**RESEARCH COUNCIL ON STRUCTURAL CONNECTIONS (RCSC)**
**MINUTES of SPECIFICATION COMMITTEE A.1**
16 June 2011, 8:00AM, Oakland, CA

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| **Members Present: (33)** | P. Birkemoe, D. Bogarty, R. Brown, B. Cornelissen, C. Curven, N. Deal, D. Ferrell, P. Fortney, K. Frank, J. Gialamas, J. Greenslade, A. Harrold, C. Hundley, C. Kanapicki, P. Kasper, L. Kruth, C. Larson, B. Lindley, K. Lohr, B. Lund, C. Mayes, G. Miazga, G. Mitchell, H. Mitchell, T. Schlafly, G. Schroeder, R. Shaw, V. Shneur, J. Swanson, R. Tide, F. Vissat, A. Wong, J. Yura |
| **Members Absent: (15)** | R. Baxter**,** D. Droddy, J. Fisher, B. Germuga, M. Gilmor, J. Kennedy, G. Kulak, J. Mehta, C. McGee, N. McMillan, L. Shoemaker, T. Tarpy, B. Tinney, W. Thornton, C. Wilson |
| **Guests: (17)** | T. Anderson**,** A. Astaneh-Asl, D. Auer, D. Bornstein, B. Butler, C. Carter, P. Dusicka, R. Gibble, R. Hayes, T. Helwig, E. Jefferson, D. Kaufman, J. McGromley, J. O'Brien, A. Prchlik, G. Rassati, T. Ude, |

**AGENDA**

**ITEM 1.0 Chairman's Remarks: (Harrold)**

- Specification Committee Chairman Harrold introduced host Emmanuel Jefferson. All members and guests participating in the SFOBB tour need to sign two wavier sheets (contractor & Caltran).
- Specification Committee A.1 meeting will conclude around 11:00AM, followed by two presentations (Brown & Curven).
- Council Roster was circulated for verification and update of email address, phone and fax numbers and any additional comments as required. Presently, there are forty-eight members on Specification Committee A.1; guests were also asked to sign-in.
- Discussions and voting shall be limited to Specification Committee A.1 members only.
- Discussions shall be limited only to agenda items listed.
- New Specification edition was published last year and is available on the Council website.

**ITEM 2.0 Approval of Minutes of the June 2010 Meeting: (Harrold)**

- No additional comments, corrections and discussions took place. Therefore, Harrold ascertained that no comments are an approval of the minutes as written.

**ITEM 3.0 Approval of Agenda: (Harrold)**

- No additional agenda items were suggested; therefore Harrold concluded that the proposed agenda is approved as written.

**ITEM 4.0 Membership: (Harrold)**

- Roster was circulated for sign-in and updating of information.

- If guests are interested in joining Specification Committee A.1, they were asked to see Harrold during the break or after the meeting.
- The following guests indicated on the attendance roster that they would like to join the Specification Committee: A. Astaneh-Asl, D. Bornstein, R. Gibble, J. O'Brien, and G. Rassati. Welcome!

**ITEM 5.0 <u>Resolution of Ballot Results (Affirmative/Negative/Abstain):</u> (Harrold)**

- There were no active ballot items voted on since the 2010 meeting.

**ITEM 6.0 <u>Discussions of Proposed Specification Changes:</u> (Harrold)**

- To make changes to the present specification, download a Proposed Change form from the RCSC web site, fill-out the proposed change, include rationale or justification for the change and add commentary as needed. The completed form needs to be submitted to the Chairman of the Executive Committee for consideration and assignment to the Specification Committee chair for creation of a task group or to become an agenda item at the next committee meeting. Proposed changes submitted after the Executive Committee meeting, typically in March, will not be acted on until the following year.

6.1 Appendix B. Allowable Stress Design (ASD) Alternative merge into Main Specification; Glossary, Sections 1.2, 5.1, 5.2, 5.3 and 5.4 (see attached RCSC Proposed Change: S11-033) (Harrold): Information has been duplicated into Appendix B from Section 5. Limit States in Bolted Joints. The AISC and AISI Specifications have shown that a specification can handle ASD and LRFD philosophies within the body of the same specification without a great deal of difficulty. This proposal applies the same approach to the RCSC Specification.
Further discussion followed (Frank, Yura). Review Appendix A, creep test using service load level in light of Appendix B changes.

Tide motioned and Mitchell seconded the motion to forward the proposed specification change to ballot.
Harrold requested a vote with results as follows:

29 for the changes
0 against the changes
1 abstained

**ACTION ITEM 2011-1 (A.1)**: Proposed changes were considered and adopted for inclusion into the next revision of the specification. In order for the proposed changes to be included in the next revision to the specification, the changes will need to be balloted.

**ACTION ITEM 2011-2 (A.1)**: Yura to consult with Harrold regarding Appendix A creep tests using service load level.

6.2 Section 3.3 Hole Definitions (see attached RCSC Proposed Change: S11-035) (Shaw): Similar to Section 4. Joint Type, the Engineer of Record (EOR) shall specify the joint type. The same type of language is being proposed for Section 3.3 Bolt Holes; the EOR shall specify the hole type and orientation of slotted holes. Removes the EOR requirements to approve the type of hole provided the hole type meets the governing specification. New language was developed in Section 1.4 Drawing Information to include hole type and direction of loading if slotted holes. Further discussion followed (H. Mitchell, Curven, Yura, Mayes, Shneur, Gibble, Kruth, Frank, Harrold, Schlafly). Direction of loading relative to the slot orientation will need to be defined. This was considered editorial in nature and will be incorporated into the proposed change. EOR should specify actual hole size of oversized holes; EOR needs to understand how the oversized holes will affect the structures behavior. This was considered new business.

Shaw motioned and Miazga seconded the motion to forward the proposed specification change to ballot.
Harrold requested a vote with results as follows:

26 for the changes
2 against the changes
0 abstained

**ACTION ITEM 2011-3 (A.1)**: Proposed change was considered and adopted with editorial modification regarding loading direction relative to slotted hole orientation for inclusion into the next revision of the specification. In order for the proposed change to be included in the next revision to the specification, the change will need to be balloted.

**ACTION ITEM 2011-4 (A.1)**: New language needs to be developed, that directs the EOR to define the actual hole size for oversized holes; considered new business for 2012.

6.3 Glossary – Pretension (see attached RCSC Proposed Change: S11-036) (Shaw): The terms Pretension and Torque are regularly used, but do not have official definitions within the Specification. Further discussion followed (Curven, Ferrell, Harrold, Shaw, McGormley, Schroeder, Mayes, Mitchell, Kasper, Shneur, Yura). Most of the discussion was related to defining Torque. As defined in Section 8.2.2 Calibrated Wrench Pretensioning, tables and equations that claim to relate torque to pretension should not be used. Torque is a means to achieve pretension. Definition should be written in context as it relates to bolts, not in the physics definition as written in the proposed change.

Shaw withdrew the definition of Torque from the proposed change; will be considered as new business for 2012.

Shaw motioned and Curven seconded the motion to forward the proposed specification change to ballot.
Harrold requested a vote with results as follows:

27 for the changes
0 against the changes
1 abstained

**ACTION ITEM 2011-5 (A.1)**: Proposed change was considered and adopted, excluding the definition of Torque, for inclusion into the next revision of the specification. In order for the proposed change to be included in the next revision to the specification, the change will need to be balloted.

**ACTION ITEM 2011-6 (A.1)**: Definition for Torque as related to bolt tension needs to be developed; considered new business for 2012.

6.4 Table 8.2. Nut Rotation from Snug-Tight Condition for Turn-of-Nut Pretensioning, sub note ‘a’ tolerance (see attached RCSC Proposed Change: S06-002B/S06-003) (TG – Shaw): The present RCSC Specification has no limit on bolt tension for the snug condition, hence no well-defined maximum “starting line” for pretensioning, thus it makes little sense to reject a bolt because it exceeds the “finish line.” A bolt is not too tight until it breaks.
Further discussion followed (Frank, Mayes, Deal, Kasper, Tide, Birkemoe). Suggest not using minus 45 degrees; select rotation degrees that lineup with or are half-way between the bolt hex head and/or nut corner points. Match marking is presented in the Commentary, Sections 8.2.1 and 9.2.1, but is not mandatory. In order to install and observe the required rotations, the present match marking language needs to be placed in the main body of the specification and made mandatory.
Frank motioned and Mitchell seconded the motion to change rotation tolerances so all nut or bolt rotations use plus 60 degrees and minus 30 degrees for simplicity with installation and inspection observation.
Harrold requested a vote with results as follows:

29 for the change
1 against the change
0 abstained

Shaw motioned and Deal seconded the motion to forward amended proposal specification change to ballot.
Harrold requested a vote with results as follows:

30 for the change
0 against the change
0 abstained

**ACTION ITEM 2011-7 (A.1)**: Amended change was considered and adopted for inclusion into the next revision of the specification. In order for the proposed change to be included in the next revision to the specification, the change will need to be balloted.

**ACTION ITEM 2011-8 (A.1)**: Review of match marking language in Specification, Sections 8.2.1 and 9.2.1 will be considered new business for 2012.

6.5 Preinstallation Verification Language (see attached RCSC Proposed Change: S11-038) (Curven): Present language in Sections 8.2.1 and 8.2.3 does not state clearly that preinstallation verification is mandatory, whereas Sections 8.2.2 and 8.2.4 clearly states that pre-installation verification specified in Section 7 shall be performed. Additionally, Section 9.2.1 and 9.2.3 states that the *inspector* shall observe the pre-installation verification testing required in Section 8.2.1 and 8.2.3 respectively.
Further discussion followed (Kasper, Carter, Shaw). Group agreed that the language changes are editorial in nature and the proposed new language does not need to be balloted.

**ACTION ITEM 2011-9 (A.1):** A task group composed of Curven, Carter & Birkemoe to propose new language and submit to Executive Board for review and consideration for Specification Committee action.

**ITEM 7.0 <u>Task Group (TG) Reports:</u>**

7.1 Relubrication at Direction of Manufacturer (S08-023) (Kasper): See attached TG report.

**ACTION ITEM 2009-13 (A.1)**: Proposed change was considered and defeated for inclusion into the next revision of the specification. A TG composed of Kasper, Deal, Mitchell and Wilson reviewed the as presented proposal.

The TG stated that between the RCSC Specification and the ASTM product Specification, to which the bolts must be produced, it is sufficiently clear that there is a critical relationship between lubrication of the fasteners and the functional performance of the TC bolt assembly. There is adequate warning and description stating that altering the lubrication requires retesting and recertification.

The definition of manufacturers seems to be a small point and is not one which RCSC should try to direct as it is covered in the ASTM product Specification. For the purposes of structural joint design and application of the fasteners, the TG concludes that the current definition of manufacturer is sufficient. RCSC does not want to be in a position which sounds like they endorse modifying TC bolts from their factory supplied conditions.

Further discussion followed (Kasper, Lohr, Mitchell, Shaw, Schroder, Curven, Frank, Larson). The definition of Manufacturer is not consistent between ASTM F1789, F1852 and F2280. RCSC should not redefine the definition; that responsibility should be left to ASTM. Anyone who changes out lubrication or assembly components other than the manufacturer, becomes the responsible party and must retest and recertify the assembly. Metallic coatings are not permitted on ASTM F2280 assemblies, but are permitted on ASTM A490 assemblies. Overtap limits have not been defined in ASTM A325, A490 or F1136. Discussions are ongoing in the ASTM Structural Bolt Task Group, which presently does not allow ASTM F1136 coatings on TC bolts (F1852 & F2280). RCSC Bulletin on ASTM F1136/F1136M Zinc/Aluminum Coatings for use with ASTM A490/A490M Structural Fasteners, dated April 31, 2011 is posted on the RCSC web page as an advisory to manufacturers, suppliers and end users on the limitations of currently available product specifications.

Kasper motioned and G. Mitchell seconded the motion to not consider the original ballot item any further and leave the RCSC Specification as written.

Harrold requested a vote with results as follows:

33 for dismissing original ballot
0 against dismissing the original ballot
0 abstained

Task group was dismissed from any further study and reporting.

Thank you for your efforts.

7.2 Turn-of-the-Nut Parameters - A325T (S08-020B) (Greenslade):

Should A325T bolts require different turn-of-nut requirements than standard A325 bolts? Nucor (Hamilton) started testing several years ago; preliminary results indicated that within turn tolerance, there were no differences in tension between bolt types. Nucor (Gialamas) is picking-up the testing program where Hamilton left off. Expect research report next year.

7.3 Slip Critical Connections (AISC) (Schlafly): See attached proposal.

Changes to Specification, Section 5.4, 5.4.1 and B5.4 Commentary were distributed during the 2010 Specification Committee meeting; received only one comment to the proposal. Proposal will be revised and reissued to accommodate ballot item S11-033; merging Appendix B into main specification.

**ACTION ITEM 2011-10 (A.1)**: Proposal will be revised to accommodate ballot item S11-033 changes and re-introduced to the Specification Committee.

7.4 Skidmore Testing Temperature Tolerances (Kasper): See attached TG report, UNYTITE Inc. testing report dated June 11, 2010 and Ferguson Structural Engineering Laboratory Check of Skidmore Bolt Gage at Lower Temperature testing report dated May 17, 2007.

UNYTITE tested a Skidmore Model MS performance at three temperature ranges: ambient, +170ºF and +8.5ºF using a Tinius Olsen calibrated load cell; no fasteners were involved with the testing. Results showed that there were no significant variations compared with tension readings taken at room ambient temperature conditions. Ferguson Laboratory conducted a similar test comparing room ambient tension values to those done under Skidmore initial test temperature of -9ºF, at 30 seconds and at 60 seconds and initial Skidmore test temperature of 30.4ºF, at 30 seconds and at 60 seconds. Test results did show a slightly lower tension value at the cold initial reading, but at the 30 and 60 second readings, the tension values compared well with the load cell readings. TG reported that with the limited test data provided, results do not indicate that there are severe changes in performance of the Skidmore load cells which would affect field performance. Most field complaints have been related to cold temperature testing of bolt assemblies in the Skidmore, which is not what the TG was asked to investigate and report on.

Further discussion followed (Hundley, Birkemoe, O'Brien, Frank, Lohr, Bornstein, Deal, Kasper, H. Mitchell, Swanson, G. Mitchell, Tide). Glycerin was used in the Ferguson Skidmore gage, which is a non-standard fluid; standard fluid is oil. Below 40ºF, glycerin does become sluggish. Skidmore did their own in-house testing of their units, similar to the tests done by UNYTITE and found no variations in test results. Skidmore Model H is constructed using an aluminum frame and steel piston, which could cause the piston to bind under temperature fluctuations; Model HS are constructed using all steel components. ASTM F1852 and F2280 lists specific temperature conditions which must be met when conducting assembly installation tension test; testing temperature range between 50ºF and 90ºF. Adding testing temperature ranges to the Pre-Installation Verification section of the RCSC Specification was discussed and dismissed; product specification specifies the temperature testing criteria.

G. Mitchell motioned and Larson seconded the motion to accept the TG report and drop further action on this item.

Further discussion followed (Frank, Birkemoe, Shaw, Bornstein, Greenslade).

Language in the Specification needs to be added which defines the accuracy of a hydraulic tension calibrator within an established temperature range. Suggestion was made to request Education Committee to consider creation of an Educational Bulletin related to this subject. Skidmore is willing to determine and publish in their product specification the accuracy of their equipment within an established temperature range.

Harrold requested a vote with results as follows:

33 for dismissing task group
0 against dismissing task group
0 abstained

Task group was dismissed from any further study and reporting.

Thank you for your efforts.

**ACTION ITEM 2011-11 (A.1)**: Education Committee to discuss and report to Council whether or not they plan to issue an Educational Bulletin related to this subject.

7.5 Oversize Holes – Shear Connections (Yura):
Beam shear connections subject to gravity loads only; accommodate rotation in the joint without fully tensioning the bolts. New language will be developed for ballot.

7.6 Minimum Shim Thickness (Harrold):
Specification does not address the maximum gap required before shims are required for snug tight joints. TG dismissed due to inaction on item.

7.7 Calibrated Wrench Installation (CWI) (Vissat): See attached TG report & LPR letter.
A summary of the RCSC Questionnaire on High-Strength Bolt Installation Practice was passed out during the meeting. The survey was finalized in May of 2011 and sent to 457 certified and non-certified steel erectors through the AISC marketing group. Twenty of the 457 responded; a 4.4% participation rate. Eighteen questions were asked ranging from which of the four methods of pretensioned bolt installation is used in their practice to what type of tools are being used with the various methods of pretensioned bolt installation. The survey revealed that 62% use twist-off TC bolts, 27% use the turn of nut method, 5% use DTI's and 6% use the calibrated wrench method. Further discussion followed (Mayes, Kasper, Deal, Larsen). Depending on which market is most active, commercial market tends to use more TC bolts and the bridge market uses all heavy hex head bolts. A 40% to 60% usage of TC bolts is not unusual. The calibrated wrench method can be very time consuming and costly, but is being used at job sites, therefore should not be eliminated as an acceptable installation method.
Task group was dismissed from any further study and reporting.
Thank you for your efforts.

7.8 SI Specification (Greenslade):
ASME is in the balloting process on creating a metric standard for structural fasteners (B18.2.8M). RCSC metric specification will be reviewed after that effort is completed.

7.9 Thick Coating – (Resolution of negative on S06-005B) (Birkemoe):
No progress to report.

7.10 Turn-of-Nut – Drop preinstallation test requirement (Resolution of negative on S08-018) (Schlafly): See attached TG report and TG Summary of Comments.
The purpose of the TG was to review preinstallation verification testing of fasteners to be installed using Turn-of-Nut Pretensioning method with the intent of deleting the requirement provided it would not reduce the quality of the bolted joint; limited to black (un-coated) bolts less than or equal to 1-1/8 inch diameter only. TG members submitted their comments, issues and field related experiences that had bearing on the proposal to delete the preinstallation testing requirement. TG chair collected the TG comments and presented the summary to the Specification Committee for discussion. Further discussion followed (Larsen, G. Mitchell, Yura, Frank, Deal, Schroeder). Larsen and Greenslade were expert witnesses involving a structural collapse, which resulted in $600M in damages. Erector installed Grade 2 nuts with A490 bolts. Preinstallation verification was not performed; inspection of the connections was carried out, but inspector was not familiar with the RCSC preinstallation verification requirements. If testing is removed, erectors that have not been complying with the testing requirements will be justified in their past actions; incorrect bolt assembly materials will not be identified. The purpose of the test is to verify that the bolt and nut will work together properly independently of the method of installation. The US is one of the last countries

that permit bolts and nuts to be supplied not as an assembly. To reduce the amount of field testing, require the bolt, nut and washer to be supplied as an assembly and the testing/certification are provided by the manufacturer of the assembly. FHWA requires that all bolt, nut and washers for bridge work to be supplied as an assembly. The rotational capacity test of the lot assembly would satisfy the testing requirements. Training the bolt assembly installer is a separate issue. TG chair added a fourth option to the poll; includes dropping existing testing provision provided bolts, nuts and washers are shipped as assemblies and tested by the supplier and include an installer qualification program.
TG chair requested a straw vote on the following options:

- -To leave existing provision as they are now, i.e., continue preinstallation testing: 24 votes
- -To drop existing provision as proposed: 1 vote
- -To drop existing provision and institute an installer qualification program: 1 vote
- -To drop existing provision when bolts, nuts and washers are shipped as assemblies and tested by the supplier and institute an installer qualification program: 7 votes

Further discussion followed (G. Mitchell, Carter, Lohr, Kasper, McGormley). Users' demand/acceptance for assembled and/or un-assembled fasteners varies from project to project; in many cases, cost drives the demand/acceptance. Education Committee will consider training requirements for an installer qualification program, which can be incorporated into the specification at a later date.
Task group was dismissed from any further study and reporting.
Thank you for your efforts

**ACTION ITEM 2011-12 (A.1)**: Education Committee to discuss and report to Council whether or not they plan to consider developing the training requirements for an Installer Qualification Program.

7.11 Use of TC bolts in snug-tight joints (Schlafly):
TG recommends the following language be added to the Commentary of Section 8.1:

> *If ASTM F1852 and F2280 bolts are used in snug-tightened joints, it is not necessary for the splined end to be severed during installation as long as the bolts are installed in a manner as described in Section 8.1*.

Further discussion followed (G.Mitchell, Fortney, Shneur, Butler, Frank, Shaw). Presently, erectors have been trained that for bolts to be properly tensioned, the spline needs to be removed. Some inspectors want the spline removed if the design requires a pretensioned or slip-critical joint and some inspectors require the spline removed even for snug-tightened joints. When using TC bolts, fabricators are clearly indicating on shop/erection drawings where snug-tightened, pretensioned or slip-critical joints are required. There are many connections where TC bolts are used in snug-tightened joints and pretensioning is not permitted, i.e., slotted connections.

Shaw motioned and Ferrell seconded the motion to move proposed commentary language to ballot.
Harrold requested a vote with results as follows:

30 for the change
0 against the change
0 abstained

**ACTION ITEM 2011-13 (A.1)**: The proposed Commentary language was considered and adopted for inclusion into the next revision of the specification. In order for the proposed change to be included in the next revision to the specification, the change will need to be balloted.

7.12 Definition of standard hole size for bolts 1-1/4" and larger (Carter):
No progress to report.

7.13 Shear Allowables (from Ballot S08-024) (Yura):
No progress to report. Suggest getting meeting notes out earlier so task groups can be aware what needs to be accomplished. Task group (Yura, Gibble, Grondin, Frank, McGromley, Carter) will meet after the specification meeting.

**ITEM 8.0 <u>Old Business: </u>(Harrold)**

- None.

**ITEM 9.0 <u>New Business:</u> (Harrold)**

9.1 Length Tolerance on bolts (Lohr):
Looking for feedback from producers regarding bolt length tolerances specified in ASME B18.2.6. For 1-inch diameter and smaller bolt lengths 6" and shorter, length tolerance is specified at +0.00", -1/8" (for 1/2" & 5/8" diameter bolts) and +0.00", -3/16" (for 3/4" – 1.0" diameter bolts); 1-1/8 inch diameter and larger bolts, length tolerance is specified at +0.00", -1/4". For bolt lengths greater than 6", length tolerance is specified at +0.00", -1/8" (for 1/2" diameter bolts) and 5/8" diameter and larger bolts, +0.00", -1/4". Detailers are assuming the bolt length specified is the actual length they are getting without considering manufacturing tolerances. In many cases for the larger diameter bolts, the actual lengths required are coming up short by as much as ¼-inch. Would like RCSC to propose to ASME a revised bolt length tolerance of say +/-1/16". Further discussion followed (Lohr, Greenslade, Mitchell, Kasper). Most producers manufacture their bolt lengths per specification. Infasco actually manufactures their TC bolt lengths a bit longer than tolerance. ASME B18.2.6 specification underwent a major re-write in 2010. Greenslade will take whatever proposed change to the current specification Lohr proposes to the ASME Specification Committee.

**ACTION ITEM 2011-14 (A.1)**: Lohr to propose language change to ASME B18.2.6 regarding bolt length tolerance and present to Joe Greenslade. Greenslade will present proposed change to ASME Specification Committee.

9.2 University of Cincinnati Bolt Research – What do we do with it? (Harrold): Further discussion followed (Tide, Yura, Swanson). Research confirmed current process as conservative. ASTM A325 bolt materials being provided are testing quite a bit higher than the minimum required per specification; caution when using Φ factors to account for minimum material strengths required verses that which is being provided. Further studies are necessary to recognize variables other than the bolt itself in the joint.

**ACTION ITEM 2011-15 (A.1)**: If someone wants to pursue this research for further discussion, they are to send Harrold a reminder to add to the 2012 agenda.

9.3 Modify prohibition of non-steel items in grip (Schlafly):
Sustainability is a bigger driver in the structural steel industry today than what it was 5 years ago. One component of sustainability is the concept of thermal bridging between bolted joint connections of inside and outside members. Present specification provisions (Section 3.1 Connected Plies) requires that "All connected plies that are within the grip of the bolt and any materials that are used under the head or nut shall be steel… Compressible materials shall not be placed within the grip of the bolt". In order to accommodate thermal bridging demands on bolted joints, research and a change to the present specification language needs to look into; consider permissible non-steel materials within the joint, undeveloped fillers and alternates to the joint design and installation.

**ACTION ITEM 2011-16 (A.1)**: If someone wants to pursue this topic for further discussion, they are to send Harrold a reminder to add to the 2012 agenda.

9.4 Delayed failures of ASTM A325 galvanized and A490 black bolts on bridge work when tightened from the head side (Mitchell):
If anyone has had similar experience or input to this issue they are to get with G. Mitchell after the meeting.

**ACTION ITEM 2011-17 (A.1)**: Harrold will add to 2012 agenda and G. Mitchell will report on this topic at that time.

**ITEM 10.0 Liaison Reports:**

- Due to lack of time, no reports were presented.

**ITEM 11.0 Date and time of next meeting:**

- To be coincident with the next annual meeting of the Research Council on Structural Connections

**ITEM 12.0 Adjournment:**

- No motion was presented, Harrold declared the Specification Committee A.1 meeting adjourned; meeting disbanded at 12:15pm.

**ITEM 13.0 Attachments:**

13.1 Proposed Specification Changes (Item 6.0)
- (6.1) S11-033
- (6.2) S11-035
- (6.3) S11-036
- (6.4) S06-002B
- (6.5) S11-038

13.2 Task Group Reports (Item 7.0):
- (7.1a) Relubrication at Direction of Manufacturer (S08-018)
- (7.1b) RCSC Bulletin on ASTM F1136/F1136M Zinc/Aluminum Coatings for use with ASTM A490/A490M Structural Fasteners
- (7.4) Skidmore Testing Temperature Tolerances
- (7.7a & b) Calibrated Wrench Installation & LPR letter
- (7.10a & b) Turn-of-Nut – Drop Preinstallation Test Requirements (S08-018)

# RCSC Proposed Change: S11-033

**Name:** Allen Harrold  **E-mail:** ajharrold@butlermfg.com
**Phone:** 816-968-5719  **Fax:** 816-968-6512

**Rationale or Justification for Change (attach additional pages as needed):**

This proposal is intended to blend the Appendix B ASD provisions into the body of the Specification.

There is very little distinction to be made between ASD service load evaluations and LRFD service-level load evaluations. Information has been duplicated into Appendix B from Section 5 with very little modification. There is extra effort required during revision proposals to insure that the two areas stay in sync in regard to their philosophy and in fact the combined bending and tension process is not currently on the same basis. The AISC and AISI Specifications have shown that a specification can handle ASD and LRFD philosophies within the body of the same specification without a great deal of difficulty. This proposal applies the same approach to the RCSC Specification.

**Proposed Change:**

**Glossary**
Add the following definition.
*Allowable Strength. Nominal strength* divided by the safety factor, $R_n / \Omega$.

**Section 1.2**

**1.2. Loads, Load Factors and Load Combinations**
The design and construction of the structure shall conform to either an applicable load and resistance factor design specification for steel structures or to an applicable allowable strength design specification for steel structures. Because factored load combinations account for the reduced probabilities of maximum loads acting concurrently, the *design strengths* given in this Specification shall not be increased.

**Commentary:**
This Specification is written in a dual format covering both load and resistance factor design (LRFD) and allowable strength design (ASD). Both approaches provide a method of proportioning structural components such that no applicable limit state is exceeded when the structure is subject to all appropriate load combinations. ~~This Specification is written in the load and resistance factor design (LRFD) format, which provides a method of proportioning structural components such that no applicable limit state is exceeded when the structure is subject to all~~

------------------------------------For Committee Use Below---------------------------------------------

Date Received: 3/11____ Exec Com Meeting: 3/11_____ Forwarded: Yes X /No ☐

Committee Assignment: Executive -A. ☐ Editorial -B. ☐ Nominating -C. ☐

Specifications -A.1 X Research -A.2 ☐ Membership & Funding -A.3 ☐ Education -A.4 ☐
Committee Chair: Harrold Task Group #: ___________ T.G. Chair: ________________
Date Sent to Main Committee: _______________Final Disposition: ______________________

~~appropriate load combinations.~~ When a structure or structural component ceases to fulfill the intended purpose in some way, it is said to have exceeded a limit state. Strength limit states concern maximum load-carrying capability, and are related to safety. Serviceability limit states are usually related to performance under normal service conditions, and usually are not related to strength or safety. The term "resistance" includes both strength limit states and serviceability limit states.

The *design strength* $\phi R_n$ is the *nominal strength* $R_n$ multiplied by the resistance factor $\phi$. The factored load is the sum of the nominal loads multiplied by load factors, with due recognition of load combinations that account for the improbability of simultaneous occurrence of multiple transient load effects at their respective maximum values. The *design strength* $\phi R_n$ of each structural component or assemblage must equal or exceed the *required strength* ($V_u$, $T_u$, etc.).

The *allowable strength* $R_n / \Omega$ is the *nominal strength* $R_n$ divided by the safety factor $\Omega$. The design load is the sum of the nominal loads multiplied by load factors that account for the improbability of simultaneous occurrence of multiple transient load effects at the respective maximum values. The *allowable strength* $R_n / \Omega$ of each structural component or assemblage must equal or exceed the *required strength* ($V_a$, $T_a$, etc.).

Although loads, load factors and load combinations are not explicitly specified in this Specification, the safety and resistance factors herein are based upon those specified in ASCE 7. When the design is governed by other load criteria, the safety and resistance factors specified herein should be adjusted as appropriate.

**Section 5**

## SECTION 5. LIMIT STATES IN BOLTED JOINTS

The design shear strength and design tensile strength of bolts shall be determined in accordance with Section 5.1. The interaction of combined shear and tension on bolts shall be limited in accordance with Section 5.2. The design bearing strength of the connected parts at bolt holes shall be determined in accordance with Section 5.3. Each of these *design strengths* shall be equal to or greater than the *required strength*. The axial load in bolts that are subject to tension or combined shear and tension shall be calculated with consideration of the effects of the externally applied tensile load and any additional tension resulting from *prying action* produced by deformation of the connected parts.

When slip resistance is required at the *faying surfaces* subject to shear or combined shear and tension, slip resistance shall be checked at either the factored-load level or service-load level, at the option of the *Engineer of Record*. When slip of the *joint* under factored loads would affect the ability of the structure to support the factored loads, the *design strength* determined in accordance with Section 5.4.1 shall be equal to or greater than the *required strength*. When slip resistance under service loads is the design criterion, the strength determined in accordance with Section 5.4.2 shall be equal to or greater than the effect of the service loads. In addition, slip-critical connections must meet the strength requirements to resist the factored loads as shear/bearing joints. Therefore, the strength requirements of Sections 5.1, 5.2 and 5.3 shall also be met.

When bolts are subject to cyclic application of axial tension, the stress determined in accordance with Section 5.5 shall be equal to or greater than the stress due to the effect of the service loads, including any additional tension resulting from prying action produced by deformation of the connected parts.

**Commentary:**
This section of the Specification provides the design requirements for *high-strength bolts* in bolted *joints*. However, this information is not intended to provide comprehensive coverage of the design of *high-strength bolted connections*. Other design considerations of importance to the satisfactory performance of the connected material, such as block shear rupture, shear lag, *prying action* and *connection* stiffness and its effect on the performance of the structure, are beyond the scope of this Specification and Commentary.

The design of bolted *joints* that transmit shear requires consideration of the shear strength of the bolts and the bearing strength of the connected material. If such *joints* are designated as *slip-critical joints*, the slip resistance must also be checked. This serviceability check can be made at the factored-load level (Section 5.4.1) or at the service-load level (Section 5.4.2). Regardless of which load level is selected for the check of slip resistance, the prevention of slip in the service-load range is the design criterion.

Parameters that influence the shear strength of bolted *joints* include:

(1) Geometric parameters – the ratio of the net area to the gross area of the connected parts, the ratio of the net area of the connected parts to the total shear-resisting area of the bolts and the length of the *joint*; and,

(2) Material parameter – the ratio of the yield strength to the tensile strength of the connected parts.

Using both mathematical models and physical testing, it was possible to study the influences of these parameters (Kulak et al., 1987; pp. 89-116 and 126-132). These showed that, under the rules that existed at that time the longest (and often the most important) *joints* had the lowest factor of safety, about 2.0 based on ultimate strength.

In general, bolted *joints* that are designed in accordance with the provisions of this Specification will have a higher reliability than will the members they connect. This occurs primarily because the resistance factors used in limit states for the design of bolted *joints* were chosen to provide a reliability higher than that used for member design. Additionally, the controlling strength limit state in the structural member, such as yielding or deflection, is usually reached well before the strength limit state in the *connection*, such as bolt shear strength or bearing strength of the connected material. The installation requirements vary with *joint* type and influence the behavior of the *joints* within the service-load range, however, this influence is ignored in all strength calculations. Secondary tensile stresses that may be produced in bolts in *shear/bearing joints*, such as through the flexing of double-angle *connections* to accommodate the simple-beam end rotation, need not be considered.

It is sometimes necessary to use *high-strength bolts* and fillet welds in the same *connection*, particularly as the result of remedial work. When these fastening elements act in the same shear plane, the combined strength is a function of whether the bolts are snug-tightened or pretensioned, the location of the bolts relative to the holes in which they are located and the orientation of the fillet welds. The fillet welds can be parallel or transverse to the direction of load. Manuel and Kulak (1999) provide an approach that can be used to calculate the *design strength* of such *joints*.

## 5.1. Nominal Shear and Tensile Strengths

Shear and tensile strengths shall not be reduced by the installed bolt pretension. For *joints*, the nominal shear and tensile strengths shall be taken as the sum of the strengths of the individual bolts.

$$R_n = F_n A_b \qquad \text{(Equation 5.1)}$$

where

$R_n$ = nominal strength (shear strength per shear plane or tensile strength) of a bolt, kips;

The *design strength* in shear or the *design strength* in tension for an ASTM A325, A490, F1852 or F2280 bolt is $\phi R_n$, where $\phi$= 0.75~~;~~The *allowable strength* in shear or the *allowable strength* in tension for an ASTM A325, A490, F1852 or F2280 bolt is $R_n/\Omega$ where $\Omega$ = 2.00.

### Table 5.1. Nominal Strengths per Unit Area of Bolts

<table>
<tr><th colspan="3" rowspan="2">Applied Load Condition</th><th colspan="2">Nominal Strength per Unit Area, $F_n$, ksi</th></tr>
<tr><th>ASTM A325 or F1852</th><th>ASTM A490 or F2280</th></tr>
<tr><td rowspan="2">Tension [a]</td><td colspan="2">Static</td><td>90</td><td>113</td></tr>
<tr><td colspan="2">Fatigue</td><td colspan="2">See Section 5.5</td></tr>
<tr><td rowspan="4">Shear [a,b]</td><td rowspan="2">Threads included in shear plane</td><td>$L_s \le 38$ in.</td><td>54</td><td>68</td></tr>
<tr><td>$L_s > 38$ in.</td><td>45</td><td>56</td></tr>
<tr><td rowspan="2">Threads excluded from shear plane</td><td>$L_s \le 38$ in.</td><td>68</td><td>84</td></tr>
<tr><td>$L_s > 38$ in.</td><td>56</td><td>70</td></tr>
<tr><td colspan="5">[a] Except as required in Section 5.2.<br>[b] Reduction for values for $L_s > 38$ in. applies only when the joint is end loaded, such as splice plates on a beam or column flange.</td></tr>
</table>

$F_n$ = nominal strength per unit area from Table 5.1 for the appropriate applied load conditions, ksi, adjusted for the presence of fillers as required below, and,

$A_b$ = cross-sectional area based upon the nominal diameter of bolt, in.$^2$

When a bolt that carries load passes through fillers or shims in a shear plane that are equal to or less than 1/4 in. thick, $F_n$ from Table 5.1 shall be used without reduction. When a bolt that carries load passes through fillers or shims that are greater than 1/4 in. thick, they shall be designed in accordance with one of the following procedures:

(1) For fillers or shims that are equal to or less than 3/4 in. thick, $F_n$ from Table 5.1 shall be multiplied by the factor [1 - 0.4($t'$ - 0.25)], where $t'$ is the total thickness of fillers or shims, in., up to 3/4 in.;
(2) The fillers or shims shall be extended beyond the *joint* and the filler or shim extension shall be secured with enough bolts to uniformly distribute the total force in the connected element over the combined cross-section of the connected element and the fillers or shims;
(3) The size of the *joint* shall be increased to accommodate a number of bolts that is equivalent to the total number required in (2) above; or,
(4) The *joint* shall be designed as a *slip-critical joint*. The slip resistance of the *joint* shall not be reduced for the presence of fillers or shims.

**Commentary:**
The nominal shear and tensile strengths of ASTM A325, F1852, A490 and F2280 bolts are given in Table 5.1. These values are based upon the work of a large number of researchers throughout the world, as reported in the *Guide* (Kulak et al., 1987; Tide, 2010). The *design strength* equals the *nominal strength* multiplied by a resistance factor $\phi$. The *allowable strength* equals the *nominal strength* divided by a safety factor $\Omega$.

The nominal shear strength is based upon the observation that the shear strength of a single *high-strength bolt* is about 0.62 times the tensile strength of that bolt (Kulak et al., 1987; pp. 44-50). In addition, a reduction factor of 0.90 is applied to joints up to 38 in. in length to account for an increase in bolt force due to minor secondary effects resulting from simplifying assumptions made in the modeling of structures that are commonly accepted in practice (e.g. truss bolted connections assumed pinned in the analysis model). Second order effects such as those resulting from the action of the applied loads on the deformed structure, should be accounted for through a second order analysis of the structure. As noted in Table 5.1, the average shear strength of bolts in *joints* longer than 38 in. in length is reduced by a factor of 0.75 instead of 0.90. This factor accounts for both the non-uniform force distribution between the bolts in a long joint and the minor secondary effects discussed above. Note that the 0.75 reduction factor does not apply in cases where the distribution of force is essentially uniform along the *joint*, such as the bolted *joints* in a shear *connection* at the end of a deep plate girder.

The average ratio of nominal shear strength for bolts with threads included in the shear plane to the nominal shear strength for bolts with threads excluded from the shear plane is 0.83 with a standard deviation of 0.03 (Frank and Yura, 1981). Conservatively, a reduction factor of 0.80 is used to account for the reduction in shear strength for a bolt with threads included in the shear plane but calculated with the area corresponding to the nominal bolt diameter. The case of a bolt in double shear with a non-threaded section in one shear plane and a threaded section in the other shear plane is not covered in this Specification for two reasons. First, the manner in which load is shared between these two dissimilar shear areas is uncertain. Second, the detailer's lack of certainty as to the orientation of the bolt placement might leave both shear planes in the threaded section. Thus, if threads are included in one shear plane, the conservative assumption is made that threads are included in all shear planes.

The tensile strength of a *high-strength bolt* is the product of its ultimate tensile strength per unit area and some area through the threaded portion. This area, called the tensile stress area, is a derived quantity that is a function of the relative thread size and pitch. For the usual sizes of structural bolts, it is about 75 percent of the nominal cross-sectional area of the bolt. Hence, the nominal tensile strengths per unit area given in Table 5.1 are 0.75 times the tensile strength of the bolt material. According to Equation 5.1, the nominal area of the bolt is then used to calculate the *design strength* *or allowable strength* in tension. The ~~*nominal*~~ *strengths* so-calculated are intended to form the basis for comparison with the externally applied bolt tension plus any additional tension that results from *prying action* that is produced by deformation of the connected elements.

If pretensioned bolts are used in a *joint* that loads the bolts in tension, the question arises as to whether the pretension and the applied tension are additive. Because the compressed parts are being unloaded during the application of the external tensile force, the increase in bolt tension is minimal until the parts separate (Kulak et al., 1987; pp. 263-266). Thus, there will be little increase in bolt force above the pretension load under service loads. After the parts separate, the bolt acts as a tension member, as expected, and its *design strength* is that given in Equation 5.1 multiplied by the resistance factor $\phi$, and its *allowable strength* is that given in Equation 5.1 divided by the safety factor $\Omega$.

Pretensioned bolts have torsion present during the installation process. Once the installation is completed, any residual torsion is quite small and will disappear entirely when the fastener is loaded to the point of plate separation. Hence, there is no question of torsion-tension interaction when considering the ultimate tensile strength of a *high-strength bolt* (Kulak et al., 1987; pp. 41-47).

When required, pretension is induced in a bolt by imposing a small axial elongation during installation, as described in the Commentary to Section 8. When the *joint* is subsequently loaded in shear, tension or combined shear and tension, the bolts will undergo significant deformations prior to failure that have the effect of overriding the small axial elongation that was introduced during installation, thereby removing the pretension. Measurements taken in laboratory tests confirm that the pretension that would be sustained if the applied load were removed is essentially zero before the bolt fails in shear (Kulak et al., 1987; pp. 93-94). Thus, the shear and tensile strengths of a bolt are not affected by the presence of an initial pretension in the bolt.

See also the Commentary to Section 5.5.

## 5.2. Combined Shear and Tension

When combined shear and tension loads are transmitted by an ASTM A325, A490, F1852 or F2280 bolt, the ~~ultimate~~ factored limit-state interaction shall be:

$$\left[\frac{T_u}{(\phi R_n)_t}\right]^2 + \left[\frac{V_u}{(\phi R_n)_v}\right]^2 \leq 1 \qquad \text{(Equation 5.2a)}$$

where

$T_u$ = *required strength* in tension (factored tensile load) per bolt, kips;
$V_u$ = *required strength* in shear (factored shear load) per bolt, kips;
$(\phi R_n)_t$ = *design strength* in tension determined in accordance with Section 5.1, kips; and,
$(\phi R_n)_v$ = *design strength* in shear determined in accordance with Section 5.1, kips.

When combined shear and tension loads are transmitted by an ASTM A325, A490, F1852 or F2280 bolt, the allowable limit-state interaction shall be:

$$\left[\frac{T_a}{(R_n/\Omega)_t}\right]^2 + \left[\frac{V_a}{(R_n/\Omega)_a}\right]^2 \leq 1 \qquad \text{(Equation 5.2b)}$$

where

$T_a$ = *required strength* in tension (service tensile load) per bolt, kips;
$V_a$ = *required strength* in shear (service shear load) per bolt, kips;
$(R_n/\Omega)_t$ = *allowable strength* in tension determined in accordance with Section 5.1, kips; and,
$(R_n/\Omega)_v$ = *allowable strength* in shear determined in accordance with Section 5.1, kips.

**Commentary:**
When both shear forces and tensile forces act on a bolt, the interaction can be conveniently expressed as an elliptical solution (Chesson et al., 1965) that includes the elements of the bolt acting in shear alone and the bolt acting in tension alone. Although the elliptical solution provides the best estimate of the strength of bolts subject to combined shear and tension and is thus used in this Specification, the nature of the elliptical solution is such that it can be approximated conveniently using three straight lines (Carter et al., 1997). Earlier editions of this specification have used such linear representations for the convenience of design calculations. The elliptical interaction equation in effect shows that, for design purposes, significant interaction does not occur until either force component exceeds 20 percent of the limiting strength for that component.

## 5.3. Nominal Bearing Strength at Bolt Holes

For *joints*, the nominal bearing strength shall be taken as the sum of the strengths of the connected material at the individual bolt holes.

The design bearing strength of the connected material at a standard bolt hole, oversized bolt hole, short-slotted bolt hole independent of the direction of loading or long-slotted bolt hole with the slot parallel to the direction of the bearing load is $\phi R_n$, where $\phi$ = 0.75:

The allowable bearing strength of the connected material at a standard bolt hole, oversized bolt hole, short-slotted bolt hole independent of the direction of loading or long-slotted bolt hole with the slot parallel to the direction of the bearing load is $R_n$,/Ω where Ω = 2.00 and:

(1) when deformation of the bolt hole at service load is a design consideration;

$$R_n = 1.2 L_c t F_u \leq 2.4 d_b t F_u \qquad \text{(Equation 5.3)}$$

(2) when deformation of the bolt hole at service load is not a design consideration;

$$R_n = 1.5 L_c t F_u \leq 3 d_b t F_u \qquad \text{(Equation 5.4)}$$

The design bearing strength of the connected material at a long-slotted bolt hole with the slot perpendicular to the direction of the bearing load is $\phi R_n$, where $\phi$ = 0.75The allowable bearing strength of the connected material at a long-slotted bolt hole with the slot perpendicular to the direction of the bearing load is $R_n$/Ω where Ω = 2.00 and:

$$R_n = L_c t F_u \leq 2 d_b t F_u \qquad \text{(Equation 5.5)}$$

In Equations 5.3, 5.4 and 5.5,

$R_n$ = *nominal strength* (bearing strength of the connected material), kips;
$F_u$ = specified minimum tensile strength per unit area of the connected material, ksi;
$L_c$ = clear distance, in the direction of load, between the edge of the hole and the edge of the adjacent hole or the edge of the material, in.;
$d_b$ = nominal diameter of bolt, in.; and,
$t$ = thickness of the connected material, in.

**Commentary:**
The contact pressure at the interface between a bolt and the connected material can be expressed as a bearing stress on the bolt or on the connected material. The connected material is always critical. For simplicity, the bearing area is expressed as the bolt diameter times the thickness of the connected material in bearing. The governing value of the bearing stress has been determined from extensive experimental research and a further limitation on strength was derived from the case of a bolt at the end of a tension member or near another fastener.

The design equations are based upon the models presented in the *Guide* (Kulak et al., 1987; pp. 141-143), except that the clear distance to another hole or edge is used in the Specification formulation rather than the bolt spacing or end distance as used in the *Guide* (see Figure C-5.1). Equation 5.3 is derived from tests (Kulak et al., 1987; pp. 112-116) that showed that the total elongation, including local bearing deformation, of a standard hole that is loaded to obtain the ultimate strength equal to $3d_btF_u$ in Equation 5.4 was on the order of the diameter of the bolt.

This apparent hole elongation results largely from bearing deformation of the material that is immediately adjacent to the bolt. The lower value of $2.4d_btF_u$ in Equation 5.3 provides a bearing strength limit-state that is attainable at reasonable deformation (4 in.). Strength and deformation limits were thus used to jointly evaluate bearing strength test results for design.

When long-slotted holes are oriented with the long dimension perpendicular to the direction of load, the bending component of the deformation in the material between adjacent holes or between the hole and the edge of the plate is increased. The nominal bearing strength is limited to $2d_btF_u$, which again provides a bearing strength limit-state that is attainable at reasonable deformation.

The design bearing strength has been expressed as that of a single bolt, although it is really that of the connected material that is immediately adjacent to the bolt. In calculating the design bearing strength of a connected part, the total bearing strength of the connected part can be taken as the sum of the bearing strengths of the individual bolts.

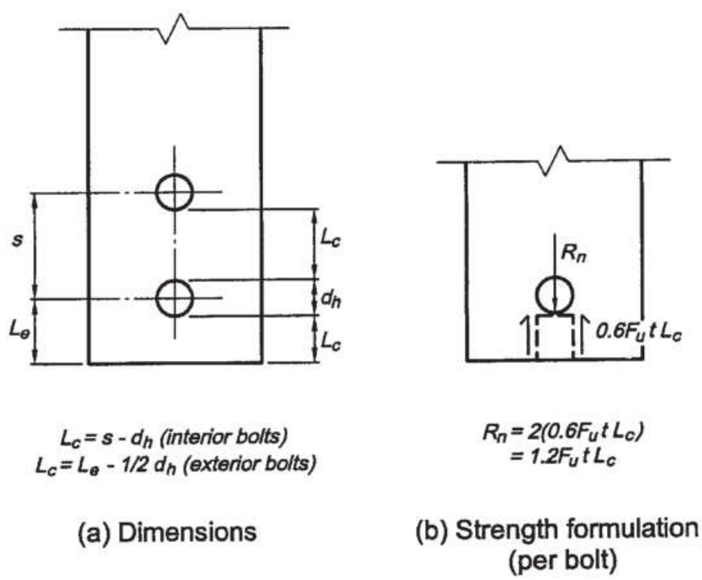


*Figure. C-5.1. Bearing strength formulation.*

## 5.4. Design Slip Resistance

5.4.1. At the Factored-Load Level: The design slip resistance is $R_u$ and:

$$R_u = \Phi \mu D_u T_m N_b \left(1 - \frac{T}{D T_m N_b}\right) \qquad \text{(Equation 5.6)}$$

$$\cancel{R_n = \mu D_u T_m N_b \left(1 - \frac{T_u}{D_u T_m N_b}\right)} \qquad \text{~~(Equation 5.6)~~}$$

where

~~ϕ~~Φ = 1.0 for standard holes
= 0.85 for oversized and short-slotted holes
= 0.70 for long-slotted holes perpendicular to the direction of load
= 0.60 for long-slotted holes parallel to the direction of load;

~~$R_n$~~ $R_u$ = ~~*nominal*~~*design* *strength* (slip resistance) of a slip plane, kips;

μ = *mean slip coefficient* for Class A, B or C *faying surfaces*, as applicable, or as established by testing in accordance with Appendix A (see Section 3.2.2(b))
= 0.33 for Class A *faying surfaces* (uncoated clean mill scale steel surfaces or surfaces with Class A coatings on blast-cleaned steel)
= 0.50 for Class B surfaces (uncoated blast-cleaned steel surfaces or surfaces with Class B coatings on blast-cleaned steel)
= 0.35 for Class C surfaces (roughened hot-dip galvanized surfaces);

$D_u$ = 1.13, a multiplier that reflects the ratio of the mean installed bolt pretension to the specified minimum bolt pretension $T_m$; the use of other values of $D_u$ shall be approved by the *Engineer of Record;*

$T_m$ = specified minimum bolt pretension (for *pretensioned joints* as specified in Table 8.1), kips;

$N_b$ = number of bolts in the *joint*; and,

$T_u$ = *required strength* in tension (tensile component of applied factored load for combined shear and tension loading), kips
= zero if the *joint* is subject to shear only

5.4.2. At the Service-Load Level: The service-load slip resistance is $R_a$ ~~ϕwhere Φ is as defined in Section 5.4.1~~ and:

$$R_a = \Phi \mu D T_m N_b \left(1 - \frac{T_a}{D T_m N_b}\right) \qquad \text{(Equation 5.7)}$$

$$\cancel{R_n = \mu D T_m N_b \left(1 - \frac{T}{D T_m N_b}\right)} \qquad \text{~~(Equation 5.7)~~}$$

where

$D$ = 0.80, a slip probability factor that reflects the distribution of actual slip coefficient values about the mean, the ratio of mean installed bolt pretension to the specified minimum bolt pretension, $T_m$, and a slip probability level; the use of other values of $D$ must be approved by the *Engineer of Record*; and,

~~$T$~~ $T_a$ = applied service load in tension (tensile component of applied service load for combined shear and tension loading), kips
= zero if the *joint* is subject to shear only

and all other variables are as defined for Equation 5.6.

**Commentary:**

The design check for slip resistance can be made either at the factored-load level (Section 5.4.1) or at the service-load level (Section 5.4.2). These alternatives are based upon different design philosophies, which are discussed below. They have been calibrated to produce results that are essentially the same. The factored-load level approach is provided for the expedience of only working with factored loads. Irrespective of the approach, the limit state is based upon the prevention of slip at service-load levels.

If the factored-load provision is used, the *nominal strength* $R_n$ represents the mean resistance, which is a function of the *mean slip coefficient* μ and the specified minimum bolt pretension (clamping force) $T_m$. The 1.13 multiplier in Equation 5.6 accounts for the expected 13 percent higher mean value of the installed bolt pretension provided by the calibrated wrench pretensioning method compared to the specified minimum bolt pretension $T_m$ used in the calculation. In the absence of other field test data, this value is used for all methods.

If the service-load approach is used, a probability of slip is identified. It implies that there is 90 percent reliability that slip will not occur at the calculated slip load if the calibrated wrench pretensioning method is used, or that there is 95 percent reliability that slip will not occur at the calculated slip load if the turn-of-nut pretensioning method is used. The probability of loading occurrence was not considered in developing these slip probabilities (Kulak et al., 1987; p. 135).

For most applications, the assumption that the slip resistance at each fastener is equal and additive with that at the other fasteners is based on the fact that all locations must develop the slip force before a total *joint* slip can occur at that plane. Similarly, the forces developed at various slip planes do not necessarily develop simultaneously, but one can assume that the full slip resistances must be mobilized at each plane before full *joint* slip can occur. Equations 5.6 and 5.7 are formulated for the general case of a single slip plane. The total slip resistance of a *joint* with multiple slip planes can be calculated as that for a single slip plane multiplied by the number of slip planes.

Only the *Engineer of Record* can determine whether the potential slippage of a *joint* is critical at the service-load level as a serviceability consideration only or whether slippage could result in distortions of the frame such that the ability of the frame to resist the factored loads would be reduced. The following comments reflect the collective thinking of the Council and are provided as guidance and an indication of the intent of the Specification (see also the Commentary to Sections 4.2 and 4.3):

(1) If *joints* with standard holes have only one or two bolts in the direction of the applied load, a small slip may occur. In this case, *joints* subject to vibration should be proportioned to resist slip at the service-load level;

(2) In built-up compression members, such as double-angle struts in trusses, a small relative slip between the elements especially at the end *connections* can increase the effective length of the combined cross-section to that of the individual components and significantly reduce the compressive strength of the strut. Therefore, the *connection* between the elements at the ends of built-up members should be checked

at the factored-load level, whether or not a *slip-critical joint* is required for serviceability. As given by Sherman and Yura (1998), the required slip resistance is $0.008P_uLQ/I$, where $P_u$ is the axial compressive force in the built-up member, kips, $L$ is the total length of the built-up member, in., $Q$ is the first moment of area of one component about the axis of buckling of the built-up member, in.$^3$, and $I$ is the moment of inertia of the built-up member about the axis of buckling, in.$^4$;

(3) In *joints* with long-slotted holes that are parallel to the direction of the applied load, the designer has two alternatives. The *joint* can be designed to prevent slip in the service-load range using either the factored-load-level provision in Section 5.4.1 or the service-load-level provision in Section 5.4.2. In either case, however, the effect of the factored loads acting on the deformed structure (deformed by the maximum amount of slip in the long slots at all locations) must be included in the structural analysis; and,

(4) In *joints* subject to fatigue, design should be based upon service-load criteria and the design slip resistance of Section 5.4.2 because fatigue is a function of the service load performance rather than that of the factored load.

Extensive data developed through research sponsored by the Council and others during the past twenty years has been statistically analyzed to provide improved information on slip probability of *joints* in which the bolts have been pretensioned to the requirements of Table 8.1. Two variables, the *mean slip coefficient* of the *faying surfaces* and the bolt pretension, were found to affect the slip resistance of *joints*. Field studies (Kulak and Birkemoe, 1993) of installed bolts in various structural applications indicate that the Table 8.1 pretensions have been achieved as anticipated in the laboratory research.

An examination of the slip-coefficient data for a wide range of surface conditions indicates that the data are distributed normally and the standard deviation is essentially the same for each surface condition class. This means that different reduction factors should be applied to classes of surfaces with different *mean slip coefficients*—the smaller the mean value of the coefficient of friction, the smaller (more severe) the appropriate reduction factor—to provide equivalent reliability of slip resistance.

The bolt clamping force data indicate that bolt pretensions are distributed normally for each pretensioning method. However, the data also indicate that the mean value of the bolt pretension is different for each method. As noted previously, if the calibrated wrench method is used to pretension ASTM A325 bolts, the mean value of bolt pretension is about 1.13 times the specified minimum pretension in Table 8.1. If the turn-of-nut pretensioning method is used, the mean pretension is about 1.35 times the specified minimum pretension for ASTM A325 bolts and about 1.26 for ASTM A490 bolts.

The combined effects of the variability of the *mean slip coefficient* and bolt pretension have been accounted for approximately in the single value of the slip probability factor $D$ in the equation for nominal slip resistance in Section 5.4.2. This implies 90 percent reliability that slip will not occur if the calibrated wrench pretensioning method is used and 95 percent reliability if the turn-of-nut pretensioning method is used. For values of $D$ that are appropriate for other *mean slip coefficients* and slip probabilities, refer to the *Guide* (Kulak et al., 1987; p. 135). The values given therein are suitable for direct substitution into the formula for slip resistance in Section 5.4.2.

The calibrated wrench installation method targets a specific bolt pretension, which is 5 percent greater than the specified minimum value given in Table 8.1. Thus, regardless of the actual strength of production bolts, this target value is unique for a given fastener grade. On the other hand, the turn-of-nut installation method imposes an elongation on the fastener. Consequently, the inherent strength of the bolts being installed will be reflected in the resulting pretension because this elongation will bring the fastener to its proportional limit under combined torsion and tension. As a result of these differences, the mean value and nature of the frequency distribution of pretensions for the two installation methods differ. Turn-of-nut installations result in higher mean levels of pretension than do calibrated wrench installations. These differences were taken into account when the design criteria for *slip-critical joints* were developed.

Statistical information on the pretension characteristics of bolts installed in the field using direct tension indicators and twist-off-type tension-control bolts is limited.

In any of the foregoing installation methods, it can be expected that a portion of the bolt assembly (the threaded portion of the bolt within the *grip* length and/or the engaged threads of the nut and bolt) will reach the inelastic region of behavior. This permanent distortion has no undesirable effect on the subsequent performance of the bolt.

Because of the greater likelihood that significant deformation can occur in *joints* with oversized or slotted holes, lower values of design slip resistance are provided for *joints* with these hole types through a modification of the resistance factor $\phi$. For the case of long-slotted holes, even though the slip load is the same for loading transverse or parallel to the axis of the slot, the value for loading parallel to the axis has been further reduced, based upon judgment, in recognition of the greater consequences of slip.

Although the design philosophy for *slip-critical joints* presumes that they do not slip into bearing when subject to loads in the service range, it is mandatory that *slip-critical joints* also meet the requirements of Sections 5.1, 5.2 and 5.3. Thus, they must meet the strength requirements to resist the factored loads as *shear/bearing joints*.

Section 3.2.2(b) permits the *Engineer of Record* to authorize the use of *faying surfaces* with a *mean slip coefficient* $\mu$ that is less than 0.50 (Class B) and other than 0.33 (Class A). This authorization requires that the following restrictions are met:

(1) The *mean slip coefficient* $\mu$ must be determined in accordance with Appendix A; and,
(2) The appropriate slip probability factor *D* must be selected from the *Guide* (Kulak et al., 1987) for design at the service-load level.

Prior to the 1994 edition of this Specification, $\mu$ for Class C surfaces was taken as 0.40. This value was reduced to 0.35 in the 1994 edition for better agreement with the available research (Kulak et al., 1987; pp. 78-82).

## 5.5. Tensile Fatigue

The tensile stress in the bolt that results from the cyclic application of externally applied service loads and the prying force, if any, but not the pretension, shall not exceed the stress in Table 5.2. The nominal diameter of the bolt shall be used in calculating the bolt stress. The connected parts shall be proportioned so that the calculated prying force does not exceed 30 percent of the externally applied load. *Joints* that are subject to tensile fatigue loading shall be specified as pretensioned in accordance with Section 4.2 or slip-critical in accordance with Section 4.3.

**Table 5.2. Maximum Tensile Stress for Fatigue Loading**

| Number of Cycles | Maximum Bolt Stress for Design at Service Loads [a], ksi | |
|---|---|---|
| | ASTM A325 or F1852 | ASTM A490 or F2280 |
| Not more than 20,000 | 45 | 57 |
| From 20,000 to 500,000 | 40 | 49 |
| More than 500,000 | 31 | 38 |

[a] Including the effects of *prying action*, if any, but excluding the pretension.

**Commentary:**
As described in the Commentary to Section 5.1, *high-strength bolts* in *pretensioned joints* that are nominally loaded in tension will experience little, if any, increase in axial stress under service loads. For this reason, pretensioned bolts are not adversely affected by repeated application of service-load tensile stress. However, care must be taken to ensure that the calculated prying force is a relatively small part of the total applied bolt tension (Kulak et al., 1987; p. 272). The provisions that cover bolt fatigue in tension are based upon research results where various single-bolt assemblies and *joints* with bolts in tension were subjected to repeated external loads that produced fatigue failure of the pretensioned fasteners. A limited range of prying effects was investigated in this research.

## APPENDIX B. ALLOWABLE STRESS DESIGN (ASD) ALTRNATIVE

**DELETE IN ITS ENTIRETY**

# RCSC Proposed Change: S11-035

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**Proposed Change:**

**1.4. Drawing Information**

The Engineer of Record shall specify the following information in the contract documents:
(1) The ASTM designation and type (Section 2) of bolt to be used;
(2) The hole type and direction of loading, if slotted hole (Section 3);
(~~2~~3) The joint type (Section 4);
(~~3~~4) The required class of slip resistance if slip-critical joints are specified (Section 4); and,
(~~4~~5) Whether slip is checked at the factored-load level or the service-load level, if slip-critical joints are specified (Section 5).

**Commentary:**

A summary of the information that the Engineer of Record is required to provide in the contract documents is provided in this Section. The parenthetical reference after each listed item indicates the location of the actual requirement in this Specification. In addition, the approval of the Engineer of Record is required in this Specification in the following cases:
(1) For the reuse of non-galvanized ASTM A325 bolts (Section 2.3.3);
(2) For the use of alternative washer-type indicating devices that differ from those that meet the requirements of ASTM F959, including the corresponding installation and inspection requirements that are provided by the manufacturer (Section 2.6.2);
(3) For the use of alternative-design fasteners, including the corresponding installation and inspection requirements that are provided by the manufacturer (Section 2.8);
(4) For the use of faying-surface coatings in slip-critical joints that provide a mean slip coefficient determined per Appendix A, but differing from Class A or Class B (Section 3.2.2(b));
(5) For the use of thermal cutting in the production of bolt holes (Section 3.3);
~~(6) For the 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;~~
(7) For the use of a value of Du other than 1.13 (Section 5.4.1); and,
(8) For the use of a value of D other than 0.80 (Section 5.4.2).

**3.3 Bolt Holes**

The Engineer of Record shall specify the hole type in the contract documents as standard, oversized, short-slotted or long-slotted holes, and for slotted holes, their orientation. The nominal dimensions of standard, oversized, short-slotted and long-slotted holes for *high strength bolts* shall be equal to or less than those shown in Table 3.1. Holes larger than those shown in Table 3.1 are permitted when specified or approved by the *Engineer of Record*. Where thermally cut holes are permitted, the surface roughness profile of the hole shall not exceed 1,000 microinches as defined in ASME B46.1. Occasional gouges not more than 1/16 in. in depth are permitted.

-----------------------------------For Committee Use Below---------------------------------------------

Date Received: 6/1/11 Exec Com Meeting: _______ Forwarded: Yes ☐ /No ☐

Committee Assignment: Executive -A. ☐ Editorial -B. ☐ Nominating -C. ☐

Specifications -A.1 X Research -A.2 ☐ Membership & Funding -A.3 ☐ Education -A.4 ☐
Committee Chair: Harrold Task Group #: ___________ T.G. Chair: Shaw
Date Sent to Main Committee: _______________Final Disposition: ______________________

Thermally cut holes produced by mechanically guided means are permitted in statically loaded *joints*. Thermally cut holes produced free hand shall be permitted in statically loaded joints if approved by the *Engineer of Record*. For cyclically loaded joints, thermally cut holes shall be permitted if approved by the *Engineer of Record*.

*{Note: Table 3.1 Nominal Bolt Hole Dimensions is unchanged and not reproduced here.}*

3.3.1. Standard Holes: ~~In the absence of approval by the *Engineer of Record* for the use of other hole types, s~~ Standard holes ~~shall be used~~ are permitted in all plies of bolted *joints.*

3.3.2. Oversized Holes: ~~When approved by the *Engineer of Record*, o~~ Oversized holes are permitted in any or all plies of *slip-critical joints* as defined in Section 4.3.

3.3.3. Short-Slotted Holes: ~~When approved by the *Engineer of Record*, s~~ Short-slotted holes are permitted in any or all plies of *snug-tightened joints* as defined in Section 4.1, and *pretensioned joints* as defined in Section 4.2, provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot. ~~When approved by the *Engineer of Record*, s~~ Short-slotted holes are permitted in any or all plies of *slip-critical joints* as defined in Section 4.3 without regard for the direction for the applied load.

3.3.4. Long-Slotted Holes: ~~When approved by the *Engineer of Record*, l~~ Long-slotted holes are permitted in only one ply at any individual *faying surface* of *snug-tightened joints* as defined in Section 4.1, and *pretensioned joints* as defined in Section 4.2, provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot. ~~When approved by the *Engineer of Record*, l~~ Long-slotted holes are permitted in one ply only at any individual *faying surface* of *slip-critical joint*s as defined in Section 4.3 without regard for the direction of the applied load. Fully inserted finger shims between the *faying surfaces* of load-transmitting elements of bolted *joints* are not considered a long-slotted element of a *joint*; nor are they considered to be a ply at any individual *faying surface*. However, finger shims must have the same faying surface as the rest of the plies.

**Commentary:**

No Commentary changes are proposed.

**Rationale or Justification for Change:**

After lengthy debate regarding the default joint type for Section 4 and their associated installation requirements leading up to the 2000 RCSC Specification, it was determined that the Council should not establish a default condition for joint types, leaving this to the governing specification invoking the RCSC, such as AISC 360, AISC 341 and CSA S16. The language used for Section 4 is that the "Engineer shall specify ..."

The revisions to the language proposed for Section 3.3, and in 3.3.1 through 3.3.4, continues with this philosophy in that the RCSC Specification would not establish a default hole type. Any defaults should be addressed in the invoking specification (AISC, CSA, etc) rather in the RCSC Specification. Using language similar to that used in Section 4, this change requires that the Engineer specify the hole type, as appropriate for the project's connections, and may rely upon the invoking specification's default for guidance. As an example, AISC 360 Section J3.2, 2nd paragraph allows use of short-slotted holes when normal to direction of load, as follows: "Standard holes or short-slotted holes transverse to the direction of the load shall be provided in accordance with the provisions of this specification, unless oversized holes, short-slotted holes parallel to the load or long-slotted holes are approved by the engineer of record." In addition, the 4th paragraph of the same section permits their use in slip-critical joints and in bearing-type joints when loaded perpendicular to direction of stress. As currently written, the RCSC Specification requires the Engineer's approval to use short-slotted holes, even when normal to direction of load.

There is nothing in the RCSC Specification that prohibits a fabricator from discussing and encouraging modification to the Engineer's original requirements. The existing language fixes the hole type as standard, and for any deviations from that, the Engineer must permit the change. Often, Engineers are reluctant to permit anything but the "standard detail". Hence, the language as proposed would encourage Engineering consideration of project needs, without reliance upon an RCSC default.

# RCSC Proposed Change: S11-036

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**Proposed Change:**

## Additions to Glossary

Pretension (verb). The act of tightening a fastener assembly to a specific level of tension or higher.

Pretension (noun). A level of tension achieved in a fastener assembly through its installation, as required for pretensioned and slip-critical joints.

Torque. The measure of a force's tendency to produce rotation about an axis, equal to the magnitude of the force multiplied by the distance from its point of application to an axis of rotation (ft-lbs)

**Rationale or Justification for Change:**

These terms are regularly used, but do not have official definitions within the Specifcation.

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Date Received: 3/22/11 Exec Com Meeting: _______ Forwarded: Yes ☐ /No ☐

Committee Assignment: Executive -A. ☐ Editorial -B. ☐ Nominating -C. ☐

Specifications -A.1 ☐ Research -A.2 ☐ Membership & Funding -A.3 ☐ Education -A.4 ☐
Committee Chair: ____________ Task Group #: ___________ T.G. Chair: ________________
Date Sent to Main Committee: _______________Final Disposition: ______________________

# RCSC Proposed Change: S06-002B
(S06-003 is incorporated into this proposed change.)

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**Proposed Change:**

**Section 8.2.1:**

8.2.1. Turn-of-Nut Pretensioning: All bolts shall be installed in accordance with the requirements in Section 8.1, with washers positioned as required in Section 6.2. Subsequently, the nut or head rotation specified in Table 8.2 shall be applied to all *fastener assemblies* in the *joint*, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts. The part not turned by the wrench shall be prevented from rotating during this operation. Upon completion of the application of the required nut rotation for pretensioning, it is not permitted to turn the nut in the loosening direction except for the purpose of complete removal of the individual

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Date Received: 2006 Exec Com Meeting: 03/2007 Forwarded: Yes X / No ☐

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Specifications -A.1 X Research -A.2 ☐ Membership & Funding -A.3 ☐ Education -A.4 ☐

Committee Chair: Owen Task Group #: ___________ T.G. Chair: Muir

Date Sent to Main Committee: ________________Final Disposition: ________________________

## Table 8.2. Nut Rotation from Snug-Tight Condition for Turn-of-Nut Pretensioning [a,b]

| Bolt Length [c] | Disposition of Outer Faces of Bolted Parts | | |
|---|---|---|---|
| | Both faces normal to bolt axis | One face normal to bolt axis, other sloped not more than 1:20 [d] | Both faces sloped not more than 1:20 from normal to bolt axis [d] |
| Not more than $4d_b$ | 3 turn | 2 turn | q turn |
| More than $4d_b$ but not more than $8d_b$ | 2 turn | q turn | y turn |
| More than $8d_b$ but not more than $12d_b$ | q turn | y turn | 1 turn |

[a] Nut rotation is relative to bolt regardless of the element (nut or bolt) being turned. For required nut rotations of 2 turn and less, the tolerance is plus 60 degrees (1/6 turn) and minus 30 degrees ~~plus or minus 30 degrees~~; for required nut rotations of q turn and more, the tolerance is plus 60 degrees (1/6 turn) and minus 45 degrees ~~plus or minus 45 degrees~~.

[b] Applicable only to *joints* in which all material within the *grip* is steel.

[c] When the bolt length exceeds $12d_b$, the required nut rotation shall be determined by actual testing in a suitable *tension calibrator* that simulates the conditions of solidly fitting steel.

[d] Beveled washer not used.

fastener assembly. Such fastener assemblies shall not be reused except as permitted in Section 2.3.3.

**Commentary:**
The turn-of-nut pretensioning method results in more uniform bolt pretensions than is generally provided with torque-controlled pretensioning methods. Strain-control that reaches the inelastic region of bolt behavior is inherently more reliable than a method that is dependent upon torque control. However, proper implementation is dependent upon ensuring that the *joint* is properly compacted prior to application of the required partial turn and that the bolt head (or nut) is securely held when the nut (or bolt head) is being turned.

Match-marking of the nut and protruding end of the bolt after snug-tightening can be helpful in the subsequent installation process and is certainly an aid to inspection.

As indicated in Table 8.2, there is no available research that establishes the required nut rotation for bolt lengths exceeding $12d_b$. The required turn for such bolts can be established on a case-by-case basis using a *tension calibrator*.

Significant research indicates that, at rotations exceeding those specified in Table 8.2, the level of pretension in the bolt will still be above the specified minimum pretension. In addition, the pretension is likely to remain high until just prior to twist-off of the fastener. The rotational margin against twist-off is large. A325 and A490 bolts 7/8 in. diameter and 5-1/2 in. long with 1/8 in. of thread in the grip were tested. The installation condition for bolts of this length and diameter is 1/2 turn past snug. The A325 bolts did not fail until about 1-3/4 turns past snug, and the A490 bolts did not fail until about 1-1/4 turns past snug. Bolts with additional threads in the grip would exhibit additional ductility and tolerance for over-rotation.

Non-heat-treated nuts (A563 Grades C, C3 and D) manufactured near the lower range of permitted strength and hardness may strip if the bolt is tightened far beyond the specified level of pretension. For A325 bolts, nuts with a hardness of 89 HRB or higher should have adequate resistance to thread stripping. For A490 bolts, only heat-treated nuts are used. Deliberate over-rotation should be avoided to minimize risk of inducing nut stripping with low-hardness nuts, and inducing nut cracking with high-hardness and heat-treated nuts. Nut stripping or cracking would be considered cause for rejection of the installed fastener.

**Section 9.2.1:**

9.2.1. Turn-of-Nut Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section 8.2.1. Subsequently, it shall be ensured by *routine observation* that the bolting crew properly rotates the turned element relative to the unturned element by the amount specified in Table 8.2. Alternatively, when *fastener assemblies* are match-marked after the initial fit-up of the *joint* but prior to pretensioning, visual inspection after pretensioning is permitted in lieu of routine observation. No further evidence of conformity is required. A pretension that is greater than the value specified in Table 8.1 shall not be cause for rejection. A rotation that exceeds the required values, including tolerance, specified in Table 8.2 shall not be cause for rejection.

**Commentary:**

Match-marking of the assembly during installation as discussed in the Commentary to Section 8.2.1 improves the ability to inspect bolts that have been pretensioned with the turn-of-nut pretensioning method. The sides of nuts and bolt heads that have been impacted sufficiently to induce the Table 8.1 minimum pretension will appear slightly peened.

The turn-of-nut pretensioning method, when properly applied and verified during the construction, provides more reliable installed pretensions than after-the-fact *inspection* testing. Therefore, proper inspection of the method is for the inspector to observe the required pre-installation verification testing of the *fastener assemblies* and the method to be used, followed by monitoring of the work in progress to ensure that the method is routinely and properly applied, or visual inspection of match-marked assemblies.

Some problems with the turn-of-nut pretensioning method have been encountered with hot-dip galvanized bolts. In some cases, the problems have been attributed to an especially effective lubricant applied by the *manufacturer* to ensure that bolts and nuts from stock will meet the ASTM Specification requirements for minimum turns testing of galvanized fasteners. Job-site testing in the *tension calibrator* demonstrated that the lubricant reduced the coefficient of friction between the bolt and nut to the degree that “the full effort of an ironworker using an ordinary spud wrench” to snug-tighten the *joint* actually induced the full required pretension. Also, because the nuts could be removed with an ordinary spud wrench, they were erroneously judged by the *inspector* to be improperly pretensioned. Excessively lubricated *high-strength bolts* may require significantly less torque to induce the specified pretension. The required pre-installation verification will reveal this potential problem.

Conversely, the absence of lubrication or lack of proper over-tapping can cause seizing of the nut and bolt threads, which will result in a twist failure of the bolt at less than the specified pretension. For such situations, the use of a *tension calibrator* to check the bolt assemblies to be installed will be helpful in establishing the need for lubrication.

**Rationale or Justification for Change**

I have become aware of a project where 1000 bolts were replaced because they were over-rotated. I am also aware that sometimes the turned element is backed off to stay within the tolerance, which causes the achieved tension to drop dramatically. In essence, this over-rotation tolerance is causing more problems than the few bolts that may be saved from being broken or nuts that may strip from over-rotation.

Section 9.2.1 states "A pretension that is greater than the value specified in Table 8.1 shall not be cause for rejection." This statement initially was stated in the 1960 Commentary on Inspection to address torque measurements higher than that determined, as follows: “Readings higher than the calibrated minimum tension equivalent are not cause for rejection.” However, we make no such statement about over-rotation, and the two issues are not directly related by the users. Indeed, the achieved pretension typically significantly exceeds Table 8.1, even when staying within rotation tolerance.

Bethlehem’s “High-Strength Bolting for Structural Joints”, December 1972, provides a historical perspective on turn-of-nut. Page 8 states that “The tolerance on nut rotation has been reduced to plus or minus 30 deg to reduce the tendency to tighten beyond minimum required preload.” It appears the tolerance was established to reduce wasted time and effort going beyond the necessary rotation, not because of poor fastener or joint performance when over-rotated.

Because we have no limit on bolt tension for the snug condition, hence no well-defined maximum "starting line" for pretensioning, it makes little sense to reject a bolt because it exceeds the "finish line."

Essentially, a bolt is not too tight until it breaks. Stripping should not be an issue unless the nut is at the very low end of the Spec (for A563 Grades C, C3, and D). For a bolt to form a crack in the threads and not continue to fracture when using an impact wrench is highly unlikely. A small percentage of bolt elongation/rotation v. tension curves show that it is possible to have the pretension drop below the required pretension at extreme rotations, usually for high hardness bolts and minimal threads in the grip.

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For reference, the following text is from the Guide, section 4.3 on Installation.

The American Association of Railroads (AAR), faced with the problem of tightening bolts in remote areas without power tools, conducted a large number of tests to determine if the turn-of-nut could be used as a means of controlling bolt tension. (4.14, 4.15) These tests led to the conclusion that one turn from a finger-tight position produced the desired bolt tension. In 1955 the RCRBSJ adopted one turn of the nut from hand-tight position as an alternative method to installation.

Experience with the one full turn method indicated that it was impractical to use finger or hand tightness as a reliable point for starting the one turn. Because of out-of flatness, thread imperfections, and dirt accumulation, it was difficult and time consuming to determine the hand-tight position. Bethlehem Steel Corporation developed a modified "turn-of-nut" method, using the AAR studies and additional tests of their own. (4.16, 4.17) This method called for running the nut up to a snug position using an impact wrench rather than the fingertight condition. From the snug position the nut was given an additional ½ or ¾ turn, depending on the length of the bolt. The snug condition was defined as the point at which the wrench started to impact. This occurred when the turning of the nut was resisted by friction between the face of the nut and the surface of the steel. Snug-tightening the bolts induces small clamping forces in the bolts. In general, at the snug-tight condition the bolt clamping forces can vary considerably because elongations are still within the elastic range. This is illustrated in Fig. 4.18 where the range of bolt clamping force and bolt elongation at the snug tight condition is shown for 7/8 in. dia. A325 bolts installed in an A440 steel test joint. The average clamping force at the snugtight condition was equal to about 26 kip. The bolts in this test joint were snug tightened by means of an impact wrench. This modified turn-of-nut method was eventually incorporated into the 1960 specification of the council.

Controlling tension by the turn-of-nut method is primarily a strain control. If the elongation of the bolt remains within the elastic range, both the starting point (i.e., snug tight) and the amount and accuracy of the nut rotation beyond snug tight will be influential in determining the preload. However, in the inelastic region the load versus elongation curve is relatively flat, with the consequence that variations in the snug-tight condition result in only minor variations in the preload of the installed bolt. This inelastic behavior will be a characteristic of practically all installed bolts. It results from local yielding of the short length of thread between the underside of the nut and the gripped material. It has no undesirable effect on the subsequent structural performance of the bolt. Figure 4.18 illustrates these points.

Research in the 1960s indicated that one-half turn of the nut from the snug-tight condition was adequate for all lengths of A325 bolts that were then commonly used. (4.2, 4.5–4.7, 4.9) Based on this experience, the 1962 edition of the council specification required only one-half turn, regardless of bolt length.

In 1964 the council incorporated the A490 bolt into its specification. In order to make the specification applicable to both the A325 and the A490 bolts, the turn-of-nut method was modified again. Tests of A490 bolts had indicated that when the grip length was increased to about eight times the bolt diameter, a somewhat greater nut rotation (two-thirds turn) was needed to reach the required minimum bolt tension. Although the additional rotation was not needed for A325 bolts, the two-thirds turn provision has been applied to the A325 bolts as well in the interest of uniformity in field practice.

Calibration tests of A325 bolts with grips more than 4 diameters or 4 in. showed that the one-half turn of the nut rotation produced consistent bolt tensions in the inelastic range. (4.2) These tests also showed a sufficient margin of safety against fracture by excessive nut rotation. Bolts with grips of more than 4 in. or 4 diameters and short thread length under the nut can be given a one-half turn of the nut and have sufficient deformation capacity to sustain two additional half turns before failure. Bolts with long thread lengths in the grip can sustain three to five additional half turns, as illustrated in Fig. 4.19. Similar tests conducted on A490 bolts allow the comparison with A325 bolts shown in Fig. 4.20. A325 and A490 bolts gave substantially the same load versus nut rotation relationships up to the elastic limit. (4.1, 4.3, 4.9) At one-half turn from the snug position, the A490 bolts provided approximately 20% greater load than A325 bolts because of the increased strength of the A490 bolt. However, the higher strength of the A490 bolts results in a small decrease in nut rotation capacity as compared with the A325 bolt. These studies show that the factor of safety against twist-off for a bolt installed to one-half turn from snug is about three and one-half for A325 bolts and about two and one-half for A490 bolts. Moreover, it must be recognized that the only source of additional rotation after a bolt is installed would have to be vandalism. Because of the high torque required to produce additional rotation, even this source is unlikely.

Studies on short grip bolts (length less than or equal to four bolt diameters) have shown that their factor of safety against twist-off was less than two when one-half turn was used. This resulted in the adoption in 1974 of one-third turn for bolts whose length was less than four diameters. More care needs to be taken in their installation in order to avoid twist-off.

Figure 4.21 shows load versus elongation curves for 7/8 in. diameter A325 bolts 2¼ in. long. (4.36) Some tests were done on low hardness bolts and some on high hardness bolts, and there were either 1½ or 2½ threads unengaged below the nut. It is clear that both parameters had an influence on the ductility of these bolts. High hardness means high strength and reduced ductility. Because most of the bolt elongation is occurring in the threaded portion below the nut, an increase in this length also increased ductility. However, it can be noted that in all cases the specification requirement of one-third turn beyond snug produced a preload greater than the specified minimum value.

It should be apparent that short grip A490 bolts will be potentially less ductile than A325 bolts. Large diameter, short grip bolts will also be of concern because the ratio of tensile stress area to gross area decreases as bolt diameter increases. Figure 4.22 shows unpublished test results on large diameter, short grip A490 bolts. (4.37) Because of the relatively large length of unengaged thread below the nut (7/8 in.), these bolts showed reasonable ductility for both low hardness and high hardness cases. However, for the same reason, one-third turn beyond snug was not sufficient to produce the specified preload in the bolts. Users of large diameter high-strength bolts, especially A490 bolts, should be aware that the RCSC specification requirement for installation of short grip bolts may not produce the required preload. If such bolts are to be used in a slip-resistant joint, calibration tests in a load-indicating device are advisable.

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For reference, the following figures have been extracted from the Guide:

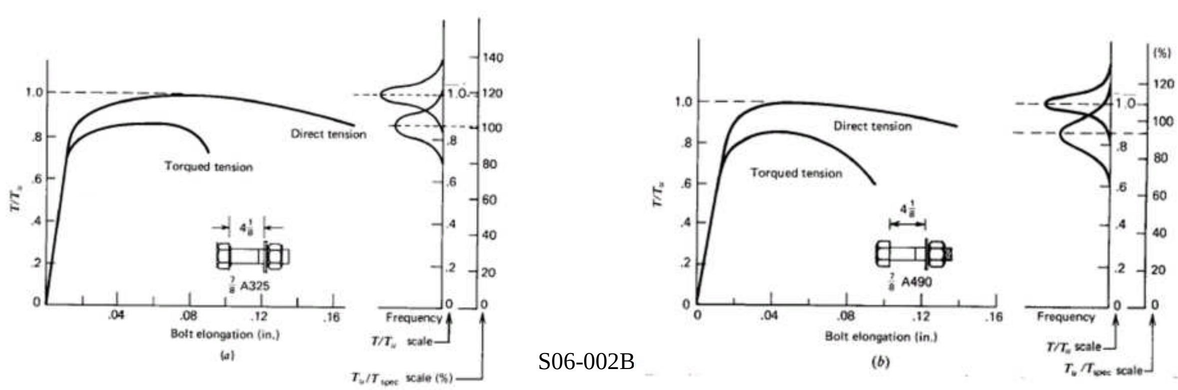




**Fig 4.4.** (a) Load versus elongation relationship and frequency distribution of A325 bolts tested in torqued tension and direct tension; (b) A490 bolts.

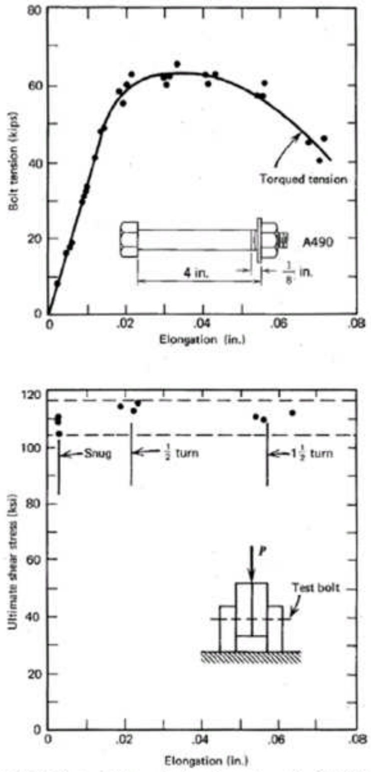

Fig 4.15. Effects of bolt preload on shear strength of A490 bolts.

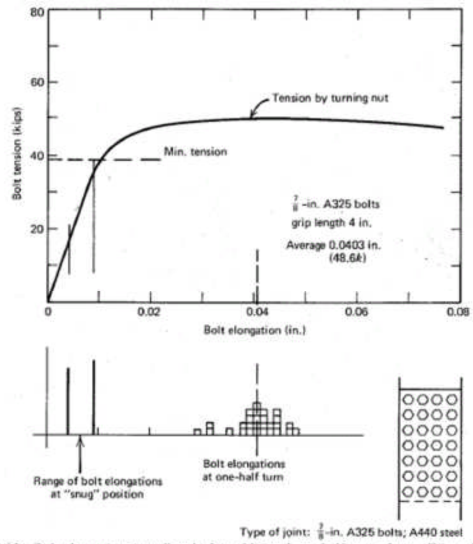

Fig 4.18. Bolt elongation "snug" and after additional one-half turn of nut. Type of joint 7/8 in. dia. A325 bolts; A440 steel.

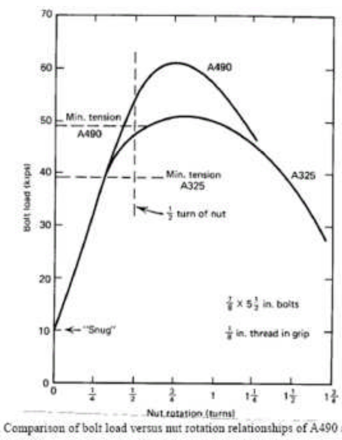

Fig 4.20. Comparison of bolt load versus nut rotation relationships of A490 and A325 bolts.

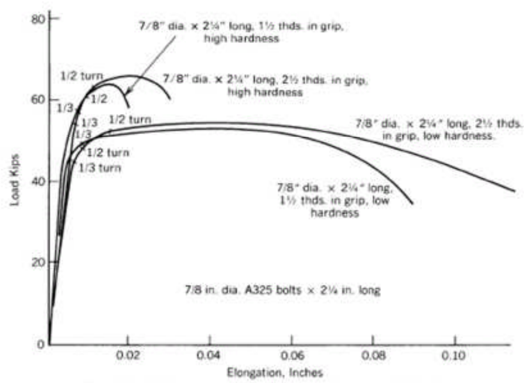

Fig 4.21. Bolt load versus elongation for short grip A325 bolts.

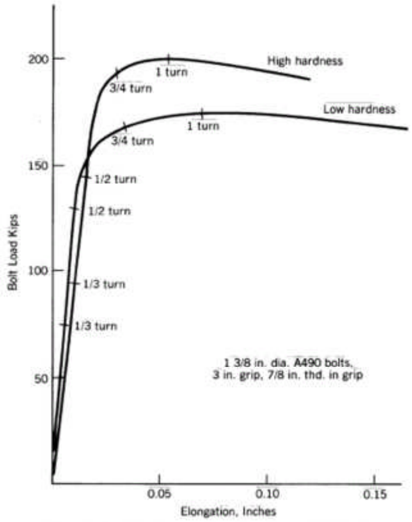

Fig 4.22. Bolt load versus elongation for grip A490 bolts.

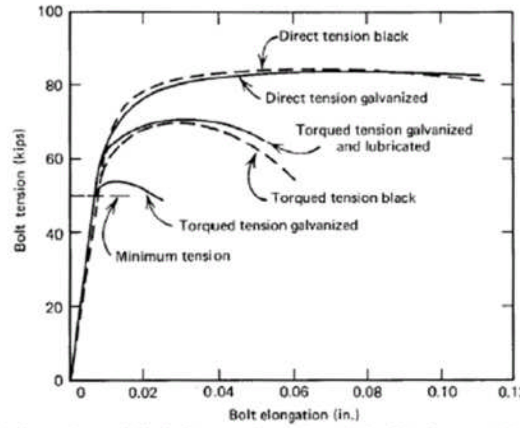

Fig 4.25. Comparison of bolt load versus elongation relationships between 1–in. black and galvanized A325 bolts.

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Extracted from: High-Strength Bolting, W. H. Munse, Engineering Journal, January 1967, AISC (note – figure for A490 bolts)

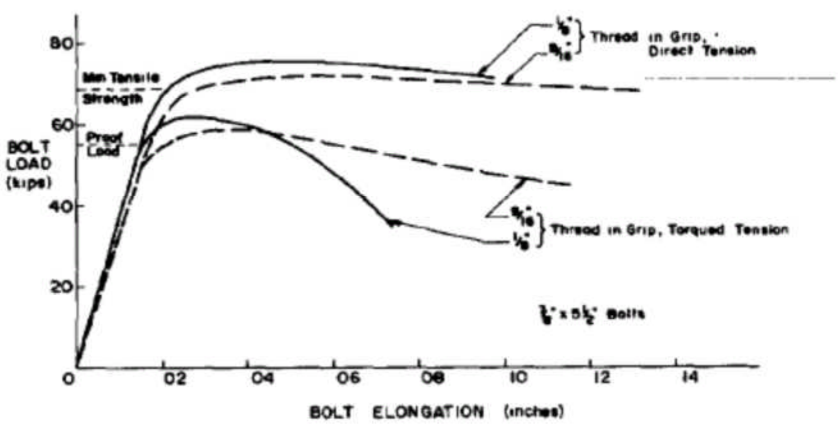

*Fig. 9. Reduction of bolt strength with method of loading (Ref. 7)*

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***From previous editions of the RCRBSJ / RCSC Specifications:***

**1954, section 9, Tension Control by Rotation of Nut (Appendix B, App'd Dec 15, 1955)**
In the range of bolt sizes and lengths usually used in structures, the nut an be rotated two to three turns before failure by breaking the bolt or stripping the threads. The turns are measured from the hand tight position after the steel surfaces have been drawn together with fitting-up bolts. If the nut cannot be seated properly by hand, it should be hand wrenched to seat and then backed off and re-seated by hand. One full turn of the nut will insure at least minimum bolt tension without damage to the bolt. Successful applications of this method of tension control have been made using bolts as large as 1" by 9". The Council approves one turn of the nut as a satisfactory method of tension control. When using air impact wrenches, the wrench capacity and air supply should be arranged so as to give one full turn in about ten seconds, but not more than fifteen seconds.

**1960, section 5d, Turn-of-Nut**
Before final tightening of the bolts by this method, the several parts of the joint shall be properly compacted by bringing a sufficient number of bolts to a snug tight condition such as can be produced by a few blows of an impact wrench, or by an ordinary spud wrench. All bolts shall be tightened in accordance with the provisions given in Table 3, progressing from the most rigid part of the joint towards the free edges.

| Bolt diameter in inches | From snug tight rotate | |
|---|---|---|
| | ½ turns for grips | ¾ turn for grips |
| 3/4 | Up to 5 in. | Above 5 in. |
| 7/8 | Up to 5 in. | Above 5 in. |
| 1 | Up to 8 in. | Above 8 in. |
| 1-1/8 | Up to 8 in. | Above 8 in. |
| 1-1/4 | Up to 8 in. | Above 8 in. |

Impact wrenches shall be of adequate capacity and sufficiently supplied with air to perform the required tightening in approximately ten seconds.

**1962, section 5(d), Turn-of-Nut Tightening**
When the turn-of-nut method is used to provide the bolt tension specified in 5(a), there shall be first be enough bolts brought to a “snug tight” condition to insure that the parts of the joint are proper compacted. Snug tight shall be defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench. Following this initial step, bolts shall be placed in any remaining holes in the connection and brought to snug tightness. All bolts in the joint shall then be tightened additionally by the applicable amount of nut rotation specified in Table 3, with tightening progressing systematically from the most rigid part of the joint to its free edges.

| Table 3 – Nut Rotation (a) from Snug Tight Condition | | |
|---|---|---|
| Disposition of Outer Faces of Bolted Parts | | |
| Both faces normal to bolt axis | One face normal to axis and other face sloped 1:20 (bevel washers not used) | Both faces sloped 1:20 from normal to bolt axis (bevel washers not used) |
| 1/2 turn | 3/4 turn | 1 turn |
| (a) Nut rotation is rotation relative to bolt regardless of the element (nut or bolt) being turned. Tolerance on rotation; 1/6 turn ($60^o$) over, nothing under. For coarse thread heavy hexagon structural bolts of all sizes and length and heavy hexagon semi-finished nuts. | | |

**1964, section 5(d), Turn-of-Nut Tightening**
When the turn-of-nut method is used to provide the bolt tension specified in paragraph 5(a), there shall be first be enough bolts brought to a “snug tight” condition to insure that the parts of the joint are brought into full contact with each other. Snug tight shall be defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench. Following this initial operation, bolts shall be placed in any remaining holes in the connection and brought to snug tightness. All bolts in the joint shall then be tightened additionally by the applicable amount of nut rotation specified in Table 4, with tightening progressing systematically from the most rigid part of the joint to its free edges. During this operation, there shall be no rotation of the part not turned by the wrench.

| Table 4 – Nut Rotation (a) from Snug Tight Condition | | |
|---|---|---|
| Disposition of Outer Faces of Bolted Parts | | |
| Both faces normal to bolt axis, or one face normal to axis and other face sloped 1:20 (bevel washer not used) | | Both faces sloped 1:20 from normal to bolt axis (bevel washers not used) |
| Bolt length(b) not exceeding 8 diameters or 8 inches | Bolt length (b) exceeding 8 diameters or 8 inches | For all lengths of bolts |
| 1/2 turn | 2/3 turn | 3/4 turn |
| (b) Nut rotation is rotation relative to bolt regardless of the element (nut or bolt) being turned. Tolerance on rotation; 1/6 turn ($60^{o}$) over and nothing under. For coarse thread heavy hexagon structural bolts of all sizes and length and heavy hexagon semi-finished nuts.<br>(b) Bolt length is measured from underside of head to extreme end of point. | | |

**1966, section 5(d), Turn-of-Nut Tightening**

When the turn-of-nut method is used to provide the bolt tension specified in paragraph 5(a), there shall be first be enough bolts brought to a “snug tight” condition to insure that the parts of the joint are brought into good contact with each other. Snug tight shall be defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench. Following this initial operation, bolts shall be placed in any remaining holes in the connection and brought to snug tightness. All bolts in the joint shall then be tightened additionally by the applicable amount of nut rotation specified in Table 4, with tightening progressing systematically from the most rigid part of the joint to its free edges. During this operation, there shall be no rotation of the part not turned by the wrench.

| Table 4 – Nut Rotation (a) from Snug Tight Condition | | |
|---|---|---|
| Disposition of Outer Faces of Bolted Parts | | |
| Both faces normal to bolt axis, or one face normal to axis and other face sloped 1:20 (bevel washer not used) | | Both faces sloped 1:20 from normal to bolt axis (bevel washers not used) |
| Bolt length(b) not exceeding 8 diameters or 8 inches | Bolt length (b) exceeding 8 diameters or 8 inches | For all lengths of bolts |
| 1/2 turn | 2/3 turn | 3/4 turn |
| (c) Nut rotation is rotation relative to bolt regardless of the element (nut or bolt) being turned. Tolerance on rotation; $30^{o}$ over and under. For coarse thread heavy hexagon structural bolts of all sizes and length and heavy hexagon semi-finished nuts.<br>(b) Bolt length is measured from underside of head to extreme end of point. | | |

**1976, section 5(d), Turn-of-Nut Tightening**

When the turn-of-nut method is used to provide the bolt tension specified in subsection 5(a), there shall be first be enough bolts brought to a “snug tight” condition to insure that the parts of the joint are brought into good contact with each other. Snug tight shall be defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench. Following this initial operation, bolts shall be placed in any remaining holes in the connection and brought to snug tightness. All bolts in the connection shall then be tightened additionally by the applicable amount of nut rotation specified in Table 4, with tightening progressing systematically from the most rigid part of the joint to its free edges. During this operation, there shall be no rotation of the part not turned by the wrench.

| Table 4 – Nut Rotation (a) from Snug Tight Condition |
|---|

| Disposition of Outer Faces of Bolted Parts | | | |
|---|---|---|---|
| Bolt length (as measured from underside of head to extreme end of point ) | Both faces normal to bolt axis | One face normal to bolt axis and other face sloped not more than1:20 (bevel washer not used) | Both faces sloped not more than 1:20 from normal to bolt axis (bevel washers not used) |
| Up to and including 4 diameters | 1/3 turn | 1/2 turn | 2/3 turn |
| Over 4 diameters but not exceeding 8 diameters | 1/2 turn | 2/3 turn | 3/4 turn |
| Over 8 diameters but not exceeding 12 diameters (b) | 2/3 turn | 5/6 turn | 1 turn |
| (a) Nut rotation is rotation relative to bolt regardless of the element (nut or bolt) being turned. Tolerance on rotation; 30$^{o}$ over and under. For coarse thread heavy hexagon structural bolts of all sizes and length and heavy hexagon semi-finished nuts.<br>(b) No research work has been performed by the Council to establish turn-of-nut procedure when bolt lengths exceed 12 diameters. Therefore, the required rotation must be determined by actual tests in a suitable tension device simulating the actual conditions. | | | |

**1978, section 5(d), Turn-of-Nut Tightening**
When the turn-of-nut method is used to provide the bolt tension specified in subsection 5(a), there shall be first be enough bolts brought to a "snug tight" condition to insure that the parts of the joint are brought into good contact with each other. Snug tight is defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench. Following this initial operation, bolts shall be placed in any remaining holes in the connection and brought to snug tightness. All bolts in the connection shall then be tightened additionally by the applicable amount of nut rotation specified in Table 4, with tightening progressing systematically from the most rigid part of the joint to its free edges. During this operation, there shall be no rotation of the part not turned by the wrench.

| Table 4 – Nut Rotation (a) from Snug Tight Condition | | | |
|---|---|---|---|
| | Disposition of Outer Faces of Bolted Parts | | |
| Bolt length (as measured from underside of head to extreme end of point) | Both faces normal to bolt axis | One face normal to bolt axis and other face sloped not more than 1:20 (bevel washer not used) | Both faces sloped not more than 1:20 from normal to bolt axis (bevel washers not used) |
| Up to and including 4 diameters | 1/3 turn | 1/2 turn | 2/3 turn |
| Over 4 diameters but not exceeding 8 diameters | 1/2 turn | 2/3 turn | 3/4 turn |
| Over 8 diameters but not exceeding 12 diameters (b) | 2/3 turn | 5/6 turn | 1 turn |

(a) Nut rotation is rotation relative to bolt regardless of the element (nut or bolt) being turned. For bolts installed by ½ turn and less, he tolerance should be plus or minus 30$^o$; for bolts installed by 2/3 turn and more, the tolerance should be plus or minus 45$^o$.
(b) No research work has been performed by the Council to establish turn-of-nut procedure when bolt lengths exceed 12 diameters. Therefore, the required rotation must be determined by actual tests in a suitable tension device simulating the actual conditions.

# RCSC Proposed Change:  S11-038

**Name:** Chris Curven **E-mail: chrisc@appliedbolting.com**

**Phone:** 802-460-3100______ **Fax:** ______________________________________

**Proposed Change:**
8.2.1. and 8.2.3. both should have wording inserted to read as follows, “The pre-installation verification procedures specified in Section 7 shall be performed…” The other option could be to remove it (“The pre-installation verification procedures specified in Section 7 shall be performed…”) from 8.2.2. and 8.2.4. and then state it more clearly the requirements in 8.2.

**Rationale or Justification for Change (attach additional pages as needed):**
Section 9.2.1. states:
“Turn-of-Nut Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section 8.2.1.”

Section 8.2.1., I notice it makes NO mention of the pre-installation verification.

Section 9.2.3. states:
“Twist-Off-Type Tension-Control Bolt Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section 8.2.3.”

Section 8.2.3., I notice it makes NO mention of the pre-installation verification.

This might confuse the reader and give no clear instruction that the pre-installation verification is required for both methods.  Correcting this would also make bring these two corrections in line with 8.2.2. and 8.2.4.

-----------------------------------For Committee Use Below--------------------------------------------

Date Received:  6/10/11  Exec Com Meeting: _______  Forwarded: Yes ☐ /No ☐

Committee Assignment:  Executive -A. ☐  Editorial -B. ☐  Nominating -C. ☐

Specifications -A.1 ☐  Research -A.2 ☐  Membership & Funding -A.3 ☐  Education -A.4 ☐
Committee Chair: ____________ Task Group #: ___________ T.G. Chair: ________________
Date Sent to Main Committee: _______________Final Disposition: ______________________

## Relubrication of TC Bolts
## RCSC TG S08-023
## 6-16-11

**History-**
**Originated in 2008 when balloting was being done for the RCSC specification, and the question was raised by Ken Lohr about re-lubrication of TC bolts. Previously, the specification had simply said that re-lubrication of TC bolt assemblies is not permitted. He explained that in ASTM, the standard does address re-lubrication, and he described the situation where he was disassembling TC bolt assemblies which did not tension up correctly, and re-lubricating or replacing the original nuts. He thought that RCSC should address this function in the standard.**

**Notes from ballot:**

**Ballot of Specification for Structural Joints Using ASTM A325 or A490 Bolts**
**Comments Submitted**
**Due Date:** January 12, 2009

**Ballot Item 12: (S08-023) - Section 2.2 "Relubrication"**

**Gilbert Grondin: (NEGATIVE)**
I agree with the proposed changes except for a few things as follows. 1) The term "requalified" is better than "retested" since retesting does not necessarily mean that the bolts will be found to be qualified after the tests. 2) Can we change "pretensioned joints" to "joints with pretensioned bolts"? In this case we do not need to add "slip-critical joints". 3) I don't see the need for limitation (2) since I don't see which fastener would fall into this category. The Huck bolt is not an alternative design fastener that would need to be lubricated or relubricated. However, I don't object to the addition. The word Engineer at the end of this limitation should be changed to Engineer of record.

**David McKenzie: (NEGATIVE)**
The wording is not clear in the use of the term "supplier". The rationale infers that this would include the fabricator or erector while the RCSC "Glossary" defines "Supplier: as being the party that sells the fastener components to the party that will install them in the work." I agree that the fabricator or sometimes the erector supplies the fasteners but our glossary does not define the supplier in this way so we need to revise the definition or the text in 2.2.2.

**Charles Wilson: (NEGATIVE)**
This proposal conflicts with ASTM F1852. See note 2 of paragraph 6.4 in this document.

**Helen Chen: (AFFIRMATIVE)**
1. Suggest the first sentence under (1) be rephrased "Twist-off-type tension control bolt assemblies shall be permitted to be lubricated or relubricated only by the manufacturer or by the supplier..."; 2. Please specify the ASTM standard for "Assembly Lot Tension Test"; 3. The first sentence in (2) is suggested to be rephrased to "Alternative design fasteners that meeting the requirements of Section 2.8 shall be permitted to be lubricated or relubricated only by the manufacturer...."; 4. At the end of (2) should it be "engineer of record"?.

**Ian Hodgson: (AFFIRMATIVE)**
Section 2.2.2 Item (2), 3rd line: Change "lubricated" to "lubrication".

**Neil McMillan: (AFFIRMATIVE)**
2.2.2(2) Second sentence – Following lubricated...ion.

**Tom Murray: (AFFIRMATIVE)**
Editorial: Add "successfully" before "retested" in Section 2.2.2, line 4. Just retesting does not seem to be sufficient.

**Current RCSC and ASTM specification coverage:**
**Section 2.2 of the RCSC Specification addresses storage conditions for TC bolting, as well as the issue of re-lubrication or alteration of their condition, and states that it can only be done by the manufacturer, consistent with the ASTM requirements.**

To facilitate manufacture, prevent corrosion and facilitate installation, the *manufacturer* may apply various coatings and oils that are present in the as-manufactured condition. As such, the condition of supplied fastener components or the *fastener assembly* should not be altered to make them unsuitable for pretensioned installation.
If fastener components become dirty, rusty, or otherwise have their as-received condition altered, they may be unsuitable for pretensioned installation. It is also possible that a *fastener assembly* may not pass the pre-installation verification requirements of Section 7. Except for ASTM F1852

and F2280 twist-off-type tension-control bolt assemblies (Section 2.7) and some alternative-design fasteners (Section 2.8), fastener components can be cleaned and lubricated by the fabricator or the erector. Because the acceptability of their installation is dependent upon specific lubrication, ASTM F1852 and F2280 twist-off-type tension-control bolt assemblies and some alternative design fasteners are suitable only if the *manufacturer* lubricates them.

**ASTM covers the lubrication and alteration of the factory supplied condition of the TC bolt assemblies, in F1852 states:**

6.5 *Secondary Processing*:

6.5.1 If heat treatment, zinc coating, lubrication or other processing affecting properties are performed by any source on any unit of a component lot after the manufacturer's test to qualify a lot has been performed, the component lot shall be treated as newly manufactured and shall be reinspected and retested in accordance with the requirements of its original manufacturing specification after such processing is completed. Retesting shall be the responsibility of the party supplying the component.

6.5.2 Secondary processing shall not be permitted to an assembly lot.

ASTM F1852 further states:

**13. Testing**

13.1 *Testing Responsibility*:

13.1.1 Each component lot and assembly lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 13.2 through 13.5.

13.1.2 When components or assemblies are furnished by a source other than the manufacturer, the responsible party as defined in Section 18 shall be responsible for assuring all tests have been performed and the components and assemblies comply with the requirements of this specification.

**18. Responsibility**

18.1 The party responsible for the assemblies shall be the organization that supplies the assemblies to the purchaser.

Discussion:

It appears clear in the RCSC specification and the ASTM specifications that lubrication or altering the TC bolt from the condition from which it was supplied by the manufacturer requires re-testing to confirm it meets all of the required functional properties. While RCSC uses the term that only the 'manufacturer' can alter the lubrication, ASTM does provide more detail and describes that anyone making changes to the TC system must re-test and re-certify the fasteners, and that the responsibility becomes that of the party which supplies the fasteners.

The only point open is the definition of 'manufacturer' as used in the RCSC specification.

This philosophy is in keeping with the requirements contained within the Fastener Quality Act, which state that: "(11) "manufacturer" means a person who fabricates fasteners for sale in commerce;".

**TG Recommendations-**

It is felt that between the RCSC specification and the ASTM product specifications to which the bolts must be produced, it is sufficiently clear that there is a critical relationship of the lubrication of the fasteners to the functional performance of the TC bolt assembly. There is adequate warning and description that altering the lubrication requires retesting and re-certification.

The definition of manufacturer seems to be a small point, and is not one which RCSC should try to direct as it is covered in the ASTM product specifications, and for the purposes of structural joint design and application of the fasteners, it is felt that the current definition is sufficient. RCSC does not want to be in a position which sounds like they endorse modifying TC bolts from their factory supplied conditions.

# Bulletin on ASTM F1136/F1136M Zinc/Aluminum Coatings for use with ASTM A490/A490M Structural Fasteners.

April 2011

**Background-**

There has been a need among designers, engineers, owners and end users of high strength (150 ksi min. tensile) structural fasteners for a reliable coating which can safely and cost effectively provide long term corrosion protection. Traditional metallic coatings used in the structural fastener industry have not been permitted for use with A490/A490M grade fasteners due to concerns over potential hydrogen embrittlement.

The ASTM F16.02 committee approved a coating for use with A490/A490M grade fasteners. This coating is ASTM F1136/F1136M Zinc Aluminum Coating, known to many within the industry as Dacromet®. Testing performed by IBECA Technologies Corp. concluded that A490 fasteners coated with F1136 coating do not suffer from the effects of hydrogen embrittlement.

Since this is the first coating to be approved by ASTM for A490 fasteners, there are a number of issues that should be addressed and understood by the designer, engineer, owner and end user regarding the effective use of F1136 coatings. Understanding potential issues can aid in the successful implementation of this newly approved coating. Eventually, practical experience, specification updates and modifications, as well as additional research will provide more standards-based guidance for the use of F1136 coatings. Until then, this document has been reviewed jointly by the ASTM F16.93 coating committee and the Research Council on Structural Connections.

**Nut Over-tap**

F1136 coatings are relatively thin and uniform compared to traditional coatings used on structural fasteners. Many factors can influence the need for over-sizing the nut thread to allow for the thickness of the coating. These include material dimensional limits, dimensional deviation, coating thickness, coating variation, accumulation of tolerances, coating application method, coating grade, and the coating applicator.

The F1136/F1136M specification mentions the potential need for thread over-sizing, but provides no guidance on oversized threads. Component material conditions and dimensional tolerances may permit the use of non-oversized threads with thinner deposits of F1136. Practically speaking, thread over-sizing the pitch diameter between .008" and .018" may be required.

Over-sizing threads for use with high strength fasteners should be done with caution, as the loss of functional engagement may reduce stripping strength of the fastener assembly, and in some cases change the failure mode of an assembly from bolt tensile failure to bolt thread failure. Tensile failure is always the preferred method of failure.

Studies performed on inch and metric structural fasteners indicate that A563 DH nuts manufactured to .024" or greater over-size have the potential for bolt thread failure during installation or service when used with A490 grade fasteners. A small study of large diameter metric A490 fasteners indicated that over sizing up to 0.018" still allowed for the full development of the tensile strength of the bolt. This study was limited in sizes and only performed on product from one bolt and one nut manufacturer, using standard tolerances. Proper allowance to permit free assembly in the field and interference free fit should be discussed with suppliers prior to ordering.

**Proof Load Testing**

Most structural fastener assemblies include an ASTM A563 DH nut. Specification requirements for this grade of nut reduce the proof load testing requirement of over-sized heavy hex nuts to 150,000 psi. Non-oversized DH nuts are required to be proof load tested to 175,000 psi, which appropriately exceeds the permitted maximum tensile of A490 bolts.

The purchaser and supplier should specify and ensure that when over-sized DH nuts are required, that the manufacturer performs nut proof load testing to a level exceeding the permitted maximum tensile strength of the bolt it will be mated with. This is to help ensure that bolt tensile failure will most likely remain the mode of failure. The customer should also consider full size axial pull tests until additional research or rotational capacity requirements are specified through additional research.

**Coating Thickness**

While thinner than traditional metallic coatings, F1136 has some variability in coating thickness. Deposits are often significantly thicker than specified minimum values, with high spots often near 4 times the specified minimum value. The effect of the accumulation of these tolerances and the impact on product thread gauging should be understood.

Coating thickness for ASTM fasteners is frequently measured using cost effective means such as magnetic induction. A potential issue with F1136 coatings and A490 grade fasteners is the effect of magnetic particle testing on the results of magnetic induction coating thickness testing. When performed on A490 fasteners, magnetic particle testing can leave residual magnetic fields which interfere with the results of magnetic induction testing. A490 fasteners for use with F1136 coating should be demagnetized after testing, or another method of coating thickness evaluation should be agreed upon between the supplier, the applicator and the user.

**Rotational Capacity**

Coated A325 structural fasteners have a requirement for rotation capacity testing. With the approval of coatings for A490 fasteners there is also a need to provide guidance on rotational capacity testing for these fasteners. Currently, the A490 and A490M specifications do not have provisions for rotational capacity testing. Research will need to be done to determine the proper degrees of rotation for A490 fasteners. If required, rotational capacity testing should be as agreed upon between the supplier and user. Generally speaking, A490 grade fasteners lack the ductility to routinely pass RC testing using degrees of rotation established for A325 fasteners.

**Reactivity with Concrete**

The effects or possible reaction of aluminum components of F1136/F1136M coatings with wet concrete have not been researched. When specifying F1136 for use where coated fasteners may be in direct contact with wet concrete the user should exercise caution.

**Paint Adhesion**

A study has been performed which indicated that paint adheres well to F1136 coatings. Users should understand that these results were determined using F1136 Grade 3 coating, not F1136 Grade 5 coating, which has a lubricated sealer. Future research will need to be performed to determine paint adhesion on Grade 5 coatings. Grade 5 is the recommended coating grade for A563 nuts.

**F1136 Grade**

For the best performance, F1136 coatings should be specified as Grade 3 for bolts (sprayed or dip-spin depending on fastener size), Grade 3 dip-spin for washers, and Grade 5 dip-spin for nuts. Application variables will depend on the product weight /dimensions, the processor, and any special customer requirements.

**Summary**

Having coatings available for ASTM A490/A490M fasteners will solve many application problems associated with the specification and use of high strength structural bolts and will no doubt benefit the steel construction industry. This advisory is to help the manufacturer, supplier, and end user understand the limitations of currently available product specifications. Until additional research and standards-based guidance can be provided, understanding and addressing these points prior to ordering will be beneficial to all parties.

**Skidmore Wilhelm Temperature Effects**
RCSC TG
6-16-11

History-
This topic came up at the June 2008 RCSC meeting as new business when discussing the performance and accuracy of the Skidmore Wilhelm load cells under adverse field conditions.

RESEARCH COUNCIL ON STRUCTURAL CONNECTIONS
SPECIFICATION COMMITTEE MEETING REPORT
June 19, 2008, 9:00 AM to 2:30 PM

9.0 NEW BUSINESS
9.1 Skidmore Testing Temperature Tolerances (Lohr)
A discussion was held in regard to Skidmore performance at low temperatures. It was felt that there should be some additional parameters added to the testing protocol to reflect low temperature conditions. A task group consisting of Ken Lohr, Pete Birkemoe, Nick Oeal and Peter Kasper was assigned to draft a Research Proposal for future funding.
A related issue was whether Skidmore testing evaluation should be based on the average of the tests versus the low end test value only? Ken Lohr and Bob Shaw will discuss further.

Independent Testing Evaluations Submitted-
At the 2010 RCSC meeting, the testing results from the study conducted by Chuck Hundley at Unytite were presented, and additional member test data and experience were requested. Subsequent to the meeting, Karl Frank shared some testing done at Ferguson Research Laboratory.

The tests done at Unytite compared Skidmore performance at both higher than ambient (170F) and lower than ambient (7F) temperatures, and using a Tinius Olsen calibrated load cell found no significant variations with tension reading taken at ambient temperature conditions. (ref: test report dated June 11, 2010)

The tests done at Ferguson Research Laboratories did a similar test comparing ambient tension values to those done under cold conditions of -9F and 30F. While these results did show a slightly lower tension when cold, it is interesting that they noted the time change for the unit to respond to the load. Load values were taken at immediately once the load was applied, at 30 seconds and at 60 seconds. Those values taken immediately exhibited lower load values, but after 30 or 60 seconds, the load results compared well with the actual applied load. (ref: test data dated May 17, 2007)

Similar testing was conducted at Skidmore Wilhelm Inc. using the same calibrated load cells used to verify and certify the calibration of the field units, and similar to what was found at Unytite, no appreciable differences in indicated loads between cold and ambient were noted.

**Discussion-**
It is interesting to note as we discussed the findings, that most field complains mentioned involved TC bolt testing, and the purpose of this effort is not to evaluate the performance of TC bolts under field conditions compared to ambient temperatures, but to isolate the performance of the Skidmore Wilhelm load cell from that of the fastener being tested.

Skidmore has indicated that they have experienced a potential change in load indicating properties for one model of tester (model H) which uses dissimilar materials for the piston and the frame/body of the unit. In this case, the frame is aluminum while the piston is steel. The piston seal is fitted under ambient conditions, and due to the differences in thermal expansion/contraction between steel and aluminum, there is a possibility of friction or binding which can cause errors in the indicated loads at low temperatures. They recognize this issue and are revising their design. However, they also note that for the most commonly utilized Skidmore test units used at jobsites around the world, this phenomena of dissimilar metals is not an issue, and they have not seen friction or binding at low temperatures to be an issue.

The ASTM product standards for TC bolting (F1852 and F2280) list specific temperature conditions which must be met when conducting the functional testing- between 50 and 90F.

14.4 *Assembly Installation Tension Test*:

14.4.1 *Test Conditions*— Conduct tests at an ambient temperature between 50° and 90° F (10 and 32°C).

It is felt that specifying the test temperature range is done in order to provide guidelines for the fastener manufacturer that the product must meet, but also gives good repeatability.

**Recommendations-**
The limited test data provided does not indicate that there are severe changes in performance of the Skidmore load cells which would affect field performance, other than the slower reaction time at lower temperatures to provide the test value. My feeling is that a 60 second delay to record test results would be a practical solution, but should be contained in the manufacturers operating instructions.

While Skidmore Wilhelm is interested in having independent research continued to support these findings, the council needs to affirm if these tests give sufficient evidence to answer the initial question about temperature effects on the load cell, or if funding from the Research Council is justified. If this is the case, then research proposals will be solicited and a testing budget prepared for the council.

# Check of Skidmore Bolt Gage at Lower Temperature

By

Blake Stasney and Karl H. Frank

Ferguson Structural Engineering Laboratory

May 17, 2007

**Test Procedure:**

The Skidmore was place in the freezer to lower it's temperature and then removed for test. The test consisted of loading the Skidmore in a compression test machine with a load cell used to measure the applied load. The load measured by the load and that shown on the gage of the Skidmore were recorded. The Skidmore reading were taken just after the application of the load and 30 second intervals after applying the load. The temperatures were measured with Thermocouples.

**Test Results:**

**Test 1-Room Temperature tests: 67.6 F**

| Skidmore-kip | Load Cell-kip |
| --- | --- |
| 0 | 0 |
| 20.0 | 20.0 |
| 39.5 | 40.0 |
| 59.5 | 60.0 |
| 80.0 | 80.0 |
| 99.0 | 100.0 |

**Test 2-Skidmore Initial Test Temperature -9 F**(ambient temp: 65.1 F, Oil temperature in Skidmore 16 minutes after completion of test: 21.1F)

| Skidmore-kip Initial Reading | Skidmore-kip After 30 seconds | Skidmore-kip After 60 seconds | Load Cell-kip |
|---|---|---|---|
| 0 | | | 0 |
| 20.0 | | | 20.0 |
| 32.0 | 39.0 | | 40.0 |
| 52.0 | 59.0 | 59.5 | 60.0 |
| 73.0 | 78.0 | 79.0 | 80.0 |
| 92.0 | 99.0 | 99.0 | 100.0 |

**Test 3-Skidmore oil 30.4 F at start of test 43.5 F after test**

| Skidmore-kip Initial Reading | Skidmore-kip After 30 seconds | Skidmore-kip After 60 seconds | Load Cell-kip |
|---|---|---|---|
| 0 | | | 0 |
| 20.0 | | | 20.0 |
| 39.0 | 39..5 | 40 | 40.0 |
| 59.0 | 59..5 | 60.0 | 60.0 |
| 79.0 | 79.0 | 79.0 | 80.0 |
| 99.0 | 99.0 | 99.5 | 100.0 |

**Observations and Comments**

The glycerin in the gage was apparently very stiff since the trapped air bubbles did not move much if at all. The gage dial move sluggishly initially when the Skidmore/oil was cold. It is likely that you might see even greater differences between actual and measure bolt tension when checking the tension on a bolt since the rate of application of the loads is faster then these tests.

Based on these tests, this Skidmore bolt gage underestimates the actual bolt tension when the temperature of the Skidmore is 40F or lower. It also appears that the error in the Skidmore increases as the temperature is lowered.

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June 11, 2010

## SCOPE:

Chuck Hundley was requested by Chad Larson and Joe Greenslade to conduct a test on Skidmore-Wilhelm tension calibrators to verify load cell accuracy under different temperature conditions. The objective was to determine if there was a significant or measurable difference in the applied pressure on the Skidmore gage reading at various temperatures using a calibrated universal testing machine.

## OBJECTIVE:

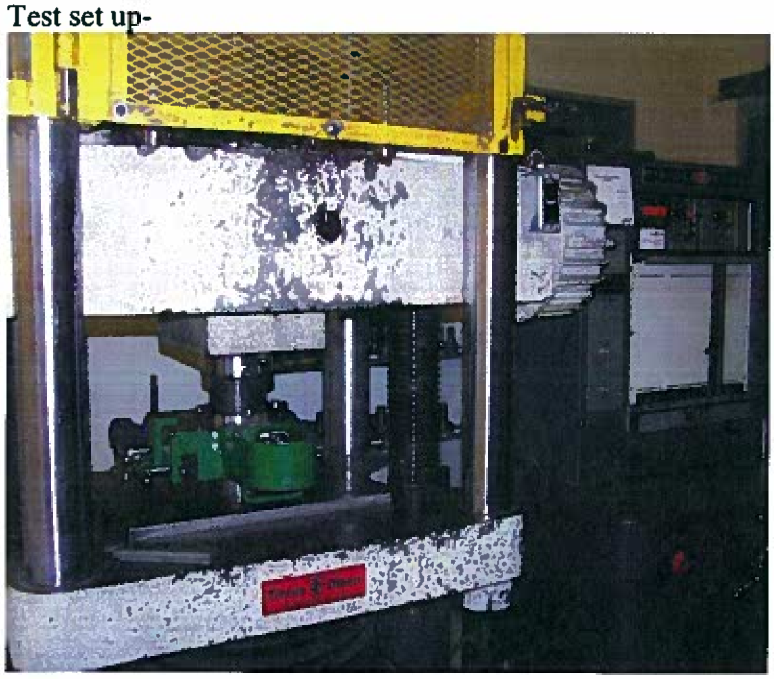
1. Apply load of 50,000 lbs to Skidmore using Tinius Olsen at three temperature ranges.
    a. First test at ambient temperature, as the equipment is stored to use as baseline information.
    b. Second is to place Skidmore in freezer overnight for cold test.
    c. Third is to place Skidmore in oven for elevated temperature test.

## TEST PROCEDURE:

1. Ambient Temperature Test

    2. Skidmore was placed in the Tinius-Olsen machine:

        a. Test set up-



b. Temperature 79.4 F

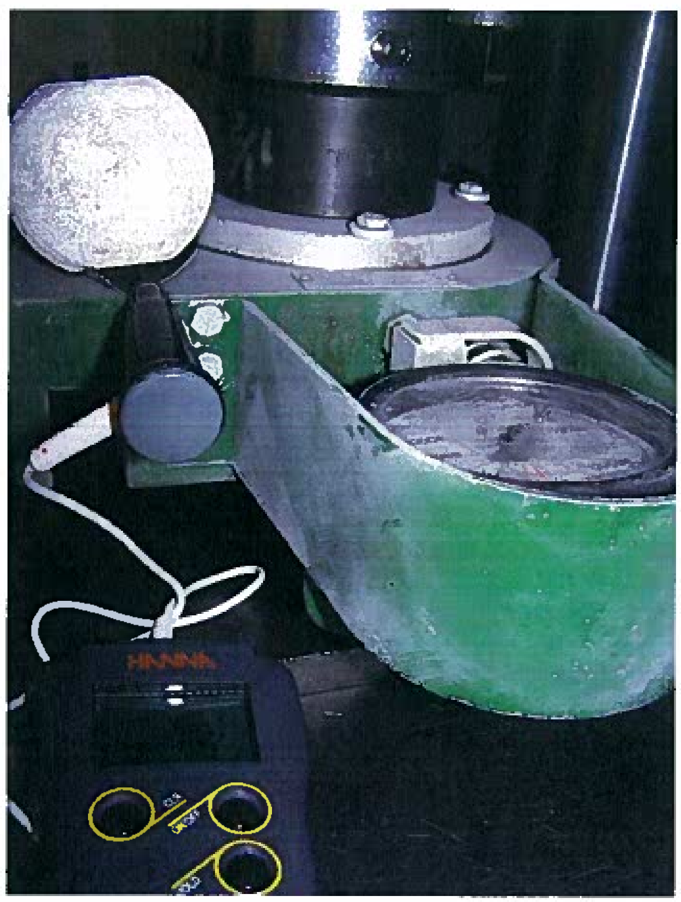

c. Applied load 50,000lbs


d. Skidmore results at applied load = Approx 51,000lbs

3. Cold Test

   a. Skidmore placed in freezer for 24 hours, load applied 50,000lbs

      i. Test set-up



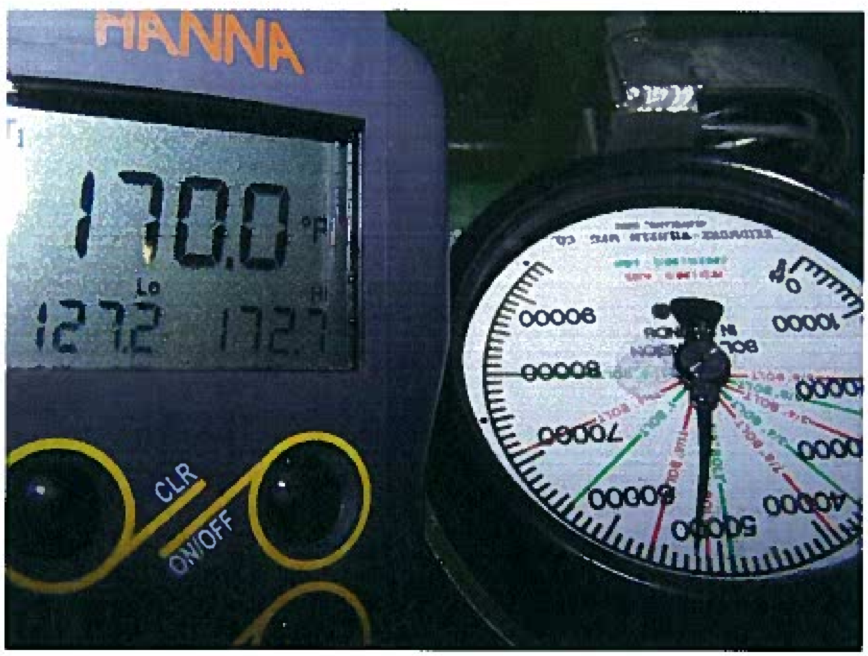
ii. Applied load of 50,000lbs


iii. Temperature of Skidmore 8.5 degrees, Skidmore reading = Approx 50,000lbs

4. Hot Test

a. Skidmore placed in oven for 24-hours, load applied 50,000lbs


b. Temperature of Skidmore 170 degrees, Skidmore reading Approx 51,000lbs.



## 5. CONCLUSION

a. Results from my test found no significant difference in the Skidmore in the three test conditions. Further testing should be conducted at different loads and various temperatures for more detailed information.

If you have any questions please do not hesitate to call me at 815-224-2221.

Sincerely,

Dan Savage

Dan Savage
Quality Supervisor

**Calibrated Wrench Installation Task Group**
**RCSC Questionnaire on High-Strength Bolt Installation Practice**

End of February 2011, first draft of questionnaire was forwarded to task group for input. May 2, 2011 questionnaire was finalized and AISC marketing along with the help of Janet Cummins sent to 457 certified and non-certified erectors. AISC used MSC mailing list and IMPACT list. May 16, 2011, questionnaire results were compiled; twenty respondents (4.4% participation).

Summary results of the questionnaire:

1. Your Information *(optional)* (name, company, Email address):
**14 responded and 6 skipped the question.**

2. How many tons of steel does your company erect in a good year?
**20 responded**
**-Range: 0 to 80,000 tons per year**

3. There are four methods provided by RCSC for pretensioned bolt installation. In addition, we've added a modified calibrated wrench practice below that is unapproved, yet often performed. On a percentage basis, how often have you used these methods in the past 5 years?
**15 responded and 5 skipped the question**

- % turn-of-nut (RCSC Specification Sect. 8.2.1):
  **26.7% use this method**
- % calibrated wrench (RCSC Specification Sect. 8.2.2):
  **5.7% use this method**
- % calibrated wrench with less pre-verification testing (RCSC Specification Sect. 8.2.2 modified):
  **0.7% use this method**
- % twist-off-type tension-control bolts (RCSC Specification Sect. 8.2.3):
  **62.7% use this method**
- % direct-tension-indicator (RCSC Specification Sect. 8.2.4):
  **4.3% use this method**
- % other method:
  **0.0% use this method**

4. If calibrated wrench with less pre-verification testing above, please describe the modifications taken:
**2 responded and 18 skipped the question**
**-Use Skidmore, run down bolt to at least 105% one time at start of shift at ground level**
**-Lab usually does not provide a Skidmore (?)**

5. If other method above, please describe what method you are using:
**0 responded and 20 skipped the question**

6. On a percentage basis, please indicate what type of tools you use for the Turn-of-Nut installation method:
**15 responded and 5 skipped the question**

- Electric:
  **27.5% use this type tool**
- Air:
  **55.7 use this type tool**
- Hydraulic:
  **8.1% use this type tool**
- Other:
  **8.7% use this type tool**

7. If other tool above, please describe what tool you are using:
**3 responded and 17 skipped the question**
**-Ratchet in tight corner, check with torque wrench**
**-Wrench**
**-Hand wrench**

8. On a percentage basis, please indicate what type of tools you use for the Calibrated Wrench installation method:
**8 responded and 12 skipped the question**

- Electric:
  **31.1% use this type tool**
- Air:
  **24.4% use this type tool**
- Hydraulic:
  **0.8% use this type tool**
- Other:
  **43.8% use this type tool**

9. If other tool above, please describe what tool you are using:
**4 responded and 16 skipped the question**
**-Torque wrench**
**-Never use the Calibrated Wrench method (?)**
**-None (?)**
**-Not applicable (?)**

10. On a percentage basis, please indicate what type of tools you use for the Twist-off-Type Tension-Control-Bolts installation method:
**14 responded and 6 skipped the question**

- Electric:
  **85.7% use this type tool**

- Air:
  **12.1% use this type tool**
- Hydraulic:
  **2.1% use this type tool**
- Other:
  **0.0% use this type tool**

11. If other tool above, please describe what tool you are using:
**0 responded and 20 skipped the question**

12. On a percentage basis, please indicate what type of tools you use for the Direct-Tension-Indicator installation method:
**8 responded and 12 skipped the question**

- Electric:
  **27.8% use this type tool**
- Air:
  **51.9% use this type tool**
- Hydraulic:
  **11.5% use this type tool**
- Other:
  **8.8% use this type tool**

13. If other tool above, please describe what tool you are using:
**1 responded and 19 skipped the question**
**-Hand wrench**

14. What tool manufacturer provides your tools?
**15 responded and 5 skipped the question**

- Chicago Pneumatic: **32.1%**
- Ingersoll Rand: **25.0%**
- Tone: **28.6%**
- Makita: **10.7%**
- Other (please specify): **3.6% (Reaction Tool)**

15. On a percentage basis, who provides training for your bolt installation crews?
**15 responded and 5 skipped the question**

- % in-house personnel: **75.3%**
- % outside consultants: **10.3%**
- % other source: **14.3%**

16. If other source above, please describe:
**3 responded and 17 skipped the question**
**-Ironworkers Apprentice Program and OJT**
**-Local Union Training**
**-Union Training. OJT from other union job sites**

17. RCSC develops provisions for the design and installation of high strength bolts in steel structures. The provisions for installing bolts include compliance requirements for steel erectors as well as inspection requirements for quality control and quality assurance personnel.

There are provisions for four methods to install bolts: turn-of-nut, calibrated wrench, direct-tension-indicator (DTI's) and twist-off-type tension-control bolts. Each method has requirements for installers and inspection requirements. The calibrated wrench method has resulted in bolts that do not meet the minimum tension required. Therefore, the calibrated wrench method includes a requirement for a pre-verification test conducted every day. Even with that requirement, there is evidence of bolts that are installed with less than the required tension.

RCSC is evaluating three options in response to this evidence and is seeking your opinion about which option they should choose.

Please rank the following from 1 to 3 in order of preference, where 1 is your preferred choice.
**15 responded and 5 skipped the question**

Leave the RCSC Specification, Section 8.2.2 (Calibrated Wrench Pre-tensioning) as is (no modifications):
1 **13.3%;** 2 **<u>46.7%</u>**; 3 **40.0%**

Revise the RCSC Specification, Section 8.2.2 (Calibrated Wrench Pre-tensioning) by increasing the training and testing requirements:
1 **26.7%;** 2 **<u>40.0%</u>**; 3 **33.3%**

Eliminate the RCSC Specification, Section 8.2.2 (Calibrated Wrench Pre-tensioning) making the calibrated wrench method not permitted:
1 **<u>60.0%;</u>** 2 **13.3%**; 3 **26.7%**

18. Any other thoughts you'd like to share?

- **These answers are from QMC audit observations for AISC certification.**

- **I believe when using the turn of the nut method the bolts get over torqued. We qualify these bolts on a Skidmore with hand tools. When bolting we use a ½" electric impact on 3/4 and 7/8 bolts to achieve tight iron. At this point we have already loaded the bolt to more than hand wrench tight. When we turn the nut to its' calibrated turn, it then becomes torqued more than necessary.**

- **I would go with TC and DTI squirters only; I constantly have to conduct training and constant inspection when on job sites. TC and DTI Squiters are the best way to go.**

- **We find this method is costly with more risk to our company.**

- **Usually when bolts are discovered as not being to the proper tension it is because of one main factor: the plies of iron are in a bind with the fasteners and the faying surfaces are not in contact before tensioning occurs. In this case as each additional fastener is tensioned it relieves tension from previously tensioned bolts. The only practical solution is to increase the safety factor of the connection by adding an additional bolt to the design, if even that is necessary. I believe that just as long as the threads are not in the shear plane, the connection if calculated properly will not fail. A small amount of movement is not a concern. This is not my opinion in the case of bridge design where the dynamic loading is far greater than most structures. And in that case the engineer should outline the specific tensioning procedure he desires in the erection/construction notes.**

- **The proper set up of the clicker wrench, thru a Skidmore has worked fine, the set up and testing in the field of each lot is unrealistic. There should more use of t/c bolts on DOT projects; also the mfg, spec sheet and test sheet for each keg should be sufficient.**

LPR Construction conducted a study last year regarding bolt installation method to be used for the Marlins ballpark retractable roof project; 8 month duration, average 10 bolt lots installed daily, pre-installation verification would amount to 4,000 to 6,000 bolts. Under the current RCSC pre-installation verification requirements, the calibrated wrench installation method was not implemented.

Considered usage:

- Same length bolts on project
- Small lot count relative to the total bolt count
- Short duration projects
- Where pre-tensioning is not required; snug tight

Current pre-installation verification can be very time consuming and costly:

- Consider “lot grouping”

# L.P.R. Construction Co.

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August 11, 2010

Floyd J. Vissat
URS - Washington Division
7800 East Union Avenue, Suite 100
Denver, CO 80237

RE: Calibrated Wrench Method considerations for the future.

LPR recently did an assessment of the Calibrated Wrench installation method on our Marlins Ballpark Retractable roof project. This project has allows the use of Tension Control fasteners which are being used where possible, but there is a high percentage of the bolts that must be hex head bolts due to bolt insertion and tool access limitations. We openly debated the pros and cons of calibrated wrench vs. turn of the nut method. The Marlins project has just about every length of bolt commonly available plus several lengths of "special order" longer bolts as well. With an average of 10 lots installed on any given day and an 8 month duration, we calculated a pre-verification test count of somewhere between 4,000 and 6,000 bolts. We also discussed the options with the fabricator, where we got a lot of resistance to provide all the additional daily test bolts. "Special order" long bolts had a 5-6 week lead time. After the debate, the decision was made not to implement the calibrated wrench method on the Marlins project.

At this time, based on our serious look at the calibrated wrench installation requirements, we are probably going to only consider the calibrated wrench method on jobs that have a small lot count relative to the total quantity of bolts on the project. This will usually mean that there are vast numbers of similar length (lot) bolts on a job that must be hex head (not TC bolts). In most cases when a project has large quantities of the same bolt length to be tensioned in a single day, that job is a high production, simple office building or warehouse or manufacturing facility with lots of beams in bay after bay after bay. In that case, the bolt design criteria for those highly repetitive situations is usually bearing bolts (where pretensioning is not necessary). It seems that most of the time if there is a job that requires fully pretensioned bolts, then there will be many different bolt lengths and we will most likely run into the same issues leading to a decision to not use the calibrated wrench method.

In conclusion, it seems to me that the calibrated wrench method is rendered almost useless by the current RCSC Pre-installation verification rules requiring daily testing of each lot.

Potential future solutions: I think that the RCSC Calibrated Pre-installation verification rules could possibly be modified to allow jobsite lot testing of multiple lengths of like diameter and type bolts to determine if a common installation torque could be established across multiple lots (lengths) of bolts. These bolts would have to all be in a similar condition and from the same manufacturer. I am suggesting that a new term "Lot Group" could be established. If a particular group of similar lots were found to require the same torque to tension relationship (within an established range), then pre-installation verification of 3 bolts with in the "Lot Group" would be all that would be necessary on the daily basis. This could dramatically reduce the volume of daily verification testing required while still assuring the proper tensions in the connections. More extensive jobsite testing establishing acceptable “Lot Groups” would be performed initially on the job and also on a periodic basis as new lots of bolts arrived at the project site. Shorter bolts from a given “Lot Group” could be used for the daily testing, resulting in lower test bolt cost for the project.

Item # 4 on RCSC Educational bulletin # 2, entitled “FACTORS MERITING SPECIAL ATTENTION BY THE ENGINEER” seems to be grasping this “Lot Group” concept while addressing the short grip bolt issue. “…Alternatively, a tightening torque may be determined in a tension measuring device using a longer bolt with a hardened washer under the turned element. This torque may then be used for testing shorter bolts with a hardened washer under the turned element in a steel plate provided lubrication and condition of threads for the long and short bolts are similar.”

Unless the RCSC spec is changed to accommodate new rules as suggested above, I think it is highly improbable that LPR will use calibrated wrench method in the future where full pretensioning is a requirement. We will continue to use the calibrated wrenches on projects where full pretensioning is not a requirement, but an owner or engineer might be specifying “more than snug tight” to avoid fastener loosening due to vibration considerations.

Sincerely,

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Report to the specification committee
Task Group reviewing preinstallation verification testing for fasteners with Turn of Nut tightening

TG members
Schlafly Chair
Baxter
Bornstein
Curven
Deal
Droddy
Ferrell
Frank
Hay
Kruth
Mayes
Mitchell
Shaw

The charter of this TG was to review preinstallation verification testing of fasteners to be installed using turn of nut installations with the intent of deleting the requirement if it would not reduce quality of bolted joints.

The task group was invited to present any information or comments or anecdotal or documented incidents of preinstallation verification testing that had bearing on this decision. The responses fell into the following categories.

1. No failures found in many years of tests
2. Test intended to evaluate bolt assemblies, installer qualifications and tools
3. Avoid mixed mechanical and hot dipped galvanized
4. The required turns for large A490s are incorrect*
5. Bolt surface conditions deleteriously effect tension in Turn of Nut installations
6. Installers need training
7. Preverification is the only assembly test for plain assemblies
8. Assures the required turns obtain required tension*
9. Make consistent with other methods
10. avoid misperception that RCSC prefers ToN
11. suggestions to revise the current test requirements
12. Pretension is a variable in slip strength
13. examples of recent installation errors
14. lack of installer awareness
15. Find under strength bolts
16. find problems with soft nuts

Dr Yura sent report FHWA RD-87. This report is available on request from TJS. It does indicate problems with bolt assemblies. The vast majority of problems are with galvanized fasteners. The majority of the few black bolt assemblies with problems were explained as test variables.

As a result of reading the FHWA report and some of the issues brought by the TG the proposal the TG was asked to consider was modified to delete preinstallation verification testing of black bolt assemblies with a diameter equal or less than 1 1/8 inch.

No preinstallation verification test failures were reported by the task group.

Issue 2 No failures were reported and the test does not evaluate installers or tools
Issue 3&4 (galvanized and large are no longer in the proposal
Issue 5 assembly condition: The test does not evaluate assembly condition
Issue 6 Installer qualification The test does not evaluate installers
Issue 7 Assembly test: no failures were reported
Issue 8: Assures required turns obtain pretension: FHWA report says Skidmore cannot be used to determine the required number of turns and this means the RCSC specification may be wrong.
Issue 9 Consistency between methods: This is not a valid reason and if it is then we need to perform the test daily because we are not consistent with the calibrated wrench method.
Issue 10 avoid perception RCSC prefers ToN: RCSC simply requires what is necessary to achieve pretension, not any preference.
Issue 11 Suggestions to revise the current test requirements: This is not part of the scope of this task group
Issue 12 Pretension is a variable in slip: Deleting test does not mean pretension will reduce.
Issue 13 examples of installation errors: Preinstallation test does not eliminate installation errors
Issue 14 Installer awareness: Preinstallation test does not increase awareness of installation requirements
Issue 15 under strength bolts: no preinstallation failures were reported.
Issue 16 soft nuts: no preinstallation failures were reported.

The task group discussed the fact that preinstallation verification testing was expensive. This becomes even more clear when considering that many projects have a few bolts of unusual length. Each of these lengths is required to have three bolts tested. Many projects have bolts shipped in sequences so the lots vary. This increases the need for testing. There was some discussion of revising the preinstallation test requirements to reduce some of these costs but no agreement was reached particularly in light of the thought that the unusual lengths seem to be associated with critical connections.

In spite of the fact that preinstallation testing does not address installer qualifications some on the task group held the opinion an installer qualification requirement should be adopted before the preinstallation test was deleted. The task group discussed two visions of an installer qualification requirement: one with a nationally recognized system of qualification agencies and tests and another with a company qualification similar to the way AWS qualifies welders. Some members of the task group expressed the opinion that this task group was not appropriate for proposing an installer qualification proposal.

The Chair chose not to vote the proposal but rather to report the issues raised by the task group. This decision was made because the task group was not carefully selected as a representation of the full committee or any other stakeholder group so a vote would simply be an artificial way to stop the proposal. A member of the task group expressed the opinion that the Chairs decision was not in compliance with RCSC committee rules. A member of the task group expressed the opinion that supporters of the proposal were obligated to provide a preponderance of evidence that elimination of the test would not reduce pretensions achieved in the field and that supporters had not accomplished that requirement. The Chair did not accept that burden.

Conclusion:
The Chair has distributed documents with the opinions of the TG to avoid limiting the Specification Committee to the bias of this report.
The Chair of the TG requests that the Chair of the Specification Committee rule on the procedural questions in the previous paragraph of this report and relieve the Chair of the TG if he has acted inappropriately.
The Chair of the TG asks the Specification Committee to conduct a poll with three options:

1. Leave preinstallation verification testing as is
2. Develop language deleting preinstallation verification testing for Turn of Nut installations
3. Adjust the membership of the TG and develop language deleting preinstallation verification testing for Turn of Nut installations and develop a scheme for company qualification of bolt installers.

Respectfully submitted
TJS

Proposal

Section 8.2
When it is impractical to turn the nut, pretensioning by turning the bolt head is permitted while rotation of the nut is prevented, provided that the washer requirements in Section 6.2 are met. A pretension that is equal to or greater than the value in Table 8.1 shall be provided. The pre-installation verification procedures specified in Section 7 shall be performed using *fastener assemblies* that are representative of the condition of those that will be pretensioned in the work.
Pre-installation testing shall be performed for each fastener assembly lot prior to the use of that assembly lot in the work. The testing shall be done at the start of the work. For calibrated wrench pretensioning, this testing shall be performed daily for the calibration of the installation wrench. Plain (uncoated) bolt assemblies with a diameter equal to or less than 1 1/8 in. (27mm) that are to be pretensioned using the Turn of Nut method are exempt from the preinstallation verification test requirement.

**Commentary:**
The minimum pretension for ASTM A325 and A490 bolts is equal to 70 percent of the specified minimum tensile strength. As tabulated in Table 8.1, the values have been rounded to the nearest kip.
Four pretensioning methods are provided without preference in this Specification. Each method may be relied upon to provide satisfactory results when conscientiously implemented with the specified *fastener assembly* components in good condition. However, it must be recognized that misuse or abuse is possible with any method. With all methods, it is important to first install bolts in all holes of the *joint* and to compact the *joint* until the connected plies are in *firm contact*. Only after completion of this operation can the *joint* be reliably pretensioned. Both the initial phase of compacting the *joint* and the subsequent phase of pretensioning should begin at the most rigidly fixed or stiffest point.
In some *joints* in thick material, it may not be possible to reach continuous contact throughout the *faying surface* area, as is commonly achieved in *joints* of thinner plates. This is not detrimental to the performance of the *joint*. If the specified pretension is present in all bolts of the completed *joint*, the clamping force, which is equal to the total of the pretensions in all bolts, will be transferred at the locations that are in contact and the *joint* will be fully effective in resisting slip through friction.
If individual bolts are pretensioned in a single continuous operation in a *joint* that has not first been properly compacted or fitted up, the pretension in the bolts that are pretensioned first may be relaxed or removed by the pretensioning of adjacent bolts. The resulting reduction in total clamping force will reduce the slip resistance.
In the case of hot-dip galvanized coatings, especially if the *joint* consists of many plies of thickly coated material, relaxation of bolt pretension may be significant and re-pretensioning of the bolts may be required subsequent to the initial pretensioning. Munse (1967) showed that a loss of pretension of approximately 6.5 percent occurred for galvanized plates and bolts due to relaxation as compared with 2.5 percent for uncoated *joints*. This loss of bolt pretension occurred in five days; loss recorded thereafter was negligible. Either this loss can be allowed for in design, or pretension may be brought back to the prescribed level by re-pretensioning the bolts after an initial period of "settlingin."
As stated in the *Guide* (Kulak et al 1987; p. 61), "...it seems reasonable to expect an increase in bolt force relaxation as the *grip* length is

decreased. Similarly, increasing the number of plies for a constant *grip* length might also lead to an increase in bolt relaxation."

Preinstallation verification testing of plain bolt asemblies installed using turn of nut method not required due to the basic principal relating strain due to the turns to the required pretension and because testing short bolts is not possible using commonly available equipment.

Summary of comments regarding
Preverification tests for turn-of-nut tightening

1) recommend we delete preverification testing for ToN of plain bolt/nut assemblies
2) Correct the editorial error Curven points out in Chapter 9 Inspection.

| **commenter** | **comment** | TJS reply | |
|---|---|---|---|
| Droddy | No failures found. Redundant and expensive | | |
| Curven | Meant to evaluate bolt assy, installer and tool. | | |
| | May mix MG with HDG | | |
| | Turns wrong for large A490 | | |
| | Condition effects ToN results | I do not see how condition can reduce tension for a given number of turns Preverification does not evaluate condition | |
| | Need training | Ok but not relevant to preverification testing | |
| | Preverification is the only assembly test for plain uncoated assemblies | | |
| | Commentary 7.2 says preverification to account for condition, tolerances and lubrication and assure turns obtains tension. | FHWA says Skidmore is not suitable for determining turns as it is not as stiff as plies of plate | |
| Baxter 5/19 | Delete the requirement | expensive | |
| Shaw 5/9 | Make consistent with other methods; no advantage to one method | This is not fair to methods that do not require a procedure to be done correctly | |
| | Avoid misperception we prefer ToN and think it is | | |

| | | | |
|---|---|---|---|
| | better | | |
| | Should require by installers and on condition | | |
| | Add bolter qualification | | |
| | Example of improper procedure | | |
| | AISC and CISC use Du which depends on installation | | |
| | Suggest lab test with installer qualification | | |
| Ferrell | Recent examples of problems caused by improper installation. Would not be eliminated by PV test | | |
| Ferrell 5/19 | PV does not help ToN. Favors installer qualification | | |
| Hay 5/10 | Gross lack of installer awareness. In favor of qualification /training | | |
| Mayes 5/19 | Find understrength and counterfeit bolts | No examples | |
| | Favors assembled sets | | |
| | Favors qualification | | |
| Frank (5/20) | History PV added to ToN to even with DTIs and TCs | | |
| | Finds problems with soft nuts | | |
| | Installers do not understand ToN or need for snugging | | |
| | | | |
| | | | |
| *Yura | See report | | |

High Strength Bolts for Bridges December 1987 FHWA /RD-87/088
Yura, Frank, Polyzois
Status of recommendations on page 127
Recommendations Status

| | | |
|---|---|---|
| | | |
| Require a lubricant and use a dye | ASTM A563: Lubricant required for galvanized nuts Dye is a supplementary requirement | |
| Increase thread length to 2Ds+1/4 | Not done | |
| Revise certification requirement to show zinc thickness and result of turn test | Done | |
| Eliminate or correct overtap for galvanized to 0.015 in | Not done | |
| disallow type C and D nuts | C&D not permitted for galvanized | |
| | | |
| Turn test on plate, not Skidmore* | Skidmore permitted | |

* This is not a recommendation at the end of the paper but is in the text of the paper The paper says A325 requires a test on plate but manufacturers were not complying with the requirement. The current A325 -10 permits turn tests on a Skidmore. The paper says this will change the number of turns to 10%, reqd tension, full tension and failure.

**From:** Tom Schlafly [mailto:schlafly@aisc.org]
**Sent:** Wednesday, May 04, 2011 6:34 PM
**To:** doug.ferrell@ferrellengineering.com; Bornstein; Chris Curven; cmayes@lprconstruction.com; Deal, Nick; Dean Droddy; Gene Mitchell; Karl H. Frank; lkruth@douglassteel.com; Robert A. Hay III; rshaw@steelstructures.com
**Subject:** preverrification testing of bolts installed with Turn of Nut

Last June I stood in front of the RCSC and asked for a task group to investigate elimination of preverification testing for bolts tightened by turn of the nut.
I would like a TG discussion of the issues. First I would like to collect the relevant issues via email. Then I will propose a conference call.

Permit me to start by stating the case that made me stand up in the first place and then add some facts as I understand them. Then I will invite you to comment and send information that will be compelling to the task group and the specification committee.

I requested this task group because I believe the performance and recordkeeping for preverification testing is expensive so it should only be required where it provides a true improvement in reliability.. The basic engineering principles of Turn-of-Nut method lead to the conclusion that it should achieve the required pretension virtually every time, if performed properly.
Preverification testing is required in the specification and I think four reasons are given for it: confirming the installation procedure is achieving the required pretension, evaluating the current condition of the bolt/nut assembly, training of the installers and testing the properties of the bolt/nut assembly.

With regard to Turn-of-Nut pretensioning, the required number of turns have been established for a very long time and I am aware of no information that they do not achieve the required pretension, in fact the turn of nut method averages 13% above the required pretension, higher than any of the other methods. The number of turns is function of the bolt geometry and the stress strain relationship of the bolt nut assembly.
The current condition of bolt assemblies should not prevent the method from achieving the required pretention. The required number of turns will result in a consistent strain in the bolt and therefore a consistent tension.
Using preverification testing to 'train' installers is an ineffective and invalid method to train. The current RCSC specification requires a detailed installation procedure. That procedure and routine observation of the installation are the appropriate tools for assuring the installer is performing he task properly. Preverification testing is expensive and may not be performed or even observed by the installers.
The remaining justification for preverification testing of bolts installed by Turn-of-Nut is to confirm the bolt assemblies meet the requirements of the ASTM specifications. Clearly this testing is redundant with the quality requirements of ASTM. The ASTM standards have a quality test and sampling plan selected to provide assurance the bolts and nuts meet the mechanical requirements. More testing will always result in some increase I reliability but testing beyond the specified amount is expensive and inefficient. Additionally, fasteners that do not meet the required mechanical properties by a significant amount should become apparent in early installations.

I do understand there is variation between the desired practices and some field practice so some of the logic above may not reflect what is seen on the job. But preverification testing is expensive and if it is to remain in the specification it should be evident that it is providing increased reliability. Toward that end I invite you to send documented evidence of turn-of nut installations with problems found by preverification testing. I would also welcome arguments refuting the rationale above. I anticipate there is anecdotal information available. I plan to assemble the information I receive and have the task group respond to it. I will try to have anecdotal information considered appropriately.

2
1/6/13

Preinstallation Verification Turn of Nut

Tom,

You've touched on many a valid point. One of the reasons we have PIV testing for TON is to make it consistent with the other methods, not to give one method an advantage over the other. Removal of such a requirement may lead to inferred thoughts that we think TON is foolproof.

Our efforts back in the late 90's to make the PIVT consistent failed in the area of mandating its performance by those workers doing the actual installations using their actual tools in a location similar to where it is being performed, 200 feet from the compressor. Instead, it has been relegated in many cases to the old man in the trailer who makes up bolts for the crew, next to the trailer where the bolts are kept, close to the compressor, with his favorite wrench that has not been abused.

Removal of PIV testing for TON does not correct this situation. Rather, we should strive to improve the definition of by whom, where, and under what conditions the PIVT is done. In that process, perhaps we can see opportunities for further refinement in what is performed for each of the four pretensioning methods we provide in 8.2.

As a separate issue, perhaps we should consider biting the bullet and begin a bolting installer qualification test, so that once we know an individual has the knowledge and skills to perform a particular method, then we could relax the PIVT for installations by that individual.

You may call it anecdotal, but I can cite numerous instances of projects I was called to advise on where TON was done incorrectly, such as:

a) 1/3 turn on all bolts, including electroplated 1" x 5", which broke before reaching the required turns (and ASTM does not prohibit electroplating, much to my chagrin)
b) 1/3 turn on 1-1/2" by 7"
c) ¼ turn on all bolts
d) "we never do turn of nut unless the bolt is over 1" diameter"
e) Proper turns attempted, but failed to reach those turns because of inadequate wrench, poor lube, or a combination thereof
f) Stripping because of inadequate air and excessive impacting time

Others can cite problems with galvanized assemblies where the bolt and nut were mismatched, and stripping occurred.

Given that CISC and AISC 360-10 (*Du in Eqn J3-4)* have connection design ramifications based upon achieved pretensions using TON (to interpret how it will be used), I don't think we need to reduce PIVT, but rather improve PIVT to verify that the Du selected will actually be achieved.

We could also establish that producers that use accredited testing facilities in the testing of their fastener products could be exempted from PIVT when the installers are qualified fastener installers using a new knowledge and skills test to be developed. Fasteners from non-accredited laboratories must be subjected to PIVT by production lot. For US producer accreditation, using US FQA requirements. For others, consider agencies accrediting under auspices of ILAC (International Laboratory Accreditation Cooperation, www.ilac.org ).

Can I cite a good bolt that failed to provide the required pretension, when in proper condition and properly installed? That answer is "no". Hence, perhaps the alternate scheme described above should be considered.

Bob

**When I volunteered to participate in this task group, my position was similar to Tom's. However over the last year we have consulted on two projects using TON which are requiring extensive field corrections and replacement of bolts. I agree that Pre-Certification testing would have had little impact on the condition of these projects. However, some pre-qualification of the installer should be required. TON is the most dependant on the installers understanding of the procedure and intent. Perhaps instead of verification that proper pretension can be achieved using TON, the Pre-Certification should be verifying that the installers know the process. I agree that pre-certification is an additional expense. But, in my recent experience this expense would have been welcomed in comparison to the re-work still underway.**

**I agree with Tom that pre-certification of bolt pretension is an antiquated requirement for TON, based on the current knowledge. But, as Bob noted below, pre-certification on the installer might need to be an additional requirement.**

**Doug Ferrell**

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**www.FerrellEngineering.com**

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**From:** Robert E Shaw Jr [mailto:rshaw@steelstructures.com]
**Sent:** Monday, May 09, 2011 4:33 PM
**To:** 'Tom Schlafly'; doug.ferrell@ferrellengineering.com; 'Bornstein'; 'Chris Curven'; cmayes@lprconstruction.com; 'Deal, Nick'; 'Dean Droddy'; 'Gene Mitchell'; 'Karl H. Frank'; lkruth@douglassteel.com; 'Robert A. Hay III'
**Subject:** RE: precertification testing of bolts installed with Turn of Nut

All,

I have a similar position to that of Mr. Shaw. My company provides testing and inspection services for all construction materials. Structural steel is a very large part of our work and we allow only ICC / AWS certified bolting inspection personnel to participate on projects with high strength bolting (yes – AWS has a bolting certification program). Our project sizes range from very large (30,000 to 70,000 ton) to very small (20 ton). I have spent many of the last 27 years in the field or as a supervisor.

It is my experience that few erection companies are the least bit prepared for PIVT. Recently, the larger erectors we encounter on a regular basis are just now beginning to realize what is expected of them. I have four Skidmores in house that are fairly busy because the erection companies in the Chicago market don't understand the requirements of Section 7 and thus, do not own a Skidmore. The Skidmores we do encounter are in poor condition, not calibrated, or missing components necessary to complete PIVT. Many erectors we encounter believe that no PIVT is required for DTI or TC installation and are usually unprepared for any QC functions much less PIVT. .

Aside from being unprepared, most problems we encounter are rarely with the bolting components but with the installers and equipment. I have encountered very few ironworkers who can determine required rotation for a variety of bolt lengths and diameters. There is little comprehension of the TON method out in the field. The bolting foreman traditionally have a better understanding than the detailing crew. (I have handed out dozens of copies of Bob Shaw's bolting book at preconstruction meetings.) Generally speaking, I have met just a handful of knowledgeable site personnel in my career. Most recently, three very large erectors at the ThyssenKrupp Project in Mobile. I can't think of many others besides the larger firms here in Chicago. In regard to equipment, we often find pneumatic equipment not capable of providing the required energy to tighten larger size A490 bolts. PIVT is helpful in exposing these problems with TON. It is confusing that I encounter well skilled, well educated, and intelligent welders quite often but few of the same for bolting personnel. I think this possibly may be an inherent problem in the ironworker's training programs where welding is focused upon and bolting is somewhat neglected.

In addition, very few installers also understand much about the effects of lubrication, torque vs. tension, types of galvanized components, slotted hole rules, etc. Possibly there is room for discussion of a installers certification program of some type. It is my position that removal of PIVT, for TON or any of the other three methods, is not in the best interest for the industry at this time. I am open to any discussion on the topic at our meeting.

Looking forward to San Fran.

Bob Hay

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**From:** Doug Ferrell [mailto:Doug.Ferrell@FerrellEngineering.com]
**Sent:** Monday, May 09, 2011 5:18 PM
**To:** rshaw@steelstructures.com; 'Tom Schlafly'; 'Bornstein'; 'Chris Curven'; cmayes@lprconstruction.com; 'Deal, Nick'; 'Dean Droddy'; 'Gene Mitchell'; 'Karl H. Frank'; jkruth@douglassteel.com; Robert Hay
**Subject:** RE: precertification testing of bolts installed with Turn of Nut

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**From:** Robert E Shaw Jr [mailto:rshaw@steelstructures.com]
**To:** 'Tom Schlafly'; doug.ferrell@ferrellengineering.com; 'Bornstein'; 'Chris Curven'; cmayes@lprconstruction.com; 'Deal, Nick'; 'Dean Droddy'; 'Gene Mitchell'; 'Karl H. Frank'; lkruth@douglassteel.com; 'Robert A. Hay III'
**Subject:** RE: precertification testing of bolts installed with Turn of Nut

I have waited a while to respond, hoping to gather some thoughts from others. I will not re-iterate any opinions here, but just express what I am beginning to conclude from review of the responses along with my own thoughts and experiences (or lack thereof).

First of all, the current RCSC commentary page 16.2-50 indicates one of the reasons for PIV for any of the installation methods. Quote below...

Pre-installation verification testing of as-received bolts and nuts is also a requirement in this Specification because of instances of under-strength and counterfeit bolts and nuts. Pre-installation verification testing provides a practical means for ensuring that non-conforming *fastener assemblies* are not incorporated into the work. Experience on many projects has shown that bolts and/or nuts not meeting the requirements of the applicable ASTM Specification would have been identified prior to installation if they had been tested as an assembly in a *tension calibrator*. The expense of replacing bolts installed in the structure when the non-conforming bolts were discovered at a later date would have been avoided.

I do not believe that this particular commentary can be overlooked when considering the turn-of-nut method.

Also, non-galvanized hex head fasteners do not have the requirement for the manufacturer to perform rotational capacity tests on an assembly, so the potential for an incompatible bolt / nut assembly may exist (although I am not aware of an actual case). Pre-installation verification testing should be able to flush out this potential problem. I have only heard of this potential tolerance mismatch problem and I do not have firsthand knowledge of the specifics. Maybe I am spreading an invalid rumor here. Can someone comment?

In the absence of other stop-gap measures to reveal non-conforming fastener assemblies before they are installed in the field,
I cannot condone the elimination of pre-installation verification testing for turn-of-nut installation method. There has to be a way to expose under-strength, counterfeit or tolerance mismatched fastener assemblies that may have slipped through the cracks and found their way to the jobsite. I do believe that there could be better and more cost effective ways to do this. An example is the Lohr Matched Hex Sets (fastener assemblies) that are delivered to the job pre-assembled, eliminating many of the possible lot combinations. I believe that if all hex heads fasteners were delivered to this standard, then pre-installation verification testing costs would be dramatically reduced for turn-of-nut method.

There has been discussion of developing "certified bolter" requirements similar to "certified welder" requirements. Not a bad idea. I say this, even though LPR has a training program that is very extensive compared to the average erector. LPR owns (and utilizes) about 18 Skidmores. We still struggle to keep our workers up to speed with bolting installation knowledge. This information is easily forgotten since it is so extremely boring. Just ask my wife. ; )

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**From:** Robert Hay [mailto:RAHay@floodlabs.com]
**Sent:** Tuesday, May 10, 2011 8:31 AM
**To:** Doug.Ferrell@FerrellEngineering.com; rshaw@steelstructures.com; Tom Schlafly; Bornstein; Chris Curven; Curtis Mayes; Deal, Nick; Dean Droddy; Gene Mitchell; Karl H. Frank; lkruth@douglassteel.com

Per my conversation with Tom at the NASCC, I have discussed the issues on my recent projects with the fabricators, erectors, contractors, and most importantly with the erectors making the repairs. As I mentioned in my previous email we have been consulted on two recent projects where TON method has been used, and later inspections have found gross problems with the bolt pretensions. These projects have an enormous number of bolts which are presently being replaced and pretensioned again by TON. The unanimous response has been that PIV would not have prevented any of the issues with these projects. The quality of the bolt assemblies have not been questioned. The general agreement is that the primary cause is poor understanding of the requirements by the iron workers and poor documentation and reporting of non-conformances by the testing agencies.

I am returning to my original position. I don't believe PIV is a necessary requirement for TON installation. Research and field experience has shown that TON is a consistent method of providing adequate pretension. Providing a level playing field for all installation methods is not a reasonable argument. All approved methods have advantages and disadvantages.

However, perhaps this group or another task group should discuss RCSC's position on the qualification of the iron workers making the installations. Few iron workers understand even the simplest intent of pretensioning bolts. Regardless of the installation method, RCSC should consider expanding the defined qualifications of the installer and require verification of their ability to identify non-conformances. This is a common position among most of the email responses I have received.
Historically, the requirement for verifying turn of the nut by a Pre Installation Verification (PIV) came about from complaints from suppliers of DTI's and Twist off bolts. They felt they were signaled out since they were required to perform a PIV but turn of the nut was not. It seemed at the time a no brainer, a simple verification of turn of the nut would help to prevent some of

the field problems that had occurred when installations were attempted with too small a wrench of soft nuts were encountered which stripped during installation. At about the same time the rotational capacity test for all fasteners was being introduced into the bridge specifications along with the concept of a tested rotational capacity (RC) lot which consisted of the nuts, washers, and bolt tested. At the time of the development of the RC test and lot, the ASTM specification for RC testing of the bolts did not require the nuts (which are the key ingredient determining the success during the RC test since they are overtapped and lubricated) to be shipped with the bolts. The ASTM A325 specification now has wording that requires a matched assembly. The bridge specifications required the assignment of the tested components to an RC lot. The development of the RC lot testing requirements was to eliminate the problems of stripping occurring when nuts with large overtapping, no lubrication, or soft nuts were used. Stripping of fastener assemblies during installation produces low bolt tensions even though the required snugging and turns were performed. Post installation inspection using torque is useless since the torques will be the high but the tension low.

Soft nuts continue to be a potential problem. The recommended nut for black A325 bolts in ASTM A563 is type C which can be supplied as non heat treated nut with a low minimum hardness, Rockwell B78 in contrast to the minimum hardness for a DH nut Rockwell C24. The rotational capacity test performed by the manufacturer or supplier insures that the fastener assemblies will perform as assumed in the TON. If a type C nut has sufficient hardness to pass the RC test with the matching bolt then it is acceptable, however the present mixing of nuts and bolts from various lots allowed in building construction does not provide this assurance. The PIV test provides a means of catching a problem with the fastener assemblies prior to bolt installation but only the assemblies used in the PIV. So the PIV handles some of the fastener assembly problems but not all since not all fastener assemblies are included. It would seem that the best solution is to require RC testing and the formulation of RC lots by the manufacturers. This would go a long way to reducing the uncertainty of TON installation. This is presently required for all new bridges. As a side issue, RC testing is probably not necessary for twist off bolts but certainly PIV is extremely important for twist off bolts. Bolts in shear bearing joints should not be required to undergo RC lot testing nor TON verification.

My experience in the field is that the ironworkers do not understand TON. They don't understand the need for snugging and need to bring the plies into contact before applying the TON. The PIV can be used to instruct them how to do the installation properly and to make sure the wrenches are capable of tightening the bolts. Possibly what needs to be done is to require that ironworker installing bolts in pretensioned connections must go through some training and they be required to demonstrate their knowledge by performing a PIV at the job site.

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**From:** Doug Ferrell [mailto:doug.ferrell@ferrellengineering.com]
**Sent:** Thursday, May 19, 2011 6:57 PM
**To:** Curtis Mayes
**Cc:** Robert Hay; rshaw@steelstructures.com; Tom Schlafly; Bornstein; Chris Curven; Deal, Nick; Dean Droddy; GeneMitchell; Karl Frank; lkruth@douglassteel.com
**Subject:** Re: precertification testing of bolts installed with Turn of Nut

What was the defect that caused bolts to be replaced? Why were bolts replaced? Were PV tests not done? What was gained by replacing these bolts?

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**From:** Doug Ferrell [mailto:Doug.Ferrell@FerrellEngineering.com]
**To:** rshaw@steelstructures.com; 'Tom Schlafly'; 'Bornstein'; 'Chris Curven'; cmayes@lprconstruction.com; 'Deal, Nick'; 'Dean Droddy'; 'Gene Mitchell'; 'Karl H. Frank'; lkruth@douglassteel.com; 'Robert A. Hay III'

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**From:** Robert E Shaw Jr [mailto:rshaw@steelstructures.com]
**To:** 'Tom Schlafly'; doug.ferrell@ferrellengineering.com; 'Bornstein'; 'Chris Curven'; cmayes@lprconstruction.com; 'Deal, Nick'; 'Dean Droddy'; 'Gene Mitchell'; 'Karl H. Frank'; lkruth@douglassteel.com; 'Robert A. Hay III'
**Subject:** RE: precertification testing of bolts installed with Turn of Nut

**No non-conformance reports regarding the bolt installation were prepared during erection. After erection, an inspector noted missing bolts and many locations where bolts could be turned by hand. This condition was similar on both projects. Both projects were industrial galvanized steel, and required slip critical connections. With OVS holes in most of the bracing connections. The initial question was how to verify pretension 12-18 months after installation, and do the RCSC Arbitration guidelines apply. The recommended torque values for calibrated wrench verification varied dramatically, depending on the source. Apparently the bolts did not satisfy even the smallest torque value. Due to the potential litigation at the end of these projects, no one is offering clear opinions on the cause of the loose bolts. But, both projects stated that PIV was conducted. Most people involved agreed that the problems occurred during the actual installation of bolts. Whether the initial snug-tight condition was not achieved, "relaxing" of the galvanized faying surfaces, poor quality bolt assemblies, or a lack of adequate inspection. The end result was a lack of confidence from the owner, and a requirement to replace all existing pretensioned bolts. On one project this process is continuing now, nearly 2 years after construction was completed.**

**In any case, PIV had no benefit to these projects. However, had it been omitted it would have been on the list possible reasons.**

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**From:** Tom Schlafly [mailto:schlafly@aisc.org]
**Sent:** Thursday, June 09, 2011 2:26 PM
**To:** Doug.Ferrell@ferrellengineering.com

Thx

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**From:** Doug Ferrell [mailto:Doug.Ferrell@FerrellEngineering.com]

**Sent:** Thursday, June 09, 2011 2:52 PM
**To:** 'Tom Schlafly'

**No non-conformance reports regarding the bolt installation were prepared during erection. After erection, an inspector noted missing bolts and many locations where bolts could be turned by hand. This condition was similar on both projects. Both projects were industrial galvanized steel, and required slip critical connections. With OVS holes in most of the bracing connections. The initial question was how to verify pretension 12-18 months after installation, and do the RCSC Arbitration guidelines apply. The recommended torque values for calibrated wrench verification varied dramatically, depending on the source. Apparently the bolts did not satisfy even the smallest torque value. Due to the potential litigation at the end of these projects, no one is offering clear opinions on the cause of the loose bolts. But, both projects stated that PIV was conducted. Most people involved agreed that the problems occurred during the actual installation of bolts. Whether the initial snug-tight condition was not achieved, "relaxing" of the galvanized faying surfaces, poor quality bolt assemblies, or a lack of adequate inspection. The end result was a lack of confidence from the owner, and a requirement to replace all existing pretensioned bolts. On one project this process is continuing now, nearly 2 years after construction was completed.**

**Doug Ferrell**

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**From:** Tom Schlafly [mailto:schlafly@aisc.org]

I agree with the logic prevented, it seems an unnecessary expense, both of time and money.

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**From:** Tom Schlafly [mailto:schlafly@aisc.org]
**Sent:** Wednesday, May 04, 2011 3:38 PM
**To:** Rodney Baxter
**Subject:** FW: preverrification testing of bolts installed with Turn of Nut

Last June I stood in front of the RCSC and asked for a task group to investigate elimination of preverification testing for bolts tightened by turn of the nut.
I would like a TG discussion of the issues. First I would like to collect the relevant issues via email. Then I will propose a conference call.

Permit me to start by stating the case that made me stand up in the first place and then add some facts as I understand them. Then I will invite you to comment and send information that will be compelling to the task group and the specification committee.

I requested this task group because I believe the performance and recordkeeping for preverification testing is expensive so it should only be required where it provides a true improvement in reliability. The basic engineering principles of Turn-of-Nut method lead to the conclusion that it should achieve the required pretension virtually every time, if performed properly.
Preverification testing is required in the specification and I think four reasons are given for it: confirming the installation procedure is achieving the required pretension, evaluating the current condition of the bolt/ nut assembly, training of the installers and testing the properties of the bolt/nut assembly.

With regard to Turn-of-Nut pretensioning, the required number of turns have been established for a very long time and I am aware of no information that they do not achieve the required pretension, in fact the turn of nut method averages 13% above the required pretension, higher than any of the other methods. The number of turns is function of the bolt geometry and the stress strain relationship of the bolt nut assembly.
The current condition of bolt assemblies should not prevent the method from achieving the required pretention. The required number of turns will result in a consistent strain in the bolt and therefore a consistent tension.
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The remaining justification for preverification testing of bolts installed by Turn-of-Nut is to confirm the bolt assemblies meet the requirements of the ASTM specifications. Clearly this testing is redundant with the quality requirements of ASTM. The ASTM standards have a quality test and sampling plan selected to provide assurance the bolts and nuts meet the mechanical requirements. More testing will always result in some increase I reliability but testing beyond the specified amount is expensive and inefficient. Additionally, fasteners that do not meet the required mechanical properties by a significant amount should become apparent in early installations.

I do understand there is variation between the desired practices and some field practice so some of the logic above may not reflect what is seen on the job. But preverification testing is expensive and if it is to remain in the specification it should be evident that it is providing increased reliability. Toward that end I invite you to send documented evidence of turn-of nut installations with problems found by preverification testing. I would also welcome arguments refuting the rationale above. I anticipate there is anecdotal information available. I plan to assemble the information I receive and have the task group respond to it. I will try to have anecdotal information considered appropriately.

Tom I'm in total agreement with you on this. I work for National Steel City out of Plymouth MI, and we have used the turn-of-the- nut method on several of our projects throughout the country. Prior to the installation of bolts our company test each Lot#, length and dia in a Skidmore. I have never had any bolts not meet the required tension when the required rotation is implemented . This is redundant testing and very expensive to the erector.

Dean Droddy

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**From:** Tom Schlafly [mailto:schlafly@aisc.org]
**Sent:** Wednesday, May 04, 2011 6:34 PM
**To:** doug.ferrell@ferrellengineering.com; Bornstein; Chris Curven; cmayes@lprconstruction.com; Deal, Nick; Dean Droddy; Gene Mitchell; Karl H. Frank; lkruth@douglassteel.com; Robert A. Hay III; rshaw@steelstructures.com
**Subject:** preverrification testing of bolts installed with Turn of Nut

Tom,

I have modified my email from last year.

Here is my attempt at trying to keep Pre-Installation Verification (PIV) in place for all tightening procedures. Sadly, my opinion might be marginalized as I work for DTI manufacturer and I lack the research experience that the academia will bring to the discussion. However, there are many reasons why turn-of-nut is not beyond the flaws that the Pre-Install test is designed to catch.

The idea of leaving out Turn-of-Nut from Section 7, Pre-Install is not a good idea. It is listed in the Section 7 commentary that pre-install test is done to make sure the bolt assembly, installation tool, and bolt installers all work in unison to achieve at least 5% over the minimum required preload. The idea that t-of-n is some how perfect, the installers always know how to do it, that the individual bolt assembly parts were made correctly and fit together, or someone in the field hasn't mixed an mg nut with a HDG bolt is all very risky. For the RCSC to state t-of-n is fool proof, would open the steel industry replacing many, many bolts if the mistake was ever caught. The pre-install test is designed to make sure the minimum preload has been met for connection design reasons and that replacing bolts that are still in the kegs are for more cost effective and safer than changing out bolts in the steel work.

This is even before we get into that research has shown the degree of rotation of some L/D's prescribed by the RCSC does NOT work. Referring to Kulak's Design Criteria for Bolted and Riveted Joints, "Users of large diameter high-strength bolts, especially A490 bolts, should be aware that the RCSC specification requirement for installation of short grip bolts may not produce the required preload. If such bolts are to be used in a slip-resistant joint, calibration tests in a load-indicating device are advisable.

In regards to Tom's email, there are some flaws.

Turn-of-nut is affected by the condition of the fastener. Dry bolts or rusty bolts affect the out come of the achieved clamp load.

PIV is not indented to train bolt installers, only to verify their knowledge of the chosen bolting method. I have not seen where the bolt spec requires a detailed bolt installation and inspection plan. There are only two things that hold up structural steel; bolts and welds, and you only need to be certified to do one of them. There should be some method of training implemented before PIV happens.

ASTM does not require testing for plain bolt assemblies. Most often, tests at the mfg only test individual items not that the bolt assemblies have the capacity to work in unison to achieve the minimum required clamp load. Therefore, PIV is not redundant. It is usually the first time the bolt, nut, and washer are tested as an assembly in the torque tension condition.

The notion t-of-n not going well will be caught in the first few bolts, is not worth the ensuing heart ache. Fabricators and jobsites do get HDG and MG "assemblies" mixed up as they might have bolts or nuts supplied from different distributors or different fabricators. Or jobsites might need to order more HDG nuts as they ran short, but didn't know that they had MG bolts. This happens. And it is better to find out in a Skidmore, before 5,000 bolts are stuffed. By the way, when these mismatched assemblies have the nuts turned the prescribed amount in the steel, it will be easy to hit that 1/3 of a turn as the threads strip, but the match-mark indicates clamp load. I have been to many jobsite where this condition was identified because somebody was using a load cell.

<u>Please note the commentary from section 7.2</u>

*When pretensioned installation is required, it is essential that the effects of the accumulation of tolerances, surface condition and lubrication be taken into account. Hence, pre-installation verification testing of the complete fastener assembly is required as indicated in Section 8 to ensure that the fastener assemblies and installation method to be used in the work will provide a pretension that exceeds those specified in Table 8.1. It is not, however, intended simply to verify conformance with the individual ASTM specifications.*

If we would like to reduce the cost of installed bolts on structural steel, we on the bolt council need to help educate the community using our specifications.

Regards,

Chris Curven
<u>Applied Bolting</u>

Last June I stood in front of the RCSC and asked for a task group to investigate elimination of preverification testing for bolts tightened by turn of the nut.
Turn-of-Nut Task Group-

Rereading the bolt spec for research into Tom Schlafly's request to remove the requirement for PIV on T-of-N, I was amazed by what I read *into* the RCSC spec. It takes a clear and empty mind to read our spec accurately. Sometimes "knowing" what the spec should say leads us to miss very important errors.

For example:

Section 9.2.1. states:
"Turn-of-Nut Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section 8.2.1."

Upon reading section 8.2.1., I notice it makes NO mention of the pre-installation verification.

Section 9.2.3. states:
"Twist-Off-Type Tension-Control Bolt Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section 8.2.3."

Upon reading section 8.2.3., I notice it makes NO mention of the pre-installation verification.

These obvious editorial errors (oversights) should be corrected right away so as the users of this specification do perform the required PIV for T-of-N and twist-offs. 8.2.1. and 8.2.3. both should have wording inserted to read as follows, "The pre-installation verification procedures specified in Section 7 shall be performed…" The other option could be remove it from 8.2.2. and 8.2.4. and then state it more clearly in 8.2.
Last June I stood in front of the RCSC and asked for a task group to investigate elimination of preverification testing for bolts tightened by turn of the nut.
I think what we were trying to do was to more specifically define the PIV for the two methods – CW and DTI – with those specific references contained in 8.2.2 and 8.2.4. There is a general statement in 8.2 that applies to all –

The pre-installation verification procedures specified in Section 7 shall be performed using *fastener assemblies* that are representative of the condition of those that will be pretensioned in the work.

Pre-installation testing shall be performed for each fastener assembly lot prior to the use of that assembly lot in the work. The testing shall be done at the start of the work. For calibrated wrench pretensioning, this testing shall be performed daily for the calibration of the installation wrench.

Editorially, I think the first sentence above should have been the paragraph that follows it.

Perhaps the appropriate language in 9.2.1 etc would be to reference 8.2 rather than the subsections only, and add the subsections 8.2.2 and 8.2.4 where appropriate. Or have each 8.2 subsection have the appropriate language inserted, removing from the general text of 8.2. I think we were probably trying to eliminate duplication of words by using 8.2, and it looks like editorial efficiency led to an editorial oversight.

Bob

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**Subject:** RE: preverrification testing of bolts installed with Turn of Nut