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WELDING STRUCTURAL STEEL WHAT'S IT ALL ABOUT? - PART I

This article describes some of the fundamentals of welding; including design of welded joints, shop and field welding, workmanship, and welding techniques. The Department's specifications for welding are found in the American Welding Society (AWS) Codes, MDOT Standard Specifications for Construction (1990), and MDOT's most recent version of the "Special Provision for Structural Steel and Aluminum Construction."

Welding is a highly technical, ever changing field. Many different types of materials in addition to steel can be welded including plastics, aluminum, and cast iron. For every type of material and atmospheric condition there are as many different specifications and requirements. Similar materials, such as steels, can be of many different chemistry and strength grades, each having its own welding requirements. With this large variation in types of material all facets of a welding procedure must be closely controlled.

Design of Welds

The two most common types of welded joints are fillet and butt welded joints. There are many other types of welded joints as well as numerous joint configurations for fillet and butt welds. Fillet welds are used where two or more surfaces meet at an angle to each other, usually at 90 degrees. Butt welds are used when surfaces in the same plane are joined.

The weld symbol on a plan has an arrowhead pointing to the fillet weld on the left side of Figure 1, which specifies the weld size. Penetration of the weld metal into the base metal (the metal making up the item to be welded) is one of the most critical controls required for all welded joints. Penetration is denoted by the cross-hatched area ① in the figure. Penetration is very important, as it ties both plates together and provides continuity between the base metal and the weld metal. In Figure 1, ② locates the area where no weld penetration occurs, typical of most fillet welding applications.

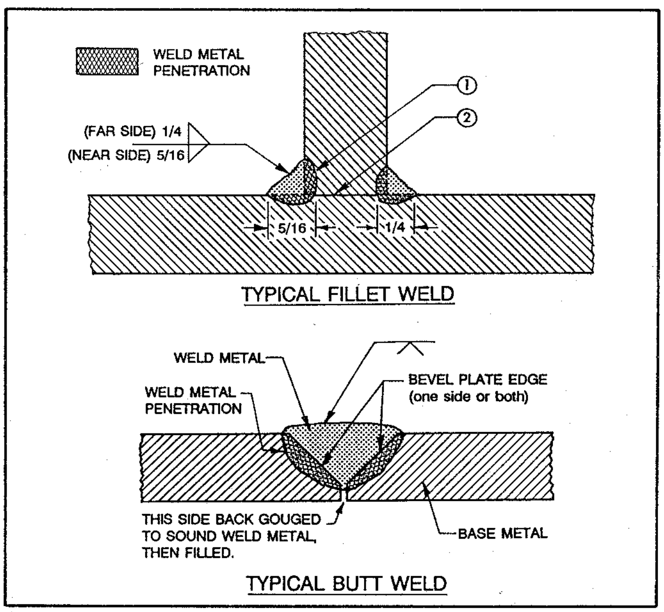

Figure 1

Typically, there are two types of butt welds, complete penetration groove welds and partial penetration groove welds. Complete joint penetration groove welds are welds where melting penetrates all the way through the complete length of the joint. Typically, the joint will be beveled on one plate end prior to welding (Fig. 1). After welding is completed on the beveled side, the plate is turned over and the joint is back-gouged with an air-arc gouger until weld metal is reached. This new groove is then ground smooth to a specified contour, and the joint is completed by welding the back-gouged side, thus completing full penetration of the joint.

Partial penetration groove welds are similar to a fillet welded joint because there is no weld metal penetration into the middle of the joint. Two plates are butted together with one or both plate ends prepared for welding. In general, partial penetration groove welds are welded from only one side of the joint, or welded from both sides of the joint without back gouging. Such welds are considerably weaker than full penetration welds, and would not be used for members subjected to repeated tension loading.

Workmanship

Workmanship is the operator's ability to control base metal preparation prior to welding, assembly and fit-up of plates, control of distortion and shrinkage, controlling the weld profile, and starting and stopping the weld outside the base metal.

Weld metal will not penetrate or blend well with a poorly prepared joint. Prior to welding, all joints must be cleaned of rust, oil, grease, dirt, and any other contaminants. The specifications require various conditions of precleaning, depending on the type of welded joint being produced.

Joint assembly and fit-up require dimensions and angles to be exact prior to welding. Large structural members, such as a main beam for a bascule bridge, require extensive fixturing in the fabrication shop to handle all the different welding positions. Usually clamping and special supports are used for fit-up prior to welding.

Distortion of the plates being welded is caused by residual stresses built up in the base/weld metals due to weld metal shrinkage. These residual stresses are controlled by the cooling rate of the welded joint and other parameters. Cooled too fast, the plates will distort causing warping and sometimes cracking. With proper joint design, preheat prior to welding, and a well controlled cooling rate after welding, distortion can be kept to a minimum.

Fillet weld profiles are visually inspected. If the fillet weld is visually poor in appearance, or not properly sized, chances are something is not correct with the welding process. Butt welds are usually ground flush with the base metal. Special techniques are required for butt weld inspection and will be discussed in Part II.

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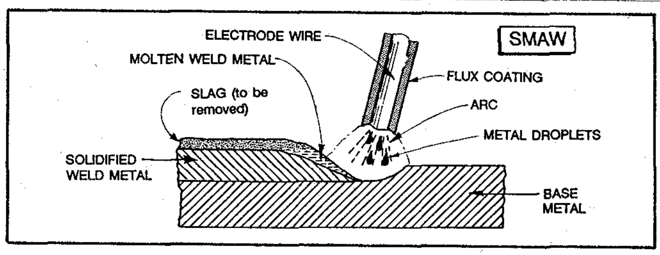
Starting and stopping the weld outside the joint and base metal area is important. This will prevent slag inclusions in the weld metal which may create holes or stress raisers in the base metal.

Welding Techniques

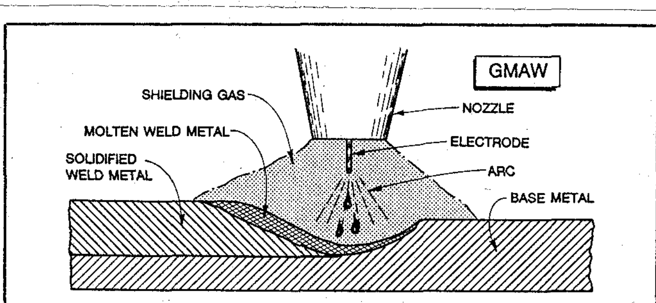
Welding technique depends on the welding process used and which type of electrode/flux combinations are used. Technique also involves properly matching filler (welding rod) metals with base metals and determining minimum preheat/interpass temperatures prior to starting the welding operation. If joints are properly prepared and the welding is performed correctly, weld metal typically will have better mechanical properties than the adjoining base metal.

MDOT typically uses three types of steels for bridge beams: ASTM A36, A572 (Grade 50), and A588. These are the base metals with which we are concerned. With these three types of steels, four types of welding processes are allowed. They are: shielded metal arc welding (SMAW) commonly known as 'stick welding,' gas metal arc welding (GMAW), flux cored arc welding (FCAW), and submerged arc welding (SAW). Each technique is used for different applications.

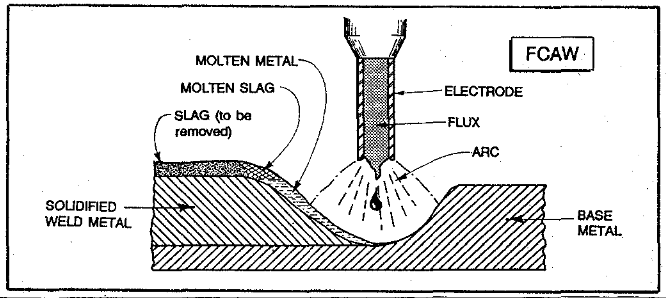
During the welding process, molten metal is attacked rapidly by oxygen or hydrogen in the air, if it is not protected by some material during cooling and solidification. Slag formed by the molten flux or oxygen-free gases are used to shield the weld. Shielded metal arc welding (SMAW) uses an electrode core that is covered or shielded by a flux coating. In production the electrode melts back with the coating and the molten coating forms a protective slag over the weld puddle, thus shielding the weld from the atmosphere (moisture, foreign matter, etc.). The molten flux floats to the top of the weld pool along with any impurities in the molten metal, where it solidifies to a very hard, glassy material which is removed by chipping to expose the finished weld bead. One advantage of SMAW is the versatility in confined areas or where unusual geometric conditions prevent the use of other methods.



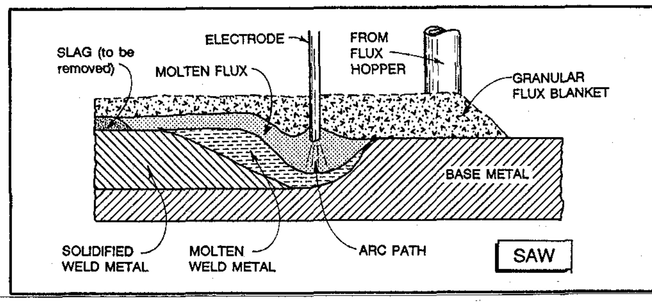
The gas metal arc process (GMAW) provides a covering or shielding of the molten pool with gas (typically 75 percent argon and 25 percent carbon dioxide). This gas shield prevents moisture, harmful gases, or impurities in the atmosphere from contaminating the metal as it solidifies. This process is only allowed in shop welding applications because wind or drafty conditions will blow the shielding flux gas away from the molten weld, thus losing its shielding effect.



In flux cored arc welding (FCAW) the electrode is a continuous wire coil with a flux core middle. The flux core melts with the electrode thus shielding the molten weld metal during the welding process. This process is good for welding in all positions with excellent weld bead control, good weld penetration and smooth weld/bead profiles.



Submerged arc welding (SAW) is considered to be the 'Cadillac' of welding. Submerged arc welding uses an arc that is submerged in flux powder which melts and forms a protective slag covering for the molten metal. It is used for 90 percent of all welds in bridge beams because of high quality and relatively low costs that result from high weld metal deposition rates. SAW produces smooth, usually defect-free welds with good mechanical properties. With the electrode submerged completely in flux granules, the electrode wire is automatically fed into the joint as flux covers the molten pool and is deposited slightly in front of it. When properly used, this process allows maximum penetration, excellent weld profile, and easy operator control. SAW is limited to welding in the flat or horizontal positions.



Preheat and interpass temperatures of the pieces being welded are critical to avoid hydrogen cracking in the weld and base metals. Hydrogen cracking, often called cold cracking, occurs after the weld has cooled. Most cracking occurs in the first 48 hours; however, cracking can occur up to several weeks later. Usually this cracking can be attributed to lack of proper preheat, or hydrogen contamination from moisture or impurities, especially in field welding applications. Preheating the base metal prior to welding requires heating the steel to a specified temperature just before striking the welding arc with the electrode. The AWS code specifies a "minimum arc start temperature" which establishes the required temperature just before arc strike. The reasons for requiring preheat are:

1) Slower cooling rates result in more ductile weld metal.

2) Preheating prolongs the time the weld and heat affected zone (HAZ, that portion of the base metal affected by heat due to the welding process) are kept at elevated temperatures which allows hydrogen to leave the weld metal without causing cracking.

3) Helps to remove gases which may cause porosity.

4) Removes moisture, hydrocarbons, and other contaminants which may cause hydrogen cracking or interfere with welding fusion.

5) Helps to reduce residual stresses in the joint.

6) Improves the overall mechanical properties of the weld metal and the HAZs.

At this point, you can appreciate the various critical factors that must be addressed in the welding process. Part II of this article will discuss qualification requirements and inspection techniques.

-Steve Cook