NSBA Guide to Navigating Routine Steel Bridge Design

Domenic Coletti, PE

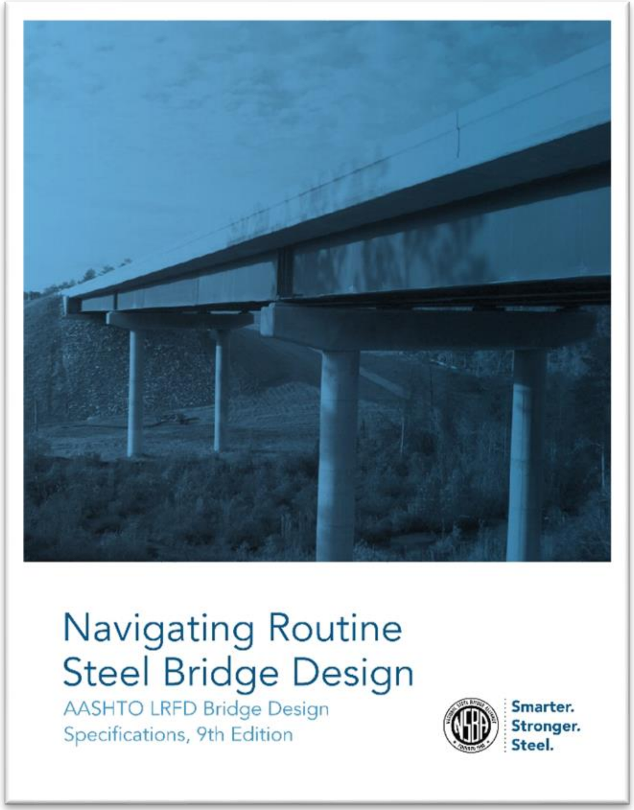
Agenda

Background of the Guide

Concept for the Guide

Content of the Guide

Summary



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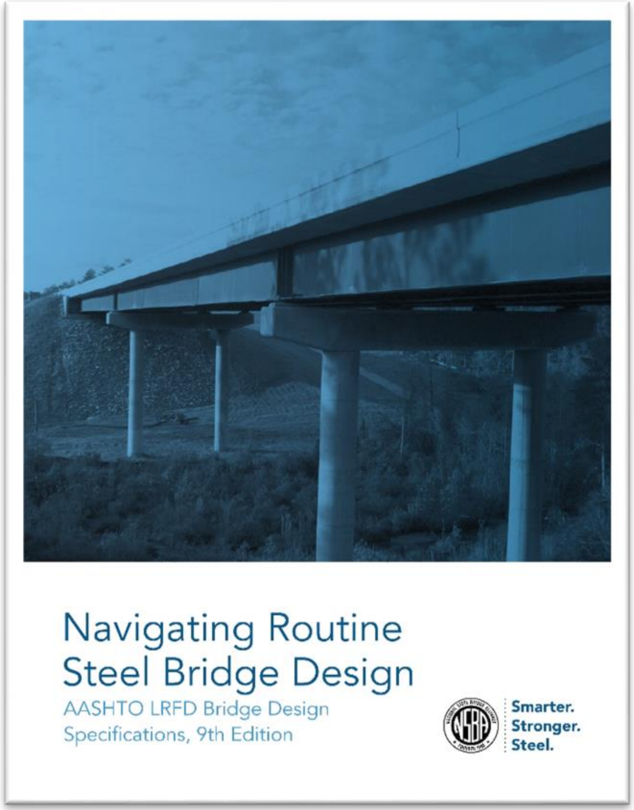

Background of the Guide

The current situation…

- The AASHTO LRFD BDS is comprehensive
- The AASHTO LRFD BDS is thick (1900+ pages)
- The AASHTO LRFD BDS is a bit overwhelming
- Not everything in the BDS applies to every structure

Bottom line…

- A way to identify just the provisions applicable to routine steel I-girder bridge design would be nice

Background of the Guide

Result

- AISC hired HDR in 2019 to create a guide
- *NSBA Guide to Navigating Routine Steel Bridge Design*

Authors

- Mike Grubb (MA Grubb & Associates)
- Domenic Coletti (HDR)
- Tony Ream (HDR)
- Al Nelson (HDR)

Peer Reviewers

- Too many to name… representatives from NSBA, owner-agencies, and both large and small consulting design firms

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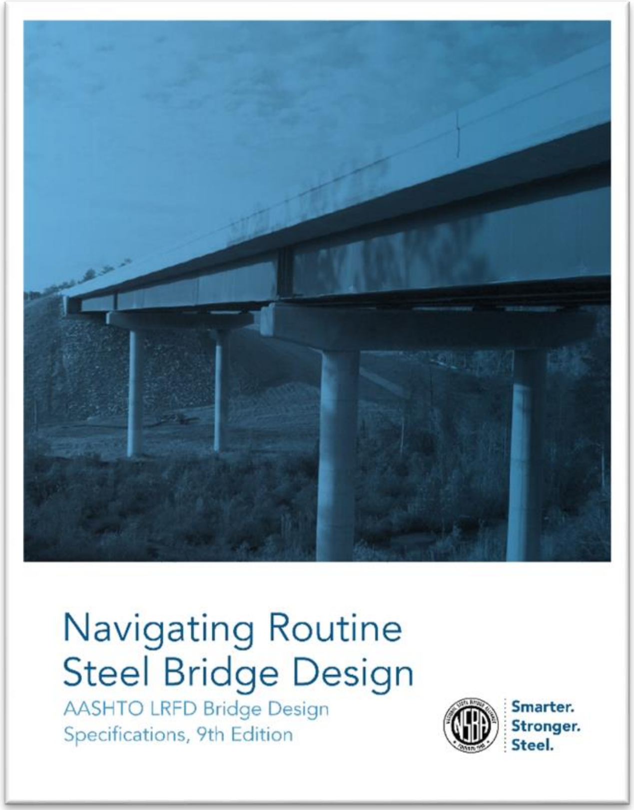

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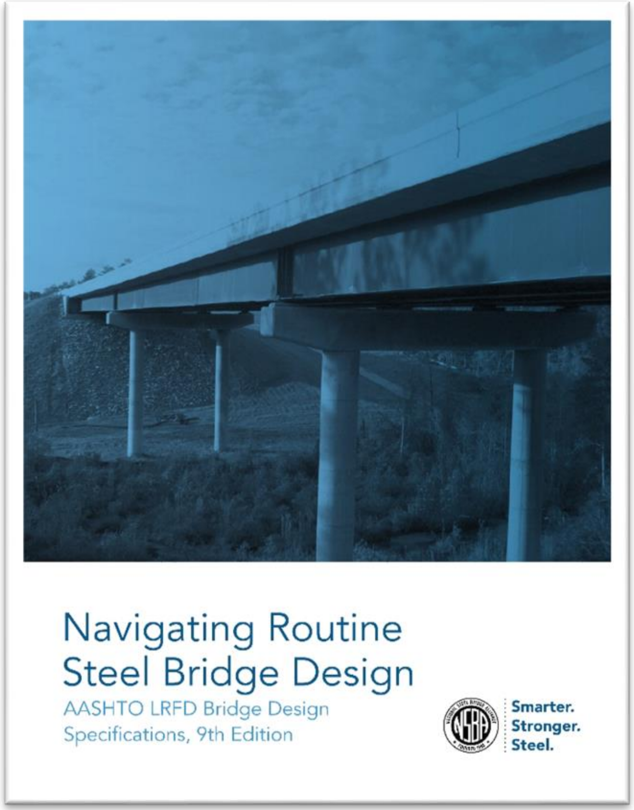

Concept for the Guide

Basic Themes

- Filter for the AASHTO LRFD BDS
- Discussion of the AASHTO LRFD BDS
- Audience = designers with less steel bridge experience

Concept for the Guide

Key Ideas

- Definition of a “Routine Steel I-Girder Bridge”
- Applicability Determinations
- Discussions
- The role of the Guide vs. the BDS

Concept for the Guide

Definition of a "Routine Steel I-Girder Bridge"

- Straight girders, straight deck, little or no skew
- Constant width, constant depth
- Spans < 200'
- Stringer-type cross-section with at least 4 girders
- Contiguous truss-type cross-frames or solid diaphragms
- Composite concrete deck
- **LINE GIRDER ANALYSIS**

Concept for the Guide

Definition of a “Routine Steel I-Girder Bridge”

DEFINITION CHECKLIST FOR A “ROUTINE STEEL I-GIRDER BRIDGE”

Answer all questions with “Yes” or “No”. If any questions are answered “No”, the bridge does not satisfy the definition of a routine steel I-girder bridge for the purposes of this Guide. For further detail on any of these criteria, please see the preceding section of the Guide: DEFINITION OF A “ROUTINE STEEL I-GIRDER BRIDGE”

If a given bridge somehow falls partially outside the limits of the definition of a “routine steel I-girder bridge”, or outside the exclusions of this scope, this Guide may still provide value to designers; in such cases, senior bridge engineers with extensive experience in steel bridge design should be consulted when determining if and how to apply any of the recommendations provided herein.

- ☐ Are the girders straight (non-curved)?
- ☐ Is the deck straight?
- ☐ Is the skew not more than 20 degrees?
- ☐ Are all supports parallel (or within 10 degrees of being parallel)?
- ☐ Are the cross-frames contiguous?
- ☐ Are the girders parallel?
- ☐ Is the deck constant width?
- ☐ Is the Skew Index (Eq. 4.6.3.3.2-2) less than or equal to 0.30?
- ☐ Do the girders have a constant web depth?

Concept for the Guide

Definition of a "Routine Steel I-Girder Bridge"

Concept for the Guide

Definition of a "Routine Steel I-Girder Bridge"

Concept for the Guide

Definition of a "Routine Steel I-Girder Bridge"

Concepts of the Guide

Applicability Determinations

The various Determinations are defined as follows:

1. **Applicable:** The Article, in its entirety, is fully applicable to the design of routine steel I-girder bridges
2. **Partially Applicable:** Parts of the Article are applicable to the design of routine steel I-girder bridges, other parts are not applicable; see the Discussion for explanation
3. **Conditionally Applicable**: Some or all of the Article may be applicable to the design of routine steel I-girder bridges depending on the circumstances; see the Discussion for explanation
4. **Not Applicable:** None of the Article is applicable to the design of routine steel I-girder bridges
5. **Beyond Scope of Superstructure Design:** Some or all of the Article may be applicable to some aspect of the design of routine steel I-girder bridges, but is not applicable to superstructure design; see the Discussion for explanation

Concepts of the Guide

Discussions

- Guide "Discussions" are differentiated from AASHTO "Commentary"
- Discussions explain why the Determination is what it is
- Discussions offer helpful application suggestions
- Discussions include references and links to other industry design guidelines and design aids

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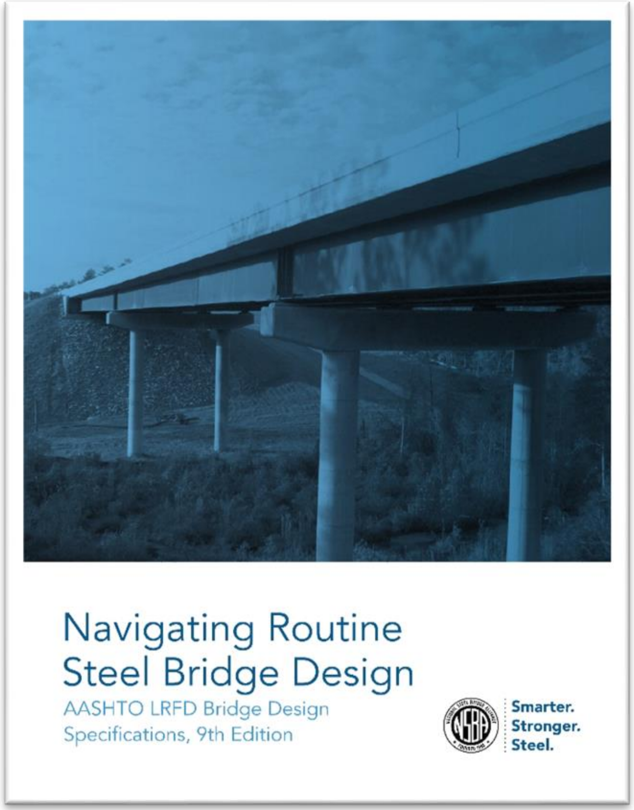

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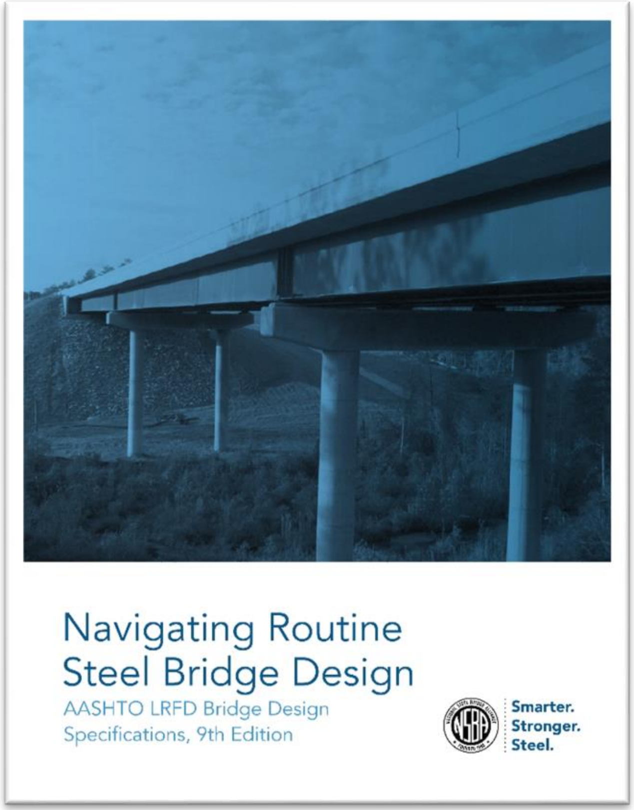

Content of the Guide

Delivery Formats

- PDF of the Guide
  - Use as an interactive design aid
  - Index of design tasks
  - Design Task Quick Links
  - Internal hyperlinks and bookmarks to aid navigation
  - External hyperlinks to many free resources
- Eventual web-based interactive design aid

Content of the Guide

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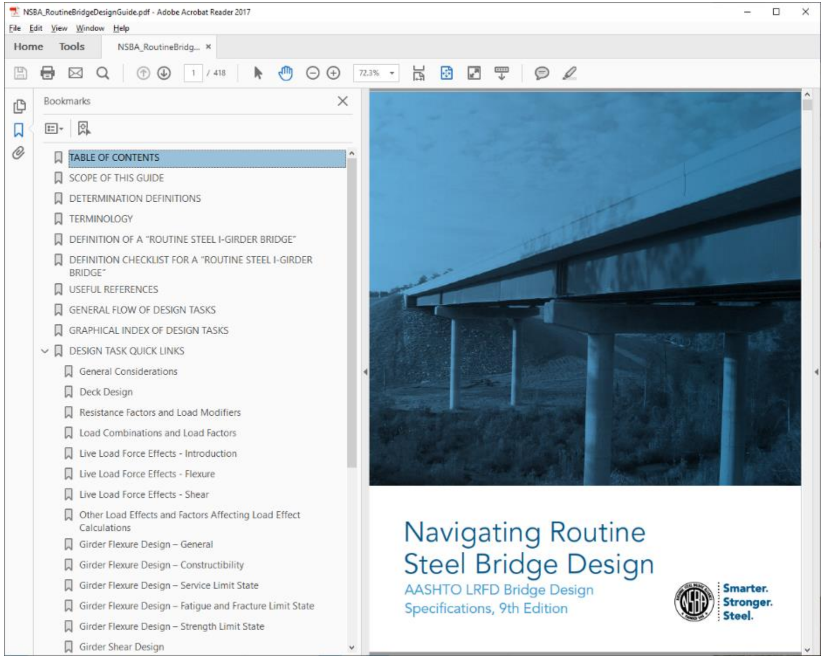

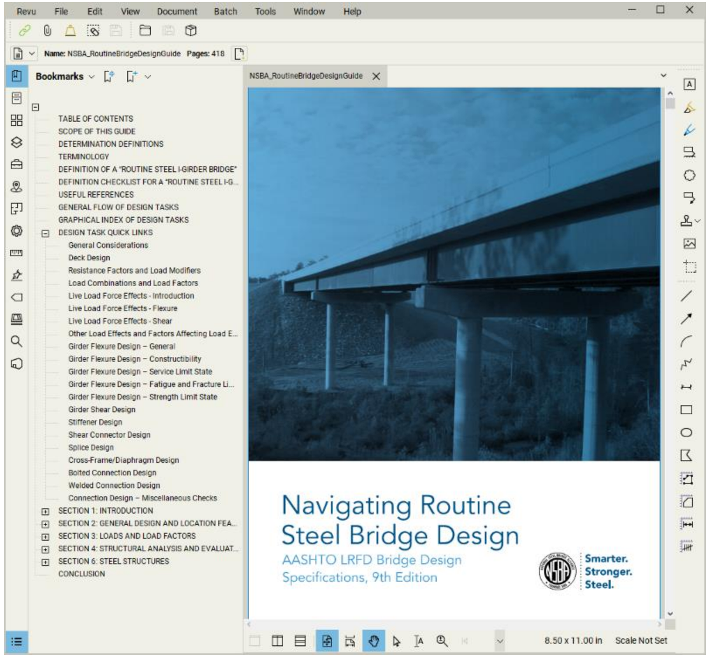

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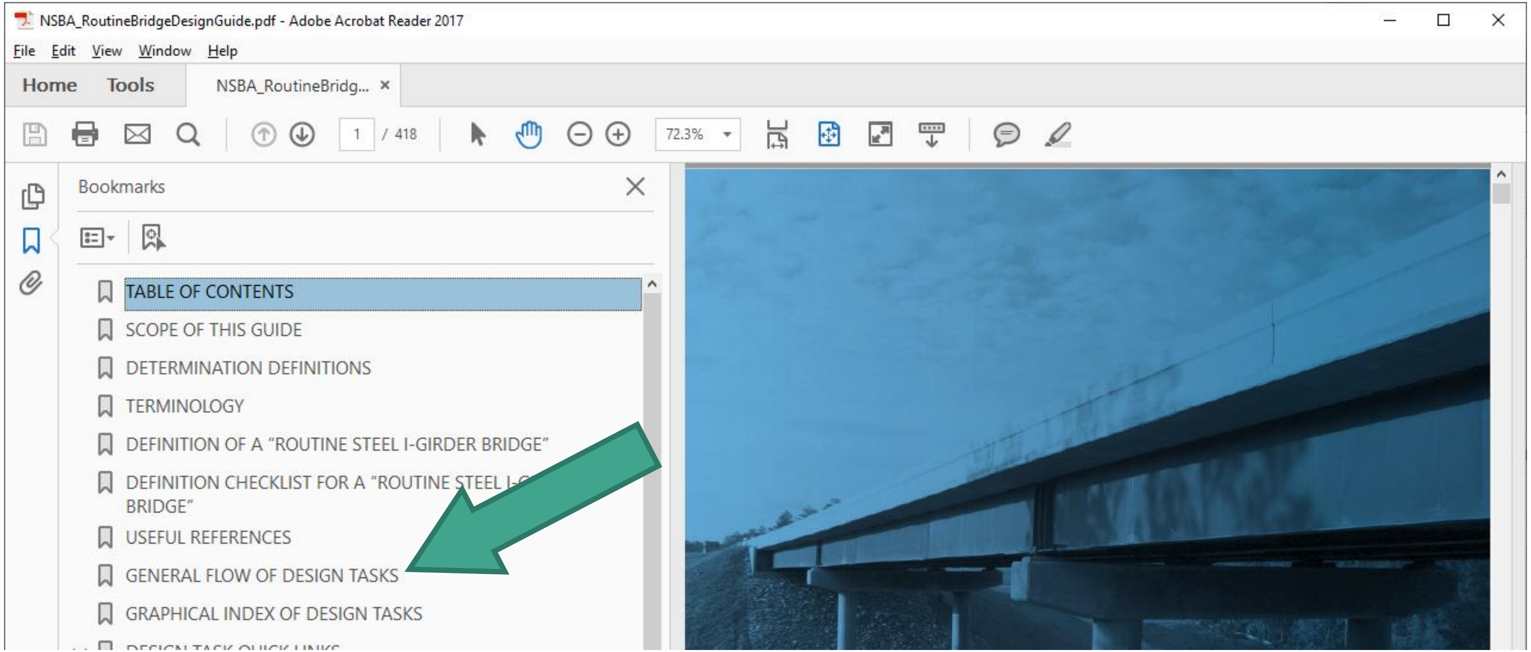

Content of the Guide

General Flow of Design Tasks

GENERAL FLOW OF DESIGN TASKS

Listed below are the general Design Tasks associated with the typical flow of design of a routine steel I-girder bridge superstructure. The list of Design Tasks is presented in roughly the typical order that they occur in the superstructure design process. However, as noted below, some topics apply to several Design Tasks. And, of course, the process of designing a bridge typically involves some degree of iteration; the initial results of later Design Tasks may suggest that revising part of the design which occurred earlier in the process might be beneficial. When iterating through a design in this manner, the designer is reminded that all steps of the design process should be checked to see if the revision of one part of the design might affect other parts. Each task/topic below is hyperlinked to its associated Design Task Quick Links page.

General Flow of Design Tasks:

1. General Considerations
2. Deck Design
3. Resistance Factors and Load Modifiers
4. Load Combinations and Load Factors
5. Live Load Force Effects - Introduction
6. Live Load Force Effects - Flexure
7. Live Load Force Effects - Shear
8. Other Load Effects and Factors Affecting Load Effect Calculations
9. Girder Flexure Design – General
10. Girder Flexure Design – Constructibility
11. Girder Flexure Design – Service Limit State
12. Girder Flexure Design – Fatigue and Fracture Limit State
13. Girder Flexure Design – Strength Limit State
14. Girder Shear Design
15. Stiffener Design
16. Shear Connector Design
17. Splice Design
18. Cross-Frame/Diaphragm Design

Topics Which May Apply to Several Design Tasks:

- Bolted Connection Design
- Welded Connection Design
- Connection Design – Miscellaneous Checks

Content of the Guide

Design Task Quick Links pages

SPLICE DESIGN

Quick links to applicable AASHTO LRFD BDS provisions, with Discussion

Design field splices (if present), considering the following:

- Bolted field splices of flexural members
  - General considerations (6.13.6.1.3a)
  - Flange splices (6.13.6.1.3b)
  - Web splices (6.13.6.1.3c)
- Welded splices (6.13.6.2)
- Minimum thickness requirements (6.7.3)

Determine flange sizes and locations of welded shop splices, considering the following:

- Welded splices (6.13.6.2)
- Minimum thickness requirements (6.7.3)

Quick links to helpful industry design guidelines, references, and examples

For more explanation and examples of field splice design, see:

- The Reference Manual for NHI Course 130081, Load and Resistance Factor Design (LRFD) for Highway Bridge Superstructures
  - Sections 6.6.5 (Splices), especially 6.6.5.2 (Flexural Members) (NOTE: The explanations in these references are written in the context of the bolted field splice provisions prior to publication of the 8th Edition of the AASHTO LRFD BDS and are thus out of date).
- The AASHTO-NSBA Steel Bridge Collaboration Guidelines G12.1-2020 Guidelines to Design for Constructability and Fabrication
  - Section 1.5.3 (Flange Plate Width) and Table 1.5.2.A, Section 2.2.1 (Field Connections)
- NSBA's Bolted Field Splices for Steel Bridge Flexural Members – Overview and Design Examples

Quick links to useful tools

The NSBA Splice Microsoft Excel-based bolted field splice design spreadsheet is available for free download from the NSBA website is also a valuable tool for the design of routine steel I-girder bridges. It performs the design of a bolted field splice for a steel I-girder in accordance with the provisions of Article 6.13.6.1.3, greatly reducing the time and effort required of the designer. Other commercial software packages with the ability to design bolted field splices are also available.

Users should verify the capabilities, assumptions, and general correctness of any program's calculations prior to initial use.

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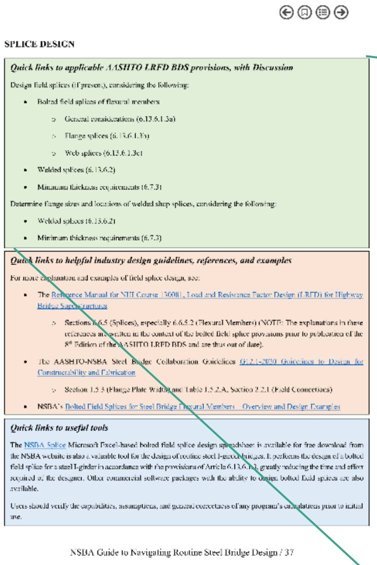

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6.13.6.1.3 Flexural Members

6.13.6.1.3a General

Determination of applicability, *All Routine Steel I-girder Bridges*: Applicable.

Discussion:

A splice is defined as a group of bolted connections (or a welded connection) sufficient to transfer the moment, shear, axial force or torque between two structural elements joined at their ends to form a single, longer element. Bolted splices are typically used to connect member sections together in the field; hence, the term "field splice" is often used. The provisions of this Article cover general provisions for the design of bolted field splices for members subject to flexure, and hence, are applicable to the routine steel I-girder bridges covered by this Guide.

Bolted beam or girder field splices generally include top flange splice plates, web splice plates and bottom flange splice plates. In addition, if the plate thicknesses on one side of the joint are different than those on the other side, filler plates are used to match the thicknesses within the splice (see the Discussion of Article 6.13.6.1.4 in this Guide). For the flange splice plates, there is typically one plate on the outside of the flange and two smaller plates on the inside of the flange; one on each side of the web. For the web splice plates, there are two plates; one on each side of the web, with at least two rows of high-strength bolts over the depth of the web used to connect the splice plates to the member.

As required by Articles 6.13.6.1.3b and 6.13.6.1.3c, bolted flange and web splice connections are

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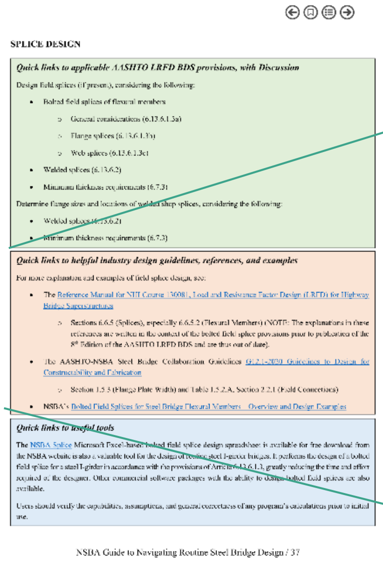

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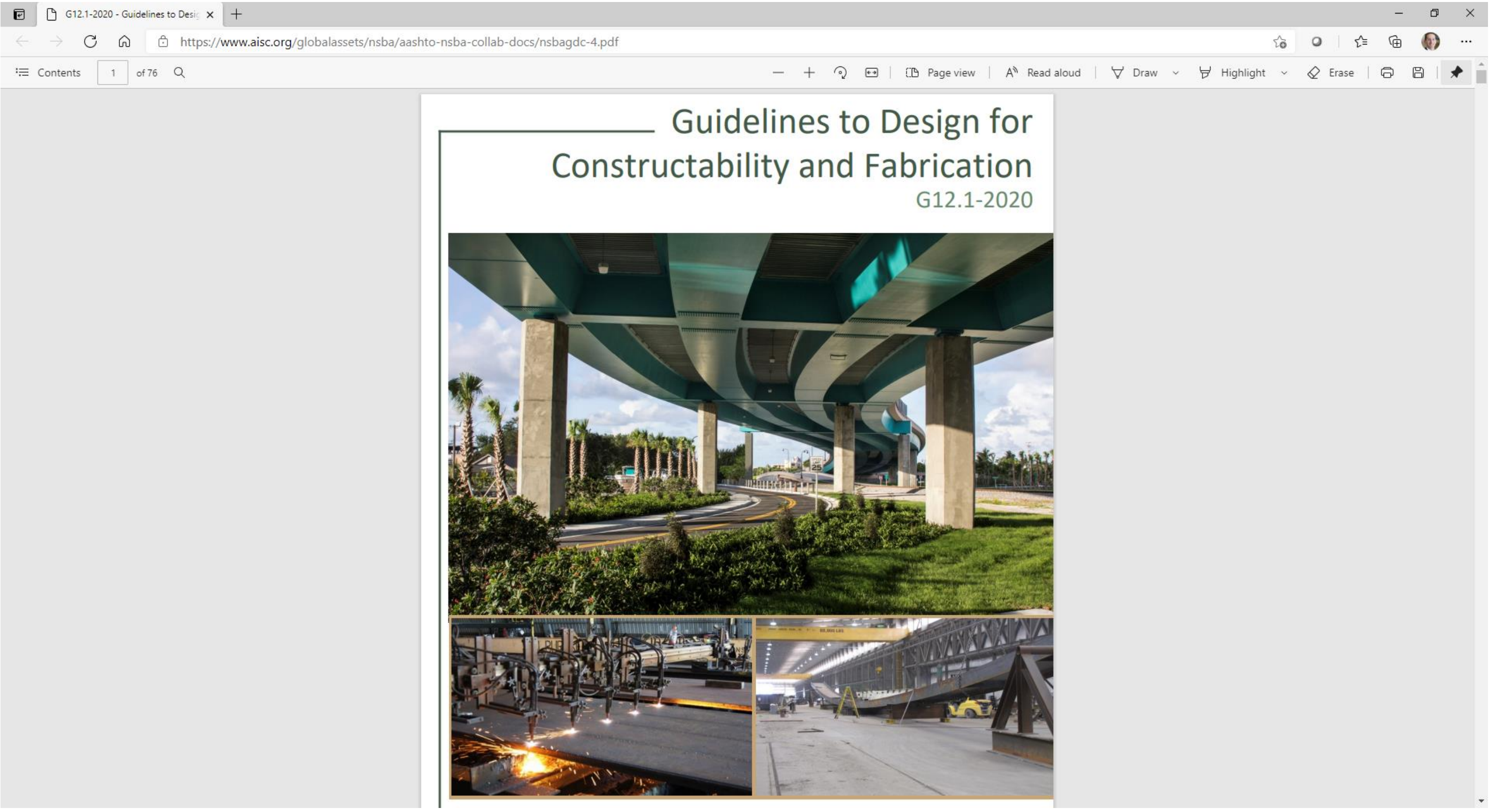

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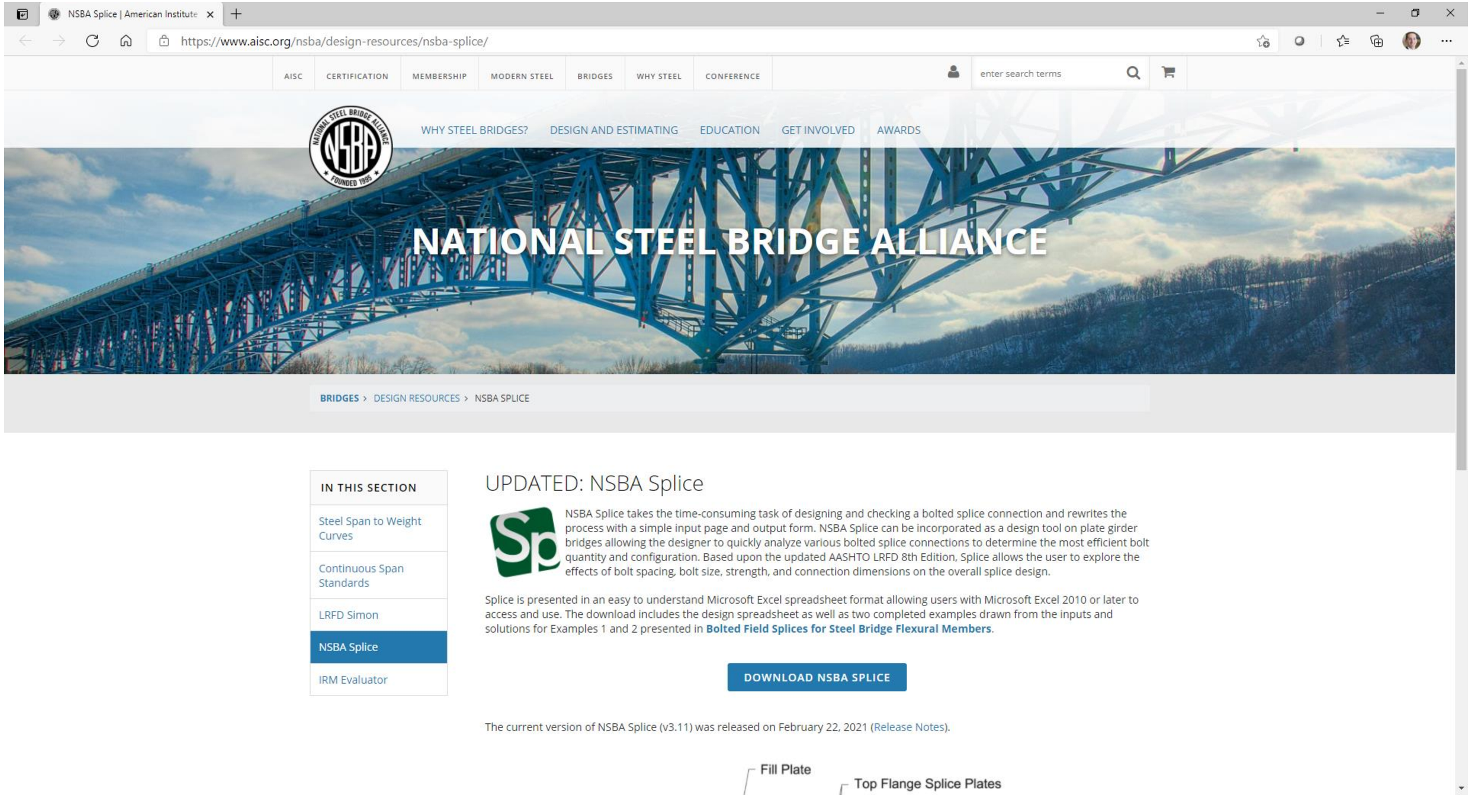

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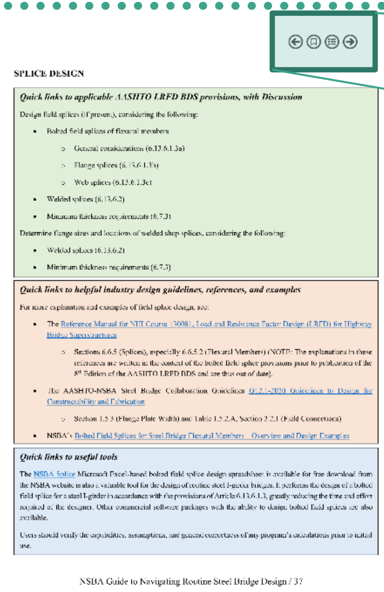

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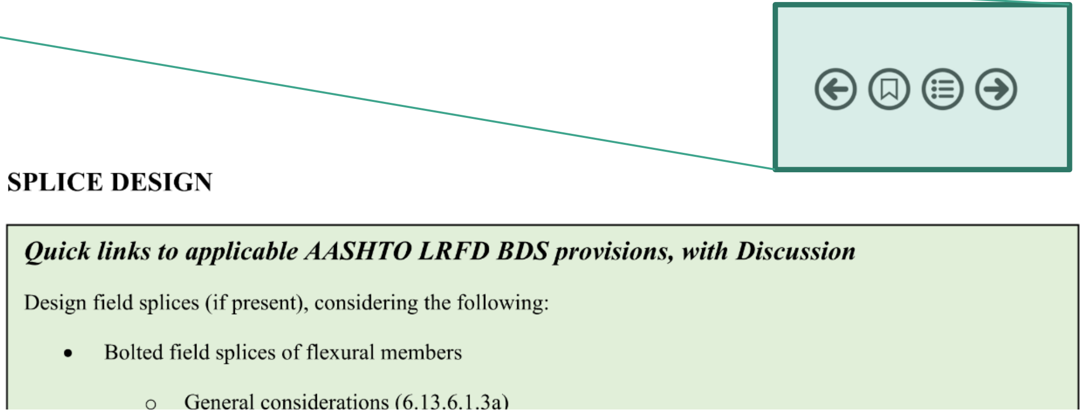

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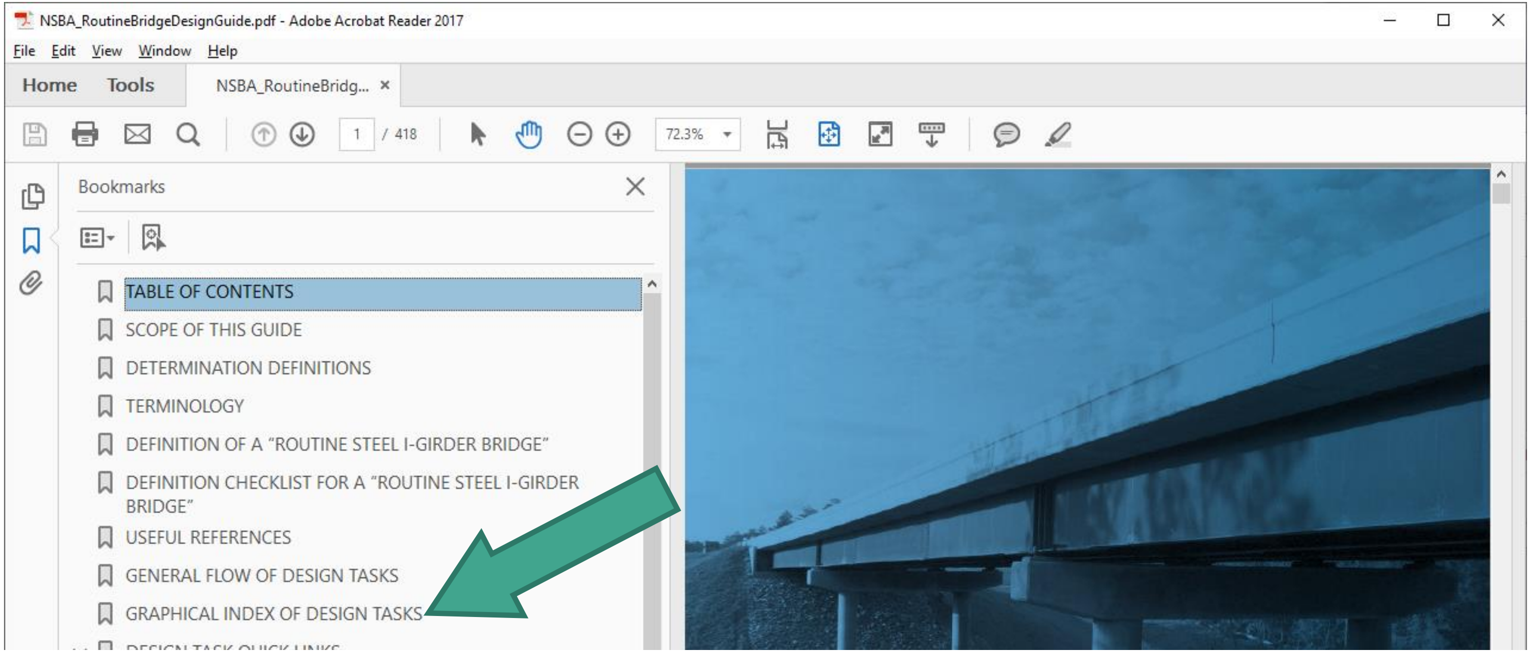

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Graphical Index of Design Tasks

GRAPHICAL INDEX OF DESIGN TASKS

The general Design Tasks associated with the typical steps in the design of a routine steel I-girder bridge superstructure are grouped graphically below. Each task/topic is hyperlinked to its associated Design Task Quick Links page.

General Considerations

General considerations prior to beginning detailed superstructure design include understanding the LRFD design philosophy and the concept of limit states design, selecting basic design parameters such as target girder depth and spacing, identifying superstructure materials, and deciding whether or not to make the deck composite with the girders. The following Design Tasks apply – each task is hyperlinked to its associated Design Task Quick Links page.

- General Considerations

Deck Design

The design of decks for routine steel I-girder bridges is beyond the scope of this Guide; see the Owner-agencies design policy manual for standard deck designs or guidance on acceptable deck design methods, or design the deck per the provisions of Chapter 9 of the AASHTO LRFD BDS. The following Design Tasks apply – each task is hyperlinked to its associated Design Task Quick Links page.

- Deck Design

Loads

The identification and calculation of various load effects is typically accomplished early in the design process. It is difficult to design the superstructure of a routine steel I-girder bridge if the applicable loads are not known. The process of determining those loads begins with identification of the applicable limit states, definition of their associated load combinations, and quantification of the various load modifiers and load factors. Resistance factors are typically identified and quantified as well. Then the specific loading effects are calculated. The following Design Tasks apply – each task is hyperlinked to its associated Design Task Quick Links page.

- Resistance Factors and Load Modifiers
- Load Combinations and Load Factors
- Live Load Force Effects - Introduction
- Live Load Force Effects - Flexure
- Live Load Force Effects - Shear
- Other Load Effects and Factors Affecting Load Effect Calculations

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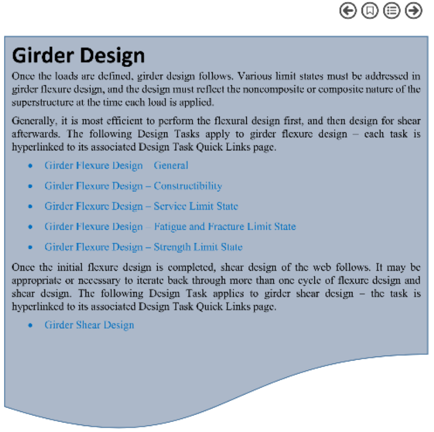


Girder Design

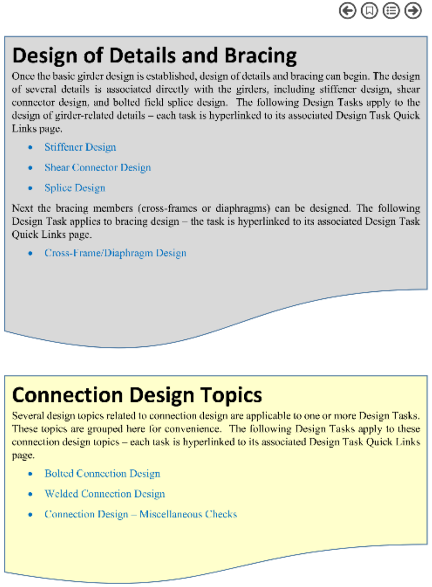
Once the loads are defined, girder design follows. Various limit states must be addressed in girder flexure design, and the design must reflect the noncomposite or composite nature of the superstructure at the time each load is applied.

Generally, it is most efficient to perform the flexural design first, and then design for shear afterwards. The following Design Tasks apply to girder flexure design – each task is hyperlinked to its associated Design Task Quick Links page.

- Girder Flexure Design – General
- Girder Flexure Design – Constructibility
- Girder Flexure Design – Service Limit State
- Girder Flexure Design – Fatigue and Fracture Limit State
- Girder Flexure Design – Strength Limit State

Once the initial flexure design is completed, shear design of the web follows. It may be appropriate or necessary to iterate back through more than one cycle of flexure design and shear design. The following Design Task applies to girder shear design – the task is hyperlinked to its associated Design Task Quick Links page.

- Girder Shear Design



Design of Details and Bracing

Once the basic girder design is established, design of details and bracing can begin. The design of several details is associated directly with the girders, including stiffener design, shear connector design, and bolted field splice design. The following Design Tasks apply to the design of girder-related details – each task is hyperlinked to its associated Design Task Quick Links page.

- Stiffener Design
- Shear Connector Design
- Splice Design

Next the bracing members (cross-frames or diaphragms) can be designed. The following Design Task applies to bracing design – the task is hyperlinked to its associated Design Task Quick Links page.

- Cross-Frame/Diaphragm Design

Connection Design Topics

Several design topics related to connection design are applicable to one or more Design Tasks. These topics are grouped here for convenience. The following Design Tasks apply to these connection design topics – each task is hyperlinked to its associated Design Task Quick Links page.

- Bolted Connection Design
- Welded Connection Design
- Connection Design – Miscellaneous Checks

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Graphical Index of Design Tasks

Girder Design

Once the loads are defined, girder design follows. Various limit states must be addressed in girder flexure design, and the design must reflect the noncomposite or composite nature of the superstructure at the time each load is applied.

Generally, it is most efficient to perform the flexural design first, and then design for shear afterwards. The following Design Tasks apply to girder flexure design – each task is hyperlinked to its associated Design Task Quick Links page.

- Girder Flexure Design – General
- Girder Flexure Design – Constructibility
- Girder Flexure Design – Service Limit State
- Girder Flexure Design – Fatigue and Fracture Limit State
- Girder Flexure Design – Strength Limit State

Once the initial flexure design is completed, shear design of the web follows. It may be appropriate or necessary to iterate back through more than one cycle of flexure design and shear design. The following Design Task applies to girder shear design – the task is hyperlinked to its associated Design Task Quick Links page.

- Girder Shear Design

General Flow of Design Tasks:

1. General Considerations
2. Deck Design
3. Resistance Factors and Load Modifiers
4. Load Combinations and Load Factors
5. Live Load Force Effects - Introduction
6. Live Load Force Effects - Flexure
7. Live Load Force Effects - Shear
8. Other Load Effects and Factors Affecting Load Effect Calculations
9. Girder Flexure Design – General
10. Girder Flexure Design – Constructibility
11. Girder Flexure Design – Service Limit State
12. Girder Flexure Design – Fatigue and Fracture Limit State
13. Girder Flexure Design – Strength Limit State
14. Girder Shear Design

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Design of Details and Bracing

Once the basic girder design is established, design of details and bracing can begin. The design of several details is associated directly with the girders, including stiffener design, shear connector design, and bolted field splice design. The following Design Tasks apply to the design of girder-related details – each task is hyperlinked to its associated Design Task Quick Links page.

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- Shear Connector Design
- Splice Design

Next the bracing members (cross-frames or diaphragms) can be designed. The following Design Task applies to bracing design – the task is hyperlinked to its associated Design Task Quick Links page.

- Cross-Frame/Diaphragm Design

SHEAR CONNECTOR DESIGN

Quick links to applicable AASHTO LRFD BDS provisions, with Discussion

Design shear connectors for the fatigue and strength limit states, considering the following:

- General provisions (6.10.10.1, 6.10.10.1.1, 6.10.10.1.2, 6.10.10.1.3, 6.10.10.1.4)
- Fatigue resistance (6.10.10.2)
- Special requirements for points of permanent load contraflexure (6.10.10.3)
- Strength limit state (6.10.10.4.1, 6.10.10.4.2, 6.10.10.4.3)

Quick links to helpful industry design guidelines, references, and examples

For more explanation and examples of the determination of the design of shear connectors at the fatigue and strength limit states, see:

- The Reference Manual for NHI Course 130122, Design and Evaluation of Steel Bridges for Fatigue and Fracture
  - Section 6.3.6.3 (Shear Studs)
- The Reference Manual for NHI Course 130081, Load and Resistance Factor Design (LRFD) for Highway Bridge Superstructures
  - Section 6.6.2 (Shear Connectors)
- FHWA's Steel Bridge Design Handbook
  - Design Example 1, Three-Span Continuous Straight Composite Steel I-Girder Bridge
  - Design Example 2A, Two-Span Continuous Straight Composite Steel I-Girder Bridge
  - Design Example 2B, Two-Span Continuous Straight Composite Steel Wide-Flange Beam Bridge

Quick links to useful tools

NSBA's LRFD Simon line-girder analysis and design software. Simon is available for free download from the NSBA website is also a valuable tool for the design of routine steel I-girder bridges. It performs design calculations addressing the demand on, and resistance of, shear connectors at the fatigue and strength limit states in accordance with the provisions of the AASHTO LRFD BDS, greatly reducing the time and effort required of the designer. Other commercial software packages with the ability to analyze and design routine steel I-girder bridges are also available.

Users should verify the capabilities, assumptions, and general correctness of any program's calculations prior to initial use.

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Graphical Index of Design Tasks

SHEAR CONNECTOR DESIGN

Quick links to applicable AASHTO LRFD BDS provisions, with Discussion

Design shear connectors for the fatigue and strength limit states, considering the following:

- General provisions (6.10.10.1, 6.10.10.1.1, 6.10.10.1.2, 6.10.10.1.3, 6.10.10.1.4)
- Fatigue resistance (6.10.10.2)
- Special requirements for points of permanent load contraflexure (6.10.10.3)
- Strength limit state (6.10.10.4.1, 6.10.10.4.2, 6.10.10.4.3)

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6.10.10.2 Fatigue Resistance

Determination of applicability, *All Routine Steel I-girder Bridges*: Partially applicable.

Discussion:

The provisions of this Article are used to determine the fatigue resistance of an individual shear connector, Z_r. Z_r is used in the calculation of the required pitch, p, at the fatigue limit state (Article 6.10.10.1.2). Only the provisions for stud shear connectors should be considered applicable to the routine I-girder bridges covered by this Guide.

When the 75-year single lane Average Daily Truck Traffic $(ADTT)_{SL}$ (Article 3.6.1.4.2) is greater than or equal to 1,090 trucks per day, the fatigue shear resistance for infinite life determined from Eq. 6.10.10.2-1 is used for Z_r. Otherwise, the fatigue shear resistance for finite life determined from Eq. 6.10.10.2-2 is used for Z_r. For a fatigue design life other than 75 years and/or a number of stress cycles per truck passage (n from Table 6.6.1.2.5-2) other than 1.0, see the specification Commentary for this Article.

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For more explanation and examples of the determination of the design of shear connectors at the fatigue and strength limit states, see Section 6.3.6.3 of Reference Manual for NHI Course 130122, Design and Evaluation of Steel Bridges for Fatigue and Fracture, Section 6.6.2 of Reference Manual for NHI Course 130081, Load and Resistance Factor Design (LRFD) for Highway Bridge Superstructures as well as FHWA's Steel Bridge Design Handbook, Design Example 1, Three-Span Continuous Straight Composite Steel I-Girder Bridge, Design Example 2A, Two-Span Continuous Straight Composite Steel I-Girder Bridge, and Design Example 2B, Two-Span Continuous Straight Composite Steel Wide-Flange Beam Bridge.

The NSBA's LRFD Simon line-girder analysis and design software available for free download from the NSBA website is also a valuable tool for the design of routine steel I-girder bridges. It performs design calculations addressing the demand on, and resistance of, shear connectors at the fatigue and strength limit states in accordance with the provisions of the AASHTO LRFD BDS, greatly reducing the time and effort required of the designer. Other commercial software packages with the ability to analyze and design routine steel I-girder bridges are also available. Users should verify the capabilities, assumptions, and general correctness of any program's calculations prior to initial use.

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Agenda

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Concept for the Guide

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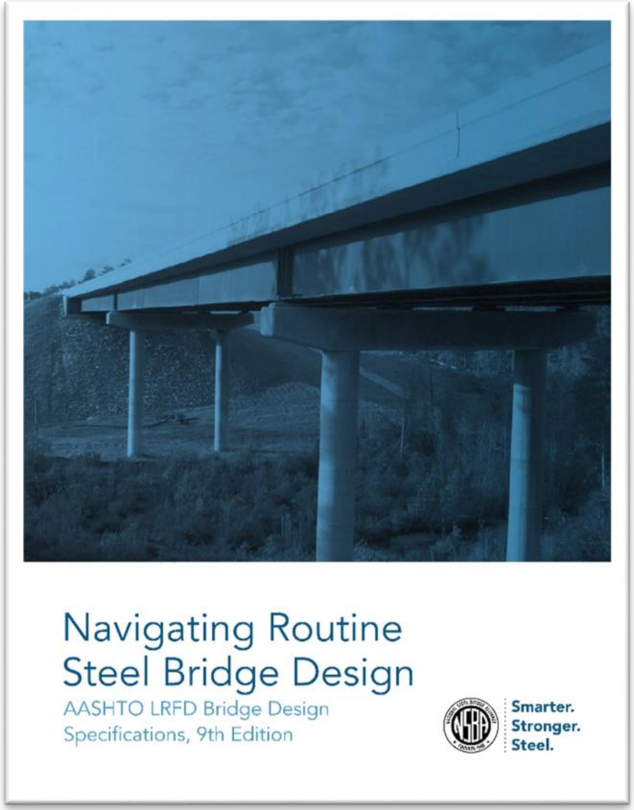
Summary



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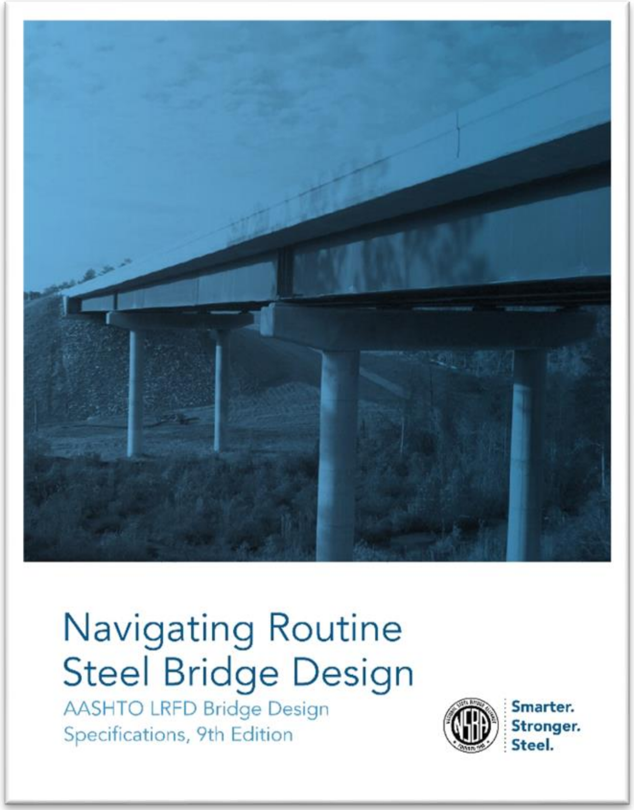


Questions

NSBA's new guide, *Navigating Routine Steel Bridge Design*, is intended to:

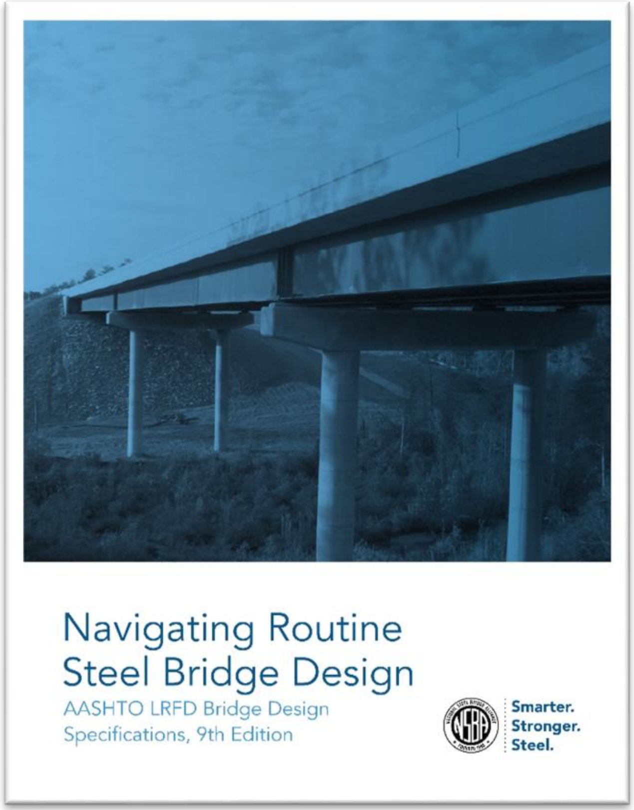
A. Replace the AASHTO LRFD BDS

B. Replace the FHWA Steel Bridge Design Handbook

C. Replace the NHI course Reference Manuals

D. Replace the AASHTO/NSBA Steel Bridge Collaboration Guidelines

E. Complement all of the above



Questions

True or False:

All bridge engineers should you read NSBA's new guide, "Navigating Routine Steel Bridge Design," from cover to cover.

NSBA's new guide, *Navigating Routine Steel Bridge Design*, includes links directly to numerous references and resources. How many of them are free?

A. All of them

B. None of them

C. About 37.64% of them