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Acoustics I: building acoustics

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introduction

introduction

- building acoustics $\rightarrow$ noise abatement in buildings (suppression of noise from neighbors)
- annoying sound is usually transmitted by vibrations of the building structure and then radiated by walls or ceilings
- excitation of these vibrations:
  - airborne sound sources such as e.g. voices, loudspeakers
  - structure borne sound $\rightarrow$ vibration sources such as e.g. footsteps

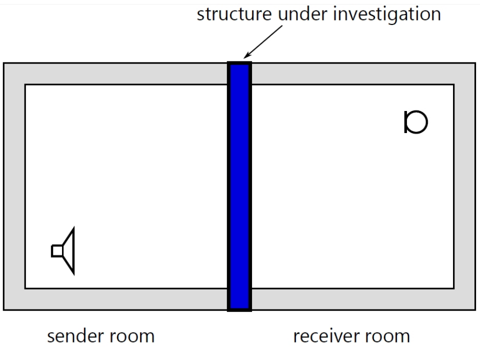
introduction

- property of a structure to suppress airborne sound transmission $\rightarrow$ **airborne sound insulation**
- property of a structure to suppress structure borne sound transmission $\rightarrow$ **impact sound insulation**

airborne sound insulation

airborne sound insulation

experiment:



airborne sound insulation

- sound insulation index R (independent of the test object area):

$$R = 10 \log \left(\frac{P_1}{P_2} \right) \qquad [\mathrm{dB}]$$

where
P_1: incident sound power on the sender side
P_2: sound power that is radiated by the rear side of the structure

airborne sound insulation

- measurement of R:

$$P_1 = \frac{\frac{p_1^2}{\rho c}}{4} S$$

p_1: diffuse field sound pressure in sender room
S: area of the structure under consideration

$$P_2 = \frac{\frac{p_2^2}{\rho c}}{4} A_2$$

p_2: diffuse field sound pressure in receiver room
A_2: total absorption of receiver room $= 0.16 V_2 / T_2$

airborne sound insulation

from above follows:

$$R = 10\log\frac{p_1^2}{p_2^2} + 10\log\frac{S}{A_2}$$

and finally:

$$R = L_1 - L_2 + 10\log\left(\frac{S}{A_2}\right) \qquad [\mathrm{dB}]$$

with:

L_1: average sound pressure level in the sender room (in third octaves)

L_2: average sound pressure level in the receiver room (in third octaves)

airborne sound insulation

- sound insulation index R is frequency dependent
- rated sound insulation index R_w: single value obtained by weighting of the frequency response with a reference curve

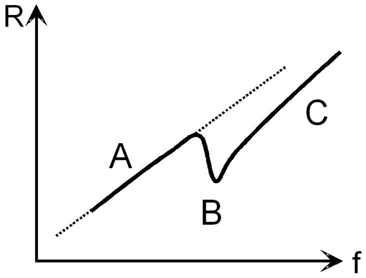
sound insulation of single walls

sound insulation of single walls

- for plates, R depends on:
  - area specific mass m''
    - thickness
    - density
  - modulus of elasticity
  - frequency

sound insulation of single walls

typical frequency dependency of R:



domain A mass law: $R = 20\log(f \cdot m'') - 47 \quad [\text{dB}]$

domain B coincidence collapse f(ϕ):

$$\lambda_{\text{bending:wave:plate}} = \lambda_{\text{projection:air:borne:sound:wave}}$$

domain C above coincidence, increase about 25 dB/decade

sound insulation of double walls

sound insulation of double walls

- construction:
  - wall 1 + spacing (usually air) + wall 2
  - assumption of piston movement of walls: mass + spring + mass
- $\rightarrow$ resonance leads to a collapse of sound insulation
- above resonance massive increase of sound insulation with frequency

standard sound pressure level difference

standard sound pressure level difference

- disturbance due to to a noisy neighbor depends on
  - sound insulation index R of the structural elements
  - common area F of the structural elements
  - reverberation of the receiver room
- $\rightarrow$ standard sound pressure level difference D_{nT}

standard sound pressure level difference

it can be found (standard reverberation time 0.5 s):

$$D_{nT} = R + 10\log\left(\frac{V}{F}\right) - 4.9$$

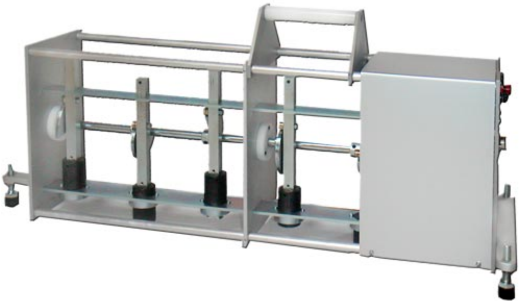
with:
V: room volume of the receiver room [m^3]
F: common area

- rated sound insulation index R_w $\rightarrow$ rated standard sound pressure level difference $D_{nT,w}$

impact sound insulation

impact sound insulation

- excitation by hammers → standardized tapping machine
  - hammers of specified weight
  - specified falling height
  - specified excitation frequency



impact sound insulation

- measurement of average sound pressure level L_i in third octaves in the receiver room
- calculation of standard impact sound level L_n in third octaves: total absorption of 10 m^2 in the receiver room is assumed

$$L_n = L_i - 10 \log \left(\frac{10\,T_i}{0.163\,V} \right)$$

where:
V: volume of the receiver room [m^3]
T_i: reverberation time in the receiver room in third octaves

- transformation into single value $L_{n,w}$ analogous to sound insulation index by using a reference curve.

Swiss standard SIA 181

SIA 181: Noise protection in buildings

- SIA 181: defines building acoustical requirements according to state of the art in building technology
- noise protection defined for two classes:
  - *minimal requirements*
    - have to be fulfilled always
  - *increased requirements*
    - have to be applied for single family houses that are built together
    - may be applied in other situations with agreement by contract

SIA 181: Noise protection in buildings

- requirements defined as limiting values for
  - sound pressure level differences for
    - *exterior airborne sound*
    - *interior airborne sound*
  - impact sound

SIA 181: Noise protection in buildings

- two-dimensional scheme of limiting values:
  - first dimension: intensity of the source
  - second dimension: degree of sensitivity of the inhabitants for a certain usage of the room

construction hints for good building acoustical conditions

construction hints for good building acoustical conditions

arrangement of rooms:

- suitable arrangement of rooms may help to avoid noise problems
- good strategy: no rooms with different usage next to each other (horizontally and vertically)

construction hints for good building acoustical conditions

doors and windows:

- typical maximal sound insulation of doors and windows: 35 to 40 dB
- usually significantly weaker than walls
- for increased requirements special constructions have to be used

construction hints for good building acoustical conditions

leakage:

- already small openings (cracks) reduce sound insulation between adjacent rooms drastically
- typical leakage elements: lead-throughs for cables or ventilation ducts

construction hints for good building acoustical conditions

floating floors:

- bad idea to put walls directly on concrete floor $\rightarrow$ high structure borne sound transmission
- remedy: floating floors:
  - put layer of low stiffness on the concrete floor
  - floating top cover without contact to walls

movie Cremer / Fröbe

movie Cremer / Fröbe

Lehrfilm Cremer Fröbe - Teil 1 Lehrfilm Cremer Fröbe - Teil 2 eth-acoustics-1