Arc Welding Light Gage Steel

By Duane K. Miller, Sc.D., P.E.

Cold-formed steel now represents over 45 percent of the steel construction market, according to the American Iron and Steel Institute (AISI). For relatively light weight construction such as condominiums and residential housing, cold-formed steel members offer an environmentally friendly alternative to lumber, which is subject to shrinkage, warpage and termites. Floors, walls and roofs may be framed in, or composed of, cold-formed steel. In the highway industry, light gage steel has been used for culverts, guard rails, median barriers and signs. In traditional heavy structural steel buildings, sheet steel often supports the concrete slabs. Given the wide number of applications for such materials, the AISI statistic is not surprising.

Gage steel applications may be initially viewed as "non-critical" applications, but this impression is far from accurate. Consider for example material storage racks, typically made of cold-formed material, and rack supported buildings. Highway guard rails play an obvious safety role. Building elements such as purlins, girts, and braces perform essential functions. Space frame systems have been made of cold-formed steel members, yielding light weight yet strong roof systems. The appearance of light weight should not prompt a casual attitude about the critical function these members perform.

Wherever steel is found, welding is typically there too, and cold-formed steel construction is no different. However, the similarities between welding hot rolled structural shapes and cold-formed light gage are a bit like comparing a lion to a housecat: they may both be furry and yellow, but the differences are greater than the similarities. Not only are the welding processes and techniques different for joining the thinner materials, but so are the applicable codes, weld joints, weld types and the nature of potential problems.

Welds to such gage metal applications should not be viewed as "non-critical" welds either. Just like their counterparts on heavy steel, welds joining sheet steel elements are important, and may be critical to the performance of the system.

Codes

Traditional structural steel construction with hot rolled, wide flange shapes is typically governed by the American Institute of Steel Construction's (AISC) *Design Specification for Structural Steel Buildings*. When structures employ cold-formed steel members, the project usually falls under the purview of the AISI's Specifications for the *Design of Cold-Formed Steel Structural Members*. Similarly, welding of hot rolled structural steel is typically governed by the American Welding Society's *D1.1 Structural Welding Code-Steel*, while sheet steel is covered by AWS *D1.3 Structural Welding Code—Sheet Steel*. D1.1 is "…not intended to be used for …steels less than ⅛ inch [3 mm] thick…" (D1.1-2004, para. 1.2) whereas D1.3 "…covers arc welding of structural sheet/strip steels, including cold formed members…. which are equal to or less than 3/16 inch (0.188 inch/4.8 mm) in nominal thickness." (D1.3-98, para 1.1).

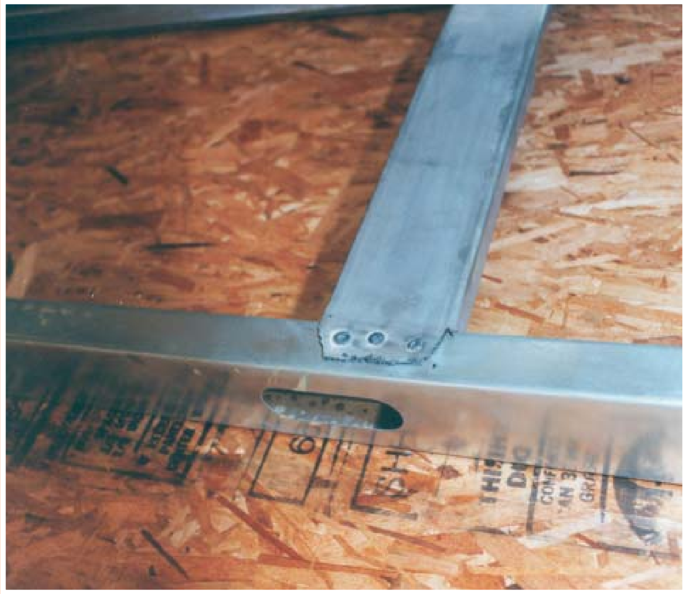

Figure 1: Plug welds are common in sheet steel construction but limited in their use on heavy structural steel.

D1.3 was specifically created to address the welding processes, joints, weld types, materials and other details associated with the welding of thinner members. For example, when welding on heavy material, the challenge to the welder is to achieve good fusion so that a strong weld results. When welding sheet steel, the welder's greatest challenge is to avoid melting through the base metal. Accordingly, D1.3 has incorporated appropriate qualification tests which measure the skills required for this type of work. Similarly, the joints and welds likely to be used in sheet steel construction are addressed in D1.3.

There is a deliberate overlap in the thickness of steels governed by the two codes: both cover the range of ⅛-inch to 3/16-inch (3 to 4.8 mm). While this overlap has caused some confusion over the years, the advantage is that it may permit the use of one code to cover an entire project. For example, if all the steel to be welded on a building is ⅛-inch and greater, D1.1 alone could be used to govern the whole project. Similarly, if everything is lighter than 3/16-inch, then only D1.3 would be required.

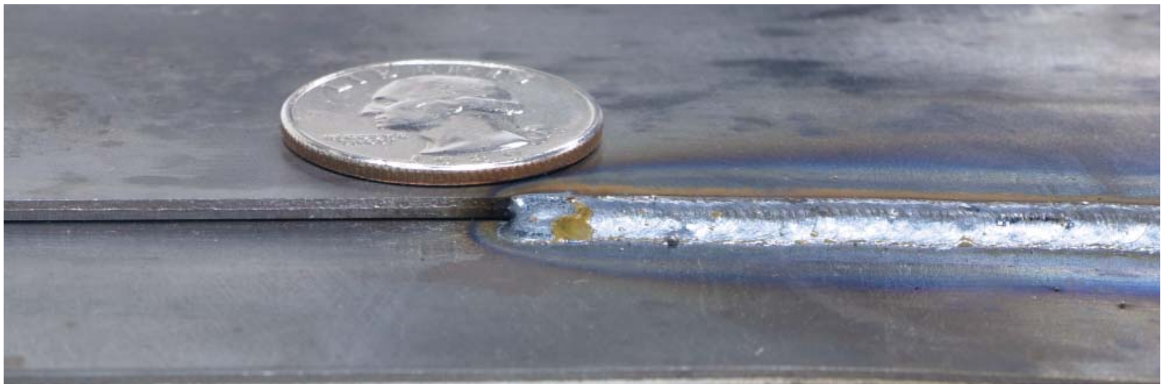

Figure 2: Gas metal arc welding can be used to make high quality welds on sheet steel.

In some cases, thin materials are joined to thick. Perhaps the most common such application is where sheet steel decking is welded to supporting structural steel beams. In such cases, the applicable provisions of both D1.1 and D1.3 are used to ensure that the requisite quality is achieved.

It is important to specify the appropriate standards for a given project. Over the years, many project specifications have called for welding gage steel in accordance with D1.1. Assume for illustration that the actual project involved 16 gage (0.0598 inch/1.519 mm) material. The thinnest standard welder qualification test in D1.1 is a ⅜-inch thick test plate, and when this has been successfully welded, the operator can weld on materials from ⅛-inch minimum to ¾-inch maximum (see D1.1 Table 4.10). Obviously, that does not cover the 16 gage application. To get around this problem, contractors would use the 1-inch test plate which qualifies for unlimited thicknesses. Perhaps this approach met the letter of the law, but the skills required for welding on 1-inch plate are totally unrelated to those required for welding on 16 gage sheet steel.

The corrective action is easy: specify the proper welding code. With D1.3, the welder has the option of being qualified on the thickness of steel to be used in production, or on 16 gage steel (which qualifies for welding on 18 gage and thinner), or on 10 gage steel (which qualifies for welding on 16 gage or thicker). In all cases, the qualification test is appropriate for the application.

Figure 3: Small, portable 120 volt wire feeder/power source combinations may look lightweight, but when produced by a reputable welding manufacturer, they can be ideally suited for welding on gage materials—even for structural applications.

Weld Types

The welds associated with light gage steel are different from their counterparts on heavy steel, and the design criteria for such welds are also different. For thin material, butt joints often receive square edge groove welds, whereas heavy steel will often have some type of groove preparation. Flare vee and flare bevel groove welds are common in cold-formed steel applications since the corners form a natural groove, while such details are infrequently found when dealing with shapes and plates. In lap joints of light or heavy steel, a plug weld is made by welding through a hole in one member. Such welds are seldom used on heavy plate, but are common in sheet steel construction (*See Figure 1*). A puddle weld, commonly used for joining decking to supporting steel, is made by melting through the sheet steel, and fusing into the heavier steel below.

Both heavy steel and light gage steel can be joined with fillet welds. However, the design basis for the two is different: for fillet welds governed by D1.1, the throat is assumed to be the controlling element, and the capacity of the connection depends in part on the strength of the deposited weld metal. In sheet steel applications, D1.3 assumes that the connection capacity is determined by the strength of the sheet steel. As a result, it is the strength of the sheet steel, not the deposited weld metal, that is used in design calculations. The same philosophy is applied to flare vee and flare bevel groove welds, as well as arc spot (puddle) welds. This approach is supported both by research and experience: in their limit state, connections of thin members typically fail by pulling the weld out of or away from the base metal.

Welding Processes

By now, it should be no surprise that the appropriate processes and techniques for welding on sheet steel may be quite different from those used for heavy shape welding. Whereas shielded metal arc welding (SMAW, or "stick") can be used for gage applications with smaller diameter electrodes and low welding current, today most contractors will select the easier-to-use semi-automatic welding processes. However, a mainstay SMAW sheet steel application that remains is that of welding decking to supporting steel. Here, the simplicity, portability and capability of SMAW make it the process of choice. AWS class E6022 electrodes are typically used because of their easy re-striking capability and deep penetration characteristics.

In other gage applications, however, penetration is the welder's enemy. Melt-through (commonly but inaccurately called "burn through") is a constant threat. This is where the semi-automatic processes can really shine: with the use of smaller diameter electrodes (such as 0.035 inch and 0.045 inch), sheet steel welding has never been easier (*See Figure 2*). The two most commonly used processes are gas metal arc welding (GMAW) and flux cored arc welding (FCAW). Both are "wire welding" processes. GMAW uses a solid steel electrode,

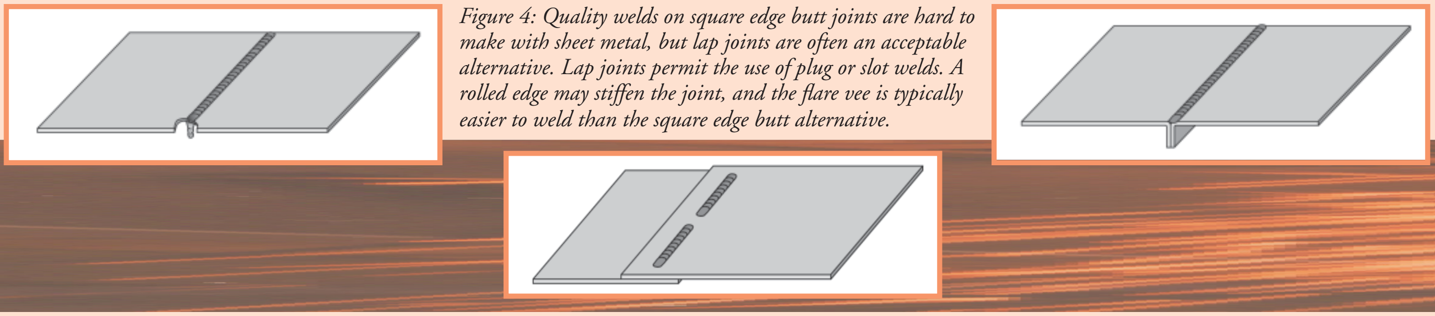

Figure 4: Quality welds on square edge butt joints are hard to make with sheet metal, but lap joints are often an acceptable alternative. Lap joints permit the use of plug or slot welds. A rolled edge may stiffen the joint, and the flare vee is typically easier to weld than the square edge butt alternative.

and always employs a shielding gas to protect the weld pool. There are two versions of FCAW: gas-shielded and self-shielded. The gas-shielded version of FCAW is much like GMAW, except that a tubular filler metal is used. Inside the electrode are fluxing ingredients which, in conjunction with the gas, protect the weld pool. The self-shielded version similarly uses a cored electrode, but no shielding gas is required. This makes self-shielded FCAW more portable, and better suited for windy conditions.

In D1.1, one mode of metal transfer with GMAW is uniquely restricted: short circuit transfer may not be used unless the welding procedure specifications (WPSs) are qualified by test. In addition, the welders who use GMAW short circuit transfer must be specifically qualified to use this mode of transfer. GMAW short circuit transfer is a reduced energy mode of metal transfer, meaning that the process and mode are ideally suited for sheet steel applications, but prone to fusion-type defects when used on heavier steel. Thus, D1.1 restricts the process, but D1.3 specifically acknowledges its acceptability (see D1.3 para. 1.3.1).

Gas tungsten arc welding (GTAW) is also ideally suited for sheet steel applications, albeit a slower and more costly means of welding. Automatic, high speed submerged arc welding (SAW) can be used for welding on gage steel as well, and when appropriate, can make quality welds at very high travels speeds. Resistance spot and seam welding is routinely used to fabricate sheet steel components in shop conditions.

Before leaving the subject of welding processes, a comment about equipment is in order. Today, a variety of power source/wire feeder machines are available that operate on 120 volt power. Typically rated for around 100 amp output, these machines are ideally suited for welding on gage materials. They may look like "hobby equipment" and not machines suited for construction applications. However, reputable, mainline welding equipment manufacturers have produced quality combinations that have been proven in demanding applications, providing the welding is done within the capacity of the machines (*See Figure 3*). For most sheet steel applications, contractors will select a combination wire feeder/power source in the 200 amp capacity range. Today, highly flexible equipment makes a full range of processes—SMAW, GTAW, FCAW and GMAW—available from a single power source, permitting the user to select the optimal process for an application without having to purchase additional equipment.

Melt-through

The number one challenge to welding sheet steel is the tendency toward melt-through. Using the proper welding process, procedure and technique is one tool to address this issue. However, several other tools are available to limit this tendency. When arc welding is to be performed, selecting the proper thickness of material is critical. While thinner materials can be welded, a general rule of thumb is to use at least 18 gage steel (0.0478 inch/1.214 mm) material. Although the difference may not seem great, 16 gage is significantly easier to weld than 18 gage.

Quality welds are tough to make on sheet metal butt joints. Variations in fit-up make it particularly difficult to avoid melt-through on thin applications. However, in many connections, butt joints can be replaced with lap joints (*See Figure 4*). This doubles the thickness of metal in the connection, and may permit the use of easier-to-make spot or slot welds. In other situations, longitudinal square edge groove welds on butt splices can be replaced with flare bevel groove welds. The lip formed under the joint stiffens the joint, aids in fit-up of the parts, and acts as a heat sink, limiting melt-through tendencies.

For repetitive applications, weld fixturing can be used to limit melt-through. Not only do fixtures assist in providing good fit-up of the parts, but copper chill bars can be added, drawing away the heat that would otherwise be problematic.

Figure 5: Plasma arc cutting provides for fast, quality cuts on sheet steel, something that is nearly impossible with oxy-fuel cutting. Additionally, plasma cutting can be used to cut nearly any electrically conductive material, including stainless steel and aluminum.

Welding Challenges

For heavy section welding, cracking is a concern, requiring control of base metals, weld material, preheat and other factors. For sheet steel applications, cracking is rarely a problem. With gage steel applications, however, right behind the tendency of melt-through is the potential problem of distortion. Buckling, warping and twisting are ongoing challenges. The solution is fairly simple, however: keep the weld sizes small, and make the welds as quickly as possible (that is, with the lowest level of heat input). Low heat input GMAW—short circuit transfer mode has another advantage: less distortion is experienced as compared to typical SMAW techniques.

Many of the sheet steels in common use are also coated. Galvanized steel may be used to provide corrosion resistance, but such coatings provide some welding challenges. Welders must be protected from the fumes generated from welding on galvanized steel, and special electrodes and/or techniques may be required to successfully weld such materials. Sheet steels may also receive special paint-type coatings which can create similar welding challenges.

Cutting Sheet Steel

Sheet steel can be processed in a variety of ways, including shears, nibblers and other mechanical means. Oxyfuel cutting, commonly used for heavy structural steel, will quickly make a mess of sheet steel. However, plasma cutting is ideally suited to such applications (*See Figure 5*). The process is fast, and permits cuts of nearly any shape. The thickness capacity of a plasma cutter depends on the amperage rating of the unit: a rough rule of thumb is that one amp of energy is required to cut each hundredths of an inch of steel thickness. Thus, a 25 amp machine will cut about 25 hundredths, or ¼-inch steel. Today, machines are available that plug into readily available 120 volt electrical power, and operate on compressed air.

Summary

The use of sheet steel in construction applications has already been established, and is likely to continue to grow. Welding has proven itself to be an essential fabrication tool for building and erecting structures made of hot rolled structural shapes, and its essential role in sheet steel applications is no different. However, the approach toward welding is different between the two applications, whether it is in the applicable codes, processes, weld types or challenges. Successfully fabricating gage materials merely calls for some minor adjustments in thinking and fabrication techniques.▪

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