Effect of Span Length and Crossbeam Spacing on Load Distribution Factor at Girder Bridges

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***Abstract*—Load distribution factor at concrete girder bridges and steel girder bridges with different span length and crossbeam spacing are analyzed with finite element method. No matter which material girder is, span length doesn't affect to load distribution factor. Although load distribution at interior girders are not influenced by cross beam, exterior girders are influenced by cross beam. Moreover effectiveness of cross beam is affected by the number of lanes and distance from exterior girder to curb. The proposed load distribution factor includes cross beam effect with the number of lanes and distance from exterior girder to curb. Since AASHTO code introduces conservative load distribution factor to girder bridge, the proposed load distribution factor suggests very reasonable and reliable distribution factors compared to AASHTO.**

***Index Terms*—load distribution factor, crossbeam spacing, span length, girder bridge**

I. Introduction

In bride design, since bridge is complicated structure, load distribution calculation requires a lot of effort. For efficiency in design code, Load Distribution Factor (LDF) is suggested. AASHTO LRFD (2012) suggests different shear load distribution factor to interior girder and exterior girder [1], [2]. Also for girder bridge, with crossbeam or bracing, AASHTO uses different load distribution factor based on rigid body analysis. Moreover it uses same load distribution factor for concrete and steel girder. Since it ignores many factors such as span length, crossbeam spacing or number of lane which affect load distribution, LDF gives conservative result. It causes economical waste with less efficiency [3]-[5].

II. 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)

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

where S is distance between adjacent girders(mm).

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

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

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)

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

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.

In the design code, it doesn't contain effect of span length or crossbeam properties such as spacing and position. Moreover it is also very conservative since it assumed bridge acting as rigid body. For economical design, load distribution factor should be more specific. Therefore these factors are needed to be considered [6].

TABLE I. 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

III. Geometic and Structural Properties

I-shape girder brides with fixed girder spacing and various span length 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.

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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

IV. Finite Element Method

Finite element method (FEM) is used to analysis load distribution with commercial finite element software, ABAQUS. Girders, crossbeam and slab are modeled by solid elements (ABAQUS C3D20) [7]-[9].

V. Result

Fig. 1-Fig. 4 are results of FEM about span length effect to interior and exterior girders. Fig. 1 and Fig. 3 are results of concrete girder and Fig. 2 and Fig. 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.

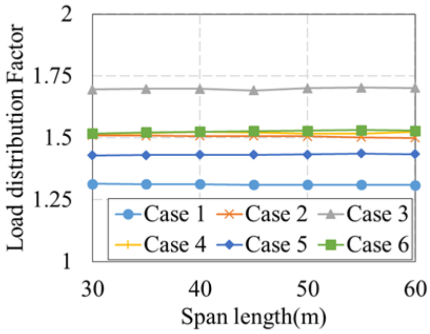

Figure 1. Load distribution factor about interior concrete girder

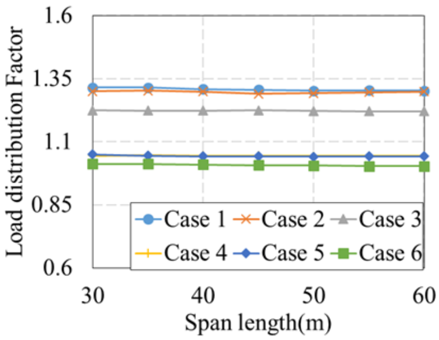

Figure 2. Load distribution factor about interior steel girder.

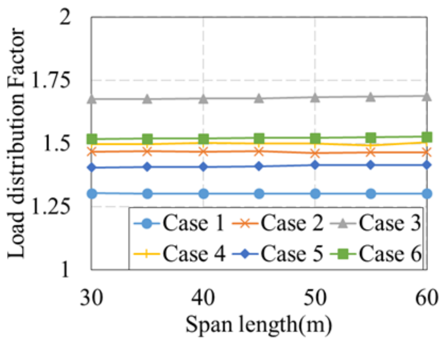

Figure 3. Load distribution factor about exterior concrete girder.

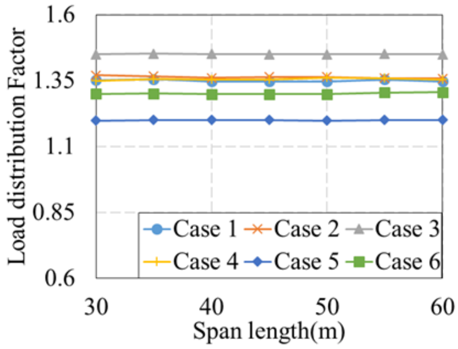

Figure 4. Load distribution factor about exterior steel girder.

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

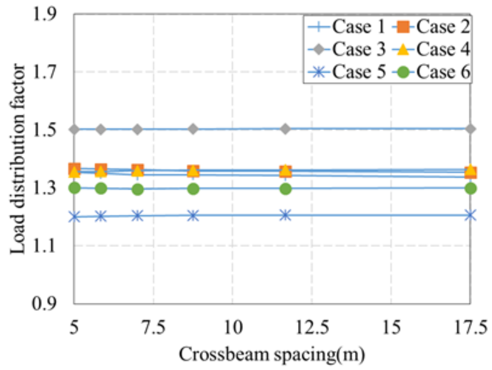

Figure 5. Interior concrete girder.

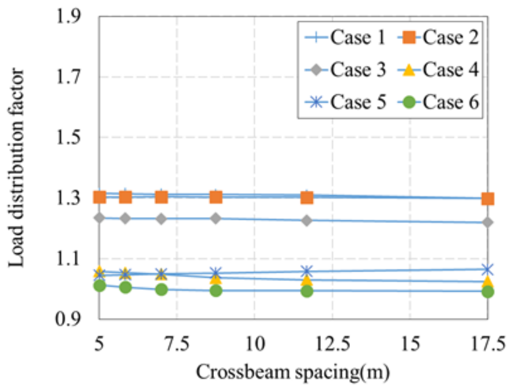

Figure 6. Interior steel girder.

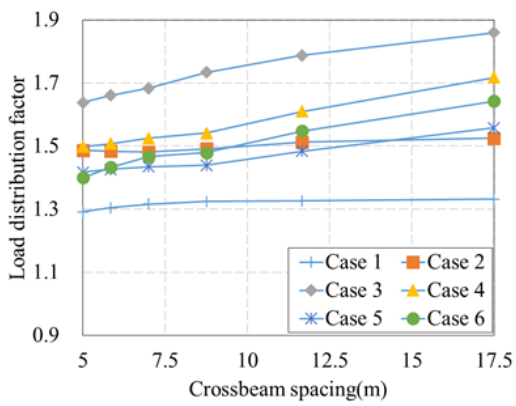

Figure 7. Exterior concrete girder.

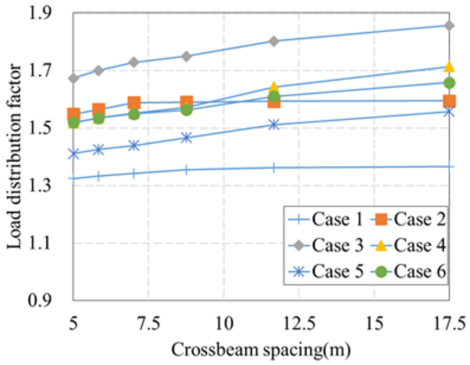

Figure 8. Exterior steel girder.

Fig. 5 and Fig. 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 Fig. 5 and Fig. 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

Fig. 7 and Fig. 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.

VI. 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).

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

where N_l is the number of lane, d_e 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.

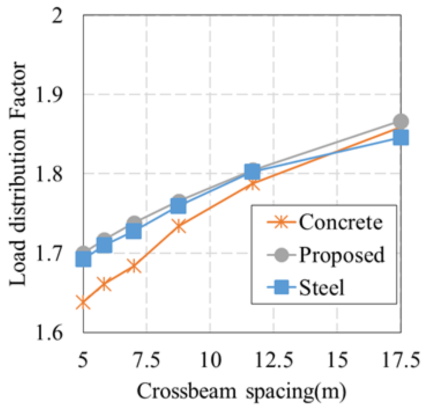

Figure 9. Comparison at Case 3.

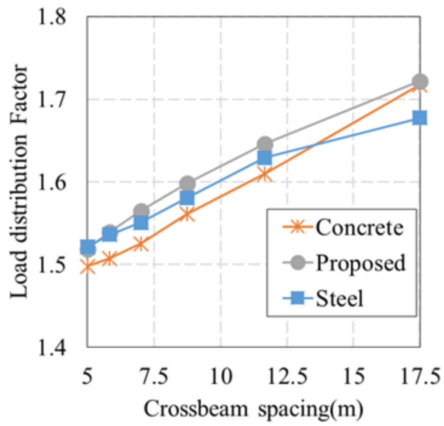

Figure 10. Comparison at Case 4.

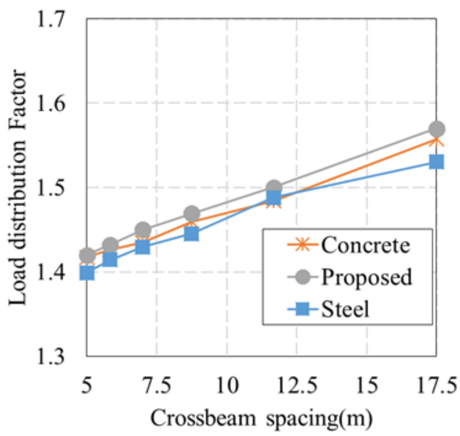

Figure 11. Comparison at Case 5.

Comparisons between FEM result and proposed equation are shown in Fig. 9-Fig. 12. Proposed equation properly predicts load distribution factor in concrete and steel girders.

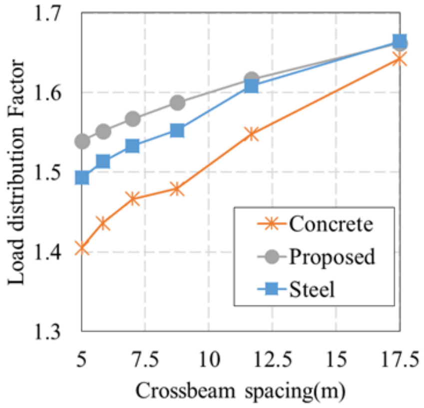

Figure 12. Comparison at Case 6.

Fig. 13 and Fig. 14 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 way of analyzing load distribution. Grillage method shows cross beam effect but it gives the lowest load distribution factors. Therefore, proposed equation is more efficient than AAHSO code and provide more safety than Grillage method.

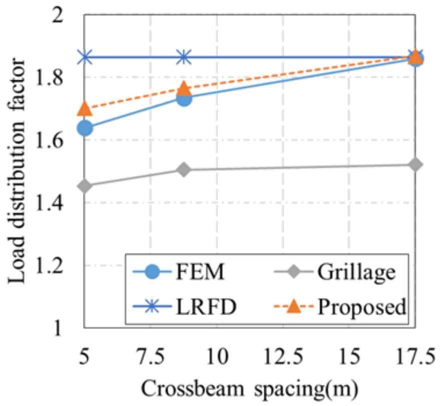

Figure 13. Comparison with method at concrete girder.

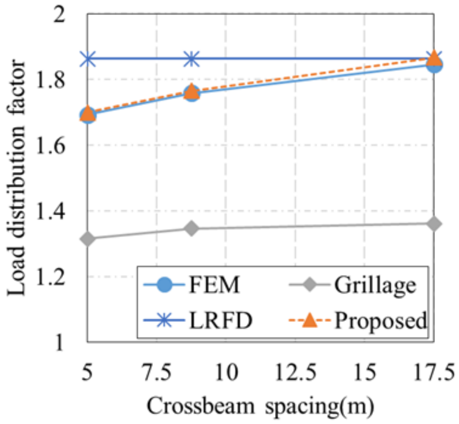

Figure 14. Comparison with methods at steel girder.

VII. Conclusion

Span length is one of important design factor. However span length doesn't affect to load distribution. Therefore in load distribution analysis, span length can be ignored.

Purpose of crossbeam is load distribution to adjacent girders. From the 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 so that the load distribution factor is decreased. Therefore crossbeam prevents the girder from destruction due to concentrated vehicle load.

AASHTO LRFD suggests very conservative load distribution factor and uses different equations depending on presence of crossbeam. Since proposed equation includes load distribution factor of non-crossbeam case, it can be generally used without considering crossbeam presence. Therefore proposed equations is more comprehensive than AASHTO and safer than grillage method.

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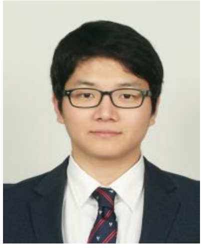

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