AASHTO/AWS D1.5M/D1.5:2015
An American National Standard

Bridge Welding Code

A Joint Publication of

American Association of State Highway and Transportation Officials

American Welding Society®

Approved American National Standard ANSI

AASHTO/AWS D1.5M/D1.5:2015
An American National Standard

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Bridge Welding Code

7th Edition

Supersedes AASHTO/AWS D1.5M/D1.5:2010

Prepared by the
American Welding Society (AWS) D1 Committee on Structural Welding
AASHTO Highway Subcommittee on Bridges and Structures

Under the Direction of the
AWS Technical Activities Committee
AASHTO Executive Committee

Approved by the
AWS Board of Directors
AASHTO Board of Directors/Policy Committee

Abstract

This code covers the welding requirements for AASHTO welded highway bridges made from carbon and low-alloy constructional steels. This 2015 edition contains dimensions in metric SI Units and U.S. Customary Units. Clauses 1 t rough 7 constitute a body of rules for the regulation of welding in steel construction. The provisions for Clause 9 have t en distributed throughout the D1.5 code. Clauses 8, 10, and 11 do not contain provisions, as their analogue D1.1 sec- t ns are not applicable to the D1.5 code. Clause 12 contains the requirements for fabricating fracture critical members.

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Foreword

This foreword is not part of AASHTO/AWS D1.5M/D1.5:2015,
Bridge Welding Code, but is included for informational purposes only.

The original preparation of this specification was undertaken in response to a need for a common welding specification for the fabrication of steel highway bridges across the country. Prior to its publication, the departments of highways and transportation that make up the American Association of State Highway and Transportation Officials (AASHTO) had routinely used other specifications of the American Welding Society (AWS) Structural Welding Committee, with various unique modifications, to produce contract documents suitable for the construction of bridges. The proliferation of disparate requirements resulted in the need for a single specification that could facilitate uniformity and improved economy in steel bridge fabrication, while at the same time addressing the issues of structural integrity and public safety.

The first AWS code for *Fusion Welding and Gas Cutting in Building Construction* was published in 1928. In 1934, a committee was appointed to prepare specifications for the design, construction, alteration, and repair of highway and railway bridges. The first bridge specification was published in 1936. Until 1963, there were separate AWS committees for bridges and buildings. These two committees joined in 1963 to form the Structural Welding Committee of the American Welding Society. The committee has since promulgated standards for the application of welding to the design and construction of structures.

The Federal Highway Administration of the United States Department of Transportation requires states using federal funds for the construction of welded highway bridges to conform to specified standards for design and construction. Conformance to the AWS *Specification for Welded Highway and Railway Bridges* was first specified in the third edition of the AASHTO *Standard Specifications for Highway Bridges* in 1941. In 1962, the Bureau of Public Roads, now the Federal Highway Administration (FHWA), required conformance to a Circular Memorandum, dated November 13, 1962, which transmitted additional provisions for welding A36 steel pending publication of an AWS specification which would contain certain essential provisions not then in the code. Another Circular Memorandum, dated February 11, 1965, specified requirements for CVN testing, and a further Circular Memorandum, dated August 19, 1966, modified provisions of the 1966 Edition of the AWS D2.0-66, *Specification for Welded Highway and Railway Bridges*.

In 1974, AASHTO published the first edition of the *Standard Specification for Welding of Structural Steel Highway Bridges.* The Eleventh Edition of the AASHTO *Standard Specifications for Highway Bridges*, dated 1977, directed "Welding shall conform to the requirements of the AASHTO *Standard Specifications for Welding of Structural Steel Highway Bridges* 1974 and subsequent interim specifications…" AASHTO published the Second and Third editions of the *Standard Specifications for Welding of Structural Steel Highway Bridges* in 1977 and 1981. All of the AASHTO specifications were required to be part of the Contract Documents as modifications or additions to the AWS *Structural Welding Code—Steel.* This was a cumbersome procedure.

In 1982, a subcommittee was formed jointly by AASHTO and AWS, with equal representation from both organizations, to seek accommodation between the separate and distinct requirements of bridge owners and existing provisions of AWS D1.1. The *Bridge Welding Code* is the result of an agreement between AASHTO and AWS to produce a joint AASHTO/AWS *Bridge Welding Code* for steel bridges that addresses essential AASHTO needs and makes AASHTO revisions mandatory.

The first edition of the *Bridge Welding Code*, published in 1988, provided for the qualification of welding procedures by test to assure that welds have the strength, ductility, and toughness necessary for use in redundant structures. Nonredundant fracture critical bridge members were not provided for in the first edition of the code. While qualification of welding procedures is required, a major effort has been made to specify the minimum number of tests and the simplest tests

that give reasonable assurance of required mechanical properties. Efforts are made to discourage individual States from requiring duplication of weld testing unless that testing is specified in the bid documents. Special attention is directed to avoidance of unnecessary hardening of base metal HAZs and the avoidance of hydrogen and other items that can lead to weld or base-metal cracking.

Consequently, while the D1.5-88 document has a superficial resemblance to D1.1 in its general format, there are significant differences that users should be aware of, among them the lack of provisions relating to statically loaded structures, tubular construction or the modification of existing structures. Users are encouraged to develop their own requirements for these applications or use existing documents (e.g., D1.1) with the appropriate modifications.

Changes in Code Requirements. Underlined text in the clauses, subclauses, tables, figures, or forms indicates a change from the 2010 edition. A vertical line in the margin of a table or figure also indicates a change from the 2010 edition.

The publication of AASHTO/AWS D1.5M/D1.5:2015 was justified by the need to monitor, revise, and update code provisions based on the needs of AASHTO member states and industry. The following is a list of the most significant revisions in the 2015 edition:

Summary of Changes

Clause/Table/ Figure/Annex	Modification
2.11.3	Created to include groove welds in corner and T-joints. As such, this requirement was deleted from the notes for Figures 2.4 and 2.5; it was note f in the 2010 edition.
3.5.6.1	Modified to clarify how variation from flatness is measured.
3.5.1.7	Revised to include directions on how to measure combined warpage and tilt of flange.
3.6	Reorganized for clarification and now includes new subclauses on fillet welds, groove welds, removal of weld reinforcement, and surface finish.
3.6.2	Revised to clarify weld reinforcement and associated ground flush requirements.
Figure 3.3	Created to show flange offset for tube girders.
4.1.3	Revised consumable requirements to establish two approaches - manufacturer quality assurance and heat or lot testing.
4.1.4	Revised and reorganized for the clarification of consumable certifications.
4.2.7	Expanded with two new subclauses on the extent of preheat and interpass.
4.10 and 4.11	Consolidated into new subclause 4.10.
Table 4.1	Test requirements were extracted and placed as new Table 5.1.
Clause 5	Revised the heat input qualification by broadening voltage limits and adding a new amperage limit table; for the production qualification method, removed prequalification-based restrictions in lieu of variable qualified by test; and removed the groove weld requirement for qualification of single-pass fillet weld procedures.
5.3	Removed expiry limits for nonfracture critical PQRs.
Table 5.1	Content extracted from Table 4.1 in the 2010 edition.
Table 5.4	Modified to include qualification requirements with Figure 5.8 with the exception of EGW.
Table 5.10	Created to indicate the amperage limits for heat input welding procedure qualification.
Figure 5.8	Modified to include dihedral angle.

Summary of Changes (Continued)

Clause/Table/ Figure/Annex	Modification
6.7.6.2	Revised to include pulsed DC.
6.7.8	Created to introduce phased array ultrasonic testing.
12.6.1	(Heat or Lot Testing) was deleted.
12.7.4	Revised to indicate no limits to the period of effectiveness for fillet weld soundness test and increase the period of effectiveness for PQRs from 36 months to 60 months.
Annex K	New annex that addresses phased array ultrasonic testing.
C-12.6.1.1	Deleted.
C-12.7.3	Deleted.
C-Annex K	New commentary added for Annex K.
Global	"Chemistry" replaced with "Chemical composition."
Global	"Grade 100" replaced with "HPS 100W."

Commentary. The Commentary is nonmandatory and is intended only to provide insightful information into provision rationale.

Normative Annexes. These annexes address specific subjects in the code and their requirements are mandatory requirements that supplement the code provisions.

Informative Annexes. These annexes are not code requirements but are provided to clarify code provisions by showing examples, providing information, or suggesting alternative good practices.

Index. As in previous codes, the entries in the Index are referred to by subclause number rather than by page number. This should enable the user of the Index to locate a particular item of interest in minimum time.

Errata. It is the Structural Welding Committee's Policy that all errata should be made available to users of the code. Therefore, any significant errata will be published in the Society News Section of the *Welding Journal* and posted on the AWS web site at: http://www.aws.org/technical/d1/.

Suggestions. Your comments for improving AWS D1.5M/D1.5:2015, *Bridge Welding Code* are welcome. Submit comments to the Managing Director, Technical Services Division, American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166; telephone (305) 443-9353; fax (305) 443-5951; e-mail info@aws.org; or via the AWS web site <http://www.aws.org>.

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List of Forms

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Bridge Welding Code

1. General Provisions

1.1 Application

1.1.1 This code covers welding fabrication requirements applicable to welded highway bridges. The code is applicable to both shop and field fabrication of steel bridges and bridge components. The code is to be used in conjunction with the *AASHTO Standard Specification for Highway Bridges* or the *AASHTO LRFD Bridge Design Specifications*.

The code is not intended to be used for the following:

(1) Steels with a minimum specified yield strength greater than 690 MPa [100 ksi]

(2) Pressure vessels or pressure piping

(3) Base metals other than carbon or low-alloy steels

(4) Structures composed of structural tubing

Fabrication of structures or components not specifically addressed by this code shall be performed in conformance with the special provisions of the contract or in conformance with the written directives of the Engineer who may choose to reference an alternate applicable welding standard.

1.1.2 The fundamental premise of the code is to provide general stipulations applicable to any routine bridge situation. Acceptance criteria for production welds different from those described in the code may be used for a particular application, provided they are suitably documented by the proposer and approved by the Engineer.

Such alternate acceptance criteria may be based on the evaluation of suitability for service using past experience, experimental evidence, or engineering analysis considering material type, service load effects, and environmental factors.

1.1.3 The term *Engineer* as used in this code shall mean the State Bridge Engineer, or the Bridge Engineer's designated representative. The Engineer acts on behalf of the State or Owner and unless otherwise specified, shall be the Owner's official representative. All references to acceptance or approval shall mean acceptance or approval by the Engineer.

1.1.4 The term *Contractor* as used in this code indicates the party responsible for performing the work as required by the contract documents. The term Contractor is used collectively to mean contractor, manufacturer, fabricator, erector, or other party performing the work.

1.2 Base Metal

1.2.1 Specified Base Metal. The contract documents shall designate the specification and classification of base metals to be used.

1.2.2 Approved Base Metals. Unless otherwise specified, base metals to be welded under this code shall meet the requirements of the latest edition of AASHTO M 270M/M 270 (ASTM A709/A709M) for the grade of steel shown on the plans or described in the specifications. All Grade 345 (50) steel that is to be welded shall be Type 1, 2, or 3. Other steels may be approved by the Engineer. Thickness limitations shall not apply to bearing components.

M 270M/M 270 steels of a designated grade are essentially the same as ASTM A709/A709M steels of the same grade. The provisions of this code are not intended for use with steels having a minimum specified yield strength over 690 MPa [100 ksi].

1.2.3 Thickness Limitations. The provisions of this code do not apply to welding base metals less than 3 mm [1/8 in] thick. Where base metals thinner than 3 mm [1/8 in] are to be welded, the requirements of AWS D1.3/D1.3M, *Structural Welding Code—Sheet Steel*, should apply. When used in conjunction with AWS D1.3/D1.3M, the applicable provisions of this code shall be observed.

1.3 Welding Processes

1.3.1 This code addresses SMAW, SAW, FCAW, GMAW, ESW, EGW, and SW. Other welding processes may be used if approved by the Engineer. These processes shall be qualified by the applicable tests described in 5.12.4 and any other tests required by the Engineer. In conjunction with the tests, the WPSs and limitations of essential variables applicable to the specific welding process shall be established by the Contractor developing the WPS. The ranges of essential variables shall be based on documented evidence of experience with the process, or a series of tests shall be conducted to establish the limits of variables. Any change to an essential variable outside the established range shall require requalification.

1.3.2 Shielded metal arc welding (SMAW) WPSs (Welding Procedure Specifications) that conform to the provisions of Clauses 2, 3, and 4, are operated within the limitation of variables recommended by the manufacturer, and that produce weld metal with a minimum specified yield strength less than 620 MPa [90 ksi], shall be deemed prequalified and exempt from the tests described in Clause 5. WPSs for SAW, FCAW, GMAW, ESW, and EGW shall be qualified as described in 5.12, as applicable.

1.3.3 Electrogas (EGW) welding may be used for groove welds in butt joints in compression, provided the WPSs conform to the applicable provisions of Clauses 2, 3, and 4, and are qualified in accordance with the requirements of 5.13. EGW shall be subject to nondestructive testing, as specified in Clause 6.

1.3.4 Electroslag (ESW) may be used for Zone I and II non-fracture-critical bridge members and member components, including components subject to tensile stresses or reversal of stress, provided the WPSs conform to the applicable provisions of Clauses 2, 3, and 4, and are qualified in accordance with the requirements of 5.14. ESW shall be subject to nondestructive testing, as specified in Clause 6. Only the "narrow-gap improved" ESW process (ESW-NG) shall be permitted, unless another process is approved in accordance with Annex J. 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.

1.3.5 Stud welding may be used, provided the WPSs conform to the applicable provisions of Clause 7.

1.3.6 GMAW-S (short circuit arc) is not recommended for the construction of bridge members and shall not be permitted without written approval of the Engineer.

1.3.7 Welding of Ancillary Products. Unless otherwise provided in the contract documents, ancillary products, such as drainage components, expansion dams, curb plates, bearings, hand rails, cofferdams, sheet piling, and other products not subject to calculated tensile stress from live load and not welded to main members in tension areas as determined by the Engineer, may be fabricated without performing the WPS qualification tests described in Clause 5, subject to the following restrictions:

(1) SMAW, SAW, FCAW, and GMAW WPSs shall be considered prequalified and exempt from the qualification tests described in Clause 5, provided that welding is performed in conformance with all other provisions of the code.

(2) All welding performed in conformance with this subclause shall be conducted within the limitations of welding variables recommended by the filler metal manufacturer. Welds attaching ancillary products to main members shall meet all requirements of the code, including WPS qualification testing.

(3) The Engineer shall be the final judge of which products are considered ancillary and exempt from qualification tests.

1.4 Fabricator Requirements

Fabricators shall be certified under the AISC Quality Certification Program, Simple Steel Bridges, Intermediate Steel Bridges, or Complex Steel Bridges as required by the Engineer, or an equivalent program acceptable to the Engineer.

1.5 Definitions

The welding terms used in this code shall be interpreted in conformance with the definitions given in the latest edition of AWS A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, supplemented by Annex D of this code.

1.6 Welding Symbols

Welding symbols shall be those shown in AWS A2.4:2007, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*. Special conditions shall be fully explained by notes or details.

1.7 Safety Precautions

This standard does not address all welding and health hazards. However, pertinent information can be found in the following documents:

(1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

(2) Manufacturer's safety literature on equipment and materials

(3) Other pertinent documents as appropriate

These documents shall be referred to and followed as required.

NOTE: This code may involve hazardous materials, operations, and equipment. It does not purport to address all of the safety problems associated with its use. It is the responsibility of the user to establish appropriate safety and health practices. The user should determine the applicability of any regulatory limitations prior to use.

1.8 Standard Units of Measurement

This standard makes use of both U.S. Customary Units and the International System of Units (SI). The measurements may not be exact equivalents; therefore, each system shall be used independently of the other without combining in any way. The standard with the designation D1.5M:2015 uses SI Units. The standard designation D1.5:2015 uses U.S. Customary Units. The latter are shown within brackets [ ].

1.9 Welding Procedure Specifications (WPSs)

All production welding shall be performed in conformance with the provisions of an approved Welding Procedure Specification (WPS), which is based upon successful test results as recorded in a Procedure Qualification Record (PQR) unless qualified in conformance with 1.3.2. All WPSs shall reference the PQR that is the basis for acceptance. A copy of the proposed WPS and referenced PQR shall be submitted to the Engineer for approval. Recommended forms for WPSs and PQRs are provided in Annex O. WPSs for SMAW that meet the requirements of 5.11 shall be considered prequalified and exempt from qualification testing.

1.10 Mechanical Testing

The latest edition of AWS B4.0 or B4.0M, *Standard Methods for Mechanical Testing of Welds*, provides additional details of test specimen preparation and details of test fixture construction.

1.11 Reference Documents

See Annex P for a description of the documents referenced in AASHTO/AWS D1.5M/D1.5:2015.

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2. Design of Welded Connections

Part A
General Requirements

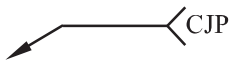
2.1 Drawings

2.1.1 Full and complete information regarding location, type, size, and extent of all welds shall be clearly shown on the drawings. The drawings shall clearly distinguish between shop and field welds. Unless specifically indicated in the design, all groove welds, both shop and field, shall be complete joint penetration (CJP) groove welds.

2.1.2 Those joints or groups of joints for which it is especially important that the welding sequence and technique be carefully controlled to minimize shrinkage stresses and distortion shall be so noted on shop and working drawings.

2.1.3 Contract design drawings shall specify the effective weld length and, for partial joint penetration (PJP) groove welds, the required weld size, as defined in 2.3. Shop or working drawings shall specify the groove angles (α and β) and depths (S) applicable for the weld size (E) required for the welding processes and position of welding to be used.

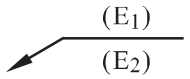
2.1.3.1 It is recommended that contract design drawings show CJP or PJP groove weld requirements. The welding symbol without dimensions designates a CJP weld, as follows:



complete joint penetration groove weld (CJP)

The welding symbol with dimensions above or below the arrow designates a PJP weld, as follows:

2.1.3.2 Special groove details shall be specified where required.



(E1) } partial joint
(E2) } penetration groove weld (PJP)

where
(E1) = effective weld size, other side
(E2) = effective weld size, arrow side

2.1.4 Detail drawings shall clearly indicate by welding symbols or sketches the details of groove welded joints and the preparation of material required to make them. Both width and thickness of steel backing shall be detailed.

2.1.5 Any special inspection requirements shall be noted on the drawings or in the specifications.

2.1.6 Use of Undermatched Filler Metals. Undermatching filler metal may be used:

(1) For all fillet and PJP groove welds, when consistent with design requirements.

(2) For all CJP groove welds where the stress in the weld is tension or compression parallel to the weld axis, providing shear on the effective weld area meets AASHTO design requirements for all applications.

For CJP groove welds in compression, undermatching up to 70 MPa [10 ksi] may be used. Weld sizes shall be based on the strength of filler metal that is required to be used, or the strength of filler metal that may be used. Weld sizes and weld metal strength levels shall be in conformance with AASHTO Design Specifications. Design drawings shall show the weld size and, where required or allowed, the undermatching filler metal strength classification shall be shown. Shop drawings shall show the weld size and filler metal strength classification when undermatching filler metal is to be used. When no filler metal strength is shown, matching filler metal shall be used.