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BENDING MOMENT OF SIMPLE BRIDGES DUE TO MEASURED TRAIN LOAD

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Abstract

This paper examines the design live load model ls22 applied for common railway bridges in Korea through the analysis of load effect using measured train load data. The analysis of load effect considers the bending moment developed at mid-span of simple bridges with span length varying from 1m to 100m. The maximum effect for a period of 100 years is analyzed by means of the maximum load effect caused by a single train and the upper 20% of the data. Results reveal that the currently applied live load model ls22 does not secure sufficient safety. Accordingly, need is to develop a live load model based on theory and actually measured data.

Keywords: Live Load Model, Railway Bridges, Common Railway

1 Introduction

The live load model in the railway bridge design code is a critical factor having direct influence on the stability and economical efficiency of the railway bridge. Reflecting rationally the weight and volume of traffic of actually operating trains is of importance when setting the live load model. Therefore, a model that is not reflecting such features is likely to degrade the stability of the railway bridge or lead to non-economical design.

The worldwide increase of transported goods due to the rapid industrialization and concentration of the population is appearing in the railway and road sectors through the augmentation of the volume of traffic and enlargement of the vehicles. Accordingly, advanced countries are opting for design codes providing design loads and structural performances based on actual data and theory rather in order to reflect rationally and economically such phenomenon in the design.

Europe initiated this approach in the railway field for the first time and proposed live load models based on actual data. The European Railway Research Institute (ERRI) concluded that the previous live load model lm71 was not reflecting adequately the axle load and volume of traffic of the trains operating in Europe and proposed a new model lm2000 considering the axle load and traffic volume of possible current and future trains operating in Europe[2]. However, Korea implemented a very few researches devoted to load models to date. The railway bridge live load model (ls18/22)[3] currently applied for common railway in Korea takes root on the steam locomotive that was operating in USA 200 years ago and is thus obsolete in reflecting the actual environment (Fig. 1).

This paper investigates the appropriateness of the live load model ls22 applied for the design of common railway bridges by evaluating the extent by which this model is reflecting the actual train traffic environment in Korea. Therefore, the sectional force caused by train loads measured during 6 days is analyzed for comparison with that provided by LS22 load and the 100-year maximum sectional force is predicted based on the sectional force due to the measured loads.

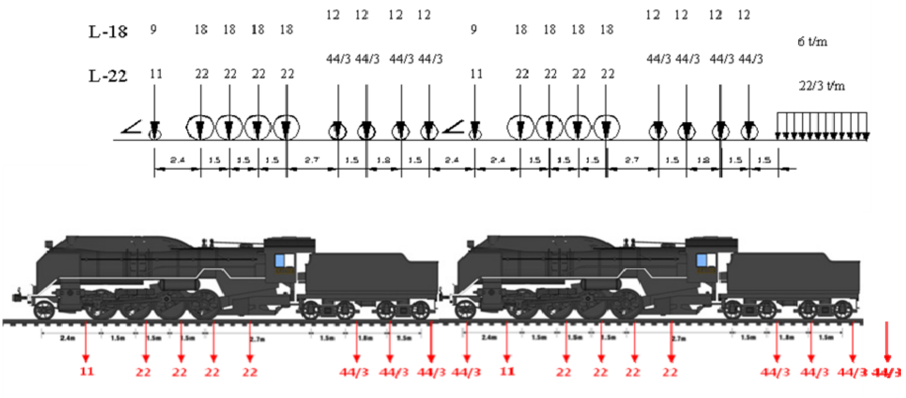


Figure 1 LS load model

2 Computation of sectional force due to measured train loads

2.1 Measurement of train loads

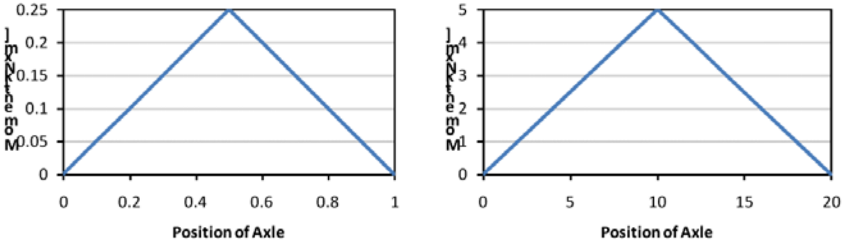
This paper exploits the axle load data measured by the railway weigh-in-motion (RWIM) system developed by the Korea Railroad Research Institute in order to compare the load effects of the trains operating in common railway of Korea and the ls22 load model. The RWIM system is an automated system enabling long-term measurement of the axle load, number of axles, wheel base and speed without stopping the train in operation (Fig. 2)[4].

Figure 2 rwim System

The acquisition of data was performed on the Joong-ang railway line in Korea featured by the high passage frequency of freight trains. The measured data correspond to 289 convoys with a percentage of 38% of freight trains.

2.2 Computation of section force using influence lines

the flexural moment at mid-span of the simple bridge is considered for the analysis of the load effect. The span length range is varied from 1m to 100m. The influence lines for the bending moment at mid-span per span length are used to consider the maximum moment developed according to the passage of the train over the bridge (Fig. 3).



(a) Span length: 5m (b) Span length: 50m

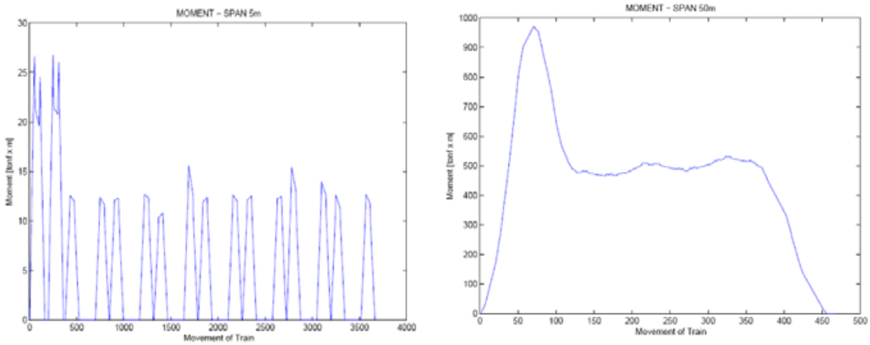
Figure 3 Influence lines for the flexural moment at mid-span per span length

The determination of the section force by the influence lines requires knowledge of the wheel base and axle load of the train. The axle load is provided by the data acquired from the 289 convoys measured by the RWIM system and the wheel base is set using the dimensions of the trains. This could be done owing to the limited number of train types operating in common lines in Korea as shown in Table 1. There is only one type of passenger train and the wheel base of freight trains shows small variation.

Table 1 Types and characteristics of trains operating in common lines in Korea

Class	Type	Number of axles	Wheel base		
			D1	D2	D3
Freight	Covered/open wagon	4	1.8	8.8	1.8
	Container	4	1.676	12.924	1.676
	Coil carrier train	4	1.8	6	1.8
Passenger	Mugunghwa	4	2.3	13.6	2.3

Fig. 4 plots the influence line analysis results obtained for one specific train among the acquired data. Fig. 4(a) and 4(b) presents the graphs for span lengths of 5m and 50m, respectively. It can be observed that the maximum moment occurs when the locomotive steps on the bridge.



(a) Span length: 5m (b) Span length: 50m

Figure 4 Influence line analysis results obtained from measured data

3 Analysis of load effect

3.1 examination of the maximum bending moment due to single train

Fig. 5 plots the maximum load effect resulting from a single train by the measured data. Even if the current live load model ls22 exhibits approximately 20% of margin for most of the span length when considering the trains actually operating, it appears that the model is inadequate in the case of very short span lengths.

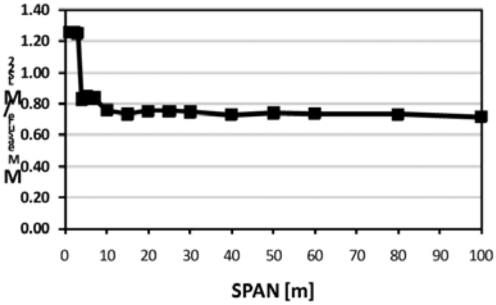


Figure 5 Maximum load effect per span length based on the measured data

3.2 Analysis of 100-year maximum bending moment

Since the design life of bridge is generally set to 100 years, the design load should provide sufficient margin. Accordingly, this study analyzes the load effect produced by the measured train loads so as to predict the 100-year maximum load effect. The so-obtained load effect is then compared to that produced by the ls22 live load model.

From the probability distribution theory, it is known that the distribution of the maximum or minimum value of an arbitrary probabilistic variable exhibits the features of extreme distribution[1]. Therefore, the 100-year maximum load effect is predicted using the upper 20% of the measured data assuming Gumbel distribution. Table 2 arranges the corresponding prediction of the 100-year maximum bending moment per span length. Considering the 289 measured convoys, the current ls22 model shows a margin of about 10% for several span lengths even when the 100-year maximum load effect is applied. However, the model seems to be inadequate for spans shorter than 10m and lengths ranging from 25 to 30m.

Table 2 100-Year maximum moment per span length

Span [m]	100-yr max. bending moment	Span [m]	100-yr max. bending moment
1	$1.34M_{LS22}$	20	$0.96\ M_{LS22}$
2	$1.34\ M_{LS22}$	25	$1.07\ M_{LS22}$
3	$1.33\ M_{LS22}$	30	$1.05\ M_{LS22}$
4	$0.92\ M_{LS22}$	40	$0.86\ M_{LS22}$
5	$1.40\ M_{LS22}$	50	$0.92\ M_{LS22}$
7	$1.44\ M_{LS22}$	60	$0.94\ M_{LS22}$
10	$1.08\ M_{LS22}$	80	$0.98\ M_{LS22}$
15	$0.90\ M_{LS22}$	100	$0.92\ M_{LS22}$

4 Conclusion

Since the live load model ls22 adopted for common railway lines in Korea is based on the load diagram of the steam locomotive that operated in 1800 in USA, this model is not reflecting the actual railway conditions. Accordingly, this paper investigated the ls22 load model by analyzing the load effect based on measured data for a total of 289 convoys. The load effects produced by ls22 and single trains giving the maximum load effect among the measured data were compared. Results revealed that LS22 is reflecting inadequately the operating trains for very short span lengths. Furthermore, based on the 100-year maximum load effect obtained by the upper 20% data, it appeared that ls22 seems to reflect inadequately the current railway conditions for the whole set of single bridge spans when considering a bridge lifetime of 100 years. Consequently, further research is required to develop a live load model enabling to reflect rationally the traffic and load conditions of the trains operating in Korea.

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