steelwise

BEAR IT AND GRIN

Getting a bearing on bearing can help you design more efficient connections for a variety of steel assemblies.

BY LARRY MUIR, P.E.

STRUCTURAL ENGINEERS PERPETUALLY STRIVE for more economical designs.

Finding ways to reduce needed material is often one of the first steps, but opportunities for reducing the cost (while maintaining the value) of the steel package are also available when it comes to connections. One method of getting more out of connections is to have them resist compressive loads through steel-on-steel bearing. But as the saying goes, "With great power comes great responsibility"—and if we are going to rely on bearing, then we also have to ensure bearing will exist.

The AISC *Specification* provides opportunities for designers to incorporate bearing, and taking advantage of them can lead to better, more efficient connection design.

The Power

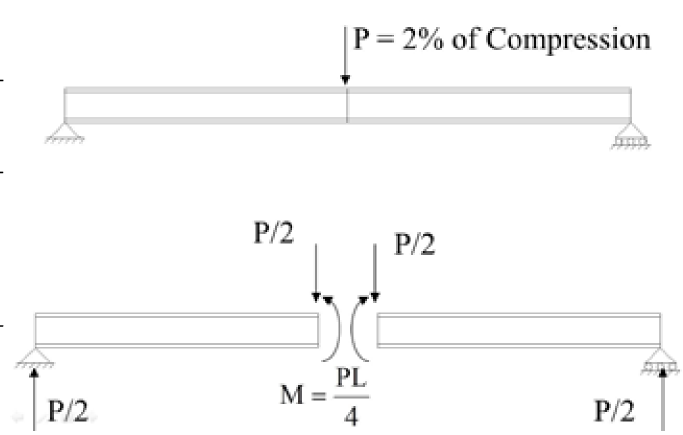
Section J1.4 of the AISC *Specification* addresses the required strength of the connections joining compression members in bearing. One thing that is immediately obvious is that the member types are separated into two groups: columns and members other than columns. This distinction occurs repeatedly in the AISC *Specification*, and members other than columns are generally subjected to more stringent requirements. The reason is that the conditions that exist for a column are assumed to be well defined and beneficial to ensuring the transfer of loads through bearing. A column splice will generally look similar to the typical splices shown in part 14 of the AISC *Steel Construction Manual*. By definition, a column is "nominally vertical" and therefore during erection gravity will tend to push the joint into bearing, a condition that may not exist in a compression chord splice in a truss, for instance.

We also know that a typical column splice can transfer a great deal of moment, easily satisfying OSHA requirements and likely developing the strength and stiffness required to prevent global buckling of the member even when not specifically checked to do so. For these reasons, J1.4 only requires that the connectors at column bearing splices and plates be sufficient to hold the parts securely in place. In contrast, the connectors in members other than columns that bear must be designed for stated demands of the lesser of either 50% of the required compressive strength of the member or the moment and shear resulting from a transverse load equal to 2% of the required compressive strength of the member applied at the location of the splice.

These requirements are not at all onerous, since the same mechanisms that often allow us to treat column splices as "okay by inspection" can also be employed to satisfy the connections for members other than columns. The explicit requirements serve the purpose of making an engineer stop and think about the condition and its behavior. The largest demand is produced when the splice is located mid-span, as shown in Figure 1. Moving the splice close to a braced point, such as a floor or a truss node, can reduce the demand significantly.

The AISC *Specification* provides further requirements for welds used in connections that bear. Relative to joints that employ PJP groove welds and transfer load through bearing,

Figure 1: AISC *Specification* Section J1.4 requirement.



Larry Muir (muir@aisc.org) is AISC's director of technical assistance.

the *Specification* once again distinguishes between columns and members other than columns. In Table J2.5, consistent with Section J1.4(1), the PJP welds between columns in bearing are not required to resist any defined load and instead exist merely to hold the parts together. In contrast, PJP groove welds used in bearing joints for members other than columns are obviously subject to the loads provided in Section J1.4(1). This is no surprise. What might be unexpected is the assumed design strength of these welds, which is given as 0.6 F_{EXX}. The Commentary does not provide an explanation as to why this reduction in the strength of the weld is applied for the case of a bearing connection. It does state that it "...has been used since the early 1960s to compensate for the notch effect of the unfused area of the joint, uncertain quality in the root of the weld due to the inability to perform nondestructive evaluation and the lack of a specific notch-toughness requirement for filler metal. It does not imply that the tensile failure mode is by shear stress on the effective throat, as in fillet welds."

Many of these stated reasons for the reduction do not apply to joints that are assumed to remain in compression. Notch-toughness and notch effects are considerations for joints in tension, and the statement that the failure mode is not by shear stress on the effective throat is equally applicable to welds in compression. Again, it comes down to uncertainty about the joint. With a column, the configuration of the joint is well defined and gravity will tend to aid in attaining bearing, but this might not be the case with other configurations.

The Responsibility

As we've demonstrated, the AISC *Specification* gives the engineer great power to decide that bearing will exist and therefore eliminate a great deal of the material and labor that would otherwise have to be incorporated into the joint. Now for the responsibility part.

In order to transfer loads through bearing, bearing must actually exist—but what constitutes bearing? The answer is scattered throughout the AISC *Specification* and the AISC *Code of Standard Practice* (though primarily can be found in Chapter M of the *Specification*). AISC *Specification* Section M2.6 states:

"Compression joints that depend on contact bearing as part of the splice strength shall have the bearing surfaces of individual fabricated pieces prepared by milling, sawing or other suitable means."

This is a general requirement and is intended to ensure the surface is relatively straight and smooth. Section M4.4 of the *Specification* addresses the required fit of the bearing surfaces, at least for columns, and states:

"Lack of contact bearing not exceeding a gap of 1⁄16 in. (2 mm), regardless of the type of splice used (partial-joint-penetration groove welded or bolted), is permitted. If the gap exceeds 1⁄16 in. (2 mm), but is equal to or less than ¼ in. (6 mm), and if an engineering investigation shows that sufficient contact area does not exist, the gap shall be packed out with non-tapered steel shims. Shims need not be other than mild steel, regardless of the grade of the main material."

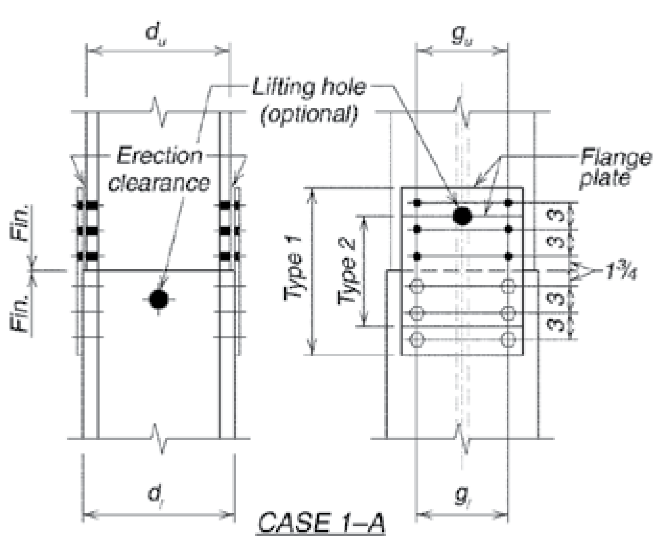
The Commentary indicates that tests have shown that small gaps due to out-of-square can be accommodated without any loss of strength. Section M2.8 of the *Specification* addresses requirements related to ensuring that the bearing surface of plates is sufficiently flat. Though explicitly addressing columns, these requirements could form the basis of project-specific requirements.

Power (and Responsibility) in Action

Let's take a look at some examples, using various scenarios, of how bearing can improve connections.

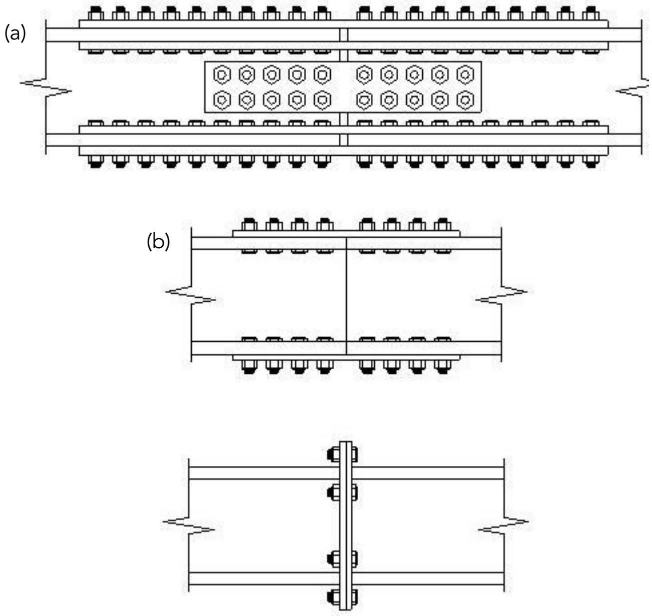
Column splices. Figure 2 illustrates a typical column splice, like those provided in Part 14 of the AISC *Manual*. In addition to the AISC *Specification* requirements, OSHA 1926.756(d) requires these splices to be able to resist the effects of a 300-lb force applied 18 in. off the center of the column. Engineers also may apply their own more stringent requirements to account for erection loads, such as designing for some lateral load to account for conditions during erection. The same concept that results in the 2% of the compressive demand in Section J1.4 could also be applied to columns, though again there is no explicit requirement. The moment strength of the splice can be checked assuming bearing on the compression side and using the bolts to resist the tension. Though the AISC *Specification* requirements explicitly ensure a specified strength, stiffness at the splice is also critical to ensuring that the column can develop its required strength. In general, joints in bearing can be assumed to have sufficient stiffness.

Figure 2: Typical column splice.



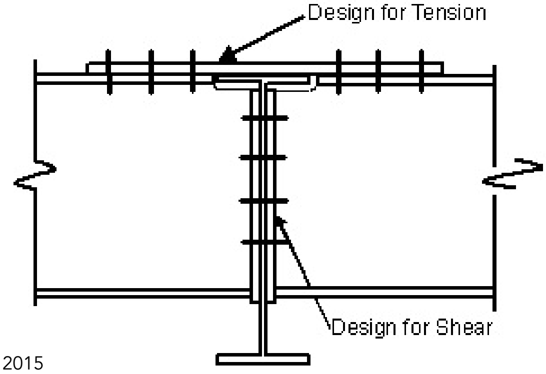
Truss splices. Often, trusses resist gravity loads such that the top chord remains in compression. Though engineers often configure the top and bottom chord splice similarly, half of the splices can often be economized by taking advantage of compression bearing. Figure 3(a) shows a splice designed to transfer compression through a bolted splice without bearing. Figure 3(b) provides two alternatives designed to transfer compression through bearing.

Figure 3: Truss splices.



Cantilevered beams. Another common condition where bearing can be used to considerable advantage is at cantilevered beams. Figure 4 shows a detail in which the tension side of the moment is resisted by a bolted flange plate while bearing is used to resist the compression. The web connection bolts resist only vertical shear. In this case, the use of bearing to resist compression results in less shop and field work. It also has the added advantage that finger shims can be driven under the end plate to adjust the elevation at the far end of the cantilever.

Figure 4: Cantilevered beam.



Hearst diagrid. Diagrid assemblies are another situation where bearing can be used to enhance connections. All of the diagrid connections for the Hearst Tower in New York, N.Y., for example, employed bearing, which significantly reduced the amount of welding that had to be done in the shop and the number of bolts that had to be installed in the field. It should be noted that while compression was the predominant demand, these members were not subjected to compression loads alone. A complex set of moments, shears and even uplift also had to be resisted (and were resisted through the bolts and welds).

Bearing was ensured through careful detailing and milling of the plates at the bearing surfaces. Even so, in one instance either the joint was not properly assembled or somehow the geometry changed during erection, and a gap was noticed in the joint after the erection of four subsequent floors. It was impractical to disassemble the joint and refit the member. It was decided to continue erection while monitoring the joint in hopes that the weight of the structure would force the elements into bearing. Fortunately, this proved to be the case and no remedial action was required. If the gap had not closed, shims would have been installed in accordance with Section M4.4 of the AISC *Specification*. Again, if bearing is relied upon in the design then bearing must be ensured in the final structure. (See "Something Old, Something New" in the April 2007 issue and "A New Angle" in the July 2006 issue, both available at **www.modernsteel.com**.)

Knowing where to find bearing guidance and how to apply it to different scenarios can help you create better connections that result in a more economical project. ■

The signature diagrid of Hearst Tower in New York.