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Influence of the structural arrangement of bridges on the noise induced by traffic

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ABSTRACT

Many articles and papers about mitigating the impacts of the transport infrastructure on the environment have pointed out that one of the factors influencing the usage of underbridges for mammal migration is the noise induced by traffic. However, this phenomenon has not yet been properly investigated and verified. This paper describes the influence of the structural arrangement of bridges, mainly the bearings and expansion joints, and the location of the bridge in the countryside, on the noise induced by traffic. The findings come from noise measurements on several structures on the D1 motorway and the R35 expressway in the Czech Republic. The measured noise levels are juxtaposed with the migration potential of the bridge for wildlife.

1. Introduction

According to the available literature focused on mitigating the impacts of the transport infrastructure on the environment, one of the factors influencing the usage of underbridges for mammal migration is the noise induced by traffic. This phenomenon has not yet been properly investigated and verified. To verify this assumption, a noise measurement program was designed and undertaken on highway bridges on selected sections of the D1 motorway and the R35 expressway in the Czech Republic. Simultaneous measurements were made of the noise level and of the use of the bridges for mammal migration. The noise measurements were carried out in summer 2010 and summer 2011. Special attention was paid to the influence of expansion joints and bearings on the noise impact caused by heavy traffic entering the bridge.

The experimental program described here was preceded by a review of the literature on mitigating the impacts of the transport infrastructure on the environment and on the migration of mammals over roads and motorways.

Long-term monitoring of mammal migration usually focuses on the influence of the structural arrangement on the migration success rate. Several long-term migration monitoring campaigns were performed on the Trans-Canada highway in the Banff National Park [1–4]. Migration monitoring was aimed at minimizing migration mortality by specifying structural parameters that would increase the migration success rate of new or existing structures.

A total of 11,592 migrations at 11 structures were recorded in [1]. The migration success factors were arranged according to their importance: (1) underpass openness (openness factor = width × height/length [5]), (2) noise level, (3) underpass width, and (4) distance to the nearest drainage. Structures with a high openness factor are chosen for migration by most of the studied animals [2], mainly by ungulates.

Moose use more open structures, and [6] recommends an openness factor of 2.3, with a minimum width of 11 m. Deer can use narrower structures, and [6] recommends an openness factor of 1.4, with a minimum width of 7 m.

However, other monitoring campaigns have shown that ungulates are less sensitive to the openness factor [1,4], and even that the structure with the smallest openness factor had the biggest number of migrations [1]. Accordingly, the minimum dimensions for ungulate migration were specified in [3] as a minimum height of 3.6 m and a minimum width of 3 m, with an openness factor of 0.25.

Ref. [11] states that the grizzly bear (*Ursus arctos*) can adapt more at roads with stable traffic flow. The effect of noise on the migration of mammals was confirmed in [12].

In the following text, a methodology for noise measurement evaluation is established. This is followed by a description of the set-up of the experimental program. Noise measurement results for the studied bridges are presented in the form of equivalent

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and peak values, and are illustrated by noise frequency distribution diagrams, which lead on to further discussion.

2. Selecting the noise weighting functions

Special methods for evaluating noise measurements are needed in order to express human noise perception. Equal loudness contours were established for this purpose. Equal-loudness contours depict levels of acoustic pressure that are needed to induce the perception of equal intensity. The values are determined for frequencies within the human hearing range, approximately from 20 Hz to 20 kHz. The contours are given in Phon. Nowadays, decibels [dB] are used to describe the level of acoustic pressure. At a frequency of 1 kHz, the value for the acoustic level of a measured signal is the same in decibels and in Phon. The parameters of equal-loudness contours are defined in the ISO 226 standard [7]. Equal loudness contours are shown in Fig. 1. The dash–dot line represents the hearing threshold which is equivalent to an acoustic level of 0 Phon. Conversely, an acoustic level of 120 Phon is the pain threshold pressure, and is not drawn in the figure. The dashed lines are used for contours without enough experimental data for their verification. For a better understanding of human noise perception, it should be mentioned that amplification of the signal by 6 dB is perceived as twice as loud.

The so-called weighted sound pressure levels are used as filters in measuring instruments. Weighting functions A, B and C correspond approximately to the mirror image of equal-loudness contours of 40, 60 and 70 Phon. The implementation of these weighting filters provides an assessment of the measured values in subjective human perception.

The principle of frequency weighting is based on reducing or increasing the measured values for each frequency, depending on the chosen frequency weighting function. By this method, the different sensitivity of human hearing to different sound frequencies is introduced into the measurement. The A-weighting function is currently used to determine the impact of noise on humans. The C-weighting function is less widely used, mainly for measurements of impulse noises. Both weighting functions were used for evaluating the noise measurements described further in this paper. The main motivation for the noise measurements presented here is to determine the influence of the structural arrangement of bridges on the noise induced by traffic, and then on the use of underbridges for mammal migration. The hearing range varies for different wild mammals, as does the most sensitive hearing zone, which lies between 1 and 6 kHz for humans. The hearing ranges for various mammals are very hard to obtain, and not much relevant experimental data is available. It can be assumed that wild mammals can hear with higher sensitivity over the whole human hearing range. The hearing ranges and the higher sensitivity zones of selected mammals are introduced in Fig. 2.

The assumption of different auditory sensitivity of mammals leads to the use of the C-weighting function, which provides a different reduction of the measured values than to the widely used A-weighting function. The B weighting function derived for an acoustic level of 60 Phon is no longer used, and it is not discussed in the text. Weighting functions A and C are defined in European code EN 61672-1 [9] together with the Z function, which is the zero function and has no influence on the measured data. The Z weighting function is now replacing the former linear function *Lin*. The weighting functions are defined by the following equations, and are shown in Fig. 3.

$$R_A(f) = \frac{12\,194^2 \cdot f^4}{(f^2 + 20{,}6^2)\cdot\sqrt{(f^2 + 107.7^2)\cdot(f^2 + 737.9^2)}\cdot(f^2 + 12\,194^2)} \quad (1)$$

$$A(f) = 2{,}0 + 20\log(R_A(f))$$

$$R_C(f) = \frac{12\,194^2 \cdot f^2}{(f^2 + 20{,}6^2)\cdot(f^2 + 12\,194^2)} \quad (2)$$

$$C(f) = 0{,}06 + 20\log(R_C(f))$$

$$Z(f) = 0 \quad (3)$$

where $R_x(f)$ is the acoustic pressure for the given frequency f in Pa, and $X(f)$ is the value of the weighting function in dB.

The A-weighting function significantly reduces the measured values in the range of low frequencies below 1 kHz, as is shown in Fig. 3, and there is a smaller reduction for higher frequencies from 6.3 kHz. Conversely, in the mid ranges (1–6.3 kHz) corresponding to the maximum sensitivity of human hearing, the A function increases the measured values. The C-weighting function reduces very low frequencies below 0.2 kHz, and frequencies from 2.0 kHz are reduced more than when using function A. The advantage of the Z function lies in the possibility of modifying the measured values with other functions which the measuring instrument does not support. The objective of the constants in Eqs. (1)–(3) is to obtain a value of 0 dB for a frequency of 1.0 kHz.

A further factor influencing the measured values is the integration time of the measuring instrument, the so-called time weighting. Basically, there are three types of time weighting: fast (F), slow (S) and impulse (I). These weightings take into account the time for which the instrument is averaging the measured values: 0.125 s for fast weighting, 1.0 s for slow weighting, and 0.035 s for impulse weighting. It is important to choose the correct time weighting for different types of noise source, because the ordinary

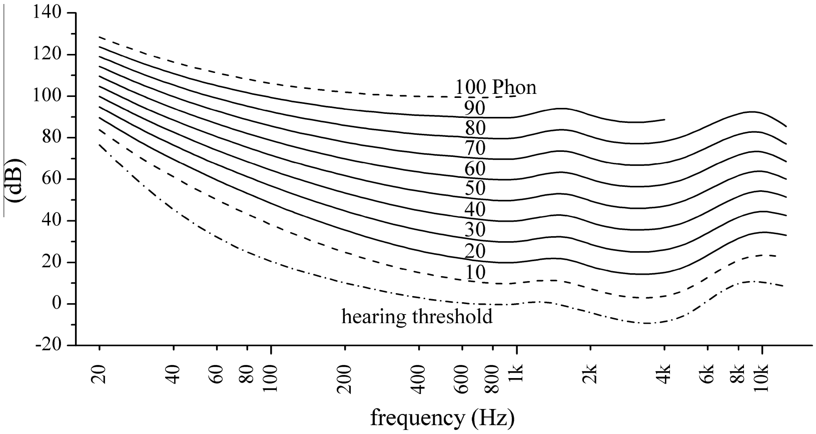

Fig. 1. Equal-loudness contours according to ISO 226 [7].