SHEAR AND REACTION DISTRIBUTION IN SKEW MULTICELL BOX-BEAM BRIDGES

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Abstract - This paper presents a study of skewness effect on live load reactions at piers and shear forces of continuous multicell box-girder concrete bridges (MCB). Two MCB bridges were selected for the research, one bridge with two-span and the other with three-span. To study the effect of skewness, the skew angles varied from 0o to 60o with 150 increment. The selected bridges were modeled using finite element methods and analyzed to obtained bridge responses. It was concluded that there is a significant difference between the reaction and shear distribution factors of skewed bridges, so that the reaction distribution factor corner is higher than that of the beam shear. The reaction distribution factor in external girders is increased more strikingly and rapidly than that in internal girders.

Index Terms - Piers, Shear, Distribution Factor.

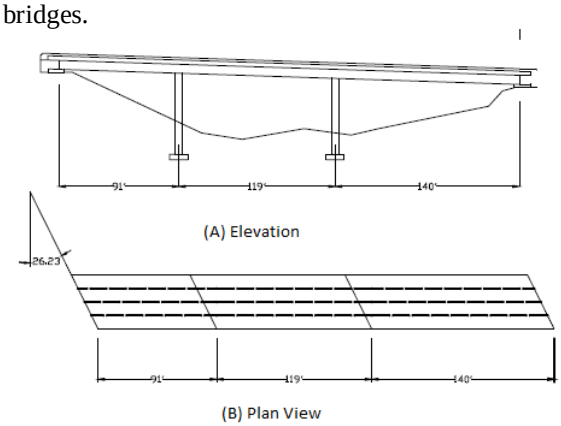
I. INTRODUCTION

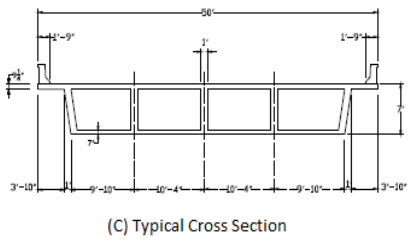
Currently, the live distribution factor for stress and bending moment is commonly calculated using the North American Codes (AASHTO 2002; AASHTO LRFD 2014). In the AASHTO LRFD Specifications, it requires that shear in the external girder at the obtuse corner of the bridge be adjusted because of skewness. This code recommended several skew correction factors to take into account the effects of skew angle on live load distribution factor (LDF) for shear and bending moment of bridges. However, distribution of reaction due to vehicle loads is an important design term for substructure design, The current Specifications do not determined any specific modification for LDF of reactions in straight and skew bridges. traditionally, the effect of skew angle on LDFof reactions at piers of MCB bridges are calculated either by using the skew correction factor (SCF) for shear or by neglecting the effect of skewness (Huo and Zhang, 2008; ASIC 1986, Samman et al., 2005; Barr and Amin 2011). Current studies indicated that the LDF of reactions at piers in a skewed continuous bridge are amplified and the skew correction factors for reactions are unique from those for beam shear forces (Zhang, 2008). The researchers at Modjeski and Masters, Inc. carried out a research on shear in skewed multi-beam bridges in the NCHRP Project 20- 7/Task 107. They concluded that SCF for live load distribution factor for reactions at piers of continuous bridges are significantly different from LDF of shear forces.

therefore, it is highly recommended to develop significant studies on distribution of live load reaction on bridges, since nowadays most of the bridges are continuous and skewed bridges, use of inaccurate prediction of LDF may results in unreliable (conservative or unconservative) design for continues and skewed bridge superstructures (Mensah et al. 2014). Although extensive studies have been performed for the skew effect on live load shear distribution (Mensah, 2014, Mohseni and Khalim, 2013), very little consideration has been paid on the influence of skew angle on LDF reactions of continuous bridges. The main goal of this study is to evaluate the influence of bridge skewness on LDF for reactions at supports of continuous MCB bridges.

II. BRIDGE GEOMETRY AND LOADING CONDITIONS

The bridges considered in this study were taken from two surveyed continuous skewed multicell box girder bridges located in the United States, which include Bridge #15 and Bridge #14 of the NCHRP 12-26 project (Huo et al 2003). The effect of skewness on structural responses of bridges was studied by changing the skew angle from 0° to 60° in 15° increments. In addition, the effect of overhang of the bridge deck on the live LDFs was studied by varying the overhang from 0.6 to 1.40 m in 0.20-m increments. Figure 1 shows the typical plan view of the bridges and Figure 2 shows the plan view of changing in skew angles. Table 1 shows the characteristics of selected bridges.





(C) Typical Cross Section

Fig. 1: Elevation, Plan View, and Typical Cross Section Bridge #14

No. #	Number of Spans	Span length (m)	Number Beams	Beam Spacing	Width (m)	Overhang (m)
14	3	43	4	3.14	15.25	0.80
15	2	33.5	3	2.90	11.00	0.60

Table1: Cast-In-Place MCB bridges

Finite element method using CSIbridge software (CSI, 2015) was used to investigate the bridge responses. A quadrilateral shell element (shell with 6 degrees of freedom at each point) was used to model the top and bottom slabs and the web of the beams. Top and bottom shell elements of the web are integrated with the top and bottom slabs at connection points to ensure compatibility of deformation (Mohseni and Khalim, 2013). Boundary condition are provided using hinges and rollers were defined for external and internal bearing locations of prototype bridges. Figure 2 illustrates a typical FE mesh used in the analyses of for abridge #14. AASHTO HL 93 live load was used in this study. The designated HL 93 (AASHTO LRFD 2014), consisting of design trucks plus design lane loads or design tandems plus lane loads, was used to calculate the maximum structural responses of skewed multicell box girder bridges. Figure 3 shows a typical model of AASHTO LRFD designated truck, HL98.

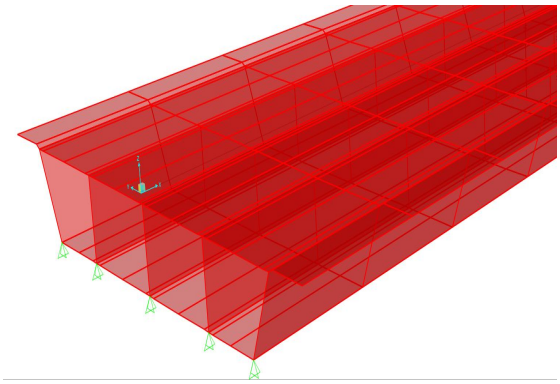


Fig 2. Finite Element Model of Bridge #14

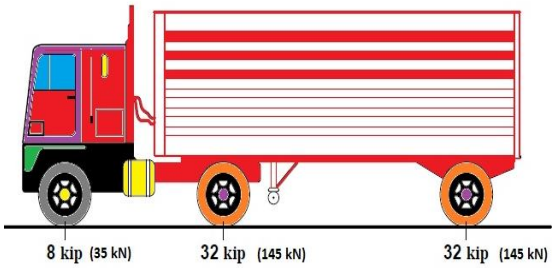


Fig.3. HL93 trucks (LRFD)

III. RESULTS OF ANALYSIS AND COMPARISON

3.1 Variation of Distribution Factor of Live load Reaction at Supports

The live LDF is defined as a ratio of maximum shear and reaction from bridge analysis ($F_{refined}$) over the maximum shear and reaction from a simple beam line model analysis (F_{beam}) at the corresponding locations (LDF= $F_{refined}/F_{beam}$). Although ASHTO LRFD specifications (AASHTO LRFD 2014) have been widely used in bridge design all over the world, there is no simplified method to calculate the skew effect on the reactions at the piers of bridges. The reaction distribution factor of skewed bridges is determined either by using the skew correction factor of shear or by applying that used for straight bridges. The obtained analytical results include the maximum live load reactions and shear forces at supports on the external beam line A and the internal beam line B in each bridge, as shown in Figures 6 to 9. It can be observed from Figure 6 that the reaction distribution factor at the obtuse corner (A1) of Bridge 1 was increased by 46% by increasing the skew angle from 0° to 60°. The reaction distribution at the intermediate supports (A2) varies in the same way as that at the corner A1 with an increase in the amount of skewness.

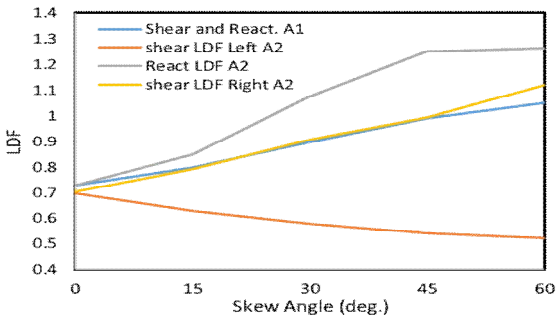


Fig. 5 LDF for External Girder Bridge #14

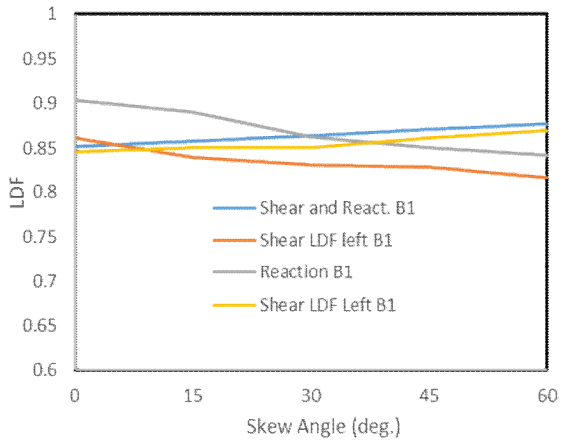


Fig. 6 LDF for Internal Girder Bridge #14

Figure 6 shows the variations of the reaction distribution factors at the first internal girder. The reaction distribution factors at the obtuse corner (B1) increased with increasing skewness. The same trend is

revealed in point B2 at the first internal girder. Therefore, when the distance between the support and trucks is decreased, the skew angle is increased, and higher stress and reaction at the first internal girder are obtained. For an external girder, the position of trucks on the superstructure provides a larger eccentricity to the external girder than to the internal one. This eccentricity, therefore, intensifies the effect of the torsional moment, which results in reducing the shear and reaction of the external girder. Furthermore, for both external and internal girders, the live LDFs of the reaction are slightly higher than those of the shear. These differences between reaction and shear for the live LDFs become more significant when the skew angle is more than 30°, and it is higher for external girders than internal ones. The same trend was observed for Bridge 2 as shown in Figures 7 and 8.

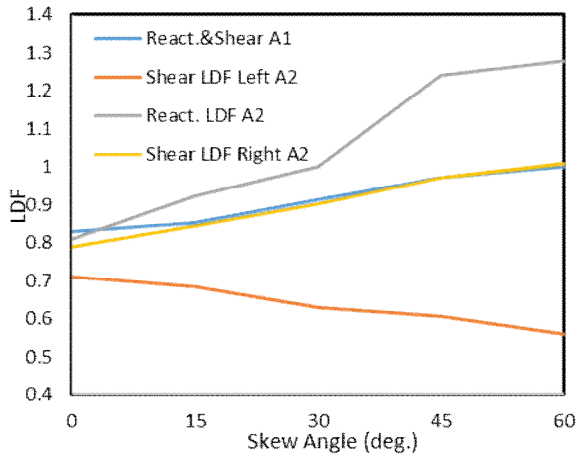


Fig. 7 LDF for External Girder Bridge #15

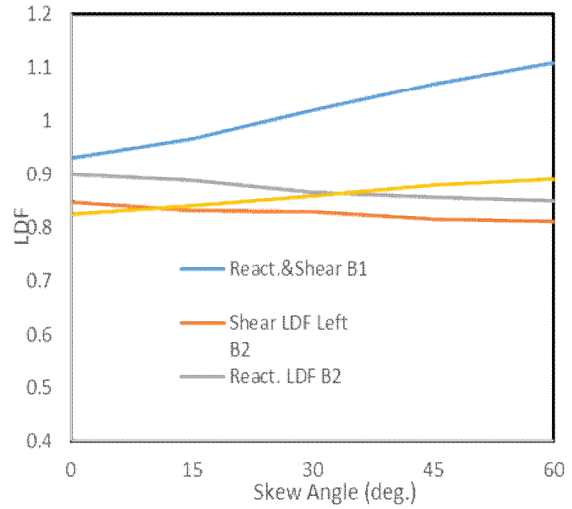


Fig. 8 LDF for Internal Girder Bridge #15

3.2 Compression with Codes and Specifications

Figure 9 shows the ratio of the reaction and average shear distribution factor obtained from FE analysis versus the AASHTO LRFD specifications and lever rule method of Bridge #15. The AASHTO LRFD distribution factors are found to be very small, especially for the external girder. The average ratio of FE analysis to LRFD for selected bridges is 0.812. The maximum differences between FE analysis and LRFD specifications are approximately 31% and 25%, respectively, for external girders at Piers A2 and A3, and about 51% for internal girders with a skew angle of 60°. In addition, the lever rules method, which is a static method based on simple beam line analysis, is unable to predict the skew effect on the reaction and shear of multicell box girder bridges.

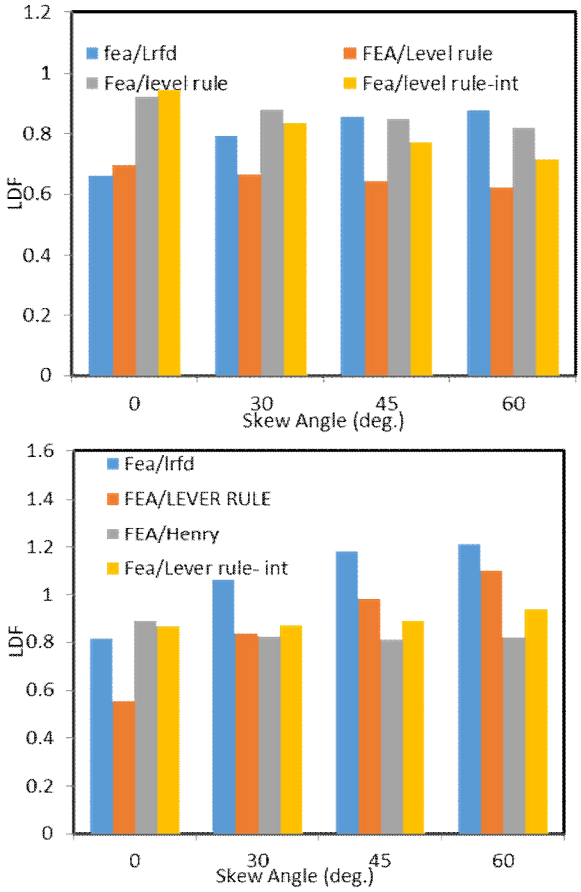


Figure 9 Ratio of LDF from FEA vs. LDF of current methods

The average ratio of FE analysis to lever rule for this type of bridge is 0.890 for the reaction and shear distribution factor of the external girder and 0.653 for the shear distribution factor of the internal girder. Further investigations demonstrated that the lever rule method with the SCF can enhance the accuracy of prediction, but it needs more simplifications to be practical for bridge design. This tremendous difference is not only because the AASHTO LRFD SCF is unable to present the skew effect properly but also because the SCF of shear and reaction are utterly different. the reaction and average shear distribution factor obtained from FE analysis versus the AASHTO LRFD specifications and lever rule method of Bridge #15. The AASHTO LRFD distribution factors are found to be very small, especially for the external girder. The average ratio of FE analysis to LRFD for selected bridges is 0.812. The maximum differences

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CONCLUSIONS

Based on the results of this limited study, the following conclusions are made:

1. The reaction distribution factors at the piers of continuous skewed bridges increase with increased skew angles.
2. The AASHTO LRFD skew correction factors equations, in most cases, showed conservative values for the shear and reaction distribution factors of skewed bridges.

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