Chapter 16

BRIDGE DECKS

NDOT STRUCTURES MANUAL

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Chapter 16
BRIDGE DECKS

Sections 3, 4 and 9 of the *LRFD Bridge Design Specifications* present the AASHTO criteria for the structural design of bridge decks. Section 3 specifies loads for bridge decks, Section 4 specifies their analyses, and Section 9 specifies the resistance of bridge decks. Unless noted otherwise in this Chapter of the *NDOT Structures Manual*, the *LRFD Specifications* applies to the design of bridge decks in Nevada.

This Chapter documents NDOT criteria on the design of bridge decks that are constructed compositely in conjunction with concrete and steel girders and top slabs of cast-in-place, post-tensioned box girders. Chapter 14 discusses the design of CIP concrete slabs.

16.1 GENERAL

16.1.1 Protection of Reinforcing Steel

Reference: LRFD Articles 2.5.2.1 and 5.12

NDOT typical practice is to use epoxy-coated reinforcing steel (except in Clark County) for all reinforcing within 12 in of the riding surface. This includes both layers of deck reinforcing and all reinforcing extending into the deck from precast and cast-in-place construction. The epoxy-coated reinforcing steel is combined with a minimum cover of 2½ in from the top surface of the deck to the top layer. In addition, all concrete for deck slabs, approach slabs and barrier rails shall use a high-performance concrete having a low water/cement ratio and low permeability. A variety of other methods are available to protect the reinforcing steel in new decks and to retard the rate of corrosion. NDOT occasionally uses some of these other methods to protect reinforcing steel in new bridge decks.

16.1.2 Traditional Design Using the "Strip Method"

Reference: LRFD Articles 9.7.3, 4.6.2.1.1, 4.6.2.1.3 and Appendix A4

The application of the strip method to concrete decks is based on the design table for deck slabs in the Appendix to Section 4 of the *LRFD Specifications* (LRFD Table A4-1). An introduction to the LRFD Table discusses its application.

LRFD Table A4-1 shall be used to design the concrete deck reinforcement. LRFD Table A4-1 tabulates the resultant live-load moments per unit width for slab steel design as a function of the girder or web spacings, S. The Table distinguishes between negative moments and positive moments and tabulates these for various design sections as a function of the distance from the girder or web centerline to the design section. LRFD Article 4.6.2.1.6 specifies the design sections to be used. NDOT design practice is to use a 40-kip axle instead of the 32-kip axle specified in the *LRFD Specifications*. Therefore, the bridge designer must multiply the design moments shown in LRFD Table A4-1 by 1.25.

16.1.3 Empirical Design

Reference: LRFD Article 9.7.2

NDOT prohibits the use of the empirical deck design methodology.

16.2 DESIGN DETAILS FOR BRIDGE DECKS

16.2.1 General

The following general criteria apply to bridge decks that are constructed compositely in conjunction with concrete girders, steel girders and the top slabs of cast-in-place, post-tensioned box girders:

1. Thickness. The thickness of reinforced concrete decks shall typically be 8 in but not less than 7½ in for all girder-type bridges. The composite deck over precast side-by-side box girders shall be a 5½-in minimum CIP reinforced concrete slab.

2. Reinforcing Steel Strength. The specified yield strength of reinforcing steel shall be 60 ksi.

3. Exposure Condition. Use a Class 2 exposure factor in LRFD Equation 5.7.3.4-1 for all bridge decks.

4. Reinforcement Cover. The bottom reinforcement cover shall be a minimum of 1½ in. The top reinforcement cover shall be a minimum of 2½ in, which includes a ½-in sacrificial wearing surface. The primary reinforcement in the top and bottom mats shall be the closer reinforcement to the concrete face. See Figure 14.3-B for additional concrete cover criteria.

5. Placement of Top and Bottom Transverse Reinforcing Steel. The top and bottom transverse reinforcing steel shall be offset, preferable at half the spacing, so that the top mat is not placed directly above the bottom mat.

6. Reinforcing Steel Spacing. Maintain a minimum of 1½ in vertical separation between the top and bottom reinforcing mats. Where conduits are present between mats, the 1½ in must be increased. Maintain a minimum horizontal spacing of 5 in on center (with 6 in preferred) between adjacent bars within each mat. The maximum horizontal reinforcing steel spacing is 8 in for primary (transverse) steel. See Figure 14.3-C for additional information on reinforcing steel spacing.

7. Reinforcing Bar Size. The minimum reinforcing steel size used for bridge deck reinforcement is a #4 bar.

8. Sacrificial Wearing Surface. The 2½-in top reinforcement concrete cover includes ½ in that is considered sacrificial. For both the deck and superstructure, its weight shall be included as a dead load, but its structural contribution shall not be included in the structural design.

9. Concrete Strength. The minimum specified 28-day compressive strength of concrete for bridge decks shall be 4.0 ksi in Clark County and 4.5 ksi elsewhere in the State.

10. Length of Reinforcement Steel. For detailing, the maximum length of reinforcing steel in the deck shall be 60 ft.

11. Placement of Transverse Reinforcing Steel on Skewed Bridges. The following applies:

    a. Skews $\leq$ 20°: Place the transverse reinforcing steel parallel to the skew.

b. Skews > 20°: Place the transverse reinforcing steel perpendicular to the longitudinal reinforcement.

See Section 16.2.4 for a definition of skew angle and for structural considerations related to skewed reinforcing steel placement.

12. Splices/Connectors. Use lap splices for deck reinforcement unless special circumstances exist. Mechanical connectors may be used where clearance problems exist or on a phased-construction project that precludes the use of lap splices. See Section 14.3.1.8 for more discussion on splices.

    Transverse slab reinforcement should be lapped, if necessary, as follows: Negative moment steel in the positive-moment region between the slab supports and positive moment steel in the negative-moment region over the slab supports.

13. Shear Connectors For Concrete Girder Bridges. Stirrups shall project from the girders into the slab to provide a composite section. Detail bars to hook around longitudinal deck reinforcement.

14. Post-Tensioning. Post-tensioning is not normally used in cast-in-place concrete decks. It can be used where spans exceed 14 ft and as approved by the Chief Structures Engineer.

16.2.2 Detailing Requirements for Concrete-Deck Haunches

16.2.2.1 General

Haunches, concrete between the top of a steel flange or concrete girder and the bottom of the bridge deck, are provided to account for construction variations and tolerances. The haunch varies across the width of the flange due to cross slope, the length of the girder due to flange thickness, camber variation and profile. In all cases, however, there shall be a minimum of a ½-in haunch.

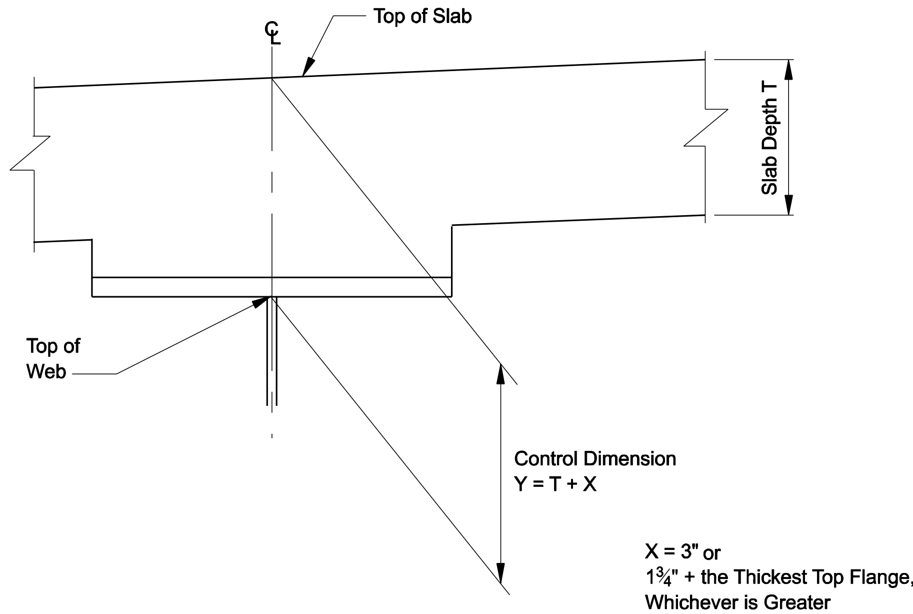
The girder haunch should be included in the load calculations as dead load by applying the maximum haunch dimension throughout the span. The haunch, however, should be ignored in the calculation of the section's resistance.

The Control Dimension "Y" is measured at the centerline of bearing and varies along the span to compensate for variations in camber and superelevation ordinate. In some cases where vertical curve corrections are small, the vertical curve ordinate can be accommodated in the haunch without including it in the girder.

The haunch should be detailed flush with the vertical edge of the top flange.

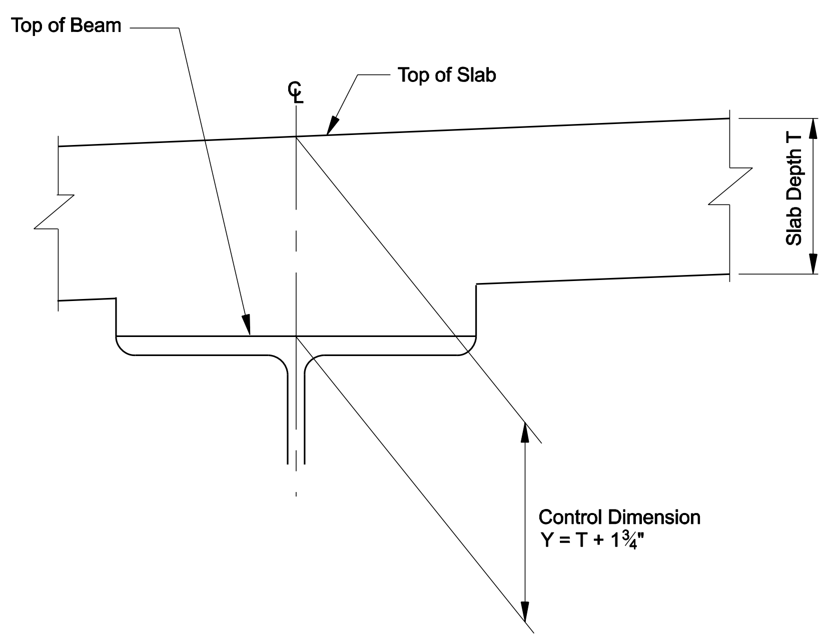
16.2.2.2 Haunch Dimensions for Steel Girders

Figure 16.2-A illustrates the controlling factors used to determine the haunch dimension for steel plate girders. Figure 16.2-B illustrates a steel rolled beam. For plate girders, the control dimension "Y" is the deck thickness "T" plus a dimension "X". "X" is the greater of 1¾ in plus the thickest top flange or 3 in. The 1¾ in dimension represents the maximum positive camber fabrication tolerance allowed by AWS D-1.5 of 1½ in plus a moderate deck cross slope. For rolled beams, the control dimension "Y" includes the deck thickness "T" plus 1¾ in.



HAUNCH DIMENSION FOR STEEL PLATE GIRDERS

Figure 16.2-A



HAUNCH DIMENSION FOR STEEL ROLLED BEAMS

Figure 16.2-B

16.2.2.3 Haunch Dimensions for Precast Concrete Girders

Figure 16.2-C illustrates the controlling factors used to determine the haunch dimension for precast concrete girders. Control dimension "Y" is the deck thickness "T" plus 3 in. The 3-in dimension is used to account for camber growth in the girder at the center of span. The amount of camber growth can vary even between girders cast at the same time.

16.2.2.4 Reinforcement for Deep Haunches

Provide additional reinforcement in haunches greater than 4 in deep. The additional reinforcement shall consist of a minimum of #4 U-shaped reinforcing bars spaced at a maximum of 12 in. These reinforcing bars shall be properly developed into the bridge deck.

16.2.3 Stay-in-Place Forms

Steel stay-in-place forms are typically used with steel I-girders. Although not typical, steel stay-in-place forms can be used with precast concrete girders. Stay-in-place forms are not allowed in bays having longitudinal joints nor in deck overhangs.

Design loads for stay-in-place forms shall be applied for all girder bridges and consist of 0.015 ksf for the metal forms and form corrugation fill applied over the areas of the forms. If the Contractor elects not to use stay-in-place forms, the bridge designer should consider revising the camber calculations. NDOT prohibits field welding of the stay-in-place forms to steel flanges.

16.2.4 Skewed Decks

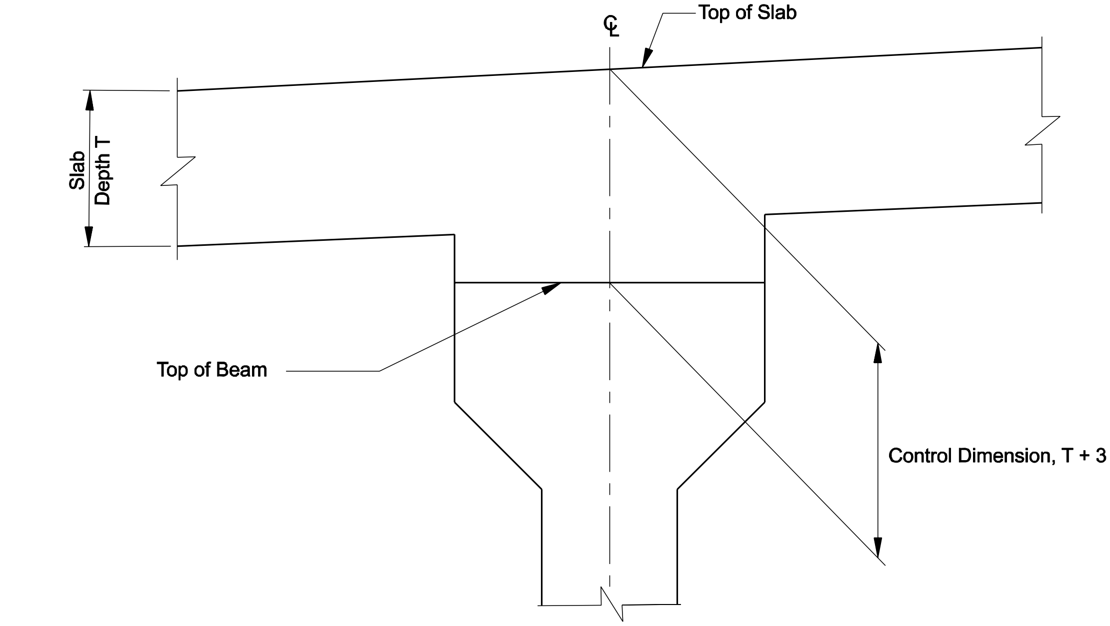
Reference: LRFD Article 9.7.1.3

Skew is defined by the angle between the centerline of support and the normal drawn to the longitudinal centerline of the bridge at that point. See Figure 16.2-D. The support skews can be different. In addition to skew, the behavior of the superstructure is also affected by the span-length-to-bridge-width ratio.

The *LRFD Specifications* suggests that the effects of skew angles not exceeding 25° can be neglected for concrete decks, but the *LRFD Specifications* assumes the typical case of bridges with relatively large span-length-to-bridge-width ratios. Further, the Commentary indicates that the 25° limit is "somewhat arbitrary." Therefore, the traditional NDOT 20° threshold is acceptable for use.

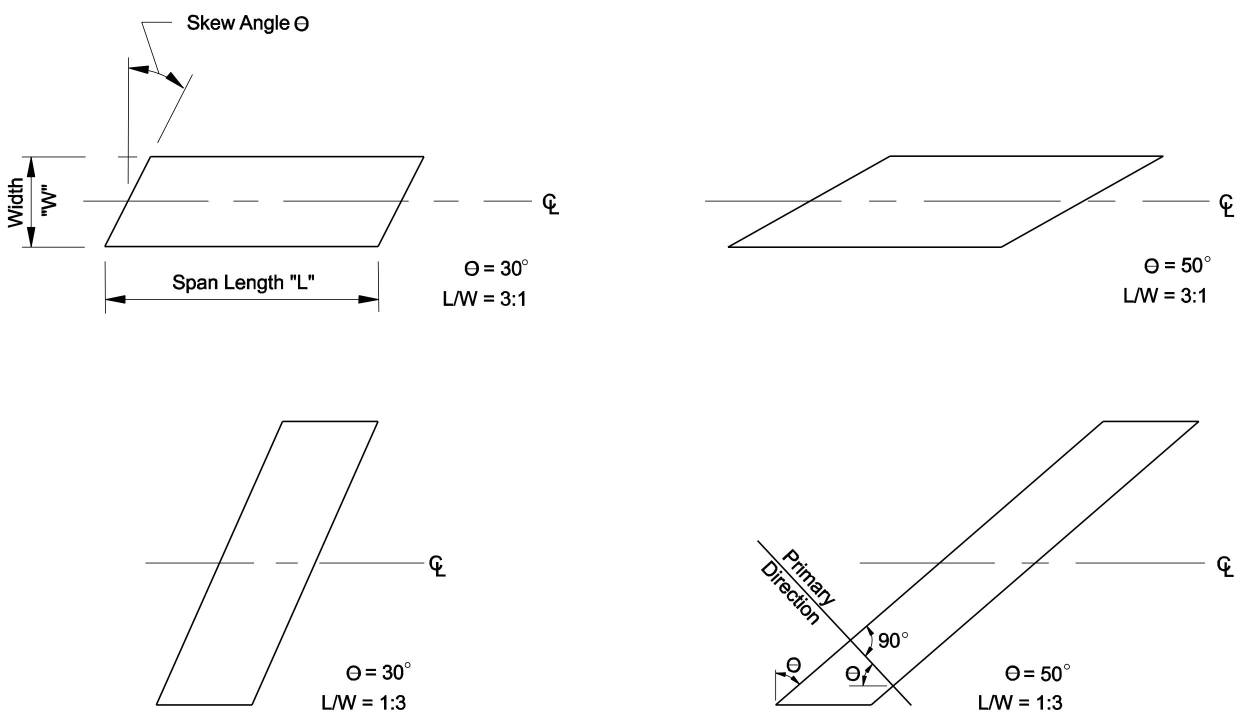
Figure 16.2-D illustrates four combinations of skew angles 30° and 50° and length-to-width ratios of 3:1 and 1:3. Both the 50° skew and the 1:3 length-to-width ratio may be considered extreme values for bridges, but this often occurs where the deck constitutes the top slab of a box culvert.

Both combinations with 30° skew may be orthogonally modeled for design with the skew ignored.



HAUNCH DIMENSION FOR CONCRETE I-GIRDERS

Figure 16.2-C



SKEW ANGLE AND LENGTH/BRIDGE WIDTH RATIOS

Figure 16.2-D

The combinations with 50° skew may require additional thought. Consider, for example, the combination of 50° skew and L/W = 1:3. If the deck is a cast-in-place concrete slab without girders, the primary direction of structural action is perpendicular to the span not in the direction of the span. In this case, consider running the primary reinforcement in that direction and fanning it as appropriate in the side zone. With this arrangement, the secondary reinforcement could then be run parallel to the skew, thus regaining the orthogonality of the reinforcement as appropriate for this layout.

16.2.5 Deck Pouring Sequence for Bridge Decks that are Constructed Compositely in Conjunction with Concrete And Steel Girders

Reference: LRFD Article 2.5.3

16.2.5.1 NDOT Typical Practice

The designer determines the need for a bridge deck pouring sequence based on factors such as size of pour, configuration of the bridge, potential placement restrictions, direction of placement, deck tensile stresses and any other special circumstances that might affect the bridge deck placement. In addition, provide a deck pouring schedule for bridges that have any of the following features:

- continuous bridges,
- bridges with curved or non-parallel deck edges, or
- wide or long single span bridges.

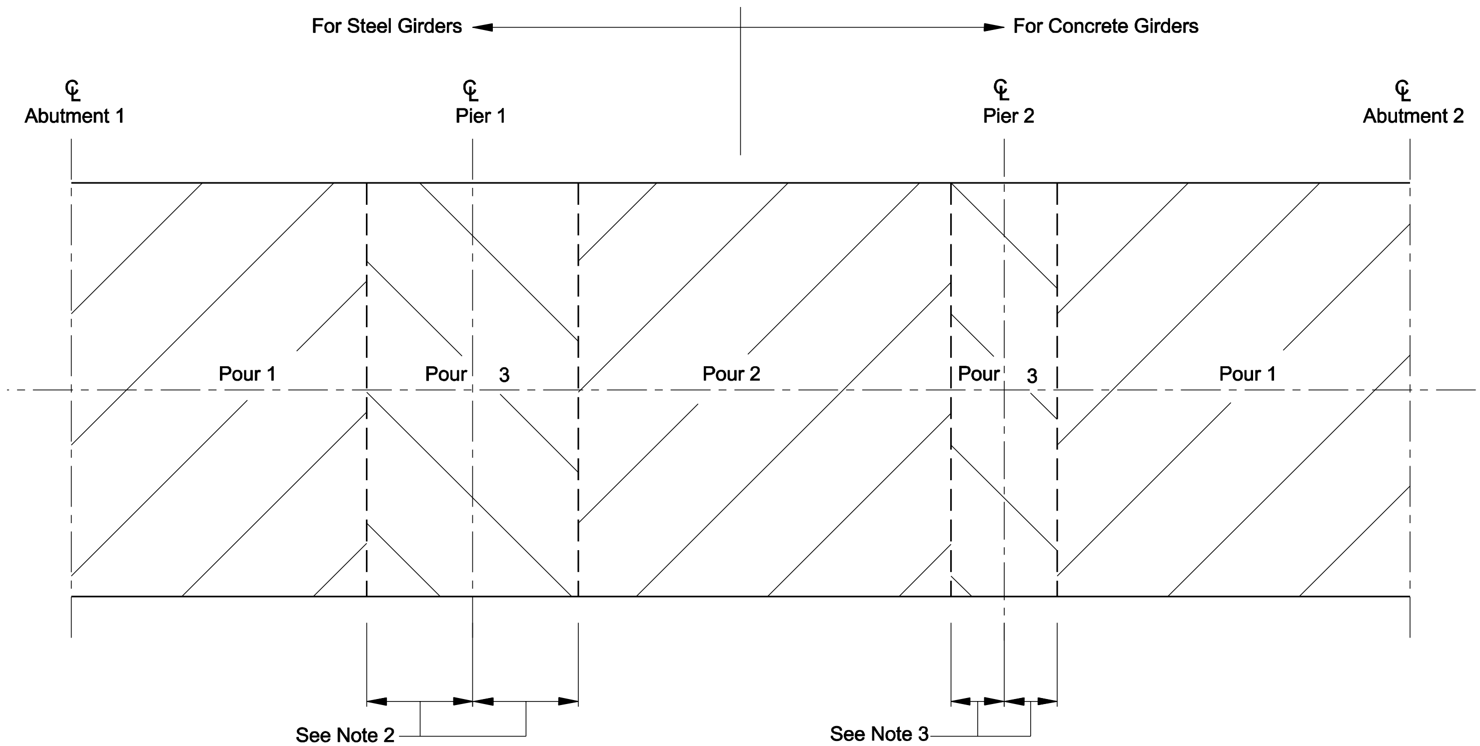
Where required, the bridge designer will present in the contract documents the sequence of placing concrete in various sections (separated by transverse construction joints) of deck slabs on continuous spans. The designated sequence should avoid or minimize the dead-load tensile stresses in the slab during concrete setting to minimize cracking, and the sequence should be arranged to cause the least disturbance to the portions placed previously. In addition, for longer span steel girder bridges, the pouring sequence can lock-in stresses far different than those associated with the instantaneous placement typically assumed in design. Therefore, for these bridges, the designer shall consider the pouring sequence in the design of the girders.

Deck placement shall be uniform and continuous over the full width of the superstructure. The first pours shall include the positive-moment regions in all spans. For all deck pours on a longitudinal gradient of 3% or greater, the direction of pouring should be uphill.

Figure 16.2-E illustrates a sample pour sequence diagram for a continuous girder bridge. For precast concrete girders, the cast-in-place diaphragm over the abutment is cast integrally at the same time as the deck above it. The negative-moment regions for steel girders extend between the points of beam dead load contraflexure. For precast concrete girders, the designer should use a minimum of 3 ft on each side of the center of support or 5% of the span length, whichever is greater.

For simple spans, it is desirable to pour the entire deck at once. If this is not practical, the deck may be poured in a series of longitudinal strips with closure pours as needed. For steel bridges, the designer should carefully investigate potential differential deflections.

Precast concrete girders made continuous for live load and superimposed dead load shall be treated as a special case. The deck segment and diaphragm over supports shall be poured after the mid-span regions of the deck have been poured as simple-span loads.



Notes:

1. The direction of pour should be shown for each pour.
2. Pour 3 limits for steel girders are at the points of beam dead load contraflexure.
3. Pour 3 limits for precast girders are 5% of span length or 3' minimum.

TYPICAL POUR DIAGRAM

(Continuous Steel and Precast Girders)
Figure 16.2-E

End wall concrete in integral abutments will usually be cast concurrently with applicable portions of the superstructure (e.g., bottom slab, web/diaphragm, deck). The contract documents shall indicate the requirements for a special placement sequence.

16.2.5.2 Transverse Construction Joints

Place a transverse construction joint in the end span of bridge decks on steel superstructures where uplift is a possibility during the deck pour. Where used, transverse construction joints should be placed parallel to the transverse reinforcing steel. They shall not be placed over field splices.

A bridge with a relatively short end span (60% or less) when compared to the adjacent interior span is most likely to produce this form of uplift. Uplift during the deck pour can also occur at the end supports of curved decks and in superstructures with severe skews. If analysis using the appropriate permanent load factors of LRFD Article 3.4.1 demonstrates that uplift occurs during deck placement, require a construction joint in the end span and require placing a portion of the deck first to act as a counterweight.

16.2.6 <u>Longitudinal Construction Joints</u>

Longitudinal construction joints in bridge decks can create planes of weakness that can lead to maintenance problems. In general, NDOT discourages the use of construction joints, although they cannot be avoided under certain circumstances (e.g., widenings, phased construction). The following will apply to longitudinal construction joints:

1. <u>Usage</u>. Longitudinal construction joints need not be used on decks having a constant cross section where the width is less than or equal to approximately 120 ft. For deck widths greater than 120 ft (i.e., where the finishing machine span width must exceed 120 ft), the designer shall make provisions to permit placing the deck in practical widths. The designer shall detail either a longitudinal joint or a longitudinal closure pour, preferably not less than 3 ft in width. Lap splices in the transverse reinforcing steel shall be located within the longitudinal closure pour. Such a joint should remain open as long as the construction schedule permits to allow transverse shrinkage of the deck concrete. The designer should consider the deflections of the bridge on either side of the closure pour to ensure proper transverse fit up.

2. <u>Location</u>. If a longitudinal construction joint is necessary, do not locate it underneath a wheel line. Preferably, a construction joint should be located outside the girder flange and in a shoulder or median area.

3. <u>Closure Pours</u>. For staged construction projects, a closure pour shall be used to connect the slab between stages. A closure pour serves two useful purposes: It defers final connection of the stages until after the deflection from deck slab weight has occurred, and it provides the width needed to make a smooth transition between differences in final grades that result from construction tolerances. The closure width should relate to the amount of relative dead-load deflection that is expected to occur across the pour after the closure is placed. A minimum closure width of 3 ft is recommended. Greater closure widths may be required when larger relative dead-load deflections are anticipated. The required width can be estimated by considering the closure pour to be a fixed-fixed beam and by limiting the stresses in the concrete to the cracking stress. When a closure pour is used, the following apply:

- Stay-in-place forms shall not be used under the closure pour.

- Diaphragms/cross frames in the staging bay of structural steel girders shall not be rigidly connected until after the adjacent stages of the deck have been poured. Construct concrete diaphragms in the staging bay of prestressed concrete girders after adjacent portions of the bridge are complete. The diaphragms may be poured as part of the closure.

- Reinforcing steel between different stages shall not be tied or coupled until after the adjacent stages of the deck have been poured.

- Support the finishing machine on an overhang jack that is connected to the girder loaded by the deck pour. Do not place the finishing machine on a previously poured deck. The bridge designer must indicate in the contract documents that this method of constructing the closure pour is not allowed. See Figure 16.2-F.

16.2.7 Longitudinal Deck Joints

Reference: LRFD Article 14.5.1.1

Open longitudinal joints, used on slab-on-girder bridges, are not typically needed except on the widest of bridges. The requirement for open longitudinal joints in bridges is based on the bridge width, skew and span configuration. NDOT has not adopted a specified maximum bridge width that can be used without a longitudinal open joint although, as an approximate guide, widths up to 120 ft without a joint are usually acceptable. Open longitudinal joints may be needed where the width of the bridge exceeds 120 ft or on multiple-span bridges with large skews.

The following applies:

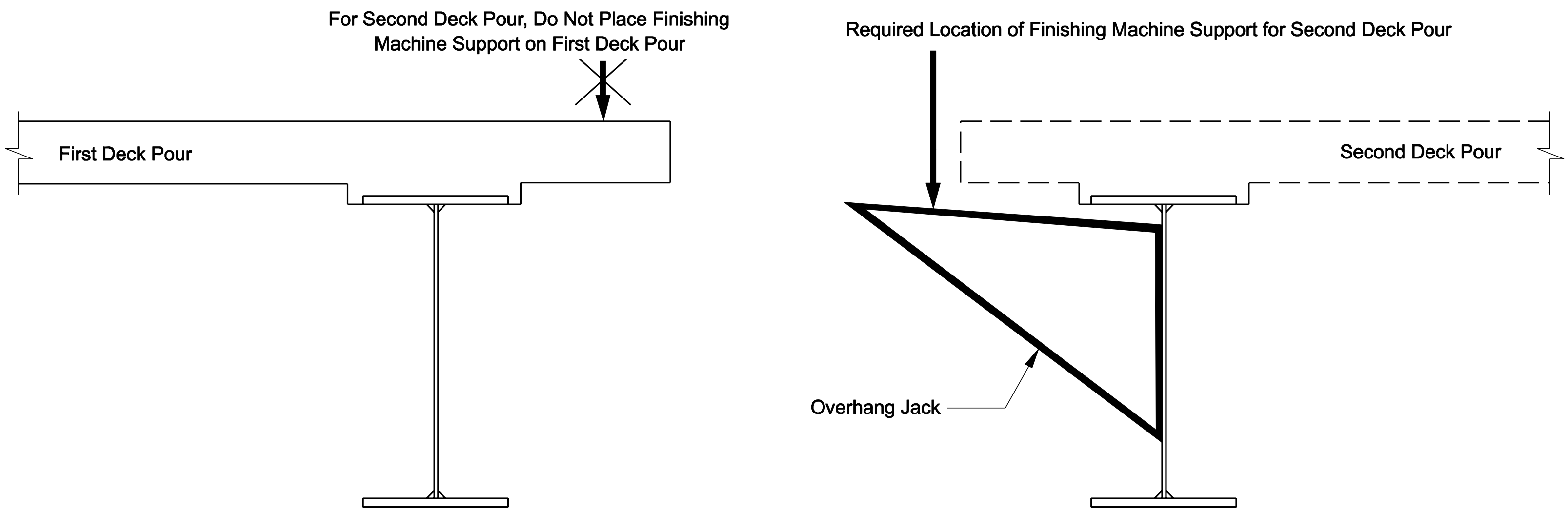
1. Column Design. A longitudinal open joint should be used where transverse temperature controls the column design. Desirably, the column design will be controlled by seismic loads and not other load combinations.

2. Location. Longitudinal open joints shall not be placed over a girder flange. If a longitudinal joint is used, it should be placed in both the superstructure and substructure.

16.2.8 Transverse Edge Beam for Steel Girder Bridges

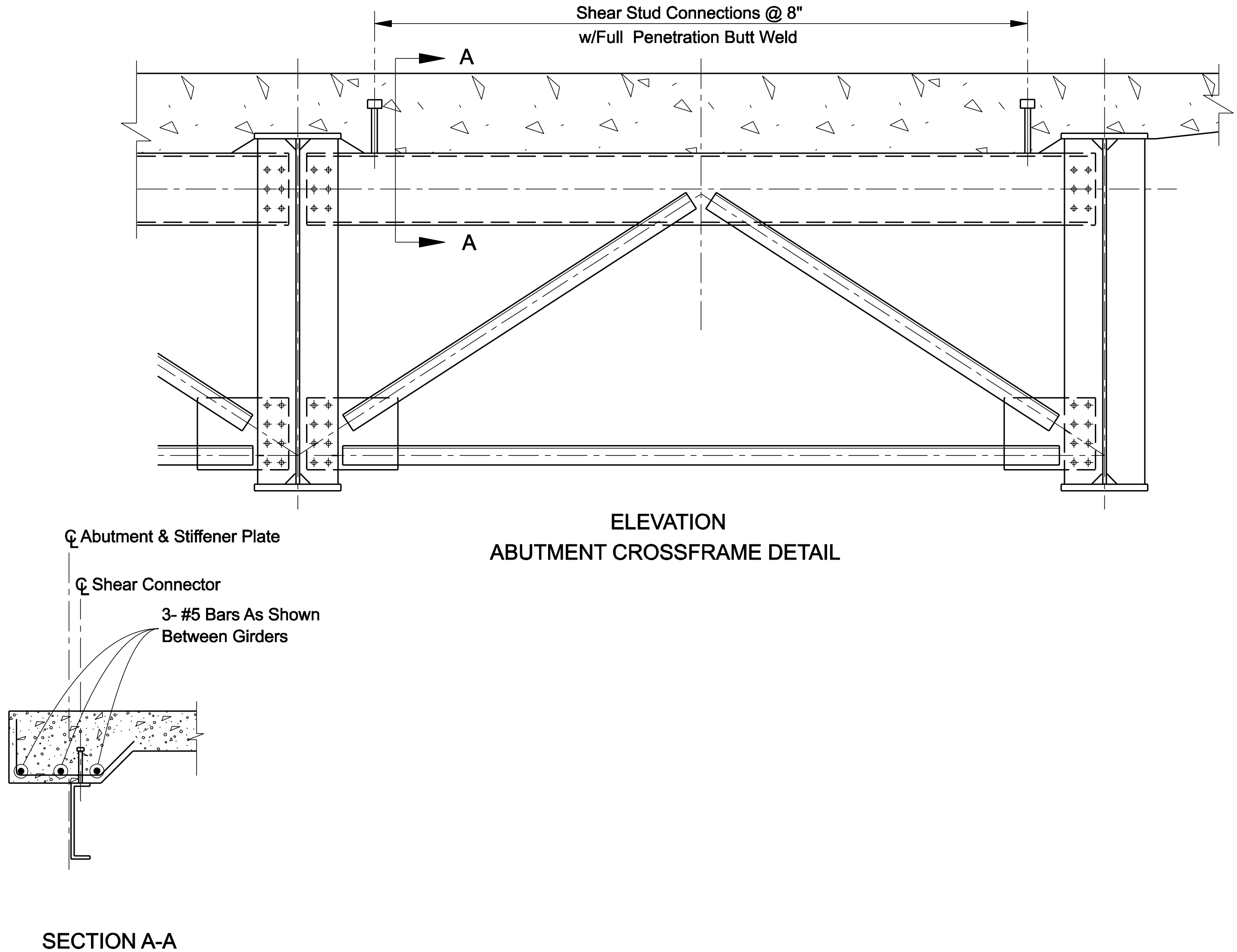
Reference: LRFD Article 9.7.1.4

NDOT practice is to provide a transverse edge beam to support wheel loads near the transverse edge of the deck in conjunction with an end diaphragm for steel girder bridges. See Figure 16.2-G.



SUPPORT FOR FINISHING MACHINE

Figure 16.2-F



TRANSVERSE EDGE BEAM

Figure 16.2-G

16.2.9 <u>Deck Overhang/Bridge Rail</u>

Reference: LRFD Article 9.7.1.5

16.2.9.1 Overhang Width and Thickness

Bridge deck overhang is defined as the distance between the centerline of the exterior girder to the outside edge of the deck. Typically, NDOT practice is that the overhang width will not be more than 40% of the girder spacing. The thickness of the overhang at the outside edge of deck should be the same as the interior deck thickness. The thickness of the overhang at outside edge of girder should be the deck thickness plus the haunch depth.

16.2.9.2 Construction

Typical NDOT practice is to construct the exterior overhang of the bridge deck slab using an overhang jack for steel and precast concrete girders or falsework for CIP concrete bridges. Overhang jacks are connected to the girder at their top and braced against the web or bottom flange on the bottom. Large overhang widths can cause excessive lateral distortion of the bottom flange and web of the girder. See Section 15.6.4, which requires that the contractor check the twist of the exterior girder and bearing of the overhang bracket on the web. See Figure 16.2-H for typical overhang construction forming on concrete and steel girders and Figure 16.2-I for cast-in-place concrete.

16.2.9.3 Structural/Performance Design

Reference: LRFD Articles 13.6.1, 13.6.2 and 13.7.2

All combination bridge rail/deck overhang designs shall meet the structural design requirements to sustain rail collision forces in LRFD Article A13.2. All bridge rails shall meet the performance requirements of LRFD Article 13.7.2; see Section 16.5. Use a Class 2 exposure factor in LRFD Equation 5.7.3.4-1 for all bridge rails and deck overhang designs.

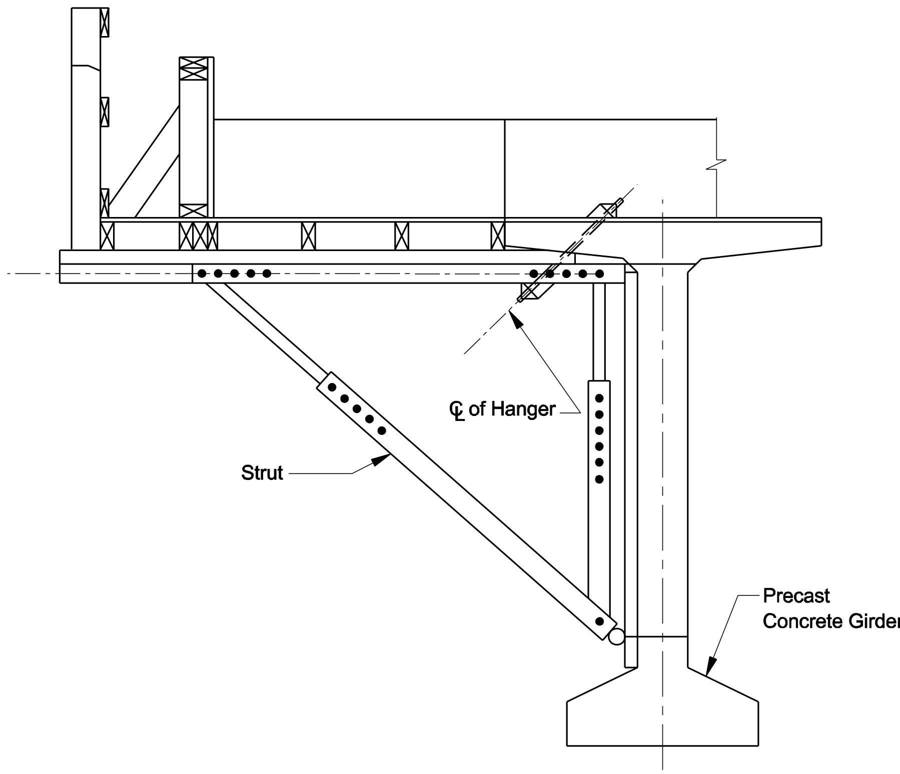
When designing the deck overhang for Extreme Event II, include a vertical wheel load located 12 in from the face of bridge rail in conjunction with transverse and longitudinal bridge rail loads; do not apply the wheel load in combination with vertical rail loads. Design the deck overhang using the rail resistance instead of the rail load. This ensures failure in the rail before the deck overhang.

Sidewalks, when used, are placed on the outside edge of bridge decks adjacent to rails. Assume the point of fixity for the design of the rail at the deck level and not the top of sidewalk.

16.2.9.4 Bridge Rail Joints

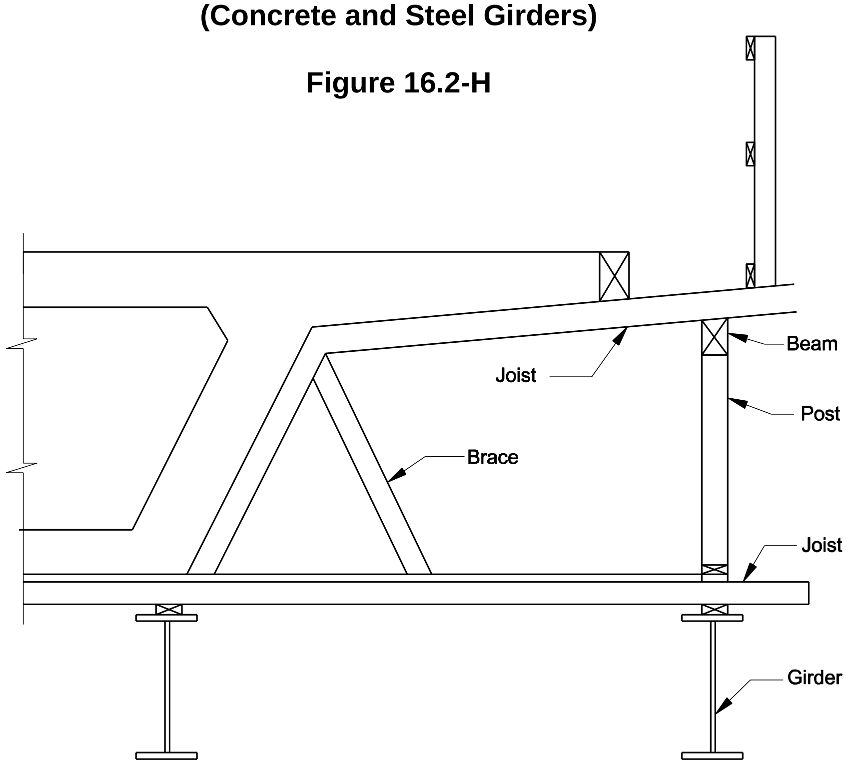
The following applies to bridge rail joints:

1. <u>Concrete Bridge Rail Joints</u>. Joints on concrete bridge rails shall be provided at all locations of expansion in the bridge; i.e., the joints on the bridge deck and barrier will



TYPICAL OVERHANG FORMING SYSTEM
(Concrete and Steel Girders)

Figure 16.2-H



TYPICAL OVERHANG FORMING SYSTEM
(Cast-in-Place Box Girder)

Figure 16.2-I

match. In addition, 2-in open joints in the barrier, extending from the top of the barrier downward 2 ft, shall be provided at the mid-span of each span and over supports. Additional open joints should be considered on longer spans. Open joints shall be designed as discontinuities.

2. Barrier Rail Connection. In Clark County, the expansion joint should extend up into the barrier rail at least 6 in; in the remainder of the State, the extension should be 12 in up the face of the rail.

16.3 APPROACH SLABS

16.3.1 Usage

Approach slabs are required on all bridges. See Section 11.4.7.

16.3.2 Design Criteria

See the *NDOT Drafting Guidelines* and *Standard Plans* for the typical approach slab details. The roadway ends of approach slabs should be designed parallel to the bridge ends except when the skew is more than 20° on approaching roadways with concrete pavement. The following design criteria apply to approach slabs:

1. Materials. Concrete shall be 4 ksi in Clark County and 4.5 ksi in the remainder of the State. The class of concrete used in the approach slabs shall be consistent with the class used in the deck to which they are attached. Grade 60 reinforcing bars shall be used in the design of all approach slabs. In areas outside Clark County, all reinforcing steel in the approach slab shall be epoxy coated.

2. Profile Grade with Asphalt Pavements. For asphalt pavements, NDOT practice is to place the profile grade at the top of the dense graded mix. The actual riding surface on asphalt paving is higher than the profile grade due to the placement of an open grade asphaltic concrete layer. Therefore, bridge decks and the approach slabs must be constructed higher than the profile grade on the approaching roadway. Confirm the thickness of the open grade AC layer with the roadway designer (typically ¾ in, but sometimes other thicknesses are used), and provide a note in the contract documents that indicates this elevation adjustment has been reflected in the plans.

3. Profile Grade with Concrete Pavements. For concrete pavements, NDOT practice is to place the profile grade at the riding surface. Therefore, if the approaching roadway pavement is concrete, bridge decks and the approach slabs will be constructed at the elevation of the profile grade.

4. Analysis. If a special design is used, the approach slab shall be modeled as a simple span.

5. Bridge Approach Joints. Provide a terminal joint or pavement relief joint at the end of the roadway at the bridge approach slab, if the approaching roadway is concrete.

6. Skews. When concrete pavement and skews of 20° or greater exist, a redesign of the typical NDOT approach slab may be necessary. See the *NDOT Standard Plans* for guidance on the layout.

7. Deep End Spans. The minimum approach slab length should be the larger of two times the structure depth plus 3 ft, or 24 ft. Approach slabs longer than 24 ft shall be designed as a longitudinally reinforced slab. The design shall assume that the approach slab is a simple span supported by the bridge on one end and by 3 ft of competent soil at the approach roadway end.

8. Wingwalls. The design forces for wingwalls are due to earth pressure only. It is NDOT practice to extend the approach slabs over the wingwall, which eliminates the live load surcharge in the design of the wingwall. Seismic forces from the soil behind the wingwall must also be considered in the design of wingwalls.

16.3.3 Construction

Approach slabs shall be finished and cured by the same methods used to construct bridge decks.

16.4 DECK DRAINAGE

Reference: LRFD Article 2.6.6

16.4.1 Importance of Bridge Deck Drainage

The bridge deck drainage system includes the bridge deck, sidewalks, railings, gutters, inlets and, for a closed drainage system, the underdeck closed pipe system. The primary objective of the drainage system is to remove runoff from the bridge deck before it collects in the gutter to a point that exceeds the allowable design spread. Proper bridge deck drainage provides many other benefits, including:

- Efficiently removing water from the bridge deck enhances public safety by decreasing the risk of hydroplaning.
- Long-term maintenance of the bridge is enhanced.
- The structural integrity of the bridge is preserved.
- Aesthetics are enhanced (e.g., the avoidance of staining substructure and superstructure members).
- Erosion on bridge end slopes is reduced.

16.4.2 Responsibilities

The Hydraulics Section calculates the flow of water and recommends the location, type and spacing of the deck drain. The bridge designer uses this information to design the deck drains, pipes, cleanouts, support system and outlets. The bridge designer should work with the Hydraulics Section to locate inlets near piers or abutments. The Environmental Services Division determines if the outflow can be placed directly into another drainage facility or if it must be first treated before release to a natural waterway.

16.4.3 Open vs Closed Drainage

The first option, as determined by the Hydraulics Section, is to avoid placing deck drains on the bridge deck. Where this option is not practical, NDOT policy is to use a closed drainage system. An open, free-falling drainage system may be used if all of the following are satisfied:

- The Environmental Services Division determines that an open, free-falling drainage system is acceptable for the proposed location.
- The free-falling discharge is not over or likely to be over travel lanes, shoulders, bicycle facilities or sidewalks beneath a bridge.
- A free-falling discharge is not allowed on railroad right-of-way.
- The free-falling discharge does not have the potential to erode earth slopes or natural ground.

- The free-falling discharge will not flow onto substructure elements. Downspouts should extend at least 2 in below the bottom of the girder. Downspouts should not be located within 5 ft of the end of any substructure units or where water could easily blow over and run down a substructure element. Downspouts should not be located such that a 45° cone of splash beneath the downspout will touch any structural component. Downspouts shall not encroach upon the required vertical or horizontal clearances.

16.4.4 <u>Design of Deck Drainage</u>

16.4.4.1 Deck Slope

To provide proper bridge deck drainage, the absolute minimum profile grade of the bridge should be 0.5% but, preferably, not be less than 1%. The transverse slope of the bridge deck must be accommodated by providing a suitable roadway cross slope, typically 2%.

16.4.4.2 Pipes and Cleanouts

Pipes and cleanouts shall be of a rigid steel pipe, either galvanized or painted, with a diameter not less than 6 in but preferably 8 in. Pipes shall have a minimum grade of not less than 6%. Provide cleanouts at each turn in the pipe and every 100 ft where practical.

16.4.4.3 Structural Considerations

The primary structural considerations in drainage system design are:

1. <u>Decks</u>. Inlet sizing and placement must be compatible with the structural reinforcement and other components of a bridge deck. For example, inlets for reinforced concrete bridge decks must fit within the reinforcing bar design. Thickening of the deck and additional reinforcement may be required to maintain clearances and deck resistance.

2. <u>Caps, Columns and Other Concrete Elements</u>. Pipes entering or exiting caps, columns or other concrete elements must do so where relocating reinforcing steel will not have an adverse effect on the resistance of the element. For example, pipes entering or exiting columns must do so outside the plastic hinge zone. Either relocate the pipe so that it enters or exits outside the plastic hinge zone or place the pipe external to the column. Do not cut reinforcement to accommodate drainage pipes.

3. <u>Corrosion and Erosion</u>. The drainage system should be designed to deter runoff (and the associated corrosives) from contacting vulnerable structural members and to minimize the potential for eroding embankments. To avoid corrosion and erosion, the design must include the proper placement of outfalls. Water running to the end of a bridge must be directed away from the end of wingwalls to prevent erosion.

4. <u>Expansion, Deflection and Rotation</u>. Special attention is required where drainage pipes cross points of expansion or where the superstructure is more flexible than the substructure. Where horizontal pipes cross a point of expansion, the pipe must have an expansion device capable of expanding, contracting and deflecting with thermal and seismic movements while maintaining a closed system. When the superstructure is flexible compared to the substructure, a vertical pipe needs to have some flexibility to account for rotation.

5. Pipe Supports. Pipe runs must be supported by pipe hangers connected to the deck or cross frames. The pipe hanger should have a roller on the bottom to facilitate erection of the pipe and an adjustment screw to set the proper pipe grade. The maximum spacing of hangers shall be 25 ft but no longer than that required by design. Assume that the pipe is full of water when designing hanger spacings.

16.4.4.4 Maintenance Considerations

The drainage system will not function properly if it becomes clogged with debris. Therefore, it is important that maintenance requirements be considered in the design. The bridge designer should avoid drainage designs that provide inadequate room for maintenance personnel on the bridge deck or access beneath the bridge or that provide unsafe working areas for maintenance personnel. Outlets should daylight above the ground to provide access for backflushing, rodding or air-pressure cleaning equipment.

Downspouts for free-falling drainage systems should be located so that the maintenance crews can access them from underneath the bridge and preferably from the ground.

16.5 BRIDGE DECK APPURTENANCES

16.5.1 <u>Bridge Rails</u>

Reference: LRFD Article 13.7

16.5.1.1 Test Levels

Reference: LRFD Article 13.7.2

LRFD Article 13.7.2 identifies six test levels for bridge rails, which have been adopted from NCHRP 350 *Recommended Procedures for the Safety Performance Evaluation of Highway Features*. Test Levels One and Two have no application in Nevada. The following identifies the general test level applications:

1. <u>TL-3 (Test Level 3)</u>. A TL-3 bridge rail is the minimum acceptable performance level for all bridges in Nevada except on NHS facilities. TL-3 is generally acceptable for a wide range of high-speed arterial highways with very low mixtures of heavy vehicles and with favorable site conditions. Performance crash testing is at 60 mph with a 1.55-kip passenger car and a 4.5-kip pickup truck.

2. <u>TL-4 (Test Level 4)</u>. A TL-4 bridge rail is the minimum performance level for bridges on the National Highway System (NHS). TL-4 is generally acceptable for the majority of applications on high-speed highways, freeways and expressways and Interstate highways with a mixture of trucks and other heavy vehicles. Performance crash testing is at 60 mph with a 1.55-kip passenger car and a 4.5-kip pickup truck plus an 18-kip single-unit truck at 50 mph.

3. <u>TL-5 (Test Level 5)</u>. TL-5 is for a special case where large trucks make up a significant portion of the vehicular mix. A TL-5 rail can only be used when approved by the Chief Structures Engineer.

4. <u>TL-6 (Test Level 6)</u>. TL-6 is for a special case where alignment geometry may require the use of an extra height rail. A TL-6 rail can only be used when approved by the Chief Structures Engineer.

16.5.1.2 Bridge Rail Types/Usage

The *NDOT Bridge Drafting Guidelines* presents details for those bridge rail types used by NDOT. The following identifies typical NDOT usage for bridge rails:

1. <u>32-in Concrete F-Shape Bridge Rail</u>. NDOT typically uses this bridge rail on all bridges for which the 42-in F-shape and 42-in vertical wall are not applicable; see Items #2 and #3 below. The 32-in F-shape bridge rail meets the height criteria for a TL-4. The concrete bridge rail's advantages when compared to a metal beam rail include its superior performance when impacted by large vehicles, its relatively low maintenance costs and its better compatibility with the bridge deck system (i.e., the concrete rail can be constructed integrally with the bridge deck). The concrete bridge rail's disadvantages include its higher dead weight.

2. <u>42-in Concrete F-Shape Bridge Rail</u>. NDOT typically uses this bridge rail:

- if the roadway approach barrier is 42 in,
- across railroads,
- across multiple-use (pedestrian, bicycle) facilities, or
- curved structures with high degree of curvature.

The 42-in concrete F-shape bridge rail meets the TL-5 height criteria.

3. 42-in Vertical Concrete Wall. NDOT typically uses this rail where sidewalks are present on the bridge and where the bridge rail is located between the sidewalk and roadway. Its height conforms to the LRFD requirements for pedestrian rails; therefore, its use where sidewalks are present avoids the need to extend the height of a 32-in concrete bridge rail to meet the height requirements of a pedestrian rail or bicycle rail. The 42-in vertical concrete wall meets the TL-5 height criteria.

4. Metal Beam Bridge Rail. NDOT generally discourages the use of any metal beam bridge rail system. Its use may only be considered where aesthetics or other special conditions are important. The Chief Structures Engineer must approve the use of any metal beam bridge rail. When compared to a concrete bridge rail, a metal beam rail's advantages include lower dead weight and providing a more open view of the surrounding scenery. The comparative disadvantages include a lesser ability to contain heavier vehicles, higher maintenance costs, and a more complex structural connection to the bridge deck system.

5. TL-6 Rail. This special rail may be considered on bridges where extra protection for semi-trucks is warranted because:

- The road is a high-speed facility.
- There are a significant number of trucks using the facility.
- The alignment has a sharp degree of curvature.
- The potential consequences of rail penetration would be catastrophic.

The advantage of this system is the extra protection it provides to higher profile vehicles (e.g., a tanker truck). The disadvantages include the poor aesthetics due to its height (90 in) and the design of the bridge deck and superstructure must include the extra weight of the rail and impact loads. The impact loads are also not clearly defined.

16.5.1.3 Guardrail-To-Bridge-Rail Transitions

Standard Plan details are used for most applications of guardrail-to-bridge-rail transitions. Special designs, if required for unusual circumstances, are developed by the bridge designer with input from the Roadway Design Division.

16.5.1.4 Bridge Rail/Sidewalk

Reference: LRFD Articles 13.4 and 13.7.1.1

As discussed in Section 11.9.4.4, the Roadway Design Division determines the warrants for a sidewalk on a bridge. At lower speeds, a raised sidewalk is separated from the adjacent roadway by a vertical curb, which is typically 6 in high. The 42-in bridge rail is located on the outside edge of the sidewalk. However, at higher speeds, the vertical curb is not considered to be adequate protection; the 42-in bridge rail is located between the roadway and sidewalk. For this arrangement, a raised sidewalk is typically not used. A 42-in pedestrian railing is used at the outside edge of the sidewalk.

16.5.2 Bicycle Rails

Reference: LRFD Article 13.9

As discussed in Section 11.9.4.5, the Statewide Bicycle/Pedestrian Coordinator determines if bicycle accommodation is required across a bridge. Where required, a bicycle rail that meets the geometric and loading requirements of LRFD Article 13.9 must be provided. The required height of the bicycle rail is 42 in.

Bicycle paths are bikeways that are physically separated from motorized vehicular traffic by an open space or barrier and may be either within the highway right-of-way or within an independent right-of-way. Bridges that are part of a bicycle path require a 42-in bicycle rail.

16.5.3 Protective Fencing

Protective fencing is used across bridges when protection to facilities adjacent to or beneath the structure is warranted. Fencing is typically required for:

- all overpasses in urban areas, and
- all overpasses over railroads.

Protective fencing may be considered at other locations on a case-by-case basis.

Protective fencing is designated as "pedestrian railing" in the *NDOT Standard Plans* and contract bid items. Standard NDOT pedestrian railings includes:

1. Type M Pedestrian Rail. Type M pedestrian rails are used adjacent to sidewalks where there is no bridge rail on the outside edge of bridge. The Type M pedestrian rail is mounted on a short concrete pedestal. The lower portion is vertical with the upper portion extending back over the sidewalk.

2. Type M Modified Pedestrian Rail. Type M Modified pedestrian rails are used adjacent to sidewalks where there is a bridge rail on the outside edge of bridge. The Type M Modified pedestrian rail is a short version of the Type M pedestrian rail and is mounted on top of the exterior bridge rail.

3. Type V Pedestrian Rail. Type V pedestrian rails are used on bridges where no sidewalks are present. They are located adjacent to traffic and are mounted on the top of the exterior bridge rail. Type V pedestrian rails are vertical.

16.5.4 Utility Attachments

The Structures Division will coordinate with the Utilities Section within the Right-of-Way Division and with the Roadway Design Division for any utility attachments proposed on the bridge.

Utility companies frequently request approval from NDOT to attach utility lines or pipes to bridges. The Structures Division's concern is that the structural performance and function of the bridge not be compromised; that the safety of the individuals using the bridge not be compromised; and that NDOT maintenance of the bridge is not unduly complicated. On new or replaced bridges, the bridge designer should consider detailing two 2-in diameter conduits in each concrete bridge rail (or other similar accommodations) for the future use of NDOT or Utility Companies.

The following guidelines apply to attaching utilities to NDOT-owned structures:

1. Utility lines cannot be attached to the outside edge of new or replaced bridges where the structure crosses another highway or where aesthetics are a concern. The attachment shall be within box cells or between girders, preferably in the outside bays. On existing bridges, it is acceptable but not preferred to mount utility lines on the outside edge.

2. Utility lines cannot hang below the bottom of the girders or below the bottom of the deck on CIP concrete bridges.

3. No field welding is allowed on steel girders. Field drilling may be allowed on concrete girders only at approved locations.

4. All attachments to concrete shall be made with permanent-type, approved epoxy-resin anchors. Attachment hardware shall be galvanized or stainless steel. Some epoxies creep when subjected to permanent tension loads; therefore, provide special attention to the attachment to ensure that appropriate bonding materials are used under these circumstances.

5. Provide expansion couplings at the bridge's points of expansion.

6. New utility lines will not be allowed on bridges with a limiting load posting.

7. Utility attachments must be made in accordance with Nevada State laws. The Utility cannot unilaterally hook up to a bridge because it is convenient without notifying NDOT.

8. Utility attachments are inspected as part of the Nevada Bridge Inspection Program. The utility owner will be notified of any necessary maintenance or repair work. The utility owner is required to secure necessary approvals and permits from NDOT prior to completing repairs. See Section 28.2.6.11.

9. To ensure a safe and structurally adequate installation, NDOT requires an engineered attachment plan from the Utility.

10. If the bridge cannot safely accommodate the traffic loads and the utility, the Utility will not be permitted on the bridge. Also, no attachment will be permitted that impairs NDOT inspection and maintenance activities.

11. A utility attachment that reduces the vertical clearance or freeboard will not be permitted.

12. To ensure a safe installation for the utility, NDOT requires all attachments on the downstream side of the bridge because, during floods, trees and other drift will occasionally strike the girders.

13. NDOT does not allow a utility to pass through an abutment or wing wall without specific approval; they must exit from underneath the roadway as soon as possible.

14. The Utility will not be allowed to bolt through the deck or girders.

15. Because NDOT frequently has maintenance work on bridge rails, bridge rail mounting is not preferred.

16. Trenching operations that are so close to the bridge footings such that there may be undercutting or sloughing will not be allowed.

17. NDOT is not the final approval authority for attachments to historic bridges; these must also be cleared with other agencies.

18. The Utility is responsible for any damage resulting from the presence of the utility on the bridge.

19. Installation of the utility should not interfere with the NDOT contractor constructing the bridge.

20. For a pipeline containing fluids or gases, the installation must be cased the full length of the bridge and extend a minimum of 50 ft beyond the end of abutment or 10 ft beyond the end of the approach slab. Trenches close to footings or piles may also require casing on a case-by-case basis.

21. The utility attachment shall be designed to prevent discharge of the pipe product into the stream or river in case of pipe failure.

22. Use of bridge members to resist forces caused by moving fluids will not be permitted.

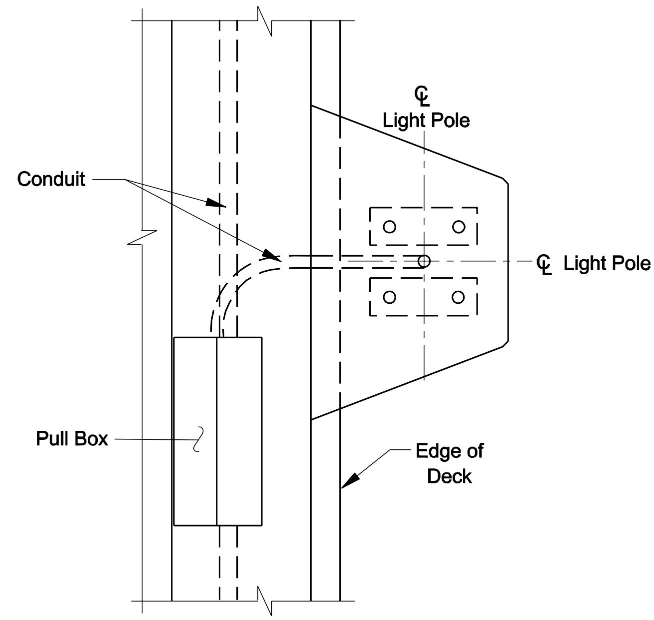
23. Utility attachments will require that an expansion-deflection device be installed where the conduit or casing crosses a bridge expansion joint.

16.5.5 Sign Attachments

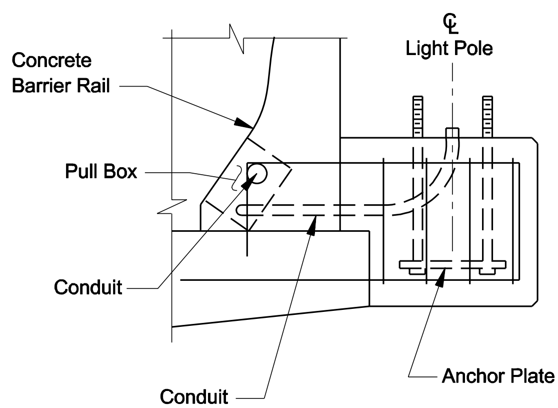
If the Traffic Engineering Section proposes to attach a sign to a bridge, the Section must coordinate with the Structures Division. The Structures Division will assess the structural impact on the bridge and, if the sign attachment is approved, the Structures Division will design the attachment details. Signs cannot decrease the vertical clearance.

16.5.6 Luminaire/Traffic Signal Attachments

The Traffic Engineering Section determines the warrants for highway lighting and traffic signals, and the Section performs the design work to determine, for example, the spacing of the luminaries and the provision of electricity. Lighting will often be included on bridges that are located in urban areas; traffic signal warrants are determined on a case-by-case basis. Where attached to a bridge, the Structures Division will design the structural support details for the luminaire and/or traffic signal attachments to the bridge. Locate soffit lighting such that it will not adversely affect vertical clearances over traffic lanes or shoulders. The design is not standardized as situations vary greatly. Figure 16.5-A presents an example of a viable solution.



PLAN



ELEVATION

EXAMPLE OF A LUMINAIRE SUPPORT

Figure 16.5-A