The influence of the track on railway induced ground vibration

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Introduction

A combined boundary – finite element method had been developed to calculate the vibrations of different flexible or rigid structures on the soil [1]. Railway tracks have been thoroughly investigated by this method [3]. It is shown what are the effects of *additional concrete plates* (slab track for example) and *additional elastic elements* such as rail pads and ballast mats on dynamic loads and ground vibration.

Railway induced ground vibrations have been measured at many places during the last two decades [2],[3],[4]. Some experimental results are shown to prove the theoretical consequences and to demonstrate the influence of the track on the ground vibration.

Dynamic vehicle-track-soil interaction

Irregularities s of the wheel and the track excite vibrations of the vehicle and dynamic axle-loads which are the cause of ground vibration near railway lines. The dynamic loads are found by solving the interaction problem of vehicle, track and soil. First, the compliance of different tracks on different soils are calculated by use of the FE-BE method and afterwards they are coupled with a simple vehicle model [4].

The resulting force P_S which acts on the soil is related to the nominal vehicle force $P_V = m_W\omega^2 s$ for a rigid track. These transfer functions P_S/P_V (Figures 1 to 3) start at 1 and display the vehicle-track eigenfrequency, which clearly depends on the stiffness of the soil for the *ballasted track* (Figure 1). The eigenfrequencies are highly damped due to the radiation into the soil. For *slab tracks*, the vehicle-track resonance depends on the soft rail pads (Figure 2). We get lower resonance frequencies and higher resonance amplitudes. For a track with a *plate under the ballast*, the high-frequent resonance at 90 Hz is amplified due to the reduced radiation damping (Figure 3). Tracks with a *ballast mat* have a low-frequent vehicle-track resonance and a considerable reduction of amplitudes at high frequencies. *A plate under the ballast mat* – as well as a stiffer soil - makes no difference in this reduction effect (Figure 3).

Measured vehicle and ground vibration

The measured accelerations of the wheel at a slab and a ballasted track verify the theoretic results. Whereas for the ballasted track in Figure 4, the speed dependent sleeper-passage frequency is dominant with maximum amplitudes at 80 Hz for 160 km/h, the vehicle-track resonance of the slab track at 64 Hz is much more pronounced (Figure 5). The same differences between ballasted track and slab track can be found in the ground vibrations (Figures 6 to 8). At low frequencies, we have lower amplitudes of the slab track (Figure 8), at high frequencies, we have higher amplitudes of the slab track. The differences of the ground vibration of different trains (Figures 6 and 7) are characteristic and agree well with theory, but they are small compared to the very strong differences between the ballasted and the slab track (Figures 7 and 8).

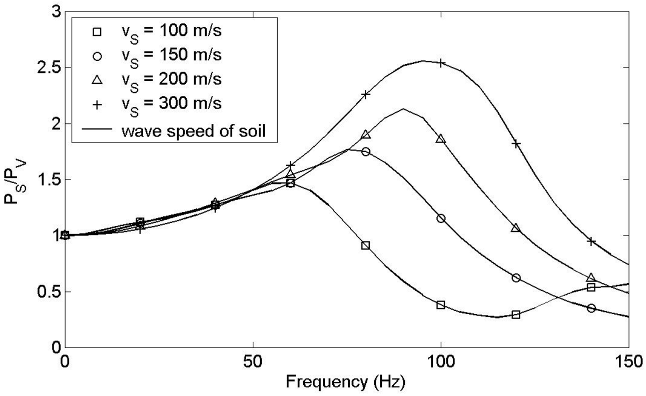

Figure 1: Transfer functions P_S/P_V of a wheel mass m_W = 1500 kg on a ballasted track on different soils.

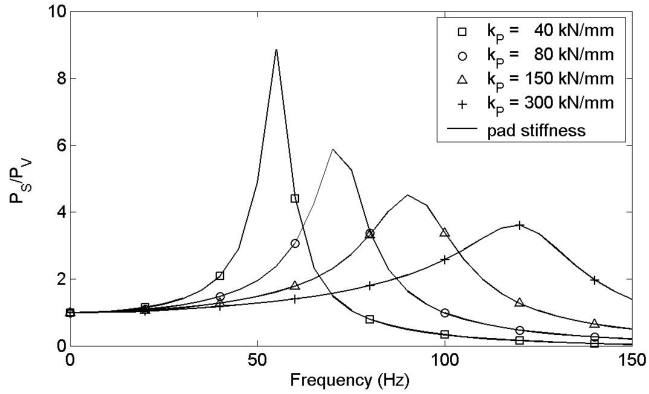

Figure 2: Transfer functions P_S/P_V of a wheel mass m_W = 1500 kg on slab tracks with different rail pads.

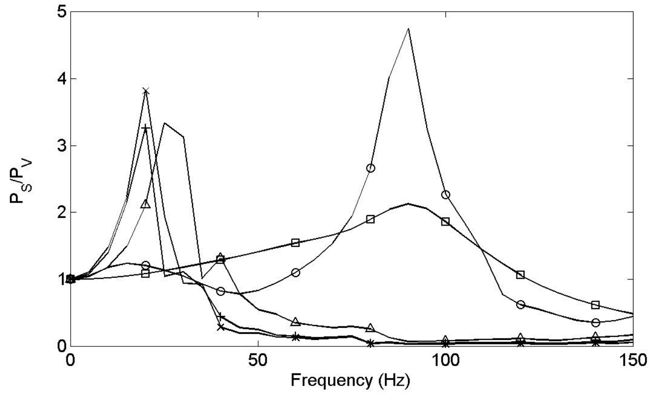

Figure 3: Transfer functions P_S/P_V of different ballasted tracks: ☐ standard, O with plate under ballast, Δ with ballast mat, + with soft ballast mat, X with plate under ballast mat

References

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[2] L. Auersch: Wave propagation in layered soil: theoretical solution in wavenumber domain and experimental results of hammer and railway traffic excitation. Journal of Sound and Vibration, 173, p. 233-264, 1994

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[4] L. Auersch, S. Said, W. Rücker: Das Fahrzeug-Fahrweg-Verhalten und die Umgebungserschütterungen bei Eisenbahnen. BAM-Forschungsbericht 243, Berlin, 2001

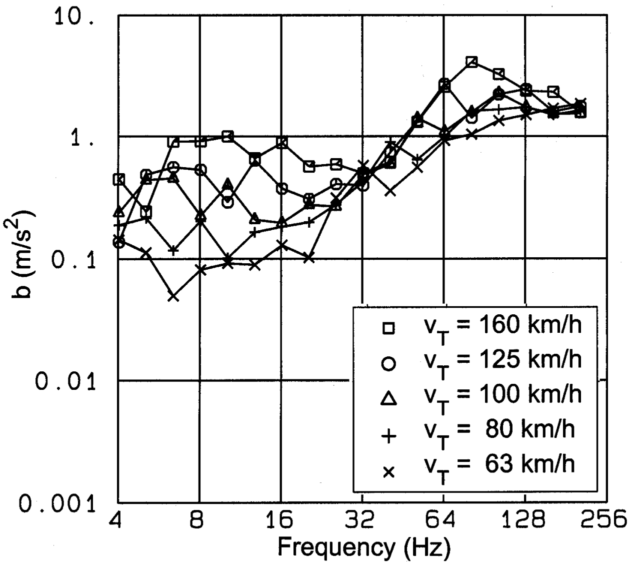

Figure 4: The acceleration of the wheel measured at different train speeds on a ballasted track.

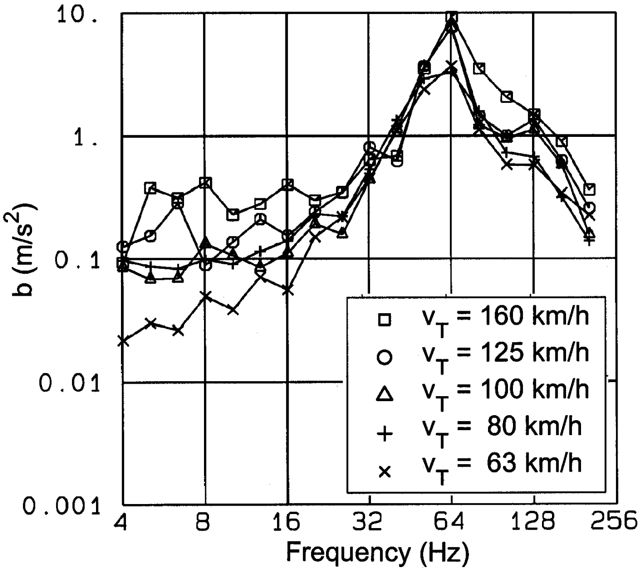

Figure 5: The acceleration of the wheel measured at different train speeds on a slab track.

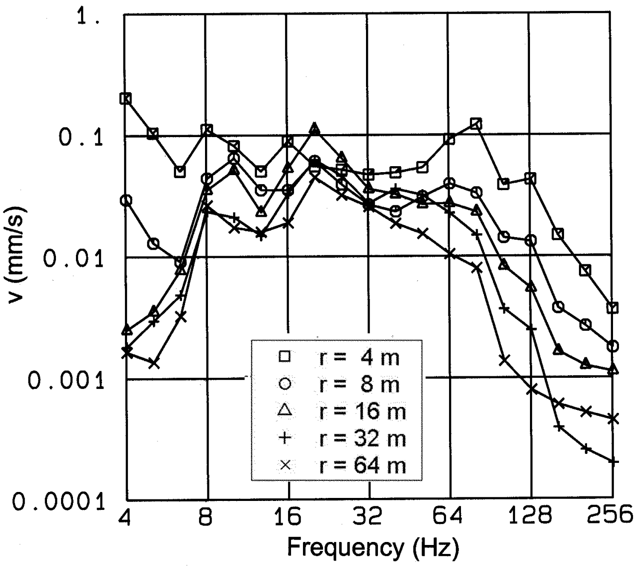

Figure 6: The ground vibration measured at different distances from a ballasted track, train^1 with $v_T = 250$ km/h.

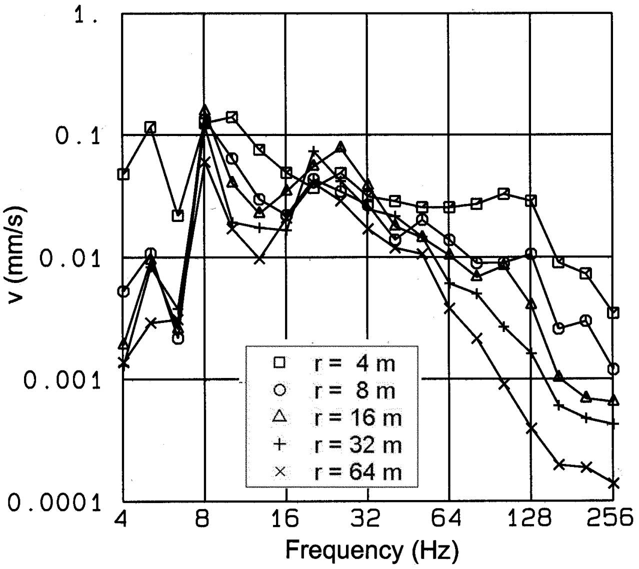

Figure 6: The ground vibration measured at different distances from a ballasted track, train^2 with $v_T = 250$ km/h.

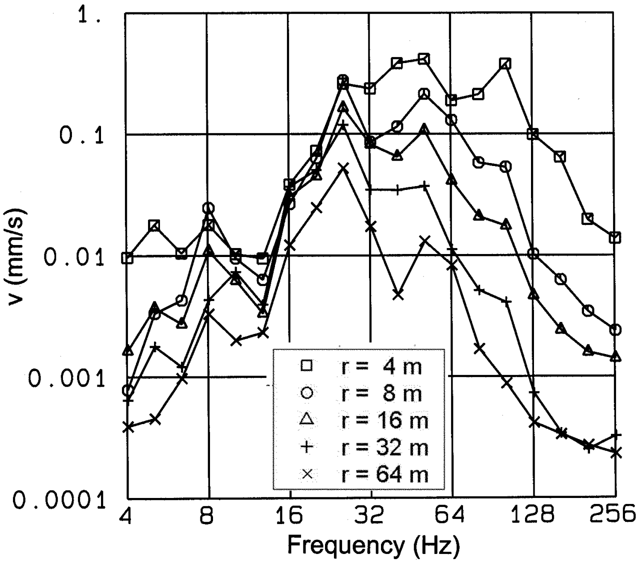

Figure 6: The ground vibration measured at different distances from a slab track, train^2 with $v_T \approx 250$ km/h.