What Every Steel Erector Should Know About Welding Requirements

(Before The Auditors Arrive)

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The AISC Erector Certification Program has been established to enhance the quality of structural steel erection. Contractors are certified based on their demonstrated experience, capability and awareness of sound erection practices. Included in the program are certain welding requirements. These provisions are not new and, in most cases, have been code requirements for many years; however, some additional documentation may be imposed. Any contractor doing work in accordance with AWS D1.1 or D1.5 is already required to comply with these code provisions.

The Structural Welding Code is a "consensus document that represents the collective wisdom of designers, fabricators, inspectors, educators and consultants, acquired over decades of experience" (Post, J.W., "Welding Solutions: Put Things in Perspective with the AWS D1.1 Code" 1998 National Steel Construction Conference Proceedings). It is not just a book of rules; rather it is a document that promotes quality work.

The erector certification program focuses on quality and safety, both of which are key to the success of a project and directly influence the cost effectiveness of steel erection. Now is the time for all erectors to get on board and join the ranks of certified erectors. In a learning curve analogous to that experienced by certified building and bridge fabricators more than 20 years ago, steel erectors will also need to expand their comfort zone as they embrace this program. Eventually, it is expected that the program will be end-user driven through contract specifications. The goals of the program are to increase awareness of quality and safety issues in erector organizations and to provided an incentive to comply with quality requirements. A commitment from management to become a certified erector in '99 will prove to be a wise decision.

The authors hope to provide some helpful insight into the welding requirements associated with the AISC Erector Certification Program, as well as some of the code requirements. This paper is not intended to be comprehensive, but will address several key issues. A thorough review of the AISC Erector Certification Program and applicable codes is recommended.

Common Misconceptions

In the realm of steel erection, there are several misconceptions related to welding requirements. To obtain certification, erectors must first move beyond the following fallacies and address the root problems in the industry.

- **Misconception #1:**
  The AWS D1.1 Structural Welding Code applies to shop fabrication only.

  The D1.1 Code specifically states that "this code contains the requirements for fabricating and erecting welded steel structures" (emphasis added, AWS D1.1-98, para. 1.1). The Code contains provisions, such as joint tolerances and fitup (AWS D1.1-98, para

5.22), that must be followed regardless of where the welding is done. In fact, many of the sections were written with field erection in mind. For example, if the root opening on a groove weld exceeds the "as-fit" tolerances, the Code provides options for resolution of this problem (AWS D1.1-98, para. 5.22.4.3 and 5.22.4.4). It is speculated that these provisions are used more frequently in the field than in the shop.
The D1.1 Code is equally applicable to both shop fabrication and field construction.

- **Misconception #2:**
  If a prequalified welding procedure is used, then a written WPS is not required.

  The D1.1 Code mandates that "all prequalified WPSs shall be written" (D1.1-98, para. 3.1). Welding Procedure Specifications are the communication tool that gives the welder instructions on how to make the weld. Items such as minimum preheat temperature, maximum interpass temperature and bead placement are listed on the WPS and must be maintained to obtain the required weld soundness and mechanical properties. More information on WPS development is included in in "Reviewing and Approving Welding Procedure Specifications" (Miller and Funderburk, NSCC 1998) and "What Every Engineer Needs to Know About Welding Procedures" (Miller, NSCC 1997).
  Written WPSs are required for all welding, including prequalified procedures.

- **Misconception #3:**
  Quality Assurance will handle all of the field inspection issues – the contractor does not need to do any inspection.

  Both the AWS D1.1 and D1.5 Codes specifically define inspection responsibilities for the contractor. D1.1 names the "Fabrication/Erection Inspector" as the designated person who acts on behalf of the contractor with regard to all inspection and quality matters (AWS D1.1-98, para. 6.1.3.1). D1.1 also says that fabrication/erection inspection "shall be performed as necessary prior to assembly, during assembly, during welding, and after welding to ensure that material and workmanship meet the requirements of the contract documents. Fabrication/erection inspection and testing are the responsibilities of the contractor unless otherwise provided in the contract documents"(AWS D1.1-98, para. 6.1.2.1). AWS D1.5 mandates that the Quality Control (QC) function is the responsibility of the erector (AWS D1.5-96, para. 6.1.1.1), and the QC Inspector works on behalf of the erector for inspection, testing and quality matters (AWS D1.5-96, para. 6.1.2.1). For many field projects, the contract will require Verification or Quality Assurance (QA) Inspection, often stipulating that NDT be performed by the Verification Inspector (AWS D1.1-98, 6.1.2.2). This does not, however, preclude or replace the QC Inspection that is required by the Code. For more information on this issue, the authors recommend "Ensuring Weld Quality in Structural Applications: The Roles of Engineers, Fabricators and Inspectors (Part I of III)" (Miller, NASCC 1996).
  The contractor is responsible for erection inspection and testing, unless specifically exempted by the contract documents.

- **Misconception #4:**
  The union hall takes care of all the welder qualification issues.

  Indeed, unions do provide a valuable service to the industry through their welder training and testing programs. Welders can even become certified welders through the AWS Welder Certification Program. However, in terms of the AWS D1.1 Code, it is the contractor's responsibility to qualify all welders, welding operators, stud welders and tack welders (AWS D1.1-98, para. 4.1.2.2 and 7.7.4). If a welder was qualified on a previous job, that performance qualification may be acceptable provided that proper documentation and evidence has been maintained and that the Engineer, not the contractor, approves it (AWS D1.1-98, para. 4.1.2.1).
  Welder qualification is the contractor's responsibility.

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To improve quality and safety, it is important that these misconceptions be exposed and corrected. These misunderstandings can lead to other problems, such as those discussed below, if they are not addressed.

Specific Audit Problems

The acceptance criteria of the audit are categorized in three areas: Application (Ap), Management (Mg) and Operations (Op). These criteria have requirements related to all aspects of steel erection, including welding. Based on results from initial audits, nonconformance has been found in the following: Welding Procedure Specifications, quality control, welder qualification and other miscellaneous welding issues. To aid the erector in the certification process, each "problem item" is quoted from the AISC Certified Advanced Steel Erector Evaluation Checklist with examples of auditor citations of specific requirements. A few of the requirements are for "Advanced" Certification only, and these are noted in the applicable sections below.

Welding Procedure Specifications

- **Are representative weld procedures submitted? (AISC, Ap10)**

"Erector did not submit any WPSs."

The contractor must have WPSs that cover every weld to be made on the job, and the erector must submit several to the auditors for review. Also, an inspector or the Engineer could ask to review the WPSs at any time (AWS D1.1-98, para. 4.1.1, 4.2.3 and 6.3.1). Therefore, WPSs should be kept current, in use by the welders and ready for submission. It also makes good business sense, because complete and proper WPSs generally encourage quality and productivity.

"No steel specification or grade was listed on the WPS."

In this case, the WPS was submitted, but it was incomplete. One of the essential variables is the base metal specification and grade (AWS D1.1-98, para. 4.7.3); this information must be explicitly stated on the WPS.

Other examples of incomplete or incorrect WPSs are the following: polarity not listed, no date shown, backing to be used without the backing material designated, no supporting PQRs for qualified procedures, and prequalified status declared with a non-prequalified process (e.g., GMAW short circuiting).

- **Are approved written welding procedures in close proximity to and used by the welders? (AISC, Advanced Program Only — Op444)**

"The WPS was for E7018, and the welder was using E71T-8."

In this example, either the welder had the wrong WPS or he was violating the WPS he was using. Whichever was the case, what the welder was doing did not match the requirements of the WPS. The auditors will often verify that the actual welding is in conformance with the WPS.

"The WPSs were not at the job site — apparently they are kept at the home office."

The home office is not "in close proximity" to the welder. One of the key objectives for WPSs is to clearly communicate the requirements to the welder and inspectors. This can not effectively take place with the instructions filed away at the office. The Code does not say that the welder must keep the WPS with him at all times. However, the welder should have quick access to it. On most job sites, the field office trailer is an adequate location for storage of the WPSs. On some projects, however, the trailer may be too far away for the welding crew to readily retrieve the documents. In this case, it may be more appropriate to issue a set of WPSs to each crew. The WPS is intended to control the welding. To do the work properly, the welders need the information recorded on the WPS, including the allowable tolerances.

"The WPS listed 225 degree F minimum preheat temperature, and the welder was using a 150 degree F crayon."

The WPS must be properly followed, and the welder must use the right tools (the correct temperature indicating crayon in this case). Here, the welder does not know if the steel is above the minimum specified preheat temperature of 225 degree F. He only knows if it is above 150 degree F, and he can not maintain the minimum specified preheat temperature.

Several other things could happen if the WPS is not followed, including: improper weld size, maximum interpass temperature exceeded, wrong electrode, incorrect travel speed, and other problems. The result could be inadequate structural performance, hydrogen cracking, lamellar tearing, increased cost, timely repairs and schedule over-runs.

"The welder was running on the wrong polarity and did not know the difference between DC positive and negative."

The auditors expect the welder to understand the fundamental issues covered by the WPS, including electrode polarity. The welder should also have a basic understanding, for exam-

ple, of welding processes (e.g., FCAW vs. SMAW), visual acceptance criteria, joint and weld types (e.g., butt joint with a single-bevel groove weld), joint fit-up tolerances, and position (e.g., 2F and 6G).

Quality Control

- **If welding is required, is a competent welding technician (such as a CWI or ACWI) employed by the applicant? (AISC, Advanced Program Only — Mg166)**

"Erector had no welding inspector."

It is important to have personnel available to the job site who have training in welding, including the AWS D1 Welding Codes, welding processes, inspection technology and quality acceptance criteria. The Certified Welding Inspector (CWI) program sponsored by AWS requires the participants to demonstrate their knowledge of these issues through job experience and examination. Having a CWI on staff is no guarantee against problems, but it does provide some level of confidence when trouble arises. The D1.1 Code does not require a AWS CWI; there are other acceptable qualification bases such as the Canadian Welding Bureau CWI (AWS D1.1-98, para. 6.1.4.1). Since quality is a core objective of the AISC Erector Certification Program, incorporating qualified people is fundamental. A CWI is not essential to obtaining a certificate but there must be someone available who has demonstrated awareness of welding and code issues.

- **Are job site superintendents and foremen conversant with current workmanship requirements such as those contained in AWS, AREA, AISC, AASHTO, specifications? (AISC, Op17)**

"The welding foreman did not know what the AWS D1.1 Code was."

No one expects the job superintendent or the foreman to know all the applicable code provisions from memory, but they should at least know what the code is and where to find answers to common code questions. For example, the auditor may ask the foreman to show him the code provisions for allowable porosity levels. The foreman should be able to fairly quickly open the AWS D1.1 Code and turn to Chapter 6 - Inspection to find the answer.

- **Has a key person been assigned the responsibility of bolting or welding joints in accordance with the applicable specifications? (AISC, Op30)**

"No one knew who was in charge of welding."

At the heart of this requirement are two issues: responsibility and specifications. To achieve high quality, key people must ensure that the work conforms to the standards established in the specifications (e.g., AWS D1.1 and contract documents). Along with responsibility must come the motivation to do the right thing and to see things through to completion. Responsibility also encourages pride of workmanship, ownership, the understanding that it has to be done correctly and that it is up to the individual to accomplish the goal. This person can be the one responsible for assuring quality of the work, but he must know the criteria and be active on the site. If this responsibility is not given to one specific person, the likelihood of conformance to the workmanship standards in the specifications is low. The person in charge of welding must also have the authority to make decisions. There is little benefit in giving responsibility to someone who can not authorize the work to be done.

- **Do the welders understand, comply with, and check their welds against the workmanship and technique requirements of AISC, AASHTO, or AWS? (AISC, Op35)**

"The welder was making welds with unacceptable undercut and didn't know what was wrong."

The Code says that, "the contractor shall be responsible for visual inspection and necessary correction of all deficiencies in materials and workmanship in accordance with the requirements of this code" (AWS D1.1-98, para. 6.6.1). This includes the following issues: cracks, weld/base metal fusion, craters, weld profiles, weld size, undercut, and porosity (AWS D1.1-98, Table 6.1). This code provision establishes the basis for the requirement that the welders must "understand, comply with, and check" their work.

According to the auditor's note in this example, the welder apparently didn't know what undercut was, or that there were unacceptable limits. Since the contractor is responsible for visual inspection, having the welders check to make sure that their work meets the visual inspection criteria is an effective first step.

Welder Qualification

- **Does the applicant have a record of the craft workers who are certified welders? (AISC, Mg7c)**

"No Welder Performance Qualification Records (WPQRs) were available."

In this example, records were inadequate to prove the qualification of the welders. AWS D1.1 states that "the Welding Performance Qualification

Record (WPQR) shall serve as written verification and shall list all of the essential variables of Table 4.10" (AWS D1.1-98, para. 4.21).

Another situation is that the erector may have the qualification records, but the results of mechanical, visual and NDT are not listed. Without test results, the qualification may be suspect. To make the qualification credible, this information must be recorded and retained. As a matter of reference, the D1.1 Code has an example WPQR form in Annex E with space included for the visual, destructive and radiographic test results (AWS D1.1-98, pg. 305).

Additionally, the date and an authorized signature must be on the WPQR. The Code says that the welder's qualification "shall be considered as remaining in effect indefinitely unless ... the welder is not engaged in a given process of welding for which the welder ... is qualified for a period exceeding six months..." (AWS D1.1-98, para. 4.2.3.1). This means that as long as the welder welds with the process for which he is qualified at least once every six months, his qualification last forever unless there is reason to question his ability. The key to this requirement is that the date must be recorded on the WPQR form when the welder was first qualified. Also, a log must be kept to verify that the welder remains current in his qualification.

To make record keeping easier, many erectors use commercially available computer software packages to track welder qualification.

- **Are welders qualified per the project requirements (i.e., AWS, AASHTO, ASME)? (AISC, Op34)**

"Some welders were welding with FCAW but were only qualified for SMAW."

The problem here is that the welder qualification provisions of AWS D1.1 have been violated. The Code states that "changes beyond the limitation of essential variables for welders... shown in Table 4.10 shall require requalification" (AWS D1.1-98, para. 4.22). The welding process (e.g., FCAW, SMAW, GMAW and GTAW) used during qualification is the first essential variable listed in Table 4.10 of the Code. This table states that if the welder is going to change to a process for which he is not qualified, he must qualify for that process as well.

Other essential variables are SMAW F-number, non-approved electrodes/shielding medium in the AWS A5 filler metal specifications, position, material thickness, vertical progression, omission of backing and number of electrodes (AWS D1.1-98, Table 4.10).

Other Welding Problems

- **In the event the applicant purchases weld wire, steel material, paint, castings, etc., are the manufacturer's test reports or certificates of compliance on file at the location where the material is being utilized? (AISC, Advanced Program Only — Op40))**

"No welding electrode Certificates of Conformance were on file."

The welding consumables (i.e., electrode, electrode/flux combination, or electrode/shielding gas) used on the job site must conform to the provisions of the appropriate AWS A5 filler metal specifications. Filler metal tests of conformance are conducted by the welding consumable manufacturer. The results of these tests are reported on a certificate of conformance. Copies of the certificates of conformance must be kept at the job site for each consumable used for the Advanced Certification Program.

The Bridge Code requires that the filler metal tests of conformance be conducted every year (AWS D1.5-96, para. 5.5), and the erector must maintain copies of the most current certificates. The Structural Code states that "when requested by the Engineer, the contractor or fabricator shall furnish certification that the electrode or electrode-flux combination will meet the requirements of the classification" (AWS D1.1-98, para. 5.3.1.1). AWS A5.01-87 Filler Metal Procurement Guidelines have several schedules that permit re-certification of electrodes to different time periods. For example, Schedule G calls for re-certification on an annual basis, while Schedule F allows for the use of the manufacturer's standard testing levels. Some manufacturers use a three year period for products unlikely to be used on bridge projects where D1.5 requires annual re-certification.

- **Are flux and rod ovens adequate and close enough to where the work is being performed and are they operating per the latest AWS requirements? (AISC, Op36)**

"Rod ovens on site, but the temperature inside the oven was only 100 degrees F."

Electrode storage ovens must be available on site, the temperature inside the oven must be maintained to at least 250 degrees F, and the oven must be reasonably close to where the welding is actually done. The D1.1 Code requires that "immediately after opening the hermetically sealed container, electrodes shall be stored in ovens held at a temperature of at least 250 degrees F (120 degrees C)" (AWS D1.1-98, para. 5.3.2.1).

Problems can arise if the consumables are not properly maintained. For example, when welding a higher strength steel, delayed cracking can occur even with low hydrogen electrodes if they are not stored and handled properly. Major rework may result, and cracking is a poten-

tial consequence if this requirement is not followed. The purpose of the rod oven is to keep the electrodes dry to help minimize the chances for problems of this nature. Make sure that the rod ovens (1) are on the job site, (2) work properly, and (3) are close to the location of welding.

Summary

In the form of the D1.1 Structural Welding Code and the D1.5 Bridge Welding Code, steel erectors have been given a readymade two-part "blueprint for excellence" that will serve them well in meeting the requirements of AISC's Erector Certification Program.

This paper is part of the 1999 North American Steel Construction Conference session: "What Every Steel Erector Should Know About Welding Requirements (Before The Auditors Arrive!)."