3.3.6. Live Load Strip Widths for Slab Bridges

In perspective of structural behavior, slab bridges are like a concrete slab act as a giant plate has a small length/width ratio (aspect ratio) that bends longitudinally between the supports and transversely as shown in Figure 3.5. concrete slabs carry loads by bending and twisting.

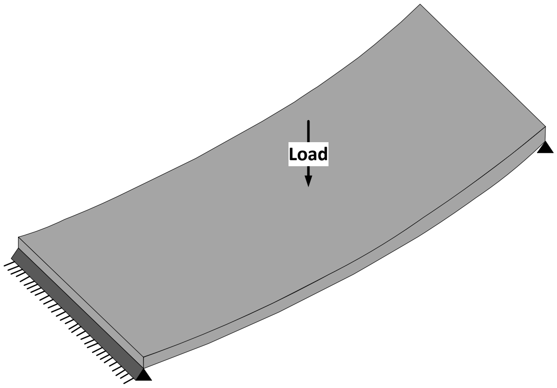

Figure 3.5: Bending of Slab Bridge under Loading

The approximate strip method is specified in LRFD specifications and shall be applied to analyze the concrete slab bridges. In this method, the live load effects are first computed on a typical interior strip (E_i) and a typical exterior strip (E_e). Each strip in a simply supported slab is assumed to carry the load of one design lane. Thus, the load effect (moment and shear) on any strip can be determined by dividing the total load due to one design lane on the width of this strip. In slab bridges, the distribution factor (DF) is the share of the designed strip from the equivalent strip (b/E) and computed as the inverse of the strip width ($1/E$) because the design of the slab would be based on ($1\ \mathrm{m}$) wide. The (DFs) are the same for live load bending and shear, but (DFs) for the interior strip is different for that of the exterior strip. However, experiences and past practices approved the slab bridges designed for moment are considered safe in shear.

3.3.6.1. Equivalent Width for Interior Strips

The equivalent width of longitudinal strips per design lane for both shear and moment with one (single) lane (E_{i1}), or two lines of wheels, loaded may be determined as:

$$E_{i1} = 0.25 + 0.42\sqrt{L_1 W_1}$$

Whereas the equivalent width of longitudinal strips per lane for both shear and moment with more than one (multi) lane (E_{i2}) loaded may be determined as:

$$E_{i2} = 2.10 + 0.12\sqrt{L_1 W_1}$$
$$\leq W/N_L$$

- $L_1 = S$ [spacing between supports]
  $\leq 18\ \mathrm{m}$
- $W_1 = W$
  $\leq 18\ \mathrm{m}$ [multi-lane loading]
  $\leq 9\ \mathrm{m}$ [single-lane loading]

3.3.6.2. Equivalent Width for Exterior Strips

The exterior strip, also known as edge strip and edge beam may be located at the longitudinal (transverse) edges. Unless otherwise specified, the edge of the deck shall either be strengthened or be supported by a beam or other line component. The longitudinal edge strip of the slab is treated as a notional edge beam supports one line of wheels plus the effecting dead loads. The equivalent width of longitudinal edge strip (E_e) may be determined as:

$$\begin{aligned} E_e &= W_e + 0.3 + E_i/4 \\ &\leq E_i/2 \\ &\leq 1.8\ \mathrm{m} \end{aligned}$$

where:

E_{i1}: equivalent width of interior strip with single-lane loading (m).
E_{i2}: equivalent width of interior strip with multi-lane loading (m).
L_1: modified span length (m).
W_1: modified edge-to-edge width of bridge (m).
W: physical edge-to-edge width of bridge (m).
W_e: distance between the edge of the deck and the inside face of the barrier (m).
N_L: number of design lanes

3.3.7. Live Load Distribution Factors for Beam Bridges

Live load distribution factor (DF) is used because the moving load (truck or tandem) cannot be concentrated on one exterior or interior girder. Thereby, presence of deck slab leads to distribute the live load into all supporting girders because the deck slab acts as a wide plate. The girder under the wheel line is subjected to a main fraction of load while the rest of fraction is participated by the adjacent girders.

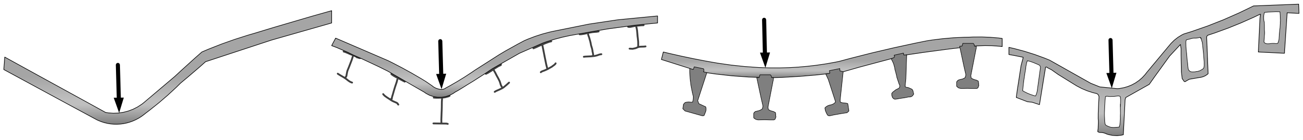

Figure 3-6: Deflection of Deck and Beams under Moving Load

The (DF) values of moment differ from that used for shear. Also, the values of interior girder are different from that of exterior girder. In general, there are values for one (single) loaded lane and two or more (multiple) loaded lanes. They (DFs) are expressed as:

- DF_{im}: for bending moment in the interior girders g_{im}
- DF_{iv}: for shear in the interior girders g_{iv}
- DF_{em}: for bending moments in the exterior girders g_{em}
- DF_{ev}: for shear in the exterior girders g_{ev}

So, the greater value governs in each interior and exterior girder. However, in case of precast prestress concrete girders, the greatest among the four values is governing.

3.3.7.1. AASHTO LRFD Tables for Moment and Shear

The (DF) values can be determined from AASHTO LRFD Tables where equations are already adopted, and multiple presence factor is included $(m = 1)$ but with local stipulations. Other cases, lever rule method is applicable where (m) value is required.

Table 3-5: Distribution of Live Load per Lane for Concrete Deck on Steel or Concrete Beams [AASHTO LRFD Tables 4.6.2.2.2 and 4.6.2.2.3]

Location	Action	Loaded Lanes	Equation	Range of Applicability
Interior	Moment	Single	$g_{im1} = 0.06 + \left(\frac{S}{4.3}\right)^{0.4}\left(\frac{S}{L}\right)^{0.3}\left(\frac{K_g}{L{h_d}^3}\right)^{0.1}$	$N_g \geq 4$ $6 \leq L \leq 73$ $1.1 \leq S \leq 4.9$ $110 \leq h_d \leq 300$ $4\text{x}10^9 \leq K_g \leq 3\text{x}10^{12}$
		Multiple	$g_{im2} = 0.075 + \left(\frac{S}{2.9}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{L{h_d}^3}\right)^{0.1}$	
			Lever Rule if $N_g = 3$	
	Shear	Single	$g_{iv1} = 0.36 + \frac{S}{7.6}$	
		Multiple	$g_{iv2} = 0.2 + \frac{S}{3.6} - \left(\frac{S}{10.7}\right)^{2.0}$	
			Lever Rule if $N_g = 3$	
Exterior	Moment	Single	Lever Rule	$-0.3 \leq d_e \leq 1.7$
		Multiple	$g_{em2} = e_m g_{im2}$ $e_m = 0.77 + \frac{d_e}{2.8}$	
			Lever Rule if $N_g = 3$	
	Shear	Single	Lever Rule	
		Multiple	$g_{ev2} = e_v g_{iv2}$ $e_v = 0.6 + \frac{d_e}{3}$	
			Lever Rule if $N_g = 3$	

where:

N_g: number of girders.

L: length of span (m).

S: spacing of girders (m).

h_d: thickness of deck slab (mm).

K_g: longitudinal stiffness parameter (mm^4).

e: transforming factor.

d_e: distance from exterior girder center to the inside edge of curb or barrier (m).

The longitudinal stiffness parameter (K_g) shall be taken as:

$$K_g = n(I_g + A_g {e_g}^2)$$
$$n = E_g / E_d$$

where:

E_g, E_d: modulus of elasticity of girder material and deck material (MPa).

A_g: area of girder (mm^2).

I_g: moment of inertia of the basic girder (mm^4).

e_g: distance between the centers of gravity of the basic girder and deck (mm).

3.3.7.2. Lever Rule

The lever rule is an analytical tool determining the reaction at the supports of a simple beam with or without a loaded overhang. This method assuming there is hinge at the interior support. Thus, the (DF) of the exterior girder is the reaction (R_e). The axle load (P) is assumed to equal one-unit weight and the presence factor (m) almost for single lane loaded.

$$R_e = X.R/S$$

$$R = 1 \rightarrow R_e = X/S$$

$$DF_e = mR_e$$

$$\rightarrow g_{em1} = g_{ev1} = 1.2(R_e)$$

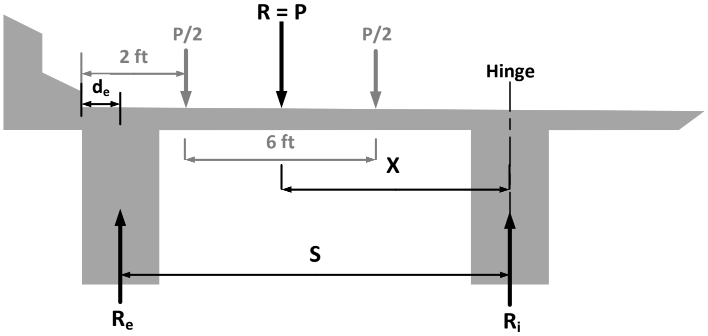

Figure 3-7: Lever Rule for Exterior Girder

3.3.7.3. Special Approach for Exterior Girders

A special analysis for determination of the (DFs) for the exterior girder depending on if the entire cross section rotates as a rigid body about the longitudinal centerline of the bridge. The reaction (R_e) on the exterior girder is calculated in terms of number of lanes loaded simultaneously but with increments of one lane a time and the presence factor (m) is considered. The value of (R_e) is given by:

$$R_e = \frac{N_L}{N_g} + \frac{x_e \sum_1^{N_L} e}{\sum_1^{N_g} x^2}$$

where:

N_L: number of loaded lanes.

N_g: number of beams/girders supporting the deck.

x_e: eccentricity of the exterior girder from the center of gravity of the pattern of girders.

e: eccentricity of design truck or lane load from the center of gravity of the pattern of girders.

x: horizontal distance from the center of gravity of pattern of girders to each girder.

3.3.8. Distribution Factors for Fatigue Limit State

Distribution factors for fatigue (DF_f) are required for checking the effects of fatigue on a bridge girder, the fatigue load is placed in a single lane.

AASHTO specification stated that multiple presence factors (m) are not to be used for the fatigue load limit check because this load is calculated for only one design truck. Thus, (DF_f) are obtained from bending moment and shear for one lane loaded with dividing on (1.2) which is the (m) for one lane loaded and embedded in those expressions.

$$DF_{fm} = g_{m1}/1.2$$

$$DF_{fv} = g_{v1}/1.2$$

3.3.9. Distribution Factors for Deflection Limit State

Distribution factors for deflection (DF_Δ) are required to control deformation of beams and girders supporting a deck. This factor is calculated as one value for all those structures.

$$DF_\Delta = mN_L/N_g$$

3.3.10. Span Length for Distribution Factor

The effective length used for calculation of live load distribution factor is alike the length used to calculate the force itself and as tabulated below.

Table 3-6: Span Length for Live Load Distribution Factor Calculation

Force Effect	Length (L) m
Positive bending moment	The length of span for which bending moment is being calculated
Negative bending moment near interior supports of continuous spans	The average length of two adjacent spans
Negative bending moment other than near interiors supports of continuous spans	The length of span for which bending moment is being calculated
Shear	The length of span for which bending moment is being calculated
Exterior reaction	The length of the exterior span
Interior reaction of continuous span	The average length of two adjacent spans

After determining the values of (DFs)m, the total live load effect (Q_{LL+IM}) is given by the following equation relating to various limit states:

$$Q_{LL+IM} = [Q_{Mo}(1 + IM) + Q_{Ln}]DF$$

By the same way, moment and shear demands shall be:

$$M_{LL+IM} = [M_{Mo}(1 + IM) + M_{Ln}]DF_m$$

$$V_{LL+IM} = [V_{Mo}(1 + IM) + V_{Ln}]DF_v$$