# Keeping Fillet Welding in CHECK

BY CARLO LINI, P.E.

A couple of common questions (and answers) on checking fillet weld designs.

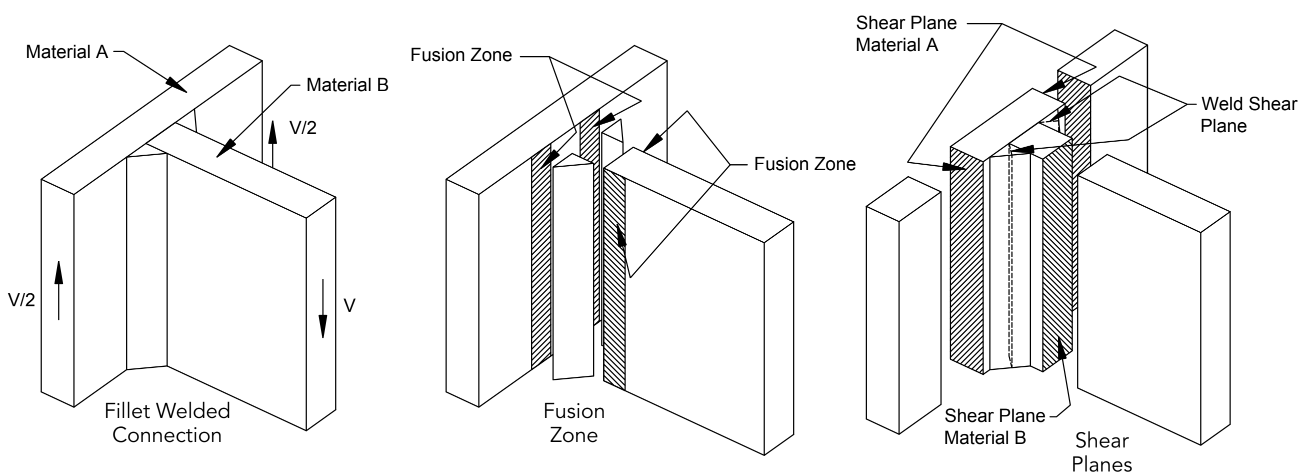


Figure 1. Shear planes and fusion zones for longitudinal shear.

**WHEN IT COMES** to welding, the AISC Steel Solutions Center receives quite a few questions on these two fillet welding topics: (1) the need to check the fusion zone for fillet welds; and (2) how and when to check the shear plane for fillet welds. Here are some insights on both.

## Fusion Zone

Let's start with the fusion zone question. Figure 1 illustrates both the fusion zone and the shear planes for a near-side far-side fillet weld. The weld shear planes are at the bisector of the dihedral angle—what we commonly call the effective throat of the fillet weld.

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The strength of fillet welds is covered in Section J2.4 of the AISC *Specification*. For the base metal, the strength is calculated based on the cross-sectional area of the base metal, $A_{BM}$, which is based on the shear planes identified in Figure 1. For the weld metal, the strength is based on the effective area of the weld, $A_{we}$, which is shown in Figure 1. Note that Figure C-J2.10 in the Commentary on the AISC *Specification* also identifies the shear planes for fillet welds loaded in longitudinal shear (Figure 2).

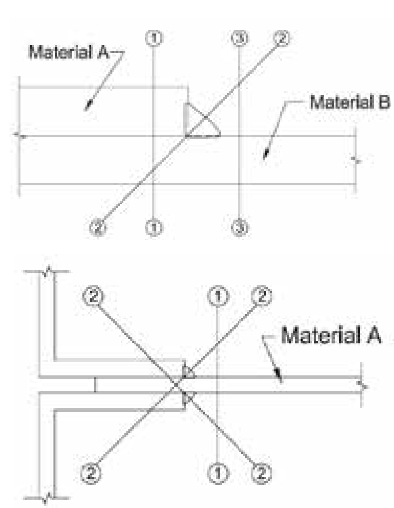


Figure 2. Shear planes for fillet welds loaded in longitudinal shear.

Notice that there are no requirements for checks on the fusion zone in Section J2.4. This check is not required because the required filler metal strength per Table J2.5 of the AISC *Specification* must be equal to or less than matching. Note that Table J2.5 does permit the use of filler metal with a strength level one greater than matching.

As stated in the footnote to Table J2.5, Section 3.3 of AWS D1.1/D1.1M defines levels of matching. However, one can loosely summarize the terms as follows:

**TABLE J2.5 (excerpt)**
**Available Strength of Welded Joints, ksi (MPa)**

| Load Type and Direction Relative to Weld Axis | Pertinent Metal | $\phi$ and $\Omega$ | Nominal Stress ($F_{nBM}$ or $F_{nw}$) ksi (MPa) | Effective Area ($A_{BM}$ or $A_{we}$) in.$^2$ (mm$^2$) | Required Filler Metal Strength Level [a][b] |
|---|---|---|---|---|---|
| FILLET WELDS INCLUDING FILLETS IN HOLES AND SLOTS AND SKEWED T–JOINTS | | | | | |
| Shear | Base | Governed by J4 | | | Filler metal with a strength level equal to or less than matching filler metal is permitted. |
| | Weld | $\phi = 0.75$<br>$\Omega = 2.00$ | $0.60F_{EXX}$ [d] | See J2.2a | |
| Tension or compression Parallel to weld axis | Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts. | | | | |

- Minimum Weld Strength < Minimum Material Tensile Strength—Undermatching Filler Metal
- Minimum Weld Strength = Minimum Material Tensile Strength—Matching Filler Metal
- Minimum Weld Strength > Minimum Material Tensile Strength—Overmatching Filler Metal

A good discussion on matching, undermatching and overmatching filler metal strengths is provided in AISC Design Guide 21: *Welded Connections—A Primer for Engineers* (a free download for AISC members at **www.aisc.org/dg**). As summarized in the guide, "Standard design procedures do not consider the base metal strength, since the assumption is that the weld metal throat will theoretically control. This is a conservative assumption, provided that matching or undermatching filler metal is used."

## Base Metal Shear Plane Checks

Regarding the second topic—when and how to check a shear plane in the base metal adjacent to the fillet welds—this stems from what seems to be an overuse of Equation 9-2 and 9-3 in Part 9 of the 14th Edition AISC *Steel Construction Manual*. The intent of providing these equations is as follows: "In many cases, the load path from a weld to the connecting element can be evaluated directly. However, in some cases, the available strength of the connecting element is not directly calculable. For example, while the strength of the beam-web welds for a double-angle connection can be directly calculated, the strength of the beam web at this weld cannot. In cases such as these, it is often convenient to calculate the minimum base metal thickness that will match the available shear rupture strength of the weld(s)."

Figure 3 illustrates a common condition where Equations 9-2 and 9-3 are used to check the base metal strength.

Unfortunately, it is not uncommon to see a similar check of the base metal even when the load path from a weld to the connecting element can be evaluated directly, such as when connecting a single-plate connection to a column flange. In such cases, it is completely sufficient to check the base metal directly and not necessary to use the comparative calculation approach we adopt when the direct check is not possible. The comparative approach, in a lot of cases, will be overly conservative when checking the base metal strength relative to the weld strength, which is likely based on a fillet weld size that has been rounded up to the nearest 1/16th of an inch or is based on a minimum fillet weld size.

One should also consider if a shear rupture check of the base metal is necessary. Whether one decides to check shear rupture at this location or similar locations is a matter of engineering judgment, although I do not believe this check is typically necessary It would be similar to checking the column flange of a bolted connection for shear rupture (Figure 4), which is typically not done. If this happens to be a controlling limit state, you should consider if the check is necessary before reinforcing is required or the member size is increased. ■

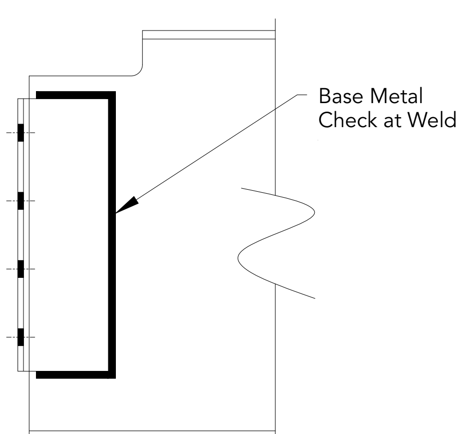


Figure 3. Base metal check along C-shaped weld.

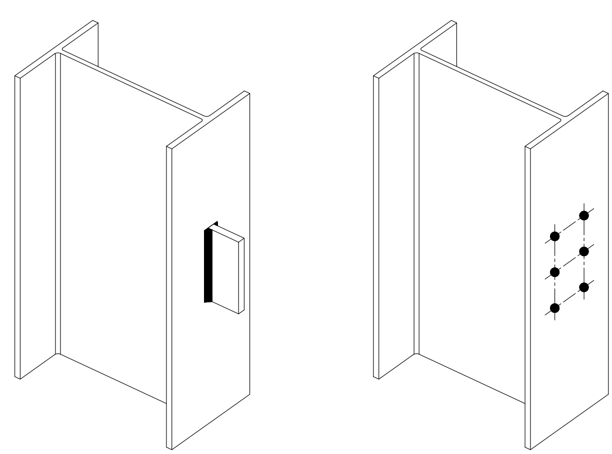

Figure 4. Comparison of a welded and bolted connection to a column flange for shear rupture checks.