October 28-29, 2025
Orlando, FL

TRANSPORTATION SYMPOSIUM

Guidelines for Steel Bent Caps

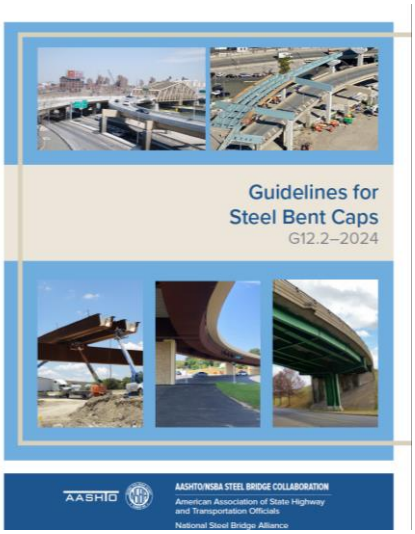
Christina Freeman, P.E.
Assistant State Structures Design Engineer

Transportation Symposium Website

SCAN ME

1

AASHTO/NSBA Guidelines for Steel Bent Caps



- New guidelines
- Available for free from AASHTO/NSBA Collaboration website
- Covers design, detailing, and constructability of steel bent caps

TRANSPORTATION SYMPOSIUM

2

2

Major Sections in Guidelines for Steel Bent Caps

1	INTRODUCTION
2	APPLICATION AND ALTERNATIVES
3	DESIGN, ANALYSIS, AND LOAD RATING CONSIDERATIONS
4	PREFERRED DETAILS
5	FABRICATION AND ERECTION
6	INSPECTION AND MAINTENANCE
7	REFERENCES

TRANSPORTATION SYMPOSIUM

3

Nomenclature

SECTION 1—INTRODUCTION

1.1—SCOPE AND PURPOSE

This document presents the state of the art at publication with respect to design, detailing, fabrication, and construction of steel bent caps. This document is a guideline and represents steel bridge community best practices. Recommendations contained herein should not be considered as strict rules. Also, this document should be used in conjunction with the other American Association of State and Highway Transportation Officials (AASHTO)/National Steel Bridge Alliance (NSBA) Collaboration documents for further clarification on specific issues. Steel bent caps are often categorized as nonredundant steel tension members (NSTMs). This document considers nonredundant design as well as other options.

1.2—NOMENCLATURE

Collaboration—Refers to the AASHTO/NSBA Collaboration.

Connection Plate—A plate used to transfer normal and/or shear stresses from one element to another via welds or an arrangement of bolts.

Integral Bent Cap—A bent cap with longitudinal steel girders framed directly into it with a bolted splice connection which provides a full moment connection between the bent cap and longitudinal girders.

Internal Redundancy—A redundancy that exists within a primary member cross-section without load path redundancy, such that fracture of one component will not propagate through the entire member, is discoverable by the applicable inspection procedures, and will not cause a portion of or the entire bridge to collapse.

Load Path Redundancy—A redundancy that exists based on the number of primary load-carrying members between points of support, such that fracture of the cross section at one location of a member will not cause a portion of or the entire bridge to collapse. The Federal Highway Administration (FHWA) considers bridges with three or more primary load-carrying members to be load path redundant.

Non-Integral, Stacked Bent Cap—A bent cap with longitudinal steel girders supported on the top of the bent cap, with a pinned or sliding connection between the bent cap and longitudinal girders.

Non-Integral, In-Line Bent Cap—A bent cap with longitudinal steel girders connected at the same level as the bent cap and supported with a pinned or sliding connection, such as on a corbel.

Nonredundant Steel Tension Member (NSTM)—A primary steel member fully or partially in tension, and without load path redundancy, system redundancy, or internal redundancy, whose failure may cause a portion of or the entire bridge to collapse. Previously referred to as fracture critical member (FCM). At publication, AASHTO has replaced the term "fracture critical member (FCM)" with NSTM. However, publications such as the AASHTO/AWS D1.5/D1.5M *Bridge Welding Code* and ASTM A709, Standard Specification for Structural Steel for Bridges, have yet to be revised and still use the FCM term. The terms NSTM and FCM are synonymous.

Steel Bent Cap—A horizontal steel beam extending across one or more columns, also commonly called a cap beam, cross-girder, cross-beam, or pier cap.

Steel Hammerhead Pier—A steel bent cap supported by one column.

Steel Straddle Bent Cap—A steel bent cap spanning over a roadway, railroad, or other feature, supported by two or more columns; also commonly called a straddle bent, straddle cap, straddle pier, or multi-column bent cap.

System Redundancy—A redundancy that exists as a bridge system without load path redundancy, such that fracture of the cross section at one location of a primary member will not cause a portion of or all of the bridge to collapse.

1.3—ABBREVIATIONS

AASHTO—American Association of State Highway and Transportation Officials
ASR—Allowable Stress Rating
ASTM—ASTM International (formerly known as American Society for Testing and Materials)

- Integral Bent Cap – A bent cap with longitudinal steel girders framed directly into it with a bolted splice connection which provides a full moment connection between the bent cap and longitudinal girders.
- Non-Integral, Stacked Bent Cap – A bent cap with longitudinal steel girders supported on the top of the bent cap, with a pinned or sliding connection between the bent cap and longitudinal girders.
- Non-Integral, In-Line Bent Cap – A bent cap with longitudinal steel girders connected at the same level as the bent cap and supported with a pinned or sliding connection, such as on a corbel.
- Steel Bent Cap – A horizontal steel beam extending across one or more columns, also commonly called a cap beam, cross-girder, cross-beam, or pier cap.
- Steel Hammerhead Pier – A steel bent cap supported by one column.
- Steel Straddle Bent Cap – A steel bent cap spanning over a roadway, railroad, or other feature, supported by two or more columns; also commonly called a straddle bent, straddle cap, straddle pier, or multi-column bent cap.

TRANSPORTATION SYMPOSIUM

4

Redundancy

- Internal Redundancy – A redundancy that exists within a primary member cross-section without load path redundancy, such that fracture of one component will not propagate through the entire member, is discoverable by the applicable inspection procedures, and will not cause a portion of or the entire bridge to collapse.
- Load Path Redundancy – A redundancy that exists based on the number of primary load-carrying members between points of support, such that fracture of the cross section at one location of a member will not cause a portion of or the entire bridge to collapse. FHWA considers bridges with three or more primary load-carrying members to be load path redundant.
- Nonredundant Steel Tension Member – A primary steel member fully or partially in tension, and without load path redundancy, system redundancy or internal redundancy, whose failure may cause a portion of or the entire bridge to collapse. Previously referred to as Fracture Critical Member (FCM). [At publication, AASHTO has replaced the term “fracture critical member (FCM)” with NSTM. However, publications such as the AASHTO/AWS D1.5 Bridge Welding Code and ASTM A709 Standard Specification for Structural Steel for Bridges have yet to be revised and still use the term FCM. The terms NSTM and FCM are synonymous.]
- System Redundancy – A redundancy that exists in a bridge system without load path redundancy, such that fracture of the cross section at one location of a primary member will not cause a portion of or all of the bridge to collapse. (Not allowed by FDOT Structures Manual)

TRANSPORTATION SYMPOSIUM

5

5

Types of Steel Bent Caps

- Generally, three types
  - Single column, with hammerhead pier
  - Simple span cap on two columns
  - Continuous cap on three or more columns
- Selection depends on
  - Width of the roadway above, and
  - Configuration of the roadway below, and possibly
  - Foundation constraints
- Regarding skew
  - Perpendicular to roadway centerline is preferable – shorter elements, less longitudinal force effect
  - Use skew if needed

TRANSPORTATION SYMPOSIUM

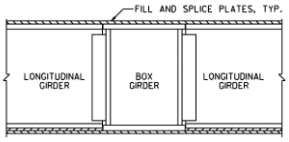
6

6

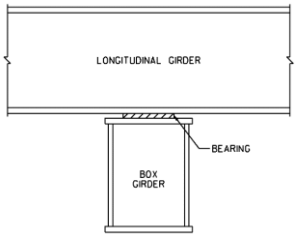
Types of Steel Bent Caps

TRANSPORTATION SYMPOSIUM

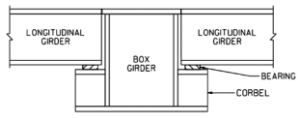
Longitudinal Girder Framing Options



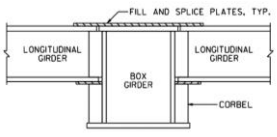
INTEGRAL SYSTEM



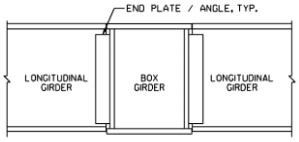
STACKED SYSTEM



CORBEL BEAM FRAMING WITH LONGITUDINAL BEAMS ON BEARINGS



CORBEL BEAM FRAMING WITH INTEGRAL CONNECTION



END PLATE/END ANGLE FRAMING (NOT RECOMMENDED)

TRANSPORTATION SYMPOSIUM

Integral Bent Cap

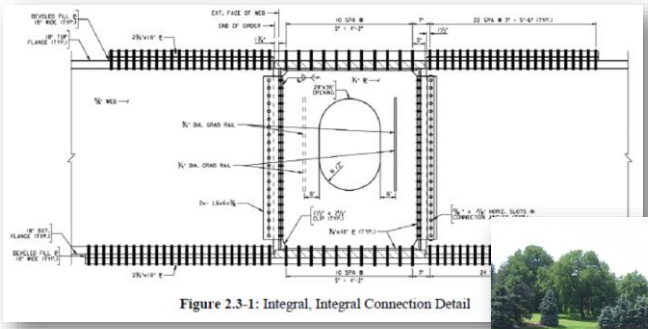


Figure 2.3-1: Integral, Integral Connection Detail

TRANSPORTATION SYMPOSIUM

9

9

Stacked Bent Cap

- Advantages
  - Simpler connections than integral
  - Simpler and faster fabrication and erection
  - More easily adapted to skewed longitudinal girders
- However
  - Significantly greater vertical clearance needs
  - Longitudinal girders do not provide lateral-torsional restraint
  - Longitudinal girders impart braking and seismic loads if they are on fixed bearings

Figure 2.3-2: Non-integral, Stacked Connection

TRANSPORTATION SYMPOSIUM

10

10

Corbel and Bolster Beam Framing

- Advantages
  - Additional vertical clearance for the feature passing below the bent
  - This is a more forgiving geometric configuration than the integral girder connection system
  - Simplified and faster fabrication, erection, and construction (time and potential cost savings) compared to the integral system
- However,
  - More bearings to fabricate and maintain
  - An expansion joint must be installed unless fixed bearings are used
  - Increased torsional loads are imparted during construction and service, and stability during construction may be more of a concern than with the stacked system
  - No lateral-torsional restraint is provided by the longitudinal girders, compared to an integral cap

End Plate and End Angle Framing

- Present in some existing bridges but not recommended
- Two types
  - Either one vertical plate per longitudinal girder is welded to the web of the bent cap, and the webs of the longitudinal girders are bolted to the vertical plates; or
  - Connection angles or bent plates are bolted to the web of the cap beam, and the web of the longitudinal girder is bolted to the outstanding legs of the angles / bent plates.
- Details
  - No bearings to construct or maintain
  - Potential for distortion-induced fatigue
  - Increased torsional loads during construction and in service
  - Stability concerns during construction

Types of Bent Caps

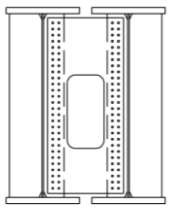
TRANSPORTATION SYMPOSIUM

13

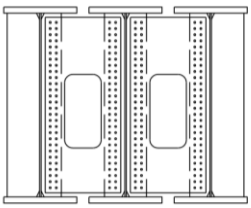
13

Bent Cap Configurations

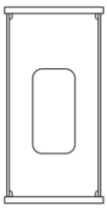
SINGLE I-SECTION



TWIN I-SECTION



TRIPLE I-SECTION



BOX SECTION

TRANSPORTATION SYMPOSIUM

14

14

Bridge System Stiffness Considerations

- Straddle bents provide more flexible support than conventional bent

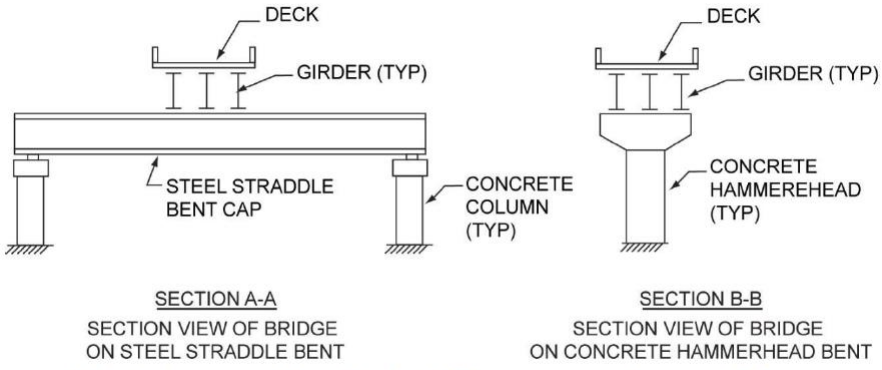


Figure 3.2-1—Girders supported by a steel straddle bent cap versus girders supported by a concrete hammerhead

TRANSPORTATION SYMPOSIUM

15

15

Bridge System Stiffness Considerations

- More flexible supports affect distribution of load

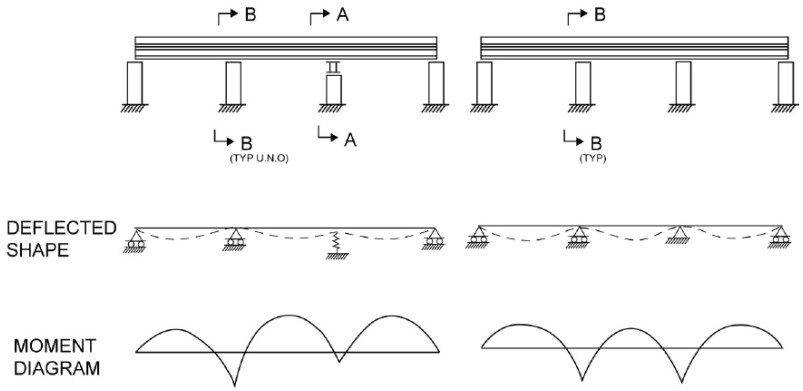


Figure 3.2-2—Bridge with three concrete hammerhead supports and one flexible steel bent cap support versus a bridge with four concrete hammerhead supports

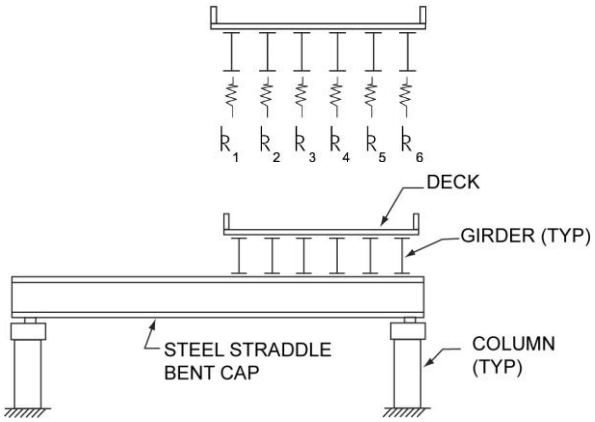
TRANSPORTATION SYMPOSIUM

16

16

Bridge System Stiffness Considerations

- Support flexibility can be different for each girder on a given straddle bent

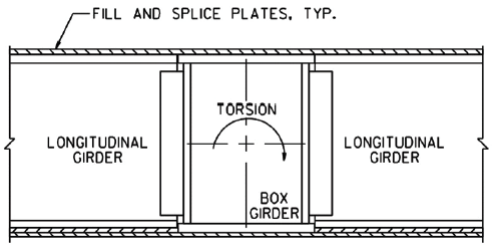


TRANSPORTATION SYMPOSIUM

17

Global Longitudinal Stability and Torsion

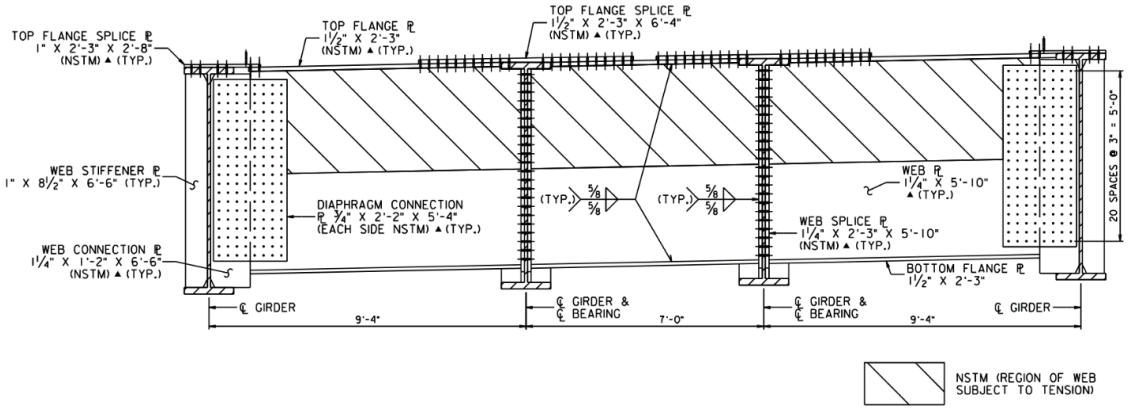
- Torsional moment about the centerline of the bent cap can result from:
  - Unbalanced vertical reactions (i.e., heavier reactions from one or the other span supported by the bent cap),
  - Integral structure moments (i.e., frame action moments when the superstructure is integral with the bent cap), or
  - Eccentrically applied longitudinal forces (i.e., longitudinal forces applied from the superstructure to the top of the steel bent cap through bearings).



TRANSPORTATION SYMPOSIUM

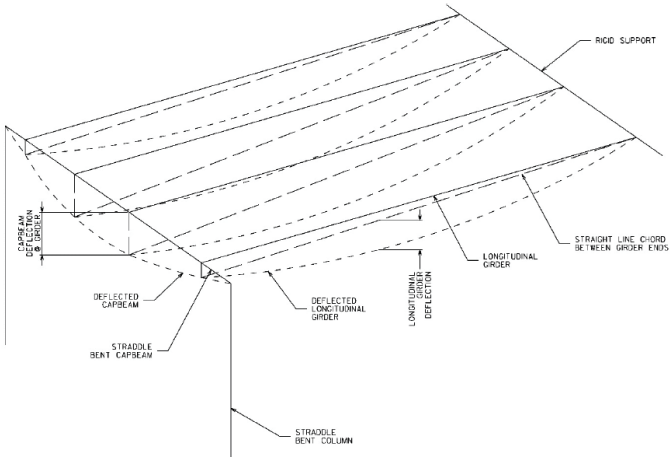
18

Redundancy and Designating NSTM



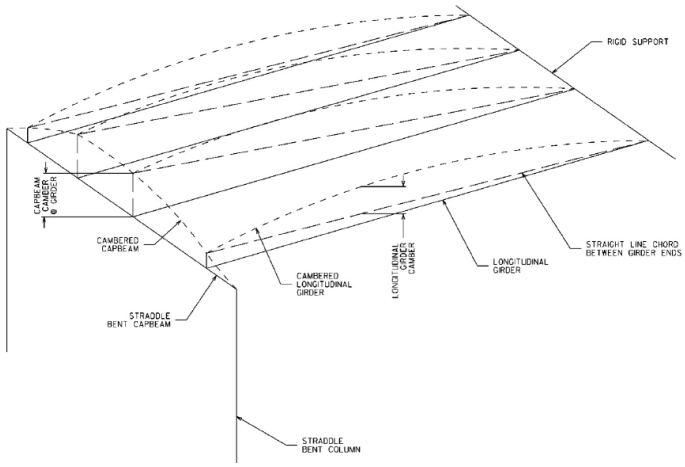
TRANSPORTATION SYMPOSIUM

Camber



TRANSPORTATION SYMPOSIUM

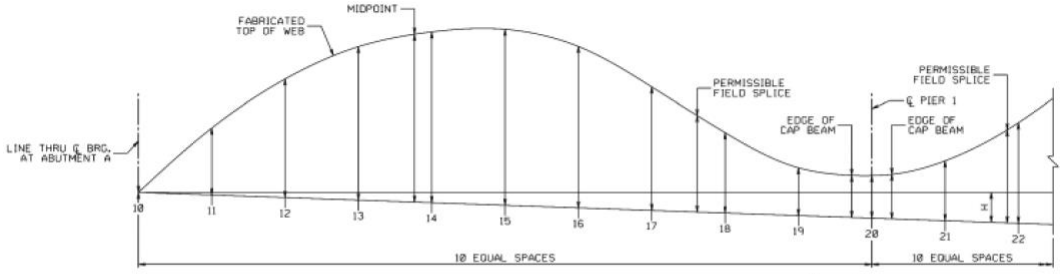
Camber



TRANSPORTATION SYMPOSIUM

21

Camber



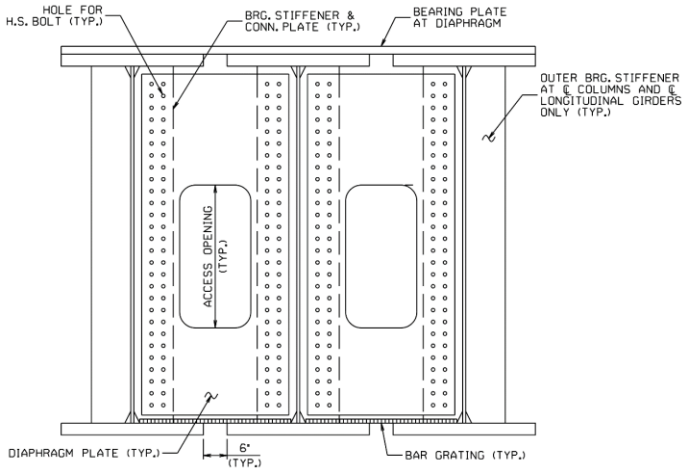
GIRDER 1	POINT	10	11	12	13	MID	14	15	16	17	SPLICE	18	19	CAP	20	CAP	21	SPLICE	22
	Δs	0	3/8	5/8	3/4	7/8	7/8	3/4	3/4	5/8	1/2	1/2	3/8	1/4	1/4	1/4	1/2	5/8	5/8
	Δ's	0	1 1/4	2 1/8	2 3/4	2 7/8	2 7/8	2 3/4	2 1/2	2	1 1/2	1 1/2	7/8	1/2	1/2	1/2	5/8	1	1 1/8
	Δc	0	1/8	1/4	1/4	1/4	1/4	1/4	1/4	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/4
	H	0	10	20	29 5/8	37 7/8	38 1/4	46 1/4	53 3/4	60 5/8	66 3/8	67	72 3/4	77	78	78 7/8	83 5/8	86 7/8	88 3/8
	TOTAL	0	11 3/4	23	33 3/8	41 7/8	42 1/4	50	57 1/4	63 3/8	68 1/2	69 1/8	74 1/8	77 7/8	78 7/8	79 3/4	84 7/8	88 5/8	90 3/8

DEAD LOAD DEFLECTIONS AT THIS POINT WOULD BE ZERO FOR AN INFLEXIBLE SUPPORT

TRANSPORTATION SYMPOSIUM

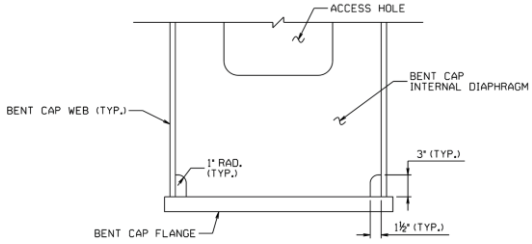
22

Preferred Details



TRANSPORTATION SYMPOSIUM

Preferred Details

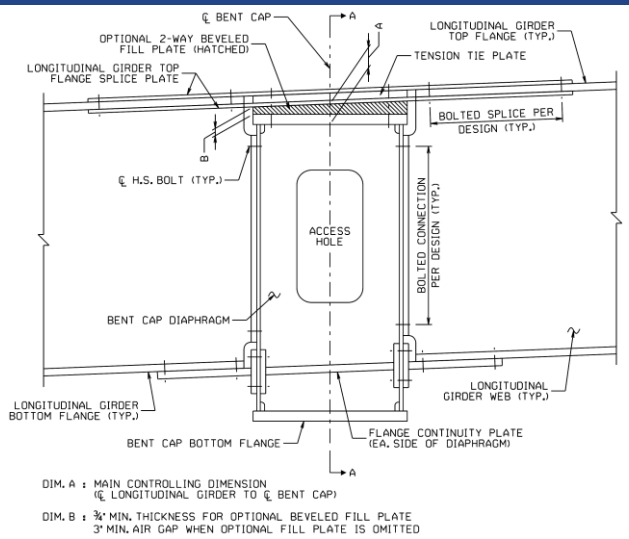


Box Corner Weld

- Order of preference:
  - Fillet welds
  - Single-bevel groove with backing
  - Double-bevel groove
  - Bolted

TRANSPORTATION SYMPOSIUM

Longitudinal Girder Connection to Steel Box Bent Cap



- Keep girders perpendicular to caps
- Avoid cross-slope transitions in the girders connecting to caps
- Avoid details that require two-way beveled fill plates

TRANSPORTATION SYMPOSIUM

25

25

Electrical and Lighting

- Provide electrical outlets and fixture for inspection, particularly for FC boxes
  - Can use outlets for lighting and fans
  - Put light switches at entry ways
  - Use six-hour reset timers
  - Use wire guards on light fixtures
  - Use stainless steel 316 for supporting hardware
  - Single coat of white paint (section 3.3)

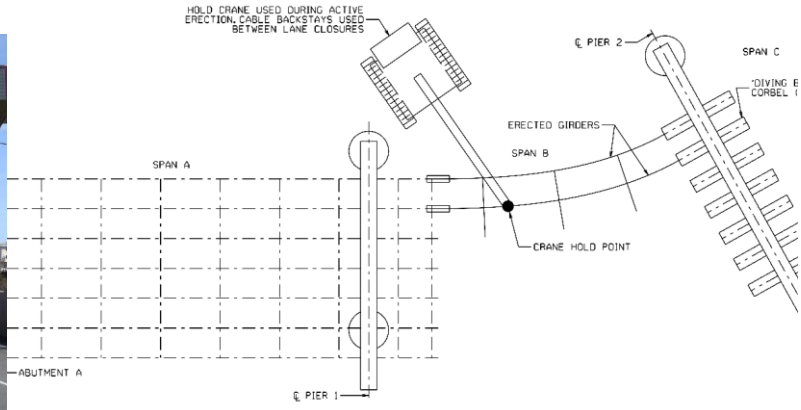
Figure 4.8-1

TRANSPORTATION SYMPOSIUM

26

26

Erection



TRANSPORTATION SYMPOSIUM

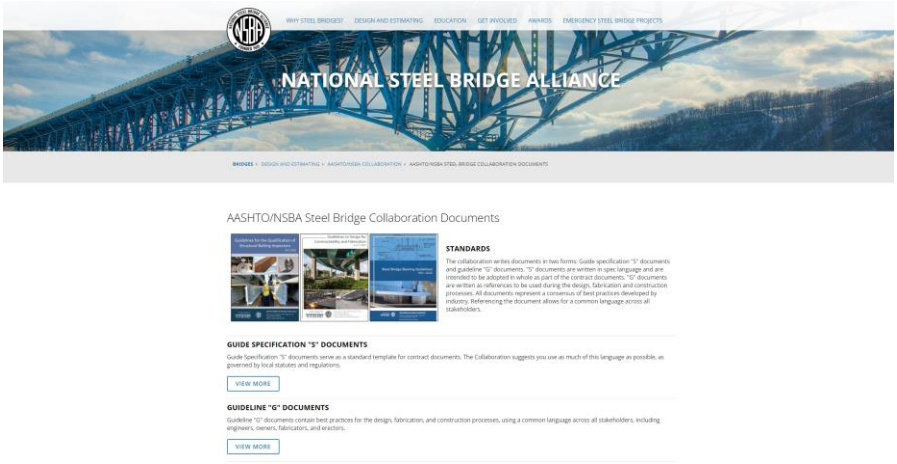
27

Erection

TRANSPORTATION SYMPOSIUM

28

Guidelines download



TRANSPORTATION SYMPOSIUM

29

29

FDOT Requirements for Steel Bent Caps

Material Requirements:

- Use ASTM A 709, HPS 50W or HPS 70W steel for integral or straddle pier caps

Deflection and Span to Depth Ratio:

- Follow LRFD 2.5.2.6.2 and 3.6.1.3.2 for deflection and span-to-depth ratio while designing bridges that incorporate straddle piers.

Structural Analysis

- A refined structural analysis is needed per LRFD 4.6.3 for continuous girder superstructure units supported on a straddle pier or integral pier caps.

TRANSPORTATION SYMPOSIUM

30

30

FDOT Requirements for Steel Bent Caps

Redundancy Factor:

- For strength limit state redundancy factor of straddle piers and integral pier caps, disregard the redundancy factors in LRFD 1.3.4 and use $\eta_R = 1.2$.
- For substructure components including straddle or integral pier caps, the redundancy factor shall not be applied to the foundation if they are separate components (i.e. a pile cap is used).
- For steel non-framed straddle or integral pier caps (bearing between cap and column allows rotation), the redundancy factor shall not be applied to the column and foundation designs.

Fracture:

- All tension components of straddle and integral piers are considered fracture critical.

TRANSPORTATION SYMPOSIUM

31

31

FDOT Requirements for Steel Bent Caps

Design Considerations for Straddle Pier:

- Stiffeners are not permitted outside the cap.
- A minimum of 32-inch x 42-inch tall access opening with proper weatherproofing.
- For a sloped roadway, match the straddle pier cap to the slope of the roadway. For a crowned roadway, match the top of the cap to the crowned roadway, with the bottom having the same shape or flat.
- Preferred Integral Steel Box Girder Straddle Pier Cap Details are provided.

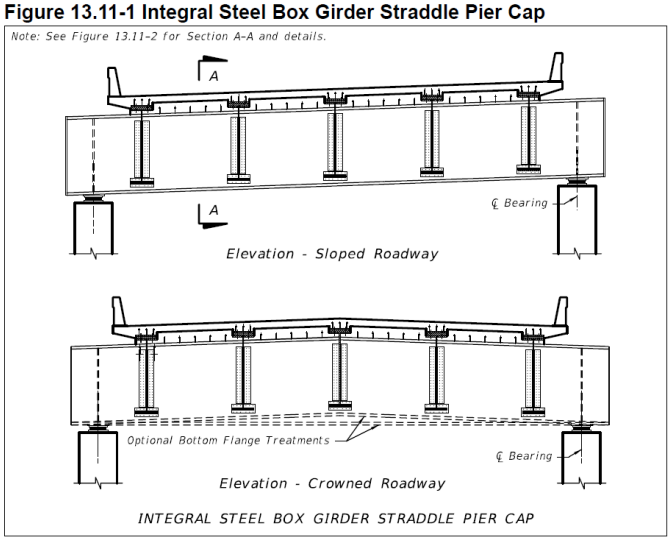
TRANSPORTATION SYMPOSIUM

32

32

FDOT Requirements for Steel Bent Caps

Figure 13.11-1 Integral Steel Box Girder Straddle Pier Cap



TRANSPORTATION SYMPOSIUM

33

33

FDOT Requirements for Steel Bent Caps

Only the following non-redundant steel superstructure systems are permitted:

- I-girders in two girder cross sections when approved by the SDO.
- Welded members in truss/arch bridges when approved by the SDO.
- Box girders in two girder cross sections.
- Non-framed non-integral straddle pier caps.
- Integral pier caps.
- Bascule bridge main girders.
- Non-redundant steel girders or floor beam systems used with continuous or non-continuous decks.

TRANSPORTATION SYMPOSIUM

34

34

FDOT Requirements for Steel Bent Caps

Designate on the plans, all:

- Components (non-fracture critical tension components) for which CVN testing only is required.
- Fracture critical components. In addition, for steel girders that are composite along any part of its length, and whose webs are subject to tension, the entire web depth shall be designated a Fracture Critical Member (FCM). Do not show tension limits for the web depth.
- Splice plate testing requirements. Splice plates are to be tested to the requirements of the tension components to which they are attached.

TRANSPORTATION SYMPOSIUM

35

35

FDOT Requirements for Steel Bent Caps

BOX SECTIONS :

- Single box sections are not permitted except for use as straddle pier caps.

Access Doors :

- For maintenance and inspection, the minimum interior height of box girder is 6 feet measured perpendicular from the top of the bottom flange to the bottom of the top flanges.

Fatigue:

- Where avoidable, do not use Detail Category E or E' as defined in LRFD [Table 6.6.1.2.3-1]. Category E welds are allowed for use in cross frame connection.
- For longitudinal Fracture Critical Members (FCM), use fatigue details classified as Detail Category C or Better as defined in LRFD [Table 6.6.1.2.3-1]

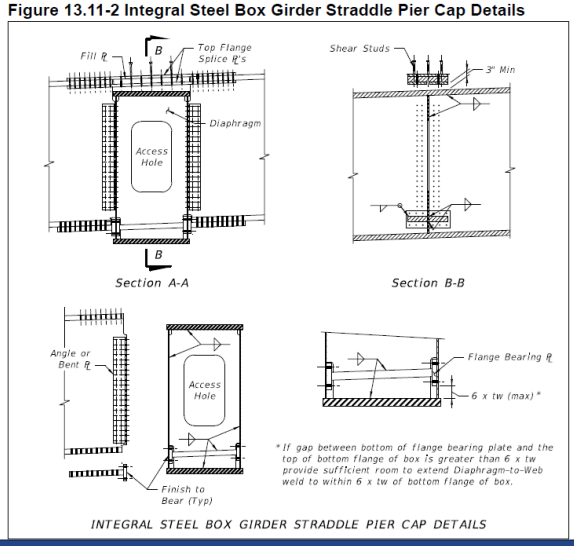
TRANSPORTATION SYMPOSIUM

36

36

FDOT Requirements for Steel Bent Caps

Figure 13.11-2 Integral Steel Box Girder Straddle Pier Cap Details

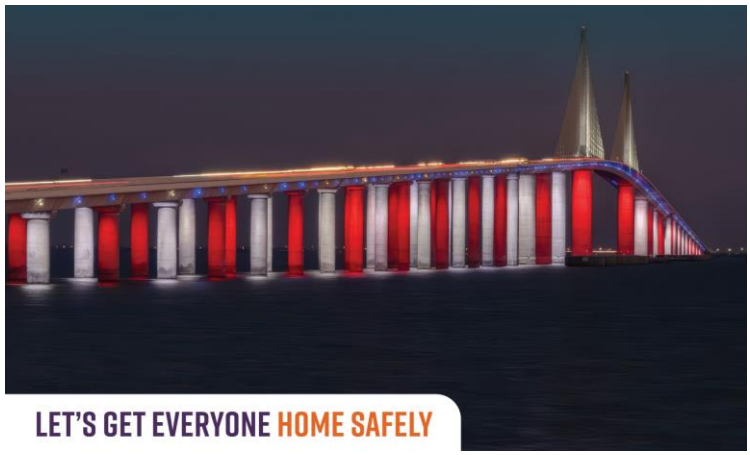


TRANSPORTATION SYMPOSIUM

37

37

Safety Message



TRANSPORTATION SYMPOSIUM

38

38

Contact Information

Christina Freeman
Assistant State Structures Design Engineer

- (850) 921-7111
- Christina.Freeman@dot.state.fl.us

TRANSPORTATION SYMPOSIUM

39

39

October 28-29, 2025
Orlando, FL

TRANSPORTATION SYMPOSIUM

DEADLINE

Please be sure to **certify your attendance** before leaving this event or no later than **November 30th**, in order to receive PDH/CEC.
Detailed instructions are available on the Transportation Symposium website.

Transportation Symposium Website

SCAN ME

40