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Three-Part Webinar Series: Structural Stainless Steel

Part 3: Connections and Fabrication

May 19, 2022

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Course Description – Submitted for AIA CE Credit

Structural Stainless Steel Connections and Fabrication
May 19, 2022

The principles of designing stainless steel bolted and welded connections will be covered in this session, with a comparison provided between the new standard, AISC 370 *Specification for Structural Stainless Steel Buildings*, and the analogous standard for carbon steel, AISC 360. The discussion will address connection design for both strength and corrosion. Best practice fabrication procedures will also be presented. An overview of the key differences between the new standard, AISC 313 *Code of Standard Practice for Structural Stainless Steel Buildings*, and the analogous standard for carbon steel, AISC 303, will be discussed.

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Learning Objectives – Submitted for AIA CE Credit

- Explain what to consider when selecting bolt assembly specifications for a given application.
- Compare the strength limit states for bolted connections for stainless steel to those for carbon steel.
- List key aspects to proper handling and storage of structural stainless steel.
- Describe how the thermal performance of stainless steel impacts fabrication.

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Structural Stainless Steel
Session 3: Connections & Fabrication

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Outline

- Stainless bolted connections
  - Specifications and fastener selection
  - Design
  - Installation
- Stainless welded connections
- Fabrication of stainless steel

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Stainless Steel Bolting

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Stainless Steel Bolting

- Present differences between stainless and carbon steel bolting
- First show carbon steel in AISC 360, in blue
- Then show differences in stainless in AISC 370, in silver

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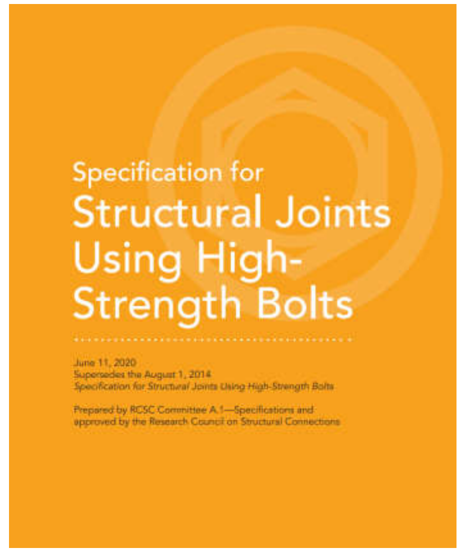
Specifying SS Bolts

AISC 360 (blue = carbon steel)

- "Use of high-strength bolts shall conform to *Specification for Structural Joints Using High-Strength Bolts*, hereinafter RCSC…"



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Specifying SS Bolts

RCSC – Bolt Types

- Applicable for the following bolt types

Group	Tensile Strength (ksi)	Bolts	Matched Bolting Assemblies
Group 120	120	ASTM F3125 Grade A325	ASTM F3125 Grade F1852
Group 144	144	-	ASTM F3148 Grade 144
Group 150	150	ASTM F3125 Grade A490	ASTM F3125 Grade F2280

No stainless bolts, so RCSC not directly applicable

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Specifying SS Bolts

AISC 370 – Bolt Types (silver = stainless steel)

- Use RCSC, with these modifications:
  - Section 1. General Requirements
  - Section 2. Fastener Components
  - Section 3. Bolted Parts
  - Section 4. Joint Type
  - Section 7. Pre-Installation Verification
  - Section 8. Installation
  - Section 9. Inspection
  - Section 10. Arbitration

Lots of details provided

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Specifying SS Bolts – Corrosion

AISC 370 – New Provisions on Galvanic Corrosion

- Galvanized steel bolts shall not be used
- Fastener assemblies shall have equivalent corrosion resistance than the most corrosion resistant alloy being joined
- Fillers shall have equivalent or greater corrosion resistance

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Specifying SS Bolt Types

AISC 370 – Bolt & Nut Types

- Refers to Section A3 with allowable bolt types:
  - ASTM A193/A193M – austenitic
  - ASTM A320/A320M – austenitic
  - ASTM A453/A453M – high temperature bolting, similar to austenitic
  - ASTM A1082/A1082M – duplex & precipitation hardening (PH)
  - ASTM F593 – austenitic & PH
- Matching nut alloys provided

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Specifying SS Bolts

Example:
ASTM A193/ A193M

Many types, conditions, heat treatments, etc. available…

Grade, Diameter, in.	Heat Treatment[B]	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
Austenitic Steels						
Classes 1 and 1D; B8, B8M, B8P, B8LN, B8MLN, B8CLN, all diameters	carbide solution treated	75	30	30	50	223 HBW or 96 HRB[C]
Classes 1 and 1D; B8, B8CLNCuB, all diameters	carbide solution treated	75	30	35	50	223 HBW or 96 HRB[C]
Classes 1 and 1D: B8ML4CuN, all diameters	carbide solution treated	70	25	35	50	90 HRB
Class 1: B8C, B8T, all diameters	carbide solution treated	75	30	30	50	223 HBW or 96HRB[C]
Class 1A: B8A, B8CA, B8CLNA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA, B8MLCuNA, all diameters	carbide solution treated in the finished condition	75	30	30	50	192 HBW or 90 HRB
Class 1A: B8ML4CuNA, all diameters	carbide solution treated	70	25	35	50	90 HRB
Classes 1B and 1D: B8N, B8MN, B8MLCuN, all diameters	carbide solution treated	80	35	30	40	223 HBW or 96 HRB[C]
Classes 1C and 1D: B8R, all diameters	carbide solution treated	100	55	35	55	271 HBW or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	100	55	35	55	271 HBW or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	95	50	35	55	271 HBW or 28 HRC
Classes 1C: B8SA, all diameters	carbide solution treated in the finished condition	95	50	35	55	271 HBW or 28 HRC
Class 2: B8, B8C, B8P, B8T, B8N,[D] ¾ and under	carbide solution treated and strain hardened	125	100	12	35	321 HBW or 35 HRC
over ¾ to 1, incl		115	80	15	35	321 HBW or 35 HRC

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Specifying SS Bolts

AISC DG 27 – Bolt Types

- Simplified tables for available bolts
- Consider
  - Stainless type
  - Tensile and yield strength

Table 10-2. Bolts Covered in Tables 10-3 and 10-4

Material	ASTM	Alloy	Condition[a]		Diameter, d in.	F_{ub} ksi	F_{yb} ksi
Austenitic	ASTM F593	Group 1 (303, 304, 304L, 305, 384, XM1, 18-9LW, 302HQ, 304J3, 303Se) Group 2 (316, 316L) Group 3 (321, 347)	AF	–	¼–1½	65	20
			A	–	¼–1½	75	30
			CW	CW1	¼–⅝	100	65
				CW2	¾–1½	85	45
			SH	SH1	¼–⅝	120	95
				SH2	¾–1	110	75
				SH3	1⅛–1¼	100	60
				SH4	1⅜–1½	95	45
	ASTM A320 and A193	B8 (304), B8C (347), B8M (316), B8T (321), etc.	Class 1/1A	–	All diameters	75	30
		B8 (304), B8C (347), B8T (321), etc.	Class 2	–	$d \le ¾$	125	100
					$¾ < d \le 1$	115	80
					$1 < d \le 1¼$	105	65
					$1¼ < d \le 1½$	100	50
		B8M (316), B8MN (316N) etc.			$d \le ¾$	110	95
					$¾ < d \le 1$	100	80
					$1 < d \le 1¼$	95	65
					$1¼ < d \le 1½$	90	50
Duplex	ASTM A1082 (ASTM, 2016b)	2205	–	–	All diameters	95	65
Precipitation Hardening	ASTM A1082	630 (17-4)	AH	–	¼–1½	135	105

[a] A—Machined from annealed or solution-annealed stock thus retaining the properties of the original material; or hot formed and solution annealed.
AF—Headed and rolled from annealed stock and then reannealed.
CW—Headed and rolled from annealed stock thus acquiring a degree of cold working. Sizes 0.75 in. and larger may be hot worked and solution annealed.
SH—Machined from strain-hardened stock or cold worked to develop the specified properties.
Class 1: Solution treated.
Class 1A: Solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement.
Class 2: Solution treated and strain hardened. Austenitic stainless steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over ¾-in. in diameter.

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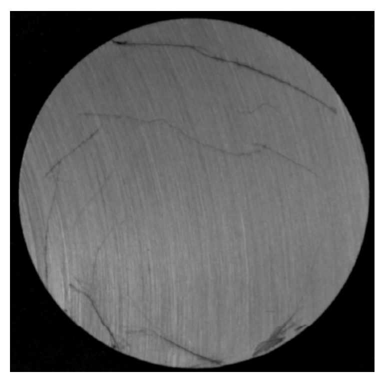
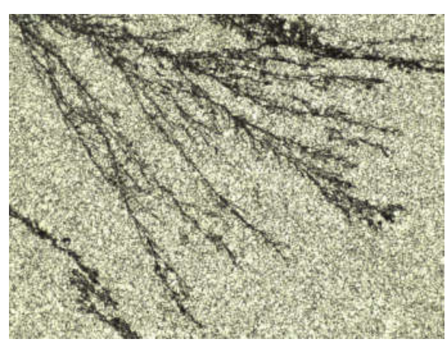
Specifying SS Bolts

AISC 370 – Stress Corrosion Cracking

- Can occur when 3 factors are present
  - Corrosive environment
  - Susceptible microstructure
  - High tensile stress
- Some stainless steels are more susceptible
  - Austenitics, especially 304
  - 17-4PH, though Condition H1150 is lower risk
- Assessment recommended





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Specifying SS Washers

AISC 370 – Washer Specifications

- No stainless washer ASTM specifications exist
- Specify chemistry and mechanical requirements of raw material
  - Choose alloy to match bolts and nuts
- Slip-critical, pretensioned, and fatigue connections
  - Washer under both bolt head and nut
  - Hardness shall be 31 Rockwell HRC

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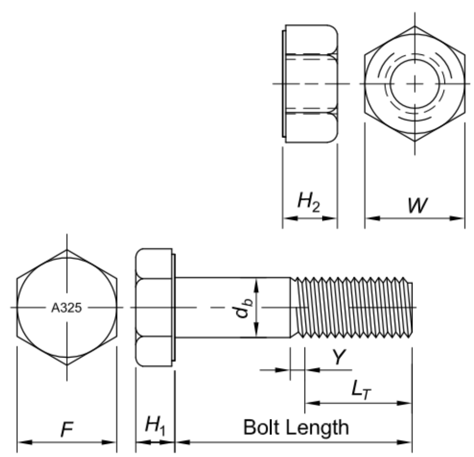
Specifying SS Bolts – Dimensions

AISC 370 – Bolting Dimensions

- Stainless bolting ASTMs have slightly different dimensional requirements
- Language for specifying
  - Bearing-type: hex or heavy hex head
  - Slip-critical or pretensioned: Heavy hex head
  - Threads according to ASME B1.1 UNC or 8 UN



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Designing SS Bolts

AISC 360 & AISC 370 – Geometry Considerations

- Same design process for:
  - Size and use of holes
  - Min and max spacing
  - Min and max edge distance

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Designing SS Bolts – Bearing & Tearout

AISC 360 – Bearing

(a) For standard, oversized, short-slotted, or parallel long-slotted holes

(i) When deformation at service loads is a design consideration

$$R_n = 2.4\ d\ t\ F_u$$

(ii) When deformation at service loads is not a design consideration

$$R_n = 3.0\ d\ t\ F_u$$

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Designing SS Bolts – Bearing & Tearout

AISC 370 - Bearing

(a) For standard, oversized, short-slotted, or parallel long-slotted holes

(i) When deformation at service loads is a design consideration

R_n = ~~2.4~~ 1.25 d t F_u

(ii) When deformation at service loads is not a design consideration

For $l_2/d_h > 1.5$

R_n = ~~3.0~~ 2.5 d t F_u

For $l_2/d_h \leq 1.5$

R_n = ~~3.0~~ 2.0 d t F_u

d_h = diameter of hole

l_2 = ½ dist between center of holes or edge distance, perpendicular to load

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Designing SS Bolts – Bearing & Tearout

AISC 370 - Tearout

(a) For standard, oversized, short-slotted, or parallel long-slotted holes

(i) When deformation at service loads is a design consideration

$$R_n = \cancel{1.2}\ 1.25 \left(\frac{l_1}{2d_h}\right) \cancel{l_c}\ d\ t\ F_u$$

(ii) When deformation at service loads is not a design consideration

$$R_n = \cancel{1.5}\ 2.5 \left(\frac{l_1}{3d_h}\right) \cancel{l_c}\ d\ t\ F_u$$

l_1 = ½ dist between center of holes or edge distance, in direction of load

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Designing SS Bolts – Bearing & Tearout

AISC 370 – Bearing and Tearout

(b) For perpendicular long-slotted holes

(1) Bearing

$$R_n = \cancel{2.0}\ 1.04\ d\ t\ F_u$$

(2) Tearing

$$R_n = \cancel{1.0}\ 1.04 \left(\frac{l_1}{2d_h}\right) \cancel{l_c}\ d\ t\ F_u$$

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Designing SS Bolts – Bearing Type

AISC 360 – Nominal Strength

- Equation J3-1

$$R_n = F_n A_b$$

Where

A_b = unthreaded area (in^2)

F_n = F_{nt} (tensile) or F_{nv} (shear) (ksi)

- Table for tensile or shear strength
  - Bolt type
  - Thread location

TABLE J3.2
Nominal Strength of Fasteners and Threaded Parts, ksi (MPa)

Description of Fasteners	Nominal Tensile Strength, F_{nt}, ksi (MPa)[a]	Nominal Shear Strength in Bearing-Type Connections, F_{nv}, ksi (MPa)[b]
A307 bolts	45 (310)[c]	27 (186)[c] [d]
Group A (e.g., A325) bolts, when threads are not excluded from shear planes	90 (620)	54 (372)
Group A (e.g., A325) bolts, when threads are excluded from shear planes	90 (620)	68 (469)
Group B (e.g., A490) bolts, when threads are not excluded from shear planes	113 (780)	68 (469)
Group B (e.g., A490) bolts, when threads are excluded from shear planes	113 (780)	84 (579)
Group C (e.g., F3043) bolt assemblies, when threads and		

Designing SS Bolts – Bearing Type

AISC 370 – Nominal Strength

- Many different types of SS bolts, so simple table not possible
- Equation J3-1

$$R_n = F_n A_b$$

Where

Tensile Strength = $F_{nt} = 0.75F_u$

Shear Strength = $F_{nv} = 0.45F_u$ for threads not excluded

$= 0.55F_u$ for threads excluded

Equations instead of table

F_u taken from appropriate ASTM

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Designing SS Bolts – Bearing Type

AISC DG 27 – Nominal Strength

- Design tables are available

Table 10-3
Available Shear Strength of Bolts, kips

Nominal Bolt Diameter, d, in.			⅝		¾		⅞		1	
Nominal Bolt Area, in.^{2}			0.307		0.442		0.601		0.785	
Austenitic Stainless Steel Bolts										
Condition[a]	Thread Cond.	Loading	r_n/Ω ASD	ϕr_n LRFD	r_n/Ω ASD	ϕr_n LRFD	r_n/Ω ASD	ϕr_n LRFD	r_n/Ω ASD	ϕr_n LRFD
AF	N	S	4.49	6.73	6.46	9.69	8.79	13.2	11.5	17.2
		D	8.97	13.5	12.9	19.4	17.6	26.4	23.0	34.5
	X	S	5.48	8.23	7.90	11.8	10.7	16.1	14.0	21.1
		D	11.0	16.5	15.8	23.7	21.5	32.2	28.1	42.1
A Class 1/1A	N	S	5.18	7.77	7.46	11.2	10.1	15.2	13.3	19.9
		D	10.4	15.5	14.9	22.4	20.3	30.4	26.5	39.8
	X	S	6.33	9.49	9.11	13.7	12.4	18.6	16.2	24.3
		D	12.7	19.0	18.2	27.3	24.8	37.2	32.4	48.6
CW	N	S	6.90	10.4	8.45	12.7	11.5	17.3	15.0	22.5
		D	13.8	20.7	16.9	25.3	23.0	34.5	30.0	45.1
	X	S	8.44	12.7	10.3	15.5	14.1	21.1	18.4	27.5
		D	16.9	25.3	20.7	31.0	28.1	42.2	36.7	55.1
SH	N	S	8.28	12.4	10.9	16.4	14.9	22.3	19.4	29.2
		D	16.6	24.9	21.9	32.8	29.8	44.6	38.9	58.3
	X	S	10.1	15.2	13.4	20.0	18.2	27.3	23.8	35.6
		D	20.2	30.4	26.7	40.1	36.4	54.6	47.5	71.3

Table 10-4
Available Tensile Strength of Bolts, kips

Nominal Bolt Diameter, d, in.	⅝		¾		⅞		1	
Nominal Bolt Area, in.^{2}	0.307		0.442		0.601		0.785	
Austenitic Stainless Steel Bolts								
Condition[a]	r_n/Ω ASD	ϕr_n LRFD	r_n/Ω ASD	ϕr_n LRFD	r_n/Ω ASD	ϕr_n LRFD	r_n/Ω ASD	ϕr_n LRFD
AF	7.48	11.2	10.8	16.2	14.7	22.0	19.1	28.7
A and Class 1/1A	8.63	12.9	12.4	18.6	16.9	25.4	22.1	33.1
CW	11.5	17.3	14.1	21.1	19.2	28.8	25.0	37.6
SH	13.8	20.7	18.2	27.3	24.8	37.2	32.4	48.6
Class 2B8	14.4	21.6	20.7	31.1	25.9	38.9	33.9	50.8
Class 2B8M	12.7	19.0	18.2	27.3	22.5	33.8	29.5	44.2
Duplex Stainless Steel Bolts								
Alloy[a]	r_n/Ω ASD	ϕr_n LRFD	r_n/Ω ASD	ϕr_n LRFD	r_n/Ω ASD	ϕr_n LRFD	r_n/Ω ASD	ϕr_n LRFD
S32205	10.9	16.4	15.7	23.6	21.4	32.1	28.0	42.0
Precipitation Hardening Stainless Steel Bolts								
Alloy[a]	r_n/Ω ASD	ϕr_n LRFD	r_n/Ω ASD	ϕr_n LRFD	r_n/Ω ASD	ϕr_n LRFD	r_n/Ω ASD	ϕr_n LRFD
AH	13.8	20.8	19.9	30.0	27.1	40.8	35.3	53.3
Nominal Bolt Diameter, d, in.	1⅛		1¼		1⅜		1½	

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Designing SS Bolts – Bearing Type

AISC 370 – Nominal Strength

- Differences in resistance factors for PH bolts in previous equation J3-1
  - Austenitic and duplex: $\Phi = 0.75$, $\Omega = 2.00$
  - PH: $\Phi = 0.67$, $\Omega = 2.25$
- Reduced factors accounts for lack of test data of PH bolts

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Designing SS Bolts – Slip-Critical

AISC 360 – Slip Resistance

- Equation J3-4

$$R_n = \mu D_u h_f T_b n_s$$

Where

μ = mean slip coefficient

D_u = 1.13, reflects ratio of installed bolt tension to specified minimum bolt pretension

h_f = factor for fillers

T_b = minimum fastener tension

n_s = number of slip planes

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Designing SS Bolts – Slip-Critical

AISC 370 – Slip Resistance

- Equation J3-4

$$R_n = \mu D_u h_f T_b n_s$$

Where

μ = mean slip coefficient

D_u = 1.13, reflects ratio of installed bolt tension to specified minimum bolt pretension

h_f = factor for fillers – same for SS bolts

T_b = minimum fastener tension

n_s = number of slip planes – same for SS bolts

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Designing SS Bolts – Slip-Critical

AISC 360 – Slip Resistance

- Equation J3-4

$$R_n = \mu D_u h_f T_b n_s$$

μ = mean slip coefficient

Surface Class	Description	Mean Slip Coefficient, μ
Class A	Mill scale, Class A coatings, galvanized	0.30
Class B	Blast-cleaned, Class B coatings	0.50

Other Surface Classes can be used if tested according to RCSC Appendix A

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Designing SS Bolts – Slip-Critical

AISC 370 – Slip Resistance

- Equation J3-4

$$R_n = \mu D_u h_f T_b n_s$$

μ = mean slip coefficient

Surface Class[a]	Mean Slip Coefficient, μ
Class SSB	0.20
Class SSC	0.40
Class SSD	0.50
[a]Classes defined in Section M2 (Fabrication & Erection)	

All faying surfaces shall be grit-blasted

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Designing SS Bolts – Slip-Critical

AISC 370 – Slip Resistance

- Equation J3-4

$$R_n = \mu D_u h_f T_b n_s$$

μ = mean slip coefficient

Surface Class[a]	Mean Slip Coefficient, μ
Class SSB	0.20
Class SSC	0.40
Class SSD	0.50
[a]Classes defined in Section M2 (Fabrication & Erection)	

Classes defined by roughness, not finish type

Surface Class	Rz[a], μin.	Rt[b], μin.
Class SSB	≥ 1400	≥ 2000
Class SSC	≥ 1800	≥ 2400
Class SSD	≥ 2200	≥ 2800
[a]Rz is roughness according to ASTM D7127 [b]Rt is roughness according to ASTM D4417		

Designing SS Bolts – Slip-Critical

AISC 370 – Slip Resistance

- Equation J3-4

$$R_n = \mu D_u h_f T_b n_s$$

μ = mean slip coefficient

  – If other surface types are desired, check AISC DG 27 Appendix B for guidance

Appendix B
Testing Method to Determine the Slip Coefficient in Stainless Steel Bolted Joints

B.1 GENERAL PROVISIONS

B.1.1 Purpose and Scope

The purpose of this testing procedure is to determine the mean slip coefficient for use in the design of slip-critical joints made of stainless steel. The mean slip coefficient is determined upon successful completion of both short-term compression tests and long-term tension creep tests.

The testing procedure described in this appendix largely follows the testing procedure given in RCSC *Specification* Appendix A for determining the mean slip coefficient of faying surfaces with applied coatings, with the exceptions necessary for assessing the slip resistance of an uncoated stainless steel joint.

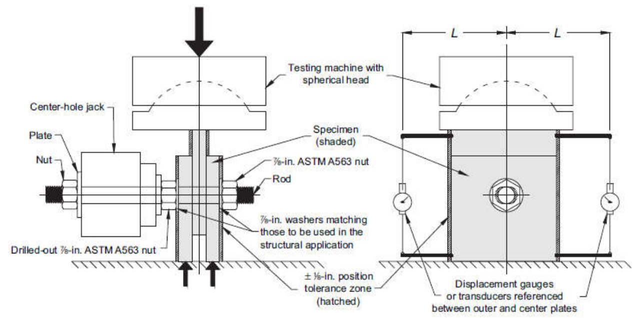
This appendix provides designers with a method to qualify an uncoated stainless steel faying surface not covered in

B.1.3 Retesting

A surface condition that fails to meet the creep requirements in Section B.4 of this appendix may be retested in accordance with methods in Section B.4 at a lower slip coefficient without repeating the static short-term tests specified in Section B.3 of this appendix. Essential variables should remain unchanged in the retest. Retests should use new bolts because preloading stainless steel bolting assemblies causes irreversible viscoplastic deformation in the bolts (Afzali et al., 2019), and reuse of stainless steel bolting assemblies results in smaller viscoplastic deformations, which improves the relaxation behavior of the bolted joint

B.2 TEST PLATES FOR THE SPECIMENS

B.2.1 Test Plates



Designing SS Bolts – Slip-Critical

AISC 360 – Slip Resistance

- Equation J3-4

$$R_n = \mu D_u h_f T_b n_s$$

D_u = 1.13, reflects ratio of installed bolt tension to specified minimum bolt pretension (based on statistical data)

AISC 370

D_u = 1.0
(based on lack of data for stainless steel bolts)

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Designing SS Bolts – Slip-Critical

AISC 360 – Slip Resistance

- Equation J3-4

$$R_n = \mu D_u h_f T_b n_s$$

T_b = minimum bolt pretension

TABLE J3.1
Minimum Bolt Pretension, kips[a]

Bolt Size, in.	Group A[a] (e.g., A325 Bolts)	Group B[a] (e.g., A490 Bolts)	Group C, Grade 2[b] (e.g., F3043 Gr. 2 bolts)
1/2	12	15	–
5/8	19	24	–
3/4	28	35	–
7/8	39	49	–
1	51	64	90
1 1/8	64	80	113
1 1/4	81	102	143
1 3/8	97	121	–
1 1/2	118	148	–

[a] Equal to 0.70 times the minimum tensile strength of bolts as specified in ASTM F3125/F3125M for Grade A325 and Grade A490 bolts with UNC threads, rounded off to nearest kip.
[b] Equal to 0.70 times the minimum tensile strength of bolts, rounded off to nearest kip, for ASTM F3043 Grade 2 and ASTM F3111 Grade 2.

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Designing SS Bolts – Slip-Critical

AISC 370 – Slip Resistance

- Equation J3-4

$$R_n = \mu D_u h_f T_b n_s$$

- Too many bolt types to specify T_b in a table
  - T_b = minimum bolt pretension = $0.7 F_{yb} A_s$
  - F_{yb} = specified minimum yield strength, ranges from 80-116 ksi

Why yield strength, instead of ultimate strength?

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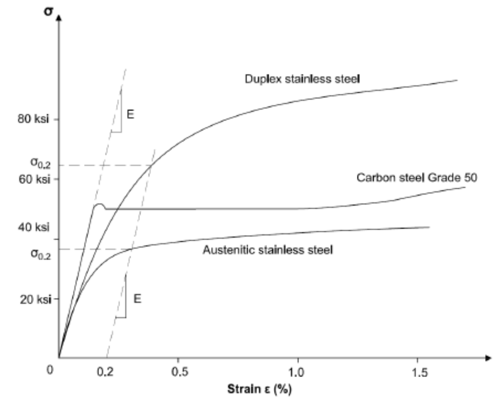
Designing SS Bolts – Slip-Critical

AISC 370 – Slip Resistance

- Why use yield strength for stainless steel bolt pretension?
- Remember from previous webinars…



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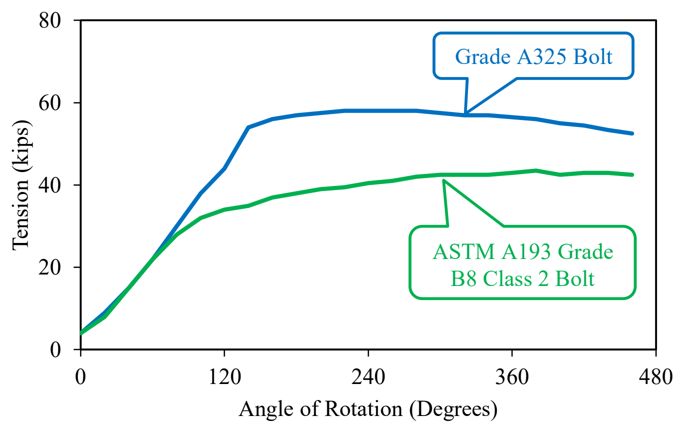
Designing SS Bolts – Slip-Critical

AISC 370 – Slip Resistance

- Why use yield strength for stainless steel bolt pretension?
- Behavior of stainless bolts is similar to plates



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Designing SS Bolts – Slip-Critical

AISC 370 – Slip Resistance

- Equation J3-4

$$R_n = \mu D_u h_f T_b n_s$$

  - Too many bolt types to specify T_b in a table

    T_b = minimum bolt pretension = 0.7 $F_{yb} A_s$

    F_{yb} = specified minimum yield strength, ranges from 80-116 ksi

    A_s = net tensile area

What is net tensile area?

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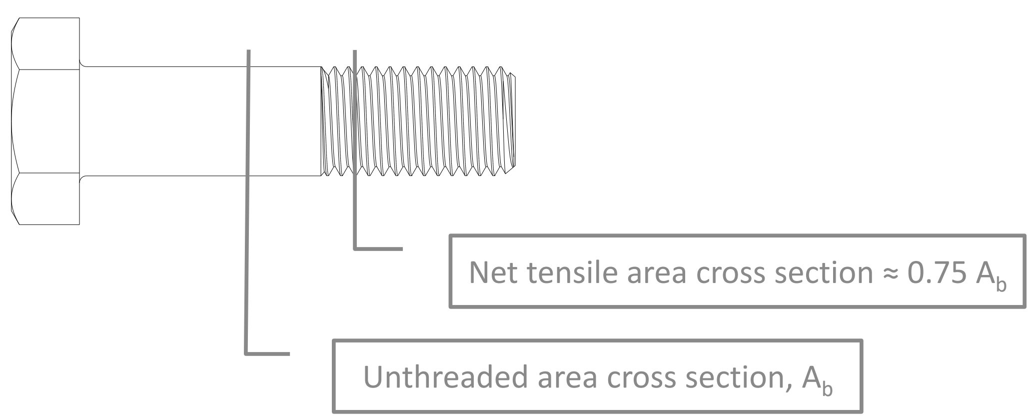
Designing SS Bolts – Slip-Critical

AISC 370 – Slip Resistance

- What is net tensile area?



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Designing SS Bolts – Slip-Critical

AISC 370 – Slip Resistance

- Net tensile area accounted for in tables in AISC 360
- Common values for A_s provided in Commentary

TABLE C-J3.1
Net Tensile Area of Bolts

Bolt Diameter, *d*, in.	Net Tensile Area, A_s[a], in.^{2}	Threads per Inch, *n*[b]
5/8	0.226	11
3/4	0.334	10
7/8	0.462	9
1	0.606	8
1 1/8	0.763	7
1 1/4	0.969	7
1 3/8	1.16	6
1 1/2	1.41	6

[a] Net tensile area = $(\pi/4)(d - 0.9743/n)^2$
[b] For diameters listed, thread series is UNC (coarse).

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Designing SS Bolts – Dissimilar Metals

AISC 370 – New Provisions on Isolation

- If dissimilar metals are used in wet environments, electrical isolation shall be used
- Isolation details
  - Method appropriate for exposure
  - Prevent crevice corrosion
  - Accommodate thermal movements
- More info in DG 27

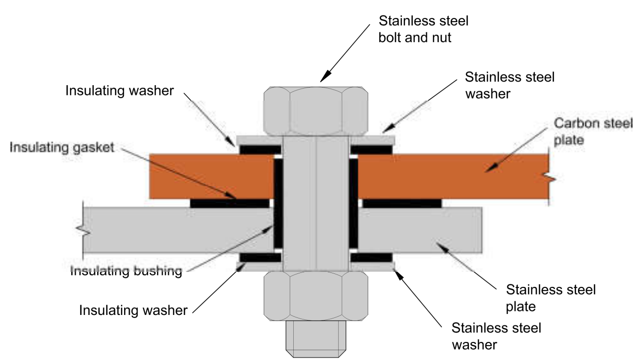

Image from DG 27

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Installing SS Bolts – Installation Method

AISC 360 & RCSC – Installation Methods

- Turn-of-Nut
- Calibrated Wrench
- Twist-Off Tension Control Bolt
- Direct Tension Indicator
- Combined (new in RCSC 2020)

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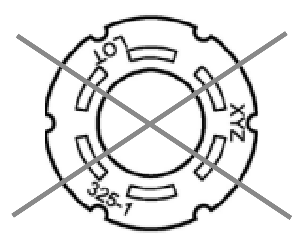
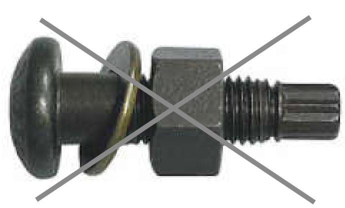
Installing SS Bolts – Installation Method

AISC 370 – Installation Methods

- Turn-of-Nut
- Calibrated Wrench
- ~~Twist-Off Tension Control Bolt~~
- ~~Direct Tension Indicator~~





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Installing SS Bolts – Galling

AISC 370 – New Provisions

- *Galling* – displacement of material between mating threads…that causes interference…or seizing of threads
- Shall be considered in the design if disassembly is performance requirement
- What is galling?

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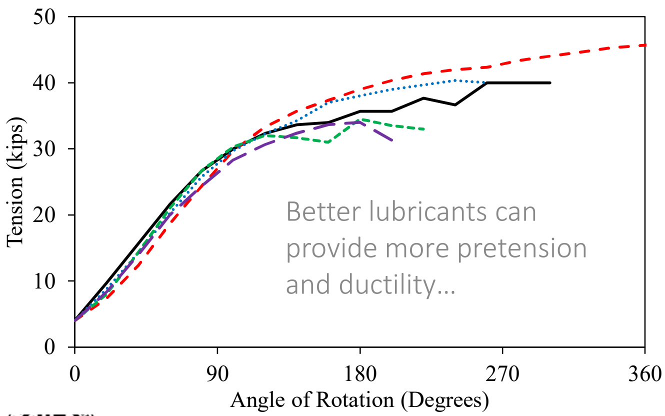
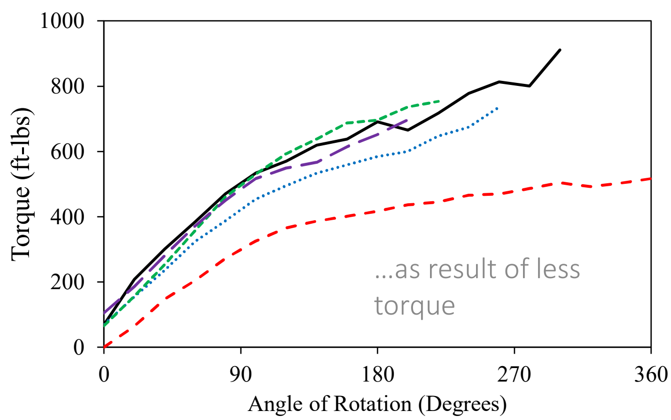
Installing SS Bolts – Galling

Experimental test data on ASTM A193 Grade B8 Class 2 bolts

- 5 different lubricants to evaluate galling





Installing SS Bolts – Galling

AISC 370

- Galling guidance provided in User Note

User Note: When surfaces are under load and in relative motion, fastener thread galling may occur. Galling is more likely to occur in stainless steel bolting assemblies than in other steel alloy bolting assemblies. Galling can be avoided by taking the following measures:

- Lubricate the internal or external threads with products containing molybdenum disulfide, anti-seize products containing silver or copper powders, mica, graphite, or talc, or a suitable proprietary pressure wax.
- Reduce bolt tightening speed.
- Use of galling-resistant, high-silicon (e.g., S21800) stainless steels or alloys of different hardness for the bolt and nut.
- Make sure that the threads, as well as the bearing surfaces, are undamaged with no burrs.
- Keep the bolted interface clean and free of grit and abrasive materials.

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Installing SS Bolts – Installation Parameters

AISC 360 & RCSC

- Guidance on how to properly pretension bolts

Installation Method	Installation Parameter in RCSC
Turn-of-Nut	Nut rotation from snug
Calibrated Wrench	Installation torque
Combined	Initial torque & nut rotation

Table 8.1
Nut Rotation from Snug-Tight Condition for Turn-of-Nut Method Pretensioning[a,b]

Bolt Length[c]	Disposition of Outer Faces of Bolted Parts		
	Both Faces Normal to Bolt Axis	One Face Normal to Bolt Axis, Other Sloped Not More Than 1:20[d]	Both Faces Sloped Not More Than 1:20 from Normal to Bolt Axis[d]
Not more than $4d_b$	⅓ turn	½ turn	⅔ turn
More than $4d_b$ but not more than $8d_b$	½ turn	⅔ turn	⅚ turn
More than $8d_b$ but not more than $12d_b$	⅔ turn	⅚ turn	1 turn

a Nut rotation is relative to bolt regardless of the element (nut or bolt) being turned. For all required nut rotations, the tolerance is plus 60 degrees (⅙ turn) and minus 0 degrees.
b Applicable only to joints in which all material within the *grip* is steel.
c When the bolt length exceeds $12d_b$, the required nut rotation shall be determined by actual testing in a suitable *bolt tension measurement device*; see *turn-of-nut* Commentary.
d Beveled washer not used.

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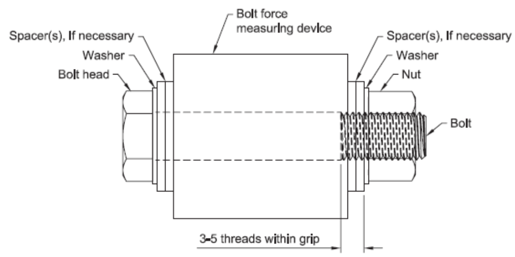
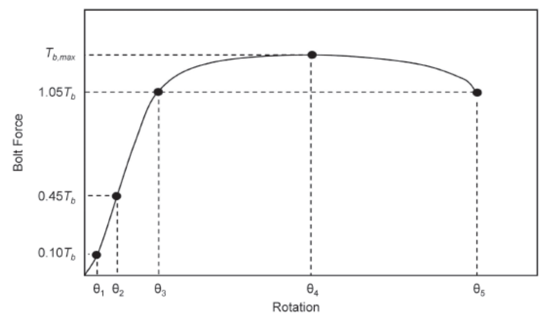
Installing SS Bolts – Installation Parameters

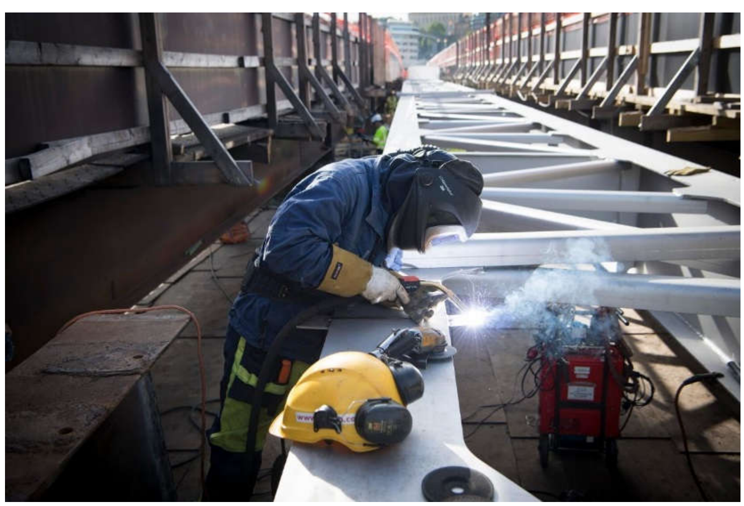
AISC 370

- No standard installation parameters provided
  - Many bolts types with different installation behavior
  - Lack of existing test data
- DG 27 Appendix B provides guidance to determine parameters for all methods
  - Testing conducted by bolt manufacturer or supplier





Stainless Steel Welding



Courtesy *Stål & Rörmontage AB* and Outokumpu

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Welding Stainless Steel – Specifications

AISC 360 – Welding Specifications

- All provisions of the AWS D1.1/D1.1M Structural Welding Code - Steel shall apply with some exceptions

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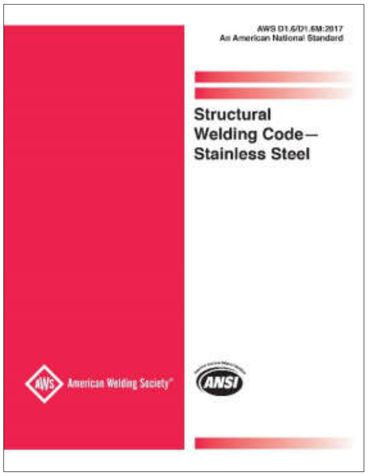
Welding Stainless Steel – Specifications

AISC 370 – Welding Specifications

- All provisions of the AWS D1.6/D1.6M Structural Welding Code – Stainless shall apply for austenitic or duplex stainless steels
- Welded details are generally same as carbon steel



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Welding Stainless Steel – Filler Metals

AISC 360 – Filler Metal and Electrode Requirements

- Filler metal shall comply with D1.1/D1.1M
- Select filler for equal or better strength
  - E.g. E70 electrodes used in most cases

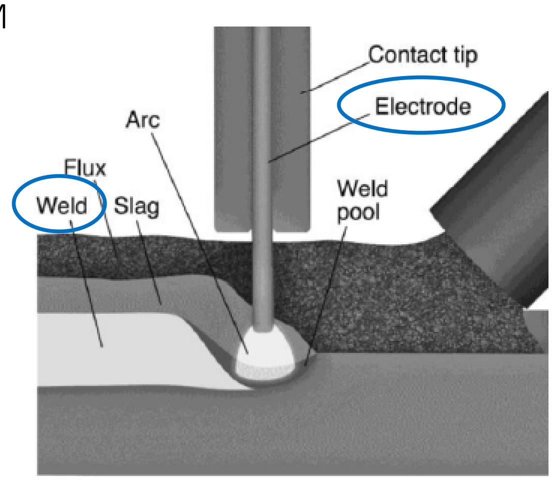

Image from Lincoln Electric

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Welding Stainless Steel – Filler Metals

AISC 370 – Filler Metal and Electrode Requirements

- Weld metal shall have equivalent corrosion resistance to base metal
- Fillers are overalloyed to account for dilution

DG 27

- Table for common austenitic fillers
- D1.6/D1.6M provides non-mandatory list for higher alloyed austenitics and duplexes

Table 10-1. Prequalified Filler Metal Classifications from AWS D1.6/D1.6M

AWS A5.4/A5.4M (AWS, 2012a)	AWS A5.9/A5.9M (AWS, 2017b)	AWS A5.22/A5.22M (AWS, 2012b)	AWS A5.30/A5.30M (AWS, 2007)
Filler Metal Group A—70-ksi Minimum Tensile Strength, F_{EXX}			
E316L-XX	ER316L	E316LTX-X	IN316L
–	ER316LSi	R316LT1-5	–
–	–	EC316L	–
Filler Metal Group B—75-ksi Minimum Tensile Strength, F_{EXX}			
E308L-XX	ER308L	E308LTX-X	IN308L
E308moL-XX	ER308MoL	E308LMoTX-X	IN316
E309L-XX	ER309L	E309LTX-X	–
E309MoL-XX	ER309MoL	E309LMoTX-X	–
E316-XX	ER316	E309LCbTX-X	–
E316HL-XX	ER316H	E316TX-X	–
E317L-XX	ER317L	E317LTX-X	–
E347L-XX	ER347	E347TX-X	–
–	–	R308LT1-5	–
–	–	R309LT1-5	–
–	–	R347T1-5	–

Notes:
1. The base metal grouping of the following prequalified austenitic stainless steels is as follows:
Base Metal Group A: S30403 and S31603 to ASTM A240/A240M and ASTM A276/A276M.
Base Metal Group B: S30400 and S31600 to ASTM A240/A240M, A276/A276M, A554/A554M and S30403 and S31603 to ASTM A554/A554M.
2. Filler metals of Group B are prequalified for Group A base metals. For prequalified base and filler metals groups of higher strength, refer to AWS D1.6/D1.6M, clause 5.

Welding Stainless Steel – Dissimilar

AISC 370 – New Specifications on Dissimilar Metals

- Consider corrosion resistance and strength matching
  - AWS D1.6/D1.6M
  - Consider low carbon fillers to prevent cracking
- Paint systems shall extend 2” past weld
- Zinc in weld can cause solid metal embrittlement

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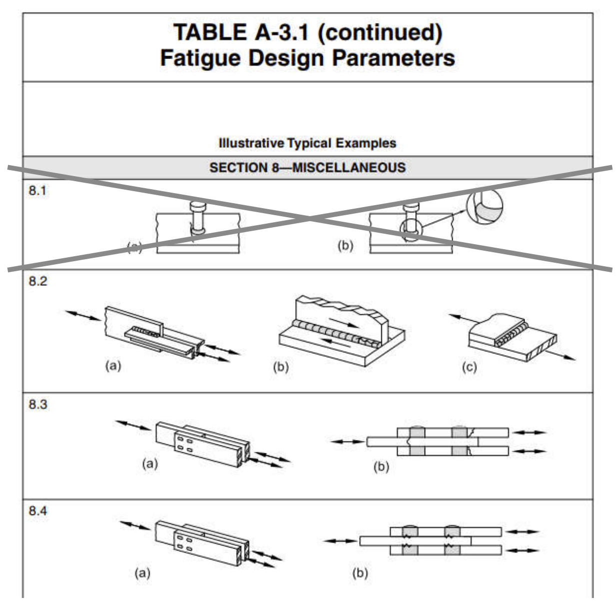
Fatigue of Stainless Steel

AISC 370 Appendix 3 – Fatigue

- Similar crack growth behavior to carbon steel
- Minor changes from 360
- No composite details
- Effect of seawater corrosion not covered



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Outline

1. Fabrication and Erection (ANSI/AISC 370-21 Chapter M)
2. QA/QC (ANSI/AISC 370-21 Chapter N)
3. *Code of Standard Practice for Structural Stainless Steel Buildings*, AISC 313-21

Fabrication – Handling and Storage

Key to successful fabrication and erection of structural stainless steel

Keep it clean!

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Fabrication – Handling and Storage

- Avoid free iron and other metal contamination
  - Work in segregated area, away from carbon steel
  - Cover or protect carbon steel storage racks, lift rigging, lift truck forks, temporary supports
  - Cannot use magnetic lifting equipment for austenitic stainless steel

Vector Custom Fabricating, Inc., Chicago

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Fabrication – Handling and Storage

Photos courtesy of Catherine Houska

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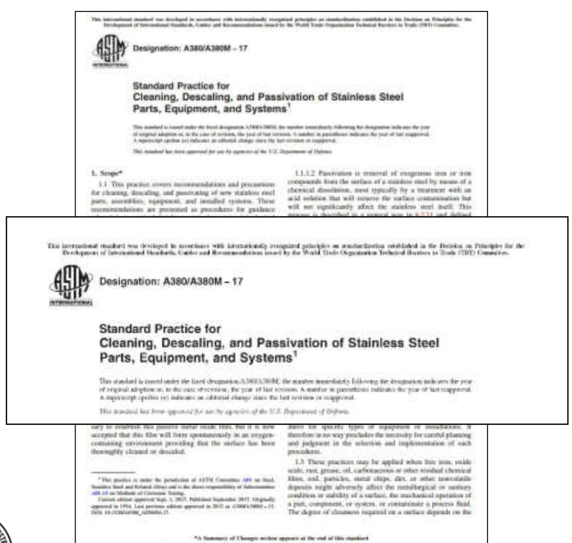
Fabrication – Handling and Storage



Designation: A380/A380M – 17

Standard Practice for
Cleaning, Descaling, and Passivation of Stainless Steel
Parts, Equipment, and Systems[1]

- Pickling
  - Removes <u>embedded</u> iron and other particles
  - Removes heat damaged metal
- Process
  - Preclean to remove oil and grease
  - Acid treatment
  - Water rinse
  - Chemical passivation

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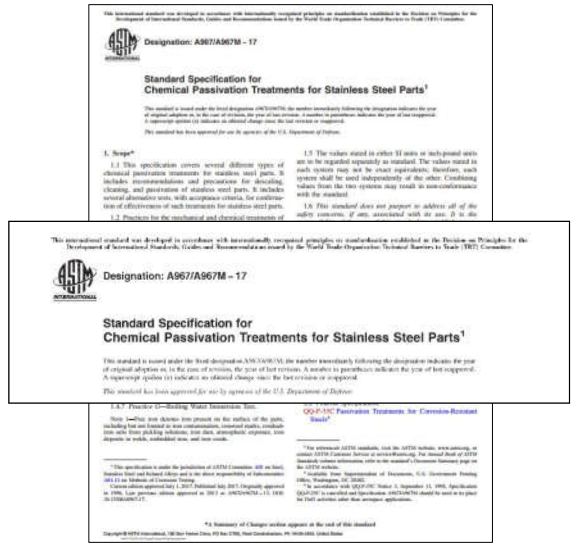
Fabrication – Handling and Storage

- Passivation
  - Removes free iron and other foreign matter from the surface
- Process
  - Preclean to remove oil, grease, rust, scale, and other foreign matter
  - Acid treatment
  - Water rinse
  - Post-cleaning treatment


Designation: A967/A967M – 17

Standard Specification for
Chemical Passivation Treatments for Stainless Steel Parts[1]

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Fabrication – Handling and Storage

- All ASTM Standards referenced in
  - AISC 360
  - AISC 303
  - AISC 370
  - AISC 313

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Fabrication – Handling and Storage

Photos courtesy of Catherine Houska

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Fabrication – Handling and Storage

- Avoid free iron and other metal contamination
  - Dedicated tools, especially grinding wheels and wire brushes
  - Wire brushes and wire wool should be stainless steel
  - Avoid contact with chemicals and acids, including dyes, glues, adhesive tape, hydrochloric acid, cleaning products containing chlorine/chlorides, and excessive amounts of oil and grease

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Fabrication – Handling and Storage

- Use protective film
- Use UV rated film for exposure to sunlight
- Remove film as soon as possible
  - Residual adhesive retains dirt, salt, moisture
  - Use solvents to remove adhesive

Photo courtesy of Catherine Houska

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Fabrication – Camber, Curving, Straightening

- Mechanical means are preferred
- Use heat only if it can be carefully controlled
  - Maximum temperature for austenitic stainless steels: 900°F (480°C)
  - Maximum temperature for duplex stainless steels: 750°F (400°C)
    - Duplex stainless steel require full anneal and rapid quench if temperature is exceeded
- Strain hardening in austenitic stainless steels increases required force

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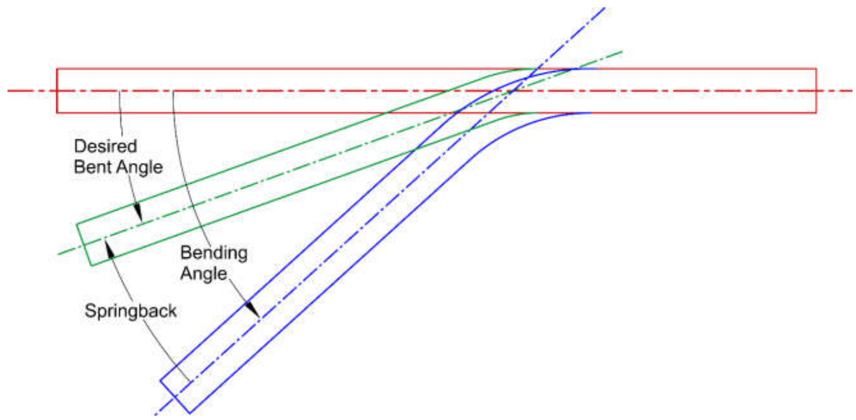
Fabrication – Camber, Curving, Straightening

- Springback



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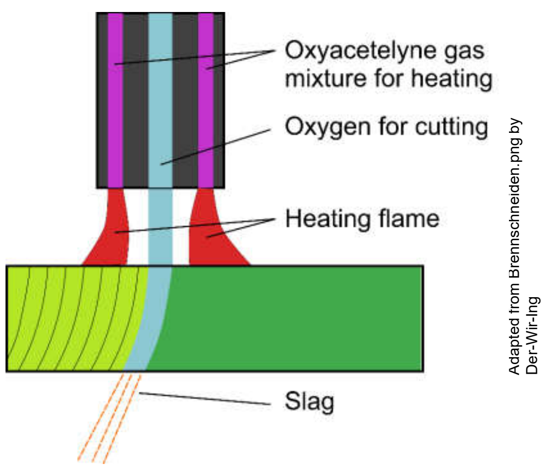
Fabrication – Cutting

- Oxyacetylene cutting "strongly discouraged" for stainless steel



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Fabrication – Cutting

- Permissible cutting methods
  - Shearing
  - Sawing
  - Abrasive cutting
  - Water jet cutting
  - Thermal cutting by plasma or laser

The Runners, 16-foot sculpture by Dr. Theodoros Papagiannis
O'Hare International Airport, Chicago

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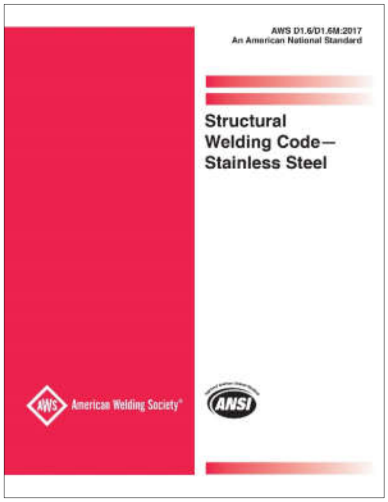
Fabrication – Welding

- AWS D1.6/D1.6M, *Structural Welding Code – Stainless Steel*
- Austenitic stainless steels
  - Generally easily welded
- Duplex stainless steels
  - Weldable
- No preheat



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Fabrication – Welding

- Weld distortion likely, especially with austenitic stainless steels

Material	Thermal Conductivity at 20 °C (68 °F)			Thermal Expansion between 20 and 100 °C (68 and 212 °F)		
	W/m.K	BTU/ hr.ft.°F	Compared to Carbon Steel	10^{-6}/°C	10^{-6}/°F	Compared to Carbon Steel
Carbon Steel	53.3	30.8	--	11.7	6.5	--
Austenitic Stainless Steel	15.0	8.7	-72%	16.0	8.9	+36%
Duplex Stainless Steel	15.0	8.7	-72%	13.0	7.2	+11%

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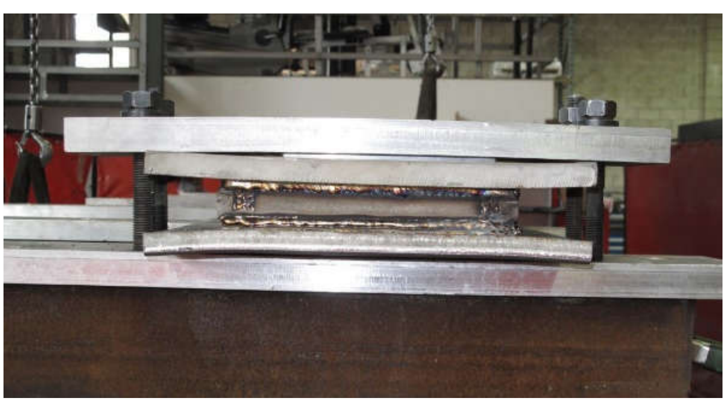
Fabrication – Welding



Photos courtesy of Tripyramid Structures, Inc.

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Fabrication – Welding

- Remove heat tint and additional metal to restore corrosion resistance

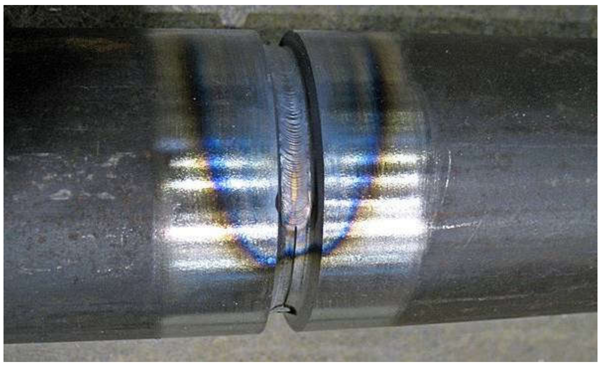

Photo courtesy of ASSDA

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Fabrication – Bolting

- Thermal cut (laser or plasma) holes permitted
  - At least 1/8" of material must be mechanically removed
- Faying surfaces of slip-critical connections

TABLE M2.1
Definition of Surface Classes for Slip-Critical Faying Surfaces

Class	Rz[a]		Rt[b]	
	μin.	μm	μin.	μm
SSB	≥ 1400	≥ 35	≥ 2000	≥ 50
SSC	≥ 1800	≥ 45	≥ 2400	≥ 60
SSD	≥ 2200	≥ 55	≥ 2800	≥ 70

[a] Rz is the surface roughness according to ASTM D7127.
[b] Rt is the surface roughness according to ASTM D4417.

- Must use clean stainless steel grit to blast clean surfaces

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Erection

- Keep it clean
- Fit-up, alignment, stability all the same as AISC 360
- Final cleaning – specify in contract documents

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QA/QC Inspection

- Same as AISC 360, Chapter N
- Magnetic particle testing not acceptable for austenitic stainless steels
- Standard UT does not work on duplex stainless steel because of the dual-phase microstructures

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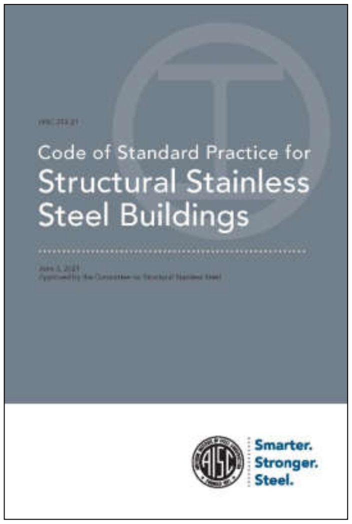
Code of Standard Practice



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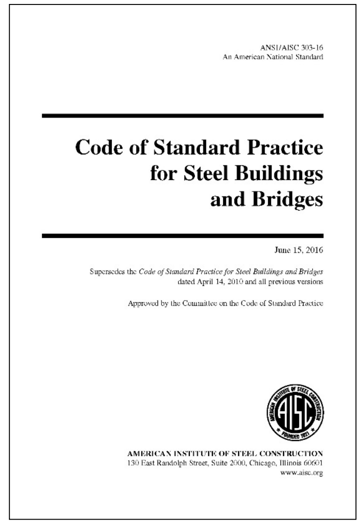

Code of Standard Practice for Structural Stainless Steel Buildings, AISC 313-21

Code of Standard Practice for Steel Buildings and Bridges, ANSI/AISC 303-16

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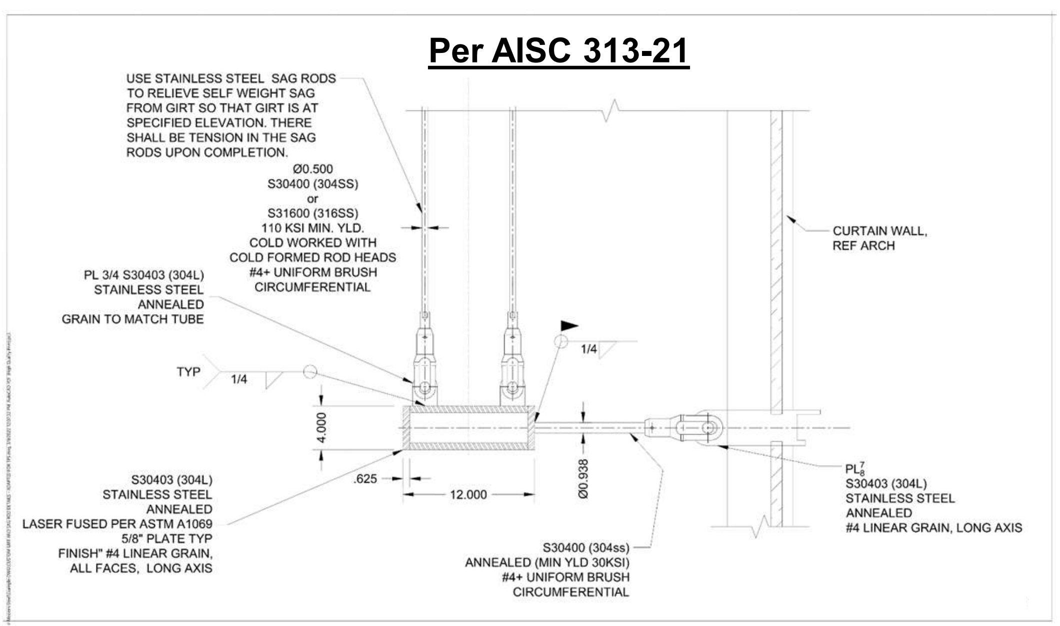
Code of Standard Practice – AISC 313



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Code of Standard Practice – AISC 313

- Materials
  - Sections tolerances per appropriate ASTM standard
  - Stock materials must have mill certification or material test report from independent testing company
- Fabrication
  - Surface roughness of cut edges may increase accumulation of corrosive deposits
  - Tolerances same as AISC 303

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Code of Standard Practice – AISC 313

- Erection
  - Temporary bracing and temporary bolts should have corrosion resistance equal or better than neighboring material
  - Tolerances same as AISC 303
  - Erector is responsible for final cleaning
  - Thermal movement

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Code of Standard Practice – AISC 313

- Architecturally Exposed Structural Stainless Steel (AESSS)
  - AESSS 1 through AESSS 4 all require components be protected for shipping and erection
  - Solvent cleaning per SSPC-SP 1 and meet passivation requirements of ASTM A967
  - Synthetic material for shipping tie-downs and slings

Chattanooga Boiler and Tank Company

Stainless steel canopy over the entrance to Shady Grove underground station - one of 40 similar canopies on the Washington Metro

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AISC | Questions?

Steel Solutions Center

YOU HAVE QUESTIONS. WE HAVE ANSWERS.

Email: solutions@aisc.org
Call: 866.ASK.AISC

Smarter.
Stronger.
Steel.

CEU / PDH Certificates

For those participating at their own connection…

- Reporting attendance is not necessary.
- Certificates will be issued based on AISC's attendance record.
- You will be receiving certificates via email from registration@aisc.org.

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Steel.

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.)
    - 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.

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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.)
- 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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Course Resources

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

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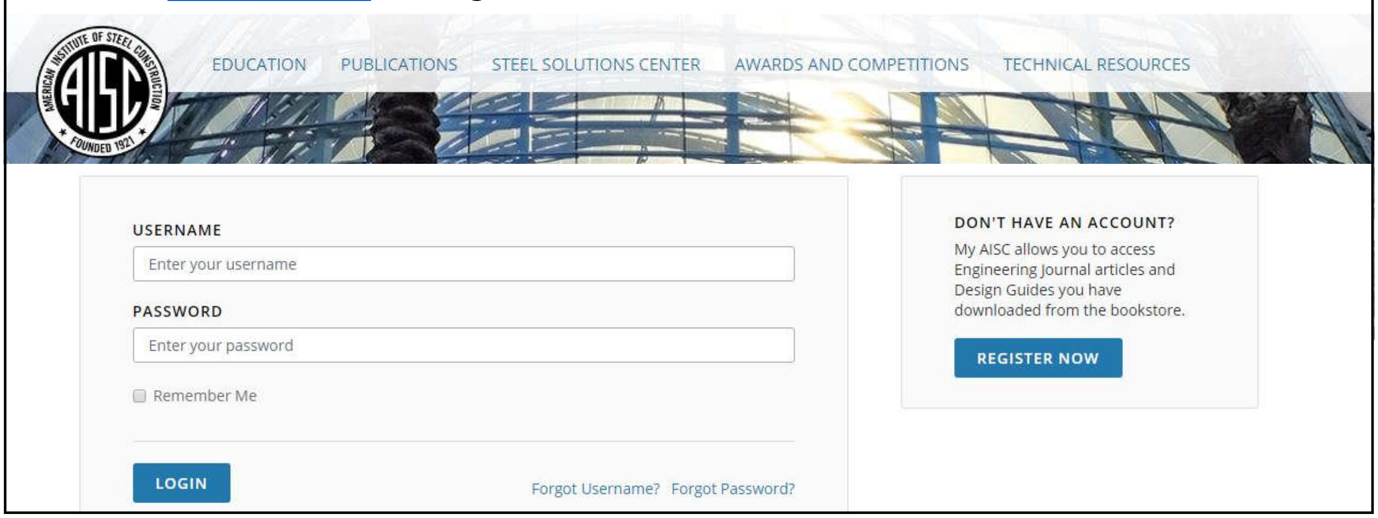
3-Session Registrants

Course Resources

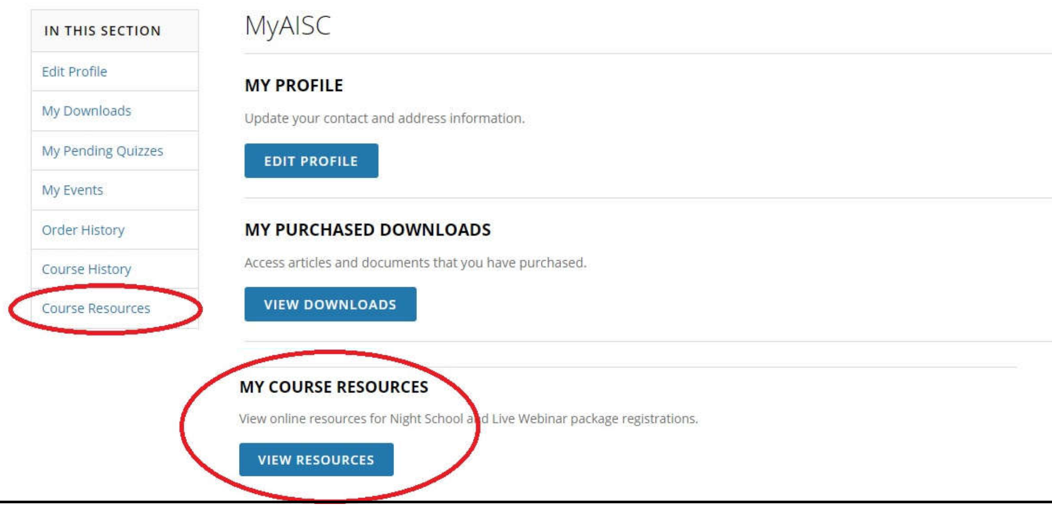
Go to www.aisc.org and sign in.



3-Session Registrants

Course Resources

Go to www.aisc.org and sign in.



3-Session Registrants

Course Resources

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

EDUCATION PUBLICATIONS AWARDS AND COMPETITIONS TECHNICAL RESOURCES STEEL SOLUTIONS CENTER

AISC › MY ACCOUNT › COURSE RESOURCES › DESIGN OF FACADE ATTACHMENTS PACKAGE RESOURCES

Design of Facade Attachments

4-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
R1: Facade Fundamentals	N/A	Handouts	View Passcode: AZNS175	Pass Score: 100	N/A
L1: Façade Attachments Part 1	May 9 2019 1:30PM EDT	Handouts	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	Handouts	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	Handouts	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

Smarter.
Stronger.
Steel.