The Use and Validation of Measured, Theoretical, and Approximate Point-Load Solutions for the Prediction of Train-Induced Vibration in Homogeneous and Inhomogeneous Soils

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The layered soil is calculated in the frequency wavenumber domain and the solutions for fixed or moving point or track loads follow as wavenumber integrals. The resulting point load solutions can be approximated by simple formula. Measurements yield the specific soil parameters for the theoretical or approximate solutions, but they can also directly provide the point-load solution (the transfer function of that site). A prediction method for the train-induced ground vibration has been developed, based on one of these site-specific transfer functions. The ground vibrations strongly depend on the regular and irregular inhomogeneity of the soil. The regular layering of the soil yields a cut-on and a resonance phenomenon, while the irregular inhomogeneity seems to be important for high-speed trains. The attenuations with the distance of the ground vibration, due to point-like excitations such as vibrator, hammer, or train-track excitations, were investigated and compared. All theoretical results were compared with measurements at conventional and high-speed railway lines, validating the approximate prediction method.

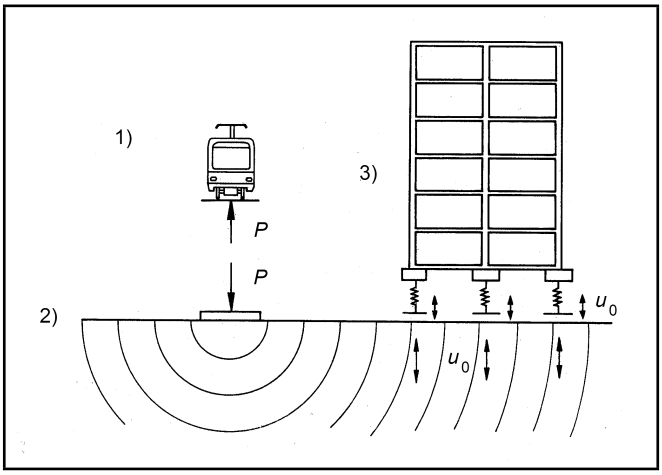

Figure 1. Emission, transmission, and immission of ground-borne vibration; the separation of the three parts of the prediction of railway induced vibration.

1. INTRODUCTION

The prediction of railway-induced vibration consists of the following aspects, as seen in Fig. 1. The emission of vibration includes the vehicle-track-soil interaction, the vehicle and track irregularities, and the dynamic axle loads.[1] The transmission of waves through layered soils constitutes the second part, and the immission concerns the transfer of vibration from the soil to the building.[2] This contribution is concentrated on investigating the transmission component, the influence of the layering and the damping of the soil on the vibration amplitudes, and their characteristic variation with the frequency of excitation and the distance from the track.

The dynamic problems of layered soils can be calculated in the frequency-wavenumber domain.[3,4] The transfer function for the propagation of waves through a layered soil is obtained by an (infinite) integral over the wavenumbers.[5,6] This wavenumber integral method has also been applied to moving forces.[7–14] These methods are specially used for high-speed trains, if the train speed reaches the wave velocity of a very soft soil. For normal train-soil situations, some simplifications of the complete methods are possible.

Simplified rules and models have been established from the results of the detailed models and from experimental experience. These have been integrated in a unique, consistent, prediction scheme.[15] Simple models are necessary to get short computer times, and, most importantly, to get a simple input with only a few relevant parameters. Therefore, a complete prediction of railway vibration is available for specialists and non-specialists. Other simplified prediction schemes, for example,[16,17] are often not so complete, namely because their transmission parts comprise only transfer functions related to a reference vibration amplitude v_0. A full transmission prediction needs a transfer function related to the excitation force F to properly incorporate the different responses of different soils. The excitation force between the track and the soil is the link between the emission and transmission parts of the prediction, and it is calculated by the analysis of the vehicle-track-soil interaction. The emission model should include the soil under the track[1] (see reference[18] for a counterexample, and see reference[19] for the correction).

Another simplified but complete prediction scheme has been developed[20] and is now part of the official prediction method of the US.[21] One of the simplifications is the use of fixed instead of moving loads, which has recently been verified.[22] The central part of the prediction is a specific experimental transfer function for a train load. The prediction of this contribution is