This month's SteelWise features answers to general questions on fabrication and erection tolerances in structural steel framing systems.

steelwise

ON TARGET AND WITHIN TOLERANCE

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AISC IS UPDATING the Frequently Asked Questions section of its website (**www.aisc.org**). As these updates are created, selected sections will be published as SteelWise articles. This month's installment covers fabrication and erection tolerances.

3. Fabrication and Erection Tolerances

The AISC *B*, the *C* *B* *B*, AWS D1.1 and other existing speci cations and codes cover tolerance requirements for the fabrication and erection of structural steel. The FAQs in this section include a discussion of portions of these provisions and subsequent recommendations.

The structural steel fabrication industry has traditionally achieved a remarkable degree of dimensional accuracy in the fabrication and erection of steel structures. This is particularly evident when considering the variety and levels of skills essential to coordinate and perform the planning, detailing, fabrication and erection of many unique and complex steel buildings, bridges and other special structures.

3.1. Member Cross-sectional Tolerances

3.1.1. Can out-of-tolerance mill material be adjusted by the fabricator so that it conforms to the appropriate tolerances?

Sometimes, yes. Infrequently, material is discovered after delivery to be beyond mill tolerances. When material received from the rolling mill does not conform to the requirements of ASTM A6/A6M (or more restrictive tolerances that are speci ed in the contract documents and purchasing documents), the fabricator can use controlled heating, mechanical straightening or a combination of both methods, consistent with manufacturer recommendations, to adjust cross-section, atness, straightness, camber and/or sweep.

3.1.2. What is the tolerance on depth for built-up girders and trusses?

The appropriate tolerances for a welded cross-section are speci ed in AWS D1.1 Clause 5.23. However, at bolted splices for such members, this AWS information is silent on this subject. AISC recommends that the permissible deviations for girder depth given by AWS D1.1 be applied to depth at bolted splices as well. Any differences within the prescribed tolerances at such joints should be taken up, if necessary, by shimming.

3.1.3. What is the atness tolerance for webs of built-up girders?

For members in statically loaded structures, web atness does not affect the structural integrity of a girder because it primarily resists shear. Accordingly, neither the AISC nor the AISC *C* includes a limitation on the out-of- atness of girder webs. Such a tolerance is speci ed for welded plate girders, however, in AWS D1.1 Clause 5.23.6.

Shrinkage of web-to- ange welds and/or welds that attach stiffeners to the web can create operational dif culties in girder webs, particularly those less than 5⁄16 in. thick. Therefore, webs under 5⁄16 in. thick should be avoided. If a girder web less than 5⁄16 in. thick is speci ed, the dimensional tolerance for deviation from atness, with or without stiffeners, in statically loaded structures should be determined as the larger of ½ in., from A6, or the value determined in AWS D1.1 Clause 5.23.6.2. In cyclically loaded structures, the value in AWS D1.1 Clause 5.23.6.3 should be observed. If architectural considerations require a more restrictive atness tolerance, it should be speci ed in the contract documents. In all cases, the web thickness speci ed should be adequate to minimize such distortion.

3.2. Member Straightness Tolerances

3.2.1. How are the permissible deviations from straightness described in ASTM A6/A6M accounted for in fabrication and erection?

In most cases, deviations from true straightness and dimension of individual members (within the tolerances speci ed in ASTM A6/A6M) are compensated for during erection by the

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In many cases, individual member deviations that exceed established tolerances will have no adverse effect on the overall structural steel frame. However, in other instances individual member deviations that accumulate can cause the overall structural steel frame to substantially exceed the overall permissible tolerances for plumbness, level and line. It is essential that the effect of individual member tolerances on the overall structural steel frame be recognized and accounted for with practical detailing and fabrication techniques that permit compliance with overall tolerances.

3.5. Other General Information

3.5.1. How are tolerances determined if they are not addressed in the applicable standards?

The fabrication and erection tolerances in the AISC - , the AISC *C* , AWS D1.1 and other applicable speci cations and codes have evolved for nearly a century. Although these standards generally present a workable format for the fabricator and erector, they tend to address individual members rather than the role of individual members in the completed structure.

Tolerances for assemblies—such as those on shop-assembled bents, frames, platforms, pairs of girders, etc.—are not covered by any code or standard. AWS D1.1 Clause 5.23.12 states that "other dimensional tolerances of members not covered by [Clause] 5.23 shall be individually determined and mutually agreed upon by the contractor and the owner with proper regard for erection requirements." This practice is recommended in all cases. The agreed-upon tolerances should account for the erection tolerances speci ed in the AISC *C* .

3.5.2. If special or more restrictive tolerances than those shown in the AISC *Code of Standard Practice* are required for the overall structural steel frame, can they be met?

Possibly, but this might involve a higher cost. Special clearances or tolerances may be dif cult or impossible to achieve because of considerations such as temperature change, fabrication and construction procedures and erection stresses. When speci ed, such requirements must be identi ed in the contract documents. The additional cost of special or more restrictive tolerance requirements should be justi ed.

3.5.3. How can the accumulation of mill, fabrication, and erection tolerances be economically addressed?

While individual member tolerances are usually self-compensating and of minor signi cance in the overall structure, the possibility exists that these tolerances may accumulate and lead to unacceptable misalignments that are dif cult to correct in the eld. As an example of the effect individual member tolerances may have on the total structure, consider the tolerances on columns and beams. Individual column and beam members are shown with their respective permissible tolerances in Figure 3.5.3-1. These tolerances come from several sources: permissible camber and sweep are speci ed in ASTM A6/A6M and AWS D1.1; permissible variation from detailed length for members framed to other steel parts is speci ed in the AISC *C* ; and mill tolerances on the

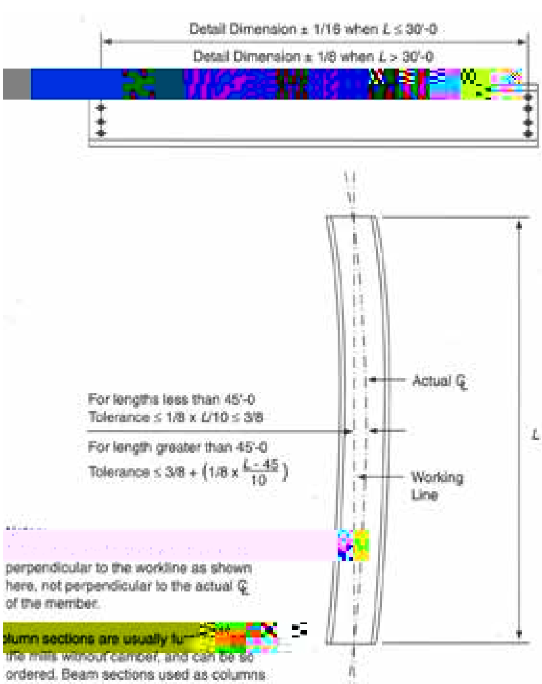

Fig. 3.5.3-1. Beam and column fabrication tolerances.

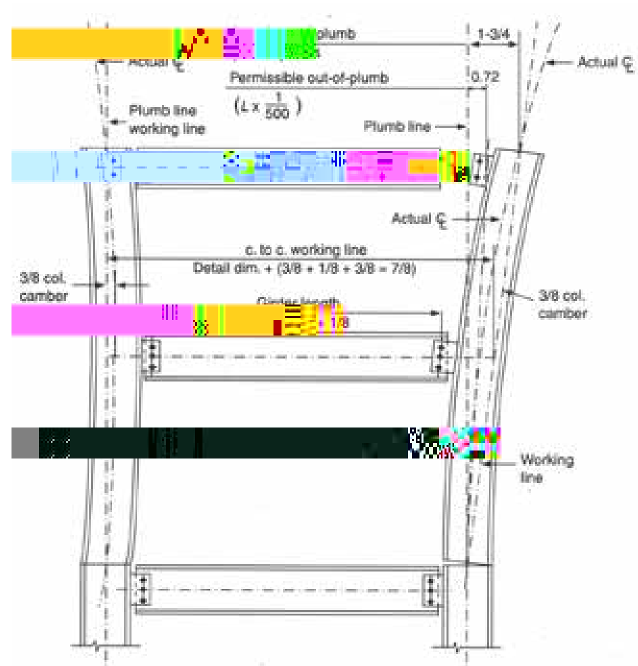

Fig. 3.5.3-2. Possible (but unlikely) accumulation of tolerances when details are located from actual centerlines.

cross section are illustrated in the AISC *C* - Figure C-5.1. The foregoing example involves a possible but highly unlikely scenario.

A case where individual members fabricated within permissible tolerances could make it impossible to erect a heavy two-story column within the plumbness tolerance of ±1:500 is illustrated in Figure 3.5.3-2. Although the condition shown would be unusual and represents the worst case with all member tolerances maximized and accumulated in one direction, it is evident that the accumulation of tolerances requires special consideration. Other possible examples include double-angle and end-plate connections to columns, attached shelf or spandrel angles, large plan dimensions in which many pieces line up, long bracing, expansion joints and vertical systems such as stairs and multi-story wall panels. Deflections of cantilevered members and tolerance accumulation on complex framing systems involving a long series of connections before the load is in the column (causing accumulation of vertical tolerances) should also be considered.

Details for material supported by the steel framing must provide for the standard tolerances. For example, in buildings with large plans, it is bene cial to develop special details that accommodate the accumulation of fabrication tolerances. Note that building expansion joints cannot be adjusted to proper position without a provision for this adjustment.

The use of oversized holes, short-slotted holes, and long-slotted holes provides a satisfactory method for achieving erection within tolerances, as illustrated in Figures 3.5.3-3 and 3.5.3-4. Other satisfactory methods include the use of nger shims, shop layout to theoretical working lines and recognition of tolerance accumulation in details for nishes, such as the façade attachments. See AISC Design Guide No. 22: *A* - *B* (a free download for AISC members at **www.aisc.org/designguides**) for further information. ■

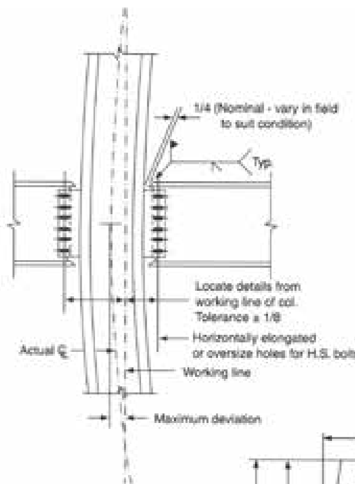

Fig. 3.5.3-3. Adjustments for column curvature in beam-to-column connections.

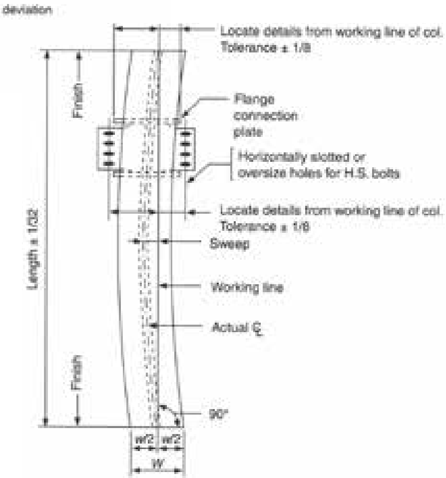

Fig. 3.5.3-4. Adjustments for column sweep in beam-to-column connections.