

**Structural  
Bolting  
Handbook  
2016**



# Structural Bolting Handbook 2016

**a reference guide for fabricators,  
erectors, ironworkers, inspectors, and  
all others involved in bolting for  
structural steel buildings and bridges**



**4" by 8" pocket-sized convenience, 144 pages**

This 2016 edition of the Structural Bolting Handbook is based principally upon the June 2014 edition of the RCSC *Specification for Structural Joints Using High-Strength Bolts*, cited by the 2010 AISC *Specification for Structural Steel Buildings* (AISC 360-10). However, significant changes regarding structural bolting were implemented by the 2016 AISC *Specification for Structural Steel Buildings* (AISC 360-16) that are not addressed by the 2014 RCSC *Specification*, including:

- an increase in STD bolt hole diameter and SSL and LSL slot width for bolts 1 inch diameter and above,
- recognition of the new ASTM F3125 standard, which consolidates and replaces ASTM A325, A325M, A490, A490M, F1852 and F2280,
- increased minimum bolt pretensions for Grade A325 bolts of 1-1/8 inch diameter and greater, which also affects pre-installation verification testing, and
- introduction of new AISC Group C bolts with 200 ksi tensile strength, ASTM F3043 and ASTM F3111

This Handbook has included information using both:

- the 2010 AISC *Specification* with 2014 RCSC *Specification* provisions, and
- the 2016 AISC *Specification* provisions with appropriate updated information, where possible, for use until such time as the RCSC *Specification* is updated.

This Handbook provides:

- Step-by-step instructions for performing bolt installation using RCSC turn-of-the-nut, calibrated wrench, twist-off bolt and direct tension indicator methods
- Step-by-step instructions for performing bolt installation of new 200 ksi ASTM F3043 and F3111 Grade 2 assemblies, ASTM F3148 TnA144 assemblies, and Squirter® DTIs
- Step-by-step pre-installation tests for each method
- Step-by-step inspection procedures for each method
- Step-by-step arbitration of disputes procedure
- AASHTO / FHWA rotational capacity test procedures
- Bolted joint descriptions
- Snug-tight joint acceptance criteria
- Bolt, nut and washer product identification markings
- Manufacturer mark and source information
- Torque estimation tables
- Installation wrench selection tables
- Bolt length tables

1 - 4 copies	\$ 20.00 each
5 - 9 copies	\$ 18.00 each
10 - 24 copies	\$ 16.00 each
25 - 99 copies	\$ 15.00 each
100+ copies	\$ 13.50 each

# Structural Bolting Handbook 2016

## Table of Contents

<b>IMPORTANT NOTICE</b>	2
<b>Common Acronyms</b>	8
<b>Frequently Used Terms and Definitions</b>	9
<b>Joint Types</b>	10
<i>Shear-Bearing Load Transfer</i>	10
<i>Friction Load Transfer</i>	12
<i>Direct Tension Load Transfer</i>	13
<b>Guide to RCSC Specification</b>	14
<i>Shear Loading Only</i>	14
<i>Combined Shear and Tension Loading</i>	15
<i>Tension Loading Only</i>	16
<b>Snug-Tightened Joints</b>	17
<i>Installation</i>	17
<i>Inspection</i>	19
<b>Pretensioned and Slip-Critical Joints</b>	21
<i>Pre-Installation Verification</i>	21
Table PIV-1a Pre-Installation Verification, Required Pretension based on AISC 360-16	21
Table PIV-1b Pre-Installation Verification, Required Pretension based on AISC 360-10	22
Table PIV-2 Pre-Installation Verification, Required Pretension for XT <sup>B</sup> ™ ASTM F3043 and F3111 Grade 2 based on AISC 360-16	22
<i>Minimum Bolt Pretensions</i>	23
Table P-1a Required Minimum Bolt Pretension based on AISC 360-16	23
Table P-1b Required Minimum Bolt Pretension based on AISC 360-10	23
Table P-2 Required Minimum Bolt Pretension for XT <sup>B</sup> ™ ASTM 3043 and F3111 Grade 2 based on AISC 360-16	24
Table P-3 Required Minimum Bolt Pretension for TnA <sup>®</sup> 144 (ASTM 3148)	24
<b>Turn-of-Nut Method</b>	25
<i>Pre-Installation Verification</i>	25
Using Bolt Tension Measurement Device (BTMD)	25
For Bolts Too Short to Fit into the Bolt Tension Measurement Device (BTMD)	26
<i>Pretensioning</i>	27
Turning the Nut	27
Turning the Bolt Head	28
Table TURN-1 Turn-of-Nut Method, Required Rotation for Pretensioning, Flat Surfaces under Bolt Head and Nut	30
Table TURN-2 Turn-of-Nut Method, Required Turns for Pretensioning, Sloped Surfaces under Bolt Head and/or Nut	32
Table TURN-3 Required Rotation for Turn-of-Nut Method	34
<i>Inspection</i>	35
<b>Twist-Off-Type Tension-Control Bolt Method</b>	37
<i>Pre-Installation Verification</i>	37
Using Bolt Tension Measurement Device (BTMD)	37
For Bolts Too Short to Fit into the Bolt Tension Measurement Device (BTMD), using Calibrated DTIs	38
<i>Pretensioning</i>	39
<i>Inspection</i>	40

<b>Twist-Off-Type Tension-Control Bolt Method for XTB™ ASTM F3043 Grade 2 Matched Bolting Assemblies</b>	42
<i>Pre-Installation Verification Using Bolt Tension Measurement Device (BTMD)</i>	42
<i>Pretensioning</i>	43
<i>Inspection</i>	44
<b>Direct-Tension-Indicator (DTI) Method</b>	46
Table DTI-1 ASTM F959 Direct-Tension-Indicator (DTI) Dimensions	46
<i>Pre-Installation Verification</i>	47
Using Bolt Tension Measurement Device (BTMD) with DTI placed under Bolt Head	47
Using Bolt Tension Measurement Device (BTMD) with DTI placed under Nut	49
For Bolts Too Short to Fit into the Bolt Tension Measurement Device (BTMD) with DTI placed under Bolt Head	51
For Bolts Too Short to Fit into the Bolt Tension Measurement Device (BTMD) with DTI placed under Nut	53
<i>Pretensioning</i>	55
DTI placed under Bolt Head	55
DTI placed under Nut	56
Table DTI-2 DTI Gaps and Refusals	58
<i>Inspection</i>	59
<b>Combined Method for XTB™ ASTM F3111 Heavy Hex Grade 2 Matched Bolting Assemblies</b>	61
<i>Pre-Installation Verification Using Bolt Tension Measurement Device (BTMD)</i>	61
<i>Pretensioning</i>	63
<i>Inspection</i>	65
<b>Combined Method for TnA®144 ASTM F3148 Matched Bolting Assemblies</b>	67
<i>Pre-Installation Verification Using Bolt Tension Measurement Device (BTMD)</i>	67
<i>Pretensioning</i>	69
<i>Inspection</i>	70
<b>Squirter® DTI Method</b>	72
<i>Calibration</i>	72
Using Bolt Tension Measurement Device (BTMD)	72
For Bolts Too Short to Fit into the Bolt Tension Measurement Device (BTMD)	73
<i>Pretensioning</i>	74
<i>Inspection</i>	76
<b>Calibrated Wrench Method</b>	78
<i>Pre-Installation Verification - Installation Wrench Calibration Procedure</i>	78
Using Bolt Tension Measurement Device (BTMD)	78
For Bolts Too Short to Fit into the Bolt Tension Measurement Device (BTMD)	79
<i>Pretensioning</i>	81
<i>Inspection</i>	82
<b>Inspection under the 2016 AISC Specification for Structural Steel Buildings (AISC 360-16)</b>	84
<b><i>N5.6 Inspection of High-Strength Bolting</i></b>	84
AISC 360-16 Table N5.6-1 Inspection Tasks Prior to Bolting	85
AISC 360-16 Table N5.6-2 Inspection Tasks During Bolting	85
AISC 360-16 Table N5.6-3 Inspection Tasks After Bolting	85
<b>Arbitration of Disputes</b>	86
<b><i>Torque Method</i></b>	86
Using a Bolt Tension Measurement Device (BTMD)	86
For Bolts Too Short to Fit into the Bolt Tension Measurement Device (BTMD)	89

<b>Hole-making</b>	91
Table H-1a Nominal Hole Sizes for AISC 360-16	92
Table H-1b Nominal Hole Sizes for AISC 360-10	93
<b>Jobsite Storage</b>	94
<b>Lubrication of Uncoated Bolting Assemblies</b>	95
<b>Lubrication of Galvanized Bolting Assemblies</b>	97
<b>Systematic Approach</b>	98
<b>Requirements for Washers</b>	99
Table WSHR-1 ASTM F436 Washer Dimensions	102
<b>Bolt Stickout</b>	103
<b>Torque</b>	104
Table TORQUE-1a Approximate Torques for ASTM F3125 Grade A325 and Grade F1852, based on AISC 360-16	105
Table TORQUE-1b Approximate Torques for ASTM A325 and ASTM F1852, based on AISC 360-10	105
Table TORQUE-2 Approximate Torques for ASTM F3125 Grade A490 and Grade F2280, ASTM A490 and ASTM F2280, based on AISC 360-10 and AISC 360-16	106
<b>Installation Wrenches</b>	104
Table WRENCH-1 Air Impact Wrench Working Torque Ranges	107
Table WRENCH-2 Electric Wrenches	108
<b>Overtightening High-Strength Bolts</b>	109
<b>Thread Stripping</b>	111
<b>Reuse of Bolts Previously Pretensioned</b>	112
<b>AASHTO / FHWA Rotational Capacity Test Procedure</b>	113
<i>Using a Bolt Tension Measurement Device (BTMD)</i>	113
<i>For Bolts Too Short to Fit into the Bolt Tension Measurement Device (BTMD)</i>	116
<b>Bolt Tension Measurement Devices</b>	119
Table SW-1 Skidmore-Wilhelm Bolt Tension Calibrator Capacity Ranges	120
Table SW-2 Minimum Bolt Lengths for Skidmore-Wilhelm Bolt Tension Calibrators	120
<b>Determining DTI Calibration for Use as Bolt Tension Verification Device</b>	121
<b>Bolt Head Markings</b>	123
ASTM A325 and ASTM F3125 Grade A325	123
ASTM A490 and ASTM F3125 Grade A490	123
ASTM A449	123
ASTM F1852 and ASTM F3125 Grade 1852	124
ASTM F2280 and ASTM F3125 Grade F2280	124
ASTM A354	125
ASTM A307	125
Table BOLT-1 A325 and A490 Heavy Hex Bolt Dimensions	126
Table BOLT-2 F1852 and F2280 Twist-Off-Type Tension-Control Bolt Dimensions	127
Table BOLT-3 ASTM A307, ASTM A449 and ASTM A354 Hex Bolt Dimensions	128
<b>Manufacturer's Marks for Principal North American Manufacturers of Structural Bolts</b>	129
<b>Major Distributors of Structural Bolts</b>	130

<b>Nut Markings</b>	<b>131</b>
ASTM A563	131
ASTM A194	131
Table NUT-1 ASTM A563 and ASTM A194 Heavy Hex Nut Dimensions	132
Table NUT-2 ASTM A563 Hex Nut Dimensions	132
Table NUT-3 Permitted Heavy Hex Nuts for use with A325 and A490 Bolts	133
Table NUT-4 A354 Recommended and Suitable Heavy Hex and Hex Nuts for use with ASTM A354 Bolts	134
Table NUT-5 A449 Recommended and Suitable Heavy Hex and Hex Nuts for use with ASTM A449 Bolts	135
Table NUT-6 A307 Recommended and Suitable Heavy Hex and Hex Nuts for use with A307 Bolts	136
<b>Bolt Lengths</b>	<b>137</b>
Table LENGTH-A Bolt Length Estimating Table for A325, F1852, A490 and F2280 Bolts	137
Table LENGTH-3/4 Suggested Bolt Lengths for 3/4 inch Diameter	138
Table LENGTH-7/8 Suggested Bolt Lengths for 7/8 inch Diameter	140
Table LENGTH-1 Suggested Bolt Lengths for 1 inch Diameter	142
<b>NOTES</b>	<b>144</b>

## Publications Order Form

Structural Bolting Handbook 2016  
 Structural Welding Quality Handbook 2010  
 Structural Steel Inspector's Workbook (2014)  
 Shop Inspection Handbook for Structural Steel Buildings 2010



Name	
Title	
Firm/Agency	
Address	
City	State / Province
Zip / Postal Code	Country
Phone	Fax
email	

	Structural Bolting Handbook 2016		Structural Welding Quality Handbook 2010		Structural Steel Inspector's Workbook 2014	Shop Inspection Handbook for Structural Steel Buildings 2010	
		1 - 4	\$ 20.00 ea	1 - 4	\$ 15.00 ea	\$ 44.00 ea	1
	5 - 9	\$ 18.00 ea	5 - 9	\$ 13.00 ea	2 - 5		\$ 60.00 ea
	10 - 24	\$ 16.00 ea	10 - 24	\$ 12.00 ea	6+		\$ 50.00 ea
	25 - 99	\$ 15.00 ea	25 - 99	\$ 11.00 ea			
	100+	\$ 13.50 ea	100+	\$ 10.00 ea			
<b>Order Quantity</b>							
<b>Unit Price</b>	\$		\$		\$ 44.00	\$	
<b>Subtotal</b>	\$		\$		\$	\$	

<b>Publications Total</b>	\$
<b>##Shipping and Handling (see next page)</b>	\$
<b>Sales Tax (Michigan businesses &amp; residents only)</b>	\$
<b>Total Amount</b>	\$

Credit Card Type (circle) — Visa MasterCard American Express Discover	
Credit Card Number	
Credit Card Expiration Date (month / year)	Card Security Code (see below)
Cardholder's Name	
Card Billing Address	
Check Number (if enclosed)	

**Michigan businesses and residents, add 6% sales tax on Publications Total amount plus Shipping and Handling amount.**

**Prepayment by check, Visa, MasterCard, Discover or American Express required. Checks must be drawn on a US bank. No foreign checks accepted.**

**Card Security Code — for Visa, MasterCard and Discover, provide last three digits on back of card for American Express, provide four digits on front of card**

**Orders accepted by fax, scan and email, or by telephone (note: limited telephone availability)**

### Steel Structures Technology Center, Inc.

5277 Leelanau Ct.  
 Howell, MI 48843-5437  
 phone (734) 878-9560 fax (734) 878-9571  
[www.steelstructures.com](http://www.steelstructures.com)  
[info@steelstructures.com](mailto:info@steelstructures.com)

## Delivery/Shipping Method and Policies

Standard Shipping & Handling charges are listed below.

Sales Amount (USD)	USA	Canada	Mexico	Other International
Up to 100.00	7.00	20.00	30.00	40.00
100.01 – 250.00	12.00	30.00	40.00	60.00
250.01 and over	18.00	50.00	60.00	90.00

Within the USA and Canada, Standard Shipping of most products is done using United States Postal Service (USPS), most commonly using Priority Mail. Small orders may be shipped First Class Mail. Our alternative method of shipping is FedEx Ground. We do not use United Parcel Service (UPS).

Orders are typically shipped within five business days after receipt of order. However, longer shipping times may occur during holiday periods, office vacation shutdown, and extended international business activities. Such closed dates are posted and updated in this section, as follows:

July 25 – August 5, 2016

Express shipping can be provided only when arranged via email to [info@steelstructures.com](mailto:info@steelstructures.com) and agreed to by SSTC, or when arranged by telephone to (734) 878-9560 and agreed to by SSTC. Additional charges for express shipping will be quoted in advance upon request.

For most shipments, when a PO Box is to be used for your receipt of your mail delivery, please supply your PO Box address and zip code / postal code. For shipments known to be shipped by FedEx, please supply a physical address, including the zip code / postal code for the physical address.

For information on delivery time outside the USA and Canada, to request alternate or express shipping, to get a shipping price quote, or for questions, contact SSTC at [info@steelstructures.com](mailto:info@steelstructures.com).

International Delivery (including Canada) may include additional fees such as duties and/or taxes imposed by your local Customs Office. These additional fees are not covered by SSTC's shipping and handling charge and you are responsible for these costs; as well as verifying that the product can lawfully be imported into the destination country. If you have any questions regarding these fees, please contact your local Customs Office, as they can provide you with all the necessary information regarding customs fees.

If you have any questions regarding these policies, please email SSTC at [info@steelstructures.com](mailto:info@steelstructures.com) or call (734) 878-9560.

---

## Returns & Exchanges Policy

Products may be returned in new, resalable condition within 30 days. Claims for shortages or damage must be made within 5 days of receipt of merchandise, and must be requested by email to [info@steelstructures.com](mailto:info@steelstructures.com).

All returns must include a printed copy of the email from SSTC authorizing the return. Unauthorized returns will be delayed in processing and may not be accepted for credit and/or may get returned to the customer. Returned merchandise must be shipped prepaid to SSTC. Shipping and handling charges for returning items are borne by the buyer. It is strongly recommended that returned merchandise be shipped using a trackable shipping service.

All returns are subject to a restocking fee of 20 percent of the original selling price. Please note that we do not refund SSTC's shipping charges. No refund will be issued on overpayments less than \$5.00.

Most refunds are issued based on the payment method used at the time of purchase.

Payment Method	Refund Method	Refund Time (After Return Is Received)
Credit Card	Refund	3-5 days, however it may take 2-3 additional business days for the refund to display on your credit card statement.
Bank Account	Bank Account	Up to 10 business days

### RETURN ADDRESS/CONTACT:

Steel Structures Technology Center, Inc.  
Attn: Returns  
5277 Leelanau Ct.  
Howell, MI 48843-5437 USA  
[info@steelstructures.com](mailto:info@steelstructures.com)

If you have any questions on these policies, please email SSTC at [info@steelstructures.com](mailto:info@steelstructures.com).

Updated: May 21, 2016