How Effective Are Your Arc Spot Welds?

By Jeremy L. Achter, S.E., LEED AP

An effective diaphragm is an essential component of a structurally sound building. The diaphragm provides lateral stability for the columns and/or bearing walls, braces the compression edge of floor framing members, and distributes wind and seismic forces to elements of the vertical lateral force-resisting system.

Diaphragms are divided into two main categories: rigid and flexible. Rigid diaphragms are often idealized as infinitely rigid plates that rotate about the center of rigidity and distribute loads based on the relative stiffness of each vertical lateral force-resisting element. Concrete slabs are often analyzed as rigid diaphragms. Flexible diaphragms experience distortion under the application of lateral loads and distribute those forces based on the geometric layout of the vertical lateral forces-resisting elements. Cold-formed steel decking without a concrete topping slab is generally considered a flexible diaphragm. Whether rigid or flexible, the connection of the diaphragm to the supporting structure is critical to the performance of the system.

Several different methods are used to attach cold-formed steel decking to the supporting structure: arc spot welds, shot-pins, or screws are the most common.

For flexible diaphragms, the demand is calculated for the required earthquake and wind loads in accordance with the adopted code. Manufacturer's literature and ICC/IAPMO report's contain shear capacity and flexibility factors the engineer can use to determine the needed metal deck gage and fastening pattern to achieve the required diaphragm stiffness and shear resistance.

Read either the footnotes of the Support Fastening section of the manufacturer's literature or the corresponding ICC/IAPMO report and you'll likely find that the published values are based on a fusion area resulting from a ½-inch effective diameter, d_e, arc spot weld. An arc spot weld can be thought of like a mushroom with a short stem rooted in the supporting structure. Achieving the correct effective fusion area is key to the performance of the diaphragm.

What does effective fusion area mean and how can it be correlated to the information contained in the structural drawings? In my experience as a designer and having reviewed structural drawings from many different firms, most engineers show the industry standard for diaphragm construction and indicate in the structural drawings that a ¾-inch diameter nominal arc spot weld is required.

Effective Diameters of ¾″ Visible Arc Spot Welds (d=0.75″)					
Deck Gage and Thickness		One Layer of Sheet Steel (Typical in Field of Sheet)		Two Layers of Sheet Steel (Typical at End Laps)	
Gage	Thickness (inches)	t (Inches)	d_e (inches)	2t (Inches)	d_e (inches)
22 gage	0.0295	0.0295	0.48″	0.059	0.44″
20 gage	0.0358	0.0358	0.47″	0.072	0.42″
18 gage	0.0474	0.0474	0.45″	0.095	0.37″
16 gage	0.0598	0.0598	0.44″	0.120	0.35″

Per section 2210.1.1 of the 2012 *International Building Code*, steel roof decks shall be designed and constructed in accordance with ANSI/SDI-RD1.0. Section 3.2 of ANSI/SDI-RD1.0 states that all welding of steel deck shall be in accordance with ANSI/AWS D1.3. Figure 2.4 of AWS D1.3 provides the following equation for calculating the effective weld size of arc spot welds.

$d_e = 0.7d-1.5t$

where

d_e = Effective diameter of fused area at the plane of maximum shear transfer

d = Visible diameter of the outer surface of the arc spot weld

t = Total combined base steel thickness of sheets involved in shear transfer above the plane of maximum shear transfer

The effective diameter is calculated, using the above equation, as follows:

This table indicates that the effective diameter of a ¾-inch visible arc spot weld does not comply with the ½-inch minimum required by the independent evaluation reports. Perhaps, through mathematical rounding, one can justify that the specified ¾-inch diameter arc spot weld achieves the ½-inch required effective weld; however, this type of reasoning may be harder to justify with 18 gage deck or thicker, and is unreasonable at lap conditions where the design thickness (t) is twice the single sheet thickness. In these cases, a nominally larger diameter weld, or the use of weld washers may be required by design.

Should the ubiquitous ¾-inch diameter arc spot welds be replaced with larger ⅞-inch or 1-inch diameter welds? Should published deck shear values be provided with nominal or visible weld diameters instead of effective diameters? If their values are based on testing, then yes they should. The design values should be based on verifiable data, not prescriptive provisions. Should construction drawings specify an effective weld diameter as opposed to a visible diameter and let the contractor figure it out? This option is not viable because a contractor has no idea what effective means and the welds cannot be verified by the inspector, contractor, or engineer.

An engineer might consider that calculated diaphragm shears rarely result in a demand-to-capacity ratio of 0.99; deck spans are often rounded to the next highest ½-foot increment to achieve published load values; or, that a 0.47-inch effective diameter spot weld through 20 gage material is 0.03-inch less than the required ½-inch effective diameter, approximately 6%. These are reasons to believe the ¾-inch diameter weld is within the realm of acceptable "construction tolerances." However, it is also worth considering that any attorney can make a big deal out of such a small number.▪

Jeremy L. Achter is an Associate Principal at ARW Engineers in Ogden, Utah. He currently serves on the UBC Commission Structural Advisory Committee and serves as a member of the STRUCTURE Editorial Board. He can be reached at ***jeremya@arwengineers.com****.*

Since the writing of this article, AISI has published a new report on the resistance of arc spot welds loaded in shear and tension for building and construction. The information in this article has not been compared to, or reviewed against, the new report. The report can be found at **www.steel.org**.