

All About BOLTS

David I. Ruby, P.E., S.E.

Are the technical and cost implications of using snug-tightened, pretensioned or slip-critical bolted joints getting you twisted? This month's *SteelWise* relieves the tension!

Steel connection costs are more heavily influenced by labor costs than by steel weight. Least weight is *not* least cost!

The 2000 RCSC *Specification for Structural Joints Using ASTM A325 or A490 Bolts*, which is incorporated into the 3rd Edition AISC *LRFD Manual of Steel Construction*, uses revised terminology for the three types of bolted joints: “snug-tightened,” “pretensioned” and “slip-critical.” What are the technical and economic differences between these types of bolted joints?

These three types of joints are extensively described in Section 4 of the RCSC *Specification*. The reader is encouraged to obtain and become familiar with that information, which is available as a free download at www.boltcouncil.org.

SELECTION OF JOINT TYPE

The behavior of the joint and how it affects the in-service structure is the dictating factor in the proper selection of the joint type. Table 4.1 of the RCSC *Specification* provides excellent guidance in this area.

Pretensioned joints are only required in the following applications:

1. Joints in which fastener pretension is required in the governing code or specification;
2. Joints that are subject to significant load reversal;
3. Joints that are subject to fatigue load with no reversal of the loading direction;
4. Joints with ASTM A325 or F1852 bolts that are subject to tensile fatigue;
5. Joints with ASTM A490 bolts that are subject to tension or combined shear and tension, with or without fatigue.

Slip-critical joints are only required in the following applications:

1. Joints subject to fatigue load with reversal of the loading direction;
2. Joints that utilize oversized holes;
3. Joints that utilize slotted holes, except those with the applied load approximately normal to the long dimension of the slot;
4. Joints in which slip at the faying surfaces would be detrimental to the performance of the structure.

Snug-tightened joints are permitted for all other applications.

DESIGN CONSIDERATIONS

Snug-tightened and pretensioned joints have the same strengths. Pretensioned joints and slip-critical joints have similar installation requirements, though slip-critical joints require special faying surface preparation where pretensioned joints do not.

When the bolt shear-strength limit state is checked for each of these three types of joints, the designer can select the threads-excluded option or the threads-included option.

X = threads are excluded from the shear plane.

N = threads can be in the shear plane.

Table 7-2 in the 3rd Edition AISC *LRFD Manual* provides a convenient tabulation of combinations of grip, ply thickness adjacent to nut, and number of washers needed when it is desired to exclude the threads from the shear plane.

The bolts, ASTM A325 or A490, are the same bolts regardless of which of the three types of joints is selected and

Estimating Bolting Costs

Consider a 59 kip factored load using ASTM A325 high-strength bolts. The cost estimates include one fabricator's estimate of the associated labor costs:

		Cost	Cost Factor
Slip Critical (N or X)	6 bolts @ 10.4 kips/bolt = 62.4 kips	\$66.00	3.1
Pretensioned (N)	4 bolts @ 15.9 kips/bolt = 63.6 kips	\$34.00	1.6
Pretensioned (X)	3 bolts @ 19.9 kips/bolt = 59.7 kips	\$25.50	1.2
Snug-tightened (N)	4 bolts @ 15.9 kips/bolt = 63.6 kips	\$28.00	1.3
Snug-tightened (X)	3 bolts @ 19.9 kips/bolt = 59.7 kips	\$21.00	1.0

whether the threads are included or excluded.

Recognizing that the ultimate strength of a connection is independent of the bolt pretension and slip movement, there are numerous practical cases in the design of structures where, if slip occurs, it will not be detrimental to the serviceability of the structure. Additionally, there are cases where slip of the joint is desirable to permit rotation in a joint, to eliminate the "banging bolt" syndrome or to minimize the transfer of moment. To provide for these cases while at the same time making use of the shear strength of high strength bolts, snug-tightened joints are permitted.

RELATIVE COSTS

Why spend the time choosing between snug-tightened, pretensioned and slip-critical joints? Simply put, snug-tightened joints are the most economical bolted joints and should be specified wherever possible. Slip-critical joints are by far the most costly joints, and should be specified only when the unique qualities of slip-critical joints are required for proper joint performance. The table below (using one fabricator's estimate of labor costs) shows clearly that snug-tightened bolts are cost-effective.

The Structural Engineer of Record primarily is concerned with the structural adequacy of the facility, while attempting to design the lightest structure—which is often erroneously assumed to correspond to the least cost. Actually the cost is more influenced by labor in the detail connections, the shop and field hours required for material preparation, punching, drilling, cleaning, painting, masking, inspection, installation and testing of the high-strength bolts.

Slip-critical joints cost appreciably more because of the associated faying surface preparation requirements (see Section 3.2.2 of the RCSC *Specification*), which can include:

1. Removal of loose mill scale (achieved by power-brush cleaning or brush blasting)
2. Removal of burrs on punched or drilled holes (achieved with hand or power grinding)
3. Special coating options:
 - free of coatings, including overspray (which requires masking of surfaces prior to painting)
 - special paint systems that are rated for slip-resistance—consult a steel fabricator.

Slip-critical joints also require more design time because all the limit states

for the bearing condition must be checked in addition to that for slip-resistance. Even though a slip-critical joint has a calculable frictional resistance, the joint can slip into bearing and must have adequate bearing strength should that happen (read more about this in the Commentary to Section 5.4 of the RCSC *Specification*).

RECOMMENDATIONS

Whenever possible, specify snug-tightened joints. If snug-tightened joints are not permitted, and slip-resistance is not required, specify pretensioned joints. Simply using the proper joint type can save a lot of money on your project. ★

David I. Ruby, P.E., S.E., is president of Ruby & Associates, P.C., Farmington Hills, MI, and is a member of AISC's Technical Activities Committee.