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Influence of cross beam spacing on load distribution factor at girder bridges

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ABSTRACT

Load distributions at concrete girder bridges and steel girder bridges with different cross beam space are analyzed by FEM. Interior girders are not influenced by cross beam. Different from AASHTO code, cross beam affects to load distribution at exterior girder. Effectiveness of cross beam is influenced by the number of lanes and distance from exterior girder to curb. The proposed load distribution factor include cross beam effect with the number of lanes and distance from exterior girder to curb. The proposed load distribution factor produce very reasonable and reliable distribution factors compared to AASHTO and grillage method.

1. INTRODUCTION

In bride design, load distribution calculation is complicated due to complex factors. Calculation of load distribution takes so many efforts. Therefore Load Distribution Factor(LDF) is used for efficiency in design. AASHO (2012) code introduces different shear load distribution factor to interior girder and exterior girder. Also girder bridges with crossbeam or bracing, it introduces another load distribution factor based on rigid body analysis. Since it ignores many other factors such as cross beam spacing or number of lane which affect load distribution, LDF is conservative compare to real load distribution. It causes economical waste with less efficiency.

2. AASHTO LRFD load distribution factor

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

$$LDF = 0.2 + \frac{S}{12} - \left(\frac{S}{35}\right)^{2.0} \tag{1}$$

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where S is distance between adjacent girders(ft). Load distribution factor for exterior I-shaped girder is shown in Eq (2).

$$LDF = (0.6 + \frac{d_e}{10}) \times LDF_{interior} \tag{2}$$

,where d_e is distance from exterior girder to curb.
Load distribution factor with crossbeam or bracing is derived based on rigid body analysis.

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

where N_L is 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 number of beams or girders.
In the design code, it doesn't consider effect of crossbeam properties such as spacing and position. It is also very conservative since it assumed bridge acting as rigid body.

3. Geometric and Structural Properties

I-shape girder brides with same girder spacing and same span length are chosen to make same load distribution factors for interior girder. Girder spacing is 2.5m and span length is 35m. Six different bridge cross sections are considered based on the number of girder and distance of exterior girder to curb. The properties of bridge model are shown in Table 1.

Table 1 Properties of bridge model

Case	1	2	3	4	5	6
The number of girder	3	3	4	5	6	6
The 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

The number of intermediate crossbeam is changed from one to six. So the crossbeam spacing changes from 5m to 17.5m. AASHO LRFD uses same load distribution factor for concrete girder and steel girder. So in this research, concrete girder and steel girder are used. The boundary condition of bridge is simply supported.

4. Finite Element Method

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

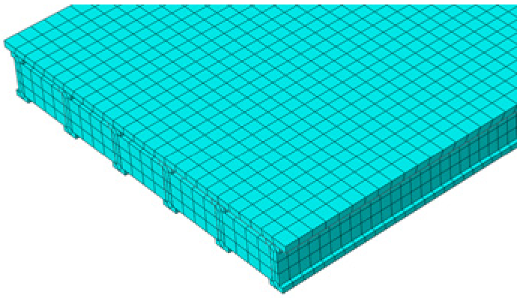

Fig. 1 Concrete FEM model

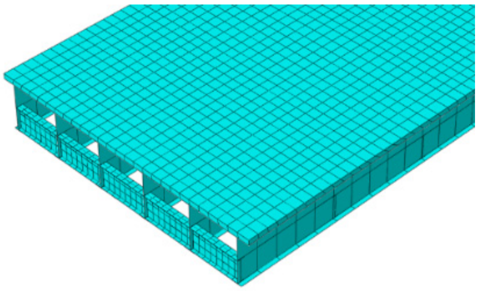

Fig. 2 Steel FEM model

5. Result

Fig. 3~6 show variation of load distribution factor of interior and exterior girders. Fig. 3 and Fig.4 are results of interior girder. Variation of load distribution factors in interior girder is less than 2%. So it can figure out that load distribution in interior girder does not affected by crossbeam spacing. AASHTO code suggest interior load distribution factor with girder spacing. So six cases should have same load distribution factor. But from Fig. 3 and Fig. 4, it can find that interior load distribution factor is rather affected by the number of girders, distance from exterior girder to curb and girder material.
Fig. 5 and Fig. 6 are results of exterior girder. Case 1 and Case 2 show little variation due to crossbeam spacing which is less than 3% difference. Case 3~6 show higher variation due to crossbeam spacing which is at least 10%. Case 1 and Case 2 are the bridge supported by three girder. From this, it can figure out that crossbeam affects load distribution in the case of the four or more girders bridge.

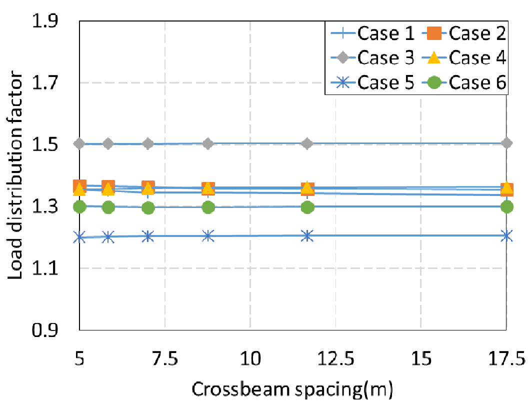

Fig. 3 Interior Concrete girder

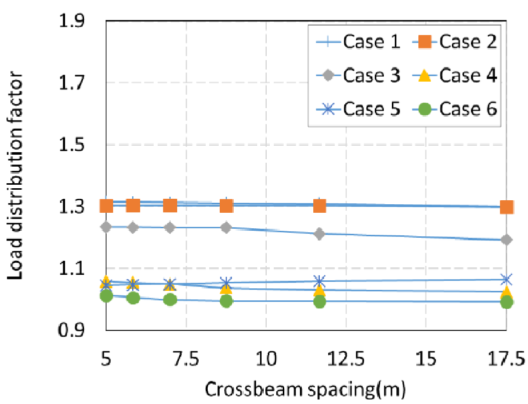

Fig. 4 Interior Steel girder

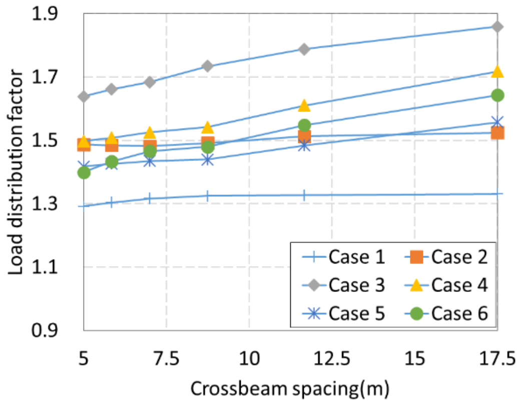

Fig. 5 Exterior Concrete girder

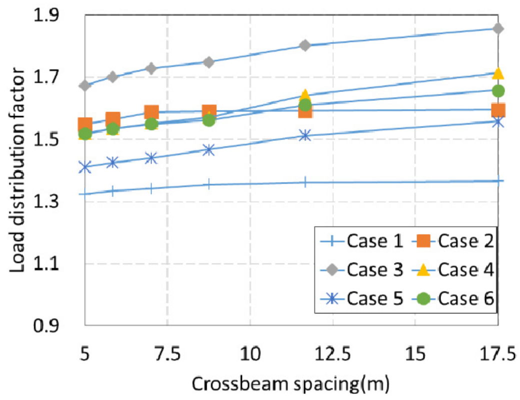

Fig. 6 Exterior Steel girder

The effect of crossbeam is varied depending on the number of lanes and distance from exterior girder to curb. The cases with three number of lanes(Case 3 and Case 4) show higher variation than the cases with four number of lanes(Case 5 and Case 6). This is because of slab. As the number of lane increases, so as the slab width. Therefore the wide slab affects to load distribution more than crossbeam. Distance of exterior girder to curb shows higher effect to crossbeam than the number of lane. The cases with shorter distance of exterior girder to curb vary more than longer distance cases. The reason is that if distance of exterior girder to curb is longer, the more vehicle load is applied at outside of exterior girder where is far away from interior girder, so effect of cross beam between exterior and interior girder is reduced.

6. Proposed Load distribution factor

The number of girder should be more than four to be affected by cross beam. As spacing between cross beam increase, 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, the slope of variation of load distribution factor increase. Therefore the proposed load distribution factor is shown in Eq (4)

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

,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 non-cross beam AASHTO LRFD code which is Eq (2). Comparison between FEM result and proposed equation are shown in Fig. 7-10. It can find that proposed equation properly suggests load distribution factor in concrete and steel girder.

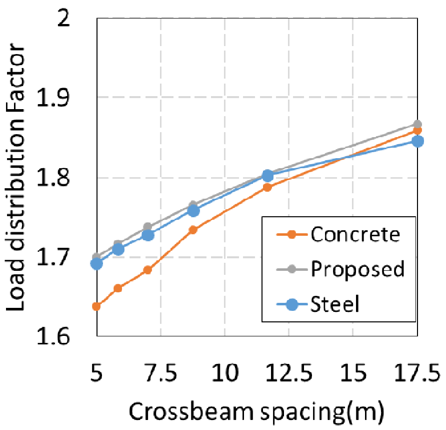

Fig. 7 Proposed Equation (Case 3)

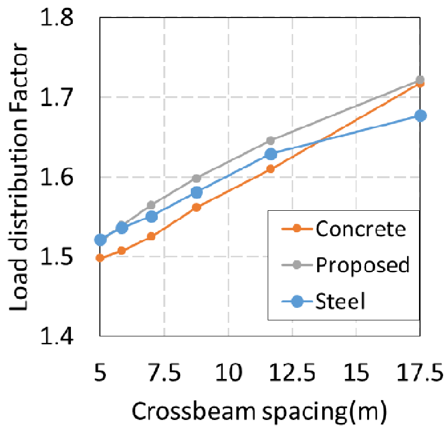

Fig. 8 Proposed Equation (Case 4)

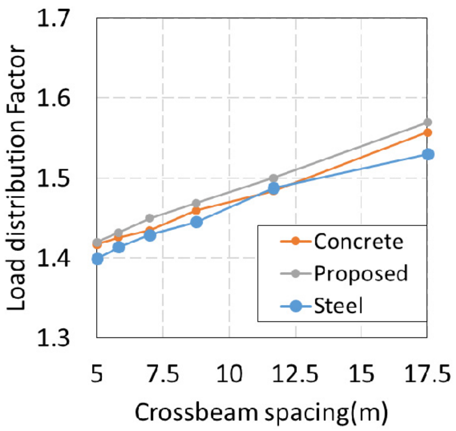

Fig. 9 Proposed Equation (Case 5)

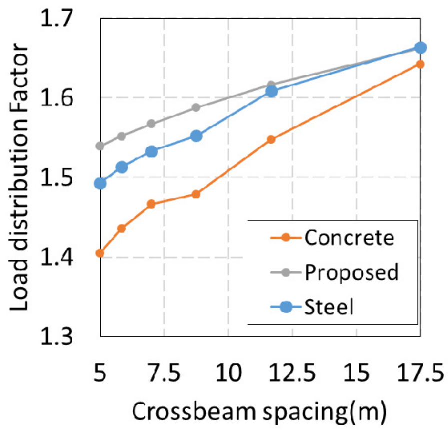

Fig. 10 Proposed Equation (Case 6)

Fig. 11 and Fig. 12 are comparison between FEM, Grillage method, LRFD and proposed Equation. AASHTO LRFD (Eq. (3)) suggests conservative load distribution factor. Therefore, proposed equation is more efficient than AAHSO code and provide more safety than grillage method.

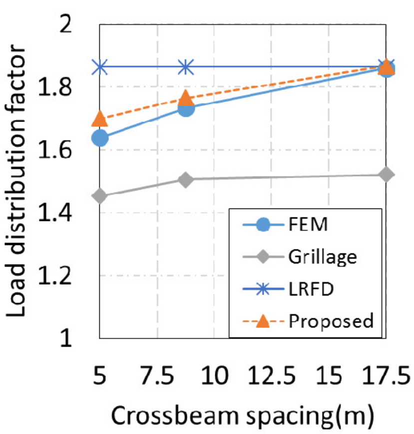

Fig. 11 Comparison in Concrete girder

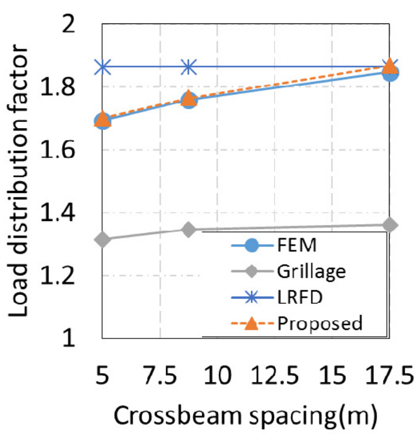

Fig. 12 Comparison in Steel girder

7. Conclusion

One of reason for crossbeam is for load distribution. Crossbeam is effective in girder bridges with more than four girders. As the number of crossbeam increases, the load distribution factor is decreased. Therefore crossbeam prevents the girder from destruction due to concentrated load.
AASHTO LRFD suggests very conservative LDF and uses different equations depending on crossbeam. Since proposed equation includes LDF at non-crossbeam case, it can use for non-crossbeam and crossbeam cases. Therefore proposed equations is efficient than AASHTO and safer than grillage method.

Acknowledgement

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