U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: **ACTION**: Use of Electroslag Welding in Highway Bridges and Structures

Date: May 10, 2018

From: /Original signed by/
Joseph L. Hartmann, PhD, P.E.
Director, Office of Bridges and Structures

In Reply Refer To: HIBS-10

To: Directors of Field Services
Division Administrators
Federal Lands Highway Division Directors

PURPOSE

The purpose of this memorandum is to provide updated guidance on the specification and use of electroslag welding in highway bridges and other structures.

SUPERSEDED DOCUMENTS

This memorandum supersedes and cancels a previous memo:

- "Narrow-Gap Electroslag Welding for Bridges", March 20, 2000.

Three related FHWA documents are rescinded:

- Notice (N 5040.23) *"Electro-Slag Welding"*, February 16, 1977 (rescinded in 2000).
- Notice (N 5040.25) *"Electro-Slag Welding"*, June 28, 1977.
- Notice (N 5040.27) *"Recommendations Concerning Steel Thickness"*, August 17, 1977.

RELATED FHWA RESEARCH REPORTS

Six valuable FHWA sponsored research reports are available upon request for information and reference:

- *"Improved Fracture Toughness and Fatigue Characteristics of Electroslag Welds"*, FHWA/RD-87/026, October 1987.
- *"Repair of Process-related Defects in Electroslag Welding",* FHWA-RD-93-035, December 1994.
- *"Industrial Field Trials of Oregon Graduate Institute Developed Electroslag Welding Technology"*, FHWA-RD-93-036, December 1994.
- *"Training Manual for Narrow-Gap Improved Electroslag Welding"*, FHWA-SA-96-051, November 1995.

- *"Technical Information Guide for Narrow-Gap Improved Electroslag Welding"*, FHWA-SA-96-052, January 1996.
- *"Process Operational Guide for Narrow-Gap Improved Electroslag Welding"*, FHWA-SA-96-053, February 1996.

BACKGROUND

On February 16, 1977, FHWA issued a Notice (N 5040.23) banning the use of electroslag welding (ESW) on main structural tension members. This ban was based on field experiences including the brittle fracture of a fracture critical member (FCM) on the I-79 bridge near Pittsburgh, PA, which initiated at an ESW weld repair. At the time, the ESW process used high heat inputs and oscillating consumables with manual process controls that lead to large grain structures and low Charpy toughness.

To take advantage of the efficiency of the ESW process and to assure safety and economy of steel bridges, FHWA invested in several R&D programs to improve ESW technology and technique. This effort developed a refined process that was called "Narrow Gap Improved Electroslag Welding" (NGI-ESW). The new process utilized a narrower gap and a fixed, consumable, electrode guide in combination with reduced voltages and higher welding currents. This reduced heat input and increased travel speed produced more uniform heat affected zone (HAZ) toughness, and reduced weld defect tendency. Additionally, electrode oscillation was prohibited and strict placement guidelines for the guide and electrode(s) were imposed to provide uniform melting of the base metal.

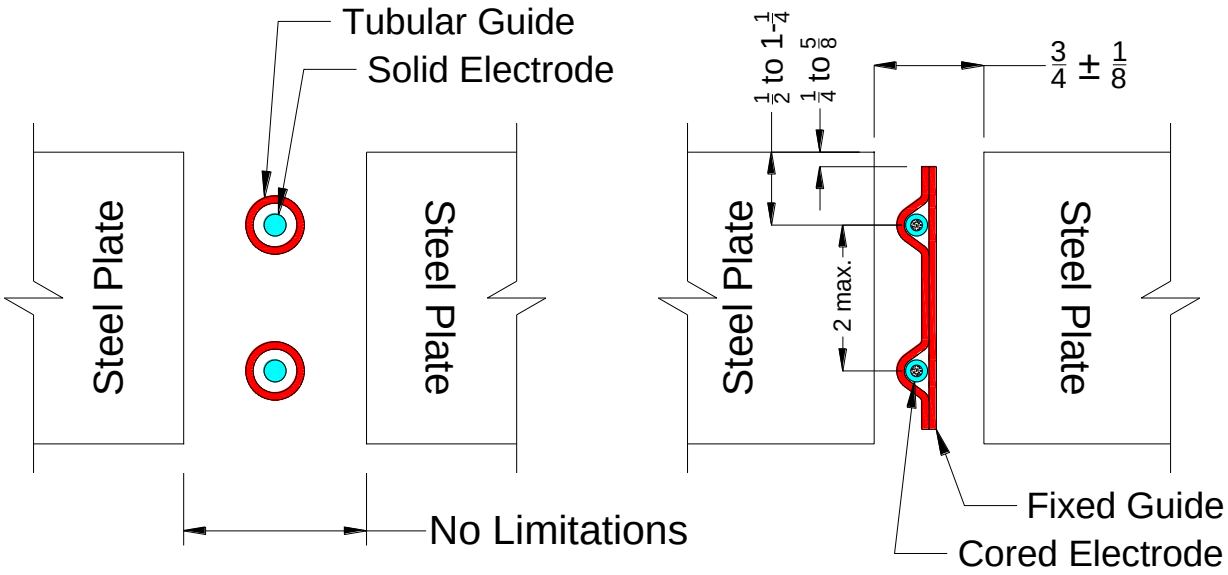
The most significant change was the control of the travel speed or vertical rate of rise of the weld. This is controlled by the amperage and rate of wire feed which are different for different thicknesses of material. The control of the casting process which produces the rate of rise is the most important control variable for ESW. Alloy additions were also used to improve the weld microstructure. ESW produced in this way exhibit satisfactory toughness in both weld metal and in the heat affected zone. As a result, FHWA rescinded the moratorium imposed by N 5040.23 with a memorandum dated March 20, 2000 and allowed for the use of NGI-ESW to weld non-fracture critical tension and/or stress reversal members in temperature zones 1 and 2.

After several years, the NGI-ESW process was integrated into the AASHTO/AWS D1.5 *Bridge Welding Code:2010*, with a synonymous name, "Electroslag Welding-Narrow Gap" (ESW-NG). The provisions for ESW-NG set forth within various clauses and annexes are consistent with the process developed in the FHWA research. The acronym ESW and ESW-NG are used interchangeably through the code, meaning that ESW used in new design/fabrication will utilize the improved process. The code also provides an annex for acceptance of alternative ESW processes other than ESW-NG. The code prohibits the use of ESW on FCMs and HPS, which is a precautionary limitation due to a lack of research and experience.

PROCESS DESCRIPTIONS

The figure below helps to illustrate the main differences between the original ESW (AASHTO/AWS D1.5:2008 and prior editions), and the newer NGI-ESW/ESW-NG process (AASHTO/AWS D1.5:2010 and later editions). The NGI-ESW/ESW-NG process reduces the

initial gap between plates to ¾ inch, while the older process may be double that. Narrowing the gap increases the rate of rise of the weld pool, reduces the heat input and yields more favorable Charpy toughness. With the narrower gap, the guides have been redesigned into fins in lieu of tubular guides, spanning the width of the joint, and precluding electrode oscillation. Winged electrode guides are not mandatory, but have been proven successful. Alignment of the guides and electrodes within the joint is critical and is controlled in the specifications. This spreads the welding current more uniformly through the joint, and mitigates the large columnar grain structures that formed around the older guide tubes. There was also a change from solid to cored electrodes which allows for easier alloy additions into the weld. Lastly, the new process is fully computer controlled where voltage, amperage and wire feed are continuously monitored, and flux additions are automated based on this feedback in lieu of metering the flux manually.



Note: Units in inches

Original ESW

- Gap > ¾ inch
- Solid electrode(s)
- Round guide tube(s)
- Manual addition of flux

NGI-ESW or ESW-NG

- Gap ≤ ¾ inch
- Cored electrode(s)
- Fixed guide (one sample cross section shown here)
- Computer controlled flux addition
- Water-cooled copper shoes with regulated flow and temperature (not shown for simplicity)
- Electrode oscillation prohibited

FHWA POLICY ON ELECTROSLAG WELDING

To assure the quality and performance of fabricated steel for bridges, an ESW process is considered acceptable provided the process can consistently produce welds that pass the AASHTO/AWS D1.5 qualification procedures and satisfy engineering design demand. This applies to any welding process that is either prequalified, or qualified in accordance with the code.

ESW-NG/NGI-ESW is a high-efficiency, well-documented welding process. It was developed based on extensive FHWA research, and has been codified in AASHTO/AWS D1.5 since 2010. It is allowable in Federal-Aid projects.

ESW by the original process is not permitted on main structural bridge members subject to tension on new Federal-aid projects. If this type of weld is found on an existing bridge, the Owner should evaluate whether it is necessary to perform a special inspection or develop a mitigation plan, based on the risk to bridge safety (such as fracture critical members) and a past record of successful performance, unless this has already been addressed based on prior FHWA guidance.

Some Owners specify fabrication of non-vehicular bridges and ancillary highway structures per AWS D1.1 *Structural Welding Code-Steel*. In Federal-Aid projects, if ESW is used on such members that may be subject to cyclical load with a tension component, AASHTO/AWS D1.5 ESW-NG provisions should be additionally required, as AWS D1.1 is not consistent with the welding provisions developed in FHWA research.

In Federal-Aid projects, the use of ESW is not permitted on any steel bridge member subject to the supplemental provisions of the AASHTO/AWS Fracture Control Plan (FCP) for Nonredundant Members defined in AASHTO/AWS D1.5.

DISTRIBUTION AND CONTACT FOR QUESTIONS

Please share this memorandum with appropriate staff and with all State DOT, Federal agency, and tribal government partners. Questions on the guidance can be directed to Dayi Wang at (202) 366-5604 or e-mail at Dayi.Wang@dot.gov, or to Brian Kozy at (202) 493-0341 or e-mail at Brian.Kozy@dot.gov.