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Why Pre-Certified Structural Bolt Sets & DTIs Dramatically Improve Bolting Constructability

More than 100 million structural bolts are installed annually in the U.S.A. Of all the work to assemble a bolted steel frame or a bridge, bolting takes up almost HALF. That's right — almost HALF.

For instance, a medium sized power plant project's steel frame might be detailed with 20 ASTM A325 or A490 bolts per ton of structural steel. For example, the bolting might take place at 6 bolts per man-hour. At a labor rate of $60 per man-hour, an average loaded rate across the United States, that's $200 per ton of steelwork. Overall steel erection of such a frame might cost about $500 per ton, hence the figure of almost 50% for the bolting. That $200 includes hole alignment and preparation, getting the bolts to the "point" up in the steelwork, getting them into the holes, snugging the connections so the steel plies are "in firm but not necessarily continuous" contact, and then tightening the bolts and making sure they have been correctly tightened.

So it's no wonder that improving the "constructability" or "'total installed cost" or 'TIC" of the bolting labor is getting the attention of competent project managers these days. Bridges, power plants, big buildings, industrial process plants: all are undergoing intense efficiency analysis. Bringing industrial engineering analysis to bear on improving the construction process is a potentially rewarding exercise, and already is saving man-hours.

Bolting labor is currently done using structural bolts, nuts, flat washers, and often, DTIs, which have been purchased by the steel fabricator, probably from a large bolt distributor house. All these individual products carry with them manufacturers' quality certificates (MTRs). In addition to the MTRs, the bolt supplier is compelled by the ASTM specification (for A325) and by AASHTO (for A325 and A490) to make sure *an* assembly rotational capacity test (Rc test, defined below) has been performed on each "lot" of fasteners. Currently, when DTIs are to be used on bridges, each lot of DTIs must be selectively tested with each lot of bolts at whatever preload it takes to fully compress the DTI without significant plastic deformation of the bolt (see the DTI Installation Verification Test defined below).

The bolt distributor might actually do these tests themselves, for instance, prior to shipment to the site. But more importantly, it is a Research Council and AASHTO (see definitions below) requirement to duplicate these tests ON SITE prior to installation on each lot of bolt sets, to make sure that the hardware has not deteriorated to the point where it cannot be properly installed. Whatever tightening method is chosen, like calibrated wrench, turn-of-nut, twist-off bolts, or DTIs, you must know in advance whether the condition of the assemblies will actually show correct tensioning. That's what the field tests are to "guarantee." But these field tests impede the smooth execution of bolting, and when there is some difficulty with the tests, the project can actually be stopped. And then everybody gets to shouting at one another and scrambling for their specification manuals.

After all these field tests of the bolt assemblies, including DTIs, which might consume thousands of bolts on a large project, the bolts are tightened so that the DTIs are compressed on every bolt, thus demonstrating that every bolt assembly achieves at least the minimum installation preload. But isn't this exactly what the Rc test was intended to ensure? Sure it is. Here's the core truth:

Any lot of bolt assemblies which has a sufficient/y low nut factor to allow full DTI compression will still have a sufficiently low nut factor at any time in the future if the assembly is still capable of compressing a DTI.

When DTIs are used, therefore, EVERY bolt assembly, when installed with a DTI, is actually "tested" in this manner. In the field, if you know that the "nut factor" is sufficiently low to allow the bolt assembly to achieve full pretension without breaking in combined

stress, in reality the field Rc test for that assembly lot could be avoided entirely.

Whatever knowledge is gained by doing the FIELD Rc test, is also gained by doing the DTI/Bolt Installation Verification test, so why do both? And to counter the argument that the DTI could be used with components from a different set of hardware (a different nut, which might not be up to the task, for example), then why not supply a controlled '"set" of structural bolting hardware which comes either assembled or at least in the same shipping container. The "set" has, of course, a DTI attached to it, and since all DTIs come with a unique lot mark, the identity of the "Rc Approved Set' is known, right up to the point where it is to be inserted into the hole. Wow! This is blamo stuff for "PFEs", or Project Field Engineers, the new boss-persons of major projects all over the place.

For bridges, AASHTO would have to be reworded in such a way to allow bolts in bridges to be used without FIELD Rotational Capacity Tests and without FIELD DTI Installation Verification Tests — providing each bolt, nut, and DTI is procured as a "pre-certified set." The pre-certification step would occur at the time and place that the bolt, nut, and DTI are assembled, and would include the Rc test and the DTI Installation Verification Test (AASHTO Clause 11.5.6.4.7a) done ON THE ASSEMBLY.

Contractors would then simply open the containers of bolt sets having nuts and DTIs with them, stuff them into the steel building or bridge connections, and tension them by compressing the DTIs. All the inspectors have to do is to see that the joints have been brought together before bolt tightening, and then that the tightening process has compressed the DTI. No field Rc tests, no field DTI Installation Verification tests, no project delays, no inspectors puzzling over all these tests and what they mean.

Just getting on with the job, compressing the DTIs, and watching the bottom line get blacker and blacker. Savings of 20% of the total bolting labor (!) have been mentioned. O

Definitions

- **Constructability** - The term used to describe the overall ease or difficulty of managing for improved efficiency of work on a construction site.

- **Rotational Capacity Test** - The Rc test is an ASTM test of bolt/nut lubricant meant to ensure that the "nut factor" (the torque resistance divided by the tension) is less than 0.25, and in which bolt-load P is measured at the end of a specific rotation past snug call "P (end Rc)" performed in a Skidmore-Wilhelm bolt tension calibrator, without a DTI installed. In simple terms, the Rc test tries to tell you whether the nut has sufficient lubricity to allow the bolt to be tensioned correctly without breaking due to excessive combined stress from torsional and tensile forces.

- **DTI installation Verification Test** - An AASHTO (bridge) test of a bolt assembly and a DTI to ensure that the fastener will be at or above the desired installation tension when half or more of the spaces in the DTI have a gap less than .005", and to ensure that the fastener will not undergo excessive plastic deformation at the minimum DTI gap allowed on the project. (Also known as the "AASHTO App. A6' test.)

- **P(min.)** - the minimum bolt tension required from AASHTO (e.g. 39 kips for a 7/8" A325, etc.)

- P(end Rc) - The bolt tension measured in a Skidmore-Wilhelm bolt tension calibrator after the specified rotation has been applied past snug in a Rotational Capacity Test (i.e. 2 times the installation rotation).

- **P(flat DTI)** - The bolt tension measured in a Skidmore-Wilhelm bolt tension calibrator in a DTI Installation Verification Test when the DTI has been flattened to the point where a ,005" feeler gage will not enter into ANY of the DTI gaps, but where there is "...a visible gap in at least one space..."

- **AASHTO** - American Association of State Highway and Transportation Officials. This group writes the parent specification from which all state projects derive if they have some element of Federal funding.

- **Research Council on Structural Connections** (RCSC) - The group of some 60 individuals which writes the parent bolt installation specification which in turn is adopted by the AISC and AASHTO.