Effectiveness of vibration preventive measures with consideration of modified properties of trainsets

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Introduction

Railway tunnels must be equipped frequently with measures to reduce structure-borne noise, if dwelling-houses or other sensible facilities lie neighbouring. In this context the installation of ballast mats, constructed in accordance with [1] is one of the well-proven technical solutions. The effectiveness of the respective preventive measures, i.e. their insertion loss, presents itself basically as function of the so-called unsprung mass of the wheelset and the dynamic stiffness of the ballast mat in comparison with the ballast stiffness (see for example [2]). The expected insertion loss therefore implies a certain assumption towards the properties of the relevant trains, i e. the unsprung mass of the wheel set, that is typically derived from long-time experience. In this context actual technical developments indicate a general tendency to light-weigt constructions of trainsets, that demands to analyze the corresponding effects on the effectiveness of mitigation measures. By the example of a rapid-transit railway tunnel in the proximity of Munich measured and calculated values of the insertion loss of ballast mats are represented.

Results of measurements and evaluations

As basis for the prediction of vibrations in the neighbourhood of the planned tunnel, 1/3-octave-band spectra were measured in an existing tunnel with ballasted track as well in a section without as in a section with ballast mat (Sylomer C 340). Figure 1 shows the difference between both measurements (■) and gives a qualitative picture of the effectiveness of the ballast mat expressed as insertion loss. Quantitatively the comparison can contain uncertainties, which result e.g. from the comparatively large distance of the measuring points and corresponding deviations of the reaction of the tunnel construction to the structure borne excitation.

The originally expected insertion loss has been calculated by an unsprung wheel set mass by M = 3000 kg and a dynamic stiffness of the ballast mat of $s_M'' = 0{,}035$ N/mm^3. According to the well-known relationship (e.g. [1]) the expected insertion loss can be calculated. The calculated curve (♦) is presented in Figure 1 as well.

$$\Delta L_e = 20\lg\left|1+(j\omega/s_M)/(1/Z_i+1/Z_a)\right| \tag{1}$$

where:

ΔL_e :	insertion loss
j :	imaginary unit
ω :	radian frequency
s_M :	stiffness of the ballast mat
Z_i :	input impedance
Z_a :	terminating impedance

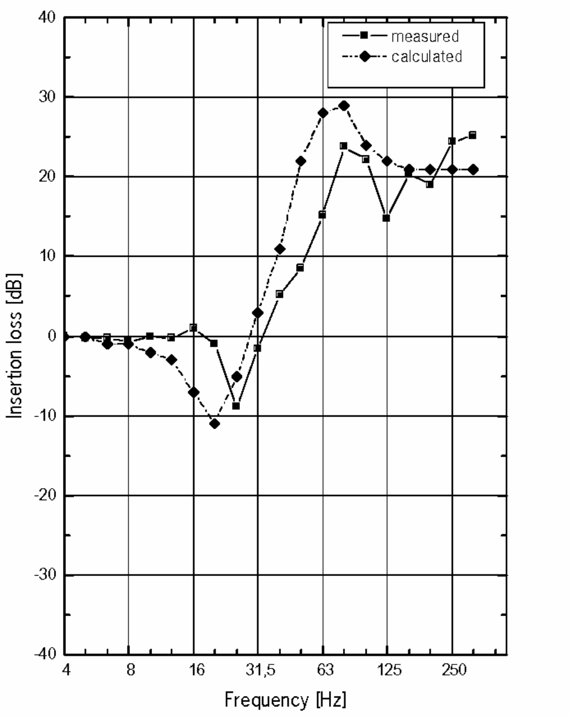

Figure 1: Measured and calculated (M = 3000 kg, $s_M'' =$ 0,035 N/mm^3, ballast stiffness $s_S = 5 \cdot 10^8$ N/m (1+j0,5)) insertion loss of the ballast mat, type Sylomer C 340 in a rapid-transit railway tunnel near Munich.

The measured values in Figure 1 compared to the expected behavior indicate a shift of the natural (eigen-)frequency from approximately 20 Hz towards 25 Hz according to one 1/3-octave-band. Causes for this effect could on the one hand be derived from a change of the ballast mats dynamic characteristics. Otherwise recent investigations [2] even at substantially older mats demonstrate a remarkable long-term stability of the ballast mat material. On the other hand the current substitution of the Class ET 420 trainsets, that had been used without any essential technical modifications over three decades, had been substituded by a modern trains of the Class ET 423. A comparison of the overall weight of both trainsets indicate a light-weight construction of the ET 423 (length = 67,4 m; total weight = 129 tons; 192 seats) compared to the ET 420 (l = 67,4 m, m = 153 tons; 192 seats).

A further indication results from a comparison of the structure-borne noise measured 8 m adjacent to the track center based on a measuring point where the new trains, Class ET 423 and residual of Class ET 420 passed by concurrently (above-ground ballasted track). Figure 2 shows a significant decrease of the exitation maximimum for the ET 423 (■) opposite to the ET 420 (♦), connected with a widening of the excitation spectrum to higher frequencies -

also this a reference to reduced dynamic loads in case of the ET 423.

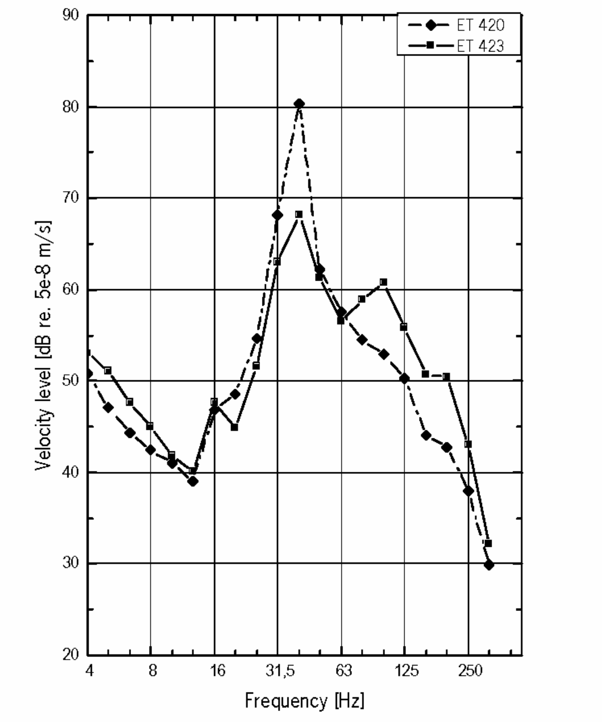

Figure 2: Structure-borne noise measured 8 m adjacent to the track center for trainsets, Class ET 420 and ET 423.

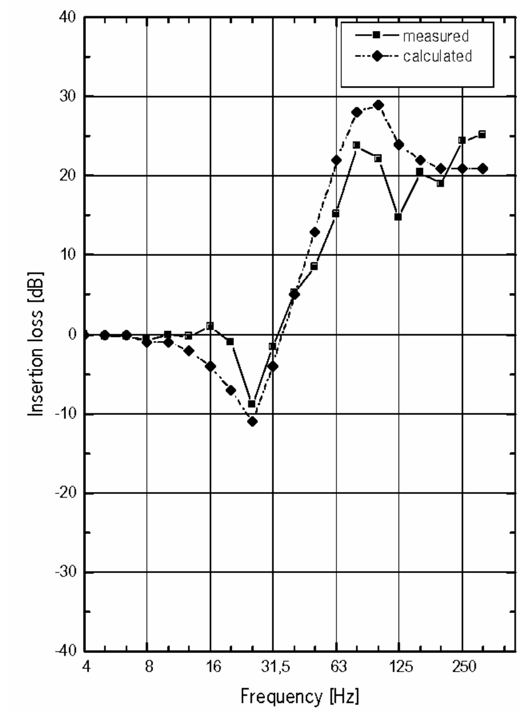

Figure 3: Measured and calculated (M = 2000 kg, s_M'' = 0,035 N/mm^3, ballast stiffness s_S = 5 • 10^8 N/m (1+j0,5)) insertion loss in a rapid-transit railway tunnel near Munich.

Referring to the unsprung mass of the wheel set, the rise of the natural frequency from $f_R \approx 20$ Hz to $f_R \approx 25$ Hz (= 1/3-octave-band = 1,25/1) corresponds according to the relationship (2):

$$f_R \approx \sqrt{s_M / M} \, / \, 2\pi \qquad (2)$$

to a decrease of the unsprung mass of the wheel set of M = 3000 kg / 1, $25^2 \approx 2000$ kg (s_M = const.).

The calculation of the insertion loss from this value and a dynamic stiffness of the ballast mat of s_M'' = 0,035 N/mm^3 shows remarkable good agreement with the measured values as depicted in Figure 3:

Conclusions

The influence of different values of the unsprung wheelset mass on the insertion loss of vibration preventive measures has previously been reported in other proceedings (e.g. [3]), however the criterion of the technical advancement of trainsets so far no large attention was given. The presented results show an increase of the natural frequency of the investigated preventive measures in a range, where the resonant frequency of concrete ceilings could be met. Ongoing measurements and calculations related to the tunnel project in discussion here indicate only a few buildings, where the effect results in a noticeable deterioration of the effectiveness of the measure. Anyhow the possibility of changing trainset-characteristics should be considered in predicting the insertion loss of vibration preventive measures, in some cases bringing about the necessity of highly effective measures e.g. ballast mats of extremly low dynamic stiffness in relation to the static stiffness as per [1] or the application of mass-spring-systems.

References

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