Effects of BMA Flyover Bridge Types on Wheel Load Distribution Factors Based on AASHTO Specifications

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Abstract

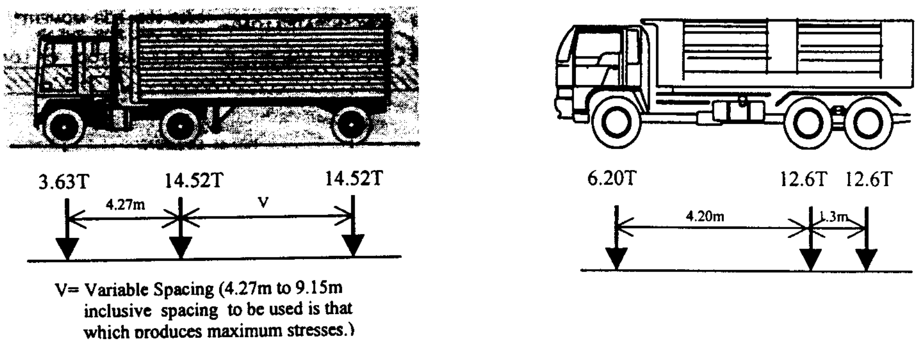
In this study, the elaborate influence line analyses of multi-girder steel and composite steel-concrete bridges are performed by using the three-dimensional finite element model. The floor systems of the three bridges selected in this study are made of the orthotropic steel deck plate and the concrete deck slab. The real Thai trucks are loaded at possible locations of the bridge in order to obtain the maximum bending stresses of the bridge. From the numerical results, the load distribution factors applied to each girder of the bridge are obtained and compared with the specified values in the current code of practice, i.e. AASHTO specifications.

1. Introduction

Flyover multi-girder steel bridges constructed by the Bangkok Metropolitan Administration in the past decade are the most popular types in order to alleviate the traffic congestion during construction. All of them are designed based on The American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Highway Bridges. The loads used to design the longitudinal girders are determined by the application of a specified AASHTO wheel load distribution factor, which is a function of girder spacing. Accordingly, the critical factor in the analysis is the lateral distribution of wheel loads to the bridge components.

In Thailand, the current design practice of steel bridges follows AASHTO specification [1], with a live load mark-up factor of 30% increment accounting for the excessive truck loading. Because of the different characteristics between AASHTO and Thai trucks (Fig.1), using the AASHTO truck in Thai current design of practice is subject to question. In addition, when the loading test is performed at the completion of bridge construction in Thailand, it is impractical to use the AASHTO truck, and hence the Thai truck is commonly used. Therefore, a detailed study on the bridge behavior under Thai truck loading is needed.

This paper presents a study on the effect of Thai truck loading on two multi-girder steel bridges with orthotropic steel deck plate and a composite steel-concrete bridge with concrete slab. The bridges are modeled by using three-dimensional finite element meshes. From the present numerical results, the critical patterns of Thai trucks are obtained by the influence line of maximum bending stresses. And the calculated wheel load distribution factors are compared with AASHTO specification [1].



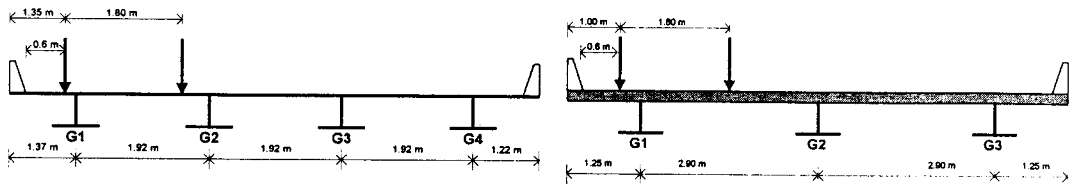
(a) AASHTO truck

(b) Thai truck

Fig.1 Characteristics of AASHTO truck and Thai truck

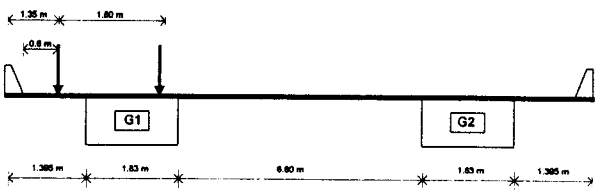
2. Bridge Geometry

For this study, three bridges with different floor systems (Bridge 1, Bridge 2 and Bridge 3) are selected. Bridge 1, a simply-supported 35-m span steel plate bridge with orthotropic steel deck plate, consists of two traffic lanes in one direction. The 12-mm orthotropic steel deck plate is supported by four steel girders, equally spaced at 1.92 meters (Fig.2(a)). Bridge 2, a simply-supported 25-m span composite steel-concrete bridge with concrete deck slab, consists of two traffic lanes in one direction. The 20-cm thick concrete deck slab is supported by three steel plate girders, equally spaced at 2.9 meters (Fig.2(b)). Bridge 3, a simply-supported 35-m span steel bridge with orthotropic steel deck plate, consists of three traffic lanes. The 12-mm orthotropic steel deck plate is supported by two steel box girders, spaced at 8.63 meters center to center of main girders (Fig.2(c)).It should be noted that there existed the full-scale test results of these bridges subjected to Thai truck loading reported in Ref. [2], [3]. Hence, the accuracy of three-dimensional finite element models of three bridges which will be discussed later could be checked through the comparison of numerical results with the full-scale test results. This is the main reason why the three bridges representing typical flyover bridges in Bangkok are selected in the present study.



(a) Bridge 1: orthotropic steel deck plate

(b) Bridge 2: concrete deck slab



(c) Bridge 3: orthotropic steel deck plate

Fig.2 Cross-sections of Bridge 1, 2 and 3 subjected to Thai truck loading

3. Bridge Loading

In the present analysis, two or three loading cases depending on bridge span are considered, i.e. one, two and three Thai-truck loading. It is noted that, AASHTO specifications [1] requires one-truck loading or lane loading representing smaller vehicles than trucks, but from the measured results [2], two-truck and three-truck loading are the most likely cases that cause maximum stresses in the bridge. Hence, two-truck and three-truck loading are also considered here. Thai trucks are placed on the external traffic lane of bridge, and no trucks on the internal traffic lane (Fig.2). The case that trucks are loaded on only external lane is the most likely one can be confirmed by the measured results [2]. The number of trucks (one, two and three trucks) on each bridge depends on the bridge span (Fig.3). In other words, Bridge 1 and Bridge 3 are subjected to one, two, three truck loading, and Bridge 2 is subjected to one, two truck loading.

4. Finite Element Analysis of Multi-Girder Bridge

The finite element model of the multi-steel girder bridges are constructed, and the verifications of the model with the measured results were made for the orthotropic steel deck bridge [2] and for the composite steel-concrete bridge. The finite element computer package called MARC is used in this analysis, and the linear elastic and small displacement theory is considered. The quadrilateral four-node plate element is used to idealize orthotropic steel deck, concrete slab and steel girders including all stiffeners (see Fig.4). It is noted that in the model of Bridge 2, the rigid link element is used to take into account the eccentricity between middle plane of thick concrete slab and that of thin steel flange plate of the girder (see Fig.2). In addition, the cold-formed steel deck plate used as the concrete formwork is also included in the model of Bridge 2. Hinges and rollers are assumed at bearing locations in order to simulate simply supported conditions.

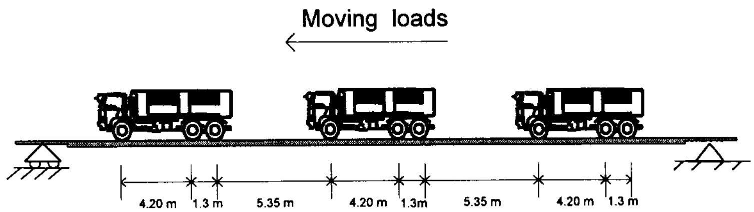
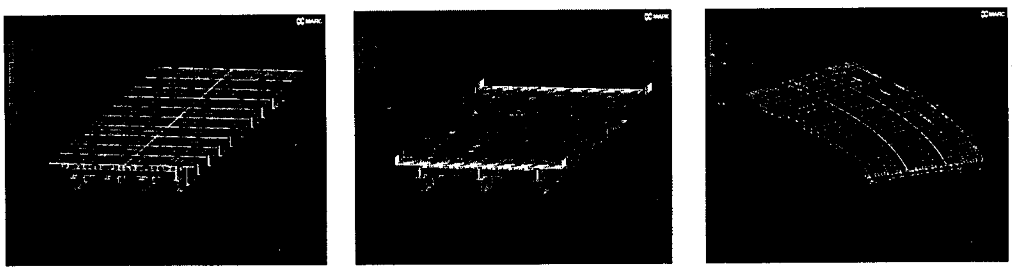
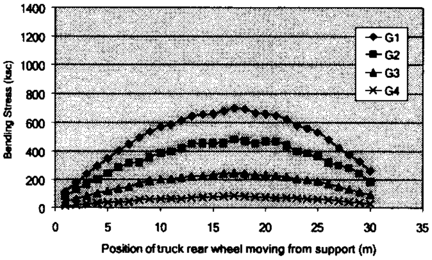


Fig.3 Bridge under Thai-truck loads (one truck, two trucks and three trucks)

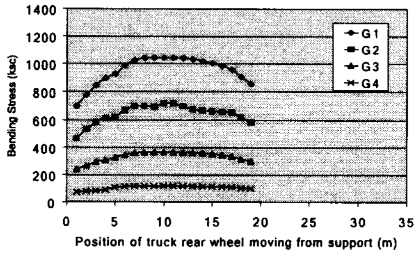


(a) Bridge 1 (b) Bridge 2 (c) Bridge 3 (Curved Bridge)

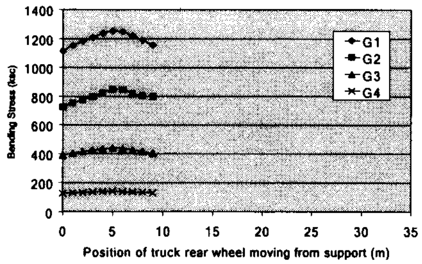
Fig.4 Three-dimensional finite element model of bridges



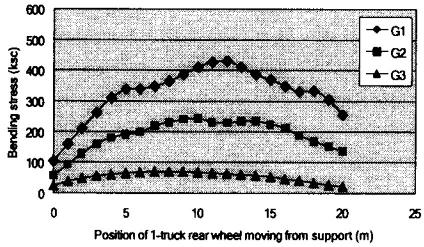
(a) 1-truck loading of Bridge 1



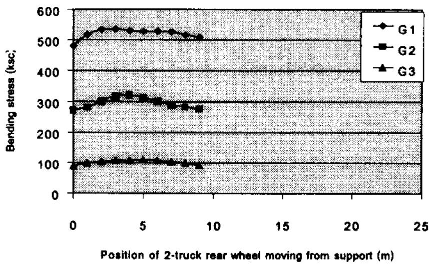
(b) 2-truck loading of Bridge 1



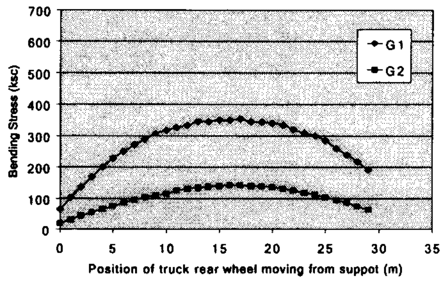
(c) 3-truck loading of Bridge 1



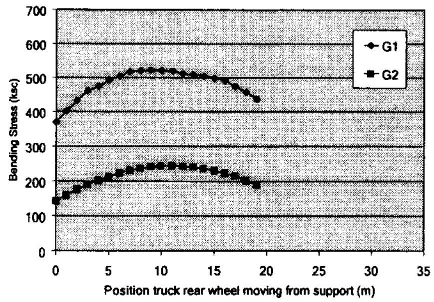
(d) 1-truck loading of Bridge 2



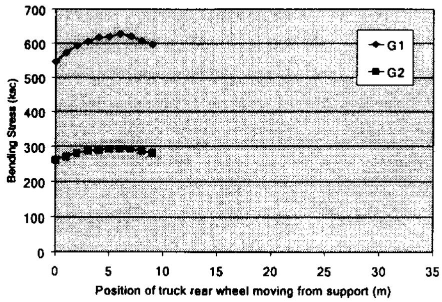
(e) 2-truck loading of Bridge 2



(f) 1-truck loading of Bridge 3

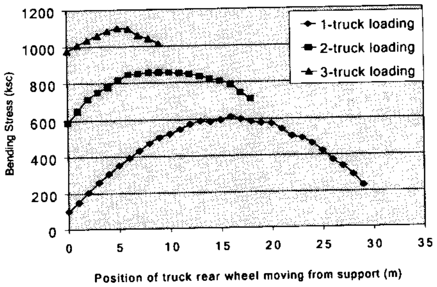


(g) 2-truck loading of Bridge 3

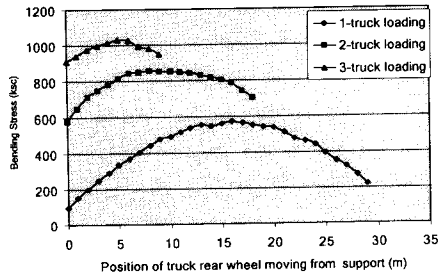


(e) 3-truck loading of Bridge 3

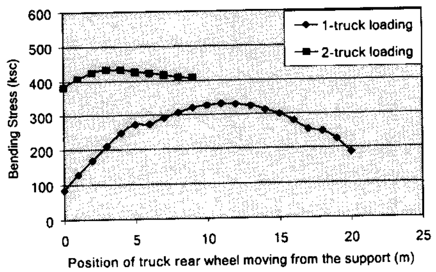
Fig.5 Results of influence line analysis of multi-girder models



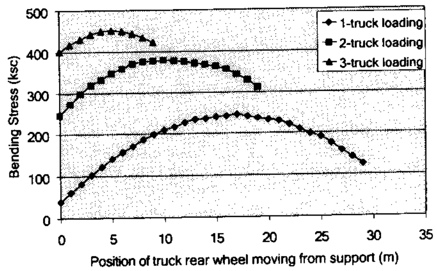
(a) 1, 2 and 3-truck loading on single girder G1 of Bridge 1



(b) 1, 2 and 3-truck loading on single girder G2 of Bridge 1



(c) 1 and 2-truck loading on single girder G1, G2 of Bridge 2



(d) 1, 2 and 3-truck loading on single girder G1 of Bridge 3

Fig.6 Results of influence line analysis of single-girder models

5. Numerical Results

As shown in Fig.5, the results of maximum bending stresses of Bridge 1, 2 and 3 are obtained by the influence line analysis due to 1-truck, 2-truck and 3-truck loading, respectively. It is noted that an interval of 1 meter along the bridge axis is used for changing the position of truck. Critical cross sections where maximum bending stresses in longitudinal girders occur are identified, and the values of maximum bending stresses in all girders for all cases are shown in Table 1. The critical cross sections approximately occur at the mid-span for all girders. Since the truck loads are applied on the external lane, the stresses are maximum in G1 for all bridges, and minimum in G4 for Bridge 1, G3 for Bridge 2 and G2 for Bridge 3 (see locations of the girders of Bridge 1, 2 and 3 in Fig.2). It is also noted that weights of trucks transfer unequally to G1 and G2, i.e. load distribution factors of G1 and G2 are different.

In order to calculate the load distribution factors employed in AASHTO [1], the maximum bending stresses are obtained from the influence line analyses of the multi-girder models and from the analyses of only single girder models. The results of analyses of single girder models for Bridge 1, 2 and 3 are shown in Fig.6. Then, the wheel load distribution factor is defined by the ratio of bending stresses when wheel loads are applied at the normal position inside the external traffic lane, and those when wheel loads are applied at the center line of the single girder [4]. A comparison between wheel load distribution factors obtained from AASHTO [1] and the present numerical results is shown in Fig.7. In Bridge 1, the numerical results are slightly higher by about 8% for G1, but considerably lower by about 47% for G2 than the AASHTO specification in case of 1-truck, 2-truck and 3-truck loading. In Bridge 2, the numerical results are lower than the AASHTO specification by 16% for G1 and 57%

for G2 in case of 1-truck loading and 2-truck loading. In Bridge 3, the numerical results are lower by about 52% for G1 than the AASHTO specification in case of 1-truck, 2-truck and 3-truck loading. Hence, the AASHTO specification currently adopted in Thailand seems to give rather conservative results in Bridge 2 and Bridge 3 except in Bridge 1 in which AASHTO gives slightly lower results for external girder.

Table 1 Results of maximum bending stresses

(a) Bridge 1

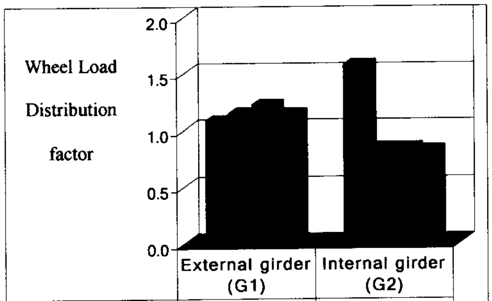
Girder	Maximum bending stress (ksc)		
	1-truck loading	2-truck loading	3-truck loading
G1	698	1044	1253
G2	481	717	845
G3	241	367	438
G4	83	120	142

(b) Bridge 2

Girder	Maximum bending stress (ksc)	
	1-truck loading	2-truck loading
G1	429	536
G2	242	320
G3	70	109

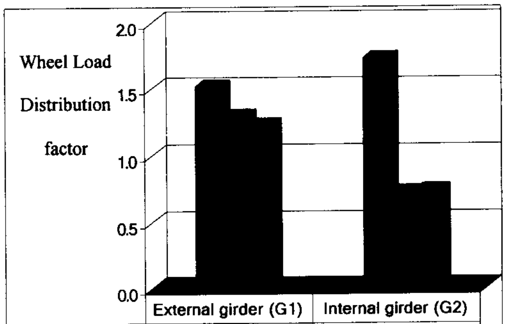
(c) Bridge 3

Girder	Maximum bending stress (ksc)		
	1-truck loading	2-truck loading	3-truck loading
G1	354	521	627
G2	142	243	292



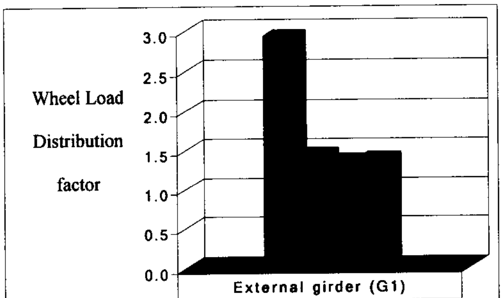
	External girder (G1)	Internal girder (G2)
■AASHTO	1.08	1.58
■1truck-loading	1.15	0.84
■2truck-loading	1.22	0.84
■3truck-loading	1.14	0.82

(a) Bridge 1



	External girder (G1)	Internal girder (G2)
■AASHTO	1.52	1.73
■1Truck-loading	1.30	0.73
■2Truck-loading	1.23	0.74

(b) Bridge 2



	External girder (G1)
■AASHTO	2.93
■1Truck-loading	1.45
■2Truck-loading	1.38
■3Truck-loading	1.39

(c) Bridge 3

Fig.7 Wheel load distribution factors

6. Concluding Remarks

This paper presents the results of three-dimensional finite element analysis of multi-girder bridges subjected to Thai truck loadings. Three bridges so-selected in the present study are representative of multi-girder bridges, made of orthotropic steel deck plate and concrete deck slab, which are used as flyover bridges in Bangkok. Three cases of loading, i.e. 1-truck, 2-truck and 3-truck loaded on only the external traffic lane, which are the most likely cases producing maximum bending stress in the girders, are considered, and the influence lines of maximum bending stresses are obtained. From the comparison between the present numerical results and Thai current practice using AASHTO specification [1], it is found that the AASHTO wheel load distribution factors are mostly more conservative than the numerical results. In case of the external girder of the orthotropic steel deck plate (Bridge 1), although the wheel load distribution factors obtained from the numerical result give slightly smaller than AASHTO specification, the difference is practically negligible. It is noted that the wheel load distribution factors basically depend mainly on the bridge geometry such as girder spacing, span length, and member stiffness. Hence, the wheel load distribution factors obtained in this study might be applicable only for the same type of multi-girder bridges selected in this study.

7. Acknowledgement

The authors are grateful to Dr. Pennung Warnitchai, Associate Professor, School of Civil Engineering, AIT for his valuable comments.

8. References

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