The 2010 AISC Specification: Changes in Design of Connections

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A revised slip resistance formula for bolted connections is among the changes that will appear in Chapter J.

THE CHARGE OVER THE LAST FIVE YEARS to the Committee on Specifications from then chair James M. Fisher, P.E., Ph.D., was to limit changes to items that would improve safety and/or economy, or simplify the AISC *Specification*. Accordingly, the technical changes in Chapter J of the 2010 AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360-10) are relatively few and are based on either new research or a reevaluation of extensive data from previous research. These changes primarily affect design of bolted connections along with some clarifications of the requirements for using the directional strength increase for fillet welds.

Changes Related to Welded Connections

Table J2.5 provides the base metal and weld metal available strengths for designing welded joints. The governing base metal strength for partial-joint-penetration welds in tension was changed from the yield strength to the rupture strength. This change was made because the welds are sized using the rupture limit. Limiting the base metal at the fusion line between the base metal and the weld metal to the yield strength was therefore inconsistent and unnecessarily restrictive.

The 2005 *Specification* required that fillet welds be loaded "in-plane" when using the directional strength increase provided by Equations J2-5 or J2-9b. Continuing research by Gilbert Grondin at the University of Alberta and Amit Kanvinde at the University of California–Davis indicated this limitation is not necessary. That is, the same provisions can be used for out-of-plane loading on fillet welds, and so the "in-plane" limitation has been removed.

The design of fillet weld groups using Sections J2.4(a) and J2.4(c) also has been clarified to indicate that these provisions apply only to uniformly sized fillet weld groups. This is important because the load-deformation behavior is affected by variations in size as well as loading angle. Fillet weld groups composed of variously sized weld elements can be designed using Section J2.4(b), which appropriately accounts for size variations.

Changes Related to Bolted Connections

One change related to bolted connections that will probably be immediately obvious is one of nomenclature. To simplify the *Specification* language, which essentially treats conventional and TC bolts as interchangeable, various bolts with common strength levels have been grouped. ASTM A325 and F1852 bolts along with A354 Grade BC and A449 bolts have been grouped together and referred to as Group A bolts. Similarly, ASTM A490 and F2280 bolts along with A354 Grade BD bolts have been grouped together and referred to as Group B bolts. These new designations are for convenience and readability. They should not to be confused with the existing faying surface preparation designations also referred to as Class A and Class B.

The nominal shear strength of fasteners and threaded parts in Table J3.2 historically has included a length reduction factor of 0.80. The length reduction factor accounted for the variation in load along the length of end-loaded connections due to deformation of the connection material. While this variation in load occurs only in end-loaded connections the reduction factor was applied to all connections for simplicity. Ray Tide reviewed and reanalyzed the test data on which the 0.80 length reduction factor was based. Using reliability-based procedures it was determined that if the connection length were limited to 38 in., a length reduction factor of 0.90 could accommodate the effects of differential strain and connection deformation effects. Again for simplicity the 0.90 factor is applied to both end-loaded connections up to 38 in. in length and all direct loaded connections.

The 2005 *Specification* also had an additional reduction factor of 0.80 for connections longer than 50 in. The 2010 *Specification* replaces this with an additional length reduction factor of 0.75 for connections longer than 38 in. That is, the

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long joint dimension has been reduced from 50 in. to 38 in. and the long joints total reduction factor has been increased from 0.64 to 0.675.

The Committee thought that since the majority of bolted connections are either not end-loaded or are less than 38 in. long, the economy provided by this change justified the work required to accommodate this change by the engineering profession and construction industry.

Slip-critical bolted connections in the 2005 *Specification* were permitted to be designed to prevent slip either as a serviceability limit state or a required strength limit state. Connections with oversize holes or slots parallel to the direction of the load were required to be designed at the required strength limit state unless otherwise designated by the engineer of record. This was a significant change from previous editions of the AISC *Specification* and the RCSC *Specification*.

Research by Grondin, Peter Dusicka at Portland State University, and Jerome Hajjar at the University of Illinois provided new information on the behavior of slip-critical connections with varying fillers and slip coefficients that provided the basis for changes in the 2010 *Specification*.

Grondin conducted a survey of available data on slip coefficients for Class A and B surfaces. He rigorously evaluated the test procedures and eliminated a substantial number of tests that did not meet the required protocol. Based on this study the value of the slip coefficient, μ, was changed from 0.35 to 0.30 primarily because of the wide variability of the slip resistance of "clean mill scale" surfaces. The slip coefficient for Class B surfaces was found to be slightly conservative but the Committee decided to leave $\mu = 0.50$ for blast cleaned surfaces and blast cleaned surfaces with Class B coatings.

Dusicka's work, which was still in process when the new specification was finalized, indicated the number of fillers in a joint could reduce the slip strength.

Hajjar tested a series of slip-critical bolted splice connections using 1⅛-in.-diameter A490 bolts in oversized holes. The tests involved sections varying in size from a W14×159 to a W14×730 upper shaft spliced to a W14×730 lower shaft with fillers as required. The base test compared the strength of a connection with standard holes to one with oversize holes and where no fillers were required. The results showed there was no reduction in slip strength with oversize holes, and also proved that the purpose of the 0.85 hole factor in the 2005 *Specification* was to provide additional resistance to slip and not to account for a loss of pretension due to the presence of oversize holes. The literature was not clear on this point, so these facts had to be reestablished. The tests also showed that multiple fillers tended to reduce the slip resistance except when additional bolts were added to develop the fillers.

These tests also were designed to determine the shear strength of bolts in oversize holes with and without fillers. The test results proved that bolts in oversize holes could develop their full design shear strength with a maximum reduction of 15% regardless of filler thickness. These tests show that not only would there be a significant increase in strength, if the connection were to slip into bearing, but also that the design requirements for development of thick fillers could be significantly changed for the better.

After all this work, there have been significant simplifications made in the corresponding provisions. The 2010 *Specification* no longer uses the concept of slip as a serviceability or required strength limit state because the resistance to slip varies depending on resistance/safety factor used for each hole type. The new Equation J3-4 is:

$$R_n = \mu D_u h_f T_b N_s$$

For standard holes and short-slotted holes perpendicular to the direction of the load

$\phi = 1.0$ $\Omega = 1.50$

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

$\phi = 0.85$ $\Omega = 1.76$

For long-slotted holes

$\phi = 0.70$ $\Omega = 2.14$

The slip coefficient, μ, has been modified as noted above to 0.30 for Class A surfaces and remains at 0.50 for Class B surfaces. D_u remains unchanged, however the engineer of record may approve other values depending on the application.

The hole factor in the 2005 *Specification* has been eliminated, and a filler factor, h_f, has been added, where:

h_f = factor for fillers determined as follows:

1) Where bolts have been added to distribute loads in the fillers:

$h_f = 1.0$

2) Where bolts have not been added to distribute loads in the fillers:

i) For one filler between connected parts

$h_f = 1.0$

ii) For two or more fillers between connected parts

$h_f = 0.85$

Where the number of fillers is not known in advance the designs may default to $h_f = 0.85$.

This design would be same as required for oversized holes designed for the required strength limit state in the 2005 *Specification*. Where the filler conditions are known, a greater economy may be achieved.

Section J5, Fillers, has been modified based on the tests noted above. Previous specifications required that fillers greater than ¾ in. thick had to be developed. The reduction factor is still $[1 - 0.4(t - 0.25)]$, however, the 2010 *Specification* states this factor need not be less than 0.85 regardless of the thickness of the filler.

There is an additional simple—but important—change in Section J3.1 that permits bolts to be installed to the snug-tight condition when used in bearing type connections except where noted elsewhere in the *Specification*. All bolts required to be tightened to a condition other than snug-tight are required to be clearly identified on the contract documents. Note that this does not preclude use of ASTM F1852 or F2280 (TC) bolts in these joints, as these are acceptable for use with the snug-tight designation, even when installed to remove the splined end.

Changes Related to Affected Elements of Members and Connecting Elements

The 2005 *Specification* addressed the strength of elements subjected to tension, shear, block shear and compression but did not address flexure. It was never the intention of the Committee to imply that elements never need to be checked for flexure, but rather to allow these checks to be addressed when appropriate in the *Manual*, similar to other connection design limits. Though the 2010 *Specification* does explicitly address the strength of elements in flexure, the discussion is brief and merely references the *Manual* and other sources. This recognizes that flexure as we normally envision it often cannot develop in short connection elements, and consideration of flexure is a matter of engineering judgment.

The 2010 AISC *Specification* is expected to be available on the AISC website at **www.aisc.org** later this year. MSC