Night School 27: Fundamentals of Welding and Bolting

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

Bolting Part 4 – Arbitration Inspection, Supplementary Requirements, Rotational Capacity Testing, Coatings, Reuse and Testing

December 7, 2021 | Chad Larson

Smarter. Stronger. Steel.

AISC Night School

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Course Description

Fundamentals of Welding and Bolting

Session 8: - Bolting Pt. 4: Arbitration Inspection, Supplementary Requirements, Rotational Capacity Testing, Coatings, Reuse and Testing

December 7, 2021

This session will provide an understanding of specific supplementary requirements for fasteners. New and old fastener coatings, bolt reuse, and rotational capacity testing will be explained.

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Learning Objectives

- Learn about **arbitration inspection.**
- Learn about **supplementary requirements.**
- Learn about **rotational capacity testing.**
- Learn about **structural fastener coatings.**
- Learn about **bolt reuse.**
- Learn about **fastener testing.**
- Gain an understanding of **nonconformances.**

Night School 27: Fundamentals of Welding and Bolting

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Night School 27: Fundamentals of Welding and Bolting

Bolting Pt. 4: Arbitration Inspection, Supplementary Requirements, Rotational Capacity Testing, Coatings, Reuse and Testing
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Part 3 Review

- Ordering Information
- Alternative Designs
- Storage and Handling
- Snug Tight
- Pretensioning Methods
  - Turn of Nut
  - Calibrated wrench
  - Twist-Off Type
  - DTI Washer
  - Combined Method

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RCSC Added ASTM F3148 and Combined Method

- **ASTM F3148**
  - New strength - Group 144
  - Uses Combined Method for pretensioning
  - Fixed spline drive
  - Minimum pretension equal to Grade A490
  - Approved in ANSI/AISC 358
  - Currently balloting in AISC 360-22
  - On Agenda for AASHTO T-14 and AREMA Committee 15

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What is ASTM F3148?

- Inner socket engages and holds the bolt
- Outer socket engages and turns the nut
- Torque reaction absorbed via gears
- Tool controls torque and angle output
- Spline stays on
- Single-side turn of nut
- Matched and tested assemblies

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Delft University of Technology

Evaluation tightening
preloaded bolt assemblies according to
EN 1090-2
"Technical requirements for steel structures"
for 95% reliability EN 1990 *

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Delft university of technology

2 Conclusions

2.1 Clause 8.5.1 of EN 1090-2 determines that "unless otherwise specified the nominal minimum preloading force $F_{p,c}$ shall be taken as $0,7\ f_{ub}A_s$".
EN 1990 determines in clause 4.2 that this nominal minimum preload $F_{p,c} = 0,7\ f_{ub}A_s$, shall be reached with a reliability of 95% according to a Normal distribution.

The values for the reliability according to the present methods mentioned in EN 1090-2 are determined as:

1. The torque method:	reliability	79,4	%
2. The combined method:	reliability	100	%
3. The HRC method:	reliability	81	%
4. The direct tension indicator (DTI) method:	reliability	> 95	%

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Arbitration inspection

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Arbitration Inspection

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SECTION 10. ARBITRATION - RCSC

- When it is suspected after inspection in accordance with Section 9.2 or Section 9.3 that bolts in *pretensioned* or *slip-critical joints* do not have the proper *pretension*, the following arbitration procedure is permitted.

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Section 10 - Arbitration

- (1) A representative sample of five bolt and nut assemblies of each combination of diameter, length, grade and *lot* in question shall be installed in a *bolt tension measurement device*. The material under the turned element shall be the same as in the actual installation— that is, structural steel or hardened washer. The bolt shall be partially tightened to approximately 15 percent of the *pretension* specified in Table 5.2 Subsequently, the bolt shall be *pretensioned* to the minimum value specified in Table 5.2.
- (2) A torque wrench that indicates torque by means of a readout, or one that may be adjusted to give an indication that a defined torque has been reached, shall be applied to the *pretensioned* bolt. The torque that is necessary to rotate the nut or bolt head five degrees (approximately 1 in. at 12-in. radius) relative to its mating component in the tightening direction shall be determined.

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Section 10 - Arbitration

- (3) The *arbitration torque* shall be determined by rejecting the high and low values and averaging the remaining three.
- (4) Bolts represented by the above sample shall be tested by applying the *arbitration torque* in the tightening direction to 10 percent of the *bolting assemblies*, but no fewer than two *bolting assemblies*, selected at random in each *joint* in dispute. If no nut or bolt head is turned relative to its mating component by the application of the *arbitration torque*, the *joint* shall be accepted as properly *pretensioned*.

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Section 10 - Arbitration

- If verification of bolt *pretension* is required after the passage of a period of time and exposure of the completed *joints*, an alternative arbitration procedure that is appropriate to the specific situation shall be used.
- If any nut or bolt is turned relative to its mating component by an attempted application of the *arbitration torque*, all bolts in the *joint* shall be tested. Those bolts whose nut or head is turned relative to its mating component by the application of the *arbitration torque* shall be re-*pretensioned* by the *Fabricator* or *Erector* and reinspected. Alternatively, the *Fabricator* or *Erector*, at his/her option, is permitted to re-*pretension* all of the bolts in the *joint* and subsequently resubmit the *joint* for inspection.

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RCSC Arbitration Commentary

- **Commentary:**
- When bolt *pretension* is arbitrated using torque wrenches after *pretensioning*, such arbitration is subject to all of the uncertainties of torque-controlled *calibrated wrench method* installation that are discussed in the Commentary to Section 8.3.2. Additionally, the reliability of after-the-fact torque wrench arbitration is reduced by the absence of many of the controls that are necessary to minimize the variability of the torque to *pretension* relationship, such as:
- (1) The use of hardened washers;
- (2) Careful attention to lubrication; and
- (3) The uncertainty of the effect of passage of time and exposure in the installed condition.

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RCSC Arbitration Commentary

- Furthermore, in many cases such arbitration may have to be based upon an *arbitration torque* that is determined either using bolts that can only be assumed to be representative of the bolts used in the actual job or using bolts that are removed from completed *joints*. Ultimately, such arbitration may wrongly reject *bolting assemblies* that were subjected to a properly implemented installation procedure or accept *bolting assemblies* that were not properly installed. The arbitration procedure contained in this Specification is provided, in spite of its limitations, as the most feasible available at this time.

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Supplementary Requirements

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S1. Bolts Threaded Full Length

S1.1 A325 and A325M Bolts with nominal lengths equal to or shorter than 4D may be threaded full length. These bolts need not have a shoulder.

S1.2 Bolts shall be marked in accordance with Table 2, except that the symbol shall include a "T", for example "A325T".

S1.3 The distance from the under-head bearing surface to the first complete (full form) thread, as measured with a GO thread ring gauge, assembled by hand as far as the thread will permit, shall not exceed the length of 2½ threads for bolt sizes 1 in. and smaller, and 3½ threads for bolt sizes larger than 1 in.

S2. Alternate Dimensions

S2.1 Dimensions which differ from the requirements of this specification, such as modified head geometry or special thread lengths that do not meet the requirements of section S1, are permitted when requested by the customer.

S2.2 Bolts manufactured to S2 shall have a marking indicating "S" for "special", in addition to the marking required in Table 2, for example, "A325S" or "A490S".

Note S1—Many structural connection designs require the shear strength of a full body fastener. Increased thread lengths may place reduced diameters in shear planes reducing connection strength. Increased thread lengths may also affect installed pretensions when using the turn of the nut installation method.

S3. Lubricant

S3.1 User-specified lubrication requirements may include lubricated sealers used with coating systems, colored lubricants, or specified K factors. These may work in combination with or in replacement of lubrication requirements in the A563 and A563M specifications.

S3.2 Lubrication requirements shall be as agreed in writing between the user and supplier.

S3.3 Supplemental lubricants are not permitted on Twist-Off style assemblies except when applied by the manufacturer, see 7.5.4.

S3.4 Lubricant applied to a lot's components shall be the same as that specified by the purchaser or used by the manufacturer during testing to meet the lot's tension or rotational capacity requirements.

S4. Rotational Capacity Testing for Plain and Other Coated Assemblies.

S4.1 When specified on the inquiry and order, rotational capacity testing in accordance with Annex A2 shall be performed by the responsible party.

S4.1.1 Rotational capacity tests shall include sets of one bolt, one nut, and at least one washer. Sampling shall be to F1470, except the minimum sample size in all cases shall be two assemblies.

S4.1.2 Rotational capacity tests may be specified for plain or coated fastener assemblies.

S4.1.3 Rotational capacity testing shall result in an assembly lot number, which must be unique for each combination of bolt, nut and washer lot used.

S4.1.4 Assembly lot rotational capacity test reports and product labeling to maintain assembly lot traceability is required.

S4.1.5 Components shall be packed together when practicable to prevent comingling with other lots.

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What are F3125 S1 – S4

- **S1. Bolts Threaded Full Length**
  - Just like what it says, up to 4D
  - Special Marking "T" - *A325T*
  - Uses and cautions – Turn of Nut - Shear Strength
- **S2. Alternate Dimensions – previously pushed to A354 or A449**
  - Just like what it says
  - Special marking "S" - *A325S*
  - Uses and cautions
- **S3. Lubricant**
- **S4. Rotational Capacity Testing**

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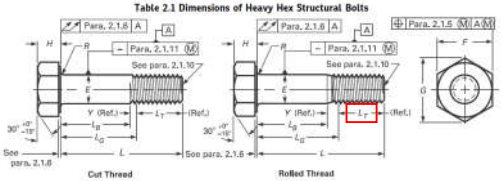
What are F3125 S1

Table 2.1 Dimensions of Heavy Hex Structural Bolts



Nominal Size or Basic Product Diameter [Note (1)]	Body Diameter, E [Notes (2) and (3)] Max.	Body Diameter, E [Notes (2) and (3)] Min.	Width Across Flats, F [Note (4)] Nominal	Width Across Flats, F [Note (4)] Max.	Width Across Flats, F [Note (4)] Min.	Width Across Corners, G Max.	Width Across Corners, G Min.	Head Height, H [Note (5)] Nominal	Head Height, H [Note (5)] Max.	Head Height, H [Note (5)] Min.	Radius of Fillet, R Max.	Radius of Fillet, R Min.	Thread Length, L_T [Note (6)] Ref.	Transition Thread Length, Y [Note (6)] Ref.	Maximum Total Runout of Bearing Surface FIM [Note (7)]
½	0.500	0.515	0.482	⅞	0.875	0.850	1.010	0.969	5/16	0.323	0.302	0.031	0.009	1.00	0.19	0.016
⅝	0.625	0.642	0.605	1 1/16	1.062	1.031	1.227	1.175	25/64	0.403	0.378	0.062	0.031	1.25	0.22	0.019
¾	0.750	0.768	0.729	1 1/4	1.250	1.212	1.443	1.383	15/32	0.483	0.455	0.062	0.031	1.38	0.25	0.022
⅞	0.875	0.895	0.852	1 7/16	1.438	1.394	1.660	1.589	35/64	0.563	0.531	0.062	0.031	1.50	0.28	0.025
1	1.000	1.022	0.976	1 5/8	1.625	1.575	1.876	1.796	39/64	0.627	0.591	0.093	0.062	1.75	0.31	0.028
1 1/8	1.125	1.149	1.098	1 13/16	1.812	1.756	2.093	2.002	11/16	0.718	0.658	0.093	0.062	2.00	0.34	0.032
1 1/4	1.250	1.277	1.223	2	2.000	1.938	2.309	2.209	25/32	0.813	0.749	0.093	0.062	2.00	0.38	0.035
1 3/8	1.375	1.404	1.345	2 1/16	2.188	2.119	2.526	2.416	27/32	0.878	0.810	0.093	0.062	2.25	0.44	0.038
1 ½	1.500	1.531	1.470	2 3/8	2.375	2.300	2.742	2.622	15/16	0.974	0.902	0.093	0.062	2.25	0.44	0.041

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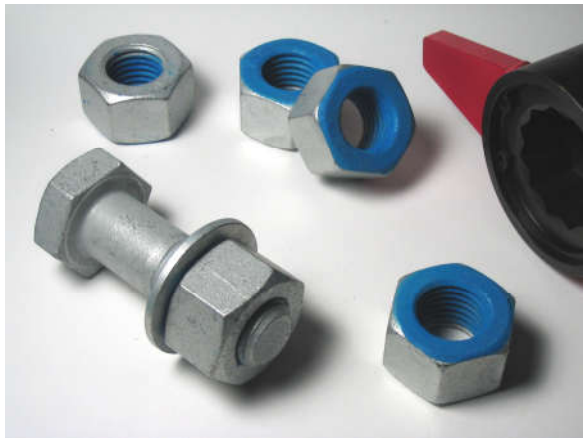
S3



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Rotational Capacity

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Original Rotational Capacity Test

ASTM

- Established by F16.02 for HDG bolts based on research that showed un-lubricated HDG fasteners could not reliably reach minimum tension prior to torsional failure. Expanded to cover Mechanically Galvanized fasteners when B695 was added.
- A means to test lubrication, which is required to prevent galling at the thread interface and bearing surface.
- Old ASTM test was a simple Pass/Fail test. You never knew if you *almost* failed.
- Vague manufacturer requirement in A325 and RCSC.
- Assuming bolt meets specification, the test is primarily a function of nut (or coating) lubrication but was part of the bolt only specification.

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Rotational Capacity Testing

AASHTO and FHWA established a similar test, adding the requirement that the test be performed on ALL structural fasteners for bridge work, not just galvanized.

- Had more specific test criteria than the simple pass/fail ASTM test.
- Added maximum torque at minimum design tension (max K factor of .25).
- Minimum tension at final rotation (1.15 * design tension).
- This test was a better overall general fastener assembly performance test.
- These agencies only use bolts subject to full pretension.

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Rotational Capacity Testing

Primary criteria tested-

- Strength (tensile)
- Thread fit (proper oversize to avoid interference fit)
- Thread strength (overtap not too large or wrong grade)
- Lubrication (too little causes torsional failure)
- Ductility (extreme plastic performance or stretch beyond yield)
- Quantifies (lubrication effectiveness)

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Problems with RC Testing

- Nature of the test makes variability inevitable. Number of producers. Number of threads in the grip. Different lubricants (or none at all).
- Required by ASTM at the producer level but really should be at the distribution and end user level (At least until we require bolts to be treated as matched assemblies from the producer).
- Not all fastener assemblies need this level of performance by design. Think Snug.
- A490 previously held to the same criteria as A325, but A490 is much less ductile.
- AASHTO, FHWA did not like (appropriately) the ASTM test, so they maintained their own versions of the test. Thankfully, the industry has now aligned on the new ASTM tests in F3125 and F3148.

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Rotational Capacity Test - F3125 Annex A2.1.1

- Details rotational capacity (RC) tests intended to evaluate the presence of lubricant, the efficiency of lubricant and the compatibility of assemblies. The test serves as a further quality control measure against excessively overtapped nuts, material with insufficient ductility, and generally assures the assembly of elements (bolt, nut, and washer) will function together as a unit to achieve required preloads. When tested to meet the requirements of this Annex, assemblies shall be purchased and installed as matched sets of a Heavy bolt, a Heavy Hex Nut, and at least one Hardened Washer. Assemblies shall be purchased and installed as matched sets.
- This test is intended primarily for galvanized heavy hex fastener assemblies that must be fully tensioned in structural applications. This test may also be requested by the purchaser for other coated or plain assemblies that must be fully pretensioned.

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Rotational Capacity Test

- *Equipment Required:*
- Calibrated bolt tension-measuring device appropriate for the bolts to be tested.
- Calibrated torque wrench and spud wrenches.
- Appropriate bushings and spacers.

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Rotational Capacity Test

- Install the bolt and any required spacers in the tension measuring device so that the bolt stick-out is flush with the nut to a maximum of three threads stick-out. This will typically provide three to five threads within the grip.
- Tighten the fastener assembly to the tensions listed in Table A2.1 (-0/+2 kips or -0/+8 kN).

F3125/F3125M – 19ε2

TABLE A2.1 Pre-tension Requirements by Strength and Diameter

Strength	Bolt Dia. (in.)	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½
120 ksi min.	Initial Tension (kips)	1	2	3	4	5	6	8	10	12
150 ksi min.	Initial Tension (kips)	1	2	4	5	6	8	10	12	15
	Bolt Dia. (mm)	12	16	20	22	24	27	30		36
830 MPa min.	Initial Tension (kN)	4	9	13	18	22	27	31		44
1040 MPa min.	Initial Tension (kN)	9	13	18	22	27	36	40		58

- Match-mark the bolt, nut and faceplate of the calibrator.

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Rotational Capacity Test

- Tighten the fastener assembly to at least the minimum installation tension in Table A2.2 and record both the tension and torque. The torque shall be read with the nut in motion. Maximum torque values at minimum tension are provided for convenience in Table A2.2. For tensions exceeding minimum tension, the torque shall not exceed 0.25 PD, where P = tension in pounds, and D = Dia. (in.)/12 = bolt diameter in feet.

TABLE A2.2 Maximum Permitted Torque at Minimum Design Tension[A]

Strength	Bolt Dia. (in.)	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½
120 ksi min.	Tension (kips)[A]	12	19	28	39	51	64	81	97	118
	Maximum Torque (ft. lbs.)	125	247	437	710	1062	1502	2120	2779	3688
150 ksi min.	Tension (kips)[A]	15	24	35	49	64	80	102	121	148
	Maximum Torque (ft. lbs.)	156	312	546	893	1333	1875	2656	3466	4625
	Bolt Dia. (mm)	12	16	20	22	24	27	30		36
830 MPa min.	Tension (kN)[A]	49	93	142	178	205	267	325		476
	Maximum Torque (Nm)	150	380	719	976	1234	1803	2440		4284
1040 MPa min.	Tension (kN)[A]	61	114	178	221	257	334	408		595
	Maximum Torque (Nm)	190	461	895	1220	1546	2251	3064		5369

[A] Minimum design in the RCSC Specification for Structural Joints Using High-Strength Bolts. It represents 70% of minimum specified tensile strength.

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Lubrication

Bolt Dia. 0.75		K - Factor 0.09	K - Factor 0.11	K - Factor 0.13	K - Factor 0.15	K - Factor 0.17	K - Factor 0.19	K - Factor 0.21	K - Factor 0.23	K - Factor 0.25
Tension	1000	6	7	8	9	11	12	13	14	16
in lbs.	5000	28	34	41	47	53	59	66	72	78
	10000	56	69	81	94	106	119	131	144	156
	15000	84	103	122	141	159	178	197	216	234
	20000	113	138	163	188	213	238	263	288	313
	25000	141	172	203	234	266	297	328	359	391
	30000	169	206	244	281	319	356	394	431	469
	35000	197	241	284	328	372	416	459	503	547
	40000	225	275	325	375	425	475	525	575	625
	45000	253	309	366	422	478	534	591	647	703

Torque, ft./lbs.

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Rotational Capacity Test

- Further tighten the nut to the rotation listed in Table A2.3. The rotation is measured from the initial marking. Assemblies that strip or fracture prior to this rotation fail the test.

TABLE A2.3 Minimum Required Degrees of Rotation

Bolt Length Required Rotation	Up to 4D	>4D to 8D	>8D to 12D
120 ksi (830 MPa) min	240	360	420
150 ksi (1040 MPa) min	240	300	360

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Rotational Capacity Test

- Record the tension at the completion of the rotation in Table A2.3. The tension shall equal or exceed 1.15 × the minimum installation tension. The minimum required values are listed in Table A2.4. Loosen and remove the nut. There shall be no signs of thread shear failure, stripping or torsional failure. The nut shall turn on the bolt threads to the position it was in during the test. The nut does not need to run the full length of the threads. Inability to turn the nut by hand is considered thread failure. Broken bolts fail the test.

TABLE A2.4 Minimum Tension at Full Rotation

Strength	Bolt Dia. (in.)	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½
120 ksi min.	Tension (kips)	14	22	32	45	59	74	94	112	136
150 ksi min.	Tension (kips)	17	28	40	56	74	92	117	139	170
	Bolt Dia. (mm)	12	16	20	22	24	27	30		36
830 MPa min.	Tension (kN)	57	108	164	205	235	307	373		547
1040 MPa min.	Tension (kN)	72	133	205	256	297	384	471		685

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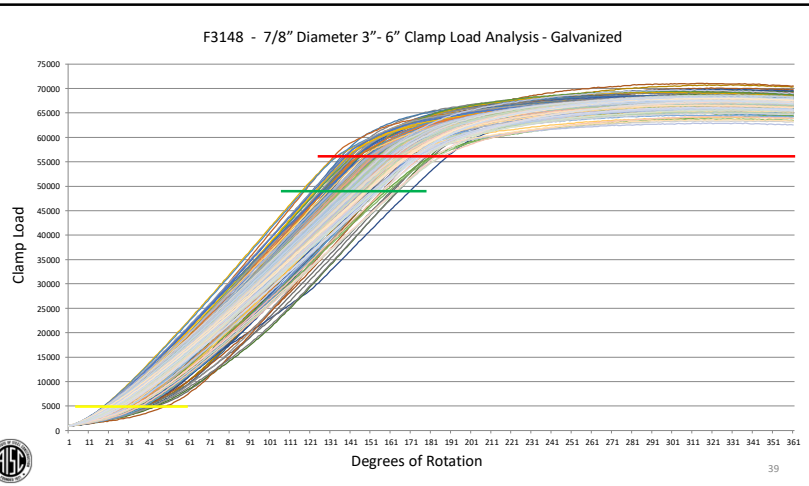

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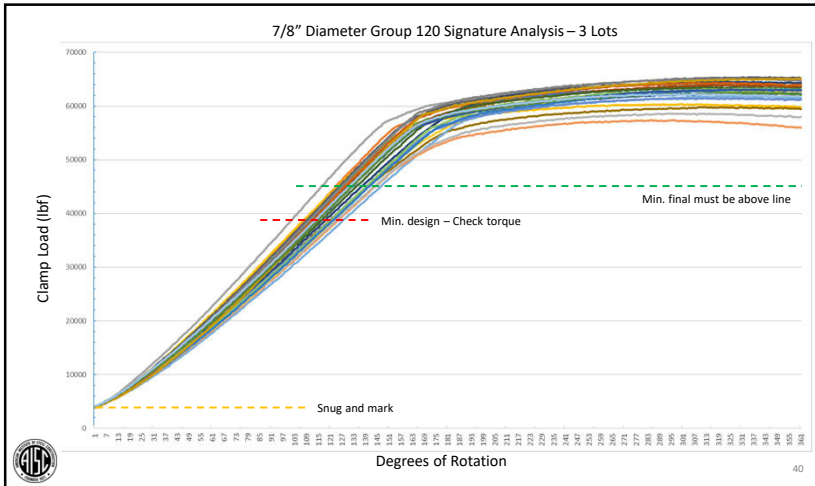

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Rotational Capacity Test

- Applicable to coated fasteners (sometimes) – ASTM.
- Required on all assembly lots (plain or galvanized) for bridge work – see AASHTO.
- Good, but extreme functional test of fasteners.
  - What if connection only requires snug tight?

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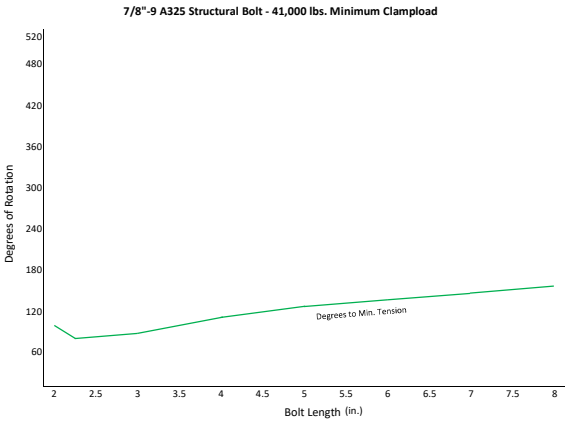

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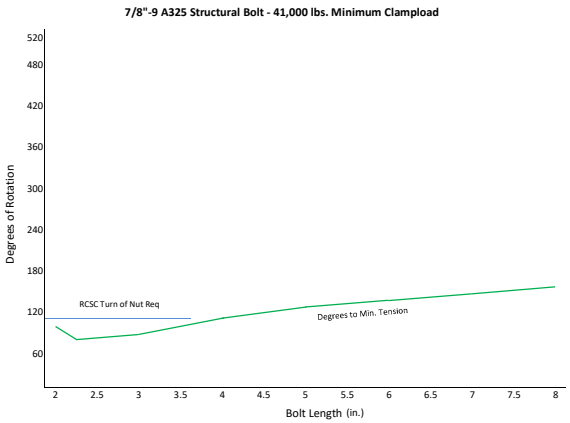

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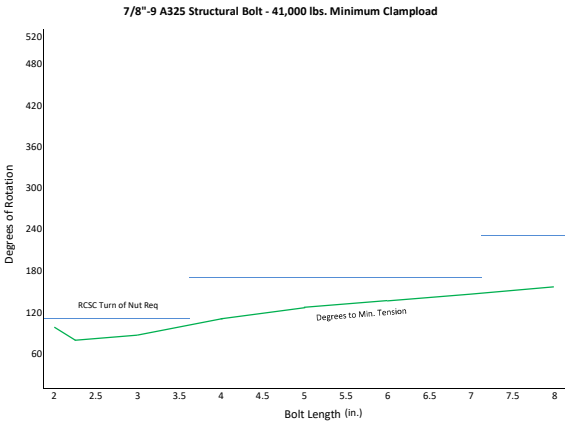

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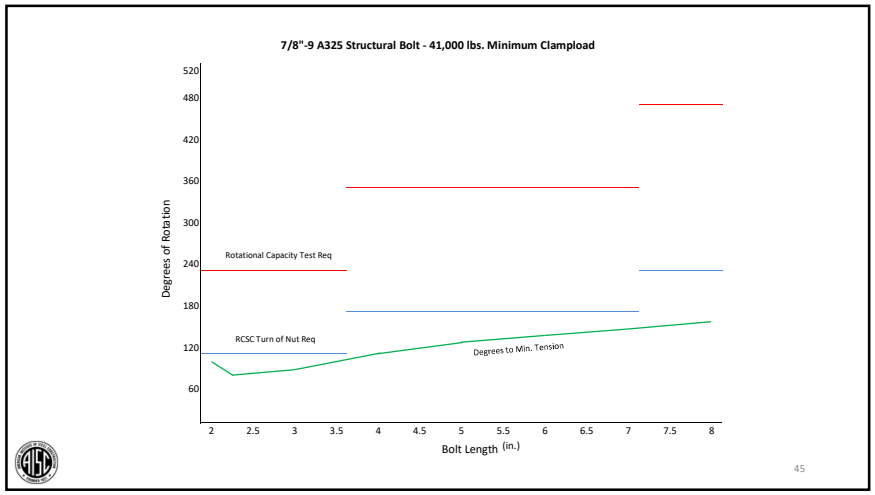

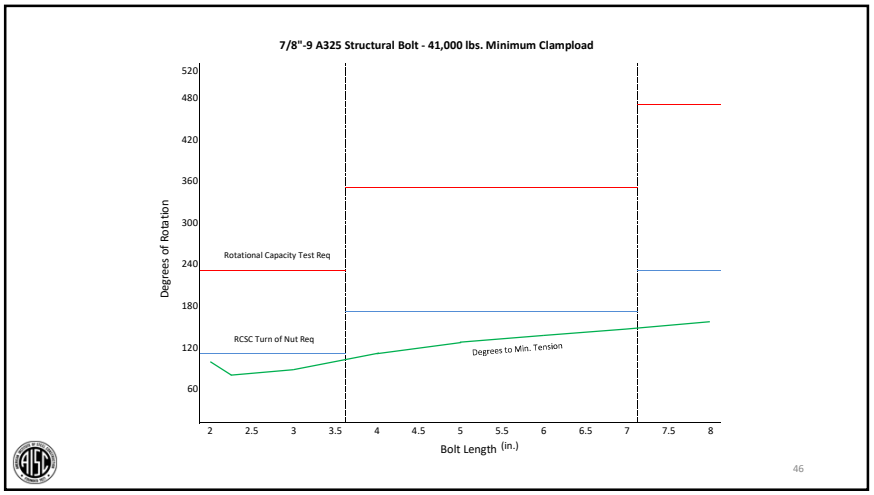

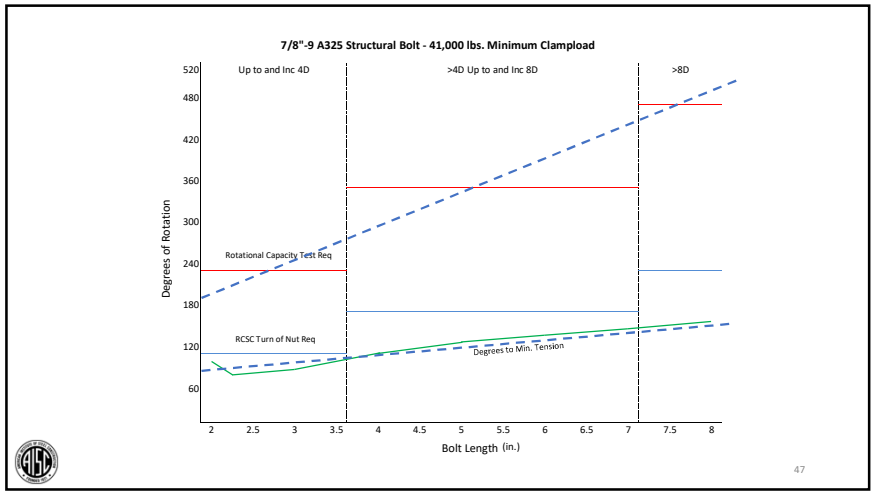

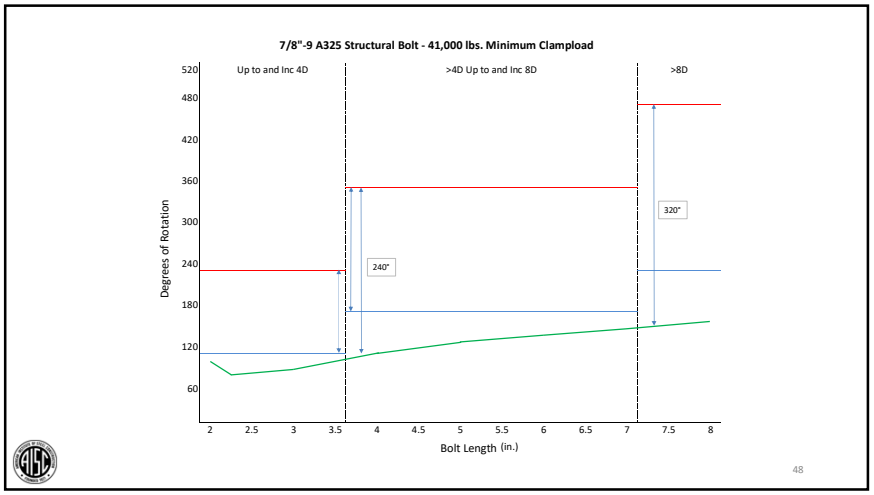

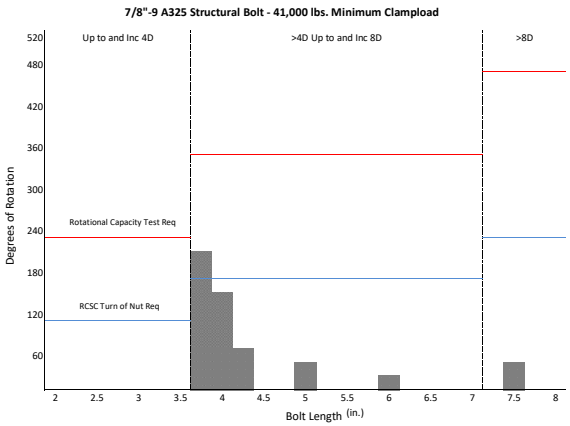

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Video – Rotational Capacity Testing

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Coatings

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Coatings on Structural Bolts

- B695 Zinc Mechanically Deposited – Group 120 Only
- F2329 Zinc Hot Dip – Group 120 except Twist-Off
  - Research to possibly permit F2329 HDG on Group 150
- F1136/F2833/F3019 Zinc/Aluminum – Group 120 or 150
  - Twist-Off depending on manufacturer
- F1941 Electrodeposited Coatings – Group 120 Hex Only

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Coatings

TABLE A1.1 Permitted Coatings

120 ksi & 830 MPa Bolt Assemblies[A]		150 ksi & 1040 MPa Bolt Assemblies[A]	
Commonly Applied Coatings	Grade or Class	Qualified Coatings	Grade or Class
F2329	Hot Dip Galvanized / 50 µm	F1136/F1136M	Bolt & Washer Grade 3, Nut Grade 5
B695	Class 55	F2833	Grade 1
Other Coatings	Grade or Class	F3019/F3019M	Grade 4
F1136/F1136M	Bolt & Washer Grade 3, Nut Grade 5	...	...
F2833	Grade 1	...	...
F3019/F3019M	Grade 4	...	...

[A] Coatings for Twist-off style bolt assemblies shall be agreed upon between the producer, supplier and user, and are not permitted except when applied under the direction of the manufacturer.

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Coatings on Structural Bolts

- Other coatings possible for 120ksi (Group 120)
- Others coming for 150ksi Grades (Group 150)
- Not always done by the manufacturer
- Significant effect on thread fit, “K” Factor, and general fastener performance

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Coatings on Structural Bolts

- Thickness only measured on significant surfaces.
- Not typically corrosion tested on a lot-by-lot basis.
- HDG on external threads only.
- Thread oversizing tolerances for newer coatings on A490 fasteners have been standardized just recently.

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Coatings

TABLE A1.2 Nut Overtap[I] Allowances

Dimensional Limits	Galvanized B695/F2329[A]			Zn/Al Coatings F1136/F1136M/F2833/F3019/F3019M[B,C,D]	
	Nut Pitch Dia. Overtap[E,F]	Bolt Pitch Dia. OS After B695 Coating[G]	Bolt Pitch Dia. OS After F2329 Coating[G]	Nut Pitch Dia. Overtap[I,E]	Bolt Pitch Dia. OS after Coating[F]
UNC Thread	in.	in.	in.	in.	in.
½-13	0.018	0.012	0.018	0.009	0.006
⅝-11	0.020	0.013	0.020	0.010	0.007
¾-10	0.020	0.013	0.020	0.010	0.007
⅞-9	0.022	0.015	0.022	0.011	0.008
1-8	0.024	0.016	0.024	0.012	0.008
1⅛-7	0.024	0.016	0.024	0.012	0.008
1¼-7	0.024	0.016	0.024	0.012	0.008
1⅜-6	0.027	0.018	0.027	0.014	0.010
1½-6	0.027	0.018	0.027	0.014	0.010
MC Thread	mm	mm	mm	mm	mm
M12 × 1.75 MC	0.45	0.30	0.45	0.23	0.16
M16 × 2.0 MC	0.50	0.33	0.50	0.25	0.17
M20 × 2.5 MC	0.50	0.33	0.50	0.25	0.17
M22 × 2.5 MC	0.55	0.36	0.55	0.28	0.19
M24 × 3.0 MC	0.60	0.40	0.60	0.30	0.20
M27 × 3.0 MC	0.60	0.40	0.60	0.30	0.20
M30 × 3.4 MC	0.70	0.46	0.70	0.35	0.24
M36 × 4.0 MC	0.70	0.46	0.70	0.35	0.24

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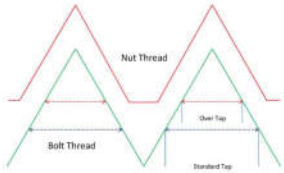
Understanding Thread Fit - Coatings

- Nut threads need to be oversized for most coatings.
- Oversizing the pitch diameter for clearance increases the nut minor diameter by geometric relationship.
- Oversized nuts have less proof load capacity, more importantly, the increase in minor diameter reduces the mated bolt stripping capacity.

57

Thread Profile Over-Sized



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Understanding Thread Fit - Coatings

- Oversizing may change failure modes from bolt tensile failure to thread stripping.
- Bolt tensile and nut proof load testing are performed with fixtures, the results do not correlate to fastener assemblies.
- Care should be taken not to “over-tension” coated fasteners.
- Understand the specifics of your selected coating.

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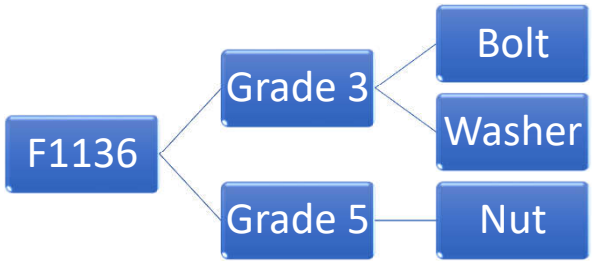
Coatings Example – Zinc Aluminum Flake



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Bolt reuse

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RCSC Section 2.11 - Reuse

- **2.11. Reuse**
- 2.11.1. Plain finish Group 120 heavy hex bolts may be *reused* (1) in *snug-tightened joints* without *Engineer of Record* approval and (2) in *pretensioned joints* and *slip-critical joints* with *Engineer of Record* approval.
- 2.11.2. Galvanized or coated bolts of any Group or grade, galvanized or coated *spline end bolting assemblies* of any Group or grade, and Group 150 heavy hex bolts shall not be *reused*.
- 2.11.3. *Touching up* shall not be considered a *reuse*.
- **Commentary:**
- *Pretensioned* installation involves the inelastic elongation of the portion of the threaded length between the nut and the thread run-out. Plain finish ASTM F3125 Grade A325 and F1852 bolts possess sufficient ductility to undergo more than one *pretensioned* installation as suggested in the *Guide* (Kulak et al., 1987). As a simple rule of thumb, a plain finish Grade A325 bolt is suitable for *reuse* if the nut can be run all the way up the threads by hand.
- On the other hand, while ASTM F3125 Grade A490 and F2280 bolts possess sufficient ductility to undergo one *pretensioned* installation, they are not consistently ductile enough to undergo a second pretensioned installation. The *Guide* also indicates that the coating on galvanized Grade A325 and F1852 bolts reduces their nut rotation capacity and are thus not to be *reused*. For additional guidance see Bowman and Betancourt (1991).

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Is it too tight?

63

Is it too tight?

- No

64

Unfortunately, This Can Happen….

65

Manufacturing inspection

66

What gets tested?

Always
- Dimensions – Geometry
- Chemistry – not usually directly
- Tensile Strength
- Proof Load
- Surface Discontinuities
- Hardness

Sometimes
- Magnetic particle
- Tensile Strength
- Rotational capacity
- Assembly tension testing
- Coating thickness
- Carburization/Decarburization

67

Tension Testing (Tensile Testing)

68

Hardness Testing

Comparison of hardness measuring procedures

Procedure, Marking	Vickers HV	Brinell HB	Rockwell HRC	Rockwell HRB
Standard	ISO 6507-1,2 (DIN 50133)	ISO 6506 (DIN 50351)	ISO 6508/EN 10004 (DIN 50103-1)	
Suitable for materials	Metallic materials with very low to very high hardness level (specification of medium hardness)	Metallic materials with very low to high hardness level (specification of partial hardness)	Hardened steels, hardened and tempered alloys	Materials of medium hardness, steels with low to medium C-content of brass, bronze ...
Tensile strength range approx. (R_m in N/mm²)	< 250 – 2000	255 – 1520	770 – 2000	250 – 800 250 – 800
Penetrator	Diamond pyramids, quadratic base area, surface angle 136°	Ball from hardened steel, diameter: 10/15/2.5 or 1mm	Diamond cone, cone angle 120° Tip: Radius of curvature 0.2mm	Ball from hardened steel Diameter: 1/16" = 1.5875mm
General dwell time (for arbitration tests, min.)	Material-dependent 10 – 30 (30) sec.	Material-dependent 10 – 30 (30) sec.	Material-dependent 2 – 25 (30) sec. two-stage impression Test load F_0 + Test load F_1 = Total test load F)	
Code (examples)	640 HV 30 — applied test load F = 294 N/30 kp — Vickers Hardness — determined hardness value 180 HV 50/30 — Dwell time/sec.	350 HB — Hardness Brinell — determined hardness value for ball diameter of 10mm Test load 29420 N/3000 kp Dwell time 10–15 sec. 120 HB 5/250/30 — Dwell time/sec. — Test load/kp — Ball Ø	45 HRC — Rockwell Hardness Procedure C — determined hardness value	45 HRB — Rockwell Hardness Procedure B — determined hardness value

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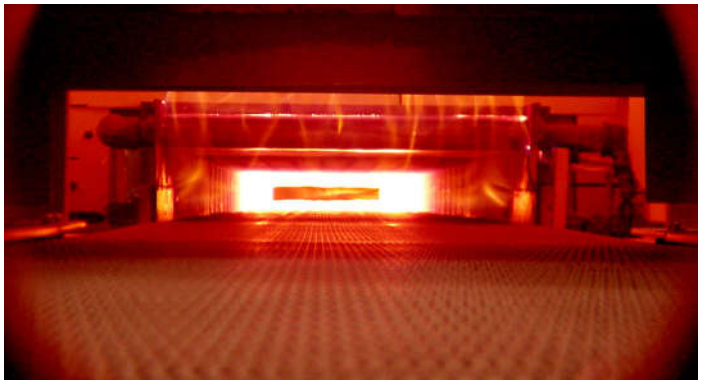
Carburization/Decarburization



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Continuous Heat Treatment

72

Batch Heat Treatment

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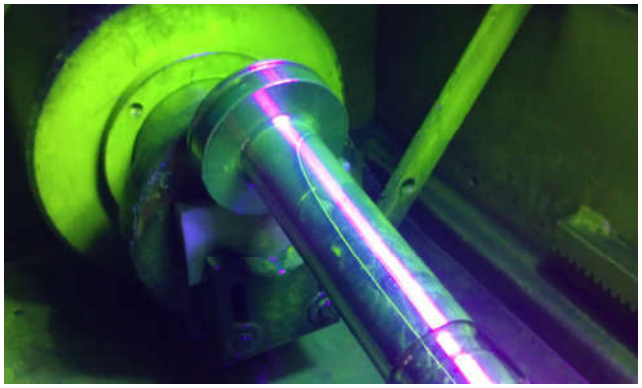
Magnetic particle inspection



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What Can Happen?

- Fatigue
- Rust or Weathering
- Coating Adhesion
- Reamed Nut Threads
- White Rust
- Seams
- Bursts
- Poor Coating Thickness
- Welded Parts
- Storage and Handling Issues
- Quench Cracks
- Improper Washer Usage
- Bolt Binding
- Poor Paint Adhesion
- No Pre-installation Testing
- Tensile Failure
- Torsional Failure
- Stress Corrosion Cracking
- Hydrogen Embrittlement
- Shank Out/Negative Stick-out
- Low Fastener Tension
- RC Test Failure
- Inadequate Installation Tools
- Lack of Installer Training
- High or Low Hardness
- Thread Stripping
- No Control of Snug Tight
- No Installation Clearance
- Improper Mating Components
- No Verification on Site

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A number of things can go wrong, but…

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Surface Discontinuities – ASTM F788 or F812

Burst

Seam

77

Bursts Are Quite Common

Head burst

Head burst

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Burst, Seam or Crack?

Seam

Quench crack

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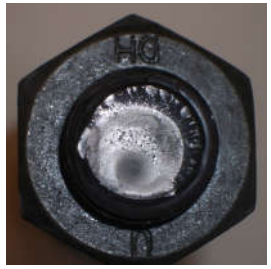
Quench Crack

Quench crack

Quench crack



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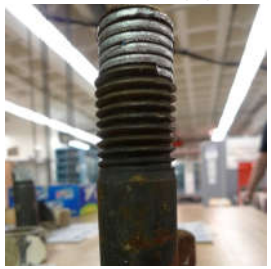
Other Problems

Bad threads or lack of engagement?



Adhesion, excessive impacting or possibly a bound bolt.

81

Too Brittle?

82

Or Wrong Size?

83

Hot Forged, Split Die

Fin – in specification

Fin profile with a bit of swell

84

Misc. Problems

Coating Fixture Marks

Reamed Nut

85

Workmanship

Bolt problem or hole problem?

Adhesion

86

87

Trained Installer, Match-Marked, Witnessed, Signed-off, didn't break.

88

Rust - How Much is Too Much?

Will need requalification

Most likely scrap

89

Hole Size/Bolt Size Problem

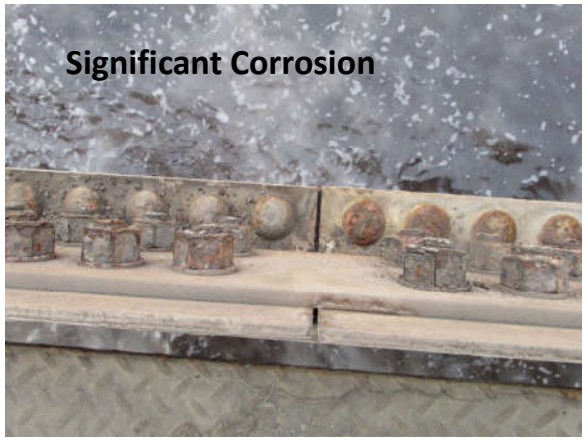
90

Bad Storage

Water

91

Significant Corrosion



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Engagement

95

96

Flatness

97

98

Problems

Most projects go as planned, but……

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Problems

- Here is a breakdown of typical construction problems according to ENR Magazine.

- 65% from insufficient, inappropriate or conflicting information
- 17% from human error
- 8% from weather
- 5% from poor workmanship
- 5% from materials failure

100

Understand the chain of command

- Owner
- Architect
- Engineer
- Inspector
- Project manager
- Prime or general contractor
- Sub-contractor

101

Problems

- Regardless of the scale of the project, the owner and end user expect to get what they pay for. This means a safe, attractive, functional structure, which performs throughout its service life with minimal risk and maintenance. Our job as suppliers is simply to meet their expectations.
- Being prepared to respond to quality and technical questions, having the proper knowledge of your product, and reacting in a timely and professional manner can prevent a simple question from turning into problem or a simple non-conformance from turning into a large claim.

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The Most Common Problems

Be prepared and well versed in the most common of problems.

- Surface discontinuities (head bursts, seams)
- Low tension during preinstallation verification (equipment, training fastener quality)
- Broken bolts or stripping during installation (often coatings and lubrication)
- Storage and handling
- Rotational capacity testing
- No testing being performed on site
- Thread damage

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The Most Common Questions

- Washer requirements
- Typos and mistakes on test reports or shipping docs
- Where can I get my TC tool calibrated
- Can I substitute grade 5 bolts or grade 8 bolts for A325 or A490
- F3125/A325 labels and certificates
- What is the proper torque for installation

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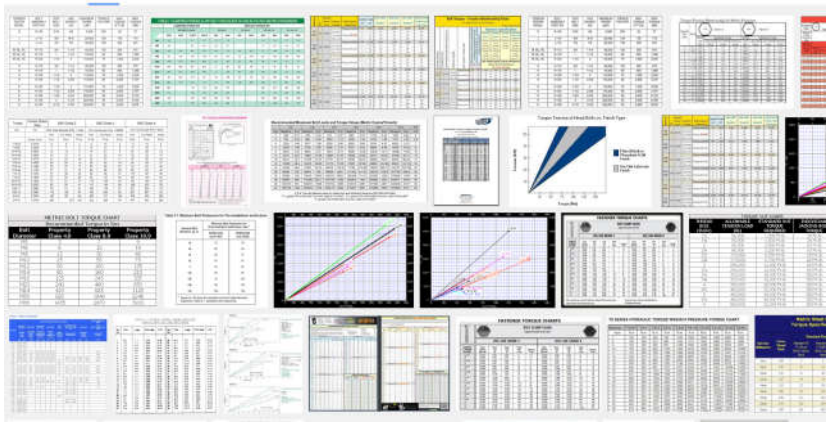

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Closing

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Unusual Aspects of Structural Bolting

- Bolts are tensioned well into yield, this is a no-no in virtually every other engineered fastener application.
- Bolts are not sold as matched sets in many/most cases.
- Thread lengths are very short, bolts perform better in tension with longer threads.
- Acceptance testing is frequently done in the field, which is often the 1st point of assembly.
- There is no industry requirement for "K" Factor.
- Snug tight as it pertains to fully tensioned bolts is highly variable - operator, equipment, lubrication and installation procedures.

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What Else Can You Do?

- Get additional fastener training, several options exist.
- Get more familiar with standards.
- Ask questions.
- Get involved in committee work.
- Work with reputable contractors and suppliers.
- Be willing to work through problems.

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Good Reading

- John H. Bickford, An Introduction to the Design and Behavior of Bolted Joints.
- Industrial Fasteners Institute, Fastener Standards.
- Geoffrey L. Kulak, John W. Fisher, John H. A. Struik, Guide to Design Criteria for Bolted and Riveted Joints. (currently being revised)
- Geoffrey L. Kulak, High Strength Bolts: A Primer for Structural Engineers, Steel Design Guide 17.
- PCB Load & Torque Knowledge Library
  - Understanding Torque-Angle Signatures of Bolted Joints
  - Fundamentals of Torque-Tension and Coefficient of Friction Testing
  - Engineering Fundamentals of Threaded Fastener Design and Analysis

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Thank You!

- AISC
- Brent
- Nate

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Thank you!

AISC | Questions

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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

PDH Certificates

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

Quiz 8 issued: December 9, 2021
Final Exam issued: December 14, 2021
Quiz 8 and Final Exam due: January 4, 2021

PDH Certificates and EEU Certificates of Completion will sent by:
January 11, 2021

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

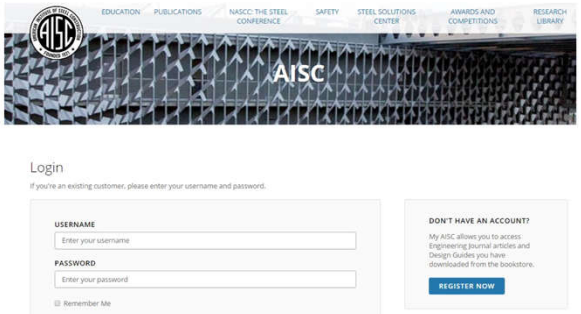
Night School Resources

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.



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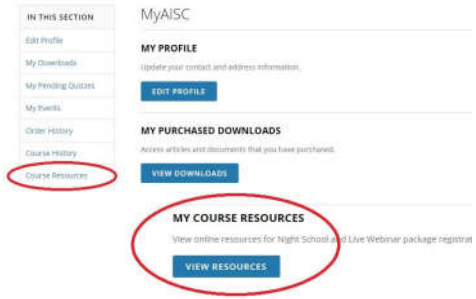


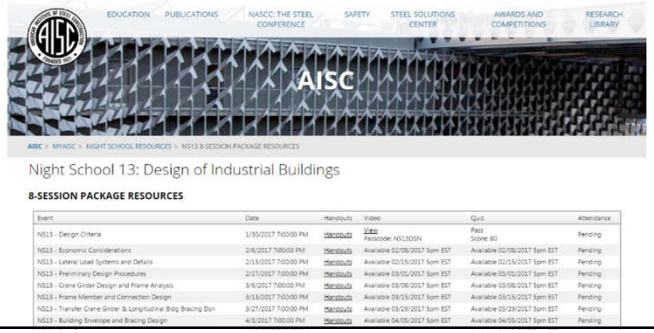
8-Session Registrants

Night School Resources

Course Resources

8-Session Registrants

Night School Resources



8-Session Registrants

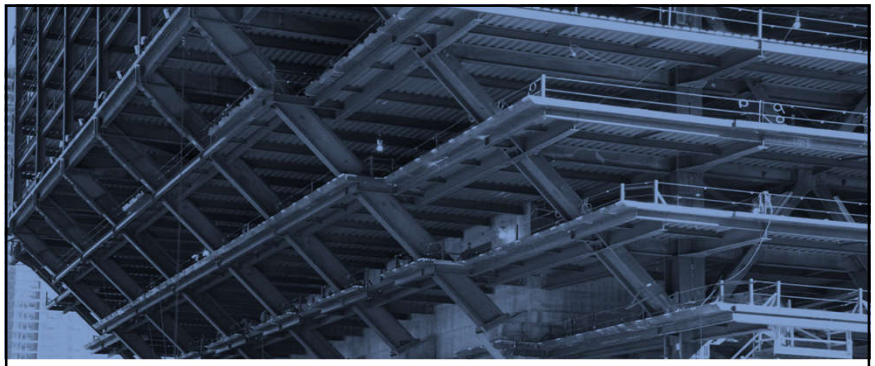
Night School Resources

- 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



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