LOW FREQUENCY AIRBORNE NOISE IN THE VICINITY OF RAILROAD TRACKS

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1. INTRODUCTION

No general criterion is available for the assessment of low frequency sound. Firstly, one must distinguish between inaudible (infra) and audible sound. Secondly, additional criteria for nuisance or annoyance most certainly require a consideration similar to the "normal" range of sound, e.g. pure tone, impulsiveness, etc. For the special case of low frequency sound immission in buildings during underground train passages - a rather common problem - a rating criterion is proposed as outlined in the following.

2. Different thresholds

The passage of an underground train causes ground vibrations. They are transmitted to the adjacent buildings. The building vibrations may be feelable at walls and from ceilings. In addition, the vibrating surfaces radiate airborne sound. A part of the radiated sound which belongs to the frequency range above 30 Hz is generally audible when the vibration is above the feeling threshold. But even for rather weak vibrations below the feeling threshold, the radiated sound may be audible and may cause annoyance. In the frequency range below 30 Hz, the opposite may occur. Vibrations above the feeling threshold may not be audible and sound is then no cause of annoyance.

3. Frequency characteristics

In most cases the frequency range of strongest building vibrations observed during train passages is the octave-band centered at 63 Hz (see fig. 1). Weaker vibrations can be observed at frequencies up to 250 Hz. Low frequency
vibrations at and below 30 Hz are mostly due to rail switches or joints and to ceiling resonances of the building (see fig. 2). For these spectral components, radiated noise causes no annoyance unless the feeling threshold is exceeded. Since criteria are set for vibration signals (in DIN 4150, VDI 2057, ISO 2631) there is no need for further consideration of the frequency range below 30 Hz. However, annoyance from signals in the 63 Hz octave-band is mostly related to airborne sound, rather than vibration which is way beyond the feeling threshold.

4. Radiated sound

Measurements have shown that vibration levels of ceilings are considerably higher than those of walls (about 10 - 15 dB). Thus, most of the sound is radiated from the ceilings and the sound pressure level $L_p$ can be calculated from

$$L_p = L_v - 10 \lg \frac{A}{4S} + 10 \lg \delta \quad \text{(1)}$$

where $L_v$ denotes the level of vibration velocity, $S$ is the total area of floor and ceiling, $A$ is the room absorption and $\delta$ is the radiation efficiency. In the frequency range above 63 Hz, one may assume $\delta \approx 1$. The error is generally less than 3 dB. Even for concrete ceilings, measurements have shown that $\delta \approx 0.5$ at 63 Hz (see fig. 3).

The next step toward a simplified relation between $L_v$ and $L_p$ is based on numerous measurements indicating that in typical dwellings (living and bedrooms) the room absorption $A$ is related to the floor area $S$ by $A \approx 0.8 S$. Neglecting the radiation from walls and setting $S = 2 G$, one obtains from equation (1):

$$L_p = L_v - 10 \lg \frac{0.8S}{4 \times 2G} = L_v + 10 \text{ dB} \quad \text{(2)}$$

The vibration level $L_v$ is referred to $5 \cdot 10^{-8}$ m/s and the sound pressure level to $2 \cdot 10^{-5}$ Pa.

5. Potential criteria

The assessment of annoyance from underground trains may be based on:

a) Vibration signals exclusively

Since weak vibrations may not be feelable (10 dB below threshold) but audible in the frequency range at and above 63 Hz, this concept is insufficient.

b) A-weighted overall sound pressure level

It is well known from measurements that the annoyance of
secondary airborne sound from underground trains is mostly due to contributions in the frequency band below 100 Hz, while higher frequency components are overestimated by A-weighting. Overall A-weighted levels of typically 35 to 40 dB(A) do not correspond to the actual annoyance (see fig. 4).

c) A-weighted octave-band level at 63 Hz

This criterion avoids the disadvantages described above. However, there are serious drawbacks from considerable problems to distinguish between measurements of rail traffic and other noise sources.

6. Proposed criterion

Based on a maximum permissible A-weighted octave-band sound pressure level of 35 dB(A) at 63 Hz (corresponding to an unweighted octave-band level of 35 + 26 = 61 dB) it is proposed to set a criterion for underground trains in terms of the vibration level, which follows from eq (2) as:

\[ L_V(63 \text{ Hz - oct.}) = L_p - 10 \text{ dB} = 60 - 10 = 50 \text{ dB} \]  

(3)

This octave-band vibration level corresponds to an average velocity of 5 \( \times \) 10^{-5} m/s.
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**FIG. 1**
TYPICAL FREQUENCY CHARACTERISTIC DUE TO AN UNDERGROUND TRAIN

**FIG. 2**
HIGH LEVELS AT FREQUENCIES BELOW 30 HZ DUE TO SWITCHES AND JOINTS

**FIG. 3**
RADIATION EFFICIENCY $\eta$ OF A CONCRETE CEILING

**FIG. 4**
OVERESTIMATING OF FREQUENCIES ABOVE 63 HZ BY $A$-WEIGHTING