Workable Flange Gages

BY VICTOR SHNEUR, P.E.

The workable gages from Table 1-1 provide a good guide, but others can be used as needed.

THE TERM *GAGE* used in structural steel fabrication refers to the transverse center-to-center spacing of fasteners. For wide-flange shapes, the centerline of the gage coincides with the centerline of the web.

In the column "Steel Interchange" in *Modern Steel Construction* (August 2002) Bill Liddy, a 60-year steel industry veteran, provided the following definition and history for workable gages:

"Workable gages are derived from past recommendations from fabricators that effectively fulfilled two purposes. The first was to satisfy minimum edge distance and spacing requirements, as well as providing for entering/tightening clearances. The second purpose was that it made punching or drilling holes in the old days easier, because standardizing gages reduced the need to adjust the gage distance in the punching/drilling line, which increased fabrication efficiency.

"The standard gages were dropped after the 7th edition *Manual* because people were unnecessarily insisting that only the 7th edition gages could be used, while at the same time new fabrication equipment was available that allowed fabricators to conveniently change gages on the beam line. They were reintroduced in the 3rd edition *LRFD Manual* as workable gages with clarification that any other gage that satisfies edge distance and entering/tightening clearances can also be used. Using these workable gages will often save the fabricator time and the owner money."

Table 1–1 in the AISC *Steel Construction Manual*, 13th edition, lists workable gages for W-shape flanges. Depending on section sizes and/or properties, they are 2¼ in., 2¾ in., 3½ in., 4 in., 5½ in., 7½ in., and 3 in.–7½ in.–3 in. The last set of three numbers in that list is for four bolts across the flange, and applies to W14x145 through W14x730 sections. Similar to the 3rd edition *LRFD Manual*, the 13th edition *Manual* allows other gages that meet *Specification* requirements and provide for entering and tightening clearances. This article will review standard practices and parameters that affect W-shape flange gages, as well as special examples when workable gages in Table 1–1 cannot be used.

Standard Practice

The majority of members that require holes in flanges are columns. Generally, on a specific project, we use typical shear connections with the same gage throughout the project. Some projects may have more than one gage used. For typical double–angle shear connections, gages are usually 4 in. and 5½ in. Projects with heavier columns with a larger k_1 distance may require larger gages to avoid encroachment upon the fillets (see "Minimum Gages" below). For this type of connection, gages are controlled by entering and tightening clearances. If the same bolts are used for braced frame and/or moment connections, it is a good practice not to change the gage. Using multiple gages needs to be done carefully to help eliminate fabrication mistakes. For this reason all gage changes should be clearly identified on shop drawings.

Holes in beam flanges typically are only for special connections like the following:

1. Column base/cap plate connections
2. Bolted joist connections when the joist span is equal to or exceeds 40 ft (holes in the top flange only)
3. Bolted flange-plated moment connections
4. Hanger connections
5. Seated connections.

Using the workable gages from Table 1–1 is always suggested to help standardize details and simplify coordination, for example between the joist supplier and the steel fabricator. However, there may be cases when other gages are needed for more efficient connections. For example:

1. Four bolts across the flange (of course, when the flange is wide enough) in a bolted flange-plated moment connection makes the connection more compact;
2. Smaller gages may be required for hanger connections to eliminate reinforcement for flange bending.

Bolted truss connections are a unique connection category. Although actual gages are determined by a number of different parameters including loads, member sizes and connection geometry, the workable gages in Table 1–1 still should be used as a guide. For example, consider a W14x132 bottom chord splice requiring two 1-in.-diameter, A490–Slip Critical–OVS bolts across each flange, with inside flange splice plates (see Figure 1). In this case a gage larger than 5½ in. should be used to provide adequate width of inside splice plates. A 9-in. gage allows using 5½-in.-wide splice plates without fillet encroachment. As with all other connections, though, it is a good idea to change the gages as infrequently as possible.

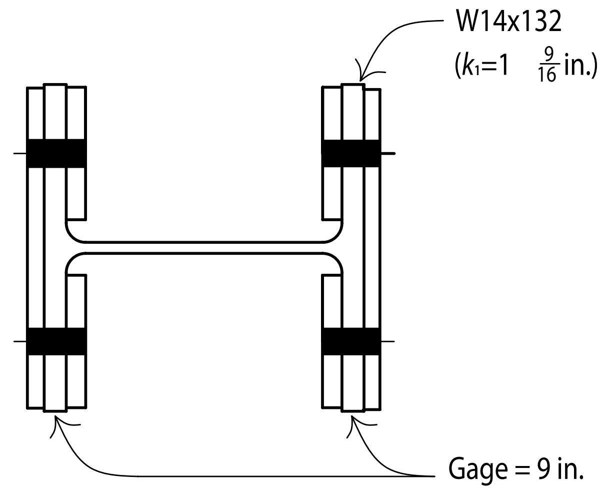


Figure 1: For this chord splice use of a gage larger than the suggested workable gauge allows the splice plates to be adequately sized.

Minimum Gages

There are cases when it is beneficial to use gages smaller than the workable gage, like hanger connections and standard double-angle connections to large W-column flanges. For these types of connections minimum gages need to be carefully reviewed.

Minimum gages are controlled by:

1. W-shape k_1 distances
2. Bolt sizes
3. Bolt entering and tightening clearances
4. Typical gages used for connections.

The W-shape k_1 distance and the bolt size need to be checked first to determine the minimum gage for any connection.

Example:

Column: W14×283 (k_1 = 1⅞ in.)

Bolts: 1 in. diameter, F1852

Per ASTM F1852, Fig. 1, bolt head bearing surface diameter D = 1.771 in. (call it 1¾ in.).

Note: Typically, tension-control bolts are oriented with nuts outside of the column to make pretensioning easier, and to allow the erector to use standard equipment.

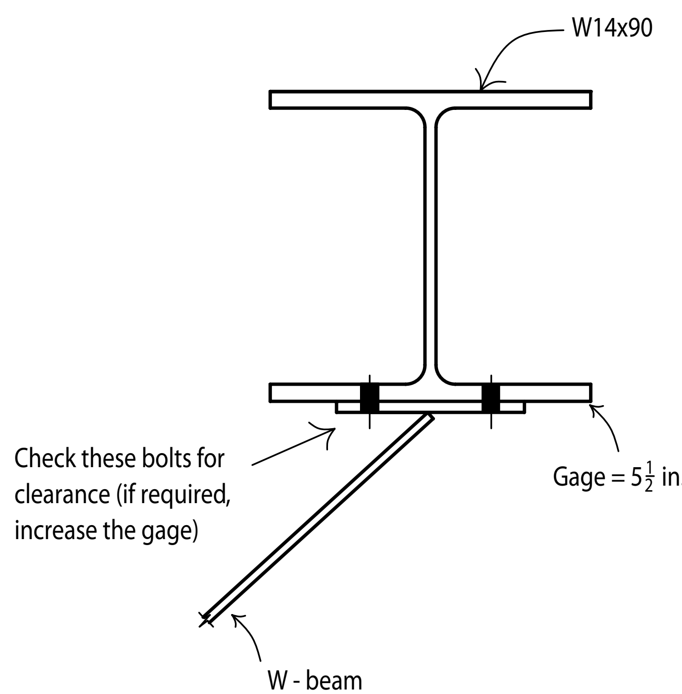
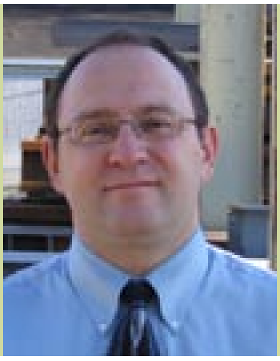


Figure 2: Skewed connections may reduce clearances required for bolt installation, requiring some suitable modification.

Minimum column gage without encroachment =
2 x (1⅞ in.) + (1¾ in.)/2) = 5½ in.

Bolt entering and tightening clearances should always be considered during connection design and detailing. Ignoring this will almost certainly lead to fabrication and erection problems when bolts can't be installed or pretensioned in the shop or in the field. Figure 2 illustrates a skewed W-shape beam-to-column shear end-plate connection, which should be checked for installation clearance. Using hex head bolts in lieu of tension-control bolts might be a solution when clearances are tight. Hex head bolts are shorter



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than tension-control bolts and can be tightened/pretensioned by turning either the nut or the bolt head.

The AISC *Manual*, 13th edition provides important information for checking entering and tightening clearances for bolts:

1. For conventional A325 and A490 hex head bolts: Table 7–16
2. For tension control F1852 and F2280 bolts: Table 7–17
3. For all bolted and bolted/welded skewed connections: Table 10–13.

In some cases it may be beneficial to use smaller gages to, for example, specify thinner angles or end plates that resist axial loads. However, the engineer should keep in mind that changing the gage along the column (or any other member for that matter) risks fabrication mistakes. It might be better to use thicker connection material than to find out that 40 bolt holes don't match in the field.

Maximum Gages

Maximum gages are normally required when:

1. The flange is narrow (for example, W10x19, which has a 4-in. flange width);
2. Four bolts are placed across the flange (like in truss connections);
3. Using skewed beam-to-column framing (see Figure 3 for example).

Maximum gages are limited by minimum edge distances required by AISC *Specification* Section J3.4. In determining minimum edge distance, Section J3.4 refers to Tables J3.4/J3.4M and J3.5/J3.5M if other than standard holes are used, and Section J3.10 as required for checking bearing strength at the bolt holes. The *Commentary* for Section J3.4 states: "The minimum edge distances given in Table J3.4 and Table J3.4M are to facilitate construction and do not necessarily satisfy the bearing and tearout strength requirements in Section J3.10. Lesser values are permitted if the requirements of Section J3.10 are satisfied."

Special Cases

There are connections when workable gages listed in Table 1–1 simply can't be used. In other cases, the workable gage is one possible solution but not the only solution. The following scenarios show some examples of this.

Scenario #1: workable gage is inappropriate.

Gravity column splices. Gages listed for bolted column splices in Table 14–3 in the AISC *Manual* don't match workable gages in Table 1–1. For example, for a W14x132 column splice an 11½ in. gage needs to be used.

Scenario #2: workable gage has an acceptable alternative.

W-shape framing into a W12x35 column flange (b_f = 6½ in.) with a standard double-angle connection with ¾-in. diameter A325–N bolts and a 4-in. gage. Even though Table 1–1 lists a 3½-in. workable gage, a 4-in. gage also would be acceptable because providing 1¼-in. edge distance exceeds 1-in. minimum edge distance at rolled edges of shapes per *Specification* Section J3.4.

Scenario #3: other requirements prohibit using workable gage.

W16x31 cantilever (b_f = 5½ in.) connected to W14x550 (k_1 = 2⅜ in.) column flange with an extended end-plate moment connection. The bolts used are ⅞-in. diameter A325–N (D = 1.535 in.). The minimum gage for the W14x550 column is 6¼ in., however per the requirements for extended end-plate moment connections, the maximum gage should be equal to the flange width of the framing W-shape (5½ in.) Specify a 5½-in. gage for this connection with a shop note for the column: "Shop note: verify ⅞-in. diameter F1852 bolts can be installed at Gage = 5½ in." From a practical perspective, the bolts in this case are likely to encroach upon the fillet on one or both sides of the web. That encroachment is acceptable up to the limits shown in Figure 10-3 of the *Manual*. For larger encroachment, we also include in the shop note, "If required, grind column fillets at bolt locations."

Conclusion

In most cases, deciding on the correct gage is a straightforward procedure, and the answer may change from project to project. However, in all cases during connection design, the most efficient solution should be based on these considerations:

1. AISC *Specification*
2. Special connection requirements
3. Loads
4. Actual framing
5. Clearances
6. Connection economy
7. Standard practice.

And that is what makes connection design interesting! MSC

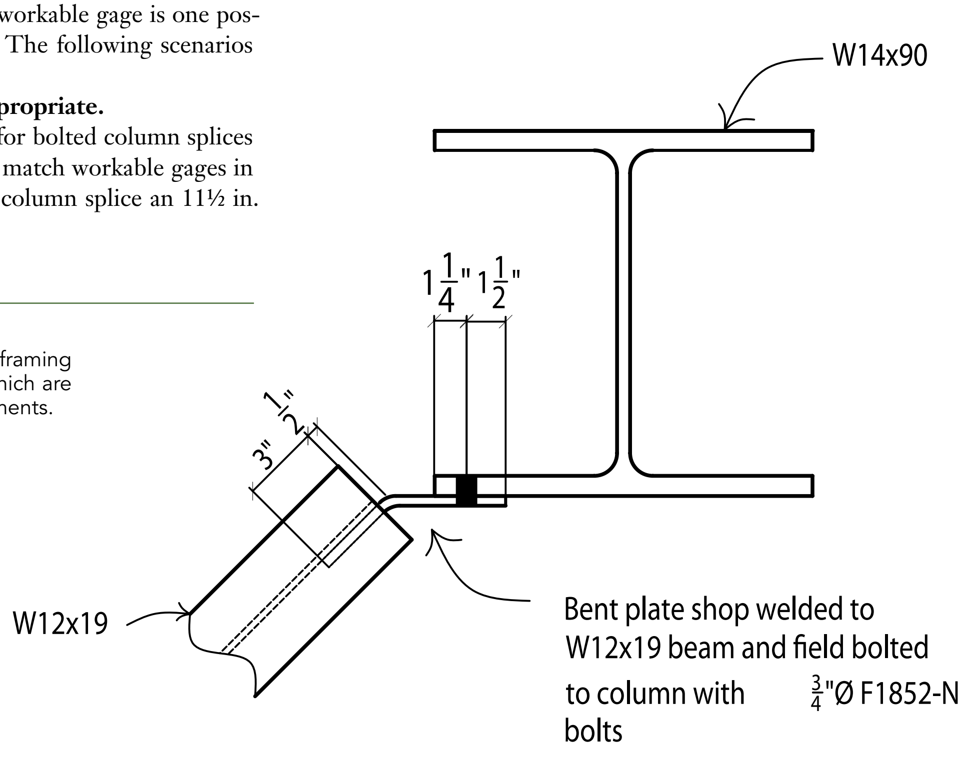

Figure 3, right: Skewed beam-to-column framing may require the use of maximum gages, which are limited by minimum edge distance requirements.