604 STEEL STRUCTURES

604-1 Description

The most common steel structures found on ADOT projects are sign structures, sign posts, light and traffic signal poles, handrails, cattle guards, underdrains, and steel piling. Although these are all steel structures, only underdrains, sign structures, poles, and cattle guards refer to Section 604 for additional specification requirements.

Steel bridges are less common on ADOT projects, but do fall under this specification when they are built.

Field inspection of steel structures is a straightforward process when compared to reinforced concrete structures. With reinforced concrete, the structure is built from scratch. The Contractor must build forms to shape the structure and very little off-site fabrication is done except when precast members are used. On the other hand, much prefabrication and pre-assembly is done with steel construction. The steel is made and shaped in a steel mill. A steel fabricator cuts, punches, bends, and welds the basic steel shapes from the mill to form each member of the structure. The fabricator may even assemble part of the steel structure in the shop before shipping. By the time the components of the structure arrive on the job site, most of the work has been done. All that is left for the Inspector and Resident Engineer is to oversee the erection and final assembly.

Erection and final assembly inspection basically involves making sure the Contractor follows the requirements in the approved shop drawings and the specifications. The shop drawings will show how each part of the structure is to be connected together; which parts are to be used; what specs they must meet; and what order the parts are to be assembled.

Good inspection of steel structure construction involves:

1. Ensuring that all the steel and steel parts delivered are the correct type and grade specified (ex. steel plates and members are usually ASTM A36 steel, high strength bolts are the A325 type). This involves checking the Project Plans, shop drawings, and the markings on the steel (also checking the paperwork that accompanies each steel shipment).

2. Verifying that each component has the correct dimension as shown on the approved shop drawings or required by the specifications. The sections on standard mill practices and structural shapes in the Manual of Steel Construction are excellent guides (see the references at the end of this chapter).

3. Ensuring that the structure is erected and assembled in strict accordance with the procedures described in the approved shop drawings, the Special Provisions and the Standard Specification; especially that no components are bent, over-stressed, cut, punched, drilled, or otherwise damaged to expedite the erection procedures (unless approved by the Structure Designer or Bridge Group). Monitoring the erection process for safety and structural stability is important.

4. <u>Paying close attention to how connections are made</u>. In steel construction, *connections* are defined as the method by which two or more steel members are joined. Connections are either welded, bolted, or pinned. In assembling a steel structure, the Inspector must ensure proper connection installation. Most steel structures are designed to fail in the steel members where the steel will yield and warn people of the danger (breakaway post are the exception). Failures in a connection are highly undesirable. They are usually sudden and without warning. Proper inspection of field connections by the Inspector will help to ensure that the structure will behave safely and predictably when placed in service.

These are the overall goals for the inspection of steel structures. The rest of this section describes in more detail structural steel inspection procedures and the underlying engineering objectives.

604-2 Materials

604-2.01 Structural Steel

ADOT steel structures are made of high-grade carbon steel (usually "A36" steel). This kind of steel is stronger and more ductile than the steel found in more common items such as refrigerators and filing cabinets. A36 steel will yield considerably (or stretch) before breaking warning people that the structure is about to fail.

This type of safety mechanism will only work if the right kind of steel is supplied to the project. The Inspector must examine all steel members, plates, bolts, nuts, washers, and other hardware for:

- shipping documents that accurately identify the quantities, shapes, and type of steel shipped;
- Certificate of Analyses that are complete and descriptive of the materials supplied including grade identification, test results, and the applicable lot or heat number;
- the appropriate markings which would show the type and grade of steel used (not all structural steel is marked); and
- compliance with key dimensional requirements such as thickness, length, width, diameter, and section shape.

Steel structures are most likely to fail if the wrong materials are used. This is why it is important for the Inspector to verify that only the proper materials (correct grade, shape and size) are supplied.

604-2.03 High-Strength Bolts, Nuts and Washers

In this section, high-strength bolts and high-strength bolted connections will be discussed. Bolted connections are the most common type of field connection. Careful inspection of bolted connections will help ensure that they do not become the weakest link in a structure.

Identifying and Sampling High-Strength Bolts

AASHTO and ASTM recognize only three types of bolts for structural work. A307 bolts are the everyday normal strength bolts used in a wide variety of applications from holding up light fixtures to cattle guard assembly. The maximum allowable tensile stress in A307 bolts is 20 ksi (138 MPa). The two other types of bolts are designated as high-strength bolts. A325 bolts have a maximum allowable tensile strength of 44 ksi (303 MPa) more than double the strength of an A307 bolt while A490 bolts have a maximum strength of 54 ksi (372 MPa).

With such a wide range of strengths, it is easy to see why it is so important to identify the type of bolt used in a connection. There have been documented cases in which the wrong type of bolt or an inferior counterfeit bolt had been used in a structural connection with devastating results.

Exhibit 604-2.03-1 illustrates how to identify high strength bolts, nuts, and washers. Exhibit 604-2.03-2 gives dimensional information on structural bolts and washers. The Commentary on Specifications for Structural Joints Using ASTM A325 or A490 Bolts found in the *Manual of Steel Construction* can provide additional information in identifying high-strength bolts, nuts, and washers.

High-strength bolts need to be properly lubricated before being placed in a connection. The lubrication is necessary to limit the amount of friction developed between the bolt, the nut, and the connection plates. The head of the bolt can be twisted off during torquing if too much friction develops.

Inspectors should sample bolts, nuts, and washers in accordance with the Sampling Guide and deliver them to Materials Group for testing. Make sure the Contractor orders extra hardware so the correct number of samples can be taken without leaving the project short.

Understanding Bolted Connections

A structural connection transfers loads from one structural component to another. Bolted connections consist of plates, bolts, nuts, and washers--they all play a part in transferring loads across the connection.

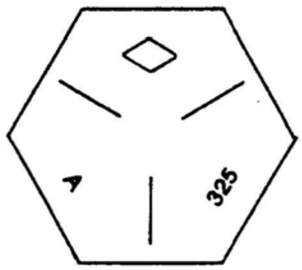
There are two types of bolted connections. Both look the same, only the function of the bolts changes. The first type is the *bearing connection*. Loads are transferred across the joint by shear stresses on the bolt and bearing stresses on the plates caused by the bolts. If the loads get too high, either the bolts will shear or the plates will rupture as the bolts tear out of their holes. When bearing-type connections are specified, the bolts only need to be snug tight to keep the bolt properly aligned and secure after installation.

The other type of connection is the *slip-critical connection*. Loads are transferred by means of friction between the plates and the structural members at the connection. The role of the bolts, nuts, and washers is to provide a clamping force between the connection plates and the structural members to prevent any sliding. This connection is designed to prevent any movement of the plates or bolts during normal loading conditions. Under extreme loading conditions (after slippage has occurred), the connection behaves just like a bearing-type connection. However the idea behind the slip-critical connection is to design the connection so it doesn't slip. Loads are transferred only through friction. The bearing properties of the connection are used only as an added factor of safety. (Connections where the bolts are placed in direct tension by the loads in the members also fall under the slip-critical category since the design and behavior of the connection are similar.)

Slip-critical connections are used more often in highway structures than bearing-type connections because they more effectively handle stress reversals, impacts, vibrations and other extreme stress changes. Slip-critical connections are more efficient than bearing connections, as they require fewer bolts in the connection to carry the same load. Bearing connections are more prone to metal fatigue when they are subject to repetitive stress changes.

HIGH STRENGTH BOLT IDENTIFICATION

A - 325 BOLT



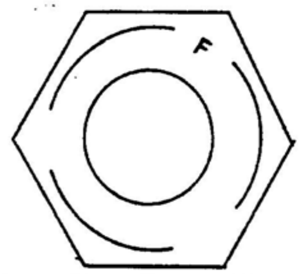
Bolts **must** be marked A-325 or M-164 and have manufacturers symbol.

Type 1 may have 3 radial lines at 120°.

Type 2 **shall** have 3 radial lines at 60°.

Type 3 **shall** have A-325 or M-164 underlined.

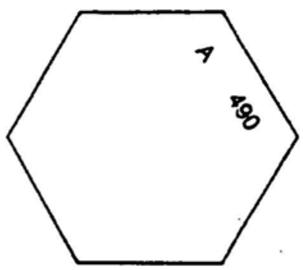
NUT



Nuts **must** have 3 curved lines and may have letter symbol.

Length of curved lines may vary

A - 490 BOLT

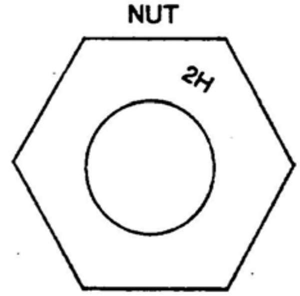


Bolts **must** be marked A-490 or M-253

Type 2 **shall** have 6 radial lines at 30°.

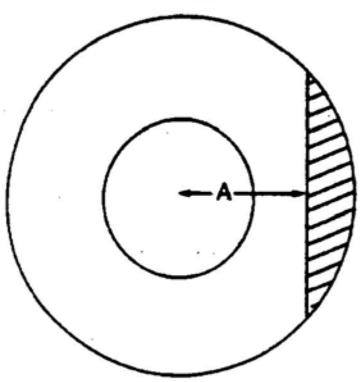
Type 3 **shall** have A-490 or M-253 underlined.

NUT



Nuts are marked 2H or DH and may have a manufacturers symbol

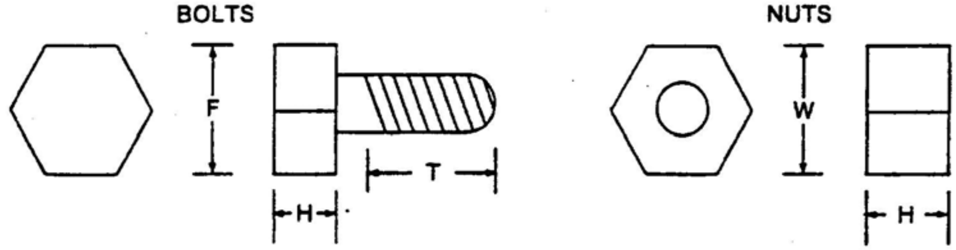
CLIPPED WASHERS



The minimum dimension "A" is ⅞ of the bolt diameter.

Exhibit 604-2.03-1 High Strength Bolt Identification

HEAVY HEXAGON STRUCTURAL BOLTS & NUTS DIMENSIONS



NOMINAL BOLT SIZE - D	WIDTH ACROSS FLATS - F	HEIGHT BOLT - H	THREAD LENGTH - T	HEIGHT NUT - H
1/2	7/8	5/16	1	31/64
5/8	1-1/16	25/64	1-1/4	39/64
3/4	1-1/4	15/32	1-3/8	47/64
7/8	1-7/16	35/64	1-1/2	55/64
1	1-5/8	39/64	1-3/4	63/64
1-1/8	1-13/16	11/16	2	1-7/64
1-1/4	2	25/32	2	1-7/32
1-3/8	2-3/16	27/32	2-1/4	1-11/32
1-1/2	2-3/8	15/16	2-1/4	1-15/32

WASHER DIMENSIONS

	Circular Washers				Square or Rectangular		
BOLT SIZE - D	NOMINAL OUTSIDE DIA. *	NOMINAL HOLE DIA	THICKNESS MAX	THICKNESS MIN	MIN. SIDE DIMEN.	MEAN THICKNESS	SLOPE OF TAPER
1/2	1-1/16	17/32	.097	.177	1-3/4	5/16	1:6
5/8	1-5/16	21/32	.122	.177	1-3/4	5/16	1:6
3/4	1-15/32	13/32	.122	.177	1-3/4	5/16	1:6
7/8	1-3/4	15/16	.136	.177	1-3/4	5/16	1:6
1	2	1-1/16	.136	.177	1-3/4	5/16	1:6
1-1/8	2-1/4	1-1/4	.136	.177	2-1/4	5/16	1:6
1-1/4	2-1/2	1-3/8	.136	.177	2-1/4	5/16	1:6
1-3/8	2-3/4	1-1/2	.136	.177	2-1/4	5/16	1:6
1-1/2	3	1-5/8	.136	.177	2-1/4	5/16	1:6
1-3/4	3-3/8	1-7/8	.178**	.28	—	—	—
2	3-3/4	2-1/8	.178	.28	—	—	—
Over 2 to 4 incl.	2D-1/2	D+1/8	.24***	.34	—	—	—

* May be exceeded by 1/4 in.
** 3/16 in. nominal
***1/4 in. nominal

Exhibit 604-2.03-2 High Strength Bolt and Nut Dimensions

You can identify the type of bolted connection by checking the Project Plans or the shop drawings to determine how the bolts are to be tightened. If the bolts are specified to be snug tight, the connection is the bearing type. If the bolts are required to be tensioned, the connection is slip-critical.

Snug-Tight Bolts

The Inspector must verify that all bolts in a bearing connection are snug tight. Even bolts in a slip-critical connection are to be in a snug-tight condition before tensioning. AASHTO paragraph 11.5.6.4.1 (from Section 11, Steel Structures, the Inspector should have a copy) defines *snug tight.* Section C8 of the Commentary on Specifications for Structural Joints Using ASTM A325 or A490 Bolts in the *Manual of Steel Construction* is helpful in determining when a bolt is snug tight.

If the bolt length is long enough, snug-tight bolts should contain two nuts with the second following the first (double nutting). This prevents the first nut from loosening after the bolt has been snugged tight.

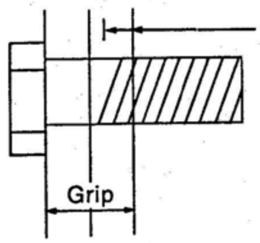
Bolts are always tightened and tensioned from the most rigid (stiffest) part of the connection to free edges. *Most rigid* is usually defined as the thickest or stiffest part of the connection or the interior of the connection. Check with the Resident Engineer if you are unsure where to start tightening.

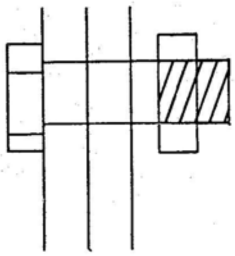
Bolt and Thread Lengths

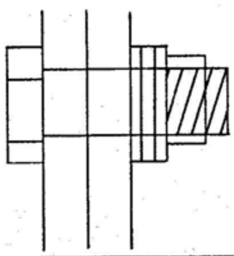
Bolted connections are much stronger when the threaded portion of the bolt shaft is kept out of the *grip,* which is defined as the connection plates and the adjoining structural members. For this reason, limits are placed on how far the threads can penetrate into the grip (see Exhibit 604-2.03-3). On the other hand, if the thread is too far out of the grip, the nut may run out of thread before the bolt is properly tightened. Washers can be added to remedy this situation. If washers are used, the bolt length should be increased in 5/32-inch (4-millimeter) increments for flat washers and 1/4-inch (6millimeter) increments for beveled washers. The bolt lengths determined by the above procedure should then be increased to the next greater 1/4-inch (6-millimeter) increment. These lengths allow for manufacturer's tolerances and will provide an adequate length of bolt protrusion through the nut (see Exhibit 604-2.03-3 for calculating bolt lengths).

The Inspector must check each bolt in a connection to verify these conditions are satisfied. The Inspector should also check the bolt length to ensure that at least two threads are exposed after all the washers and the nut or double nuts have been added.

DETERMINING CORRECT BOLT LENGTH







Bolt Size, in Inches	To determine required bolt length add to grip, in inches
½	11/16
⅝	⅞
¾	1
⅞	1⅛
1	1¼
1⅛	1½
1¼	1⅝
1⅜	1¾
1½	1⅞

TO DETERMINE CORRECT BOLT LENGTH

- ➛ Use the table to determine the bolt length then take the next ¼ inch increment.
- ➛ Check that the thread does not protrude more than the specified amount into the connected members.
- ➛ Check that the nut will not run out of thread (use the dimensions in Exhibit B)
- ➛ Check that the bolt will protrude from the nut.

Exhibit 604-2.03-3 Determining Correct Bolt Length

Tensioning Bolted Connections

For slip-critical connections, the bolts are tensioned to at least 70 percent of their allowable tensile strength. This provides the clamping force needed to keep the connection plates from sliding. The Inspector must closely monitor and document this process. At least 10 percent of the bolts in a connection should be checked by the Inspector for proper tensioning. If one bolt fails, the entire connection should be re-tightened and the checking process repeated.

Tightening can be done with a manual torque wrench or a power impact wrench. Over-tightening up to 85 percent of allowable strength is acceptable.

The Project Plans or shop drawings will specify which bolts are to be tensioned. Bolts that are not specified to be tensioned should be snug tight. The Inspector should not allow the tensioning of bolts unless specified. For example, anchor bolts embedded in concrete foundations and bolts on breakaway-type base plates are never tensioned.

When tensioning is specified, AASHTO Subsection 11.5.6.4 allows four methods for bolt tensioning. The Bridge Designer may override AASHTO and permit only one or two of the tensioning methods (see the Project Plans).

1. *Turn-of-Nut Tightening*

   Basically the turn-of-nut method requires the nut to be tightened a certain number of turns after a snug-tight condition is reached in the bolt. The number of turns needed to tension the bolt depends upon the length of the bolt, the slope of the outer faces of the connection plates or structural members, and the type of washers used (see Exhibit 604-2.03-4). AASHTO specifications require the Contractor to prove that this method will develop the required tension by testing the bolt and nut assembly in a direct tensioning measuring device such as the Skidmore-Wilhelm Calibrator discussed later in this subsection.

2. *Calibrated Wrench Tightening*

   This method uses a torque wrench to determine the amount of tensioning in a bolt. The method assumes that the amount of tension in a bolt is directly related to the amount of torque it takes to turn the bolt. In practice however, friction can develop between the nut and the bolt greatly increasing the amount of torque needed to achieve a given tension. This friction is dependent on temperature, moisture, and the cleanliness of the bolts. For the last few years this type of tensioning was not allowed by AASHTO. However this method is allowed again but with some stipulations.

   The first stipulation is the requirement for daily calibration of the torque wrench in a direct tension calibrator. The second is the use of only hardened washers. The third stipulation is the protection of the nuts, bolts, and washers from dirt and moisture. This last requirement has probably the greatest effect on consistent tensioning of the bolts by this method. Dirty and even slightly rusty bolts greatly affect the amount of torque needed to develop a given tension in a bolt. This method of tensioning is much more inspection intensive requiring very careful monitoring and documentation by the Inspector.

TURN-OF-NUT TIGHTENING

Bolt Length measured from underside of head to extreme end of point	Nut Rotation[1] from Snug Tight Condition		
	Both faces normal to bolt axis	One face normal to bolt axis and other face sloped not more than 1:20 (bevel washer not used)	Both faces sloped not more than 1:20 from normal to bolt axis (bevel washers not used)
Up to and including 4 diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 diameters but but not exceeding 8 diameters	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameters[2]	2/3 turn	5/6 turn	1 turn

[1]Nut rotation is relative to bolt, regardless of the element (nut or bolt) being turned. For bolts installed by 1/2 turn and less, the tolerance should be plus or minus 30°; for bolts installed by 2/3 turn and more, the tolerance should be plus or minus 45°.

[2]No research work has been performed by the Research Council on Riveted and Bolted Structural Joints to establish the turn-of-nut procedure when bolt lengths exceed 12 diameters. Therefore, the required rotation must be determined by actual tests in a suitable tension device simulating the actual conditions.

Exhibit 604-2.03-4 Turn-of-Nut Tightening

3. *Installation of Alternate Design Bolts*

This method is just a variation of the second method. It uses a breakable splined adapter that grips the nuts and breaks off after a certain torque is reached. These fasteners must be properly stored and pre-tested in a direct tension calibrator before use.

4. *Direct Tension Indicator (DTI) Tightening*

In this method, collapsible washers are used to indicate when a certain tension in the bolts is reached. The washers, which are placed under the head of the bolt, collapse when the bolt achieves a predetermined tension. This method is the most accurate for determining the tension in a bolt. However the washers should still be tested at the job site in a direct tension calibrator to demonstrate that they do collapse at the required tension. It is important for the Inspector to ensure that the collapsible washers are installed in accordance with the manufacturer's recommendations.

The commentary in *Manual of Steel Construction* and the FHWA publication called *High Strength Bolts for Bridges* provide more information on tensioning methods and inspection procedures. Their consultation is highly recommended.

Skidmore-Wilhelm Calibrator and Torque Wrenches

The Skidmore-Wilhelm Calibrator directly measures tension in a bolt. It is used to calibrate torque wrenches, verify tension in bolts tightened by the turn-of-nut method, and check the tension developed in a bolt when DTIs or alternate design bolts are used. Exhibit 604-2.03-5 shows the calibrator.

There should be a Skidmore-Wilhelm Calibrator on the project site when high-strength bolts are tensioned. The Phoenix Regional Lab has Skidmore-Wilhelm Calibrators that the field office can borrow. They also have torque wrenches available for use.

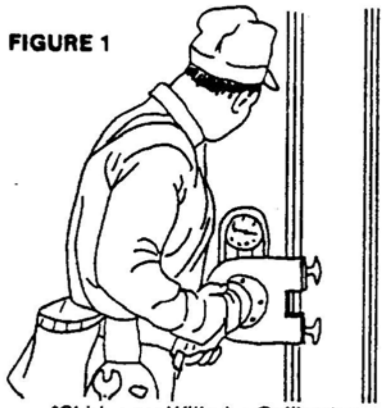
The field office is responsible for verifying that all Skidmore-Wilhelm Calibrators and torque wrenches are properly calibrated before use on the project. The Materials Group Annex (602-712-7741) can calibrate these instruments. It is permissible to use a calibrator or torque wrench supplied by the Contractor as long as these devices have been calibrated within the last year by a recognized calibration service (contact the Materials Group Annex for verification of calibration service).

Calibration of Wrenches:

The impact wrenches shall be calibrated at the beginning of each working day and each time a new size or lot of bolts are used or there is a change in wrench connections such as hose, extensions or universal sockets. Three bolts of the same grade, size and condition as those being used shall be placed individually in the calibration device. There shall be a washer under the part turned in tightening each bolt. Figure 1 shows a method of calibrating a wrench.

Calibrate wrench on the job site, Illustrated is the method using a hydraulic tension calibrator* that records on a dial the tension of the bolt.

FIGURE 1



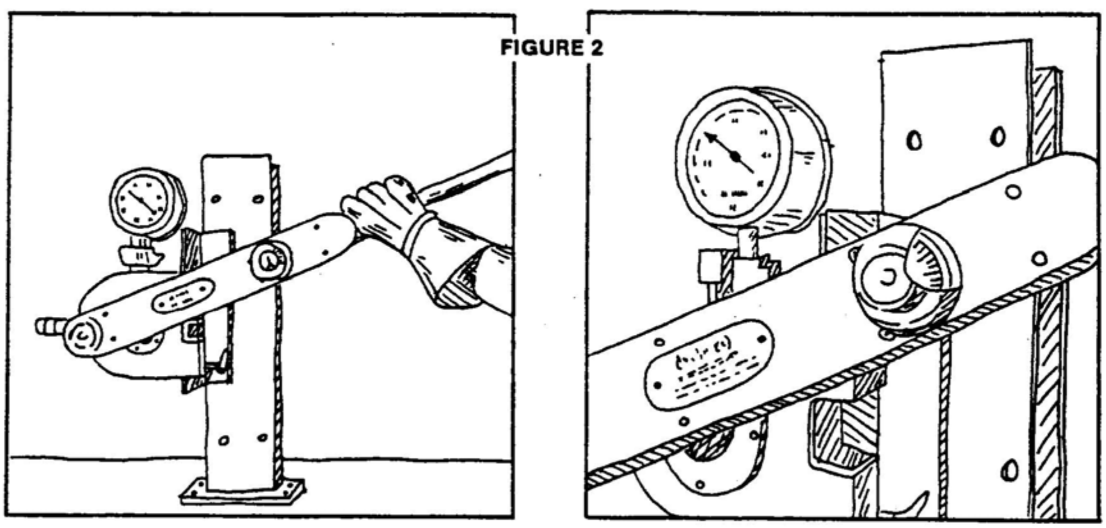
*Skidmore-Wilhelm Calibrator

a. Use same lot of fastener assemblies for testing that will be used on the job.
b. Use same length of hose and socket that will be used on the job.
c. Gage needle should be slightly **above** the required tension. Make enough checks so this reading is consistent. (Figure 3)
d. Change bolts with each check.
e. Replace equipment not reaching proper tension with larger equipment.

Calibration of Inspection Torque Wrench:

Figure 2 shows the operator calibrating a hand-indicator torque wrench. The bolt is brought to the proper tension in the calibrator. The dial on the wrench was set at "zero" and sufficient torque applied to slightly move the nut in the tightening direction. At this point, the wrench dial shows the foot-pounds required to further rotate the nut. This test should be made on at least three bolts of each lot and the torque figures averaged. This average may then be used for inspection of installed bolts of the same lot. The torque wrenches used by inspectors of both the erector and the State should be tested and compared at the same time for purposes of uniformity.

FIGURE 2



Bolt Diameter (inches)	Recommended Bolt Tension For Calibrating Wrenches in Kips		Required Minimum Bolt Tension in Kips		*Equivalent Torque For Minimum Bolt Tension in ft. lbs.	
	A325 Bolts	A490 Bolts	A325	A490	A325	A490
½	13.2	16.5	12	15	100	125
⅝	20.9	26.4	19	24	198	250
¾	30.8	38.5	28	35	350	438
⅞	42.9	53.9	39	49	570	716
1	56.1	70.4	51	64	852	1069
1⅛	61.6	88.0	56	80	1052	1503
1¼	78.1	112.2	71	102	1482	2130

Exhibit 604-2.03-5 Skidmore-Wilhelm Calibration

Documentation

Inspectors assigned to bolt tensioning should document:

- when and where hardware samples were taken for materials testing;
- which bolts or bolt groups were tensioned and the tensioning force that was achieved;
- what method was used to achieve the required tension in the bolts (turn-of-nut, DTI's, etc.);
- the order in which the bolts were tensioned (a diagram may be useful here);
- torque readings on all bolts if a torque wrench was used;
- any bolts that were tightened to only a snug-tight condition;
- any re-lubricating of bolts if ordered by the Inspector or Resident Engineer;
- how often the tensioning method was checked with the Skidmore-Wilhelm and what the results were; and
- any corrective actions that were taken to properly assemble the bolted connection, like changing bolts lengths or hole reaming.

Complete documentation of how bolted connections were constructed can become crucial if there is a failure of the structure later on. The documentation also shows that the Inspector was actively involved in verifying tensioning of bolts and reduces the chance that any serious defects exist in the connection.

604-2.10 Certification of Structural Steel

Certifications for structural steel elements such as plates, steel members, nuts, bolts, and washers require additional information above and beyond what ADOT normally requires on a certification.

Certifications for structural steel are called Certificates of Analysis and require a regular Certificate of Compliance in addition to the following test results:

Structural Steel Shapes and Plates

- Chemical analysis (metallurgical composition)
- Charpy V-notch test (CVN) for structural steel subject to tensile loading

High-Strength Bolts, Nuts, Washers

- Rotational capacity test
- Proof load test
- Zinc thickness test (when galvanized bolts are specified)

The heat number of the steel covered by the Certificate of Analysis should be shown on the test results and on the Certificate of Compliance. The type and grade of steel must be shown on the Certificate of Compliance.

604-3 Construction Requirements

604-3.01 Shop and Working Drawings

Every steel structure, whether it be a sign structure, light pole, or bridge, requires shop and working drawings showing:

- how each steel member will be fabricated;
- how each connection will be made and the details for making those connections; and
- how the structure will be erected and assembled.

The shop drawings are intended to be a complete set of step-by-step fabrication and assembly instructions—not very different from the instructions included in a model airplane kit or furniture assembly box.

Complicated steel structures may include separate erection schemes and temporary shoring drawings, but these documents still fall under the requirements for shop and working drawings.

The steel fabricator is usually the one who prepares all the shop and working drawings for a steel structure.

Shop and Working Drawings Reviews

Like all shop and working drawings, the Contractor needs to allow for sufficient review time of the shop drawings before scheduling fabrication (see Subsection 105.03). The Resident Engineer should do an initial review of all shop and working drawings as recommended in Subsection 105.03 of this manual. Then shop drawings should be forwarded to the Designer of the steel structure (either a design consultant or a design team within ADOT) for final review and approval.

Once approved, two copies of all shop and working drawings should be sent to the Bridge Project Engineer in Bridge Group assigned to oversee the project. The Bridge Project Engineer will forward approved drawings to the shop Inspector who would oversee the shop fabrication of the steel structure for the Department. A copy should also be given to the Inspector.

The fabricator's detailed shop and erection drawings, after approval by the Designer of the steel structure, become a part of the Project Plans and are used in place of the Project Plans insofar as fabrication and erection details are concerned. If the Inspector or Resident Engineer finds something in the Project Plans contrary to what is shown in the approved shop and working drawings, the Designer of the steel structure should be called for clarification.

Reproducible shop drawings (mylars or sepias) must be included with the as-built plans for any bridge structures (refer to Subsection 105.03 Standard Specifications).

604-3.04 Shop Inspection

Subsections 604-3.02 and 604-3.04 require the Contractor to make arrangements with the Department for shop inspections of structural steel components. Written notice can take the form of a shop drawing submittal, a letter if the shop drawings are not ready, or a note in the weekly meeting minutes. The key is to give adequate notice—at least three months so Shop Inspectors can be scheduled for the work.

Bridge Group is responsible for all shop inspections of steel structures except for steel poles. They use on-call consultants to provide Shop Inspectors at the fabricator’s plant.

604-3.06 Welding

Most welding on steel structures is done in the shop. ADOT’s Shop Inspectors are certified by AWS to inspect shop welds. It is rare for welding to be done in the field, but when it is, it should comply with the following welding policy.

ADOT Welding Policy

1. Welding done on any structural steel, rebar, or other metal components on any ADOT structure must be done in accordance with the Bridge Welding Code (see references). Copies of the Code are available from Bridge Group, Materials Group, and the ADOT Library.

2. All welding, regardless of where it is done (shop or field) or what components are welded (rebar, steel, or other metals), must be done by an AWS certified welder. This includes temporary steel structures such as falsework and underground shoring. Contractors must submit copies of current AWS certification for all welders to the Resident Engineer before any field welding begins.

3. All shop welds must be inspected and approved by an AWS Certified Welding Inspector. An AWS Certified Welding Inspector must inspect certain field welds. They include welds for:

   A. any bridge component (except for very minor bridge elements like sole plates);
   B. any traffic barrier system such as bridge rail, guardrail, impact attenuation systems, and handrails (barriers such as right-of-fence and other fencing used to restrict access are excluded); and
   C. any structure or structural member in which failure of the weld would risk public safety (such as sign or mast arm falling on the road). This would include, but is not limited to, overhead sign structure components, light and signal mast arms, and any overhead steel support brackets.

   AWS Certified Welding Inspectors are trained in X-raying welds and using other detection methods for precisely determining the integrity of a weld. Bridge Group has on-call Welding Inspectors that will visit the site to inspect field welds. The Resident Engineer should schedule any welding inspections through the Bridge Project Engineer assigned to monitor the project.

4. No field welding is to be done without the approval of the Steel Structure Designer. Structural pieces that are too long or too short should not be torch cut or spliced in the field just to speed up erection. Steel members that do not fit should be sent back to the shop for alteration.

604-3.08 Erection

Site Inspection

Steel erection often involves lifting equipment, safety hazards, traffic control, and a deluge of documentation. For large steel structures such as bridges, the Resident Engineer and the Contractor should have a pre-erection meeting to discuss erection procedures, traffic control, crew hours, safety procedures, paperwork, and inspection requirements. Inspectors need to have a copy of the *Manual of Steel Construction* and Section 11 of the *AASHTO Standard Specifications for Bridges* to verify steel shapes, connection preparation, and assembly procedures. They should also have a copy of all approved shop and working drawings.

Upon delivery, steel should be inspected for signs of damage and any such damage should be documented and reported to the Contractor. All steel members should be tagged or marked by the Shop Inspector to indicate their acceptance by the Shop Inspector. Untagged members should be brought to the attention of the Resident Engineer for further investigation. In general, the Shop Inspector will not tag hardware such as nuts, bolts, and bins since these items are to be inspected and sampled by the Inspectors at the project site.

The unloading of the steel must be accomplished by means of equipment and methods that will not damage the members. The steel should be moved by the use of slings and wood blocks to prevent damage to the flanges. Steel members should never be dropped.

Steel should be stored in a well-drained area that is in no danger of being flooded. The members should be handled and transported in an upright position. All beams and girders should be placed in an upright position on wooden blocks. Long members should be supported in a manner that will prevent damage due to excessive deflection. Deep members should be braced to prevent overturning.

The Contractor has to provide safe access for the Inspectors to do their inspections (see Subsection 105.12). This means that the Contractor will have to leave the fall protection equipment in place and provide the necessary access and equipment so that Inspectors can properly perform their inspections. ADOT is responsible for supplying Inspectors with the appropriate personal protective equipment, while the Contractor must provide the fall protection system and any lifting equipment necessary to inspect the work.

Bearings

Before the erection of structural steel begins, the centerline of bearings should be laid out and marked on all substructure units. Bearing areas should be checked to verify that a plane surface will provide uniform contact with the steel at the correct elevation. If the concrete surface that will be in contact with the bearing pad is rough or irregular, it should be ground flat to provide full and uniform bearing.

If a bearing area is low with respect to other areas on the unit or in relation to other units of the structure, shims of the same size as the bearing plate may be needed to adjust the bearing plate elevation. Avoid using a number of thin shims if a single one of the required thicknesses can be made from plates of standard thickness. The shims should be made from the same type of steel as that specified for the bearings. If shims are needed, approval from the Structure Designer and Bridge Group will be required.

Assembly

During erection, the Inspector should verify that all members are placed in their proper position in the structure by checking match marks or identification marks on the members with the location shown on the erection drawings.

Bearing surfaces and metal surfaces in contact with each other must be free of rust, loose mill scale, dirt, oil, or grease.

Any contact surfaces of beams, girder splices, or main truss connections to be connected by high strength bolts must be free of paint or lacquer. Primer is usually acceptable.

The steel should fit together with very little strain or distortion. If bolt holes are only slightly out of alignment, usually it is possible to bring the pieces into their proper position with drift pins. However if the holes fail to line up properly (to the extent that forcing the drift pin through would result in enlargement of the hole or distortion of the metal), the holes may be re-drilled or reamed, but only with the approval of the Designer.

Any fabrication error that cannot be corrected by a slight amount of drifting, drilling, or reaming is cause for rejection of the material. Heavy sledging of the parts to bring them into alignment or making any cuts or adjustments with a burning torch must not be permitted.

No hole reaming, field bending, or straightening of structural steel members will be done without the approval of the Designer and Bridge Group.

Any heating of steel members to facilitate bending and installation must have the prior approval of Bridge Group. Applications of heat to structural steel must be done under rigidly controlled, predetermined conditions that may require different controls for the various members.

All of the above practices, if not done carefully, will weaken the steel through metal fatigue from excessive bending; net section removal from too much drilling and reaming; or re-crystallization from overheating.

The entire structure or as a minimum, an entire unit of continuous spans, should be assembled, drift pinned, bolted, and adjusted to the proper grade and alignment in accordance with the erection drawings before permanent connections are made. If high strength bolts are to be used for the permanent connections, they may also be used for this "fitting up." Splices and field connections must have one-half of the holes filled with bolts and pins before bolting up with high strength bolts.

Elevations on tops of erected bridge girders must be checked and any necessary adjustments made to the slab build-up as noted on the bridge plans.

Connections

Inspectors must pay close attention to how connections are bolted or welded. One of the primary goals of any Inspector of a steel structure is to ensure that the connections are not the weakest link in the structure. Subsection 604-2.03 discusses the requirements for bolted connections while Subsection 604-3.06 discusses the requirements of welding. The shop drawings will detail how connections are to be made and what hardware is to be used. Inspectors must take an active role in inspecting all connections and carefully observe and document the Contractor's workmanship.

Final Alignment

Due to fabrication tolerances and inaccuracies in laying out the bearing locations, it is sometimes necessary to make slight adjustments in the position of the bearings after the erection is complete. Proper clearance between structural units and the correct opening for expansion devices are required. If the expansion bearings are of the rocker type, the rockers are adjusted according to the prevailing temperature so they will be vertical at the standard temperature shown on the Project Plans (usually 70 °F [22 °C]).