4.3—NOTATION

Add the following notations:

\[ I_{\text{eff}} = \text{effective moment of inertia of the section, transformed to concrete (in.}^4\text{)} \text{ (C4.5.2.2), (C4.5.2.3)} \]
\[ I_{gs} = \text{moment of inertia of the gross concrete section about the centroidal axis, neglecting the reinforcement (in.}^4\text{)} \text{ (C4.5.2.2), (C4.5.2.3)} \]
4.4—ACCEPTABLE METHODS OF STRUCTURAL ANALYSIS

Delete the 3rd paragraph. Delete the last paragraph.
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4.5.2.3—Inelastic Behavior

C4.5.2.3

Add the following paragraph to the end of the commentary:

For cast-in-place reinforced concrete columns supporting non-segmental bridge structures, engineers may use an estimated effective moment of inertia for the respective superstructure and column sections. The effective properties may be incorporated into the structural models to analyze non-seismic force demands. Engineers may use 50% of gross moment of inertia of column (ignoring rebar) as effective moment of inertia ($I_{eff} = \frac{I_{gr}}{2}$).
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4.6.1.1—Plan Aspect Ratio

Replace the last bullet with the following:

- The length-to-width restriction specified above does not apply to concrete box girder bridges.
4.6.2.2—Beam-Slab Bridges

4.6.2.2.1—Application

Replace the 1st paragraph with the following:

The provisions of this Article may be applied to superstructures modeled as a single spine beam for straight girder bridges and horizontally curved concrete bridges, as well as horizontally curved steel girder bridges complying with the provisions of Article 4.6.1.2.4. The provisions of this Article may also be used to determine starting point for some methods of analysis to determine force effects in curved girders of any degree of curvature in plan.

Replace the 6th paragraph with the following:

Bridge not meeting the requirements of this article shall be analyzed as specified in Article 4.6.3, or as directed by the Owner.

C4.6.2.2.1

Add a new 1st paragraph as follows:

The distribution factor method may be used when the superstructure model is analyzed as a spine beam in 1-D, 2-D, or 3-D space.
Add the following after the 8th paragraph of the article:

For curved bridges having large skews (> 45°), the designer shall consider a more refined analysis that also accounts for torsion.

Add the following at the end of the 9th paragraph of the article:

Cast-in-place multicell concrete box girder bridge types may be designed as whole-width structures. Such cross-sections shall be designed for the live load distribution factors in Articles 4.6.2.2.2 and 4.6.2.2.3 for interior girders, multiplied by the number of girders, i.e., webs. The live load distribution factors for moment shall be applied to maximum moments and associated moments. The live load distribution factor for shear shall be applied to maximum shears and associated shears.
Replace the article title for 4.6.2.2.2b with the following:

4.6.2.2.2b-i—Interior Beams with Concrete Decks

Add a new article as follows:

4.6.2.2.2b-ii—Monolithic one- and two-Cell Boxes

For cast-in-place concrete box girders shown as cross-section type “d”, the live load distribution for moment on one-cell and two-cell \((N_c = 1 \& 2)\) boxes shall be specified in terms of whole-width analysis. Such cross-sections shall be designed for the total live load lanes specified in Table 4.6.2.2.2b-2 where the moment reinforcement shall be distributed equally across the total bridge width within the effective flanges.

Add a new commentary as follows:

C4.6.2.2.2b-ii

Chung, et al (2008) conducted parametric studies on one-cell and two-cell box girder bridges using 3-D analysis. The equations for the total live load lanes are applicable to box girders that meet the following conditions:

- Equal girder spacing,
- \(0.04 \leq \frac{d}{12L} \leq 0.06\)
- Deck overhang length < 0.5S
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Add the following table after Table 4.6.2.2b-1:

Table 4.6.2.2b-2—Total Design Live Load Lanes for Moment

<table>
<thead>
<tr>
<th>Type of Superstructure</th>
<th>Applicable Cross-Section from Table 4.6.2.2.1-1</th>
<th>Total Live Load Design Lanes</th>
<th>Range of Applicability</th>
</tr>
</thead>
</table>
| Cast-in-Place Concrete Multicell Box | $d$ | One-Cell Box Girder | $N_c = 1$ | $60 < L < 240$ $35 < d < 110$ $W_{12}(1.65-0.01W)^{**}$ $1.3$ $6 \leq W < 10$ $10 \leq W \leq 24$ 
| | | Up to One Lane Loaded* | $W_{12}(1.65-0.01W)^{**}$ | $6 \leq W < 10$ |
| | | Any Fraction or Number of Lanes: | $W_{12}(1.5-0.014W)$ | $12 \leq W < 20$ |
| | | | $2.1$ | $20 \leq W \leq 24$ |
| Two-Cell Box Girder | | Up to One Lane Loaded*: | $1.3 + 0.01(W-12)$ | $12 \leq W \leq 36$ |
| | | Any Fraction or Number of Lanes: | $W_{12}(1.5-0.014W)$ | $12 \leq W \leq 36$ |

* Corresponds to one full truck, two half trucks, or one half truck wheel load conditions.
** For $6 \leq W < 10$, the equation applies to bridge widen structures that have positive moment connections to the existing bridges.
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4.6.2.2.2e—Skewed Bridges

Delete the 1st paragraph and Table 4.6.2.2.2e-1.

Replace the 1st paragraph with the following:

Caltrans does not take advantage of the reduction in load distribution factors for moment in longitudinal beams on skewed supports.
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Replace the article title for 4.6.2.2.3a with the following:

4.6.2.2.3a-i—Interior Beams

Add a new article as follows:

4.6.2.2.3a-ii—Monolithic one- and two-Cell Boxes

For cast-in-place concrete box girders shown as cross-section type “d”, the live load distribution for shear on one-cell and two-cell ($N_c = 1$ & 2) boxes shall be specified in terms of whole-width analysis. Such cross-sections shall be designed for the total live load lanes specified in Table 4.6.2.2.3a-2 where the shear reinforcement shall be equally distributed to each girder web for non-skew conditions.

Add a new commentary as follows:

C4.6.2.2.3a-ii

Chung et. al. (2008) conducted parametric studies on one-cell and two-cell box girder bridges using 3-D analysis. The equations for the total live load lanes are applicable to box girders that meet the following conditions:

- Equal girder spacing,

- $0.04 \leq \frac{d}{12L} \leq 0.06$

- Deck overhang length < 0.5S
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Add the following table after Table 4.6.2.2.3a-1:

**Table 4.6.2.2.3a-2—Total Design Live Load Lanes for Shear**

<table>
<thead>
<tr>
<th>Type of Superstructure</th>
<th>Applicable Cross-Section from Table 4.6.2.2.1-1</th>
<th>Total Live Load Design Lanes</th>
<th>Range of Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast-in-place Concrete Multicell Box</td>
<td>d</td>
<td>One-Cell Box Girder</td>
<td>$2 \left( \frac{S}{4} \right)^{0.4} \left( \frac{d}{12L} \right)^{0.06}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Two-Cell Box Girder</td>
<td>$3 \left( \frac{S}{4.8} \right)^{0.5} \left( \frac{d}{12L} \right)^{0.09}$</td>
</tr>
</tbody>
</table>
This page intentionally left blank.
4.6.2.2.3c—Skewed Bridges

Replace the 2nd paragraph with the following:

In determining the end shear in bridges with typical cross section type g (as shown in table 4.6.2.2.1-1), the skew correction at the obtuse corner shall be applied to all the beams.

Replace Table 4.6.2.2.3c-1 with the following:

**Table 4.6.2.2.3c-1—Correction Factors for Live Load Distribution Factors for Support Shear of the Obtuse Corner**

<table>
<thead>
<tr>
<th>Type of Superstructure</th>
<th>Applicable Cross-Section from Table 4.6.2.2.1-1</th>
<th>Correction Factor</th>
<th>Range of Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Deck or Filled Grid, Partially Filled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-beams, T- and Double T-section</td>
<td>a, e, k and also i, j if sufficiently connected to act as a unit</td>
<td>For exterior girder: 1.0+0.20 ( \left( \frac{12.0L_{ts}^{3}}{K_{g}} \right)^{0.3} \tan \theta )</td>
<td>0° ≤ θ ≤ 60° 3.5 ≤ S ≤ 16.0 20 ≤ L ≤ 240 Nb ≥ 4</td>
</tr>
<tr>
<td>Cast-in-place Concrete Multicell Box</td>
<td>d</td>
<td>For exterior girder: ( \frac{\theta}{50} \leq 1.6 )</td>
<td>0° &lt; θ ≤ 60° 6.0 &lt; S ≤ 13.0 20 ≤ L ≤ 240 35 ≤ d ≤ 110 Nb ≥ 3</td>
</tr>
<tr>
<td>Concrete Deck on Spread Concrete Box Beams</td>
<td>b, c</td>
<td>( 1.0+\sqrt{\frac{Ld}{12.0}} \tan \theta )</td>
<td>0° &lt; θ ≤ 60° 6.0 &lt; S ≤ 11.5 20 ≤ L ≤ 140 18 ≤ d ≤ 65 Nb ≥ 3</td>
</tr>
<tr>
<td>Concrete Box Beams Used in Multibeam Decks</td>
<td>f, g</td>
<td>1.0+ ( \frac{12.0L}{90d} \sqrt{\tan \theta} )</td>
<td>0° &lt; θ ≤ 60° 20 ≤ L ≤ 120 17 ≤ d ≤ 60 35 ≤ b ≤ 60 5 ≤ Nb ≤ 20</td>
</tr>
</tbody>
</table>
This page intentionally left blank.
4.6.2.2.5—Special Loads with Other Traffic

Replace the 1st paragraph with the following:

Except as specified herein, the provisions of this article may be applied where the approximate methods of analysis for beam-slab bridges specified in Article 4.6.2.2 and slab-type bridges specified in Article 4.6.2.3 are used. The provisions of this article shall not be applied where:

- the lever rule has been specified for both single lane and multiple lane loadings, or
- the special requirement for exterior girders of beam-slab bridge cross-sections with diaphragms, specified in Article 4.6.2.2.2d has been utilized for simplified analysis, or
- two identical permit vehicles in separate lanes are used, as specified in CA amendment to Article 3.4.1 and 3.6.1.8.
Add the following new articles:

4.6.2.6—Permanent Loads
Distribution

4.6.2.6a—Structural Element Self-Weight

Except for cast-in-place concrete box girder bridges, shears and moments due to the structural section self-weight shall be distributed to individual girders by the tributary area method.

For cast-in-place concrete multi-cell boxes (d), the shears in the exterior and first interior beams on the obtuse side of the bridge shall be adjusted when the line of support is skewed. The correction factors are applied to individual girder shears and are obtained from Table 4.6.2.6a-1. The correction factors should be applied between the point of support at the obtuse corner and mid-span, and may be decreased linearly to a value of 1.0 at mid-span, regardless of end condition. This factor should not be applied in addition to modeling skewed supports.

For cast-in-place concrete Tee Beams (e), the shears in the exterior and first interior beams on the obtuse side of the bridge shall be adjusted when the line of support is skewed. The shear correction factors are applied to individual girders and are obtained similarly to live load shears in Article 4.6.2.2.3c-1.
Table 4.6.2.6a-1—Correction Factors for Dead Load Distribution Factors for Support Shear of the Obtuse Corner

<table>
<thead>
<tr>
<th>Type of Superstructure</th>
<th>Applicable Cross-Section from Table 4.6.2.2.1-1</th>
<th>Correction Factor</th>
<th>Range of Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast-in-place Concrete Multicell Box</td>
<td>d</td>
<td>For exterior girder: $1.0 + \frac{\theta}{25} \leq 2.2$</td>
<td>$0^\circ &lt; \theta &lt; 60^\circ$, $6.0 &lt; S &lt; 13.0$, $20 &lt; L &lt; 240$, $35 &lt; d &lt; 110$, $N_c &gt; 3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For first interior girder: $1.0 + \frac{\theta}{150} \leq 1.2$</td>
<td></td>
</tr>
</tbody>
</table>
4.6.2.2.6b—Non-Structural Element Loads

Non-structural loads are appurtenances, utilities, wearing surface, futures overlays, and earth cover. Curbs and wearing surfaces, if placed after the slab has been cured, may be distributed equally to all roadway stringers or beams. Barrier loads may be equally distributed to all girders. Significant loads such as barriers with concrete or masonry soundwalls, or heavy utilities, shall not be distributed equally. For box girder bridges, the non-structural element shears in the exterior and first interior beams on the obtuse side of the bridge shall be adjusted when the line of support is skewed. The correction factors are applied to individual girder shears and are obtained similarly to permanent load shears in Article 4.6.2.2.6a.

4.6.2.2.6c—Other Loads

For cast-in-place concrete multi-cell boxes (d), the shears due to secondary prestress, creep, shrinkage, and temperature loads in the exterior and first interior beams on the obtuse side of the bridge shall be adjusted when the line of support is skewed. The correction factors are applied to individual girder shears and are obtained from Table 4.6.2.2.6a-1. The correction factors should be applied between the point of support at the obtuse corner and mid-span and may be decreased linearly to a value of 1.0 at mid-span, regardless of end condition. This factor should not be applied in addition to modeling skewed supports.
4.6.2.3—Equivalent Strip Widths for Slab-Type Bridges

Delete the 4th paragraph.

Add a new paragraph after the 1st paragraph:

Caltrans does not take advantage of the reduction in load distribution factors for moment in longitudinal beams on skewed supports.

4.6.2.5—Effective Length Factor, K

Replace the 1st paragraph with the following:

Physical column or compression member lengths shall be multiplied by an effective length factor, \( K \), to compensate for rotational and translational boundary conditions other than pinned ends.

Add the following after the 2nd paragraph:

The effective length factor, \( K \), of the top chord of an unbraced through truss shall be determined by considering a column with elastic lateral supports at the panel points. The contribution of the connection stiffness between the floorbeam and the vertical member shall be considered in determining the stiffness of the elastic lateral supports.

Add the following after the 3rd paragraph:

When fixed end connections between the floorbeams and verticals are considered in the design, the \( K \) factor for the top chord of an unbraced through truss in the unbraced plane can be obtained from Table C4.6.2.5-1A.
Table C4.6.2.5-1A—K for Variations of \( CL/P_c \) and \( n \)

<table>
<thead>
<tr>
<th>( K )</th>
<th>( n = 4 )</th>
<th>( n = 6 )</th>
<th>( n = 8 )</th>
<th>( n = 10 )</th>
<th>( n = 12 )</th>
<th>( n = 14 )</th>
<th>( n = 16 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.020</td>
<td>3.284</td>
<td>2.944</td>
<td>2.806</td>
<td>2.787</td>
<td>2.771</td>
<td>2.774</td>
<td></td>
</tr>
<tr>
<td>1.042</td>
<td>3.000</td>
<td>2.665</td>
<td>2.542</td>
<td>2.456</td>
<td>2.454</td>
<td>2.479</td>
<td></td>
</tr>
<tr>
<td>1.053</td>
<td>2.595</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.064</td>
<td>2.754</td>
<td>2.303</td>
<td>2.252</td>
<td>2.254</td>
<td>2.282</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.087</td>
<td>2.643</td>
<td>2.146</td>
<td>2.094</td>
<td>2.101</td>
<td>2.121</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.111</td>
<td>3.352</td>
<td>2.593</td>
<td>2.263</td>
<td>2.045</td>
<td>1.951</td>
<td>1.981</td>
<td></td>
</tr>
<tr>
<td>1.176</td>
<td>2.460</td>
<td>2.013</td>
<td>1.794</td>
<td>1.709</td>
<td>1.681</td>
<td>1.694</td>
<td></td>
</tr>
<tr>
<td>1.250</td>
<td>2.961</td>
<td>2.313</td>
<td>1.889</td>
<td>1.629</td>
<td>1.480</td>
<td>1.456</td>
<td>1.465</td>
</tr>
<tr>
<td>1.333</td>
<td>2.147</td>
<td>1.750</td>
<td>1.501</td>
<td>1.344</td>
<td>1.273</td>
<td>1.262</td>
<td></td>
</tr>
<tr>
<td>1.429</td>
<td>2.448</td>
<td>1.955</td>
<td>1.595</td>
<td>1.359</td>
<td>1.200</td>
<td>1.111</td>
<td>1.088</td>
</tr>
<tr>
<td>1.538</td>
<td>1.739</td>
<td>1.442</td>
<td>1.236</td>
<td>1.087</td>
<td>0.988</td>
<td>0.940</td>
<td></td>
</tr>
<tr>
<td>1.667</td>
<td>2.035</td>
<td>1.639</td>
<td>1.338</td>
<td>1.133</td>
<td>0.985</td>
<td>0.878</td>
<td>0.808</td>
</tr>
<tr>
<td>1.888</td>
<td>1.517</td>
<td>1.211</td>
<td>1.007</td>
<td>0.860</td>
<td>0.768</td>
<td>0.708</td>
<td></td>
</tr>
<tr>
<td>2.000</td>
<td>1.750</td>
<td>1.362</td>
<td>1.047</td>
<td>0.847</td>
<td>0.750</td>
<td>0.668</td>
<td>0.600</td>
</tr>
</tbody>
</table>

where:

\[ C = \text{lateral stiffness of the U-frame (Figure C4.6.2.5-1A) made of the truss verticals and the floorbeam (kip/in.)} \]

Figure C4.6.2.5-1A—U-Frame
\[ C = \frac{E}{h^2/(h/3I_c)+(b/2I_B)} \]  \hspace{1cm} (C4.6.2.5-1A)

- \( L \) = length of the chord between panel points (in.)
- \( P_c \) = maximum factored compressive load in the top chord at the Strength Limit State (kip)
- \( n \) = number of truss panels in the vertical plane on one side of the bridge along its span length
- \( \Delta \) = lateral deflection resulting from lateral load \( C \) and shown schematically in Figure C4.6.2.5-1A (in.)
- \( h \) = height of truss measured from the center line of the top chord member to the center line of the floorbeam (in.)
- \( b \) = spacing between center lines of trusses (in.)
- \( I_c \) = equivalent moment of inertia of truss vertical at one panel point (in.\(^4\))
- \( I_B \) = moment of inertia of the floor beam (in.\(^4\))
- \( E \) = modulus of elasticity of the truss material (ksi)

The \( K \) factors listed in Table C4.6.2.5-1A were developed by Holt (1952, 1956) and recommended by the Structural Stability Research Council (Ziemian 2010). Typical bridge truss proportions and transverse frame stiffness values lead to \( K \) factors less than 2.0.
In lieu of the $K$ factor determined from Table C4.6.2.5-1A, the stability of the top chords of the truss may be evaluated by using a second-order numerical analysis procedure provided the following aspects are included in the model:

- A lateral out-of-plumbness of $h/500$ in the transverse direction, where $h$ is the truss height
- Initial out-of-straightness of $L/1000$, both between panel points and across the entire length of the compression chord.
- Effects of the stiffness of vertical to floorbeam connections.

The out-of-plumbness of $h/500$ and the out-of-straightness of $L/1000$ are fabrication tolerances as specified in *AISC Code of Standard Practice for Steel Buildings and Bridges* (2016).
4.6.3—Refined Methods of Analysis

4.6.3.1—General

Replace the 2nd paragraph with the following:

Railings, barriers, and medians shall not be considered as structurally continuous, except as allowed for deck overhang load distribution in Article 3.6.1.3.4

4.6.3.2—Decks

4.6.3.2.1—General

Replace the 1st paragraph with the following:

Unless otherwise specified, flexural and torsional deformation of the deck shall be considered in the analysis but vertical shear deformation may be neglected. Yield-line analysis shall not be used.
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4.9—REFERENCES

Add the following references:


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