As in Part a, this value is smaller than the bearing strength at each hole, so the total nominal strength for the connection is
\[ R_n = 23.86 + 23.86 = 47.72 \text{ kips} \]

**ANSWER**

For LRFD, the design strength is \( \phi R_n = 0.75(47.72) = 35.8 \text{ kips} \).

For ASD, the allowable strength is \( \frac{R_n}{\Omega} = \frac{47.72}{2.00} = 23.9 \text{ kips} \).

**c.** For Group A bolts with the threads not in the plane of shear (type X), the nominal shear strength is \( F_{ny} = 68 \text{ ksi} \), and
\[
[16.1-120]
\]
Bolt shear strength
\[ R_n = F_{ny} a = 68(0.4418) = 30.04 \text{ kips} \]

At the hole nearest the edge, the bearing strength of 28.55 kips is less than the shearing strength of 30.04 kips. At the other hole, the shearing strength is smaller. The total strength is therefore
\[ R_n = 28.55 + 30.04 = 58.59 \text{ kips} \]

**ANSWER**

For LRFD, the design strength is \( \phi R_n = 0.75(58.59) = 43.9 \text{ kips} \).

For ASD, the allowable strength is \( \frac{R_n}{\Omega} = \frac{58.59}{2.00} = 29.3 \text{ kips} \).

All spacing and edge-distance requirements are satisfied. The minimum edge distance required by AISC Table J3.4 is 1 inch, and this requirement is satisfied in both the longitudinal and transverse directions. The bolt spacing \( s \) is 3 inches, which is greater than \( 2\frac{3}{4}d = 2.667(3/4) = 2 \text{ in} \).

Note that some other limit state that has not been checked, such as tension on the net area of the member, may govern the strength of the connection of Example 7.2.

**EXAMPLE 7.3**

A plate \( 3/8 \times 6 \) is used as a tension member to resist a service dead load of 12 kips and a service live load of 33 kips. This member will be connected to a \( 3/8 \)-inch gusset plate with \( 3/4 \)-inch-diameter Group A bolts. A36 steel is used for both the tension member and the gusset plate. Assume that the bearing strength is adequate, and determine the number of bolts required based on bolt shear.
For A325-X Bolts

Plug pullout = 57.11 k
Plate crush = 39.15 k
Shear bolt = 30.04 k
Rn = 30.04 k (smallest)

P.P. = 28.55 k
P.C. = 39.15 k
S.B. = 30.04 k
Rn = 28.55 k (smallest)

See \( \phi Rn = 0.75 \left( 28.55 + 30.04 \right) \)
= 43.9 k
The factored load is

\[ P_u = 1.2D + 1.6L = 1.2(12) + 1.6(33) = 67.2 \text{ kips} \]

Compute the capacity of one bolt. It is not known whether the bolt threads are in the plane of shear, so conservatively assume that they are. The nominal shear strength is therefore

\[ R_n = F_n A_b = 54(0.4418) = 23.86 \text{ kips} \]

and the design strength is

\[ \phi R_n = 0.75(23.86) = 17.90 \text{ kips per bolt} \]

The number of bolts required is

\[ \frac{67.2 \text{ kips}}{17.90 \text{ kips/bolt}} = 3.75 \text{ bolts} \]

**ANSWER** Use four \( \frac{3}{4} \)-inch-diameter Group A bolts.

The total load is

\[ P_a = D + L = 12 + 33 = 45 \text{ kips} \]

Compute the capacity of one bolt. It is not known whether the bolt threads are in the plane of shear, so conservatively assume that they are. The nominal shear strength is therefore

\[ R_n = F_n A_b = 54(0.4418) = 23.86 \text{ kips} \]

and the allowable strength is

\[ \frac{R_n}{\Omega} = \frac{23.86}{2.00} = 11.93 \text{ kips per bolt} \]

The number of bolts required is

\[ \frac{45 \text{ kips}}{11.93 \text{ kips/bolt}} = 3.77 \text{ bolts} \]

**ANSWER** Use four \( \frac{3}{4} \)-inch-diameter Group A bolts.

In Example 7.3, the bearing strength was assumed to be adequate. In an actual design situation, the spacing and edge distances would be selected once the required number of bolts was determined, and then the bearing strength could be checked. If the bearing strength was inadequate, the spacing and edge distances could be changed, or more bolts could be used. Subsequent examples will illustrate this procedure.
<table>
<thead>
<tr>
<th>Description of Fasteners</th>
<th>Nominal Tensile Strength, $F_{nt}$, ksi (MPa)$^a$</th>
<th>Nominal Shear Strength in Bearing-Type Connections, $F_{nv}$, ksi (MPa)$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A307 bolts</td>
<td>45 (310)</td>
<td>27 (188)$^d$</td>
</tr>
<tr>
<td>Group A (e.g., A325) bolts, when threads are not excluded from shear planes</td>
<td>90 (620)</td>
<td>54 (372)</td>
</tr>
<tr>
<td>Group A (e.g., A325) bolts, when threads are excluded from shear planes</td>
<td>90 (620)</td>
<td>68 (457)</td>
</tr>
<tr>
<td>Group B (e.g., A490) bolts, when threads are not excluded from shear planes</td>
<td>113 (780)</td>
<td>68 (457)</td>
</tr>
<tr>
<td>Group B (e.g., A490) bolts, when threads are excluded from shear planes</td>
<td>113 (780)</td>
<td>84 (579)</td>
</tr>
<tr>
<td>Threaded parts meeting the requirements of Section A3.4, when threads are not excluded from shear planes</td>
<td>$0.75F_u$</td>
<td>$0.450F_u$</td>
</tr>
<tr>
<td>Threaded parts meeting the requirements of Section A3.4, when threads are not excluded from shear planes</td>
<td>$0.75F_u$</td>
<td>$0.563F_u$</td>
</tr>
</tbody>
</table>

$^a$ For high-strength bolts subject to tensile fatigue loading, see Appendix 3.

$^b$ For end loaded connections with a fastener pattern length greater than 38 in. (965 mm), $F_{nv}$ shall be reduced to 83.3% of the tabulated values. Fastener pattern length is the maximum distance parallel to the line of force between the centerline of the bolts connecting two parts with one faying surface.

$^d$ For A307 bolts the tabulated values shall be reduced by 1% for each 1/16 in. (2 mm) over 5 diameters of length in the grip.

$^e$ Threads permitted in shear planes.

2. Size and Use of Holes

The maximum sizes of holes for bolts are given in Table J3.3 or Table J3.3M, except that larger holes, required for tolerance on location of anchor rods in concrete foundations, are permitted in column base details.

*Standard holes* or *short-slotted holes* transverse to the direction of the load shall be provided in accordance with the provisions of this specification, unless oversized holes, short-slotted holes parallel to the load, or *long-slotted holes* are approved.
### Table 7-1
Available Shear Strength of Bolts, kips

<table>
<thead>
<tr>
<th>Nominal Bolt Diameter, ( d ), in.</th>
<th>( \frac{3}{8} )</th>
<th>( \frac{1}{4} )</th>
<th>( \frac{7}{8} )</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Bolt Area, in.(^2)</td>
<td>0.307</td>
<td>0.442</td>
<td>0.601</td>
<td>0.785</td>
</tr>
<tr>
<td><strong>ASTM Desig.</strong></td>
<td><strong>Thread Cond.</strong></td>
<td><strong>( F_{mv}/\Omega ) (ksi)</strong></td>
<td><strong>( \phi F_{mv} ) (ksi)</strong></td>
<td><strong>Loading</strong></td>
</tr>
<tr>
<td><strong>ASD</strong></td>
<td><strong>LRFD</strong></td>
<td><strong>ASD</strong></td>
<td><strong>LRFD</strong></td>
<td><strong>ASD</strong></td>
</tr>
<tr>
<td><strong>Group A</strong></td>
<td>N</td>
<td>37.0</td>
<td>40.5</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>54.0</td>
<td>51.0</td>
<td>S</td>
</tr>
<tr>
<td><strong>Group B</strong></td>
<td>N</td>
<td>54.0</td>
<td>51.0</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>54.0</td>
<td>63.0</td>
<td>S</td>
</tr>
<tr>
<td>A307</td>
<td>–</td>
<td>13.5</td>
<td>20.3</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>D</td>
<td>8.29</td>
</tr>
<tr>
<td><strong>Nominal Bolt Diameter, ( d ), in.</strong></td>
<td>1( \frac{1}{8} )</td>
<td>1( \frac{1}{4} )</td>
<td>1( \frac{3}{8} )</td>
<td>1( \frac{1}{2} )</td>
</tr>
<tr>
<td>Nominal Bolt Area, in.(^2)</td>
<td>0.994</td>
<td>1.23</td>
<td>1.48</td>
<td>1.77</td>
</tr>
<tr>
<td><strong>ASTM Desig.</strong></td>
<td><strong>Thread Cond.</strong></td>
<td><strong>( F_{mv}/\Omega ) (ksi)</strong></td>
<td><strong>( \phi F_{mv} ) (ksi)</strong></td>
<td><strong>Loading</strong></td>
</tr>
<tr>
<td><strong>ASD</strong></td>
<td><strong>LRFD</strong></td>
<td><strong>ASD</strong></td>
<td><strong>LRFD</strong></td>
<td><strong>ASD</strong></td>
</tr>
<tr>
<td><strong>Group A</strong></td>
<td>N</td>
<td>27.0</td>
<td>40.5</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>34.0</td>
<td>51.0</td>
<td>S</td>
</tr>
<tr>
<td><strong>Group B</strong></td>
<td>N</td>
<td>34.0</td>
<td>51.0</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>42.0</td>
<td>63.0</td>
<td>S</td>
</tr>
<tr>
<td>A307</td>
<td>–</td>
<td>13.5</td>
<td>20.3</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>D</td>
<td>26.8</td>
</tr>
</tbody>
</table>

For end loaded connections greater than 38 in., see AISC Specification Table J3.2 footnote b.
7.5 INSTALLATION OF HIGH-STRENGTH BOLTS

In certain cases, high-strength bolts are installed to such a degree of tightness that they are subjected to extremely large tensile forces. For example, the initial tension in a 5/8-inch-diameter, Group A bolt can be as high as 19 kips. A complete list of minimum tension values, for those connections in which a minimum tension is required, is given in AISC Table J3.1, “Minimum Bolt Pretension.” Each value is equal to 70% of the minimum tensile strength of the bolt. The purpose of such a large tensile force is to achieve the clamping force illustrated in Figure 7.12. Such bolts are said to be fully tensioned.

As a nut is turned and advanced along the threads of a bolt, the connected parts undergo compression and the bolt elongates. The free-body diagrams in Figure 7.12a show that the total compressive force acting on the connected part is numerically equal to the tension in the bolt. If an external load P is applied, a friction force will develop between the connected parts. The maximum possible value of this force is

\[ F = \mu N \]

where \( \mu \) is the coefficient of static friction between the connected parts, and N is the normal compressive force acting on the inner surfaces. The value of \( \mu \) will depend on

\[ \sigma = \frac{P}{A} \]

(a) No external loads

(b) External load applied
### TABLE J3.1
Minimum Bolt Pretension, kips*

<table>
<thead>
<tr>
<th>Bolt Size, in.</th>
<th>Group A (e.g., A325 Bolts)</th>
<th>Group B (e.g., A490 Bolts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>5/8</td>
<td>19</td>
<td>24</td>
</tr>
<tr>
<td>3/4</td>
<td>28</td>
<td>35</td>
</tr>
<tr>
<td>7/8</td>
<td>39</td>
<td>49</td>
</tr>
<tr>
<td>1</td>
<td>51</td>
<td>64</td>
</tr>
<tr>
<td>1 1/8</td>
<td>56</td>
<td>80</td>
</tr>
<tr>
<td>1 1/4</td>
<td>71</td>
<td>102</td>
</tr>
<tr>
<td>1 3/8</td>
<td>85</td>
<td>121</td>
</tr>
<tr>
<td>1 1/2</td>
<td>103</td>
<td>148</td>
</tr>
</tbody>
</table>

*Equal to 0.70 times the minimum tensile strength of bolts, rounded off to nearest kip, as specified in ASTM specifications for A325 and A490 bolts with UNC threads.

### TABLE J3.1M
Minimum Bolt Pretension, kN*

<table>
<thead>
<tr>
<th>Bolt Size, mm</th>
<th>Group A (e.g., A325M Bolts)</th>
<th>Group B (e.g., A490M Bolts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M16</td>
<td>91</td>
<td>114</td>
</tr>
<tr>
<td>M20</td>
<td>142</td>
<td>179</td>
</tr>
<tr>
<td>M22</td>
<td>176</td>
<td>221</td>
</tr>
<tr>
<td>M24</td>
<td>205</td>
<td>257</td>
</tr>
<tr>
<td>M27</td>
<td>267</td>
<td>334</td>
</tr>
<tr>
<td>M30</td>
<td>326</td>
<td>408</td>
</tr>
<tr>
<td>M36</td>
<td>475</td>
<td>595</td>
</tr>
</tbody>
</table>

*Equal to 0.70 times the minimum tensile strength of bolts, rounded off to nearest kN, as specified in ASTM specifications for A325M and A490M bolts with UNC threads.

When bolt requirements cannot be provided within the RCSC Specification limitations because of requirements for lengths exceeding 12 diameters or diameters exceeding 1 1/2 in. (38 mm), bolts or threaded rods conforming to Group A or Group B materials are permitted to be used in accordance with the provisions for threaded parts in Table J3.2.

When ASTM A354 Grade BC, A354 Grade BD, or A449 bolts and threaded rods are used in slip-critical connections, the bolt geometry including the thread pitch, thread length, head and nut(s) shall be equal to or (if larger in diameter) proportional to that required by the RCSC Specification. Installation shall comply with all applicable requirements of the RCSC Specification with modifications as required for the increased diameter and/or length to provide the design pretension.
the surface condition of the steel—for example, whether it is painted or whether rust is present. Thus each bolt in the connection is capable of resisting a load of \( P = F \), even if the bolt shank does not bear on the connected part. As long as this frictional force is not exceeded, there is no bearing or shear. If \( P \) is greater than \( F \) and slippage occurs, shear and bearing will then exist and will affect the capacity of the connection.

How is this high tension accurately achieved? There are currently four authorized procedures for the installation of high-strength bolts (RCSC, 2009).

1. **Turn-of-the-nut method.** This procedure is based on the load-deformation characteristics of the fastener and the connected parts. One full turn of a nut corresponds to a fixed length of travel along the bolt threads, which can be correlated to the elongation of the bolt. The stress-strain relationship for the bolt material can then be used to compute the tension in the bolt.

   For any size and type of bolt, therefore, the number of turns of the nut required to produce a given tensile force can be computed. Table 8.2 in the high-strength bolt specification (RCSC, 2009) gives the required nut rotation for various bolt sizes in terms of the ratio of length to diameter. The specified rotation is from a snug position, with snug being defined as the tightness necessary to bring all elements of the connection into firm contact. In spite of all the uncertainties and variables involved, the turn-of-the-nut method has proved to be reliable and surprisingly accurate.

2. **Calibrated wrench tightening.** Torque wrenches are used for this purpose. The torque required to attain a specified tension in a bolt of a given size and grade is determined by tightening this bolt in a tension-indicating device. This calibration must be done daily during construction for bolts of each size and grade.

3. **Twist-off-type bolts.** These are specially designed bolts that must be installed with specially designed power wrenches. The bolts have splined ends over which an inner socket of the wrench fits. As the outer socket tightens the nut, the inner socket turns the splined end of the bolt in the opposite direction. The wrenches are calibrated for the size and strength of the bolt, and when the required tension is reached, the end twists off. This makes inspection of the installation particularly easy. In the Group A category, the ASTM designation is F1852 (same strength as A325). In the Group B category, the designation is F2280 (same strength as A490).

4. **Direct tension indicators.** The most common of these devices is a washer with protrusions on its surface. When the bolt is tightened, the protrusions are compressed in proportion to the tension in the bolt. A prescribed amount of deformation can be established for any bolt, and when that amount has been achieved, the bolt will have the proper tension. The deformation can be determined by measuring the gap between the nut or bolt head and the undeformed part of the washer surface. Inspection of the bolt installation is also simplified when this type of direct tension indicator is used, as only a feeler gage is required.

Not all high-strength bolts need to be tightened to the fully tensioned condition. AISC J3.1 permits the bolts in some connections to be snug tight. These include
are designed using the *nominal strength* and *resistance factor* or *safety factor* as applicable for a *partial-joint-penetration groove weld*. 

(2) Complete-joint-penetration groove welded *splices* subject to tension normal to the effective area in heavy sections as defined in Sections A3.1c and A3.1d

The manufacturer's Certificate of Conformance shall be sufficient evidence of compliance.

7. **Mixed Weld Metal**

When Charpy *V-notch toughness* is specified, the process consumables for all *weld metal*, tack welds, root pass and subsequent passes deposited in a *joint* shall be compatible to ensure notch-tough composite weld metal.

**J3. BOLTS AND THREADED PARTS**

1. **High-Strength Bolts**

Use of *high-strength bolts* shall conform to the provisions of the *Specification for Structural Joints Using High-Strength Bolts*, hereafter referred to as the RCSC Specification, as approved by the Research Council on Structural Connections, except as otherwise provided in this Specification. High-strength bolts in this Specification are grouped according to material strength as follows:

- **Group A**—ASTM A325, A325M, F1852, A354 Grade BC, and A449
- **Group B**—ASTM A490, A490M, F2280, and A354 Grade BD

When assembled, all *joint* surfaces, including those adjacent to the washers, shall be free of scale, except tight *mill scale*.

Bolts are permitted to be installed to the snug-tight condition when used in:

(a) *bearing-type connections* except as noted in Section E6 or Section J1.10
(b) *tension or combined shear and tension applications*, for Group A *bolts only*, where loosening or *fatigue* due to vibration or *load* fluctuations are not design considerations

The snug-tight condition is defined as the tightness required to bring the connected plies into firm contact. Bolts to be tightened to a condition other than snug tight shall be clearly identified on the *design drawings*.

All high-strength bolts specified on the design drawings to be used in pretensioned or *slip-critical joints* shall be tightened to a bolt tension not less than that given in Table J3.1 or J3.1M. Installation shall be by any of the following methods: *turn-of-nut method*, a direct-tension-indicator, twist-off-type tension-control bolt, calibrated wrench, or alternative design bolt.

**User Note:** There are no specific minimum or maximum tension requirements for snug-tight bolts. Fully *pretensioned bolts* such as ASTM F1852 or F2280 are permitted unless specifically prohibited on design drawings.
Turn-of-Nut Installation is one of four installation methods recognized by the Research Council on Structural Connections, RCSC, for installing Structural Bolts. When installations require pretensioned or slip-critical joints and hex head structural bolts are being utilized, this installation method results in more uniform bolt pretensions than is generally obtained with other torque-control methods. Combined with the Pre-installation Verification Procedure listed below, the “Turn-of-Nut” installation method will give your installation a proven method to achieve all of your installation requirements without torque wrenches and calibration concerns. Installation is as easy as 1-2-3 after Pre-installation Verification Testing; 1. Snug-tighten the bolts in the joint; 2. Match-mark the nut and protruding end of the bolt; and 3. Rotate the nut by the proper amount listed in the table below.

<table>
<thead>
<tr>
<th>BOLT DIAMETER (INCHES)</th>
<th>BOLT LENGTH TO 4D</th>
<th>REQUIRED TURNS</th>
<th>BOLT LENGTH OVER 4D TO 8D</th>
<th>REQUIRED TURNS</th>
<th>BOLT LENGTH OVER 8D TO 12D</th>
<th>REQUIRED TURNS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2&quot;</td>
<td>2&quot;</td>
<td>1/3 turn</td>
<td>&gt;2 to 4&quot;</td>
<td>1/2 turn</td>
<td>&gt;4 to 6&quot;</td>
<td>2/3 turn</td>
</tr>
<tr>
<td>5/8&quot;</td>
<td>2.5&quot;</td>
<td>1/3 turn</td>
<td>&gt;2.5 to 5&quot;</td>
<td>1/2 turn</td>
<td>&gt;5 to 7.5&quot;</td>
<td>2/3 turn</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>3&quot;</td>
<td>1/3 turn</td>
<td>&gt;3 to 6&quot;</td>
<td>1/2 turn</td>
<td>&gt;6 to 9&quot;</td>
<td>2/3 turn</td>
</tr>
<tr>
<td>7/8&quot;</td>
<td>3.5&quot;</td>
<td>1/3 turn</td>
<td>&gt;3.5 to 7&quot;</td>
<td>1/2 turn</td>
<td>&gt;7 to 10.5&quot;</td>
<td>2/3 turn</td>
</tr>
<tr>
<td>1&quot;</td>
<td>4&quot;</td>
<td>1/3 turn</td>
<td>&gt;4 to 8&quot;</td>
<td>1/2 turn</td>
<td>&gt;9 to 13.5&quot;</td>
<td>2/3 turn</td>
</tr>
<tr>
<td>1 1/8&quot;</td>
<td>4.5&quot;</td>
<td>1/3 turn</td>
<td>&gt;4.5 to 9&quot;</td>
<td>1/2 turn</td>
<td>&gt;10 to 15&quot;</td>
<td>2/3 turn</td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>5&quot;</td>
<td>1/3 turn</td>
<td>&gt;5 to 10&quot;</td>
<td>1/2 turn</td>
<td>&gt;11 to 16.5&quot;</td>
<td>2/3 turn</td>
</tr>
</tbody>
</table>

Rotations Tolerance:

For 1/3 Turn (120 degrees) ± 30 degrees
For 1/2 Turn (180 degrees) ± 30 degrees
For 2/3 Turn (240 degrees) ± 45 degrees

Snug Tight = The tightness that is required to bring the plies into firm contact (Typically obtained with a few impacts of an impact wrench or the full effort of an iron-worker using an ordinary spud wrench).

Bolts used in the Snug-Tightened Condition do not require Pre-installation Verification Testing.

Always turn the nut during installation if you have the choice.

Always turn the same element during testing as you plan to turn during installation.
Pre-Installation Verification Procedure for Turn-of-Nut Installation Method

1. Take 3 bolts of each diameter, length, grade and production lot; 3 washers of each diameter and production lot; and 3 nuts of each diameter, grade and production lot as they will be assembled.

2. Assemble the first set of bolt-washer-nut combination into the Skidmore-Wilhelm.

3. Snug the assembly using the same technique to be used in the structure.

4. Match mark the nut, bolt and Skidmore faceplate.

5. Apply the required rotation as listed in the above table for the assembly being tested.

6. Verify that the tension on the Skidmore dial gage is at least 5% more than the min. bolt pretension as listed in the table below.

7. Record the tension achieved in a log book.

8. Remove the assembly and repeat steps 2 through 7 until three assemblies have been tested.

Information from the RCSC “Specification for Structural Joints Using ASTM A325 or A490 Bolts”

**MATCHMARKING AND REQUIRED TURNS**

**Minimum Bolt Pretension for Pretensioned and Slip-Critical Joints**

<table>
<thead>
<tr>
<th>BOLT DIAMETER</th>
<th>ASTM A325 BOLTS AND F1852 ASSEMBLIES</th>
<th>ASTM A490 BOLTS AND F2280 ASSEMBLIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>[inches]</td>
<td>[kips]a + 5% [kips]</td>
<td>[kips]a + 5% [kips]</td>
</tr>
<tr>
<td>1/2</td>
<td>12 12.6</td>
<td>15 15.8</td>
</tr>
<tr>
<td>5/8</td>
<td>19 20.0</td>
<td>24 25.2</td>
</tr>
<tr>
<td>3/4</td>
<td>28 29.4</td>
<td>35 36.8</td>
</tr>
<tr>
<td>7/8</td>
<td>39 41.0</td>
<td>49 51.5</td>
</tr>
<tr>
<td>1</td>
<td>51 53.6</td>
<td>64 67.2</td>
</tr>
<tr>
<td>1 1/8</td>
<td>56 58.8</td>
<td>80 84.0</td>
</tr>
<tr>
<td>1 1/4</td>
<td>71 74.6</td>
<td>102 107.1</td>
</tr>
<tr>
<td>1 3/8</td>
<td>85 89.3</td>
<td>121 127.1</td>
</tr>
<tr>
<td>1 1/2</td>
<td>103 108.2</td>
<td>148 155.4</td>
</tr>
</tbody>
</table>

*aValues from RCSC Table B.1
1 kip = 1,000 pounds

**TODAY, THAT LITTLE “n” MEANS BIG THINGS!**

This Technical Data Sheet is subject to change without prior notification.
Take a blank, then form a head on one end, then form the end for the threads.

A second view.
Another view.
Then shear a hex off of the round head. See the heavy shear marks under the head? These shear marks will be ground off later.
Another view.
Then roll the threads into the shank.
These are direct tension indicator devices. The first bolt has a direct tension indicating washer. When the bolt is properly pre-tensioned, the raised arcs will be forced back down into the washer from which they were deformed. The second and third bolts have break-off tips which are engaged by the impact wrench. When the proper tension is applied by rotating the nut (holding the bolt stationary through the spline on the tip), the tip torques off.
Close up of the tension indicating washer.
Squirters - these squirt out ink when the proper pre-tension is applied to the bolt. The other side of the Squirter looks just like washer in the photo directly above.
Installed view.

A bolt failed in double shear.
SPUD WRENCH

395x
Heavy Hex Head
Rolled Thread
bearing-type connections (see Section 7.6 of this book), most tension connections (Section 7.8), and most combined shear and tension connections (Section 7.9). AISC J1.10 describes the connections for which fully tensioned bolts are *required*.

**SLIP-CRITICAL AND BEARING-TYPE CONNECTIONS**

A connection with high-strength bolts is classified as either a *slip-critical* connection or a *bearing-type* connection. A slip-critical connection is one in which no slippage is permitted—that is, the friction force must not be exceeded. In a bearing-type connection, slip is acceptable, and shear and bearing actually occur. In some types of structures, notably bridges, the load on connections can undergo many cycles of reversal. In such cases, fatigue of the fasteners can become critical if the connection is allowed to slip with each reversal, and a slip-critical connection is advisable. In most structures, however, slip is perfectly acceptable, and a bearing-type connection is adequate. (A307 bolts are used only in bearing-type connections.) Proper installation and achievement of the prescribed initial tension is necessary for slip-critical connections. In bearing-type connections, the only practical requirement for the installation of the bolts is that they be tensioned enough so that the surfaces of contact in the connection firmly bear on one another. This installation produces the *snug-tight* condition referred to earlier in the discussion of the turn-of-the-nut method.

As discussed earlier, the resistance to slip will be a function of the coefficient of static friction and the normal force between the connected parts. This relationship is reflected in the provisions of the AISC Specification. The nominal slip resistance of a bolt is given by

\[ R_n = \mu D_u h_f T_b n_s \]  

where

- \( \mu \) = mean slip coefficient (coefficient of static friction) = 0.30 for Class A surfaces
- \( D_u \) = ratio of mean actual bolt pretension to the specified minimum pretension. This is to be taken as 1.13 unless another factor can be justified.
- \( h_f \) = filler factor
- \( T_b \) = minimum fastener tension from AISC Table J3.1
- \( n_s \) = number of slip planes (shear planes)

A Class A surface is one with clean mill scale (mill scale is an iron oxide that forms on the steel when it is produced). The Specification covers other surfaces, but in this book we conservatively use Class A surfaces, which are assigned the smallest slip coefficient.

The filler factor, \( h_f \), accounts for the presence of filler plates, which are sometimes added to connections to bring elements into alignment. This can occur, for example, when members of different depths are spliced. Recent research has shown that the presence of fillers can affect the slip resistance of a connection.
User Note: Note that when the required stress, \( f \), in either shear or tension, is less than or equal to 30% of the corresponding available stress, the effects of combined stress need not be investigated. Also note that Equations J3-3a and J3-3b can be rewritten so as to find a nominal shear stress, \( F_m' \), as a function of the required tensile stress, \( f_t \).

8. High-Strength Bolts in Slip-Critical Connections

*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 surfaces subject to slip shall be prepared to achieve design slip resistance.

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

\[
R_n = \mu D_u h_f T_b n_s
\]  \hspace{1cm} (J3-4)

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

\[
\phi = 1.00 \text{ (LRFD)}
\]

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

\[
\phi = 0.85 \text{ (LRFD)}
\]

(c) For long-slotted holes

\[
\phi = 0.70 \text{ (LRFD)}
\]

where

\( \mu = \text{mean slip coefficient for Class A or B surfaces, as applicable, and determined as follows, or as established by tests:} \)

(i) 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)

\[
\mu = 0.30
\]

(ii) 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*.

\( T_b = \text{minimum fastener tension given in Table J3.1, kips, or Table J3.1M, kN} \)

\( h_f = \text{factor for fillers, determined as follows:} \)

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

\[
h_f = 1.0
\]
(ii) Where bolts have not been added to distribute the load in the filler:

(a) For one filler between connected parts

\[ h_f = 1.0 \]

(b) For two or more fillers between connected parts

\[ h_f = 0.85 \]

\[ n_s = \text{number of slip planes required to permit the connection to slip} \]

9. Combined Tension and Shear in Slip-Critical Connections

When a slip-critical connection is subjected to an applied tension that reduces the net clamping force, the available slip resistance per bolt, from Section J3.8, shall be multiplied by the factor, \( k_{sl} \), as follows:

\[ k_{sl} = 1 - \frac{T_u}{D_u T_b n_b} \quad \text{(LRFD)} \] \hspace{1cm} (J3-5a)

\[ k_{sl} = 1 - \frac{1.5 T_u}{D_u T_b n_b} \quad \text{(ASD)} \] \hspace{1cm} (J3-5b)

where

\( T_u \) = required tension force using *ASD load combinations*, kips (kN)
\( T_u \) = required tension force using *LRFD load combinations*, kips (kN)
\( n_b \) = number of bolts carrying the applied tension

10. Bearing Strength at Bolt Holes

The available bearing strength, \( \phi R_n \) and \( R_n/\Omega \), at bolt holes shall be determined for the limit state of bearing as follows:

\[ \phi = 0.75 \text{ (LRFD)} \quad \Omega = 2.00 \text{ (ASD)} \]

The nominal bearing strength of the connected material, \( R_n \), is determined as follows:

(a) For a bolt in a connection with standard, oversized and short-slotted holes, independent of the direction of loading, or a long-slotted hole with the slot parallel to the direction of the bearing force

(i) When deformation at the bolt hole at service load is a design consideration

\[ R_n = 1.2 I_c t F_u \leq 2.4 d t F_u \] \hspace{1cm} (J3-6a)

(ii) When deformation at the bolt hole at service load is not a design consideration

\[ R_n = 1.5 I_c t F_u \leq 3.0 d t F_u \] \hspace{1cm} (J3-6b)

(b) For a bolt in a connection with long-slotted holes with the slot perpendicular to the direction of force

\[ R_n = 1.0 I_c t F_u \leq 2.0 d t F_u \] \hspace{1cm} (J3-6c)
TABLE J3.1
Minimum Bolt Pretension, kips*

<table>
<thead>
<tr>
<th>Bolt Size, in.</th>
<th>Group A (e.g., A325 Bolts)</th>
<th>Group B (e.g., A490 Bolts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>5/8</td>
<td>19</td>
<td>24</td>
</tr>
<tr>
<td>3/4</td>
<td>28</td>
<td>35</td>
</tr>
<tr>
<td>7/8</td>
<td>39</td>
<td>49</td>
</tr>
<tr>
<td>1</td>
<td>51</td>
<td>64</td>
</tr>
<tr>
<td>1 1/8</td>
<td>56</td>
<td>80</td>
</tr>
<tr>
<td>1 1/4</td>
<td>71</td>
<td>102</td>
</tr>
<tr>
<td>1 5/8</td>
<td>85</td>
<td>121</td>
</tr>
<tr>
<td>1 1/2</td>
<td>103</td>
<td>148</td>
</tr>
</tbody>
</table>

*Equal to 0.70 times the minimum tensile strength of bolts, rounded off to nearest kip, as specified in ASTM specifications for A325 and A490 bolts with UNC threads.

TABLE J3.1M
Minimum Bolt Pretension, kN*

<table>
<thead>
<tr>
<th>Bolt Size, mm</th>
<th>Group A (e.g., A325M Bolts)</th>
<th>Group B (e.g., A490M Bolts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M16</td>
<td>91</td>
<td>114</td>
</tr>
<tr>
<td>M20</td>
<td>142</td>
<td>179</td>
</tr>
<tr>
<td>M22</td>
<td>176</td>
<td>221</td>
</tr>
<tr>
<td>M24</td>
<td>205</td>
<td>257</td>
</tr>
<tr>
<td>M27</td>
<td>267</td>
<td>334</td>
</tr>
<tr>
<td>M30</td>
<td>328</td>
<td>408</td>
</tr>
<tr>
<td>M36</td>
<td>475</td>
<td>595</td>
</tr>
</tbody>
</table>

*Equal to 0.70 times the minimum tensile strength of bolts, rounded off to nearest kN, as specified in ASTM specifications for A325M and A490M bolts with UNF threads.

When bolt requirements cannot be provided within the RCSC Specification limitations because of requirements for lengths exceeding 12 diameters or diameters exceeding 1 1/2 in. (38 mm), bolts or threaded rods conforming to Group A or Group B materials are permitted to be used in accordance with the provisions for threaded parts in Table J3.2.

When ASTM A354 Grade BC, A354 Grade BD, or A449 bolts and threaded rods are used in slip-critical connections, the bolt geometry including the thread pitch, thread length, head and nut(s) shall be equal to or (if larger in diameter) proportional to that required by the RCSC Specification. Installation shall comply with all applicable requirements of the RCSC Specification with modifications as required for the increased diameter and/or length to provide the design pretension.

Specification for Structural Steel Buildings, June 22, 2010
AMERICAN INSTITUTE OF STEEL CONSTRUCTION