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FATIGUE EXAMINATION IN STEEL RAILWAY BRIDGES USING HUNGARIAN TRAFFIC TYPES

Pál PLATTHY[1] and Rafik JARAMANI[2]

Department of Steel Structures
Technical University of Budapest
H–1521 Budapest, Hungary

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Abstract

During 1994–1995 the Department of Steel Structures at the Technical University of Budapest conducted a parametrical study on the effects of fatigue on railway bridges. The study was concentrated on simply supported beams. The West European proposals (i.e. Eurocode) on railway bridge construction were used as a basis for this study. The results of the study indicated that a part of the Eurocode proposals can be applied to Hungarian railway bridges. However, further examination is required on continuous beams.

Keywords: fatigue, railway bridges, steel structures.

Introduction

In previous years, West European fatigue examinations on railway bridges were conducted using the UIC proposals on traffic types. During these studies, the ideal (UIC) train loads were replaced with other load types. In this study, different ideal loads were used for improving the accuracy, for example, differentiation between passenger trains and carriage trains. This differentiation of load types (4–12) depended upon the annual volume of traffic on the railway lines.

The use of the differentiated load types requires more accepted effects and lower clarity in the work. As a consequence, the UIC ideal load was used.

The following correction factor was included in the empirical analysis to compare the calculated stress with fatigue allowable stress [1] [2] :

$$\lambda = \lambda_1 \cdot \lambda_2 \cdot \lambda_3 \cdot \lambda_4 \ , \tag{1}$$

[1]Professor of Structural Engineering

[2]PhD Student

where λ_1: is a function of the span and traffic type
λ_2: is a factor to take account of the annual volume of traffic
λ_3: is a factor to take account of the design life of the structure
λ_4: is a factor to be applied when the structural element is loaded by more than one track

The λ_2, λ_3 and λ_4 factors, however, do not depend on load types or on the structure elements. Thus, λ_1 is the most important variable, and is a function of normal stress (σ) or shear stress (τ) (i.e. λ_1 can be differentiated into $\lambda_{1\sigma}$ and $\lambda_{1\tau}$). This study focussed on the two factors.

Fatigue Design Aspects in Hungary

The previously mentioned Eurocode proposals for fatigue examination to be used in Hungary required answers for the following two questions:

- Due to differences between West European and Hungarian load types, can the results of the calculation of $\lambda_{1\sigma}$ in the West European proposals be used in Hungary ?
- Can the West European proposals, which affirm :

$$\lambda_{1\sigma} \approx \lambda_{1\tau} \tag{2}$$

be used in Hungary ?

Referring to the first question, the proposal of Sándor FORGÓ for railway traffic types was accepted, considering his study in railway traffic of the Hungarian railway company (MÁV) [3] [4].

To answer the second question, Hungarian railway types were used in this study.

Study on $\lambda_{1\sigma}$ Factor

The calculation of $\lambda_{1\sigma}$ was conducted on the center points of 3, 5, 7, 10 and 50 meter simply supported beams. The volume of traffic was 25 million tons per annum. As a result, $\lambda_2 = 1$ and the design life of the structure is 100 years (i.e. $\lambda_3 = 1$). The structural element was loaded by one track (i.e. $\lambda_4 = 1$). Therefore, $\lambda = \lambda_1$.

During the study, the Standard $S - N$ curve (i.e. Wöhler curve) and Palmgren – Miner Cumulative damage calculation were used.

In the first step, influence diagrams were constructed for each load type (refer to *Figs. 1* and *2*), these influence diagrams were used to calculate stress range ($\Delta\sigma_i$) and the load cycles (N_i) using the Reservoir method.

Following this, the reference value of fatigue stress at two million cycles ($\Delta\sigma_e$) was determined as :

$$\Delta\sigma_e = \frac{1}{\sqrt[3]{N_e}} \cdot \sqrt[3]{\sum_i \Delta\sigma_i^3 \cdot n_i \cdot \phi_i + \sum_j N_D^{0.4} \cdot \Delta\sigma_j^3 \cdot n_j^{0.6} \cdot \phi_i} \,. \tag{3}$$

The Eurocode proposal :

$$\lambda_1 = \frac{\Delta\sigma_e}{\phi_2 \cdot \Delta\sigma_{UIC}} \tag{4}$$

was then calculated, where

$\Delta\sigma_{UIC}$: is the stress range due to the UIC load diagram being placed in the most unfavourable position for the member under consideration.

ϕ_2 : is the dynamic coefficient.

$$\phi_2 = \frac{1.44}{\sqrt{L} - 0.82} + 0.82 \,, \quad (1.05 \le \phi_2 < 1.67) \tag{5}$$

ϕ_i : is the dynamic coefficient for each service train type.

$$\phi_i = 1 + 0.5(\varphi' + 0.5\varphi'') \tag{6}$$

$\phi' = \frac{K}{1+K+K^4}$ with $K = \frac{V}{160}$ for $L < 20$ m

or $K = \frac{V}{47.16 \cdot L^{0.408}}$ for $L > 20$ m

$\phi'' = 0.56 \cdot e^{-\left(\frac{L^2}{100}\right)}$

V = speed (m/s)

As seen in *Table 1*, the results of $\lambda_{1\sigma}$ in this study are similar to the Eurocode results, therefore, the Eurocode proposals can be used in Hungary.

Table 1

The volume of $\lambda_{1\sigma}$

L [m]	Type I	Type II	Type III	Type IV	Mix	EUROCODE
3.0	1.63	1.61	1.39	2.19	1.68	1.36
5.0	0.88	0.92	0.76	1.2	1.00	1.02
7.0	1.07	1.01	0.79	1.31	0.96	0.94
10.0	0.79	0.62	0.68	0.93	0.75	0.82
50.0	0.59	0.48	0.55	0.62	0.56	0.62

Study on $\lambda_{1\tau}$ Factor

$\Delta\tau_e$ was determined as:

$$\Delta\tau_e = \frac{1}{\sqrt[5]{N_e}} \cdot \sqrt[5]{\sum_i \Delta\tau_i^5 \cdot n_i \cdot \phi_i} \ . \tag{7}$$

The same method of calculation of $\lambda_{1\sigma}$ was used to calculate $\lambda_{1\tau}$.

To contrast $\lambda_{1\sigma}$ with $\lambda_{1\tau}$, the following ratio was used:

$$\alpha = \frac{\lambda_{1\sigma}}{\lambda_{1\tau}} \ . \tag{8}$$

The results of this calculation are shown in *Table 2.* The volumes of α ratio are not similar to the Eurocode results, therefore, the Eurocode proposals cannot be used in Hungary.

Table 2
The volume of α ratio

L [m]	Type I	Type II	Type III	Type IV	Mix	EUROCODE
3.0	0.60	0.76	0.60	0.60	0.68	1.00
5.0	0.98	1.28	1.03	0.86	1.06	1.00
7.0	1.20	1.41	1.48	1.18	1.42	1.00
10.0	1.16	1.87	1.31	1.25	1.48	1.00
50.0	1.61	1.90	1.67	1.52	1.66	1.00

Since the maximum moment and maximum shear force in continuous beams are applied in the same cross-section, future examination will be carried this study.

Conclusions

The results of this study show that the Eurocode proposals for moment induced fatigue in railway steel bridges can be used in Hungary, but the proposals for shear cheking fatigue as seen in *Eq.* (7) cannot be used there. However, attention is required on continuous beams as the Eurocode proposals have not yet been affirmed in this area, this is especially important in welded connections, where normal stress has an interaction with shear stress.

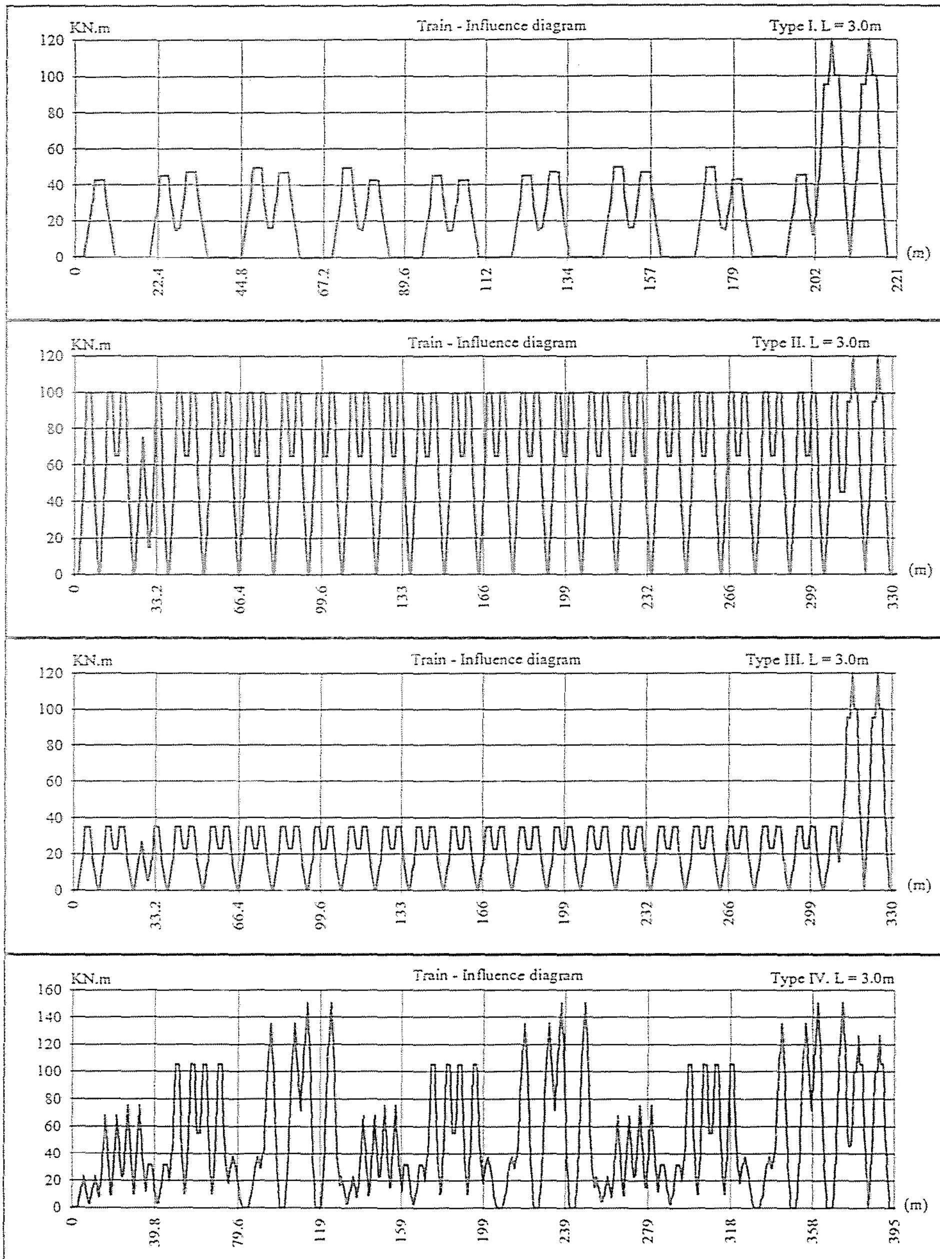

Fig. 1. Moments train-influence diagrams

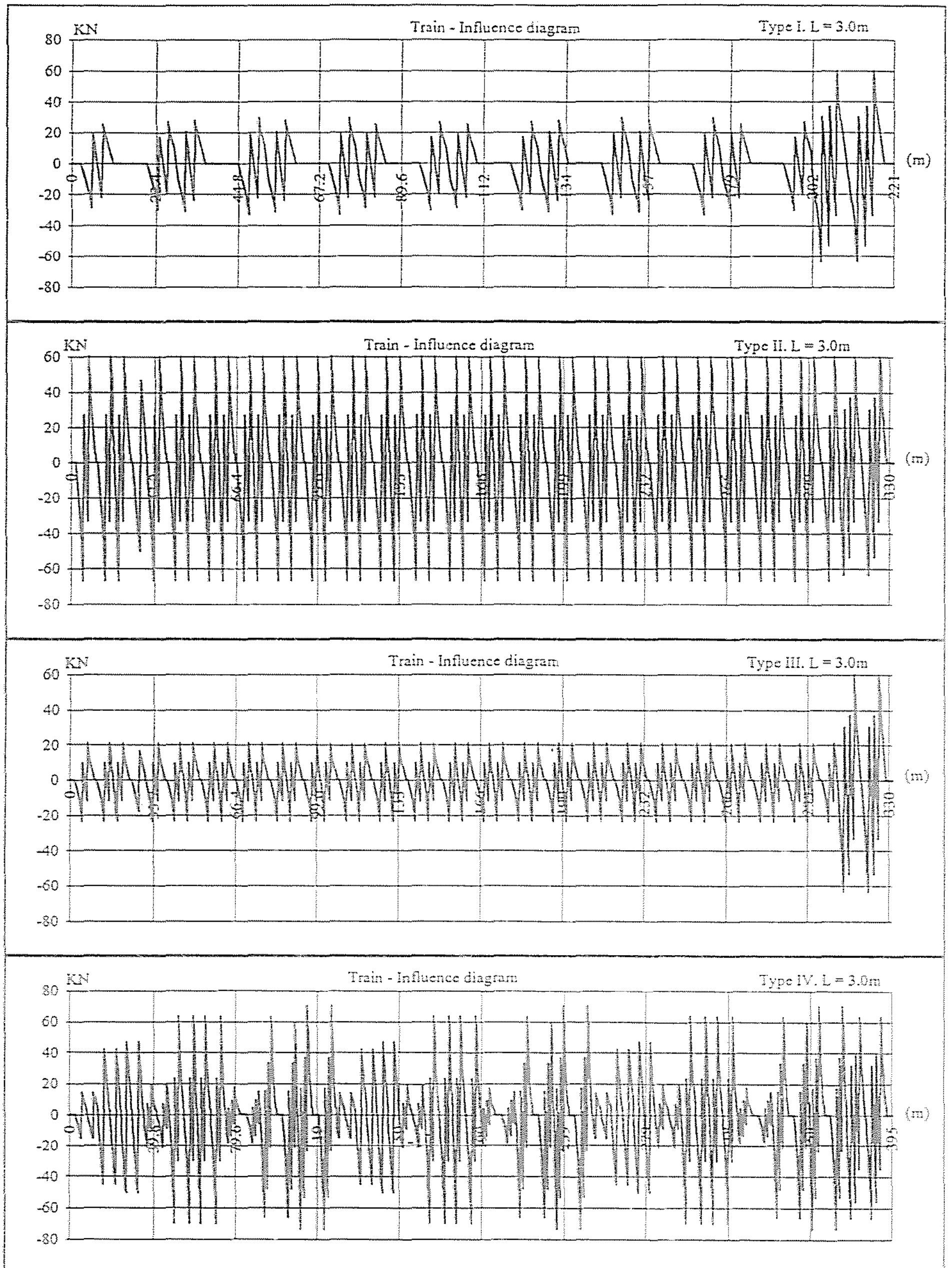

Fig. 2. Shear forces train-influence diagrams

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