Welding Wisdom

By Mike Flagg and Doug Krebs

Learn how to purchase consumables for welding under current FEMA 353 guidelines for steel moment-frame construction in seismic applications.

Created in response to the 1994 Northridge earthquake, FEMA 353 details quality assurance guidelines for construction of steel moment-frame buildings in seismic applications. Because it's a guideline and not a code, the Engineer of Record, building owner or municipality specifies which parts, if any, of the FEMA recommendations should be used on a particular construction job.

Since specifications can change from project to project, it is important for contractors and welding engineers to have a good understanding of what FEMA 353 entails. For example, electrodes meeting FEMA 353 recommendations could be more expensive than standard electrodes. In addition, special qualification of welders might be recommended. If the contractor does not take this into account, project costs could be underestimated. Also, these consumables might not be as readily available, resulting in possible project delays if not accounted for during the planning phases.

FEMA guidelines commonly are used in regions subject to seismic activity, including the U.S. West Coast, Boston, Memphis, St. Louis, Charlotte, Salt Lake City and Phoenix.

This article will examine FEMA 353 welding recommendations related to flux-cored self-shielded (FCAW-S) electrodes, typically the consumable of choice for building erection in seismic areas. For example, for on-site construction, flux-cored self-shielded electrodes can be used in winds of up to 30 mph without affecting the weld quality or degrading the mechanical properties. In comparison, gas-shielded electrodes, typically used in the fabrication shop, can have problems in winds as low as 3 mph.

The article also discusses:

- how the FEMA guidelines for electrodes differ from AWS A5 requirements;
- what to look for when purchasing electrodes; and
- what actions the erector or fabricator must take to comply with these guidelines before welding.

Please note that FEMA 353 includes design, inspection, quality control, quality assurance, joint details, and other fabrication/erection issues that are beyond the scope of this article. Readers are encouraged to review the entire FEMA 353 document for these and other guidelines. (This document, *Recommended Specifications and Quality Assurance Guidelines for Steel Moment-Frame Construction for Seismic Applications*, FEMA 353, July 2000, can be ordered by calling FEMA, 800.480.2520, or visit **www.fema.gov**.)

Comparing FEMA 353 to AWS A5 Test Requirements

AWS A5 filler-metal classification-test requirements for electrodes are not always the best indicators of how the consumable will perform in actual field conditions. FEMA 353, with significant focus on performance in the field, is more stringent and calls out testing parameters that more closely simulate actual welding conditions seen on a job site. FEMA 353 guidelines strive to ensure a high level of quality for these applications.

So where do FEMA 353 and the AWS A5 requirements differ? Here are the four primary areas:

- ***Welding Procedure Specification Toughness Verification Test***

The AWS test plate is completed at one heat input, which is specified as any heat input within the range in which the electrode will be used. In contrast, FEMA dictates two test plates at different heat inputs—a high heat input at high interpass temperature and a low heat input at low interpass temperature. During production fabrication, FEMA 353 recommends that the welder use a procedure in between those two, which provides better control of the resulting weld-metal properties.

- ***Filler Metal Trade Name and Electrode Diameter***

FEMA 353 requires that the consumable be qualified per trade name and manufacturer as well as electrode diameter. Why? Even though electrodes may be in the same AWS classification, their arc behavior can be significantly different. FEMA 353 also requires manufacturing lot control and testing, which provides a higher level of confidence.

- ***Diffusible Hydrogen Requirement***

AWS specifications allow weld-metal diffusible hydrogen tests to be run on a broad range of procedures, while FEMA 353 requires the test to be run in the top 75 percent of the procedure range. This additional stipulation typically increases the measured diffusible hydrogen level.

- ***Extended Exposure Test***

Under AWS specifications, diffusible hydrogen testing can be conducted immediately after the electrode is manufactured. However, in actual service, welding consumables are not used right after manufacturing. Again, FEMA 353 recommendations take a different approach. Here, for spooled or coiled electrode types exposed on the job longer than one day, electrodes of that type must be exposed in a humidity chamber to test diffusible hydrogen levels. In this way, FEMA electrode-exposure limits provide a more accurate picture of the actual hydrogen levels that will be achieved in the field.

In the future AWS is expected to issue D1.8, a seismic welding code that probably will incorporate the recommendations of FEMA 353.

What to Look for When Purchasing Electrodes

Below are some of the recommendations in FEMA 353 that can be used to aid contractor buying decisions regarding welding filler metal. The manufacturer will perform most of the testing recommended under these guidelines. The contractor or erector should make sure these

tests have been completed and that the electrodes meet the guidelines set forth by FEMA.

➔ ***Filler Metal Trade Name and Electrode Diameter***

As was mentioned previously, when procedures are qualified, they must be qualified according to the electrode manufacturer's trade name and specific wire diameter. When purchasing material, the contractor must purchase the same tradename, manufacturer and diameter electrode that was qualified.

➔ ***Weld Strength Recommendations***

It is recommended that all welds be made with E70 type filler metals (nominal 70 ksi tensile strength). However, if A913 Grade 65 is used, an E80 type filler metal shall be used for matching strength.

➔ ***Charpy V-Notch Toughness Recommendations***

FEMA 353 recommends that filler metals be tested at two temperatures. Charpy V-Notch (CVN) toughness levels should meet the following minimum recommendations:

1. 20 ft. lbf avg. at 0° F (using the AWS A5 filler metal classification test)
2. 40 ft. lbf avg. at 70° F (using the FEMA 353 Appendix A test)

➔ ***Welding Procedure Specification Toughness Verification Test***
(FEMA 353 Appendix A Test)

The contractor, or a third party like the electrode manufacturer, are to run a Welding Procedure Specification (WPS) Toughness Verification Test to determine the heat input range qualified for the electrode. The contractor must use a WPS that falls within the range of heat inputs and interpass temperatures tested. The toughness verification test results must meet the following minimum mechanical properties: 70 ksi tensile, 58 ksi yield, 22 percent elongation and average CVN toughness of 40 ft. lbf at 70° F.

➔ ***Diffusible Hydrogen Requirement***

FEMA 353 recommends that filler metals meet the H16 diffusible hydrogen levels, as defined by the applicable AWS filler-metal specification. Diffusible hydrogen levels should be tested in accordance with AWS A4.3 and can be reported on the manufacturer's typical certificate of conformance. Ask manufacturers for evidence of this disclosure on their typical certificates of conformance.

➔ ***Packaging***

FEMA 353 recommends that flux-cored arc-welding electrodes (FCAW) be received and stored in a sealed moisture-resistant package until ready for use. New foil bags and other package types are used to meet these guidelines.

➔ ***Extended Exposure Test***

The exposure time for an electrode can be extended if it passes an extended exposure test. Look for manufacturers that have performed this test when purchasing electrodes.

What Actions Should the Erector or Fabricator Take to Comply?

➔ ***Seismic Weld Categories***

Contractors must be aware of the seismic weld categories into which each weld falls as well as the ramifications for welding and quality assurance on those joints in accordance with FEMA 353. The guidelines recommend each weld be classified and listed on the shop and erection drawings. For example, each weld should list a Seismic Weld Demand Category and a Seismic Weld Consequence category—this will dictate the weld property recommendations, the level of inspection and other fabrication issues. (See FEMA 353, July 2000, Part II Tables 5-1, 5-2, 5-3 and 5-4.)

➔ ***Supplemental Welder Qualification Testing***

FEMA 353 recommends that welders pass a "Supplemental Welder Qualification Test" within the 12 months prior to starting on the project. Basically, for each process that the welder is going to use on the job, the ability to make a sound weld must be proved.

➔ ***Intermixing FCAW-S Test***

When flux-cored self-shielded (FCAW-S) arc welding is used with another welding process, a test is recommended to confirm the CVN toughness of the intermixed zone to meet 40 ft. lbf. at 70° F. For contractors, intermixing situations could include tack welds or welds made in the shop with gas-shielded flux-cored, and then erected on site using self-shielded over those welds.

➔ ***Electrode Exposure – Time Limits***

Electrode exposure time is restricted to minimize the risk of hydrogen cracking. If welding stops for more than eight hours, unless extended exposure testing has been performed, the electrode cannot be used unless it has been removed from the welding machine and stored in an oven. Contractors also have to dispose of an electrode 24 hours after the package is opened or up to the manufacturers' recommendations on exposure limits.

➔ ***Wind Velocity Limit***

For all gas-shielded processes, contractors and welders are limited to 3-mph winds in the vicinity of the arc. This guideline is intended to minimize the loss of shielding gas that has a detrimental effect on the weld-metal mechanical properties.

➔ ***Maximum Preheat and Interpass Temperature***

The maximum recommended preheat and interpass temperature is 550° F, to avoid excessively slow cooling rates which could affect mechanical properties.

➔ ***Welded Joint Details***

Tack welds attaching steel backing should be placed in the weld joint. After welding has been completed, backing is removed, where indicated, and back-welded with a $^{5}/_{16}$" leg fillet, to minimize stress concentrations. (Refer to FEMA 353 for complete details.)

Conclusion

When purchasing electrodes for jobs specifying FEMA 353 guidelines, make sure the manufacturer offers a product that has:

➔ Undergone extended exposure testing.
➔ Been subject to testing at both low and high heat inputs.
➔ Been sealed in robust, moisture-resistant containers such as a foil bag or a hermetically sealed pail.

In conclusion, it should be noted that not all manufacturers carry tested and lot-controlled material in stock. If your application is one in which you will need immediate access to such consumables, find a manufacturer that can accommodate your request. ★

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