A Study on Load Distribution Effect for Bridge Structures
(교량 구조의 하중분배 효과에 관한 연구)

정철헌*　　　오병환**
Chung, Chul Hun　　　Oh, Byung Hwan

ABSTRACT

Design live load and girder distribution factors play an important role in the current design procedures. The fraction of vehicle load effect transferred to a single member may be selected in accordance with current KBDC. However, the specified values, both design load and distribution factors, involve considerable inaccuracies. These inaccuracies relate to the uncertainties of the structural analysis, especially any bias and scatter which drives from the use of simplified load distribution factors.

In this study, based on several field measurement and finite element analysis, live load distribution effects of current KBDC are evaluated. The final values of the bias and coefficient of variation of "g" according to bridge type are determined. The bridge types are reinforced concrete slab, prestressed concrete girder and steel I-beam.

---

1. INTRODUCTION

Design live load and girder distribution factors play an important role in the current design procedures. However, the specified values, both design load and distribution factors, involve considerable inaccuracies.

This variable relates to the uncertainties of the structural analysis, especially any bias and scatter which drives from the use of simplified load distribution factors.

In this study, load distribution factors are evaluated. In most bridge codes, the load distribution factors were calculated using an orthotropic plate approximations. In the orthotropic-plate analysis, the bridge, including the beam and slab, is idealized as a plate of constant thickness having different flexural and torsional properties in the orthogonal directions. However, there are serious shortcomings of modeling a girder bridge as a plate such as the transformation of beams to plate elements and the integration to convert plate stresses to beam stresses. On the other hand, the grillage method uses beam elements to represent the slab in transeverse direction, which requires several assumptions regarding the effective flange width for longitudinal elements, adequate modeling width of transverse beam elements and the dispersion of loads applied to the slab.

The fraction of vehicle load effect transferred to a single member may be selected in accordance with current KBDC. It is generally believed that these values are conservative and represent a possible combination of adverse circumstances. The option exists to substitute field-measured values, analytically calculated values. Loadings shall be placed in positions causing the

---

[*] 서울대학교 토목공학과 박사과정 수료
[**] 서울대학교 토목공학과 부교수

maximum response. Futher, if such a measurement or analysis is made and the expected distribution value is obtained, this shall be reflect possible uncertainties in the measurement or analytical model.

In this study, based on several field measurement[5] and finite element analysis, live load distribution effects of current KBDC are evaluated. The bridge types are reinforced concrete slab, prestressed concrete girder and steel I-beam.

2. LOAD DISTRIBUTION OF SLAB BRIDGES

When the span of a bridge is relatively short, a slab bridge may be used. The riding surface of the bridge is the top face of the slab, and there are no girders used to transmit the loads to the supports. In some cases voids are introduced in the slab. As the span get longer, slab bridges are not an efficient or economical way to support the design code. Slab bridges are normally reinforced by reinforcing bars, but prestressing strands and I-beams have been used. In many cases the width of the slab may equal or exceed the span of the bridge. In cases the width of the slab may equal to or greater than the span, then plate behavior of the bridge should be taken into account.

In the current KBDC code[1], the load distribution of slab bridges is specified as a distribution width, E, for each wheel line loading, expressed as eq.(2.1).

$$E = 1.2 + 0.06\ell \qquad \text{---(2.1)}$$

In this study, to evaluate the accuracy of the KBDC formula, a series of slab bridges with 5m to 35m(i.e., spans 5, 10, 15, 20, 25, 30, 35m) and width of 7.2m and 14.4m were studied using the finite element method. Two trucks(DB-24) and four trucks(DB-24) are placed close to the edge of 7.2m and 14.4m wide bridges, respectively.

The validity of the proposed finite element method for the analysis of slab bridge, was established by comparing its results with those given by those obtained from field test. The field test for a slab bridge with span length 9.1m and width 6.5m is test loaded by measuring its response(strain) to a known applied static load. One such comparison is given in Fig.2.1 for distribution coefficients for longitudinal moments in square concrete slab. In this figure, the distribution coefficient for midspan longitudinal moments due to two seperate load case as given by the finite element method are compared with experimentally obtained distribution coefficients.

As can be seen in Fig.2.1, there is excellent correlation between the finite element method and experimental results, thus confirming the validity of the former. Table 2.1 compares some field measurements[5] of the percent of total moment carried by a distribution width(E) and number of wheel lines per unit slab width($g = 1/E$) with the predicted KD values.

As shown in Table 2.1, the bias in "g" using F.E.M results will be taken as <u>1.08</u> with a C.O.V taken as <u>8.5 percent</u> for unit slab width.

The position of a truck on the bridge is shown in Fig.2.2. Fig.2.3 shows the distribution width "E" obtained from those analyses and also the KD E(eq.2.1) values. The KBDC formula seems to overestimate the wheel line distribution width considerably, resulting in an unconservative design. The bias coefficients, δ_g reflect the differences between g(i.e., 1/E) given by the field measurement and those obtained analytically.

The results obtained from the finite element method were then used to evaluate the load distribution value(1/the effective slab widths), as shown in Table 2.2 and Table 2.3. These load distribution values are evaluated at midspan of the slab bridges.

3. LOAD DISTRIBUTION OF GIRDER BRIDGES

This bridge type induces prestressed concrete girder bridges, bridges with steel I-beam and slab. The term, load distribution, is used to refer to the lateral distribution of load to longitudinal supporting elements. Therefore, the girder distribution factor herein is the percent of the gross bending moment transferred to a single girder.

In the current code, the girder distribution factor, "g", i.e., number of wheel lines per girder, is defined in eqs.(3.1).

interior girders

1-lane bridge : $g = S/2.10$ ---(3.1.a)
for $S \le 3.0\text{m}$
2-lane bridge : $g = S/1.65$ ---(3.1.b)
for $S \le 4.2\text{m}$

exterior girder

1-lane bridge : $g = S/1.65$ ---(3.1.c)
for $S \le 1.8\text{m}$
2-lane bridge : $g = S/(1.2 + 2.5S)$
for $1.8 < S \le 4.2\text{m}$ ---(3.1.d)

For larger girder spacings, the load is distributed to the girders by assuming the slab is simply supported(rather than continuous). Exterior girders are designed for moments not smaller than those for the interior girders.

Several field measurement projects and finite element analysis have suggested the present KBDC and AASHTO factors[2] may be conservative[5,7,8]. Fig.3.1 compares some field measurement of the percent of total moment carried by a single girder with predicted KBDC values for one-lane loading. As shown Fig.3.1, the mearsurements indicates that KBDC is generally conservative.

The bias and C.O.V in "g"(girder distribution factor) were determined by using Fig.3.1. Therefore, the values of the bias and C.O.V of girder bridge are given as Table 3.2.

The distribution factor for two-lane loading are compared with AASHTO load distribution factors and field test values in Table 3.1[8]. Similarly, the bias and C.O.V in "g" are given as Table 3.2. As shown in Table 3.2, the bias in "g" according to truck loading did not show any significent change, the difference being less than 1.1%. In this study, the bias and C.O.V in "g" for girder bridge were determined by Fig.3.1. Therefore, the bias in "g" will be taken as 0.91 with a C.O.V taken as 15% for girder bridge(P/C Girder, Steel I-beam).

4. CONCLUSION

In this study, based on several field measurement and finite element analysis, live load distribution effects of current KBDC are evaluated. The final values of the bias and coefficient of variation of "g" according to bridge types are determined.

In the current KBDC, the load distribution of slab bridge seems to overestimate the wheel line distribution width considerably, resulting in an unconservative design. The load distribution of girder bridges are generally conservative.

REFERENCES

1. "도로교 표준 시방서", 건설부, 1985.

2. Standard Specification for Highway Bridges, Thirteenth Edition, American Association of State Highway and Transportation Officials, Washington, D.C., 1983(see also •Interim Specifications, 1987).

3. OHBDC, "Ontario Highway Bridge Design Code", Ontario Ministry of Transportationd Communication, Downsview, Ontario, Second Edition, 1983.

4. F. Moses and D. Verma, "Load Capacity Evaluation of Existing Bridges", National Cooperative Highway Research Program Report 301, 1987, December.

5. "Safety Evaluation of Existing

Bridges", Natioanl Construction Research Institute Ministry of Construction, [No. 499, 1989], [No. 450, 1984], [No. 454, 1985], [No. 487, 1988], [No. 499, 1989], [No. 519, 1991], 12.

6. ADINA USER MANUAL, "A Finite Element Program for Automatic Dynamic Incremental Nonlinear Analysis", ADINA Engineering Inc, REPORT AE 84-1, December 1984.

7. Tarek S. Aziz., M. S. Cheung., and Baidaar Bakht., "Development of a Simplified Method of Lateral Load Distribution for Bridge Superstructures", Transportation Research Record 665, Bridge Engineering Volume 2, Proceedings of a Conference Conducted by the Tranportation Research Board, September 25-27, pp.37-44, 1978.

8. Moses, F., Ghosn, M., and Gobieski, J., "Weight-In-Motion Applied to Bridge Evaluation", Final Report, FHWA/OH-85/012, submitted to Ohio DOT and FHWA (Sept. 1985).

9. Hong, Y.K., "Live Load Model of the Girder Bridge", Ph.D. Thesis, The University of Michigan, Ann Arbor, 1990.

10. Jaeger, L. G., and Bakht, B., "The Grillage Analogy in Bridge Analysis", Canadian Journal of Civil Engineering, No. 9, pp.224-235, 1982.

Table 2.1 Comparisons of Field Measurements and F.E.M Results with KD Load Distribution (Bias = 1.08, C.O.V = 8.5%)

Name of Bridge	Field Measurement		F.E.M		KD values		Refs.
	E	g(1/E)	E	g(1/E)	E	g(1/E)	
Gu Bang	1.51	0.662	1.67	0.599	1.81	0.552	5
Nong So	1.59	0.629	1.71	0.584	1.86	0.538	
Chun Pyung	1.58	0.633	1.71	0.584	1.86	0.538	
Gyo Ga	1.48	0.676	1.59	0.629	1.74	0.573	

Table 2.2 Wheel Load Distribution Width in R.C Slab Bridges for a given Span Length

span length (m)	current code	F.E.M results	
		2 trucks	4 trucks
5.0	1.50	1.423	1.401
10.0	1.80	1.616	1.516
15.0	2.10	1.756	1.641
20.0	2.10	1.761	1.682
25.0	2.10	1.768	1.712
30.0	2.10	1.775	1.741
35.0	2.10	1.779	1.744

Table 2.3 Wheel Load Distribution Factor in R.C Slab Bridges for a given Span Length

span length (m)	current code	F.E.M results	
		2 trucks	4 trucks
5.0	0.667	0.703	0.713
10.0	0.555	0.619	0.659
15.0	0.476	0.569	0.609
20.0	0.476	0.567	0.594
25.0	0.476	0.565	0.584
30.0	0.476	0.563	0.574
35.0	0.476	0.562	0.573

Table 3.1 Comparison of Field Measurements with AASHTO Girder Distribution(2 lane load)[8].

Site	Field Measurement	AASHTO
Ashtabula	0.66	0.72
Richmond	0.60	0.67
RT 88	0.64	0.72
DORR.ST	0.70	0.78

Table 3.2 The Bias and C.O.V of Girder Distribution Factor

load	bias	C.O.V	Refs.
one lane	0.91	15%	KOREA [5]
two lane	0.90	13%	U.S.A [8]

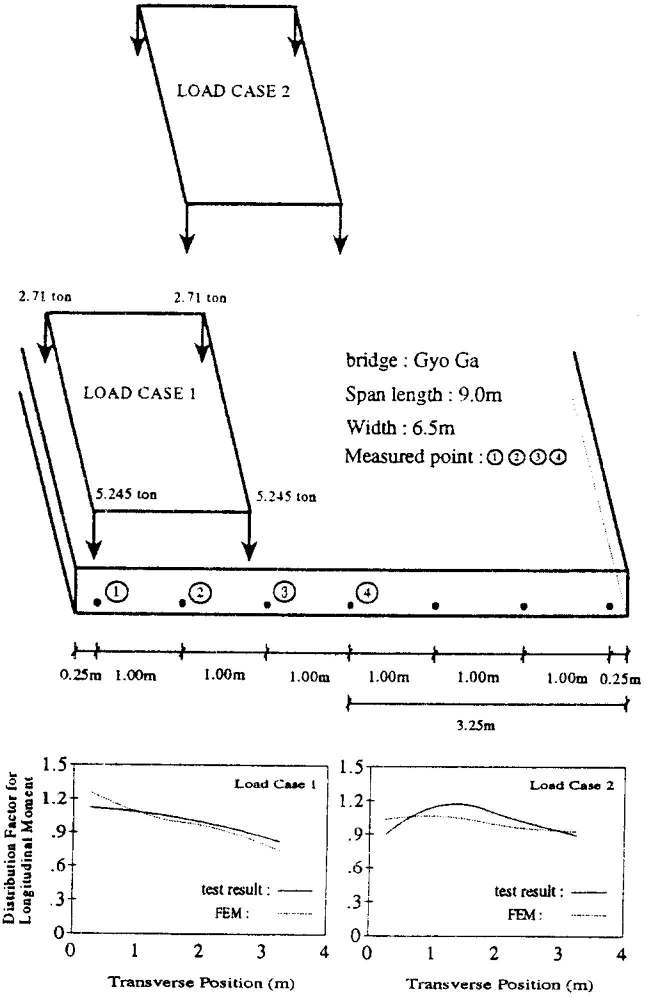

Fig.2.1 Comparison of Distribution Factors for Longitudinal Moments.

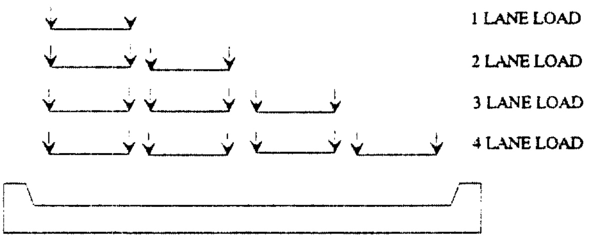

Fig.2.2 Truck position on the Slab Bridge.

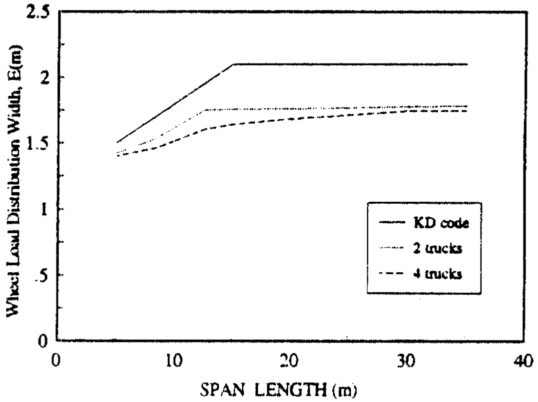

Fig.2.3 Wheel Load Distribution Width, E, Determined by using F.E.M(ADINA) for Typical Slab Bridges.

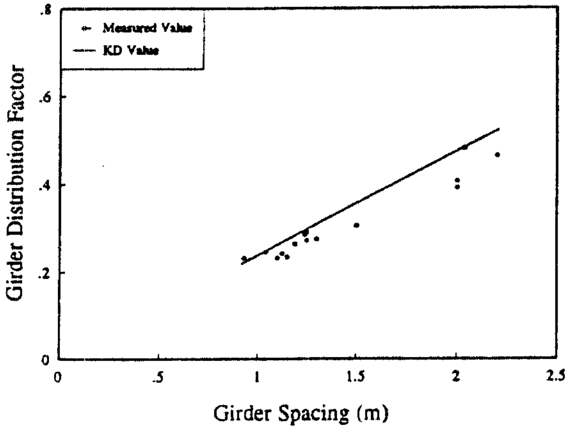

Fig.3.1 measured Girder Distribution Factors.