# APPLICABILITY OF AASHTO LRFD LIVE-LOAD DISTRIBUTION FACTOR ON CURVED RC DECK WITH STRAIGHT PC I-GIRDER SUPERSTRUCTURE

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## 1. INTRODUCTION

The calculation of sectional forces induced by the traffic load in primary load-resisting members is a vital task for both designing and evaluating bridge superstructures. As a result, to facilitate routine design and assessment of bridges, the AASHTO LRFD specification (2022) has provided the live-load distribution factor (LLDF) equations for estimating the ratio of live-load carried by main structural components. However, the standard constrains the utilization of proposed equations based on bridge geometry configurations. Yet, the actual geometric design of superstructures can be slightly deviated from codified regulations to accommodate the traffic condition as well as the construction viability. Therefore, the investigation on the capability and limitation of the current LLDF equations is of importance. To achieve this goal, this paper conducted parametric analyses using the linear three-dimensional (3D) finite element method (FEM) on the straight precast prestressed concrete (PC) I-girders supporting curved edge reinforced concrete (RC) deck superstructure in order to determine internal forces occurring in main girders owing to live-load. To this end, these results were used for computing LLDFs and were compared to the AASHTO-specified LLDFs.

## 2. BRIDGE DESCRIPTION

The curved part of a 30-year-old U-turn bridge in Thailand was the targeted structure for this study. The superstructure was constructed using five half-joint straight PC I-girders spanned pier to pier. These main girders then supported the RC deck having curved edge geometry. Also, end and intermediate cast-in-place RC diaphragms were provided at support and midspan of the superstructure. According to structural drawings, arc span length ($L_{arc}$) and radius of curvature (R) were 12,136 and 22,700 mm, respectively. The width of carriageway measuring between the inner face of barriers was 8,000 mm resulting in two design lanes in accordance with the AASHTO LRFD specification (2022). Overall geometry and details of the superstructure and PC I-girder are illustrated in Fig. 1 and 2.

Also, material properties were obtained from the structural drawings. For the prestressed concrete, compressive strength and elastic modulus were 35 and 30,735 N/mm$^2$. The 7-wire strands with diameter of 12.7 mm were used as the prestressing reinforcement. Specific tensile strength and modulus of elasticity were 1,860 and 197,000 N/mm$^2$. For the reinforced concrete, compressive strength and elastic modulus were 26 and 26,291 N/mm$^2$. Based on structural details, two grades of ordinary reinforcements consisting of the SD30 and the SR24 classes with specific yield strength of 295 and 235 N/mm$^2$ were employed, and the modulus of elasticity for both types of reinforcement was 200,000 N/mm$^2$.

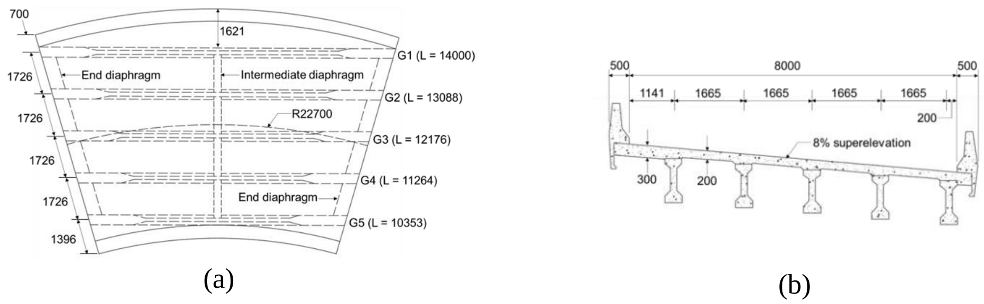
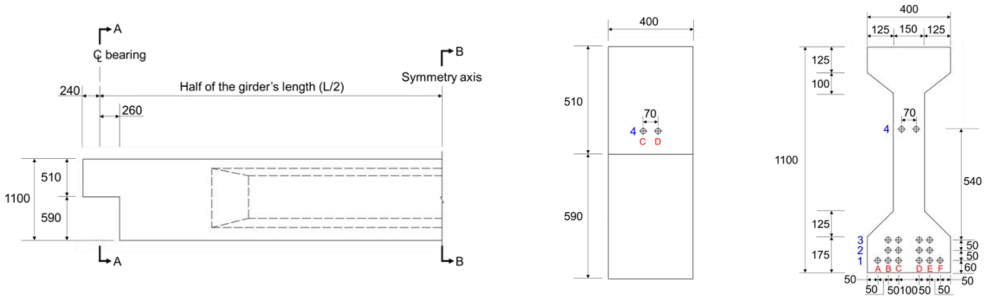



**Fig. 1** Geometry of bridge superstructure: (a) plan and (b) typical cross-section (Unit: mm)




| Rows | Debonding detail | |
|---|---|---|
| | Strands | Debonded length (mm) |
| 1 | A and F | 4000 |
| 2 | B and E | 2000 |
| 3 | C and D | 1000 |
| 4 | - | - |

**Fig. 2** Structural details of PC I-girder: (a) side view, (b) section A-A, and (c) section B-B (Unit: mm)

Keywords: Distribution factor, AASHTO LRFD, 3D-FEM, Bridge superstructure, Prestressed concrete
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## 3. FINITE ELEMENT MODELING AND PARAMETRIC STUDY

To evaluate the performance of codified LLDF equations, the parametric study was executed with the linear 3D-FEM. Numerical models were developed using the software package MIDAS/Civil (2022) to examine the effect of considered parameters on the LLDFs. Table 1 summarizes all parameters and the range of applicable values. For all models, PC I-girders and RC diaphragms were simulated via the two nodes beam element possessing six degrees of freedom (DOFs) at each node. For the RC deck, the Kirchhoff thin plate element having the in-plane axial and shear stiffnesses and the out-of-plane shear and bending stiffnesses was implemented for the structural modeling. Figure 3 shows the geometry and mesh details of the numerical model. Also, in all analyses, the simply supported boundary condition was assigned conforming to the original design condition. Note that the vehicle loads as per the AASHTO LRFD standard (2022) were used. The loading positions were decided based on the influence line analysis to maximize moment and shear responses.

**Table 1** Considered bridge parameters

| Parameter | Range of values/Condition |
|---|---|
| Curvature (-) | 0.27, 0.36, 0.57, 0.77 |
| Superelevation (%) | 4, 6, 8 |
| Girder spacing (mm) | 1400, 1500, 1600 |
| Boundary condition (-) | Pin-Roller or Pin-Pin |
| Intermediate diaphragm (-) | Presence or Absence |

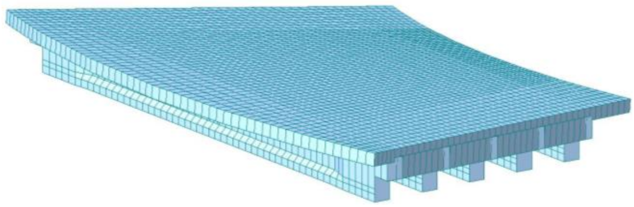
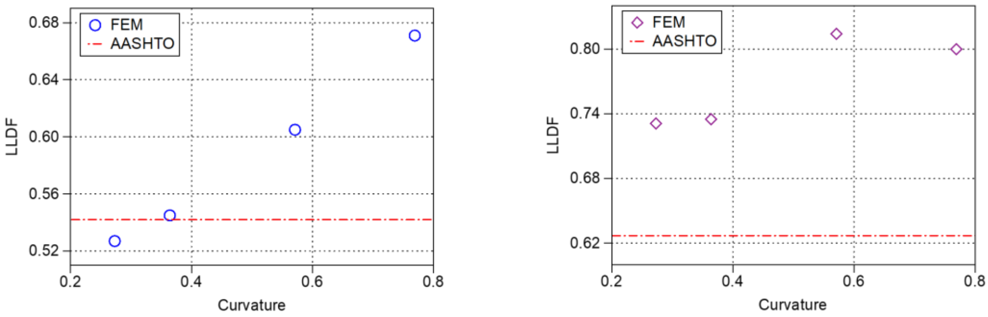


**Fig. 3** Finite element modeling of bridge superstructure

## 4. RESULT AND DISCUSSION

Moment and shear values of main girders obtained from the linear 3D-FEM were utilized for the calculation of LLDFs following the methodology proposed by Zokaie et al. (1991). Through the parametric study, it indicated that the value of LLDFs can be influenced by the variation of all investigated parameters. Nevertheless, the results were most sensitive with the discrepancies of curvature ($L_{arc}/R$) as presented in Fig. 4.




(a) (b)

**Fig. 4** Effect of curvature on FEM-based distribution factors relative to the AASHTO LRFD result for interior girder: (a) moment distribution factors and (b) shear distribution factors

According to the 3D-FEM results, the magnitude of moment and shear distribution factors increased with the increasing curvature, whereas the AASHTO equations only yielded a constant value of LLDFs regardless the fluctuation of curvature. This result occurs since the AASHTO LRFD LLDF equations do not consider the curvature effect. Therefore, the behavioral change induced by this parameter cannot be detected. Furthermore, based on the Fig. 4, it showed that the use of existing equations for estimating the LLDFs of superstructures retaining high curvature may lead to unconservative predictions which highlighted the limitations of the current equations in practical applications.

## 5. CONCLUSIONS

The applicability and limitation of the current AASHTO LLDF equations were analytically investigated. The parametric study using a linear 3D-FEM was performed on the cast-in-place curved RC deck compositely constructed with straight precast PC I-girders superstructure. Following are the conclusion based on the results of this study:

- Regarding the sensitivity study, the distribution factors for moment and shear were significantly affected by the variation of curvature. A higher curvature corresponds to a greater ratio of traffic load resisted by main girders.
- Since the curvature are not considered as one of parameters in the existing LLDF equations, the effect of this parameter on the results of moment and shear distribution factors cannot be identified.
- For bridges reserving high curvature geometry, the existing equations may underestimate the magnitude of LLDFs.

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