4.2 DEFINITIONS:

Add the following definitions:

Central Angle—The angle included between two points along the centerline of a curved bridge measured from the center of the curve as shown in Figure 4.6.1.2.3-1.

Spine Beam Model—An analytical model of a bridge in which the superstructure is represented by a single beam element or series of straight, chorded beam elements located along the centerline of the bridge.

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4.3 NOTATION

Revise the following definition:

d_e = horizontal distance from the centerline of the exterior web of exterior beam at the deck level to the interior edge of curb or traffic barrier (ft.) (4.6.2.2.1)

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 indicated in the contract documents.~~

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C4.5.2.2

Add a 2nd Paragraph as follows:

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

1. Using I_{gs} or I_{cr} in the columns does not significantly reduce or increase 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 calculations.

C4.5.2.3

Add a 4th Paragraph as follows:

For cast-in-place reinforced concrete superstructures and for reinforced concrete columns supporting non-segmental bridge structures, engineers may use an estimated cracked 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 and deflection and camber results. 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 paragraph 2 as follows:

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

4.6.1.2 Structures Curved in Plan

4.6.1.2.1 General

Add the following to the end of paragraph 1:

Analysis of sections with no axis of symmetry should consider the relative locations of the center of gravity and the shear center. The substructure shall also be considered in the case of integral abutments, piers, or bents.

C4.6.1.1

Add the following after paragraph 2:

Asymmetrical sections need to consider the relative location of the shear center and center of gravity.

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In Article 4.6.1.2.2, revise paragraph 1:

Except for concrete box girder bridges, a ~~A~~ horizontally curved, torsionally stiff single-girder superstructure meeting the requirements of Article 4.6.1.1 may be analyzed for global force effects as a curved spine beam.

Modify Article 4.6.1.2.3 as follows:

4.6.1.2.3—~~Multicell~~ Concrete Box Girder~~s~~ Bridges

Horizontally curved ~~cast-in-place multicell~~ concrete box girders may be designed ~~as single-spine beams~~ with straight segments, for central angles up to ~~34~~ 12 degrees within one span, unless concerns about other force effects dictate otherwise.

Horizontally curved nonsegmental concrete box girder bridge superstructures may be analyzed and designed for global force effects as single-spine beams with straight segments, for central angles up to 34 degrees within one span as shown in Figure 4.6.1.2.3-1, unless concerns about local force effects dictate otherwise. The location of the centerline of such a beam shall be taken at the center of gravity of the cross-section, and the eccentricity of dead loads shall be established by volumetric consideration. Where the substructure is integral with the superstructure, the substructure elements shall be included in the model and allowance made for prestress friction loss due to horizontal curvature or tendon deviation.

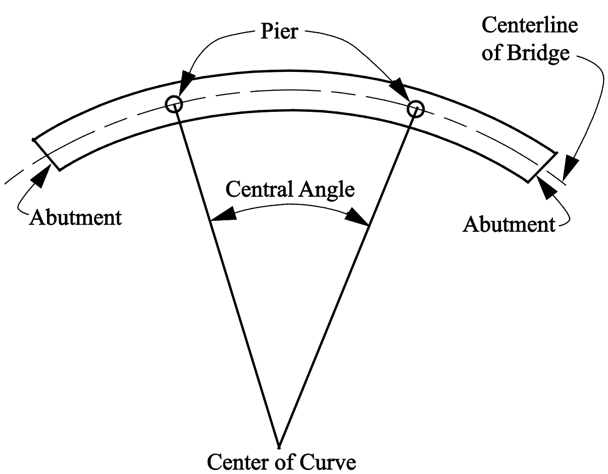

Figure 4.6.1.2.3-1—Definition of Central Angle

C4.6.1.2.3

Modify as follows:

Concrete box girders generally behave as a single-girder multi-web torsionally stiff superstructure. A parameter study conducted by Song, Chai, and Hida (2003) indicated that the distribution factors from the LRFD formulae compared well with the distribution factors from grillage analyses when using straight segments on spans with central angles up to 34 degrees in one span.

Nutt, Redfield and Valentine (2008) studied the limits of applicability for various methods of analyzing horizontally curved concrete box girder bridges. The focus of this study was on local as well as global force effects, and provided the basis for revisions in 2010. They identified three approaches for the analysis of concrete box girder bridges as follows:

1. The first method allows bridges with a central angle within one span of less than 12 degrees to be analyzed as if it were straight because curvature has a minor effect on response. This is typically done with a plane frame analysis.
2. The second method involves a spine beam analysis which the superstructure is idealized as a series of straight beam chorded segments of limited central angle located along the bridge centerline. Where the substructure is integral with the superstructure, a space frame analysis is required. Whole-width design as described in Article 4.6.2.2.1 was found to yield conservative results when space frame analysis was used. It is acceptable to reduce the number of live load lanes applied to the whole-width model to those that can fit on the bridge when global response such as torsion or transverse bending is being considered.
3. Bridges with high curvatures or unusual plan geometry require a third method of analysis that utilizes sophisticated three-dimensional computer models. Unusual plan geometry includes, but is not limited to bridges with variable widths, or unconventional orientation of skewed supports.

Horizontally curved segmental concrete box girder superstructures meeting the requirements of Article 4.6.1.1 and whose central angle within one span is between 12 degrees and 34 degrees may be analyzed as a single-spine beam comprised of straight segments provided no segment has a central angle greater than 3.5 degrees as shown in Figure 4.6.1.2.3-2. For integral substructures an appropriate three-dimensional model of the structure shall be used. Redistribution of forces due to the time-dependant properties of concrete shall be accounted for.

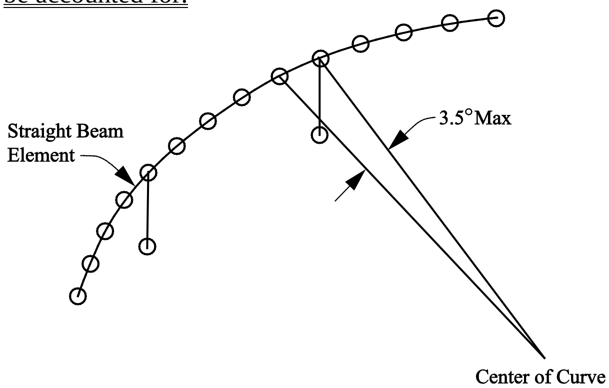

Figure 4.6.1.2.3-2—Three-Dimensional Spine Model of Curved Concrete Box Girder Bridge

For both segmental and nonsegmental box girder bridges with central angles exceeding 34 degrees within any one span, or for bridges with a maximum central angle in excess of 12 degrees with unusual plan geometry, the bridge shall be analyzed using 6 degrees of freedom in a proven three-dimensional analysis method.

The range of applicability using approximate methods herein is expected to yield results within 5 percent of the most detailed type of analysis. Analysis of force effects in curved tendons is also addressed in Article 5.10.4.3.

4.6.2.2.1 Application

Revise the 1st Paragraph 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 a starting point for some methods of analysis to determine force effects in curved girders of any degree of curvature in plan.

4.6.2.2.1 Application

Revise the 6th Paragraph as follows:

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.

C4.6.2.2.1

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. In certain cases, the two or-more-lanes loaded distribution factors for interior girders yield a 4% increase to that for exterior girder shears due to the range-of-applicability of d_e. 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.

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4.6.2.2.2 Distribution Factor Method for Moment and Shear

Revise the following:

4.6.2.2.2b-i Interior Beams with Concrete Decks

Add the following:

4.6.2.2.2b-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 in 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 2 where the moment reinforcement shall be distributed equally across the total bridge width (within the effective flanges).

C4.6.2.2.2

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,
- $0.04 \le \frac{d}{12L} \le 0.06$
- 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 1-D, 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	$60 \leq L \leq 240$ $35 \leq d \leq 110$ $N_c = 1$
		Up to One Lane Loaded*	
		$\frac{W}{12}(1.65 - 0.01W)$ **	$6 \leq W < 10$
		1.3	$10 \leq W \leq 24$
		Any Fraction or Number of Lanes:	
		$\frac{W}{12}(1.65 - 0.01W)$ **	$6 \leq W < 12$
		$\frac{W}{12}(1.5 - 0.014W)$	$12 \leq W < 20$
		2.1	$20 \leq W \leq 24$
		Two-Cell Box Girder	$60 \leq L \leq 240$ $35 \leq d \leq 110$ $N_c = 2$
		Up to One Lane Loaded*: 1.3 + 0.01 (W-12)	$12 \leq W \leq 36$
		Any Fraction or Number of Lanes: $\frac{W}{12}(1.5 - 0.014W)$	$12 \leq W \leq 36$

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

** The equation applies to bridge widen structures where the deck overhang has positive moment connections to the existing bridges.

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4.6.2.2.2e Skewed Bridges

Delete 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 10o, the bending moment in the beams may be reduced in accordance with Table 1.~~

C4.6.2.2.2e

Revise the 1st Paragraph as follows:

Accepted reduction factors are not currently available for cases not covered in Table 1. Caltrans presently does not take advantage of the reduction in load distribution factors for moment in longitudinal beams on skewed supports.

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4.6.2.2.3 Distribution Factor Method for Shear

Revise the following:

4.6.2.2.3a-i Interior Beams

4.6.2.2.3a-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 in 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 2 where the shear reinforcement shall be equally distributed to each girder web (for non-skew conditions).

C4.6.2.2.3

Add the following:

The distribution factor method for girder shear should be used when the superstructure in the mathematical model is analyzed as a spine beam in 1-D, 2-D, or 3-D space.

C4.6.2.2.3a-ii

Add the following:

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,
- $0.04 \le \frac{d}{12L} \le 0.06$
- 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 1-D, 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 $3 \cdot \left(\frac{S}{4.8}\right)^{0.5} \left(\frac{d}{12L}\right)^{0.09}$	$60 \le L \le 240$ $35 \le d \le 110$ $N_c = 2$ $6 \le S \le 14$

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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 shall be obtained from Table 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 correction factor values for exterior and first interior beams shall be obtained from Table 1 and applied to the lane fraction specified in Table 4.6.2.2.3b-1 for exterior beams and in Table 4.6.2.2.3a-1 for interior beams. The shear correction factors are applied to girders of interest between the point of support and midspan. This factor should not be applied in addition to modeling skewed supports. For cast-in-place concrete multicell boxes (d), the same correction factor shall be applied to all gravity load shear effects.

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

C4.6.2.2.3c

Add the following:

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

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

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

Revise as follows:

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	$1.0+0.20\left(\frac{12.0Lt_s^3}{K_g}\right)^{0.3}$	$0^\circ < \theta \leq 60^\circ$ $3.5 < S \leq 16.0$ $20 \leq L \leq 240$ $N_b \geq 4$
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	$0^\circ < \theta \leq 60^\circ$ $6.0 < S \leq 13.0$ $20 \leq L \leq 240$ $35 \leq d \leq 110$ $N_c \geq 3$
Concrete Deck on Spread Concrete Box Beams	b,c	$1.0+\frac{\sqrt{\frac{Ld}{12.0}}}{6S}\tan$	$0^\circ < \theta \leq 60^\circ$ $6.0 < S \leq 11.5$ $20 \leq L \leq 140$ $18 \leq d \leq 65$ $N_b \geq 3$
Concrete Box Beams Used in Multibeam Decks	f,g	$1.0+\frac{12.0L}{90d}\sqrt{\tan\theta}$	$0^\circ < \theta \leq 60^\circ$ $20 \leq L \leq 120$ $17 \leq d \leq 60$ $35 \leq b \leq 60$ $5 \leq N_b \leq 20$

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4.6.2.2.5 Special Loads with Other Traffic

Revise 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 ~~land~~ 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.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.

4.6.2.2.6 Permanent Loads Distribution

Add the following:

4.6.2.2.6a Structural Element Self-Weight

Shears and moment due to the structural section self-weight shall be distributed to individual girders by tributary area methods. For box girder bridges, 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 determined by tributary area methods and they are obtained similar 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 are less significant and shall continue to be equally distributed to all girders. 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 determined by tributary area methods and they are obtained similar to live load shears in Article 4.6.2.2.3c.

C4.6.2.2.6

Add the following:

For curved bridges having large skews (> 45^{o}), the designer should consider a more refined analysis that also considers torsion.

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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 a 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 the 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 connections at both ends: $K =$ ~~0.750~~ 0.850
- ~~For pinned connections at both ends: *K* = 0.875~~
- For single angles, regardless of end connection: $K = 1.0$

Vierendeel trusses shall be treated as unbraced frames.

C4.6.2.5

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 by the Structural Stability Research Council, are given in Table C1 for some idealized column end conditions.

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Replace equation (C4.6.2.5-3) as follows:

$$G=\frac{\Sigma\left(\frac{E_c I_c}{L_c}\right)}{\Sigma\left(\frac{E_g I_g}{L_g}\right)} \qquad \text{(C4.6.2.5-3)}$$

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4.6.2.6 Effective Flange Width

4.6.2.6.1 General

Revise as follows:

In the absence of a more refined analysis and/or unless otherwise specified, limits of the width of a concrete slab, taken as effective in composite action for determining resistance for all limit states, shall be as specified herein. The calculation of deflections should be based on the full flange width. For the calculation of live load deflections, where required, the provisions of Article 2.5.2.6.2 shall apply.

The effective span length used in calculating effective flange width may be taken as the actual span for simply supported spans and the distance between points of permanent load inflection for continuous spans, as appropriate for either positive or negative moments.

The effective flange width may be taken as:

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

$$b_{eff} = b \qquad (4.6.2.6.1\text{-}1)$$

Otherwise:

$$b_{eff} = \left[1.24 - 0.74\left(\frac{S}{L}\right)\right] b \geq b_{min} \qquad (4.6.2.6.1\text{-}2)$$

where

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

Equations 1 and 2 shall be used within the limit of skew angle $\theta \leq 60^o$. For $\theta > 60^o$, unless a more refined analysis is performed, the effective flange width may be taken as b_{min} and shall not exceed the girder spacing.

C4.6.2.6.1

Revise as follows:

Longitudinal stresses in the flanges are spread across the flange and the composite deck slab by in-plane shear stresses. Therefore, the longitudinal stresses are not uniform. The effective flange width is ~~a reduced~~ the width over which the longitudinal stresses are assumed to be uniformly distributed and yet result in the same force as the nonuniform stress distribution would if integrated over the whole width.

The effective flange width provisions 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 C1. For interior beams, the girder spacing, *S*, and the full flange width, *b*, shall be taken as the average spacing of adjacent beams. For exterior beams, the girder spacing, *S*, and the full flange width, *b*, shall be taken as the overhang width plus one-half of the adjacent interior beam spacing, and shall be limited to the adjacent interior beam spacing.

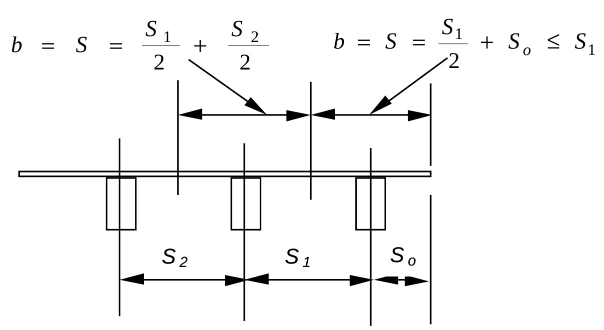

Figure C4.6.2.6.1-1 Girder Spacing and Full Flange Width.

The full flange width is proposed within the limits of the parametric study ($S \leq 16$ ft, $L \leq 200$ ft, $\theta \leq 60^o$) 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 $S/L \leq 0.25$ by Nassif et al. (*2005*). For $S/L > 0.25$, Nassif et al. (*2005*) recommends that:

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

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

- One-quarter of the effective span length;
- 12.0 times the average depth of the slab, plus the greater of web thickness or one-half the width of the top flange of the girder. ~~; or~~
- ~~The average spacing of adjacent beams.~~

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

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

Figure C2 shows a graphic illustration of Equation 1 & 2 which is 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*), Equation 1 gives the full flange width. For $S/L = 1$, Equation 2 provides one-half of the full flange width which is the same as Equation C1.

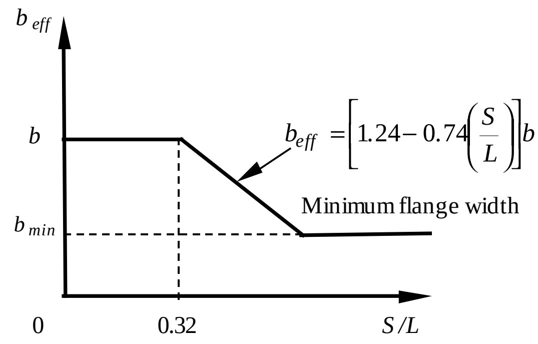

Figure C4.6.2.6.1-2 Effective Flange Width

In calculating the effective flange width for closed steel and precast concrete boxes, ~~the distance between the outside of webs at their tops will be used in lieu of the web thickness, and~~ the girder spacing will be taken as the spacing between the centerlines of adjacent boxes.

For open boxes, the effective flange width of each web should be determined as though each web was an individual supporting element.

~~For filled grid, partially filled grid, and for unfilled grid composite with reinforced concrete slab, the "slab depth" used should be the full depth of grid and concrete slab, minus a sacrificial depth for grinding, grooving and wear (typically 0.5 in.).~~

When $S/L > 0.32$, the effective flange width calculated by Equation 2 is less than the full flange width as shown in Figure C2. When $S/L > 1.68$, especially for commonly used bent cap beams, the effective flange width calculated by Equation 2 is less than zero. Since the effective flange width can not logically be less than zero, based on the past successful practice the meaningful lower limit, the minimum effective flange width, b_{min}, is added in Equation 2. The minimum effective flange width, b_{min} should be checked when $S/L > 0.32$.

For negative moment region only, one possible alternative for determining the effective flange width is provided by Equation C2:

$$\frac{b_{eff}}{b} = 0.948 + 0.003\left(\frac{L}{S}\right) - 0.0010\theta \leq 1.0 \quad \text{(C4.6.2.6.1-2)}$$

where

L = span length (ft), the lesser of the two span lengths if the two span lengths differ

θ = skew angle (^{o})

By comparing the results using the effective flange width obtained from the finite element analyses and a full slab width, the difference can be as high as 8.5%. By using Equation C2 the difference can be reduced to approximately 5.9% in the worst case investigated by Chen et al. *(2005)*.

Both the full physical flange width provision and Equation C2 were formulated based on finite element models that developed slab cracking in the negative moment sections under service loads. Thus, in negative moment regions these provisions should be used assuming the slab to be cracked, i.e., the composite section to consist of the beam section and the longitudinal reinforcement within the effective width of concrete deck.

A more refined analysis should be performed to determine the effective flange width when $\theta > 60^o$.

Where a structurally continuous concrete barrier is present and is included in the models used for analysis as permitted in Article 4.5.1, the width of overhang for the purpose of this Article may be extended by:

$$\Delta w = \frac{A_b}{2t_s} \quad \text{(C4.6.2.6.1-1)}$$

where:

A_b = cross-sectional area of the barrier (in.^{2})

t_s = depth of deck slab (in.)

For integral bent caps, the effective flange width overhanging each side of the bent cap web shall not exceed six times the least slab thickness, or 1/10 the span length of the bent cap. For cantilevered bent caps, the span length shall be taken as two times the length of the cantilever span.

The provisions for the effective flange width for the integral bent cap are based on past successful practice, specified by Article 8.10.1.4 of the 2002 AASHTO Standard Specifications.

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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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Add References:

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

State of California, Department of Transportation, Standard Plans 2010

Nutt, Redfield and Valentine in Association with David Evans and Associates, and Zocon Consulting Engineers, 2008. *Development of Design Specifications and Commentary for Horizontally Curved Concrete Box Girder Bridges*, NCHRP Report G20. Transportation Research Board, National Research Council, Washington, D.C.

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