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Acoustic Emission Monitoring of Bridges under Heavy Truck Loading

Surveillance par émissions acoustiques de ponts surchargés

Kontrolle der überlasteten Brücken unter Verwendung der akustischen Emission

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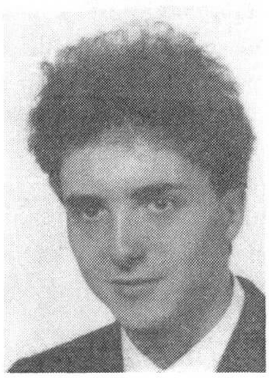

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SUMMARY

The paper reports test results of acoustic emission monitoring of two bridges under heavy truck loading. Measurement of the signals is compared with the results of calculation. Application of the acoustic emission as the method for early warning during passage of the vehicle along the bridge is shown in the paper. Post-test assessment of the stresses of structural members under heavy loading in comparison to the acoustic emission measured for normal traffic is presented.

RÉSUMÉ

L'article présente les résultats d'auscultation de deux ponts routiers à l'aide d'une méthode d'émission acoustique. Les mesures d'émission acoustique ont été comparées avec les résultats des calculs numériques. L'application d'émission acoustique ainsi que la méthode de la prévention pendant les passages des véhicules dépassant les charges admissibles sont présentées. La méthode permet d'évaluer les efforts dans les éléments de construction sous la charge d'une circulation routière normale.

ZUSAMMENFASSUNG

Im Aufsatz wurden die Ergebnisse der stetigen Kontrolle von zwei übernormativ belasteten Brücken mit der Verwendung der akustischen Emission vorgestellt. Diese Messungen wurden mit den Ergebnissen der Berechnungen verglichen. Vorgestellt werden die Verwendung der akustischen Emission als die Methode des frühzeitigen Warnens während übernormativen Überfahrten. Die Methode erlaubt de Bestimmung der Belastung der Konstruktion unter normaler Verkehrslast.

1. INTRODUCTION

Evaluation of the bridge structure subjected to special multiaxial vehicles for carrying of heavy equipment as machinery, transformer elements, etc. is very difficult problem for bridge maintenance service. Preliminary calculations of loading capacity and displacements of a structure, especially for old bridges, must be done prior to the passage of the vehicle of this type. Acoustic Emission (AE) measurement is the technique which enables monitoring of the behavior of the structure elements under loading. It seems to be efficient tool for early warning against damage of the structure members under heavy vehicles loading.

2. DESCRIPTION OF TESTED STRUCTURES

2.1. Bridge I

It is a steel three span (60.0+84.0+60.0 m between supports) road bridge over the West Odra river. The main construction consists of four double-tee section girders of 2.90 m spacing. The girders are divided by hinges into one secondary span of length 75.0 m and two cantilever spans 54.0 m long.

2.2. Bridge II

The superstructure of the bridge over the Noteć river consists of two truss girders of triangular type with 6.0 m spacing between the girders. The deck is composed of transverse and longitudinal beams. The span of the bridge is 52.2 m. Sidewalks are placed on cantilevers outside truss girders.

3. GENERAL ASSESSMENT OF TECHNICAL STATE OF STRUCTURES

The principal aim of the conducted tests was determining the ability of the bridges to carry heavy truck loading.

The evaluation of technical state is based only on observation done during the measurements and can be summarized as follows:

- bridges I exhibits significant vibrations under service load,
- no significant damage of spans and supports of bridges I was observed,
- main girders of *bridge II* are in good condition,
- the superstructure of *bridge II* seems to be insufficiently stiff.

4. TESTING PROGRAM

Four stages of testing program can be distinguished. These are:

- initial measurements of AE of mostly loaded elements of the structures under service load,
- measurements of AE under service load just before loading with heavy truck,
- measurements of AE under heavy truck load,
- static analysis in the range enabling evaluation of the AE level under real load.

Measurements of acoustic emission were carried out continuously for common traffic with different weights and technical characteristics of vehicles, random frequencies of load appearance, and variable speed of vehicles. During initial tests several 5 up to 15 minute measurements were done. In some cases the instant of vehicle appearance on a bridge and vehicle movement direction were registered.

The heavy truck moved very slowly (about several meters a minute) along the middle of bridge roadway. In order to avoid serious damage of a bridge constant monitoring of chosen measurepoint was carried out which would signal overloading by fast and unstable increase of AE rate. During crossing of the secondary span of *bridge I* the truck was stopped for some tens of seconds.

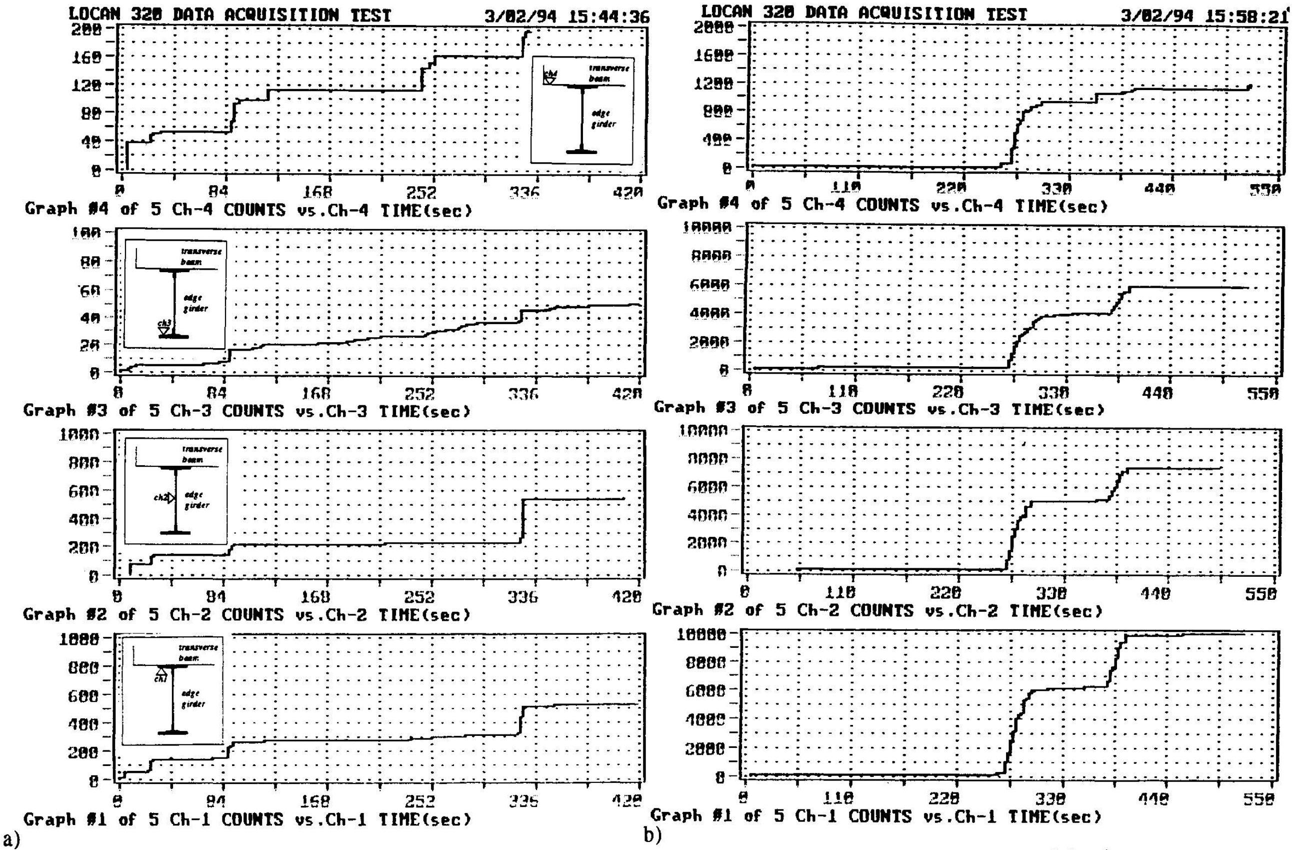


Fig.1 Comparison of number of AE counts measured for the *bridge I*, a) under service load, b) under heavy truck load

5. EQUIPMENT

Measurements of AE were obtained with the use of LOCAN 320 system made by Physical Acoustic Corporation in Princeton. LOCAN 320 is a computer aided system for measuring and acquisition of acoustic emission signals in real time. The signals of high frequencies are emitted by a loaded structure and then transformed into electric signals by piezoelectric transducers.

6. TEST RESULTS

Test results from measurement of AE signals generated by *bridge I* members are shown in Fig. 1 AE structure response under service load was compared with the signals emitted by the same members under passage of the heavy vehicle. Measurements were done with amplification of 40 dB and "floating threshold" 25 dB.

Measurements of AE for *bridge II* were done with following levels of amplification and discrimination:

- ch1 – amp. 30 dB, thresh. 40 dB,
- ch2 – amp. 30 dB, thresh. 30 dB,
- ch3,4 – amp. 24 dB, thresh 51 dB.

Test results for monitoring of the *bridge II* subjected to heavy truck loading is shown in Fig.3

7. CONCLUSIONS

The analysis of obtained results yields following conclusions grouped for service and heavy truck load.

7.1. Test results for service load

- each crossing of vehicles produces acoustic emission at monitored construction elements,
- in the *bridge I* the most emission was obtained in the web and compressed flange of main girder; in the case of dynamic load a part of AE signal can be caused by allowances, friction and knocks of deck elements at top flange of girder,
- low amplitudes (below 30 dB) of most acoustic emission registered under service load of *bridge I* point at friction as the source of signals, whereas in *bridge II* emission consists of signals of high amplitudes 40÷60 dB, 30÷70 dB and 50÷80 dB for bottom flange of truss, transverse beam and diagonal bar of truss respectively,

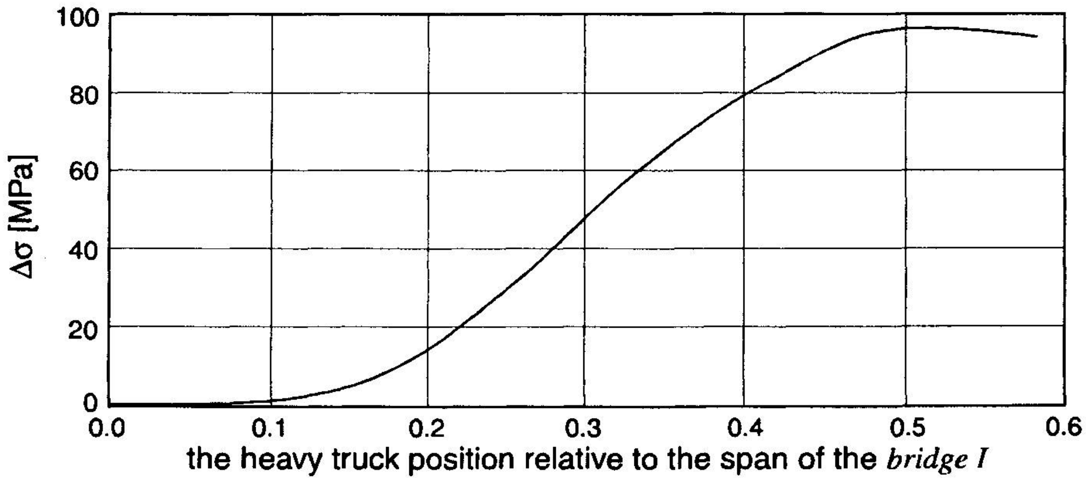
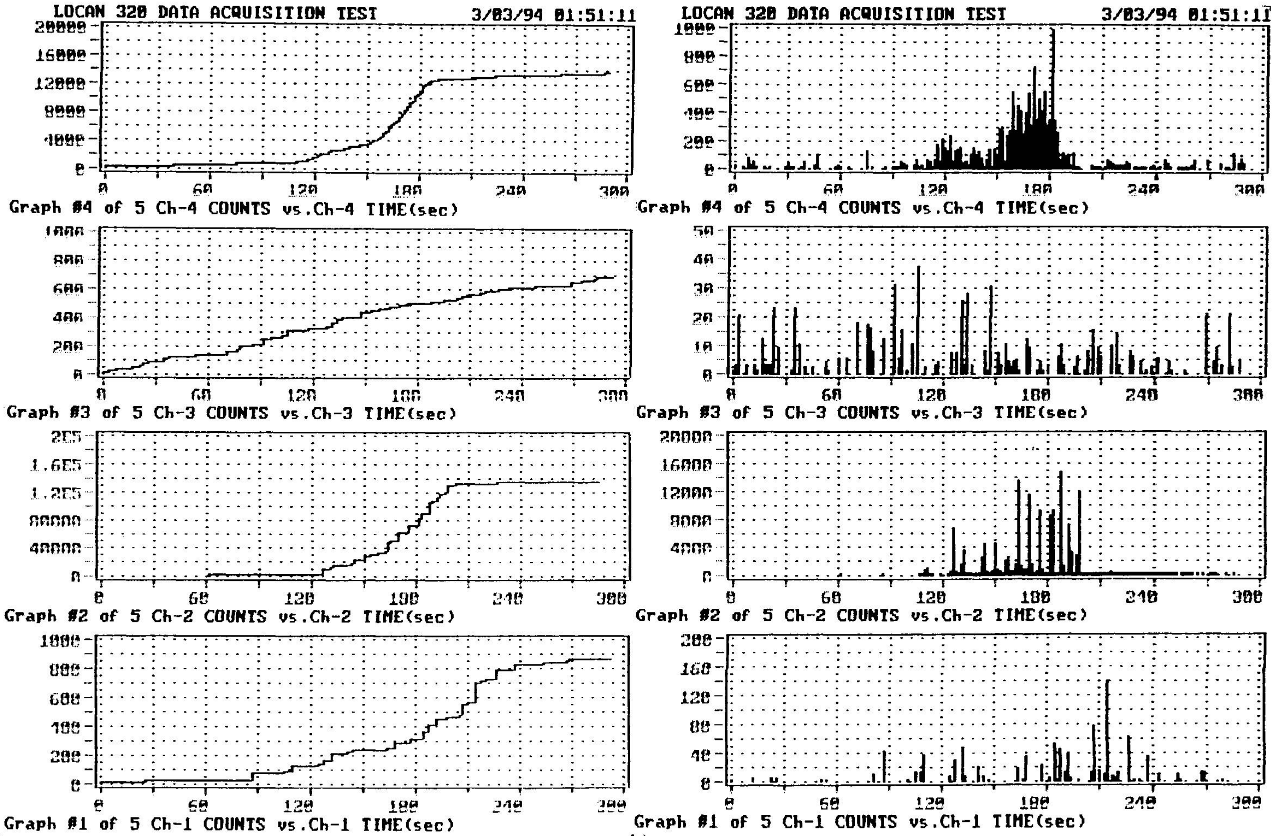


Fig. 2. Increase of maximal normal stress in the transverse beam of *bridge II* during the passage of the heavy truck



a) b)

Fig.3 Comparison of number of AE counts (a) and AE rate (b) measured for the *bridge I* I under heavy truck load; ch1 –bottom chord of the truss, ch2 –transverse beam, ch3,4 – truss diagonals acoustic emission level measured in *bridge II* regardless of less intensity of loading is significantly higher than in *bridge I*, especially high level was observed in the middle transverse beam of *bridge II* (sum of AE signals is an order higher than measured in bottom flange and diagonals).

		Maximal normal stress [MPa]		
Bridge	**Element**	**Dead weight**	**Service load**	**Heavy truck load**
bridge I	edge girder (ch 1,2,3)	97	18	32
	transverse beam (ch 4)	26	21	84
bridge II	bottom chord of truss (ch1)	125	23	42
	transverse beam (ch2)	107	44	96
	diagonal (ch3)	130	33	61
	diagonal (ch4)	158	51	94

Table 1. Maximal calculated stresses in bridge elements

7.2. Test results for heavy truck load

Measurements of AE signals during passage of heavy truck along tested bridges enabled following conclusions to be drawn.

7.2.1Bridge I

- AE was registered after the truck got to the secondary span indicating that friction in hinges was not the source of emission,
- the stopping of the truck during the passage along the bridge was accompanied by stabilization of number of AE counts (see fig. 1), especially in the web of the main girder and in transverse beam, in the flanges of the main girders AE rate also decreased, however at this level of loading the stopping of the truck caused exponential decreasing of AE,
- after the stopping further increase of AE is observed as the truck was approaching the middle of the bridge,
- the level of AE caused by heavy truck loading is an order higher than the one obtained for single vehicles in common traffic; numbers of AE counts measured in web, top and bottom flange of main girder are in the same range what shows similar effort of these elements; the number of counts registered in transverse beam is several times lower.

7.2.2Bridge II

- the heavy truck loading produced significant acoustic effect especially in transverse beam (Fig. 3, channel 2); when the truck went on the bridge acoustic emission of rapidly increasing number of counts (up to $1.4 \cdot 10^5$) appeared; such a level of emission may indicate overloading of structure element and possibility of serious damage,
- it is significant the AE rate increases with growth of applied loading (see *bridge I*, Fig. 1),
- AE signal decreased quickly after the truck went off the bridge but the signal lasted still about 100 seconds at the level of tens of counts a second,
- during the heavy truck passage amplitudes of registered signals were similar to those obtained under service load what implies that the source of AE signals was the same,
- significant increase of AE was observed in a diagonal of the truss as the truck went on the bridge,
- relatively small effort was registered in the bottom chord of the truss; the number of AE counts is comparable to that obtained with service load.