TEMPERATURE CONTROL...

What Structural Engineers Should Know About Welding

Preheat and Interpass Temperature

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Preheat and interpass temperature controls are important variables in welding the components of structural assemblies. The details of "when", "where" and "how much" preheat and interpass temperature are required are specified in the applicable codes, but the "why" is typically not addressed. This primer will supply the Structural Engineer with a basic understanding of the need for thermal controls.

Preheat

Preheating involves heating the base metal to a specific desired temperature, called the *preheat temperature*, prior to welding. There are five primary reasons to utilize preheat: (1) it slows the cooling rate in the weld metal and base metal, producing a more ductile metallurgical structure with greater resistance to cracking; (2) the slower cooling rate provides an opportunity for hydrogen that may be present to diffuse out harmlessly, reducing the potential for cracking; (3) it reduces the shrinkage stresses in the weld and adjacent base metal, which is especially important in highly restrained joints; (4) it raises some steels above the temperature at which brittle fracture might occur in fabrication; and, (5) it can help to ensure specific mechanical properties, such as weld metal notch toughness and ductility.

When Should Preheat Be Used?

For structural applications, codes specify the required level of preheat, based upon section thickness, base metal chemistry, and the type of filler metal. Structural steel is usually welded in conformance with *AWS D1.1 Structural Welding Code-Steel*. For fabrication of bridge members, *AASHTO/AWS D1.5 Bridge Welding Code* is typically required. For welding of rebar, *AWS D1.4 Structural Welding Code-Reinforcing Steel* is often stipulated. All of these codes specify minimum preheat limits. This minimum preheat temperature must be used, and while generally adequate, it may not be sufficient to prohibit cracking in every application. In such cases, higher temperatures may be required.

When heating the joint to be welded, the AWS D1.1 code requires that the minimum preheat temperature be established at a distance that is at least equal to the thickness of the thickest member, but not less than 3 inches [75 mm] in all directions from the point of welding.

Under some circumstances, a "preheat" of room temperature may be adequate. Thus, preheat may not be required for thinner sections of lower strength materials. However, D1.1 requires that steel that is less than 32 degrees F [0 degrees C] be heated to at least 70 degrees F [20 degrees C] before welding begins.

"…interpass temperature applies after the first (weld) pass is made…"

Interpass Temperature

Interpass temperature refers to the temperature of the material in the weld area immediately before the second and each subsequent pass of a multiple pass weld. Simply stated, preheat refers to the steel temperature before welding begins; interpass temperature applies after the first pass is made. Interpass temperature is just as important as, if not more important than, preheat temperature with regard to the mechanical and microstructural properties of weldments. Preheat temperature affects the properties of only the first weld pass; interpass temperature affects the properties of all subsequent passes.

The yield and ultimate tensile strengths of the weld metal are both a function of the interpass temperature. High interpass temperature values tend to reduce the weld metal strength. Additionally, higher interpass temperatures will generally provide a finer grain structure and improved Charpy V notch toughness transition temperatures. However, when interpass temperatures become excessive, this toughness trend is reversed.

Two Components

There are two aspects to interpass temperature: the minimum, and maximum, value. The minimum interpass temperature should be at least as high as the minimum preheat temperature. It may be important to impose control over the maximum interpass temperature when certain mechanical weld metal properties are required.

Particularly on sensitive base metals, the minimum interpass temperature must be sufficient to prevent cracking, while the maximum interpass temperature must be controlled to provide adequate mechanical properties. To maintain this balance, the following variables must also be considered: time between passes, base metal thickness, preheat temperature, ambient conditions, heat transfer characteristics, and heat input from welding. Heat input is a relative measure of the amount of energy delivered per unit length of weld by the welding process.

For example, weldments with smaller cross-sectional areas naturally tend to accumulate interpass temperature: as the welding operation continues the temperature of the part increases. As a general rule, if the cross-sectional area is less than 20 in² [130 cm²], the interpass temperature will tend to increase with each sequential weld pass, if normal production rates are maintained. However, if the cross-sectional area is greater than 40 in² [260 cm²], the interpass temperature generally decreases throughout the welding sequence unless an external heat source is applied.

Measuring and Controlling Preheat and Interpass Temperatures

One method of controlling preheat and interpass temperatures is to use two temperature-indicating crayons. These heat-sensitive crayons melt when the preheated material is at the crayon's melting point. The crayons are available with a variety of melting points, and each individual crayon is labeled with its approximate melting temperature.

Typically, one temperature-indicating crayon is used to measure both the minimum specified preheat temperature and the minimum specified interpass temperature, while the second is a higher temperature crayon used to measure the maximum specified interpass temperature (if required).

The welder first heats the joint to be welded and checks the base metal temperature at the code-designated location by marking the base metal with the first temperature-indicating crayon. When the minimum specified preheat temperature is reached (when the first crayon mark melts), the first welding pass can commence. Immediately before the second and subsequent passes, the minimum and maximum (if specified) interpass temperature should be checked in the proper location. The lower temperature crayon should melt, indicating that the temperature of the base metal is greater than the melting temperature of the crayon, while the higher temperature crayon should not melt, indicating that the base metal temperature is not above the maximum interpass temperature.

Maintaining specified preheat and interpass temperatures is essential to ensuring the proper performance of welded connections.

If the lower temperature crayon does not melt, additional heat should be applied to the joint until the crayon mark on the base metal melts. And, if the upper temperature crayon melts, the joint should be allowed to slowly cool in the ambient air until the upper temperature crayon no longer melts while the lower temperature crayon does melt. Then the next welding pass can begin.

Summary

Preheat and interpass temperatures determine the cooling rates that will be experienced by the weld metal and surrounding steel. The cooling rate must be properly controlled to ensure that the weld does not crack, and that the resultant weld metal will have the required properties. Controlling these temperatures is essential to ensuring that welded connections will perform as intended by the Structural Engineer.

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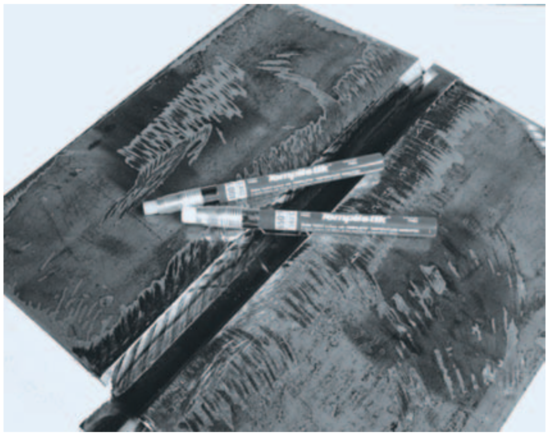

Temperature-indicating crayons such as these Tempilstiks™ are used to measure preheat and interpass temperatures.

Resources

AWS D1.1-2002 Structural Welding Code – Steel. The American Welding Society: Miami, Florida, 2002.

AWS D1.4-98 Structural Welding Code – Reinforcing Steel. The American Welding Society, 1998.

AWS D1.5-96 Bridge Welding Code. The American Welding Society, 1996.

"AWS Structural Welding Committee Position Statement on Northridge Earthquake Welding Issues." The American Welding Society, 1995.

The Procedure Handbook of Arc Welding. The Lincoln Electric Company: Cleveland, Ohio , 1995.

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Available online in pdf format at **www.weldinginnovation.com**:

Funderburk, R. Scott, "Fundamentals of Preheat," *Welding Innovation*, Vol. XIV, No. 2, 1997.

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