The determination of railway vibrations levels in practice

Invited paper

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• Effects in humans and on sensitive equipment
• Measurement procedures and requirements
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• A realistic $H_{\text{building}}$ transmission factor
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Introduction

Vibration of trains

Propagation in the ground

How to take measurements?

Disturbance due to other activities

What is $H_{\text{building}}$? (Vibration Energy Transfer in the Building itself)
Excitation mechanism for noise and vibrations

- Wheel roughness
- Rail roughness
- Rail and fasteners/sleepers discontinuity impedances
- Discontinuities of the wheel (flats)
- Discontinuities of the rail (joints and switches)
- Differential slip
- Lateral slipping
- Rubbing of wheel flange
- Semi static movement of a heavy mass

Wheel/rail interaction

- Wheel receptances
- Rail receptances

Carriage response

- Bogie response
- Wheel response

Bogie radiation

- Wheel radiation

Track forces

- Track response
- Ground response

Ground radiation

Propagations

- Propagation in the ground
- Propagation measured at wayside
- Vibration measured at wayside
- Vibration in buildings
- Radiation of wall, floor and ceiling

Noise propagation

- Noise propagation in air

Vibration measured at wayside

Structure born noise
The vibration source
The sensitivity curves for humans on vibrations of floors and on low frequency structure-borne noise

![Graph showing sensitivity curves for vibrations and noise levels](image)

- **Perceptible vibration**
- **Noise 35 dB(A)**
- **Noise 75 dB(G1)**
- **Limit of perception**

**Frequency range for perceptible vibrations**
**Assumed frequency range for audible LF noise**

Vibration velocity level in dB re 1 nm/s
Vibration velocity in mm/s

Frequency in Hz

Vibration levels range from 60 dB to 160 dB, with corresponding vibration velocities ranging from 0.001 mm/s to 1000 mm/s.
Two possible methods of doing measurements

**Method number 1**
- Measuring for a period of at least a week in the dwelling in the living room and in the bedrooms
- Room with the highest level is representative

**Method number 2**
- Measuring for a period of at least a week at the foundation of the building
- Measure for at least for 24 hours vibration energy transfer from the foundation to measurement points in the dwelling
- Calculate the level in the various rooms
- Room with the highest level is representative
Dutch Policy Regulation on Vibration Nuisance of Trains

Determination of the highest vibration level representative for a week.

Method to capture the representativeness.

• Too short measured >> surcharge on the results
  or
• Too much variation in heavy passages (e.g. one outlier per week) >> surcharge on the results
Measurement set-up to determine the vibration of trains.
Practical aspects

Which room, which floor and which position on the floor has the highest vibration level

Measurement on floors (carpeting, parquet or floating floor) effect on load on the floor (humans/furniture)

Disturbance of the vibration level or vibration of other sources
Example of the database of all the events
A random example of an event
A random example of an event of a freight train
And another event with disturbance ....
The vibration source

Where is the predominant vibration source located?

- Road crossing / bridge / switch / others
Histogram of vibration levels

Measurements in a bedroom
1243 trains
Passenger and freight trains
Measured transmission factors for massive building structure
Measurement results of continuous and non-continuous vibrations

Transfer between foundation and floor [dB]
1/3 octave [Hz]

Wijnia - Continuous vibrations
Assumption for non-continuous vibrations
Measurement results
only dwellings with a massive building structure (blue)
only light structural dwellings (orange)

The maximum of recent measurements in light structural dwellings (for non-continuous vibrations)
The maximum of recent measurements in heavy constructive dwellings (for non-continuous vibrations)

The recent measurements are only in octaves as the guideline prescribed
An overview of all the $H_{\text{building}}$ values

The recent measurements are only in octaves as the guideline prescribed.

![Graph showing transfer between foundation and floor in dB for different conditions](image)

- **Wijnia - Continuous vibrations**
- **Assumption for non-continuous vibrations**
- **Heavy constructive dwellings (for non-continuous vibrations)**
- **Light structural dwellings (for non-continuous vibrations)**

1/3 octave / octave [Hz]
Summery and conclusions

Vibration nuisance caused by railways
- feasible vibrations for a human being
- low-frequency noise produced by vibrations
- an overlap audible noise and perceptible vibrations

The guideline where you have to measure
- some of the floors of a dwelling
- a point on the foundation of the building

Disturbances by
- activities of people living in this building
- other road traffic
Summary and conclusions (2)

However, determining the strength of the vibrations and the strength of the accompanied low-frequency noise somewhere in the building is particularly complex.

More generally: Is measuring in a dwelling realistic?

Best practice:
• Take measurement on the foundation of the building
• Using a predetermined realistic $H_{\text{building}}$ transmission factor, practical values for the strength of vibrations and low-frequency noise will be determined
Further investigation

A theoretical exercise is needed to determine if the assumptions for $H_{\text{building}}$ are reliable for different types of dwellings.

For example:

- Piled buildings with concrete floors
- Piled buildings with wooden floors
- Non piled buildings with wooden floors
- Multilayer apartments and offices

Result: A better determination of the vibration strength and structure-born low frequency noise level.
Thank you for your attention

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