



TEXAS TECH UNIVERSITY

Multidisciplinary Research in Transportation

# Proposed Modifications to the LRFD Design of U-Beam Bearings

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## **Notice**

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## Section 6

### Prestressed Concrete U Beams (Types U40 and U54)

#### Materials

Use Class H concrete with a minimum  $f'_{ci} = 4.0$  ksi and  $f'_c = 5.0$  ksi.

Design beams for 0.5-in, low-relaxation strands. You may use 0.6-in, low-relaxation strands for unusual cases but should check its availability with fabricators.

Use prestressing strand with a specified tensile strength,  $f_{pu}$ , of 270 ksi.

You need not increase section properties of the beam to account for the transformed area of strands or mild steel.

#### Geometric Constraints

The maximum skew angle for U-beam bridges is 45 degrees.

The maximum allowable transverse slope for U-beam bridges using standard uniform-height steel-reinforced elastomeric bearings is 4 percent.

#### Structural Analysis

Beam designs must meet the following requirements:

- ◆ Include the overlay at the discretion of the designer or if the bridge will receive the overlay immediately after construction. Recognize that including the overlay in the design of U beams can significantly limit their ability to span longer span lengths.
- ◆ Distribute 2/3 of the rail dead load to the exterior beam and 1/3 of the rail dead load to the adjacent interior beam applied to the composite cross section.
- ◆ Each U beam has two interior diaphragms at a maximum average thickness of 13 in. They are located as close as 10 ft. from midspan of the beam. Account for each diaphragm as a 2-kip load for U40 beams and as a 3-kip load for U54 beams applied to the non-composite cross section.
- ◆ Use section properties given on the standard drawings.
- ◆ Composite section properties may be calculated assuming the beam and slab to have the same modulus of elasticity (for beams with  $f'_c < 8.5$  ksi). Do not include haunch concrete placed on top of the beam when determining section properties. Section properties based on final beam and slab modulus of elasticity may also be used.

- ◆ Live load distribution factors must conform to *AASHTO LRFD Bridge Design Specifications*, Article 4.6.2.2.2 for flexural moment and Article 4.6.2.2.3 for shear, except for exterior beam design. For exterior beam design, use a distribution factor

for two or more design lanes loaded only. Do not use the distribution factor for one design lane loaded unless the clear roadway width is less than 20.0 ft. Use 1.0 for the multiple presence factor for one lane loaded. For exterior beams, multiply the result of the lever rule by 0.9 to account for continuity. The live load used to design the exterior beam must never be less than the live load used to design an interior beam.

- ◆ For bridges with less than three girders in the cross section, assume the live load distribution factors for flexural moment and shear are equal to the number of lanes divided by the number of girders. Determine the number of lanes as required by *AASHTO LRFD Bridge Design Specifications*, Article 3.6.1.1.1.

### Design Criteria

Standard beam designs must meet the following requirements:

- ◆ Stresses at the ends of the beam are controlled with the use of debonding. Draped strands are not permitted in U beams.
- ◆ The maximum amount of debonding is limited to 75% of the strands per row and per section.
- ◆ The maximum debonded length is the lesser of the following:
  - Half-span length minus the maximum development length specified in the *AASHTO LRFD Bridge Design Specifications*, Article 5.11.3.
  - 0.2 times the span length
  - 15.0 ft.
- ◆ Grouping of U-beam designs are at the discretion of the designer. However, no exterior U beam may have less carrying capacity than that of an interior U beam of equal length. If the designer chooses to group beams, a general rule is to group beams with no more than a four-strand difference.
- ◆ See “Prestressed Concrete I Beams” and “Steel-Reinforced Elastomeric Bearings for Prestressed Concrete Beams” for other design criteria.

### Detailing

Detail span sheets for a cast-in-place slab with precast concrete panels.

**Section 2****Steel-Reinforced Elastomeric Bearings for Prestressed Concrete Beams****Materials**

Use 50-durometer neoprene for steel-reinforced elastomeric bearings.

Use a shear modulus range of 95 to 175 psi for design, using the least favorable value for the design check.

Make steel shims 0.105 in. thick.

Do not use adhesives between bearings and other components.

**Geometric Constraints**

See standard drawings available at <http://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/standard/bridge-e.htm> for standard pad details.

You may use tapered bearings if the taper does not exceed 0.055 ft./ft. For beams on steeper grades, use a beveled steel sole plate field-welded (1/4-in, fillet) to a 1/2-in, steel plate embedded in and anchored to beams with headed stud anchors. Use a minimum of four 1/2-in.-by-3-in. stud anchors with studs located between strands and reinforcement. The minimum thickness of sole plate should be 1.5 in. of steel between weld and elastomer. The sole plate should extend at least 1 in. beyond the beam flange. Sole plates should not be vulcanized to the bearing to allow slip to occur at the beam/bearing interface.

Use 1/4-in, exterior pad layers. If using 1/4-in, interior pad layers, disregard the requirements in the *AASHTO LRFD Bridge Design Specifications*, Article 14.7.6.1, specifying exterior layers no thicker than 70% of internal layers.

**Structural Analysis**

Assume a temperature change of 70 degrees Fahrenheit after erection when calculating thermal movement in one direction (not total). This provides a conservative estimate of thermal movement after erection in most regions of Texas based on the minimum and maximum temperature contour maps in the *AASHTO LRFD Bridge Design Specifications*, Article 3.12.2.2.1 (the panhandle region is the most extreme case with Tmin at 10 degrees F and Tmax at 115 degrees F).

Do not include shrinkage, creep, and elastic shortening when determining maximum movement, which will be accommodated through infrequent slip.

Do not apply IM to live load when checking compressive stress (see *AASHTO LRFD Bridge Design Specifications*, Commentary C 14.7.5.3.2).

Use appropriate shear live load distribution, modified for skew.

Use the critical DL condition (the lightest predicted DL) when checking against slip as required by *AASHTO LRFD Bridge Design Specifications*, Article 14.7.6.4.

Use Load Combination Service I for all gravity loads.

For the design of steel-reinforced elastomeric bearings for U-beam bridges placed on a transverse slope, the effect of the transverse slope shall be considered by including:

- ◆ The transverse displacement,  $\Delta_1$ , caused by the horizontal component of the end reaction;
- ◆ The distance from the centerline of the bearing and the center of gravity of the composite U-beam and deck section,  $\Delta_2$ , determined as the product of the transverse slope and the perpendicular distance from the bottom of the composite U-beam and deck section to its center of gravity;
- ◆ The transverse moment,  $M_t$ , determined by the product of the end reaction and the sum of the  $\Delta_1$  and  $\Delta_2$  distances for the Compressive Stress, Compressive Deflection, and the Rotation checks;
- ◆ The effective displacement,  $\Delta_{s,eff}$ , determined as the square root of the sum of the  $\Delta_1$  and the thermal expansion displacements for the Shear Strain check;
- ◆ The effective slope,  $\Theta_{eff}$ , determined as the square root of the sum of the transverse and longitudinal slopes for the Anchorage Slip check.

**Design Criteria**

Follow Design Method A in *AASHTO LRFD Bridge Design Specifications*, Article 14.7.6, with the following exceptions:

- ◆ DL compressive stress limit is the lesser of 1.20 ksi and 1.2 GS.
- ◆ Total compressive stress limit is the lesser of 1.50 ksi and 1.5 GS. This limit can be exceeded up to 15% at the engineer's discretion.
- ◆ For rotation check, disregard *AASHTO LRFD Bridge Design Specifications*, Article 14.7.6.3.5. Rotation is acceptable if the total compressive deflection equals or exceeds  $\frac{\Theta \times (0.8 \times L)}{2}$ , where L is the pad length defined in *AASHTO LRFD Bridge Design Specifications*, and  $\Theta$  is the total rotation. Estimate compressive deflection using *AASHTO LRFD Bridge Design Specifications*, Figure C14.7.5.3.3-1.

- ◆ Calculate total rotation for dead and live load plus 0.005 radians for construction uncertainties as required by *AASHTO LRFD Bridge Design Specifications*, Article 14.4.2.1. Take maximum live load rotation as  $4 \cdot \Delta / (\text{span length})$ , where  $\Delta$  is midspan LL deflection.
- ◆ Account for pad taper when checking against slip as required by *AASHTO LRFD Bridge Design Specifications*, Article 14.7.6.4, as follows:  $\Delta s \leq (0.2 - Gr) \times DLxh_{rt} / (GxA)$ , where Gr = beam grade in ft./ft.
- ◆ You may use hrt instead of total pad height when checking stability as required in *AASHTO LRFD Bridge Design Specifications*, Article 14.7.6.3.6.

**Detailing**

Use standard drawing IBEB for guidance on detailing custom bearing pad designs.



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