4.3—NOTATION:

Add the following definitions:

I_{cr} = moment of inertia of the cracked section, transformed to concrete (in.^{4}) (C4.5.2.2), (C4.5.2.3)
I_{gs} = moment of inertia of the gross concrete section about the centroidal axis, neglecting the reinforcement (in.^{4}) (C4.5.2.2), (C4.5.2.3)

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4.4—ACCEPTABLE METHODS OF STRUCTURAL ANALYSIS:

Delete the 3rd Paragraph as follows:

~~The name, version, and release date of software used should be identified in the contract documents.~~

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C4.5.2.2:

Add a 2nd Paragraph as follows:

Analytical studies have been performed to determine the effects of using gross and cracked moment of inertia sectional properties (I_{gs} & I_{cr}) of concrete columns. The Caltrans studies yielded the following findings on prestressed concrete girders on concrete columns:

1. Using I_{gs} or I_{cr} in the columns has minor effects on the superstructure moment and shear demands from external vertical loads. Using I_{gs} or I_{cr} in the columns will significantly affect the superstructure moment and shear demands from thermal and other lateral loads.
2. Using I_{cr} in the columns can reduce column force and moment demands.
3. Using I_{cr} in the columns can increase the superstructure deflection and camber.

C4.5.2.3:

Add a 4th Paragraph as follows:

For reinforced concrete columns supporting non-segmental bridge structures, engineers may use an estimated cracked moment of inertia for the respective column sections. The cracked properties may be incorporated into the structural models to analyze non-seismic force demands. Engineers may use methods prescribed in Section 5 for the estimated cracked moment of inertia.

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4.6.1.1—Plan Aspect Ratio

Revise the 2nd Paragraph as follows:

The length-to-width restriction specified above does not apply to ~~cast-in-place multi-cell box girders~~ concrete box girder bridges.

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4.6.2.2.1—Application

Revise the 1st and 6th Paragraphs as follows:

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.

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

4.6.2.2.1 —Application

Revise the 9th Paragraph as follows:

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 coincident shears.

C4.6.2.1.1

Revise the 8th Paragraph, as follows.

Whole-width design is appropriate for torsionally-stiff cross-sections where load-sharing between girders is extremely high and torsional loads are hard to estimate. Prestressing force should be evenly distributed between girders. Cell width-to-height ratios should be approximately 2:1. The distribution factors for exterior girder moment and the two or-more-lanes loaded distribution factors for exterior girder shear are not used because using the distribution factors for interior girders would provide a conservative design. In general, the total number of design lanes doesn't change appreciably when using interior girders distribution factors for the whole-widths. The one-design-lane-loaded distribution factor for exterior girder shear is not used because lever rule isn't appropriate for use in multi-cell boxes.

Add the following:

C4.6.2.2.2

The distribution factor method may be used when the superstructure in the mathematical model is analyzed as a spine beam in 2-D, or 3-D space.

Revise the following:

4.6.2.2.2.b-i Interior Beams with Concrete Decks

Add the following:

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

For cast-in-place concrete box girder shown as cross-section type "d", the live load distribution for moment on one-cell and two-cell (Nc = 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.b-2 where the moment reinforcement shall be distributed equally across the total bridge width (within the effective flanges).

Add the following:

C4.6.2.2.2b-ii

The Caltrans Structural Analysis Committee conducted parametric studies on one-cell and two-cell box girder bridges using SAP2000 3D 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

The distribution factor method may be used when the superstructure in the mathematical model is analyzed as a spine beam in 2-D, or 3-D space.

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Add the following after Table 4.6.2.2.2b-1:

Table 4.6.2.2.2b-2 Total Design Live Load Lanes for Moment

Type of Superstructure	Applicable Cross-Section from Table 4.6.2.2.1-1	Total Live Load Design Lanes	Range of Applicability
Cast-in-Place Concrete Multicell Box	d	One-Cell Box Girder	$60 < L < 240$ $35 < d < 110$ $N_c = 1$
		Up to One Lane Loaded*	
		$\frac{W}{12}(1.65-0.01W)$**	$6 \le W < 10$
		1.3	$10 \le W \le 24$
		Any Fraction or Number of Lanes:	
		$\frac{W}{12}(1.65-0.01W)$**	$6 \le W < 12$
		$\frac{W}{12}(1.5-0.014W)$	$12 \le W < 20$
		2.1	$20 \le W \le 24$
		Two-Cell Box Girder	$60 < L < 240$ $35 < d < 110$ $N_c = 2$
		Up to One Lane Loaded*: $1.3 + 0.01\ (W\text{-}12)$	$12 \le W \le 36$
		Any Fraction or Number of Lanes:	
		$\frac{W}{12}(1.5-0.014W)$	$12 \le W \le 36$

* Corresponds to one full truck, two half trucks, or one half truck wheel load conditions.

** For $6 \le W < 10$, 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

Revise the 1st Paragraph as follows:

~~When the line supports are skewed and the difference between skew angles of two adjacent lines of supports does not exceed 10 degrees, the bending moment in the beams may be reduced in accordance with Table 4.6.2.2.e-1.~~ Caltrans presently does not take advantage of the reduction in load distribution factors for moment in longitudinal beams on skewed supports.

C4.6.2.2.2e

Revise the 1st Paragraph as follows

~~Accepted reduction factors are not currently available for cases not covered in Table 4.6.2.2.e-1.~~

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Add the following:

C4.6.2.2.3

The distribution factor method may be used when the superstructure in the mathematical model is analyzed as a spine beam in 2-D, or 3-D space.

Revise the following:

4.6.2.2.3.a-i Interior Beams

Add the following:

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

For cast-in-place concrete box girder shown as cross-section type "d", the live load distribution for shear on one-cell and two-cell (Nc = 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 the shear reinforcement shall be equally distributed to each girder web (for non-skew conditions).

Add the following:

C4.6.2.2.3a-ii

The Caltrans Structural Analysis Committee conducted parametric studies on one-cell and two-cell box girder bridges using SAP2000 3D 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 < $0.5S$

The distribution factor method may be used when the superstructure in the mathematical model is analyzed as a spine beam in 2-D, or 3-D space.

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Add the following after Table 4.6.2.2.3a-1:

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

Type of Superstructure	Applicable Cross-Section from Table 4.6.2.2.1-1	Total Live Load Design Lanes	Range of Applicability
Cast-in-Place Concrete Multicell Box	d	One-Cell Box Girder $2 \cdot \left(\frac{S}{4}\right)^{0.4} \left(\frac{d}{12L}\right)^{0.06}$	$60 \le L \le 240$ $35 \le d \le 110$ $N_c = 1$ $6 \le S \le 14$
		Two-Cell Box Girder $3 \cdot \left(\frac{S}{4.8}\right)^{0.5} \left(\frac{d}{12L}\right)^{0.09}$	$60 < L < 240$ $35 < d < 110$ $N_c = 2$ $6 \le S \le 14$

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4.6.2.2.3c —Skewed Bridges

Revise as follows:

Shear in the exterior and first interior beams on ~~at~~ the obtuse side ~~corner~~ of the bridge shall be adjusted when the line of support is skewed. The ~~value of the~~ correction factor values for exterior and first interior beams shall be obtained from Table 4.6.2.2.3c-1. It is applied to the lane fraction specified in Table 4.6.2.2.3a-1 for interior beams and in Table 4.6.2.2.3b-1 for exterior beams. The shear correction factors are applied to girders of interests between the point of support and midspan. This factor should not be applied in addition to modeling skewed supports.

~~In determining the end shear in multibeam bridges, the skew correction at the obtuse corner shall be applied to all the beams.~~

C 4.6.2.2.3c

Add the following:

The factors in Table 4.6.2.2.3c-1 may decrease linearly to a value of 1.0 at midspan, regardless of end condition.

Revise Table 4.6.2.2.3c-1 as follows:

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

Type of Superstructure	Applicable Cross-Section from Table 4.6.2.2.1-1	Correction Factor	Range of Applicability
Concrete Deck, Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on steel or Concrete Beams; Concrete T-Beams, T- and Double T-Section	a, e, k and also i, j if sufficiently connected to act as a unit	$1.0+0.20\left(\frac{12.0Lt_s^3}{K_g}\right)^{0.3}\tan\theta$ For exterior girder $1.0+\left(0.20\left(\frac{12.0Lt_s^3}{K_g}\right)^{0.3}\tan\theta\right)/6$ For first interior girder of T-Sections	$0^o < \theta \leq 60^o$ $3.5 < S \leq 16.0$ $20 \leq L \leq 240$ $N_b \geq 4$
Cast-in-place Concrete Multicell Box	d	~~$1.0+\left(0.25+\frac{12.0L}{70d}\right)\tan\theta$~~ $1.0+\frac{\theta}{50}$ for exterior girder $1.0+\frac{\theta}{300}$ for first interior girder	$0^o < \theta \leq 60^o$ $6.0 < S \leq 13.0$ $20 \leq L \leq 240$ $35 \leq d \leq 110$ $N_c \geq 3$
Concrete Deck on Spread Concrete Box Beams	b,c	$1.0+\frac{\sqrt{\frac{Ld}{12.0}}}{6S}\tan\theta$	$0^o < \theta \leq 60^o$ $6.0 < S \leq 11.5$ $20 \leq L \leq 140$ $18 \leq d \leq 65$ $N_b \geq 3$
Concrete Box Beams Used in Multibeam Decks	f,g	$1.0+\frac{12.0L}{90d}\sqrt{\tan\theta}$	$0^o < \theta \leq 60^o$ $20 \leq L \leq 120$ $17 \leq d \leq 60$ $35 \leq b \leq 60$ $5 \leq N_b \leq 20$

4.6.2.2.5 - Special Loads with Other Traffic

Revise the 1st Paragraph as follows:

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 either:

- 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 4.6.2.2.2.d has been utilized for simplified analysis.
- Two identical permit vehicles in separate lanes are used, as specified in CA amendment to Article 3.4.1.

Add the following:

4.6.2.2.6 Permanent Loads Distribution

4.6.2.2.6a- Structural Element Self-Weight

Except for 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) and 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.

4.6.2.2.6b- Non-Structural Element Loads

Non-structural loads apply to appurtenances, utilities, wearing surface, future overlays, earth cover, and planned widenings. 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. Barriers with soundwalls that constitute significant loads, e.g., concrete or masonry walls, 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 they are obtained similar to live load shears in Article 4.6.2.2.3c.

4.6.2.5 - Effective Length Factor, *K*

Revise as follows:

Physical ~~column~~ lengths of compression members shall be multiplied by an effective length factor, *K*, to compensate for rotational and translational boundary conditions other than pinned ends.

In the absence of more refined analysis, where lateral stability is provided by diagonal bracing or other suitable means, the effective length factor in the braced plane, *K*, for compression members shall be taken as unity, unless structural analysis shows a smaller value may be used. In the absence of a more refined analysis, the effective length factor in the braced plane for steel in ~~triangulated trusses,~~ trusses ~~and frames~~ may be taken as:

- For compression chords: K = 1.0
- For bolted or welded end conditions at both ends: K = 0.85 ~~0.75~~
- ~~For pinned connections at both ends: K = 0.875~~
- For single angles regardless of end connections: K = 1.0

Vierendeel trusses shall be treated as unbraced frames.

C 4.6.2.5

Revise the 1st and 2nd Paragraphs as follows:

Equations for axial ~~the compressive~~ resistance of columns and moment magnification factors for beam-columns include a factor, *K*, which is used to modify the length according to the restraint at the ends of the column against rotation and translation.

K is a factor that when multiplied by the actual length of the end-restrained compression member, gives the length of an equivalent pin-ended compression member whose buckling load is the same as that of the end-restrained member. The Structural Stability Research Council (SSRC) Guide (Galambos 1988) recommends K = 1.0 for compression chords on the basis that no restraint would be supplied at the joints if all chord members reach maximum stress under the same loading conditions. It also recommends K = 0.85 for web members of trusses supporting moving loads. The position of live load that produces maximum stress in the member being designed also results in less than maximum stress in members framing into it, so that rotational restraint is developed. ~~the ratio of the effective length of an idealized pin-end column to the actual length of a column with various other end conditions.. *KL* represents the length between inflection points of a buckled column influenced by the restraint against rotation and translation of column ends.~~ Theoretical values of *K*, as provided the Structural Stability Research Council, are given in table C4.6.2.5-1 for some idealized column end conditions.

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4.6.2.6—Effective Flange Width

4.6.2.6.1— General

Revise the 3rd Paragraph as the follows:

The slab effective flange width in composite girder and/or stringer system or in the chords of composite deck trusses may be taken as: ~~one- half the distance to the adjacent stringer or girder on each side of the component, or one-half the distance to the adjacent stringer or girder plus the full overhang width.~~

If $S/L \le 0.32$, then:

$$b_e = b \qquad (4.6.2.6.1\text{-}2)$$

Otherwise:

$$b_e = \left[1.24 - 0.74\left(\frac{S}{L}\right)\right]b \ \ge b_{\min} \qquad (4.6.2.6.1\text{-}3)$$

where

b = full flange width (ft)
b_e = effective flange width (ft)
b_{min} = minimum effective flange width (ft)
L = span length (ft)
S = girder spacing (ft)

For interior girders, the minimum effective flange width, b_{min} may be taken as the least of:

- One-quarter of the effective span length;
- 12.0 times the average deck slab depth, plus the greater of web thickness or one-half the girder top flange width**.**

For exterior girders, the minimum effective flange width, b_{min} may be taken as one-half the effective width of the adjacent interior girder, plus the least of:

- One-eighth of the effective span length;
- 6.0 times the average deck slab depth, plus the greater of one-half the web thickness or one-quarter of the girder top flange width**.**

Otherwise, the slab effective flange width should be determined by a refined analysis when:

C4.6.2.6.1

Insert the following paragraphs after the 2nd Paragraph.

Eqs. (4.6.2.6.1-2) and (4.6.2.6.1-3) are based on state-of-the-art research by Chen, et al. (*2005*), Nassif et al. (*2005*), and Caltrans revisions. The concrete deck slabs shall be designed in accordance with Article 9.7.

The girder spacing and the full flange width are shown in Figure C4.6.2.6.1-1. For interior girders, the girder spacing, *S*, and the full flange width, *b*, shall be taken as the average spacing of adjacent girders. For exterior girders, the girder spacing, *S*, and the full flange width, *b*, shall be taken as the overhang width plus one-half of the adjacent interior girder spacing, and shall be limited to the adjacent interior girder spacing.

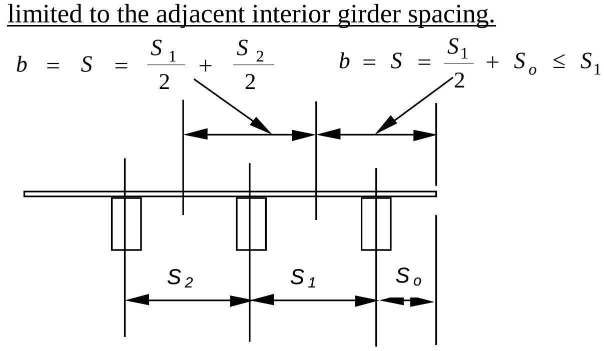

Figure C4.6.2.6.1-1 Girder Spacing and Full Flange Width.

The full flange width is proposed within the limits of the parametric study ($S \le 16$ ft, $L \le 200$ ft, $\theta \le 60^o$) by Chen et al. (*2005*) based on an extensive and systematic investigation of bridge finite element models. The full flange width is also proposed within the limit of $S/L \le 0.25$ by Nassif et al. (*2005*). For $S/L > 0.25$, Nassif et al. (*2005*) recommends that:

$$\frac{b_e}{b} = 1.0 - 0.5\left(\frac{S}{L}\right) \qquad \text{(C4.6.2.6.1-1)}$$

Figure C4.6.2.6.1-2 shows a graphic illustration of Eqs 4.6.2.6.1-2 and 4.6.2.6.1-3 which are a good combination of the effective flange width criteria proposed by Chen et al. (*2005*) and Nassif et al. (*2005*). For $S/L \leq 0.32$, the exact parametric study limit adopted by Chen et al. (*2005*), Eq. 4.6.2.6.1-2 gives the full flange width. For $S/L = 1$, Eq. 4.6.2.6.1-3 provides one-half of the full flange width which is as same as Equation C4.6.2.6.1-1.

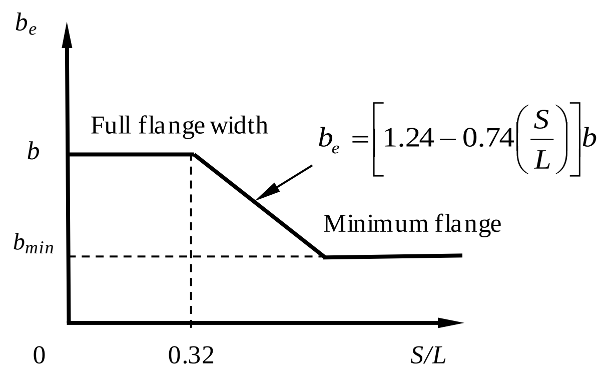

Figure C4.6.2.6.1-2 Effective Flange Width.

When $S/L > 0.32$, the effective flange width calculated by Eq. 4.6.2.6.1-3 is less than the full flange width as shown in Figure C4.6.2.6.1-2. When $S/L > 1.68$, the effective flange width calculated by Eq. 4.6.2.6.1-3 is less than zero. A meaningful minimum effective flange width, b_{min}, based on past successful practice, is added in Eq. 4.6.2.6.1-3. The minimum effective flange width, b_{min} should be checked when $S/L > 0.32$.

4.6.3.1-—General

Revise the 2nd Paragraph as follows:

~~A structurally continuous railing, barrier, or median, acting compositely with the supporting components, may be consider to be structurally active at service and fatigue limit states.~~ 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

C4.6.3.1

Revise the 2nd Paragraph as follows:

This provision reflects the experimentally observed response of bridges. This source of stiffness has traditionally been neglected but exists and may be included, per the limits of Article 3.6.1.3.4, provided that full composite behavior is assured.

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4.6.3.2.1- General

Revise the 1st Paragraph as follows:

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 reference:

Chung, P.C., Shen, Bin, Bikaee, S., Schendel, R., Logus, A., "Live Load Distribution on One and Two-Cell Box - Girder Bridges- Draft," Report No. CT-SAC-01, California Department of Transportation, November 2008.

Revise the following reference:

Nassif, H., A.-A. Talat, and S. El – Tawil. 200~~6~~5. "Effective Flange Width Criteria for Composite Steel Girder Bridges." Annual Meeting CD-ROM, Transportation Research Board, National Research Council, Washington, D.C.

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