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steel interchange

Fabrication Tolerances

ASTM A6 Table 22 tabulates the permitted variations in length for W-shapes as +/-3⁄8 in. for W24 and smaller sections that are less than or equal to 30 ft in length. Larger tolerances are allowed for greater depths and longer lengths. Alternatively, the AISC *Code of Standard Practice* Section 6.4.1 stipulates the fabrication tolerances on the length of beams and columns as ranging from +/-1⁄32 in. to 1⁄8 in. Are these tolerances meant to work in conjunction with one another? How does a fabricator fabricate to within the +/-1⁄32 in. to 1⁄8 in. range if the material received from suppliers arrives at an acceptable 3⁄8 in. under-length?

Mill material is usually sold in stock lengths that are then cut by the fabricator. Thus, the A6 tolerance applies to what the mill sells and the AISC *Code* tolerance applies to what the fabricator makes from that. They are not applied in conjunction with each other as a result. There is more to it as well, so let me expand upon this.

Ultimately, the steel must be fabricated and erected within the tolerances stated in the AISC *Code of Standard Practice*. Also, neither the mill tolerances nor the fabrication tolerances (or any combination of the two) can be such that the structure cannot be erected within the AISC *Code* erection tolerances.

AISC *Code* Section 6.4.1 does not state that the length of the wide-flange section must be within +/-1⁄32 in. to 1⁄8 in., but rather says that the length of the member must be within these tolerances. For example, consider double-angle connections shop welded to the beam. The distance from the end of the angles at one end to the other must be within this AISC *Code* tolerance; the wide-flange section itself could be a little longer or a little shorter. Now consider the same beam with shear tabs; the holes in the beam that accept the shear tab connection must be within the AISC *Code* tolerance, but again the length of the wide-flange section could be a little longer or a little shorter, and this tolerance is not governed by the AISC *Code*.

Mill tolerances are governed by ASTM A6. In the past it was common for fabricators to order steel cut to length. When this was done, ASTM A6 governed the tolerances unless some other purchasing agreements were worked out. Fabricators, therefore, had to use details that could accommodate the mill tolerances. Many fabricator engineers perform their calculations with these tolerances "baked in." In other words, fabrication practice acknowledged and accepted these mill tolerances through standard practices. Today, however, this may not be necessary as steel is rarely bought cut-to-length and is instead typically bought in standard lengths and then cut to order by the fabricator.

For the vast majority of situations (gravity-loaded beams) there is no conflict between the mill tolerances and the fabrication tolerances, as standard fabrication practices have been developed to accommodate the mill tolerances—even if the beams are ordered to-length. There are instances, however, where ordering to-length without recognizing the mill tolerances could present a problem. As an example, consider a column with only a cap plate and a base plate that is intended to bear between two other members. AISC *Code* Section 6.4.1 allows only a 1⁄32 in. tolerance, but the mill has a 3⁄8 in. tolerance. Obviously in such a case the fabricator must order a piece that is long enough to ensure the final column will be long enough even if the section received is on the lower end of the length tolerance.

Larry S. Muir, P.E.

Heat-Straightening

What resources are available for the use of heat-straightening to repair damaged steel sections?

AISC 360 Section M2.1 and AWS D1.1 Clause 5.26.2 provide an allowance to use heat as a means to correct or repair sections that have been damaged or are out of tolerance. These provisions also provide the maximum temperature requirements so that the application of heat does not adversely affect the metallurgical properties of the steel member. The following are some resources on the topic:

- "What You Should Know about Heat-Straightening Repair of Damaged Steel," *Engineering Journal*, 1st Quarter 2001 (**www.aisc.org/ej**).
- "Heat-Straightening of Steel: From Art to Science" by Richard Avent, 1988 AISC *Conference Proceedings* (proceedings are free download at **www.aisc.org/searchtaxonomy/conproceedings.aspx?id=4424**).
- "Principles and Practice of Heat-Straightening Repair" by Richard Avent, 2001 AISC *Conference Proceedings*.
- AISC 2005 *Code of Standard Practice* Section 6.4 for cross-sectional tolerances used in fabrication.
- "Cambering Steel Beams" by David Ricker, *Engineering Journal*, 4th Quarter 1989.
- "Heat-Straightening Repairs of Damaged Steel Bridges," Report No. FHWA-IF-99-004, U.S. Department of Transportation, Federal Highway Administration, October 1998.

Erin Criste

Fillet Weld Directional Strength Increase

Can the directional strength increase for fillet welds found in AISC 360-05 Section J2.4 be used for out-of-plane loading? AISC 360 Sections J2.4 (a) and (b) seem to restrict the use to in-plane loading, but the eccentrically loaded weld group tables in Part 8 of the AISC *Steel Construction Manual* seem to apply the strength increase to welds loaded out-of-plane. Which is correct?

For a number of years an unusual situation existed in which the AISC *Specification* restricted the directional strength increase for use with in-plane loading, while the AISC *Manual*, in the Part 8 eccentrically loaded weld tables, accounted for the directional strength increase even when the loading was out-of-plane. Practice among individual engineers varied.

The in-plane restriction existed because some were concerned that there was not enough ductility to justify the use of the directional strength increase for welds loaded out-of-plane. More recent testing has shown that these concerns were not warranted and the in-plane restriction has been removed from the 2010 AISC *Specification*.

Larry S. Muir, P.E.

Plasma Cutting of Bolt Holes

Is a CNC plasma cutter an acceptable alternative to drilling or punching bolt holes in structural steel?

Thermally cut holes for bolted connections are explicitly allowed in the AISC *Specification*; see Section M2.5, which states:

"Bolt holes shall comply with the provisions of the RCSC *Specification for Structural Joints Using High-Strength Bolts*, hereafter referred to as the RCSC *Specification*, Section 3.3 except that thermally cut holes are permitted with a surface roughness profile not exceeding 1,000 µin. (25 µm) as defined in ASME B46.1. Gouges shall not exceed a depth of 1/16 in. (2 mm). Water jet-cut holes are also permitted."

The glossary to the *Specification* then defines "thermally cut" as being "cut with gas, plasma or laser" (see page 16.1-liv of the 2010 *Specification*).

So, assuming that the plasma equipment can produce holes of the necessary quality, it would be permitted—and indeed plasma equipment is becoming extremely common due to the efficiencies they can provide.

The above applies to buildings and building-like structures. If you are working on bridges, thermally cut holes may be prohibited by the owner. However, plasma equipment manufacturers currently are working with DOTs and FHWA to eliminate this restriction.

Martin Anderson

Beam Camber

Can you camber a beam that is spliced at mid-span?

Yes. The process of furnishing and erecting a cambered assembly is to draw and fabricate the individual pieces with their camber requirements defined from a work line oriented to that piece. This usually is a chord through the end points of the bottom flange. Camber in the shipping pieces will be formed either with heat or a mechanical press. This can be done in one or more locations along the piece as required to obtain a reasonably smooth profile.

For field operations, the detailer should provide an assembly sketch showing the assembly with an offset from another work line (this time, a chord through the outer ends of the assembled pieces). The erector will use the drawing and assemble the pieces in the cambered profile before making the splice. The erector will either lay the pieces down in an assembly (if they have the space and lift capacity to place the piece after it is assembled) or will set the piece on shoring (or hold it with a second crane) so that it is in the cambered geometry before the splice is made.

Thomas J. Schlafly

Clevis and Turnbuckle Factor of Safety

We suspend elements from building roofs quite often using standard rigging components (i.e., cable slings, shackles, turnbuckles, etc.). The objects are permanently suspended. We have typically used a factor of safety equal to 5 for most components. I have been told a factor of safety equal to 3 is sufficient for permanent installation. Is this correct?

Part 15 of the 14th Edition *Manual* lists a safety factor of 3 rather than the historical 5 for clevises and turnbuckles. This was a decision made by the Manual Committee years ago to address differences between permanent and temporary installations. The factor of safety of 5 is intended for rigging and lifting operations and accounts for uncertainties inherent in those operations, but is not intended for static, permanent applications.

It should also be noted that these items are often subject to "proof testing" to twice the service load when used in lifting operations—something not required for components in building structures. In addition, ASCE publishes a guide on the design of cables (ASCE 19-10). This document also does not use a factor of safety of 5.

Ultimately, you must use your own judgment to decide what is appropriate for your situation. When making your judgments, you should compare the uncertainties involved in rigging and lifting applications to those inherent in your intended applications.

Larry S. Muir, P.E.

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If you have a question or problem that your fellow readers might help you solve, please forward it to us. At the same time, feel free to respond to any of the questions that you have read here. Contact Steel Interchange via AISC's Steel Solutions Center:

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