8 Sound insulation in buildings
ELEC-E5640 - Noise Control P

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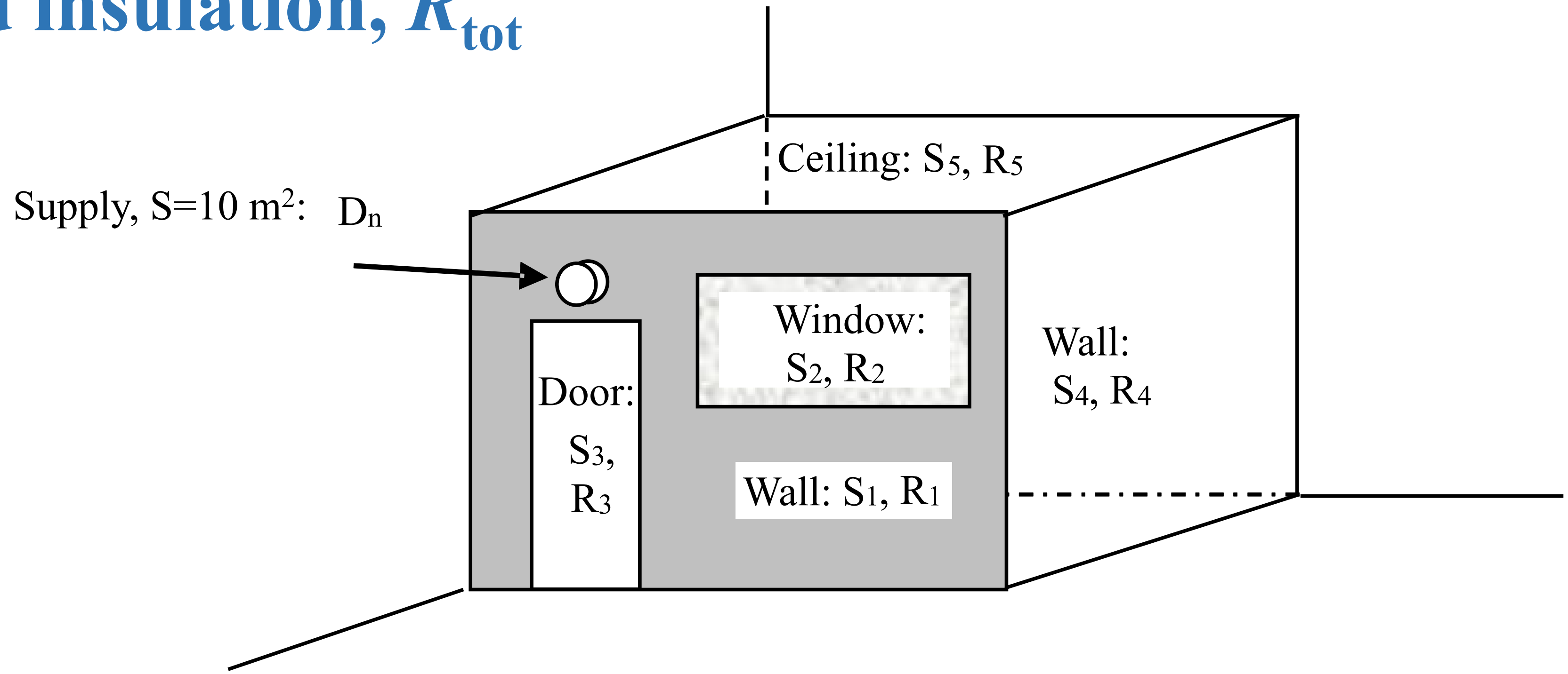
Total sound insulation, R_{tot}



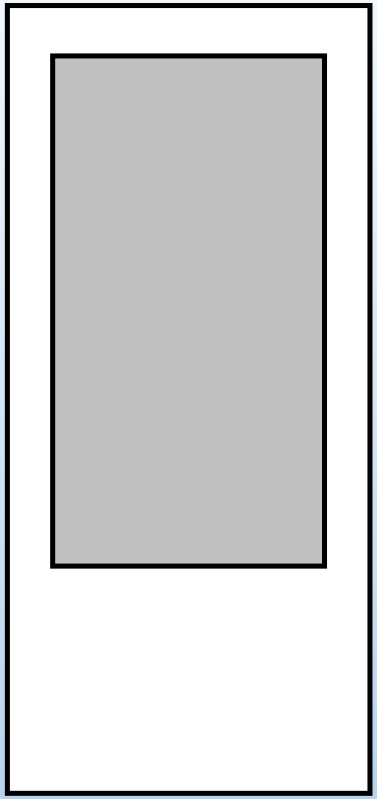
- S_i [m^2] is the area of component i
- R_i [dB] is the SRI of component i

$$R_{tot} = 10\log_{10}\frac{\sum_i S_i}{\sum_i S_i 10^{-R_i/10}}$$

8.1

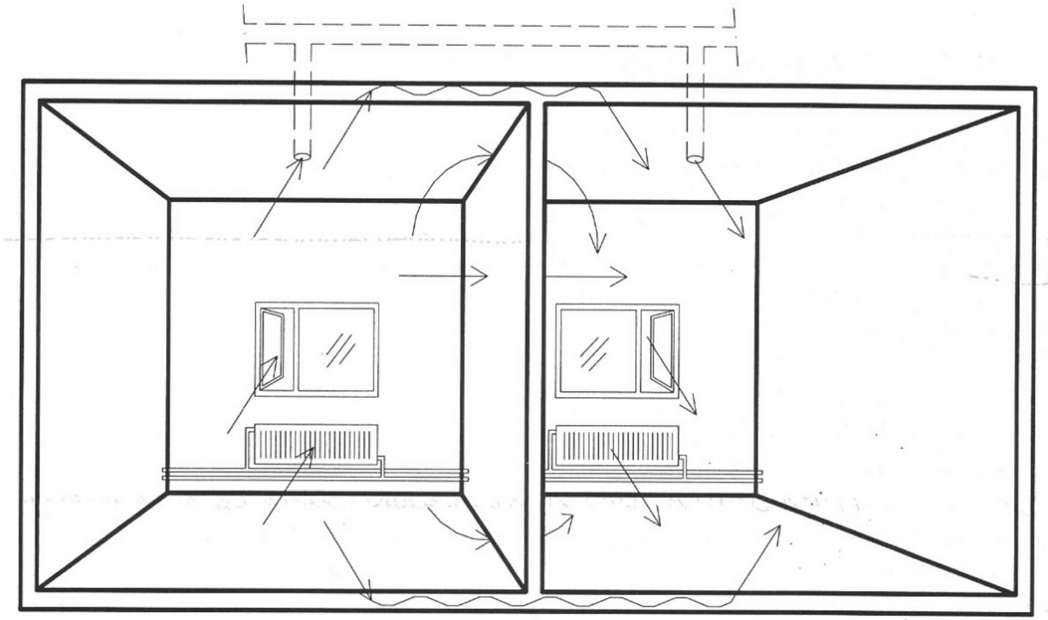
Door 10M x 21M.
Glazing 7M x 14M.
Door Rw36dB.
Glazing Rw47dB.
Total sound insulation?

$$R_{tot} = 10 \lg \frac{\sum_i S_i}{\sum S_i 10^{-R_i/10}}$$



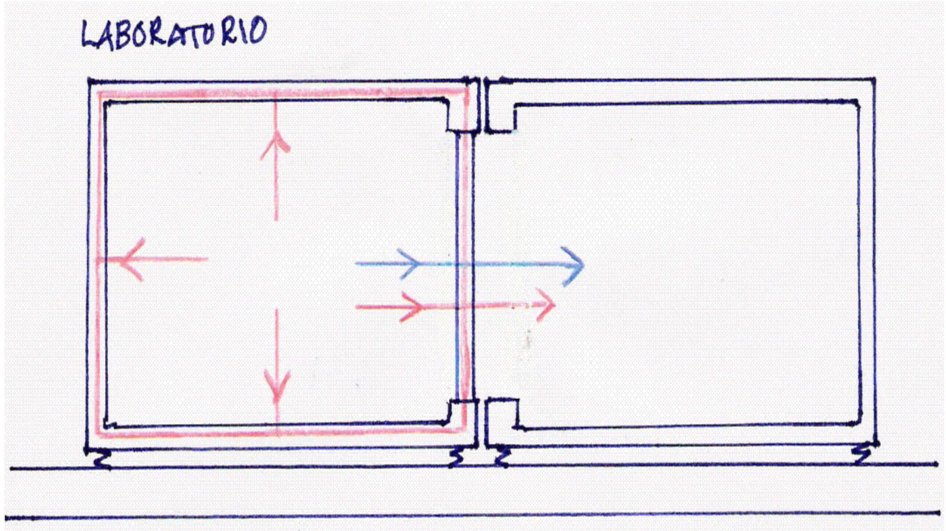
Sound insulation inside buildings

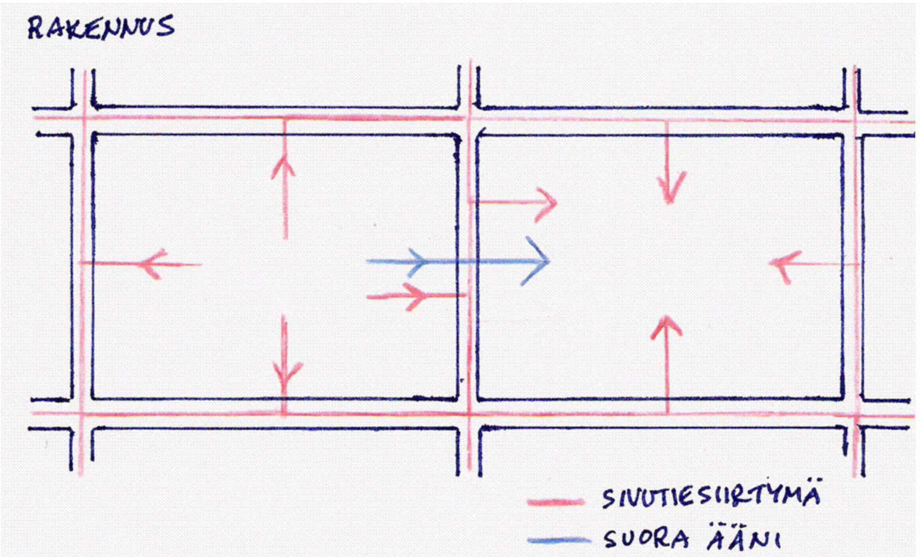
Sound transmission paths:



- **Direct sound** through the separating element
- **Structural transmission** via flanking paths
  - floor, ceiling, walls
  - columns and flues
- **Air paths**
  - via windows or doors
- **HVAC**
  - via duct walls
  - via ducts
- **Slits**

Airborne sound insulation – lab vs. field



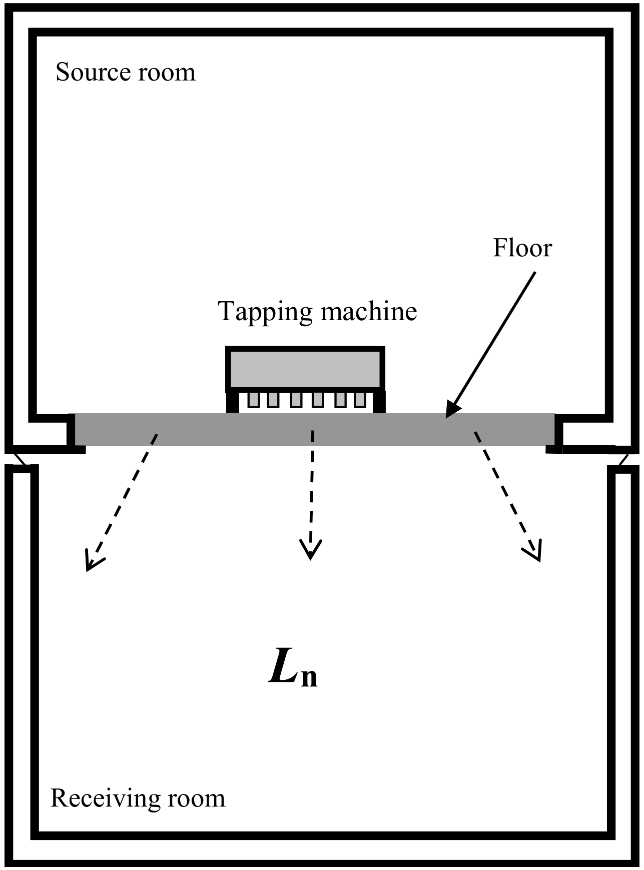


- Laboratory:
  - ***R*** or ***D*****n,e**
  - direct sound
- Building:
  - ***R'*** from 1998 to 2017
  - D_{nT} after 2018
  - direct sound and flanking paths

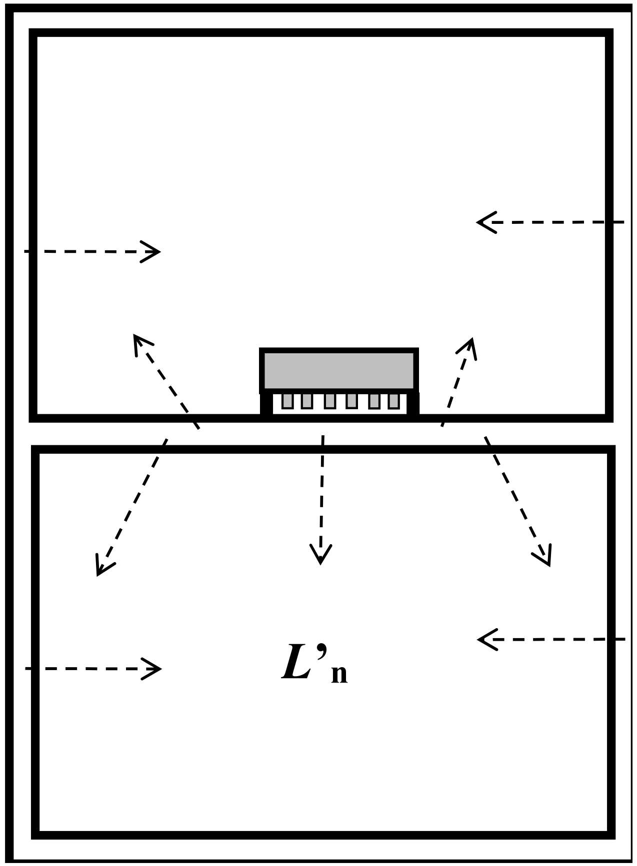
Impact sound insulation – lab vs. field

- Field
  - 1998-2017: $L'_{n,w} + C_{I,50\text{-}2500}$
  - 2018 $L'_{nT,w} + C_{I,50\text{-}2500}$
- Lab:
  - $L_{n,w}$
  - $L_{n,w} + C_{I,50\text{-}2500}$

LABORATORY: Rooms are mechanically detached from each other



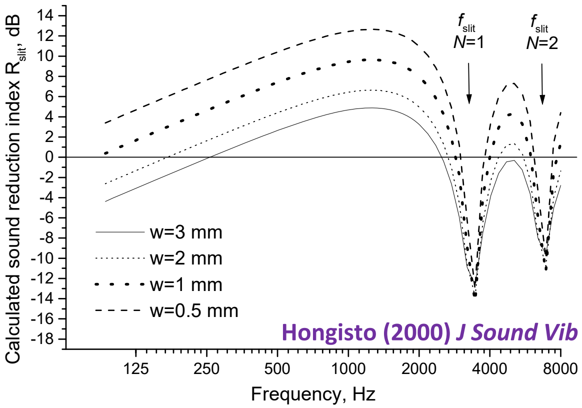
REAL BUILDING: Rooms are mechanically connected to each other



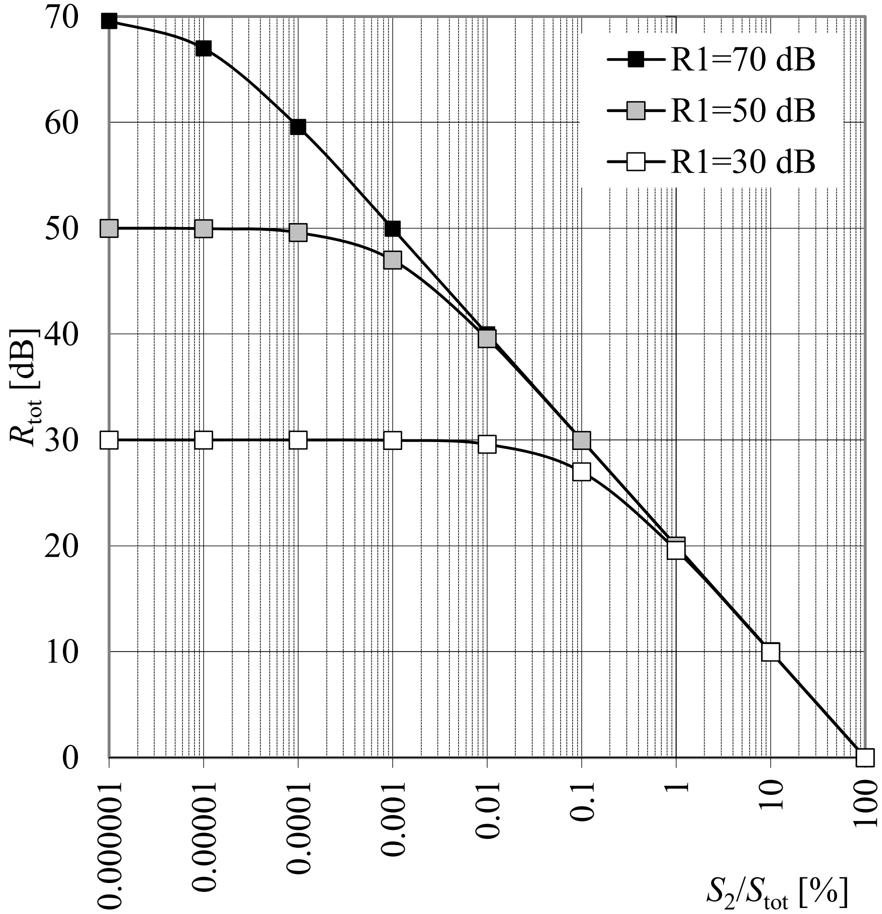
Effect of slits on SRI

- S_1 [m^2] is the area of structural component
- R_1 [dB] is the SRI of structural component
- S_2 [m^2] is the area of slits and holes
- $S_{tot}=S_1+S_2$
- R_2 [dB] is the SRI of slits and holes
- First approximation: R_2=0 dB (independent on frequency) is applied in the exercise.
- Frequency dependent models include the dimensions of the slit: SRI of the slit is negative at frequencies where the slit depth is the multiple of half wavelength

The SRI of a slit of depth 45 mm with varying widths W.



$$R_{tot} = 10\lg \frac{S_1 + S_2}{S_1 \cdot 10^{-R_1/10} + S_2 \cdot 10^{-R_2/10}}$$

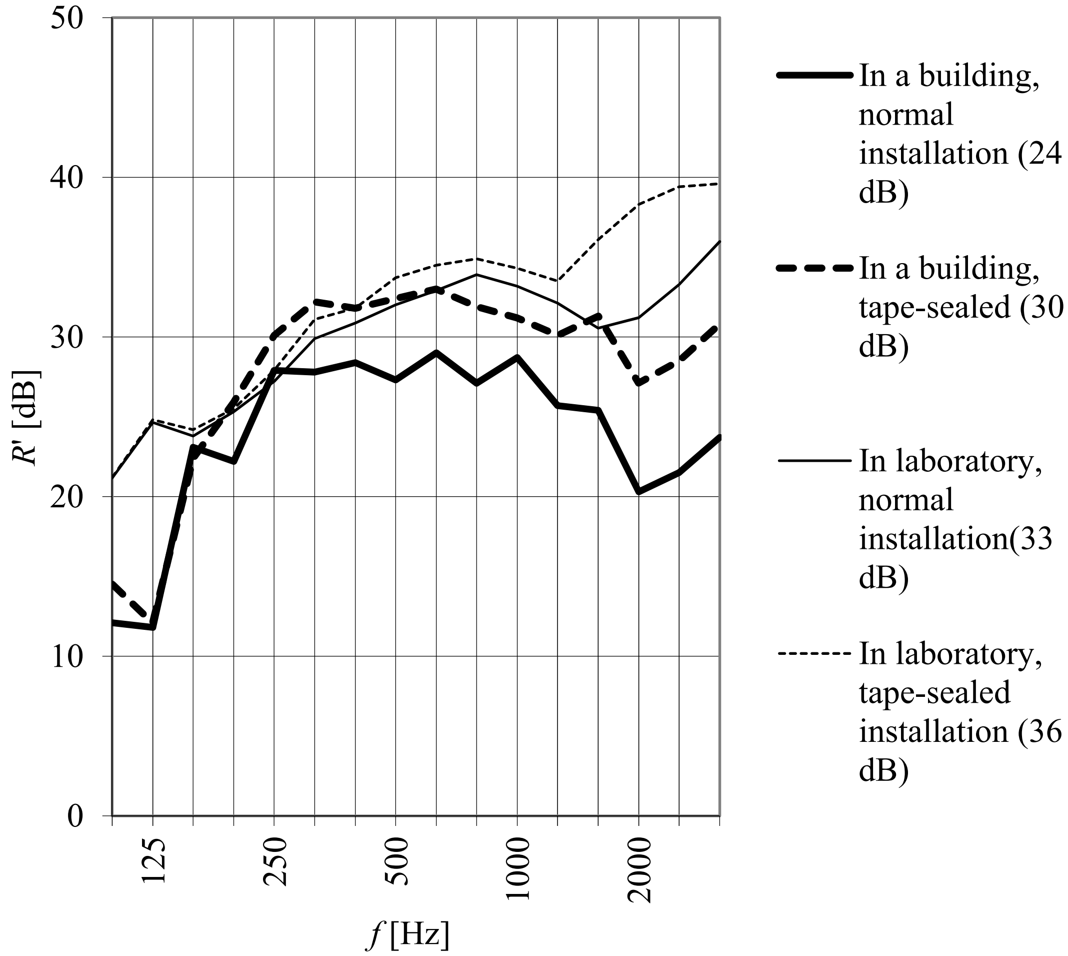


Effect of slits on SRI – office door

- Measured values of a typical office door
  - sound insulation class 25 dB
  - 33 dB R_w
- Small slits are usual due to improper workmanship.
- Therefore, the classification for doors and mobile walls (SFS 5907:2004) involve a 5 to 8 dB safety margin.

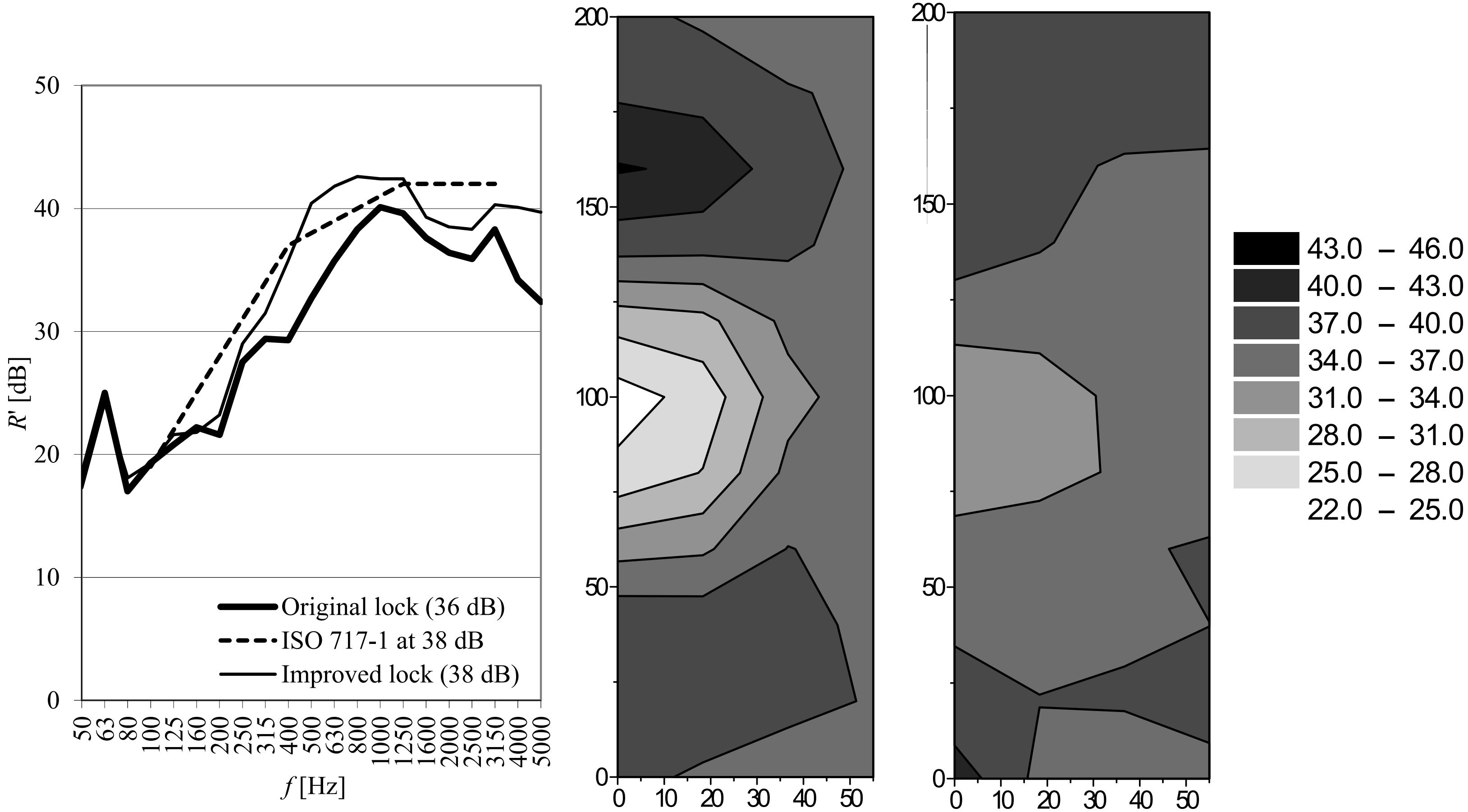
Table A.1 Door sound insulation classes and their requirements

Sound insulation class	Required minimum values achieved in laboratory measurements, R_w
25	30
30	37
35	42
40	48
45	53



Localization of sound leak using intensity method

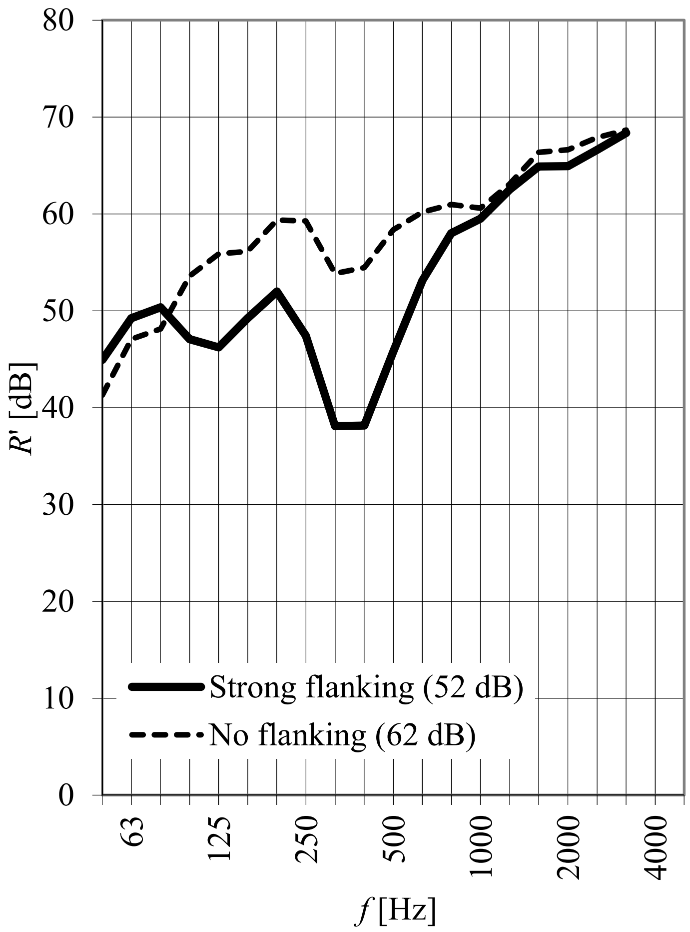
- Sound intensity level was measured at a distance of 15 cm from the door surface at a grid of 5x20 points
- Strong radiation of the lock around 500 Hz
- Lock was improved by a "sound trap"

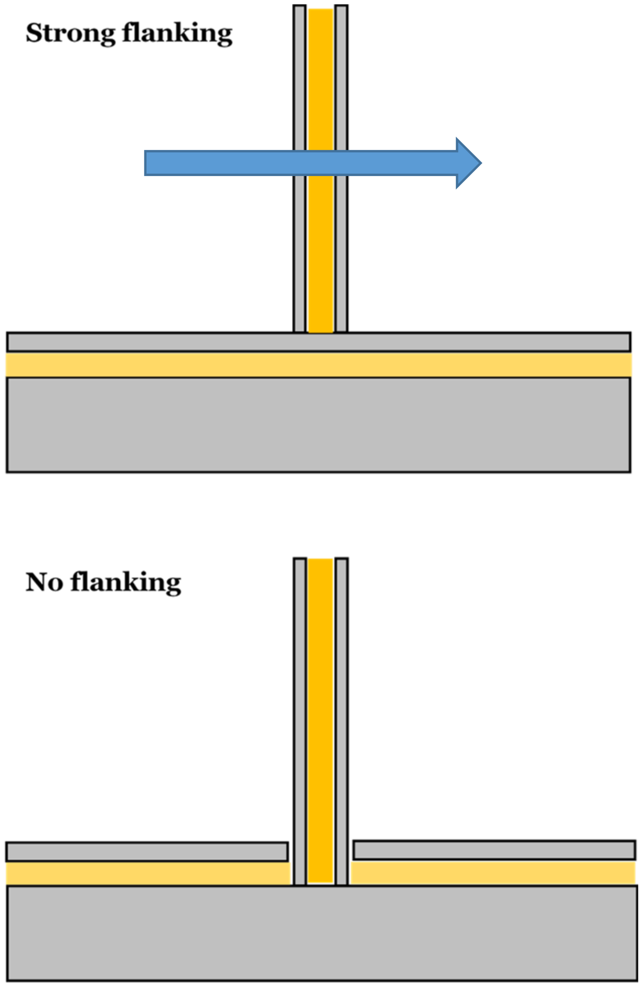


Hongisto et al. (1997) **Noise Con Eng J**

Example of strong flanking via floating floor

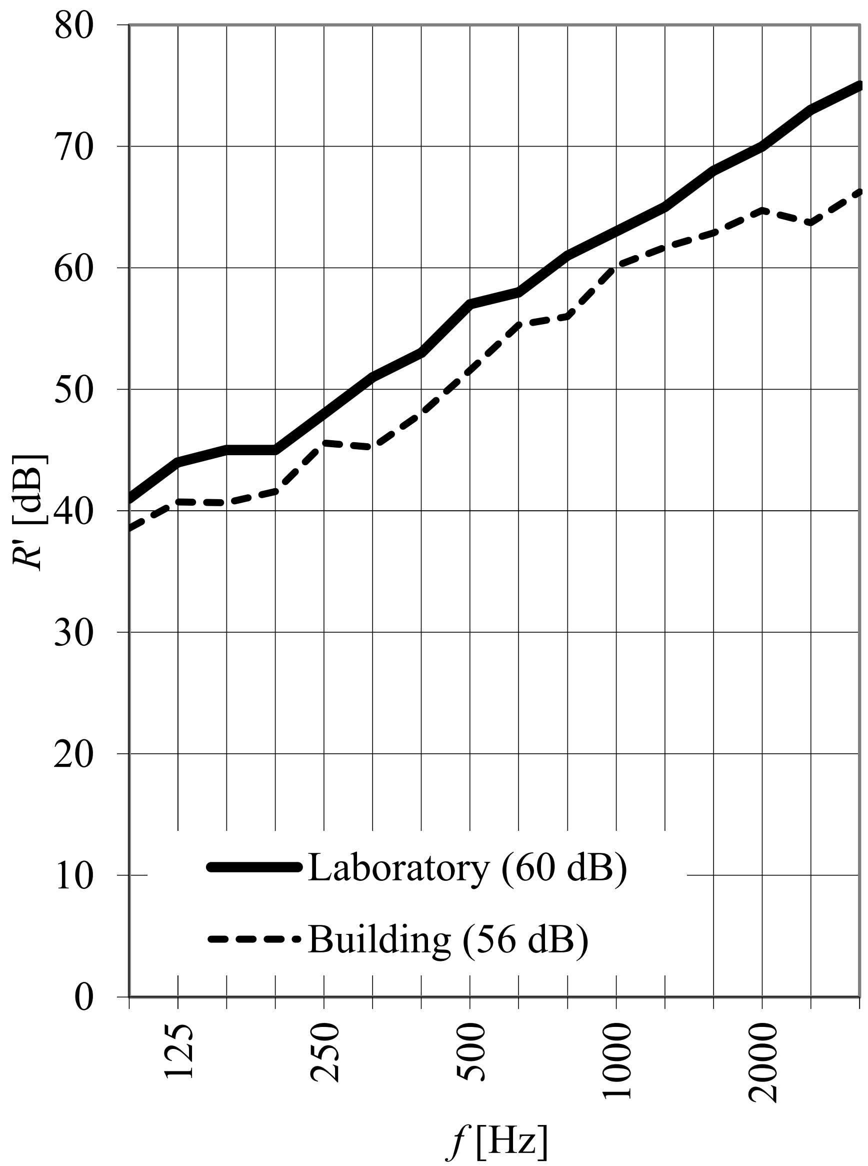
- A double wall was built above a 60-mm-thick floating floor plate
- The laboratory value of the double wall was 65 dB R_w .
- Measured value was 52dB R'_w . The target was 60 dB. Coincidence frequency of the floor plate was 400 Hz. Strong flanking both below and above 400 Hz.
- Cutting the plate resulted in 62 dB.





Steel reinforced concrete slab 180 mm

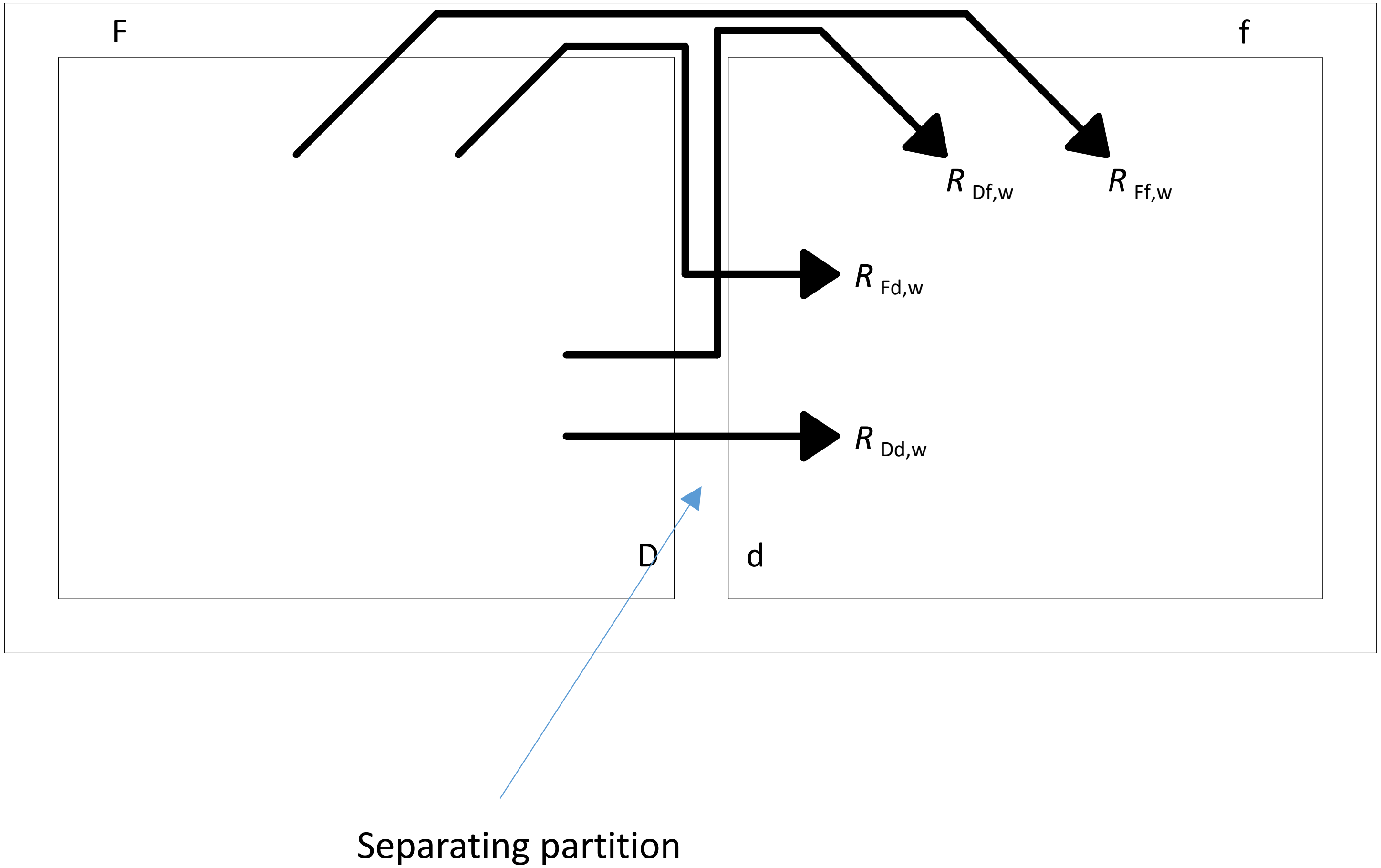
- It is typical that the field value is 3-5 dB lower than the laboratory value due to structural flanking.



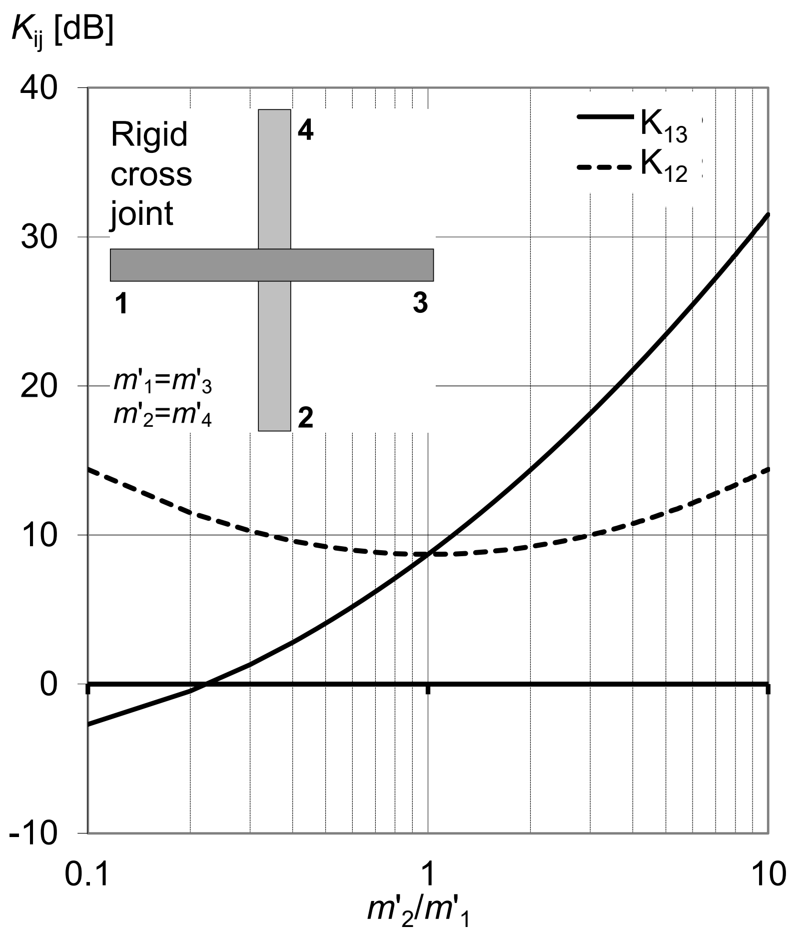
Modeling of airborne flanking transmission – 13 paths

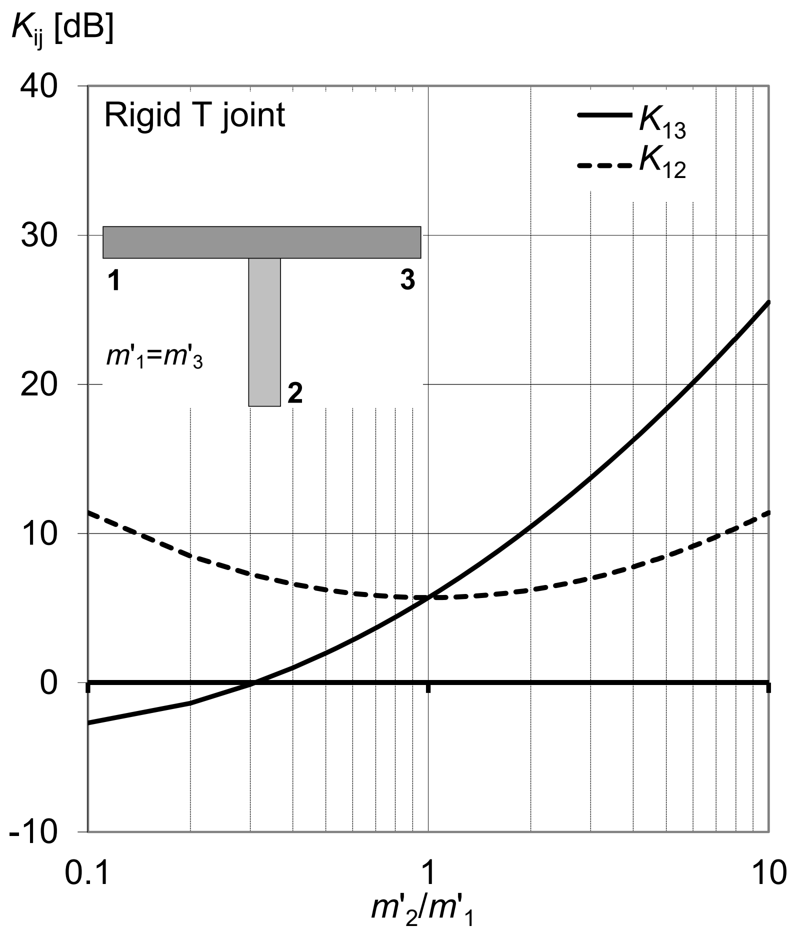
- One direct path (Dd).
- Four first order flanking paths (Ff)
- Four second order flanking paths (Df)
- Four third order flanking paths (Fd)
- The separating partition has an area S_s

- The separating partition has four joints of lenght l – joint is the line connecting the flanking surfaces and the partition



Coupling loss factor *K* of a joint





RULE OF THUMB: If $m'_1=m'_2=m'_3=m'_4$, X-joint isolation is 9 dB and T-joint isolation is 6 dB.

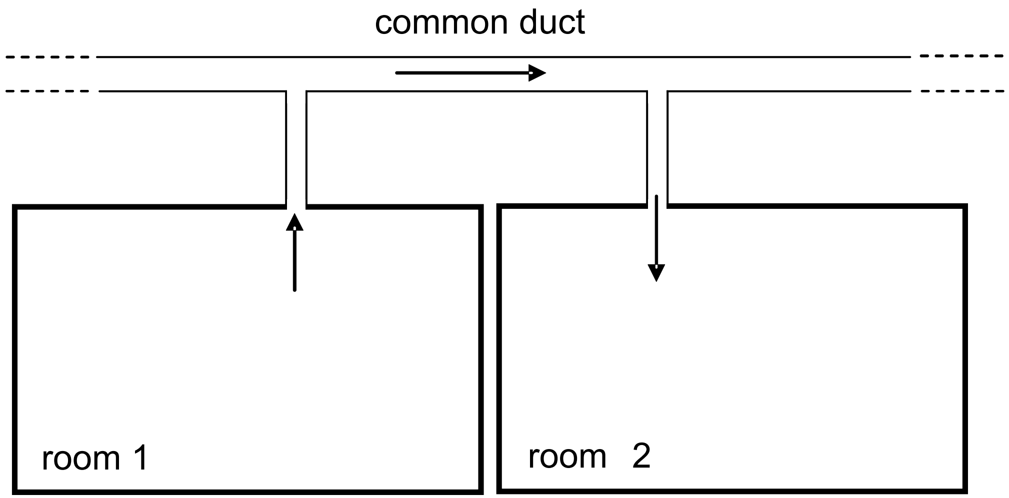
EN 12354-1 simplified method for calculating the apparent airborne sound reduction index R'

- R_s , R_F and R_f [dB] are the laboratory values of the concrete structures in laboratory
- ΔR_{Dd} [dB] is the improvement of R_w obtained with a lining wall in laboratory conditions.
- S_s [m^2] is the area of the separating wall
- l_f [m] is the length of the joint under question
  - either the height or the width of separating construction

- Direct path: $$R_{Dd,w} = R_{s,w} + \Delta R_{Dd,w}$$
- Flanking paths:
$$R_{Ff,w} = \frac{R_{F,w} + R_{f,w}}{2} + \Delta R_{Ff,w} + K_{Ff} + 10\lg\frac{S_s}{l_f}$$
$$R_{Fd,w} = \frac{R_{F,w} + R_{d,w}}{2} + \Delta R_{Fd,w} + K_{Fd} + 10\lg\frac{S_s}{l_f}$$
$$R_{Df,w} = \frac{R_{D,w} + R_{f,w}}{2} + \Delta R_{Df,w} + K_{Df} + 10\lg\frac{S_s}{l_f}$$
- All 13 paths:
$$R'_w = -10\lg\left[10^{-R_{Dd,w}/10} + \sum_{F=f=1}^{4} 10^{-R_{Ff,w}/10} + \sum_{f=1}^{4} 10^{-R_{Df,w}/10} + \sum_{F=1}^{4} 10^{-R_{Fd,w}/10}\right]$$

Airborne flanking via ducts

- Flanking is noticeable when the partition is better than 35…45 dB R'_w
- Flanking is prevented by a silencer
- Flanking increases with increasing duct size because the impedance of the hole increases with decreasing size



- SRI of the duct, R_D [dB] can be roughly estimated by

$$R_D = D_1 + D_s + D_d + D_2$$

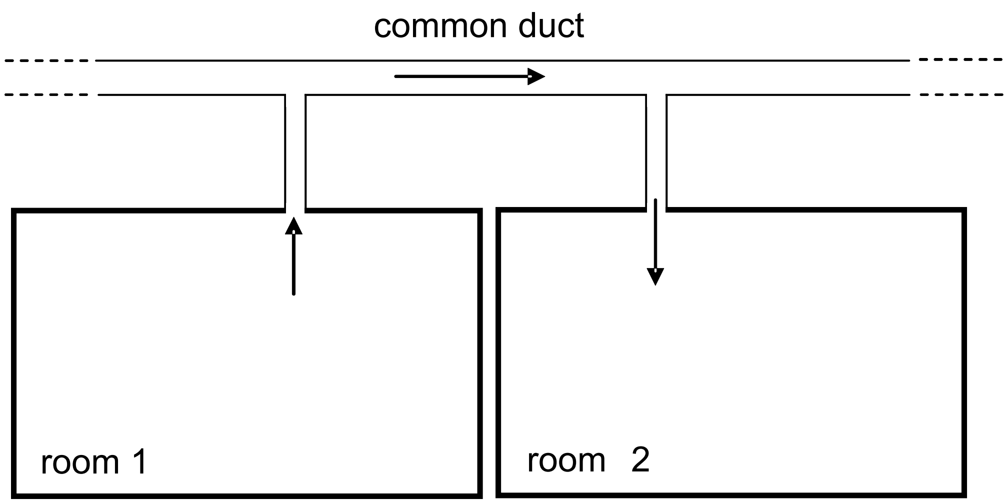
  - D_1=attenuation of the terminal in room 1
    - Product values are not available in terminal speficications so one needs to use $D_1=D_2$.
    - Open terminal: $D_1=0$
  - D_s is the total attenuation of silencers in the duct
  - D_g is the attenuation caused by the duct divisions (branches)
  - D_2=is the attenuation of terminal in room 2
    - Product values are available in terminal specifications
- Aggregate sound reduction index

$$R_{tot} = 10\lg\left[\frac{S_D + S_W}{S_D 10^{-R_D/10} + S_W \cdot 10^{-R_W/10}}\right]$$

  - S_S [m^2] is the physical area of the duct towards room 1
  - S_W [m^2] is the physical area of the wall between rooms
  - R_W [dB] is the sound reduction index of the partition

Airborne flanking via ducts – Laboratory testing

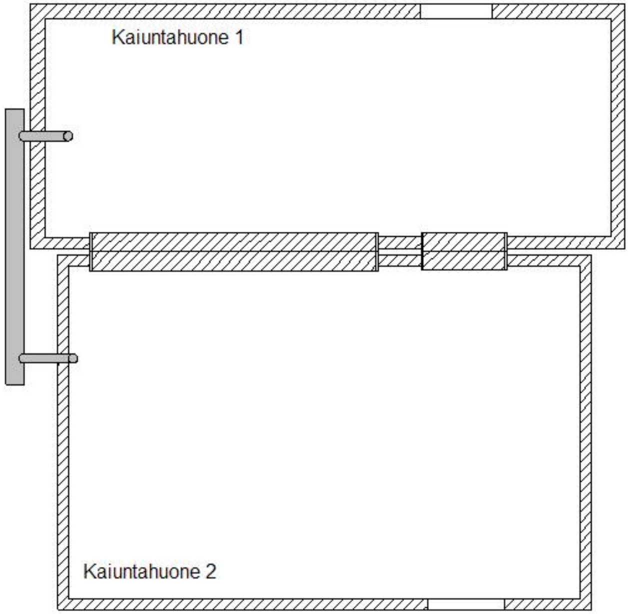
- terminal (such as range hood) is installed to both rooms
- terminals are connected by a duct
- common duct is terminated by a silencer in both ends to avoid reflections

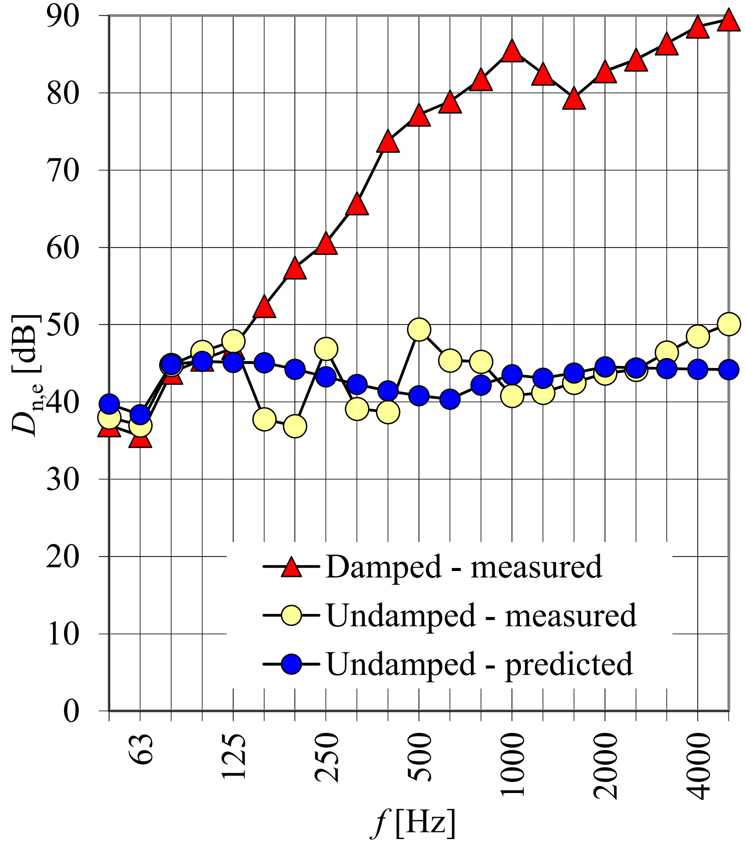


Airborne flanking via ducts – A measurement result

Duct components from room 1 to room 2:

- room 1
- 90° bend in 125 mm duct
- 125 mm duct 600 mm
- 125 to 160 mm transformer
- T-branch from 160 to 250 mm
- 250 mm duct 3000 mm
- T-branch from 250 to 160 mm
- 125 mm duct 600 mm
- 90° bend in 125 mm duct
- room 2





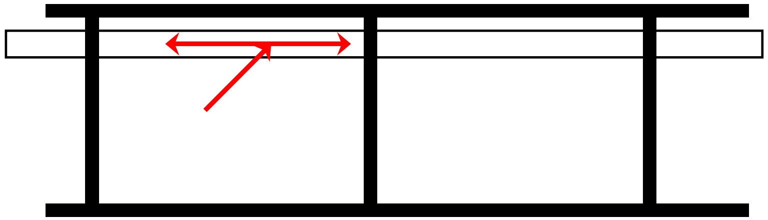
- Hongisto V, Häggblom H, Työterveyslaitos, 2009. p. 29

- Undamped - open duct ends, no terminal
- Damped – duct ends are covered with steel plug

Transmission of airborne sound to and from the duct

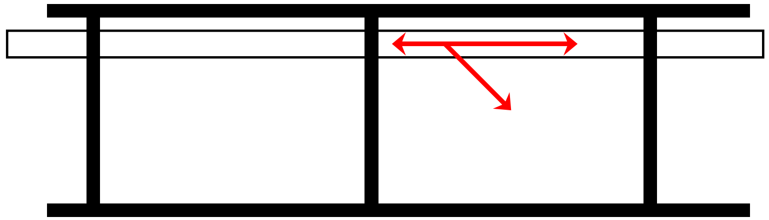
- L_{W2} [dB] is the sound power level inside the duct
- $L_{p,1}$ [dB] is the SPL in the room outside the duct
- R [dB] is the sound reduction index of the duct wall
- S_k [dB] is the surface area of the duct in the room

$$L_{W,2} = L_{p,1} - R + 10\lg S_k - 6$$



- $L_{p,2}$ [dB] is the SPL in the room [dB]
- L_{W1} [dB] is the sound power level inside the duct
- A [m²] is the absorption area of the room

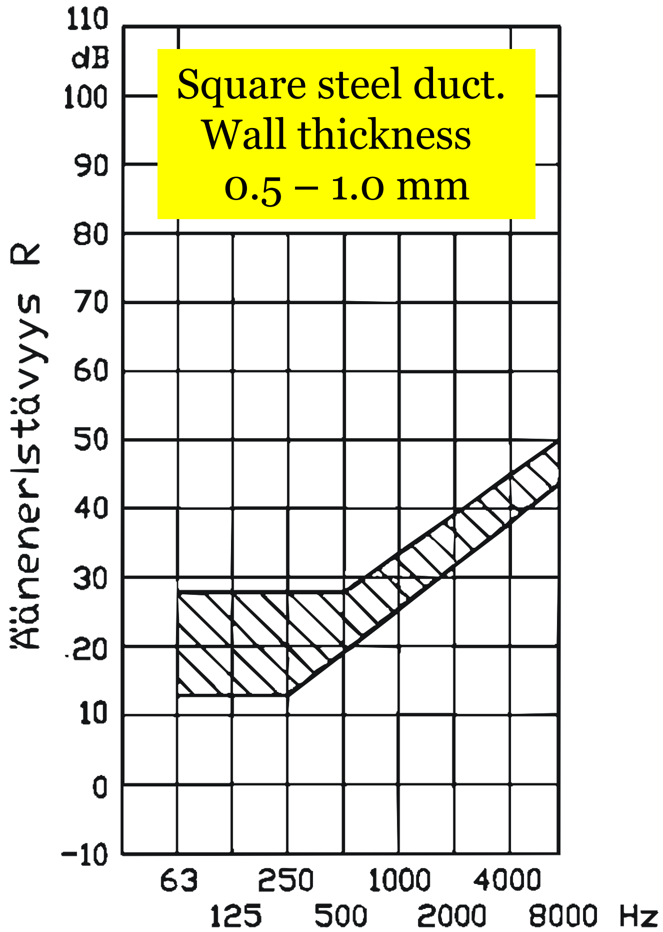
$$L_{p,2} = L_{W,1} - R + 10\lg \frac{S_k}{A_2 S_1} + 3$$

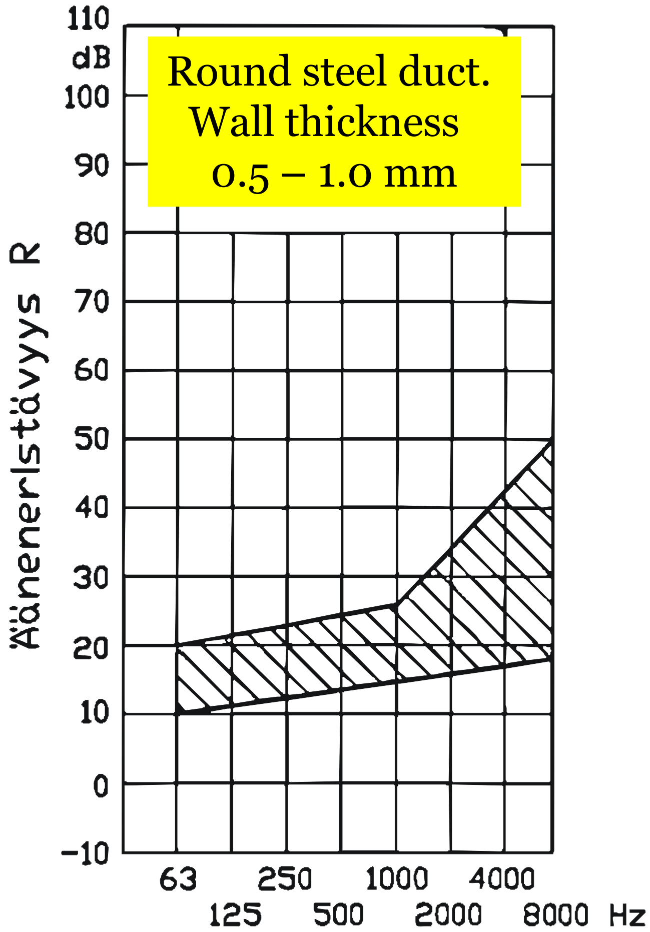


VDI 2081

Sound reduction index R of duct walls

- The values can be used to estimate the transmission through the duct walls.





Laine, Suomen LVI-Liitto r.y.

Sound insulation demand of facades

- Facades shall be dimensioned so that the regulated values for **indoor noise level,** $L_{A,eq,s}$, are not exceeded
- Outdoor noise level $L_{A,eq,u}$ is estimated, measured or predicted
  - the level without the reflecting effect of the house under question
  - If the level is measured within 10 mm distance from the facade, 6 dB is reduced from the measured value to obtain the value without the effect of standing wave
- Alternative markings in land use plans:
  - $\Delta L = L_{A,eq,u} - L_{A,eq,s}$
    - when the use of the building is known
    - $L_{A,eq,s}$ is the regulated indoor noise level
  - $L_{A,eq,u}$
    - when the use of the building is unknown

Decision of government 993/92

	Day time 07-22 T=15 h	Night time 22-07 T=9 h
Regulated values outdoors	$L_{A,eq,T}$ [dB]	$L_{A,eq,T}$ [dB]
Residential areas, recreational areas, health care accommodations	55	50
New areas	55	45
Educational areas	55	-
Residential areas for holiday seasons, camping areas, protected natural areas	45	40
Regulated values indoors	$L_{A,eq,T}$ [dB]	$L_{A,eq,T}$ [dB]
Living, patient and accommodation rooms	35	30
Education and meeting spaces	35	-
Service and office rooms	45	-

NOTE. If the noise includes impulsive or narrow-band character, 5 dB is added to the measured or predicted value before comparing to the tabulated values.

Dimensioning of facade and its components (Ministry method)

Ympäristöopas 108, ympäristöministeriö

$R_{A,tr} = R_w + C_{tr}$

1. Required level difference ΔL [dB] i.e. demand: $$\Delta L = L_{A,eq,u} - L_{A,eq,s}$$
2. Required total sound insulation $R_{tr,vaad}$ [dB]: $$R_{tr,vaad} = \Delta L + K_1 + 7$$
3. Required total sound insulation $R_{A,tr,kok}$ [dB]: $$R_{A,tr,kok} \geq R_{tr,vaad}$$
   - Requirements concern the single-number quantity $\boldsymbol{R_w + C_{tr}}$
4. Requirement for windows and doors, $R_{A,tr,ikk}$ [dB]: $$R_{A,tr,ikk} \geq R_{tr,vaad} + K_2$$
5. Requirement for the wall $R_{A,tr,seinä}$ [dB]: $$R_{A,tr,seinä} \geq R_{tr,vaad} + 3$$
6. Requirement for small element $D_{n,e,A,tr}$ [dB]: $$D_{n,e,A,tr} \geq R_{tr,vaad} + 5$$

Correction factors:

S/S_H	2.5	2.0	1.6	1.3	1.0	0.8	0.6	0.5	0.4
K_1 (dB)	5	4	3	2	1	0	-1	-2	-3

$(\Sigma S_i)/S$	0.10	0.13	0.15	0.20	0.25	0.30	0.40	0.50
K_2 (dB)	-6	-5	-4	-3	-3	-2	-1	0

S [m^2] area of the facade in the room

S_H [m^2] is the floor area of the room

ΣS_i [m^2] is the total area of windows and doors in the facade

Event-based environmental noises such as railway or airport noise: mean of the maximum levels L_{AFmax} should not exceed the requirement for $L_{A,eq,s}$ more than 10 dB.

Alternative method, RT 084.30 (1975)

- Facade elements are not always available with precisely desired values given by the Ministry method
- RT method is applied to check the outcome with the true values.
- The level difference $\Delta L_{A,i}$ caused by component i is:

$$\Delta L_{A,i} = R_w + C_{tr} - 7 - 10 \cdot \log_{10}\left(\frac{S_i}{S_H}\right)$$

  - S_i [m^2] is the area of component
  - S_H [m^2] is the room's floor area
- Level difference produced by all N components of the facade, $\Delta L_{A,tot}$, is

$$\Delta L_{A,tot} = -10 \cdot \log_{10}\left(\sum_{i=1}^{N} 10^{-\Delta L_{A,i}/10}\right)$$

- The value shall exceed ΔL of the facade stated in previous slide

References

- Finnish Government resolution of reference values of noise levels № 993/1992 (1992, October 29), Retrieved March 31, 2015, from http://www.finlex.fi/fi/laki/alkup/1992/19920993.
- Hongisto V, Keränen J, Lindgren M, Sound insulation of doors - Part 2: Comparison between measurement results and predictions, Journal of Sound and Vibration 230(1) 2000 149-170.
- Hongisto V, Viljanen V, Koskela H, Nieminen K, Lindgren M, An automatic system and a test procedure for sound insulation measurements using sound intensity technique, Noise Control Engineering Journal 45 (2) 1997 85-94.
- Hongisto, V. (2000). Sound insulation of doors - Part 1: Prediction models for structural and leak transmission, Journal of Sound and Vibration 230(1) 133-148.
- Hongisto, V. (2001). A case study of flanking transmission through double structures, Applied Acoustics, 62(5) 589-599.
- Ministry of the Environment. (2003). “Dimensioning of the sound insulation of building façades,” Environment Guide 108, Helsinki, Finland (Available in Finnish).
- RIL 243-1-2007 Rakennusten akustinen suunnittelu. Akustiikan perusteet. Suomen Rakennusinsinöörien Liitto RIL ry., 224 s, Helsinki, 2007. (In Finnish).
- VDI 2081 "Geräuscherzeugung und Lärmminderung in Raumlufttechnischen Anlagen", Verein Deutcher Ingenieure, Germany,