RESEARCH COUNCIL ON STRUCTURAL CONNECTIONS (RCSC)
MINUTES of SPECIFICATION COMMITTEE A.1
6 June 2013, 8:00AM, Cincinnati, OH

Members Present: (37)	T. Anderson, P. Birkemoe, D. Bogarty, D. Bornstein, R. Brown, C. Curven, D. Ferrell, P. Fortney, B. Germuga, J. Gialamas, J. Greenslade, A. Harrold, T. Helwig, C. Kanapicki, P. Kasper, L. Kruth, C. Larson, B. Lindley, K. Lohr, C. Mayes, C. McGee, K. Menke, G. Miazga, G. Mitchell, H. Mitchell, G. Rassati, T. Schlafly, G. Schroeder, R. Shaw, V. Shneur, L. Shoemaker, J. Swanson, W. Thornton, R. Tide, F. Vissat, A. Wong, J. Yura
Members Absent: (15)	A. Astaneh-Asi, R. Baxter, B. Cornelissen, N. Deal, D. Droddy, J. Fisher, K. Frank, R. Gibble, M. Gilmor, C. Hundley, J. Kennedy, N. McMillan, J. Mehta, T.Tarpy, C. Wilson
Guest: (19)	D. Auer-Collis, R. Babik, G. Byrne, R. Connor, C. Carter, G. DePhillis, P. Dusicka M. Eatherton, M. Friel, B. Goldsmith, P. Herbst, E. Jefferson, J. McGormley, J. Ocel, B. Porter, R. Shanley, J. Soma, T. Ude, W. Wloszek

AGENDA

ITEM 1.0 <u>Chairman's Remarks:</u> (Harrold)

- Specification Committee Chairman Harrold introduced hosts Jim Swanson & Gian Rassati from the University of Cincinnati.
- Specification Committee A.1 meeting will conclude around 12:00 Noon.
- Task Groups can meet after lunch; 2:00pm testing of super-high-strength bolts at high bay lab; 4:00pm tour of the Cincinnati Museum Center (old train station).
- Council Roster was circulated for verification and update of Email address, phone and fax numbers and any additional comments as required. Presently, there are fifty-two members on Specification Committee A.1; guests were also asked to sign-in.
- Introduction of attendees.
- Discussions and voting shall be limited to Specification Committee A.1 members only.
- Discussions shall be limited only to agenda items listed.
- New specification to be issued by end of 2014; therefore ballot items need to be resolved by 2014 annual meeting.

ITEM 2.0 <u>Approval of Minutes of the June 2012 Meeting:</u> (Harrold)

Vissat noted that Item 5.4 was incorrectly written in the 2012 meeting minutes. The corrected editorial changes are as follows:
Pretension (verb). The act of tightening a fastener assembly <u>such that the minimum specified tensile force exists.</u> ~~to a specific level of tension or higher~~.
Pretension (noun). A level of <u>minimum specified tensile force remaining</u> ~~tension achieved~~ in a fastener assembly ~~through~~ <u>after</u> ~~its~~ installation, as required for pretensioned and slip-critical joints.
No additional comments, corrections and discussions took place; therefore Harrold concluded an approval of the minutes as noted.

ITEM 3.0 Approval of Agenda: (Harrold)

- Changes to agenda are as follows: Requested by Brown to add Item 6.4 to Discussion of Proposed Specification Changes section as related to ASTM F959 revision. Requested by Shaw to add Item 9.2 to New Business section regarding XTB bolts. Requested by Mayes to add Item 9.3 to New Business section regarding Snug Tight definition. Requested by Shaw to add Item 9.4 to New Business section regarding large holes and large bolts. No additional agenda items were suggested; therefore Harrold concluded that the proposed agenda, with noted changes incorporated, is approved as modifed.

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, after the meeting or send an email to Harrold.
- Geoff Kulak was approved by exec committee as a life member and has resigned from Specification Committee A.1.
- After the meeting, Rachel Shanley, Jim Soma and Peter Dusicka sent Harrold email requesting Specification Committee A.1 membership.

ITEM 5.0 Resolution of Ballot Results (Affirmative/Negative/Abstain): (Harrold)

5.1 S11-038 Sections 8.2, 8.2.1, and 8.2.3 - Pre-installation Verification Testing Language (Curven): (2012-13 Ballot Item 1 summary: 61/5/2 – Affirmative /Negative/Abstention). The ballot had 5 negatives (Ferrell, McGormley, G. Mitchell, H. Mitchell, and Tide). Addressing the first negative, Curven moved and Shaw seconded to find Ferrell's negative vote for the balloted proposed change to be non-persuasive. Discussion followed (Ferrell, McGormley, Carter, Harrold, Curven, Schroder, H. Mitchell, G. Mitchell, Yura). All five negative votes had similar comments; repeating the pre-installation verification in the definition of each installation method is not necessary. Incorrect references need to be corrected; considered editorial in nature.
Harrold requested a vote for the motion to find Ferrell's negative vote non-persuasive, with results as follows:

2 for the vote to be non-persuasive
19 against the vote to be non-persuasive
11 abstained

A task group was created to modify the language.

ACTION ITEM 2013-01 (A.1) (S11-038): The as-balloted item with proposed changes to the Specification was considered and defeated for inclusion into the next revision of the Specification. A task group composed of Curven (chair), Carter, G. Mitchell, Shaw, and Ude will review and revise the "as presented" proposal language.

5.2 S12-039 Table 2.1 – Delete Zn/Al coating from F1852 and F2280 assemblies (Schlafly): (2012-13 Ballot Item 2 summary: 61/3/4 – Affirmative/Negative/Abstention). The ballot had three negatives (Kasper, Lohr, Mayes), all generally had similar issues; successful usage worldwide of Zn/Al coatings on TC bolts without ASTM language explicitly allowing the coating. Discussion followed (Harrold, Lohr, Larsen, Schafly, Curven, Kasper, Mayes, Greenslade, McGormley, Shaw). With several new coatings being introduced to the market, suggest referencing ASTM approved coatings list verses constantly updating RCSC Table 2.1. If the manufacture or user introduces a secondary process change (coating or lubrication) to the assembly, then the entire assembly needs to be tested and re-certified.
Tide moved and Shneur seconded to find all three negative votes for the balloted proposed change to be non-persuasive. Harrold requested a vote for the motion with the understanding that a Task Group would add Commentary language; result of the vote was as follows:

24 for the votes to be non-persuasive
5 against the votes to be non-persuasive
6 abstained

ACTION ITEM 2013-02 (A.1) (S12-039): The as-balloted item with proposed changes to the Specification was considered and accepted for inclusion into the next revision of the Specification with the understanding that a Task Group will draft Commentary language that discusses ramifications of using non-ASTM approved coatings on ASTM F1852 & F2280 TC bolt assemblies. The Task Group is composed of Schlafly (chair), Auer-Collis, Babik , Gialamas, Kasper, Lohr, Mayes, G. Mitchell and Soma.

5.3 S12-042 Section 5.4 – Slip Critical Equations (Schlafly): (2012-13 Ballot Item 3 summary: 48/3/17 – Affirmative/Negative/Abstention). The ballot had eight affirmative votes with comments. Schlafly considered no actions/changes required from Baxton, Eatherton and Helwig comments. Changes as follows from Birkemoe, Chen, Connor, H. Mitchell and Schlafly were considered and accepted as editorial: in new Commentary language, include the words 'reliability index,' before the word 'beta,'; in Section 5.4, third paragraph, replace 'The available slip resistance for the limit state…'.with 'The *nominal* slip resistance *per bolt* for the limit state…'; remove Item (4) from Section 1.4; delete Commentary paragraph that begins with 'Because of the greater….'; change Commentary Item (2), second sentence 'should be' to '*are*'; change Commentary Item (3), first sentence 'can be' to '*is*'. The ballot had three negatives (Tide, Yura & Wong). Comments from Tide were editorial in nature; poor grammar and poor specification writing. Schlafly will include in the first sentence of Section 5.4 references to Sections 5.1, 5.2 and 5.3 for bearing-type connection limit states. With the understanding that editorial comments from Tide would be considered and accepted, Tide withdrew his negative vote. Yura suggested that in Section 5.4, reference to ASD and Canadian LSD be removed; Schlafly agreed with removing the Canadian reference, but not the LRFD & ASD duel system callout (LRFD (Φ) & ASD (Ω) is used throughout the Specification to align with AISC; see Ballot Item S11-033). Schlafly previously agreed with deleting Commentary paragraph that begins with 'Because of the greater…., change Commentary Item (2), second sentence 'should be' to 'are' and change Commentary Item (3), first sentence 'can be' to 'is'. Schlafly agreed to include at the end of the second to last sentence of the first paragraph in the Commentary '*for specimens tightened using the calibrated wrench method*' and remove from the first sentence of the seventh paragraph 'approximately in the single value of the slip probability factor D_u'. With the additions and deletions discussed and agreed upon, Yura withdrew his negative vote. Wong provided no explanation for the negative and per the bylaws of the Council that negative vote was ignored.

ACTION ITEM 2013-3 (A.1) (S12-042): The as-balloted item with proposed changes to the Specification were considered and accepted for inclusion into the next revision of the Specification with the understanding that several editorial comments from affirmative and negative votes be included.

5.4 S12-043 Section 8.1 Commentary – TC bolts in Snug Tight joints (Schlafly): (2012-13 Ballot Item 4 summary: 66/1/1 – Affirmative/Negative/Abstention). Ballot language was written to eliminate economical or esthetical favoritism to either condition of having the splines of TC bolts twisted off or left in place. The ballot had five affirmative votes with comments. Schlafly considered no actions/changes required from Astaneh, Hay and Vissat comments. Chen comment not related to the ballot proposal, but considered new business if Chen desires to pursue. McGormley suggested that the word 'twisted-off" be replaced with the word 'removed'. A twisted-off condition would indicate that the bolt assembly was fully pre-tensioned. Discussion followed (McGormley, G. Mitchell, H. Mitchell, Mayes, Schroder, Ferrell, Kruth). Schlafly will consider the revised wording. The ballot had one negative (Frank). Further discussion followed (Yura, Shoemaker, Harrold, Fortney, Shneur, Larsen, Shaw, Ferrell). If so required by the engineer that a snug tightened joint not have the splines removed, Commentary language should direct that required information be included on the Design Drawing or in the Specification. There is no maximum preload required for a snug tightened joint.

Schlafly moved and Ferrell seconded to find the negative vote for the balloted proposed change to be non-persuasive. Harrold requested a vote for the motion as follows:

33 for the vote to be non-persuasive
0 against the vote to be non-persuasive
3 abstained

ACTION ITEM 2013-04 (A.1) (S12-043): The as-balloted item with proposed changes to the Specification was considered and accepted for inclusion into the next revision of the Specification.

5.5 S12-044 Section 5.1 – Fillers (Schlafly): (2012-13 Ballot Item 5 summary: 57/2/9 – Affirmative/Negative/Abstention). The ballot had eight affirmative votes with comments. Schlafly considered no actions/changes required from Birkemoe comment; changes from Chen, Ricles & Tide were considered and accepted as editorial; Conner comment to change *they* to *the connection* was accepted; Frank comment not related to the ballot proposal, but considered new business if Frank desires to pursue; Shaw comment that (4) be split into (4) and (5) was considered and accepted as editorial; Shoemaker comment regarding clarification to the number of tests using 24-bolt connections was considered and accepted as editorial.

The ballot had two negatives (Baxter, Dusicka). Further discussion followed (Schlafly, Yura, Shaw, Harrold). Baxter negative vote does not have data to support including alternate design fasteners (TC bolts) in (4). Schlafly moved and Shaw seconded to find Baxter's negative vote for the balloted proposed change to be non-persuasive. Harrold requested a vote for the motion as follows:

25 for the vote to be non-persuasive
0 against the vote to be non-persuasive
12 abstained

Dusicka negative vote basis needs further work with supporting data, therefore Schafly requested Dusicka to withdraw his negative vote and consider negative comment as New Business; Dusicka agreed to withdraw his negative vote.

ACTION ITEM 2013-05 (A.1) (S12-044): The as-balloted item with proposed changes to the Specification was considered and accepted for inclusion into the next revision of the Specification with the understanding that several affirmative votes with comments would be included.

5.6 S12-045 Sections 8.2.3, 9.2.1, 9.2.2, 9.2.3 – Inspection Process (Curven): (2012-13 Ballot Item 6 summary: 52/10/6 – Affirmative/Negative/Abstention). The ballot had 10 negatives (Ferrell, Hay, Helwig, Lohr, Mayes, McGormley, G. Mitchell, H. Mitchell, Tide and Ude). Discussion followed (Curven, Harrold, Shaw). Since this ballot item is similar to Ballot Item 1 (S11-038), it was suggested that the 10 negative votes be found persuasive and the same Task Group for Ballot Item 1 also address Ballot Item 6.

ACTION ITEM 2013-06 (A.1) (S12-045): The as-balloted item with proposed changes to the Specification was considered and defeated for inclusion into the next revision of the Specification. A task group composed of Curven (chair), Carter, G. Mitchell, Shaw, and Ude will review and revise the as presented proposal language.

5.7 S12-047 Section 3.3 – Hole Definitions (Kruth): (2012-13 Ballot Item 7 summary: 63/3/2 – Affirmative/Negative/Abstention). The ballot had three negatives (Curven, Frank, Helwig). Modifications (5/10/13) to the as-balloted items, shown as either double strikethrough or double underline, were made to satisfy Frank and Helwig negatives. These modifications in

essence find Frank and Helwig negative votes persuasive. Kurth moved and Shneur seconded to find Curven negative vote for the balloted proposed change to be non-persuasive.
Discussion followed (McGormley, Harrold, Kruth, Ferrell, Shneur, H. Mitchell, Fortney, Helwig). Since changes have been made to the as-balloted items, these changes will need to be re-balloted. The re-write to Section 3.3.3 Commentary needs to address end connection rotation effects on beam/girder members that are not laterally or torsionally restrained. The EOR needs to define not using short slotted holes; use permitted unless otherwise defined as not acceptable. The ballot item was returned to the task group for further discussion regarding the proposal.

ACTION ITEM 2013-07 (A.1) (S12-047): The as-balloted item with proposed changes was considered and defeated for inclusion into the next revision of the specification. The original task group composed of Kurth (chair), Carter, Ferrell, Fortney, Gibble, and Shneur will review and revise the as presented proposal language.

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

- To make changes to the present specification, download from the RCSC web site a Proposed Change form, 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 S12-048 Section 1.5 – ASTM Name (Harrold): ASTM, as referenced in the Specification, is now referred to as ASTM International without spelling out what the letters ASTM formerly meant. Executive Committee approved the change as editorial.

6.2 S13-049 Section 6.2.4 – Hardened Washers with DTI's (Brown): Section 6.2.4 is very specific regarding the use of ASTM F436 hardened washers in conjunction with ASTM F959 DTI's. Rowan University published testing results of curved protrusion DTI's without incorporating hardened washers, with acceptable pre-installation tensioning results. For bolt sizes 1-inch and less, ASTM F436 hardened washers have a flatness deviation tolerance of 0.010-inch and for bolt sizes greater than 1-inch, the flatness deviation tolerance is 0.015-inch. Recent field pre-installation verification testing results indicated unacceptable pre-tension results due to hardened washer installation orientation (concaved face). Further discussion followed (Brown, Harrold, Curven, Kasper, Schroeder, Shneur, G. Mitchell, Shaw). Remove language that addresses proprietary requirements as related to curved protrusions. Section 2.6.2 addresses Alternative Washer-Type Indicating Devices; suggest including a section that includes Alternative Fastener Installation Methods. Hole diameter tolerance for ASTM F436 hardened washers provides challenges in obtaining pre-installation tensioning results.
A task group composed of Brown (chair), Curven, G. Mitchell & Shaw shall propose new specification language which addresses the usage of ASTM F436 hardened washers with ASTM F959 DTI's and include the removal of heat treatment requirements in Section 8.2.4 Commentary per the latest ASTM F959.

ACTION ITEM 2013-08 (A.1): Task group to propose new language and submit to Harrold for consideration. In order for the proposed change to be included in the next revision to the Specification, the change will need to be balloted. Task group is composed of Brown (chair), Curven, G. Mitchell, and Shaw.

6.3 S13-050 Section 2.3 Commentary – Bolt Length Increments (H. Mitchell): Further discussion followed (Harrold, Friel, Miazga). No reference made in Commentary to support adjusting Table C-2.2 to the nearest ½-inch length increment for bolt lengths exceeding 5 or 6 inches. A task group composed of H. Mitchell (chair), Germuga & Gialamas will propose new language in Section 2.3 Commentary to define length increment value(s) based on input obtained from the various bolt manufacturers.

ACTION ITEM 2013-09 (A.1): Task group to propose new language and submit to Harrold for consideration. In order for the proposed change to be included in the next revision to the Specification, the change will need to be balloted. Task group is composed of H. Mitchell (chair), Germuga, and Gialamas.

6.4 S12-040 Section 8.2.4 Commentary – Removal of Hardened Requirement (Brown): Due to lack of time, no discussion took place. Subject will be addressed by Item 6.2 task group.

ACTION ITEM 2013-10 (A.1): Task group to propose new language and submit to Harrold for consideration. In order for the proposed change to be included in the next revision to the Specification, the change will need to be balloted. Task group is composed of Brown (chair), Curven, G. Mitchell, and Shaw.

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

7.1 Match-marking language for Turn-of-Nut (Kasper): Present language in the Specification does not require match-marking the nut and bolt position when pre-tensioning the assembly using the turn-of-nut method. In other parts of the world, match-marking is a requirement. Task group (Kasper (chair), Mayes, G Mitchell, Shaw) did not meet, but Kasper recommended continuing the task group. In addition to match-marking requirements, the task group will also consider introducing new tool technology that controls nut rotation.

ACTION ITEM 2013-11 (A.1): Task group to propose new language and submit to Harrold for consideration. In order for the proposed change to be included in the next revision to the Specification, the change will need to be balloted. Task group is composed of Kasper (chair), Mayes, G. Mitchell, and Shaw.

7.2 Glossary Definition of Torque (Curven): A task group composed of Curven (chair), Birkemoe, Brown, Mayes & Shneur is close to language agreement and ready to issue recommendation for balloting.

ACTION ITEM 2013-12 (A.1): Task group to propose new language and submit to Harrold for consideration. In order for the proposed change to be included in the next revision to the Specification, the change will need to be balloted. Task group is composed of Curven (chair), Birkemoe, Brown, Mayes, and Shneur.

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

8.1 Failures due to tightening bolts from the head side (G. Mitchell): Delayed failures of ASTM A325 galvanized and A490 black bolts on bridge and power plant work when tightened from the head side. Limited testing has taken place, but not completed. Set-up similar to that of a compression slip test specimen: (3) ¾-inch Grade 50 steel plates, 7/8-inch diameter A325 bolts, hardened washer under the turned element, installed by turn-of-nut method. Checking torque values when bolt heads and nuts are turned with a load applied to the ¾-inch steel plates, which bears on the shank of the bolt. Further discussion followed (Schroder, Harrold, Brown, Larson). Consider lubricating the turned element (bolt head and or hardened washer). Second paragraph of Section 8.2 will need to be re-written to include lubrication requirements. Pre-installation verification testing will need to consider the as installed condition; with and without lubrication.

ACTION ITEM 2013-13 (A.1): Research Committee chair, Todd Ude, to look for funding from RCSC, AISC, AASHTO and FHWA to support additional research on this issue.

8.2 Thick Coatings (Birkemoe): Due to lack of time, no discussion took place.

8.3 Shear Allowables (from Ballot S08-024) (Yura): Due to lack of time, no discussion took place.

8.4 Oversize Holes - Slip Critical? (Shear Connections) (Yura): Due to lack of time, no discussion took place.

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

9.1 Appendix A creep tests at service load level (Yura): Due to lack of time, no discussion took place.

9.2 XTB (Shaw): Due to lack of time, no discussion took place.

9.3 Snug-Tight Definition: Mayes (LPR Construction) conducted a field study of nut rotations from snug-tight condition for turn-of-nut pre-tensioning and found pre-tension results not in line with specification requirements. A new Task Group composed of Mayes (chair), Larson, McGormley, Birkemoe, Kasper, G. Mitchell, Shneur, and Jefferson to re-study snug-tight definition as currently written in the Specification Glossary.

ACTION ITEM 2013-14 (A.1): Task group to propose new language and submit to Harrold for consideration. In order for the proposed change to be included in the next revision to the Specification, the change will need to be balloted. Task group is composed of Mayes (chair), Birkemoe, Jefferson, Kasper, Larson, McGormley, G. Mitchell, and Shneur.

9.4 Large Holes and Large Bolts: (Shaw): Due to lack of time, no discussion took place.

ITEM 10.0 <u>Liaison Reports:</u>

10.1 AISC (Carter): Due to lack of time, no reports were presented.

10.2 S16 (Miazga): Due to lack of time, no reports were presented.

10.3 ASTM F16 (Greenslade): Due to lack of time, no reports were presented.

ITEM 11.0 <u>Date and time of next meeting:</u>

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

ITEM 12.0 <u>Adjournment:</u>

No motion was presented, Harrold declared the Specification Committee A.1 meeting adjourned; meeting disbanded at 12:04PM.

ITEM 13.0 <u>Attachments:</u>

13.1 Agenda (Item 3.0):

13.2 Resolution of Ballot Results (Item 5.0)

- S11-038
- S12-039

- S12-042
- S12-043
- S12-044
- S12-045
- S12-047

13.3 Discussions of Proposed Specification Changes (Item 6.0)

- S12-048
- S13-049
- S13-050

RESEARCH COUNCIL ON STRUCTURAL CONNECTIONS

SPECIFICATION COMMITTEE A.1 MEETING JUNE 6, 2013
8:00 AM - 12:00 PM

AGENDA

0.1 ATTENDANCE

1.0 CHAIRMAN'S REMARKS

2.0 APPROVAL OF MINUTES OF JUNE 2012 MEETING

3.0 APPROVAL OF AGENDA

4.0 MEMBERSHIP
- 4.1 Review and Update Membership List

5.0 RESOLUTION OF BALLOT RESULTS (Affirmative/Negative/Abstain)

5.1	S11-038	Sections 8.2, 8.2.1, and 8.2.3 - Pre-install Verif. Testing Language (61/5/2)	(Curven)
5.2	S12-039	Table 2.1 – Delete Zn/Al coating from F1852 and F2280 assemblies (61/3/4)	(Schlafly)
5.3	S12-042	Section 5.4 – Slip Critical Equations (48/3/17)	(Schlafly)
5.4	S12-043	Section 8.1 Commentary – TC bolts in Snug Tight joints (66/1/1)	(Schlafly)
5.5	S12-044	Section 5.1 – Fillers (57/2/9)	(Schlafly)
5.6	S12-045	Sections 8.2.3, 9.2.1, 9.2.2, 9.2.3 – Inspection Process (52/10/6)	(Curven)
5.7	S12-047	Section 3.3 – Hole Definitions (63/3/2)	(Kurth)

6.0 DISCUSSION OF PROPOSED SPECIFICATION CHANGES

6.1	S12-048	Section 1.5 – ASTM Name (Approved Editorially)	(Harrold)
6.2	S13-049	Section 6.2.4 – Hardened Washers with DTI's	(Brown)
6.3	S13-050	Section 2.3 Commentary – Bolt Length Increments	(H. Mitchell)

7.0 TASK GROUP REPORTS

7.1	Matchmarking language for turn-of-the-nut	(Kasper)
7.2	Glossary Definition of Torque	(Curven)

8.0 OLD BUSINESS

8.1	Failures due to tightening bolts from the head side	(G. Mitchell)
8.2	Thick Coatings	(Birkemoe)
8.3	Shear Allowables (from Ballot S08-024)	(Yura)
8.4	Oversize Holes - Slip Critical? (Shear Connections)	(Yura)

9.0 NEW BUSINESS

9.1	Appendix A creep tests at service load level	(Yura)

10.0 LIAISON REPORTS

10.1	AISC	(Carter/Schlafly)
10.2	S16	(Miazga)
10.3	ASTM F16	(Greenslade)

11.0 NEXT MEETING

12.0 ADJOURNMENT

RCSC Proposed Change: S11-038

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

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

Ballot History:

2012-13 Ballot Item # 1

61 Affirmative,

5 Negative (Ferrell, McGormley, G. Mitchell, H. Mitchell, Tide)

2 Abstain

Proposed Change:

8.2. Pretensioned Joints and Slip-Critical Joints

One of the pretensioning methods in Sections 8.2.1 through 8.2.4 shall be used, except when alternative-design fasteners that meet the requirements of Section 2.8 or alternative washer-type indicating devices that meet the requirements of Section 2.6.2 are used, in which case, installation instructions provided by the *manufacturer* and approved by the *Engineer of Record* shall be followed.

{Table 8.1 "Minimum Bolt Pretension, Pretensioned and Slip-Critical Joints" is unchanged and will not be reproduced here.}

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 as indicated in Sections 8.2.1 through 8.2.4, using *fastener assemblies* that are representative of the condition of those that will be pretensioned in the work.

The required p~~P~~re-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.

Commentary:
{There are no proposed changes to the commentary for this subsection.}

8.2.1. Turn-of-Nut Pretensioning: The pre-installation verification procedures specified in Section 7 shall demonstrate that the required rotation from snug-tight shall reach at least the minimum required tension in Table 7.1. All bolts shall be

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

Date Received: 6/10/11 Exec Com Meeting: _6/11___ 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: Curven

Date Sent to Main Committee: _______________Final Disposition: ______________________

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

{Table 8.2 "Nut Rotation from Snug-Tight Condition for Turn-of-Nut Pretensioning" is unchanged and will not be reproduced here.}

Commentary:
{There are no proposed changes to the commentary for this subsection.}

8.2.2. Calibrated Wrench Pretensioning:
{There are no proposed changes to this subsection.}

8.2.3. Twist-Off-Type Tension-Control Bolt Pretensioning: Twist-off-type tension-control bolt assemblies that meet the requirements of ASTM F1852 or F2280 shall be used. The pre-installation verification procedures specified in Section 7 shall demonstrate that, when the splined end is severed off with the required tool, the bolt tension shall be at least equal to that required in Table 7.1.

All *fastener assemblies* shall be installed in accordance with the requirements in Section 8.1 without severing the splined end and with washers positioned as required in Section 6.2. If a splined end is severed during this operation, the *fastener assembly* shall be removed and replaced. Subsequently, all bolts in the *joint* shall be pretensioned with the twist-off-type tension-control bolt installation wrench, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts.

Commentary:
{There are no proposed changes to the commentary for this subsection.}

8.2.4. Direct-Tension-Indicator Pretensioning:
{There are no proposed changes to this subsection.}

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

Sections 9.2.1 and 9.2.3 make a reference to the pre-installation verification testing in Sections 8.2.1 and 8.2.3 respectively. There is currently no language in Sections 8.2.1 and 8.2.3 that refer to the pre-installation testing.

This proposal corrects that omission and makes all four subsections of Section 8.2 refer to Chapter 7 pre-installation requirements in an equivalent manner.

Ballot Actions and Information:

2012-13 Ballot Item # 1

61 Affirmative,

5 Negative (Ferrell, McGormley, G. Mitchell, H. Mitchell, Tide)

2 Abstain

Affirmative with Comments:

Peter Birkemoe:

Commentary in Section 7 suggests that the hydraulic calibrator is softer than solid steel and the readings of turns to achieve a given load will be higher. Without specific recommendations on how to account for this when verifying T.O.N., it would be assumed that the verification is "that the assembly can reach the required pretension by turning." Similarly, for bolts too short to fit in a calibrator it is permitted to verify T.O.N. by tightening an assembly in solid steel by turning the nut. Since the force in the bolt can not be verified, it would be assumed here that the verification is "the survival by the assembly of the applied turn." The "clarification" in this Ballot puts more focus on the parallel requirement for Verification of T.0.N. and I would suggest some clarification of this aspect of the associated commentary. Also, in 8.2 the first amended paragraph would be improved by adding "and configuration" after "condition." If the bolt head is turned, that is the way the assembly performance should be verified.

Robert Hay:

Language provided helps to clarify preinstallation requirements.

Bob Shaw:

Editorial only – in 8.2.1 third line, change "reach" to "provide"

Joe Yura:

For turn-of-nut method, the last sentence in the Commentary of Section 7.1 states that short bolts do not need verification of the bolt tension in Table 7.1 so perhaps the following should be added to Section 8.2.1: "… in Table 7.1, except for short bolts where the required turns must be verified."

Negative with Comments:

Doug Ferrell:

In my opinion the requirement of pre-Installation verification is adequately stated in the wording of 8.2. Repeating this requirement in the definition of each installation method is not necessary. Also the additional performance requirements of each method is not necessary.

Jonathan McGormley:

As it stands today, the current text indirectly achieves its purpose via Section 8.2. The proposed text could be eliminated by changing the references to 8.2.1 and 8.2.3 in Sections 9.2.1 and

9.2.3, respectively, to Section 8.2 which currently, without modification, requires pre-installation verification. Similar modifications should be made to 9.2.2 and 9.2.4. Less text is better, in my opinion.

Eugene Mitchell:
Section 7 doesn't detail any installation procedures. This can be handled once in 8.2 with a statement like: "Regardless of the installation method, the pre-installation verification shall demonstrate that the bolt assemblies tested reach an installed tension that is equal to or greater than the minimum required tension in Table 7.1." The current wording in 8.2.4 can be removed and nothing needs to be added to 8.2.2 & 8.2.3.

Heath Mitchell:
I'm not convinced that there is any confusion resulting from the spec as-is in this case, but for the sake of consistency these changes are likely warranted. I think the implementation can use a little more work to be consistent in style and terminology across all installation methods. See attached revisions and comments (See Attachment A).

Ray Tide:
Item S11 – 038, I agree that Chris has uncovered some inconsistencies in the Spec. However, the topic of pre-installation verification has been contentious for many years. Now would be a good time to make one more effort to resolve the broader problem. My recommendation is for the steel industry reps to get together and come up with the language that will remove the more onerous part of pre-installation verification.

First, separate Calibrated wrench from the other three methods (turn-of-nut, tension control and load indicator washers).

Second, accept the fact that there are times when some Contractors/Fabricators/Erectors take short cuts and there are job-site screw ups. The steel industry representatives need to come up with the language that will protect the EOR and the Owner in these cases. Short of new language with this in mind you will NEVER get the votes to make the appropriate changes.

Because of the inconsistencies that Chris has uncovered, now is the time and opportunity to make a meaningful overall change on this topic.

RCSC Proposed Change: S11-038

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

Ballot History:
2012-13 Ballot Item # 1

Proposed Change:

8.2. Pretensioned Joints and Slip-Critical Joints

One of the pretensioning methods in Sections 8.2.1 through 8.2.4 shall be used, except when alternative-design fasteners that meet the requirements of Section 2.8 or alternative washer-type indicating devices that meet the requirements of Section 2.6.2 are used, in which case, installation instructions provided by the *manufacturer* and approved by the *Engineer of Record* shall be followed.

{Table 8.1 "Minimum Bolt Pretension, Pretensioned and Slip-Critical Joints" is unchanged and will not be reproduced here.}

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 as indicated in Sections 8.2.1 through 8.2.4, using *fastener assemblies* that are representative of the condition of those that will be pretensioned in the work.

The required p~~P~~re-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.

Commentary:
{There are no proposed changes to the commentary for this subsection.}

8.2.1. Turn-of-Nut Pretensioning: The pre-installation verification procedures specified in Section 7 shall demonstrate that ~~the required rotation from snug tight shall reach at least the minimum required tension in Table 7.1.~~ 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*,

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

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

{Table 8.2 "Nut Rotation from Snug-Tight Condition for Turn-of-Nut Pretensioning" is unchanged and will not be reproduced here.}

Commentary:
{There are no proposed changes to the commentary for this subsection.}

8.2.2. Calibrated Wrench Pretensioning:
{There are no proposed changes to this subsection.}

8.2.3. Twist-Off-Type Tension-Control Bolt Pretensioning: Twist-off-type tension-control bolt assemblies that meet the requirements of ASTM F1852 or F2280 shall be used. The pre-installation verification procedures specified in Section 7 shall demonstrate that, when the splined end is severed off with the ~~required tool~~, the bolt tension shall be at least equal to that required in Table 7.1.

All *fastener assemblies* shall be installed in accordance with the requirements in Section 8.1 without severing the splined end and with washers positioned as required in Section 6.2. If a splined end is severed during this operation, the *fastener assembly* shall be removed and replaced. Subsequently, all bolts in the *joint* shall be pretensioned with the twist-off-type tension-control bolt installation wrench, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts.

Commentary:
{There are no proposed changes to the commentary for this subsection.}

8.2.4. Direct-Tension-Indicator Pretensioning:
{There are no proposed changes to this subsection.}

RCSC Proposed Change: S12-045

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Ballot Actions:
2012-13 Ballot Item # 6

Proposed Changes:

8.2.3. Twist-Off-Type Tension-Control Bolt Pretensioning: Twist-off-type tension-control bolt assemblies that meet the requirements of ASTM F1852 or F2280 shall be used.

All *fastener assemblies* shall be installed in accordance with the requirements in Section 8.1 without severing the splined end and with washers positioned as required in Section 6.2. If a splined end is severed during this operation, the *fastener assembly* shall be removed and replaced. Subsequently, all bolts in the *joint* shall be ~~pretensioned~~ ~~tightened~~ with the twist-off-type tension-control bolt installation wrench~~ until the splined end shears off~~, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts.

Commentary:
ASTM F1852 and F2280 twist-off-type tension-control bolt assemblies have a splined end that extends beyond the threaded portion of the bolt. During installation, this splined end is gripped by a specially designed wrench chuck and provides a means for turning the nut relative to the bolt. This product is, in fact, based upon a torque-controlled installation method to which the *fastener assembly* variables affecting torque that were discussed in the Commentary to Section 8.2.2 apply, except for wrench calibration, because torque is controlled within the *fastener assembly*.

Twist-off-type tension-control bolt assemblies must be used in the as-delivered, clean, lubricated condition as specified in Section 2. Adherence to the requirements in this Specification, especially those for storage, cleanliness and verification, is necessary for their proper use.

9.2.1. Turn-of-Nut Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section 8.2.1. ~~Subsequently, but prior~~ to pretensioning and optional match-marking, it shall be ensured by *routine observation* that the plies have been brought into *firm contact*. 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

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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: _______________________

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.

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.

9.2.2. Calibrated Wrench Pretensioning: The *inspector* shall observe the daily pre-installation verification testing required in Section 8.2.2. ~~Subsequently, but prior~~ to pretensioning, it shall be ensured by *routine observation* that the plies have been brought into *firm contact*. Subsequently, it shall be ensured by *routine observation* that the bolting crew properly applies the calibrated wrench to the turned element. 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.

Commentary:
For proper inspection of the method, it is necessary 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 within the limits on time between removal from *protected storage* and final pretensioning.

9.2.3. Twist-Off-Type Tension-Control Bolt Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section 8.2.3. ~~Subsequently, but prior~~ to pretensioning, it shall be ensured by *routine observation* that the plies have been brought into *firm contact* without the splined ends being severed. If the splined end is severed, the bolt must be removed and replaced. Subsequently, it shall be ensured by *routine observation* that the splined ends are properly severed during installation by the bolting crew. 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.

Commentary:
The sheared-off splined end of an installed twist-off-type tension-control bolt assembly merely signifies that at some time the bolt was subjected to a torque that was adequate to cause the shearing. If in fact all fasteners are individually pretensioned in a single continuous operation without first properly snug-tightening all fasteners, they may give a misleading indication that the bolts have been properly pretensioned. Therefore, it is necessary that the *inspector* observe the required pre-installation verification testing of the *fastener assemblies*, and the ability to apply partial tension prior to twist-off is demonstrated. This is followed by monitoring of the work in progress to ensure that the method is routinely and properly applied within the limits on time between removal from *protected storage* and final twist-off of the splined end.

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

8.2.3 does not actually state when the installer is to stop tightening or when the bolt is deemed tight. It states what type of installation tool to be used, but not what the installer is looking for.
For example, 8.2.1. states to rotate the head or nut as specified in table 8.2., 8.2.2. states to apply the installation torque determined by the pre-installation verification, and 8.2.4. has the installer making sure the achieved gap is less than the job inspection gap.

Also, Section 9.2.4. is the only installation method that has the inspector verify that snugging of the bolts and plies have taken place before the chosen pretensioning method takes place. 9.2.1., 9.2.2.,and 9.2.3. would obviously like to have inspection of the snug condition, but it is not listed.
For example, 9.2.4. …All bolts shall be installed in accordance with the requirements in Section 8.1, with washers positioned as required in Section 6.2. The installer shall verify that the direct-tension-indicator protrusions have not been compressed to a gap that is less

RCSC Proposed Change: S12-039

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Ballot History:

2012-13 Ballot Item # 2
61 Affirmative
3 Negative (Kasper, Lohr, Mayes)
4 Abstain.

Proposed Change:
Table 2.1

Table 2.1. Acceptable ASTM A563 Nut Grade and Finish and ASTM F436 Washer Type and Finish

ASTM Desig.	Bolt Type	Bolt Finish[d]	ASTM A563 nut grade and finish[d]	ASTM F436 washer type and finish[a,d]
A325	1	Plain (uncoated)	C, C3, D, DH[c] and DH3; plain	1; plain
		Galvanized	DH[c]; galvanized and lubricated	1; galvanized
		Zn/Al Inorganic, per ASTM F1136 Grade 3	DH[c]; Zn/Al Inorganic, per ASTM F1136 Grade 5	1; Zn/Al Inorganic, per ASTM F1136 Grade 3[b]
	3	Plain	C3 and DH3; plain	3; plain
F1852	1	Plain (uncoated)	C, C3, DH[c] and DH3; plain	1; plain[b]
		Mechanically Galvanized	DH [c]; mechanically galvanized and lubricated	1; mechanically galvanized[b]
		~~Zn/Al Inorganic, per ASTM F1136 Grade 3~~	~~DH[c]; Zn/Al Inorganic, per ASTM F1136 Grade 5~~	~~1; Zn/Al Inorganic, per ASTM F1136 Grade 3[b]~~
	3	Plain	C3 and DH3; plain	3; plain[b]
A490	1	Plain	DH[c] and DH3; plain	1; plain
		Zn/Al Inorganic, per ASTM F1136 Grade 3	DH[c]; Zn/Al Inorganic, per ASTM F1136 Grade 5	1; Zn/Al Inorganic, per ASTM F1136 Grade 3[b]
	3	Plain	DH3; plain	3; plain

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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: ______________________

F2280	**1**	**Plain**	DH[c] and DH3; plain	1; plain
	3	**Plain**	DH3; plain	3; plain

[a] Applicable only if washer is required in Section 6.

[b] Required in all cases under nut per Section 6.

[c] The substitution of ASTM A194 grade 2H nuts in place of ASTM A563 grade DH nuts is permitted.

[d] "Galvanized" as used in this table refers to hot-dip galvanizing in accordance with ASTM F2329 or mechanical galvanizing in accordance with ASTM B695.

[e] "Zn/Al Inorganic" as used in this table refers to application of a Zn/Al Corrosion Protective Coating in accordance with ASTM F1136 which has met all the requirements of IFI-144.

Section 2.3.3 Commentary

{Modification is to the fourth paragraph of the commentary. All other portions of the Commentary are unchanged.}

An extensive investigation conducted in accordance with IFI-144 was completed in 2006 and presented to the ASTM F16 Committee on Fasteners (F16 Research Report RR: F16-1001). The investigation demonstrated that Zn/Al Inorganic Coating, when applied per ASTM F1136 Grade 3 to ASTM A490 bolts, does not cause delayed cracking by internal hydrogen embrittlement, nor does it accelerate environmental hydrogen embrittlement by cathodic hydrogen absorption. It was determined that this is an acceptable finish to be used on Type 1 ASTM A325 and A490 bolts~~ and F1852 and F2280 twist-off-type tension-control bolt assemblies~~.

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

At the present time, ASTM has not accepted the use of the Zn/Al Inorganic coating on either the F1852 or F2280 tension-control bolt assemblies. There have been some concerns raised regarding the proper fabrication of the assembly parts given the significantly different coefficient of friction generated by the Zn/Al coating in comparison with normal lubricated assemblies. This difference could result in bolts that have not been properly tensioned.

Ballot Actions and Information:

2012-13 Ballot Item # 2

61 Affirmative

3 Negative (Kasper, Lohr, Mayes)

4 Abstain.

Affirmative with Comments:

Abolhassan Astaneh:

I support the change and hope research can be done to convince ASTM to accept Zn/Al Inorganic coating on F1852 and F2280 tension-control bolt assemblies. This can be helpful particularly for steel bridges.

Salim Brahimi:

This comment is for consideration by the committee. The question of formal inclusion in ASTM standards of Zn/Al coatings, or any other metallic coating on TC bolt products has nothing to do with the coatings themselves, but has to do with the fact that the product must be sold as a calibrated assembly by the manufacturer. If a manufacturer coats his F1850 products with an F1136 coating, then he will make the necessary process/product modifications to ensure that the assembly reaches a mimum tension consistently. The risk here is that concerns the ASTM F16 committee is if a distributor, end user or third party (other than the manufacturer decides to coat the parts. In that case the assembly will certainly perform differently during tightening. Having sated the above, if there was to be a coating formally approved in ASTM F1850 (to be applied by the manufacturer only), Zn/Al coatings such as ASTM F1136 and F2833 would be the most appropriate for consistency and controllability of torque/tension characteristics. I would venture that these coatings might even be easier to control from a manufacturing point of view. Respectfully submitted.

Bruce Butler:
Since we verify proper tension, I'm assuming the reason for deleting Zn/Al is that there is excessive variability in a single lot.

Robert Connor:
In the commentary, reference is made to F2280 bolts, though they are not and were not included in the table…at least not in my version. In the rational, reference is made to the fact that a "significantly different coefficient" of friction is observed. I presume this means "lower".

Negative with Comments:

Peter Kasper:
I see no reason not to list Zinc Aluminum Flake Coatings as acceptable for use on TC style bolting. These finishes have been used on TC bolting regularly for many projects, and are available from many manufacturers – mainly outside of the USA. While these finishes are deemed acceptable for hex bolts, including A490 bolting, ASTM still needs to adequately require functional testing of the coated hex head bolt assembly (similar to galvanized A325 bolting/assemblies), so unlike for coated hex bolting, any questions for functionality are covered in the TC bolt standards because there already is functional testing required of the assemblies after the coatings are applied. In my opinion, the only area lacking may be for environmental testing, but this is not a requirement for plain finish TC bolts either, so the same pattern applies. I would suggest that we leave the listing for F1136 finishes as currently shown, and consider to expand it to include the F2833 Zinc Aluminum finish which has been shown to be accept able for A490 bolting at ASTM also.

Ken Lohr:
I disagree with the rational, based on the fact that using Zn/Al Inorganic Coatings on F1852 and F2280 TC have been supplied successfully for a number of years. We have been successfully supplying this coating for many years for use on power plants, chemical plants, industrial and mining construction, both in the US and overseas. There are sufficient safeguards listed in ASTM that require the manufacturer to conduct and report testing to assure the fastener sets meet the specification. Further addition safeguards are required in RCSC that the fasteners must pass the pre-installation verification testing prior to use on the project. There have been many successful installations using Zn/Al Inorganic Coatings; therefore I feel there is no reason to penalize suppliers that are supplying fasteners that can be properly tensioned.

Curtis Mayes:
LPR has successfully installed 1000's of Dacromet coated F1852 TC bolts on multiple jobs with no problems. Any TC bolt manufacturer is responsible for proper fabrication, design and assembly of the fastener and must find a successful combination of material, surface roughness, coating, lubrication and geometry for the tension control fastener assemblies to work as intended. Just because someone has had difficulty finding the right combination to make a fastener assembly work, is not a good reason to disallow use of Zn/Al coatings on TC fasteners. Am I correct to say that we know that Zn/Al is a good coating and the chemical interaction of Zn/Al with A325 is exactly the same as with F1852?

RCSC Proposed Change: S12-042

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Ballot Actions:

2012-13 Ballot Item # 3

48 Affirmative

3 Negative (Tide, Yura, Wong)

17 Abstain

Proposed Change:

{Proposal S11-033 which blended Appendix B back into the main Specification also had modified Section 5.4. This proposal will fully replace the language proposed by that proposal for this section.}

5.4. Design Slip Resistance

Slip-critical connections shall be designed to prevent slip and for the limit states of bearing-type connections. When slip-critical bolts pass through fillers, all *faying surfaces* subject to slip shall be prepared to achieve design slip resistance.

At US LRFD or Canadian LSD load levels the design slip resistance is fR_n and at ASD load levels the allowable slip resistance is R_n/W where R_n,, f and W are defined below.

The available slip resistance for the limit state of slip shall be determined as follows:

$$R_n = \mu D_u h_f T_b n_s k_{sc} \qquad \text{Equation 5.6}$$

For standard size and short-slotted holes perpendicular to the direction of the load

f = 1.00 (LRFD, LSD) Ω = 1.50 (ASD)

For oversized and short-slotted holes parallel to the direction of the load

f = 0.85 (LRFD, LSD) Ω = 1.76 (ASD)

For long-slotted holes

f = 0.70 (LRFD, LSD) Ω = 2.14 (ASD)

where

μ = mean slip coefficient for Class A or B surfaces, as applicable, and determined as follows, or as established by tests:

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Committee Chair: Harrold Task Group #: ___________ T.G. Chair: Schlafly

Date Sent to Main Committee: _______________Final Disposition: ______________________

(1) For Class A surfaces (unpainted clean mill scale steel surfaces or surfaces with Class A coatings on blast-cleaned steel or hot-dipped galvanized and roughened surfaces)

$\mu = 0.30$

(2) For Class B surfaces (unpainted blast-cleaned steel surfaces or surfaces with Class B coatings on blast-cleaned steel)

$\mu = 0.50$

D_u = 1.13; a multiplier that reflects the ratio of the mean installed bolt pretension to the specified minimum bolt pretension; the use of other values may be approved by the engineer of record.

T_b = minimum fastener tension given in Table 8.1, kips

h_f = factor for fillers, determined as follows:

(1) Where there are no fillers or bolts have been added to distribute loads in the filler

$h_f = 1.0$

(2) Where bolts have not been added to distribute the load in the filler:

(i) For one filler between connected parts

$h_f = 1.0$

(ii) For two or more fillers between connected parts

$h_f = 0.85$

n_s = number of slip planes required to permit the connection to slip

$$k_{sc} = 1 - \frac{T_u}{D_u T_b n_b} \quad \text{(LRFD, LSD)}$$

$$= 1 - \frac{1.5T_a}{D_u T_b n_b} \quad \text{(ASD)}$$

where

T_a = required tension force using *ASD load combinations*, kips
T_u = required tension force using US *LRFD or Canadian LSD load combinations*, kips
n_b = number of bolts carrying the applied tension

~~5.4.1. At the Factored Load Level: The design slip resistance is ϕR_n, where ϕ is as defined below and:~~

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

~~where~~

~~ϕ~~	~~=~~	~~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~~	~~=~~	~~*nominal 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 ϕR_s, where ϕ is as defined in Section 5.4.1 and:~~

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

~~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~~	~~=~~	~~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~~ 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.~~ statistical relationship between calculated slip resistance and historical measured test results. 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.~~

The nominal resistance in 5.4 results in a reliability consistent with the reliability of structural member design. The engineer should not need to design to a higher reliability in normal structural applications. ~~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~~to prevent slip, 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~~ the governing cyclic design specification 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~~ 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*~~D_u 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.~~with a beta of at least 2.6 regardless of the method of pretensioning.

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. Twist-off type tension control bolt and direct tension indicator pretensions are similar to those of calibrated wrench. 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 ϕ. 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* μ that is less than 0.50 (Class B) and other than ~~0.33~~ 0.30 (Class A). This authorization requires that the *mean slip coefficient* μ must be determined in accordance with Appendix A. ~~following restrictions are met:~~

~~(1) The *mean slip coefficient* μ 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, μ for ~~Class C~~ galvanized 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) and to 0.30 in the 2014 edition to be consistent with slip coefficients cited previously.

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

Modify the RCSC equations to reflect the information that is contained in the AISC 2010 Specification. This reflects the most recent research on the subject.

Recent research by Hajjar et al, Dusicka et al and Grondin support changes to the formulation for slip resistance. The proposal results in reliability at levels acceptable for use in slip critical connections regardless of whether the slip limit state is considered to be a serviceability or strength limit.

Significant changes from the current specification include:

- The current specification includes three formulae for slip resistance
  - $R_n = \mu D_u T_m N_b \left(1 - \frac{T_u}{D_u T_m N_b}\right)$ *(Equation 5.6)*
  - $R_n = \mu D T_m N_b \left(1 - \frac{T}{D T_m N_b}\right)$ (Equation 5.7)
  - $R_n = H \mu D T_m N_b \left(1 - \frac{T}{D T_m N_b}\right)$ (Equation B5.5)

  All three equations should lead to the same number of bolts. Eq 5.6 uses LRFD loads. Eqs 5.7 and B5.5 use ASD loads. Bolt limit states can be formulated as a nominal resistance factored by a resistance factor (phi) or a safety factor (omega). This method is clear and concise and recommended as (near) future business. But it has not been adopted by RCSC so for consistency this proposal uses the nominal resistance formulation in the text and refers to it in Annex B.
- The basic slip coefficient is 0.30 instead of 0.33. This results in more uniform reliability across bolt strength levels and faying surface slip classes
- The current RCSC equation is for one slip plane but all bolts. The proposed is for any number of slip planes but one bolt.
- Caution has been added to commentary regarding galvanized surfaces because no research has been done subsequent to finding some surfaces with a low coefficient.

Ballot Actions and Information:

2012-13 Ballot Item # 3

48 Affirmative

3 Negative (Tide, Yura, Wong)

17 Abstain

Affirmative with Comments:

Rodney Baxter:

Appears to be a typo, delete “and” from first sentence in Section 5.4.

Peter Birkemoe:

In the third added text in the commentary “with a beta at least 2.6 regardless…etc.” BETA should be defined or replaced with wording more common to the reader. I vote affirmative on the basis that the numbers for ASD have been checked.

Helen Chen:
See Attachment B.

Robert Connor:
The sentence above proposed Eq. 5.6 should read, “The available slip resistance per bolt for the limit…..”.i.e., ad “per bolt”. It would be nice to define what ksc is for since it is a new variable. Though not part of this ballot, item #1 in the commentary that refers to joints with only one or two bolts. The text states that a small slip may occur. As a result, we say joints subjected to vibration should be proportioned to resist slip. This statement always troubled me. Are we saying that if they are 1 or 2 bolt connections AND subjected to vibration, then they should be proportioned for slip? If no vibration is expected, than no need to worry about slip? It seems to me this should be up to the designer regardless. If they are not worried about slip under vibration, it is up to the designer. Mention is made of “…coefficients cited previously” in last sentence of the commentary. Cited previously where? Previous sentence, in previous editions? Need to clarify. Lastly, in rational, mention is made that “caution is give” regarding slip coef. For galvanized joints. I don’t see any caution, just information. If caution is needed, should come out and say it clearly.

Matthew Eatherton:
It’s a shame we’re losing some of the discussion about the probability of slip in the commentary, but I can understand why it’s being replaced by the statement that the probability is consistent with member design.

Todd Helwig:
I voted affirmative for this, but I had a few comments about the material pulled out of the appendix and also on some of the changes in the commentary to the section. I see a factor 1.5 has been added to Ta in the ASD formulation of ksc – while this seems like a reasonable effective load factor – has there been much discussion on this? I think there should be some explanation of this in the commentary. Also, in the commentary it talks about the reliability of the connection resistance is consistent with the reliability of the member. Does the work cited in the rational for this change (Hajjar et al, Dusicka et al and Grondin) provide the reliability comparison? If so – we should cite that work where the commentary says the reliability of the connection is the same as in the member.

Heath Mitchell:
I suggest that we change the Commentary reference from “beta of at least 2.6” to something like “reliability coefficient, beta, of at least 2.6” and maybe add a reference to the JSE LRFD edition. I believe this is the only place that beta is mentioned in our Specification. Commentary should also be added to explain this change. Both the direct inclusion of ASD and the reversion to a single slip equation. The rationale could be used as a basis for such Commentary. Finally, item (4) in Section 1.4 should be stricken since we no longer have two levels of slip resistance.

Tom Schlafly:
Delete para in commentary starting “Because of the greater likelihood that significant. Change ‘should be ‘ to ‘ are’ in (2) Change ‘can be’ to ‘is’ in (3)

Negative with Comments:

Ray Tide:
I agree with the principle of the changes, but I believe it needs considerable editorial clean-up before I can approve. See my mark-ups. I think the 20 years needs revision. Time as slipped by. See Attachment C.

Joe Yura:
I do not have any problem with the basic formulas or any numbers but I feel this section needs a major rewrite. The introduction of references to AISC, Canadian, ASD Specs and the use of omegas deviates from the form throughout the other sections of the Bolt Spec. For fatigue, simply use phi x Rn / 1.5 for the service load check. I have attached a marked version to illustrate how the section can be simplified without changing the formulations. There are some comments in the Commentary that I do not agree with. These are noted in the attachment. See Attachment D.

Alfred Wong:
Voted negative with no comment.

Abstain with Comments:

Larry Kloiber:
I find this ballot technical correct but I find the provisions for determining Filler Factor to be ambiguous with no clear procedure for determining how to design bolts to be added to develop multiple fillers. The commentary on end connections for built up members indicates slip should be checked per Sherman/Yura equation and does not provide comment on the simple requirement in the AISC specification that the connection to be detailed slip critical but designed for shear/bearing. We are currently finding that EOR's are requiring that we provide calculations for every limit state even if it is obvious they do not control because the AISC publications show this procedure. We can not even reference other connections in the connection design package to indicate they do not control. The alternate provision should be referenced or removed from the AISC Specification.

RCSC Proposed Change: S12-042

Name: Tom Schlafly **E-mail:** schlafly@aisc.org

Phone: 312-670-5412 **Fax:**

Ballot Actions:
2012-13 Ballot Item # 3

Proposed Change:
{Proposal S11-033 which blended Appendix B back into the main Specification also had modified Section 5.4. This proposal will fully replace the language proposed by that proposal for this section.}

5.4. Design Slip Resistance

Slip-critical connections shall be designed to prevent slip and for the limit states of bearing-type connections. When slip-critical bolts pass through fillers, all *faying surfaces* subject to slip shall be prepared to achieve design slip resistance.

At US LRFD or Canadian LSD load levels the design slip resistance is ϕR_n and at ASD load levels the allowable slip resistance is R_n/Ω where R_n,, ϕ and Ω are defined below.

The available slip resistance for the limit state of slip shall be determined as follows:

$$R_n = \mu D_u h_f T_b n_s k_{sc} \qquad \text{Equation 5.6}$$

For standard size and short-slotted holes perpendicular to the direction of the load
$\phi = 1.00$ (LRFD, LSD) $\Omega = 1.50$ (ASD)

For oversized and short-slotted holes parallel to the direction of the load
$\phi = 0.85$ (LRFD, LSD) $\Omega = 1.76$ (ASD)

For long-slotted holes
$\phi = 0.70$ (LRFD, LSD) $\Omega = 2.14$ (ASD)

where
μ = mean slip coefficient for Class A or B surfaces, as applicable, and determined as follows, or as established by tests:

(1) For Class A surfaces (unpainted clean mill scale steel surfaces or surfaces with Class A coatings on blast-cleaned steel or hot-dipped galvanized and roughened surfaces)

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

Date Received: 5/30/12 Exec Com Meeting: 6/6/12 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: Schlafly
Date Sent to Main Committee: ________________Final Disposition: ________________________

Summary of Comments on Microsoft Word - S11-038 Section 8.2 PreInstallation

Page: 6

Number: 1 Author: hchen Subject: Sticky Note Date: 1/23/2013 10:41:22 AM

The first sentence seems not tight with the available strength proposed. The following recommendation is for your consideration:"Slip-critical connections shall be designed with the available resistance for the limit state of slip and with the bearing resistance for the limit state of bearing-type connections in accordance with AISC Specification Section (?).

Number: 2 Author: hchen Subject: Sticky Note Date: 1/23/2013 10:41:41 AM

Revise "available" to "nominal"

RCSC Proposed Change: S12-042

Name: Tom Schlafly **E-mail:** schlafly@aisc.org

Phone: 312-670-5412 **Fax:**

Ballot Actions:
2012-13 Ballot Item # 3

Proposed Change:
{Proposal S11-033 which blended Appendix B back into the main Specification also had modified Section 5.4. This proposal will fully replace the language proposed by that proposal for this section.}

5.4. Design Slip Resistance what?

Slip-critical connections shall be designed to prevent slip and for the limit states of bearing-type connections. When slip-critical bolts pass through fillers, all *faying surfaces* subject to slip shall be prepared to achieve design slip resistance. — not good language - what?

contradiction?

equivalent

At US LRFD or Canadian LSD load levels the design slip resistance is ϕR_n and at ASD load levels the allowable slip resistance is R_n/Ω where R_n,, ϕ and Ω are defined below.

The available slip resistance for the limit state of slip shall be determined as follows:

$$R_n = \mu D_u h_f T_b n_s k_{sc} \qquad \text{Equation 5.6(a)}$$

N_b - missing?

n_b

For standard size and short-slotted holes perpendicular to the direction of the load
ϕ = 1.00 (LRFD, LSD) Ω = 1.50 (ASD)

For oversized and short-slotted holes parallel to the direction of the load
ϕ = 0.85 (LRFD, LSD) Ω = 1.76 (ASD)

For long-slotted holes
ϕ = 0.70 (LRFD, LSD) Ω = 2.14 (ASD) } parallel and perpendicular to loads? - new

where
μ = mean slip coefficient for Class A or B surfaces, as applicable, and determined as follows, or as established by tests:

(1) For Class A surfaces (unpainted clean mill scale steel surfaces or surfaces with Class A coatings on blast-cleaned steel or hot-dipped galvanized and roughened surfaces)

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

Date Received: 5/30/12 Exec Com Meeting: 6/6/12 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: Schlafly
Date Sent to Main Committee: ______________Final Disposition: ______________________

$\mu = 0.30$

(2) For Class B surfaces (unpainted blast-cleaned steel surfaces or surfaces with Class B coatings on blast-cleaned steel)

$\mu = 0.50$

D_u = 1.13; a multiplier that reflects the ratio of the mean installed bolt pretension to the specified minimum bolt pretension; the use of other values may be approved by the engineer of record.

T_b = minimum fastener tension given in Table 8.1, kips

h_f = factor for fillers, determined as follows:

(1) Where there are no fillers or bolts have been added to distribute loads in the filler

$h_f = 1.0$

(2) Where bolts have not been added to distribute the load in the filler:

(i) For one filler between connected parts

$h_f = 1.0$

(ii) For two or more fillers between connected parts

$h_f = 0.85$

N_b - ? n_b

n_s = number of slip planes required to permit the connection to slip

$$k_{sc} = 1 - \frac{T_u}{D_u T_b n_b} \quad \text{(LRFD, LSD)}$$

Equation 5.6 (b)

← space between

$$= 1 - \frac{1.5T_a}{D_u T_b n_b} \quad \text{(ASD)}$$

Equation 5.6 (c)

where

T_a = required tension force using *ASD load combinations*, kips
T_u = required tension force using US *LRFD or Canadian LSD load combinations*, kips
n_b = number of bolts carrying the applied tension

~~5.4.1. At the Factored Load Level: The design slip resistance is ϕR_n, where ϕ is as defined below and:~~

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

~~where~~

~~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 = *nominal 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 ϕR_s, where ϕ is as defined in Section 5.4.1 and:~~

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

~~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 = 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:

~~at the factored-load level~~to prevent slip, 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~~ the governing cyclic design specification 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.

20 years ?
Table 8.1 is older than 20 years?

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~~ 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~~D_u 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~~

reliability index

~~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.~~with a beta of at least 2.6 regardless of the method of pretensioning.

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. Twist-off type tension control bolt and direct tension indicator pretensions are similar to those of calibrated wrench. 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 ϕ. 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* μ that is less than 0.50 (Class B) and other than ~~0.33~~ 0.30 (Class A). This authorization requires that the *mean slip coefficient* μ must be determined in accordance with Appendix A. ~~following restrictions are met:~~

~~(1) The *mean slip coefficient* μ 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, μ for ~~Class C~~ galvanized 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) and to 0.30 in the 2014 edition to be consistent with slip coefficients cited previously.

RCSC Proposed Change: S12-042

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Ballot Actions:
2012-13 Ballot Item # 3

Proposed Change:
{Proposal S11-033 which blended Appendix B back into the main Specification also had modified Section 5.4. This proposal will fully replace the language proposed by that proposal for this section.}

5.4. Design Slip Resistance

Slip-critical connections shall be designed to prevent slip and for the limit states of bearing-type connections. When slip-critical bolts pass through fillers, all *faying surfaces* subject to slip shall be prepared to achieve design slip resistance.

~~At US LRFD or Canadian LSD load levels t~~The design slip resistance is ϕR_n ~~and at ASD load levels the allowable slip resistance is R_n/Ω where R_n, ϕ and Ω are defined below.~~ where

~~The available slip resistance for the limit state of slip shall be determined as follows:~~

$$R_n = \mu D_u h_f T_b n_s k_{sc} \quad \text{Equation 5.6}$$

and $\phi = 1.00$ for standard size and short-slotted holes perpendicular to the direction of the load,
~~$\phi = 1.00$ (LRFD, LSD) $\Omega = 1.50$ (ASD)~~

$\phi = 0.85$ for oversized and short-slotted holes parallel to the direction of the load,
~~$\phi = 0.85$ (LRFD, LSD) $\Omega = 1.76$ (ASD)~~

$\phi = 0.70$ for long-slotted holes
~~$\phi = 0.70$ (LRFD, LSD) $\Omega = 2.14$ (ASD)~~

where
μ = mean slip coefficient for Class A or B surfaces, as applicable, and determined as follows, or as established by tests:

(1) For Class A surfaces (unpainted clean mill scale steel surfaces or surfaces with Class A coatings on blast-cleaned steel or hot-dipped galvanized and roughened surfaces)

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

Date Received: 5/30/12 Exec Com Meeting: 6/6/12 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: Schlafly
Date Sent to Main Committee: ______________ Final Disposition: ____________________

$\mu = 0.30$

(2) For Class B surfaces (unpainted blast-cleaned steel surfaces or surfaces with Class B coatings on blast-cleaned steel)

$\mu = 0.50$

D_u = 1.13; a multiplier that reflects the ratio of the mean installed bolt pretension to the specified minimum bolt pretension; the use of other values may be approved by the engineer of record.

T_b = minimum fastener tension given in Table 8.1, kips

h_f = factor for fillers, determined as follows:

(1) Where there are no fillers or bolts have been added to distribute loads in the filler

$h_f = 1.0$

(2) Where bolts have not been added to distribute the load in the filler:

(i) For one filler between connected parts

$h_f = 1.0$

(ii) For two or more fillers between connected parts

$h_f = 0.85$

n_s = number of slip planes required to permit the connection to slip

$$k_{sc} = 1 - \frac{T_u}{D_u T_b n_b} \quad \text{(LRFD, LSD)}$$

$$= 1 - \frac{1.5 T_a}{D_u T_b n_b} \quad \text{(ASD)}$$

where

T_a = required tension force using *ASD load combinations*, kips
T_u = required tension force using US *LRFD or Canadian LSD load combinations*, kips
n_b = number of bolts carrying the applied tension

In joints subjected to fatigue, the slip resistance at service load shall be $\phi R_n / 1.5$.

~~5.4.1. At the Factored Load Level: The design slip resistance is ϕR_n, where ϕ is as defined below and:~~

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

for specimens tightened using the calibrated wrench method.

~~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~~ 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.~~ statistical relationship between calculated slip resistance and historical measured test results. 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.~~

The nominal resistance in 5.4 results in a reliability consistent with the reliability of structural member design. The engineer should not need to design to a higher reliability in normal structural applications. ~~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

must

~~at the factored load level~~to prevent slip, 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]; must

(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~~ the governing cyclic design specification 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~~ 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~~D_u 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~~

not true by the ϕ factor. not D_u

~~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.~~ with a beta of at least 2.6 regardless of the method of pretensioning.

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. Twist-off type tension control bolt and direct tension indicator pretensions are similar to those of calibrated wrench. 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 ϕ. 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.

remove ¶ no longer true

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* μ that is less than 0.50 (Class B) and other than ~~0.33~~ 0.30 (Class A). This authorization requires that the *mean slip coefficient* μ must be determined in accordance with Appendix A. ~~following restrictions are met:~~

~~(1) The *mean slip coefficient* μ 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, μ for ~~Class C~~ galvanized 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) and to 0.30 in the 2014 edition to be consistent with slip coefficients cited previously.

RCSC Proposed Change: S12-043

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Ballot Actions:

2012-13 Ballot Item # 4

66 Affirmative

1 Negative (Frank)

1 Abstain

Proposed Change:

8.1. Snug-Tightened Joints

All bolt holes shall be aligned to permit insertion of the bolts without undue damage to the threads. Bolts shall be placed in all holes with washers positioned as required in Section 6.1 and nuts threaded to complete the assembly. Compacting the *joint* to the snug-tight condition shall progress systematically from the most rigid part of the *joint*. Snug tight is the condition that exists when all of the plies in a *connection* have been pulled into *firm contact* by the bolts in the *joint* and all of the bolts in the *joint* have been tightened sufficiently to prevent the removal of the nuts without the use of a wrench.

Commentary:

As discussed in the Commentary to Section 4, the bolted *joints* in most shear *connections* and in many tension *connections* can be specified as *snug-tightened joints*. The snug tightened condition is typically achieved with a few impacts of an impact wrench, application of an electric torque wrench until the wrench begins to slow or the full effort of a worker on an ordinary spud wrench. More than one cycle through the bolt pattern may be required to achieve the *snug-tightened joint*. The splines on twist-off type tension-control bolts may be twisted off or left in place in snug tightened joints.

The actual pretensions that result in individual fasteners in *snug-tightened joints* will vary from *joint* to *joint* depending upon the thickness, flatness, and degree of parallelism of the connected plies, as well as the effort applied. In most *joints*, plies of *joints* involving material of ordinary thickness and flatness can be drawn into complete contact at relatively low levels of pretension. However, in some *joints* in thick material or in material with large burrs, 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 generally not detrimental to the performance of the *joint*.

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

Date Received: 5/29/12 Exec Com Meeting: 6/6/12 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: ______________________

As used in Section 8.1, the term “undue damage” is intended to mean damage that would be sufficient to render the product unfit for its intended use.

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

The proposed revision is in response to occasional inspector requirements to remove the splines of TC bolts even where they are to be snug tight.

Ballot Actions and Information:

2012-13 Ballot Item # 4
66 Affirmative
1 Negative (Frank)
1 Abstain

Affirmative with Comments:

Abolhassan Astaneh:
I wonder why it says “The splines … may be twisted off..”. OIsn’t twisting off the splines costs money? Why not just say “may be left in place”? May be the intention of mentioning “may be twisted off’ is to ensure that in case the fabricators/erectors tighten the slip critical bolts by mistake and twist off the spline, the inspectors would not force them to take the bolts out and replace them with bolts not tightened beyond the snug-tight position? This can be a good justification, but, then the problem might be that in a snug tight connections some bolts can have spline twisted off and some kept in place (snug tight). Doesn’t this create some problem with the behavior and make those tightened bolts “unequal” to others in carrying the load, at least before they slip? May be it could say something to the effect that in a given snug tight bolted connection either ALL splines should be left in place or ALL should be twisted off. With this change, if some bolts are tightened and spline is twisted off, the others in the same connection can also be tightened to have uniform load distribution to all bolts.

Helen Chen:
See Attachment E.

Robert Hay:
This one of the most frequently asked questions regarding snug tight bolts.

Jonathan McGormley:
I agree with proposal; however, suggest that the word “twisted” be replaced with “removed” in the proposed text because “twisted” would require the bolt be fully pre-tensioned to break the spline. In some cases, engineers do not want anything more than snug-tight and pretensioning the bolt to break the spline will not achieve this result.

Floyd Vissat:
I support the language presented for Section 8.1, Commentary. It was suggested at the 2012 Specification Committee A.1 meeting that the same language be included in Section 9.1, Commentary; editorial in nature.

Negative with Comments:

Karl Frank:
If the splines are broken off the bolt is not snug tight but fully tensioned. I think the wording should be:” The splines on twist-off type tension-control bolts shall be left in place in snug tightened joints”.

RCSC Proposed Change: S12-043

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Ballot Actions:

2012-13 Ballot Item # 4

Proposed Change:

8.1. Snug-Tightened Joints

All bolt holes shall be aligned to permit insertion of the bolts without undue damage to the threads. Bolts shall be placed in all holes with washers positioned as required in Section 6.1 and nuts threaded to complete the assembly. Compacting the *joint* to the snug-tight condition shall progress systematically from the most rigid part of the *joint*. Snug tight is the condition that exists when all of the plies in a *connection* have been pulled into *firm contact* by the bolts in the *joint* and all of the bolts in the *joint* have been tightened sufficiently to prevent the removal of the nuts without the use of a wrench.

Commentary:

As discussed in the Commentary to Section 4, the bolted *joints* in most shear *connections* and in many tension *connections* can be specified as *snug-tightened joints*. The snug tightened condition is typically achieved with a few impacts of an impact wrench, application of an electric torque wrench until the wrench begins to slow or the full effort of a worker on an ordinary spud wrench. More than one cycle through the bolt pattern may be required to achieve the *snug-tightened joint*. The splines on twist-off type tension-control bolts may be twisted off or left in place in snug tightened joints.

The actual pretensions that result in individual fasteners in *snug-tightened joints* will vary from *joint* to *joint* depending upon the thickness, flatness, and degree of parallelism of the connected plies, as well as the effort applied. In most *joints*, plies of *joints* involving material of ordinary thickness and flatness can be drawn into complete contact at relatively low levels of pretension. However, in some *joints* in thick material or in material with large burrs, 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 generally not detrimental to the performance of the *joint*.

As used in Section 8.1, the term "undue damage" is intended to mean damage that would be sufficient to render the product unfit for its intended use.

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

Date Received: 5/29/12 Exec Com Meeting: 6/6/12 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: ________________________

Page: 14

Number: 1 Author: hchen Subject: Sticky Note Date: 1/23/2013 10:42:48 AM

The last sentence is in the definition of "snug-tightened joint" and may not be needed (not a spec language).

RCSC Proposed Change: S12-044

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Ballot Actions:

2012-13 Ballot Item # 5
- 57 Affirmative
- 2 Negative (Baxter, Dusicka)
- 9 Abstain

Proposed Change:

{Note: Proposed Change S11-033 also makes modifications to this section. The proposed changes are mutually exclusive and should not impact technical decisions on this item.}

5.1. Design Shear and Tensile Strengths

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

The design strength in shear or the design strength in tension for an ASTM A325, A490, F1852 or F2280 bolt is ϕR_n, where $\phi = 0.75$ and:

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

where

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

Table 5.1. Nominal Strengths per Unit Area of Bolts

Applied Load Condition			*Nominal Strength* per Unit Area, F_n, ksi	
			ASTM A325 or F1852	ASTM A490 or F2280
Tension [a]	Static		90	113
	Fatigue		See Section 5.5	
Shear [a,b]	Threads included in shear plane	$L_s \le 38$ in.	54	68
		$L_s > 38$ in.	45	56
	Threads excluded from shear plane	$L_s \le 38$ in.	68	84
		$L_s > 38$ in.	56	70

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

Date Received: 5/31/12 Exec Com Meeting: 6/6/12 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: ______________________

[a] Except as required in Section 5.2.
[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.

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)] but not less than 0.85, 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* using Class A surfaces with Turn-of-Nut pretensioning or Class B surfaces. ~~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 ϕ.

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* 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 f .

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.

Tests of 24 bolt A490 1 1/8 diameter connections indicated the reduction in bolt shear strength in connections with filler as required in section 5.1 (1) is limited to 85%. (Borello, Denavit, Hajjar Behavior of Bolted Steel Slip Critical Connections with Fillers UIUC August 2009) . Review of available data on slip critical connections revealed that connections with Class A surfaces pretensioned by Turn-of-Nut and connections with Class B surfaces provide a sufficient reliability against slip to eliminate the need to fasten the fills outside the connection or reduce the bolt shear capacity. Grondin, Ming, Josi Slip Critical Bolted Connections - A Reliability Analysis for Design at the Ultimate Limit State. University of Alberta, April 2008.

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

The provisions governing fillers in Section 5.1 have limits and may be incorrect. Example issues include: The equation in (1) stops at ¾ in. Fillers can be thicker. There is a question about whether (4) can be considered valid if slip critical joints need to be checked for bearing. Dr Hajjar conducted a study of the effect of fillers on SC joints. Dr Grondin performed a statistical review of slip critical connections. The proposal is an outcome of those studies. The equations as proposed match the equivalent equations in the AISC Specification.

Ballot Actions and Information:

2012-13 Ballot Item # 5

57 Affirmative

2 Negative (Baxter, Dusicka)

9 Abstain

Affirmative with Comments:

Peter Birkemoe:

Looks like TON required for Class A

Helen Chen:

See Attachment F.

Robert Connor:

Seems to be some typos where dimensions are made regarding ¼" When a bolt that carries load passes through fillers or shims that are greater than 4 in. thick, "they" shall be designed in accordance with one of the following procedures: May be good to clarify what "they" refers to. Fills, fasteners, both.

Karl Frank:
At some point we should consider the equation used in AASHTO which accounts for the 0.85 reduction in an explicit manner.

James Ricles:
Equal to or less than /4 in. thick. Is it supposed to read “one-quarter”? Seems the pdf may have mucked up fraction, or there is a typo (this appears twice in the paragraph in question).

Bob Shaw:
Editorial only – Suggest that (4) be split and become “(4) The joint shall be designed as a slip-critical joint using Class A surfaces and bolts installed using the turn-of-nut pretensioning method.” and “(5) The joint shall be designed as a slip-critical joint using class B faying surfaces.”

Lee Shoemaker:
Commentary is worded oddly to start – were the tests with 24 bolts in the connection or were there 24 tests?

Ray Tide:
I agree with the principle of the changes, but I suggest that the commentary section that I have marked up needs a little clean up concerning "brackets and quotation marks". See Attachment G.

Negative with Comments:

Rodney Baxter:
Section 5.1 (4) should include Alt. Design fasteners (F1852/.F2280) for SC-A Joints.

Peter Dusicka:
Reduction limit of 0.85 may not always be applicable. While appropriate for single side filler of a single splice connection such as those tested with 24 bolts A490 1 1/8” diameter (Borello, Denavit & Hajjar), single side filler on a double-splice connections have since been shown to result in larger strength reductions, especially for oversized holes. These tests conducted as part of Dusicka’s RCSC research were not available at time of Borello et al report. It may be that single side with double-splice connection with large filler thickness is not common/practical in which case this negative vote can be overturned, but I did want to point this out in case this aspect should be considered.

Abstain with Comments:

Larry Kloiber:
The provision in 5.1(4) indicates its propose is to increase reliability of fillers in slip critical joints. It is not clear but it appears to be to be an addition to the Filler Factor provisions to develop multiple fillers and use a factor of 1.0. If this is the intent the provision should be moved to the filler factor section or at least the proper filler factor should be clearly shown for multiple fills.

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 Section 5.5.

Tests of 24 bolt A490 1 1/8 diameter connections indicated the reduction in bolt shear strength in connections with filler as required in section 5.1 (1) is limited to 85%. (Borello, Denavit, Hajjar Behavior of Bolted Steel Slip Critical Connections with Fillers UIUC August 2009) . Review of available data on slip critical connections revealed that connections with Class A surfaces pretensioned by Turn-of-Nut and connections with Class B surfaces provide a sufficient reliability against slip to eliminate the need to fasten the fills outside the connection or reduce the bolt shear capacity. Grondin, Ming, Josi Slip Critical Bolted Connections - A Reliability Analysis for Design at the Ultimate Limit State. University of Alberta, April 2008.

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

The provisions governing fillers in Section 5.1 have limits and may be incorrect. Example issues include: The equation in (1) stops at ¾ in. Fillers can be thicker. There is a question about whether (4) can be considered valid if slip critical joints need to be checked for bearing. Dr Hajjar conducted a study of the effect of fillers on SC joints. Dr Grondin performed a statistical review of slip critical connections. The proposal is an outcome of those studies. The equations as proposed match the equivalent equations in the AISC Specification.

Page: 19

Number: 1 Author: hchen Subject: Sticky Note Date: 1/23/2013 10:13:48 AM

add a dash: "1-1/8"

Number: 2 Author: hchen Subject: Sticky Note Date: 1/23/2013 10:18:39 AM

Should a pair of parentheses be added to the last sentence to be consistent with the other reference in the para.?

S12-044

"SCHLAFLY"

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.

Tests of 24 bolt A490 1 1/8 diameter connections indicated the reduction in bolt shear strength in connections with filler as required in section 5.1 (1) is limited to 85%. (Borello, Denavit, Hajjar "Behavior of Bolted Steel Slip Critical Connections with Fillers", UIUC August 2009) . Review of available data on slip critical connections revealed that connections with Class A surfaces pretensioned by Turn-of-Nut and connections with Class B surfaces provide a sufficient reliability against slip to eliminate the need to fasten the fills outside the connection or reduce the bolt shear capacity. Grondin, Ming, Josi, "Slip Critical Bolted Connections - A Reliability Analysis for Design at the Ultimate Limit State". University of Alberta, April 2008.

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

The provisions governing fillers in Section 5.1 have limits and may be incorrect. Example issues include: The equation in (1) stops at ¾ in. Fillers can be thicker. There is a question about whether (4) can be considered valid if slip critical joints need to be checked for bearing. Dr Hajjar conducted a study of the effect of fillers on SC joints. Dr Grondin performed a statistical review of slip critical connections. The proposal is an outcome of those studies. The equations as proposed match the equivalent equations in the AISC Specification.

RCSC Proposed Change: S12-045

Name: Chris Curven **E-mail:** **chrisc@appliedbolting.com**
Phone: 802-460-3100 **Fax:**

Ballot Actions:

2012-13 Ballot Item # 6

52 Affirmative

10 Negative (Ferrell, Hay, Helwig, Lohr, Mayes, McGormley, G. Mitchell, H. Mitchell, Tide, Ude)

6 Abstain

Proposed Changes:

8.2.3. Twist-Off-Type Tension-Control Bolt Pretensioning: Twist-off-type tension-control bolt assemblies that meet the requirements of ASTM F1852 or F2280 shall be used.

All *fastener assemblies* shall be installed in accordance with the requirements in Section 8.1 without severing the splined end and with washers positioned as required in Section 6.2. If a splined end is severed during this operation, the *fastener assembly* shall be removed and replaced. Subsequently, all bolts in the *joint* shall be ~~pretensioned~~ tightened with the twist-off-type tension-control bolt installation wrench until the splined-end shears off, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts.

Commentary:

ASTM F1852 and F2280 twist-off-type tension-control bolt assemblies have a splined end that extends beyond the threaded portion of the bolt. During installation, this splined end is gripped by a specially designed wrench chuck and provides a means for turning the nut relative to the bolt. This product is, in fact, based upon a torque-controlled installation method to which the *fastener assembly* variables affecting torque that were discussed in the Commentary to Section 8.2.2 apply, except for wrench calibration, because torque is controlled within the *fastener assembly*.

Twist-off-type tension-control bolt assemblies must be used in the as-delivered, clean, lubricated condition as specified in Section 2. Adherence to the requirements in this Specification, especially those for storage, cleanliness and verification, is necessary for their proper use.

9.2.1. Turn-of-Nut Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section 8.2.1. Subsequently, but prior to pretensioning and optional match-marking, it shall be ensured by *routine*

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

Date Received: 5/31/12 Exec Com Meeting: 6/6/12 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: ______________________

observation that the plies have been brought into *firm contact.* 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.

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.

9.2.2. Calibrated Wrench Pretensioning: The *inspector* shall observe the daily pre-installation verification testing required in Section 8.2.2. Subsequently, but prior to pretensioning, it shall be ensured by *routine observation* that the plies have been brought into *firm contact.* Subsequently, it shall be ensured by *routine observation* that the bolting crew properly applies the calibrated wrench to the turned element. 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.

Commentary:
For proper inspection of the method, it is necessary 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 within the limits on time between removal from *protected storage* and final pretensioning.

9.2.3. Twist-Off-Type Tension-Control Bolt Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section 8.2.3. Subsequently, but prior to pretensioning, it shall be ensured by *routine observation* that the plies have been brought into *firm contact* without the splined ends being severed. If the splined end is severed, the bolt must be removed and replaced. Subsequently, it shall be ensured by *routine observation* that the splined ends are properly severed during installation by the bolting crew. 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.

Commentary:
The sheared-off splined end of an installed twist-off-type tension-control bolt assembly merely signifies that at some time the bolt was subjected to a torque that was adequate to cause the shearing. If in fact all fasteners are individually pretensioned in a single continuous operation without first properly snug-tightening all fasteners, they may give a misleading indication that the bolts have been properly pretensioned. Therefore, it is necessary that the *inspector* observe the required pre-installation verification testing of the *fastener assemblies*, and the ability to apply partial tension prior to twist-off is demonstrated. This is followed by monitoring of the work in progress to ensure that the method is routinely and properly applied within the limits on time between removal from *protected storage* and final twist-off of the splined end.

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

8.2.3 does not actually state when the installer is to stop tightening or when the bolt is deemed tight. It states what type of installation tool to be used, but not what the installer is looking for.
For example, 8.2.1. states to rotate the head or nut as specified in table 8.2., 8.2.2. states to apply the installation torque determined by the pre-installation verification, and 8.2.4. has the installer making sure the achieved gap is less than the job inspection gap.

Also, Section 9.2.4. is the only installation method that has the inspector verify that snugging of the bolts and plies have taken place before the chosen pretensioning method takes place. 9.2.1., 9.2.2.,and 9.2.3. would obviously like to have inspection of the snug condition, but it is not listed.

For example, 9.2.4. …All bolts shall be installed in accordance with the requirements in Section 8.1, with washers positioned as required in Section 6.2. The installer shall verify that the direct-tension-indicator protrusions have not been compressed to a gap that is less than the job inspection gap during this operation, and if this has occurred, the direct tension indicator shall be removed and replaced….

Ballot Actions and Information:

2012-13 Ballot Item # 6

52 Affirmative

10 Negative (Ferrell, Hay, Helwig, Lohr, Mayes, McGormley, G. Mitchell, H. Mitchell, Tide, Ude)

6 Abstain

Affirmative with Comments:

Peter Birkemoe:
Re: 9.2.3 The second “subsequently” if changed to “afterward” would improve the distinction of the two requirements. The note of indication of ”impacting” in the Commentary to 8.2, Par 1 should be amended unless “only impact wrenches” can be employed to perform the prescribed turns; if that remains, electric geared reaction wrenches and the hydraulic wrenches that are used on larger fastener assemblies are implicitly disallowed.

Helen Chen:
See Attachment H.

Chris Curven:
“snug tightened” needs to be hyphenated.

Bob Shaw:
Editorial only – suggest 8.2.3 9th line use “twists off” instead of “shears off”

Joe Yura:
Editorial suggestions – remove the word “subsequently in all the sections. There is one “subsequently” followed by another “subsequently”. The word is just not necessary.

Negative with Comments:

Doug Ferrell:
Commentary of 8.2 adequately explains the requirements of snug-tight and all plies in firm contact before pretensioning. Perhaps this paragraph of commentary should be moved to within the main text of 8.2. This is a necessary requirement of all installation methods, except perhaps DTI.

Robert Hay:
The proposed additional language regarding the inspection of the snug tight condition would be redundant since 9.1 clearly requires the inspection prior to pretensioning. The modification to 8.2.3 is subtle and I have no objection to that.

Todd Helwig:
While you can tell around the edge that the plies have been brought into contact, how do you tell in the middle of the plate that the plies have been brought into contact? I'm don't think this is something that can be reliably checked.

Ken Lohr:
I feel we need to look at the wording proposed and that if changes are needed that they be applied to all methods of installation.

Curtis Mayes:
This ballot item does not change the spec which is already clear. All Pretensioning methods already require snug tightening section 9.1. This proposal adds redundancy to the spec. We need less redundancy. I might vote for only modifying section 9.2.3 with, “If the splined end is severed, the bolt must be removed and replaced.”

Jonathan McGormley:
Section 9.1 already requires that the inspector verify that the plies are in firm contact. Section 9.2 which includes all of the tightening methods requires conformance with Section 9.1; therefore, adding repeated language to the tightening methods is verbose. With respect to the langue in Section 9.2.4, it is needed in order to form the basis (start point) for determining whether the pretension method has worked.

Eugene Mitchell:
Instead of adding the statement to all the other installation methods, delete from the DTI specification.

Heath Mitchell:
Voted negative with no comment.

Ray Tide:
Although a slightly different topic, if the above changes are forthcoming then these changes recommended by Chris would require additional changes. One editorial item is raised by Chris in the second paragraph of Section 8.2.3, fifth line where he has changed “pretensioned” to “tightened”. However, throughout the total RCSC Spec we use “pretensioned”. I do NOT agree with this proposed change.

Todd Ude:
As I read 9.2 and 9.3, they both flow back to require the 9.1 inspection and verification of the snug tight condition (plies in firm contact) prior to final tensioning, regardless of method? This makes additions to 9.2.1 and 9.2.2 unnecessary? I take no exception and would vote affirmative to the changes proposed for 8.2.3 and 9.2.3.

Abstain with Comments:

Matthew Eatherton:
I’m abstaining on this ballot item because I’m not confident about whether the change is appropriate or not. I’m unsure if specifying daily inspections in 9.2.2. is necessary or too onerous. Also, it’s unclear to me why the snug tight condition would need to be inspected for the calibrated wrench method or the twist-off bolt method.

Commentary:
For proper inspection of the method, it is necessary 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 within the limits on time between removal from *protected storage* and final pretensioning.

9.2.3. Twist-Off-Type Tension-Control Bolt Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section 8.2.3. Subsequently, but prior to pretensioning, it shall be ensured by *routine observation* that the plies have been brought into *firm contact* without the splined ends being severed. If the splined end is severed, the bolt must be removed and replaced. Subsequently, it shall be ensured by *routine observation* that the splined ends are properly severed during installation by the bolting crew. 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.

Commentary:
The sheared-off splined end of an installed twist-off-type tension-control bolt assembly merely signifies that at some time the bolt was subjected to a torque that was adequate to cause the shearing. If in fact all fasteners are individually pretensioned in a single continuous operation without first properly snug-tightening all fasteners, they may give a misleading indication that the bolts have been properly pretensioned. Therefore, it is necessary that the *inspector* observe the required pre-installation verification testing of the *fastener assemblies*, and the ability to apply partial tension prior to twist-off is demonstrated. This is followed by monitoring of the work in progress to ensure that the method is routinely and properly applied within the limits on time between removal from *protected storage* and final twist-off of the splined end.

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

8.2.3 does not actually state when the installer is to stop tightening or when the bolt is deemed tight. It states what type of installation tool to be used, but not what the installer is looking for.
For example, 8.2.1. states to rotate the head or nut as specified in table 8.2., 8.2.2. states to apply the installation torque determined by the pre-installation verification, and 8.2.4. has the installer making sure the achieved gap is less than the job inspection gap.

Also, Section 9.2.4. is the only installation method that has the inspector verify that snugging of the bolts and plies have taken place before the chosen pretensioning method takes place. 9.2.1., 9.2.2.,and 9.2.3. would obviously like to have inspection of the snug condition, but it is not listed.
For example, 9.2.4. …All bolts shall be installed in accordance with the requirements in Section 8.1, with washers positioned as required in Section 6.2. The installer shall verify that the direct-tension-indicator protrusions have not been compressed to a gap that is less

Page: 22

Number: 1 Author: hchen Subject: Sticky Note Date: 1/23/2013 10:21:32 AM

change "must" to "shall"

RCSC Proposed Change: S12-047

Name: Lawrence F. Kruth
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Phone: 517-999-4113
Fax: 517-322-0050

Ballot Actions:

2012-13 Ballot Item # 7

63 Affirmative

3 Negative (Curven, Frank, Helwig)

2 Abstain

Proposed Change:
{This proposal is in response to persuasive negatives on Proposal S11-035. The proposed language modifies the current 2009 Specification language without regard to the previous proposal S11-035 which has been terminated.}

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 *joint* type (Section 4);

(3) The required class of slip resistance if *slip-critical joints* are specified (Section 4); and,

(4) 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);

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

Date Received: 6/8/12 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: Kurth

Date Sent to Main Committee: _______________Final Disposition: ______________________

(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 D_u 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 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 z in. in depth are permitted.

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*.

Commentary:
The footnotes in Table 3.1 provide for slight variations in the dimensions of bolt holes from the nominal dimensions. When the dimensions of bolt holes are such that they exceed these permitted variations, the bolt hole must be treated as the next larger type.

Slots longer than standard long slots may be required to accommodate construction tolerances or expansion *joints*. Larger oversized holes may be necessary to accommodate construction tolerances or misalignments. In the latter two cases, the Specification provides no guidance for further reduction of *design strengths* or allowable loads. Engineering design considerations should include, as a minimum, the effects of edge distance, net section, reduction in clamping force in *slip-critical joints*, washer requirements, bearing capacity, and hole deformation.

For thermally cut holes produced free hand, it is usually necessary to grind the hole surface after thermal cutting in order to achieve a maximum surface roughness profile of 1,000 microinches.

Slotted holes in statically loaded *joints* are often produced by punching or drilling the hole ends and thermally cutting the sides of the slots by mechanically guided means. The sides of such slots should be ground smooth, particularly at the junctures of the thermal cuts to the hole ends.

For cyclically loaded *joints*, test results have indicated that when no major slip occurs in the *joint*, fretting fatigue failure usually occurs in the gross section prior to fatigue failure in the net section (Kulak et al., 1987, pp. 116, 117). Conversely, when slip occurs in the *joints* of cyclically loaded *connections*, failure usually occurs in the net section and the edge of a bolt hole becomes the point of crack initiation (Kulak et al., 1987, pp. 118). Therefore, for cyclically loaded *joints* designed as slip critical, the method used to produce bolt holes (either thermal cutting or drilling) should not influence the ultimate failure load, as failure usually occurs in the gross section when no major slip occurs.

3.3.1. Standard Holes: ~~In the absence of approval by the *Engineer of Record* for the use of other hole types, standard~~ Standard holes ~~shall~~ are permitted to be used in all plies of *snug-tightened joints* as defined in Section 4.1, *pretensioned* joints as defined in Section 4.2 and slip critical joints as defined in Section 4.3. ~~bolted *joints*.~~

Table 3.1. Nominal Bolt Hole Dimensions

Nominal Bolt Diameter, d_b, in.	Nominal Bolt Hole Dimensions [a,b], in.			
	Standard (diameter)	Oversized (diameter)	Short-slotted (width × length)	Long-slotted (width × length)
½	9/16	5/8	9/16 × 11/16	9/16 × 1 1/4
5/8	11/16	13/16	11/16 × 7/8	11/16 × 1 9/16
¾	13/16	15/16	13/16 × 1	13/16 × 1 7/8
7/8	15/16	1 1/16	15/16 × 1 1/8	15/16 × 2 3/16
1	1 1/16	1 ¼	1 1/16 × 1 5/16	1 1/16 × 2 ½
≥1 1/16	d_b + 1/16	d_b + 5/16	(d_b + 1/16) × (d_b + 3/8)	(d_b + 1/16) × (2.5d_b)

[a] The upper tolerance on the tabulated nominal dimensions shall not exceed 1/32 in. Exception: In the width of slotted holes, gouges not more than 1/16 in. deep are permitted.

[b] The slightly conical hole that naturally results from punching operations with properly matched punches and dies is acceptable.

Commentary:

The use of bolt holes 1/16 in. larger than the bolt installed in them has been permitted since the first publication of this Specification. Allen and Fisher (1968) showed that larger holes could be permitted for *high-strength bolts* without adversely affecting the bolt shear or member bearing strength. However, the slip resistance can be reduced by the failure to achieve adequate pretension initially or by the relaxation of the bolt pretension as the highly compressed material yields at the edge of the hole or slot. The provisions for oversized and slotted holes in this Specification are based upon these findings and the additional concern for the consequences of a slip of significant magnitude if it should occur in the direction of the slot. Because an increase in hole size generally reduces the net area of a connected part, the use of oversized holes or of slotted holes is subject to approval by the *Engineer of Record*.

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

Commentary:
See the Commentary to Section 3.3.1.

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 and slip critical joints as defined in Section 4.3, 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*, 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 of the applied load.

Commentary:
See the Commentary to Section 3.3.1.

3.3.4. Long-Slotted Holes: When approved by the *Engineer of Record*, 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*, long-slotted holes are permitted in one ply only at any individual *faying surface* of *slip-critical joints* 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:
See the Commentary to Section 3.3.1.

Finger shims are devices that are often used to permit the alignment and plumbing of structures. When these devices are fully and properly inserted, they do not have the same effect on bolt pretension relaxation or the *connection* performance, as do long-slotted holes in an outer ply. When fully inserted, the shim provides support around approximately 75 percent of the perimeter of the bolt in contrast to the greatly reduced area that exists with a bolt that is centered in a long slot. Furthermore, finger shims are always enclosed on both sides by the connected material, which should be effective in bridging the space between the fingers.

Rationale or Justification for Change (attach additional pages as needed):
This ballot language is the result of a task group consensus formed following the 2012 RCSC Specification Committee meeting.

The requirements for the responsibility in specifying hole types in the RCSC Specification are in conflict with the AISC and CSC Specification. By making this change, the RCSC Specification is more in compliance with the AISC and CSC Specification.

The need to use perpendicular short slots is a constructability issue as opposed to a design issue. Due to the varying web thicknesses of beams, the outstanding legs of clip angle connections are required to have short slots in them to meet the fabricator's need to standardize connection clip angles. Short slots are also required by erectors to account for variations in plumbness in the structure due to mis-located anchor rods, sweep in columns and other erection tolerances. These issues are rarely understood or accounted for by the engineer of record.

The statement, "In the absence of the approval of the Engineer of Record for the use of other hole types, standard holes shall be used…" has caused engineers to believe that there is something wrong with the use of any other type of hole rather than a standard hole. In order to be conservative, engineers have required that standard holes be used no matter what the fabricator's or erector's reasons might be.

Ballot Actions and Information:

2012-13 Ballot Item # 7

63 Affirmative

3 Negative (Curven, Frank, Helwig)

2 Abstain

Affirmative with Comments:

Abolhassan Astaneh:
This is an excellent change.

Peter Birkemoe:
It would be an easier read if presented as a list of three items "Standard holes are permitted to be used in all plies of: 1 Snug-tightened joints as defined in Section 4.1; 2 Pre-tensioned joints….." note that these Ballot Comments are restricted to text input and if the italics shown used in the recommended changes are adopted they should be used in a parallel manner in the series whether a list is used or not.

Allen Harrold:
Table 3.1 has a variety of bogus entries due to format conversions, however there were no proposed changes to the table in actuality. Editorial corrections will be made to insure that the table reads correctly in the final version.

Joe Yura:
Although it is not part of this ballot, item 1.4 (4) needs to be removed because of the changes recommended in Ballot #3

Negative with Comments:

Chris Curven:

Current wording is concise in its requirements. It allows short-slotted allows but keeps the EOR in the decision making process. Proposed changes makes it easy for fabricators to misinterpret the specification. For 3.3.1, new wording, in particular "permitted" implies that hole type is an option without contacting EOR. For 3.3.3, the first sentence makes short-slotted hole permissible without contacting EOR. Current wording clearly states that the EOR must approve hole type, not limiting them. The RCSC need not follow AISC's lead. They are two different groups. AISC can choose not to adopt the RCSC specification.

Karl Frank:

I firmly believe that short slotted holes should not be used unless the EOR approves their use. I would think the commentary could be expanded to point out in simple shear connections of gravity loaded beams, short slotted holes in conjunction with snug tight bolts can provide the shear capacity and allow the beam to rotate which matches the design assumptions.

Todd Helwig:

I don't have a problem with getting rid of the first sentence of Section 3.3.1; however I don't agree with the changes to the change on the paragraph in section 3.3.3. While the use of slotted holes can make erection easier, I think the EOR needs to be consulted in many applications where the use of the slot can affect the behavior of the structural member. The end connections are very important to the stability of the member and the use of slotted holes can result in relatively large twists/lateral movements that can affect the behavior of the member. There are cases where member stability could be affected if a short slotted hole is used with a snug tight bolt.

5/10/13 Proposal with changes to satisfy the Frank and Helwig negatives:

{Modifications are shown as either double strikeout or double underscore to distinguish the proposed changes from the balloted changes. Changes exist in the Commentary to Sections 3.3.1, 3.3.2, and 3.3.3}

1.4. Drawing Information

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

(5) The ASTM designation and type (Section 2) of bolt to be used;

(6) The *joint* type (Section 4);

(7) The required class of slip resistance if *slip-critical joints* are specified (Section 4); and,

(8) 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:

(9) For the reuse of non-galvanized ASTM A325 bolts (Section 2.3.3);

(10) 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);

(11) For the use of alternative-design fasteners, including the corresponding installation and inspection requirements that are provided by the *manufacturer* (Section 2.8);

(12) 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));

(13) For the use of thermal cutting in the production of bolt holes (Section 3.3);

(14) 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;

(15) For the use of a value of D_u other than 1.13 (Section 5.4.1); and,

(16) For the use of a value of D other than 0.80 (Section 5.4.2).

3.3. Bolt Holes

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 z in. in depth are permitted.

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*.

Commentary:

The footnotes in Table 3.1 provide for slight variations in the dimensions of bolt holes from the nominal dimensions. When the dimensions of bolt holes are such that they exceed these permitted variations, the bolt hole must be treated as the next larger type.

Slots longer than standard long slots may be required to accommodate construction tolerances or expansion *joints*. Larger oversized holes may be necessary to accommodate construction tolerances or misalignments. In the latter two cases, the Specification provides no guidance for further reduction of *design strengths* or allowable loads. Engineering design considerations should include, as a minimum, the effects of edge distance, net section, reduction in clamping force in *slip-critical joints*, washer requirements, bearing capacity, and hole deformation.

For thermally cut holes produced free hand, it is usually necessary to grind the hole surface after thermal cutting in order to achieve a maximum surface roughness profile of 1,000 microinches.

Slotted holes in statically loaded *joints* are often produced by punching or drilling the hole ends and thermally cutting the sides of the slots by mechanically guided means. The sides of such slots should be ground smooth, particularly at the junctures of the thermal cuts to the hole ends.

For cyclically loaded *joints*, test results have indicated that when no major slip occurs in the *joint*, fretting fatigue failure usually occurs in the gross section prior to fatigue failure in the net section (Kulak et al., 1987, pp. 116, 117). Conversely, when slip occurs in the *joints* of cyclically loaded *connections*, failure usually occurs in the net section and the edge of a bolt hole becomes the point of crack initiation (Kulak et al., 1987, pp. 118). Therefore, for cyclically loaded *joints* designed as slip critical, the method used to produce bolt holes (either thermal cutting or drilling) should not influence the ultimate failure load, as failure usually occurs in the gross section when no major slip occurs.

3.3.1. Standard Holes: ~~In the absence of approval by the *Engineer of Record* for the use of other hole types, standard~~ Standard holes ~~shall~~ are permitted to be used in all plies of *snug-tightened joints* as defined in Section 4.1, *pretensioned* joints as defined in Section 4.2 and slip critical joints as defined in Section 4.3. ~~bolted *joints*.~~

Table 3.1. Nominal Bolt Hole Dimensions

Nominal Bolt Diameter, d_b, in.	Nominal Bolt Hole Dimensions [a,b], in.			
	Standard (diameter)	Oversized (diameter)	Short-slotted (width × length)	Long-slotted (width × length)
½	9/16	5/8	9/16 × 11/16	9/16 × 1 1/4
5/8	11/16	13/16	11/16 × 7/8	11/16 × 1 9/16
¾	13/16	15/16	13/16 × 1	13/16 × 1 7/8
7/8	15/16	1 1/16	15/16 × 1 1/8	15/16 × 2 3/16
1	1 1/16	1 ¼	1 1/16 × 1 5/16	1 1/16 × 2 ½
≥1 1/16	d_b + 1/16	d_b + 5/16	(d_b + 1/16) × (d_b + 3/8)	(d_b + 1/16) × (2.5d_b)

[a] The upper tolerance on the tabulated nominal dimensions shall not exceed 1/32 in. Exception: In the width of slotted holes, gouges not more than 1/16 in. deep are permitted.

[b] The slightly conical hole that naturally results from punching operations with properly matched punches and dies is acceptable.

Commentary:

The use of bolt holes 1/16 in. larger than the bolt installed in them has been permitted since the first publication of this Specification. Allen and Fisher (1968) showed that larger holes could be permitted for *high-strength bolts* without adversely affecting the bolt shear or member bearing strength. However, the slip resistance can be reduced by the failure to achieve adequate pretension initially or by the relaxation of the bolt pretension as the highly compressed material yields at the edge of the hole or slot. ~~The provisions for oversized and slotted holes in this Specification are based upon these findings and the additional concern for the consequences of a slip of significant magnitude if it should occur in the direction of the slot. Because an increase in hole size generally reduces the net area of a connected part, the use of oversized holes or of slotted holes is subject to approval by the *Engineer of Record*.~~

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

Commentary:
See the Commentary to Section 3.3.1. The provisions for oversized holes in this Specification are based upon these findings and the additional concern for the consequences of a slip of significant magnitude if it should occur in the oversized hole. Because an increase in hole size generally reduces the net area of a connected part, the use of oversized holes is subject to approval by the *Engineer of Record*.

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 and slip critical joints as defined in Section 4.3, 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*, 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 of the applied load.

Commentary:
See the Commentary to Section 3.3.1. The use of short-slotted holes approximately perpendicular to the applied load in conjunction with snug tight bolts can provide the shear capacity and may allow the beam to rotate which matches the design assumptions. End connections are very important to the stability of the member. The use of short-slotted holes may result in twists and or lateral movement that may affect the behavior of the member. In cases where the use of short-slotted holes affects the behavior of the structural member, the *Engineer of Record* should be consulted.

The provisions for short-slotted holes in a direction that is other than perpendicular to the applied loading are based upon these findings and the additional concern for the consequences of a slip of significant magnitude if it should occur in the short-slotted hole. Because an increase in hole size generally reduces the net area of a connected part, the use of slotted holes other than perpendicular to the applied loading is subject to approval by the *Engineer of Record.*

3.3.4. Long-Slotted Holes: When approved by the *Engineer of Record*, 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*, long-slotted holes are permitted in one ply only at any individual *faying surface* of *slip-critical joints* 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:
See the Commentary to Section 3.3.1.

Finger shims are devices that are often used to permit the alignment and plumbing of structures. When these devices are fully and properly inserted, they do not have the same effect on bolt pretension relaxation or the *connection* performance, as do long-slotted holes in an outer ply. When fully inserted, the shim provides support around approximately 75 percent of the perimeter of the bolt in contrast to the greatly reduced area that exists with a bolt that is centered in a long slot. Furthermore, finger shims are always enclosed on both sides by the connected material, which should be effective in bridging the space between the fingers.

RCSC Proposed Change: S12-048

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

Ballot Actions:
Approved Editorially by Exec Committee on 2/25/13

Proposed Change:

Section 1.5

1.5 Referenced Standards and Specifications
The following standards and specifications are referenced herein:

American Institute of Steel Construction
Specification for Structural Steel Buildings, June 22, 2010

American National Standards Institute
ANSI/ASME B18.2.6-06 *Fasteners for Use in Structural Applications*

~~**American Society for Testing and Materials**~~ **ASTM International**
ASTM A123-09 *Standard Specification for Zinc* (*Hot-Dip Galvanized*) *Coatings on Iron and Steel Products*
{Remainder of section is unchanged.}

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

ASTM now goes by the name ASTM International without actually spelling out what the letters ASTM formerly meant. This is in line with their efforts to expand recognition of these standards worldwide and diminish the old label of "American Society … ".

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

Date Received: _Nov 2012 Exec Com Meeting: 2/25/13 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: Approved - Editorial

RCSC Proposed Change: S13-049

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Fax: 215-750-6300

Proposed Change:

6.2.4. Direct-Tension-Indicator Pretensioning: When the direct-tension-indicator pretensioning method is used, an ASTM F436 washer shall be used as follows:

(1) When the nut is turned and the direct tension indicator is located under the bolt head, an ASTM F436 washer shall be used under the nut;
(2) When the nut is turned and the direct tension indicator is located under the nut, an ASTM F436 washer shall be used between the nut and the direct tension indicator except when using direct tension indicator designs with curved protrusions, then the ASTM F436 washer can be eliminated;
(3) When the bolt head is turned and the direct tension indicator is located under the nut, an ASTM F436 washer shall be used under the bolt head, except when using direct tension indicator designs with curved protrusions, then the ASTM F436 washer can be eliminated; and,
(4) When the bolt head is turned and the direct tension indicator is located under the bolt head, an ASTM F436 washer shall be used between the bolt head and the direct tension indicator.

{Table 6.1 is not included here. There are no changes to the table.}

{Note the commentary is for the entire Section 6, not just section 6.2.4.}

Commentary:
It is important that shop drawings and *connection* details clearly reflect the number and disposition of washers when they are required, especially the thick hardened washers or plate washers that are required for some slotted hole applications. The total thickness of washers in the *grip* affects the length of bolt that must be supplied and used.

The primary function of washers is to provide a hardened non-galling surface under the turned element, particularly for torque-based pretensioning methods such as the calibrated wrench pretensioning method and twist-off-type tension-control bolt pretensioning method. Circular flat washers that meet the requirements of ASTM F436 provide both a hardened non-galling surface and an increase in bearing area that is approximately 50 percent larger than that provided by a heavy-hex bolt head or nut. However, tests have shown that washers of the standard E in. thickness have a minor influence on the pressure distribution of the induced bolt pretension. Furthermore, they showed that a larger thickness is required when ASTM A490 bolts are used with material that has a minimum specified yield strength that is less than 40 ksi. This is necessary to

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

Date Received: 02/12/13 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: ______________________

mitigate the effects of local yielding of the material in the vicinity of the contact area of the head and nut. The requirement for standard thickness hardened washers, when such washers are specified, is waived for alternative design fasteners that incorporate a bearing surface under the head of the same diameter as the hardened washer. The elimination of the hardened washer when using Direct Tension Indicators under the turned element must be approved during the Pre-Verification Installation Tests.

Heat-treated washers not less than 5/16 in. thick are required to cover oversized and short-slotted holes in external plies, when ASTM A490 or F2280 bolts of diameter larger than 1 in. are used, except as permitted by Table 6.1 footnotes a and d. This was found necessary to distribute the high clamping pressure so as to prevent collapse of the hole perimeter and enable the development of the desired clamping force. Preliminary investigation has shown that a similar but less severe deformation occurs when oversized or slotted holes are in the interior plies. The reduction in clamping force may be offset by "keying," which tends to increase the resistance to slip. These effects are accentuated in *joints* of thin plies. When long-slotted holes occur in an outer ply, ⅜ in. thick plate washers or continuous bars and one ASTM F436 washer are required in Table 6.1. This requirement can be satisfied with material of any structural grade. Alternatively, either of the following options can be used:

(1) The use of material with F_y greater than 40 ksi will eliminate the need to also provide ASTM F436 washers in accordance with the requirements in Section 6.2.1 for ASTM A490 or F2280 bolts of any diameter; or,
(2) Material with F_y equal to or less than 40 ksi can be used with ASTM F436 washers in accordance with the requirements in Section 6.2.1.

This specification previously required a washer under bolt heads with a bearing area smaller than that provided by an ASTM F436 washer. Tests indicate that the pretension achieved with a bolt having the minimum ASTM F1852 or F2280 bearing circle diameter is the same as that of a bolt with the larger bearing circle diameter equal to the size of an ASTM F436 washer, provided that the hole size meets the RCSC Specification limitations (Schnupp, 2003).

Rationale or Justification for Change (attach additional pages as needed):
Research performed and published in the Engineering Journal by Douglas B. Cleary, William T. Riddell and Christopher J. Lacke of Rowan University on the *Effect of Washer Placement on the Performance of Direct Tension Indicators with Curved Protrusions*, provides evidence that the use of an ASTM F436 washer is not needed in these applications.

Excerpt from Summary and Conclusions:

Based on the results of this test program, it is concluded that the use of direct tension indicators with curved protrusions with or without hardened washers against the turned element for ASTM A325 3/4- and 7/8-in.-diameter bolts and ASTM A490 1-in.-diameter bolts results in comparable performance in providing the required bolt pretension if a Grade DH or harder nut is used. In addition, the presence or absence of the hardened washer made no difference in the performance of the direct tension indicators at the load levels required to close all but one or all of the gaps.

Engineering Journal

American Institute of Steel Construction

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Effect of Washer Placement on Performance of Direct Tension Indicators with Curved Protrusions

DOUGLAS B. CLEARY, WILLIAM T. RIDDELL and CHRISTOPHER J. LACKE

ABSTRACT

A series of tests was performed to evaluate the effect of a hardened washer placed between the turned element and a direct tension indicator (DTI) with curved protrusions. Configurations with ¾-, ⅞- and 1.0-in.-diameter bolts with and without hardened washers were evaluated. Tests were also performed with ¾- and ⅞-in. bolts using a new type of DTI, where the DTI is staked to a nut. The purpose of these tests was to compare the performance of the various configurations, as measured by the number of gaps open at the specified pretension level, the load required to close at least half of the gaps, and the tensile load on the bolts when all or all but one of the gaps in the DTI are closed. When an ASTM A563 grade DH nut was used for a given bolt diameter, some differences were observed to be statistically significant. However, no consistent trends were observed in these differences, and the actual differences were of the same order of magnitude as the load increments used in testing. Therefore, it was concluded that there are no practical differences between the various configurations considered when grade DH nuts are used. However, the DTI did not perform well without a secondary hardened washer when an ASTM A563 Grade C nut was used.

Keywords: direct tension indicators, hardness, washers, bolting.

Tension indicating washers, commonly called direct tension indicators (DTIs), are one of several methods used to achieve or demonstrate adequate bolt pretension when such pretension is required in a bolted connection. Other methods include turn-of-the-nut, calibrated wrenches, and twist-off-type tension-control bolts. ASTM F959-09 states that a direct tension indicator is a "*washer-type element inserted under the bolt head or hardened washer, having the capability of indicating the achievement of a required minimum bolt tension by the degree of direct tension indicator plastic deformation*." The plastic deformation is indicated by the collapse of protrusions on the face of the tension indicating washer. The extent to which the protrusions have collapsed is determined by the number of gaps between protrusions that a 0.005-in.-thick indicator can be inserted. Direct tension indicators were introduced in the 1960s and their design has evolved over the ensuing years. Previous studies of use of DTIs in structural connections can be found in the literature (Schmeckpeper et al., 1999; Struik et al., 1973).

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The Research Council on Structural Connections (RCSC, 2004) *Specification for Structural Joints Using ASTM A325 or A490 Bolts* notes that washers are not required in pretensioned joints and slip-critical joints except in cases of sloping surfaces, oversized or slotted holes, and for certain situations with lower yield strength base material and A490 connectors. In addition, there are requirements for the use of washers under turned elements when using calibrated wrench pretensioning, twist-off-type, tension-control bolt pretensioning and direct tension indicators. As noted in the Commentary of Section 6 of the RCSC specification, "The primary function of washers is to provide a hardened non-galling surface under the turned element, particularly for torque-based pretensioning methods…" Although direct tension indicators are not torque-based, the specification does require an ASTM F436 washer between the direct tension indicator and the turned element.

The original tension indicating washers developed by Cooper and Turner Ltd. required use of hardened washers per the manufacturer's installation instructions because the indicator protrusions in some cases were outside the bearing surface of the bolt or nut. In addition, the protrusions were harder and had a straight-sided shape that could cut or gall the bearing surface of the turned element (Laboratory Testing Inc., 1999). An amendment to ASTM F959 in 1993 ensured that DTIs conforming to that specification would have protrusions that fall within the geometric limits of bolt or nut bearing surfaces. The hardness of current DTIs varies by manufacturer.

Table 1. Matrix of Configurations Considered in Testing						
	Diameter, in.	Type	Surface Finish	Hardened Washer	Nut Grade	Number of Tests
TurnaSure DTI						
Lot 343I76	¾	325	Plain	Yes	DH	30
Lot 343I76	¾	325	Plain	No	DH	30
Lot 783F63-3	⅞	325	Plain	Yes	DH	30
Lot 783F63-3	⅞	325	Plain	No	DH	30
Lot 014B10	1	490	Plain	Yes	DH	30
Lot 014B10	1	490	Plain	No	DH	30
Lot 343I74	¾	325	Plain	No	DH	10
Lot 783F63-3	⅞	325	Plain	No	C	10
TurnAnut DTI						
34TNA6A	¾	325	Plain	No	DH	30
34TNA7A	¾	325	Galvanized	No	DH	30
78TNA6A	⅞	325	Plain	No	DH	30
78TNA6A	⅞	325	Galvanized	No	DH	30

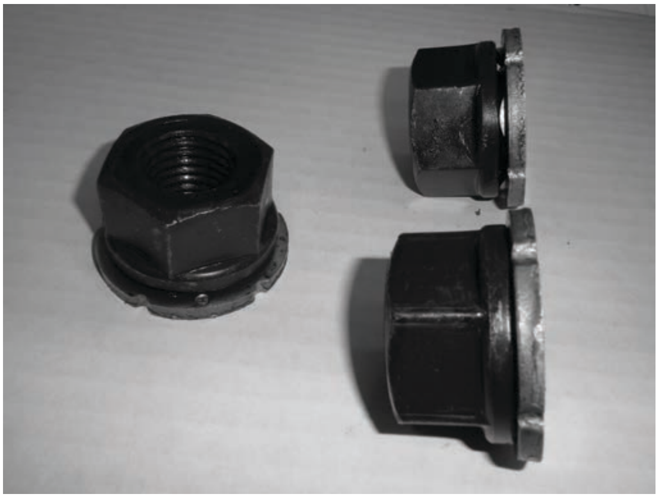
PURPOSE AND SCOPE

The purpose of this study was to evaluate the performance of direct tension indicators with curved protrusions for various washer configurations under controlled laboratory conditions. Tests were performed for ASTM A325 ¾- and ⅞-in.-diameter bolts and ASTM A490 1-in.-diameter bolts with standard ASTM F959 direct tension indicators, with and without ASTM F436 standard hardened washers against ASTM A563 Grade DH nuts. For the ASTM A325 ¾- and ⅞-in. bolts, both galvanized and plain finish proprietary TurnAnut DTIs are also evaluated. The TurnAnut DTI consists of a nut to which a DTI has been attached by staking. An additional test series with ⅞-in.-diameter bolts with ASTM A563 Grade C nuts was also performed. All DTIs were manufactured by TurnaSure, LLC. The test conditions are summarized in Table 1.

CODE REQUIREMENTS FOR DIRECT TENSION INDICATORS

Direct tension indicators must meet the requirements of ASTM F959. Section 7 of the RCSC *Specification* describes the requirements to verify that fastener assemblies

(a) TurnaSure DTI



(b) TurnaSure TurnAnut DTI

Fig. 1. Views of TurnaSure DTI and TurnAnut DTI. The images show the devices before and after testing.

Table 2. Relevant Tensile Forces for Pretensioned and Slip Critical Bolts						
Nominal Bolt Diameter, d_b, in.	Specified Minimum Bolt Pretension, T_m, kips		1.05 times Specified Minimum Bolt Pretension, kips		Minimum Tensile Capacity, kips	
	ASTM A325 Bolts	ASTM A490 Bolts	ASTM A325 Bolts	ASTM A490 Bolts	ASTM A325 Bolts	ASTM A490 Bolts
¾	28	—	29	—	40	—
⅞	39	—	41	—	56	—
1	—	64	—	67	—	91

and procedures result in the required post tightening performance (RCSC, 2004). The specification calls for the use of a tension calibrator to confirm the performance of the fastener assembly and the pretensioning method to be used by the bolting crew. Section 8 describes installation of fastener components. Section 8.2.4 specifically describes direct-tension-indicator pretensioning.

The RCSC *Specification* calls for a representative sample of fastener assemblies to be tested for each combination of diameter, length, grade and lot to be used. In the snug-tight condition at least half of the DTI gaps must remain open. Testing then proceeds until at least half of the gaps are closed to a 0.005-in. feeler gage. The purpose of the testing is to ascertain that the fastener assembly and fastening procedure develops a pretension equal to or greater than 1.05 times the values specified in Table 8.1 of the RCSC *Specification*. The values from Table 8.1 of interest to this test program, as well as the values scaled by 1.05 used for initial pretensioning in this study are reported in Table 2.

EXPERIMENTAL PROGRAM

The experimental program consisted of tension tests of TurnaSure DTIs (Type 325 ¾ in., ⅞ in. and Type 490 1 in.) and TurnaSure TurnAnut DTIs (Type 325 ¾ in. diameter and ⅞ in. diameter). The devices tested are shown in Figure 1. The tests of DTIs were performed with four configurations, including plain-finish DTIs bearing directly against the face of the nut, plain-finish DTIs bearing against a hardened washer, and both plain and mechanically galvanized TurnAnut DTIs as shown in Figures 1 and 2. In the initial round of testing, 30 assemblies of each configuration were tested with Grade DH nuts. All DTIs of the same size were from the same production lot in the initial round of testing. Two additional series consisted of 10 assembly tests each. The first employed ¾-in.-diameter assemblies with Grade DH nuts and no hardened washer, employing DTIs from a different production lot than was used in the initial round. The second additional series was for ⅞-in. assemblies using the same DTI lot as the initial series against Grade C nuts without hardened washers. The nuts were turned with an electric wrench. A summary of the program was provided in Table 1. The Rockwell hardness measurements for all DTIs, nuts, and washers used are shown in Table 3.

While the nuts were tightened, the tension of the bolts was measured with a Skidmore-Wilhelm bolt tension calibrator with a digital readout. For loading, the bolts were placed through the back of the calibrator and the nut was the turned element. The bolts were initially tensioned to 1.05 times the load specified in Table 8.1 of the RCSC *Specification*. The number of gaps open more than 0.005 in. was determined using a feeler gauge. The bolts were then subjected to incremental increases in tension, with the number of open gaps measured and recorded at each increment, until only one gap remained open. The load increments were on the order of 1 kip to 3 kips. In some instances, the final load increment resulted in all gaps closing. The tension load required to close all or all but one gap was recorded. After loading, it was verified that the nut could be rethreaded for the length of the bolt. The loading plates of the bolt tension calibrator required re-facing at regular intervals. No more than 20 test repetitions were performed on a plate without re-facing. The test equipment is shown in Figure 3.

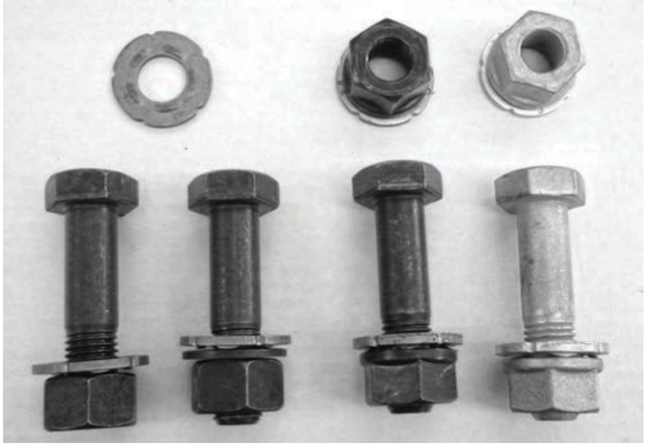


Fig 2. Test configurations from left to right; DTI without washer, DTI with washer, plain TurnAnut DTI, galvanized TurnAnut DTI.

Table 3. Rockwell Hardness of Connection Components (Scale)				
	Diameter, in.	DTI Avg./STD	Washer Avg./STD	Nut Avg./STD
TurnaSure DTI Tests with DH Nuts				
Lot 343I76	¾	87.6/3.09 (B)	39.1/2.48 (C)	30.1/0.42 (C)
Lot 783F63-3	⅞	94.4/1.74 (B)	40.2/1.64 (C)	26.6/1.75 (C)
Lot 014B10	1	83.4/8.91 (B)	42.8/0.84 (C)	28.9/2.53 (C)
Lot 343I74	¾	90.4/3.80 (B)	43.0/2.53 (C)	30.3/2.84 (C)
TurnaSure DTI Tests with C Nuts				
Lot 783F63-3	⅞	94.4/1.74 (B)	Not used	88.37/3.00 (B)

RESULTS

Results of three key load points are reported in this study. The first result reported is the number of gaps open when the pretension in the bolt reaches 1.05 times that specified in Table 8.1 of the RCSC *Specification*. These required pretension values were noted in Table 2. These data are used, similar to pre-installation verification of assemblies as outlined in Section 7 of the RCSC *Specification*, to verify that the required pretension is reached. The required pretension values should be reached prior to half of the DTI gaps closing. The second result reported is the load required to close all or all but one of the DTI gaps. The third finding is the distribution of measured bolt tensions when the DTI indicated that the specified bolt pretension requirements were met (half of the gaps closed).

The average numbers of gaps open at 1.05 times the minimum pretension load and the standard deviation of these results are provided in Table 4. Table 5 provides the distribution of the number of gaps open at this load from tests on ¾-, ⅞- and 1-in.-diameter bolts, respectively. The preload values were 29 kips for ¾-in.-diameter A325 bolts, 41 kips for ⅞-in.-diameter A325 bolts, and 67 kips for 1-in.-diameter A490 bolts.

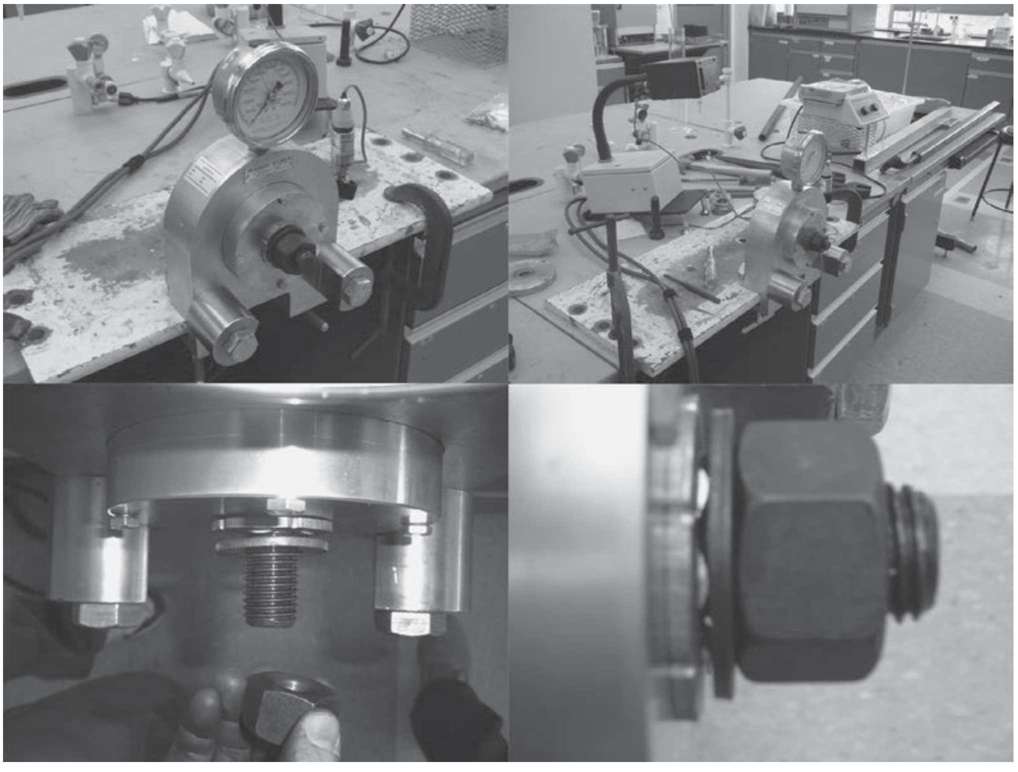


Fig. 3. Test setup.

Table 4. Average Numbers of Gaps Open at 1.05 Times Minimum Pretension Load (Grade DH Nut Unless Otherwise Indicated)		
Assembly (Preload)	**Avg. Number of Gaps Open**	**Standard Deviation**
¾-in. A325 (29 kips)	(5 possible)	
Lot 343I76 without washer	4.10	0.82
Lot 343I76 with washer	3.57	0.73
Lot 343I74 without washer	4.10	1.10
Plain TurnAnut DTI	4.87	0.43
Galvanized TurnAnut DTI	5.00	0.00
⅞-in. A325 (41 kips)	(5 possible)	
Lot 783F63-3 without washer	3.72	0.80
Lot 783F63-3 with washer	3.49	0.85
Lot 783F63-3 without washer (Grade C Nut)	0.91	1.14
Plain TurnAnut DTI	4.93	0.37
Galvanized TurnAnut DTI	4.27	0.74
1-in. A490 (67 kips)	(7 possible)	
Lot 014B10 without washer	6.60	0.89
Lot 014B10 with washer	5.33	1.35

For ¾-in.-diameter assemblies with Grade DH nuts, 39 of 40 tests without a washer and 30 of 30 tests with a backing washer passed simulated pre-installation verification testing. For the ⅞-in.-diameter assemblies with Grade DH nuts, 30 of 30 tests without a washer and 26 of 30 tests with a backing washer passed. All 1-in.-diameter assemblies with DH nuts, with or without a washer, passed the test. All TurnAnut assemblies also passed the simulated pre-installation verification testing. Use of a DTI alone resulted in a higher average number of gaps open at the preload compared to use of a DTI with a hardened washer against the face of the DH nut for all size bolts tested. The TurnAnut DTI, whether plain or galvanized, tended to have the most gaps open at preload and the smallest spread in the results.

The tests of ⅞-in. assemblies with Grade C nuts and without a hardened washer resulted in most of the gaps indicating as closed with the feeler gage at the specified preload (ASTM value times 1.05). This poor performance of the DTI coincided with significant galling of the surface of the Grade C nut.

The average loads required to close all but one or all of the DTI gaps are reported in Table 6. Excluding the results from Grade C nuts, on average, these peak loads are 82 to 96% of the specified minimum tensile capacity of the bolts. Five of 30 tests of galvanized ¾-in. bolts exceeded the minimum specified tensile capacity of the bolt when all or all but one gap was closed. Two tests with ¾-in. galvanized TurnAnut exceeded the minimum specified tensile capacity of the bolt. No other tests exceeded the minimum. Use of a hardened washer against the face of the nut tended to result in a slightly greater spread in the peak load data compared with a DTI directly against the nut face. All nuts could be rethreaded for the length of the bolt after testing, indicating that the bolt did not undergo significant plastic deformation.

Cumulative density functions of the loads measured when at least half of the DTI gaps were first observed to be closed are shown in Figures 4, 5 and 6 for ¾-, ⅞- and 1-in.-diameter assemblies with Grade DH nuts, respectively. These figures indicate the spread in pretension measured under the acceptance condition. The minimum pretension had been developed under this condition for all assemblies tested. The spread of the results was smaller for tests without a hardened washer for ¾- and ⅞-in. assemblies and larger for the 1-in. assemblies. The TurnAnut produced higher pretension than the assemblies in which the washer, DTI or both were free to "float" while the assembly was tightened.

The requirement to place a hardened washer between the turned element and a DTI was because of the potential for DTIs to gall the underside of the nut or bolt head, resulting in incorrect indication of tension. Following this testing, a selection of washers and nuts were inspected both visually and with a profilometer. Visual observation shows that the DTI produced limited polishing of the washer or Grade DH nuts in a ring described by the indicators' protrusions. The profilometer measurements showed no evidence of surface galling. However, the surface of the polished region was

Table 5. Distribution of Gaps Open at 1.05 Times Minimum Pretension Load (Grade DH Nut Unless Otherwise Indicated)						
Assembly (Preload)	**Percentage of Tests with Number of Gaps Open**					
¾-in. A325 (29 kips)	**5**	**4**	**3**	**2**	**1**	**0**
Lot 343I76 without washer ($n = 30$)	38	34	28	0	0	0
Lot 343I76 with washer ($n = 30$)	13	30	57	0	0	0
Lot 343I74 without washer ($n = 10$)	50	20	20	10	0	0
Plain TurnAnut DTI ($n = 30$)	90	7	3	0	0	0
Galvanized TurnAnut DTI ($n = 30$)	100	0	0	0	0	0
⅞-in. A325 (41 kips)	**5**	**4**	**3**	**2**	**1**	**0**
Lot 783F63-3 without washer ($n = 30$)	21	31	48	0	0	0
Lot 783F63-3 with washer ($n = 30$)	13	32	42	13	0	0
Lot 783F63-3 without washer (Grade C nut) ($n = 10$)	0	0	20	30	10	40
Plain TurnAnut DTI ($n = 30$)	97	0	3	0	0	0
Galvanized TurnAnut DTI ($n = 30$)	43	40	17	0	0	0
1-in. A490 (67 kips)	**7**	**6**	**5**	**4**	**3**	**2**
Lot 014B10 without washer ($n = 30$)	80	6	7	7	0	0
Lot 014B10 with washer ($n = 30$)	37	0	23	40	0	0

noticeably smoother, possibly due to limited removal of mill scale as the nut or washer rotated relative to the DTI protrusions. This result was expected because the DTI material is softer than that of either the washer or Grade DH nut. As noted previously however, there was significant galling of the Grade C nuts when the DTI was used without a hardened washer.

ANALYSIS AND DISCUSSION

The test program clearly shows that the tested DTI cannot be used without a hardened washer between it and a Grade C nut. However, in the case of a hardened nut, the extra washer does not appear to be necessary. For the assemblies tested with a sample size of 30 tests, independent sample *t*-test analyses were performed to determine if there were statistically significant differences in the average loads required to close all but one or all of the gaps of the DTI to refusal of the 0.005-in. feeler gauge. The Shapiro-Wilk test was used to assess the validity of the normality condition ($\alpha = 0.2$). Non-pooled *t*-tests were used when the larger standard deviation was more than twice the value of the smaller standard deviation. Results of this analysis, which are exclusive to testing with Grade DH nuts, were:

- The differences in the measured average peak loads were not statistically significant when comparing the "with-washer" configuration to the TurnAnut DTI configuration for plain A325 ¾- or ⅞-in.-diameter bolts.

- The differences in the measured average peak loads were statistically significant when comparing the "with-washer" configuration to the TurnAnut DTI configuration for galvanized A325 ¾-in. bolts. However, the difference was not statistically significant when comparing the "with-washer" configuration

Table 6. Average Loads Required to Close All But One or All of the DTI Gaps (Grade DH Nuts Only)			
Assembly (Minimum Specified Tensile Strength)	**Avg. Peak Load (kips)**	**Standard Deviation (kips)**	**Percent of Minimum Specified Tensile Strength**
¾-in. A325 (40 kips)			
Lot 343I76 without washer	35.1	1.03	88
Lot 343I76 with washer	35.9	1.74	90
Lot 343I74 without washer	34.6	2.27	87
Plain TurnAnut DTI	35.3	1.50	88
Galvanized TurnAnut DTI	38.2	1.60	96
⅞-in. A325 (56 kips)			
Lot 783F63 without washer	45.8	1.42	82
Lot 783F63 with washer	47.4	2.46	85
Plain TurnAnut DTI	48.2	0.89	86
Galvanized TurnAnut DTI	47.2	1.65	84
1-in. A490 (91 kips)			
Lot 014B10 without washer	80.0	3.47	88
Lot 014B10 with washer	77.4	3.92	85

to galvanized A325 ⅞-in.-diameter TurnAnut DTIs. The "with-washer" configuration with ¾-in.-diameter bolts resulted in lower peak bolt tension required to close one or all gaps than was required with the galvanized TurnAnut DTI.

- The differences in the measured average peak loads were statistically significant when comparing the "with-washer" condition to the "without-washer" configuration for all sizes tested. However, the differences were not in the same direction for all sizes. For A325 ¾-in. or ⅞-in.-diameter bolts, the force required to close one or all of the gaps to less than 0.005 in. was higher for the hardened washer configuration. The trend was reversed in the 1-in.-diameter A490 bolts.

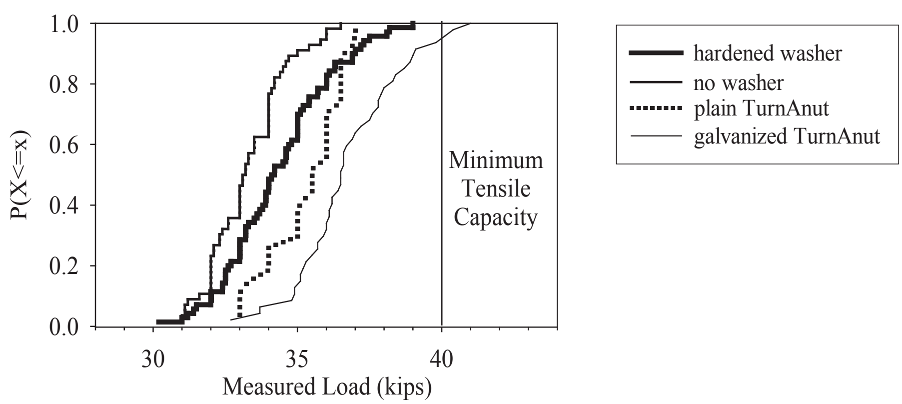


Fig. 4. Cumulative density function of loads required to close half of the gaps, ¾-in.-diameter A325 bolts (minimum pretension is 28 kips and minimum tensile strength is 40 kips).

While the analysis performed indicates there are statistically significant differences in some of the measured results, there was not a consistent trend in these differences. In addition, these statistical findings must be considered in light of the test program itself. The peak loads recorded were those required to close all but one or all of the gaps between the DTI and washer or bolt. This was because in some instances the load increment applied to the bolt resulted in enough gaps closing to bypass the one-gap-closed condition. In addition, the load increments typically ranged from 0.4 kip to 1.5 kips. Therefore, the load increments are equal to or of the same magnitude as the measured differences in peak load values. Given these considerations, these results should not be extended beyond stating that the comparable behavior was achieved with all of the bolt/DTI/washer/nut configurations considered.

SUMMARY AND CONCLUSIONS

Tests of bolt assemblies that involved direct tension indicators with curved protrusions were performed to evaluate the effect of nut and washer configuration on pretension loads achieved. Test configurations included plain DTIs against the face of the nut, DTI's and hardened washer against the face of the nut, and plain and mechanically galvanized

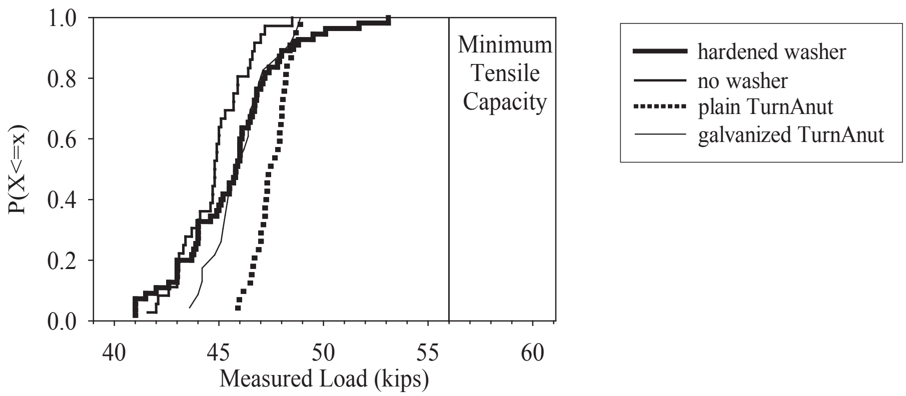


Fig. 5. Cumulative density function of loads required to close half of the gaps, ⅞-in. A325 bolts (minimum pretension is 39 kips and minimum tensile strength is 56 kips).

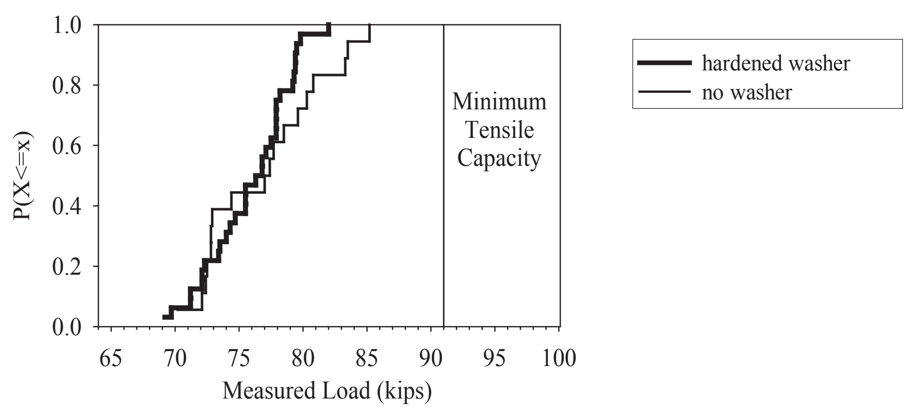


Fig. 6. Cumulative density function of loads required to close half of the gaps, 1-in. A490 bolts (minimum pretension is 64 kips and minimum tensile strength is 91 kips).

TurnaSure TurnAnut DTIs. For all tests, the nut was the turned element. It was found that a hardened washer is necessary if a DTI is used with a Grade C nut. However, it was found that when a Grade DH nut was used, the assembly performed just as well with or without the hardened washer placed between the DTI and the nut.

Additional findings specific to Grade DH nuts were

- Use of a DTI alone resulted in a higher average number of gaps open at the preload compared to use of a DTI with a hardened washer against the face of the nut for all size bolts tested, even when such DTIs were from the same production lot.

- The TurnAnut DTI, whether plain or galvanized, tended to have the most gaps open at preload and the smallest spread in the results.

- In simulated pre-installation verification testing, similar performance of DTI assemblies with or without a hardened washer was observed with a small percentage of assemblies not passing the testing.

- Use of a hardened washer against the face of the nut tended to result in a slightly greater spread in the peak load data compared with a DTI directly against the nut face. For the condition of half of the gaps closed the finding was similar for ¾- and ⅞-in.-diameter assemblies but opposite with 1-in.-diameter assemblies.

- In some cases statistically significant differences were measured for the average tensile loads required to close all but one or all of the gaps to less than 0.005 in. However, the trends were not consistently in the same direction and the differences in the means were less than or comparable to the load increments being applied during the testing.

Based on the results of this test program, it is concluded that the use of direct tension indicators with curved protrusions with or without hardened washers against the turned element for ASTM A325 ¾- and ⅞-in.-diameter bolts and ASTM A490 1-in.-diameter bolts results in comparable performance in providing the required bolt pretension if a Grade DH or harder nut is used. In addition, the presence or absence of the hardened washer made no difference in the performance of the direct tension indicators at the load levels required to close all but one or all of the gaps. The staking of a direct tension indicator to a nut to produce the TurnAnut DTI configuration with either plain or galvanized surfaces also resulted in behavior comparable to a DTI with and without a hardened washer against the turned element. However, the testing does not support elimination of the hardened washer for softer grades of nuts.

ACKNOWLEDGMENTS

The work presented was sponsored by Turnasure, LLC. The views presented do not necessarily represent those of the project sponsors. The testing was carried out by undergraduate research assistants Mr. Matt Janas and Mr. Ryan Headley with assistance from Mr. Charles Linderman.

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RCSC Proposed Change: S13-050

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Proposed Change:

Section 2.3 Commentary

Next to last paragraph in Commentary – All other content remains the same as currently printed.

To determine the required bolt length, the value shown in Table C-2.2 should be added to the *grip* (i.e., the total thickness of all connected material, exclusive of washers). For each ASTM F436 washer that is used, add E in.; for each beveled washer, add c in. The tabulated values provide appropriate allowances for manufacturing tolerances and also provide *sufficient thread engagement* with an installed heavy-hex nut. The length determined by the use of Table C-2.2 should be adjusted to the nearest 1/4-in. length increment (1/2-in. length increment for lengths exceeding ~~6~~ 5 in.). A more extensive table for bolt length selection based upon these rules is available (Carter, 1996).

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

It is my understanding that the change to ½ in. length increments occurs above 5 in., not 6 in.

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

Date Received: 4/26/13 Exec Com Meeting: 6/5/13 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: ________________________