

4 HAZ zones can be resolved microscopically

- i) Course Grain
- ii) Fine Grain
- iii) Intercritical, and
- iv) Tempered HAZ

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TECHNICAL NOTES - Praful Patel, Ph.D., P.E., C.Eng (UK), Metallurgical Engineer

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WELDING PREHEAT - *Sizzling Stuff!*

Although a relatively low-temperature application, welding preheat can profoundly influence the integrity of the completed welded joint. Its purpose commonly misunderstood, it creates an overwhelming tendency to omit especially for non-structural temporary welds. Yet the logic for preheat that applies to the main structural welds is also valid for temporary welds. The applied preheat does not distinguish between the welds.

So What Is Preheat?

Welding preheat and temperature are defined as 'The heat applied to the base metal or substrate to attain and maintain preheat temperature'. The preheat temperature is thus 'The temperature of the base metal in the volume surrounding the point of welding immediately before welding is started.

In a multipass weld, it is also the temperature immediately before the second and subsequent passes are started. Typically for construction steel and reinforcing bar, the maximum preheat temperature is generally 500 °F dependant upon material chemistry, level of restraint, and material thickness.

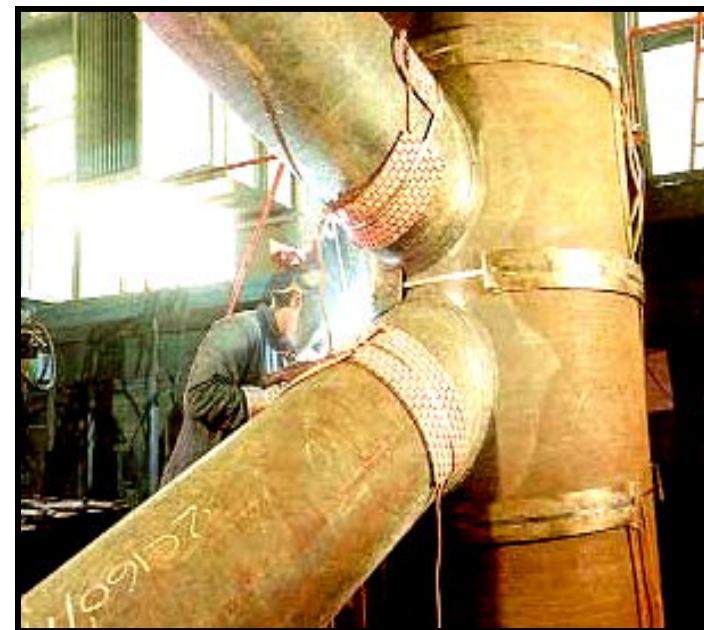


Fig. 1 - Preheating with electrical thermal pads. This method offers more precise control of temperature. (Courtesy TWI, UK).

Preheat -

The heat applied to the base metal or substrate to attain and maintain preheat temperature

In accordance with the structural welding code D1.1, temporary or tack-welds are subject to the same WPS requirements as the final welds except single-pass tack welds that are to be remelted and incorporated into continuous SAW (submerged arc welds) welds.

Why Preheat?

The three primary reasons for the application of preheat are: i) To retard the cooling rate of the weld metal, HAZ and base metal to avoid a hard brittle metal microstructure susceptible to cracking; ii) Reduce residual and shrinkage stresses due to joint restraint, and; iii) Permit any dissolved hydrogen to permeate out without causing cracking. Preheat can also be used to achieve specific mechanical properties such as notch toughness.

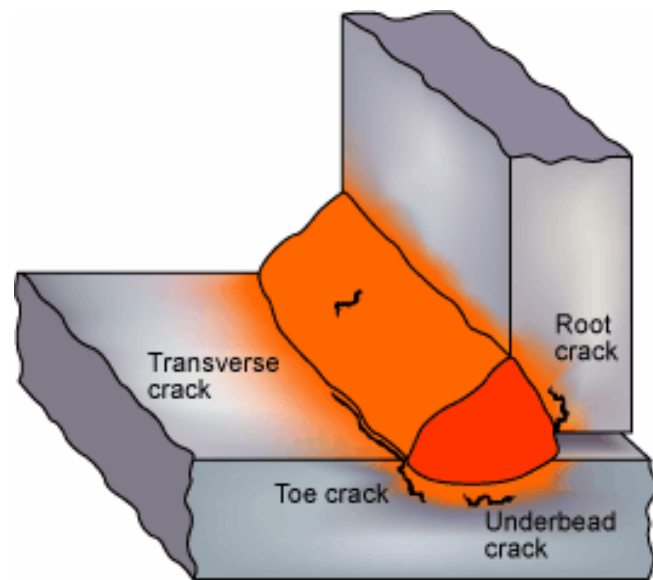


Fig. 2 - Schematic Orientation Of Hydrogen Cracks In Fillet Weld. Not All Types Occur In The Same Weld. (Courtesy TWI, UK).

Cracking only occurs when there is hydrogen in the weld-HAZ, **and** in the presence of a hard metal microstructure. Both conditions must be present simultaneously. The sources of hydrogen can be damp electrodes, high humidity; moisture or grease on metal surfaces, or the lubrication on electrode wires. Typical orientation of hydrogen induced cracking in a fillet weld is schematically shown in Fig. 2, and microscopically in Fig. 3. Often such cracking is only apparent after 48 to 72 hours when the hydrogen gradually diffuses out. Thus some codes call for non-destructive testing after this period.

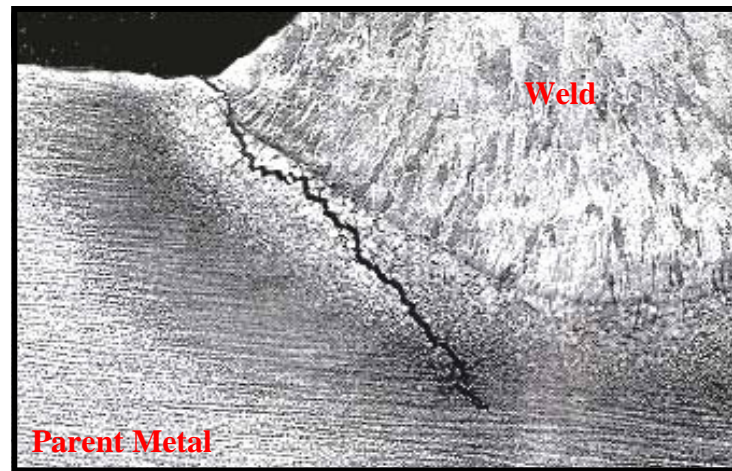


Fig. 3 - Microscopical Image Of Typical Hydrogen Crack In The Coarse Grained HAZ.

Frequently industrial practices call for the preheat to be maintained for a period of some 2-4 hours after welding. AASHTO/AWS D1.5M/D1.5: 2002 Bridge Welding Code recommends a post-heat hydrogen treatment especially for Fracture Critical Members. The treatment requires weld and adjacent base metal to be heated to a temperature of 450 °F minimum to 600 °F maximum for not less than 1 hour for each 1.0-in of weld thickness or two hours whichever is less. When hydrogen diffusion treatment is requested, the weld is not allowed to cool below the minimum interpass or preheat temperature before being raised to the hydrogen diffusion postweld heat treatment temperature.

Why Preheat -

- ▶ To control cooling rate after welding
- ▶ To prevent cold cracking
- ▶ To avoid a hard HAZ

In relatively thin (typically under 3/4-in) pre-qualified materials, preheat is generally not required per AWS D1.1, Table 3.2. This is because the heat-flow is modeled as two dimensional. The thin material rapidly heats thru with the welding heat input keeping the material hot that retards the cooling rate. For relatively thick material where the heat-flow is three dimensional heat from welding is rapidly drawn away resulting in faster cooling rate of the weld metal, HAZ and base metal thus requiring preheat.

Code requirements, material chemistry, joint restraint, history of cracking, filler metal hydrogen content, and material thickness dictate both the need and level of preheat application. The Carbon Equivalent (C.E) determined from the material chemistry is a measure of a materials hardenability, that is, if it will harden by a relatively normal air cooling following welding. Generally the C.E increases with increasing steel alloying content and thus the preheat temperature will also increase. Similarly increasing material thickness and joint restraint will necessitate higher preheat temperatures.

Evaluating Preheat Requirement

The preheat levels given in AWS D1.1, Table 3.2 are considered overly conservative, or in some cases insufficiently demanding. Hence Annex XI offers an alternative method for evaluating preheat. Two methods are given as a basis for welding conditions to minimize cold cracking: i) HAZ hardness control method that is restricted to fillet welds, and; ii) Hydrogen control.

In the HAZ hardness control method the assumption is that cracking is avoided when the hardness of the HAZ is below a critical level by controlling the cooling rate. The relatively small size of tack welds are frequently subjected to high cooling rates that may cause excessive hardening. The critical cooling rate can be determined from the graphical presentation and is solely based on the C.E. It does not account for severity of joint restraint nor the hydrogen content of the electrode. However, the methods value is in relating the minimum welding heat input hence the fillet weld size that prevents excessive hardening. That is, as the welding energy input increases, the cooling rate decreases, an effect similar to preheating.

The second method (hydrogen control) is based on the assumption that the potential for cracking is minimized when the residual hydrogen after the weld has cooled (~ 120 °F) is less than a critical value depending on steel chemistry and level of joint restraint.

The method involves: i) Calculating the composition (similar to C.E) parameter; ii) Calculating the susceptible index related to the composition parameter and filler metal diffusible hydrogen content, and; iii) Determining the preheat temperature from the material thickness, susceptibility index, and joint restraint.

Preheat Temperature -

The temperature of the base metal in the volume surrounding the point of welding immediately before welding is started

Skipping Preheat may cause weld/HAZ cracking and/or excessive hardening. Cracking of sufficient length and depth when orientated favorably to the principal stresses may lead to catastrophic failure. Cracks act as stress concentrators that may propagate rapidly by residual, static or cyclic stresses. Even in temporary welds, as the weld/HAZ are fused to the base metal (Fig. 3) a continuous path is readily available for crack propagation. The excessively hardened weld/HAZ due to its lowered ductility may also crack under applied stresses.

In summary -

- *Preheat can prevent cracking and/or achieve specific mechanical properties such as notch toughness*
- *Preheat must be used when code specified*
- *When not specified, the Welding Engineer should evaluate if preheat is required and determine preheat temperature*
- *AWS D1.1, Annex XI or other appropriate codes be consulted for evaluating proper pre-heat*