

## AISC Live Webinars

Thank you for joining our live webinar today.  
We will begin shortly. Please standby.

**Three-Part Webinar Series: Structural Stainless Steel**  
Part 2: Design  
May 12, 2022



**Smarter.  
Stronger.  
Steel.**

## AISC Live Webinars

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Please type any questions or comments in the Q&A window.



**Smarter.  
Stronger.  
Steel.**



## AISC Live Webinars

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## AISC Live Webinars

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## AISC Live Webinars

### Course Description – Submitted for AIA CE Credit

Structural Stainless Steel Design  
May 12, 2022

This session will lead the designer through the process of designing stainless steel tension members, beams, and columns in accordance with the new standard, AISC 370 *Specification for Structural Stainless Steel Buildings*, highlighting the differences compared to the rules for carbon steel in AISC 360 *Specification for Structural Steel Buildings*. Methods of analysis unique to structural stainless steel, including the continuous strength method, will be discussed, as will structural performance at elevated temperatures.



## AISC Live Webinars

### Learning Objectives – Submitted for AIA CE Credit

- Describe the stress-strain behavior of stainless steel.
- Identify the parts of the design curves for flexural buckling and lateral-torsional buckling for stainless steel members.
- Identify the limits of applicability for use of AISC 370 for various types of load effects.
- Explain the continuous strength method and compare the results of the continuous strength method to a conventional design approach for compression members.



# Structural Stainless Steel Session 2: Design



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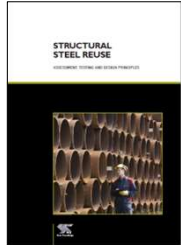
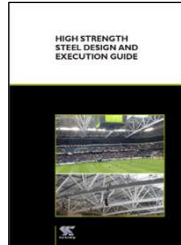
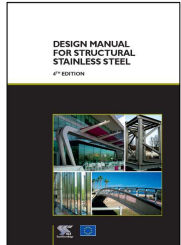


## Introducing the Steel Construction Institute (SCI)

SCI is an independent centre of excellence providing technical expertise & disseminator of best practice to the steel construction sector

### SCI Activities

- Technical publications
- Standards development
- Product development
- Independent assessment
- Research & Testing
- Engineering software
- Advisory Service
- Problem resolution

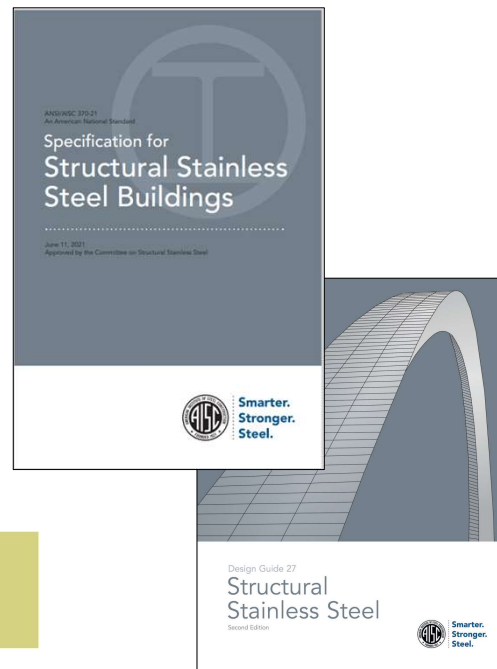


## Objectives of this session

1. Scope of AISC 370
2. Differences in design provisions with respect to AISC 360
3. Background of design provisions not included in AISC 360
4. AISC DG27 2<sup>nd</sup> Ed.

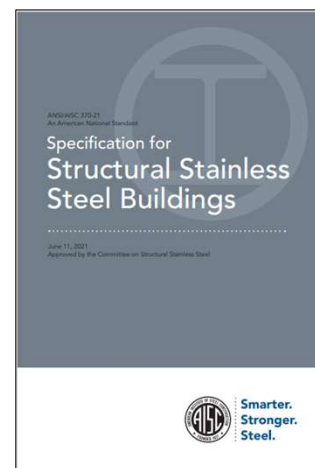


AISC 313: Code of standard practice for  
Structural Stainless Steel Buildings  
– next week's webinar!



## Outline

1. Introduction
2. Design requirements  
(Chapter B)
3. Serviceability  
(Chapter L)
4. Design of members  
(Chapters D, E, F, G, H, App. 2)
5. Structural analysis  
(Chapter C and App. 1)
6. Design for fire  
(Appendix 4)
7. Stainless steel material behaviour  
(Appendix 7)



## Review of last week's session - what can you remember?

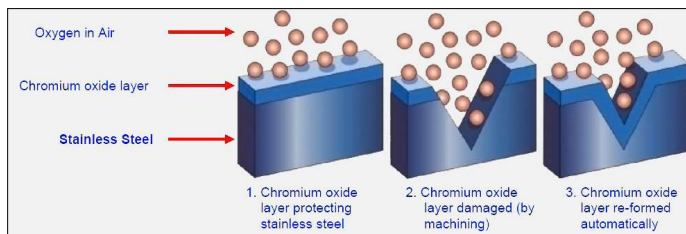
What makes stainless steel 'stainless'?



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## What is stainless steel?

Corrosion resistant steel with Cr content >10.5%



Protective passive film forms **IF**

- Alloy composition is corrosion resistant enough for the environment
- Surface is clean and exposed to oxygen (atmospheric or in fluids)

- More than 200 stainless steel alloys
- Only a few used in construction



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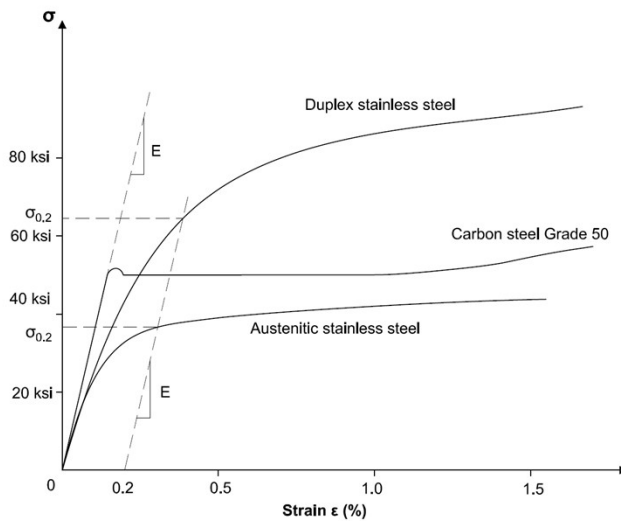
## Review of last week's session - what can you remember?

Are the mechanical properties of stainless and carbon steel the same?



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## Stress-strain characteristics: low strains



Modulus of elasticity very similar to carbon steel, but form of stress-strain curve is fundamentally different.

Yield strength,  $F_y$  = strength at 0.2% offset permanent strain

$F_y$  values from ASTMs are given in Commentary to Chap A (material in the annealed condition)

$F_y$  = 30 ksi austenitics

$F_y$  = 65 ksi duplexes



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## Structural design of stainless steel



Huge amount of research carried out over the last 30 years studying welded members, cold formed members, hollow sections, decking, welded connections, bolted connections, fatigue, 3D printed members, fire, composite construction....



Economic and comprehensive design standards



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## Impact of the non-linear stress-strain curve on buckling

### Low slenderness

- Columns attain/exceed yield load (squash load)
- Benefits of strain hardening apparent
- **Stainless steel behaves at least as well as carbon steel column**

### Intermediate slenderness

- Average stress in column is between the limit of proportionality and the 0.2% permanent offset strain
- **Stainless steel column less strong than carbon steel column**

### High slenderness

- Low axial strength
- Stresses low and in relatively linear region of stress-strain curve
- **Stainless steel behaves similarly to carbon steel**



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## Scope of AISC 370

### Materials

- Austenitic and duplex alloys
- Precipitation hardening alloys for tension members & fasteners

### Shapes

- Hot rolled, welded, extruded open structural sections
- Round and rectangular HSS
- Plate and bar

### Exclusions

- Seismic design
- Shapes: Angles in flexure, unequal angles, equal angles with slender cross-section
- Chapter I: Composite members
- Chapter K: HSS connections (limited scope)

Use same  $\phi$  and  $\Omega$   
factors as AISC 360

Except G and J4:  
Rolled I shapes in  
shear

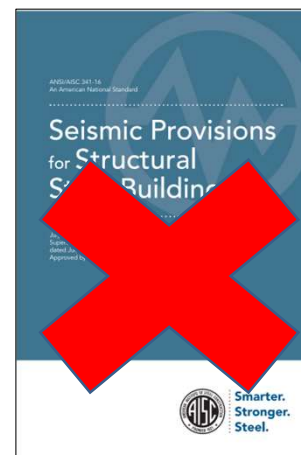


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## Stainless steel structures in seismic applications

Stainless steel applications subject to seismic loading  
- stairs, railings, catwalks, platforms, pipe and  
equipment supports, canopies

- Greater ductility of stainless steel → greater energy dissipation
- Outside scope of AISC 370 and AISC 341
- Do not adopt carbon steel R factors (non-linear stress-strain characteristics)
- Work underway to provide better guidance

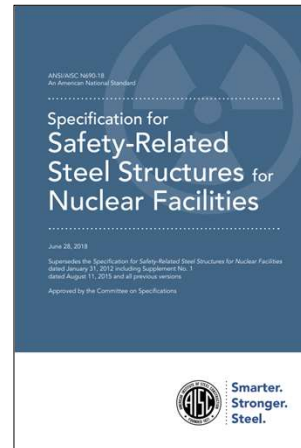


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## Stainless steel structures in nuclear applications

### N690-18 *Specification for Safety-Related Steel Structures for Nuclear Facilities*

Uses AISC 360 as baseline, modifying specific portions to make applicable to structures in nuclear industry.  
Refers to AISC 303 for tolerances, contract documents etc



### Next edition N690-24

Use AISC 360 and AISC 370 as baseline documents, modifying specific portions to make applicable to structures in nuclear industry  
Refer to AISC 303 and AISC 313 for tolerances etc



# Chapter B



## Chapter B – Design Requirements

The chapter is organized as follows:

- B1. General Provisions
- B2. Loads and Load Combinations
- B3. Design Basis
- B4. Member Properties
- B5. Fabrication and Erection
- B6. Quality Control and Quality Assurance
- B7. Evaluation of Existing Structures

Moment redistribution provisions for beams are not included in AISC 370



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## Chapter B – Design Requirements

### B4. Member Properties

- Width-to-thickness limits for elements → More simplified in AISC 370
- Design thickness
- Strength increase in stainless steel cold-formed HSS → Added to AISC 370



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## Chapter B – Width-to-thickness limits for elements

### AISC 360

### AISC 370

**TABLE B4.1a**  
 Width-to-Thickness Ratios: Compression Elements  
 Members Subject to Axial Compression

Case	Description of Element	Width-to-Thickness Ratio	Limiting Width-to-Thickness Ratio (non-slender/slender)	Examples
1	Flanges of rolled I-shape sections, plates projecting from rolled I-shape sections, outstanding legs of built-up angles, connections with continuous contact flanges of channels and I-beam tees	$b/t$	$0.95 \sqrt{E/F_c}$	
2	Flanges of built-up I-shape sections and plates or angle legs projecting from built-up I-shape sections	$b/t$	$0.64 \sqrt{E/F_c}$	
3	Legs of single angle, legs of double angles with separators, and all other unstiffened elements	$b/t$	$0.45 \sqrt{E/F_c}$	
4	Stems of tees	$d/t$	$0.75 \sqrt{E/F_c}$	
5	Walls of square, round and built-up rectangular hollow sections and channels	N/A	$1.49 \sqrt{E/F_c}$	

6	Walls of rectangular HSS	$b/t$	$1.40 \sqrt{E/F_c}$	
7	Flange cover plates and stiffening plates between line of fasteners of webs	$b/t$	$1.40 \sqrt{E/F_c}$	
8	All other stiffened elements	$b/t$	$1.40 \sqrt{E/F_c}$	
9	Round HSS	$D/t$	$0.91 \sqrt{E/F_c}$	

**TABLE B4.1a**  
 Width-to-Thickness Ratios: Compression Elements  
 Members Subject to Axial Compression

Case	Description of Element	Width-to-Thickness Ratio	Limiting Width-to-Thickness Ratio, $\lambda_c$ (non-slender/slender)	Examples
1	Flanges of built-up or rolled I-shaped sections and channels, plates, or angle legs projecting from built-up or rolled I-shaped sections, outstanding legs of built-up angles connected with continuous contact flanges and stems of tees, legs of single angles, legs of double angles with separators, and all other unstiffened elements	$b/t$ or $d/t$	$0.41 \sqrt{E/F_c}$	
2	Webs of built-up or rolled I-shaped sections and channels, and walls of rectangular HSS and box sections of uniform thickness	N/A or $d/t$	$1.24 \sqrt{E/F_c}$	
3	Round HSS	$D/t$	$0.91 \sqrt{E/F_c}$	



## Chapter B – Design Thickness

### AISC 360

For HSS produced to standards other than A1065/A1065M or A1085/A1085M

$$t_{des} = 0.93 t_{nom}$$

### AISC 370

For HSS

$$t_{des} = 0.95 t_{nom}$$

For built-up, hot-rolled and flat bar sections

When  $t_{nom} > 3/16$  in.

$$t_{des} = t_{nom}$$

When  $t_{nom} \leq 3/16$  in.

$$t_{des} = 0.95 t_{nom}$$

(unless the section has a minimum thickness tolerance less than 0.05 times the nominal thickness, in which case it is permitted to use the nominal thickness.)



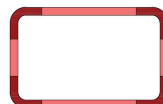
## Chapter B – Strength increase in stainless steel cold-formed HSS

- Take advantage of strain hardening of stainless steel
- Only applicable to cold-formed square, rectangular and round HSS
- $F_{y,avg}$  can be used in design according to Chapters E, F, and H, and Appendices 1 and 2

Significantly larger than for carbon steel

(a) For cold-formed rectangular HSS

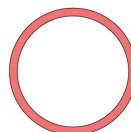
$$F_{y,avg} = \frac{F_{y,corner} A_{corner} + F_{y,wall} (A_g - A_{corner})}{A_g} \leq F_u$$



Largest increase in strength around the corners  
 Flat portions also experience an increase in strength

(b) For cold-formed round HSS

$$F_{y,avg} = F_{y,rd}$$



Even increase all around



## Chapter B – Strength increase in stainless steel cold-formed HSS

Square HSS		$F_{y,avg} / F_y$	
	b/t	Austenitic	Duplex
HSS 4 x 4 x 0.120	33	1.40	1.03
HSS 4 x 4 x 0.250	14	1.60	1.10
HSS 12 x 12 x 0.250	49	1.35	1.02
HSS 12 x 12 x 0.312	38	1.40	1.03



Round HSS		$F_{y,avg} / F_y$	
	D/t	Austenitic	Duplex
HSS 4.5 x 0.12	40	1.16	1
HSS 4.5 x 0.25	19	1.31	1
HSS 7.5 x 0.12	67	1.08	1
HSS 7.5 x 0.25	32	1.20	1



# Dimension and property tables

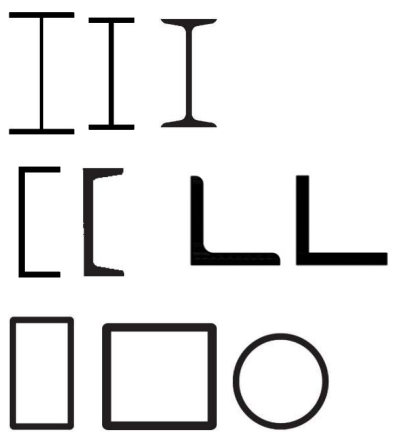


Table 4-1  
**W-Shapes (Welded\*)**  
 Dimensions

Shape	Area, A <sub>x</sub>	Nominal Wt.	Depth, d	Web		Flange		Distance				Workable Gage	
				Thickness, t <sub>w</sub>	t <sub>w</sub> /2	Width, b <sub>f</sub>	Thickness, t <sub>f</sub>	k	k <sub>1</sub>	T	W		
W4 x 140 <sup>(1)</sup>	40.2	130	24.7	0.625	12.35	12.0	1.00	1.00	1.00	1.00	1.00	22 1/2	0%

Table 4-1 (continued)  
**W-Shapes (Welded)**  
 Properties

Axis	Axis X-X				Axis Y-Y				r <sub>x</sub>	r <sub>y</sub>	Torsional Properties	
	r	Z	I	S	r	Z	I	S			J	C <sub>w</sub>
1	15.3	386	358	25.5	2.96	85.4	3.52	23.7	10.2	1032	10320	



# Serviceability (Chapter L)



## Chapter L – Design for Serviceability

The chapter is organized as follows:

- L1. General Provisions
- L2. Deflections
- L3. Drift
- L4. Vibration
- L5. Wind-Induced Motion
- L6. Thermal Expansion and Contraction
- L7. Connection Slip



## Chapter L – Design for Serviceability

### L2. Deflections

Reduced modulus of elasticity,  $E_r$

$$E_r = \frac{E_{st} + E_{sc}}{2}$$

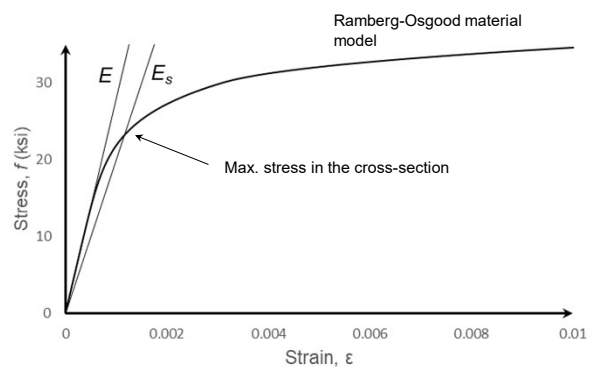
where

$E_{sc}$  = secant modulus corresponding to the maximum compressive stress in the cross section, ksi (MPa)

$E_{st}$  = secant modulus corresponding to the maximum tensile stress in the cross section, ksi (MPa)

Secant modulus

$$E_s = \frac{E}{1 + 0.002 \frac{E}{f} \left( \frac{f}{F_y} \right)^n}$$



# Member design (Chapter D)



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## Chapter D – Design of Members for Tension

The chapter is organized as follows:

- D1. Slenderness Limitations
- D2. Tensile Strength
- D3. Effective Net Area
- D4. Built-Up Members
- D5. Pin-Connected Members

Applicable to

- **austenitic** and **duplex** stainless steel members,
- **precipitation hardening** stainless steel rods.

The design of eye bars is not covered.



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## Chapter D – Design of Members for Tension

### D2. Design tensile strength (Difference compared to AISC 360)

(a) For tensile yielding in the gross section

$$P_n = F_y A_g$$

For austenitic and duplex stainless steel tension members

$$\phi_t = 0.90 \text{ (LRFD)} \quad \Omega_t = 1.67 \text{ (ASD)}$$

For precipitation hardening stainless steel tension rods

$$\phi_t = 0.80 \text{ (LRFD)} \quad \Omega_t = 1.88 \text{ (ASD)}$$



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## Chapter D – Design of Members for Tension

### D5. Pin-connected members (Difference compared to AISC 360)

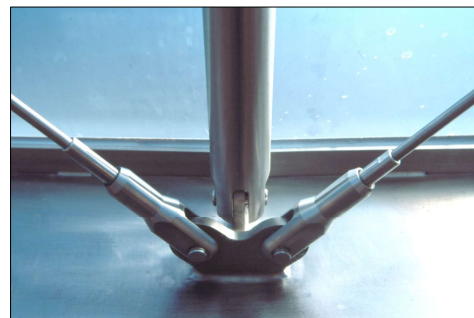
Tensile strength

Given by the lowest limit state of:

- Yielding
- Tensile rupture
- Shear rupture
- Bearing

Dimensional requirements – small differences:

- Greater flexibility in the shape of the pin-connected member beyond the pin hole
- New requirement to check bearing strength of pin (when pin-connected members are high strength)



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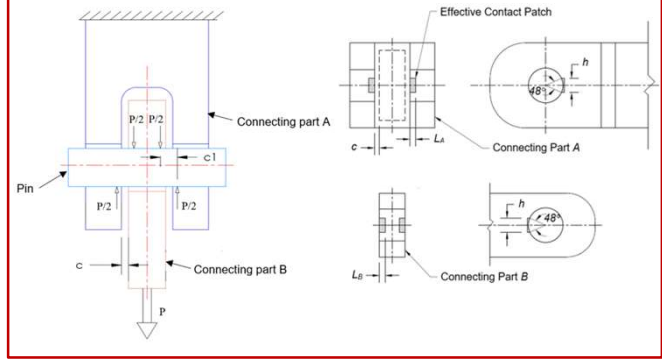
# Section J8 – Pins

## Design of pins

Given by the lowest limit state of:

- Bearing strength
- Shear rupture
- Flexural strength
- Combined shear and flexure

### Commentary to Section J8 - Pins Method for calculating the moment in the pin



# Chapter E



## Chapter E – Design of Members for Compression

The chapter is organized as follows:

- E1. General Provisions
- E2. Effective Length
- E3. Flexural Buckling of Members without Slender Elements
- E4. Torsional and Flexural-Torsional Buckling of Single Equal-Leg Angles and Members without Slender Elements
- E5. Single Equal-Leg-Angle Compression Members Without Slender Elements
- E6. Built-Up Members
- E7. Members with Slender Elements

The design of unequal-leg angles is not covered.

Built-up members interconnected by cover plates or lacing with tie plates are not covered.



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## Chapter E – Column buckling curve

Comparison between AISC 360 and AISC 370

### AISC 360

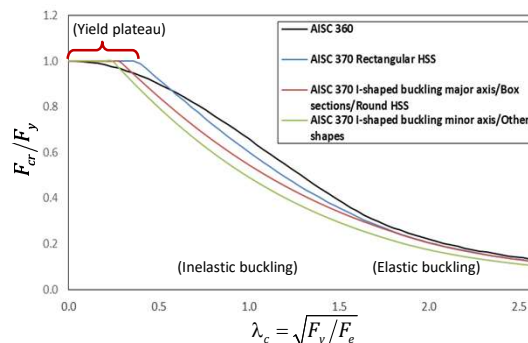
- One buckling curve
- Curve composed of **two** parts:
  - Inelastic buckling
  - Elastic buckling

No yield plateau  
 Elastic buckling starts at  $\lambda_c = 1.50$

### AISC 370

- Three buckling curves
- Curves composed of **three** parts:
  - Yielding
  - Inelastic buckling
  - Elastic buckling

Yield plateau  
 Elastic buckling starts at  $\lambda_c = 1.8$



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## Chapter E – Column buckling curve

### Comparison between AISC 360 and AISC 370

$$F_e = \frac{\pi^2 E}{\left(\frac{L_c}{r}\right)^2} \quad (\text{Euler stress}) \quad \lambda_c = \sqrt{\frac{F_y}{F_e}} \quad (\text{column slenderness})$$

#### AISC 360

When  $\frac{F_y}{F_e} \leq 2.25$  (Inelastic buckling)

$$F_{cr} = \left(0.658 \frac{F_y}{F_e}\right) F_y$$

When  $\frac{F_y}{F_e} > 2.25$  (Elastic buckling)

$$F_{cr} = 0.877 F_e$$



#### AISC 370

When  $\frac{F_y}{F_e} \leq \left(\frac{\beta_0}{\pi}\right)^2$  (Yielding)

$$F_{cr} = F_y$$

When  $\left(\frac{\beta_0}{\pi}\right)^2 < \frac{F_y}{F_e} \leq 3.20$  (Inelastic buckling)

$$F_{cr} = 1.2 \left(\beta_1 \left(\frac{F_y}{F_e}\right)^n\right) F_y$$

When  $\frac{F_y}{F_e} > 3.20$  (Elastic buckling)

$$F_{cr} = \beta_2 F_e$$

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## Chapter E – Column buckling curve

### Comparison between AISC 360 and AISC 370

$$F_e = \frac{\pi^2 E}{\left(\frac{L_c}{r}\right)^2} \quad (\text{Euler stress}) \quad \lambda_c = \sqrt{\frac{F_y}{F_e}} \quad (\text{column slenderness})$$

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When  $\frac{F_y}{F_e} > 3.20$  (Elastic buckling)

$$F_{cr} = \beta_2 F_e$$

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## Chapter E – Column buckling curve

### Comparison between AISC 360 and AISC 370

$$F_e = \frac{\pi^2 E}{\left(\frac{L_c}{r}\right)^2} \quad (\text{Euler stress}) \quad \lambda_c = \sqrt{\frac{F_y}{F_e}} \quad (\text{column slenderness})$$

Member Type	Alloy Family	Curve	$\alpha$	$\beta_0$	$\beta_1$	$\beta_2$
Rolled or built-up I-shaped sections buckling about the minor axis, and other sections not specified in this table	Austenitic and duplex	A	0.56	0.759	0.409	0.690
Rolled or built-up I-shaped sections buckling about the major axis, welded box sections, and round HSS	Austenitic and duplex	B	0.58	0.891	0.455	0.820
Rectangular HSS	Austenitic and duplex	C	0.69	1.195	0.501	0.820



### AISC 370

When  $\frac{F_y}{F_e} \leq \left(\frac{\beta_0}{\pi}\right)^2$  (Yielding)  
 $F_{cr} = F_y$

When  $\left(\frac{\beta_0}{\pi}\right)^2 < \frac{F_y}{F_e} \leq 3.20$  (Inelastic buckling)  
 $F_{cr} = 1.2 \left( \beta_1 \left( \frac{F_y}{F_e} \right)^{\alpha} \right) F_y$

When  $\frac{F_y}{F_e} > 3.20$  (Elastic buckling)  
 $F_{cr} = \beta_2 F_e$

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## Chapter E – Column buckling curve

### Comparison between AISC 360 and AISC 370

$$F_e = \frac{\pi^2 E}{\left(\frac{L_c}{r}\right)^2} \quad (\text{Euler stress}) \quad \lambda_c = \sqrt{\frac{F_y}{F_e}} \quad (\text{column slenderness})$$

Member Type	Alloy Family	Curve	$\alpha$	$\beta_0$	$\beta_1$	$\beta_2$
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### AISC 370

When  $\frac{F_y}{F_e} \leq \left(\frac{\beta_0}{\pi}\right)^2$  (Yielding)  
 $F_{cr} = F_y$

When  $\left(\frac{\beta_0}{\pi}\right)^2 < \frac{F_y}{F_e} \leq 3.20$  (Inelastic buckling)  
 $F_{cr} = 1.2 \left( \beta_1 \left( \frac{F_y}{F_e} \right)^{\alpha} \right) F_y$

When  $\frac{F_y}{F_e} > 3.20$  (Elastic buckling)  
 $F_{cr} = \beta_2 F_e$

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## Chapter E – Members with slender elements

### E7.1 Slender element members excluding round HSS (Effective width method)

#### AISC 360

$$b_e = b \left( 1 - c_1 \sqrt{\frac{F_{el}}{F_{cr}}} \right) \sqrt{\frac{F_{el}}{F_{cr}}} \leq b$$

**TABLE E7.1**  
**Effective Width Imperfection Adjustment Factors,**  
 **$c_1$  and  $c_2$**

Case	Slender Element	$c_1$	$c_2$
(a)	Stiffened elements except walls of square and rectangular HSS	0.18	1.31
(b)	Walls of square and rectangular HSS	0.20	1.38
(c)	All other elements	0.22	1.49



#### AISC 370

$$b_e = 0.772b \left( 1 - 0.10 \sqrt{\frac{F_{el}}{F_{cr}}} \right) \sqrt{\frac{F_{el}}{F_{cr}}} \leq b$$

For all type of elements (i.e. stiffened or unstiffened) and sections (i.e. cold-formed or welded)

For cold-formed HSS → may be used with  $F_{y,avg}$  ( $F_{y,avg} > F_y$  !)

For other sections → use with  $F_y$

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## Chapter E – Members with slender elements

### E7.1 Slender element members excluding round HSS (Effective width method)

#### AISC 360

$$b_e = b \left( 1 - c_1 \sqrt{\frac{F_{el}}{F_{cr}}} \right) \sqrt{\frac{F_{el}}{F_{cr}}} \leq b$$

**TABLE E7.1**  
**Effective Width Imperfection Adjustment Factors,**  
 **$c_1$  and  $c_2$**

Case	Slender Element	$c_1$	$c_2$
(a)	Stiffened elements except walls of square and rectangular HSS	0.18	1.31
(b)	Walls of square and rectangular HSS	0.20	1.38
(c)	All other elements	0.22	1.49



#### AISC 370

$$b_e = 0.772b \left( 1 - 0.10 \sqrt{\frac{F_{el}}{F_{cr}}} \right) \sqrt{\frac{F_{el}}{F_{cr}}} \leq b$$

For all type of elements (i.e. stiffened or unstiffened) and sections (i.e. cold-formed or welded)

Alternatively, only for cold-formed HSS:

$$b_e = b \left( 1 - 0.22 \sqrt{\frac{F_{el}}{F_{cr}}} \right) \sqrt{\frac{F_{el}}{F_{cr}}} \leq b \rightarrow \text{use only with } F_y$$

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## Chapter E – Members with slender elements

### E7.2 Round HSS (Effective area)

**AISC 360**

(a) When  $\frac{D}{t} \leq 0.11 \frac{E}{F_y}$

$$A_e = A_g$$

(b) When  $0.11 \frac{E}{F_y} < \frac{D}{t} < 0.45 \frac{E}{F_y}$

$$A_e = \left[ \frac{0.038E}{F_y (D/t)} + \frac{2}{3} \right] A_g$$

**AISC 370**

(a) When  $\lambda \leq \lambda_r \frac{F_y}{F_{cr}}$        $\lambda_r \frac{F_y}{F_{cr}} = \text{const} \frac{E}{F_y} \cdot \frac{F_y}{F_{cr}} = \text{const} \frac{E}{F_{cr}}$

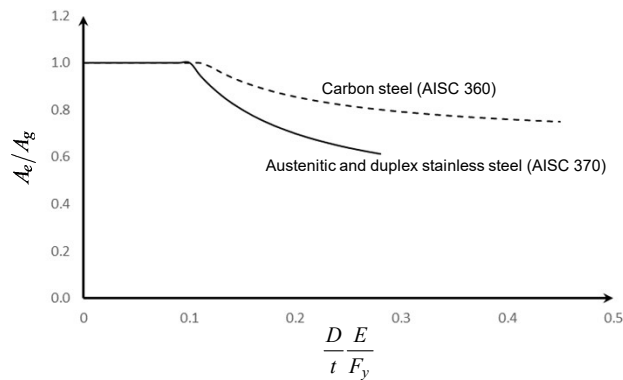
$$A_e = A_g$$

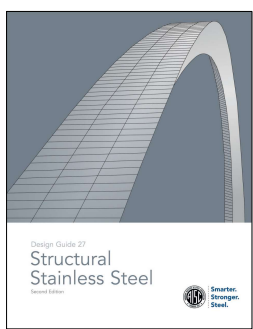
(b) When  $\lambda_r \frac{F_y}{F_{cr}} < \lambda < 2.8 \lambda_r \frac{F_y}{F_{cr}}$

$$A_e = \left( \frac{0.6 \lambda_r \frac{F_y}{F_{cr}}}{\lambda} + \frac{2}{5} \right) A_g$$


## Chapter E – Members with slender elements

### E7.2 Round HSS (Effective area)





Design tables:  
 Compression

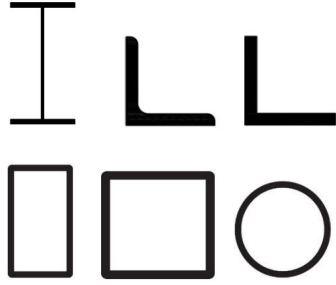


Table 6-3  
 Available Strength in Axial Compression, kips  
 Rectangular HSS

Austenitic Stainless Steel  
 $F_y = 30$  ksi

Shape	HSS16-in.						HSS14-in.					
	0.500		0.312 <sup>1</sup>		0.250 <sup>1</sup>		0.500		0.375		0.356	
Flange, in.	0.475	0.356	0.296	0.238	0.192	0.156	0.475	0.356	0.296	0.238	0.192	0.156
Web, in.	0.475	0.356	0.296	0.238	0.192	0.156	0.475	0.356	0.296	0.238	0.192	0.156
Design	$P_n$	$\phi_c P_n$	$P_n$	$\phi_c P_n$	$P_n$	$\phi_c P_n$	$P_n$	$\phi_c P_n$	$P_n$	$\phi_c P_n$	$P_n$	$\phi_c P_n$
5	383	276	277	416	200	315	151	227	383	276	202	430
6	383	276	277	416	200	315	151	227	383	276	202	430
7	383	276	277	416	200	315	151	227	383	276	202	430
8	383	276	277	416	200	315	151	227	383	276	202	430
9	383	276	277	416	200	315	151	227	383	276	202	430
10	383	276	277	416	200	315	151	227	383	276	202	430
11	374	263	273	411	207	311	149	224	383	276	202	430
12	365	256	265	403	203	305	146	220	383	276	202	430
13	355	248	257	395	199	299	144	216	377	269	199	424
14	345	240	249	388	195	293	141	212	369	263	195	420
15	335	232	241	380	191	288	138	207	361	257	191	416
16	325	224	233	372	187	282	135	203	353	251	187	412
17	315	216	225	364	183	276	132	199	345	245	183	408
18	305	208	217	356	179	270	129	194	337	239	179	404
19	295	200	209	348	175	264	126	190	329	233	175	400
20	285	192	201	340	171	258	123	186	321	227	171	396
21	275	184	193	332	167	252	120	181	314	221	167	392
22	265	176	185	324	163	246	117	177	306	215	163	388
23	255	168	177	316	159	240	114	173	298	209	159	384
24	245	160	169	308	155	234	111	169	290	203	155	380
25	235	152	161	300	151	228	108	165	282	197	151	376
26	225	144	153	292	147	222	105	161	274	191	147	372
27	215	136	145	284	143	216	102	157	266	185	143	368
28	205	128	137	276	139	210	99	153	258	179	139	364
29	195	120	129	268	135	204	96	149	250	173	135	360
30	185	112	121	260	131	198	93	145	242	167	131	356
32	165	92	101	232	112	178	81	127	214	145	112	328
34	174	201	130	203	115	172	80	126	213	144	111	327
36	160	241	125	188	106	159	81	123	206	139	106	320
38	148	222	115	173	97	147	77	118	192	130	102	312
40	136	204	106	160	90	135	72	109	181	122	96	304

i-13 (continued)  
 Available Strength in Axial Compression, kips  
 Equal-Leg Angles (Hot Rolled)

L2 <sup>1</sup> x L2 <sup>1</sup>	L2 <sup>1</sup> x L2 <sup>1</sup>				L2 <sup>1</sup> x L2 <sup>1</sup>				
	$P_n$	$\phi_c P_n$	$P_n$	$\phi_c P_n$	$P_n$	$\phi_c P_n$	$P_n$	$\phi_c P_n$	
6.01	4.13	4.76	3.28						
ASD	LFRD	ASD	LFRD	ASD	LFRD	ASD	LFRD	ASD	LFRD
31.1	40.7	21.4	32.1	24.6	37.0	17.0	25.5		
30.5	40.0	21.1	31.7	22.9	34.5	15.8	23.8		
28.3	36.5	19.7	29.1	17.0	25.0	11.8	17.7		
19.0	28.5	13.1	19.8	12.4	18.7	8.96	12.9		
14.7	22.0	10.1	15.2	8.94	13.4	6.18	9.29		
11.2	16.9	7.75	11.7	6.37	9.57	4.41	6.62		
8.57	12.9	5.91	8.89	4.50	6.78	3.11	4.60		
6.46	9.73	4.47	6.72						
4.96	7.45	3.43	5.15						

Properties

$A_g$ , in. <sup>2</sup>	2.11	1.44	1.73	1.19	1.37	0.944
$r_x$ , in.	0.581	0.481	0.482	0.386	0.387	
ASD	LFRD					
$\phi_c = 1.67$	$\phi_c = 0.90$					

Note 2: Heavy-line indicates  $L_x$ ,  $r_x$ , equal to or greater than 200.

# Chapter F



## Chapter F – Design of Members for Flexure

The chapter is organized as follows:

F1. General Provisions

The design of single angles in flexure is not covered.

F2. Doubly Symmetric Compact I-Shaped Members and Channels Bent about Their Major Axis

F3. Doubly Symmetric I-Shaped Members **and Channels** with Compact Webs and Noncompact or Slender Flanges Bent about Their Major Axis

F4. Doubly Symmetric I-Shaped Members with Noncompact Webs Bent about Their Major Axis

F5. Double Symmetric I-Shaped Members with Slender Webs Bent about Their Major Axis

F6. I-Shaped Members and Channels Bent about Their Minor Axis

F7. Square and Rectangular HSS and Box Sections

Only sections with  $h/b \leq 3$  are covered. No LTB.

F8. Round HSS

F9. Solid rectangular Shapes and Rounds

F10. Other Shapes

Only sections without slender elements.

F11. Proportions of Beams and Girders



Specific design provisions for singly symmetric I-shaped members, tees and double angles are not given. However, they are covered under F10.

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## Chapter F – Design of Members for Flexure

Main differences between AISC 360 and AISC 370

- Lateral-torsional buckling curve
- Flange local buckling curve
- Other minor differences



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## Chapter F – Lateral-torsional buckling curve

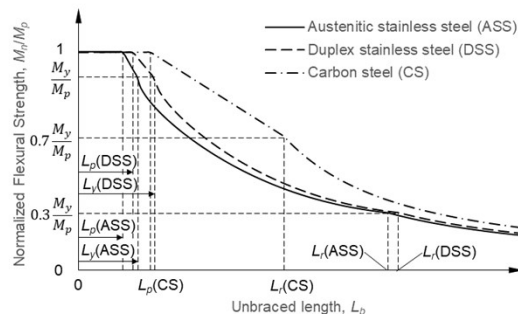
Comparison between AISC 360 and AISC 370

### AISC 360

- One buckling curve  
 Curve composed of **three** parts:
- Yielding
  - Inelastic buckling
  - Elastic buckling

### AISC 370

- Two buckling curves:  
 ■ Austenitic  
 ■ Duplex
- Curves composed of **four** parts:
- Yielding
  - Inelastic buckling ( $M_n > M_y$ )
  - Inelastic buckling ( $M_n < M_y$ )
  - Elastic buckling



## Chapter F – Lateral-torsional buckling (LTB) curve

AISC 360 - LTB for **compact** I-shaped members and channels

When  $L_b \leq L_p$

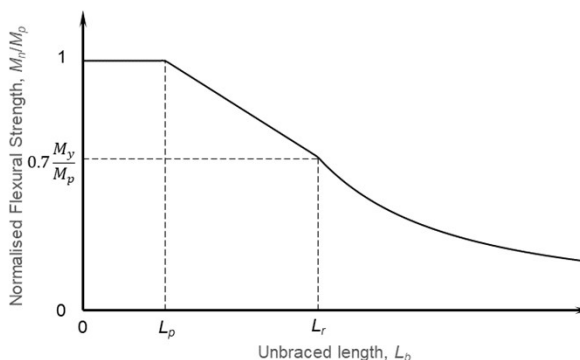
$$M_n = M_p$$

When  $L_p \leq L_b \leq L_r$

$$M_n = C_b \left[ M_p - (M_p - 0.7F_y S_x) \left( \frac{L_b - L_p}{L_r - L_p} \right) \right] \leq M_p$$

When  $L_b > L_r$

$$M_n = F_{cr} S_x \leq M_p$$



## Chapter F – Lateral-torsional buckling (LTB) curve

AISC 360 - LTB for **compact** I-shaped members and channels

When  $L_b \leq L_p$

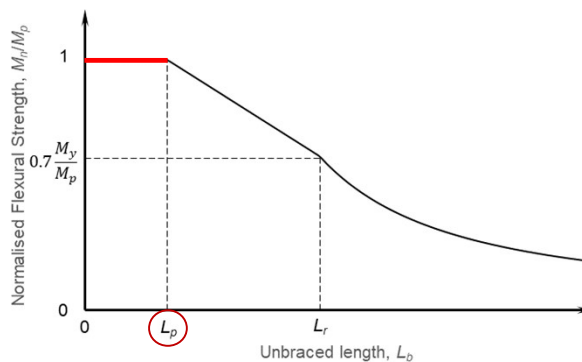
$$M_n = M_p$$

When  $L_p \leq L_b \leq L_r$

$$M_n = C_b \left[ M_p - (M_p - 0.7F_y S_x) \left( \frac{L_b - L_p}{L_r - L_p} \right) \right] \leq M_p$$

When  $L_b > L_r$

$$M_n = F_{cr} S_x \leq M_p$$



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## Chapter F – Lateral-torsional buckling (LTB) curve

AISC 360 - LTB for **compact** I-shaped members and channels

When  $L_b \leq L_p$

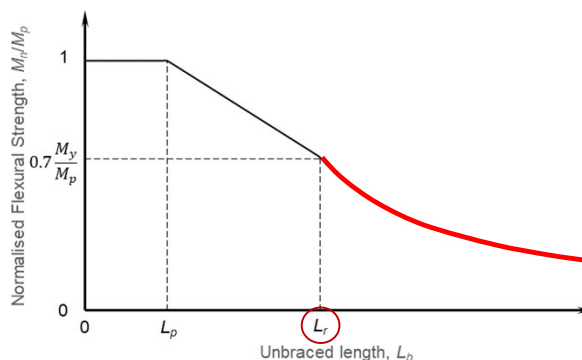
$$M_n = M_p$$

When  $L_p \leq L_b \leq L_r$

$$M_n = C_b \left[ M_p - (M_p - 0.7F_y S_x) \left( \frac{L_b - L_p}{L_r - L_p} \right) \right] \leq M_p$$

When  $L_b > L_r$

$$M_n = F_{cr} S_x \leq M_p$$



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## Chapter F – Lateral-torsional buckling (LTB) curve

### AISC 360 - LTB for **compact** I-shaped members and channels

When  $L_b \leq L_p$

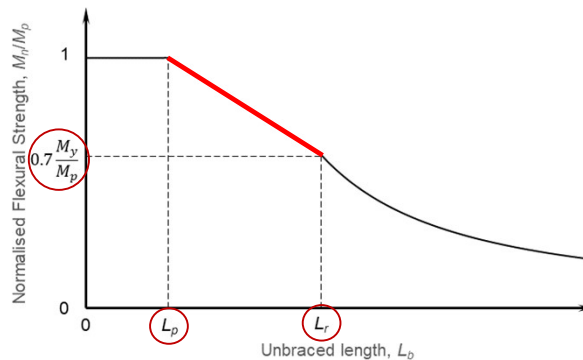
$$M_n = M_p$$

When  $L_p \leq L_b \leq L_r$

$$M_n = C_b \left[ M_p - (M_p - 0.7F_y S_x) \left( \frac{L_b - L_p}{L_r - L_p} \right) \right] \leq M_p$$

When  $L_b > L_r$

$$M_n = F_{cr} S_x \leq M_p$$



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## Chapter F – Lateral-torsional buckling (LTB) curve

### AISC 370 - LTB for **compact** I-shaped members and channels

When  $L_b \leq L_p$

$$M_n = M_p$$

When  $L_p \leq L_b \leq L_y$

$$M_n = C_b \left[ M_p - (M_p - F_y S_x) \left( \frac{L_b - L_p}{L_y - L_p} \right) \right] \leq M_p$$

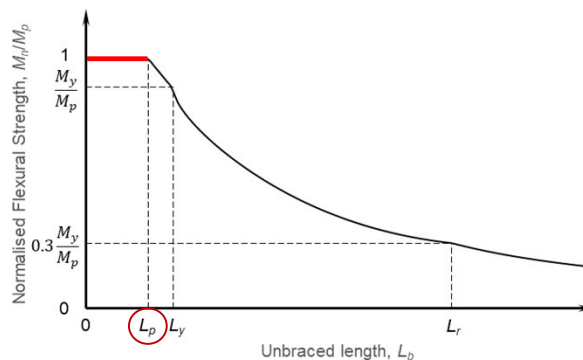
When  $L_y \leq L_b \leq L_r$

$$M_n = C_b \left[ M_y - (M_y - 0.30F_y S_x) \left( \frac{L_b - L_y}{L_r - L_y} \right)^{\alpha_{LT}} \right] \leq M_p$$

$$\alpha_{LT} = 0.60 - 0.40 \left( \frac{L_b - L_y}{L_r - L_y} \right)$$

When  $L_b > L_r$

$$M_n = \beta_{LT} F_{cr} S_x \leq M_p$$



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## Chapter F – Lateral-torsional buckling (LTB) curve

### AISC 370 - LTB for **compact** I-shaped members and channels

When  $L_b \leq L_p$

$$M_n = M_p$$

When  $L_p \leq L_b \leq L_y$

$$M_n = C_b \left[ M_p - (M_p - F_y S_x) \left( \frac{L_b - L_p}{L_y - L_p} \right) \right] \leq M_p$$

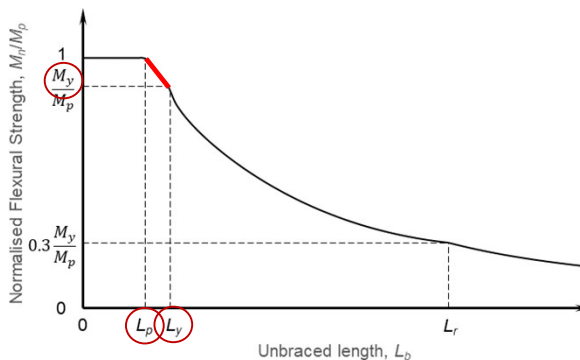
When  $L_y \leq L_b \leq L_r$

$$M_n = C_b \left[ M_y - (M_y - 0.30 F_y S_x) \left( \frac{L_b - L_y}{L_r - L_y} \right)^{\alpha_{LT}} \right] \leq M_p$$

$$\alpha_{LT} = 0.60 - 0.40 \left( \frac{L_b - L_y}{L_r - L_y} \right)$$

When  $L_b > L_r$

$$M_n = \beta_{LT} F_{cr} S_x \leq M_p$$



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## Chapter F – Lateral-torsional buckling (LTB) curve

### AISC 370 - LTB for **compact** I-shaped members and channels

When  $L_b \leq L_p$

$$M_n = M_p$$

When  $L_p \leq L_b \leq L_y$

$$M_n = C_b \left[ M_p - (M_p - F_y S_x) \left( \frac{L_b - L_p}{L_y - L_p} \right) \right] \leq M_p$$

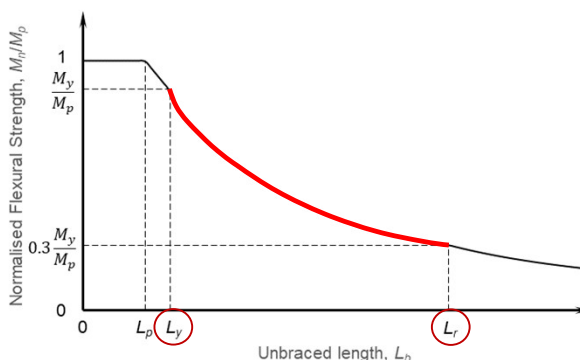
When  $L_y \leq L_b \leq L_r$

$$M_n = C_b \left[ M_y - (M_y - 0.30 F_y S_x) \left( \frac{L_b - L_y}{L_r - L_y} \right)^{\alpha_{LT}} \right] \leq M_p$$

$$\alpha_{LT} = 0.60 - 0.40 \left( \frac{L_b - L_y}{L_r - L_y} \right)$$

When  $L_b > L_r$

$$M_n = \beta_{LT} F_{cr} S_x \leq M_p$$



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## Chapter F – Lateral-torsional buckling (LTB) curve

### AISC 370 - LTB for **compact** I-shaped members and channels

When  $L_b \leq L_p$

$$M_n = M_p$$

When  $L_p \leq L_b \leq L_y$

$$M_n = C_b \left[ M_p - (M_p - F_y S_x) \left( \frac{L_b - L_p}{L_y - L_p} \right) \right] \leq M_p$$

When  $L_y \leq L_b \leq L_r$

$$M_n = C_b \left[ M_y - (M_y - 0.30 F_y S_x) \left( \frac{L_b - L_y}{L_r - L_y} \right)^{\alpha_{LT}} \right] \leq M_p$$

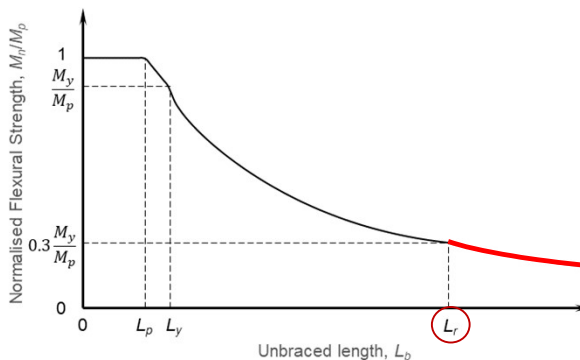
$$\alpha_{LT} = 0.60 - 0.40 \left( \frac{L_b - L_y}{L_r - L_y} \right)$$

When  $L_b > L_r$

$$M_n = \beta_{LT} F_{cr} S_x \leq M_p$$



Alloy Family	$\beta_{LT}$
Austenitic	0.82
Duplex	0.86



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## Chapter F – Lateral-torsional buckling (LTB) curve

### LTB for I-shaped members and channels with **noncompact web**

#### AISC 360

When  $I_{yc}/I_y > 0.23$

When  $\frac{h_c}{t_w} \leq \lambda_{pw}$

$$R_{pc} = \frac{M_p}{M_{yc}}$$

When  $\frac{h_c}{t_w} > \lambda_{pw}$

$$R_{pc} = \left[ \frac{M_p}{M_{yc}} - \left( \frac{M_p}{M_{yc}} - 1 \right) \left( \frac{\lambda - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}} \right) \right] \leq \frac{M_p}{M_{yc}}$$

When  $I_{yc}/I_y \leq 0.23$

$$R_{pc} = 1.0$$



#### AISC 370

When  $I_{yc}/I_y > 0.23$

$$R_p = \left[ \frac{M_p}{M_y} - \left( \frac{M_p}{M_y} - 1 \right) \left( \frac{\lambda - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}} \right) \right] \leq \frac{M_p}{M_y}$$

When  $I_{yc}/I_y \leq 0.23$

$$R_p = 1.0$$

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## Chapter F – Lateral-torsional buckling (LTB) curve

LTB for I-shaped members and channels with **noncompact web**

### AISC 360

When  $I_y/I_x > 0.23$

When  $\frac{h_c}{t_w} \leq \lambda_{pw}$

$$R_{pc} = \frac{M_p}{M_{yc}}$$

When  $\frac{h_c}{t_w} > \lambda_{pw}$

$$R_{pc} = \left[ \frac{M_p}{M_{yc}} - \left( \frac{M_p}{M_{yc}} - 1 \right) \left( \frac{\lambda - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}} \right) \right] \leq \frac{M_p}{M_{yc}}$$

When  $I_y/I_x \leq 0.23$

$$R_{pc} = 1.0$$



### AISC 370

When  $I_y/I_x > 0.23$

$$R_p = \left[ \frac{M_p}{M_y} - \left( \frac{M_p}{M_y} - 1 \right) \left( \frac{\lambda - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}} \right) \right] \leq \frac{M_p}{M_y}$$

When  $I_y/I_x \leq 0.23$

$$R_p = 1.0$$

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## Chapter F – Lateral-torsional buckling (LTB) curve

AISC 360 - LTB for I-shaped members with **noncompact web**

When  $L_b \leq L_p$

$$M_n = R_{pc} M_{yc}$$

When  $L_p \leq L_b \leq L_r$

$$M_n = C_b \left[ R_{pc} M_{yc} - (R_{pc} M_{yc} - 0.7 F_y S_{xc}) \left( \frac{L_b - L_p}{L_r - L_p} \right) \right] \leq R_{pc} M_{yc}$$

When  $L_b > L_r$

$$M_n = F_{cr} S_{xc} \leq R_{pc} M_{yc}$$



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## Chapter F – Lateral-torsional buckling (LTB) curve

### AISC 360 - LTB for I-shaped members with **noncompact web**

When  $L_b \leq L_p$

$$M_n = R_{pc} M_{yc}$$

When  $L_p \leq L_b \leq L_r$

$$M_n = C_b \left[ R_{pc} M_{yc} - (R_{pc} M_{yc} - 0.7 F_y S_{xc}) \left( \frac{L_b - L_p}{L_r - L_p} \right) \right] \leq R_{pc} M_{yc}$$

When  $L_b > L_r$

$$M_n = F_{cr} S_{xc} \leq R_{pc} M_{yc}$$



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## Chapter F – Lateral-torsional buckling (LTB) curve

### AISC 360 - LTB for I-shaped members with **noncompact web**

When  $L_b \leq L_p$

$$M_n = R_{pc} M_{yc}$$

When  $L_p \leq L_b \leq L_r$

$$M_n = C_b \left[ R_{pc} M_{yc} - (R_{pc} M_{yc} - 0.7 F_y S_{xc}) \left( \frac{L_b - L_p}{L_r - L_p} \right) \right] \leq R_{pc} M_{yc}$$

When  $L_b > L_r$

$$M_n = F_{cr} S_{xc} \leq R_{pc} M_{yc}$$

Limiting unbraced length $L_p$	
Compact web	Noncompact web
$L_p = 1.76 r_y \sqrt{\frac{E}{F_y}}$	$L_p = 1.1 r_t \sqrt{\frac{E}{F_y}}$



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## Chapter F – Lateral-torsional buckling (LTB) curve

### AISC 360 - LTB for I-shaped members with **noncompact web**

When  $L_b \leq L_p$

$$M_n = R_{pc} M_{yc}$$

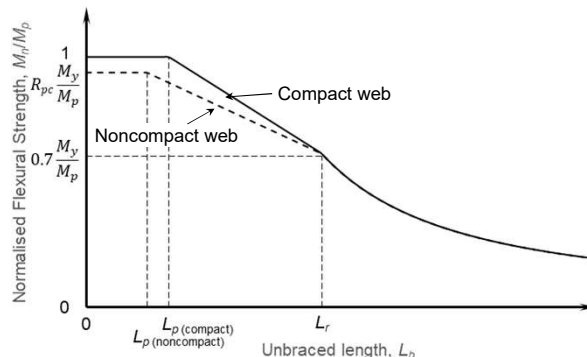
When  $L_p \leq L_b \leq L_r$

$$M_n = C_b \left[ R_{pc} M_{yc} - (R_{pc} M_{yc} - 0.7 F_y S_{xc}) \left( \frac{L_b - L_p}{L_r - L_p} \right) \right] \leq R_{pc} M_{yc}$$

When  $L_b > L_r$

$$M_n = F_{cr} S_{xc} \leq R_{pc} M_{yc}$$

Limiting unbraced length $L_p$	
Compact web	Noncompact web
$L_p = 1.76 r_y \sqrt{\frac{E}{F_y}}$	$L_p = 1.1 r_t \sqrt{\frac{E}{F_y}}$



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## Chapter F – Lateral-torsional buckling (LTB) curve

### AISC 370 - LTB for I-shaped members and channels with **noncompact web**

When  $L_b \leq L_p$

$$M_n = R_p M_y$$

When  $L_p \leq L_b \leq L_y$

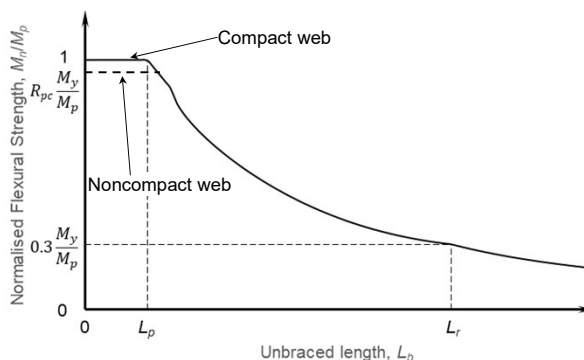
$$M_n = C_b \left[ M_p - (M_p - F_y S_x) \left( \frac{L_b - L_p}{L_y - L_p} \right) \right] \leq R_p M_y$$

When  $L_y \leq L_b \leq L_r$

$$M_n = C_b \left[ M_y - (M_y - 0.30 F_y S_x) \left( \frac{L_b - L_y}{L_r - L_y} \right)^{\alpha_{LT}} \right] \leq R_p M_y$$

When  $L_b > L_r$

$$M_n = \beta_{LT} F_{cr} S_x \leq R_p M_y$$



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## Chapter F – Lateral-torsional buckling (LTB) curve

AISC 370 - LTB for I-shaped members and channels with **noncompact web**

**AISC 370**

When  $L_b \leq L_p$   
 $M_n = R_p M_y$

When  $L_p \leq L_b \leq L_y$

$$M_n = C_b \left[ M_p - (M_p - F_y S_x) \left( \frac{L_b - L_p}{L_y - L_p} \right) \right] \leq R_p M_y$$

When  $L_y \leq L_b \leq L_r$

$$M_n = C_b \left[ M_y - (M_y - 0.30 F_y S_x) \left( \frac{L_b - L_y}{L_r - L_y} \right)^{\alpha_{LT}} \right] \leq R_p M_y$$

When  $L_b > L_r$   
 $M_n = \beta_{LT} F_{cr} S_x \leq R_p M_y$

**AISC 360**

When  $L_b \leq L_p$   
 $M_n = R_{pc} M_{yc}$

When  $L_p \leq L_b \leq L_r$

$$M_n = C_b \left[ R_{pc} M_y - (R_{pc} M_{yc} - 0.7 F_y S_{xc}) \left( \frac{L_b - L_p}{L_r - L_p} \right) \right] \leq R_{pc} M_{yc}$$

When  $L_b > L_r$   
 $M_n = F_{cr} S_{xc} \leq R_{pc} M_{yc}$



## Chapter F – Lateral-torsional buckling (LTB) curve

LTB for I-shaped members with **slender web**

**AISC 360**

$$R_{pg} = 1 - \frac{a_w}{1,200 + 300a_w} \left( \frac{h_c}{t_w} - 5.7 \sqrt{\frac{E}{F_y}} \right) \leq 1.0$$

**AISC 370**

$$R_{pg} = 1 - \frac{a_w}{6.75 + 2.12a_w} \left( \frac{\lambda}{\lambda_{rw}} - 1.0 \right) \leq 1.0$$

(the same for austenitic and duplex stainless steel)



## Chapter F – Lateral-torsional buckling (LTB) curve

LTB for I-shaped members with **slender web**

### AISC 360

$$R_{pg} = 1 - \frac{a_w}{1,200 + 300a_w} \left( \frac{h_c}{t_w} - 5.7 \sqrt{\frac{E}{F_y}} \right) \leq 1.0$$

### AISC 370

$$R_{pg} = 1 - \frac{a_w}{6.75 + 2.12a_w} \left( \frac{\lambda}{\lambda_{rw}} - 1.0 \right) \leq 1.0$$

(the same for austenitic and duplex stainless steel)



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## Chapter F – Lateral-torsional buckling (LTB) curve

LTB for I-shaped members with **slender web**

### AISC 360

When  $L_b \leq L_p$

$$M_n = R_{pg} M_{yc}$$

When  $L_p \leq L_b \leq L_r$

$$M_n = C_b R_{pg} \left[ M_{yc} - (0.3 F_y S_{xc}) \left( \frac{L_b - L_p}{L_r - L_p} \right) \right] \leq R_{pg} M_{yc}$$

When  $L_b > L_r$

$$M_n = R_{pg} F_{cr} S_{xc} \leq R_{pg} M_{yc}$$

### AISC 370

When  $L_b \leq L_y$

$$M_n = R_{pg} M_y$$

When  $L_p \leq L_b \leq L_r$

$$M_n = C_b R_{pg} \left[ M_y - (M_y - 0.3 F_y S_x) \left( \frac{L_b - L_y}{L_r - L_y} \right)^{\alpha_{LT}} \right] \leq R_{pg} M_y$$

When  $L_b > L_r$

$$M_n = \beta_{LT} R_{pg} F_{cr} S_x \leq R_{pg} M_y$$



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## Chapter F – Flange local buckling curve

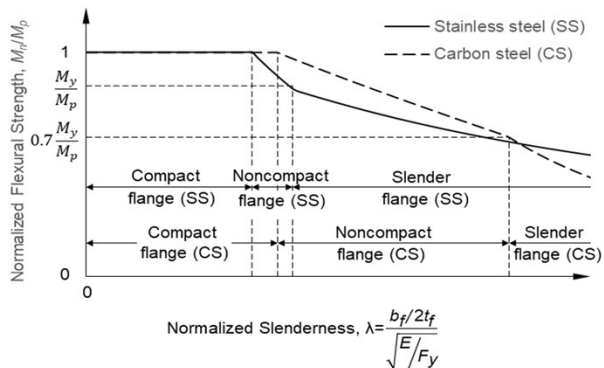
Noncompact flanges:

AISC 370 follows the same principle as AISC 360

Slender flanges:

AISC 370 → Effective width method (accounts for post buckling strength)

AISC 360 → Elastic local buckling (no post buckling strength)



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## Chapter F – Flange local buckling curve

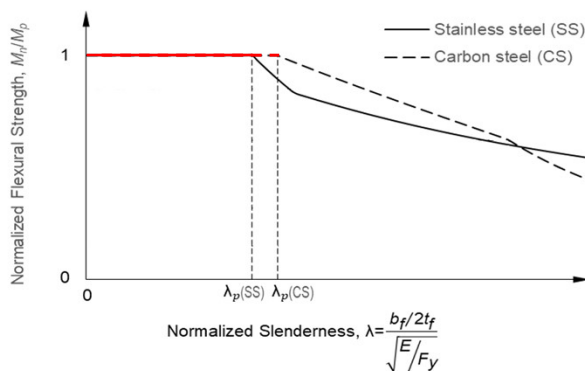
Noncompact flanges:

AISC 370 follows the same principle as AISC 360

Slender flanges:

AISC 370 → Effective width method (accounts for post buckling strength)

AISC 360 → Elastic local buckling (no post buckling strength)



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## Chapter F – Flange local buckling curve

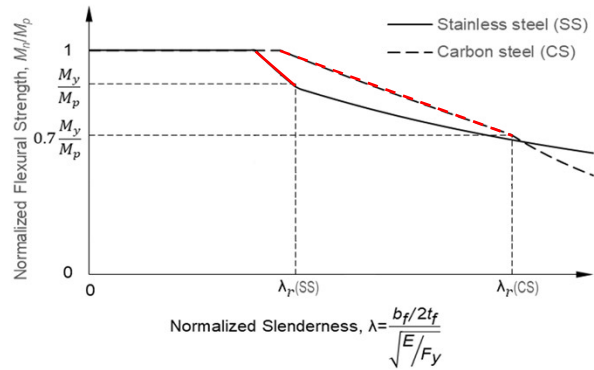
Noncompact flanges:

AISC 370 follows the same principle as AISC 360

Slender flanges:

AISC 370 → Effective width method (accounts for post buckling strength)

AISC 360 → Elastic local buckling (no post buckling strength)



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## Chapter F – Flange local buckling curve

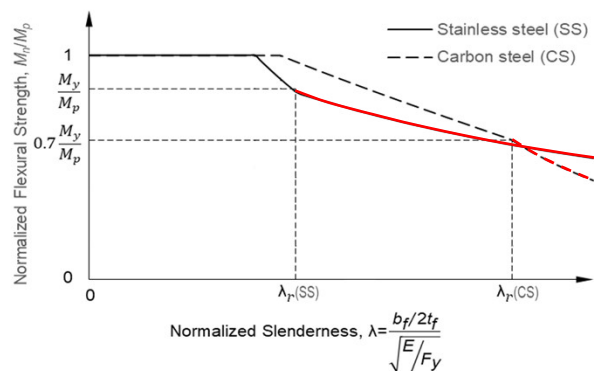
Noncompact flanges:

AISC 370 follows the same principle as AISC 360

Slender flanges:

AISC 370 → Effective width method (accounts for post buckling strength)

AISC 360 → Elastic local buckling (no post buckling strength)



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# Chapter F – Flange local buckling curve

AISC 370 - Flange local buckling for sections with **slender flanges**

Effective width method

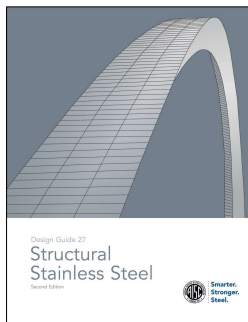
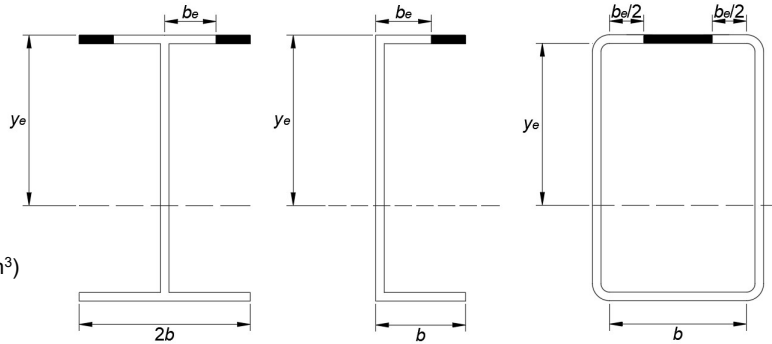
$$b_e = 0.772b \left( 1 - 0.10 \sqrt{\frac{F_{el}}{F_{cr}}} \right) \sqrt{\frac{F_{el}}{F_{cr}}} \leq b$$

$$M_n = F_y S_{xe}$$

where:

$S_{xe}$  = effective section modulus, in.<sup>3</sup> (mm<sup>3</sup>)

$$= \frac{I_{xe}}{y_e}$$



Design tables:  
Flexural members

Duplex Stainless Steel  
 $F_y = 65 \text{ ksi}$

Table 7-2 (continued)  
W-Shapes (Welded)  
Selection by  $Z_x$

$Z_x$

Shape	$Z_x$ in. <sup>3</sup>	$M_x, \phi_b M_n$		$\phi_b P_n$		$\phi_b V_n$		$\phi_b M_{n2}$		$L_p$	$L_r$	$V_p$	$\phi_b V_n$
		kip-ft	kgm	kip-ft	kgm	kip-ft	kgm	kip-ft	kgm				
W12 x 22	27.9	78.2	118	14.6	22.0	22.6	33.3	90.4	136	2.64	2.87	12.0	67.8
W8 x 20 <sup>HL</sup>	26.0	75.6	114	4.10	6.34	15.5	22.5	62.8	134	3.59	3.96	29.0	65.2
W30 x 22 <sup>HL</sup>	26.5	73.5	110	7.20	10.8	17.9	26.0	75.6	114	3.01	3.27	18.2	62.4
W12 x 18	23.5	67.2	101	13.2	19.8	20.6	30.0	77.5	117	2.01	2.78	11.3	54.9
W8 x 16 <sup>HL</sup>	23.2	67.8	102	3.34	5.77	13.9	20.9	71.0	107	3.59	3.40	27.0	56.0
W10 x 19	21.6	61.2	92.0	9.58	14.4	16.8	25.2	70.2	105	2.08	3.02	13.4	62.8
W8 x 21	20.5	59.2	89.0	4.83	7.26	13.5	20.3	66.4	99.9	2.84	4.38	20.9	57.1
W12 x 16 <sup>HL</sup>	19.0	52.3	78.6	13.3	19.9	16.2	24.4	56.0	84.2	1.90	2.61	10.3	54.0
W6 x 25	18.6	53.4	80.2	2.59	3.90	9.90	14.7	60.2	90.5	3.38	6.03	34.4	55.9
W30 x 17	17.9	50.0	75.2	6.72	10.0	14.6	21.6	56.0	87.2	2.00	3.81	11.9	61.0
W12 x 14 <sup>HL</sup>	17.4	47.5	71.4	15.3	22.9	25.5	46.4	68.8	106	2.53	3.91	53.6	60.6
W8 x 18 <sup>HL</sup>	16.4	47.2	70.9	4.76	7.15	11.5	17.3	48.1	72.3	2.76	4.02	18.0	50.0
W10 x 15 <sup>HL</sup>	16.4	42.4	63.7	8.72	14.6	12.8	19.0	45.3	68.1	1.94	2.70	11.1	61.2
W6 x 20 <sup>HL</sup>	15.0	43.7	65.6	2.34	3.52	8.92	13.0	48.5	68.4	3.33	5.47	29.1	43.4
W8 x 15	13.3	37.6	60.6	6.86	10.2	15.4	43.2	64.9	2.07	3.02	13.6	50.0	
W10 x 12 <sup>HL</sup>	12.4	34.9	52.4	7.70	11.6	10.7	16.1	34.0	51.1	1.96	2.68	10.6	35.7
W6 x 16	11.6	33.0	49.5	2.97	4.46	7.48	11.2	37.5	56.4	2.20	3.73	20.5	44.0
W8 x 13 <sup>HL</sup>	11.2	31.4	47.2	6.79	8.71	8.90	13.4	33.4	50.2	2.00	2.87	12.0	36.0
W5 x 16	11.1	31.6	47.6	1.65	2.49	5.93	8.91	36.0	54.1	2.82	5.43	32.4	40.4
W8 x 10 <sup>HL</sup>	10.3	30.0	45.1	2.06	3.12	6.71	10.1	24.1	39.3	3.23	4.79	22.3	36.9
W5 x 18 <sup>HL</sup>	9.32	26.8	40.3	1.57	2.37	5.33	8.02	29.9	44.9	2.78	4.94	28.2	36.1
W8 x 10 <sup>HL</sup>	9.13	26.0	39.1	4.53	6.80	7.80	11.6	25.4	38.2	2.01	2.80	11.4	32.7
W6 x 12 <sup>HL</sup>	8.09	23.2	34.8	2.77	4.17	5.94	8.62	25.9	38.9	2.12	3.23	15.8	37.2
W6 x 9 <sup>HL</sup>	6.25	18.0	27.1	2.41	3.63	4.97	7.47	17.6	26.4	2.07	3.00	13.3	28.6
W4 x 13	6.25	17.6	26.5	1.10	1.66	3.47	5.21	20.3	20.5	2.27	4.06	28.8	32.6

Table 7-19  
Available Flexural  
Strength, kip-ft  
Round HSS

Austenitic  
Stainless Steel  
 $F_y = 30 \text{ ksi}$

Shape	$M_x, \phi_b M_n$ kip-ft	$\phi_b P_n$ kip-ft	$\phi_b V_n$ kip-ft
HSS12x12	2.50	2.98	4.47
	0.180	2.24	3.36
	0.120	1.56	2.33
	0.109	1.42	2.14
	0.0850	1.10	1.65
	0.0630	0.843	1.27
HSS10x10	2.50	2.72	4.10
	0.180	2.05	3.08
	0.148	1.73	2.60
	0.120	1.42	2.14
	0.109	1.31	1.96
	0.0850	1.01	1.52
	0.0630	0.773	1.17
	0.0490	0.609	0.915
HSS8x8	0.180	1.67	2.62
	0.120	1.30	1.96
	0.109	1.20	1.80
	0.0850	0.924	1.39
HSS6x6	0.250	2.25	3.39
	0.180	1.71	2.56
	0.148	1.44	2.18
	0.120	1.19	1.79
	0.109	1.09	1.64
	0.0850	0.843	1.27
	0.0630	0.609	1.01
HSS4x4	0.250	1.83	2.75
	0.180	1.39	2.09
	0.148	1.18	1.77
	0.120	0.972	1.46
	0.109	0.894	1.34
	0.0850	0.653	1.04
	0.0630	0.504	0.803
	0.0490	0.420	0.631



ASD	LRFD
$\phi_x = 1.67$	$\phi_x = 0.90$
$\phi_y = 1.67$	$\phi_y = 0.90$



# Chapter G



## Chapter G – Design of Members for Shear and Torsion

The chapter is organized as follows:

- G1. General Provisions
- G2. I-Shaped Members and Channels Subject to Major-Axis Shear
- G3. Rectangular HSS and Box Sections Subject to Shear
- G4. Round HSS Subject to Shear
- G5. Doubly Symmetric I-Shaped Members and Channels Subject to Minor-Axis Shear
- G6. Other Singly or Doubly Symmetric Shapes Subject to Shear
- G7. Beams and Girders with Web Openings Subject to Shear
- G8. **Round and Rectangular HSS, and Box Sections Subject to Torsion**
- G9. **Doubly Symmetric I-Shaped Members and Channels Subject to Torsion**

The design of single angles in shear is not covered.

Angles, tees, and singly symmetric I-shaped members subject to torsion are also not included.



## Chapter G – Design of Members for Shear and Torsion

Main differences between AISC 360 and AISC 370

- Shear buckling coefficients  $C_{v1}$  and  $C_{v2}$
- Shear strength of Round HSS
- Torsional strength of Round HSS
- Torsional strength of Rectangular HSS
- Other minor differences



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## Chapter G – Shear buckling coefficients

G2. I-Shaped Members and Channels Subject to Major-Axis Shear

TFA →  $C_{v2}$   
No TFA: →  $C_{v1}$

G3. Rectangular HSS and Box Sections Subject to Shear

G5. Doubly Symmetric I-Shaped Members and Channels Subject to Minor-Axis Shear

No TFA, but  $C_{v2}$

G6. Other Singly or Doubly Symmetric Shapes Subject to Shear



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## Chapter G – Shear buckling coefficients

### G2. I-Shaped Members and Channels Subject to Major-Axis Shear

#### 1. Shear Strength of Webs without Tension Field Action

$$V_n = 0.6F_y A_w C_{v1}$$

#### AISC 360

When  $h/t_w \leq 1.10\sqrt{k_v E / F_y}$

$$C_{v1} = 1.0$$

When  $h/t_w > 1.10\sqrt{k_v E / F_y}$

$$C_{v1} = \frac{1.10\sqrt{k_v E / F_y}}{h / t_w}$$

#### AISC 370

When  $\lambda \leq 0.59\sqrt{k_v E / F_y}$

$$C_{v1} = 1.2$$

When  $\lambda > 0.59\sqrt{k_v E / F_y}$

$$C_{v1} = \frac{1.55\sqrt{k_v E / F_y}}{0.7\sqrt{k_v E / F_y} + \lambda}$$



## Chapter G – Shear buckling coefficients

### G2. I-Shaped Members and Channels Subject to Major-Axis Shear

#### 1. Shear Strength of Webs without Tension Field Action

$$V_n = 0.6F_y A_w C_{v1}$$

#### AISC 360

When  $h/t_w \leq 1.10\sqrt{k_v E / F_y}$

$$C_{v1} = 1.0$$

When  $h/t_w > 1.10\sqrt{k_v E / F_y}$

$$C_{v1} = \frac{1.10\sqrt{k_v E / F_y}}{h / t_w}$$

#### AISC 370

When  $\lambda \leq 0.59\sqrt{k_v E / F_y}$

$$C_{v1} = 1.2$$

When  $\lambda > 0.59\sqrt{k_v E / F_y}$

$$C_{v1} = \frac{1.55\sqrt{k_v E / F_y}}{0.7\sqrt{k_v E / F_y} + \lambda}$$



## Chapter G – Shear buckling coefficients

### G2. I-Shaped Members and Channels Subject to Major-Axis Shear

#### 1. Shear Strength of Webs without Tension Field Action

$$V_n = 0.6F_y A_w C_{v1}$$

#### AISC 360

When  $h/t_w \leq 1.10\sqrt{k_v E / F_y}$

$$C_{v1} = 1.0$$

When  $h/t_w > 1.10\sqrt{k_v E / F_y}$

$$C_{v1} = \frac{1.10\sqrt{k_v E / F_y}}{h/t_w}$$

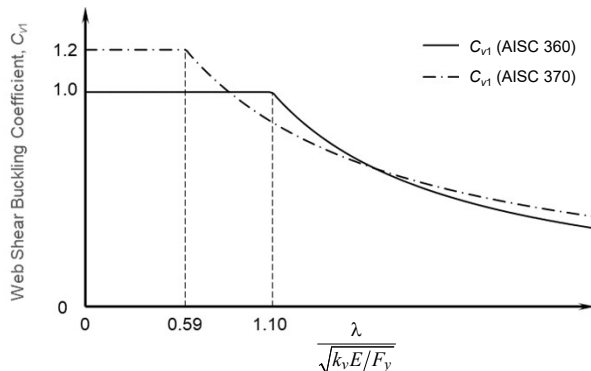
#### AISC 370

When  $\lambda \leq 0.59\sqrt{k_v E / F_y}$

$$C_{v1} = 1.2$$

When  $\lambda > 0.59\sqrt{k_v E / F_y}$

$$C_{v1} = \frac{1.55\sqrt{k_v E / F_y}}{0.7\sqrt{k_v E / F_y} + \lambda}$$



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## Chapter G – Shear buckling coefficients

### Definition of $C_{v2}$ in AISC 360 and AISC 370

#### AISC 360

When  $h/t_w \leq 1.10\sqrt{k_v E / F_y}$

$$C_{v2} = 1.0$$

When  $1.10\sqrt{k_v E / F_y} < h/t_w \leq 1.37\sqrt{k_v E / F_y}$

$$C_{v2} = \frac{1.10\sqrt{k_v E / F_y}}{h/t_w}$$

When  $h/t_w > 1.37\sqrt{k_v E / F_y}$

$$C_{v2} = \frac{1.51k_v E}{(h/t_w)^2 F_y}$$

#### AISC 370

When  $\lambda \leq 0.33\sqrt{k_v E / F_y}$

$$C_{v2} = 1.2$$

When  $0.33\sqrt{k_v E / F_y} < \lambda \leq 0.97\sqrt{k_v E / F_y}$

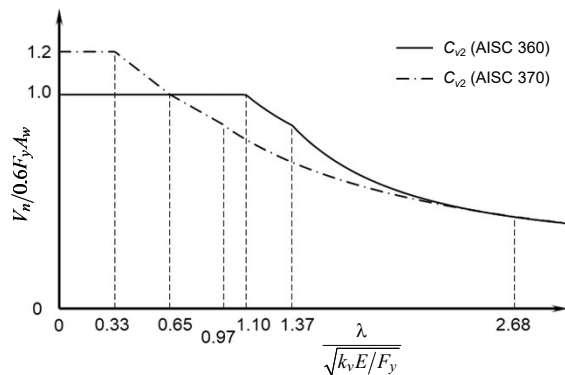
$$C_{v2} = 1.2 - 0.62 \left( \frac{\lambda}{\sqrt{k_v E / F_y}} - 0.33 \right)$$

When  $0.97\sqrt{k_v E / F_y} < \lambda \leq 2.68\sqrt{k_v E / F_y}$

$$C_{v2} = \frac{5.02\sqrt{k_v E / F_y} - \lambda}{1.62\sqrt{k_v E / F_y} + 3.55\lambda}$$

When  $\lambda > 2.68\sqrt{k_v E / F_y}$

$$C_{v2} = \frac{1.51k_v E}{\lambda^2 F_y}$$

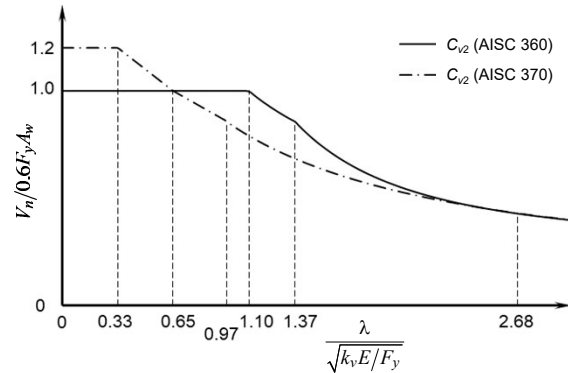


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## Chapter G – Shear buckling coefficients

Definition of  $C_{v2}$  in AISC 360 and AISC 370

AISC 360	AISC 370
When $h/t_w \leq 1.10\sqrt{k_v E/F_y}$ $C_{v2} = 1.0$	When $\lambda \leq 0.33\sqrt{k_v E/F_y}$ $C_{v2} = 1.2$
When $1.10\sqrt{k_v E/F_y} < h/t_w \leq 1.37\sqrt{k_v E/F_y}$ $C_{v2} = \frac{1.10\sqrt{k_v E/F_y}}{h/t_w}$	When $0.33\sqrt{k_v E/F_y} < \lambda \leq 0.97\sqrt{k_v E/F_y}$ $C_{v2} = 1.2 - 0.62 \left( \frac{\lambda}{\sqrt{k_v E/F_y}} - 0.33 \right)$
When $h/t_w > 1.37\sqrt{k_v E/F_y}$ $C_{v2} = \frac{1.51k_v E}{(h/t_w)^2 F_y}$	When $0.97\sqrt{k_v E/F_y} < \lambda \leq 2.68\sqrt{k_v E/F_y}$ $C_{v2} = \frac{5.02\sqrt{k_v E/F_y} - \lambda}{1.62\sqrt{k_v E/F_y} + 3.55\lambda}$
	When $\lambda > 2.68\sqrt{k_v E/F_y}$ $C_{v2} = \frac{1.51k_v E}{\lambda^2 F_y}$

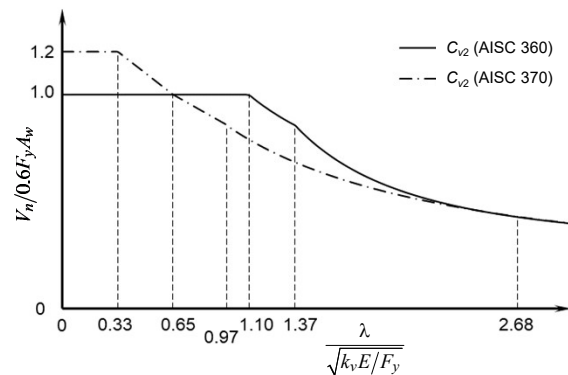


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## Chapter G – Shear buckling coefficients

Definition of  $C_{v2}$  in AISC 360 and AISC 370

AISC 360	AISC 370
When $h/t_w \leq 1.10\sqrt{k_v E/F_y}$ $C_{v2} = 1.0$	When $\lambda \leq 0.33\sqrt{k_v E/F_y}$ $C_{v2} = 1.2$
When $1.10\sqrt{k_v E/F_y} < h/t_w \leq 1.37\sqrt{k_v E/F_y}$ $C_{v2} = \frac{1.10\sqrt{k_v E/F_y}}{h/t_w}$	When $0.33\sqrt{k_v E/F_y} < \lambda \leq 0.97\sqrt{k_v E/F_y}$ $C_{v2} = 1.2 - 0.62 \left( \frac{\lambda}{\sqrt{k_v E/F_y}} - 0.33 \right)$
When $h/t_w > 1.37\sqrt{k_v E/F_y}$ $C_{v2} = \frac{1.51k_v E}{(h/t_w)^2 F_y}$	When $0.97\sqrt{k_v E/F_y} < \lambda \leq 2.68\sqrt{k_v E/F_y}$ $C_{v2} = \frac{5.02\sqrt{k_v E/F_y} - \lambda}{1.62\sqrt{k_v E/F_y} + 3.55\lambda}$
	When $\lambda > 2.68\sqrt{k_v E/F_y}$ $C_{v2} = \frac{1.51k_v E}{\lambda^2 F_y}$



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## Chapter G – Shear strength of Round HSS

### AISC 360 - Round HSS Subject to Shear

$$V_n = F_{cr} A_g / 2$$

where  $F_{cr}$  shall be the larger of:

$$F_{cr} = \frac{1.60E}{\sqrt{\frac{L_v}{D} \left(\frac{D}{t}\right)^{5/4}}} \quad \text{(For round HSS with intermediate length)}$$

$$F_{cr} = \frac{0.78E}{\left(\frac{D}{t}\right)^{3/2}} \quad \text{(For round HSS with long length)}$$

but  $F_{cr} \leq 0.6F_y$



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## Chapter G – Shear strength of Round HSS

### AISC 360 - Round HSS Subject to Shear

$$V_n = 0.6C_v F_y A_g / 2$$

where  $C_v$  shall be the larger of:

$$C_v = \frac{2.67E}{\sqrt{L_v/D} \lambda^{1.25} F_y} \quad \text{(For round HSS with intermediate length)}$$

$$C_v = \frac{1.30E}{\lambda^{1.5} F_y} \quad \text{(For round HSS with long length)}$$

but  $C_v \leq 1.0$

$$\lambda = \frac{D}{t}$$



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## Chapter G – Shear strength of Round HSS

### AISC 370 - Round HSS Subject to Shear

$$V_n = 0.6C_vF_y A_g / 2$$

where

When  $\frac{L_v}{D} \leq 4.21\sqrt{\lambda}$  (**Intermediate length**)

$$C_v = C_{vM}$$

When  $\frac{L_v}{D} > 4.21\sqrt{\lambda}$  (**Long length**)

$$C_v = C_{vL}$$



**Intermediate length  $C_{vM}$**

When  $\lambda \leq 0.32 \left( \frac{E/F_y}{\sqrt{L_v/D}} \right)^{0.80}$   
 $C_{vM} = 1.0$

When  $0.32 \left( \frac{E/F_y}{\sqrt{L_v/D}} \right)^{0.80} < \lambda \leq 4.65 \left( \frac{E/F_y}{\sqrt{L_v/D}} \right)^{0.80}$   
 $C_{vM} = 1 - 0.61 \left( 0.47 \sqrt{\frac{\sqrt{L_v/D} \lambda^{1.25}}{E/F_y}} - 0.23 \right)$

When  $\lambda > 4.65 \left( \frac{E/F_y}{\sqrt{L_v/D}} \right)^{0.80}$   
 $C_{vM} = \frac{2.67E}{\sqrt{L_v/D} \lambda^{1.25} F_y}$

**Long length  $C_{vL}$**

When  $\lambda \leq 0.24(E/F_y)^{0.67}$   
 $C_{vL} = 1.0$

When  $0.24(E/F_y)^{0.67} < \lambda \leq 2.23(E/F_y)^{0.67}$   
 $C_{vL} = 1 - 0.61 \left( 0.68 \sqrt{\frac{\lambda^{1.50}}{E/F_y}} - 0.23 \right)$

When  $\lambda > 2.23(E/F_y)^{0.67}$   
 $C_{vL} = \frac{1.30E}{\lambda^{1.50} F_y}$

## Chapter G – Shear strength of Round HSS

### Comparison between AISC 360 and AISC 370

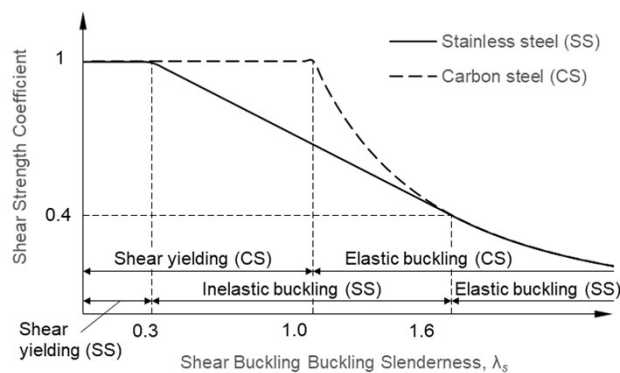
$$\lambda_s = \sqrt{\frac{0.6F_y}{F_{cr}}}$$

where

$$F_{cr} = \frac{1.60E}{\sqrt{\frac{L_v}{D} \left( \frac{D}{t} \right)^{3/4}}}$$

Or

$$F_{cr} = \frac{0.78E}{\left( \frac{D}{t} \right)^{3/2}}$$



## Chapter G – Torsional strength of Round HSS

### AISC 370 - Round HSS Subject to Torsion

$$V_n = 0.6CC_vF_y$$

where

When  $\frac{L}{D} \leq 4.21\sqrt{\lambda}$  (**Intermediate length**)

$$C_v = C_{vM}$$

When  $\frac{L}{D} > 4.21\sqrt{\lambda}$  (**Long length**)

$$C_v = C_{vL}$$

#### Intermediate length $C_{vM}$

When  $\lambda \leq 0.26 \left( \frac{E/F_y}{\sqrt{L/D}} \right)^{0.80}$

$$C_{vM} = 1.0$$

When  $0.26 \left( \frac{E/F_y}{\sqrt{L/D}} \right)^{0.80} < \lambda \leq 3.77 \left( \frac{E/F_y}{\sqrt{L/D}} \right)^{0.80}$

$$C_{vM} = 1 - 0.61 \left( 0.54 \sqrt{\frac{L/D \lambda^{1.25}}{E/F_y}} - 0.23 \right)$$

When  $\lambda > 3.77 \left( \frac{E/F_y}{\sqrt{L/D}} \right)^{0.80}$

$$C_{vM} = \frac{2.05E}{\sqrt{L/D} \lambda^{1.25} F_y}$$

#### Long length $C_{vL}$

When  $\lambda \leq 0.20(E/F_y)^{0.67}$

$$C_{vL} = 1.0$$

When  $0.20(E/F_y)^{0.67} < \lambda \leq 1.87(E/F_y)^{0.67}$

$$C_{vL} = 1 - 0.61 \left( 0.77 \sqrt{\frac{\lambda^{1.50}}{E/F_y}} - 0.23 \right)$$

When  $\lambda > 1.87(E/F_y)^{0.67}$

$$C_{vL} = \frac{E}{\lambda^{1.50} F_y}$$



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## Chapter G – Torsional strength of Rectangular HSS and Box sections

### AISC 370 – Rectangular HSS and Box Sections Subject to Torsion

$$T_n = 0.6CC_vF_y$$

When  $\lambda \leq 0.74\sqrt{E/F_y}$

$$C_{v2} = 1.2$$

When  $0.74\sqrt{E/F_y} < \lambda \leq 2.17\sqrt{E/F_y}$

$$C_{v2} = 1.2 - 0.28 \left( \frac{\lambda}{\sqrt{E/F_y}} - 0.74 \right)$$

When  $2.17\sqrt{E/F_y} < \lambda \leq 5.99\sqrt{E/F_y}$

$$C_{v2} = \frac{11.23\sqrt{E/F_y} - \lambda}{3.62\sqrt{E/F_y} + 3.55\lambda}$$

When  $\lambda > 5.99\sqrt{E/F_y}$

$$C_{v2} = \frac{7.56E}{\lambda^2 F_y}$$

**Same as for shear  
 (with  $k_v = 5.0$ )**



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# Chapter H



## Chapter H – Design of Members for Combined Forces ~~and Torsion~~

The chapter is organized as follows:

- H1. Doubly Symmetric I-Shaped Members, Channels, HSS, and Box Sections Subject to Flexure and Axial Force
- H2. Doubly Symmetric I-Shaped Members, Channels, HSS, and Box Sections Subject to Combined Torsion, Flexure, Shear, and/or Axial Force
- H3. Rupture of Flanges with Holes Subjected to Tension

The design of tees, single equal-leg angles, and double angles used in compression when other forces are present is outside the scope of this chapter.



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# Chapter I

## (Design of Composite members)

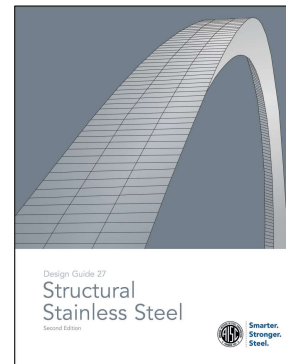


# Appendix 2



## Appendix 2 – The Continuous Strength Method

- The CSM is a new design method.
- Only applicable to members not susceptible to global buckling.
- Particularly beneficial for compact or nonslender sections.
- Account for the beneficial effect of strain hardening. **Higher strengths can be achieved**
- Can also be used with slender sections.



## Appendix 2 – The Continuous Strength Method

The appendix is organized as follows:

- 2.1. Limitations
- 2.2. Material Modeling
- 2.3. Deformation Capacity
- 2.4. Tensile Strength
- 2.5. Compressive Strength
- 2.6. Flexural Strength
- 2.7. Combined Flexure and Compression



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## Appendix 2 – The Continuous Strength Method

The appendix is organized as follows:

- 2.1. Limitations
- 2.2. Material Modeling
- 2.3. Deformation Capacity
- 2.4. Tensile Strength
- 2.5. Compressive Strength
- 2.6. Flexural Strength
- 2.7. Combined Flexure and Compression

The CSM is applicable to:

- Doubly-symmetric I-shaped members
- HSS and box sections
- Channels, angles and tees

Range of applicability of the CSM

	Compression members	Flexural members	Combined loading
I-shaped, channels, angles, tees, square and rectangular HSS, and box sections	$\frac{L_c}{r} \leq 0.63 \sqrt{\frac{E}{F_y}}$ or $\frac{F_y}{F_e} \leq 0.04$ and $\lambda_1 \leq 1.6$	$L_b \leq 0.50 L_p$ and $\lambda_1 \leq 1.6$	Requirements for both compression and flexural members shall be satisfied
Round HSS	$\frac{L_c}{r} \leq 0.63 \sqrt{\frac{E}{F_y}}$ or $\frac{F_y}{F_e} \leq 0.04$ and $\lambda_1 \leq 0.6$	$\lambda_1 \leq 0.6$	Requirements for both compression and flexural members shall be satisfied



## Appendix 2 – The Continuous Strength Method

The appendix is organized as follows:

- 2.1. Limitations
- 2.2. Material Modeling
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- 2.7. Combined Flexure and Compression

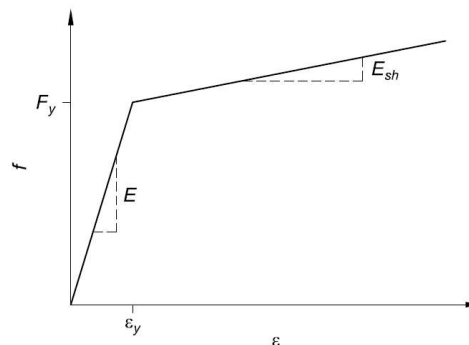


Fig. A-2.2.1. CSM material model.



## Appendix 2 – The Continuous Strength Method

The appendix is organized as follows:

- 2.1. Limitations
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- 2.4. Tensile Strength
- 2.5. Compressive Strength
- 2.6. Flexural Strength
- 2.7. Combined Flexure and Compression



## Appendix 2 – The Continuous Strength Method

The CSM base curves

**For I-Shaped, channels, angles, tees, square and rectangular HSS, and box sections**

(a) When  $\lambda_l \leq 0.68$

$$\frac{\epsilon_{csm}}{\epsilon_y} = \frac{0.25}{\lambda_l^{3.6}} \leq \text{minimum} \left( 15, \frac{0.10(1-F_y/F_u)}{\epsilon_y} \right)$$

(b) When  $\lambda_l > 0.68$

$$\frac{\epsilon_{csm}}{\epsilon_y} = \left( 1 - \frac{0.222}{\lambda_l^{1.05}} \right) \frac{1}{\lambda_l^{1.05}}$$

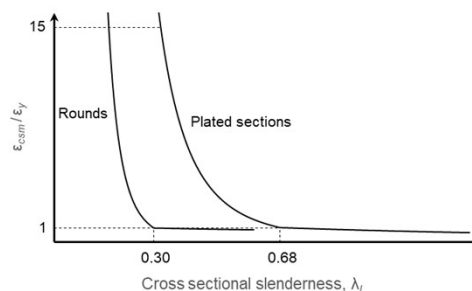
**For rounds**

(a) When  $\lambda_l \leq 0.30$

$$\frac{\epsilon_{csm}}{\epsilon_y} = \frac{4.44 \times 10^{-3}}{\lambda_l^{4.5}} \leq \text{minimum} \left( 15, \frac{0.10(1-F_y/F_u)}{\epsilon_y} \right)$$

(b) When  $\lambda_l > 0.30$

$$\frac{\epsilon_{csm}}{\epsilon_y} = \left( 1 - \frac{0.224}{\lambda_l^{0.342}} \right) \frac{1}{\lambda_l^{0.342}}$$



## Appendix 2 – The Continuous Strength Method

### Tensile strength

(a) For tensile yielding in the gross section

$$P_n = f_{csm,t} A_g$$

where

$$f_{csm,t} = F_y + E_{sh} (\epsilon_{csm,t} - \epsilon_y)$$

$$\epsilon_{csm,t} = \text{minimum} [15\epsilon_y, 0.10(1 - F_y/E_u)]$$

$$E_{sh} = \frac{F_u - F_y}{0.16(1 - F_y/E_u) - \epsilon_y}$$

$$\phi_t = 0.90 \text{ (LRFD)} \quad \Omega_t = 1.67 \text{ (ASD)}$$

(b) For tensile rupture in the net section

$$P_n = F_u A_e$$

$F_u$  may be replaced with  $f_{max}$  as given in Chapter D



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## Appendix 2 – The Continuous Strength Method

### Compressive strength

When  $\epsilon_{csm} / \epsilon_y < 1.0$

$$P_n = \frac{\epsilon_{csm}}{\epsilon_y} F_y A_g$$



Local buckling takes place before  $F_y$  is reached.  
 No benefit from strain hardening.

When  $\epsilon_{csm} / \epsilon_y \geq 1.0$

$$P_n = f_{csm} A_g$$



Compressive strength  $> P_y$  due to strain hardening.

where

$$f_{csm} = F_y + E_{sh} \epsilon_y \left( \frac{\epsilon_{csm}}{\epsilon_y} - 1 \right)$$

$$\phi_c = 0.90 \text{ (LRFD)} \quad \Omega_c = 1.67 \text{ (ASD)}$$



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## Appendix 2 – The Continuous Strength Method

### Flexural strength

When  $\epsilon_{csm} / \epsilon_y < 1.0$

$$M_n = \frac{\epsilon_{csm}}{\epsilon_y} M_y$$



Local buckling takes place before  $M_y$  is reached.  
 No benefit from strain hardening.

When  $\epsilon_{csm} / \epsilon_y \geq 1.0$

$$M_n = M_p \left( 1 + \frac{E_{sh}}{E} \frac{S}{Z} \left( \frac{\epsilon_{csm}}{\epsilon_y} - 1 \right) - \left( 1 - \frac{S}{Z} \right) / \left( \frac{\epsilon_{csm}}{\epsilon_y} \right)^\alpha \right)$$



Flexural strength  $> M_y$  due to strain hardening.

$$\phi_b = 0.90 \text{ (LRFD)} \quad \Omega_b = 1.67 \text{ (ASD)}$$



## Appendix 2 – The Continuous Strength Method

### Combined flexure and compression

For I-Shaped, channels, angles, tees, square and rectangular HSS, and box sections	For rounds
When $\lambda_l \leq 0.60$	When $\lambda_l \leq 0.27$
$\frac{P_r}{P_c} + 8 \left( \frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}} \right) \leq 1.0$ or $\frac{P_r}{2P_c} + \left( \frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}} \right) \leq 1.0$ <b>(From Chapter H)</b>	
When $\lambda_l > 0.60$	When $\lambda_l > 0.27$
$\frac{P_r}{P_c} + \left( \frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}} \right) \leq 1.0$	

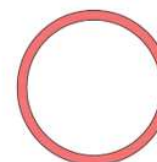


## Appendix 2 – The Continuous Strength Method

Comparison of CSM and Chapter E design provisions

	$P_n(CSM - F_{y,avg}) / P_n(Chap E - F_y)$		$P_n(CSM - F_y) / P_n(Chap E - F_y)$	
<b>Square hollow sections</b>	<b>Austenitic</b>	<b>Duplex</b>	<b>Austenitic</b>	<b>Duplex</b>
HSS 4 x 4 x 0.180	1.62	1.10	1.17	1.04
HSS 4 x 4 x 0.250	1.98	1.31	1.24	1.23
HSS 12 x 12 x 0.250	1.31	1.13	1.07	1.12
HSS 12 x 12 x 0.500	1.60	1.09	1.12	1.02

<b>Round hollow sections</b>	<b>Austenitic</b>	<b>Duplex</b>	<b>Austenitic</b>	<b>Duplex</b>
HSS4.500 x 0.109	1.22	1.01	1.10	1.01
HSS4.500 x 0.250	1.62	1.16	1.24	1.15
HSS7.500 x 0.120	1.10	1.21	1.03	1.21
HSS7.500 x 0.250	1.37	1.03	1.22	1.03



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# Structural analysis (Chapter C)



## Chapter C – Design for Stability

The chapter is organized as follows:

- C1. General Stability Requirements
- C2. Calculation of Required Strengths
- C3. Calculation of Available Strengths

Based on the direct analysis method, similar to AISC 360



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## Chapter C – Design for Stability

### General Stability Requirements in AISC 370 and AISC 360

- Type of deformations to be accounted (i.e. flexural, shear and axial member deformations, etc.)
- Requirements for accounting for second order effects
- Type of loading to consider
- LRFD and ASD load combination allowed
- Modeling of system imperfections (i.e. direct modeling or using notional loads)
- Adjustment of stiffness → **Similar to AISC 360. Only differ in the expressions for  $\tau_g$  and  $\tau_b$**

**Same as the requirements in AISC 360**



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## Chapter C – Design for Stability

### Adjustment of stiffness in AISC 360 and AISC 370

#### AISC 360

$$\tau_g = 0.80$$

When  $\alpha P_r / P_{ns} \leq 0.5$

$$\tau_b = 1.0$$

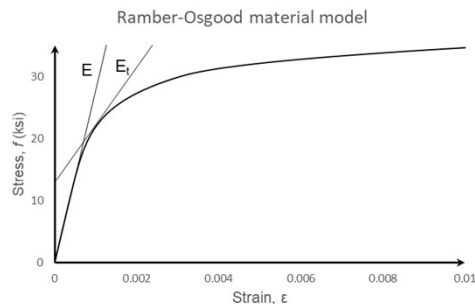
When  $\alpha P_r / P_{ns} > 0.5$

$$\tau_b = 4(\alpha P_r / P_{ns}) [1 - (\alpha P_r / P_{ns})]$$

#### AISC 370

$$\tau_g = 0.70$$

$$\tau_b = \frac{1.0}{1.0 + 0.002 n_{eff} \frac{E}{F_y} \left( \frac{\alpha P_r}{P_{ns}} \right)^{(n_{eff}-1)}}$$



where

$\alpha = 1.0$  (LRFD);  $\alpha = 1.6$  (ASD)

$P_r$  = required axial compressive strength using LRFD or ASD load combinations, kips

$P_{ns}$  = cross-section compressive strength, kips

$n_{eff}$  = auxiliary coefficient (depends on the alloy family)



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## Chapter C – Design for Stability

### Adjustment of stiffness in AISC 360 and AISC 370

#### AISC 360

$$\tau_g = 0.80$$

When  $\alpha P_r / P_{ns} \leq 0.5$

$$\tau_b = 1.0$$

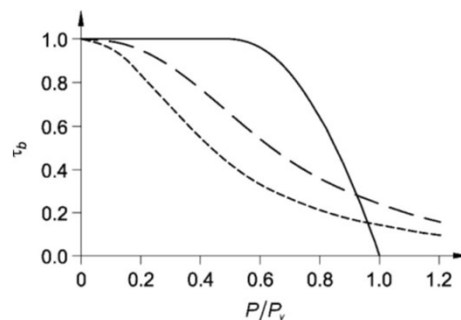
When  $\alpha P_r / P_{ns} > 0.5$

$$\tau_b = 4(\alpha P_r / P_{ns}) [1 - (\alpha P_r / P_{ns})]$$

#### AISC 370

$$\tau_g = 0.70$$

$$\tau_b = \frac{1.0}{1.0 + 0.002 n_{eff} \frac{E}{F_y} \left( \frac{\alpha P_r}{P_{ns}} \right)^{(n_{eff}-1)}}$$



where

$\alpha = 1.0$  (LRFD);  $\alpha = 1.6$  (ASD)

$P_r$  = required axial compressive strength using LRFD or ASD load combinations, kips

$P_{ns}$  = cross-section compressive strength, kips

$n_{eff}$  = auxiliary coefficient (depends on the alloy family)



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# Appendix 1



## Appendix 1 – Design by Advanced Analysis

The appendix is organized as follows:

- 1.1 General Requirements
- 1.2 Design by Elastic Analysis
- 1.3 Design by Inelastic Analysis

The strength of the member can be determined using the CSM design rules given in Appendix 2.

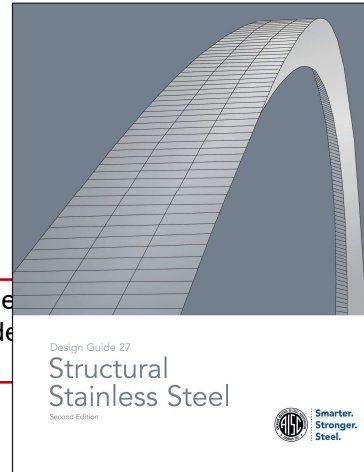


## Appendix 1 – Design by Advanced Analysis

The appendix is organized as follows:

- 1.1 General Requirements
- 1.2 Design by Elastic Analysis
- 1.3 Design by Inelastic Analysis

Only applicable to doubly symmetric members, I-shaped members, square and rectangular HSS, and box sections, unless evidence is provided to the contrary for other member types.



## Appendix 1 – Design by Advanced Analysis

The appendix is organized as follows:

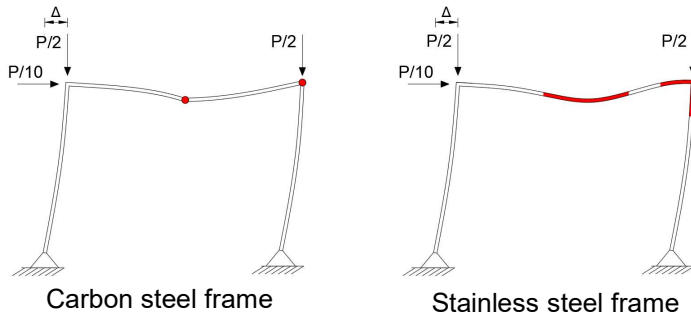
- 1.1 General Requirements
- 1.2 Design by Elastic Analysis
- 1.3 Design by Inelastic Analysis

Only applicable to doubly symmetric I-shaped members, square and rectangular HSS, and box sections.



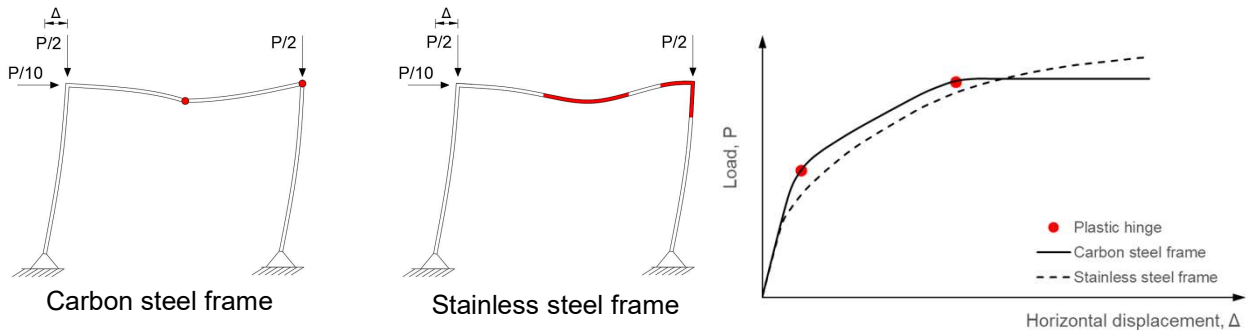
## Appendix 1 – Design by Advanced Analysis

### Design by Inelastic Analysis



## Appendix 1 – Design by Advanced Analysis

### Design by Inelastic Analysis



## Appendix 1 – Design by Advanced Analysis

### Design by Inelastic Analysis

#### CSM strain limits

$$\frac{\epsilon_r}{\epsilon_y} \leq \frac{\epsilon_{csm}}{\epsilon_y}$$

When  $\lambda_l \leq 0.68$

$$\frac{\epsilon_{csm}}{\epsilon_y} = \frac{0.25}{\lambda_l^{3.6}} + \frac{0.002}{\epsilon_y} \leq \Lambda$$

When  $0.68 < \lambda_l < 1.00$

$$\frac{\epsilon_{csm}}{\epsilon_y} = \left(1 - \frac{0.222}{\lambda_l^{1.05}}\right) \frac{1}{\lambda_l^{1.05}} + \frac{0.002(f/F_y)^n}{\epsilon_y}$$



where

- $F_y$  = specified minimum yield stress, ksi (MPa)
- $f$  = stress at outer compressive fiber, ksi (MPa)
- $\epsilon_{csm}$  = CSM strain limit
- $\epsilon_y = F_y/E$
- $\lambda_l$  = local cross-section slenderness

$$= \sqrt{\frac{F_y}{F_{el}}}$$

- $F_{el}$  = elastic local buckling stress of full cross section, ksi (MPa)
- $\Lambda$  = upper bound strain limit with a recommended value of 15

## Appendix 1 – Design by Advanced Analysis

### Design by Inelastic Analysis

#### CSM strain limits

$$\frac{\epsilon_r}{\epsilon_y} \leq \frac{\epsilon_{csm}}{\epsilon_y}$$

When  $\lambda_l \leq 0.68$

$$\frac{\epsilon_{csm}}{\epsilon_y} = \frac{0.25}{\lambda_l^{3.6}} + \frac{0.002}{\epsilon_y} \leq \Lambda$$

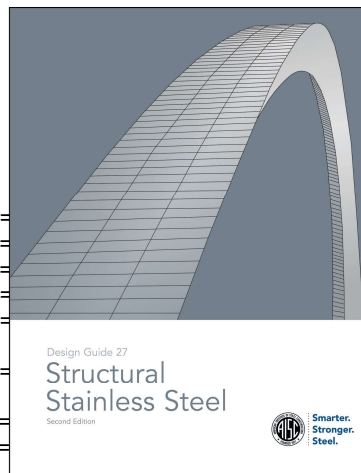
When  $0.68 < \lambda_l < 1.00$

$$\frac{\epsilon_{csm}}{\epsilon_y} = \left(1 - \frac{0.222}{\lambda_l^{1.05}}\right) \frac{1}{\lambda_l^{1.05}} + \frac{0.002(f/F_y)^n}{\epsilon_y}$$



where

- $F_y$  = specified minimum yield stress, ksi (MPa)
- $f$  = stress at outer compressive fiber, ksi (MPa)
- $\epsilon_{csm}$  = CSM strain limit
- $\epsilon_y = F_y/E$
- $\lambda_l$  = local cross-section slenderness



- $F_{el}$  = elastic local buckling stress of full cross section, ksi (MPa)
- $\Lambda$  = upper bound strain limit with a recommended value of 15

# Appendix 4



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## Appendix 4 – Structural Design for Fire Conditions

The appendix is organized as follows:

- 4.1. General Provisions
- 4.2. Structural Design for Fire Conditions by Analysis
- 4.3. Design by Qualification Testing

The scope of the appendix has been reduced because composite members are not covered in AISC 370



Stainless steel offshore escape tunnel  
© Booth Industries



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## Appendix 4 – Structural Design for Fire Conditions

### 4.2. Structural Design for Fire Conditions by Analysis

#### Coefficient of Thermal Elongation

For carbon steel:  $7.8 \times 10^{-6} / ^\circ\text{F}$

For austenitic stainless steel:  $11 \times 10^{-6} / ^\circ\text{F}$  (41% larger than for carbon steel)

For duplex stainless steel:  $9.0 \times 10^{-6} / ^\circ\text{F}$  (15% larger than for carbon steel)

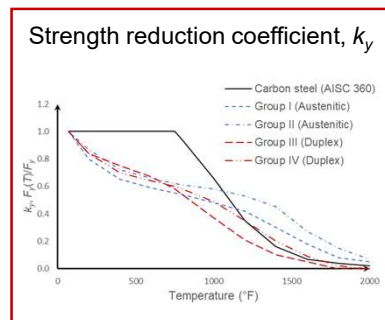
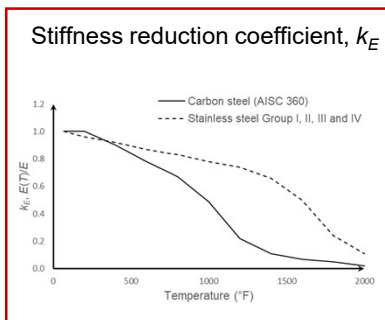


## Appendix 4 – Structural Design for Fire Conditions

### 4.2. Structural Design for Fire Conditions by Analysis

#### Deterioration of strength and stiffness at elevated temperatures

- Austenitic Group I: S30400/S30403
- Group II: S31600/S31603 and S32100
- Duplex Group III: S32202 and S32304
- Group IV: S32003, S32101, S32205 and S82441



# Appendix 7



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## Appendix 7 – Modeling of Material Behavior

The appendix is organized as follows:

- 7.1. Material Behavior at Ambient Temperature
- 7.2. Material Behavior at Elevated Temperatures



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## Appendix 7 – Modeling of Material Behavior

### 7.1. Material Behavior at Ambient Temperature

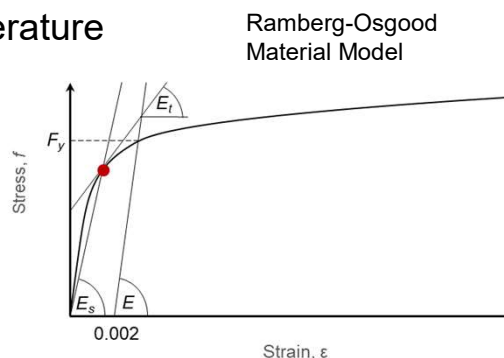
#### Stress-Strain Behavior

For  $f \leq F_y$

$$\epsilon = \frac{f}{E} + 0.002 \left( \frac{f}{F_y} \right)^n$$

For  $F_y < f \leq F_u$

$$\epsilon = 0.002 + \frac{F_y}{E} + \frac{f - F_y}{E_{ty}} + \left( \epsilon_u - 0.002 - \frac{F_y}{E} - \frac{F_u - F_y}{E_{ty}} \right) \left( \frac{f - F_y}{F_u - F_y} \right)^m$$



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## Summary

- Structural performance is similar to carbon steel but some modifications needed due to the non-linear stress-strain curve.
- Scope and contents in AISC 370 is aligned to those in AISC 360.
- AISC 360 should not be used for the design of stainless steel members that are outside the scope of AISC 370.



19 May: Jason Provines and Benjamin Baer

- Connections
- Fabrication
- Code of Standard Practice



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**AISC** | Questions?



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- You will be receiving certificates via email from [registration@aisc.org](mailto:registration@aisc.org).



## CEU / PDH Certificates

### For those participating at one connection with a group...

- Main registrant will report attendance via an online form. (The link will be provided in an email from [registration@aisc.org](mailto:registration@aisc.org).)
  - Username: Same as AISC website username.
  - Password: Same as AISC website password.
- Once attendance has been reported, each group member will be receiving certificates via email from [registration@aisc.org](mailto:registration@aisc.org).



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## 3-Session Registrants

### CEU / PDH Certificates

One certificate will be issued at the conclusion of the course.



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## 3-Session Registrants

### Attendance and PDH Certificates

- You have two options to receive credit for each session.
  - Option 1: Watch the live session.
  - Option 2: Watch the recording and pass the associated quiz.

### Videos and Quizzes

- For each session, find access within two business days after the live air date. (An email will be sent from [webinars@aisc.org](mailto:webinars@aisc.org).)
- Quiz scores are displayed in the Course Resources table.

### Distribution of Certificates

- All certificates will be issued after the course is completed.
- Only the registrant will receive a certificate for the course.



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## 3-Session Registrants

### Course Resources

Access to video recordings and quizzes can be found on your AISC account.



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# 3-Session Registrants

## Course Resources

Go to [www.aisc.org](http://www.aisc.org) and sign in.

# 3-Session Registrants

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# 3-Session Registrants

## Course Resources

Event	Start Date
Seismic Design in Steel	1/1/1900 12:00:00 AM
4-Session Package-Design of Façade Attachments	5/9/2019 1:30:00 PM
NS 15 8-Session Package-Night School 15 - Fundamentals of Connection Design	10/3/2017 7:00:00 PM
NS 16 8-Session Package-Night School 16 - Seismic Design in Steel	2/5/2018 7:00:00 PM
NS 17 4-Session Package-Night School 17: Design of Façade Attachments	7/16/2018 7:00:00 PM
NS 18 8-Session Package-Night School 18: Steel Construction: Mill To Topping Out	10/15/2018 7:00:00 PM
NS 19 8-Session Package-Night School 19: Connection Design	2/4/2019 7:00:00 PM
NS 20 8-Session Package-Night School 20: Classical Methods of Structural Analysis	6/3/2019 7:00:00 PM
8-Session Package-Seismic Design in Steel - Concepts & Examples	7/16/2018 1:30:00 PM

# 3-Session Registrants

## Course Resources

Design of Façade Attachments

**4-SESSION PACKAGE RESOURCES**

Event	Date	Handouts	Video	Quiz	Attendance
R1: Façade Fundamentals	N/A	<a href="#">Handouts</a>	<a href="#">View</a> Passcode: AZNS175	Pass Score: 100	N/A
L1: Façade Attachments Part 1	May 9 2019 1:30PM EDT	<a href="#">Handouts</a>	Available 05/11/2019 5:00PM EDT	Available 05/11/2019 5:00 PM EDT	Pending
L2: Façade Attachments Part 2	May 16 2019 1:30PM EDT	<a href="#">Handouts</a>	Available 05/18/2019 5:00PM EDT	Available 05/18/2019 5:00 PM EDT	Pending
L3: Façade Attachments - Building Lateral Drifts	May 23 2019 1:30PM EDT	<a href="#">Handouts</a>	Available 05/25/2019 5:00PM EDT	Available 05/25/2019 5:00 PM EDT	Pending
Final Exam	N/A			Available 5/27/2019 5:00 PM EDT	





**AISC** | Thank you

