SECTION 9
DECK AND DECK SYSTEMS

9.1 GENERAL REQUIREMENTS

The following section provides CDOT practice for bridge deck thickness, overhangs, transverse and longitudinal reinforcement, protection criteria, and supplemental deck components. The Designer shall coordinate with Staff Bridge regarding project-specific circumstances warranting deviations from standard practices referenced herein.

To improve service life, weather resistance, and ease of future maintenance procedures, all bridge decks shall be designed as continuous and without expansion devices when possible. Additionally, the Designer shall incorporate a deck protection strategy on all bridge decks in accordance with this BDM. When the top slabs of CBCs are intended to be used as a driving surface, they shall be protected with waterproofing membrane and asphalt or polymer concrete similar to bridge decks.

Use of alternative deck systems, including but not limited to, open, filled, and partially filled metal grid decks, orthotropic steel decks, aluminum decks, fiber reinforced polymer (FRP) decks, and sandwich deck panels, requires discussions with Staff Bridge during the preliminary design phase and approval by Unit Leader in coordination with the State Bridge Engineer and shall be documented in the Structure Selection Report.

Use of wood decks and bare concrete decks on new bridge construction is not permitted.

Bridges should be designed to allow future deck replacement. This is important for post-tensioned bridges for which detensioning may be required. See Section 5.8.6 of this BDM for design requirements.

9.2 CODE REQUIREMENTS

Unless otherwise modified by this section of the BDM, the minimum requirement for loading, limit states, design analysis, and detailing for bridge deck and deck systems shall be in accordance with Sections 3, 4, and 9 of the current AASHTO *LRFD Bridge Design Specifications* (AASHTO). This section is intended to supplement AASHTO code requirements. Any requests to vary from methodologies presented herein shall be discussed with Staff Bridge.

The Design Engineer is encouraged to review Design Example 6 – Deck Design located in Appendix A.

9.3 PERFORMANCE REQUIREMENTS

9.3.1 Service Life

To minimize corrosion and deterioration, newly constructed bridge decks shall implement practical designs, construction materials, and deck protection strategies as specified in this BDM for the purpose of achieving a minimum service life of 75 years.

A greater level of durability to attain a minimum service life of 100 years is required for qualified bridges funded through the Colorado Bridge Enterprise

(CBE) Program. Prior to final design, Staff Bridge will provide the Designer CBE's Strategies for Enhancing Bridge Service Life Memorandum for reference to approved deck protection methods of qualified bridges.

9.3.2 Maintenance Requirements

Bridge decks shall be designed and detailed to facilitate future maintenance and inspection. This includes the following:

- Providing continuous and joint free bridges, where feasible
- Minimizing construction joints when required
- Using corrosion resistant reinforcing with recommended clear cover
- Specifying deck protection
- Optimizing placement of bridge deck drains.

Additionally, the Designer will give consideration to future deck repairs and the inevitable replacement of bridge overlays during the initial design process.

Refer to BDM Section 5.4, Reinforced Concrete.

9.4 ANALYSIS METHOD

9.4.1 General

The approximate method of analysis specified in AASHTO shall be used for the design of concrete deck slabs that are within the limitations outlined for its use. ***AASHTO 4.6.2.1***

For atypical bridge decks not meeting the conditions explicit to the approximate method of analysis, refined methods of analysis, as identified in AASHTO*,* shall be used. ***AASHTO 4.6.3.2***

The Designer may propose the use of the AASHTO empirical design method for consideration by Staff Bridge during the preliminary design phase. Prior to CDOT consideration, the Designer will confirm that the design conditions satisfy those outlined in AASHTO. Upon approval by Unit Leader in coordination with the State Bridge Engineer, an explanation for the use of the empirical method will be documented in the Structure Selection Report. ***AASHTO 9.7.2***

Use of AASHTO exposure factor coefficient in deck design shall be as follows: ***AASHTO 5.6.7***

- Use Class 1 exposure factor when deck has a waterproofing membrane and overlay or polyester overlay installed.
- Use Class 2 in all other cases.

9.4.2 Deck Design Tables

To maintain consistency in detailing, this section provides deck design values, including recommended deck slab thicknesses, overhang widths, transverse and longitudinal reinforcing, for a variety of girder arrangements (see Tables 9-1 to 9-4 and Figure 9-1). These design tables are valid for old CDOT standard BT girders and rolled steel or steel plate girders with a 12 in. minimum top flange width. The designs may be conservative and can be used for preliminary estimates. The Designer is responsible for exercising design judgment when using these tables for final design, noting the following limitations in their development:

- LRFD approximate method using 32 kip axle AASHTO design truck with three or more girders.
- 3 in. wearing surface dead load = 36.67 psf.
- Deck skews less than 25°.
- Minimum concrete clear cover to bottom transverse reinforcement = 1 in.
- For economy, the maximum tension reinforcement ratio, ρ, is approximately half the balanced reinforcement ratio, $\rho_{bal.}$ This assumes that controlling deck deflections is not critical to bridge performance.
- Top primary reinforcing extending into deck overhangs may not be adequate to resist rail impact loads and shall be designed accordingly for each project. Refer to BDM Section 9.7 for additional information.
- Use of precast deck panels is accommodated in the deck thicknesses listed; however, the Designer shall confirm that the deck thickness selected from the tables is adequate to accommodate both the deck panels, if used, and any necessary negative moment reinforcing while providing the minimum clearances. Refer to BDM Section 9.13.2 for additional information.
- Use exposure factor of 1.0, assuming a waterproofing membrane or polyester polymer overlay on the surface of the deck.
- Load modifier η_i = 0.95 is used in the design (LRFD 1.3.2)

Table 9-1: CDOT Standard CBT Girder Load and Resistance Factor Design (f_y = 60 ksi)

Girder spacing CL to CL	Concrete deck thick. (w/o haunch)	* Maximum overhang	Transverse reinforcing		Longitudinal reinforcing	
			Top / bot. mat slab reinforcing.		** Top mat (#4 min.)	Bot. mat/ "D" bar (#5)
(ft.)	(in.)	(ft. - in.)	Size	Max. Spacing (in.)	Max. Spacing (in.)	Max. Spacing (in.)
4.00	8.00	2' - 3.5"	#5	9	12	12
4.25	8.00	2' - 3.5"		9		12
4.50	8.00	2' - 3.5"		9		12
4.75	8.00	2' - 4.5"		9		12
5.00	8.00	2' - 6"		9		12
5.25	8.00	2' - 7.5"		9		12
5.50	8.00	2' - 9"		9		12
5.75	8.00	2' - 10.5"		9		12
6.00	8.00	3' - 0"		9		12
6.25	8.00	3' - 1.5"		9		12
6.50	8.00	3' - 3"		9		12
6.75	8.00	3' - 4.5"		9		12
7.00	8.00	3' - 6"		9		12
7.25	8.00	3' - 7.5"		9		12
7.50	8.00	3' - 9"		9		12
7.75	8.00	3' - 10.5"		9		12
8.00	8.00	4' - 0"		9		12
8.25	8.00	4' - 1.5"		8.5		12
8.50	8.00	4' - 3"		8.5		12
8.75	8.00	4' - 4.5"		8		11
9.00	8.00	4' - 6"		8		11
9.25	8.00	4' - 7.5"		8		11
9.50	8.00	4' - 9"		7.5		11
9.75	8.00	4' - 10.5"		7.5		11
10.00	8.00	5' - 0"		7.5		11
10.25	8.50	5' - 1.5"		7.5		11
10.50	8.50	5' - 3"		7.5		11
10.75	8.50	5' - 4.5"		7		10
11.00	8.50	5' - 6"		6.5		9
11.25	8.50	5' - 7.5"		6.5		9
11.50	9.00	5' - 9"		6.5		9
11.75	9.00	5' - 10.5"		6.5		9
12.00	9.00	6' - 0"		6		8

<u>NOTES:</u>
The design data does not apply to deck overhang that need to be designed according to AASHTO LRFD, Section A13.4.1.
* The deck overhang varies from 27.5" to 0.5 times the girder spacing that is measured from the center of the exterior girder.
** Negative moment reinforcing steel over the pier is not included.

Table 9-2: Rolled Steel Beams/Steel Plate Girders (12 in. [min.] wide top flange) Load and Resistance Factor Design (f_y = 60 ksi)

Girder spacing CL to CL	Concrete deck thick. (w/o haunch)	* Maximum overhang	Transverse reinforcing		Longitudinal reinforcing	
			Top / bot. mat slab reinforcing.		** Top mat (#4 min.)	Bot. mat/ "D" bar (#5)
(ft.)	(in.)	(ft. - in.)	Size	Max. Spacing (in.)	Max. Spacing (in.)	Max. Spacing (in.)
4.00	8.00	1' - 6"	#5	9	12	12
4.25	8.00	1' - 6"		9		12
4.50	8.00	1' - 6"		9		12
4.75	8.00	1' - 7"		9		12
5.00	8.00	1' - 8"		9		12
5.25	8.00	1' - 9"		9		12
5.50	8.00	1' - 10"		9		12
5.75	8.00	1' - 11"		9		12
6.00	8.00	2' - 0"		8.5		12
6.25	8.00	2' - 1"		8.5		12
6.50	8.00	2' - 2"		8		11
6.75	8.00	2' - 3"		8		11
7.00	8.00	2' - 4"		7.5		11
7.25	8.00	2' - 5"		7.5		11
7.50	8.00	2' - 6"		7.5		11
7.75	8.00	2' - 7"		7		10
8.00	8.00	2' - 8"		7		10
8.25	8.00	2' - 9"		7		10
8.50	8.00	2' - 10"		6.5		9
8.75	8.00	2' - 11"		6.5		9
9.00	8.00	3' - 0"		6.5		9
9.25	8.00	3' - 1"		6		8
9.50	8.00	3' - 2"		6		8
9.75	8.00	3' - 3"		5.5		8
10.00	8.00	3' - 4"		5.5		8
10.25	8.50	3' - 5"		5.5		8
10.50	8.50	3' - 6"		5.5		8
10.75	8.50	3' - 7"		5		7
11.00	8.50	3' - 8"		5		7
11.25	8.50	3' - 9"		5		7
11.50	9.00	3' - 10"		5		7
11.75	9.00	3' - 11"		4.5		6
12.00	9.00	4' - 0"		4.5		6

NOTES:
The design data does not apply to deck overhang that need to be designed according to AASHTO LRFD, Section A13.4.1.
* The deck overhang varies from 21" to 0.33 times the girder spacing that is measured from the center of the exterior girder.
** Negative moment reinforcing steel over the pier is not included.

Table 9-3: CDOT Standard CBT Girder Load and Resistance Factor Design (f_y = 100 ksi)

Girder spacing CL to CL	Concrete deck thick. (w/o haunch)	* Maximum overhang	Transverse reinforcing		Longitudinal reinforcing	
			Top / bot. mat slab reinforcing.		** Top mat (#4 min.)	Bot. mat/ "D" bar (#4)
(ft.)	(in.)	(ft. - in.)	Size	Max. Spacing (in.)	Max. Spacing (in.)	Max. Spacing (in.)
4.00	8.00	2' - 3.5"	#4	9	12	12
4.25	8.00	2' - 3.5"		9		12
4.50	8.00	2' - 3.5"		9		12
4.75	8.00	2' - 4.5"		9		12
5.00	8.00	2' - 6"		9		12
5.25	8.00	2' - 7.5"		9		12
5.50	8.00	2' - 9"		9		12
5.75	8.00	2' - 10.5"		9		12
6.00	8.00	3' - 0"		9		12
6.25	8.00	3' - 1.5"		9		12
6.50	8.00	3' - 3"		8.5		12
6.75	8.00	3' - 4.5"		8.5		12
7.00	8.00	3' - 6"		8		11
7.25	8.00	3' - 7.5"		8		11
7.50	8.00	3' - 9"		7.5		11
7.75	8.00	3' - 10.5"		7		10
8.00	8.00	4' - 0"		7		10
8.25	8.00	4' - 1.5"		7		10
8.50	8.00	4' - 3"		6.5		9
8.75	8.00	4' - 4.5"		6.5		9
9.00	8.00	4' - 6"		6.5		9
9.25	8.00	4' - 7.5"		6		8
9.50	8.00	4' - 9"		6		8
9.75	8.00	4' - 10.5"		5.5		8
10.00	8.00	5' - 0"		5.5		8
10.25	8.50	5' - 1.5"		5.5		8
10.50	8.50	5' - 3"		5.5		8
10.75	8.50	5' - 4.5"		5.5		8
11.00	8.50	5' - 6"		5.5		8
11.25	8.50	5' - 7.5"		5		7
11.50	9.00	5' - 9"		5		7
11.75	9.00	5' - 10.5"		5		7
12.00	9.00	6' - 0"		5		7

NOTES:
The design data does not apply to deck overhang that need to be designed according to AASHTO LRFD, Section A13.4.1.
* The deck overhang varies from 27.5" to 0.5 times the girder spacing that is measured from the center of the exterior girder.
** Negative moment reinforcing steel over the pier is not included.

Table 9-4: Rolled Steel Beams/Steel Plate Girders (12 in. [min.] wide top flange) Load and Resistance Factor Design (f_y = 100 ksi)

Girder spacing CL to CL	Concrete deck thick. (w/o haunch)	* Maximum overhang	Transverse reinforcing		Longitudinal reinforcing	
			Top / bot. mat slab reinforcing.		** Top mat (#4 min.)	Bot. mat/ "D" bar (#4)
(ft.)	(in.)	(ft. - in.)	Size	Max. Spacing (in.)	Max. Spacing (in.)	Max. Spacing (in.)
4.00	8.00	1' - 6"	#4	9	12	12
4.25	8.00	1' - 6"		9		12
4.50	8.00	1' - 6"		9		12
4.75	8.00	1' - 7"		8.5		12
5.00	8.00	1' - 8"		8		11
5.25	8.00	1' - 9"		7.5		11
5.50	8.00	1' - 10"		7.5		11
5.75	8.00	1' - 11"		7		10
6.00	8.00	2' - 0"		7		10
6.25	8.00	2' - 1"		6.5		9
6.50	8.00	2' - 2"		6.5		9
6.75	8.00	2' - 3"		6.5		9
7.00	8.00	2' - 4"		6		8
7.25	8.00	2' - 5"		6		8
7.50	8.00	2' - 6"		5.5		8
7.75	8.00	2' - 7"		5.5		8
8.00	8.00	2' - 8"		5.5		8
8.25	8.00	2' - 9"		5.5		8
8.50	8.00	2' - 10"		5.5		8
8.75	8.00	2' - 11"		5		7
9.00	8.00	3' - 0"		5		7
9.25	8.00	3' - 1"		5		7
9.50	8.00	3' - 2"		4.5		6
9.75	8.00	3' - 3"		4.5		6
10.00	8.00	3' - 4"		4.5		6
10.25	8.50	3' - 5"		4.5		6
10.50	8.50	3' - 6"		4.5		6
10.75	8.50	3' - 7"		4.5		6
11.00	8.50	3' - 8"		4.5		6
11.25	8.50	3' - 9"		4.5		6
11.50	9.00	3' - 10"		4.5		6
11.75	9.00	3' - 11"		4.5		6
12.00	9.00	4' - 0"		4.5		6

NOTES:
The design data does not apply to deck overhang that need to be designed according to AASHTO LRFD, Section A13.4.1.
* The deck overhang varies from 18" to 0.33 times the girder spacing that is measured from the center of the exterior girder.
** Negative moment reinforcing steel over the pier is not included.

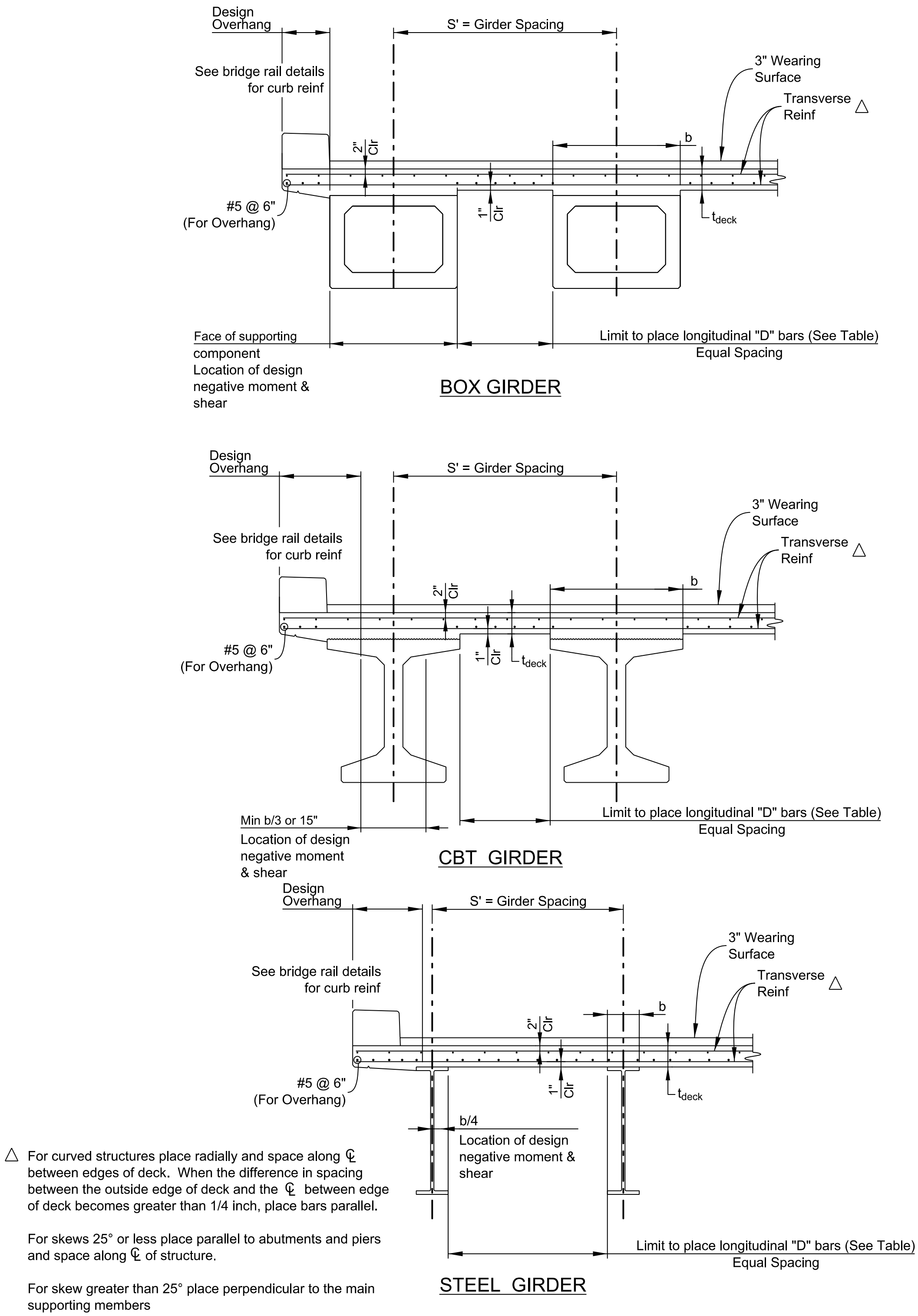

Figure 9-1: Deck Design Table Detail

9.5 DECK THICKNESS

The minimum deck thickness, not including allowances for haunch depth or the wearing surface thickness (asphalt or PPC overlay), shall be as specified:

- Decks with overlays: 8 in.
- Adjacent box girders/T-beams/CBT girders: 5 in.

The flange thickness of precast box girders and T-beams shall be as determined by design per AASHTO, but the combined composite thickness of the cast-in-place deck slab and top flange shall not be less than 8 in. ***AASHTO 9.7.1.1***

9.6 LONGITUDINAL REINFORCEMENT

9.6.1 Minimum Required Reinforcing

The minimum longitudinal reinforcing steel in the top of concrete bridge decks shall be #4 at 12 in. spacing. This new spacing is assumed adequate for crack control due to the use of Class DF with macrofibers as well as the required use of deck protection such as waterproofing membrane and asphalt or Polyester Polymer concrete. The designer will need to verify that all AASHTO requirements are still met including distribution steel per 9.7.3.2 of negative moment over girders.

The spacing of #4 at 6 in. was chosen in the early 1990s from an original #5 at 18” to improve crack control when bare deck bridges were still allowed. Cracking was seen in bridge rail with a spacing of #4 at 18” and the cracking was eliminated when changing to #6 at 18” (.41% of the section).

Longitudinal reinforcement in the bottom of the deck slab (D bars) shall be as indicated in Tables 9-1 to 9-4 in Section 9.4.2. For girder arrangements or specific circumstances not meeting the design table requirements, the longitudinal reinforcement shall be distributed as a percentage of the primary reinforcement in accordance with AASHTO. ***AASHTO 9.7.3.2***

To control transverse cracking at the bottom of deck overhangs, D bars shown in Tables 9-1 to 9-4 in Section 9.4.2 for various overhang widths is adequate reinforcing. When the project requires a larger overhang, the Designer shall design the longitudinal reinforcing steel in accordance with AASHTO. ***AASHTO 9.7.3.2***

9.6.2 Negative Moment Reinforcing

For simple span bridges made continuous, the negative moment at the pier may be taken at the face of the concrete diaphragm. Negative moment reinforcing shall be designed for composite load moments at the strength limit state. Negative moment reinforcing shall terminate beyond the inflection point per AASHTO. ***AASHTO 5.10.8.1.2c***

To accommodate the longitudinal reinforcement required for negative moment regions, small size bars bundled together or bars placed in two layers is permitted. Use the smallest bar size allowed by design to meet clearance requirements and avoid overcrowding bars when precast deck panels are permitted.

Unless stay-in-place deck forms are prohibited by the contract documents, bridge deck designs shall consider only the top longitudinal deck reinforcing when determining the continuity reinforcing capacity.

9.7 DECK OVERHANG DESIGN

9.7.1 Overhang Requirements

Deck overhang shoring subject to screed rail loads and construction loads has resulted in excessive deflections and torsional rotation of the exterior girders. To eliminate potential construction problems from deflections and rotation, the limits for deck overhangs shall be as described herein. The maximum deck overhang for various beam types, measured from the centerline of girder web to edge of deck, is presented as follows, where S' (ft.) is the center to center spacing of the webs for I girders or web of adjacent boxes or U girders, and b (in.) is the top flange width:

- CBT girders, steel box, and concrete box girders: (S/2) <= 6 ft
- Steel I girders: Maximum overhangs shall not exceed the larger value:
  - (S/3) <= 6 ft
  - (b/2) + 12 in. <= 6 ft

Tables 9-1 and 9-2 in Section 9.4.2 calculate and show the maximum overhang widths for both CBT and steel I girders.

On curved decks where the overhang varies along the bridge length, the maximum overhang width should not exceed the average overhang width by more than 1 ft.

A ¾ in. V-drip groove shall be located 6.00 in. from back face of barrier on the underside of the deck overhang for all bridges. Where 6 in. cannot be provided due to a minimal overhang width, 3 in. shall be used.

Deck overhangs shall extend beyond the edge of the top flange or box girder web a minimum of 6.00 in. to prevent water from dripping onto the girder. Additionally, cantilever shall extend 1 in. below the top of girder flange, and the bottom flange or web shall not extend beyond the formed drip groove of the deck.

Any exceptions to the above criteria shall be addressed on a project-specific basis and must be approved by Unit Leader.

9.7.2 Deck Overhang Loading and Design

AASHTO 3.6.1.3.4

To balance exterior girder designs with interior girder designs, overhangs should generally be limited to less than half the interior girder spacing or less as described in Section 9.7.1 of this BDM. Deck overhangs shall be designed for bridge rail and self-weight dead loads, HL-93 live loads, and barrier impact loads in accordance with AASHTO. The area of top transverse reinforcing provided in Tables 9-1 and 9-2 in Section 9.4.2 may be counted toward the area of steel required to resist moments caused by all overhang loads (see Deck Design Example 6). Deck reinforcing required to resist overhang loads shall be developed per AASHTO 5.11; larger reinforcing bars may require hooks at the edge of deck to meet development length requirements. As mentioned in Section 3.8 of this BDM, overhangs shall be evaluated for construction loads as well. Some of these loads are discussed in Section 6.6.4.2 of this BDM and are generally applicable to all girder types.

Refer to BDM Section 9.6 for recommended longitudinal reinforcing in the bridge deck overhang.

9.8 SKEWED DECK LIMITS

The Designer is encouraged to reduce the skew of new bridges during the preliminary bridge layout process. Highly skewed bridges are associated with unwanted shear stresses at the deck corners and promote maintenance concerns for expansion joints and bearings. Refer to BDM Section 4.6, Skew Effects on Bridges, for additional information.

9.8.1 Transverse Reinforcement

AASHTO 9.7.1.3

When the skew angle of the deck does not exceed 25°, the primary reinforcement may be placed in the direction of the skew. As an alternative, the primary reinforcing may be placed in a splayed arrangement as shown in Figure 9-2, with reinforcing gradually adjusting along the bridge length from its placement parallel to the skew near the bearings to perpendicular to the main supporting members.

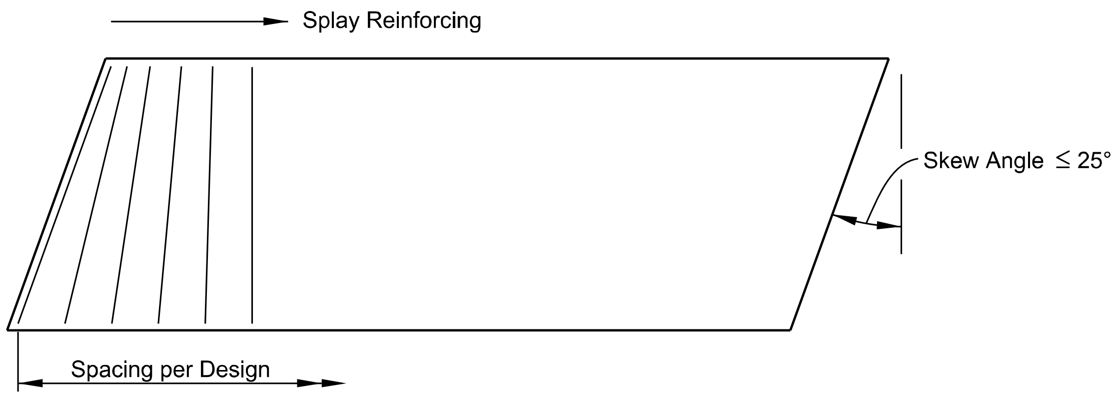

Figure 9-2: Splayed Deck Reinforcing

For skew angles exceeding 25°, the primary reinforcement shall be placed perpendicular to the main supporting members. The Designer shall consider performing a refined method of analysis as referenced in BDM Section 9.4.1 for the design of decks with extreme skews to limit cracking in the acute corners. The design span length is taken parallel to the primary reinforcement, as shown in Figure 9-3.

9.8.2 Reinforced End Zones

If the bridge skew exceeds 25°, additional reinforcement should be evaluated to be placed below the main top mat (transverse and longitudinal) reinforcing steel in the acute corners of the deck slab to control cracking and spalling of the concrete. A finite element model may be helpful in determining additional reinforcement requirements.

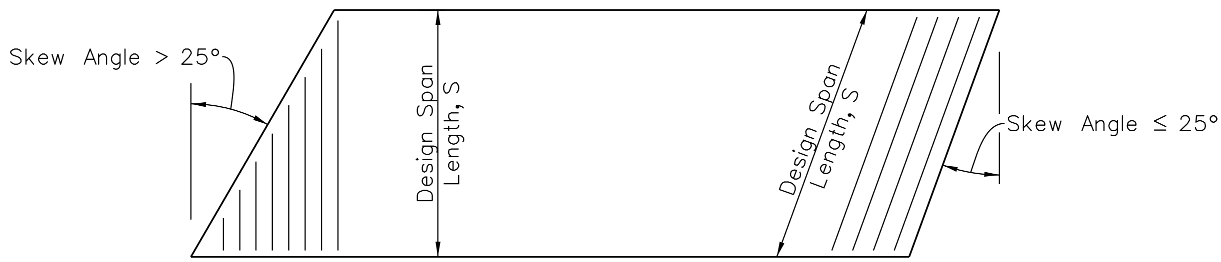

Figure 9-3: Skewed Deck Reinforcing Placement

The reinforcing shall be extended one development length past the centerline of the exterior girder in accordance with AASHTO (see Figure 9-4). ***AASHTO 5.10.8.2.1a***

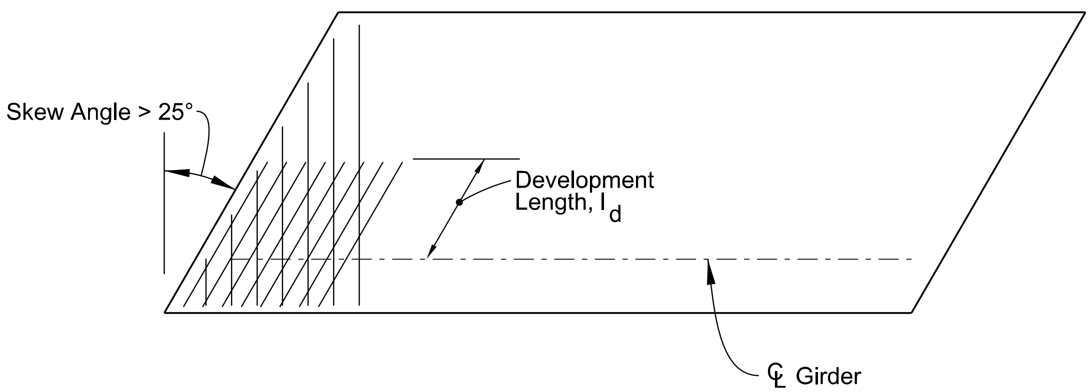

Figure 9-4: Acute Corner Reinforcing

9.9 OVERLAYS

New bridge construction shall use one of the following deck protection strategies:

1. 3 in. asphalt wearing surface over a waterproofing membrane applied over the concrete bridge deck and approach slabs to allow future mill and fill without damaging the waterproofing membrane. Asphalt overlays may not be desirable where concrete roadway is adjacent to the bridge and will be used as warranted by roadway requirements.

2. Polyester Polymer Concrete (PPC) overlay applied over the concrete bridge deck and approach slabs. PPC overlays shall have a minimum thickness of ¾ in, Requests to revise the thickness shall be at the approval of Unit Leader in coordination with the Overlay SMEs. The layer of PPC shall be omitted from the deck section properties.

New concrete deck slabs shall be designed to include 3 in. of asphalt overlay of 36.67 psf applied as a superimposed dead load over the bridge deck area.

Concrete decks with a PPC overlay shall consider the asphalt overlay load as a future load applied without the PPC in place. Construction notes shall include a note stating that the PPC must be removed before placing an asphalt wearing surface.

The Designer may discuss the use of alternative bridge deck overlays (e.g., Silica Fume modified concrete and Epoxy-polymer concrete) with Staff Bridge during the preliminary design phase. Discussions shall be documented in the Structure Selection Report.

9.10 WATERPROOFING

9.10.1 Membranes

All bridge decks using asphalt pavement as a deck and approach slab protection measure shall require a waterproofing membrane between the concrete deck and the asphalt overlay to serve as a deck surface sealant.

9.10.2 Sealer

Due to their low tolerance to abrasion and minimal service life, application of concrete sealers on bridge decks is not permitted.

Sidewalks placed on bridges do not require a protective concrete sealer.

9.11 DECK POURING SEQUENCE

9.11.1 Rate of Pour and Direction

The rate of placing concrete shall equal or exceed half the span length per hour but need not exceed 100 cy/hour for bridges designed as continuous. Concrete pumps can reasonably be expected to provide 100 cy/hour without significant malfunctions.

In general, the deck pour should progress uninterrupted from one end of the bridge to the other, in the direction of increasing grade along the longitudinal length of the bridge. If the bridge deck cannot be completed as a single pour, the Designer shall follow the direction presented in Section 9.11.2 and Section 9.12.

9.11.2 Deck Pour Sequence Details

All bridges with decks containing more than 300 cy of concrete shall have the pouring sequence shown on the plans, including sections to be placed first and last, pouring direction, and locations of transverse construction joints as specified in Section 9.12. If the Designer elects not to detail on the plans, the Designer shall add a note stating that the Contractor will submit a pouring sequence for approval by the Engineer of Record in coordination with the Fabrication/Construction Unit and Unit Leader.

As an alternative to starting at the ends of longer bridges, the deck pour sequence may begin at any location along the bridge, completing positive moment regions first and ending with negative moment regions over the piers.

Uplift at supports, girder deflections and stresses, in span hinges, and cut-off points for continuity reinforcing shall be considered when designing and detailing the deck pour sequence.

9.11.3 Diaphragms

For bridge abutment diaphragms and pier diaphragms designed integral with the deck slab, the deck pour shall include the diaphragm and deck as one continuous pour, with optional construction joint locations specified in Section 9.12.

9.12 DECK JOINTS

9.12.1 Transverse Joints

Optional transverse construction joints are permitted on continuous concrete deck structures to limit the concrete volume in a single pour. If used, locate transverse construction joints near the ¾ point of the span being poured in the direction of pour to minimize cracking in the negative moment region.

The General Notes drawing in the project plans shall include a note stating that the Contractor shall notify the Engineer of Record for approval of emergency construction joints.

For skewed bridges, transverse construction joints shall be parallel to the transverse reinforcement.

9.12.2 Longitudinal Joints

Longitudinal joints are generally discouraged, even for wide bridges since CDOT has not seen any durability issues without them. Longitudinal construction joints may be necessary due to phasing and finishing machine limitations for wide bridges. Construction joints are generally located near girder edges to allow for deck forming but should be located under barriers for additional protection when possible.

Use of closure pours shall be project specific and based on considerations such as:

- Excessive dead load deflection that may prevent transverse reinforcing bars from lining up properly prior to the closure pour.
- Excessive live load deflection during construction that may cause poor concrete bond to the reinforcing. Lane closures adjacent to closure pours should be used where possible.
- Construction phasing.
- Maintenance of traffic impacts.

Reinforcement through the construction joint shall be designed to limit deflections and shall be detailed in the project plans. Refer to BDM Section 5, Concrete Structures, for detailed reinforcing splice lengths.

9.13 STAY-IN-PLACE FORMS

9.13.1 General

The use of metal stay-in-place (SIP) deck forms is optional unless requested by the Region or Staff Bridge. A note stating whether metal SIP deck forms are required, prohibited, or optional shall be included on the General Notes drawing in the final bridge plans. Metal SIP deck forms are encouraged for the following conditions:

- Structures crossing over heavy traffic, interstate highways, or railroads
- Where form removal is difficult or hazardous
- As requested by the Region or Staff Bridge

Transparent or Precast concrete panel deck forms are preferred to metal SIP deck forms.

Stay-in-place deck forms shall not be permitted for cantilevered portions of decks or where architectural constraints prohibit their use.

Refer to BDM Section 5 for special requirements concerning SIP forms for the regions of deck over U girders.

9.13.2 Concrete Stay-in-Place Forms

When partial depth precast concrete deck panels are used, one layer each of both transverse and longitudinal reinforcing is required over the panels with a minimum 3/8 in. clear distance between the top of deck panel and bottom of longitudinal reinforcing.

Placing deck reinforcement with no clearance to the top of precast concrete deck panels is not permitted. The Designer shall confirm that the deck thickness selected from the deck design tables in Section 9.4.2 is adequate to provide the required clearance when detailing longitudinal reinforcing in the negative moment regions over piers.

Refer to CDOT Bridge Structural Drawings for additional information.

9.13.3 Metal Stay-in-Place Forms

All form flutes shall be kept free of concrete either by filling them with polystyrene or by topping them with sheet metal covers.

The ability to perform comprehensive deck inspections and future deck maintenance is restricted when using metal deck forms. Consideration for their use should be acknowledged on a project-specific basis. The Contractor can remove regions of metal deck forms to provide discrete location for inspecting the deck subject to Unit Leader in coordination with the Fabrication/Construction Unit approval. When not permitted, the final project plans shall include a note disallowing their use.

9.13.4 Transparent Stay-in-Place Forms

For full depth CIP bridge decks, transparent SIP forms may be used. Transparent forms allow for inspection during and after construction. Routine inspection and maintenance can be performed with over 70% visibility to the underside of the deck.

9.14 FULL DEPTH PRECAST CONCRETE DECK PANELS

Full depth precast concrete deck panels are an acceptable design solution for bridges qualified under accelerated bridge construction techniques. Use of full depth panels shall be discussed with Staff Bridge during the preliminary design process, with discussions and approval by Unit Leader documented in the Structure Selection Report.

9.15 DECK DRAINS

The Designer shall follow the deck drain procedures and details outlined in AASHTO. Additionally, the Hydraulic Engineer shall use FHWA publications Design of Bridge Deck Drainage, Hydraulic Engineering Circular 21 and 22 (HEC-21 and HEC-22) to determine the type and size of bridge deck drains appropriate for the bridge geometry and design storm.

AASHTO 9.4.2

Due to the high maintenance requirements associated with deck drainage structures, it is preferred that the Designer minimize the number of bridge deck drains by carrying the water to approach drainage grates off the bridge. Deck drains shall be placed as necessary to intercept water away from expansion joints and bearing devices and shall discharge water away from all girders, pier and abutment caps, roadways, railroad properties, and pedestrian trails. Openings in deck slabs due to drainage components shall include additional reinforcing to account for changes in structural capacity.

Refer to BDM Section 2.11.3, Deck Drainage Requirements, and the CDOT Drainage Design Manual for additional deck drain requirements.

9.16 LIGHTS AND SIGNS ON DECK

Bridge mounted lighting and signs should be avoided when possible to avoid additional load and to avoid vibrations that may increase maintenance. Where project circumstances require that a light or sign be located on the bridge, it shall be located directly over the pier. The structure, including the anchor bolt connection to the deck, shall be designed in accordance with the current *AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals.*

9.17 CONDUIT IN DECK

Conduit used by CDOT for bridge deck lighting, traffic signals, or anti-icing systems may be embedded in the concrete deck as an alternative to embedding in the bridge rail if approved by Unit Leader. The conduit shall be rigid and placed between the top and bottom reinforcing mats with consideration for providing adequate concrete cover and reinforcement spacing.

Conduit pipes for private utilities are not permitted in concrete decks and must otherwise be attached externally to the structure in accordance with agreements between CDOT and the private utility company. For aesthetic and safety reasons, conduits are not permitted under deck overhangs or on bridge railings.

9.18 ANTI-ICING SYSTEMS

Anti-icing systems involve treating the bridge deck before inclement weather to prevent snow and ice accumulation, thus reducing traffic accidents and snow removal efforts. Use of Fixed Automated Spray Technology (FAST) is a recent development and is best suited for bridges with a higher level of service due to the cost, attention, and commitment necessary for installation and future maintenance. Installation of automatic anti-icing systems in new bridge decks shall be discussed with Staff Bridge on a project-specific basis and shall be approved by CDOT Maintenance in coordination with the Unit Leader and AntiIcing SMEs, for qualified bridges. When implemented, the manufacturer shall provide the locations of anti-icing nozzles in the bridge deck.

Anti-icing systems are often necessary when the super-elevation reverses on a bridge due to the zero cross-slope and ponding issues. Efforts should be made to eliminate or shift super-elevation reversals on a bridge.

Refer to CDOT Bridge Structural Drawings B-614-1 through B-614-4 and Anti-Icing Project Special Provisions for additional guidance.