

steelwise

BLODGETT'S TREASURES

BY ERIN CRISTE

Practical advice from
a master of weld design.

IF YOU'VE EVER DESIGNED a structural weld, you've likely heard of Omer W. Blodgett. His book *Design of Welded Structures* remains a go-to reference even though it dates back more than 40 years. But while you may know his name, you might not know how Mr. Blodgett came to be the face of welding.

Blodgett first started learning to weld on his grandfather's Lincoln welder at the age of 10, which he says began his life's journey of learning and teaching welding principles. (Much of this is captured in an interview that is posted on AISC's Podcasts page at www.aisc.org/content.aspx?id=25892; scroll down to Episode 9.)

Blodgett is known for his ability to distill complex concepts into simple summaries. He also has coined many memorable sayings that are easily transferred from one generation to another. Here, we've presented a brief summary of some of the key points pulled from his books (particularly *Design of Welded Structures*), papers, articles and lectures.



Don't design with your heart.

Blodgett has said, "It's OK to fall in love with your heart. But, when it comes to making engineering decisions, don't design with your heart." His point is that there are a variety of things that may intuitively seem to be correct, but analysis might lead to another answer. Take web penetrations or openings, for example. The

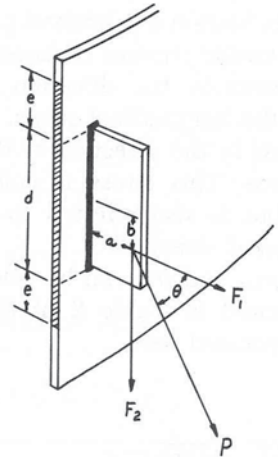
"heart's" first reaction to any opening or reduction in area is to add reinforcing. While reinforcing might be necessary in some cases, it is not needed in all cases. And in cases where it is needed, how do you determine the reinforcing?

AISC *Steel Design Guide 2: Design of Steel and Composite Beams with Web Openings* provides guidance for compact wide-flange beams. For non-compact

beams, Section 4.7 of Blodgett's *Design of Welded Structures* provides guidance on designing beams and girders with web openings using first principles of engineering mechanics to check: web shear, web buckling and Vierendeel bending. Next time you have a project requiring an opening or want to see what effect a reduction in area of the web has on your section, don't design with your heart; use some analysis to see if reinforcement is required, using the procedures in AISC *Design Guide 2* or as outlined by Blodgett.

Provide a path for the load to enter into the member that lies parallel.

A typical oversight when designing welded connections is the failure to provide a proper load path so that a transverse force can enter that part of the member that lies parallel to the force. The flexibility afforded by the welding process permits materials to be configured and connected in a variety of ways—including ways in which the loads cannot be properly transferred between the members. While this principle applies to many situations, one common occurrence is in the design of hangers and supports. Section 6.6 of *Design of Welded Structures* provides guidance on designing such weldments.



One must account for a proper load path and consider the orientation of the weld to the force to minimize mistakes in real-world applications. Providing a proper load path can be more apparent when the section and the joints are square. However, when designing a curved section (such as pipe and supports/hangers) it might not be as obvious. In this case and many others, it is important to think of how the force will transfer through the weldment when selecting its details and configuration. One must always provide a proper load path so the force can enter into the section that lies parallel. There are many examples and discussion throughout the Blodgett resources, such as in Section 6.6 on hangers.

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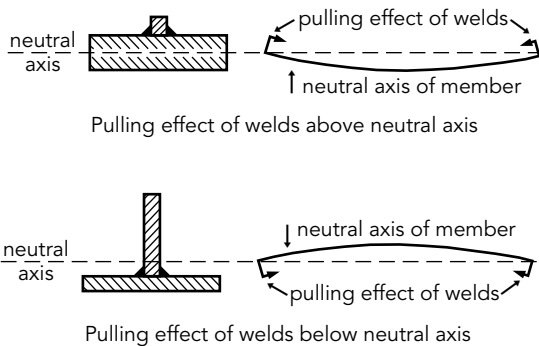
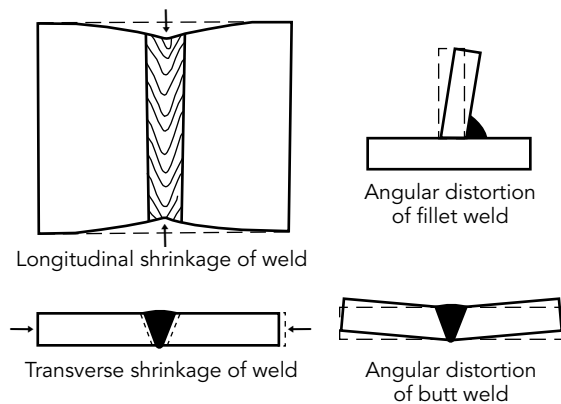


Understand distortion and shrinkage.

Blodgett provides explanation, details and examples of calculating, controlling and designing for distortion and shrinkage in Section 7.7 of *Design of Welded Structures*. While distortion in welded connections is often visible, the principles of minimizing distortion are not always readily understood. In brief, distortion is caused when hot, expanded metal (whether the weld metal or heated base metal) shrinks, causing flexible members and their cross-sectional elements to move.

When it comes to controlling distortion, a key principle is to minimize the weld metal volume. Decreasing the weld size and length will reduce the shrinkage forces and help minimize the overall distortion in the weldment. In the case of complete joint penetration (CJP) groove welds, weld details such as root opening and included angles can be optimized to reduce weld metal volumes, as well as the corresponding distortion, while maintaining the same weld strength.

Another important factor is not over-welding. Not only does over-welding increase the amount of weld, it also increases the heat input (which results in larger shrinkage forces) and the overall cost and potential for additional repair costs. Blodgett provides techniques that reduce distortion and can lead to cost savings on a project. For more on over-welding, see “Control Costs by Avoiding Overwelding” (07/2011).

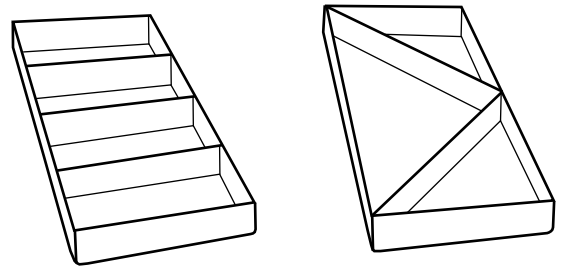


There are many factors that affect the distortion and shrinkage in a weldment, and distortion control principles go beyond simply reducing the weld size. Balancing the welds around the neutral axis of the member reduces the shrinkage moment and reduces the overall distortion in the member.

Think outside the box.

There are discussions of torsion in Section 2.10 and 6.4 of *Design of Welded Structures*. Three basic rules to address torsion in weldment design are:

- Use closed sections where possible. Closed sections, such as hollow structural sections (HSS) and steel pipe, have much higher strength and stiffness under torsional loading than do open sections.
- Use diagonal braces to restrain members against twisting.
- Make rigid end connections to keep flanges from swinging.

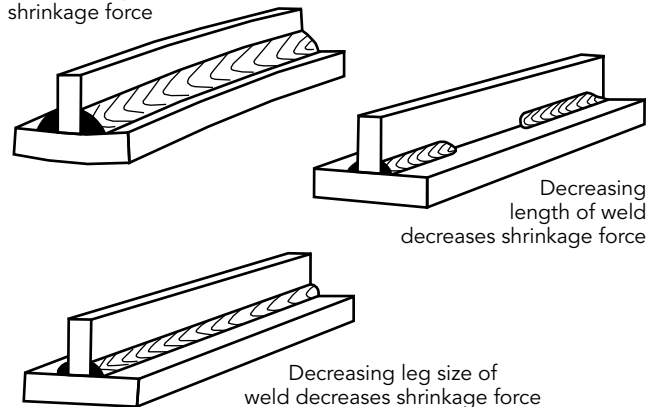


Blodgett covers these points in detail in his book. Less commonly known is that he also provides a method he developed to permit calculation of the angular twist along the length of such members.

Use smaller fillet welds.

There is a perception that more is better. However, when it comes to welding, this is often not the case. Consider for example a small fillet versus a CJP groove weld. If both are sufficient for the design, the fillet weld option is typically better. While for strength that might be true, there are other considerations in determining the size of welds. Section 7.4 of *Design of Welded Structures* discusses how to determine weld sizes.

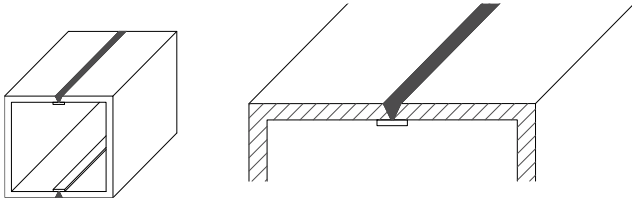
Overwelding increases the shrinkage force



For economical designs, it is preferred to make fillet welds smaller in size and longer in length; smaller fillet welds generally provide economy over large fillet welds. Why is this? Because the weight and cost of the weldment increases by the square of the leg size of the weld. Thus, savings in the weight of the weld metal for each weld and the arc time it takes to make each weld can be achieved by specifying the smallest, longest fillet weldment. Not only are there savings but the smaller, longer welds also help reduce heat input and the distortion of the base metal. It's a win-win!

There are no secondary members in welded design.

This is a simple principle to remember but probably the toughest lesson (or mistake) to make or realize in practice. A weldment provides a path through which the stress flows. Section 2.9 of *Design of Welded Structures* highlights how this can cause concern or difficulty when designing for fatigue.



Discontinuous backing bars inside box members can lead to stress risers that initiate crack growth in fatigue loading. Prohibited by AISC for cyclically loaded structures and for all structures by AWS D1.1, the unfused interface between segments of discontinuous backing can create stress concentrations in the root of the weld. Accordingly, if backing must be spliced, the AISC *Specification* requires CJP groove welds at the butt joint and reinforcement ground prior to assembly.

Not a case of fatigue but another example of this principle is steel backing. Left-in-place backing can, in some situations, create stress concentrations in the weld root that may be problematic. Such an example is when backing bars are used at the bottom flange of a high-seismic moment connection. AISC 341 refers to AWS D1.8 in this case, which requires the complete removal of bottom flange backing bars (with some exceptions in areas of anticipated low strain).

These are just a few of the many insightful design philosophies expressed from a humble education enthusiast and lifetime contributor to the steel industry. As Omer Blodgett is known for saying, "Experience is learning from past mistakes." His teachings, articles and books have given us many of his lessons, insights and treasures.

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