Turmoil constantly swirls around the topic of bolt specifications. To help answer questions about bolt buying, specifiying and quality assurance, the Research Council on Structural Connections has issued a series of bulletins, the fifth of which is printed here. The previous four bolt bulletins were printed in the October 1993 issue of Modern Steel Construction.

Research Council on Structural Connections Education Committee

Bulletin No. 5

The Effect Of Burrs On The Shear Capacity Of Bolted Connections

Small burrs will form around drilled and/or punched holes even when equipment is in good condition and the equipment operator is experienced and attentive. That is, burrs are inherently associated with all hole making methods. Burrs may extend above the plate surface by as little as several thousandths of an inch or more than a tenth of an inch. Questions are raised from time to time regarding the effect of burrs upon the performance of connections, both bearing type and slip critical type.

Bearing Connections

The 1994 edition of *Specification for Structural Joints Using ASTM A325 or A490 Bolts* (Section3(b)) does not require removal of burrs which extend $^{1}/_{16}$ in. or less above the plate surface for connections which are not slip cirtical. The 1994 Edition retains the earlier requirement in Section 8(c) that bolts in connections that are not slip critical be tightened to the snug tight condition, and retains the definition of snug tight as the tightness that exists when the plies of the joint are in firm contact. However, the definition of snug tight in Section 8(d) has been clarified by the addition of the direct statement that it is not necessary to have all plies of a joint in continuous contact. The modifications to Sections 3(b) and 8(d) are in recognition of the fact that plies of a joint can be in firm contact without being in contact at every point.

Surface contact and bolt tension do not affect the ultimate capacity of a connection. In a recently completed research project[1,2], burrs ranging in height from 0.0 to 0.176 in. were intentionally produced by out-of-specification punching (See AISC Spec. M2.5) of $^{13}/_{16}$ in. diameter holes in 1-in. plate. The plates were used to build 45 four-ply connections. The $^{3}/_{4}$ in. ASTM A325 bolt/nut fastener assemblies were tightened only to the finger tight condition. In some test specimens, gaps larger than $^{1}/_{8}$ in. could be seen between the plates and the nuts could not be brought flush with the end of the bolts by finger tightening. In spite of the extremely poor fit-up and negligible bolt tension, the average bolt shear strength of all connections tested was 82.0 ksi. with bolt shear strength on individual connections ranging from 69.7 to 93.9 ksi. The nominal capacity listed for A325 bolts in the Specification is 60 ksi. This capacity is based upon tests of joints free of burrs which exhibited an average bolt shear capacity of 80.6[3] ksi. The recently completed tests clearly demonstrate that it is not necessary to remove burrs to achieve ultimate capacities compatible with design values listed in the Specification.

Slip Critical Connections

Unlike bearing capacity of connections, the slip capacity of a connection is highly dependent upon bolt tension and the quality of contact between faying surfaces. The Specification, in Section 3(b), requires the removal of burrs that would prevent solid seating of the connected parts in the snug tight condition for all slip critical connections. However, as mentioned above, snug tight is not to be interpreted as requiring continuous contact between connected parts. Slip capacity is dependent upon the slip coefficient of the faying surfaces and the total contact force between the surfaces, not upon the area of contact.

In the research program described above, in addition to bearing tests, separate tests were conducted to determine the effect of burrs on the slip capacity of connections. The results of tests on 180 single-bolt connections and 60 four-bolt connections demonstrated that, with fully tensioned bolts, small burrs actually increased the slip load. As burr height was increased, slip load increased to a maximum at a burr height of $^1/_{16}$ in. When burr height was further increased, slip load decreased until the slip load for $^1/_8$ in. burrs was approximately the same as for faying surfaces with no burrs.

Although the slip load is not adversely affected by burrs in the connection, the presence of large burrs in a connection makes it more difficult to achieve proper tension in all bolts. Since the slip load is dependent upon the total contact force between the plies (equal to the sum of the bolt tensions in the connection), low tension in any of the bolts can lead to reduced slip capacity.

The Specification requires that for all tightening techniques, the bolts shall first be brought to the snug tight condition by progressively tightening bolts systematically from the most rigid part of the joint to the free edges until all bolts are uniformly snug tight. Final tightening also must progress systematically from the most rigid part of the joint to the free edges. The Specification also states that proper tensioning may require more than a single cycle of systematic tightening. The required process is necessary because each time a bolt is tightened, it compresses material under previously tightened adjacent bolts and thus reduces the final total bolt tension in the connection. The more rigid the material under the bolts, the less the material will be compressed by subsequently tightened bolts and the smaller will be the decrease in total bolt tension.

Burrs cause the material within the grip of a bolt to be more compressible. Therefore, more cycles of tightening are required to achieve uniform bolt tension when burrs are present. (Similar conclusions were drawn in reference 4.) In the research described above, each bolt in the connections was tightened $^1/_4$ turn per tightening cycle. In specimens with the smallest burrs, the burrs were flattened by the snugging operation. The amount of final tightening rotation required to achieve the proper tension was essentially the same as if no burr existed. In the specimens with the largest burr, one and one-half turns past snug tight were commonly required to achieve the proper uniform bolt tension (the Specification calls for one-half turn for the bolt length and diameter that was used in the tests). An incremental approach, as used in the tests, is necessary with calibrated wrench, direct tension indicator and tension control bolt tensioning methods to achieve the proper bolt tension with acceptable uniformity. Proper tension can be achieved using the turn-of-nut method only when the material contains small burrs which are flattened during the snugging operation.

Conclusions

The test program confirmed the appropriateness of the provisions of the *Specification for Structural Joints Using ASTM A325 or A490 Bolts*. In answer to the question posed in the first paragraph of this bulletin, burrs are not detrimental to the performance of bearing connections. If burrs are present in slip critical connections, extra effort is required to assure proper bolt tension. The level of extra effort varies with the size of the burr. If the burrs are so small that they are flattened during the snugging, it is not necessary that they be removed, and no extra attention is required. In fact, removal of these small burrs by grinding and smoothing the plate surface will have the undesirable effect of reducing slip capacity. However, if burrs are large enough to cause noticeable gaps between the plates after snugging, installation crews must use a calibrated wrench, direct tension indicators, or tension control bolts, and take the time to progressively tighten the bolts as required by the Specification.

References

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3. Wallaert, J. J. and J. W. Fisher, "Shear Strength of High-Strength Bolts," *Journal of the Structural Division Proceedings of the American Society of Civil Engineers*, Vol. 91, No. ST3, June 1965, pp. 99-125.

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