Vibrations of traffic, from the source to the recipient the problem of resonances

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Introduction

The prognosis and evaluation of traffic vibrations depend to a considerable degree on suitable models for the determination of the relevant evaluation values. With the propagation of vibrations, which are due to the railway or road traffic, always also structures are involved, which become lively in many cases with relevant resonant vibrations. Simple computer models in connection with many measuring data contributed in recent time to substantial improvements in the forecasts of vibrations with new planned traffic requirements or new developments.

From the source to the recipient

Between source and receiver the spreading oscillations go through different materials and structures, which become lively in very different extent resonant vibrations. The more the occurrence of resonances, the more difficult is the exact forecast of the behaviour of a structure relative to vibration. For this reason the building structures are, for example tunnels or houses concerned, of decisive importance in the context of a prognosis. In the context of an investigation for new traffic requirements in an existing development it is however impossible to analyse the structural dynamic of all concerned buildings in detail. Therefore a procedure is to be found, which supplies useful results at justifiable expenditure.

Semi-empirical model

The simplest way would be to determine out of a source spectrum by means of several factors (Q_x) according to formula (1) an immission spectrum and from this the relevant evaluation value, for example a KB value according to DIN 4150-2.

$$I = E \cdot Q_1 \cdot Q_2 \cdot Q_3 \cdot Q_4 \qquad (1)$$

(all factors as a function of the frequency (f))

I : Immission spectrum

E : Emission spectrum

Q_x: Transmission spectra

Q_1 : Surrounding of the source (substructure, tunnel, etc.)

Q_2 : Soil spreading (distance, soil type, layers)

Q_3 : Transition soil – building

Q_4 : Spreading inside the building

We concentrate here on the transmission spectra of Q_3 and Q_4.

In the context of a research project of the Austrian railways [1] Rutishauser Eng. developed and evaluated a data base from mostly own measuring data of over 200 buildings. By means of this data base it is possible to make statistical statements about the behaviour relative to vibration of different building types.

Figure 1 shows an evaluation of transmission spectra between a field measuring point in front of the house to a measuring point on a floor slab in the house. Important is the resonant frequency of the floor slab, here evaluated for all floors with resonant frequencies with approx. 20 Hz. For different resonant frequencies of floors other similarly running curves resulted.

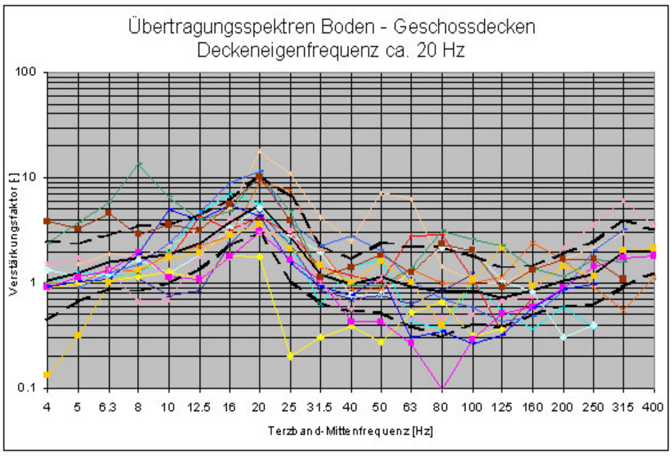

Figure 1: Transmission spectra for floors (E-frequ. Approx. 20 Hz) with average value and standard deviation [1]

From the multitude of research data some characteristic values resulted, by which the spectra can be significantly differentiated:

- Mass of the building (and foundation soil)
- Primly eigenfrequency of the floor
- Building material (concrete construction, timber construction)

These characteristic values should be known for each house in question. Then the appropriate transmission spectra can be determined due to the data base. The partial strongly strewing measuring data in the data base were replaced by smoothed and standardised functions (e.g. fig. 2 and 3). If the characteristic values are not known, all possible transfer functions are calculated according to formula (1) and the transmission-functions according e.g. fig. 2 and 3. From this we get the „worst case".

Figure (2) shows the determined and used transmission spectrum between one point at the surface directly in front of the house and one point at the building foundation.

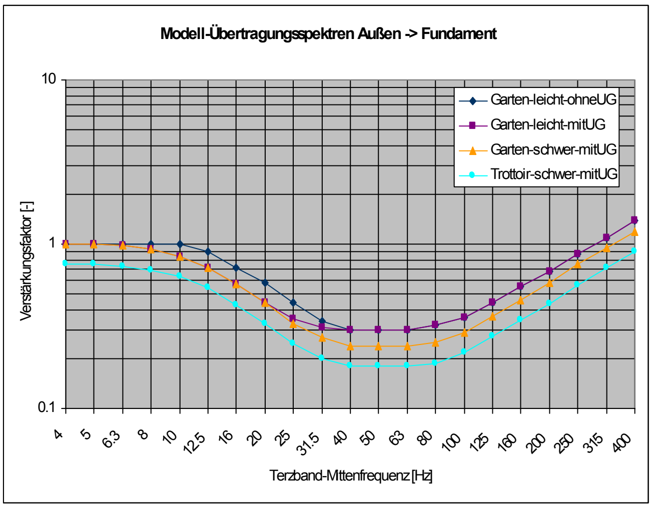

Figure 2: Model - transmission spectra between field outdoor and foundation of light and heavy buildings [1]

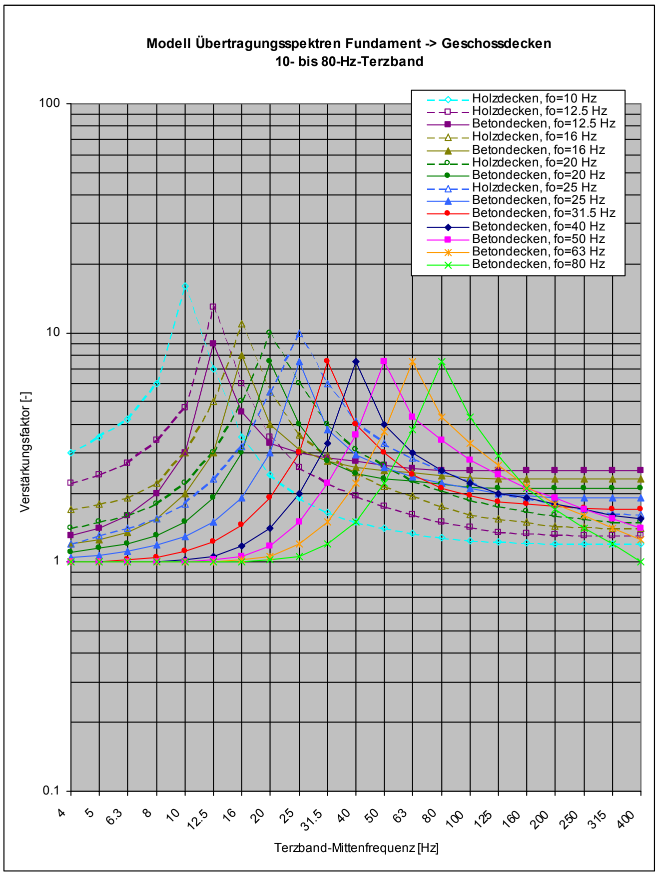

Figure 3: Model transmission spectra between foundation and floor for different floor resonant frequencies [1]

Figure (3) shows the different spectral transfer functions for houses with wood and concrete floor slabs in dependence to the resonant frequency of the floor. This resonant frequency can be determined in many cases at justifiable expenditure:

1. For existing buildings by a simple natural frequency measurement on the floor
2. For new a building by a structure-dynamic calculation

Less well to determine however are the higher resonant vibrations and the damping of the floor slabs themselves. Here the spectral transfer functions won from the data base do a good job. The data base is maintained continually and the prognosis model is gradually improved.

Proceeding during a new highway covering

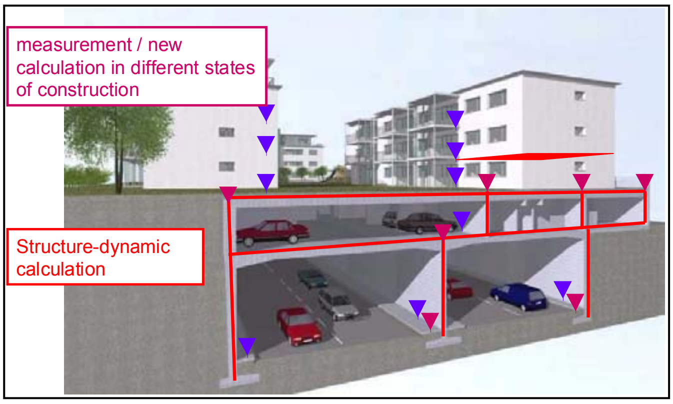

Figure 4: Highway covering with direct development, proceeding with typical measuring points

For the project of a new highway covering the following proceeding (Fig. 4) worked in the best way:

1. Structure-dynamic calculation of the tunnel and the buildings with determination of the relevant resonant frequencies
2. Influence on the static system and construction of the loadbearing structures
3. Preventive design of measures relative to vibrations in variants
4. Vibration measurement in different states of building construction
5. Decision about the measures to be taken regarding the results of measurement and the revised prognoses at the latest possible moment

The special measures relative to vibration needed little effort and the construction costs only increased by a few percent.

The high requirements for comfort of the investor could be fulfilled owing to this proceeding. The traffic vibrations are not noticeable in the houses and the secondary airborne sound is hardly audible. It lies on the average of all trucks going past under L_{max} = 30 dB(A).

References

[1] Rutishauser G., Egger A., Ausbreitung von Schwingungen und sekundärem Luftschall in Gebäuden. Arbeitsgruppe Lärm- und erschütterungsarmer Oberbau (LEO); Paket 3b; Schlussbericht; ÖBB, BEG, HL-AG, Januar 2003 (not published)