Live Load Transfer Factor for Different Girder of Highway Bridges

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Abstract: **Live load distribution factors are used to determine the live-load moment for bridge girder design when a two dimensional analysis is conducted. A simple, analysis of bridge superstructures are considered to determine live-load factors that can be used to analyze different types of bridges. The distribution of the live load factors distributes the effect of loads transversely across the width of the bridge superstructure by proportioning the design lanes to individual girders through the distribution factors. This research study consists of the determination of live load distribution factors (LLDFs) in both interior and exterior girders for horizontally curved concrete box girder bridges that have central angles, with one span exceeding 34 degrees. Also, in this study, 3-D modeling analyses for different span lengths (80, 90, 100, 115, 120, and 140 ft) have been first conducted for straight bridges, and then the results compared with AASHTO LRFD, 2012 equations. The point of starting with straight bridges analyses is to get an indication and conception about the LLDF obtained from AASHTO LRFD formulas, 2012 to those obtained from finite element analyses for this type of bridge (Concrete Box Girder). After that, the analyses have been done for curved bridges having central angles with one span exceeding 34 degrees. Theses analyses conducted for various span lengths that had already been used for straight bridges (80, 90, 100, 115, 120, and 140 ft) with different central angles (5º, 38º, 45º, 50º, 55º, and 60º). The results of modeling and analyses for straight bridges indicate that the current AASHTO LRFD formulas for box-girder bridges provide a conservative estimate of the design bending moment. For curved bridges, it was observed from a refined analysis that the distribution factor increases as the central angle increases and the current AASHTO LRFD formula is applicable until a central angle of 38º which is a little out of the LRFD`s limits.**

Keywords: **Live Load, Interior Girders, Exterior Girders, Box Girder, AASHTO LRFD, Finite Element**

I. INTRODUCTION

Integral bridges (IBs) have no expansion joints. They possess structural system mainly consists of stub abutments supported on a single row of steel H-piles. In these type of bridges, the abutments are cast integral with the deck and the girders. The monolithic construction of the slab and girders with abutments in IBs provide tensional and rotational rigidity to the slab and the girders. Consequently, under live loads, the superstructure and abutments act together because of the continuity at the superstructure – abutment joint. IBs have many economical and functional advantages over regular jointed bridges.

A. Live Load Distribution Factors

The live load conveyance factors (LLDF) depicted in the AASHTO-LFD particulars had been utilized for over 50 years before their refresh in the AASHTO-LRFD Bridge Design Specification. The equations spoke to in AASHTO-LFD depend on the support dividing just and are generally displayed as S/D, where S is the separating and D is a steady in light of the scaffold write. This technique is suited to straight and non-skewed extensions as it were. While the equations spoke to in AASHTO-LRFD are more valuable and precise since they consider more parameters, for example, connect length, piece thickness, and number of cells for the crate support connect typ. The change in AASHTO-LRFD conditions has produced some enthusiasm for the extension building world and has brought up a few issues.

Skewed Bridges will be picked up by utilizing AASHTO-LRFD Specification [3].Live load distribution factors enable engineers to analyze bridge response by treating the longitudinal and transverse effects of wheel loads separately. These factors have simplified the design process by allowing engineers to consider the girder design moment as the static moment caused by AASHTO standard truck or design lane loads, multiplied by the live-load distribution factor calculated through AASHTO LRFD, 4.6.2.2.2b [4]. Fig 1.1 shows the interior and exterior girders that carry the truck loads. The distribution factor decreases when the bridge shares and distributes the load efficiently among adjacent girders. This leads to a low design moment for a given.

B. Objective of the Study

The objective of this study is to calculate live load distribution factors (LLDFs) for interior and exterior girders of horizontally curved concrete box girder bridges that have central angles, within one span exceeding 34 degrees.

All straight and curved bridges that used in this study are prismatic in cross section and continuous over the interior support.

II. DESCRIPTION OF MODEL BRIDGE & LIVE LOADING

A. Selection of the Span Length for the Box Girder Bridge

In this study, different span lengths from support to support are used (80, 90, 100, 115, 120, 140) ft to study the effect of various span lengths on LLDF. These lengths lie within the typical length of precast concrete box girder bridges according to design aids published by the California Department of Transportation [13]. All straight and curved bridges that used are prismatic in cross section and continuous over the interior support. Figs 3.1-3.2 show the span length that considered for straight and curved bridge.

III. STRAIGHT BRIDGE MODEL & ANALYZING

A. Modeling Straight Bridges

3-D modeling analyses have been conducted for straight bridges, Fig 4.1, for different span lengths (80, 90, 100 and 115 ft) and then the results compared with AASHTO LRFD, 2012 equations. This will help to get an indication and conception about the LLDF obtained from AASHTO LRFD formulas, 2012 to those obtained from finite element analyses for this type of bridge (Concrete Box Girder). Table 4.6.2.2.2b-1 and 4.6.2.2.2d-1, from AASHTO LRFD, 2012 [1] were used to calculate the LLDF for both interior and exterior girders, typical cross section (d) for Cast-in- Place Concrete Multi-cell Box, Fig 1.1. CSi Bridge 2015, finite element analysis software program is being used to conduct 3-D modeling and the analyses as mentioned in details in Chapter 3.

B. Results & Discussions for Straight Bridges

The analysis is conducted for different span lengths (80, 90, 100, 115, 120, 140 ft) to study the effect of different span lengths on LLDF and for different depths (4.1- 8.3 ft) that change along with span length. Also, other parameters like web thickness, top, and bottom slab thickness are considered to be variable with span length. No skew has been taken into account. For each length, the following six conditions are considered for straight bridges. The notations K and S are used for HL-93 design truck loads to distinguish between the two types of trucks as mentioned in section 3.4.1.

Left design lane loaded only by one truck (HL-93K) Right design lane loaded only by one truck (HL-93K) Two design lanes loaded by one truck (HL-93K)

Left design lane loaded only by two trucks (HL-93S) Right design lane loaded only by two trucks (HL-93S) Two design lanes loaded by two trucks (HL-93S)

R= 360 L/ 2л θ	(Formula 5.2)
Where:	L: span length of the bridge from support to support
	Θ: central angle between one span length

C. Distribution Factor Results (LLDF) for Central Angle of 5º

Tables 5.1-5.6 show the LLDF on curved bridges using HL-93K and HL-93S truck loading on one and two traffic lanes separately with a central angel equal to 5º. These tables state the LLDF for interior girders that usually carry larger moments than those on exterior girders.

D. Comparison of Results for Central Angle of 5º

Figures 5.6 shows the comparison of results that obtained from finite element analyses for HL-93S between LLDF for straight bridges and LLDF for curved bridges with a central angles of 5º. Fig 5.7-5.8 show the comparison for HL-93K loading type. The results that determined from AASHTO LRFD are also plotted.

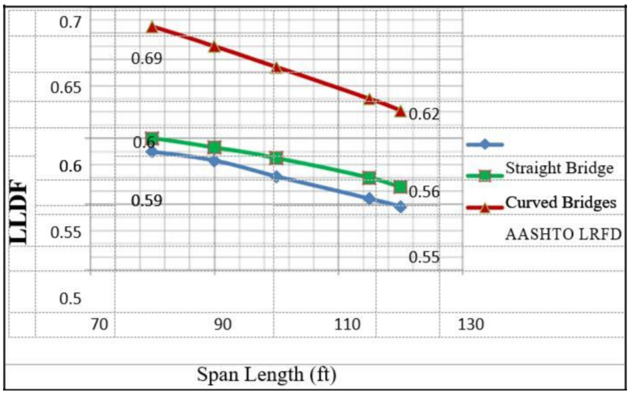

Fig. 5.8: HL-93K- Two Lanes Loaded- Negative Moment Distribution Factors for Central Angles of 38º, 45º, 50º, 55º, 60º

Tables 5.7-5.11 show the LLDF on curved bridges using HL-93K loading on two traffic lanes with a central angel equal to 38º, 45º, 50º, 55º, and 60º. These tables state the LLDF for interior girders that usually carry larger moments than those on exterior girders.

LLDF for HL-93K- Two Lanes Loaded-Negative Moment

Span Length (ft)	AASHTO LRFD	FEA
		Curved Bridge (θ = 38º)
80	0.69	0.70
90	0.67	0.68
100	0.65	0.65
115	0.63	0.63
120	0.62	0.62
140	0.60	0.60

Table 5.7: LLDF for Curved Bridge with a Central Angle of 38º LLDF for HL-93K- Two Lanes Loaded-Negative Moment

Span Length (ft)	AASHTO LRFD	FEA
		Curved Bridge (θ = 45º)
80	0.69	0.71
90	0.67	0.70
100	0.65	0.68
115	0.63	0.66
120	0.62	0.64
140	0.60	0.62

Table 5.8: LLDF for Curved Bridge with a Central Angle of 45º LLDF for HL-93K- Two Lanes Loaded-Negative Moment

Span Length (ft)	AASHTO LRFD	FEA
		Curved Bridge (θ = 50º)
80	0.69	0.74
90	0.67	0.72
100	0.65	0.70
115	0.63	0.67
120	0.62	0.66
140	0.60	0.63

Table 5.9: LLDF for Curved Bridge with a Central Angle of 50º LLDF for HL-93K- Two Lanes Loaded-Negative Moment

Span Length (ft)	AASHTO LRFD	FEA
		Curved Bridge (θ = 55º)
80	0.69	0.76
90	0.67	0.74
100	0.65	0.72
115	0.63	0.69
120	0.62	0.68
140	0.60	0.65

Table 5.10: LLDF for Curved Bridge with a Central Angle of 55º LLDF for HL-93K- Two Lanes Loaded-Negative Moment

Span Length (ft)	AASHTO LRFD	FEA
		Curved Bridge (θ = 60º)
80	0.69	0.79
90	0.67	0.77
100	0.65	0.75
115	0.63	0.72
120	0.62	0.71
140	0.60	0.67

Table 5.11: LLDF for Curved Bridge with a Central Angle of 60º

E. Comparison of Results for Central angles of 38º, 45º, 50º, 55º, 60º

Figures 5.9-5.13 show the LLDF for curved bridge with different central angles (38º, 45º, 50º, 55º, 60º). The results were plotted for just greatest LLDF determined by maximum moments obtained from finite element analyses that accrued at negative moment and two lanes loaded by the truck HL-93K. The result compared with the LLDF results that determined from AASHTO LLRDF for straight bridge (central angles = 0).

Max LLDF on Individual Girder			Max LLDF on Entire Bridge		
Span	AASHTO	Interior	Number	AASHTO	Interior
Length	LRFD	Girder	of	LRFD	Girder

Observation indicates that, on average about every 50th truck is followed by another truck with the headway distance less than 30 m. It also assumed that about every 150th truck is followed by a partially correlated truck, and about every 500th truck is followed by a fully correlated truck. The parameters of the two truck in lane, including N (the considered truck is a maximum of N trucks). The maximum values of moment are calculated by simulations. The parameters considered include truck configuration, weight, headway distance and frequency of occurrence. The mean 75 year values are shown span moments, shears and negative moments, respectively.

(ft)		(Analysis)	Webs		(Analysis)
80	0.69	0.71	4	2.76	2.84
90	0.67	0.69	4	2.70	2.76
100	0.65	0.67	4	2.61	2.60
115	0.63	0.64	4	2.52	2.57
120	0.62	0.63	4	2.50	2.54
140	0.60	0.61	4	2.40	2.44

Table 5.12: Maximum LLDF for the Entire Bridge
Curved Bridge (θ = 45º)

Max LLDF on Individual Girder			Max LLDF on Entire Bridge		
Span Length (ft)	AASHTO LRFD	Interior Girder (Analysis)	Number of Webs	AASHTO LRFD	Interior Girder (Analysis)
80	0.69	0.73	4	2.76	2.92
90	0.67	0.71	4	2.70	2.82
100	0.65	0.68	4	2.61	2.74
115	0.63	0.66	4	2.52	2.64
120	0.62	0.65	4	2.50	2.60
140	0.60	0.62	4	2.40	2.48

Table 5.13: Maximum LLDF for the Entire Bridge
Curved Bridge (θ = 50º)

Max LLDF on Individual Girder			Max LLDF on Entire Bridge		
Span Length (ft)	AASHTO LRFD	Interior Girder (Analysis)	Number of Webs	AASHTO LRFD	Interior Girder (Analysis)
80	0.69	0.74	4	2.76	2.97
90	0.67	0.72	4	2.70	2.88
100	0.65	0.70	4	2.61	2.80
115	0.63	0.67	4	2.52	2.68
120	0.62	0.66	4	2.50	2.64
140	0.60	0.63	4	2.40	2.52

Table 5.14: Maximum LLDF for the Entire Bridge
Curved Bridge (θ = 55º)

Max LLDF on Individual Girder			Max LLDF on Entire Bridge		
Span Length (ft)	AASHTO LRFD	Interior Girder (Analysis)	Number of Webs	AASHTO LRFD	Interior Girder (Analysis)
80	0.69	0.76	4	2.76	3.04
90	0.67	0.74	4	2.7	2.96
100	0.65	0.72	4	2.61	2.88
115	0.63	0.69	4	2.52	2.77
120	0.62	0.68	4	2.50	2.72
140	0.60	0.65	4	2.40	2.60

Table 5.15: Maximum LLDF for the Entire Bridge

Curved Bridge (θ = 60º)

Max LLDF on Individual Girder			Max LLDF on Entire Bridge		
Span Length (ft)	AASHTO LRFD	Interior Girder (Analysis)	Number of Webs	AASHTO LRFD	Interior Girder (Analysis)
80	0.69	0.79	4	2.76	3.16
90	0.67	0.77	4	2.70	3.08
100	0.65	0.75	4	2.61	3.00
115	0.63	0.72	4	2.52	2.88
120	0.62	0.71	4	2.50	2.83
140	0.60	0.67	4	2.40	2.69

Table 5.16: Maximum LLDF for the Entire Bridge

V. SUMMARY & CONCLUSIONS

A. Summary

1) Straight Box Girder Bridges

Consistent with the AASTHO LRFD, the magnitude of the distribution factors that obtained from finite element analysis decreases with an increase in span length. Since the longitudinal stiffness if found to be related to the span length (L). The general trend of the relationship is the stiffness increases as span length increases. That leads to decrees the stress which in turns to decrease the distribution factors. The results show that distribution factors from the refined analysis are smaller than those calculated from the LRFD formula. Results indicate that the current LRFD specifications distribution factor formulas for box-girder bridges generally provide a conservative estimate of the design bending moment. Distribution factors are generally more conservative for exterior girders than for interior girders. Also, the LLDF obtained from both the analyses and AASHTO LRFD for one design lane loaded is less than two lanes loaded for all cases mentioned before. In addition, the LRFD specification distribution factor became less conservative with an increase in span length for both girder types.

2) Curved Box Girder Bridges

The AASHTO LRFD Design Specifications provide a set of live load distribution factor formulas for determining the distribution of bending moment effects in both the interior and exterior girders of highway bridges. However, there are limitations on the use of these distribution factors, such as the central angle that is limited up to 34º. As a result, refined analyses using 3D models are required to design bridges outside of these limits.

The analyses of various curved box girder models are carried out in CSi Bridge software by varying span lengths and central angles. The models are conducted by varying the span lengths while the angle of curvature is kept constant. From the results obtained after the analysis of curved box girder, the following conclusions are made.

LLDFs decrease with an increase of span lengths within the same central angle. That is because the effect of the curvature goes down as the radius of curvature goes up, due to the increase in span lengths. Also, the stiffness of girders increases as the span length increases, as pointed out before.

It is observed from a refined analysis that the distribution factor increases as the curvature of box girder increases. Using a span length of 80 ft. as an example, the

LLDF for a straight bridge is 0.69 from LRFD`s formula and 0.73 from a refined analysis, with a central angle of 45º. The percentage difference is about 6%, even though a 45º angle is quite far away from the limits of the LRFD specification (34º).

The value of LLDFs that are determined from an analysis for a central angle of 38º is a little higher than those obtained from LRFD equations for straight bridges. Therefore, AASHTO LRFD formulas can be used for curved box girder

Bridges up to its limits of 34º central angle or even until a little outside of the LRFD limits. Also, these values of LLDF state that the distribution factor formulas for box-girder bridges obtained from the current AASHTO LRFD provide a conservative LLDF due to the bending moment.

The distribution factor for curved bridges with a central angle of 5º does not vary significantly with the LLDF obtained from the analysis for straight bridges.

B. Conclusions Curved Bridge

It was observed from a refined analysis that the distribution factor increases as the central angle increases.

The current AASHTO LRFD formulas for multi-cell box girder bridges are applicable for curved bridges that have central angels up to 34º or even until 38º, which is a little out of the LRFD`s limits.

The maximum moment on the exterior girders increases very significantly due to the effect of centrifugal and braking forces. And, the bending moment generally increases under the braking force. The results of LLDF for a prismatic curved box girder bridge for different central angles and span lengths are tabled and plotted. These results provide distribution

VI. FUTURE SCOPE

In future all same process is apply in steel bridges.

In future use composite materials in bridge and all analysis done.

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