Paper 178

Proceedings of the Eleventh International Conference
on Computational Structures Technology,
B.H.V. Topping, (Editor),
Civil-Comp Press, Stirlingshire, Scotland

Paraseismic Loading of Bridge Structures

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Abstract

This paper deals with the spectral characteristics identification of selected bridge structures. The dynamic load and response from the microtremor effect were subject to a roadway and a railway. For both bridges the dominant frequency bands were identified which correspond with the natural frequency peaks in the numerical model simulation. For all these case studies, it was observed that the frequency transfer (using spectral characteristics) and the vibration level decreases depending on the distance from the vibration source. These case studies showed some dominant frequency bands for railways and for roadways [3]

Keywords: natural frequency, natural mode, bridge structure, spectral density.

1 Introduction

Currently there is a sharp increase in the intensity of all modes of transport. With this in mind it is important to enhance the effects of technology on seismic building standing in close proximity to transport routes. These buildings are increasingly affected by various types of mechanical stress waves arising from microtremors caused by traffic. Such structures are also economically and technically demanding bridge construction objects. Their durability and reliability depends on the fatigue processes to which they are subjected.. Cyclic changes of materials are most often caused by vibrations arising from dynamic loading.

This paper deals with the analysis of spectral characteristics of the load and the response of selected bridge structures in relation to microtremors caused by traffic.

2 Theoretical approaches to spectral analysis of the vibration source

The solution of a random phenomenon should be analysed as a stochastic process (action). The character of the analysis is divided to deterministic and stochastic parts.

The properties of random processes can be evaluated for:

1. time domain (time histories),
2. correlation (correlation functions – depending on time):

- the effective value of the relationship

$$\sigma_x = RMS = x_{ef} = \sqrt{\frac{1}{T}\int_0^T x(t)^2\,dt}. \tag{1}$$

- **the** auto correlation function

$$R_{xx}(\tau) = \lim_{T\to\infty}\frac{1}{T}\int_0^T x(t)x(t+\tau)dt. \tag{2}$$

- the cross correlation function of the processes x(t), y(t)

$$R_{xy}(\tau) = \lim_{T\to\infty}\frac{1}{T}\int_0^T x(t)y(t+\tau)dt. \tag{3}$$

1. frequency (harmonic analysis of the signal),
2. spectral (spectral power distribution of the frequencies)

- power spectral density $G_{xx}(f)$

$$G_{xx}(f) = 2\int_{-\infty}^{\infty} R_{xx}(\tau)e^{-i2\pi f\tau}dt \tag{4}$$

- coherency function

$$\gamma_{xy}(f)^2 = \frac{\left|G_{xy}(f)\right|^2}{G_{xx}(f)G_{yy}(f)} \le 1. \tag{5}$$

- transfer funcion

$$H(if) = \frac{G_{xy}(f)}{G_{xx}(f)}. \tag{6}$$

3. probabilistic (statistic evaluation),
4. information (effective evaluation – determined in white noise signal).

2.1 Computational models of vehicles

The theoretical expression of the spectral characteristics of load vehicles is a complicated process. The parameters entering the problem are either highly variable

or are not sufficiently known and must be identified experimentally. The development of new programs, working on the basis of the finite element method makes it possible to create more reliable computer models describing the passage of vehicles over a bridge construction.

The vehicle is a driving system, in which there is a change in the position of matter with time, according to the position of the vehicle. The solution of the problem is still very difficult as in the past it was necessary to resolve the role of simplified assumptions.

2.2 Computational models

The computational models can be divided into four groups:

1. The vehicle is a simple model of a system with one degree of freedom in which the damping *b* and stiffness *k* expresses the elastic connection of the vehicle body.

2. The vehicle is modelled as a model with two degrees of freedom. This computational model is again a very crude simplification but for practical purposes is sufficiently accurate.

3. The vehicle can be modelled as a system with multiple degrees of freedom. The vehicle is still modelled as a planar system.

4 The vehicle is modelled as a spatial system. This computational model already requires the use of computer technology.

2.3 Vibration of transfer medium (soil structure)

In the continuous infinite elastic medium is a material source of vibration spreading independently of each other two types of waves and longitudinal waves and transverse waves. These are investigated at sufficient points, not far from the source where they appear as plane waves.

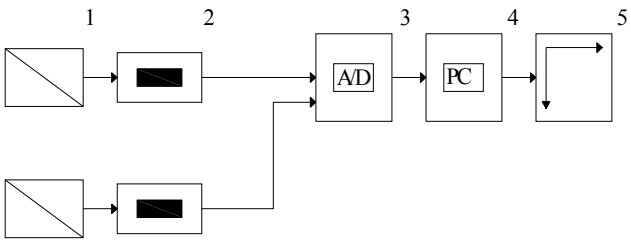
Elastic waves progress near the surface and are influenced by surface soil, and they are very complicated. The surface waves can be detected as two types of waves, named after the physicists who were the first to deal with their theory. They are the Rayleigh waves (called the R) and the Love waves (Q).

3 Description of measurement techniques and procedures for experimental measurements

Dynamic characteristics are the natural frequencies of vibration, natural modes and attenuation of the structure. Knowledge of these basic characteristics opens the door for a deeper analysis of the dynamic response of structures to various types of load

variables over time. To measure the spread of the dynamic effects of the surroundings of the route as well as in determining the dynamic characteristics of the spectral analysis of building structures are characterized by a random vibration function. Experimental procedures can be devloped for the "on line" (see Figure 1) and "off line" (see Figure 2) method of measurement and the evaluation of random signals.

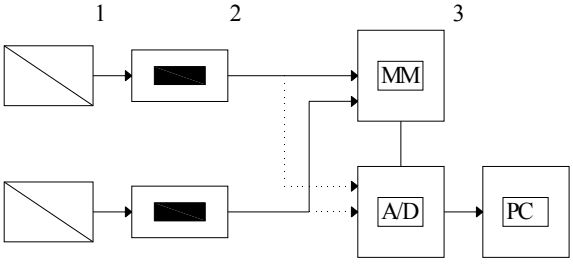
Measuring Method „on line"



1 – piezoelectric accelerometers with external power (Brűel&Kjaer (B&K) 8306, Robotron KB 12 - RFT)
2 – integration amplifier (B&K 2635, Robotron 00042)
3 – A/D converter (NI)
4 – notebook (PC) with software (DAS 16, DISYS, NI Lab View)
5 – graphic or data export (printer, file export)

Figure 1: Measuring line „in situ", method „ on line"

Measuring method „off line"



1 - piezoelectric accelerometers with external power (Brűel& Kjaer (B&K) 8306, Robotron KB 12 - RFT)
2 - integration amplifier (B&K 2635, Robotron 00042)
3 – measuring data storage (B&K 7005) or PC with software (DAS, DISYS, NI Lab View) with A/D converter

Figure 2: Measuring line „in situ", method „ off line"

Software used for the loading records of measurements and their evaluation were: DAS, DI-SYS, ARTEMIS.

4 Theoretical approaches to detection of bridge structures spectral characteristics

To solve the spectral characteristics of bridge construction it is necessary to implement a dynamic calculation of a computational model of the bridge construction. Selecting the type of computational model and method used for the calculation depends on the type of construction and accuracy of the results, either in the frequency or the amplitude domain.

4.1 Natural vibration of bridge structures

Natural vibration clearly defines the individuality of dynamic bridge construction. Solution of natural vibration parameters is therefore an important part of the overall dynamic analysis of the bridge construction.

The choice of method for solving natural vibration is a conditional choice of physical computational model. For the classical solution we have basically two options. Select a discrete computational model with a finite number of degrees of freedom, or work with the calculation model with continuously distributed parameters.

Currently, conventional computational methodsare pushed into the background by the extensive use of the finite element method (FEM). [5] In terms of the choice of computational model the FEM has a specific position in the sense that on the one hand solutions are the result of discrete values

In the final number of points - element discretization, on the other hand, operates with the continuous functions of the elements. The great versatility of this method, a wide range of commercially available software systems, effective pre and post processing in recent years led to its significant use. [6]

5 Spectral analysis of real case studies of structures

The intention of finding the spectral characteristics of actual structures was selected to monitor real-construction:

5.1 Spectral response and load characteristics – The Bridge over Kysucká way – Žilina

In determining the spectral response characteristics of a load microtremor arising from traffic, theoretical calculations and experimental measurements were carried out of the existing bridge structure on the bypass road corridor Ľavobrežná street Žilina - "The Bridge over Kysucká way." The modes of natural vibration determined

from the finite element model and the experimental spectrums for selected measurement example samples are shown in Figure 3.

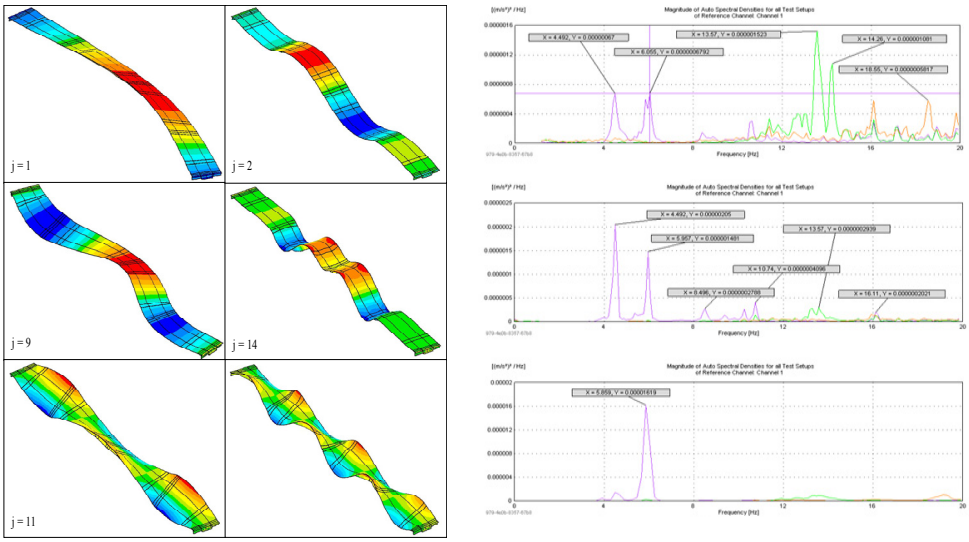


Figure 3: Spectral analysis results examples – road traffic

5.2 Spectral response and load characteristics of bridge structure - D201 - 00 – CI / 11 Žilina – Viaduct

By analysing the spectral response characteristics of a load of microtremor due to traffic induced by a railway, a theoretical and experimental study of bridge construction (Viaducts), located before the busy intersection of Košice - Ľavobrežná at theTesco Store in Žilina. The modes of natural vibration from the finite element model and the experimental spectrums for selected measurement example samples are given in Figure 4.

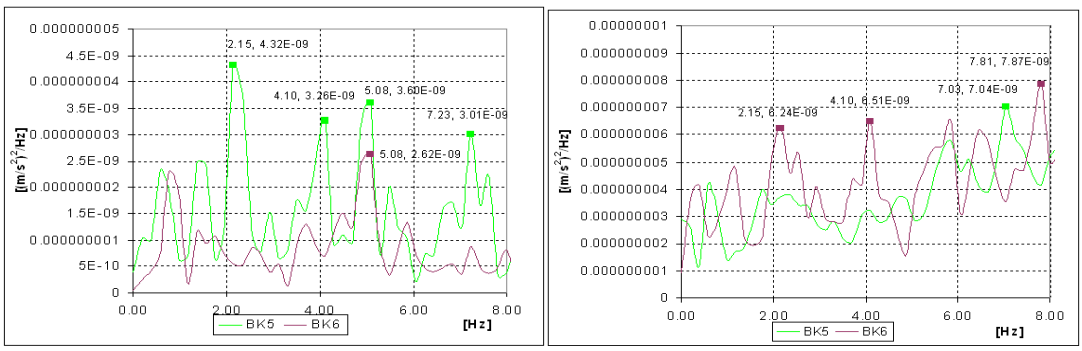


Figure 4: Spectral analysis results examples – rail traffic

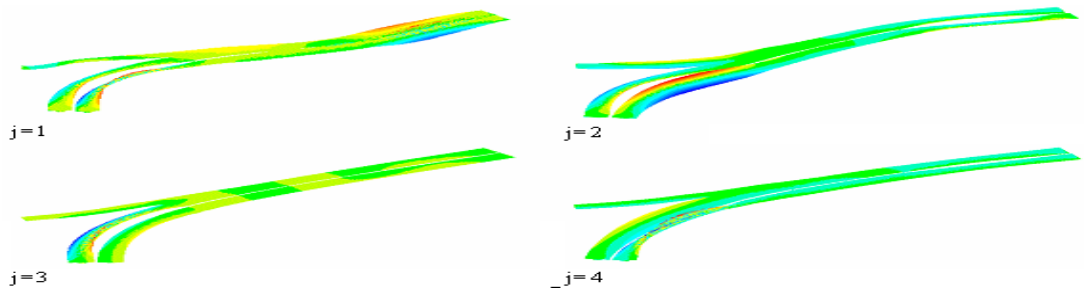


Figure 4 (Continued): Spectral analysis results examples – rail traffic

5.3 Measurement of vibrations from road traffic, location stadium MŠK Žilina (Road Transport)

Measurement of the MŠK Žilina stadium site was made because of the relatively short distance from the investigation of the structure of the Kysucká bridge (300m). This site was chosen using the same assumption about the geology of the subsoil and thus it is possible to compare the results of the frequency analysis of two independent measurements. Sample vibration levels depending on a dominant distance and averaging spectra from twenty experimental measurements can be seen in the Figure 5.

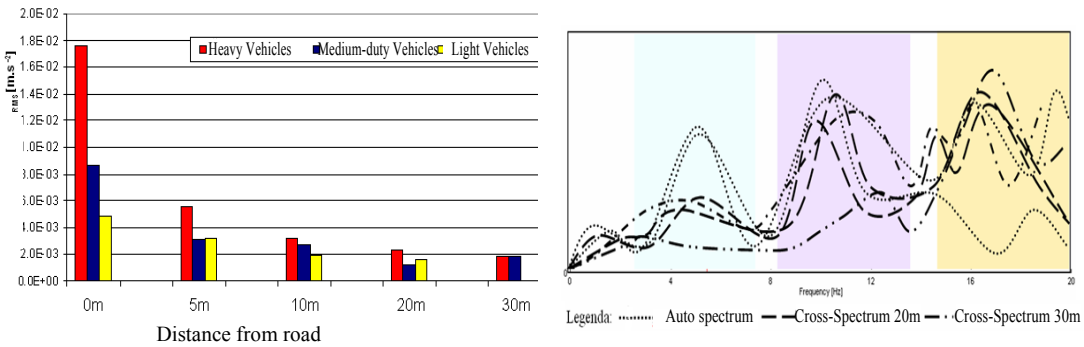


Figure 5: Graphic experimental results – road traffic vibration of soil

5.4 Measurement of vibrations from rail traffic in location the Teplička over the Váh River

The location of the Teplička over the Váh River was selected for the main railway line at a point where there were no service roads or other technological installations, which would cause spurious vibrations. Sample vibration levels decrease with distance from the railway line and the resulting spectral envelope can be seen in the Figure 6.

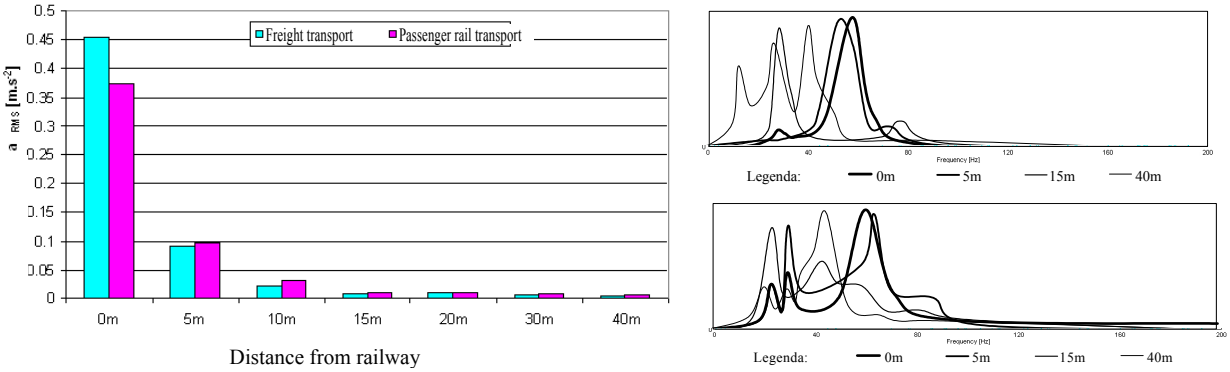


Figure 6: Graphic experimental results – rail traffic vibration of soil

6 Conclusions

Based on the evaluation of spectral characteristics of the experimental measurements and a comparison of the results of the numerical calculations it is possible to debug the computing model and use it as a further refined model for other static and dynamic analysis.

The following conclusions were drawn from the results of the case studies for the transmission of the vibration environment of the soil. :

The intensity of the vibration from the source of vibration through the rock and soil environment to the base of bridge supports decreases exponentially with distance, as well as from the road and rail transport.

- It is important to identify the dominant vibration associated with the vehicle but for the precise specification it would be necessary to carry out more measurements.. With the rail vibration two kinds of dominant frequency can be expected for the domain and the region associated with the natural vibration of the structure and the track grid associated with the vibration of railway vehicles. The case study identified the dominant frequency: 55-65 Hz (track grid with vehicle mass) and 22-36 Hz (above-rail vehicle vibration modes).
- Transfer functions and basic mechanical properties of the soil in the study area were identified based on the impulse seismic method (ISM). The inter-frequency transmission is most realized in the frequency range 35-45 Hz [4]

Acknowledgement

We kindly acknowledge the research project VEGA, Nr.G1/01692/12 granted by Scientific Grant Agency of the Slovak Republic Ministry of Education. We should also like to thank the Civil Engineering Faculty – University of Žilina for additional feed in this field research activity.

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