American Association of State Highway and Transportation Officials
AASHTO

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ERRATA for
S2.1, Steel Bridge Fabrication Guide Specification, 2016 Edition

March 2017

Dear Customer:

Recently, we were made aware of some technical revisions that need to be applied to the *Steel Bridge Fabrication Guide Specification,* 2016 Edition.

Please scroll down to see the full erratum.

In the event that you need to download this file again, please download from AASHTO's online bookstore at:

http://downloads.transportation.org/NSBASBF-3-Errata.pdf

Then, please replace the existing pages with the corrected pages to ensure that your edition is both accurate and current.

AASHTO staff sincerely apologizes for any inconvenience to our readers.

Summary of Errata Changes for NSBASBF-3, March 2017

Page	Existing Text	Corrected Text
6	**2.4.2** The Owner will provide design, construction, and QA inspection representatives as appropriate.	**2.4.2** The Owner will provide design, construction, and ~~QA~~ verification inspection representatives as appropriate.
7	**2.4.3** The Fabricator representatives will include the plant manager; engineering, production, and quality control inspection personnel as appropriate; and, if applicable, subcontractor representatives (e.g., painter, subcontract fabricators, or testing agencies).	**2.4.3** The Fabricator representatives ~~will~~ should include the plant manager; engineering, production, and quality control inspection personnel as appropriate; and, if applicable, subcontractor representatives (e.g., painter, subcontract fabricators, or testing agencies).
7	**2.4.4** Review these aspects of the job: • Progress on shop drawing submittal and approval; • Plant and personnel certification; • Organizational structure and primary (lead) plant personnel; • Handling of MTRs; • Traceability of materials; • Fabrication procedures, especially shop assembly, welding, and painting; • Supply and sampling of paint bolts, and other materials, if applicable; • Work schedule; • Availability and advance notification of quality assurance inspectors (QAIs); • Inspector's office; • Appropriate lines of communication; • Project-specific areas of concern for fabrication and inspection, including any special applications of non-destructive examination and testing (NDE/NDT); • Handling of non-conformance and repair issues; • Special requirements, especially any exceptions to this specification;	**2.4.4** ~~Review these aspects of the job:~~The review should include, at a minimum, the following aspects of the job: • Progress on shop drawing submittal and approval; • Plant and personnel certification; • Organizational structure and primary (lead) plant personnel; • Handling of MTRs; • Traceability of materials; • Fabrication procedures, especially shop assembly, welding, and painting; • Supply and sampling of ~~paint~~ coatings bolts, and other materials, if applicable; • Work schedule; • Availability and advance notification of ~~quality assurance~~ verification inspectors ~~(QAIs)~~; • Hold points • Inspector's office;

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	• Project details, requirements, or processes that have caused prior difficulties; and • Loading and shipping.	• Appropriate lines of communication; • Planned coverage of shop operations by QC personnel • Project-specific areas of concern for fabrication and inspection, including any special applications of non-destructive examination and testing (NDE/NDT); • Handling of non-conformance and repair issues; • Special requirements, especially any exceptions to this specification; • Project details, requirements, or processes that have caused prior difficulties; and • Loading and shipping.
7	**C2.4.4** 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 QA inspection will be accomplished, including identification of inspectors, the intended inspection schedule, 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. The Owner should have at least one designer, one acceptance representative, and one QA inspector present at the meeting. The Fabricator should have representatives from	**C2.4.4** 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 ~~QA~~ verification inspection will be accomplished, including identification of inspectors, the intended inspection schedule, and

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	production, engineering, quality control, and general management. The Contractor, other subcontractors, and suppliers may be included. All parties should be given the opportunity to ask questions or express concerns. It is not necessary to have a prefabrication meeting before every project, especially if the Owner and Fabricator work together on a regular basis.	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. The Owner should have at least one designer, one acceptance representative, and one ~~QA~~ verification inspector present at the meeting. The Fabricator should have representatives from production, engineering, quality control, and general management. The Contractor, other subcontractors, and suppliers may be included. All parties should be given the opportunity to ask questions or express concerns. It is not necessary to have a prefabrication meeting before every project, especially if the Owner and Fabricator work together on a regular basis.
8	**2.5.1** Written procedures must be maintained for the fabrication processes listed below. These are subject to the Owner's review and acceptance. • Material traceability; • Cutting and fitting. • Heat-assisted and cold bending; • Welding (welding procedure specifications and supporting documentation must have Engineer approval before they can be used); • Cambering and heat-curving, including temperature measurement, patterns, and sequences (must have Engineer approval to be used);	**2.5.1** Written procedures must be maintained for the fabrication processes listed below. These are subject to the Owner's review and acceptance. • Material traceability; • ~~Cutting and fitting.~~ • Heat-assisted and cold bending; • Welding (welding procedure specifications and supporting documentation must have Engineer approval before they can be used); • Cambering and heat-curving, including

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	• Shop assembly/laydown, including drilling and punching; • Postheat and stress-relieving procedures; • Shop installation of fasteners, with rotational capacity (RC) test, if applicable; and • Blast cleaning and painting.	temperature measurement, patterns, and sequences (must have Engineer approval to be used); • Shop assembly/laydown, including drilling and punching; • Postheat and stress-relieving procedures; • Shop installation of fasteners, with rotational capacity (RC) test, if applicable; and • Blast cleaning and ~~painting~~ <u>coating</u>.
8–9	**2.5.2** Each procedure must explain how tasks will be accomplished, evaluated, and accepted by both the quality control inspector (QCI) and the QAI verification inspector (as applicable) prior to subsequent operations.	**2.5.2** Each procedure must explain how tasks will be accomplished, evaluated, and accepted by both the quality control inspector ~~(QCI)~~ and the ~~QAI~~ verification inspector (as applicable) prior to subsequent operations.

Summary of Errata Changes for NSBASBF-3, March 2017

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9	**C2.7** Generally, Owners have one representative who oversees fabrication of steel bridge members; this may or may not be the same individual responsible for review of shop drawings. In order for fabrication to proceed smoothly, the Owner should clearly identify the individuals responsible for shop drawing review and approval, for QA during fabrication, and for questions about contract requirements and changes. When a consultant is responsible for the design or shop drawing review, an Owner's employee should act as the intermediary to coordinate inquiries or disagreements between the Fabricator and consultant.	**C2.7** Generally, Owners have one representative who oversees fabrication of steel bridge members; this may or may not be the same individual responsible for review of shop drawings. In order for fabrication to proceed smoothly, the Owner should clearly identify the individuals responsible for shop drawing review and approval, for ~~QA~~ quality verification during fabrication, and for questions about contract requirements and changes. When a consultant is responsible for the design or shop drawing review, an Owner's employee should act as the intermediary to coordinate inquiries or disagreements between the Fabricator and consultant.
12	**3.2.1** Provide MTRs for all steel materials used in fabrication, including plates, bars, shapes, and fasteners. MTRs must originate from the producer of the material and not from a supplier, unless the Owner permits specific supplemental testing of stock or service center supplied material for toughness or other parameters may come directly from the party that performs the supplemental testing.	**3.2.1** Provide MTRs for all steel materials used in fabrication, including plates, bars, shapes, and fasteners. MTRs must originate from the producer of the material and not from a supplier, ~~unless the Owner permits specific~~ except that reports for supplemental ~~testing of stock or service center supplied material~~ tests for toughness or other parameters may come directly from the party that performs the supplemental testing.
15	**4.1.1** Cut and shear materials in accordance with *Bridge Welding Code* tolerances and with the following: • For primary member plate components thicker than in. (15 mm), plane in. (5 mm) off sheared edges that remain exposed after fabrication; • Cut and fabricate steel plates for primary member components and	**4.1.1** Cut and shear materials in accordance with *Bridge Welding Code* tolerances and with the following: • For primary member plate components thicker than ⅝ in. (15 mm), plane $^{3}/_{16}$ in. (5 mm) off

Page	Existing Text	Corrected Text
	splice plates 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 unless otherwise shown on the contract drawings; and • Cut flanges to within + in., −in. (+6 mm, −3 mm) of the specified width.	sheared edges that remain exposed after fabrication; • Cut and fabricate steel plates for primary member components and splice plates 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 unless otherwise shown on the contract drawings; and • Cut flanges to within +¼ in., −⅛in. (+6 mm, −3 mm) of the specified width.
24	**4.6.5** When slotted holes are required by the contract: • Use AASHTO short slotted holes if the contract calls for slotted holes but does not provide dimensions. • Make slots by a single punch or by joining two adjacent drilled or punched holes using guided thermal cutting. Do not make slotted holes more than $^{1}/_{32}$ in. greater in width or $^{1}/_{16}$ in. greater in length than specified.	**4.6.5** When slotted holes are required by the contract: • Use AASHTO short slotted holes if the contract calls for slotted holes but does not provide dimensions. • Make slots by a single punch or by joining two adjacent drilled or punched holes using guided thermal cutting. Do not make slotted holes more than $^{1}/_{32}$ in. (1 mm) greater in width or $^{1}/_{16}$ in. (2 mm) greater in length than specified.

<table>
<tr><th>Page</th><th>Existing Text</th><th>Corrected Text</th></tr>
<tr>
<td>24–25</td>
<td>C4.6.10

Minimum edge distances in Table 4.6.10-1 or 4.6.10-2 are approximately 1.75 times the bolt hole diameter for sheared edges and 1.25 times the bolt diameter for rolled or thermally cut edges. These criteria come from the AASHTO LRFD Bridge Design Specifications and are similar to those in the AISC Code but less conservative than the earlier AASHTO LRFD Bridge Design Specifications. Since the specifications allow smaller edge distances, the Owner has less latitude to accept holes made closer to edges than specified.</td>
<td>C4.6.10

Minimum edge distances in Table 4.6.10-1 or 4.6.10-2 are approximately 1¼~~.75~~ times the bolt hole diameter ~~for sheared edges and 1.25 times the bolt diameter for rolled or thermally cut edges~~. These criteria come from the AASHTO LRFD Bridge Design Specifications (starting with the 2016 Interim Revisions to the 7th Edition), and are similar to those in the AISC Code but less conservative than the earlier AASHTO LRFD Bridge Design Specifications and Standard Specifications for Highway Bridges. Since the specifications allow smaller edge distances, the Owner has less latitude to accept holes made closer to edges than specified.</td>
</tr>
<tr>
<td>25–27</td>
<td>Tables appear out of context in 4.6.16 as Table 4.6.16-1 and 4.6.16-2 on pp 26–27.</td>
<td>These tables should have been located under 4.6.10 as 4.6.10-1 and 4.6.10-2 on pp 25–26.</td>
</tr>
<tr>
<td>25–27</td>
<td>Table 4.6.16-1 (now 4.6.10-1) previously read as follows:

<table>
<tr><th>Fastener Size (in.)</th><th>Sheared Edges (in.)</th><th>Rolled or Gas-Cut Edges (in.)</th></tr>
<tr><td>5/8</td><td>1 1/8</td><td>7/8</td></tr>
<tr><td>3/4</td><td>1 1/4</td><td>1</td></tr>
<tr><td>7/8</td><td>1 1/2</td><td>1 1/8</td></tr>
<tr><td>1</td><td>1 3/4</td><td>1 1/4</td></tr>
<tr><td>1 1/8</td><td>2</td><td>1 1/2</td></tr>
<tr><td>1 1/4</td><td>2 1/4</td><td>1 5/8</td></tr>
<tr><td>1 3/8</td><td>2 3/8</td><td>1 3/4</td></tr>
</table>
</td>
<td>Table 4.6.10-1—Minimum Fabricated Edge Distances for Standard Holes (U.S. Customary Units)

<table>
<tr><th>Fastener Size, d (in.)</th><th>Edge Distance (in.)</th></tr>
<tr><td>⅝</td><td>⅞</td></tr>
<tr><td>¾</td><td>1</td></tr>
<tr><td>⅞</td><td>1⅛</td></tr>
<tr><td>1</td><td>1¼</td></tr>
<tr><td>1⅛</td><td>1½</td></tr>
<tr><td>1¼</td><td>1⅝</td></tr>
<tr><td>Over 1¼</td><td>1¼ × d</td></tr>
</table>
</td>
</tr>
</table>

<table>
<tr><th>Page</th><th>Existing Text</th><th>Corrected Text</th></tr>
<tr>
<td>25–27</td>
<td>Table 4.6.16-2 (now 4.6.10-2) previously read as follows:
<table>
<tr><th>Fastener Size (mm)</th><th>Sheared Edges (mm)</th><th>Rolled or Gas-Cut Edges (mm)</th></tr>
<tr><td>16</td><td>28</td><td>22</td></tr>
<tr><td>20</td><td>34</td><td>26</td></tr>
<tr><td>22</td><td>38</td><td>28</td></tr>
<tr><td>24</td><td>42</td><td>30</td></tr>
<tr><td>27</td><td>48</td><td>34</td></tr>
<tr><td>30</td><td>52</td><td>38</td></tr>
<tr><td>36</td><td>64</td><td>46</td></tr>
</table>
</td>
<td>**Table 4.6.10-2—Minimum Fabricated Edge Distances for Standard Holes (SI Units)**
<table>
<tr><th>Fastener Size, *d* (mm)</th><th>Edge Distance (mm)</th></tr>
<tr><td>16</td><td>22</td></tr>
<tr><td>20</td><td>26</td></tr>
<tr><td>22</td><td>28</td></tr>
<tr><td>24</td><td>30</td></tr>
<tr><td>27</td><td>34</td></tr>
<tr><td>30</td><td>38</td></tr>
<tr><td>Over 30</td><td>1¼ × *d*</td></tr>
</table>
</td>
</tr>
<tr>
<td>31</td>
<td>**4.8.2**

Do not mark fascia surfaces. Use one of the following methods as soon as possible to remove any markings or any other foreign material that adheres to the steel during fabrication and that could inhibit the formation of oxide film:
• SSPC-SP 1, *Solvent Cleaning*
• SSPC-SP 2, *Hand Tool Cleaning*
• SSPC-SP 3, *Power Tool Cleaning*
• SSPC-SP 7, *Brush-Off Blast Cleaning*</td>
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• SSPC-SP 2, *Hand Tool Cleaning*
• SSPC-SP 3, *Power Tool Cleaning*
• SSPC-SP 7, *Brush-Off Blast Cleaning*

Where marks are removed by local blast cleaning, provide a gradual transition to the adjacent surface.</td>
</tr>
<tr>
<td>34</td>
<td>**5.2—Heat Curving for Sweep of Bridge Members**</td>
<td>**5.2— ~~Heat Curving for Sweep of Bridge Members~~ Heat-shrink or Upset-shortening Method**</td>
</tr>
</table>

Page	Existing Text	Corrected Text
35	**C5.3** …If the flanges are thicker than 1 in. (30 mm), both surfaces of each flange should be heated.	**C5.3** …If the flanges are thicker than 1¼ in. (30 mm), both surfaces of each flange should be heated.
36	**C5.4** Note that the cutting of webs, as opposed to heating flanges, to achieve camber is generally the preferred means of achieving camber in built-up members. When used, cover plates are welded to beams either before or after heat-cambering.	**C5.4** ~~Note that the cutting of webs, as opposed to heating flanges, to achieve camber is generally the preferred means of achieving camber in built-up members. When used, cover plates are welded to beams either before or after heat-cambering.~~ The minimum radii for heat curving in this guide specification are based on the original AASHTO requirements that reflect practical limits. Curving outside of these limits will likely result in distorted members or, in the case of curving members with very thick flanges, will not be possible. When flanges are very thick (over 3 in. or 75 mm), the heat tends to escape through the member too quickly to realize an effective localized heat zone. When the radius is too tight for heat curving, the curve should rather be accomplished by cutting the flanges to the prescribed curve.
36	**5.4.1** Use an approved procedure that addresses support conditions, preloading (if any), and heat application and control.	**5.4.1** ~~Use an approved procedure that addresses support conditions, preloading (if any), and heat application and control.~~ Do not heat-curve beams or girders when the horizontal radius of curvature measured to the centerline of the member web is less than either value calculated using Equations 5.4.1-1 and 5.4.1-2 for US customary units or Equations 5.4.1-3 and 5.4.1-4 for SI units, or when the radius is less than 150 feet (45 meters) at any cross section throughout the length of the member.

Page	Existing Text	Corrected Text
38	**C5.7.1** "Heat-assisted bending" refers to first applying heat and then sufficient force to bend a plate about a die. The work is shaped by the force, which is aided by the heat. This is converse to heat-curving, where a limited amount of preload is introduced, then the work is heated, and the work is shaped by the heating and cooling, with the force as an aid. A typical application of heat-assisted bending is forming flanges for haunch girders. Steels, including Q&T steels, may be readily bent with heat-assisted bending, provided the temperature limits of Table 5.1.1-1 are observed and the load is not applied too quickly. Quick load applications may fracture the material. Through-thickness heating is also essential for avoiding cracks during heat-assisted bending. If the material is bent too quickly, it will crack or have severe local distortions (necking or mushrooming). (See the AASHTO *Standard Specifications for Highway Bridges* or in the AASHTO *LRFD Bridge Construction Specifications.*)	**C5.7.1** "Heat-assisted bending" refers to first applying heat and then sufficient force to bend a plate about a die. The work is shaped by the force, which is aided by the heat. This is converse to heat-curving, where a limited amount of preload is introduced, then the work is heated, and the work is shaped by the heating and cooling, with the force as an aid. A typical application of heat-assisted bending is forming flanges for haunch girders. Steels, including Q&T steels, may be readily bent with heat-assisted bending, provided the temperature limits of Table 5.1.1-1 are observed and the load is not applied too quickly. Quick load applications may fracture the material. Through-thickness heating is also essential for avoiding cracks during heat-assisted bending. If the material is bent too quickly, it will crack or have severe local distortions (necking or mushrooming). (See 11.4.3.3.3 in Division II of the AASHTO *Standard Specifications for Highway Bridges* or in the AASHTO *LRFD Bridge Construction Specifications.*)

Page	Existing Text	Corrected Text
40	**6.1.3** Fabricate steel pier caps and other substructure elements based upon mutual agreement between the Contractor and the Engineer regarding bearing plane and twist tolerances, with proper regard for erection requirements.	**6.1.3** ~~Fabricate steel pier caps and other substructure elements based upon mutual agreement between the Contractor and the Engineer regarding bearing plane and twist tolerances, with proper regard for erection requirements.~~ Rolled or fabricated sections of equal or slightly greater dimensions than the section specified may be proposed for the Engineer's acceptance. For changes that affect splice design or may significantly alter deflection, provide complete design calculations.

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In some cases the Fabricator decides 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 done without approved drawings should be concealed by subsequent work before drawings are approved.

Except for emergency situations, work should not be allowed 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.

2.3.1

Provide separate shop drawings for each steel structure on a project. Dual (twin) bridges shall have separate drawings for future reference.

2.3.2

Prepare and submit shop drawings in accordance with AASHTO/NSBA Steel Bridge Collaboration G1.3, *Shop Detail Drawing Presentation Guidelines* or equivalent.

2.3.3

Do not begin fabrication until 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 testing and examination (NDT/NDE), or partial disassembly/reassembly to satisfy the Owner's quality verification.

2.4—PREFABRICATION MEETING

2.4.1

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

2.4.2

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

2.4.3

The Fabricator representatives should include the plant manager; engineering, production, and quality control inspection personnel as appropriate; and, if applicable, subcontractor representatives (e.g., painter, subcontract fabricators, or testing agencies).

2.4.4

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

- Progress on shop drawing submittal and approval;
- Plant and personnel certification;
- Organizational structure and primary (lead) plant personnel;
- Handling of MTRs;
- Traceability of materials;
- Fabrication procedures, especially shop assembly, welding, and painting;
- Supply and sampling of coatings, bolts, and other materials, if applicable;
- Work schedule;
- Availability and advance notification of verification inspectors;
- Hold points;
- Inspector's office;
- Appropriate lines of communication;
- Planned coverage of shop operations by QC personnel;
- Project-specific areas of concern for fabrication and inspection, including any special applications of non-destructive examination and testing (NDE/NDT);
- Handling of non-conformance and repair issues;
- Special requirements, especially any exceptions to this specification;
- Project details, requirements, or processes that have caused prior difficulties; and
- Loading and shipping.

C2.4.4

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, 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.

The Owner should have at least one designer, one acceptance representative, and one verification inspector present at the meeting. The Fabricator should have representatives from production, engineering, quality control, and general management. The Contractor, other subcontractors, and suppliers may be included. All parties should be given the opportunity to ask questions or express concerns.

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

2.5—PROCEDURES

2.5.1

Written procedures must be maintained for the fabrication processes listed below. These are subject to the Owner's review and acceptance.

- Material traceability;
- Heat-assisted and cold bending;
- Welding (welding procedure specifications and supporting documentation must have Engineer approval before they can be used);
- Cambering and heat-curving, including temperature measurement, patterns, and sequences (must have Engineer approval to be used);
- Shop assembly/laydown, including drilling and punching;
- Postheat and stress-relieving procedures;
- Shop installation of fasteners, with rotational capacity (RC) test, if applicable; and
- Blast cleaning and coating.

2.5.2

Each procedure must 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.

C2.5

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 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 assurance inspections.

Procedures should convey how the Fabricator's process will satisfy specification requirements. Information presented on a shop drawing may suffice in lieu of formally submitting a written procedure.

2.5.3

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

2.6—COMMENCEMENT OF WORK

Provide a written advance notice to the Owner a minimum of two weeks before fabrication begins.

C2.6

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 Fabricators 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.

2.7—EVALUATION OF THE WORK

C2.7

Generally, Owners have one representative who oversees fabrication of steel bridge members; this may or may not be the same individual responsible for review of shop drawings. In order for fabrication to proceed smoothly, the Owner should clearly identify the individuals responsible for shop drawing review and approval, for quality verification during fabrication, and for questions about contract requirements and changes. When a consultant is responsible for the design or shop drawing review, an Owner's employee should act as the intermediary to coordinate inquiries or disagreements between the Fabricator and consultant.

2.7.1

The verification inspector will evaluate the work and accept fabricated components that satisfy the requirements of the contract documents.

2.7.2

The Engineer may accept fabricated components that do not fully conform to the contract provided the Engineer is satisfied that alternate practices or work proposed by the Fabricator will not compromise the durability, performance, or integrity of the structure.

2.8—QUALITY CONTROL

Perform QC inspection using trained and qualified personnel in accordance with applicable contract documents.

C2.8

AASHTO/NSBA S4.1 provides the Fabricator with guidelines for writing a quality control plan. These guidelines parallel many of the requirements the Fabricator must already satisfy in order to achieve AISC plant certification.

NSBASBF-3-E1: March 2017 Errata to
S2.1, *Guidelines for Resolution of Steel Bridge Fabrication Errors*, 2016 Edition

2.9—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.

C2.9

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.

documented on the test reports when the material is Q&T. There is virtually no performance difference between materials made from either process, so the Designer should not require one process over the other.

As of the 2008 editions of ASTM A709/A709M and AASHTO M 270M/M 270, Charpy requirements are no longer supplementary but required within the body of the standard for components in tension. Thus the Designer 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.

Welding consumables—Information about welding consumables is available from AASHTO/AWS D1.5M/D1.5, the AWS D1.1 *Structural Welding Code,* and associated AWS filler metal specifications. These documents are available from AWS.

3.1.2

Material meeting equivalent AASHTO and ASTM specifications may be supplied under either specification.

3.2—CERTIFICATIONS AND VERIFICATION

C3.2

Requirements for 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.

3.2.1

Provide MTRs for all steel materials used in fabrication, including plates, bars, shapes, and fasteners. MTRs must 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.

3.2.2

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

3.2.3

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

SECTION 4

WORKMANSHIP

4.1—CUTTING, SHEARING, AND MACHINING

4.1.1

Cut and shear materials in accordance with *Bridge Welding Code* tolerances and with the following:

- For primary member plate components thicker than ⅝ in. (15 mm), plane $^{3}/_{16}$ in. (5 mm) off sheared edges that remain exposed after fabrication;
- Cut and fabricate steel plates for primary member components and splice plates 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

C4.1

AASHTO/AWS D1.5M/D1.5 addresses cutting of materials. 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. In accordance with AASHTO/AWS D1.5M/D1.5, these may be repaired using a procedure approved by the Engineer. AASHTO/AWS D1.5M/D1.5 also provides guidelines that should be followed in the repair and NDE. The Owner should allow the Fabricator to develop preapproved procedures for common repairs. Preapproved procedures should apply provided the notches are less than in. (12 mm) deep and are not too frequent. The inspector can best judge what frequency is reasonable.

The AREMA (American Railway Engineering and Maintenance of Way Association) commentary provides this explanation concerning the need of 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.

Under the first bullet of Section 4.1.1, the word "exposed" 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).

plates unless otherwise shown on the contract drawings; and

- Cut flanges to within +¼ in., −⅛ in. (+6 mm, −3 mm) of the specified width.

4.1.2

Machine (grind, mill, plane, etc.) in accordance with the contract requirements and applicable codes, specifications, and accepted industry practices.

C4.1.2

Plates and shapes generally have superior properties in the direction of rolling. Further, the direction of rolling is normally prescribed for material property tests. Therefore, the direction of rolling must be the direction of the primary design stress for main components. Orientation with stress is a lesser issue with webs than with flanges, since web splices carry longitudinal (bending) stress and vertical (shear) stress. Obtaining small quantities of wide plate may be uneconomical, so permitting either direction of rolling for web splice plates is recommended. Web splice plates may then be ordered with the direction of rolling parallel to either their vertical or horizontal axes.

4.1.3

For steel that will be coated, ensure that hardening of thermal cut edges does not prevent achieving the required surface profile. Grind, machine, or heat if necessary to eliminate a hardened layer.

C4.1.3

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; there may be striations or marks that interfere with the use of replica tape or 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 anchor profile adequate for paint, but 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 that has been submitted and approved by the Engineer, and in accordance with Section 5 of this document. Grinding and machining should remove sufficient material to eliminate the hardened surface (typically no more than in.), but not enough to reduce the width of the plate beyond allowable tolerances.

4.2—CONTACT AND BEARING SURFACES

4.2.1

Finish bearings, base plates, and other contact surfaces to the ANSI surface roughness requirements defined in ANSI B46.1, "Surface Roughness, Waviness and Lay," Part I, given in Table 4.2.1-1, unless otherwise noted in the contract.

4.6.5

When slotted holes are required by the contract:

- Use AASHTO short slotted holes if the contract calls for slotted holes but does not provide dimensions.
- Make slots by a single punch or by joining two adjacent drilled or punched holes using guided thermal cutting.
- Do not make slotted holes more than $^1/_{32}$ in. (1 mm) greater in width or $^1/_{16}$ in. (2 mm) greater in length than specified.

4.6.6

Do not thermally cut holes in quenched and tempered steel, unless subsequent processes will remove all material within $^1/_{16}$ in. (2 mm) of the cut surface. Thermally cut holes in other material must be free of gouges and other cutting defects.

C4.6.6

To avoid gouges in thermally cut holes, initiate cutting with the material that will be removed.

4.6.7

Assess bolt hole quality in primary members with the members and splice plates assembled, except in cases where the use of computer numerically controlled (CNC) drilling equipment or bushed templates are allowed (see Section C7.4).

4.6.8

Holes in floor beam to primary member connections and continuous stringer to floor beam connections do
not require shop assembly verification unless specified by the contract.

4.6.9

Do not use temporary welds to secure materials while drilling or reaming through multiple plies.

4.6.10

Locate standard size bolt hole centers no closer to the nearest edge than the minimum distances given in Table **4.6.10-1** or **4.6.10-2**. For oversize or slotted holes, provide a minimum clear distance of one bolt diameter between the hole and the edge.

C4.6.10

For some tolerances, Fabricators should consider requesting permission from the Designer to position the holes slightly further from edges than the distance shown on the plans. Edge and end distances are important because a minimum amount of material is needed between the bolt hole and the edge of the plate. Contract plans typically show bolt holes with AASHTO minimum distances. Therefore, if the designer details the holes for the same clearance, there is essentially zero tolerance for mislocating holes closer to the edge of the member or splice plate. The designer should preferably detail the holes at a distance slightly greater than the AASHTO minimums, especially at field splice centerlines. Fabricators may also wish to increase edge distances from those presented in the design. If so, the Fabricator should convey this to the Owner and reflect the modified details in the shop drawings to be approved.

Minimum edge distances in Table 4.6.10-1 or 4.6.10-2 are approximately 1¼ times the bolt hole diameter. These criteria come from the AASHTO *LRFD Bridge Design Specifications* (starting with the 2016 Interim Revisions to the 7th Edition), and are similar to those in the AISC Code but less conservative than the earlier AASHTO *LRFD Bridge Design Specifications* and *Standard Specifications for Highway Bridges.* Since the specifications allow smaller edge distances, the Owner has less latitude to accept holes made closer to edges than specified.

Table 4.6.10-1—Minimum Fabricated Edge Distances for Standard Holes (U.S. customary units)

Fastener Size, *d* (in.)	Edge Distance (in.)
⅝	⅞
¾	1
⅞	1⅛
1	1¼
1⅛	1½
1¼	1⅝
Over 1¼	1¼ × *d*

Table 4.6.10-2—Minimum Fabricated Edge Distances for Standard Holes (SI units)

Fastener Size, *d* (mm)	Edge Distance (mm)
16	22
20	26
22	28
24	30
27	34
30	38
Over 30	1¼ × *d*

4.6.11

The maximum edge or end distance is the lesser of 8 times the thickness of the thinnest outside plate or 5 in. (125 mm).

C4.6.11

Limiting the maximum edge or end distance is intended for sealing against moisture.

4.6.12

The tolerance for bolt hole spacing is ± $^{3}/_{16}$ in. (5 mm), as long as edge and end distance requirements are satisfied.

4.6.13

When slip-critical faying surfaces are to be primed, use a coating and dry film thickness that is certified to provide the required slip coefficient.

C4.6.13

When bridges with bolted connections are painted, the preferred practice is to prime-coat all faying surfaces. This maintains the continuity of the prime coat and thus offers better corrosion protection. However, in slip-critical connections, the primer must provide enough friction to transfer the applied loads. The contract specifies the required coating. If the minimum required slip coefficient is not specified in the contract, the Engineer can provide this information (see Section C4.6.15). The paint manufacturer can provide the coefficient of friction for the paint and the range of dry film thickness and curing conditions (temperature, humidity, and minimum curing time) needed to achieve the required friction. If joints are bolted before the primer is properly cured, the performance of the connection may be compromised. The primer must also meet the creep characteristics required for coatings on faying surfaces, and the paint supplier will provide a certification attesting to this. More information about coating of faying surfaces is available in the RCSC Specification, Appendix A, "Testing Method to Determine the Slip Coefficient for Coating Used in Bolted Joints."

Though it is common and preferred that faying surfaces be primed, it is not recommended that other coatings, such as epoxy or urethane intermediate or top coats, be applied to the faying surfaces. The same holds true for the surfaces beneath bolt heads and washers at slip-critical connections.

4.6.14

Hot-dip galvanized slip-critical faying surfaces shall be free of high spots, and hand wire brushed to remove non-adhered material and provide some roughness.

4.6.15

Provide an SSPC-SP 6 cleaning for non-painted faying surfaces, but do not power wire-brush them. Prepare non-painted faying surfaces in accordance with the RCSC Specification.

C4.6.15

The surface preparation required by RCSC will depend on the design assumption for the mean slip coefficient (μ) of the faying surface. If μ is not noted in the contract, or approved coatings are not specified, contact the Engineer for further information. Class A (μ =

0.33) requires the removal of all loose material but permits clean, tightly adhering mill scale to remain. Class B (μ = 0.50) requires the removal of all mill scale, essentially an SSPC SP 6 surface preparation. Surface rust at the time of bolting may slightly exceed an SP 6 condition, but the faying surfaces must be free of any loose material. If loose material is present, it can typically be removed by a power wash just before bolting. Wire brushing is not permitted because this will "polish" the surface and reduce its slip resistance.

4.6.16

Ensure that faying surfaces are free of dirt, lubricants, metal shavings, burrs, and other foreign or loose material at the time of bolting that could prevent intimate contact.

4.7—BOLTING

C4.7

Quality requirements and tensioning requirements do not apply to "shop fasteners"—bolts that are used strictly in the shop to aid in fabrication or assembly of the members and do not become a permanent part of the project.

The RCSC Specification and associated commentary provide useful information about the installation of fasteners in structures. Experience in bridges has shown that two problems persist:

- Fasteners are often installed without regard for proper tightening procedures.
- There is often disagreement about what is meant by "snug tight."

The RCSC Specification provides instructions on how to achieve the snug-tight condition during installation. Proper fastener installation requires that the Contractor have trained personnel installing the bolts and that inspection be conducted.

Rotational capacity (RC) testing is required at two levels. ASTM requires RC testing in the manufacture of zinc-coated bolts, and FHWA requires that RC testing be conducted for fastener assemblies (bolt, nuts, and washers) used in structures. The result is a rotational capacity lot which consists of a specific combination of production lots of nut, bolt, and washer. Typically nuts and washers will be paired with a variety of bolt lengths. Appendices A–C to S10.1, referenced in Section 4.7, reproduce the requirements of FHWA report FHWA SA 91 031 with 1994 revisions. These provisions and methods have been incorporated into and continue to be updated in the AASHTO *LRFD Bridge Construction Specifications.*

When fasteners are galvanized, the manufacturer removes a certain amount of additional material from the nut thread (overtapping) to make room for the zinc on the bolt. There tend to be variations in the amount of zinc accumulated on the bolt threads, so it is important to verify that galvanized bolts will be capable of developing the required strength when they are installed. This is a primary reason for the manufacturer's test. When purchasing galvanized fasteners, the Material Test Report should be checked to be sure that this test requirement has been satisfied.

The RC field test mandate was a result of research conducted by the FHWA into problems that occurred with bolts in the 1980s. Complaints from the field about bolt failures prompted the study. The FHWA began by surveying inspectors, Owners, Fabricators, manufacturers, and suppliers about the problems observed, and they narrowed the results down to two primary problems:

- Bolts were sometimes supplied which were not actually represented by the paperwork supplied to the Owner.
- Lack of proper lubrication led to tightening problems.

When proper lubrication is not present, a high degree of friction results between the nut and the fastener and this makes it very difficult (or impossible) to turn the nut at all. Further, the nut can feel tight long before it is properly tightened. Fasteners must elongate to provide clamping force, and if a bolt is not properly lubricated but feels tight, the installer may be misled into thinking that the bolt has been properly tightened. Another problem exists in the plastic behavior of improperly lubricated nuts. When a bolt is properly lubricated and is tightened beyond its yield point, it demonstrates a great deal of ductility so that the nut may be turned beyond what is required without compromising the connection. But when the fastener is not properly lubricated, the fastener may be twisted, resulting in poor ductility and rupture before proper bolt tension is attained.

There are two tests that may be performed in the field and that must be done for every combination of bolt and nut heats. Both the RC test and the preinstallation verification (PIV) test give information about the bolt condition. The PIV test verifies that the proposed installation method will reach the required tension. The RC test verifies that excessive torque is not needed in order to achieve the proper tension, and also that the bolts will survive "overtightening." Although the 1991 FHWA mandate required that the RC test be performed in the field, in the years and decades following the initial research, concerns about counterfeit bolts have diminished, and having manufacturers or distributors perform the RC test has become more acceptable. In practice, the FHWA "field" RC test is often performed upon receipt of the bolts, rather than "at the point of bolting" as originally intended; some owners even require that the fabricator perform this test before the bolts are shipped to the jobsite. Even further, some owners require testing both by the fastener manufacturer or distributor and by the bolt installer. In addition, the PIV test is supposed to be done at the time of bolting as well.

In order to reduce this redundancy in testing, as of the 2016 edition of S2.1, bolts are required to be ordered RC-tested from the manufacturer or distributor; if the fasteners are maintained in good condition thereafter, there is no reason to do a "field" RC test. Appendix D to S10.1 is an alternative field RC test that ensures that proper tension can be achieved and also includes the "overtightening" component of the FHWA test. It incorporates the PIV test so that if both tests are required, they can be combined into a single test. It does not include a specific requirement for torque-to-tension ratio, avoiding the need for a calibrated torque wrench (unless it is part of the installation method).

The PIV test is intended not only to verify acceptable fastener condition but also to verify that the bolting crew is following a procedure that will achieve the required result. Because of this, it is important to have the bolting crew rather than an inspector perform the test. Effectively, the test verifies that the installer's idea of "snug" leads to the required installation tension. If the same crew is repeatedly installing the same bolts, there should be no need to repeat the verification test for turn-of-the-nut or DTI installation. Daily verification is required for the calibrated wrench method to ensure that the equipment is still accurate. Note that "snug tight" for the FHWA RC test is different from the "snug tight" prescribed for installation and the PIV or alternative field RC test.

Where daily testing is not required, it is recommended that tests on particular sizes, lengths, and grades be performed shortly before those particular fasteners are installed, rather than testing all fasteners at the beginning of the project. Testing each fastener type as it comes up for installation will help keep the crew familiar with that particular fastener assembly. Too long a time interval between testing and installation may be considered reason to question the understanding of the crew. Owner and Contractor should agree on an appropriate interval, taking into account the complexity of the project and the experience of the crew.

See further discussion in the commentary to the bolting section of S10.1.

4.7.1 Rotational Capacity Testing

Have the manufacturer perform rotational capacity (RC) tests on ASTM F3125 Grade A325, A490, A325M, and A490M fastener assemblies. Test in accordance with Collaboration standard S10.1, Appendix A, "Rotational Capacity Test (Long Bolts in Tension Calibrator)," or Appendix B, "Rotational Capacity Test (Bolts Too Short to Fit In Tension Calibrator)," as applicable. At the point of installation, if the condition of the fasteners is in question, perform the field RC test (S10.1 Appendix D, "Field Rotational Capacity Test (and Optional Combined

Installation Verification Test)") or one of the standard RC tests (S10.1 Appendix A or B).

4.7.2 Preinstallation Verification Testing

4.7.2.1

Turn-of-the-Nut and Tension-Control Bolts—When bolts are tensioned using the turn-of-the-nut method or when tension-control ("twist-off") bolts are used, verify bolt installation method prior to bolt installation, in accordance with the RCSC Specification, Section 7, "Pre-Installation Verification." Have the verification test performed by each bolting crew, for each combination of grade, length, and diameter that the crew will be installing, and whenever the condition of the bolts or the knowledge or practice of the crew is in question.

4.7.2.2

Direct Tension Indicators (DTIs)—When bolts are tensioned using DTIs, verify bolt installation method prior to bolt installation, in accordance with S10.1 Appendix C ("Direct Tension Indicators (DTI) (Verification Test Procedure)"). Have the verification test performed by each bolting crew, and for each combination of grade and diameter that the crew will be installing, and whenever the condition of the bolts or the knowledge or practice of the crew is in question.

4.7.2.3

Calibrated Wrench—When bolts are tensioned using the calibrated wrench method, verify bolt installation method prior to bolt installation, in accordance with the RCSC Specification, Section 7, "Pre-Installation Verification." Have the verification test performed daily by each bolting crew, for each combination of grade, length, and diameter that the crew will be installing, and whenever the condition of the bolts or the knowledge or practice of the crew is in question.

4.7.3 Installation

Install fasteners in accordance with the RCSC Specification, Item 8.2, "Pretensioned Joints." If special fasteners not addressed by the RCSC Specification are required, install them in accordance with the manufacturer's recommendations. Ensure that no loose mill scale, dirt, metal shavings, or other foreign material that would preclude solid seating of the parts or frictional transfer of load is present on faying surfaces at time of installation.

4.8—SURFACE PREPARATION OF UNPAINTED WEATHERING STEEL (NON-FAYING SURFACES)

C4.8

The aim of the weathering steel surface preparation requirements is to give a relatively consistent appearance from the ground without requiring a perfectly uniform finish. If part of the girder will be painted, other levels of surface preparation may be required.

4.8.1

Provide an SSPC-SP 6 blast in the shop to all fascia surfaces of unpainted weathering steel beams. Fascia surfaces include:

- Outward-facing sides and bottom flanges of exterior plate girders and rolled beams,
- All outer surfaces of tub girders (both webs and bottom flange) and box girders (both webs and both flanges),
- All surfaces of truss members,
- Webs and undersides of bottom flanges of plate diaphragms for tub structures,
- Any other surfaces designated as "fascia" on the plans.

4.8.2

Do not mark fascia surfaces. Use one of the following methods as soon as possible to remove any markings or any other foreign material that adheres to the steel during fabrication and that could inhibit the formation of oxide film:

- SSPC-SP 1, *Solvent Cleaning*
- SSPC-SP 2, *Hand Tool Cleaning*
- SSPC-SP 3, *Power Tool Cleaning*
- SSPC-SP 7, *Brush-Off Blast Cleaning*

Where marks are removed by local blast cleaning, provide a gradual transition to the adjacent surface.

4.8.3

Do not use acids to remove stains or marks.

5.2—HEAT-SHRINK OR UPSET-SHORTENING METHOD

5.2.1

Limit stresses due to preload (including loads induced by member weight) to 0.5 F_y at the extreme fiber, where F_y is the nominal yield strength of the material.

5.2.2

When jacks are used, apply and lock off load before applying heat.

5.2.3

When vee or rectangular heat patterns are used, mark the patterns on the steel prior to heating.

5.2.4

Allow the steel to cool to below 250° F (120° C) before applying another set of heating patterns.

5.2.5

When curving or cambering by vee heat, reheat a location only after at least three sets of heating patterns at other locations.

5.2.6

Do not handle, support, or load the member in a manner that causes material to yield without the application of heat.

5.3—HEAT-CURVING FOR SWEEP OF BRIDGE MEMBERS

5.3.1

Use an approved procedure that describes the method of supporting and/or loading, and also provides calculations, if applicable, that satisfy the preload limits of Section 5.2.1.

C5.3

The term “heat-curving” is usually used to describe the shaping by heat of bridge members to the curve shape required in the structure. It is often more practical to fabricate I-shape members straight and then curve them rather than building them curved. However, there are limits to what can be effectively curved, depending upon the properties of the member and how tight the radius will be. The heat-curving formula in this specification is intended to provide a conservative limit. Usually, it is best to fabricate a girder “shell,” or flanges and webs, then perform curving, and then add parts like stiffeners. Stiffeners may be added before heat curving, but then the stiffener-to-flange welds should be done after curving. Longitudinal stiffeners are added after curving to avoid twisting of the member due to asymmetry.

The two methods usually employed for heat-curving are vee and strip heating. Under vee heating, “V”-shaped patterns of heat are applied to the flanges with the wide end of the vee on the side of the girder that will be inside the curve. These should be spaced as necessary to achieve the required curve. Under the strip heating method, heat is applied along a strip near the edge of the flanges on the side that will be inside the curve. Heat is not actually applied directly to the edge, but rather to one or both surfaces of the flange. If the flanges are thicker than 1¼ in. (30 mm), both surfaces of each flange should be heated. After heating, flanges must be allowed to cool completely so that results may be evaluated before any additional series of heats are applied.

Girders may be heat-curved with the web in either the vertical or the horizontal position. When the web is in the horizontal position, the girder's weight may be used to contribute to the curving process. If so, limiting supports should be used to make sure the girder will remain within the required curve. When heat-curving is conducted on members in the vertical position, supports are vital because as the member changes shape, its center of gravity moves, and the member can become unstable or fall over.

Though heat curving is used very effectively for I-girders, it is not as effective for box girders, either trapezoidal or rectangular. Note that the cutting of flanges, as opposed to heating flanges, to achieve horizontal curvature is not prohibited; cutting flanges is necessary to achieve curvature for radii that are smaller than allowed under Section 5.4.

5.3.2

Heat-curve prior to the attachment of longitudinal stiffeners and painting.

5.3.3

When the radius is less than 1000 feet (300 meters), heat-curve only with the web in the horizontal position or preload to induce stress prior to heating. (See Sections 5.4.2 and 5.5.1).

5.3.4

When heat-curving with the web in the vertical position, support the member so that the tendency of the member to deflect laterally during the heat-curving process will not cause the member to overturn or twist, and so that camber will not significantly change.

5.3.5

Maintain intermediate "catch" blocks as needed to prevent buckling and excessive or concentrated deformations.

5.3.6

Plan and apply the heating patterns along the length of the member to produce the specified curvature, either using enough patterns to avoid visually obvious chording effects and produce a relatively uniform geometry, or heating flanges full-length with automated equipment for uniform heating.

5.4—MINIMUM RADIUS FOR HEAT-CURVING

C5.4

The minimum radii for heat curving in this guide specification are based on the original AASHTO requirements that reflect practical limits. Curving outside of these limits will likely result in distorted members or, in the case of curving members with very thick flanges, will not be possible. When flanges are very thick (over 3 in. or 75 mm), the heat tends to escape through the member too quickly to realize an effective localized heat zone. When the radius is too tight for heat curving, the curve should rather be accomplished by cutting the flanges to the prescribed curve.

5.4.1

Do not heat-curve beams or girders when the horizontal radius of curvature measured to the centerline of the member web is less than either value calculated using Equations 5.4.1-1 and 5.4.1-2 for US customary units or Equations 5.4.1-3 and 5.4.1-4 for SI units, or when the radius is less than 150 feet (45 meters) at any cross section throughout the length of the member.

$$R = \frac{14bD}{\sqrt{F_y}(\psi t)} \tag{5.4.1-1}$$

or

$$R = \frac{7500b}{F_y \psi} \tag{5.4.1-2}$$

where

- Fy = specified minimum yield point of the member web (ksi)
- ψ = ratio of the total cross-sectional area to the cross-sectional area of both flanges
- b = width of the widest flange (in.)
- D = clear distance between flanges (in.)
- t = web thickness (in.)
- R = radius (in.)

$$R = \frac{37bD}{\sqrt{F_y}(\psi t)} \tag{5.4.1-3}$$

or

$$R = \frac{51700b}{F_y \psi} \qquad (5.4.1\text{-}4)$$

where

Fy = specified minimum yield point of the member web (MPa)
ψ = ratio of the total cross-sectional area to the cross-sectional area of both flanges
b = width of the widest flange (mm)
D = clear distance between flanges (mm)
t = web thickness (mm)
R = radius (mm)

5.4.2

Do not heat-curve portions of members where the required radius of curvature is less than 1,000 feet (300 meters), and the flange thickness exceeds 3 inches (75 mm) or the flange width exceeds 30 inches (750 mm).

5.5—HEAT CAMBERING

C5.5

The cutting of webs, as opposed to heating flanges, to achieve camber is generally the preferred means of achieving camber in built-up members. When used, cover plates are welded to beams either before or after heat cambering.

5.5.1

Use an approved procedure that addresses support conditions, preloading (if any), and heat application and control.

5.5.2

Support members to be heat-cambered with the web vertical, and space supports to take maximum advantage of dead load in the member before heat is applied.

5.6—HEAT-STRAIGHTENING DAMAGED STRUCTURAL STEEL

C5.6

See Section C5.1.1 for FHWA resources on heat-straightening.

5.6.1

For heat-straightening damaged steel, use approved procedures that describe the distortion to be corrected and all steps for preloading, heating, temperature monitoring, cooling, verifying final dimensions, and non-destructive examination.

5.7—HEAT-ASSISTED BENDING (MECHANICAL HOT BENDING)

5.7.1

If heat-assisted bending is used:

- follow approved procedures
- keep the temperature above 700° F (370° C) during bending, but below the maximum temperature limits of Table 5.1.1-1
- apply heat to obtain uniform temperature throughout the plate thickness before jacking pressure is applied.

C5.7.1

"Heat-assisted bending" refers to first applying heat and then sufficient force to bend a plate about a die. The work is shaped by the force, which is aided by the heat. This is converse to heat-curving, where a limited amount of preload is introduced, then the work is heated, and the work is shaped by the heating and cooling, with the force as an aid. A typical application of heat-assisted bending is forming flanges for haunch girders. Steels, including Q&T steels, may be readily bent with heat-assisted bending, provided the temperature limits of Table 5.1.1-1 are observed and the load is not applied too quickly. Quick load applications may fracture the material. Through-thickness heating is also essential for avoiding cracks during heat-assisted bending. If the material is bent too quickly, it will crack or have severe local distortions (necking or mushrooming). (See 11.4.3.3.3. in Division II of the AASHTO *Standard Specifications for Highway Bridges* or in the AASHTO *LRFD Bridge Construction Specifications.*)

Depending on composition and manufacture, steel may exhibit brittle behavior within certain temperature ranges below the maximum limits given. To prevent unnecessary damage during heat assisted bending, the fabricator should obtain necessary guidance and employ appropriate temperature controls. The minimum temperature given in Section 5.7.1 is intended to prevent bending in the "blue brittle" temperature range.

5.7.2

When Q&T steels are bent with heat assistance, perform MT or dye penetrant testing (PT) after the steel has cooled to verify that no surface cracks resulted from the procedure.

5.8—HEAT TREATMENT

C5.8

Heat treatment is not usually stipulated in fabrication specifications, though AASHTO/AWS D1.5M/D1.5 has a procedure for stress relief of weldments. If heat treatment other than the stress relief of weldments provided in AASHTO/AWS D1.5M/D1.5 is required, it should be fully defined in the contract.

5.8.1

When thermal stress relief is required by the contract or requested by the Fabricator and approved for the project, follow AASHTO/AWS D1.5M/D1.5 requirements.

5.8.2

When normalizing and annealing are required, follow the requirements of ASTM E44. Maintain temperature uniformly throughout the furnace during heating and cooling so that the temperatures at all points on the member do not differ by more than 120° F (50° C).

SECTION 6

MEMBER GEOMETRY

6.1—GENERAL

6.1.1

As-received rolled shapes, plates, bars, and other applicable items must satisfy the quality requirements and dimensional tolerances in ASTM A6 or other applicable code requirements.

6.1.2

Fabricate built-up members in accordance with AASHTO/AWS D1.5M/D1.5 tolerances and as described below.

6.1.3

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

6.2—SUBSTRUCTURE MEMBERS

6.2.1

Fabricate steel pier caps and other substructure elements based upon mutual agreement between the Contractor and the Engineer regarding bearing plane and twist tolerances, with proper regard for erection requirements.

C6.2—SUBSTRUCTURE MEMBERS

Box girders used as bent caps generally sit on two or more bearings, and framing beams may in turn sit on bearing surfaces that are part of the girders. The box girder bearing surfaces must be true to each other for proper fit in the field. This specification does not provide tolerances for bearings oriented perpendicular to each other or in different planes because the amount of offset allowable is a function of the torsional stiffness of the box and many other factors. Proper seating may be further complicated by field conditions. Together, the Contractor and Fabricator are responsible for the fit of the structure in the field. Therefore, this specification requires that the completed structure satisfy the design requirements, but does not provide specific fabrication tolerances.

6.3—SPECIALTY STRUCTURES

6.3.1

Fabricate component parts of specialty structures, such as bascule, arch, suspension, cable-stayed, and truss bridges, to the preceding tolerances as applicable.

6.3.2

At a prefabrication meeting with the Contractor, Owner, and Erector, establish critical dimensions and tolerances required for proper installation and performance of the structure.

C6.3.2

A prefabrication meeting should be held to establish critical dimensions and tolerances necessary to meet erection and design requirements. This helps ensure final acceptance after construction. Special requirements or tolerances not fully defined in the contract can be resolved at the meeting.

6.4—PINS, PINHOLES, AND ROCKERS

6.4.1

Bore pinholes true to the specified diameter, smooth to ANSI 125 μin. (3 μm), at right angles with the axis of the member, and parallel with each other.

6.4.2

Fabricate pins and pinholes so that the pinhole diameter does not exceed the pin diameter by more than 0.02 in. (0.5 mm) for pins 5 in. (125 mm) or less in diameter, or $^{1}/_{32}$ in. (1 mm) for larger pins.

SECTION 7

BRIDGE GEOMETRY

7.1—ASSEMBLY

C7.1

Assembly—Drilling or reaming connection holes to final size with members in assembly has historically been used to ensure proper fit in the field. However, using advanced technology and techniques, some fabricators can achieve accurate field fit without shop assembly. The Engineer should consider waiving requirements for shop assembly if the Fabricator can consistently achieve proper fit of the members by other documented, demonstrated methods. Periodic check assemblies may be mandated to verify continuing accuracy, especially with highly complex structures.

The following discussion of assembly methods is to facilitate communication between owners, contractors, and subcontractors. The Owner should seek input from the construction community before requiring a special complete structure assembly.

Progressive Beam, Girder Arch Rib or Truss Assembly—Successive assemblies include at least one “carry-over” longitudinal segment (truss panel, arch section, or longitudinal member) of the previous assembly, repositioned for accurate alignment (i.e., providing the advancing assembly the proper relative rotation, horizontal, and vertical position), plus one or more longitudinal segments at the advancing end. For entire structures with lengths up to 150 feet [45 m], assembling the entire line or truss side is recommended.

Normally, transverse members are not included in the longitudinal assembly unless required in the contract documents or they are an integral part of the longitudinal assembly. If the contract requires shop-assembling specific transverse elements, either to complete their own connections (e.g., a rigid frame steel pier), or for connections involving longitudinal members (e.g., full-depth diaphragms for box girders creating an integral pier), separate subassemblies including only directly affected longitudinal elements should be permitted. Account for end rotations and deflections as necessary.

Progressive Chord Assembly—Similar to progressive truss assembly, except that the holes in truss connections are located to provide the final desired geometry. Vertical and diagonal truss panel members have connections to each truss chord made separately, based on calculated deflections, so top and bottom chords are not placed in a concurrent shop assembly. This requires that the truss members, when erected in a supported condition, must be forced to fit the end conditions. This condition introduces an initial reverse secondary stress that theoretically disappears when the structure carries its own weight and members become straight.

Special Complete Structure Assembly—When required in the contract documents, this will include simultaneously shop-assembling all structural steel, including the diaphragms, cross frames, integral steel substructure, and floor components. Miscellaneous components are not included unless specified in the contract documents. The Contractor establishes procedures for each structure or structure type including consideration of expected field conditions such as incremental erection, temporary support locations, stage construction, and final tightening of field connections.

Computer-Numerically-Controlled (CNC) Drilling with Progressive Girder, Truss, or Chord Assembly—If the Fabricator chooses to drill full-size holes in all plies of primary connections using CNC drilling procedures, assembly including both adjacent members should not be required, subject to the following:

1. Before continuing the practice, perform a check fit of the first three panels, segments or longitudinal chords; or of the entire first bent, tower face, or rigid frame produced to verify the accuracy of the CNC procedures and equipment.
2. As selected by the Engineer and before acceptance for shipping, perform another check fit of a second assembly to verify that the accuracy of the CNC procedures and equipment is being maintained.

If either of the above fails to meet the requirements, determine the source of the problem and verify correction by additional check assemblies to the satisfaction of the Owner, or revert to traditional assembly techniques. If problems are found by the second check fit, previously completed connections shall be checked to define the extent of the problem and correct errors to the Owner's satisfaction.

7.1.1

Follow an approved procedure that complies with the camber or blocking diagram shown on the approved shop drawings and describes the full or progressive assembly sequence.

C7.1.1

"Laydown" is a term used to describe the process of assembling members to match their theoretical, undeflected geometry (as opposed to the geometry of individual pieces). The term originated from the way I-girders are usually handled, with girders lying on their sides, thereby avoiding dead-load deflections. However, it is not mandatory that girders be horizontal during laydown, as long as they are supported in the no-load condition. Tub girders, for example, are generally assembled upright.

7.1.2

Assemble members from bearing to bearing at one time unless another method of sequential geometry control is described in the approved procedure.

C7.1.2

Complete shop assembly is generally only necessary for very complex or precise structures, but not for routine simple or continuous span girder structures. "Complex" may include structurally indeterminate frames and ballast-plated through-girder railroad bridges. "Precision" structures may include moveable bridges, such as bascule and swing spans requiring exact alignment for proper functioning. When the Engineer considers complete assembly to be necessary, this should be fully defined in the contract. The Engineer should contact local Fabricators for help in determining when complete assembly may be necessary.

Owners often require a three-girder assembly, incorporating at least three members in each assembly. This requirement comes from the AASHTO *LRFD Bridge Construction Specifications*. In the early days of steel bridges when members were shorter, entire girder lines would be laid down in the shop. Then, as members got longer, the norm became five, and then, finally, three. For many steel bridges, even three is difficult, especially for curved girder bridges, for which the assembly of just two members may require extensive shoring and vertical or horizontal clearance. The number of girders in a laydown is not important as long as the Fabricator has a system to accurately maintain proper geometry for key points in each assembly.

7.1.3

Complete welding (except shear connectors) and cutting of individual pieces prior to assembly.

C7.1.3

Studs must often be applied in the field because of local safety restrictions and OSHA regulations.

7.1.4

Assemble continuous rolled beam, I-girder, and box girder lines to the required geometry and prepare primary member splices.

7.1.5

Include primary members in assembly, except for transverse bracing (diaphragms, crossframes, etc.) for curved plate girders or beams. Including transverse bracing or secondary members in the assembly is not required unless mandated by the contract.

C7.1.5

Transverse bracing, e.g., cross frames, rolled shape diaphragms, plate diaphragms, lateral bracing, is typically not necessary to be assembled with the primary members. Generally, the connections of these members are planar, and the accuracy to which they are built is sufficient to maintain fit. The primary members are set up for grade and line. This validates the geometry of the primary members. The stiffeners (or other connections) are generally accurate in their placement and manufacture. If the primary members are built and assembled within tolerance, and the transverse bracing is fabricated within tolerance, this will generally produce pieces that will erect with no problems.

There are exceptions to this rule. Lateral bracing that is connected to gusset plates bolted to the flange of the girders typically uses oversized holes in one ply of the connection. This is to mitigate the difference in tolerances in sweep between girders. If two adjacent bays of cross frames or diaphragms are connected to the girder flange and each other via a moment plate, assembly of this connection, but not necessarily the entire structure, may be prudent. This also may vary with the use of oversized holes. Full-depth plate diaphragms generally do not require assembly with the primary members. With the advent of CNC machinery and the use of hardened bushing templates, fit-up problems with these connections have greatly diminished. Specifying the method of hole placement (CNC or drill templates) is preferred over assembling the connection. The exception to the full-depth plate diaphragm assembly would be if the diaphragm is used as the terminus of a discontinuous girder, or if the diaphragm connects to both flanges. Again, the strategic use of oversized holes may eliminate the need for assembly.

7.1.6

Support members in a no-load condition unless compensation for member dead loads is described in the approved procedure.

7.1.7

Bring members into proper alignment, satisfying the camber or blocking diagram, and secure all parts prior to drilling or reaming.

7.1.8

Use drift pins to align parts, but do not enlarge the holes or otherwise distort the metal.

7.1.9

When it is necessary to retain splice or fill plates in specific positions and orientations, such as in connections reamed or drilled in assembly, match-mark all components prior to disassembly. Provide diagrams showing match marking method and location on the approved shop drawings. Produce match marks using low- or mini-stress steel stamps. Other means may be used if they have been demonstrated by test to meet Fatigue Category B.

C7.1.9

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-792F(SH) 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 Category B.

7.2—BOLTED SPLICES

Provide holes for primary member connections that satisfy these workmanship tolerances:

- 85 percent of the bolt holes in any adjoining group vary no more than $^{1}/_{32}$ in. (1 mm) between adjacent thicknesses of metal and a bolt of the size specified for the connection can be inserted in every hole.
- The gap between ends of continuous girders or beams is ¼ in., +⅛, – $^{3}/_{16}$ (6 mm, +3, −4).

C7.2

A zero gap between members would impede field assembly, especially if steel is subsequently primed, and is not permitted. If members are hot-dip galvanized after splices are drilled, holes may need to be reamed or otherwise cleaned and drips or runs on member ends may need to be ground to avoid interference during assembly.

7.3—WELDED FIELD SPLICES FOR ROLLED BEAMS

For full-depth welded shop splices, prepare the ends of beams in accordance with Figure 7.3.1-1.

C7.3

The detail in Figure 7.3.1-2 might also be considered in the rare case that a full-depth shop splice of a built-up girder is required.

7.4—WELDED FIELD SPLICES

C7.4

These provisions address shop-required work for field-welded connections in primary members. The actual accomplishment of the connections is beyond the scope of this specification. The webs may be restrained by hand-installed devices while checking compliance with the tolerances of Sections 7.4.1 and 7.4.3.

7.4.1

For field-welded splices, prepare the ends of beams and girders in accordance with Figure 7.3.1-2.

7.4.2

Assemble girders to demonstrate that workmanship requirements of AASHTO/AWS D1.5M/D1.5 are satisfied.

7.4.3

Prepare joints in accordance with the alignment tolerances of AASHTO/AWS D1.5M/D1.5 clause 3.3.4. Prepare the access hole so that the sloping transition is tangent to the joint bevel.

7.5—ALTERNATE GEOMETRY CONTROL METHODS

Fabricators may propose alternate methods of geometry control for continuous girder bridges based on demonstrated accuracy that precludes the necessity for assembly

C7.5

Fabricators may use CNC equipment, "virtual assembly," or other formalized methods to establish member geometry and prepare connections so that shop assembly may be avoided or reduced. Avoiding assembly offers many production benefits, but the Engineer should be satisfied that proper fit will be achieved before authorizing alternate methods. Accuracy may be verified by assembling the first elements drilled and periodically checking assemblies thereafter, or by successful accomplishment of other work. The number of verification assemblies should be based on the variety of connection details and member sizes in a project, and on previously demonstrated success with the equipment, software and shop personnel. See Section 4.6 for quality requirements. Whether or not assembly is performed, the Contractor remains responsible for the fit of the structure in the field.

7.6—TRUSSES, ARCHES, AND FRAMES

C7.6

Field-bolted frame structures may have shop connections successfully accomplished with sequential partial assemblies. For example, a truss panel in the horizontal (no load) position may have all verticals and diagonals drilled or reamed while joined with the top chord elements, and then the verticals and diagonals drilled or reamed in a separate assembly with the bottom chord elements. Aligning the elements to compensate for anticipated displacements within the erected truss permits the verticals and diagonals to be straight in the final, full dead-load condition. This will require diagonal members to be distorted during erection, but will significantly reduce residual stress in those members. As for other structure types, use of CNC equipment and other advanced methods may preclude the need for physical assembly altogether.

7.6.1

Fabricate abutting truss chord joints considered to be close joints so that no openings are larger than ¼ in. (6 mm).

7.6.2

Bring milled and compression abutting joints in arches and truss chords into bearing and demonstrate that 75 percent of the abutting surfaces are in full bearing.

7.6.3

Shop-assemble entire units or propose an alternate geometric assembly procedure.

C7.6.3

For trusses, provide an assembly procedure that ensures components are aligned within tolerances under the steel's self weight. For trusses and arches, simultaneously shop assemble as many sections as practical, providing positive, documented geometric controls to ensure subsequent carry-over assemblies will fit within applicable tolerances.

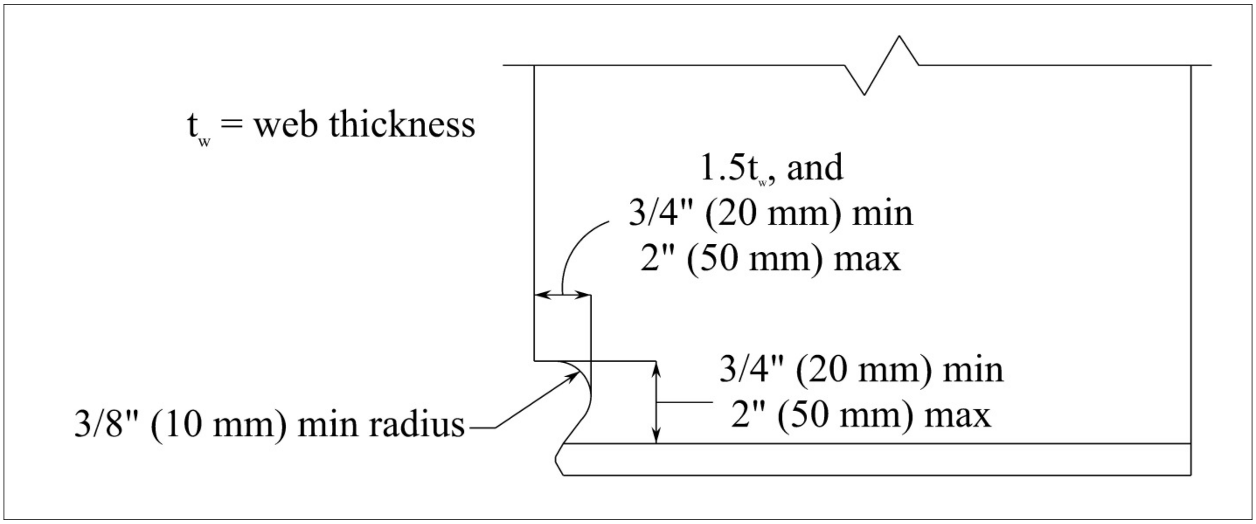

Figure 7.3.1-1—Shop Welded Splice Details

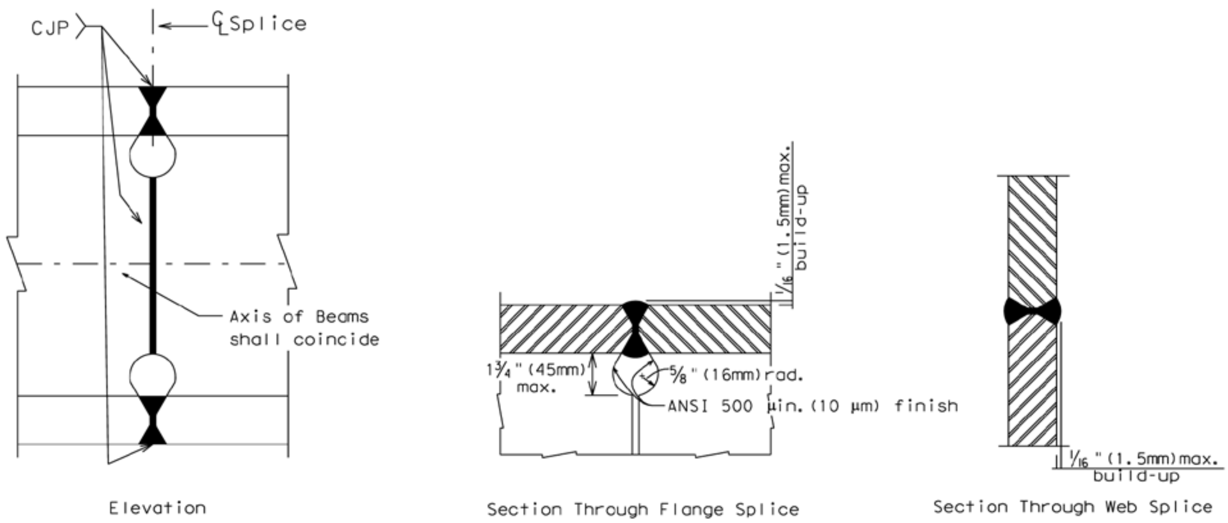

Figure 7.3.1-2—Field Welded Splice Details