Lessons Learned in the Field

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Beware the Obvious Conclusion!

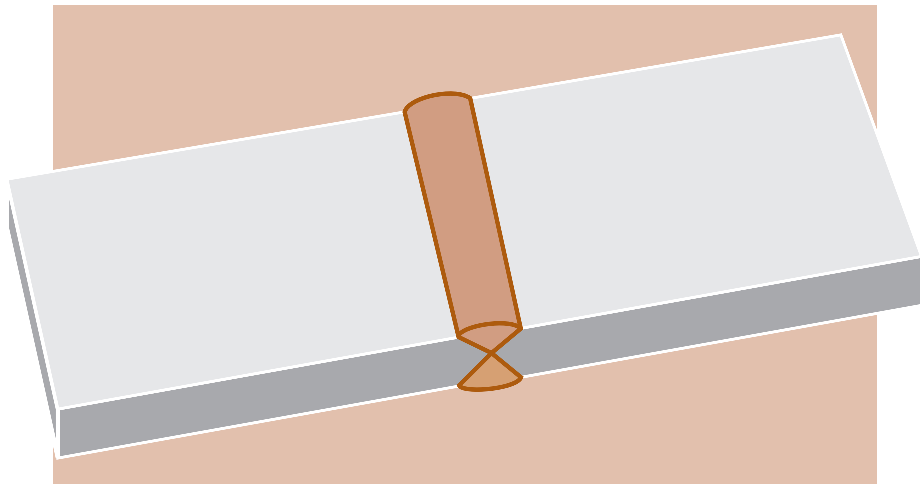

Figure 1. Test plate with flange splice.

The most dramatic example of a lesson I learned in the field occurred about five years ago. At the time, with two decades of welding industry sales and technical support experience under my belt, I thought I had pretty much "seen it all." As it turned out, I was about to get my come-uppance, and learn a lasting lesson in the process.

The Initial Trouble Call

My responsibilities in the Welding Technology Center of The Lincoln Electric Company include direct customer support. One day in the early days of the use of high performance

To our consternation, the cracking problem persisted

(HP) steel, I received a trouble call from a bridge fabrication shop that was having cracking problems while welding a test girder for the Federal Highway Turner Fairbanks Research Lab. This HP steel had a 70 ksi (485 MPa) minimum yield strength with low sulfur and carbon content, as compared to A852. I asked the usual questions and learned that the weld, specifically, a complete joint penetration groove weld, had passed the fabricator's procedure qualification tests, but for some reason, it was failing on the job. The transverse and longitudinal cracking was delayed, taking three days to show up. The fabricator was using LA -100 electrode and 960 flux, and welding in accordance with the *AWS D1.5 Bridge Welding Code*.

Together with the customer, I carefully reviewed the possible causes. The CJP groove weld was on a 1-5/16 in. (33 mm) thick plate (Figure 1), so the potential for high residual stresses existed. I also thought we might be picking up some alloy out of the base material. This scenario led me to recommend slowing down the cooling rate through increasing preheat and interpass temperature, trying to minimize the influence of the base metal on the weld deposit.

The Second Failure

The fabricator made another attempt, following all of my recommendations. To our consternation, the cracking problem persisted. At this point, I was having a hard time figuring out what we could have missed. Since the test girder was being welded for the Federal Highway Administration, their personnel became involved. The problem was starting to mushroom. Eventually, there were a lot of people giving a lot of opinions about what was really going on.

The Third Attempt

For the third attempt, two representatives and one consulting welding engineer from the Federal Highway Administration, a representative from the steel supplier, and yours truly all convened at the fabricator's facility. When we got there, we went to the office to review as much as we could, including drawings and joint designs. Once we were done reviewing the paper side of the job, we went into the shop to investigate details related to the handling of consumables, what they were doing to determine preheat, and so forth.

I was still convinced that the problem was somehow related to the steel. It just seemed to me that if we had the right preheat and interpass temperature, that would solve the problem. A tour of the shop seemed to lend some credence to my theory. I observed:

- Low winter time ambient temperature in the unheated shop
- Flux was being heated in a holding oven (Figure 2), rather than in a true flux drying oven
- The welding set-up would not permit access to the bottom of the plate for heating

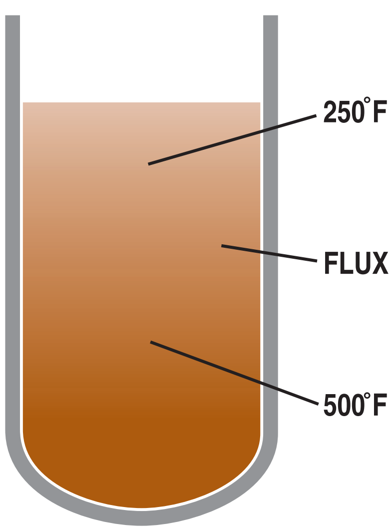

Figure 2. A flux holding oven.

We dealt with the lack of access to the bottom of the plate by increasing the preheat substantially beyond levels required by AWS D1.5. We stayed there while the CJP groove weld was again attempted on the bridge girder. In this case, the third time was a charm—the weld did not crack that day, nor in the subsequent days. But the mystery of the first two failures remained.

Lab Testing of the Failed Welds

Sections of the failed welds were distributed to the Federal Highway Administration, Lincoln Electric, and the steel supplier for analysis. After returning to our Welding Technology Center, I subjected my sample to a full array of metallographic tests in our lab. Upon analyzing the results, Marie Quintana, Lincoln's Manager of New Products, Consumables, felt that we were dealing with a case of hydrogen assisted cracking in the LA100 filler metal (Figure 3). This was something I hadn't considered. My twenty years of experience had included many examples of steels experiencing hydrogen assisted cracking, but never had weld metal been more sensitive to this type of cracking than the base metal. New developments in base metals, such as this HP steel, resulted in a new possibility. I had assumed that when you're having a cracking problem, the steel is to blame. But this time, my assumptions had misled me. The problem was actually due to the susceptible chemistry of the weld.

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It turned out that on the third attempt at the weld, our team effort to supply more than sufficient preheat, to maintain interpass temperature and to

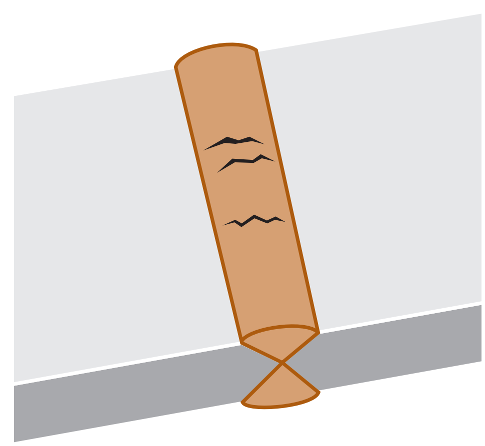

Figure 3. Weld sample with hydrogen assisted crack.

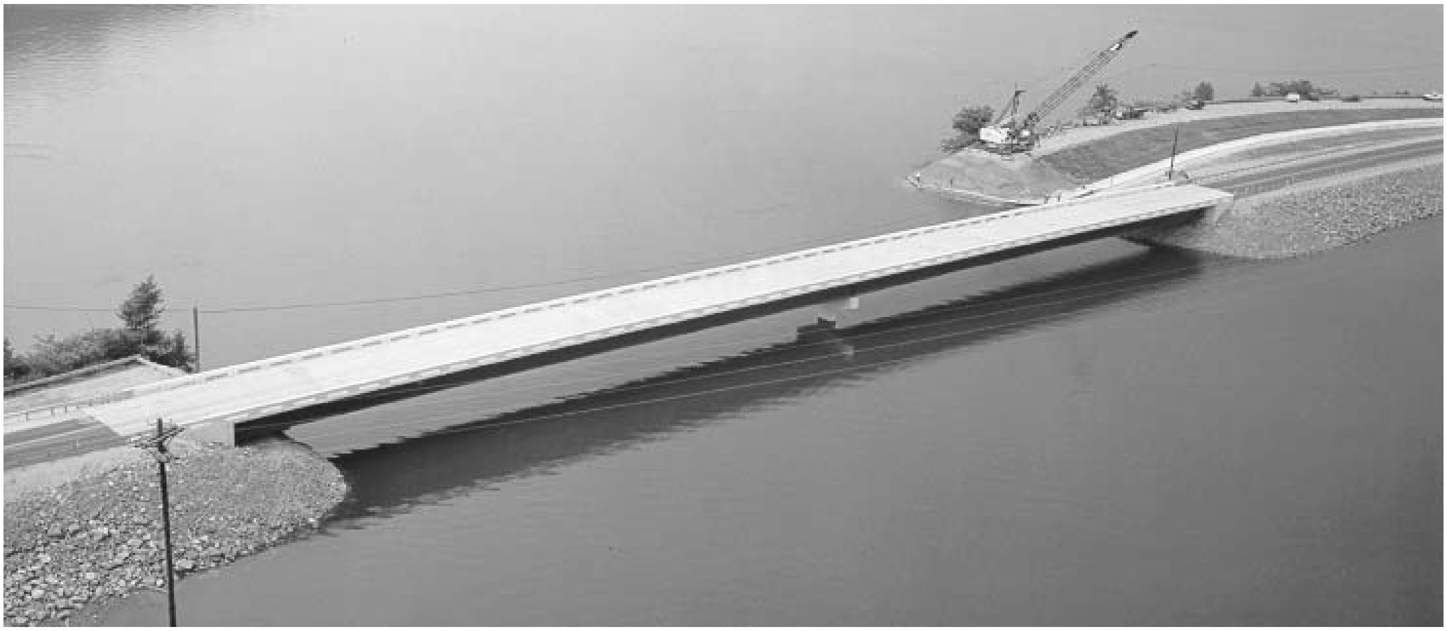

Figure 4. Girders for highway bridges such as this one require multi-pass CJP groove welds.

meticulously condition the flux had actually overcome this tendency to hydrogen assisted cracking. Even after several days, no cracks appeared. At that point, the customer and the Federal Highway Administration were satisfied.

What Took Me So Long?

I was just mystified at how I could have spent two decades in this industry, and never before run into a diffusible hydrogen cracking problem attributable to Lincoln's LA100 electrode. So I tried to remember all the times in the past when I had recommended the use of LA100. It became apparent to me that most of the applications for which I had suggested LA100 had been on projects which entailed small, single pass welds—situations that were very different from this multi-pass CJP weld on a relatively thick bridge girder such as the one shown in Figure 4.

It was a humbling experience to admit to my professional associates on this job that the actual problem was not in the HP steel, but actually in my weld metal. And it certainly taught me to look beyond the obvious when attempting to diagnose and solve a weld cracking problem.

The Consequences

As an outgrowth of this cracking problem and some other similar cases, the use of controlled hydrogen fluxes has broadened. Controlled hydrogen submerged arc fluxes have been specifically designed to resist moisture pickup and aid in the diffusion of hydrogen out of the weld deposit as the weld is being made. Different welding consumables have been tested to determine the best consumables for welding HP steel. Information about the recommended consumables is available from the American Association of State Highway and Transportation Officials (AASHTO) in the *Guide Specifications for Highway Bridge Fabrication with HPS70W Steel*, which can be accessed online at *www.aashto.org*.