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INFLUENCE OF SPAN LENGTH AND CROSSBEAM ON LOAD DISTRIBUTION FACTOR FOR GIRDER BRIDGES

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Load distribution factor at concrete girder bridges and steel girder bridges are analyzed with finite element method to see effect of span length and cross beam to load distribution factor. Span lengths of analyzed bridge models are 30m, 40m, 50m and 60m. The number of intermediate cross beam is increased from one to until distance between cross beams becomes 5m. The finite element analysis results show that concrete girder and steel girder can use same load distribution factor and span length doesn't affect to load distribution factor. Even though load distribution factor in interior girders is not influenced by cross beam, in exterior girders it is influenced by cross beam. Effect of cross beam in exterior girder is influenced by the number of lanes and distance from exterior girder to curb. Since design code introduces conservative load distribution factor, economically improved load distribution factor is proposed. The proposed load distribution factor includes cross beam effect with the number of lanes and distance from exterior girder to curb. The proposed equation is compared with AASHTO code and grillage method which is well-known method to calculate load distribution. The comparison results showed that the proposed equation is more efficient and useful than AASHTO and safer than the grillage method.

Keywords: Effect of cross beam, AASHTO code, Grillage method.

1 INTRODUCTION

Since bridge is a complex structure, calculation of load distribution is very complicated. Therefore design codes suggest load distribution factor for efficient bridge design. Regardless of girder material, AASHTO LRFD (2012) suggests different shear load distribution factor to interior girder and exterior girder (Zokaie 2000). For girder bridge with crossbeam or bracing, AASHTO introduces different load distribution factor based on rigid body analysis. Since it ignores many factors such as span length, crossbeam spacing or number of lanes which affect the load distribution, load distribution factor gives conservative result. It causes economical waste with less efficiency (Bishara *et al*. 1993, Barr and Amin 2006, Yousif and Hindi 2007).

2 AASHTO LRFD LOAD DISTRIBUTION FACTOR

Load distribution factor without crossbeam or bracing is calculated based on girder spacing(S). Load distribution factor to interior I-shaped girder is shown in (1)

$$LDF = 0.2 + \frac{S}{3600} - (\frac{S}{10700})^{2.0} \tag{1}$$

where S is distance between adjacent girders(mm).

Load distribution factor to exterior I-shaped girder is calculated based on load distribution factor of interior girder. It is shown in (2).

$$LDF = (0.6 + \frac{d_e}{3000}) \times LDF_{interior} \tag{2}$$

where d_e is distance from exterior girder to curb(mm).

Load distribution factor of exterior girder with crossbeam or bracing is derived based on rigid body analysis. It is shown in (3)

$$LDF = (\frac{N_L}{N_b}) + \frac{X_{ext}\sum^{N_L} e}{\sum^{N_b} x^2} \tag{3}$$

where N_L is the number of loaded lanes under consideration, e is eccentricity of a design truck or a design lane load from the center of gravity of the pattern of girders(ft), x is horizontal distance from the center of gravity of the pattern of girders to each girder(ft), X_{ext} is horizontal distance from the center of gravity of the pattern of girders to the exterior girder(ft), N_b is the number of beams or girders.

Keating *et al.* (1997) found that since the design code doesn't include effect of span length or crossbeam properties such as spacing and position, it gives very conservative result. Therefore for economical design, effect of span length and crossbeam properties should be considered to improve load distribution factor.

3 GEOMETRIC AND STRUCTURAL PROPERTY

I-shape girder brides with fixed girder spacing and various span lengths are chosen to obtain same load distribution factors from AASHTO Code. Girder spacing is 2.5m and span length is increased by 5m from 30m to 60m. Six different bridge cross sections are selected based on the number of girder and distance of exterior girder to curb. The properties of bridge model are shown in Table I.

The number of intermediate crossbeam is varied from one to six. So crossbeam spacing varies from 5m to 17.5m. Since AASHO LRFD uses same load distribution factor for concrete girder and steel girder, concrete girder and steel girder are selected to compare material property effect. Boundary condition of bridge is simply supported

Table 1. Properties of bridge model.

Case	1	2	3	4	5	6
Number of girder	3	3	4	5	6	6
Number of lane	2	2	3	3	4	4
Distance of exterior girder to curb(m)	0.5	0.8	0.8	0.3	0.3	0.5

4 FINITE ELEMENT METHOD

Finite element method (FEM) is used to analysis load distribution with commercial finite element software, ABAQUS. Concrete girder FEM model is from Barker and Puckett (2013) and steel girder FEM model is from Mabsout *et al*. (1997) and Chung and Sotelino (2006). Girders, crossbeam and slab are modeled by solid elements (ABAQUS C3D20).

5 RESULT

Figure 1~4 are results of FEM about span length effect to interior and exterior girders. Figure 1 and Figure 3 are results of concrete girder and Figure 2 and Figure 4 are results of steel girder. Variations of load distribution factor of all cases are less than 2%. Since load distribution factor doesn't change as span length increase, it can conclude that span length doesn't affect to load distribution factor.

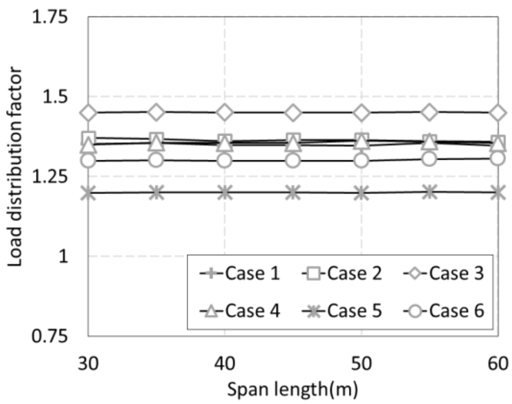

Figure 1. Load distribution factor of interior concrete girder about span length.

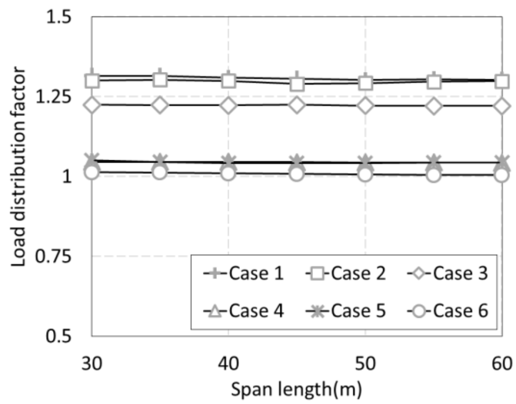

Figure 2. Load distribution factor of interior steel girder about span length.

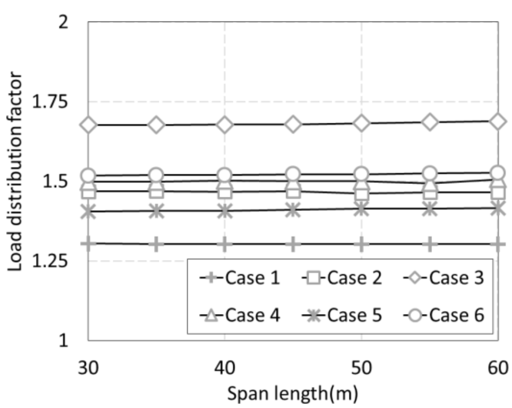

Figure 3. Load distribution factor of exterior concrete girder about span length.

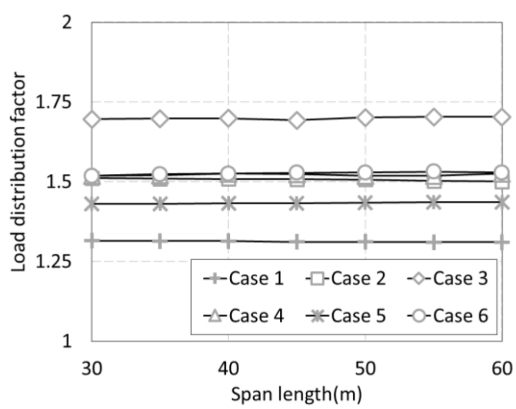

Figure 4. Load distribution factor of exterior steel girder about span length.

Figure 5~8 are results of FEM about crossbeam spacing effect to interior and exterior at 35m span length. Figure 5 and Figure 7 are results of concrete girder and Figure 6 and Figure 8 are results of steel girder.

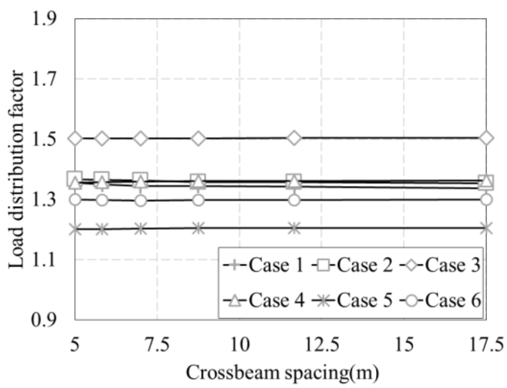

Figure 5. Load distribution factor of interior concrete girder about crossbeam spacing.

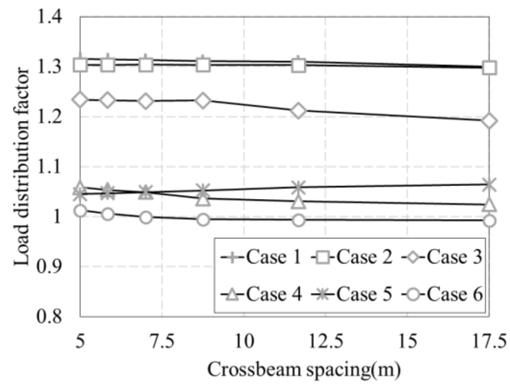

Figure 6. Load distribution factor of interior steel girder about crossbeam spacing.

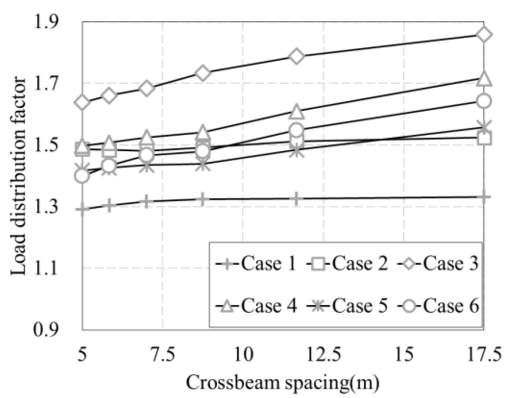

Figure 7. Load distribution factor of exterior concrete girder about crossbeam spacing.

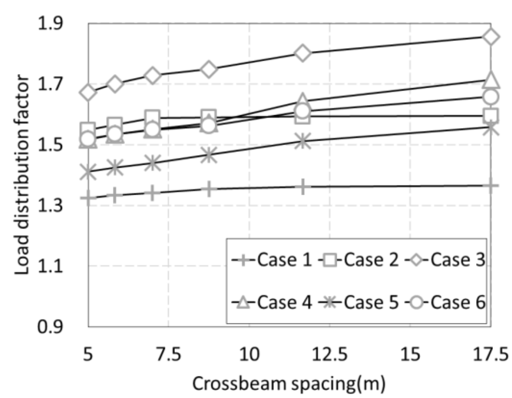

Figure 8. Load distribution factor of exterior steel girder about crossbeam spacing.

Figure 5 and Figure 6 show load distribution factors of interior girder with different crossbeam spacing. Variations of load distribution factors in interior girder are less than 2%. Therefore for interior girder, effect of crossbeam can be ignored as suggested by AASHTO.

In AASHTO, load distribution factor of interior girder is calculated only with girder spacing. So six cases should have same load distribution factor. However in Figure 5 and Figure 6, load distribution factor is rather affected by the number of girders, distance from exterior girder to curb and girder material. Even though load distribution factors of interior girder are different from case to case, all of them are below AASHTO code which is 1.66

Figure 7 and Figure 8 show load distribution factors of exterior girder with different crossbeam spacing. Case 1 and Case 2 show little variations which are less than 3%. Case 3~6 show higher variations of load distribution factor which is at least 10%. Case 1 and Case 2 are bridges supported by three girders. Therefore it can conclude that crossbeam spacing affects load distribution factor of exterior girder in the case of the four or more girders bridge.

The effectiveness of crossbeam is different depending on the number of lanes and distance from exterior girder to curb. Case 3 and Case 4 which have three lanes, show higher variations than Case 5 and Case 6 which have four lanes. This is because of slab width. As the number of lane increases, so as the slab width. Therefore wide slab affects to load distribution more than crossbeam. Also distance of exterior girder to curb shows higher effect to crossbeam than the number of lane. Slope of shorter distance cases is higher than longer distance cases. The reason is that if distance of exterior girder to curb is longer, the more vehicle load can be applied at outside of exterior girder, so effect of cross beam between exterior and interior girder is reduced.

6 PROPOSED LOAD DISTRIBUTION FACTOR

The number of crossbeam is effective to load distribution factor at exterior girder of four or more girder bridges. As spacing between crossbeams increases, load distribution factor increases. Also distance from exterior girder to curb and the number of lanes affect to slope of variation of load distribution factor. As distance from exterior girder to curb and the number of lane decrease, variation of load distribution factor due to cross beam is increased. Proposed load distribution factor includes all these factors. Therefore proposed load distribution factor is shown in (4).

$$LDF = \left(\frac{0.75}{N_l^{1.5}} + \frac{18}{d_e}\right) \times s^{0.355} + 2 \times \left(0.6 + \frac{d_e}{3000}\right) \times \left(0.2 + \frac{S}{3600} - \left(\frac{S}{10700}\right)^{2.0}\right). \qquad (4)$$

where N_l is the number of lane, de is distance from exterior girder to curb, s is distance between cross beam (m) and S is distance between girder(mm). Last term in the right equation is from AASHTO LRFD which is for non-crossbeam.

Figure 9 and Figure 10 are comparisons between FEM, Grillage method, AASHTO LRFD and proposed equation for concrete and steel girders. AASHTO LRFD gives the highest load distribution factors for both cases. Grillage method is traditional method of analyzing load distribution. Even though grillage method shows cross beam effect, it gives the lowest load distribution factors. Therefore, proposed equation is more efficient and useful than AASHTO, and safer than the grillage method.

7 CONCLUSION

Even though span length is important design factor, it doesn’t affect to load distribution. Therefore span length effect can be neglected at load distribution factor. From this research, it can figure out that crossbeam is effective at exterior girder with more than four girders. As the number of crossbeam increases, vehicle load is more equally distributed to girders which is purpose of crossbeam so that the load distribution factor is decreased. AASHTO LRFD introduces very conservative load distribution factor compare to FEM results and uses different load distribution factor depending on presence of crossbeam. The proposed equation includes load distribution factor of non-crossbeam case for convenient use so it can be used without considering crossbeam presence. Therefore proposed equation gives more efficient load distribution factor than AASHTO, and safer load distribution factor than the grillage method.

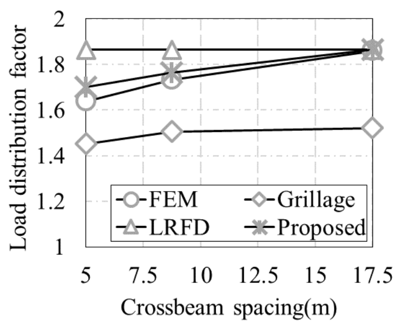

Figure 9. Comparison with methods at concrete girder.

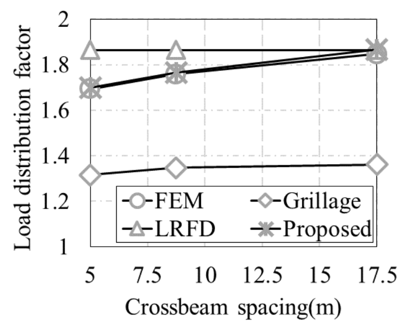

Figure 10. Comparison with methods at steel girder.

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