

11.5 LIVE LOAD DISTRIBUTION FOR ABUTMENT DESIGN

11.5.1 GENERAL

This BDM provides a simplified approximate method to calculate the equivalent number of live load lanes needed for abutment design. The total live load force transferred from the superstructure to the abutment is needed for abutment analysis using *CTAbut* and similar software. Live load movements in the transverse direction should be considered to determine the greatest effects.

Due to the past satisfactory performance of the existing bridge abutments, the magnification effect of skew and curvature of the superstructure on live load distribution is assumed to be minimal and can be ignored.

11.5.2 DESIGN CONSIDERATION

The greatest effects associated with the possible movement of live load reaction forces in a transverse direction should be considered in abutment design. Similar to simplified assumptions used by AASHTO-CA BDS-8 Figure 10.7.2.3.1-1, this method assumes that the load is distributed on a larger surface developed by a downwards incline with an angle θ from the deck to the top of the footing, as shown in Figure 11.5.2-1a. (In lieu of a refined analysis, the designer may assume $\theta = 45^\circ$)

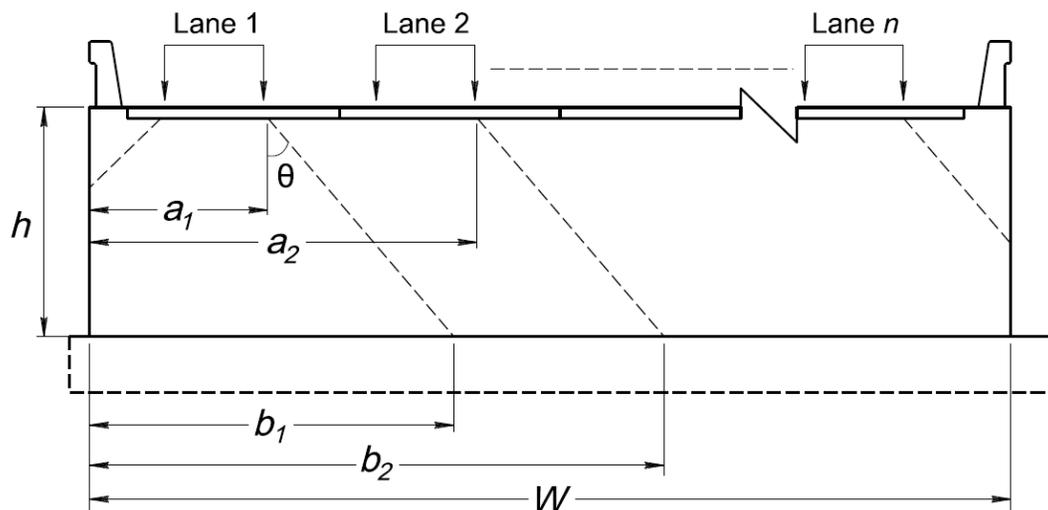


Figure 11.5.2-1a Elevation Views of Live Load Lanes on Bridge

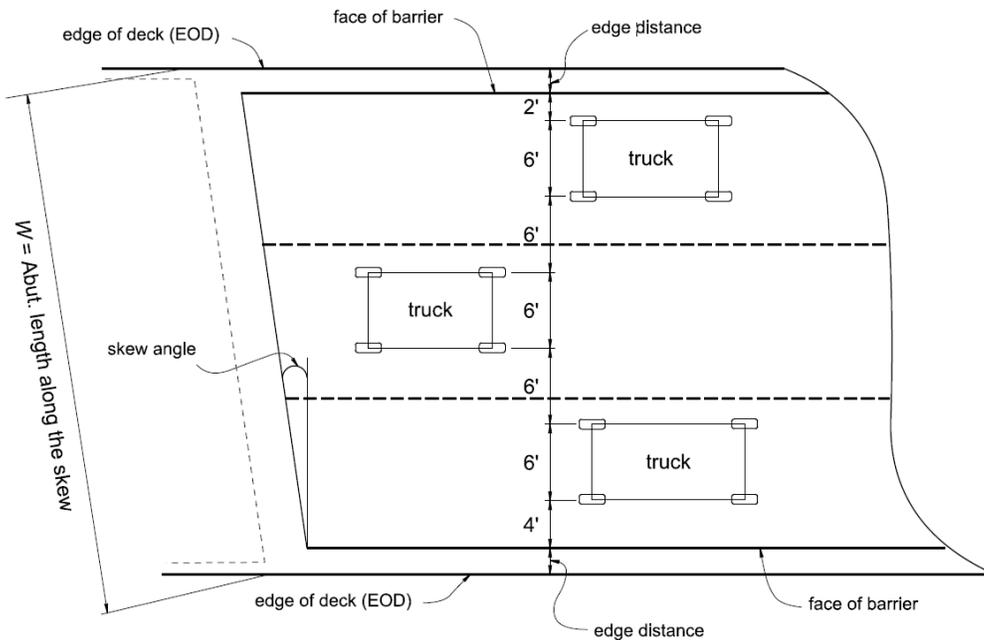


Figure 11.5.2-1b Plan Views of Live Load Lanes on Bridge

Per AASHTO-CA BDS-8 Article 3.6.1.1.1, the maximum number of design lanes that can be placed on the bridge deck is determined as the integer part of the number that results from the division of the clear roadway width between curbs or barriers, in feet, by 12. Furthermore, the number of lanes for roadway widths from 20 to 24 ft is assumed to be 2, each with a width equal to one-half of the width.

Therefore, the maximum number of live load lanes on the bridge with skew is assumed as follows:

$$n_{max} = \frac{(W * \cos(\text{skew angle}) - 2 \times \text{edge distance})}{12} \quad 11.5.2-1$$

Where:

W = length of abutment along the skew

n_{max} = maximum number of whole live load lanes the bridge can accommodate

Edge distance is the width of the barrier; however, the barriers may be disregarded, and the designer may use the edge of the deck (EOD) to EOD distance if there is a need to consider a future widening per AASHTO-CA BDS-8 Article 2.3.2.1. In such a case, the edge distance becomes zero.

When calculating the design number of live load lanes, the multiple presence factor (m) is multiplied by the number of whole lanes that can be accommodated on the bridge.

The equivalent number of lanes will be calculated as follows:

$$\text{Equivalent number of lanes } (N) = m * n * \frac{W}{b_n} \quad 11.5.2-2$$

Where:

m = multiple presence factor per AASHTO-CA BDS-8 3.6.1.1.2

n = number of whole lane(s) that is under consideration

b_n = effective live load distribution width at the top of the footing

$$b_n = a_n + h \tan(\theta) \leq W \quad 11.5.2-3$$

Where a_n is the effective live load distribution width at the deck elevation:

$$a_n = \frac{\{(8 + \text{edge distance}) + (n - 1) \times 12\}}{\cos(\text{skew angle})} \quad 11.5.2-4$$

h = abutment height (from the top of the deck to the top of the footing)

θ = angle of the load distribution (can be assumed 45°)

The equivalent number of lanes (N) is calculated for different values of n varying from 1 to n_{max} for HL-93 trucks and 1 to 2 for permit trucks. The largest numbers for HL-93 and permit trucks are calculated separately and used as an equivalent number of lanes for abutment design.

11.5.3 EXAMPLE CALCULATION OF THE EQUIVALENT NUMBER OF LIVE LOAD LANES

Assumptions:

$\theta = 45^\circ$

W = length of abutment along the skew = 62.6 ft, Edge distance=1 ft

Skew angle = 20°

h = height of the abutment = 14.25 ft

HL-93 design vehicle reaction at the abutment without impact = 98.23 kip/lane

Permit vehicle reaction at the abutment without impact = 184.01 kip/lane

Live load reactions for one lane at the abutment are from longitudinal analysis using CTBridge or similar software.

Solution:

Maximum number of whole lanes: $n_{max} = \frac{\{W \times \cos(\text{skew angle}) - 2 \times \text{edge distance}\}}{12}$

$$n_{max} = \frac{\{62.6 \times \cos(20^\circ) - 2 \times 1\}}{12}$$

$$n_{max} = 4.74 \text{ lanes}$$

Using only the integer part: $n_{max} = 4$ lanes

Since m depends on the number of lanes, the designer needs to calculate the equivalent number of lanes for each case: one, two, three, or four lanes occupying the bridge.

Effective live load distribution width at the deck elevation

$$a_n = \frac{(8 + \text{edge distance}) + (n - 1) * 12}{\cos(\text{skew angle})}$$

As an example, for two live load lanes ($n = 2$)

$$a_2 = \frac{(8 + 1) + (2 - 1) \times 12}{\cos(20^\circ)} = 22.35$$

Effective width at the top of the footing

$$b_n = a_n + h \tan(\theta) \leq W$$

For two live load lanes ($n = 2$)

$$b_2 = 22.35 + 14.25 \tan(45^\circ) = 36.60$$

The largest width is obtained for four lanes: $b_4 = 62.1 \text{ ft} < W$

Table 11.5.3-1 Summary of the calculation of a_n and b_n

| Number of lane (s) on superstructure, n | Effective live load distribution width at the deck elevation, a_n (ft) | Effective live load distribution width at the top of footing, b_n (ft) |
|---|--|--|
| 1 | $\frac{\{(8+1)+(1-1)\times 12\}}{\cos(20)} = 9.58$ | $9.58+14.25 \tan 45^\circ = 23.83$ |
| 2 | $\frac{\{(8+1)+(2-1)\times 12\}}{\cos(20)} = 22.35$ | $22.35+14.25 \tan 45^\circ = 36.60$ |
| 3 | $\frac{\{(8+1)+(3-1)\times 12\}}{\cos(20)} = 35.12$ | $35.12+14.25 \tan 45^\circ = 49.37$ |
| 4 | $\frac{\{(8+1)+(4-1)\times 12\}}{\cos(20)} = 47.89$ | $47.89+14.25 \tan 45^\circ = 62.14$ |

From those effective widths, the equivalent number of live load lanes is calculated using the equation 11.5.2-2. The results have been summarized in Table 11.5.3-2.

Table 11.5.3-2 Summary of the equivalent number of lanes for HL-93

| Number of lane (s) on superstructure, n | Multiple presence factor, m | Equivalent number of design live load lanes, N |
|---|-------------------------------|---|
| 1 | 1.2 | $1.2 \times 1 \times \frac{62.60}{23.83} = 3.15$ |
| 2 | 1.0 | $1.0 \times 2 \times \frac{62.60}{36.60} = 3.42$ |
| 3 | 0.85 | $0.85 \times 3 \times \frac{62.60}{49.37} = 3.23$ |
| 4 | 0.65 | $0.65 \times 4 \times \frac{62.60}{62.14} = 2.62$ |

In this example, the largest number of equivalent lanes is from two loaded lanes. Therefore, the equivalent number of live load lanes for the HL-93 design vehicle will be 3.42 lanes.

The same method is used for the permit trucks. However, the designer should consider only one or two lanes of permit trucks with $m = 1$ for both cases. The results for the permit trucks have been summarized in Table 11.5.3-3.

Table 11.5.3-3 Summary of the equivalent number of lanes for permit truck

| Number of lane (s) on superstructure, <i>n</i> | Multiple presence factor, <i>m</i> | Equivalent number of permit truck live load lanes, <i>N</i> |
|--|--|---|
| 1 | 1.0 | $1.0 \times 1 \times \frac{62.60}{23.83} = 2.63$ |
| 2 | 1.0 | $1.0 \times 2 \times \frac{62.60}{36.60} = 3.42$ |

The equivalent number of live load lanes for a permit truck is controlled by two lanes (side by side) and is equal to 3.42 lanes.

LRFD design vehicular live load (LL_{HL-93}) for the abutment analysis is as follows:

$$LL_{HL-93} = \text{equivalent number of lanes} \times \text{HL-93 design vehicle reaction per lane}$$

$$LL_{HL-93} = 3.42 \text{ lanes} * 98.23 \text{ kip per lane} = 335.95 \text{ kip}$$

LRFD permit vehicular live load (LL_{permit}) for the abutment analysis is as follows:

$$LL_{permit} = \text{equivalent number of lanes} \times \text{permit vehicle reaction per lane}$$

$$LL_{permit} = 3.42 \text{ lanes} * 184.01 \text{ kip per lane} = 629.31 \text{ kip}$$