13. Structural Analysis and Evaluation

13.1. Distribution of Live Load

Reference: LRFD Article 4.6.3.1

13.1.1. Definition

Live-load distribution, for application to the *Alaska Bridges and Structures Manual*, refers to determining the maximum number of loaded lanes that an individual girder of the superstructure will be expected to carry. The live-load distribution factor is the maximum number of loaded lanes per girder.

13.1.2. Approximate Methods

Reference: LRFD Article 4.6.2

General

Distribution factors allow for a simple, approximate analysis of bridge superstructures. Live-load distribution factors uncouple the transverse and longitudinal distribution of force effects in the superstructure. The approximate method distributes live-load force effects transversely by proportioning the design lanes to individual girders through the application of distribution factors. Subsequently, this method distributes the force effects longitudinally between the supports through the one-dimensional (1-D), line-girder structural analysis over the length of the girders.

Use distribution factors and 1-D, line-girder analysis where allowed by the *LRFD Specifications*. Distribution factors reduce the necessity of modeling the entire bridge using a 2-D or 3-D analysis.

Simplified Analysis

Reference: LRFD Article 4.6.2.2

General. LRFD Article 4.6.2.2.2 presents several common bridge superstructure types, with empirically derived equations for live-load distribution factors for each type. Each distribution factor provides a number of design lanes to be applied to a girder to evaluate the girder for moment or shear. The factors account for interaction among loads from multiple lanes and the effects of skewed supports.

The distribution factors represent the placement of design lanes to generate the extreme effect in a specific girder. The location of design lanes is unrelated to the location of striped traffic lanes on the bridge.

The properties used in calculating the live-load distribution factors vary along the span; for example, steel plate girder moments of inertia vary at the flange or web plate transitions. However, do not recalculate the distribution factor at each change in property. Use weighted average properties or maximum properties (e.g., in the span for positive moment and at the pier for negative moment) to calculate single acceptable distribution factors.

Limitations. The Chief Bridge Engineer must approve using the distribution-factor equations beyond the "Range of Applicability" without the use of a refined analysis. See Section 13.2 for a discussion on refined analyses.

Skewed Bridges. Do not use the skew correction factors for moment in LRFD Table 4.6.2.2.2e-1 to adjust the live load moments in skewed bridges.

Torsional moments exist about the longitudinal axis in skewed bridges due to gravity loads (both dead and live load). These moments increase the reactions and shear forces at the obtuse corners compared to the acute corners. The potential exists for reactions to become very small or negative at acute corners; avoid this condition when possible. The bridge engineer should account for the higher reactions at the obtuse corners in the design of bearings and the supporting elements.

Use the skew correction factors for shear in LRFD Table 4.6.2.2.3c-1 to adjust the live load shears and reactions in skewed bridges. Decrease the skew correction factor for shear linearly from the centerline of bearing to 1.0 at midspan. Use the following skew correction factor for decked bulb-tee girders:

$$Skew\ factor = 1.0 + 0.20\left(\frac{12.0Lt_s{}^3}{K_g}\right)^3 tan\theta$$

where:

L = span length (ft.)
t_s = top flange thickness (in.)
K_g = I_x for monolithic sections (in.^{4})
θ = skew angle (degrees)

Historically, top flange thicknesses between 5 and 7 inches have been used. Newer designs use 6-inch thick top flanges on paved bridge and 7-inch thick top flanges on unpaved bridges.

Decked Bulb-Tee Girder Example

The next two pages present a girder distribution of live loads for moment example for a decked bulb-tee girder bridge. Distribution of live loads for shear requires use of the “lever rule,” which is not presented in this example. Use the following format as a template for these types of calculations. For example:

- Provide a cross section of the girder with all dimensions.
- Use the “References/Notes” column to cite the applicable LRFD reference adjacent to each calculation.
- Ensure that a bridge engineer unfamiliar with the project can follow the sequence of calculations.

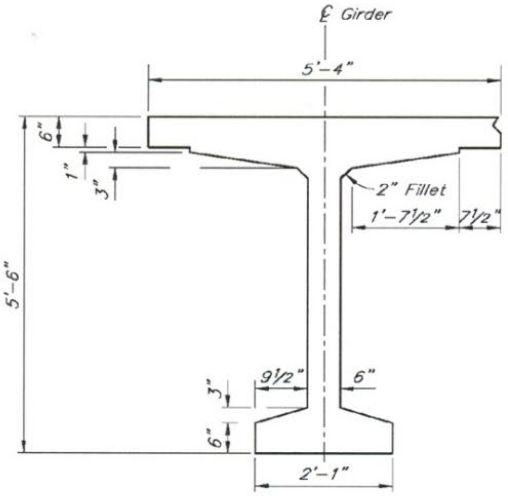
STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND
PUBLIC FACILITIES

COMPUTATIONS

Bridge No. N/A
Date 8/9/2008
For: **Girder Distribution Example**
Calc. By

Reference/Notes

Example: Decked bulb-tee girder bridge with span length, L = 146'-0", deck width, W = 43'-0" including two 1'-6" bridge rails



Section properties for this girder section:

Area, $A =$ 1,004 in^2
Moment of Inertia, $I_x =$ 570,730 in^4
$I_y =$ 160,100 in^4

Tosional Constant, $J = \dfrac{A^4}{40{*}I_p}$

Where, $I_p = I_x + I_y$

And, $J =$ 34,758 in^4

Distribution for Moment in Interior Girders:

$g_{mi} = \dfrac{S}{D}$

AASHTO LRFD
Table 4.6.2.2.2b-1

Gap between girders

Where: S = Girder Spacing = 5'-4" + ½" = 5'-4½" or, 5.4 ft

D = First, Calculate:

$C = k * (W/L) < k$

Where: $k = \sqrt{\dfrac{(1+\mu)\cdot I_x}{J}}$

Where: μ = Poisson's Ratio = 0.15 to 0.2 for concrete, will use 0.16

$$k = \sqrt{\frac{(1+0.16)\cdot 570730\,\text{in}^4}{34758\,\text{in}}}$$

or, k = 4.4

W = Deck Width = 43 ft
L = Span Length = 146 ft

And, C = 4.4 * (43'/143') = 1.29

Since C < 5,

$D = 11.5 - N_L + 1.4*N_L*(1-0.2*C)^2$

Where, N_L = Number of Lanes = $\dfrac{43'\text{-}0'' - 2*(1'\text{-}6'')}{12'\text{-}0''\text{ per lane}}$

= 3.33

or, 3 lanes

$D = 11.5 - 3 + 1.4*3*(1-0.2*1.29)^2$

= 10.8 ft

And, $g_{mi} = \dfrac{5.4\text{ feet}}{10.8\text{ feet}}$

= 0.50 lanes/girder

13.2. Refined Analysis

Reference: LRFD Articles 4.6.2.2 and 4.6.3

13.2.1. General

Use a refined analysis only with the approval of the Chief Bridge Engineer and only for bridges where the parameters fall outside of the "Range of Applicability." Where refined analysis is used, show back-calculated live-load distribution factors for each girder in the contract documents for future use in rating or rehabilitating the bridge.

13.2.2. 2-D Analysis (Horizontally Curved Bridges)

Use refined analysis methods, either grid or finite-element, for the analysis of horizontally curved bridges. LRFD Article 4.6.2.2.4 states that approximate analysis methods may be used for the analysis of curved bridges but then highlights the deficiencies of these analyses, specifically the V-load method for I-girders and the M/R method for boxes. Therefore, DOT&PF does not allow the sole use of these methods for horizontally curved bridges. Use the V-load method for preliminary design purposes or as an order-of-magnitude checking tool.

Table 13-1 provides an example DF table for plans:

Table 13-1
Design Live Load Distribution Factors

Girder Designation	Force Effect	Multiple Loaded Lanes	Single Loaded Lane
Exterior	+ Moment (near midspan)	0.88	0.69
	- Moment (at piers)	0.81	0.60
	Shear (near supports)	1.04	0.87
Interior	+ Moment (near midspan)	0.65	0.37
	- Moment (at piers)	0.74	0.41
	Shear (near supports)	0.74	0.56

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