



STRUCTURAL BOLTING USING HIGH-STRENGTH BOLTS AND DIRECT TENSION INDICATING WASHERS

VDOT Materials Division's Structures Section

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Structural Bolting at VDOT - Background

Structural Bolting using High-Strength Bolts

- **ASTM A325 Bolt**
- **ASTM A563 Hardened Grade DH Nut**
- **ASTM F436 Hardened Washer**
- **May be galvanized or “Black” uncoated Type 3 Weathering**
- **Occasionally use ASTM A490 Bolts**
- **Occasionally use ASTM A449 Bolts**
- **Together the components are called a Nut-Bolt-Washer (NBW) assembly**

Structural Bolting – ASTM Revisions

Recently the ASTM bolting specs used in the transportation (DOT) industry have been reissued in a consolidated ASTM F3125

A325 – F3125, Grade A325 (Type 1 or 3)

A490 – F3125, Grade A490 (Type 1 or 3)

F1852 – F3125, Grade F1852 (Type 1 or 3)

F2280 – F3125, Grade F2280 (Type 1 or 3)

A449 – A449 (Type 1 or 3)

Structural Bolting at VDOT - Background



H.S. Bolting Design Applications

ASTM Designation	Connection Type	Hole Type	ϕ Fv, ksi	Loading	Nominal Diameter, d , (in.)							
					5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
					Area – Based on Nominal Diameter (in ²)							
					0.3068	0.4418	0.6013	0.7854	0.9940	1.227	1.485	1.767
A307		STD, NSL	16.2	S	4.97	7.16	9.74	12.7	16.1	19.9	24.1	28.6
				D	9.94	14.3	19.5	25.4	32.2	39.8	48.1	57.3
A325	SC – Class A	STD	17.0	S	5.22	7.51	10.2	13.4	16.9	20.9	25.2	30.0
				D	10.4	15.0	20.4	26.7	33.8	41.7	50.5	60.1
		OVS, SSL	15.0	S	4.6	6.63	9.02	11.8	14.9	18.4	22.3	26.5
				D	9.2	13.3	18.0	23.6	29.8	36.8	44.6	53.0
		LSL	12.0	S	3.68	5.3	7.22	9.42	11.9	14.7	17.8	21.2
				D	7.36	10.6	14.4	18.8	23.9	29.4	35.6	42.4
	N	STD, NSL	35.1	S	10.8	15.5	21.1	27.6	34.9	43.1	52.1	62.0
				D	21.5	31.0	42.2	55.1	69.8	86.1	104.2	124.1
	X	STD, NSL	46.8	S	14.4	20.7	28.1	36.8	46.5	57.4	69.5	82.7
				D	28.7	41.4	56.3	73.5	93.0	114.9	139.0	165.4

Slip – Critical Connections

Tension

Produces

Friction

Used to Transfer Load

Installation and Inspection Methods

Calibrated Wrench Method

Turn-of-the-Nut (TOTN) Method

Direct Tension Indicating (DTI-) Washers

Twist-Off Bolts

Why use DTI - Washers

Additional Cost – Sometimes \$1 per washer, more than the cost of the fastener assembly

Which would you rather take up in a bucket to inspect the bolts?



Field Rotational Capacity Testing

Perform a field Ro-Cap test to verify the fasteners meet the spec before addressing the DTIs

Do not use DTIs in the field Ro-Cap test. They alter part of the results and may alter more than one part

The use of the DTI is also beneficial to verify the short bolts have adequate tension.

Field DTI Verification Test

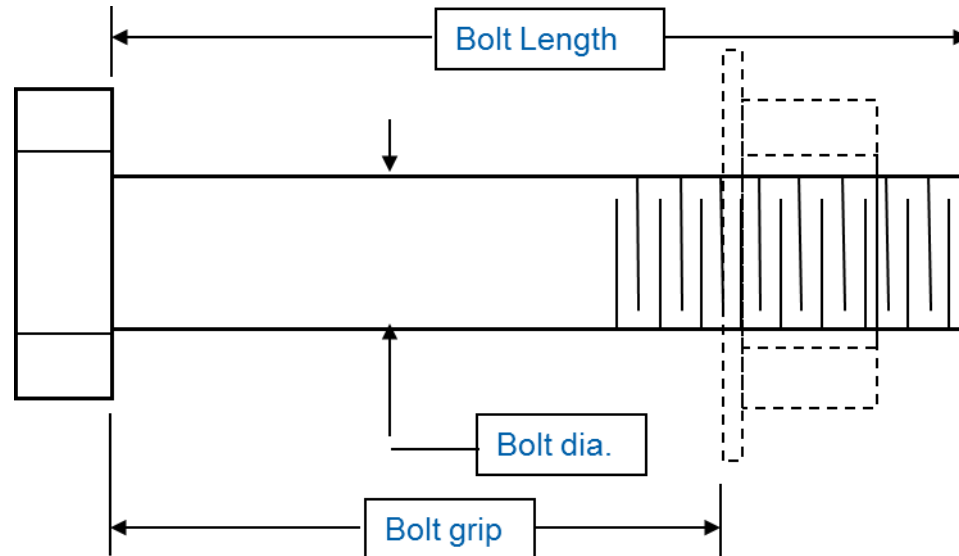
Intent: Use a Clear and Consistent Process to Verify the DTIs you receive will meet the needs of the job. There has been a lot of variability reported by some in the field.

The DTI is produced in a stamping process and is essentially cold-worked

When Hot-Dip Galvanized they undergo elevated temperature heating and cooling

H.S. Bolting

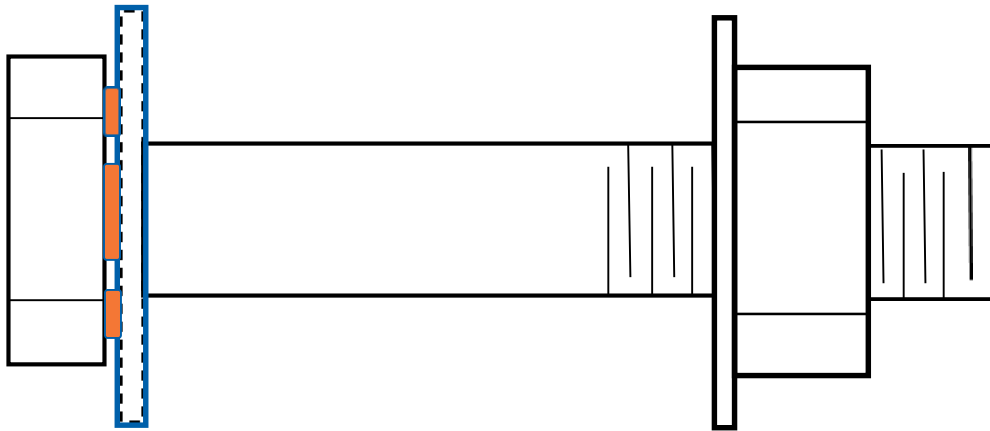
Standard nomenclature for Structural Bolting



H.S. Bolting with DTI – System 1

The preferred method of installing DTIs

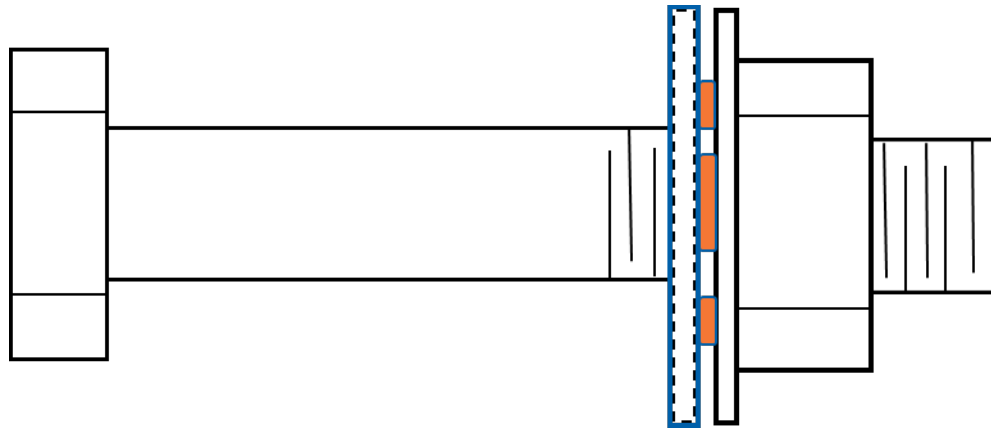
The DTI is placed against the unturned element with the dimples away from the base metal



H.S. Bolting with DTI – System 2

The alternate method of installing DTIs

A DTI placed on the unturned element side has the dimples away from the base metal and the hardened washer against the turned element



Do not allow a DTI to be installed with friction against the dimples.

Installation

After you have accepted the supply of fasteners and DTIs, then proceed with installation.



DTI Installation

A DTI is a 1-Time Use Load Cell

DTI Issues

DTIs are now coming into use in VDOT and we are having three issues.

- 1) What do we do with these things?
- 2) Uniformity from One Lot to the Next
- 3) Creep or Relaxation
- 4) Have we overtightened the bolts?

Acceptance Test

The Acceptance Test is used to Verify the Washers will Indicate the Tension Used on the Job

Uniformity is often a concern

Squirter DTIs

A special variety of DTI is produced by Applied Bolting Called a “Squirter”

The pigment that squirts from the washer is not verification the washers have reached tension. The feeler gages are used to verify the washers validate tension. But the pigment is helpful to see which connections have been tensioned and shows the iron workers they are close to being tight.

Skidmore Testing

Install a fastener assembly into the Tension Indicating Device (Skidmore Wilhelm Device)

Washers may be used as spacers (?)

Remember a hardened washer must be placed against the turned element and the dimples don't touch the base metal or the turned element.

Tighten Bolt

Bring the bolt up to the required tension in the specification

Proof Load

1.05 x Proof Load – Applied Bolting Video

1.15 x Proof Load

Check

Check the Number of Collapsed Gaps

This must be $<$ All

Repeat, repeat

Typically the test is repeated twice more.

Test 1 – 2 gaps

Test 2 – 3 gaps

Test 3 – 3 gaps

Determine Inspection Value

The inspection value is one more than the average of the results

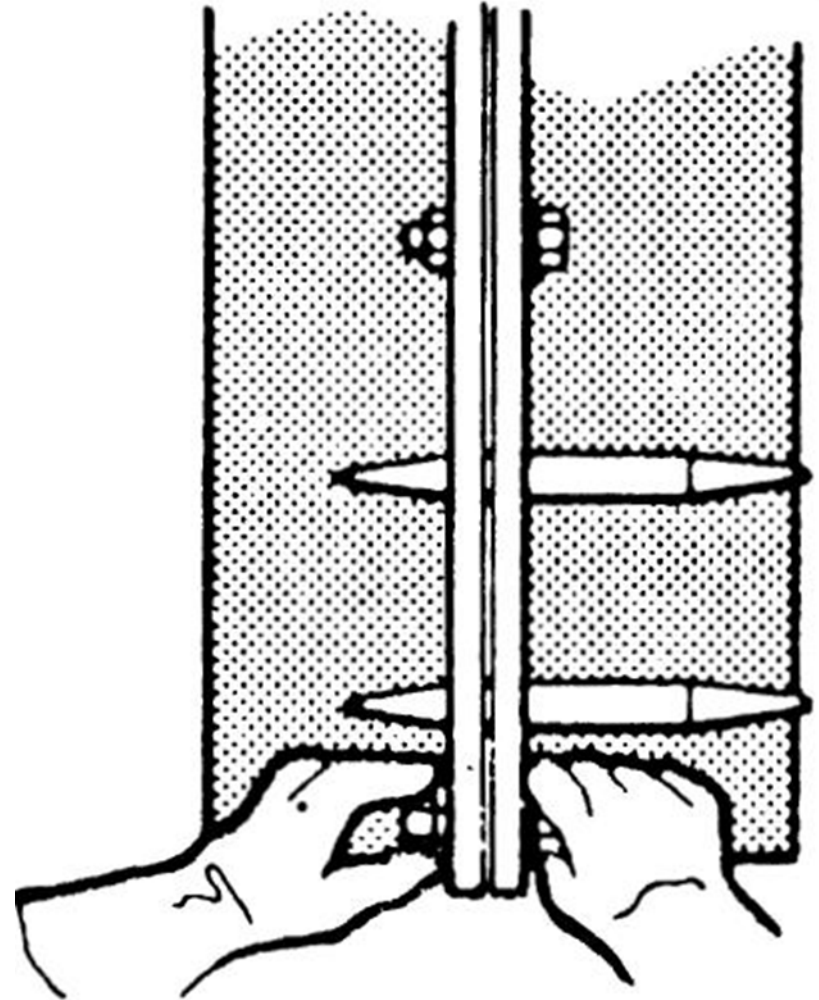
$2 \text{ gaps} + 3 \text{ gaps} + 3 \text{ gaps} = 8 \text{ gaps}$

$8 \text{ gaps} / 3 \text{ trials} = 2.7 \text{ gaps avg.} \Rightarrow 3 \text{ gaps}$

$3 \text{ gaps} + 1 \text{ gap} = 4 \text{ gaps}$

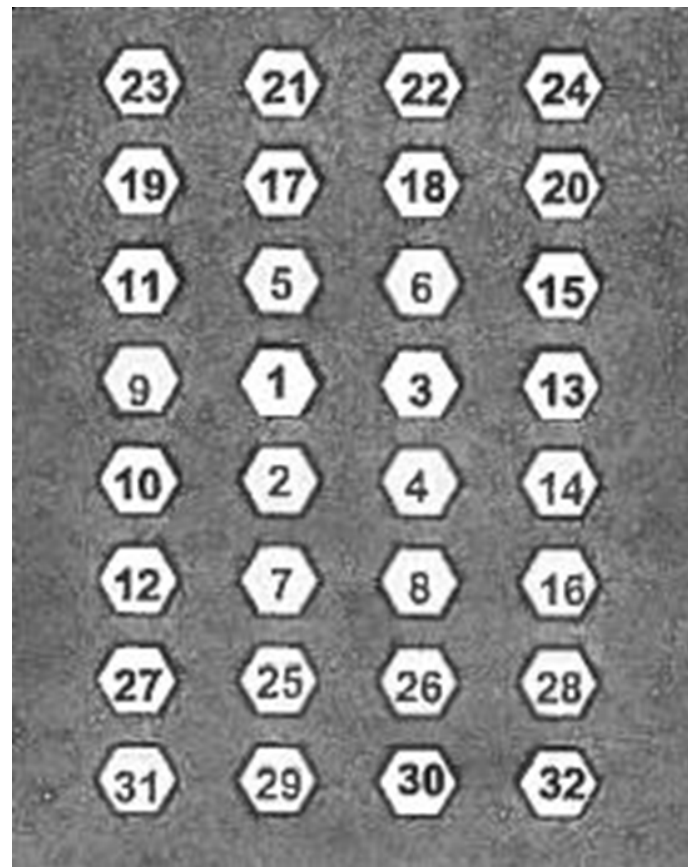
Install Steel & Fasteners

After hanging and pinning the steel, place fastener assemblies in at least 50% of the holes and snug tighten before releasing the pins. Complete the fastener installation and snug remaining. Check 100% for snug tight before moving on. Do not allow the contractor to completely collapse the fasteners as they bring the connection to snug tight.



Tighten Fasteners

Tighten the fastener group from the inside of the pattern to the outside



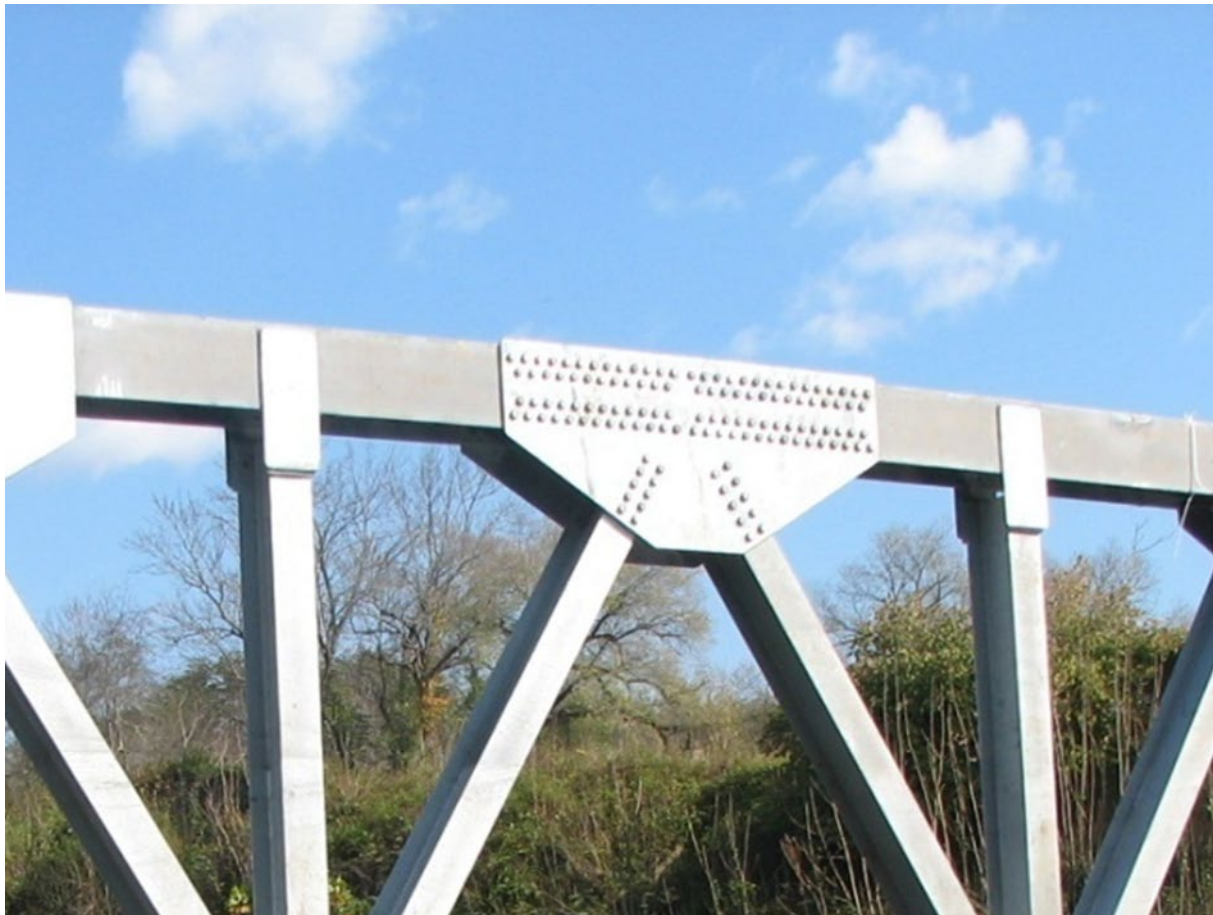
Check the DTI Gaps

A representative sample of the fasteners in the connections must be inspected by the QA.

For VDOT this has been determined to be 10% of the bolts in each connection, with a minimum of 2 bolts inspected per connection.

Game – How Many Connections?

I'll take How many Connections for 100, please.



Game – How Many Connections?

I'll take How Many Connections for 200, please.



Game – How Many Connections?

I'll take How Many Connections for 300, please.



Conducting the QA inspection

How long is the Calibration test valid for the Torque Wrench?

Doesn't matter!!

Step 1 – Perform a Visual Inspection for stick-out, all bolts present and set up the same way

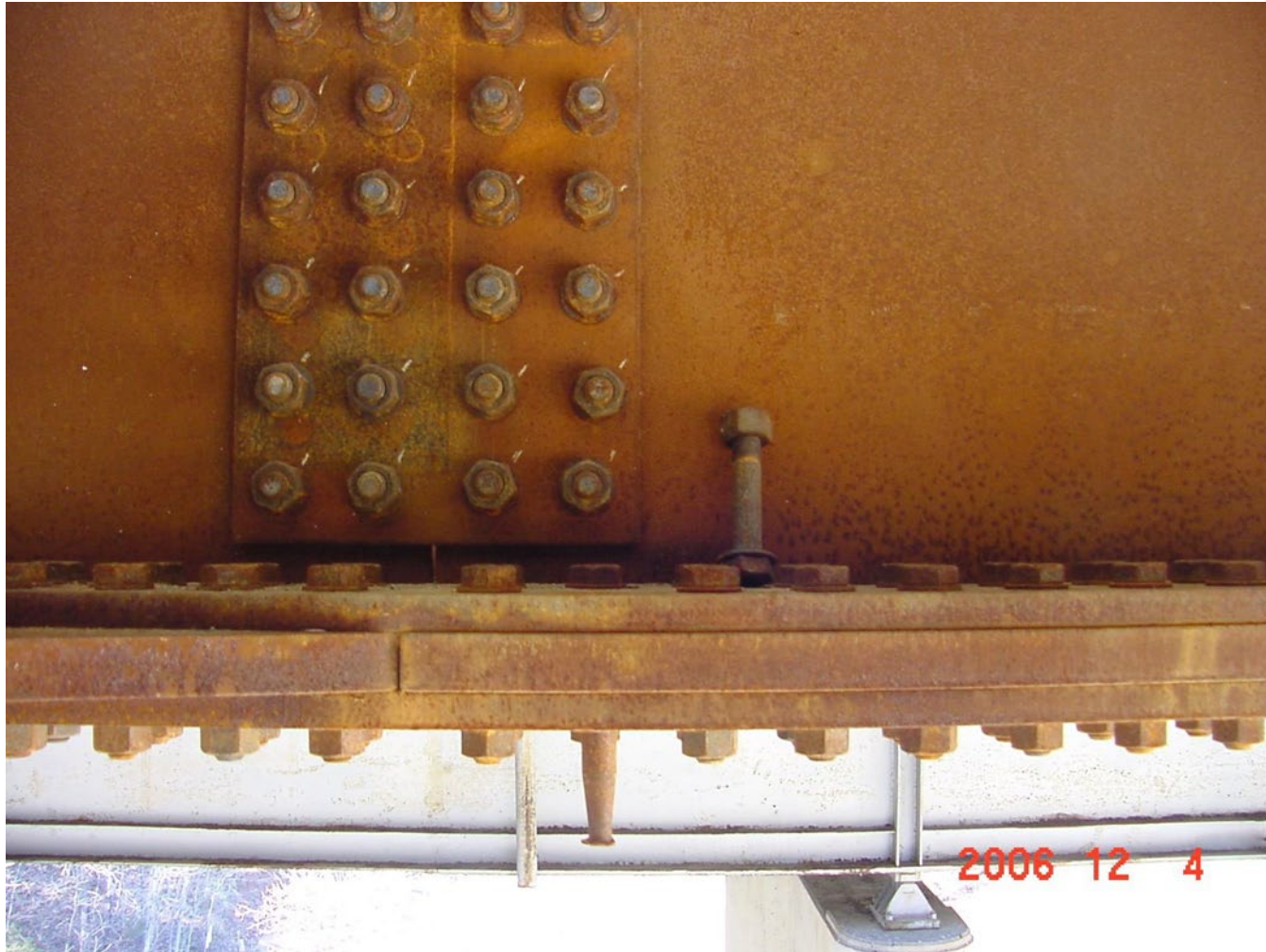
Step 2 – Use the feeler gage to check 10% or 2 fasteners minimum

Step 3 – Note the connection on the framing plan with a date

Visual Inspection



Visual Inspection



Visual Inspection



Visual Inspection



Bolt Installation with DTI Washers

Summary

High-Strength Fasteners are used in Slip-critical connections that apply compression to the steel by tensioning the bolts. Friction in the connection resists the load.

Fastener assemblies (Bolts) are tested and approved without DTI washers

Bolt Installation with DTI Washers

Summary – Continued

DTIs are tested and approved

Fasteners are installed as the steel is hung and monitored to make sure the DTIs are not prematurely collapsed

Final Inspection of 10% of all assemblies in each connection, with a minimum of 2 fasteners per connection checked

Quality Assurance with DTIs

Questions?