: Member with reentrant corners at copes, cut, block-outs or other geometric discontinuities, except weld access holes

R ≥ 1 in. (25 mm), with radius, R, formed by predrilling, subpunching and reaming or thermally cut and ground to a bright metal surface

Potential Crack Initiation Point: At any external edge or at hole perimeter

126

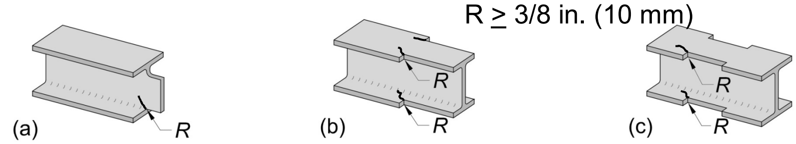
AISC 360-16 Specification for Structural Steel Buildings

Section 1: Plain Material Away from any Welding

E’

1.3

R ≥ 3/8 in. (10 mm)



Description: Member with reentrant corners at copes, cut, block-outs or other geometric discontinuities, except weld access holes

R ≥ 3/8 in. (10 mm) with radius, R, need not be ground to a bright metal surface

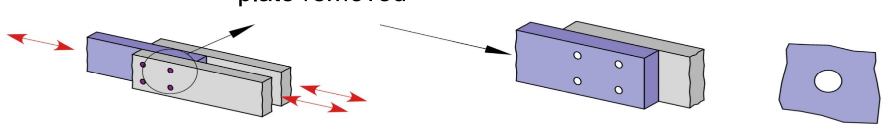
Potential Crack Initiation Point: At any external edge or at hole perimeter

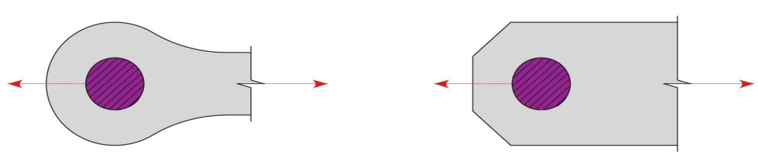
127

AISC 360-16 Specification for Structural Steel Buildings

Section 2: Connected Material in Mechanically Fastened Joints

As seen with lap plate removed





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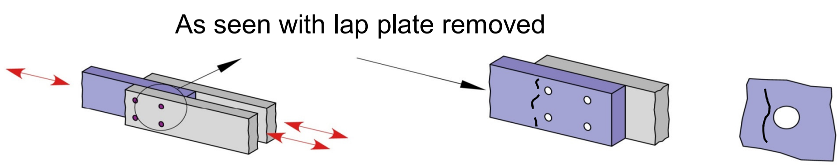
AISC 360-16 Specification for Structural Steel Buildings

Section 2: Connected Material in Mechanically Fastened Joints

B

2.1



Description: Gross area of base metal in lap joints connected by high-strength bolts in joints satisfying all requirements for slip-critical connections

Potential Crack Initiation Point: Through gross section near hole

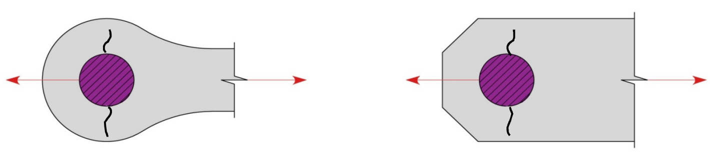
129

AISC 360-16 Specification for Structural Steel Buildings

Section 2: Connected Material in Mechanically Fastened Joints

E

2.4



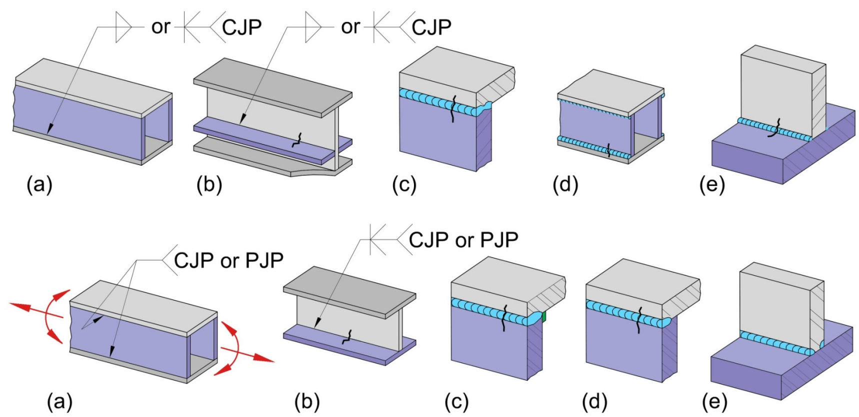
Description: Base metal at net section of eyebar head or pin plate

Potential Crack Initiation Point: In net section originating at side of hole

130

AISC 360-16 Specification for Structural Steel Buildings

Section 3: Welded Joints Joining Components of Built-Up Members



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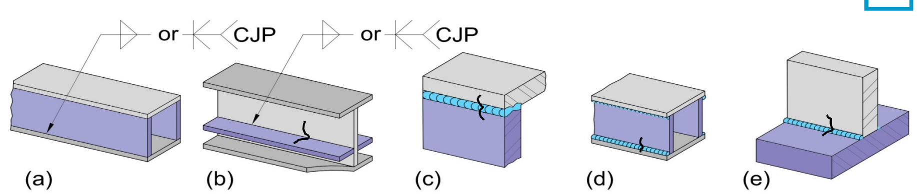
AISC 360-16 Specification for Structural Steel Buildings

Section 3: Welded Joints Joining Components of Built-Up Members

B

3.1



Description: Base metal and weld metal in members without attachments built up of plates or shapes connected by continuous longitudinal CJP groove welds, back gouged and welded from second side, or by continuous fillet welds

Potential Crack Initiation Point: From surface or internal discontinuities in weld

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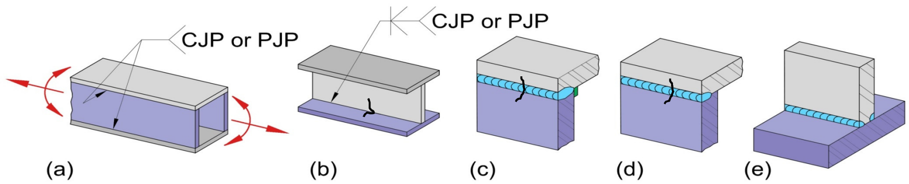
AISC 360-16 Specification for Structural Steel Buildings

Section 3: Welded Joints Joining Components of Built-Up Members

3.2

B'



Description: Base metal and weld metal in members without attachments built up of plates or shapes, connected by continuous longitudinal CJP groove welds with left-in-place steel backing, or by continuous PJP groove welds

Potential Crack Initiation Point: From surface or internal discontinuities in weld

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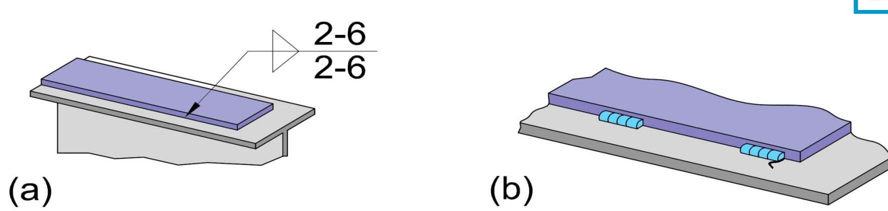
AISC 360-16 Specification for Structural Steel Buildings

Section 3: Welded Joints Joining Components of Built-Up Members

3.4

E



Description: Base metal at ends of longitudinal intermittent fillet weld segments

Potential Crack Initiation Point: In connected material at start and stop locations of any weld

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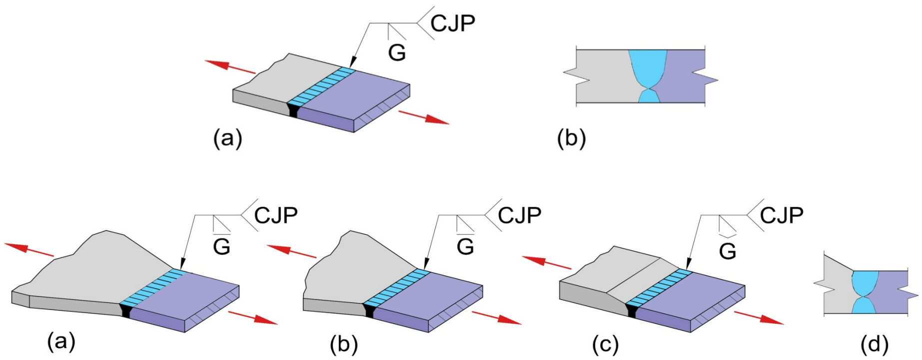
AISC 360-16 Specification for Structural Steel Buildings

Section 5: Welded Joints Transverse to Direction of Stress



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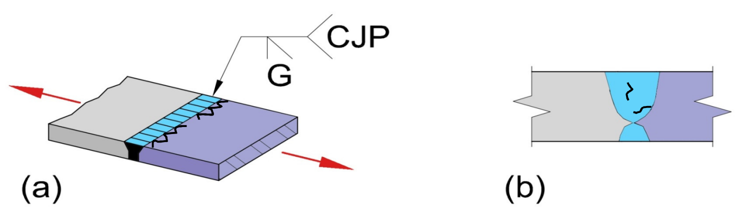
AISC 360-16 Specification for Structural Steel Buildings

Section 5: Welded Joints Transverse to Direction of Stress

5.1

B



Description: Weld metal and base metal in or adjacent to CJP groove welded splices in plate, rolled shapes, or built-up cross sections with no change in cross section with welds ground essentially parallel to the direction of stress and inspected in accordance with Section 3.6

Potential Crack Initiation Point: From internal discontinuities in weld metal or along the fusion boundary

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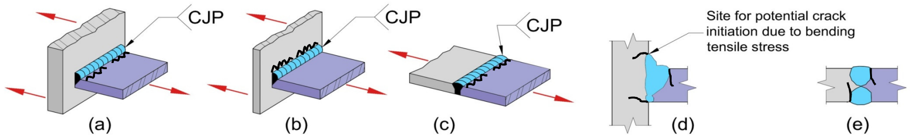
AISC 360-16 Specification for Structural Steel Buildings

Section 5: Welded Joints Transverse to Direction of Stress

C

5.4



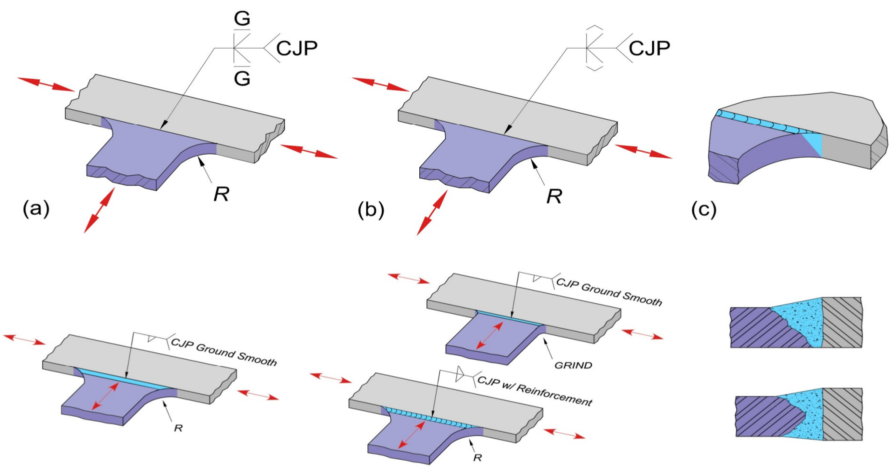
Description: Weld metal and base metal in or adjacent to CJP groove welds in T- or corner-joints or splices, without transitions in thickness or with transition in thickness having slopes no greater than 1:2 1/2, when weld reinforcement is not removed, and is inspected in accordance with Section 3.6

Potential Crack Initiation Point: From weld extending into base metal or into weld metal

137

AISC 360-16 Specification for Structural Steel Buildings

Section 6: Base Metal at Welded Transverse Member Connections



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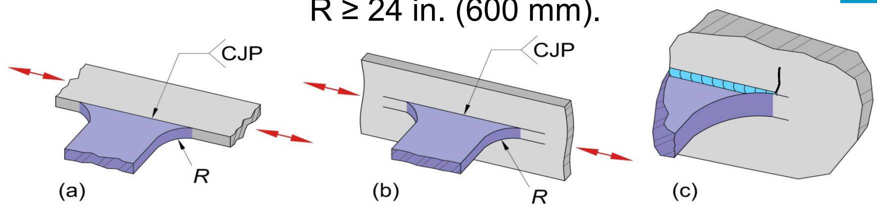
AISC 360-16 Specification for Structural Steel Buildings

Section 6: Base Metal at Welded Transverse Member Connections

R ≥ 24 in. (600 mm).

B

6.1



Description: Base metal of equal or unequal thickness at details attached by CJP groove welds subject to longitudinal loading only when the detail embodies a transition radius, R, with the weld termination ground smooth and inspected in accordance with Section 3.6

R ≥ 24 in. (600 mm).

Potential Crack Initiation Point: Near point of tangency of radius at edge of member

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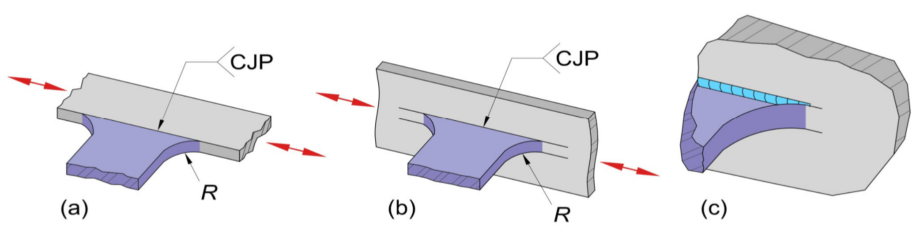
AISC 360-16 Specification for Structural Steel Buildings

Section 6: Base Metal at Welded Transverse Member Connections

6.1



R ≥ 24 in. (600 mm)	B
6 in. ≤ R < 24 in. (150 mm ≤ R < 600 mm)	C
2 in. ≤ R < 6 in. (50 mm ≤ R < 150 mm)	D
R < 2 in. (50 mm)	E

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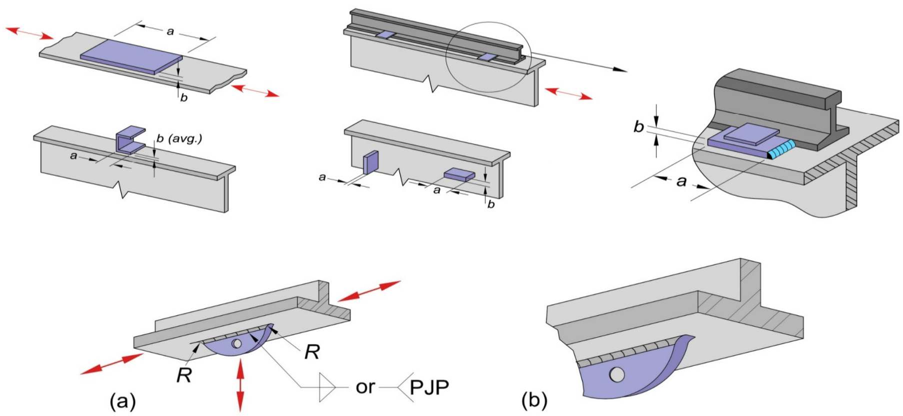
AISC 360-16 Specification for Structural Steel Buildings

Section 7-Base Metal at Short Attachments[a]



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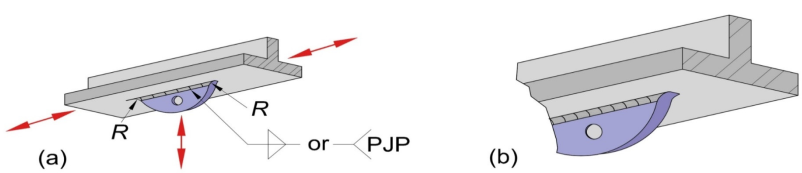
AISC 360-16 Specification for Structural Steel Buildings

Section 7-Base Metal at Short Attachments[a]

[a] "Attachment," as used herein, is defined as any steel detail welded to a member that causes a deviation in the stress flow in the member and, thus, reduces the fatigue resistance. The reduction is due to the presence of the attachment, not due to the loading on the attachment.



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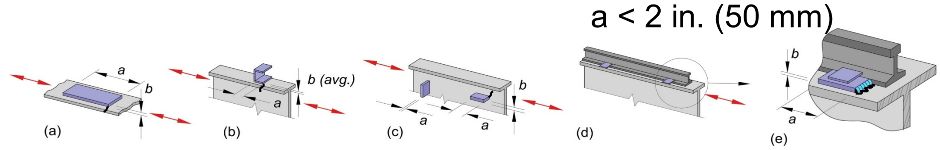
Section 7-Base Metal at Short Attachments[a]

C

7.1

a < 2 in. (50 mm)



Description: Base metal subject to longitudinal loading at details with welds parallel or transverse to the direction of stress, with or without transverse load on the detail, where the detail embodies no transition radius, *R*, and with detail length, *a*, and thickness of the attachment, *b*:

a < 2 in. (50 mm)

Potential Crack Initiation Point: Initiating in base metal at the weld termination or at the toe of the weld extending into the base metal

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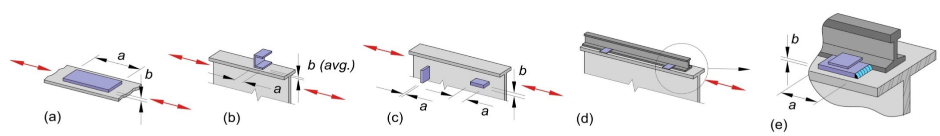
AISC 360-16 Specification for Structural Steel Buildings

Section 7-Base Metal at Short Attachments[a]

7.1



a < 2 in. (50 mm) for any thickness, b	C
2 in. (50 mm) ≤ a ≤ lesser of 12b or 4 in. (100 mm)	D
a > lesser of 12b or 4 in. (100 mm) when b ≤ 0.8 in. (20 mm)	E
a > 4 in. (100 mm) when b > 0.8 in. (20 mm)	E’

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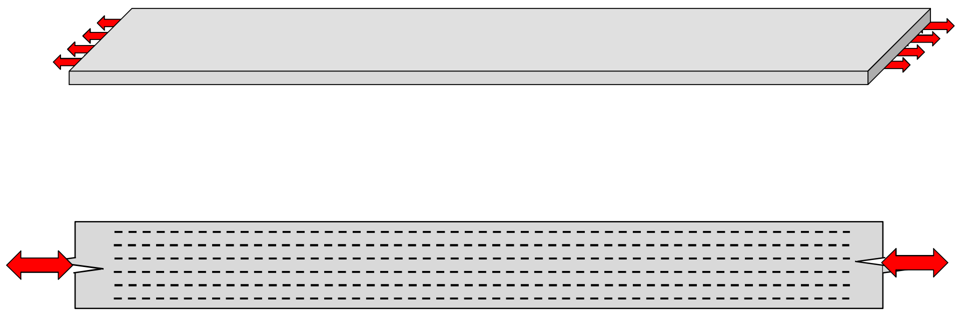
FATIGUE CONSIDERATIONS

No attachments

Category A



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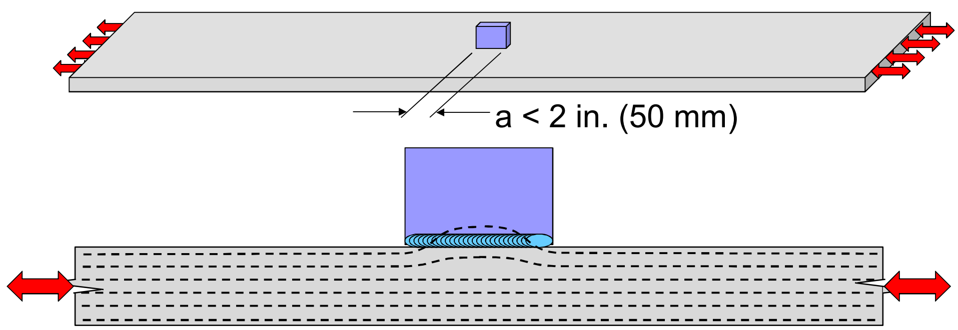
FATIGUE CONSIDERATIONS

Short attachment

Category C



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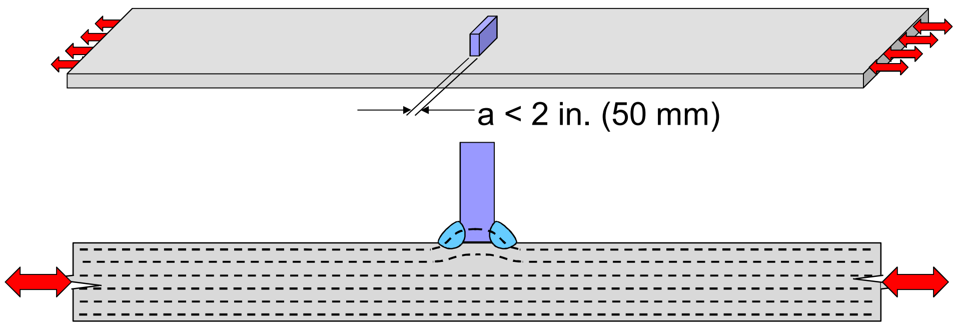
FATIGUE CONSIDERATIONS

Short attachment

Category C



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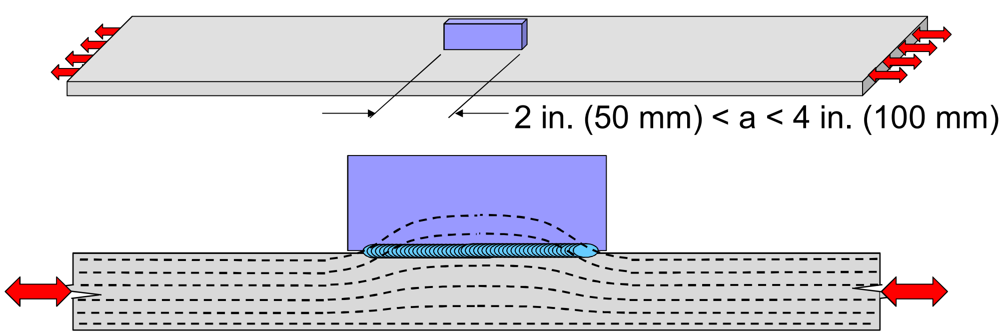
FATIGUE CONSIDERATIONS

Medium length attachment

Category D, E



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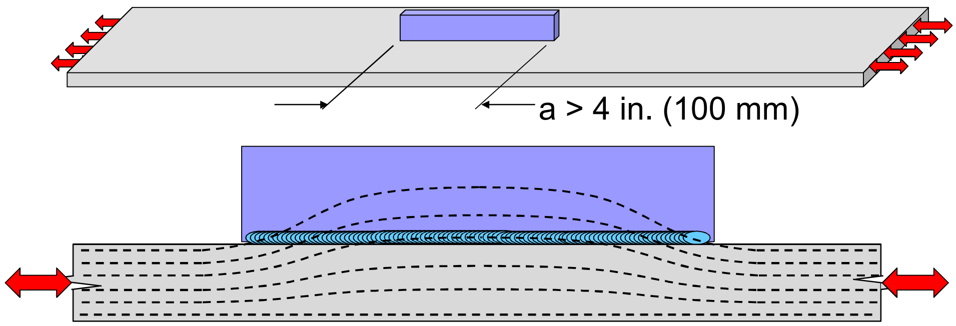
FATIGUE CONSIDERATIONS

Long attachment

Category E, E'



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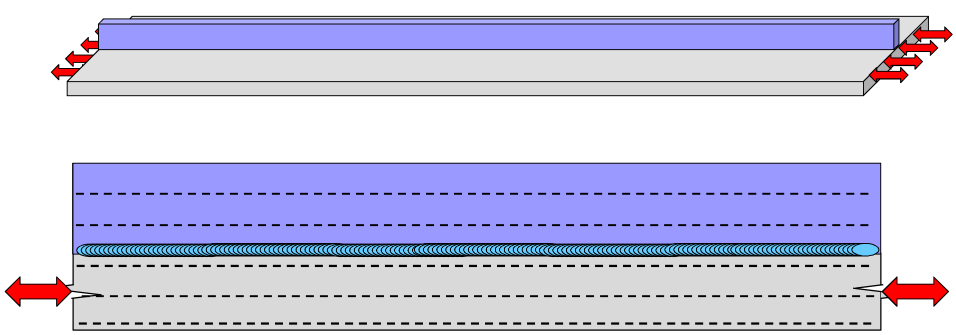
FATIGUE CONSIDERATIONS

Full length attachment

Category B



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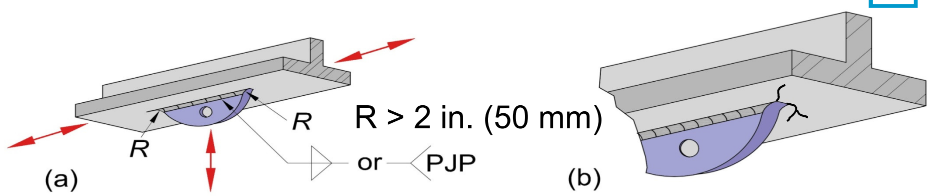
AISC 360-16 Specification for Structural Steel Buildings

Section 7: Base Metal at Short Attachments[a]

D

7.2



Description: Base metal subject to longitudinal stress at details attached by fillet or partial-joint-penetration groove welds, with or without transverse load on detail, when the detail embodies a transition radius, R, with weld termination ground smooth

R > 2 in. (50 mm)

Potential Crack Initiation Point: Initiating in base metal at the weld termination, extending into the base metal

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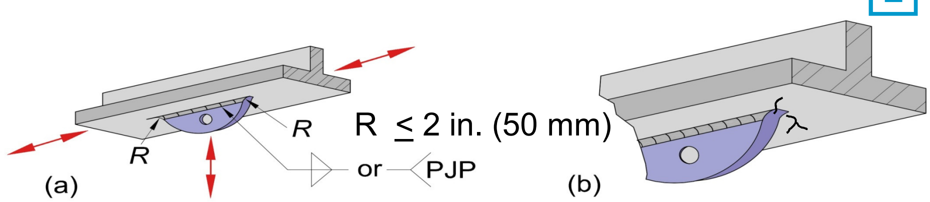
AISC 360-16 Specification for Structural Steel Buildings

Section 7: Base Metal at Short Attachments[a]

E

7.2



Description: Base metal subject to longitudinal stress at details attached by fillet or partial-joint-penetration groove welds, with or without transverse load on detail, when the detail embodies a transition radius, R, with weld termination ground smooth

R ≤ 2 in. (50 mm)

Potential Crack Initiation Point: Initiating in base metal at the weld termination, extending into the base metal

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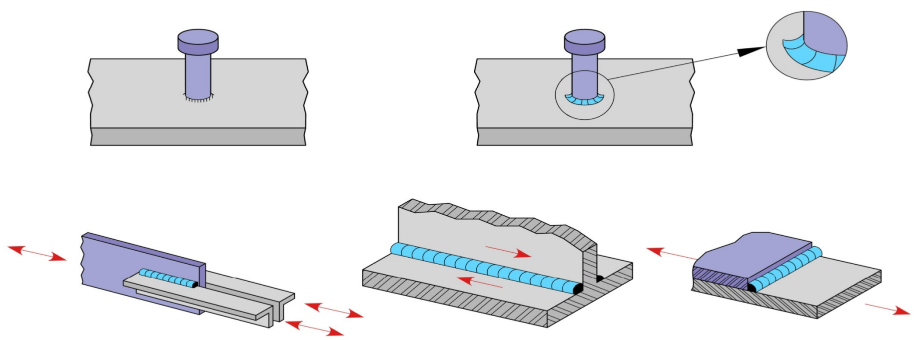
AISC 360-16 Specification for Structural Steel Buildings

Section 8: Miscellaneous



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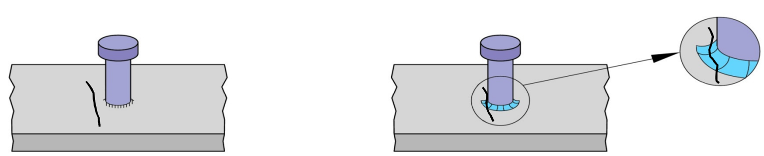
AISC 360-16 Specification for Structural Steel Buildings

Section 8: Miscellaneous

8.1

C



Description: Base metal at steel headed stud anchors attached by fillet or automatic stud welding

Potential Crack Initiation Point: At toe of weld in base metal

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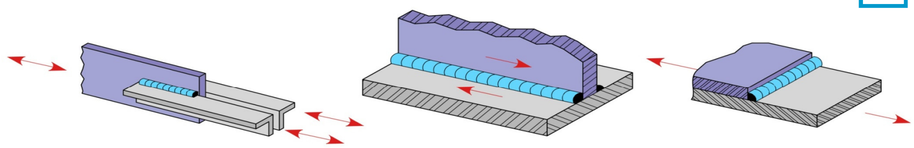
AISC 360-16 Specification for Structural Steel Buildings

Section 8: Miscellaneous

8.2

F



Description: Shear on throat of any fillet weld, continuous or intermittent, longitudinal or transverse

Potential Crack Initiation Point: Initiating at the root of the fillet weld, extending into the weld

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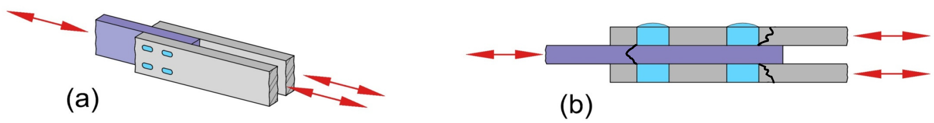
AISC 360-16 Specification for Structural Steel Buildings

Section 8: Miscellaneous

8.3

E



Description: Base metal at plug or slot welds

Potential Crack Initiation Point: Initiating in the base metal at the end of the plug or slot weld, extending into the base metal

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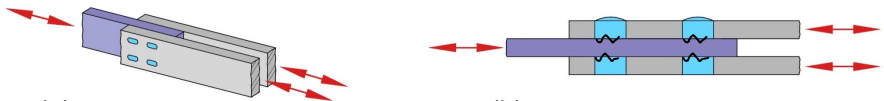
AISC 360-16 Specification for Structural Steel Buildings

Section 8: Miscellaneous

F

8.4



(a) (b)

Description: Shear on plug or slot welds

Potential Crack Initiation Point: Initiating in the weld at the faying surface, extending into the weld

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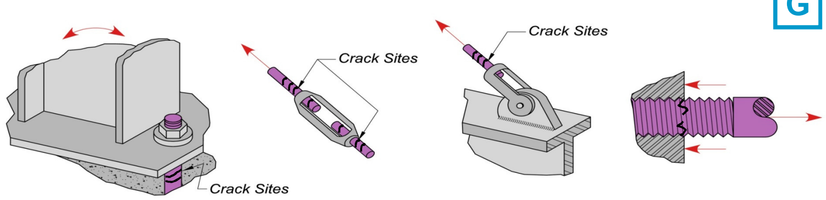
AISC 360-16 Specification for Structural Steel Buildings

Section 8: Miscellaneous

G

8.5



Description: Snug-tightened high-strength bolts, common bolts, threaded anchor rods, and hanger rods, whether pretensioned in accordance with Table J3.1 or J3.1M, or snug-tightened with cut, ground or rolled threads; stress range on tensile stress area due to applied cyclic load plus prying action, when applicable

Potential Crack Initiation Point: Initiating at the root of the threads, extending into the fastener

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FATIGUE OF WELDED CONNECTIONS

Outline

2. Design Model
   - Fatigue Testing
   - Categories of Connection Details
   - Predictive Model
   - Special Categories: C' and C''

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AISC 360-16 Specification for Structural Steel Buildings

(c) For tension-loaded plate elements connected at their end by cruciform, T or corner details with partial joint-penetration (PJP) groove welds transverse to the direction of stress, with or without reinforcing or contouring fillet welds, or if joined with only fillet welds, the allowable stress range on the cross section of the tension-loaded plate element shall be determined as the lesser of the following:

To be discussed later.

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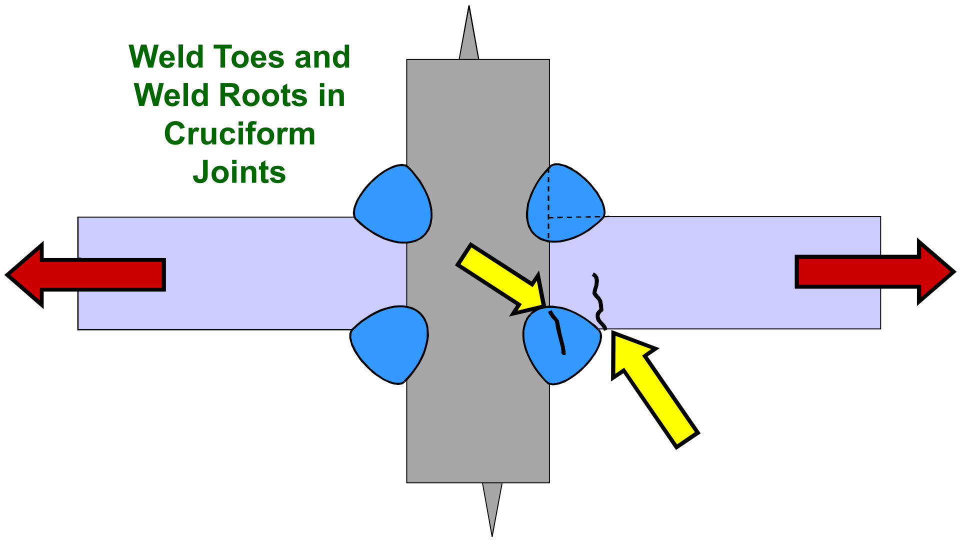
FATIGUE CONSIDERATIONS

Stress Concentrations

Weld Toes and Weld Roots in Cruciform Joints



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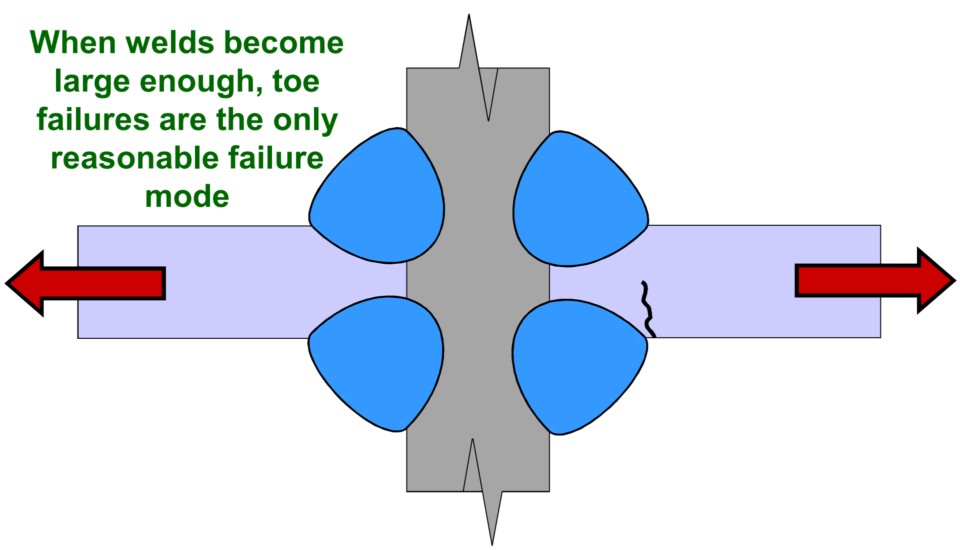
FATIGUE CONSIDERATIONS

Stress Concentrations

When welds become large enough, toe failures are the only reasonable failure mode



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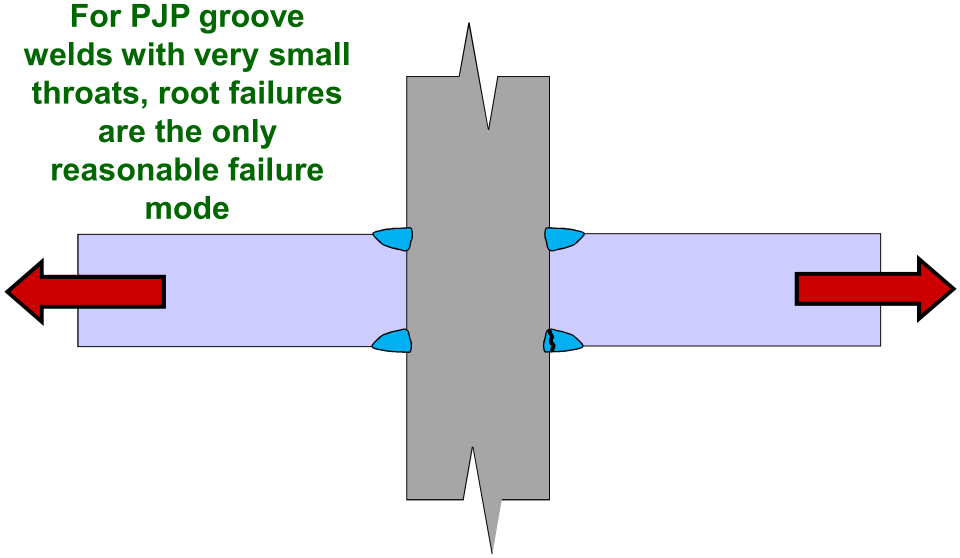
FATIGUE CONSIDERATIONS

Stress Concentrations

For PJP groove welds with very small throats, root failures are the only reasonable failure mode



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AISC 360-16 Specification for Structural Steel Buildings

(c) For tension-loaded plate elements connected at their end by cruciform, T or corner details with partial joint-penetration (PJP) groove welds transverse to the direction of stress, with or without reinforcing or contouring fillet welds, or if joined with only fillet welds, the allowable stress range on the cross section of the tension-loaded plate element shall be determined as the lesser of the following:

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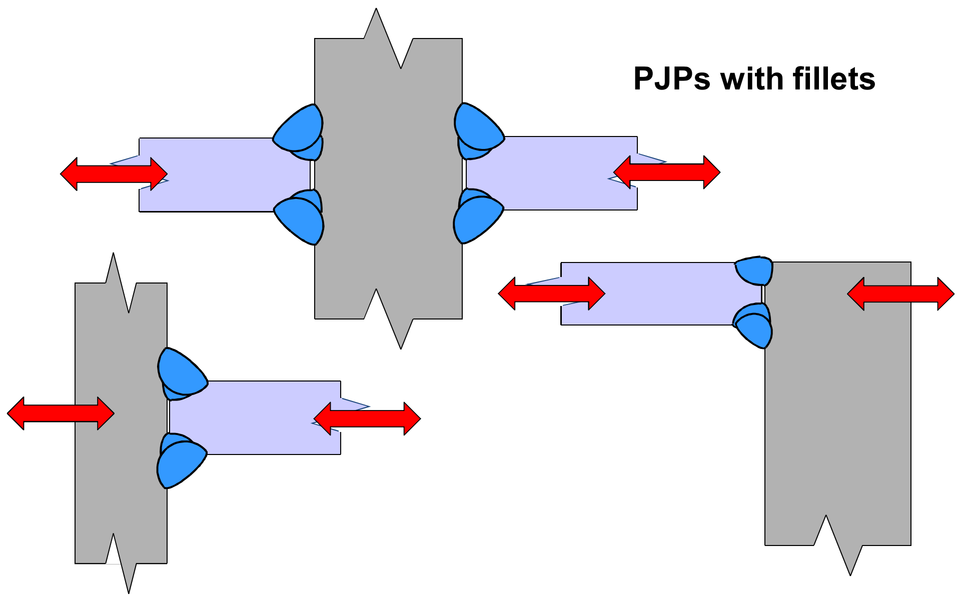
FATIGUE CONSIDERATIONS



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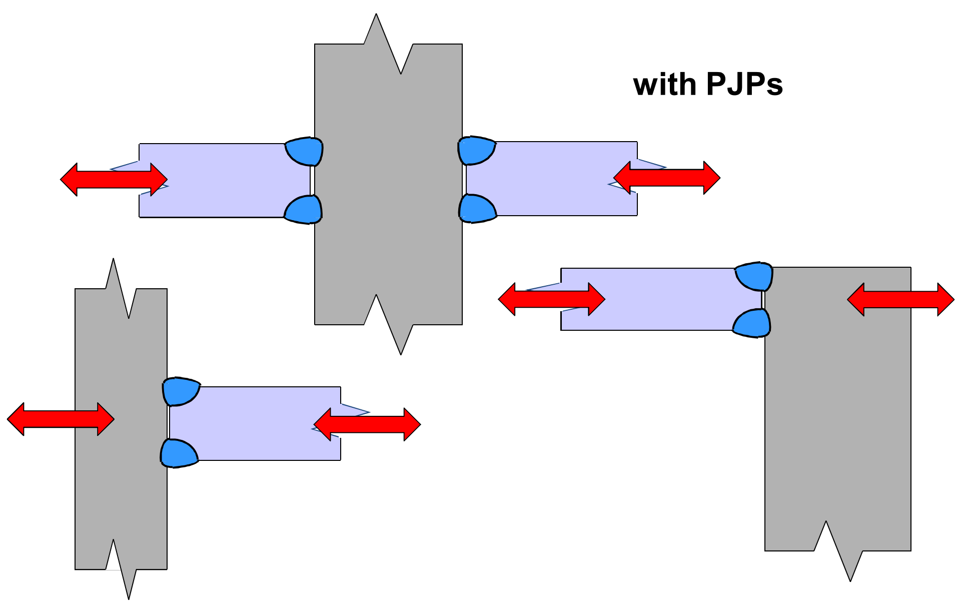
FATIGUE CONSIDERATIONS



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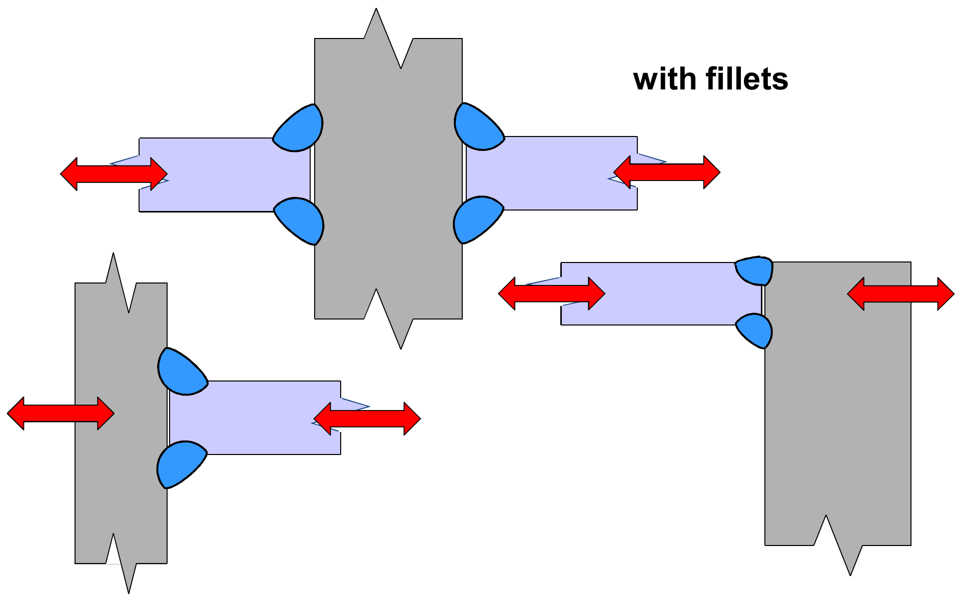
FATIGUE CONSIDERATIONS



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AISC 360-16 Specification for Structural Steel Buildings

(c) For tension-loaded plate elements connected at their end by cruciform, T or corner details with partial joint-penetration (PJP) groove welds transverse to the direction of stress, with or without reinforcing or contouring fillet welds, or if joined with only fillet welds, the allowable stress range on the cross section of the tension-loaded plate element shall be determined as the lesser of the following:

Three options follow (1, 2, 3)

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AISC 360-16 Specification for Structural Steel Buildings

(1) Based upon crack initiation from the toe of the weld on the tension-loaded plate element (i.e., when R_{PJP} = 1.0), the allowable stress range, F_{SR}, shall be determined by Equation A-3-1 or A-3-1M for stress category C.

$$F_{SR} = 1{,}000\left(\frac{C_f}{n_{SR}}\right)^{0.333} \geq F_{TH} \qquad \text{(A-3-1)}$$

$$F_{SR} = 6900\left(\frac{C_f}{n_{SR}}\right)^{0.333} \geq F_{TH} \qquad \text{(A-3-1M)}$$

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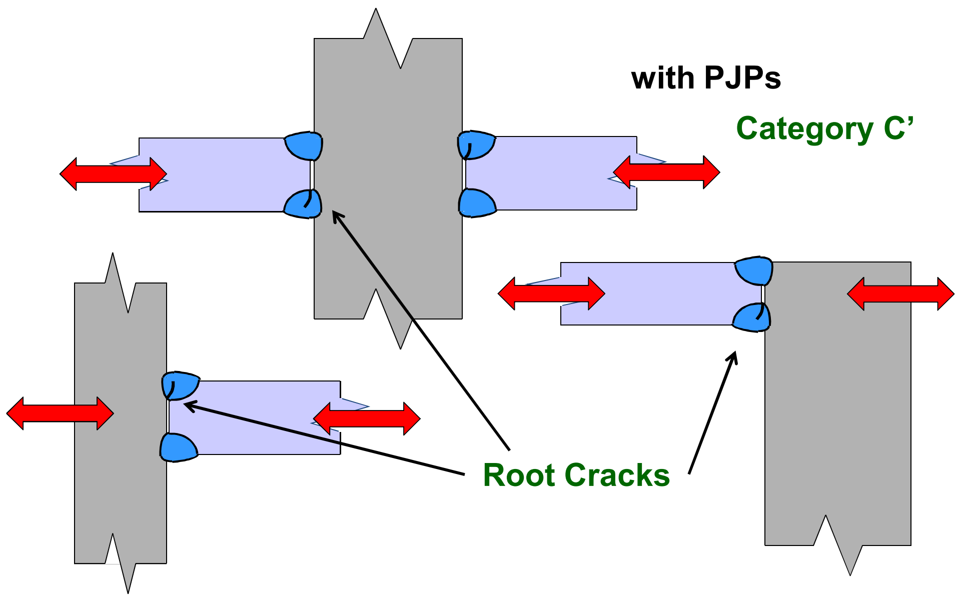
AISC 360-16 Specification for Structural Steel Buildings

(2) Based upon crack initiation from the root of the weld, the allowable stress range, F_{SR}, on the tension loaded plate element using transverse PJP groove welds, with or without reinforcing or contouring fillet welds, the allowable stress range on the cross section at the root of the weld shall be determined by Equation A-3-3 or A-3-3M, for stress category C′ as follows:

$$F_{SR} = 1{,}000R_{PJP}\left(\frac{4.4}{n_{SR}}\right)^{0.333} \qquad \text{(A-3-3)}$$

$$F_{SR} = 6900R_{PJP}\left(\frac{4.4}{n_{SR}}\right)^{0.333} \qquad \text{(A-3-3M)}$$

FATIGUE CONSIDERATIONS



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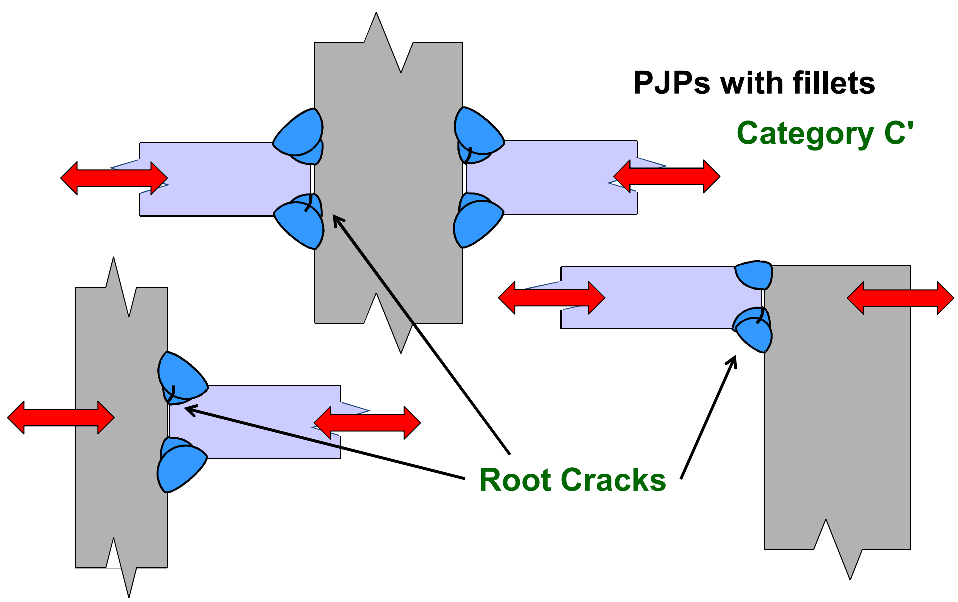
FATIGUE CONSIDERATIONS



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(2) Based upon crack initiation from the root of the weld, the allowable stress range, F_{SR}, on the tension loaded plate element using transverse PJP groove welds, with or without reinforcing or contouring fillet welds, the allowable stress range on the cross section at the root of the weld shall be determined by Equation A-3-3 or A-3-3M, for stress category C′ as follows:

$$F_{SR} = 1{,}000 \boxed{R_{PJP}} \left(\frac{\boxed{4.4}}{n_{SR}} \right)^{0.333} \quad \text{(A-3-3)}$$

Note: no value for F_{TH}

$$F_{SR} = 6900 R_{PJP} \left(\frac{4.4}{n_{SR}} \right)^{0.333} \quad \text{(A-3-3M)}$$

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AISC 360-16 Specification for Structural Steel Buildings

where
R_{PJP}, the reduction factor for reinforced or non-reinforced transverse PJP groove welds, is determined as follows:

$$\boxed{R_{PJP}} = \left(\frac{0.65 - 0.59\left(\frac{2a}{t_p}\right) + 0.72\left(\frac{w}{t_p}\right)}{t_p^{\,0.167}} \right) \le 1.0 \quad \text{(A-3-4)}$$

$$R_{PJP} = \left(\frac{1.12 - 1.01\left(\frac{2a}{t_p}\right) + 1.24\left(\frac{w}{t_p}\right)}{t_p^{\,0.167}} \right) \le 1.0 \quad \text{(A-3-4M)}$$

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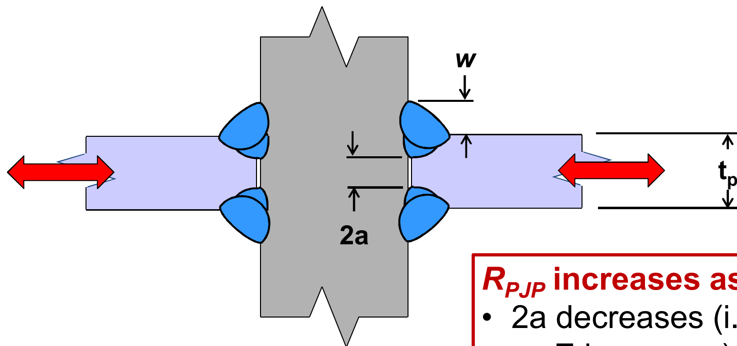
FATIGUE CONSIDERATIONS



R_{PJP} increases as
- 2a decreases (i.e., as E increases)
- w increases

$$R_{PJP} = \left(\frac{0.65 - 0.59\left(\frac{2a}{t_p}\right) + 0.72\left(\frac{w}{t_p}\right)}{t_p^{0.167}} \right) \leq 1.0$$

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(3) Based upon crack initiation from the roots of a pair of transverse fillet welds on opposite sides of the tension loaded plate element, the allowable stress range, F_{SR}, on the cross section at the root of the welds shall be determined by Equation A-3-5 or A-3-5M, for stress category C″ as follows:

$$F_{SR} = 1{,}000 \boxed{R_{FIL}} \left(\frac{4.4}{n_{SR}}\right)^{0.333} \quad \text{(A-3-5)}$$

Note: no value for F_{TH}

$$F_{SR} = 6900 R_{FIL} \left(\frac{4.4}{n_{SR}}\right)^{0.333} \quad \text{(A-3-5M)}$$

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where
R_{FIL} = reduction factor for joints using a pair of transverse fillet welds only

$$\boxed{R_{FIL}} = \left(\frac{0.06 + 0.72\left(\frac{w}{t_p}\right)}{t_p^{\,0.167}} \right) \le 1.0 \qquad \text{(A-3-6)}$$

$$R_{FIL} = \left(\frac{0.103 - 1.24\left(\frac{w}{t_p}\right)}{t_p^{\,0.167}} \right) \le 1.0 \qquad \text{(S.I.)} \quad \text{(A-3-6M)}$$

If R_{FIL} = 1.0, the stress range will be limited by the weld toe and category C will control.

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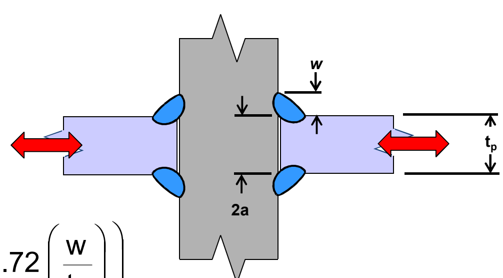
FATIGUE CONSIDERATIONS

For fillet welds, 2a = t_p.



$$R_{PJP} = \left(\frac{\overbrace{0.65 - 0.59}^{0.06}\cancelto{1}{\left(\frac{2a}{t_p}\right)} + 0.72\left(\frac{w}{t_p}\right)}{t_p^{\,0.167}} \right) \le 1.0 \qquad \text{(A-3-4)}$$

$$R_{PJP} = \left(\frac{1.12 - 1.01\left(\frac{2a}{t_p}\right) + 1.24\left(\frac{w}{t_p}\right)}{t_p^{\,0.167}} \right) \le 1.0 \qquad \text{(S.I.)} \quad \text{(A-3-4M)}$$

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where

R_{FIL} = reduction factor for joints using a pair of transverse fillet welds only

$$R_{FIL} = \left(\frac{0.06 + 0.72\left(\frac{w}{t_p}\right)}{t_p^{0.167}} \right) \le 1.0 \qquad \text{(A-3-6)}$$

$$R_{FIL} = \left(\frac{0.103 - 1.24\left(\frac{w}{t_p}\right)}{t_p^{0.167}} \right) \le 1.0 \qquad \text{(S.I.)} \quad \text{(A-3-6M)}$$

If R_{FIL} = 1.0, the stress range will be limited by the weld toe and category C will control.

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APPENDIX 3 COMMENTARY

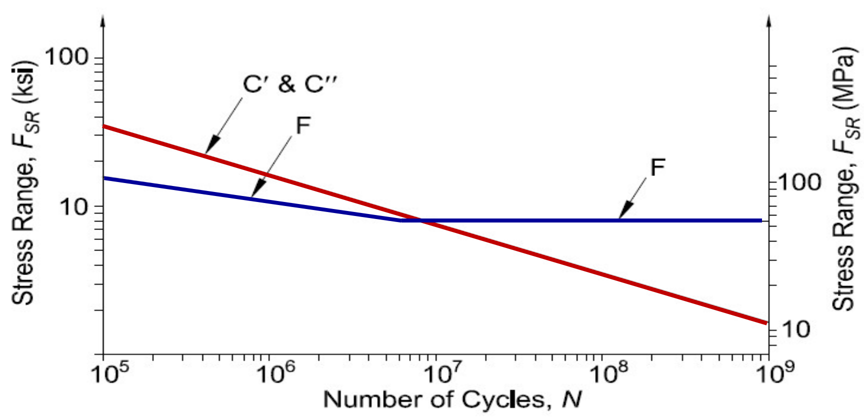

Fig. C-A-3.2. Fatigue resistance curves for stress categories C and F.

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APPENDIX 3 FATIGUE

User Note: Stress categories C′ and C″ are cases where the fatigue crack initiates in the root of the weld. These cases do not have a fatigue threshold and cannot be designed for an infinite life. Infinite life can be approximated by use of a very high cycle life such as 2×10^8. Alternatively, if the size of the weld is increased such that R_{FIL} or R_{PJP} is equal to 1.0, then the base metal controls, resulting in stress category C, where there is a fatigue threshold and the crack initiates at the toe of the weld.

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FATIGUE CONSIDERATIONS

Summary of C' and C"

- Category C: toe cracks
- Category C': root cracks for PJPs, or fillet/PJP combinations
- Category C": root cracks for fillets

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FATIGUE CONSIDERATIONS

Important note

- Categories C' and C" do not have threshold values
- Categories C' and C" never need to control: make weld size larger and C will control (and, C has a threshold value)

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FATIGUE OF WELDED CONNECTIONS

Outline

1. Background and Theory
2. Design Model
3. Details Associated with the Model
4. Summary

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AISC 360-16 Specification for Structural Steel Buildings

APPENDIX 3 FATIGUE

3.1. GENERAL PROVISIONS

The provisions of this Appendix shall apply to stresses calculated on the basis of the applied cyclic load spectrum. The maximum permitted stress due to peak cyclic loads shall be $0.66F_y$. In the case of a stress reversal, the stress range shall be computed as the numerical sum of maximum repeated tensile and compressive stresses or the numerical sum of maximum shearing stresses of opposite direction at the point of probable crack initiation.

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AISC 360-16 Specification for Structural Steel Buildings

APPENDIX 3 FATIGUE

3.1. GENERAL PROVISIONS

The cyclic load resistance determined by the provisions of this Appendix is applicable to structures with suitable corrosion protection or subject only to mildly corrosive atmospheres, such as normal atmospheric conditions.

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AISC 360-16 Specification for Structural Steel Buildings

APPENDIX 3 FATIGUE

3.1. GENERAL PROVISIONS

The cyclic load resistance determined by the provisions of this Appendix is applicable only to structures subject to temperatures not exceeding 300°F (150°C).

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APPENDIX 3 COMMENTARY

Fatigue crack growth rates are generally inversely proportional to the modulus of elasticity and therefore, at higher temperatures, crack growth rates increase. At 500°F (260°C), crack growth rates on ASTM A212B steel….are essentially the same as for room temperature (Hertzberg et al., 2012). The Appendix is conservatively limited to applications involving temperatures not to exceed 300°F (150°C). Elevated temperature applications may also have corrosion effects that are not considered by the Appendix.

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APPENDIX 3 COMMENTARY

The Appendix does not have a lower temperature limit because fatigue crack growth rates are lower. Fatigue tests as low as −100°F (−75°C) have been conducted with no observed change in crack growth rates (Roberts et al., 1980). It should be recognized that at low temperatures, brittle fracture concerns increase. The critical size to which a crack can grow before the onset of brittle fracture will be smaller for low temperature applications than will be the case for a room temperature application.

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APPENDIX 3 FATIGUE

3.6. NONDESTRUCTIVE EXAMINATION REQUIREMENTS FOR FATIGUE

In the case of CJP groove welds, the maximum allowable stress range calculated by Equation A-3-1 or A-3-1M applies only to welds that have been ultrasonically or radiographically tested and meet the acceptance requirements of *Structural Welding Code—Steel* (AWS D1.1/D1.1M) clause 6.12.2 or clause 6.13.2.

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APPENDIX 3 COMMENTARY

3.1. GENERAL PROVISIONS

This Appendix deals with high cycle fatigue (i.e., > 20,000 cycles); this behavior occurs when elastic stresses are involved. In situations where inelastic (plastic) stresses are involved, fatigue cracks may initiate at far fewer than 20,000 cycles—perhaps as few as a dozen.

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APPENDIX 3 COMMENTARY

3.1. GENERAL PROVISIONS (cont'd)

However, unlike the conditions prescribed in this Appendix, low cycle fatigue involves cyclic, inelastic stresses. This is because the applicable cyclic allowable stress range will be limited by the static allowable stress.

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FATIGUE OF WELDED CONNECTIONS

Outline

1. Background and Theory
2. Design Model
3. Details Associated with the Model
4. Summary

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AISC 360-16 Specification for Structural Steel Buildings

APPENDIX 3 FATIGUE

3.3. PLAIN MATERIAL AND WELDED JOINTS

In plain material and welded joints, the range of stress due to the applied cyclic loads shall not exceed the allowable stress range computed as follows.

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AISC 360-16 Specification for Structural Steel Buildings

(a) For stress categories A, B, B′, C, D, E and E′ the allowable stress range, F_{SR}, shall be determined by Equation A-3-1 or A-3-1M, as follows:

$$F_{SR} = 1{,}000 \left(\frac{C_f}{n_{SR}} \right)^{0.333} \geq F_{TH} \qquad \text{(A-3-1)}$$

$$F_{SR} = 6900 \left(\frac{C_f}{n_{SR}} \right)^{0.333} \geq F_{TH} \qquad \text{(S.I.)} \quad \text{(A-3-1M)}$$

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(b) For stress category F, the allowable stress range, F_{SR}, shall be determined by Equation A-3-2 or A-3-2M, as follows:

$$F_{SR} = 100 \left(\frac{1.5}{n_{SR}} \right)^{0.167} \geq 8 \text{ ksi} \qquad \text{(A-3-2)}$$

$$F_{SR} = 690 \left(\frac{1.5}{n_{SR}} \right)^{0.167} \geq 55 \text{ MPa} \qquad \text{(S.I.)} \quad \text{(A-3-2M)}$$

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(c) For tension-loaded plate elements connected at their end by cruciform, T or corner details with partial joint-penetration (PJP) groove welds transverse to the direction of stress, with or without reinforcing or contouring fillet welds, or if joined with only fillet welds, the allowable stress range on the cross section of the tension-loaded plate element shall be determined as the lesser of the following:

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(1) Based upon crack initiation from the toe of the weld on the tension-loaded plate element (i.e., when R_{PJP} = 1.0), the allowable stress range, F_{SR}, shall be determined by Equation A-3-1 or A-3-1M for stress category C.

$$F_{SR} = 1{,}000 \left(\frac{C_f}{n_{SR}} \right)^{0.333} \geq F_{TH} \qquad \text{(A-3-1)}$$

$$F_{SR} = 6900 \left(\frac{C_f}{n_{SR}} \right)^{0.333} \geq F_{TH} \qquad \text{(A-3-1M)}$$

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(2) Based upon crack initiation from the root of the weld, the allowable stress range, F_{SR}, on the tension loaded plate element using transverse PJP groove welds, with or without reinforcing or contouring fillet welds, the allowable stress range on the cross section at the root of the weld shall be determined by Equation A-3-3 or A-3-3M, for stress category C′ as follows:

$$F_{SR} = 1{,}000 R_{PJP} \left(\frac{4.4}{n_{SR}} \right)^{0.333} \qquad \text{(A-3-3)}$$

$$F_{SR} = 6900 R_{PJP} \left(\frac{4.4}{n_{SR}} \right)^{0.333} \qquad \text{(A-3-3M)}$$

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(3) Based upon crack initiation from the roots of a pair of transverse fillet welds on opposite sides of the tension loaded plate element, the allowable stress range, F_{SR}, on the cross section at the root of the welds shall be determined by Equation A-3-5 or A-3-5M, for stress category C″ as follows:

$$F_{SR} = 1{,}000 R_{FIL} \left(\frac{4.4}{n_{SR}} \right)^{0.333} \qquad \text{(A-3-5)}$$

$$F_{SR} = 6900 R_{FIL} \left(\frac{4.4}{n_{SR}} \right)^{0.333} \qquad \text{(A-3-5M)}$$

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FATIGUE CONSIDERATIONS

Important note

- Categories C' and C" do not have threshold values
- Categories C' and C" never need to control: make weld size larger and C will control (and, C has a threshold value)

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APPENDIX 3 FATIGUE

3.1. GENERAL PROVISIONS (cont'd)

When the applied cyclic stress range is less than the threshold allowable stress range, F_{TH}, no further evaluation of fatigue resistance is required. See Table A-3.1.

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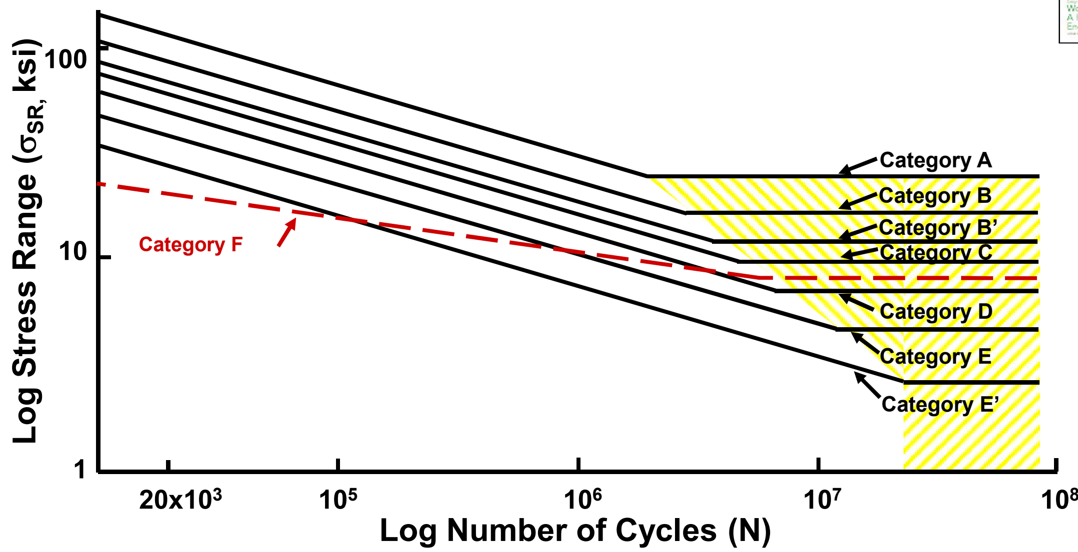
FATIGUE CONSIDERATIONS



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FATIGUE CONSIDERATIONS

Stress Category	Constant C_f	Threshold F_{TH} (ksi)
A	25	24
B	12	16
B'	6.1	12
C	4.4	10
D	2.2	7
E	1.1	4.5
E'	0.39	2.6
F	1.5	8
G	0.39	7

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APPENDIX 3 COMMENTARY

3.1. GENERAL PROVISIONS

Extensive test programs using full-size specimens, substantiated by theoretical stress analysis, have confirmed the following general conclusions (Fisher et al., 1970; Fisher et al., 1974):

(1) Stress range and notch severity are the dominant stress variables for welded details and beams.

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APPENDIX 3 COMMENTARY

3.1. GENERAL PROVISIONS (cont'd)

2) Other variables such as minimum stress, mean stress and maximum stresses are not significant for design purposes.

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AISC 360-16 Specification for Structural Steel Buildings

APPENDIX 3 COMMENTARY

3.1. GENERAL PROVISIONS (cont'd)

3) Structural steels with a specified minimum yield stress of 36 to 100 ksi (250 to 690 MPa) do not exhibit significantly different fatigue strengths for given welded details fabricated in the same manner.

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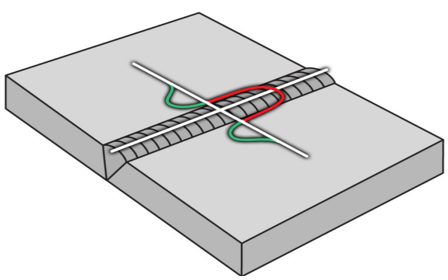
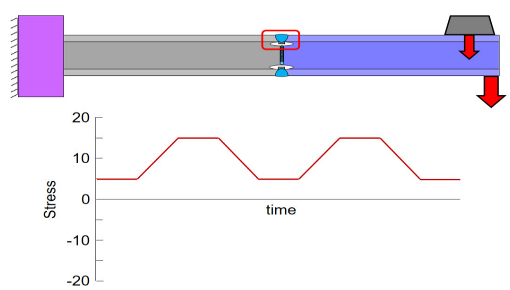
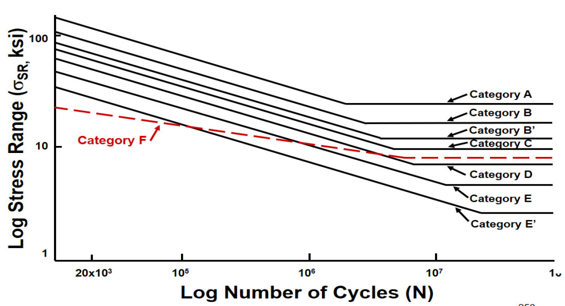
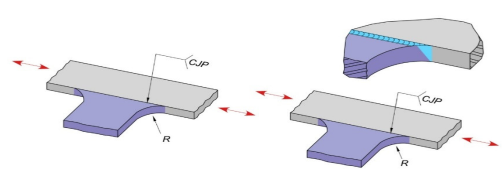
FATIGUE OF WELDED CONNECTIONS









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Thank you!

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

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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

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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

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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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Night School Resources

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

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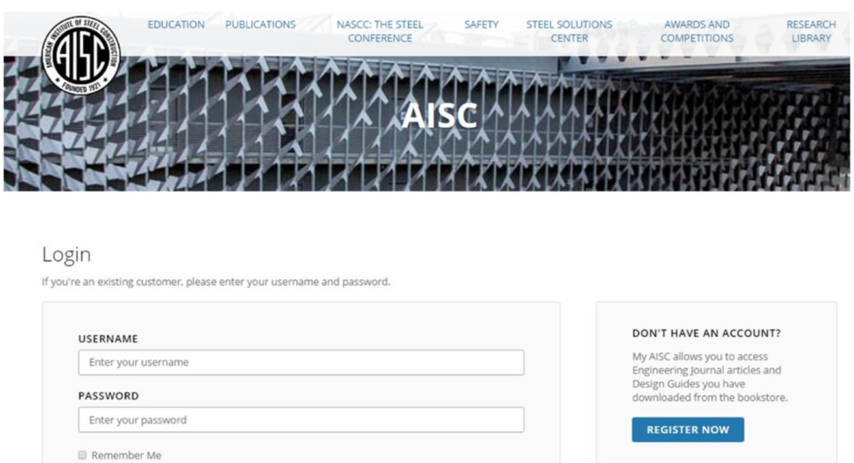

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Night School Resources

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

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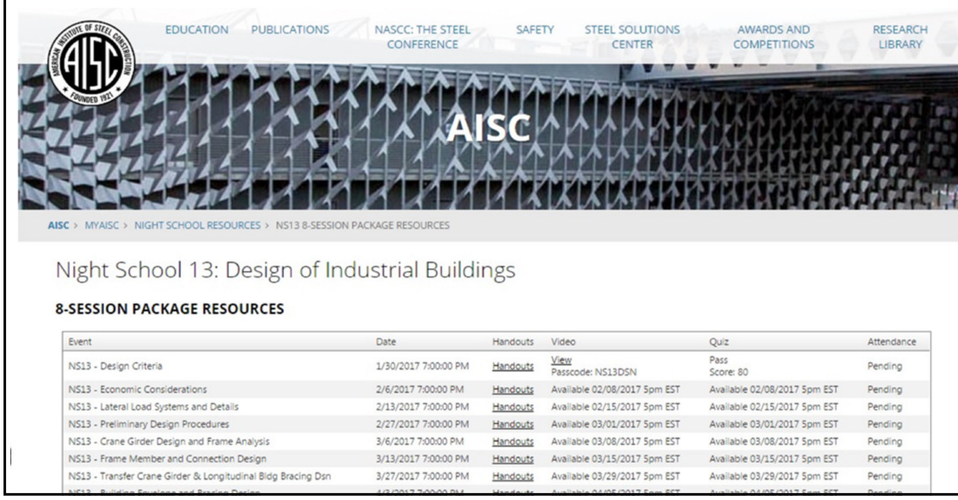
Night School Resources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Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

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

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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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Night School Resources

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

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