Project No. 10-95A

TOUGHNESS REQUIREMENTS FOR HEAT-AFFECTED ZONES OF WELDED STRUCTURAL STEELS FOR HIGHWAY BRIDGES

FINAL REPORT ATTACHMENT "Proposed Revisions to the AASHTO/AWS D1.5 Bridge Welding Code, 8th Ed."

Prepared for
NCHRP
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of

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ATTACHMENT

Proposed Specification Changes

This attachment contains proposed changes to the AASHTO/AWS D1.5 Bridge Welding Code (2020). These proposed changes are the recommendation of the research team for NCHRP Project 10-95A at the University of Kansas. These changes have not been approved by NCHRP or any AASHTO committee nor formally accepted for AASHTO specifications.

Suggested revisions to the AASHTO/AWS D1.5 Bridge Welding Code, 8th Ed. (2020)

The specific articles in the specifications to which changes are proposed are included in this chapter. Other articles to which no changes are recommended are not presented. Underlined text indicates proposed revisions to existing specifications and/or commentary. ~~Strikethrough text~~ indicates proposed deletions from existing specifications and/or commentary.

The following edits to Clauses 1.3.4 and 6.18.3 and Annex O11 are recommended, prohibiting the use of electroslag welding for members subjected to tensile stresses.

1.3.4 Electroslag (ESW) may only be used for ~~Zone I and II non-fracture-critical~~ bridge members and member components~~, including components~~ that are not subject to tensile stresses or reversal of stress, provided the WPSs conform to the applicable provisions of Clauses 4, 5, and 6, and are qualified in accordance with the requirements of 7.14. ESW shall be subject to nondestructive testing, as specified in Clause 8. Only the "narrow-gap improved" ESW process (ESW-NG) shall be permitted, unless another process is approved in accordance with Annex I. Application of ESW shall be limited to members or member components made from M 270M/M 270 (A709/A709M) Grades 250 [36], 345 [50], 345S [50S], and 345W [50W] steels.

6.18.3 ESW may only be used for welding components of members that are not subject to tensile stresses or reversal of stress~~ only when application is limited service temperatures of -35°C [-30°F] and above (AASHTO Temperature Zones I and II)~~. ESW shall not be used ~~for fracture-critical members or components,~~ for quenched and tempered steel (Q&T)~~,~~ or thermo-mechanical control processed steel (TMCP).

O11. Application Restrictions

ESW applications are described in 6.18.3. The use of ESW for tensile ~~fracture-critical or Zone III~~ applications is prohibited ~~because the research that led to the lifting of the FHWA moratorium did not investigate the performance of ESW for fracture critical members and the Charpy Impact properties were not adequate for Zone III requirements.~~ based on the research performed under NCHRP 10-95A. This work concluded that the ESW heat-affected zone exhibited inadequate fracture toughness for members subject to tensile stresses at all minimum service temperatures for both fracture critical and non-fracture critical applications.

Updated commentary for Clause 7.14 is recommended to reflect the electroslag production restrictions recommended in Clause 6.18.3. New commentary for Clause 7.16.3 is recommended to provide discussion on the ongoing state of HAZ fracture toughness research and the reasoning behind not mandating HAZ impact testing at this time.

C-7.14 Electroslag Welding

The restrictions on production welding in Clause 6 are intended to avoid mandatory HAZ CVN testing for use in tension membersprovide adequate HAZ CVN toughness without depending on CVN testing of the HAZ.

C-7.14.1 Figure 7.1. Because ESW uses a square butt joint preparation, the test plates are prepared with a square edge. Eight specimens are required instead of five because the coarse columnar grain structure of ESW leads to much higher scatter in CVN test results.

C-7.15 Type of Tests and Purpose

Weld test plates are first visually inspected, then radiographed to ensure that the WPS is capable of producing sound welds that meet all the quality requirements of the code. If visual inspection or NDT indicates that the test weld contains unacceptable weld discontinuities, there is no need to machine test specimens and conduct tests because the WPS testing is still considered a failure. When acceptable weld discontinuities are very localized and there is sufficient weld length, it is acceptable to machine all required test specimens from areas of the weld that are defect free.

Acceptance of WPSs is based on satisfactory achievement of required mechanical values for strength, ductility, and toughness, and satisfactory quality as documented by NDT and destructive tests for soundness. WPS qualification testing verifies mechanical properties based on test welds. In production welding, soundness is also verified by visual tests and NDT.

C-7.15.1 Groove Welds. These tests evaluate the soundness of the weld metal and determine the mechanical properties of the deposited weld metal. If, in exceptional situations, a test joint is required to use undermatching weld metal or two different specified base metal strengths, the reduced section tensile tests and side-bend specimens will not results in meaningful mechanical examinations.

C-7.16 Weld Specimens - Number, Type, and Preparation

C-7-16.3 CVN Tests. Research performed under NCHRP 10-95A indicated that impact energy absorption and fracture toughness in the HAZ can be significantly deteriorated from base metal levels. As part of the investigation, CVN and fracture toughness specimens were sampled and tested from AASHTO M 270 (ASTM A709) Grade 345/345W [50/50W] and HPS 485W [HPS 70W] steel containing two SAW procedures with different nominal heat inputs and cooling rates. Results indicated the 3.2 kJ/mm [80 kJ/in.] heat input, 10°C/sec [18°F/sec] cooling rate HAZ exhibited greater reduction in fracture toughness compared to base metal than the 1.6 kJ/mm [40 kJ/in.] heat input, 30°C/sec [54°F/sec] cooling rate HAZ. At this time, there is insufficient information to mandate CVN testing of the HAZ, but further research into the effects of heat input and cooling rate on HAZ fracture toughness could lead to such a requirement.

An addition to C-12.14 is recommended, noting that higher heat inputs had a more detrimental effect on HAZ fracture toughness than lower heat inputs. Because data was obtained at the lower and upper bounds of reasonable heat input for SAW, an acceptable threshold for maximum heat input was not identified.

C-12.14 Preheat and Interpass Temperature Control

Tables 12.4, 12.5, 12.6, 12.7, and 12.8 for preheat under the Fracture Control Plan have added two additional elements not considered for redundant members: the diffusible hydrogen limit of the weld metal deposited by various filler metals, and the heat input from welding. The level of required preheat is therefore a function of the type of steel, thickness of steel, hydrogen level of the filler metal, and the heat input from the welding process.

The grade of steel is one of the variables necessary to determine the required level of preheat because as the carbon content of the steel increases, or as the level of the alloy content increases, the degree of hardenability of the steel also increases. The higher the hardenability, the greater the level of required preheat to prevent cracking.

As the thickness of the steel increases, the rate of cooling experienced by the weld in the HAZ also increases, all other parameters being constant. Increased cooling rates may lead to higher hardness of the HAZs and weld metal, justifying increased levels of preheat. Reduced levels of heat input from welding results in faster cooling rates, and justifies higher preheat to preclude cracking. Research performed under NCHRP 10-95A examined HAZ fracture toughness at the upper and lower bounds of SAW heat input. Results indicated that higher heat input had a more detrimental effect on HAZ fracture toughness than lower heat input, but a maximum allowable limit of heat input was not identified.