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Numerical prediction of interior noise levels in buildings, generated by ground vibrations

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Abstract

Suburban trains, underground and other rail-bound vehicles are expected to play an increasing role in future urban traffic systems. Nevertheless, these vehicles can represent a considerable noise impact on the environment which is difficult to tackle, since ground-borne vibration components often play a dominant role in the propagation. Most often the design of new urban railway lines in a built-up environment or, in other cases, the design of new buildings in the vicinity of existing railways, is based on measurements performed under similar propagation conditions from track through soil to buildings. To the authors' knowledge, no well-established design methods for prediction of ground-borne noise components and their control are readily available.

The difficulties in developing such methods are numerous. Ground vibrations are propagating in form of compression, shear and surface waves, interfering with each other and strongly dependent on local (and mostly inhomogeneous) soil properties. Even if the excitation can be characterised by means of ground vibration measurements at the place where the a new building is to be built, the reaction of the would-be building on, and its interaction with, the ground is rather difficult to predict. Numerical methods can be used, but the computational requirements are high, the frequency range of application is limited to low frequencies and the obtained results are highly dependent on assumptions which are difficult to verify.

The aim of the paper is to explore the possibilities and limitations of standard vibro-acoustical prediction and development tools, i.e. structural Finite Element and acoustic Boundary Element methods as well as experimental modal analysis techniques, to identify the vibro-acoustical behaviour of buildings excited by ground vibrations. A relatively simple and light-weight test building was selected as subject of a verification investigation, consisting of an outer steel beam framework structure and a relatively small, 3-storeyed masonry part. The building was modelled by means of standard structural FE methods, as shown in Fig. 1. below. The eigenmodes were extracted and forced response calculations performed, by assuming various ground constraints and hypothetical input force distributions.

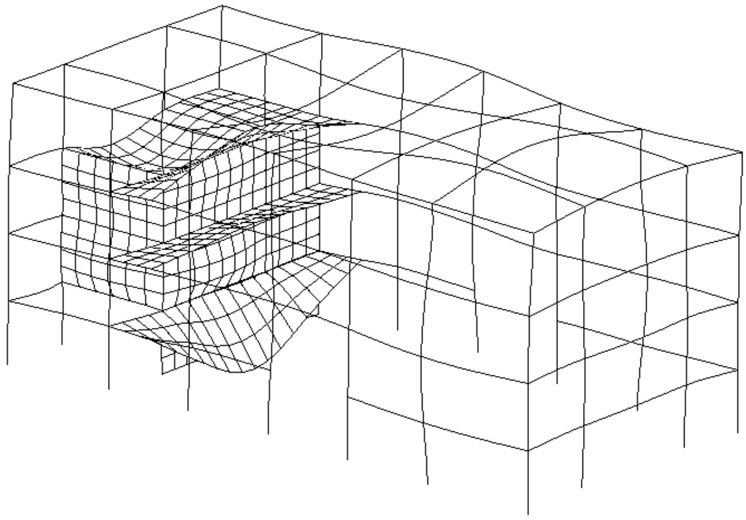

Figure 1: Calculated mode shape of a test building, used for parallel Finite Element calculations and experimental modal analysis tests

On the basis of some preliminary calculations, 50 or so measurement positions were selected along the masonry part and at key nodes of the steel beam structure. The vibration of these points were measured, while the building was excited by a heavy lead sack dropped from 2 m height on the ground at 20 m distance from the building. The response acceleration signals were recorded on an 8-channel instrumentation recorder and processed subsequently by using an LMS CADA-X data acquisition system and modal analysis software package.

The measured vibration characteristics can be used to compare with numerical predictions, to update the FE calculations which in turn can serve as a structural data base for the final BE calculations.

The evaluation of the measurement data and the acoustical calculations are in progress at the time of preparation of this manuscript. The obtained results and conclusions will be given in the oral presentation of the paper.