

**APPENDIX B**  
**LOAD DISTRIBUTION**

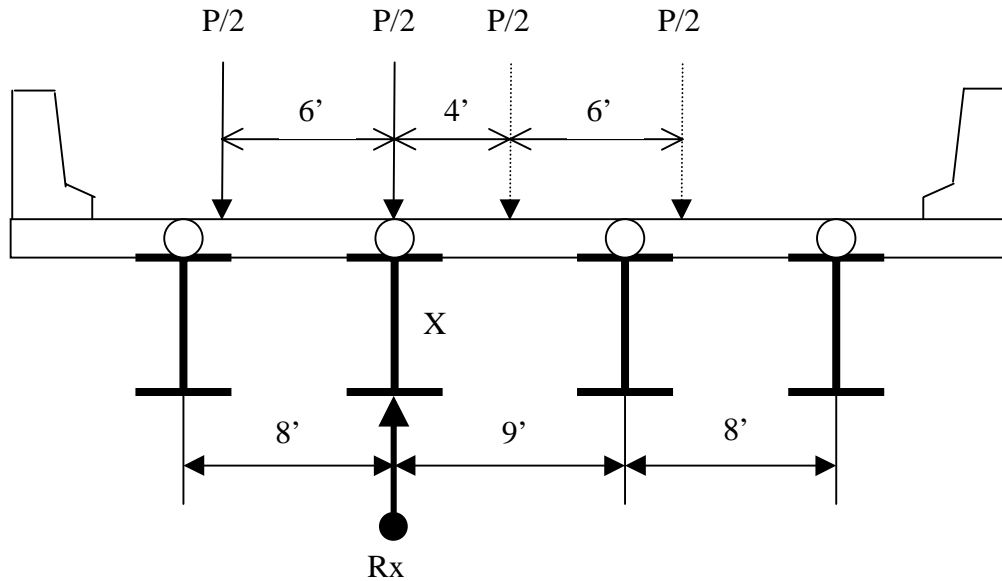
**-Distribution Factors from the Design Calculations  
(Application of the “Lever Method”)**

Note: these distribution factors are calculated as they were in the superstructure design calculations titled “VDOT Bridge Rehabilitation, RT 58 Over Little Buffalo Creek “ provided by VDOT. The truck locations represent the locations used in the design calculations.

**A) Interior Girder:**

- Given:**
- Cross section with hinge locations as explained in Chapter 4.
  - The shown transverse truck location(s). Solid lines represent one truck (one lane loaded), dotted lines plus solid lines represent two trucks (two lanes loaded).
  - Girder X is the focal point.
  - P/2 represents one-half of an axle load.
  - Neglect multiple presence.

**Determine:** Interior girder distribution factors, DF’s, for one and two-lanes loaded.



*One-Lane Loaded:*

$$R_x = \frac{P}{2} + \left(\frac{P}{2}\right)\left(\frac{2}{8}\right) = 0.625P \quad \therefore DF = 0.63$$

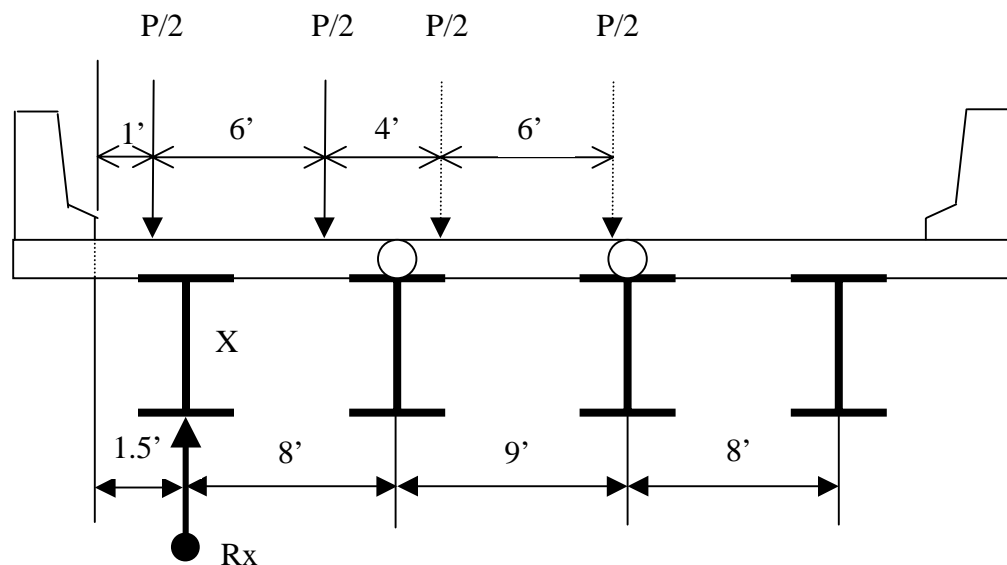
Two-Lanes Loaded:

$$R_x = \frac{P}{2} + \left(\frac{P}{2}\right)\left(\frac{2}{8}\right) + \left(\frac{P}{2}\right)\left(\frac{5}{9}\right) = 0.903P \quad \therefore DF = 0.90$$

### B) Exterior Girder

- Given:**
- Cross section with hinge locations as explained in Chapter 4.
  - The shown transverse truck location(s). Solid lines represent one truck (one lane loaded), dotted lines plus solid lines represent two trucks (two lanes loaded).
  - Girder X is the focal point.
  - P/2 represents one-half of an axle load.
  - Neglect multiple presence.

**Determine:** Exterior girder distribution factors, DF's, for one and two-lanes loaded.



One-Lane Loaded:

$$R_x = \frac{\left(\frac{P}{2}\right)(8.5') + \left(\frac{P}{2}\right)(2.5')}{8'} = 0.6875P \quad \therefore DF = 0.69$$

*Two-Lanes Loaded:*

-Same as for One-Lane Loaded because the load from the second truck cannot cross the hinge; therefore,  $DF=0.69$ . However, the exterior girder distribution factor cannot be taken less than the interior girder, thus  $DF = 0.90$ .

***Summary of Distribution Factors from the Design Calculations:***

Interior Girder:      One-Lane Loaded:       $DF = \underline{0.63}$

                                 Two-Lanes Loaded:       $DF = \underline{0.90}$

Exterior Girder:      One-Lane Loaded:       $DF = \underline{0.69}$

                                 Two-Lanes Loaded:       $DF = \underline{0.90}$

### **-Distribution Factors using AASHTO SSHB (1996)**

Note: Assumes that the aluminum deck on steel girders behaves similar to a reinforced concrete deck on steel girders.

#### **A) Interior Girder:**

**Given:** -S= 9.0' between interior girders, G2 and G3.  
-S= 8.0' between exterior girder, G1, and interior girder, G2.

**Determine:** Interior girder distribution factors, DF's, for one and two-lanes loaded.

*One-Lane Loaded: (Use Equation 4.2 with D=7.0)*

$$S_{avg} = 8.5' < 10.0' \text{ OK}$$

$$WDF = \frac{S}{D} = \frac{S_{avg}}{D} = \frac{8.5'}{7.0} = 1.214$$

$$\therefore DF = WDF/2 = 0.607 = 0.61$$

*Two-Lanes Loaded: (Use Equation 4.2 with D=5.5)*

$$S_{avg} = 8.5' < 10.0' \text{ OK}$$

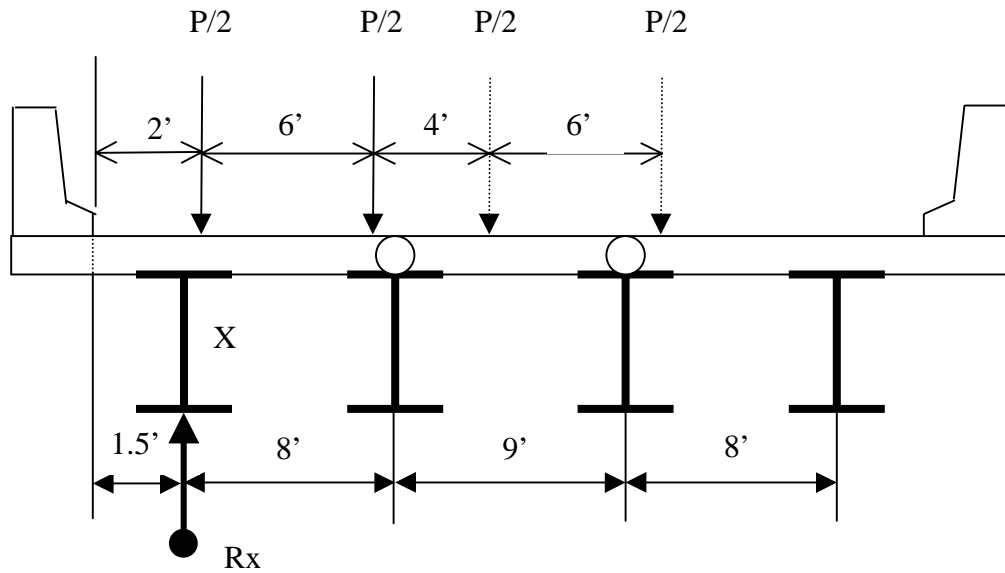
$$WDF = \frac{S}{D} = \frac{S_{avg}}{D} = \frac{8.5'}{5.5} = 1.545$$

$$\therefore DF = WDF/2 = 0.7725 = 0.77$$

#### **B) Exterior Girder: (AASHTO 1996 Specifies the use of the "Lever Method")**

**Given:** -Cross section with hinge locations as explained in Chapter 4.  
-The shown transverse truck location(s) determined from Figure 3.7.7A AASHTO SSHB (1996). Solid lines represent one truck (one lane loaded), dotted lines plus solid lines represent two trucks (two lanes loaded).  
-Girder X is the focal point.  
-P/2 represents one-half of an axle load.  
-Neglect multiple presence.

**Determine:** Exterior girder distribution factors, DF's, for one and two-lanes loaded using the "lever method" and limitations set by AASHTO SSHB (1996).



*One-Lane Loaded:*

$$R_x = \frac{\left(\frac{P}{2}\right)(7.5') + \left(\frac{P}{2}\right)(1.5')}{8'} = 0.5625P \quad \therefore DF = 0.56$$

*Two-Lanes Loaded:*

Same as for One-Lane Loaded because the load from the second truck cannot cross the hinge; therefore, DF=0.56

### **C) Limitations:**

- 1) An exterior girder shall not have less carrying capacity than an interior girder; therefore, the DF must be at least 0.61 for one-lane loaded and 0.77 for two-lanes loaded.

2) In the case of a concrete deck supported by four or more steel girders, the wheel-load distribution factor WDF, shall not be less than the value determined below for values of S between 6 ft and 14 ft (Equation 4.3 Chapter 4). The term, S, is the spacing between the exterior girder and adjacent interior girder in feet. Applicable to one and two-lanes loaded.

$$\text{WDF} = \frac{S}{4.0 + 0.25S} = \frac{8.0'}{4.0 + 0.25(8.0)} = 1.33 \quad \therefore \text{DF} = \frac{1.33}{2} = 0.67$$

*Summary of Distribution Factors from AASHTO SSHB (1996):*

Interior Girder:	One-Lane Loaded:	DF = <u>0.61</u>
	Two-Lanes Loaded:	DF = <u>0.77</u>
Exterior Girder:	One-Lane Loaded:	DF = <u>0.67</u>
	Two-Lanes Loaded:	DF = <u>0.77</u>

### -Distribution Factors using AASHTO LRFD (1994)

Note: Assumes that the aluminum deck on steel girders behaves similar to a reinforced concrete deck on steel girders.

General Criteria Check:

- 1) Is width of deck constant? Yes.
- 2) Is the number of girders greater than four? Yes.
- 3) Are the girders parallel and approximately the same stiffness? Yes.
- 4) Is the roadway part of the overhang,  $d_e$ , less than 3.0'? Yes,  $d_e = 1.5'$ .
- 5) Is the curvature in plan less than the specified limit in Article 4.6.1.2 (Specifies that the central angle subtended by a span must be less than  $3^\circ$ )? Yes, the bridge has no curvature in plan.
- 6) Is the cross-section consistent with a cross-section in Table 1 of AASHTO LRFD (1994)? The cross-section is assumed to be similar to the typical concrete deck on steel girder cross-section listed in Table 1 of AASHTO LRFD (1994).

#### A) Interior Girder:

Specific Criteria Check:

- 1) Is girder spacing,  $S$ , between 3.5 ft and 16.0 ft? Yes,  $S_{\max} = 9.0$  ft.
- 2) Is the thickness of the slab,  $t_s$ , between 4.5 in. and 12.0 in.? Yes,  $t_s = 8.0$  in.
- 3) Is the span length,  $L$ , between 20 ft and 240 ft? Yes,  $L = 53.31$  ft.
- 4) Is the number of beams,  $N_b$ , greater than four? Yes, there are four girders.

**Given:**

- Girder Spacing,  $S = S_{\text{avg}} = 8.5'$
- Moment of Inertia of Typical Girder,  $I_g = 6870.52 \text{ in}^4$
- Area of Typical Interior Girder,  $A_g = 32.54 \text{ in}^2$
- Vertical distance between the center of gravity of the basic girder and deck,  $e_g = 25.65''$
- Modular ratio of steel to aluminum,  $n = 2.87$

**Determine:** Interior girder distribution factors, DF's, for one and two-lanes loaded.

*One-Lane Loaded: (Using Equations 4.4 and 4.6)*

$$K_g = n(I_g + A_g e_g^2) = 2.87[6870.52 \text{ in}^4 + (32.54 \text{ in}^2)(25.65 \text{ in})^2] = 81161 \text{ in}^4$$

$$mDF = 0.06 + \left(\frac{S}{14}\right)^{0.4} \left(\frac{S}{L}\right)^{0.3} \left(\frac{K_g}{12.0L t_s^3}\right)^{0.1} = 0.06 + \left(\frac{8.5'}{14}\right)^{0.4} \left(\frac{8.5'}{53.31'}\right)^{0.3} \left[\frac{81161 \text{ in}^4}{12.0(53.31')(8.0'')^3}\right]^{0.1}$$

$$\therefore mDF = 0.471$$

$$\therefore DF = mDF/m = 0.471/1.2 = 0.393 = 0.39$$



*Two-Lanes Loaded: (Using Equations 4.5 and 4.6)*

$$mDF = 0.075 + \left(\frac{S}{9.5}\right)^{0.6} \left(\frac{S}{L}\right)^{0.2} \left(\frac{K_g}{12.0Lt_s^3}\right)^{0.1} = 0.075 + \left(\frac{8.5'}{9.5}\right)^{0.6} \left(\frac{8.5'}{53.31'}\right)^{0.2} \left[\frac{81161 \text{ in}^4}{12.0(53.31')(8.0'')^3}\right]^{0.1}$$

$$\therefore mDF = 0.639$$

$$\therefore DF = mDF/m = 0.639/1.0 = 0.639 = 0.64$$

### **B) Exterior Girder:**

Specific Criteria Check:

1) Is the distance between the center of the exterior girder and the interior edge of the curb or traffic barrier,  $d_e$ , between  $-1.0$  ft and  $5.5$  ft.? Yes,  $d_e = 1.5$  ft.

*One-Lane Loaded:*

-AASHTO LRFD (1994) specifies the use of the “lever method.” The transverse truck location is specified in Section 3.6.1.3.1 as  $2.0$  ft from the edge of the design lane, which is the interior face of the parapet. This location is the same location used previously for determining the exterior girder distribution factor using AASHTO SSHB (1996); therefore, refer to the AASHTO SSHB (1996) section for mathematical calculations.

$$\therefore DF = 0.56$$

*Two-Lanes Loaded: (Using Equation 4.7)*

$$e = 0.77 + \frac{d_e}{9.1} = 0.77 + \frac{1.5'}{9.1} = 0.935 \leq 1.0 \quad \therefore e = 1.0$$

$$\therefore DF = e(DF_{int}) = 1.0(0.639) = 0.64$$

### **C) Limitations:**

-Section 4.6.2.2.2d AASHTO LRFD (1994) states that in beam-slab bridges with cross-frames or diaphragms, the distribution factor for an exterior girder shall not be taken less than the value obtained by assuming the cross-section rotates and deflects as a rigid cross-section. The commentary sets the lower bound limits as the following values:

*One-Lane Loaded: (Using Equation 4.8)*

-N<sub>L</sub> = 1                      -N<sub>b</sub> = 4  
 -X<sub>ext</sub> = 12.5 ft              -x = 12.5 ft for exterior girders, 4.5 ft for interior girders  
 -e = 9.0 ft (Uses exterior edge of the 10 ft. design lane as the interior face of the concrete parapet)

$$R = \frac{N_L}{N_b} + \frac{X_{ext} \sum^{N_L} e}{\sum^{N_b} x^2} = \frac{1}{4} + \frac{12.5'(9.0')}{[2(12.5')^2 + 2(4.5')^2]} = 0.569 \quad \therefore \text{DF} = 0.57$$

*Two-Lanes Loaded:*

-N<sub>L</sub> = 2                      -N<sub>b</sub> = 4  
 -X<sub>ext</sub> = 12.5 ft              -x = 12.5 ft for exterior girders, 4.5 ft for interior girders  
 -e = 9.0 ft (Uses exterior edge of the 10 ft. design lane as the interior face of the concrete parapet)

$$R = \frac{N_L}{N_b} + \frac{X_{ext} \sum^{N_L} e}{\sum^{N_b} x^2} = \frac{1}{2} + \frac{12.5'(9.0'+9.0')}{[2(12.5')^2 + 2(4.5')^2]} = 1.137 \quad \therefore \text{DF} = 1.14$$

*Summary of Distribution Factors from AASHTO LRFD (1994):*

Interior Girder:	One-Lane Loaded:	DF = <u>0.39</u>
	Two-Lanes Loaded:	DF = <u>0.64</u>
Exterior Girder:	One-Lane Loaded:	DF = <u>0.57</u>
	Two-Lanes Loaded:	DF = <u>1.14</u>