Arizona Department of Transportation
Intermodal Transportation Division – Bridge Group
205 South Seventeenth Avenue Phoenix, Arizona 85007-3213

Janice K. Brewer
Governor

John S. Halikowski
Director

Floyd Roehrich Jr.
State Engineer

BRIDGE BULLETIN 2011-3
Issue Date 8-26-2011

To: All Bridge Designers

From: Jean A. Nehme, Ph.D., P.E.
State Bridge Engineer

Subject: ADOT Bridge Design Guidelines
http://www.azdot.gov/Highways/bridge/Guidelines/DesignGuidelines/index.asp

Please note that the following sections of the ADOT Bridge Design Guidelines have been updated:

SECTION 5 - CONCRETE STRUCTURES
- 5.1 SCOPE
- 5.4.1 General
- 5.7.3.2 Flexural Resistance
- 5.14.1.1 General
- 5.14.1.2 Precast Beams
- 5.14.1.4 Bridges Composed of Simple Span Precast Girders Made Continuous
- 5.14.1.5 Cast-in-Place Girders and Box and T-Beams
- 5.14.1.5.1c Web
- 5.14.4.1 Cast-in-Place Solid Slab Superstructures
- 5.14.4.2 Cast-in-Place Voided Slab Superstructures

SECTION 6 - STEEL STRUCTURES
- 6.1 SCOPE

SECTION 9 - DECKS AND DECK SYSTEMS
- 9.4 GENERAL DESIGN REQUIREMENTS
- 9.5.2 Service Limit States

SECTION 10 - FOUNDATIONS
- 10.1 SCOPE
- 10.5.2.2 Tolerable Movements and Movement Criteria
- 10.5.5.2.4 Drilled Shafts
- 10.6.1.1 General

SECTION 13 - RAILINGS
- 13.4 GENERAL

SECTION 14 - JOINTS AND BEARINGS
- 14.4.1 General

The following pages summarize all of the updates.

Summary of the Updates

5.1 SCOPE

This Section contains guidelines to supplement provisions of Section 5, Concrete Structures, of the AASHTO LRFD Bridge Design Specifications. These provisions apply to the design of bridges, retaining walls, and other appurtenant highway structure components constructed of normal density concrete reinforced with steel bars, welded wire reinforcement, prestressing strands, prestressing bars, or prestressing wires. Concrete deck design criteria are specified in Section 9 of these guidelines.

All design engineers are advised to review the example problems in Appendix – A of these guidelines for proper and correct application of various provisions of the AASHTO LRFD Specifications and these guidelines for design of bridge structural components.

Minimum vertical clearance for a bridge should be established based on future roadway configuration. For bridges spanning over railroads, minimum vertical clearance shall be based on the most recent railroad grade separation guidelines.

5.4 Material Properties

5.4.1 General

Design should be based on the material properties cited in these guidelines. The contract documents shall specify the grades or properties of all materials to be used and shall be in conformance with the latest edition of the ADOT Standard Specifications for Road and Bridge Construction. All structural concrete shall meet or exceed ADOT Class S requirements unless noted otherwise.

Designers shall not use epoxied anchorage systems which are constantly under pure axial tension.

5.7.3.2 Flexural Resistance

For post-tensioned box girders, in determining the ~~negative~~ flexural resistance, neither the temperature and shrinkage reinforcement nor the distribution reinforcement ~~may~~ shall be used ~~at the design engineer's discretion~~. In determining the positive flexural resistance, the longitudinal flange reinforcing may be used, if necessary, to reduce reinforcement congestion.

5.14 PROVISIONS FOR STRUCTURE TYPES

5.14.1 Beams and Girders

5.14.1.1 General

Girders shall be placed accurately on bearings to avoid creating eccentricities capable of initiating imbalance.

Girders with shapes that exceed a height to width ratio of two shall be temporarily braced. The girder width shall be determined from the outside dimension of the bottom flange.

The contractor shall secure such girders in position on the structure with temporary lateral bracing to resist loads as specified in the AASHTO Guide Design Specifications for Bridge Temporary Works. Lateral bracing shall be designed to allow for girder temperature movements. The bracing shall be placed prior to the release of the erection equipment from each girder.

Prior to erection of any girders, the contractor shall provide a lateral bracing plan, prepared and sealed by a professional engineer registered in the State of Arizona, for the Engineer's review. Such bracing plan shall be included with the working drawings specified in Subsection 105.03, and shall include supporting calculations. A girder pre-erection meeting will be scheduled following the review and prior to erection of any girders. All parties involved in the installation shall be represented, and no girders shall be placed until the plan has been approved.

No traffic shall be allowed under each newly erected girder until the girder has been laterally braced.

Temporary bracing shall remain in place until after permanent concrete diaphragms are installed at the bents, or the girder is integrated with a permanent feature that restricts the girder's lateral movement.

5.14.1.2 Precast Beams

Precast prestressed girders shall be designed as simply supported beams using composite section properties for dead and transient loads. The superstructure shall be constructed continuous over the intermediate supports and designed for transient and composite dead load. The design should include the effects of shrinkage and creep for all strength limit states. Additional non-prestressed reinforcement shall be provided in the deck slab to account for continuity over the intermediate supports. The design shall be based on the strength of concrete of the closure pour. Additional continuity reinforcement shall meet the requirements of AASHTO LRFD Article 5.11.1.2.3.

Due to the increase in the number of overweight permits, precast prestressed girder spacing shall not exceed 10.0 feet unless approved by ADOT Bridge Group.

5.14.1.4 Bridges Composed of Simple Span Precast Girders Made Continuous

~~The design engineer shall follow AASHTO LRFD Article 5.14.1.2.7, third edition, 2004. The current AASHTO LRFD Article has been rescinded.~~

5.14.1.5 Cast-in-Place Girders and Box and T-Beams

For service limit state, the allowable tensile stress in reinforcing steel, f_s, shall be limited to 28 ksi.

5.14.1.5.1c Web

Web thickness shall not be less than 12 inches (measured normal to girder for sloping exterior webs). Exterior girders webs shall be flared to a minimum thickness of 18 inches at the abutments. The flare length shall be 16 feet from the face of the abutment diaphragm. Interior webs shall be constructed vertical. A 4″x 4″ fillet shall be used at the tops of ~~interior~~ webs but is not required at the bases.

~~For girders over 8.0 feet in depth, AASHTO LRFD C5.14.1.5.1c should be followed.~~ The minimum web thickness shall be 14 inches for girders over 10.0 feet in depth.

Method of Analysis for Cast-In-Place Box Girder

Section properties shall be based on gross area of members for cast-in-place post-tensioned members.

The bottom slab, in the vicinity of the intermediate support, may be flared to increase its thickness at the face of the support when the required concrete strength exceeds 4.5 ksi. When thickened, the bottom slab thickness should be increased by a minimum of 50 percent. The length of the flare should be at least one-tenth of the span length (measured from the center of the support) unless design computations indicate that a longer flare is required.

Section properties at the face of the support should be used throughout the support; i.e., the solid cap properties should not be included in the model.

Negative moments should be reduced to reflect the effect of the width of the integral support.

The combination of dead load and prestress forces should not produce any tension in the extreme fibers of the superstructure.

Cast-in-Place multi-cell concrete box girder bridges shall be designed as one unit for the entire cross-section of the superstructure. Such cross-sections shall be designed for live load distribution factors specified in AASHTO LRFD Articles 4.6.2.2.2 and 4.6.2.2.3 for interior girders, multiplied by the number of girders, i.e., webs.

For box girders with severe sloping webs or boxes over 7 feet deep, transverse flange forces induced by laterally inclined longitudinal post-tensioning shall be considered in the design.

Single span structures should be jacked from one end only. Symmetrical two span structures may be jacked from one end or from both ends. Unsymmetrical bridges should be jacked from the long end only or from both ends as required by the design. Three span or longer structures should be jacked from both ends.

Several prestressing systems should be checked to verify that the eccentricity and anchorage details are acceptable. In determining the center of gravity of the strands, the difference between the center of gravity of the strands and the center of the ducts, shall be considered. For structures over 400 feet in length, in determining the center of gravity of the strands, the diameter of the ducts should be oversized by ½ inch to allow for ease of pulling the strands.

For horizontally curved bridges, special care shall be taken in detailing stirrups and duct ties. Loss of prestress due to friction should be based on both vertical and horizontal curvatures. In designing for horizontal curvature, the exterior web with smallest radius shall be used. A variation of prestressed force not to exceed 5% per web shall be allowed provided that total jacking force remains the same as calculated in design. The design engineer may read and implement recommended design criteria included in the article "The Cause of Cracking in Post-Tensioned Concrete Bridges and Retrofit Procedures", by Walter Podolny, published in the PCI Journal, Vol. 30, No. 2, March-April 1985.

5.14.4 Slab Superstructures

5.14.4.1 Cast-in-Place Solid Slab Superstructures

For service limit state, the allowable tensile stress in reinforcing steel, f_s, shall be limited to 28 ksi.

5.14.4.2 Cast-in-Place Voided Slab Superstructures

For service limit state, the allowable tensile stress in reinforcing steel, f_s, shall be limited to 28 ksi.

6.1 SCOPE

This section contains guidelines to supplement provisions of Section 6 of the AASHTO LRFD Bridge Design Specifications for the analysis and design of steel components, splices and connections for beam and girder structures, frames, trusses and arches, as applicable. Metal deck systems in relation to steel stay-in-place formwork are covered in Section 9 of these guidelines.

Minimum vertical clearance for a bridge should be established based on future roadway configuration. For bridges spanning over railroads, minimum vertical clearance shall be based on the most recent railroad grade separation guidelines.

9.4 GENERAL DESIGN REQUIREMENTS

A 3/4" V-drip groove shall be located on the underside of the deck overhang for all ~~steel girder~~ bridges. ~~It shall also be used for concrete bridges when a steel rail barrier system is used.~~

9.5 LIMIT STATES

9.5.2 Service Limit States

Deck design is controlled by Service Limit State I. The behavior of bridge decks shall be considered elastic. Decks shall be designed by the working stress method and as stated in this section.

Allowable tensile stress in ~~transverse~~ reinforcing steel, f_s, shall be limited to 24 ksi.

10.1 SCOPE

This Section contains guidelines to supplement provisions of Section 10 of the AASHTO LRFD Bridge Design Specifications for the analysis and design of foundations for highway structures. Provisions of this section shall apply to the design of spread footings, driven piles, and drilled shaft foundations.

Bridges that are designed based on soil-structure interaction principles shall not be used to span over roadways.

10.5 LIMIT STATES AND RESISTANCE FACTORS

10.5.2 Service Limit States

10.5.2.2 Tolerable Movements and Movement Criteria

Rotational movements shall be evaluated at the top of the substructure unit and at the deck elevation.

Tolerance of the superstructure to lateral movement will depend on bridge seat or joint widths, bearing type(s), structure type, and load distribution effects.

The bridge designer should limit the ~~total~~ settlement of a foundation per 100 ft span to ~~0.5~~ 0.75 in. Linear interpolation should be used for other span lengths. Higher ~~total~~ settlements ~~limits~~ may be used when the superstructure is adequately designed for such settlements. ~~The designer shall also check other factors such as rideability and aesthetics.~~ Any ~~total~~ settlement that is in excess of 4.0 in, including stage construction settlements if applicable, ~~higher than 2.5 in, per 100 ft span,~~ must be approved by the ADOT Bridge Group. The designer shall also check other factors, which may be adversely affected by foundation settlements, such as rideability and aesthetics.

Based on the ADOT Material Group's recommendation, the ~~differential~~ settlement, which shall be used for the structural evaluation of any span, shall be the larger of the two ~~total~~ settlements ~~of the foundations calculated~~ at either end of that span assuming ~~zero total~~ no settlement ~~for~~ at the other end ~~foundation~~. ~~The calculated settlements at each of the foundations are provided in the geotechnical report. When the bridge is being built using a stage construction method, foundation settlements that do not induce forces in the superstructure may be subtracted from the total settlement of that foundation when calculating differential settlements.~~ Settlements shall be determined from the charts which are included in the Geotechnical Report based on service limit state. For settlements in excess of 0.75 in per 100 ft of span length, the superstructure shall be designed to sustain the forces induced due to such settlement. The bridge designer should use the full value of the settlement without deducting 0.75 in per 100 ft of span length. For bridges that will be built using a stage construction method, settlements that do not induce forces in the superstructure may be subtracted from settlements obtained from the Geotechnical Report when determining the value of the settlement to be used in designing the superstructure. For bridges involving complex stage construction, the bridge designer should coordinate with the geotechnical engineer when ~~calculating~~ ~~differential~~ determining settlements.

The creep and the elasto-plastic characteristics of the soil surrounding the foundation, permit some moment relief for the columns. It is suggested that, for Service Limit State only, moments and shears due to prestressing could be reduced by 50%, and those due to thermal action could be reduced by 25%. These reductions are considered reasonable when applied to columns with a fixed connection to the foundation. When allowing limited foundation release using springs or some foundation translation, or if drilled shafts are being used, the prestress and thermal forces shall not be reduced. Therefore, reductions in the prestress and thermal forces must be used consistent with the analysis model.

10.5.5.2.4 Drilled Shafts

In general, ~~A~~ a bridge abutment or pier foundation consisting of two or more drilled shafts is considered as a redundant foundation, unless the center-to-center spacing of the drilled shafts is six diameters or more.

Substructure systems spanning roadways, such as straddle bents, and supported by single drilled shafts at each end, shall not be considered redundant.

10.6 SPREAD FOOTINGS

10.6.1 General Considerations

10.6.1.1 General

Provisions of this Article shall apply to design of isolated, continuous strip and combined footings for use in support of columns, walls and other substructure and superstructure elements.

In Arizona, the two most commonly used types of spread footings are:

- Isolated footings: which are used as individual support for the various parts of a substructure unit and may be stepped laterally.
- Combined footings: which are used to support more than one column for multi-column bents. They also could be used to support wall bents.

Spread footings shall be proportioned and designed such that the supporting soil or rock provides adequate nominal resistance, considering both the potential for adequate bearing strength and the potential for settlement, under all applicable limit states in accordance with the provisions of this Section.

Spread footings shall be proportioned and located to maintain stability under all applicable limit states, considering the potential for, but not necessarily limited to, overturning (eccentricity), sliding, uplift, overall stability and loss of lateral support.

When sound soil materials exist near the surface, shallow foundations in the form of spread footings are commonly used. For foundation units situated in a stream, spread footings may be used when they can be placed on non-erodible rock. Spread footings used as bridge foundations shall not be supported by embankment fill material including embankments consisting of mechanically or otherwise stabilized earth systems. ~~Spread footings shall not be placed on embankment filled material unless approved by ADOT Bridge Group and ADOT Material Group.~~

The bridge designer shall size the footing to ensure that the limit bearing pressure and settlement will not be exceeded for any AASHTO LRFD group loading. The footing shall be properly designed to resist the maximum applied moments and shears.

Spread footings shall be designed for limit states and resistance factors as specified in AASHTO LRFD Article 10.5. Resistance factors for the strength limit state shall be taken as specified in AASHTO LRFD Table 10.5.5.2.2-1. Resistance factors for the service limit state shall be taken as 1.0.

Bridge designers shall include the following information per footing on the structure plan sheets:

- Total settlement which is used in the design of the footing based on the geotechnical report.
- The service limit state factored net bearing resistance (capacity) (in ksf) and the strength limit state factored net bearing resistance (capacity) (in ksf) which are used in the design of the footing based on the geotechnical report.

13.4 GENERAL

Append the following to the end of the existing Section 13.4:

Bridge concrete barriers and parapets shall not be constructed using slip forms. Painting the inside of bridge barriers should be avoided due to long-term maintenance concerns.

Rustication on the exterior of bridge barriers and parapets shall be limited to a thickness of 1 ½ in. Rustication may extend the full height of the barrier and parapet, excluding the 42-inch (nominal) F-shape bridge concrete barrier. The rustication height for 42-inch (nominal) F-shape barriers shall be limited to the bottom 32 inches, measured from the top of deck.

14.4 MOVEMENTS AND LOADS

14.4.1 General

Provisions shall be made in the design of structures to resist induced stresses or to provide for movements resulting from variations in temperature, shortening of structure length due to creep, shrinkage, and prestressing or a combination of thereof. Accommodation of thermal and shortening movements will entail consideration of deck expansion joints, bearing systems, restraining devices and the interaction of these three items.

The main purpose of deck joints is to seal the joint opening to obtain a watertight joint while allowing for vertical, horizontal and rotational movement. The bearings are required to transmit the vertical and lateral loads from the superstructure to the substructure and to allow for movement in the unrestrained directions. Restraining devices are required to limit the displacement in the restrained directions. Improper design or construction of bearings or restrainers could adversely affect the movement of the structure.

The calculated displacements used in determining the required displacement (i.e. the difference between the widest and the narrowest opening of a joint) shall be the sum of 1.2 times the ~~sum of the~~ movements caused by temperature changes and 1.0 times the shortening movement caused by creep and shrinkage.