

Night School 27:
Fundamentals of
Welding and Bolting

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AISC
Night School



Bolting Part 2 – Organizations, Specifications, and Connections

November 9, 2021 | Chad Larson



Smarter.
Stronger.
Steel.



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Course Description

Fundamentals of Bolting and Welding

Session 2: - Bolting Pt. 2: Organizations, Specifications, and Connections

November 9th, 2021

This session will review of standards organizations related to bolted connections and an overview of recent changes to structural bolt standards. An explanation will be given regarding how the connection design relates to bolt selection and use. Design limit states, such as shear and bearing and slip-critical connections will be discussed, including practical suggestions for economical use and practices to minimize the potential for bolt related problems.



Learning Objectives

- List standards organizations responsible for bolted connection specifications.
- List important recent changes to fastener standards.
- Gain an understanding of the basic connection.
- Gain an understanding of how connection design relates to fasteners.
- Describe practical suggestions to keep costs down and projects on schedule.



Night School 27: Fundamentals of Welding and Bolting



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Bolt Company

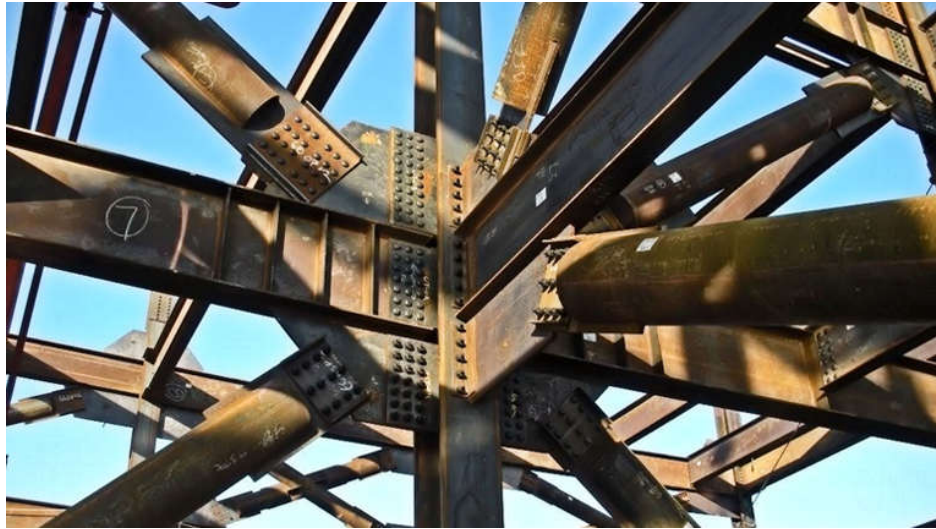


Night School 27: Fundamentals of Welding and Bolting

Bolting Part 2: Organizations, Specifications, and Connections
November 9th, 2021

Chad Larson, LeJeune Bolt Company





Session 1

- **Bolting Background and Basic Concepts**
 - Terms
 - How they are made
 - Cold Forming
 - Hot Forming
 - Thread Rolling
 - Threads and dimensions
 - Shear plane location
 - Lubrication
 - K – Factor



Session 2

- **Organizations, Specifications, and Connections**

- Standards Organizations
- Key events in structural bolting history
- Structural bolt standards
- Engineer responsibility
- Failure modes
- Basic Connections
- Practical tips



Session 3

- **Ordering, Storing, Installing, and Inspecting**

- Ordering information
- Storage and Handling
- Pre-installation testing
- Turn of Nut Method of Pretensioning
- Twist-off Bolt Method of Pretensioning
- DTI Method of Pretensioning
- Calibrated Wrench Method of Pretensioning
- Combined Method of Pretensioning
- Inspection and arbitration inspection



Session 4

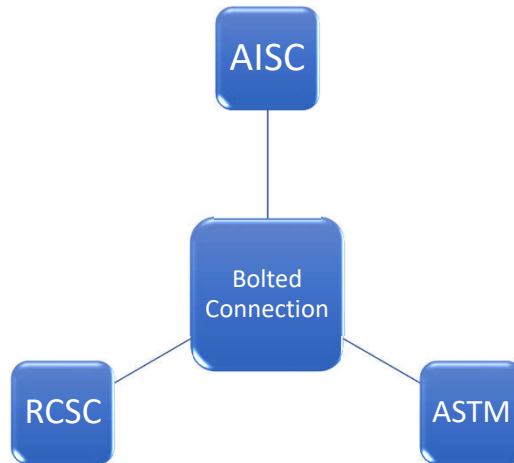
- **Supplementary Requirements, Rotational Capacity Testing, New Standards and Changes to Existing Standards**
 - Rotational capacity testing
 - Coatings on structural bolts
 - Storage and Handling
 - A325T - fully threaded bolts
 - A325S - Special
 - Surface discontinuities
 - Non-conforming material handling
 - Bolt banging
 - Problem solving and prevention



It Takes an Army.....

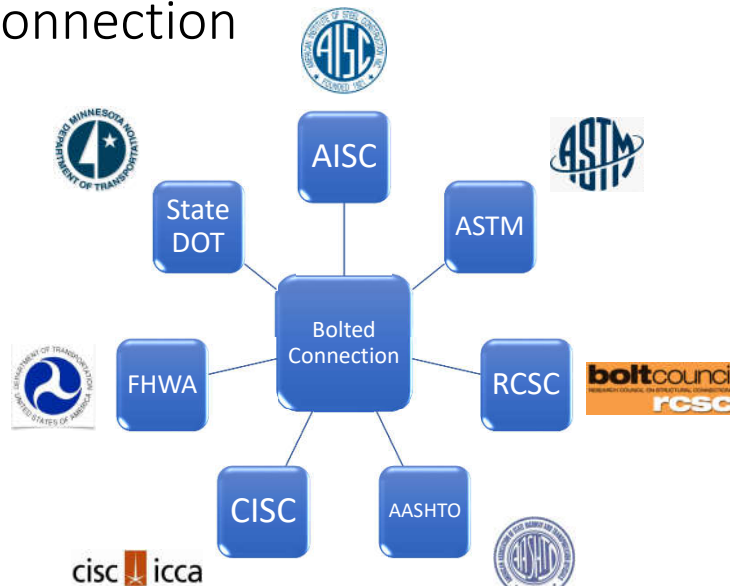


Bolted Connection



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Bolted Connection



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Organizations

- AISC – American Institute of Steel Construction
 - Not-for-profit technical institute and trade association established in 1921 to serve the structural steel design community and construction industry in the United States. AISC’s mission is to make structural steel the material of choice by being the leader in structural-steel-related technical and market-building activities. Selected volunteers and AISC technical staff.
 - Research
 - Standardize
 - Educate
 - Promote



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Organizations

- RCSC – Research Council on Structural Connections
 - The RCSC is a non-profit, volunteer organization, comprised of over 80 leading experts in the fields of structural steel connection design, engineering, fabrication, erection and bolting. Research projects funded by the RCSC serve to provide safety, reliability, and standard practice for the steel construction industry throughout the world.
 - Research
 - Convert that research to practical application
 - “Specification for Structural Joints Using High-Strength Bolts”
 - Can be found in your AISC manual or <http://www.boltcouncil.org>



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Organizations

- ASTM International – Formerly American Society for Testing and Materials
 - Globally recognized leader in the development and delivery of international voluntary consensus standards. Today, some 12,000 ASTM standards are used around the world to improve product quality, enhance safety, facilitate market access and trade, and build consumer confidence.
 - F16 Fastener Committee is 225 of the 30,000 ASTM members.
 - Maintain Structural Bolt, Nut, Washer and related standards
 - All Volunteer
 - No Technical Staff



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Organizations

- ASTM and RCSC are all volunteer.
- Standards are never aligned in real time.
- Often there are discrepancies in standards, updates and balloting to align them take a long time.



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KEY EVENTS IN STRUCTURAL CONNECTIONS

- AISC formed in 1921
- The Research Council on Riveted and Bolted Joints (RCRBSJ) was formed in 1947 as high strength bolt use was on the horizon.
- The original ASTM A325 standard was approved in 1949.
- In January, 1951, the “Specification for Structural Joints Using High-Strength Bolts” was issued by the RCRBSJ, permitting replacement of rivets with bolts on a one-to-one basis. The RCRBSJ later became the RCSC, Research Council on Structural Connections.
- In the 1950’s & 1960’s research in the US, Germany and Great Britain lead to the development of the various standards and specifications, many still in use today.



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KEY EVENTS IN STRUCTURAL CONNECTIONS

- In 1964, high strength A490 bolt research was approved, resulting in a newly titled and modified RCSC “Specification for Structural Joints Using ASTM A325 or A490 Bolts”.
- In 1970, the RCSC recognized the use of Hot Dipped Galvanized (HDG) coated A325 bolts and the use of Type 3 high-strength weathering steel.
- In 1974, the RCSC sponsored book “Guide to Design Criteria for Bolted and Riveted Joints” by J. Fisher and J. Struik, was first published. The second edition by G. Kulak, J. Fisher and J. Struik was published in 1987 and the third edition in 2002. An updated version is in draft form.
- In 1998, the ASTM F1852 standard was approved for Twist-off Tension Control Structural Bolt/Nut/Washer Assemblies.



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KEY EVENTS IN STRUCTURAL CONNECTIONS

- In 2006, the ASTM F2280 standard was approved for Twist-off Tension Control Structural Bolt/Nut/Washer Assemblies.
- In 2014, the ASTM F3043 and F3111 200 ksi standards were approved
- In 2015, the ASTM F3125 was published, which combines six structural bolt specifications into one document.
- In 2015, the ASTM F3148 144 ksi standard was approved.
- In 2020, the RCSC approved the Combined Method of pretensioning and ASTM F3148.



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Material Standards

Structural Bolts, Nuts and Washers



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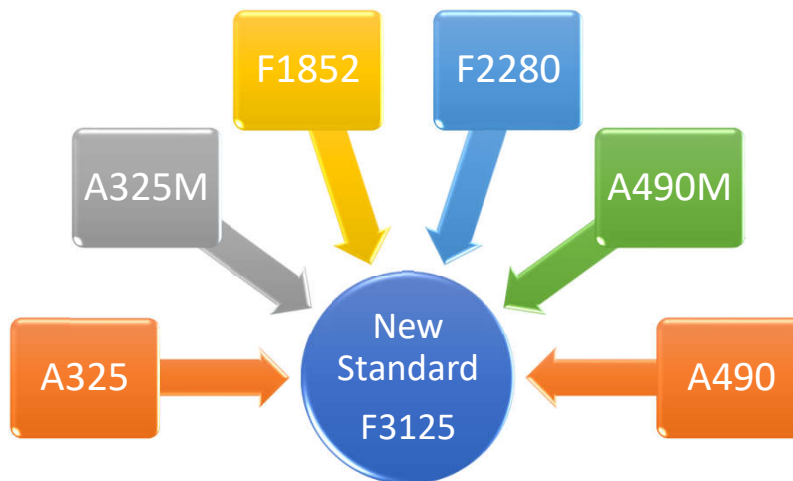
What is ASTM F3125?

- *ASTM F3125 was approved by the ASTM F16 Fastener Committee and cleared for publication by ASTM on January 1st, 2015. F3125 replaced six existing ASTM specifications; A325, A325M, A490, A490M, F1852 and F2280.*
- *Just added to RCSC 2020 edition, already in many other standards, but not all.*



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What is ASTM F3125?



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ASTM F3125



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Why

- *The intent of the combined specification is to streamline and unify language and requirements for structural bolts and to simplify specification maintenance moving forward.*
- *F3125 - nearly all previous technical requirements of the six individual standards remain but new specification adds many needed changes and improvements.*



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A few of the 100+ changes

- Reduction in the total page count from **45** pages down to **13** pages
- Reduction in the number of tables from **54** tables down to **7** tables
- Elimination of **32** cross references
- Increase in minimum tensile strength, proof load and hardness of 1-1/8" and larger A325 bolts, from 105 ksi to 120 ksi
- Addition of a "Type 3" chemistry based on a corrosion index
- Addition of a more defined and useful rotational capacity test



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Six INTO One

The consolidation of multiple ASTM structural bolt standards
will help simplify bolt specification.

BY CHAD LARSON AND THOMAS J. SCHLAFLY

<https://studylib.net/doc/18286153/six-into-one--modern-steel-construction>
<https://www.aisc.org/globalassets/modern-steel/archives/2015/11/six.pdf>



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RCSC 2020 – New Edition

Bolt Council

- 937 total changes
- Significant effort by RCSC specification committee and all volunteer membership



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Where is the RCSC Specification?

The 2014 Edition is

- In the AISC 15th Edition (current) Manual - Section 16.2
- On the AISC website
 - www.aisc.org/publications/steel-standards/
- On the RCSC website
 - www.boltcouncil.org/files/2014RCSCSpecification-withErrata.pdf

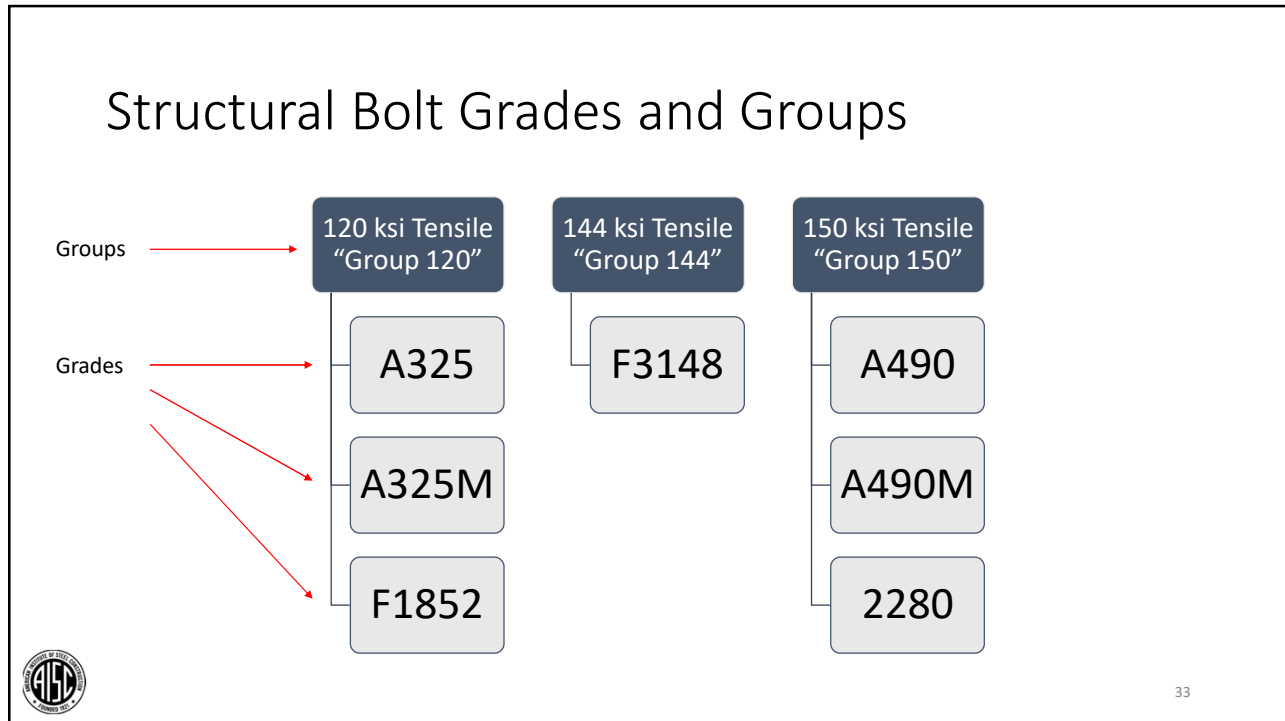
The 2020 Edition is

- On the AISC website
 - www.aisc.org/publications/steel-standards/
- On the RCSC website
 - www.boltcouncil.org/files/2020RCSCSpecification.pdf

The 2020 edition will be printed in the 2023 AISC Manual - Section 16.2




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**Table 2.1
Group Designations for Bolts and
Matched Bolting Assemblies**

RCSC Strength "Group"

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

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New Specifications to Consider

- F3148 144 ksi Fixed Spline bolt assemblies, Combined Method
- We are seeing the first North American implementation of the Combined Method of pretensioning, also known as torque and angle pretensioning
 - Common in Europe
 - Common in other fastening industries
 - Now approved in RCSC



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ASTM F3148



Designation: F3148 – 17a

**Standard Specification for
High Strength Structural Bolt Assemblies, Steel and Alloy
Steel, Heat Treated, 144ksi Minimum Tensile Strength, Inch
Dimensions¹**

This standard is issued under the fixed designation F3148; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.



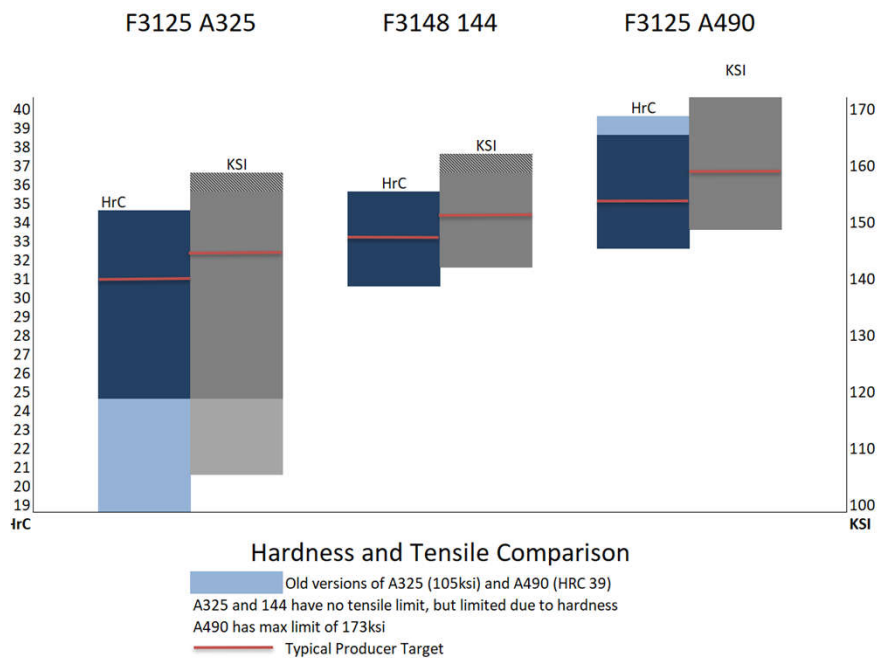
36

Why 144 ksi?

- Optimize strength
- Same materials and processes - tighter controls
- Japan JIS B1186 F10T/S10T common strength in Asia
1000 N/mm² = 145 ksi
- Permit numerous coatings, including HDG, below critical threshold for hydrogen embrittlement
- Probably would not write A325 today, but we are stuck with the legacy in design and inventory



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Structural Bolts



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New Coatings for Structural Bolts

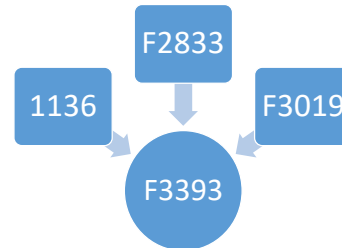
- **F2833** - Standard Specification for Corrosion Protective Fastener Coatings with Zinc Rich Base Coat and Aluminum Organic/Inorganic Type
<https://www.astm.org/Standards/F2833.htm>
- **F3019** - Standard Specification for Chromium Free Zinc-Flake Composite, with or without Integral Lubricant, Corrosion Protective Coatings for Fasteners
<https://www.astm.org/Standards/F3019.htm>
- **A1059** - Standard Specification for Zinc Alloy Thermo-Diffusion Coatings (TDC) on Steel Fasteners, Hardware, and Other Products
<https://www.astm.org/Standards/A1059.htm>



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New Coatings – New Zn/Al Combined Specification

- ASTM F1136
- ASTM F2833
- ASTM F3019



Combined into F3393-20
Zinc-Flake Coating Systems for Fasteners

<https://www.astm.org/Standards/F3393.htm>



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Other Standards Commonly Used

- Heavy hex nuts
 - A563 Grade C, C3 - Group 120, plain only
 - C3 for weathering applications
 - A563 Grade DH - Group 120 or 150, plain or coated
 - A563 Grade DH3
 - For weathering applications
- Washers
 - F436 T1 - plain or coated
 - F436 T3 –weathering applications
 - F959 Direct Tension Indicators – T1 plain or coated
 - F959 Direct Tension Indicators – T3 weathering applications



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Other Standards Used

- When to use other bolt grades
 - A449
 - A354
- Head dimensions, configuration or geometry (can also use “S” in F3125)
- Over 1-1/2” A325 or A490
- Thread length deviation (sometimes)
- Coatings



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What you should know about A354BD

- Dimensions not heavy hex unless you specify
- Consider specifying max tensile strength
- Consider Carb/Decarb testing
- Consider Magnetic Particle testing
- Be careful with thread length
- Be careful with coatings



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- Sometimes very special and unique fasteners are needed to suit design challenges.
- Decision tree should include many items
 - Strength
 - Availability
 - Familiarity
 - Commonality
 - Steel type
 - Coatings
 - Need for substitutions



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Structural Bolt Types

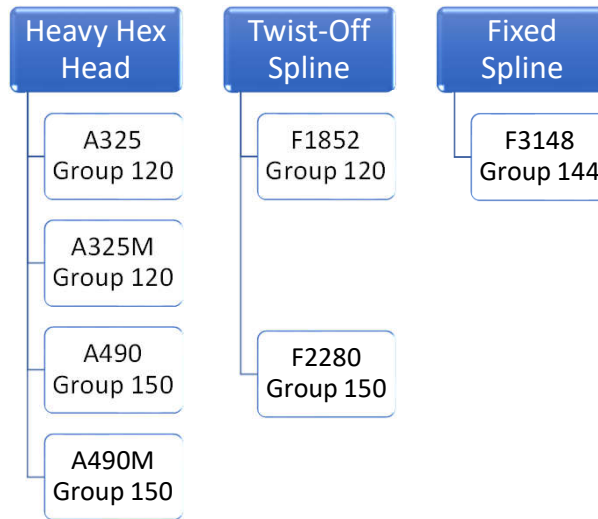
Type 1
Carbon Steel

Type 3
Weathering Steel



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Structural Bolt Styles



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RCSC Length Selection

**Table C-2.2
Bolt Length Selection**

Nominal Bolt Diameter, d_b , in.	To Determine the Required Bolt Length, Add to Grip + Washer + Direct tension indicator, in.
$\frac{1}{2}$	$\frac{1}{16}$
$\frac{5}{8}$	$\frac{7}{8}$
$\frac{3}{4}$	1
$\frac{7}{8}$	$1\frac{1}{8}$
1	$1\frac{1}{4}$
$1\frac{1}{8}$	$1\frac{1}{2}$
$1\frac{1}{4}$	$1\frac{3}{8}$
$1\frac{3}{8}$	$1\frac{3}{4}$
$1\frac{1}{2}$	$1\frac{7}{8}$



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RCSC Group and Grade Designations

**Table 2.1
Group Designations for Bolts and Matched Bolting Assemblies**

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

**Table 2.2
Permitted Nut Grades**

Group Designation	Bolt Type	Coating	ASTM A563 Nut Grade
120	1	Plain	C, C3, D, DH, and DH3
		Coated in compliance with 2.8	DH
	3	Plain	C3 and DH3
144 and 150	1	Plain	DH and DH3
		Coated in compliance with 2.8	DH
	3	Plain	DH3



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EOR Responsibility

1.6. Structural Design Drawings and Specifications

The *Engineer of Record* shall specify the following information in the contract documents:

- (1) The Group designation (Section 2.1) of bolt or *bolting assembly* and steel type (Section 2 Commentary) to be used;
- (2) The *joint* type (Section 4); and
- (3) The required class of slip resistance if *slip-critical joints* are specified (Section 4).



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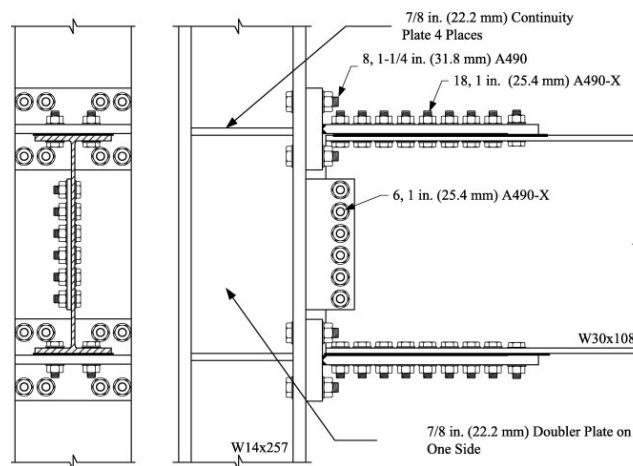
And Also..... (See RCSC Commentary)

- (1) *Bolting assembly* grade, type (type 1 or type 3), *style* (heavy hex or twistoff), coating (hot-dip galvanized, mechanically galvanized, etc.), and any other considerations on special components or installation methods related to the *bolting assembly* (Section 2);
- (2) Specifying when threads must be excluded from the shear plane, if applicable (Section 5);
- (3) Use of *faying surface* coatings in *slip-critical joints* that provide a *mean slip coefficient* determined in accordance with Appendix A, but differing from Class A or Class B coatings (Section 3.2.2(2));
- (4) Use of any materials other than steel within the *joint* (outside of the scope of the Specification, discussed in Commentary to Section 1.1);
- (5) Use of alternative-design *bolting components, assemblies, or installation methods*, including the corresponding installation and inspection requirements that are provided by the *Manufacturer* (Section 2.12);
- (6) *Reuse* of bolts (Section 2.11);
- (7) If *re-pretensioning* of galvanized *bolting assemblies* is required by the *Engineer of Record*, this must be clearly specified in the contract documents (see Commentary to Section 8.2);
- (8) Use of thermal cutting of bolt holes produced free hand or for use in cyclically loaded *joints* (Section 3.3);
- (9) Use of oversized (Section 3.3.2), short-slotted (Section 3.3.3), or long slotted holes (Section 3.3.4) in lieu of standard holes;
- (10) Use of a value of *Du* other than the value provided in Section 5.4;
- (11) Restrictions on the use of hole types (Section 3.3);
- (12) Use of hole sizes larger than permitted in Section 3.3.



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Bolted Connection Basics



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What do we need to know about bolted connections?

Connections depend on...

- Type of loading
- Strength and serviceability requirements
- Economy
- Difficulty or ease of erection



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What do we need to know about bolted connections?

- Steel connections have a direct influence on the cost of the framing system.
- Steel connections are directly related to structural integrity.
- While a connection may be efficient in the use of material, it may still be very expensive to erect.
- Repetitive connection design may save costs but can be boring.



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What do we need to know about bolted connections?

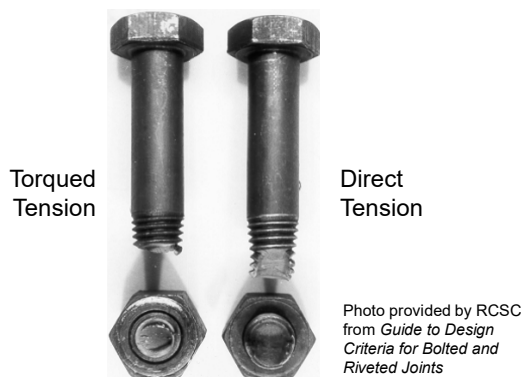
- To know what is needed to make a safe connection, we need to first understand the connection limit states, or how they might fail. Typical bolt related limit states are:
 - Bolt Tensile Rupture
 - Bolt Shear Rupture
 - Plate/Member Bearing/Tear-out
 - Plate/Member Block shear
 - Plate/Member Tensile Strength
 - Plate/Member Yield

The details of connection design and the calculations of limit states are the subjects of other AISC courses. This course is concentrating on the bolt assemblies that are a part of bolted connection design.

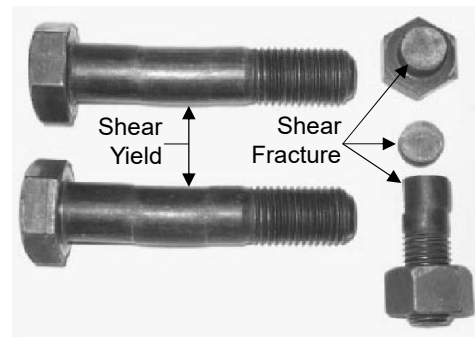


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Bolt Failure



Tension Failure

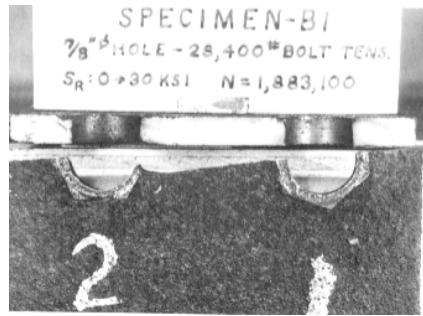
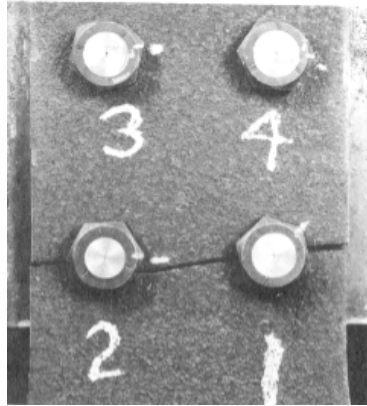


Shear Failure



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Plate Failures



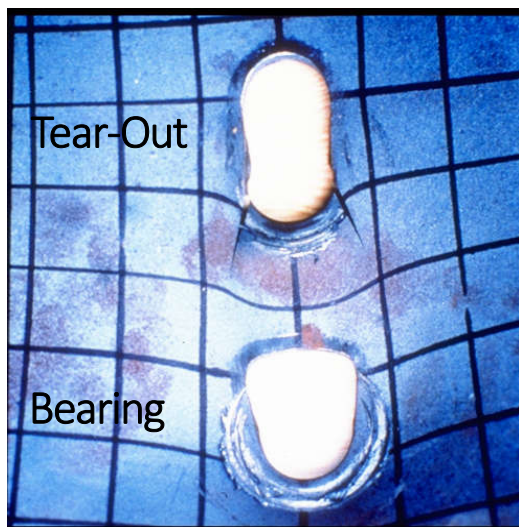
Photos provided by RCSC
from *Guide to Design
Criteria for Bolted and
Riveted Joints*

Plate Rupture - Net Section



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Plate Failures



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Joint Types



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Snug Tight – What is it?

2014 Rev. RCSC Specification

Snug-Tightened Joint. A joint in which the bolts have been installed in accordance with Section 8.1. The snug tightened condition is the tightness that is attained with a few impacts of an impact wrench or the full effort of an ironworker using an ordinary spud wrench to bring the plies into *firm contact*.

2020 Rev. RCSC Specification

Snug-Tight Condition. The joint condition in which the plies have been brought into *firm contact* and each *bolting assembly* has at least the tightness attained with either a few impacts of an impact wrench, resistance to a suitable non-impacting wrench, or the full effort of an ironworker using an ordinary spud wrench.

Snug-Tightened Joint. A joint in which the *bolting assemblies* have been installed to the *snug-tight condition*.



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Snug Tight – What is it?

- Shear/bearing connections and the bolts in them are required to be at least snug tight
- Pretensioning methods depend on achieving the snug tight condition first

2000 – 2004 Rev. RCSC Specification

“The snug-tightened condition is the tightness that is attained with a few impacts of an impact wrench or the full effort of an ironworker using an ordinary spud wrench to bring the plies into firm contact.”

2009 Rev. RCSC Specification

“Snug tight is the condition that exists when all of the plies in a connection have been pulled into firm contact by the bolts in the joint and all of the bolts in the joint have been tightened sufficiently to prevent the removal of the nuts without the use of a wrench.”



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Joint Types

- For *joints* with bolts that are loaded in shear or combined shear and tension, the *Engineer of Record* shall specify the *joint* type in the contract documents as *snug-tightened*, *pretensioned*, or *slip-critical*. For *slip-critical joints*, the required class of slip resistance in accordance with Section 5.4 shall also be specified. For *joints* with bolts that are loaded in tension only, the *Engineer of Record* shall specify the *joint* type in the contract documents as *snug-tightened* or *pretensioned*. Table 4.1 summarizes the applications and requirements of the three *joint* types.



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Table 4.1 Summary of Applications and Requirements for Bolted Joints						
Load Transfer	Application	Joint Type ^{a,b}	Faying Surface Prep.	Install per Section	Inspect per Section	Arbitrate per Section 10
Shear only	Resistance to shear load by shear/bearing.	ST	No	8.1	9.1	No
	Resistance to shear load by shear/bearing. Bolt pretension is required, but for reasons other than slip resistance.	PT	No	8.2	9.2	If req'd to resolve dispute
	Resistance to shear load by friction on faying surfaces is required.	SC	3.2.2	8.2	9.3	If req'd to resolve dispute
Combined shear and tension	Resistance to shear load by shear/bearing. Tension load is static only. ^c	ST	No	8.1	9.1	No
	Resistance to shear by shear/bearing. Bolt pretension is required, but for reasons other than slip resistance.	PT	No	8.2	9.2	If req'd to resolve dispute
	Resistance to shear load by friction on faying surfaces is required.	SC	3.2.2	8.2	9.3	If req'd to resolve dispute
Tension only	Static loading only. ^c	ST	No	8.1	9.1	No
	All other conditions of tension-only loading.	PT	No	8.2	9.2	If req'd to resolve dispute

^a Under Joint Type: ST = snug-tightened, PT = pretensioned, and SC = slip-critical; see Section 4.
^b See Sections 4 and 5 for the design requirements for each joint type.
^c Per Section 4.2, the use of Group 144 and 150 bolts in snug-tightened joints with tensile loads is not permitted.



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Table 5.1 Nominal Strengths per Unit Area of Bolts					
Applied Load Condition			Nominal Strength per Unit Area, F_n , ksi		
			Group 120	Group 144	Group 150
Tension ^a	Static		90	108	113
	Fatigue		See Section 5.5		
Shear ^{a,b}	Threads included in shear plane	$L_s \leq 38$ in.	54	65	68
		$L_s > 38$ in.	45	54	56
	Threads excluded from shear plane	$L_s \leq 38$ in.	68	81	84
		$L_s > 38$ in.	56	68	70

^a Except as required in Section 5.2.
^b Reduction for values for $L_s > 38$ in. applies only when the joint is axially end loaded, such as splice plates on a beam or column flange, but it does not apply for web connections in shear.



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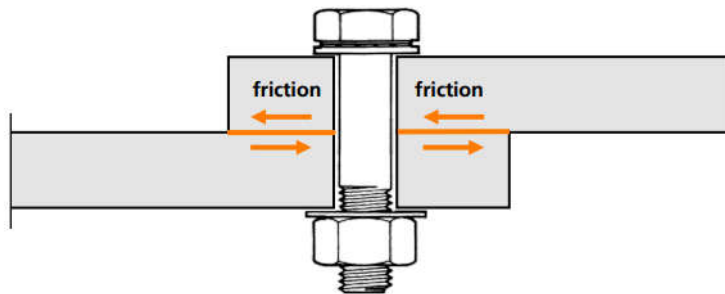
Joint Types

- All connections will have slip resistance as a result of pretension. The pretension present and condition of the faying surfaces will determine the slip resistance. Not all connections are required to be slip-critical. AISC and RCSC detail when a connection should be specified as pretensioned or slip-critical.
- Pretensioning methods (we will discuss in session 3) are the same for pretensioned and slip-critical joints. Slip-critical joints are basically an extension of pretensioned joints, adding specific requirements for faying surfaces to meet a specified level of slip resistance. Slip critical implies any slip is detrimental.



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Joint Types – Slip Critical



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Joint Types – Slip Critical

Required per RCSC 4.3:

- Joints subject to fatigue with reversal of the loading direction
- Joints with oversized holes
- Joints with slotted holes except those with applied load approximately normal to the direction of the long dimension of the slot
- Joints in which slip at the faying surfaces would be detrimental to the performance of the structure



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Joint Types – Slip Critical

Characteristics:

- Designed to prevent slip
- Designed for the limit states of bearing-type connections
- Must consider
 - Proper tension
 - Assurance of proper tension
 - Surface preparation
 - Coatings
- See AISC Sections J3.8 and J3.9 and RCSC Section 4.3 for additional requirements



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The Table Formerly Known as 8.1

- Table 5.2 “Minimum Bolt Pretension” moved from Table 8.1 to the more appropriate design section Table 5.2
- Increase in pretension for F3125 large diameter from 105 to 120 ksi
- Added strength Group 144 here and Table 5.3



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Increase and Relocation

2014

2020

Table 8.1. Minimum Bolt Pretension, *Pretensioned* and *Slip-Critical Joints*

Nominal Bolt Diameter, d_b , in.	Specified Minimum Bolt Pretension, T_m , kips ^a	
	ASTM A325 and F1852	ASTM A490 and F2280
½	12	15
¾	19	24
¾	28	35
¾	39	49
1	51	64
1¼	56	80
1¼	71	102
1¾	85	121
1½	103	148

^a Equal to 70 percent of the specified minimum tensile strength of bolts as specified in ASTM Specifications for tests of full-size ASTM A325 and A490 bolts with UNC threads loaded in axial tension, rounded to the nearest kip.

Nominal Bolt Diameter, d_b , in.	Specified Minimum Bolt Pretension, T_m , kips	
	Minimum Bolt Pretension, <i>Pretensioned</i> and <i>Slip-Critical Joints</i>	
	Group 120	Group 144 and Group 150
½	12	15
¾	19	24
¾	28	35
¾	39	49
1	51	64
1¼	64	80
1¼	81	102
1¾	97	121
1½	118	148

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Group 120 PIV – Increase from 105 ksi to 120 ksi

2014

2020

Table 7.1 Minimum Bolt Pretension for Pre-Installation Verification

Nominal Bolt Diameter, d_b , in.	Minimum Bolt Pretension for Pre-Installation Verification, kips ^a	
	ASTM A325 and F1852	ASTM A490 and F2280
½	13	16
¾	20	25
¾	29	37
¾	41	51
1	54	67
1 ¼	59	84
1 ¼	75	107
1 ¾	89	127
1 ½	108	155

Nominal Bolt Diameter, d^b , in.	Minimum Bolt Pretension for Pre-Installation Verification, kips	
	Minimum Bolt Pretension for Pre-Installation Verification, kips	
	Group 120	Group 144 and Group 150
½	13	16
¾	20	25
¾	29	37
¾	41	51
1	54	67
1 ¼	67	84
1 ¼	85	107
1 ¾	102	127
1 ½	124	155



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Slip Performance of Galvanized Plates

2014 Annual RCSC Meeting
June 6, 2014

Graduate Research Assistant: Sean Donahue
Supervisors: Todd Helwig, Joseph Yura

Project Sponsor: American Institute of Steel Construction,
Research Council on Structural Connections



The University of Texas at Austin
Ferguson Structural Engineering Laboratory

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Galvanized Faying Surfaces 3.2.2



- Testing long ago demonstrated an improvement in slip resistance when hand wire brushing was performed. RCSC has required hand wire brush roughening and prohibited power wire brushing ever since.
 - University of Texas Study (2014) showed no advantage to hand wire brushing. In fact, showed a decrease in performance.
 - As a result, RCSC no longer requires and in fact forbids roughening.
 - AISC still requires – balloting to remove requirement, but not prohibit.
- <https://www.aisc.org/globalassets/aisc/research-library/university-of-texas-report-on-galvanized-slip-coefficients-draft-final-4915.pdf>



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Slip Critical Galvanized Faying Surfaces

Between 1 and 9 slip classes over the years
3.2.2 (3)

2014

(3) *Galvanized Faying Surfaces: Galvanized faying surfaces shall first be hot dip galvanized in accordance with the requirements of ASTM A123 and subsequently roughened by means of hand wire brushing. Power wire brushing is not permitted.* When prepared by roughening, the galvanized faying surface is designated as Class A for design.

2020

(3) *Galvanized Faying Surfaces: Galvanized faying surfaces shall be hot dip galvanized in accordance with the requirements of ASTM A123. Power or hand wire brushing is not permitted.* Galvanized faying surfaces are designated as Class A for design.

2014 RCSC – Roughened by means of hand wire brushing required

2016 AISC – Roughened by means of hand wire brushing required

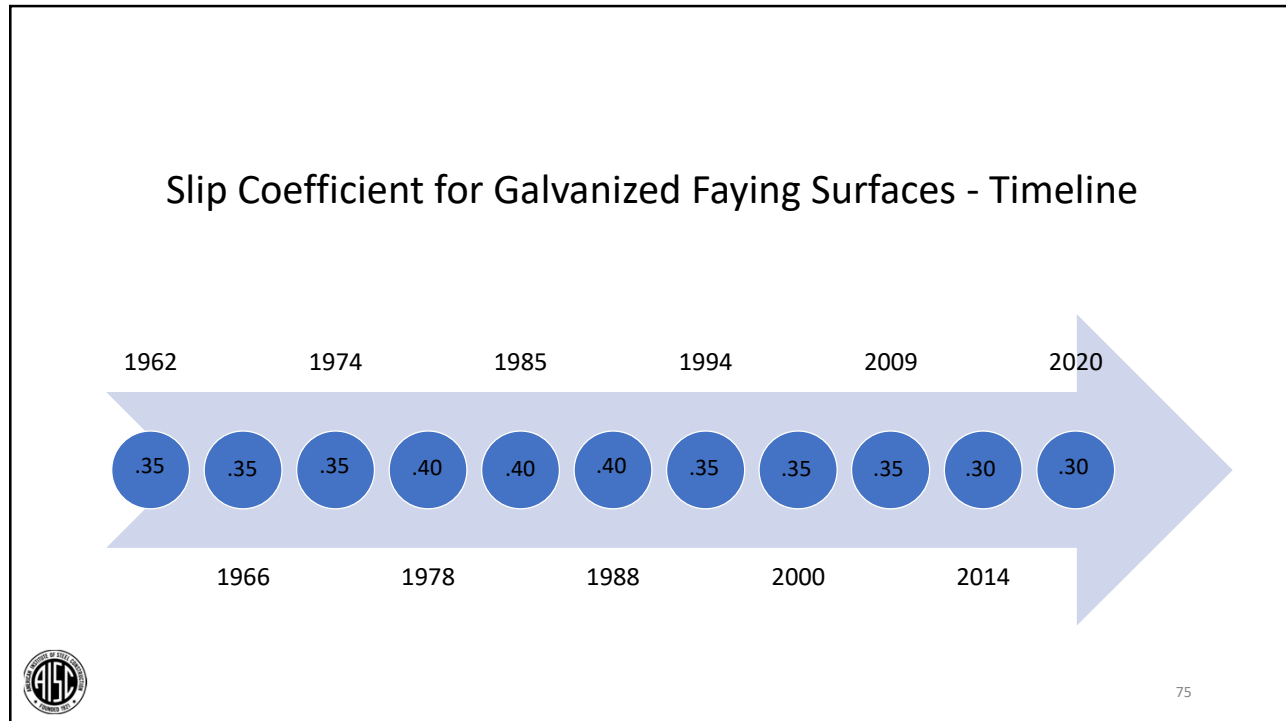
2017 AASHTO – Roughened by means of hand wire brushing no longer required, but not prohibited

2020 RCSC – Roughened by means of hand wire brushing prohibited

2022 AISC – Roughened by means of hand wire brush no longer required, but not prohibited???




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Joint Types – Pretensioned

Required per RCSC 4.2:

- *Pretensioned joints* are required in the following applications:
- (1) *Joints* in which bolt *pretension* is required in the specification or code that invokes the RCSC Specification;
- (2) *Joints* that are subject to significant load reversal;
- (3) *Joints* that are subject to fatigue load with no reversal of the loading direction;
- (4) *Joints* with Group 120 *bolting assemblies* that are subject to tensile fatigue; and
- (5) *Joints* with Group 144 or Group 150 *bolting assemblies* that are subject to tension or combined shear and tension, with or without fatigue.



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Joint Types – Pretensioned

Required per AISC 360-16 J3.1(b):

- As required by the RCSC *Specification*.
- Connection subjected to vibratory loads where bolt loosening is a consideration.
- End connections of built-up members composed of two shapes either interconnected by bolts, or with at least one open side interconnected by perforated cover plates or lacing with tie plates, as required in Section E6.1.



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Joint Types – Pretensioned

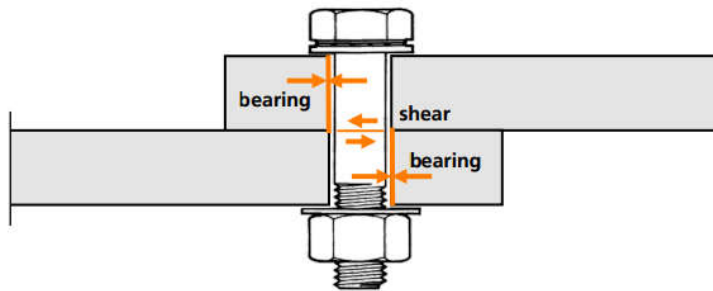
Characteristics:

- A pretensioned connection is one in which tension is required but slip is not detrimental.
- Bolt design strength is based on limit states of bolt tension rupture and shear rupture.



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Shear/Bearing Connection



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Joint Types – Snug-Tightened

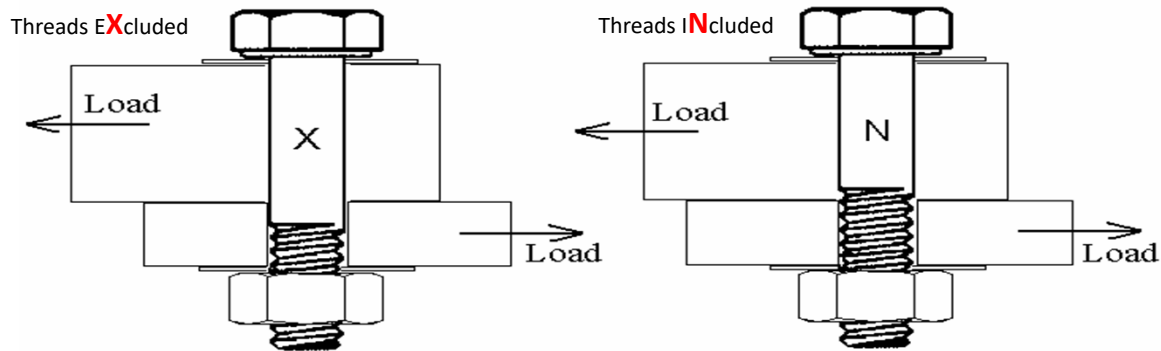
Permitted per RCSC 4.1:

- Snug-tightened joints may be used whenever pretensioned or slip-critical joints are not required.
- Most bolted connections can be specified as snug-tightened only.
- The design strength of the connection must be checked in accordance with AISC J3.
- **Snug-Tightened Joints**
- Except as required in Sections 4.2 and 4.3, *snug-tightened joints* are permitted. Bolts in *snug-tightened joints* shall be designed in accordance with the applicable provisions of Sections 5.1, 5.2 and 5.3, installed in accordance with Section 8.1, and inspected in accordance with Section 9.1. As indicated in Table 4.1, requirements for *faying surface* condition shall not apply to *snug-tightened joints*.



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Understanding Shear



Note: Threads included or excluded from the shear plane changes the design bolt shear strength, but not the physical bolt. Do not order X or N Bolts.



81

Bolts

- Shear strength is approximately 60%-65% of bolt tensile strength
 - Design takes 90% of 62% (RCSC Table 5.1)
 - Further reduced for threads (or transition) in shear plane
 - Connections with thin outer plies
 - Currently a reduction for long end-loaded joints, over 38"
 - Bolt shear is not dependent on tension
 - Installation can be snug tight only



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Table 6.1 Washer Requirements for Pretensioned and Slip-Critical Bolted Joints with Oversized and Slotted Holes in the Outer Ply				
Bolt Group	Nominal Bolt Diameter, d_b , in.	Hole Type in Outer Ply		
		Oversized	Short-Slotted	Long-Slotted
Group 120	$\frac{1}{2} - 1\frac{1}{2}$	ASTM F436 ^a		$\frac{5}{16}$ -in.-thick plate washer or continuous bar ^{b,c}
	≤ 1			
Group 144 and 150	> 1	ASTM F436 extra thick ^{a,b,d}		ASTM F436 washer with either a $\frac{3}{8}$ -in.-thick plate washer or continuous bar ^{b,c}

^a This requirement shall not apply at the head of round heads of ASTM F3125 Grades F1852 and F2280, or F3148 Grade 144 *bolting assemblies* with round heads that meet the requirements in Section 2.4 and provide a bearing circle diameter that meets the requirements of the relevant ASTM Standard.

^b See ASTM F436 Section 1.2. Multiple washers with a combined thickness of $\frac{5}{16}$ in. or larger do not satisfy this requirement.

^c The plate washer or bar shall be of structural-grade steel material, but need not be hardened.

^d Alternatively, a $\frac{3}{8}$ -in.-thick plate washer and an ordinary thickness F436 washer may be used. The plate washer need not be hardened.



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The Hole Truth

- Hole size change in Table 3.1 and addressed in 3.3.1 Commentary
- Standard hole size was nominal + 1/16" for all diameters
- This conflicted with ASME B18.2.6 which permits a fin or swell under the bolt head that could exceed the +1/16" hole size
- Many fabricators were oversizing holes to solve this and other fit problems. Pretensioning is required when oversizing holes
- Increased 1" and larger holes to nominal + 1/8" – helps erection tolerance, bolts fit better, but not considered oversized
- This change **already done in AISC 360-16**



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(2) The body diameter are shown in this table.

(a) 0.030 in. for sizes $\frac{1}{2}$ in.

(b) 0.050 in. for sizes $\frac{5}{8}$ in. and $\frac{3}{4}$ in.

(c) 0.060 in. for sizes over $\frac{3}{4}$ in. through $1\frac{1}{4}$ in.

(d) 0.090 in. for sizes over $1\frac{1}{4}$ in.

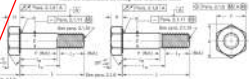


Table 3.1 Dimensions of Heavy Hex Mechanical Bolts

Nominal Size (Inches)	Head Diameter (Inches)	Head Height (Inches)	Hex Head Width (Inches)		Nominal Body Diameter (Inches)	Pitch Diameter (Inches)	Major Diameter (Inches)	Minor Diameter (Inches)	Pitch Diameter (mm)	Major Diameter (mm)	Minor Diameter (mm)
			Across Flats	Across Corners							
1/2	1.116	0.413	1.573	1.573	0.500	0.540	0.492	12.70	13.97	12.50	
5/8	1.500	0.540	2.125	2.125	0.625	0.675	0.620	15.88	17.16	15.75	
3/4	1.875	0.670	2.688	2.688	0.750	0.810	0.750	19.05	20.57	19.05	
7/8	2.250	0.800	3.250	3.250	0.875	0.940	0.875	22.23	23.91	22.23	
1	2.625	0.930	3.813	3.813	1.000	1.070	1.000	25.40	27.14	25.40	
1 1/4	3.500	1.250	5.000	5.000	1.375	1.460	1.375	34.92	37.06	34.92	
1 1/2	4.375	1.570	6.188	6.188	1.750	1.850	1.750	44.45	47.00	44.45	
2	5.750	2.120	8.125	8.125	2.125	2.240	2.125	53.97	57.15	53.97	
2 1/2	7.125	2.700	10.063	10.063	2.625	2.760	2.625	66.68	70.18	66.68	
3	8.500	3.280	12.000	12.000	3.125	3.280	3.125	79.38	83.83	79.38	
3 1/2	9.875	3.860	13.938	13.938	3.625	3.800	3.625	92.09	96.76	92.09	
4	11.250	4.440	15.875	15.875	4.125	4.310	4.125	104.80	110.00	104.80	
4 1/2	12.625	5.020	17.813	17.813	4.625	4.820	4.625	117.51	123.00	117.51	
5	14.000	5.600	19.750	19.750	5.125	5.330	5.125	130.22	136.00	130.22	
5 1/2	15.375	6.180	21.688	21.688	5.625	5.840	5.625	142.93	149.00	142.93	
6	16.750	6.760	23.625	23.625	6.125	6.360	6.125	155.64	162.00	155.64	
6 1/2	18.125	7.340	25.563	25.563	6.625	6.890	6.625	168.35	175.00	168.35	
7	19.500	7.920	27.500	27.500	7.125	7.420	7.125	181.06	188.00	181.06	
7 1/2	20.875	8.500	29.438	29.438	7.625	7.860	7.625	193.77	201.00	193.77	
8	22.250	9.080	31.375	31.375	8.125	8.300	8.125	206.48	214.00	206.48	
8 1/2	23.625	9.660	33.313	33.313	8.625	8.750	8.625	219.19	227.00	219.19	
9	25.000	10.240	35.250	35.250	9.125	9.200	9.125	231.90	240.00	231.90	
9 1/2	26.375	10.820	37.188	37.188	9.625	9.760	9.625	244.61	253.00	244.61	
10	27.750	11.400	39.125	39.125	10.125	10.320	10.125	257.32	266.00	257.32	
10 1/2	29.125	12.000	41.063	41.063	10.625	10.590	10.625	270.03	279.00	270.03	
11	30.500	12.600	43.000	43.000	11.125	10.860	11.125	282.74	292.00	282.74	
11 1/2	31.875	13.200	44.938	44.938	11.625	11.140	11.625	295.45	305.00	295.45	
12	33.250	13.800	46.875	46.875	12.125	11.420	12.125	308.16	318.00	308.16	
12 1/2	34.625	14.400	48.813	48.813	12.625	11.700	12.625	320.87	331.00	320.87	
13	36.000	15.000	50.750	50.750	13.125	11.980	13.125	333.58	344.00	333.58	
13 1/2	37.375	15.600	52.688	52.688	13.625	12.260	13.625	346.29	357.00	346.29	
14	38.750	16.200	54.625	54.625	14.125	12.540	14.125	359.00	370.00	359.00	
14 1/2	40.125	16.800	56.563	56.563	14.625	12.820	14.625	371.71	383.00	371.71	
15	41.500	17.400	58.500	58.500	15.125	13.100	15.125	384.42	396.00	384.42	
15 1/2	42.875	18.000	60.438	60.438	15.625	13.380	15.625	397.13	409.00	397.13	
16	44.250	18.600	62.375	62.375	16.125	13.660	16.125	409.84	422.00	409.84	
16 1/2	45.625	19.200	64.313	64.313	16.625	13.940	16.625	422.55	435.00	422.55	
17	47.000	19.800	66.250	66.250	17.125	14.220	17.125	435.26	448.00	435.26	
17 1/2	48.375	20.400	68.188	68.188	17.625	14.500	17.625	447.97	461.00	447.97	
18	49.750	21.000	70.125	70.125	18.125	14.780	18.125	460.68	474.00	460.68	
18 1/2	51.125	21.600	72.063	72.063	18.625	15.060	18.625	473.39	487.00	473.39	
19	52.500	22.200	74.000	74.000	19.125	15.340	19.125	486.10	500.00	486.10	
19 1/2	53.875	22.800	75.938	75.938	19.625	15.620	19.625	498.81	513.00	498.81	
20	55.250	23.400	77.875	77.875	20.125	15.900	20.125	511.52	526.00	511.52	
20 1/2	56.625	24.000	79.813	79.813	20.625	16.180	20.625	524.23	539.00	524.23	
21	58.000	24.600	81.750	81.750	21.125	16.460	21.125	536.94	552.00	536.94	
21 1/2	59.375	25.200	83.688	83.688	21.625	16.740	21.625	549.65	565.00	549.65	
22	60.750	25.800	85.625	85.625	22.125	17.020	22.125	562.36	578.00	562.36	
22 1/2	62.125	26.400	87.563	87.563	22.625	17.300	22.625	575.07	591.00	575.07	
23	63.500	27.000	89.500	89.500	23.125	17.580	23.125	587.78	604.00	587.78	
23 1/2	64.875	27.600	91.438	91.438	23.625	17.860	23.625	600.49	617.00	600.49	
24	66.250	28.200	93.375	93.375	24.125	18.140	24.125	613.20	630.00	613.20	
24 1/2	67.625	28.800	95.313	95.313	24.625	18.420	24.625	625.91	643.00	625.91	
25	69.000	29.400	97.250	97.250	25.125	18.700	25.125	638.62	656.00	638.62	
25 1/2	70.375	30.000	99.188	99.188	25.625	18.980	25.625	651.33	669.00	651.33	
26	71.750	30.600	101.125	101.125	26.125	19.260	26.125	664.04	682.00	664.04	
26 1/2	73.125	31.200	103.063	103.063	26.625	19.540	26.625	676.75	695.00	676.75	
27	74.500	31.800	105.000	105.000	27.125	19.820	27.125	689.46	708.00	689.46	
27 1/2	75.875	32.400	106.938	106.938	27.625	20.100	27.625	702.17	721.00	702.17	
28	77.250	33.000	108.875	108.875	28.125	20.380	28.125	714.88	734.00	714.88	
28 1/2	78.625	33.600	110.813	110.813	28.625	20.660	28.625	727.59	747.00	727.59	
29	80.000	34.200	112.750	112.750	29.125	20.940	29.125	740.30	760.00	740.30	
29 1/2	81.375	34.800	114.688	114.688	29.625	21.220	29.625	753.01	773.00	753.01	
30	82.750	35.400	116.625	116.625	30.125	21.500	30.125	765.72	786.00	765.72	
30 1/2	84.125	36.000	118.563	118.563	30.625	21.780	30.625	778.43	799.00	778.43	
31	85.500	36.600	120.500	120.500	31.125	22.060	31.125	791.14	812.00	791.14	
31 1/2	86.875	37.200	122.438	122.438	31.625	22.340	31.625	803.85	825.00	803.85	
32	88.250	37.800	124.375	124.375	32.125	22.620	32.125	816.56	838.00	816.56	
32 1/2	89.625	38.400	126.313	126.313	32.625	22.900	32.625	829.27	851.00	829.27	
33	91.000	39.000	128.250	128.250	33.125	23.180	33.125	841.98	864.00	841.98	
33 1/2	92.375	39.600	130.188	130.188	33.625	23.460	33.625	854.69	877.00	854.69	
34	93.750	40.200	132.125	132.125	34.125	23.740	34.125	867.40	890.00	867.40	
34 1/2	95.125	40.800	134.063	134.063	34.625	24.020	34.625	880.11	903.00	880.11	
35	96.500	41.400	136.000	136.000	35.125	24.300	35.125	892.82	916.00	892.82	
35 1/2	97.875	42.000	137.938	137.938	35.625	24.580	35.625	905.53	929.00	905.53	
36	99.250	42.600	139.875	139.875	36.125	24.860	36.125	918.24	942.00	918.24	
36 1/2	100.625	43.200	141.813	141.813	36.625	25.140	36.625	930.95	955.00	930.95	
37	102.000	43.800	143.750	143.750	37.125	25.420	37.125	943.66	968.00	943.66	
37 1/2	103.375	44.400	145.688	145.688	37.625	25.700	37.625	956.37	981.00	956.37	
38	104.750	45.000	147.625	147.625	38.125	25.980	38.125	969.08	994.00	969.08	
38 1/2	106.125	45.600	149.563	149.563	38.625	26.260	38.625	981.79	1007.00	981.79	
39	107.500	46.200	151.500	151.500	39.125	26.540	39.125	994.50	1020.00	994.50	
39 1/2	108.875	46.800	153.438	153.438	39.625	26.820	39.625	1007.21	1033.00	1007.21	
40	110.250	47.400	155.375	155.375	40.125	27.100	40.125	1019.92	1046.00	1019.92	
40 1/2	111.625	48.000	157.313	157.313	40.625	27.380	40.625	1032.63	1059.00	1032.63	
41	113.000	48.600	159.250	159.250	41.125	27.660	41.125	1045.34	1072.00	1045.34	
41 1/2	114.375	49.200	161.188	161.188	41.625	27.940	41.625	1058.05	1085.00	1058.05	
42	115.750	49.800	163.125	163.125	42.125	28.220	42.125	1070.76	1098.00	1070.76	
42 1/2	117.125	50.400	165.063	165.063	42.625	28.500	42.625	1083.47	1111.00	1083.47	
43	118.500	51.000	167.000	167.000	43.125	28.780	43.125	1096.18	1124.00	1096.18	
43 1/2	119.875	51.600	168.938	168.938	43.625	29.060	43.625	1108.89	1137.00	1108.89	
44	121.250	52.200	170.875	170.875	44.125	29.340	44.125	1121.60	1150.00	1121.60	
44 1/2	122.625	52.800	172.813	172.813	44.625	29.620	44.625	1134.31	1163.00	1134.31	
45	124.000	53.400	174.750	174.750	45.125	29.900	45.125	1147.02	1176.00	1147.02	
45 1/2	125.375	54.000	176.688	176.688	45.625	30.180	45.625	1159.73	1189.0		

Increase in Nominal Hole Size – Already Done in AISC 360-16

**Table 3.1
Nominal Bolt Hole Dimensions**

Nominal Bolt Diameter, d_b , in.	Nominal Bolt Hole Dimensions ^{a,b} , in.			
	Standard (diameter)	Oversized (diameter)	Short-Slotted (width × length)	Long-Slotted (width × length)
1/2	9/16	5/8	9/16 × 11/16	9/16 × 1 1/4
5/8	11/16	13/16	11/16 × 7/8	11/16 × 1 9/16
3/4	13/16	15/16	13/16 × 1	13/16 × 1 7/8
7/8	15/16	1 1/16	15/16 × 1 1/8	15/16 × 2 3/16
1	1 1/8	1 1/4	1 1/8 × 1 5/16	1 1/8 × 2 1/2
≥ 1 1/8	$d_b + 1/8$	$d_b + 5/16$	$(d_b + 1/8) × (d_b + 3/8)$	$(d_b + 1/8) × (2.5d_b)$

^a The detailed hole dimension shall not exceed the nominal. The fabricated hole dimension shall not exceed the nominal + 1/32 in. Exception: In the width of slotted holes, gouges not more than 1/16 in. deep are permitted.
^b The slightly conical hole that naturally results from punching operations with properly matched punches and dies is acceptable.



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Considerations

- Erector may prefer a certain bolt or joint type because of equipment, QC requirements, experience, cost, etc.
- Inspection requirements increase for slip-critical connections



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The Bolt Effect

- Many connections that do not require pretension have significant pretension
 - Effort required to straighten and compact plies
 - Sequential snugging passes create high levels of clamp load
 - Overzealous snugging
 - Good lubricants or coatings mean high pretension with little effort, especially in small diameters
 - We use bolts to tighten things our entire lives. It is counter-intuitive not to tension them, so we often do, even though design may not specifically require it.



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Efficiency and Practicality

- Start organized
 - Work with erectors for constructability and bolting preferences early on
 - Communicate with the design team and the build team
 - Try to detail your intentions along with your requirements
 - Be careful not to go overboard with requirements
- Use trusted partners whenever possible
- Get good and timely detailing
- Efficiency in design isn't always the most efficient



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Efficiency and Practicality

- Think standard
 - Use standard connections when possible
 - Specify readily available materials
 - Use standard tolerances, they are there for a reason
 - Provide for tolerances like O/S holes, S/S holes, installation tools, etc.
 - Keep load paths simple



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Efficiency and Practicality

- Don't get tripped up
 - Don't combine like diameters of different grades
 - Use common bolt sizes when possible 3/4", 7/8", 1"
 - Get a jumpstart on early sequences, especially anchors and shop bolts
- Everyone want to leave their mark or work on a signature project. It's OK if your mark is just "on time and on budget".



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Thank you!

AISC | Questions



Individual Session Registrants

PDH Certificates

- All WFH individuals associated with a group registration will be issued a certificate.
- All individuals attending at your connection: you will receive an email on how to report their attendance from: registration@aisc.org.
 - Be on the lookout: Check your spam filter! Check your junk folder!
 - Completely fill out online form. Don't forget to check the boxes next to each attendee's name!



8-Session Registrants

PDH Certificates

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



8-Session Registrants

Access to the quiz

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

Quiz and attendance records

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

Reasons for quiz

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

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



8-Session Registrants

Access to the recording

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

PDHs via recording

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



8-Session Registrants

Night School Resources

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



8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.



Login

If you're an existing customer, please enter your username and password.

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Enter your username

PASSWORD

Enter your password

Remember Me

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My AISC allows you to access Engineering Journal articles and Design Guides you have downloaded from the bookstore.

[REGISTER NOW](#)

8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.

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8-Session Registrants

Night School Resources



Course Resources

Event	Start Date
NS_13 8-Session Package: Night School 13 - Design of Industrial Buildings	1/30/2017 7:00:00 PM
NS_14 8-Session Package: Night School 14 - Fundamentals of Stability	6/5/2017 7:00:00 PM



8-Session Registrants

Night School Resources



Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	View Passcode: NS13DSN	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	Handouts	Available 02/08/2017 5pm EST	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	Handouts	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	Handouts	Available 03/01/2017 5pm EST	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girder Design and Frame Analysis	3/6/2017 7:00:00 PM	Handouts	Available 03/08/2017 5pm EST	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	Handouts	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Bldg Bracing Dan	3/27/2017 7:00:00 PM	Handouts	Available 03/29/2017 5pm EST	Available 03/29/2017 5pm EST	Pending
NS13 - Building Envelope and Bracing Design	4/3/2017 7:00:00 PM	Handouts	Available 04/05/2017 5pm EST	Available 04/05/2017 5pm EST	Pending

8-Session Registrants

Night School Resources

- Weekly “quiz and recording” email.
- Weekly updates of the master quiz and attendance record, found at www.aisc.org/nightschool27. Scroll down to Quiz and Attendance records.
 - Updated on Friday mornings.

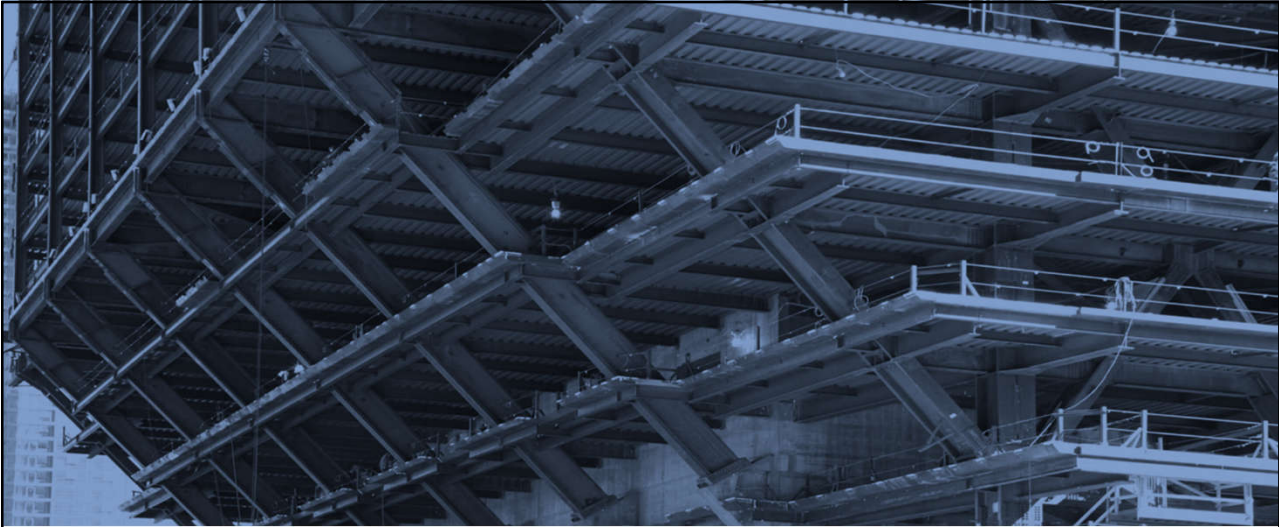


8-Session Registrants

Night School Resources

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





AISC | Thank you

