



LRFD Steel Bridge Fabrication Specifications

Cover Photos: Ronnie Medlock of High Steel Structures, LLC

© 2023 by the American Association of State Highway and Transportation Officials.
All rights reserved. Duplication is a violation of applicable law.

ISBN: 978-1-56051-806-8

Pub Code: LRFDSFS-1

EXECUTIVE COMMITTEE

2022–2023

Voting Members

OFFICERS:

PRESIDENT: Roger Millar, Washington*

VICE PRESIDENT: Paul Ajegba, P.E., Michigan*

SECRETARY-TREASURER: Russell McMurry, Georgia

EXECUTIVE DIRECTOR: Jim Tymon, Washington, D.C.

Non-Voting Members

REGIONAL REPRESENTATIVES:

REGION I: Nicole Majeski, Delaware
Everett Lott, District of Columbia

REGION II: Vacant
Lorie Tudor, Arkansas

REGION III: Nancy Daubenberger, Minnesota
Jack Marchbanks, Ohio

REGION IV: Kristina Swallow, Nevada
Joel Jundt, South Dakota

IMMEDIATE PAST PRESIDENT: Shawn Wilson, Louisiana

****Elected at the 2022 Annual Meeting***

IMMEDIATE PAST PRESIDENT: Shawn Wilson, Louisiana

AASHTO COMMITTEE ON BRIDGES AND STRUCTURES, 2022

CARMEN SWANWICK, *Chair*

SCOT BECKER, *Vice Chair*

JOSEPH L. HARTMANN, Federal Highway Administration, *Secretary*

PATRICIA J. BUSH, *AASHTO Liaison*

ALABAMA, Eric J. Christie, William “Tim”

Colquett, Jeffrey Huner

ALASKA, Leslie Daughtery, Elmer E. Marx, Richard A. Pratt

ARIZONA, David B. Benton,

David L. Eberhart, Pe-Shen Yang

ARKANSAS, Charles “Rick” Ellis, Andy Nannemar, Steve Peyton

CALIFORNIA, Erol Kaslan, Ruth Fernandes, Edmund Setberg,

COLORADO, Michael Collins, Stephen Harelson, Jessica Martinez

CONNECTICUT, Andrew Cardinali, Timothy D. Fields, Bart Sweeney

DELAWARE, Jason Arndt, Jason Hastings, Craig A. Stevens

DISTRICT OF COLUMBIA, Donald L. Cooney, Konjit C. “Connie” Eskender

FLORIDA, Felix Padilla, William Potter

GEORGIA, Donn Digamon, Doug Franks, Steve Gaston

HAWAII, James Fu, Nicholas Groves

IDAHO, Matthew Farrar

ILLINOIS, Tim A. Armbrrecht, Ruben Boehler, Jayme Schiff

INDIANA, Andrew Fitzgerald, Jennifer Hart, Anne M. Rearick, Stephanie Wagner

IOWA, Jim Hauber, James S. Nelson, Michael Nop

KANSAS, Mark Hurt, Karen Peterson, Calvin Reed

KENTUCKY, Michael Carpenter, Royce Meredith, Carl Van Zee

LOUISIANA, Arthur D’Andrea, Chris Guidry, Zhengzheng “Jenny” Fu

MAINE, Jeffrey S. Folsom, Wayne Frankhauser, Michael Wight

MARYLAND, Maurice Agostino, Jesse Creel, Jeffrey L. Robert

MASSACHUSETTS, Alexander K. Bardow, Justin Slack, Matthew Weidele

MICHIGAN, Matthew Chynoweth, Rebecca Curtis, Richard E. Liptak

MINNESOTA, Arielle Ehrlich, Ed Lutgen, Kevin Western

MISSISSIPPI, Micah Dew, Bradnado Turnquest, Scott Westerfield

MISSOURI, David Hagemeye, Bryan Hartnagel, Darren Kemna

MONTANA, Stephanie Brandenberger, Nathan Hadick, Amanda Jackson

NEBRASKA, Ross Barron, Fouad Jaber, Kyle Zillig

NEVADA, David Chase, Jessen Mortensen

NEW HAMPSHIRE, Loretta Doughty, David L. Scott

NEW JERSEY, Xiaohua “Hannah” Cheng, Eric Yermack

NEW MEXICO, Shane Kuhlman, Jeff C. Vigil

NEW YORK, Brenda Crudele, James Flynn, Ernest Holmberg

NORTH CAROLINA, Brian Hanks, Scott Hidden, Girchuru Muchane

NORTH DAKOTA, Jon D. Ketterling, Jason R. Thorenson

OHIO, Alexander B.C. Dettloff, Timothy J. Keller, Jeffrey Syar

OKLAHOMA, Justin Hernandez, Walter Peters, Tim Tegeler

OREGON, Raymond Mabey, Albert Nako, Tanarat Potisuk

PENNSYLVANIA, Richard Runyen, Shane Szalankiewicz

PUERTO RICO, (Vacant)

RHODE ISLAND, Keith Gaulin, Mary Vittoria-Bertrand

SOUTH CAROLINA, Terry B. Koon, Hongfen Li, Jeff Sizemore

SOUTH DAKOTA, Steve Johnson, Dave Madden, Todd Thompson

TENNESSEE, Ted A. Kniazewycz

TEXAS, Graham Bettis, Bernie Carrasco, Jamie F. Farris

UTAH, Mark Daniels, Rebecca Nix, Cheryl Hersh Simmons

VERMONT, Carolyn Cota, Kristin M. Higgins, Bob Klinefelter, Jim Lacroix

VIRGINIA, Kendal R. Walus, Andrew M. Zickler

WASHINGTON, Tony M. Allen, Mark A. Gaines, Bijan Khaleghi

WEST VIRGINIA, Tracy Brown, Chad Robinson

WISCONSIN, Aaron Bonk, Josh Dietsche, William Oliva

WYOMING, Jeff R. Booher, Paul G. Cortez, Michael Menghini

Associate Members

CHESAPEAKE BAY BRIDGE AND TUNNEL DISTRICT, Timothy Holloway

MARYLAND TRANSPORTATION AUTHORITY, James Harkness

MULTNOMAH COUNTY TRANSPORTATION DIVISION, Jon Henrichsen

TRANSPORTATION RESEARCH BOARD, Ahmad Abu-Hawash

UNITED STATES COAST GUARD, Kamal Elnahal

U.S. ARMY CORPS OF ENGINEERS, Phillip Sauser

This page intentionally left blank.

TABLE OF CONTENTS

SECTION 1: GENERAL	1-1
1.1—Scope	1-1
1.2—Definitions	1-2
1.2.1—Contractor	1-2
1.2.2—Fabricator	1-2
1.2.3—Owner	1-2
1.2.4—Quality Control Inspector	1-3
1.2.5—Verification Inspector	1-3
1.2.6—Contract Documents	1-3
1.2.7—Primary and Secondary Members	1-3
1.2.8—Fracture-Critical Members	1-4
1.2.9—System Redundant Members	1-4
1.3—Fabricator Certification	1-4
1.3.1—Requirements	1-4
1.3.2—Review of Audit Results	1-5
SECTION 2: COMMUNICATION	2-1
2.1—General	2-1
2.2—Commencement of Work	2-2
2.3—Prefabrication Meeting	2-3
2.4—Progress Meetings	2-4
SECTION 3: INSPECTION	3-1
3.1—Quality Control Inspection	3-1
3.2—Verification Inspection	3-1
SECTION 4: SHOP DRAWINGS	4-1
4.1—Approval	4-1
4.2—Details	4-2
SECTION 5: WRITTEN PROCEDURES	5-1
5.1—Written Procedures	5-1
SECTION 6: MATERIALS	6-1
6.1—General	6-1
6.2—Test Reports and Certifications	6-2
6.2.1—Buy America	6-2
6.2.2—Certificates of Compliance	6-2
6.3—Identification and Traceability	6-3
6.3.1—Heat Number Traceability for Primary Members	6-3
6.3.2—Preservation of Markings	6-3
6.4—Impact Testing	6-4
6.5—Iron Castings	6-4
6.5.1—Work Quality and Finish	6-4
6.5.2—Cleaning	6-4
6.6—Turned Bolts	6-4

SECTION 7: HANDLING AND STORAGE	7-1
7.1—Handling and Storage	7-1
SECTION 8: CUTTING AND SHEARING PLATES AND SHAPES	8-1
8.1—Thermal Cutting	8-1
8.2—Direction of Rolling	8-1
8.3—Sheared Edges	8-2
8.4—Thermal-Cut Edges to be Coated.	8-2
SECTION 9: BASE METAL REPAIR.	9-1
9.1—Repairs of Notches or Gouges in Thermal-Cut Edges	9-1
9.1.1—Repairs by Grinding	9-1
9.1.2—Repairs by Welding	9-1
9.2—Repair of Laminar Discontinuities in Base Metal Cut Edges.	9-1
9.2.1—Scope	9-1
9.2.2—Limits	9-2
9.2.3—Repairs by Grinding	9-3
9.2.4—Repairs by Welding	9-3
9.3—Repair of Base Metal Rolled Surfaces	9-4
SECTION 10: BENDING PLATES	10-1
10.1—General.	10-1
10.2—Minimum Plate Bending Radius	10-1
10.3—Damage Preventing During Blending (With or Without Heat).	10-1
10.4—Heat-Assisted Mechanical Bending	10-2
10.5—Upset Shortening	10-2
SECTION 11: HORIZONTALLY CURVING BEAMS AND GIRDERS.	11-1
11.1—Horizontally Curving Beams and Girders.	11-1
SECTION 12: CAMBERING BEAMS AND GIRDERS	12-1
12.1—Cambering Beams and Girders	12-1
SECTION 13: STRAIGHTENING	13-1
13.1—Straightening	13-1
SECTION 14: APPLICATION OF HEAT	14-1
14.1—General.	14-1
14.2—General Heating Process and Equipment	14-1
14.2.1—Maximum Temperature	14-1
14.2.2—Artificial Cooling.	14-2
14.2.3—Heating Tips	14-2
14.2.4—Heating Controls	14-2
14.2.5—Sequencing	14-2
14.3—Upset Shortening Methods	14-3
14.3.1—General	14-3
14.3.2—Heat Curving of Beams and Girders.	14-3
14.3.2.1—General	14-3
14.3.2.2—Minimum Radius of Curvature	14-4
14.3.2.2.1—General	14-4

14.3.2.2.2—Cross-Sectional Criteria	14-4
14.3.2.2.3—Minimum Radius for Doubly-Symmetric Beams and Girders	14-5
14.3.2.2.4—Minimum Radius of Curvature for Singly-Symmetric Beams and Girders	14-6
14.3.2.2.5—Minimum Radius of Curvature for Hybrid Girders	14-7
14.3.3—Heat Cambering or Camber Correction of Beams and Girders	14-8
14.4—Heat Assisted Mechanical Forming	14-8
SECTION 15: THERMAL TREATMENTS	15-1
15.1—Treatment Records.	15-1
15.2—Thermal Stress Relief	15-1
15.3—Annealing and Normalizing	15-1
SECTION 16: TOLERANCES	16-1
16.1—Cut Flange Width Tolerance	16-1
16.2—Straightness	16-1
16.2.1—Built-Up Axial Members	16-1
16.2.2—Built-Up Flexural Members	16-1
16.3—Camber.	16-1
16.4—Sweep.	16-4
16.5—Web Alignment	16-4
16.6—Web Flatness	16-5
16.7—Flange Warpage and Tilt	16-6
16.8—Depth	16-8
16.9—Fit of Stiffeners.	16-9
16.9.1—Bearing Stiffeners.	16-9
16.9.2—Intermediate Web Stiffeners	16-11
16.10—Abutting Joints	16-11
16.11—Alignment of Mechanically Connected Joints.	16-11
16.12—Facing of Bearing Surfaces	16-12
16.13—Steel Pier Caps	16-12
SECTION 17: BOLTED CONNECTIONS	17-1
17.0—Bolted Connections	17-1
17.1—Holes for High-Strength Bolts and Unfinished Bolts	17-1
17.1.1—Tolerances and Workmanship	17-1
17.1.2—Holemaking Methods	17-1
17.2—Holes for Turned Bolts or Other Approved Bearing-Type Bolts	17-2
17.3—Slotted Holes.	17-2
17.4—Accuracy of Hole Group	17-3
17.4.1—Edge and End Distance.	17-3
17.4.2—Hole Spacing	17-4
17.5—Methods for Aligning Connections	17-4
17.5.1—Drilling in Assembly	17-4
17.5.2—Drilling to Template.	17-5
17.5.3—Check Assembly for CNC Drilling	17-5
17.6—Shop Preassembly	17-5

17.6.1—Procedure.	17-5
17.6.2—Process	17-9
17.6.3—Special Requirements for Trusses, Arches, and Frames	17-10
17.7—Structural Bolting Using High-Strength Bolts.	17-10
17.7.1—Rotational Capacity Testing.	17-11
17.7.1.1—General	17-11
17.7.1.2—Exceptions.	17-11
17.7.2—Fastener Storage and Conditions	17-12
17.7.3—Preinstallation Verification Testing	17-12
17.7.3.1—Turn-of-Nut and Twist-Off Bolts.	17-13
17.7.3.2—Calibrated Wrench.	17-13
17.7.3.3—Direct Tension Indicators (DTIs)	17-14
17.7.3.4—Combined Method.	17-15
17.7.4—Initial Installation.	17-16
17.7.4.1—General	17-16
17.7.4.2—DTIs	17-16
17.7.4.3—Surface Conditions	17-17
17.7.4.3.1—General.	17-17
17.7.4.3.2—Slip-Critical Connections	17-17
17.7.4.3.2a—Non-Coated Joints	17-17
17.7.4.3.2b—Coated Joints	17-17
17.7.5—Snug-Tightening.	17-18
17.7.5.1—General	17-18
17.7.5.2—DTIs	17-19
17.7.6—Tensioning	17-19
17.7.6.1—General	17-19
17.7.6.2—Turn-of-Nut.	17-19
17.7.6.3—Calibrated Wrench.	17-19
17.7.6.4—Twist-Off Bolts	17-19
17.7.6.5—DTIs	17-20
17.7.6.6—Combined Method.	17-20
17.7.6.7—Bolt Reuse.	17-20
17.7.7—Inspection.	17-20
17.7.7.1—Inspection Before Installation.	17-20
17.7.7.2—Inspection During and After Installation	17-21
17.7.7.3—Torque Test	17-21
17.8—Connections Using Unfinished or Turned Bolts	17-22
17.8.1—General	17-22
17.8.2—Hole Quality	17-23
SECTION 18: SURFACE PREPARATION OF UNCOATED WEATHERING STEEL	
(NON-FAYING SURFACES)	18-1
18.0—Surface Preparation of Uncoated Weathering.	18-1

18.1—Blast Cleaning	18-1
18.2—Markings	18-1
SECTION 19: ORTHOTROPIC-DECK SUPERSTRUCTURES	19-1
19.1—General	19-1
19.2—Flatness of Panels	19-1
19.3—Straightness of Longitudinal Stiffeners Subject to Calculated Compressive Stress, Including Orthotropic Deck Ribs	19-2
19.4—Straightness of Transverse Web Stiffeners and Other Stiffeners Not Subject to Calculated Compressive Stress	19-2
SECTION 20: PINS AND ROLLERS	20-1
20.1—General	20-1
20.2—Boring Pin Holes	20-1
20.3—Threads for Bolts and Pins	20-1
SECTION 21: EYEBARS	21-1
21.1—Eyebars	21-1
SECTION 22: ULTRASONIC IMPACT TREATMENT	22-1
22.1—Ultrasonic Impact Treatment	22-1
SECTION 23: MARKING AND SHIPPING	23-1
23.1—Marking and Shipping	23-1
SECTION 24: MEASUREMENT FOR PAYMENT	24-1
24.1—Measurement for Payment	24-1
SECTION 25: REFERENCES	25-1
APPENDIX A (INFORMATIONAL): ITEMS TO BE SPECIFIED IN THE CONTRACT DOCUMENTS:	A-1
APPENDIX B (INFORMATIONAL): AASHTO DESIGNATION OF PRIMARY AND SECONDARY MEMBERS (BDS TABLE 6.6.2.1-1)	B-1
APPENDIX C (INFORMATIONAL): TABULATION OF WEB FLATNESS TOLERANCES (ARTICLE 16.6)	C-1
APPENDIX D (INFORMATIONAL): SAMPLE ULTRASONIC IMPACT TREATMENT (UIT) PROCEDURE	D-1

LIST OF ABBREVIATIONS

AISC	American Institute of Steel Construction
AREMA	American Railway Engineering and Maintenance-of-Way Association
AWS	American Welding Society
BCS	<i>AASHTO LRFD Bridge Construction Specifications</i>
BDS	<i>AASHTO LRFD Bridge Design Specifications</i>
CNC	computer-numerically-controlled
CVN	Charpy V-notch
D1.5M/D1.5	<i>AASHTO/AWS D1.5M/D1.5 Bridge Welding Code</i>
DTI	direct tension indicator
FCM	fracture-critical member
HPS	high-performance steel
MT	magnetic particle testing
MTR	material test report (or mill test report)
NDE	nondestructive evaluation
PIV	preinstallation verification
PT	penetrant testing
Q&T	quenched and tempered
QC	quality control
RC	rotational capacity
RCSC	Research Council on Structural Connections
RCSC Specification	<i>RCSC Specification for Structural Joints Using High-Strength Bolts</i>
RT	radiographic testing
SDLF	steel dead load fit
SPDI	single-point diamond interchange
TDLF	total dead load fit
TMCP	thermo-mechanically controlled processing
TSC	thermal spray coating
UIT	ultrasonic impact treatment
UT	ultrasonic testing

This page intentionally left blank.

SECTION 1: GENERAL

1.1—SCOPE

These Specifications shall govern vehicular steel bridge fabrication. This work shall consist of furnishing and fabricating steel structures and structural steel portions of other structures in accordance with these Specifications and the contract documents.

Details of design which are permitted to be selected by the Fabricator or Contractor shall conform to the provisions of the current *AASHTO LRFD Bridge Design Specifications* (BDS). All numbered references herein to specific Articles in the BDS shall refer to the 9th Edition.

Fabrication and welding, in addition to the requirements of these Specifications, shall conform to the provisions of the current AASHTO/AWS D1.5M/D1.5 *Bridge Welding Code* (D1.5M/D1.5).

Primary members or portions thereof designated in the contract documents as fracture critical members (FCMs) or system redundant members (SRMs) shall conform to the provisions of Clause 12 of the current D1.5M/D1.5.

Coatings shall be considered outside the scope of these Specifications. Fabrication of pedestrian bridges, non-bridge structures or components such as expansion joints, bearings, or tubular members shall also be considered outside the scope of this specification.

C1.1

The primary objective of these Specifications is to achieve quality and value in the fabrication of vehicular steel bridges and to help standardize vehicular steel bridge fabrication across the nation.

Historically, state Departments of Transportation (DOTs) have written their fabrication specifications based on AASHTO standards and their own individual experiences. Though this approach has worked reasonably well, many owners and fabricators recognized that all would benefit from a common specification because:

- Variations among projects in the shop would be minimized because fabricators would not need different practices, procedures, and operations for each owner, and minimizing variation improves quality and reduces errors.
- Economy in bridge fabrication would improve because fabricators would not have to change their methods and production variables from owner to owner.
- Expertise in steel bridge fabrication could be shared among states, resulting in a well-rounded, consistent fabrication standard.
- Owners would be able to share their resources, minimizing the effort each would otherwise have to expend to maintain a bridge fabrication specification.

These Specifications are based on existing state specifications, the AASHTO/NSBA Steel Bridge Collaboration S2.1, *Steel Bridge Fabrication Guide Specification* (S2.1); the AASHTO *LRFD Bridge Construction Specifications* (BCS); the AASHTO *LRFD Bridge Design Specifications* (BDS); and the AASHTO/AWS D1.5M/D1.5 *Bridge Welding Code* (D1.5M/D1.5). These Specifications defer to D1.5, the U.S. customary units specification in AASHTO/AWS D1.5M/D1.5, for specific welding requirements and for weld qualification testing requirements. The Owner is also encouraged to refer to the FHWA *Welding Reference Manual* for additional detailed information on welding. More information about AWS is available from their website at <https://www.aws.org>.

These Specifications assume that coating provisions are addressed in the referring Owner's standard specifications. For painting, the Owner is encouraged to refer to Steel Bridge Collaboration

S8.1, *Guide Specification for Application of Coating Systems with Zinc-Rich Primers to Steel Bridges*. ASTM A123/A123M, *Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products* is a commonly specified standard for galvanizing. For thermal-sprayed coatings, the Owner is encouraged to refer to Steel Bridge Collaboration S8.2, *Specification for Application of Thermal Spray Coating Systems to Steel Bridges*.

1.2—DEFINITIONS

1.2.1—Contractor

The Contractor shall be defined as the entity or its authorized representative responsible for proper completion of all tasks required by the contract documents. Subcontractors, including fabricators, erectors, and field painters, may be used by the Contractor, but the Contractor shall retain responsibility for conformance of the final product to contract requirements. The Contractor may permit direct subcontractor interaction with the Owner to expedite the project, but subcontractors shall inform the Contractor of any proposed modifications to contract requirements accepted by the Owner. The Contractor may permit or reject the changes.

1.2.2—Fabricator

The Fabricator shall be defined as the entity performing shop activities including the procurement, detailing, and manufacture of the structural steel and related components in their scope of supply. The Fabricator shall also include any agents of the Fabricator, such as subcontract fabricators. In some cases, the Fabricator may also be the Contractor, but usually the Fabricator is subcontracted by the Contractor. In these Specifications, the term Fabricator shall be used to describe roles usually performed by the Fabricator, but these roles could also be performed by the Contractor.

1.2.3—Owner

The Owner shall be defined as the entity or its authorized representative who has authority to define or accept changes to contract requirements.

C1.2.3

The Owner may have multiple representatives for various aspects or phases of the work, either as direct employees or through professional firms contracted for the work. Typically, the party responsible for the structure's adequate design is referred to as the Designer or the Engineer of Record (EOR). The Verification Inspector, defined in Article 1.2.5, represents the Owner in the shop or field, but is often

given only limited decision-making authority. The party authorized to make engineering decisions during fabrication or construction may be the EOR or some other designated individual such as a Construction Engineer or Materials Engineer. In these Specifications, the term “Owner” is usually used to encompass any relevant roles, except that “Verification Inspector” and “Designer” are used when those specific roles are discussed. In some cases, such as on public–private partnership projects and some design–build projects, the Owner is a private entity who has been granted contract authority by the government who might otherwise own the completed structure.

1.2.4—Quality Control Inspector

The Quality Control (QC) Inspector shall be defined as the duly designated person who acts for, and on behalf of, the Fabricator on inspection, testing, and quality matters to ensure that materials and workmanship satisfy the requirements of the contract documents.

1.2.5—Verification Inspector

The Verification Inspector shall be defined as the Owner’s representative who has the responsibility to accept the fabricated product based on conformance with the contract documents.

C1.2.5

This function is sometimes referred to as the Owner’s Inspector or as the Quality Assurance (QA) Inspector. The use of “QA” to refer to this function is avoided because the term is also frequently used to describe higher-level quality functions within the Fabricator’s quality management system.

1.2.6—Contract Documents

The contract documents shall be defined as any codes, specifications, drawings, or additional requirements that are contractually specified by the Owner.

C1.2.6

Appendix A includes items not specified in these Specifications that Owners should address elsewhere in their contract documents.

1.2.7—Primary and Secondary Members

The terms “primary member” and “secondary member” are defined in the BDS.

C1.2.7

The term “primary member” is defined in the 9th Edition of the BDS as follows: “a steel member or component that transmits gravity loads through a necessary as-designed load path. These members are therefore subjected to more stringent fabrication and testing requirements; considered synonymous with the term ‘main member’.”

The term “secondary member” is defined in the 9th Edition of the BDS as follows: “a steel member or component that does not transmit gravity loads through a necessary as-designed load path.”

Primary and secondary members are more specifically defined in BDS Table 6.6.2.1-1, which is provided for reference in Appendix B. Cross-frames and diaphragms in horizontally curved bridges are

defined as primary members, but do not require shop assembly.

Because it is not the Fabricator's responsibility to understand and apply design principles, the BDS requires the Designer to note all primary members or components, or portions thereof, subject to tension under Strength Load Combination I on the contract plans.

1.2.8—Fracture-Critical Members

The term “fracture-critical member” or FCM is defined in the BDS.

1.2.9—System Redundant Members

The term “system redundant member” is defined in the BDS.

C1.2.8

The term “fracture-critical member” or FCM is defined in the 9th Edition of the BDS as follows: “a steel primary member or portion thereof subject to tension whose failure would probably cause a portion of or the entire bridge to collapse.”

The BDS requires the Designer to designate which primary members or portions thereof are fracture-critical.

C1.2.9

The term “system redundant member” is defined in the 9th Edition of the BDS as follows: “A steel primary member or portion thereof subject to tension for which the redundancy is not known by engineering judgment, but which is demonstrated to have redundancy through a refined analysis.”

In essence, SRMs are members that appear to be fracture-critical based on traditional conventions but can be shown to have alternate load paths and are therefore designated as redundant. They have the same fabrication requirements as FCMs but do not become part of the Owner's fracture-critical inventory.

The BDS requires the Designer to designate which primary members or portions thereof are SRMs.

1.3—FABRICATOR CERTIFICATION

1.3.1—Requirements

Unless otherwise specified, certification from the American Institute of Steel Construction (AISC) Quality Certification Program shall be required for Fabricators to the standard and supplemental requirements appropriate for the type of work being performed. The standards include:

- AISC 207, Standard for Certification Programs, Chapters 1 and 4—required for vehicular steel bridge superstructures; and
- AISC 420/SSPC-QP 3, Certification Standard for Shop Application of Complex Protective Coating

C1.3.1

Certification is intended to help ensure that the Fabricator has the needed expertise and commitment to quality to achieve a successful project.

The Owner is advised not to require certification endorsements for categories of a higher complexity than the structure warrants. The AISC endorsement requirements have been written to be pertinent to specific structure types and may not be relevant for simpler bridges.

Systems—required for any shop painting performed on steel bridges.

The base level of certification of bridge fabricators to AISC 207 shall apply to simple bridges, which are bridges consisting of unspliced rolled sections. The following supplements to the bridge fabrication requirements of AISC 207 shall also be required, as applicable:

- *Fracture Critical Endorsement*—required for any fabrication conducted on fracture-critical members, system redundant members, or internally redundant members.
- *Intermediate Bridges*—required for bridges in the following categories:
 1. Rolled beam bridges with field or shop splices, either straight or with a radius over 500 ft;
 2. Built-up I-shaped plate girder bridges with constant web depth (except for dapped ends), with or without splices, either straight or with a radius over 500 ft;
 3. Built-up I-shaped plate girder bridges with variable web depth (e.g., haunched), either straight or with a radius over 1000 ft;
 4. Other bridges determined by the Owner to require a similar level of skill as Categories 1 through 3.
- *Advanced Bridges*—bridges that do not fall under the definition of simple or intermediate bridges.

An example of what might be designated an intermediate bridge that does not meet the typical Categories 1 through 3 listed in this Article would be a “prefabricated” truss bridge, which would be entirely or substantially pre-assembled at the certified facility and shipped in only a few sub-assemblies. Because most of the connections are made in the shop and not the field, the geometric control required to ensure fit of field connections is not as rigorous as a truss bridge fully assembled in the field. Furthermore, many fabricators of “prefabricated” truss bridges produce only this sort of bridge, and thus would not be able to qualify for the advanced bridge endorsement by fulfilling the prerequisite of producing a more typical intermediate bridge made of plate girders.

Examples of typical advanced bridges include tub or trapezoidal box girders, closed box girders, large or non-preassembled trusses, arches, bascule bridges, cable-supported bridges, moveable bridges, and bridges with particularly tight curve radius.

Chapters 1 and 3 of AISC 207 (“Metal Component Manufacturer Requirements”) are typically required for manufacturers of components such as bearings. Components are not currently included in the scope of this document.

More information, including a list of all AISC-certified fabricators, is available from the AISC website at <https://www.aisc.org>.

1.3.2—Review of Audit Results

The Owner shall be allowed to review the closing report from the most recent AISC audit.

This page intentionally left blank.

SECTION 2: COMMUNICATION

2.1—GENERAL

Lines of communication should be developed amongst the various parties to the Contract.

C2.1

Effective communication between the Owner, the Fabricator, and the Contractor is essential to a successful project. Before work begins, these parties should establish the simplest, most direct lines of communication possible and make sure that all parties understand and use them. This is an important function of the pre-fabrication meeting.

Important considerations for defining lines of communication include the following:

- Lines of communication should be agreed to by all parties, including the Designer, the Verification Inspector, the Owner's representative for fabrication, the Fabricator, and the Contractor;
- Lines of communication should be kept as simple and direct as possible;
- The Fabricator should be allowed to contact the Designer directly during shop drawing development. Without this direct contact, an Owner's representative may need to act as the intermediary to coordinate inquiries or disagreements between the Fabricator and Designer.
- On design-build jobs or other situations where the design is not complete when the Fabricator is engaged, it is particularly useful for the Designer and Fabricator to discuss complex details as they are developed in the design.
- On complex projects, communication about special aspects of the job, including tolerances or other requirements, should commence very early in the project.

Prior to beginning work, the Owner and Fabricator should identify individuals who are responsible for the following functions:

- Preparation, submittal, review, approval, and distribution of shop drawings;
- Addressing questions about contract requirements and changes.
- Approving welding and fabrication procedures and accepting proposed repairs.
- Submittal and control of material test reports (MTRs);
- QC by the Fabricator and quality verification by the Owner; and

- Engineering, including the Designer, the Fabricator's project engineer (if applicable), and the Owner's engineer for technical submittals during fabrication (if this is not the Designer).

During the project, effective communications should be maintained between the Fabricator's and the Owner's representatives. Problems and concerns should be addressed as early as possible in the work. The Fabricator may propose changes to the structure that slightly or significantly deviate from the structure's design. In such cases, the Owner may prefer that the Fabricator approach the Designer directly even if the Designer is not a direct employee of the Owner, that the Fabricator go through the Owner's organization, or that some other procedure be followed. Contractual relationships often dictate that communication pass from the Fabricator to the Contractor to the Owner contact for fabrication to the Designer but allowing direct contact between various parties is beneficial.

2.2—COMMENCEMENT OF WORK

A written advance notice shall be provided to the Owner a minimum of two weeks before fabrication begins. "Fabrication" for this purpose shall be considered to begin with the cutting of material. No material shall be manufactured or work done in the shop before the Owner has been so notified.

C2.2

Owners generally provide some level of quality verification during bridge fabrication, and they often have projects underway at a number of locations. When the Fabricator provides the Owner with an anticipated work schedule, this allows planning and preparation for inspection. The earlier notification is provided to the Owner the better, so the Fabricator should provide schedule information as soon as possible and not simply follow the prescribed minimum lead times. The Fabricator can initially provide a general estimate to the Owner and then provide more precise details as the commencement date approaches.

Owners have varying practices regarding at what point they wish to begin requiring quality verification with onsite verification personnel. Some begin at the cutting of material; others not until welding. Requiring notification two weeks prior to cutting gives the Owner the option to decide whether coverage at this stage is needed and time to make arrangements if so. The Owner may have additional requirements in the contract documents that must be satisfied before fabrication begins—approved shop drawings (see Article 4.1), approved welding and fabrication procedures, etc.

For special situations such as overseas fabrication or items requiring unusual inspection services, the Owner may elect to require longer notice.

2.3—PREFABRICATION MEETING

Before work begins, a prefabrication meeting may be held at the discretion of the Owner or if requested by the Fabricator or Contractor.

C2.3

It is not necessary to have a prefabrication meeting before every project, especially if the Owner and Fabricator work together on a regular basis.

The Owner should provide design, construction, and verification inspection representatives as appropriate.

The Fabricator representatives should include the plant manager; engineering, production, and quality control inspection personnel as appropriate; detailer if desired; and, if applicable, Contractor or subcontractor representatives, e.g., general contractor, erector, painter, subcontract fabricators, or testing agencies.

A prefabrication meeting may avert many of the problems that may complicate or delay fabrication. At the prefabrication meeting:

- The Owner and Fabricator should review the project and discuss specific concerns.
- The Fabricator should describe the expected approach to the project, including milestones or specialized work in detail.
- The Owner should describe any unusual requirements for the project.
- The Owner should describe how verification inspection will be accomplished, including identification of inspectors, the intended inspection schedule, level of verification inspector's authority, and any special inspection or hold points.
- Clear lines of communication should be established between all parties.
- The shop drawing review and fabrication schedules should be discussed and mutually understood.
- All parties should be given the opportunity to ask questions or express concerns.

The review should include, at a minimum, the following aspects of the job:

- Progress on submittal and approval of shop drawings and any other required submittals;
- Fabrication procedures, especially shop assembly, welding, and painting;
- Plant and personnel certification;
- Organizational structure and primary (lead) plant personnel;
- Handling of MTRs;
- Traceability of materials;

- Supply and sampling of coatings, bolts, and other materials, if applicable;
- Work schedule and milestones;
- Availability and advance notification of verification inspectors;
- Hold points;
- Inspector's office;
- Appropriate lines of communication;
- Restrictions on or requirements for photography, if any;
- Planned coverage of shop operations by QC personnel;
- Project-specific areas of concern for fabrication and inspection, including any special applications of nondestructive evaluation (NDE);
- Handling of non-conformance and repair issues;
- Project specifications and other special requirements, especially any exceptions to these Specifications;
- Project details, requirements, or processes that have caused prior difficulties; and
- Loading and shipping.

2.4—PROGRESS MEETINGS

Progress meetings may be held during the course of the work at the discretion of the Owner or at the request of the Fabricator or Contractor.

C2.4

Progress meetings can be used to resolve disagreements over quality requirements, determine current status of completed and in-progress work, clarify unusual or altered contract requirements, discuss current or potential problems and their resolution, and monitor the anticipated production and completion schedule.

SECTION 3: INSPECTION

3.1—QUALITY CONTROL INSPECTION

C3.1

QC inspection shall be performed using trained and qualified personnel in accordance with applicable contract documents. Documentation of qualifications shall be available for review by the Owner.

AASHTO/AWS D1.5M/D1.5 *Bridge Welding Code* has requirements for inspectors performing visual inspection and NDE of welds.

3.2—VERIFICATION INSPECTION

Verification Inspection shall be the prerogative, but not the responsibility, of the Owner.

The Verification Inspector shall have the authority to reject materials or work which does not fulfill the requirements of these Specifications. In cases of dispute, the Fabricator may appeal to the Owner, whose decision shall be final.

Inspection at the Fabricator is intended as a means of facilitating the work and avoiding errors. It is expressly understood that it shall not relieve the Fabricator of any responsibility in regard to defective material or work and the necessity for replacing the same at the Fabricator's cost.

The acceptance of any material or finished members by the Inspector shall not be a bar to their subsequent rejection, if found defective. Rejected materials and work shall be replaced as soon as practical or corrected by the Fabricator.

The Owner shall have free access at all times to any portion of the fabrication site where the material is stored or where work on the material is being performed.

This page intentionally left blank.

SECTION 4:

SHOP DRAWINGS

4.1—APPROVAL

The Fabricator shall submit copies of the detailed shop drawings for approval by the Owner. Shop drawings shall be submitted sufficiently in advance of the start of the affected work to allow time for review by the Owner and corrections by the Fabricator, if any, without delaying the work.

The Owner's approval of the shop drawings submitted by the Fabricator shall cover the requirements for "strength and detail," and the Owner shall assume no responsibility for errors in dimensions.

Fabrication shall not commence until shop drawings are approved or approved-as-noted. Work performed prior to shop drawing approval is at the Fabricator's risk, and may require additional inspection, non-destructive evaluation (NDE), or partial disassembly/reassembly to satisfy the Owner's quality verification. Approval shall not relieve the Fabricator of any responsibility under the contract for the successful completion of the work.

C4.1

These Specifications use the term "approval." The Owner may have other preferred terminology, such as "acceptance." Bridge industry documents vary with respect to usage of these terms.

The Owner's review of shop drawings is a form of quality verification and not quality control. The Owner reviews shop drawings to check that they accurately reflect the design, but the Owner does not check every detail and calculation. Regardless of the Owner's review and approval, the accuracy of shop drawings remains the Fabricator's responsibility.

The Owner should be expedient when reviewing shop drawings. Fabricators plan the flow of work and placement of jobs months in advance. They need to be able to start work on schedule to keep production moving and to satisfy field delivery requirements. Because shop drawings must be approved or approved as noted before work starts, the Owner's review may delay the Fabricator if the review takes too long. Conversely, the Fabricator must provide complete, legible, and accurate shop drawings to the Owner to facilitate prompt return. Submitting shop drawings in packages according to a mutually agreeable review schedule also facilitates prompt return.

To expedite the review process and to help obtain consistency in shop drawing review, the AASHTO/NSBA Steel Bridge Collaboration has developed a standard for shop and erection detail drawing approval, G1.1, *Shop Detail Drawings Review/Approval Guidelines*.

In some cases, the Fabricator may decide to begin fabrication before receiving approved shop drawings, and the Owner may consider requests from the Fabricator to proceed without approved shop drawings. However, work done without approved shop drawings may have to be changed based on final, approved shop drawings. No work should be done before drawings are approved if this work will be concealed or made inaccessible by later work.

In emergency situations, the Owner may permit work to proceed before shop drawings have been submitted for review.

Use of electronic drawings has proven effective and should be considered if all parties agree on the system requirements, review and approval authentication, and the storage and handling of electronic drawings.

4.2—DETAILS

Separate shop drawings shall be provided for each steel structure on a project. Dual (twin) bridges shall have separate drawings for future reference. All primary members shall have unique piece marks.

Shop drawings for steel structures shall give full, detailed dimensions and sizes of component parts of the structure and details of all miscellaneous parts, such as pins, nuts, bolts, drains, etc.

Where specific orientation of plates is required, the direction of rolling of plates shall be shown.

Shop drawings shall identify the required material specification and grade of each piece.

The shop drawings shall include the camber at each panel point in the cases of trusses or arch ribs, and at the location of field splices and fractions of span length (quarter points minimum) in the cases of continuous beams and girders or rigid frames. The camber diagram shall show calculated cambers to be used in preassembly of the structure in accordance with Article 17.6.

Rolled or fabricated sections of equal or slightly greater dimensions than the section specified may be proposed for the Owner's acceptance. For changes that affect splice design or may significantly alter deflection, complete design calculations may be required.

Cross-frames and diaphragms in horizontally curved I-girder bridges shall be detailed on the shop drawings to provide the fit condition specified in the contract documents. Should a fit condition not be specified in the contract documents, the assumed fit condition shall be indicated on the shop drawings.

Unless permitted otherwise in the contract documents, bolt holes in girder splices and primary load-carrying members shall be standard size.

Cambers provided on the contract documents shall be adhered to unless steel erection or deck placement is to be performed in a manner that will lead to deflections different from those used to determine the camber specified. If the Contractor or Fabricator intends other procedures or outcomes, the approach shall be confirmed with the Owner, and any documentation required for approval shall be provided at no cost to the Owner.

C4.2

Several of these requirements, as well as many other details, are covered in AASHTO/NSBA Steel Bridge Collaboration G1.3, *Shop Detail Drawing Presentation Guidelines*. The use of this document in the development of shop drawings is recommended.

In many cases, substitution of a higher-strength grade for a lower one, or of a weathering grade for a non-weathering grade, is acceptable, but cannot always be assumed to be acceptable. For example, Grade 36 and 50S have upper limits on strength, and weathering grades can be problematic when the material is to be galvanized.

The provisions of BDS Article 6.7.2 contain general recommendations to the Designer regarding the specification of the fit condition for the detailing of cross-frames and diaphragms in horizontally curved I-girder bridges with and without skewed supports.

The provisions of BDS Article 6.7.2 contain general instructions to the Designer regarding the camber of girders in straight skewed I-girder bridges and horizontally curved I-girder bridges with and without skewed supports.

SECTION 5

WRITTEN PROCEDURES

5.1—WRITTEN PROCEDURES

Written procedures shall be maintained and implemented for the fabrication processes listed below and shall be readily accessible to the production and inspection staff.

- Material traceability;
- Welding (welding procedure specifications and supporting documentation must have Owner approval before they can be used);
- Cold and heat-assisted bending;
- Application of heat for cambering, heat curving, plate bending, and straightening, including temperature measurement, patterns, sequences, supports and loading, preload calculations (if applicable), and control of excessive distortion or buckling (Owner approval shall be required for cambering, heat curving, and repair of damage);
- Shop assembly/laydown, including drilling and punching;
- Postheat and stress-relieving procedures;
- Testing and shop installation of fasteners; and
- Inspection and testing procedures as required by D1.5M/D1.5.

Each procedure shall explain how tasks will be accomplished, evaluated, and accepted by both the Quality Control Inspector and the Verification Inspector (as applicable) prior to subsequent operations.

The procedures may be standardized and not require resubmittal and approval for each project.

C5.1

Written procedures are intended to facilitate understanding between the Owner and the Fabricator about how various aspects of the work will progress. These procedures may be included in the documentation reviewed during the AISC Certification process. Having these procedures helps the Fabricator's employees understand requirements and providing copies for review by the Owner helps minimize conflicts once the work has begun. Most procedures reflect the Fabricator's standard practices, so they do not need to be resubmitted for routine jobs unless a specific aspect of work needs particular attention. Written procedures provide more specific guidance than the specification will, but the Owner should not use written procedures to introduce requirements beyond the intent of the specification. For repairs, the Fabricator and Owner should reach an understanding about NDE methods, scheduling, and the advance notice needed to coordinate quality control and quality verification inspections.

Procedures should convey how the Fabricator's process will satisfy specification requirements.

This page intentionally left blank.

SECTION 6: MATERIALS

6.1—GENERAL

Materials shall be provided that satisfy contract requirements. Material meeting equivalent AASHTO and ASTM specifications may be supplied under either specification.

C6.1

Material requirements for design are given in the BDS.

Almost all steel bridges in the United States use a small group of steel material specifications. Each of the steels typically used in bridges is available in both AASHTO and ASTM specifications, but there are virtually no differences between the two specifications for each material. However, some owners prefer to use AASHTO specifications, while others prefer to use ASTM specifications, so both sets of specifications continue to be maintained.

The AASHTO and ASTM steel specifications used for bridge construction have a bridge steel version (e.g., ASTM A709/A709M Grade 36 or AASHTO M 270M/M 270 Grade 36) and, for certain grades, an equivalent ASTM standalone version (e.g., ASTM A36). Hence, for a given type of steel, there may be three different specifications. The ASTM “standalone” versions are identical to the A709/A709M grades except for mandatory toughness testing, which would need to be specified for the non-A709/A709M steels if they are used in tension in bridges. The non-A709/A709M grades are most likely to be used where steel greater than 4 in. thick is needed, because A709/A709M or M 270M/M 270 is only available up to 4 in. thick.

Table C6.1-1 provides a summary of ASTM A709/A709M or AASHTO M 270M/M 270 grades and associated standalone ASTM specifications.

Table C6.1-1—Typical Steel Bridge Specifications

ASTM A709/A709M or AASHTO M 270M/ 270 Grade	ASTM Standalone
36	A36
50	A572
50S	A992
50W	A588

There are no separate designated grades for high performance steel (HPS) made by thermo-mechanically controlled processing (TMCP) or quenching and tempering (Q&T). TMCP material is available in limited thicknesses and lengths based on mill capabilities. Heat treatment temperatures must be documented on the test reports when the material

is Q&T. There is no performance difference between materials made from either process, so the Owner should not require one process over the other.

Until 2008, Charpy V-notch (CVN) requirements in ASTM A709/A709M, although mandatory for components in tension, were located in supplementary provisions of the standard. As of 2008, however, the CVN requirements are stated within the body of the standard for components. Thus, the Owner need no longer specify supplementary requirements for CVN testing for the specific materials where toughness is required but should indicate tension and fracture-critical components and temperature zone.

Information about welding consumables is available in D1.5M/D1.5 and associated AWS filler metal specifications.

6.2—TEST REPORTS AND CERTIFICATIONS

Material Test Reports (MTRs) shall be provided for all steel materials used in fabrication, including plates, bars, shapes, and fasteners. MTRs shall originate from the producer of the material and not from a supplier, except that reports for supplemental tests for toughness or other parameters may come directly from the party that performs the supplemental testing.

MTRs shall be checked for conformance with the applicable material specification, including actual values from required tests.

MTRs and certificates of compliance, Article 6.2.2, shall be furnished prior to the start of fabrication of material covered by these reports.

6.2.1—Buy America

When “Buy America” restrictions apply, MTRs shall be provided certifying that the materials were melted and manufactured in the United States and that all applicable requirements are satisfied.

6.2.2—Certificates of Compliance

With the approval of the Owner, certificates of compliance shall be furnished in lieu of mill test reports for material that normally is not supplied with mill test reports and for items such as filler plates, minor gusset plates, and similar material when quantities are small and the material is taken from stock. The certificate of compliance shall be signed by the manufacturer and shall certify that the material is in conformance with the specifications to which it has been manufactured.

C6.2

Requirements for Material Test Reports (MTRs) are generally found in the material specification or an associated specification. For example, ASTM A709/A709M requires that MTRs be in accordance with ASTM A6. In turn, ASTM A6 provides specific details about the information that must be present in the MTR. ASTM A6 does not require a signature or certification of domestic production on the MTR, but these may be required under “Buy America” mandates.

6.3—IDENTIFICATION AND TRACEABILITY

All structural steel materials shall be identified in accordance with ASTM A6 or other applicable requirements.

Material from stock shall be used only if it can be positively identified, if the appropriate documentation is provided, and if the direction of rolling, when required, can be established.

The Fabricator's system of assembly-marking individual pieces, and the issuance of cutting instructions to the shop, shall be such as to maintain identity of the original piece.

During fabrication, up to the point of assembling members, each piece of steel shall show clearly and legibly its material specification.

6.3.1—Heat Number Traceability for Primary Members

Heat numbers shall be maintained on all primary bridge materials until the material is permanently joined into a piece-marked member. Paint stick or other suitable method not detrimental to the member's function shall be used.

All primary member material identification shall be documented for shop records and copies of this documentation shall be provided to the Verification Inspector for the Owner's records.

6.3.2—Preservation of Markings

Any piece of steel which will be subject to fabricating operations such as blast cleaning, galvanizing, heating for forming, or painting which might obliterate marking prior to assembling into members, shall be required to have traceability information (grade or heat number, as applicable) marked by steel die stamping or by a substantial tag firmly attached. Steel die stamps shall be low-stress type. Other means may be used if they have been demonstrated by test to meet Fatigue Category B.

C6.3

Material traceability must be maintained throughout fabrication for all materials. The Fabricator should have an effective method for material control in the Quality Control Plan. Identification information (heat number, project number, material grade, plate dimensions) should be kept visible on stockpiled material by staggered stacking whenever possible.

Assembly-marking individual pieces and the issuance of cutting instructions to the shop are generally done by cross-referencing of the assembly marks shown on the shop drawings with the corresponding item covered on the mill purchase order.

Color codes for steels, as listed in previous versions of ASTM A6/A6M, may also be used for identification purposes. This method, which is no longer shown in ASTM A6/A6M, is being eliminated by many owners due to the complexity of the code with the many new material grades.

C6.3.2

To facilitate the low-stress condition, die stamp marks should not be too deep but need to be deep enough such that the marks are readily legible under typical paint systems.

There is no defined radius for a "low stress" die stamp but accomplishing marks with stamps that have a radius instead of a sharp point is suitable. Examples of stamps that are considered to be low-stress include dot, vibration, and rounded-V stamps. MIL-STD-792 provides a definition of low-stress die stamp in terms of tip radius and impression width and depth and describes other methods of marking as well.

It is known that surface imperfections can compromise fatigue performance of the otherwise smooth plate or rolled section. However, experience demonstrates that die stamp marks are innocuous for steels typically used for new bridges, particularly

when precautions are taken to ensure the marks are not sharp. Modern computer-controlled stamping equipment has demonstrated the capacity to provide markings with fatigue strengths equal to or exceeding Fatigue Category B.

6.4—IMPACT TESTING

All steel for use in primary member components subject to tensile stress shall conform to the applicable Charpy V-Notch (CVN) impact test requirements of ASTM A709/A709M (AASHTO M 270M/M 270), except for cross-frames and diaphragms in horizontally curved bridges.

6.5—IRON CASTINGS

6.5.1—Work Quality and Finish

Iron castings shall be true to pattern in form and dimensions, and free from pouring faults, sponginess, cracks, blow holes, and other defects in positions affecting their strength and value for the service intended.

Castings shall be boldly filleted at angles and the arrises shall be sharp and perfect.

6.5.2—Cleaning

All castings shall be sandblasted or otherwise effectively cleaned of scale and sand so as to present a smooth, clean, and uniform surface.

6.6—TURNED BOLTS

The surface of the body of turned bolts shall meet the ANSI B46.1 roughness rating value of 125 μin . Heads and nuts shall be hexagonal with standard dimensions for bolts of the nominal size specified or the next larger nominal size. Diameter of threads shall be equal to the body of the bolt or the nominal diameter of the bolt specified. Threads shall be located to fall entirely outside of the bolt holes.

C6.4

Because they are classified as primary members, some cross-frames and diaphragms and their components in curved bridges have become subject to CVN testing requirements, yet in many years of practice, no specific concerns related to the fatigue and fracture performance of these members have been demonstrated.

SECTION 7:
HANDLING AND STORAGE

7.1—HANDLING AND STORAGE

Raw and fabricated materials shall be handled, stored, and shipped in a manner that protects them from damage, facilitates subsequent inspections, and does not compromise the safety of personnel.

Raw and fabricated materials shall be placed above the ground on platforms, skids, or other supports.

Materials shall be kept free from dirt, grease, and other foreign matter, and proper drainage shall be provided for materials stored outside.

Materials shall be protected from detrimental corrosion or coating deterioration.

C7.1

Plate sagging between dunnage is not detrimental as long as the material is not kinked or permanently deformed.

Storing material outside is acceptable, provided the material is protected from water ponding, damage, and salt spray or other deleterious substances. Concentrated corrosion or pitting due to prolonged damp storage must be avoided, especially for stacked plates and unpainted splices loosely assembled for shipping.

This page intentionally left blank.

CUTTING AND SHEARING PLATES AND SHAPES

8.1—THERMAL CUTTING

In all thermal cutting, the cutting flame shall be so adjusted and manipulated as to avoid cutting beyond (inside) the prescribed lines. Steel and weld metal may be thermally cut, provided that a smooth and regular surface free from cracks and notches is secured and an accurate profile is secured by the use of a mechanical guide. Freehand thermal cutting shall be done only where approved by the Owner.

The maximum cut surface roughness value, as defined by ANSI B46.1, *Surface Texture (Roughness, Waviness, and Lay)*, shall be as follows:

- For material up to 4 in. thick where no calculated stress is present, the ends of members shall have a maximum cut surface roughness value of 2000 μin .
- For material up to 4 in. thick in all other cases, the maximum cut surface roughness value shall be 1000 μin .
- For material over 4 in. through 8 in. thick, the maximum cut surface roughness value shall be 2000 μin .

8.2—DIRECTION OF ROLLING

Steel plates for primary member components and splice plates shall be cut and fabricated with the direction of rolling parallel to the direction of primary stresses, except that the direction of rolling may be in either direction for web splice plates, gusset plates not serving as chord splices, and connection plates.

C8.1

Proper cutting and surface preparations are important for fatigue resistance. Special care must be exercised when cutting and repairing quenched and tempered steels.

Torch cutting notches should be minimized but may still occur.

The effect of thermal cutting on steel is complex. Thermal cutting is generally either oxygen cutting or plasma cutting. Performance of steel bridge members constructed with plates or shapes with thermal cut edges may be affected by both the mechanical and metallurgical properties of the cut surfaces that are subject to tensile stress. Maximum surface roughness and freedom from unrepaired notches are specified to avoid stress concentrations.

Both plasma and oxygen cutting can produce acceptable cut surfaces if the equipment is properly operated and guided. Free-hand cutting should not normally be allowed because it is difficult to achieve uniform, regular cut surfaces with this technique. However, free-hand cutting is sometimes necessary. When the Owner approves freehand cutting (without a mechanical guide), the cut surfaces still need to conform to all requirements. Thermal cutting should be done with great care, avoiding any damage to the adjacent steel.

Deviations above or below the surface corresponding to allowable roughness in this Article generally do not cause significant stress concentrations unless extremely sharp. Inspectors are not expected to measure surface roughness directly, so visual and tactile comparison with a surface roughness gauge is acceptable. AWS C4.1-G, *Oxygen Cutting Surface Roughness Gauge*, may be used as a guide for evaluating surface roughness of these edges. For materials up to and including 4 in. thick, use Sample No. 3, and for materials over 4 in. up to 8 in. thick, use Sample No. 2.

C8.2

Plates and shapes generally have superior properties in the direction of rolling, and the direction of rolling is normally prescribed for material property tests. Therefore, the direction of rolling is required to be the direction of the primary design stress for primary components. Orientation with stress is a lesser issue with webs than with flanges since web splices carry

longitudinal (bending) stress and vertical (shear) stress. Web splice plates may therefore be ordered with the direction of rolling parallel to either their vertical or horizontal axes. Web splice plates are often ordered with the direction of rolling parallel to their vertical axes because obtaining small quantities of wide plate may be uneconomical.

8.3—SHEARED EDGES

For primary member plate more than $\frac{5}{8}$ in. in thickness and carrying calculated stress, sheared edges that remain exposed after fabrication shall be planed, milled, ground, or thermal cut to a depth of $\frac{1}{4}$ in.

C8.3

The word “exposed” here means any sheared surfaces that are still visible after fabrication is complete, as opposed to sheared edges that are enclosed by welds and therefore are no longer exposed (e.g., web plates).

The AREMA commentary provides this explanation concerning the need for planing of sheared members: “Any sheared edge may have incipient cracks resulting from the shearing operation, which literally tears the material apart. Since such cracks might be harmful, the requirements for edge planing of sheared material have been included in these [AREMA] and other specifications for many years. The planing requirements need not be applied to thin A36 material because the shearing operation does not produce structurally damaging defects therein.”

8.4—THERMAL-CUT EDGES TO BE COATED

For steel that will be coated, it shall be ensured that hardening of thermal cut edges does not prevent achieving the required surface profile. If it is necessary to eliminate a hardened layer, the steel shall be ground, machined, or heated.

C8.4

Thermal-cut surfaces do not always have the same surface condition as uncut surfaces after blast cleaning. These surfaces may have been affected by the cutting process. The surfaces may have striations or marks that interfere with the use of replica tape. They may also have a condition (such as increased hardness) which inhibits the blast media from producing the same surface profile as uncut surfaces. Determination of adequate profile is best performed visually with magnification and a profile comparator.

Normal blasting practices will typically allow the formation of an anchor profile adequate for paint. However, the hardness of thermal-cut edges may be too much to allow the formation of the deeper and more angular profile required for thermal-sprayed metallic coatings. In such cases, the hardness may be reduced by machining, grinding, or a local application of heat. Heating should be performed in accordance with a procedure developed meeting the requirements set forth in Section 14 and submitted to and approved by the Owner. Grinding and machining should remove sufficient material to eliminate the hardened surface (typically no more than $\frac{1}{8}$ in.), but not enough to reduce the width of the plate beyond allowable tolerances.

SECTION 9:
BASE METAL REPAIR

**9.1—REPAIRS OF NOTCHES OR GOUGES
IN THERMAL-CUT EDGES**

9.1.1—Repairs by Grinding

The following conditions may be faired by machining or grinding, provided that the actual net cross-sectional area which will remain after fairing is 98 percent or greater of the material's nominal area:

- Roughness exceeding that permitted in Article 8.1.
- Occasional notches or gouges no more than 5 mm [$\frac{3}{16}$ in.] deep on surfaces that are otherwise satisfactory and on material edges not to be welded.

Fairing to the material surface shall have a slope not steeper than one in ten, with final machining or grinding striations parallel to the primary direction of stress. Cut surfaces and edges shall be left free of slag.

9.1.2—Repairs by Welding

Welded repairs shall be made in accordance with the provisions for welded repair of notches and gouges in thermal-cut edges in D1.5M/D1.5.

9.2—REPAIR OF LAMINAR DISCONTINUITIES IN BASE METAL CUT EDGES

9.2.1—Scope

The following provisions shall apply to allowable repairs to discontinuities discovered by either (1) visual inspection of base metal cut edges before fabrication or welding, or (2) during routine examination of welded joints by radiographic testing (RT) or ultrasonic testing (UT), in all steels listed in D1.5M/D1.5, in thicknesses up to and including 4 in. maximum.

These provisions shall not apply to discontinuities in rolled base metal surfaces. Such discontinuities may be corrected by the Fabricator in conformance with the provisions of Article 9.3.

C9.1.1

Small repairs by grinding are preferred to welded repairs, which have the possibility of introducing new discontinuities. The number of repairs allowed in one region is not limited, but if repeated attempts to repair are required, the technique used should be investigated.

C9.2.1

This Article addresses the significance of visually apparent discontinuities in cut edges. These edges are generally thermal cut edges, but may also include sheared, machined, and air carbon arc gouged edges. Most indications in edges of base metal are parallel to the rolled surface. There may be several planes of indications throughout the thickness of the material. Minimizing repair welding is desirable to avoid residual stresses and fatigue issues. However, shallow repairs may not be adequate when tensile stresses are applied through-thickness in the material.

Most indications are the result of nonmetallic inclusions, such as manganese sulfides and silicates, or are the remnants of voids left by escaping gases that are flattened out during rolling. Laminations and inclusions are generally more prevalent in thicker sections.

In ingot cast steels, there is a shrinkage cavity at the top of an ingot after solidification. The size of the cavity, called "pipe," depends on the method of casting

and the effectiveness of “killing” the steel. Killing is a degassing process through the addition of aluminum or silicon. The top of the ingot is to be “cropped,” cut off, and discarded. When there is insufficient cropping at the top of an ingot, major discontinuities may be found in the plates or shapes produced from that ingot. Plates ripped along the centerline are more likely to exhibit laminations along the edge. Many fabricators “nest” plates in odd quantities to ensure that “splitting” the plate along the centerline is avoided. Today, most structural steels are produced through a process known as continuous casting. The use of ingots is eliminated, as steel in the molten state is tapped directly from ladles into casting units. The potential problem of “pipe” is eliminated. However, there is still the possibility of small inclusions in the steel from fluxes and other foreign elements within the steel, which is subsequently cast and rolled out in the section. Weathering steels seem to have more nonmetallic inclusions than other structural steels.

Most of these indications have no bearing on the capacity of the steel to carry stress parallel or transverse to the rolling direction, and do not adversely affect weldability. Inclusions and laminations can seriously impair the capacity of steel to carry stress in the short transverse, or through-thickness “Z” direction.

9.2.2—Limits

The limits of acceptability and the repair of visually observed edge discontinuities shall be in conformance with Table 9.2.2-1. The length of discontinuity referred to in the table is the visible long dimension on the cut edge of the base metal, and the depth is the distance that the discontinuity extends into the base metal from the cut edge. Base metal edges may be at any angle with respect to the direction of rolling, but the direction of discontinuities shall be considered with respect to the direction of the base metal edges. The limits of all internal discontinuities required to be explored, which are not explored to their full depth by other means, shall be determined by UT.

Multiple discontinuities located in the same plane shall be considered continuous when they are separated by a distance less than 5 percent of the base metal thickness, or the length of the smaller of two adjacent discontinuities.

Gouging of the discontinuity may be done from either the base metal surface or edge.

C9.2.2

Edges of base metal should be inspected and required repairs completed early in the fabrication sequence. This allows maximum opportunity for the Fabricator to incorporate repaired plates in the least critical areas. Edge discontinuities should be repaired and inspected before the material is incorporated into fabricated members. If a portion of the steel is unacceptable and cannot be repaired, it needs to be replaced. In other cases, it may be desirable to put repaired plates in compression areas of the structure. This can often be done by switching top and bottom flange plates with common dimensions or turning them end for end.

In making any repairs, the amount of metal removed should be the minimum necessary to remove the discontinuity or determine that the allowable limit is exceeded.

Laminations may be discovered and mapped using longitudinal wave (straight beam) UT. Laminations are generally undetected by RT because they have no significant depth parallel to the inspecting radiation. The exception to this RT limitation is created when adjacent welds cause gases to expand out of a lamination, forming porosity that can be recorded by RT. However, what is detected is the porosity, not the lamination.