Aalto University

05 Impact sound insulation

ELEC-E5640 - Noise Control D

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Acoustics Lab in Turku: Floor test openings C & D

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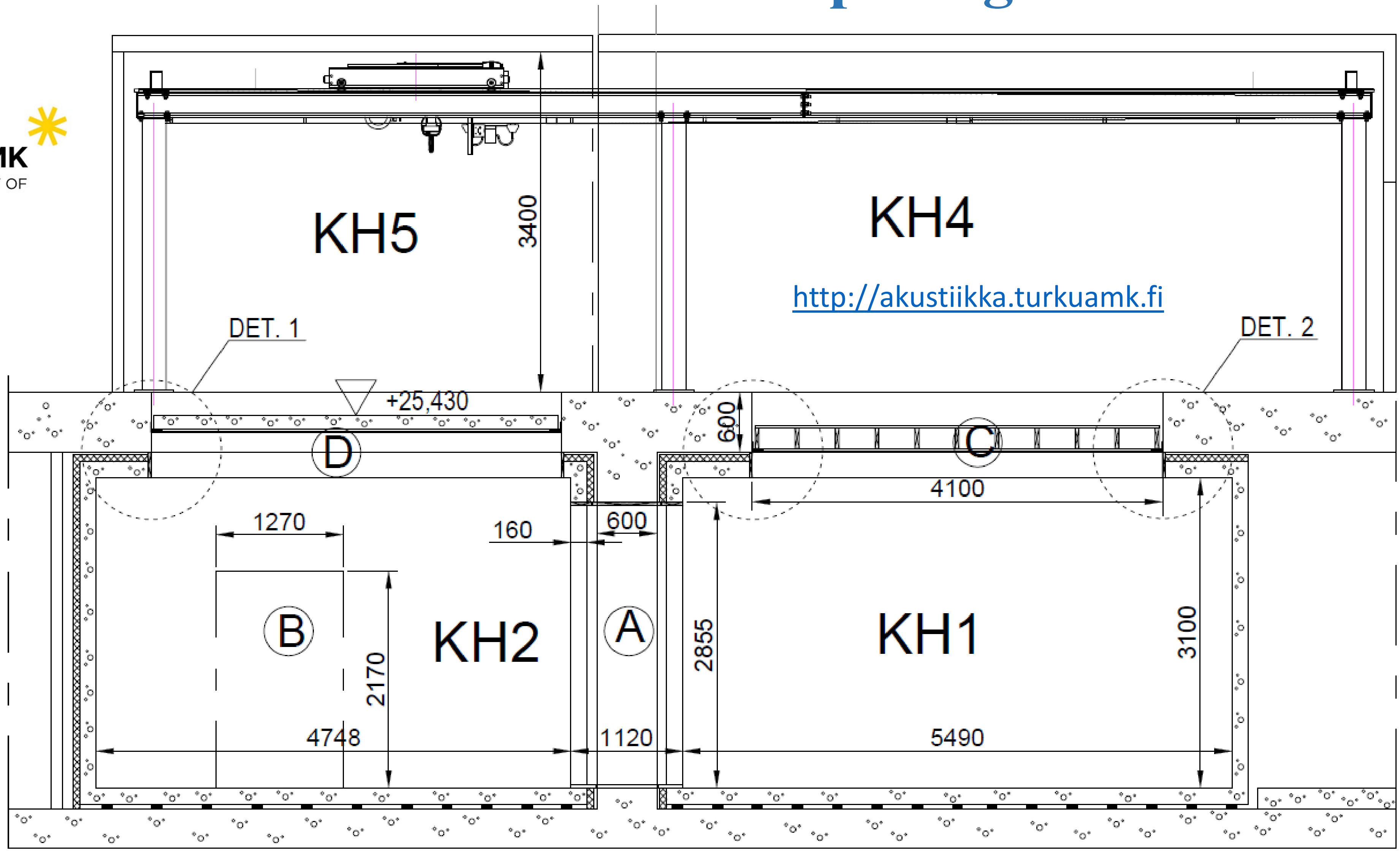
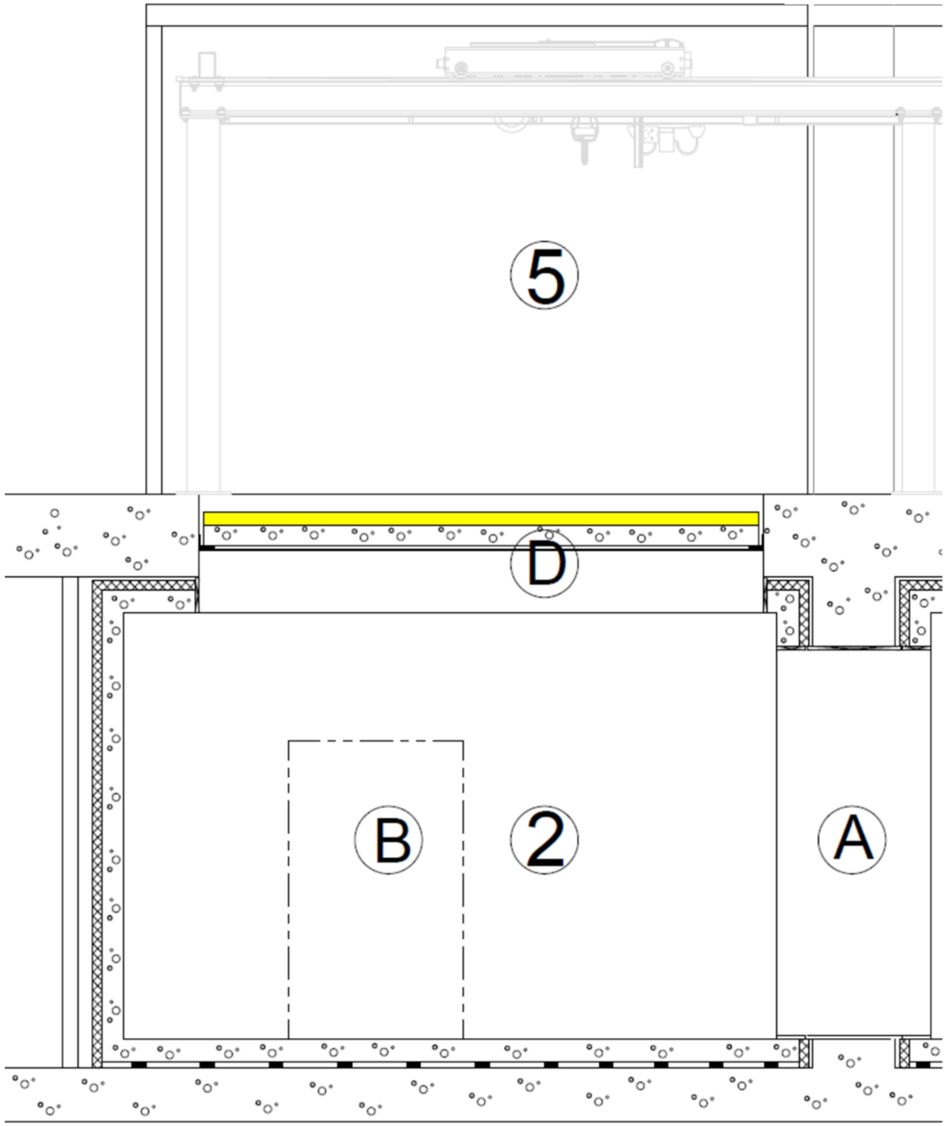


http:// akustiikka.turkuamk.fi

Acoustics Lab in Turku: Floor coverings

- Test opening D includes a standard 160 mm concrete slab
- Enables the determination of the weighted reduction of impact sound pressure level ΔL_w
  - laminate, parquet, vinyl
  - floating floors
  - Installation floors
- Specimen area 10 m^2
- Max. thickness 250 mm
- L'_{nT}-values are 3 dB larger than Ln values in this laboratory



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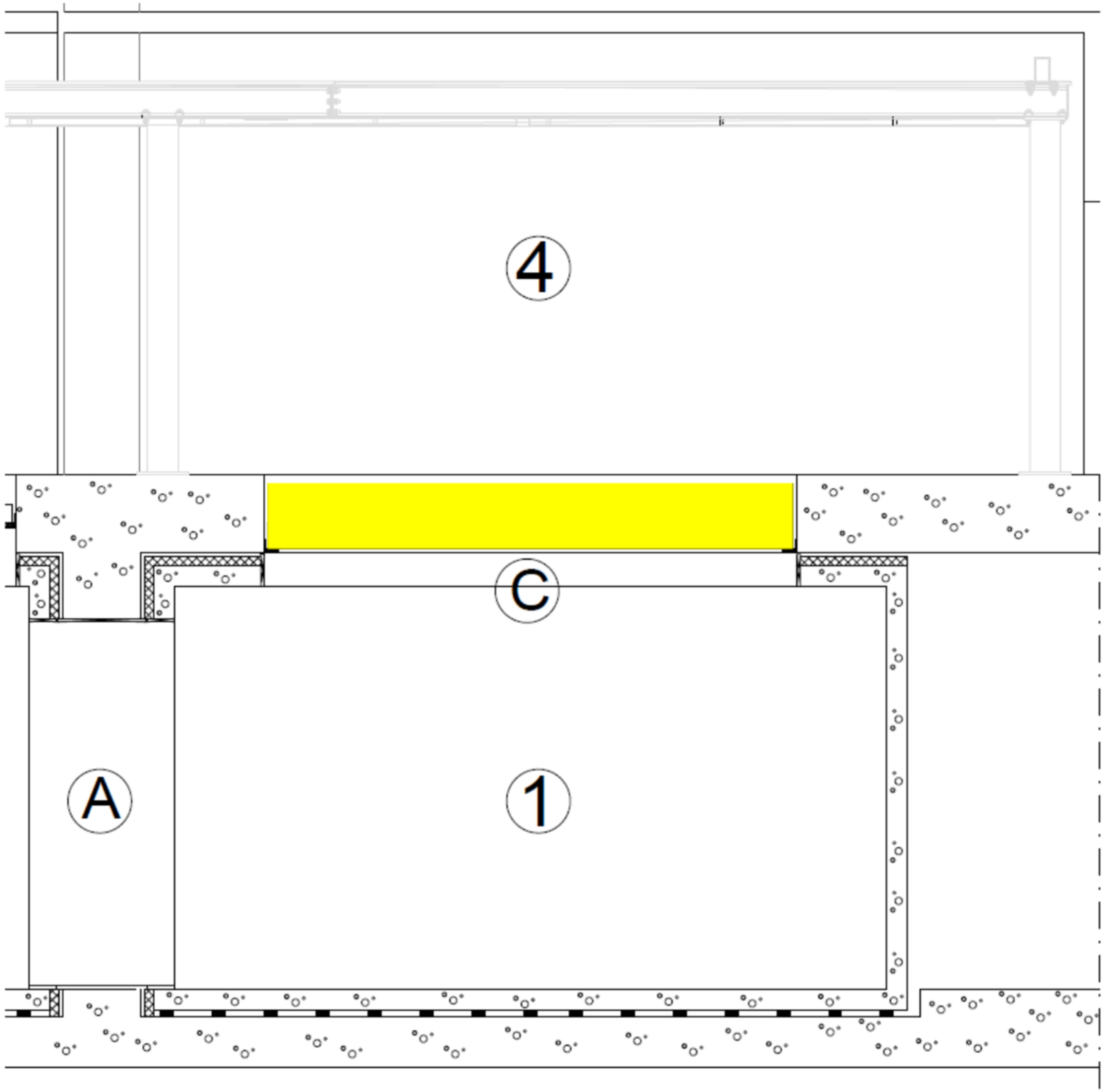
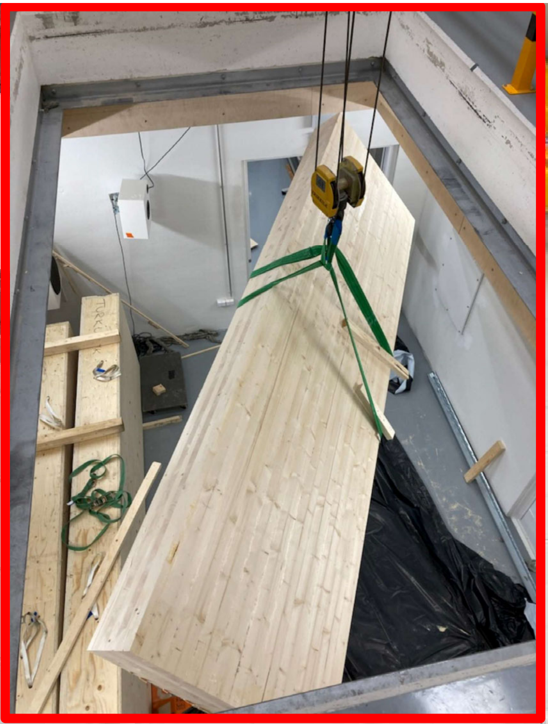
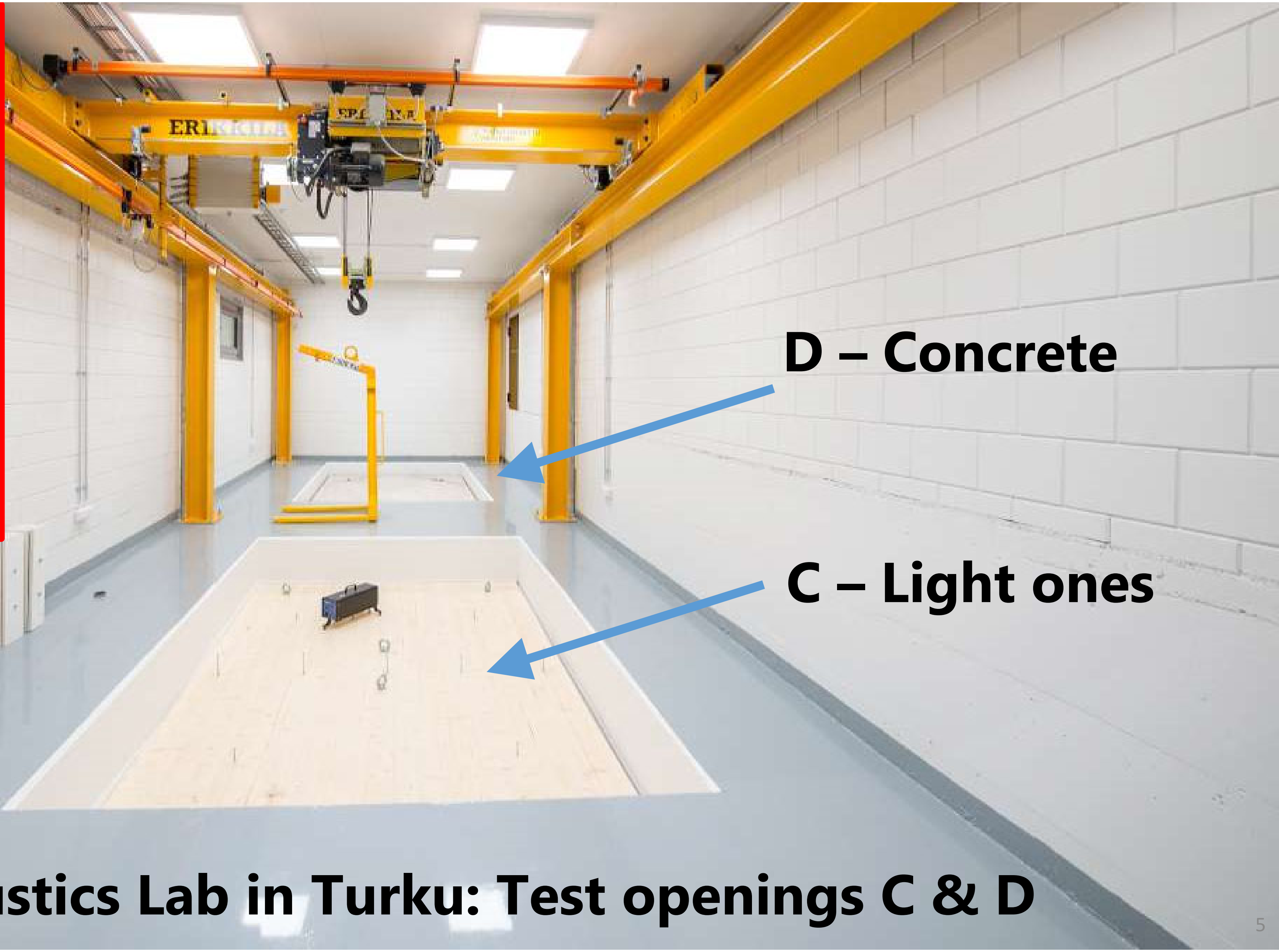
Acoustics Lab in Turku: Floors

- Impact sound pressure level of floors is tested in opening C
  - wooden floors
  - steel floors
  - hybrid floors
  - ceilings
- Test opening C
  - includes one load-bearing wooden construction
- Specimen area 10 m^2
- Max. thickness 600 mm
- Up to 400 kg/m^2
- Airborne sound insulation is possible with the same installation







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Acoustics Lab in Turku: Test openings C & D

Definition of impact sound insulation

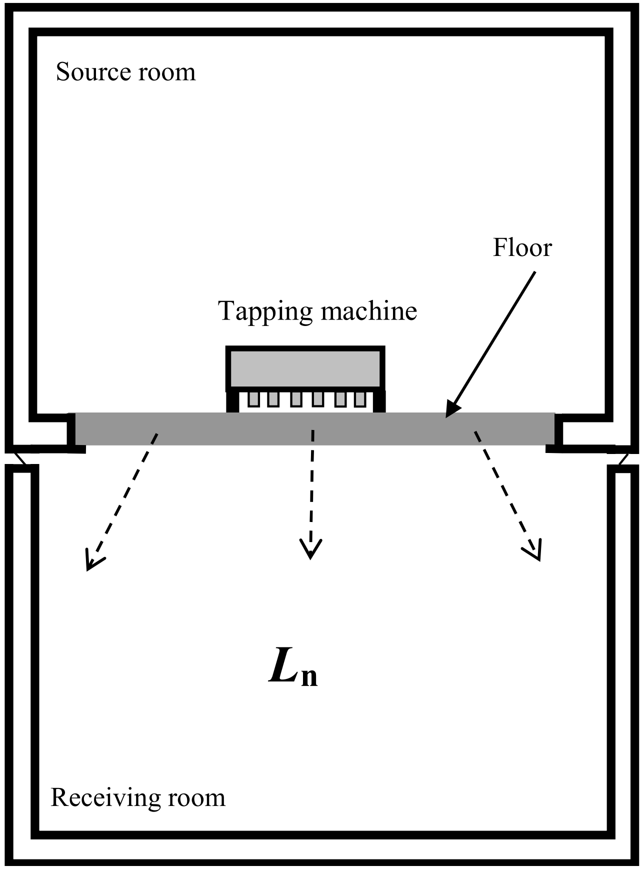
- Impact sound insulation between two rooms means, how well the sound of tapping machine running on the floor can be heard in another room.
- Physical descriptor is standardized impact sound pressure level, **L'$_{nT}$** [dB], caused by tapping machine.
- Frequency-dependent.
- The smaller is the value, the better is the impact sound insulation.
- **L'$_{nT}$** depends on

  1. Normalized impact sound pressure level, **L_n** [dB], measured in laboratory (direct sound)
  2. Flanking sound via joints

- **L'$_{nT}$ = L_n – 3**, if flanking transmission is eliminated like in our laboratory conditions

$$L_n = L_2 + 10\lg\frac{A_2}{A_0} \quad [dB]$$

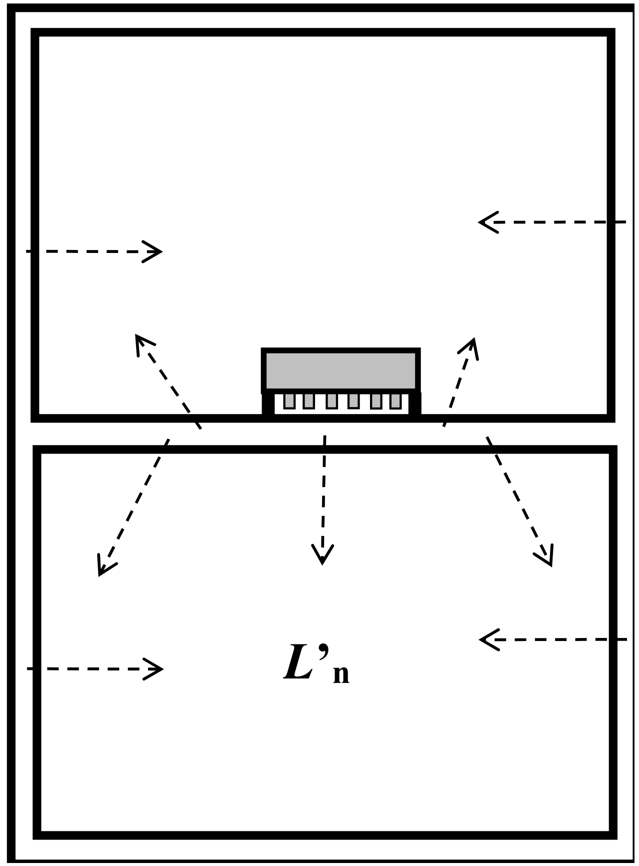
LABORATORY: Rooms are mechanically detached from each other



Laboratory measurement: ISO 10140-3

$$L'_{n,T} = L_2 - 10\lg\frac{T_2}{T_0} \quad [dB]$$

REAL BUILDING: Rooms are mechanically connected to each other



Field measurement: ISO 16283-2

Impact sound pressure levels

- **Normalized** impact SPL produced by tapping machine L_n in the receiving room:

$$L_n = L_2 + 10\lg\frac{A_2}{A_0} \quad [dB]$$

  - L_2 [dB] is the structure-borne SPL caused by the tapping machine in receiving room
    - Background noise level corrected
  - A_2 [m^2] is the absorption area in the receiving room
  - $\boldsymbol{A_0}$**=10 m²** is the normalized absorption area
- L_n is used in laboratory tests. The value represents direct transmission, no flanking occurs.

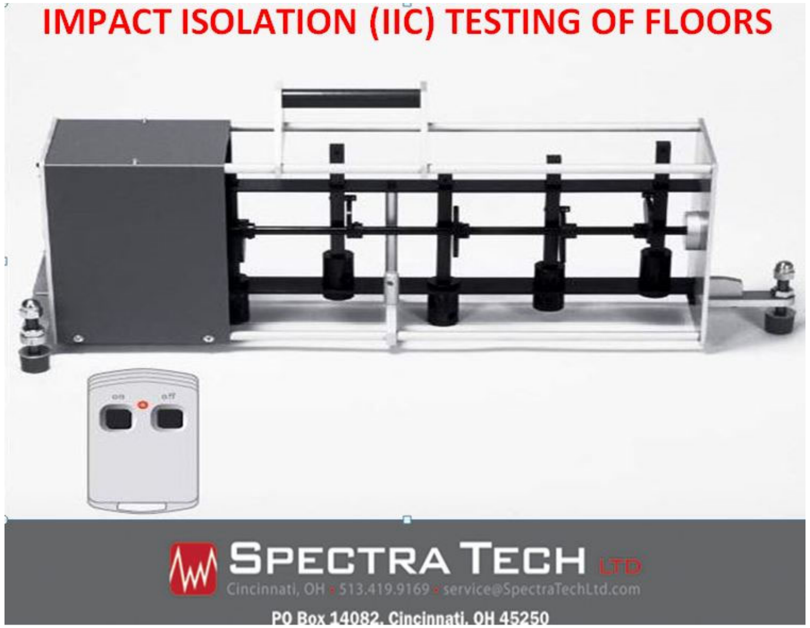
- **Standardized** impact SPL produced by tapping machine L'_n in the receiving room:

$$L'_{n,T} = L_2 - 10\lg\frac{T_2}{T_0} \quad [dB]$$

  - L_2 [dB] is the the structure-borne SPL caused by the tapping machine in the receiving room
  - T_2 [m^2] is the reverberation time in the receiving room
  - $\boldsymbol{T_0}$**=0.5 s** is the standardized reverberation time
- $L'_{n,T}$ used in field, where flanking transmission exists.
- It is applied in Finnish building code.

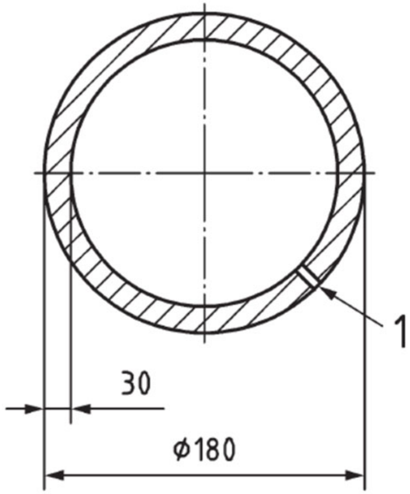
ISO 10140-3-2010

Standardized impact sound sources



Standardized tapping machine

- Hammers of m_h=0.5 kg are dropped to the floor with a frequency of f_i=10 Hz.
- Dropping height is h=0.04 m
- Measured quantity is equivalent SPL, $\mathbf{L_n}$.



Rion Impact Ball YI-01

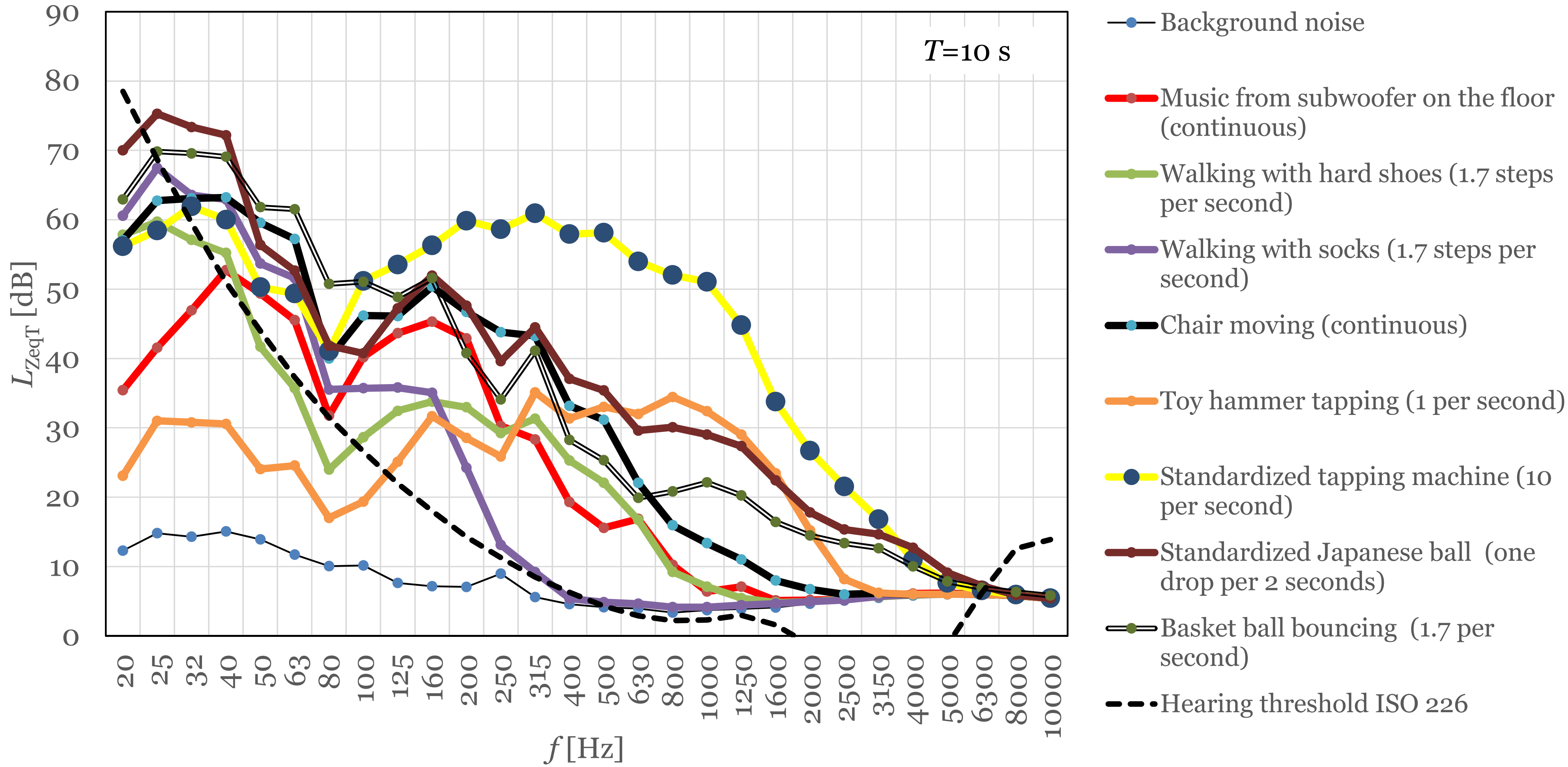
Standardized rubber ball

- 2.5 kg ball, no bouncing
- 1000 mm dropping height produces a stable force of 1500 N.
- Field measurement standard ISO 16283-2 involves an optional method for the Japanese ball but it is considered in Finnish regulations.
- Measured quantity is spatially averaged Fast-weighted maximum SPL, $\mathbf{L_{iF,max}}$.

SPLs of impact sounds in an apartment

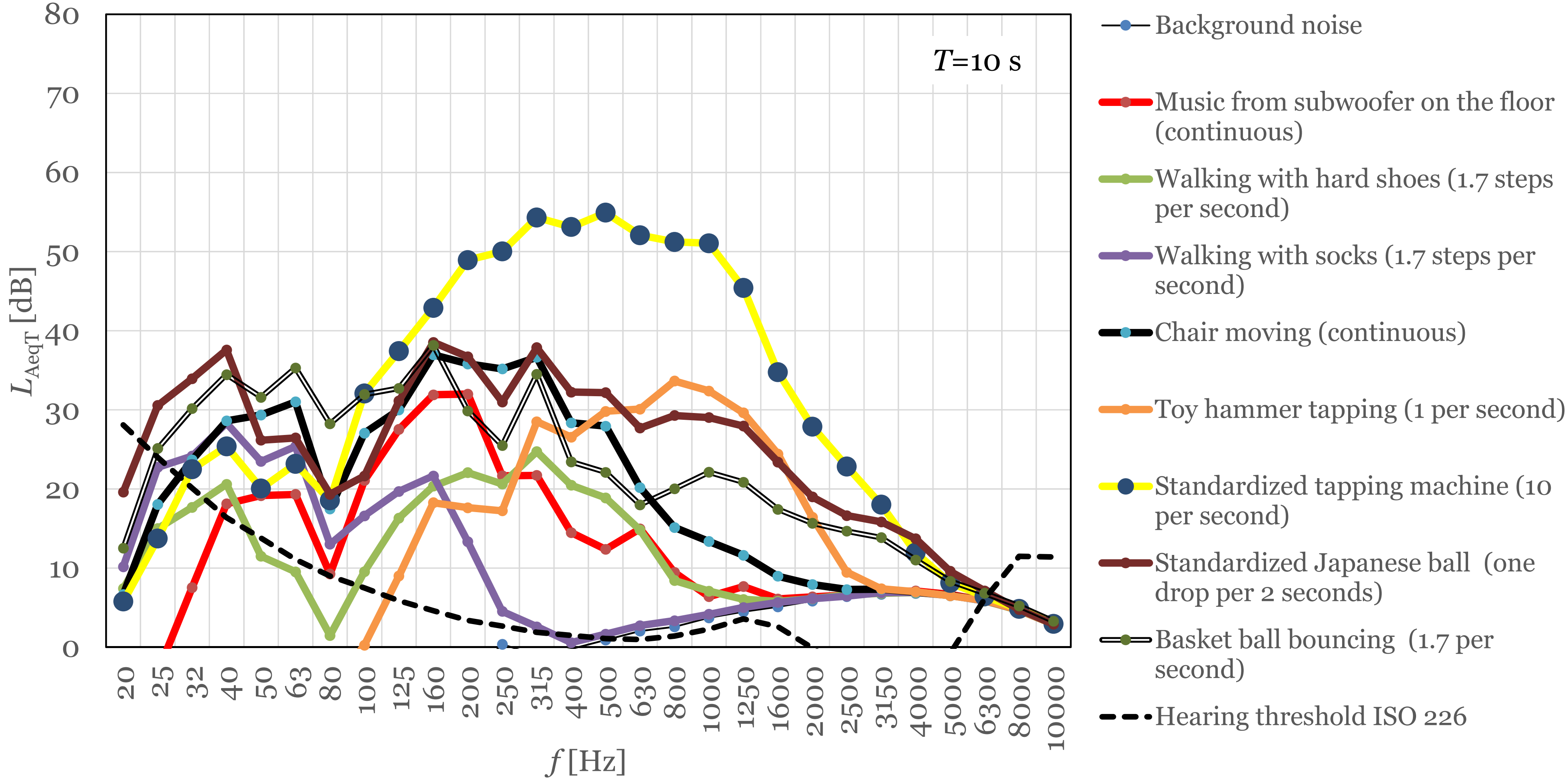
FLOOR $L'_{n,w}$ 53 dB

- 160 mm steel-reinforced concrete
- 30 mm screed filler
- vinyl carpet ΔL_W=21 dB



A-weighted
SPLs of impact sounds in an apartment

FLOOR $L'_{n,w}$ 53 dB
- 160 mm steel-reinforced concrete
- 30 mm screed filler
- vinyl carpet ΔL_W=21 dB



Old Finnish building code C1:1998
valid until the end of 2017

- $L'_{n,w}$ = 53 dB shall not be exceeded between dwellings
- $L'_{n,w}$ = 63 dB shall not be exceeded from stairway to dwelling

- Limited to range 100-3150 Hz

New Finnish building code

- Decree 796/2017 of Ministry of Environment
- Weighted standardized impact SPL ($L'_{nT,w} + C_{I,50\text{-}2500}$)

Room type	**Largest allowed $L'_{nT,w}$ + $C_{I,50\text{-}2500}$ [dB]**
Between residential dwellings and between accommodation rooms	53
From stairway to abovementioned spaces	63

Room type	**Largest recommended $L'_{nT,w}$ + $C_{I,50\text{-}2500}$ [dB]**
Between floors in education buildings	63
From handcraft education rooms to surrounding spaces	49
From music education rooms to surrounding spaces	46
Between floors in hospital, health care center etc.	63
From physical education rooms to surrounding spaces	46
Between floors in offices	63

Single-number quantity $L_{n,w}+C_{I,50\text{-}2500}$

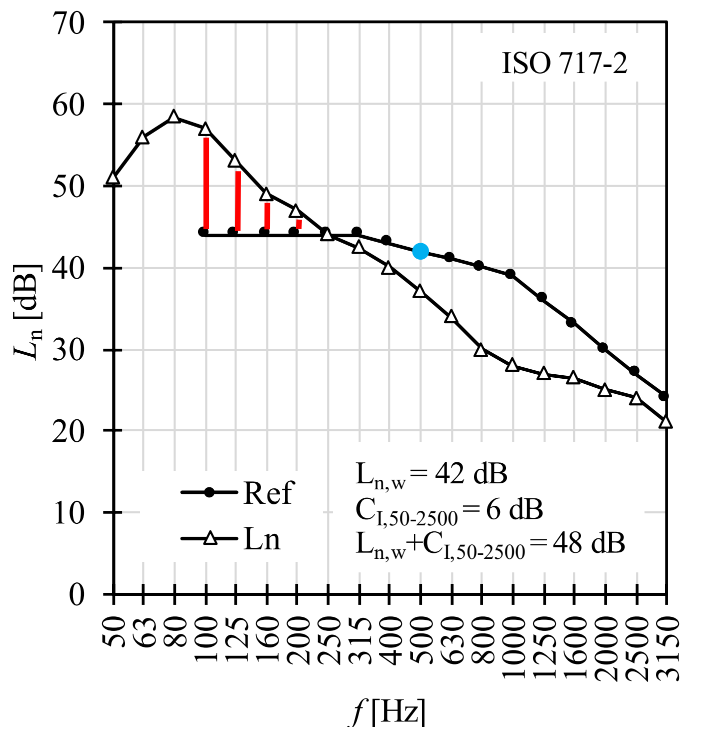
Weighted impact SPL $L_{n,w}$ is a single-number quantity globally used to describe the performance. It is determined from measured L_n values within 100-3150 Hz. Vertical location of reference curve Ref depends on the value that is given to the anchor frequency 500 Hz: as small value as possible is given to 500 Hz but the sum of unfavorable deviations must be at most 32.0 dB. Unfavorable deviation means that measured value is above the reference curve. With guess 42 dB reference curve is positioned to Ref42. Unfavorable deviations take place within 100-200 Hz. Since their sum is under 32.0 dB, the result $L_{n,w}$ = 42 dB. **$L'_{n,T,w}$** is calculated with the same method. Negative $C_{I,50\text{-}2500}$ values are forced to 0 dB.

f	L_n [dB]	Ref [dB]	Ref [dB]	Dev [dB]	$10^{L_n/10}$
50	51.0				125893
63	56.0				398107
80	58.5				707946
100	57.0	$L_{n,w}+2$	44	**13.0**	501187
125	53.0	$L_{n,w}+2$	44	**9.0**	199526
160	49.0	$L_{n,w}+2$	44	**5.0**	79433
200	47.0	$L_{n,w}+2$	44	**3.0**	50119
250	44.0	$L_{n,w}+2$	44	0.0	25119
315	42.5	$L_{n,w}+2$	44	0.0	17783
400	40.0	$L_{n,w}+1$	43	0.0	10000
500	37.0	$\boldsymbol{L_{n,w}}$	42	0.0	5012
630	34.0	$L_{n,w}-1$	41	0.0	2512
800	30.0	$L_{n,w}-2$	40	0.0	1000
1000	28.0	$L_{n,w}-3$	39	0.0	631
1250	27.0	$L_{n,w}-6$	36	0.0	501
1600	26.5	$L_{n,w}-9$	33	0.0	447
2000	25.0	$L_{n,w}-12$	30	0.0	316
2500	24.0	$L_{n,w}-15$	27	0.0	251
3150	21.0	$L_{n,w}-18$	24	0.0	

L_n: Measurement result

Ref: Reference curve at position 42 dB (500 Hz value is the chosen $L_{n,w}$)

Dev: Uinfavorable deviation: Max(0; L_n - Ref)



Sum of unfavorable deviations:

30.0 dB Highest allowed value is 32.0 dB.

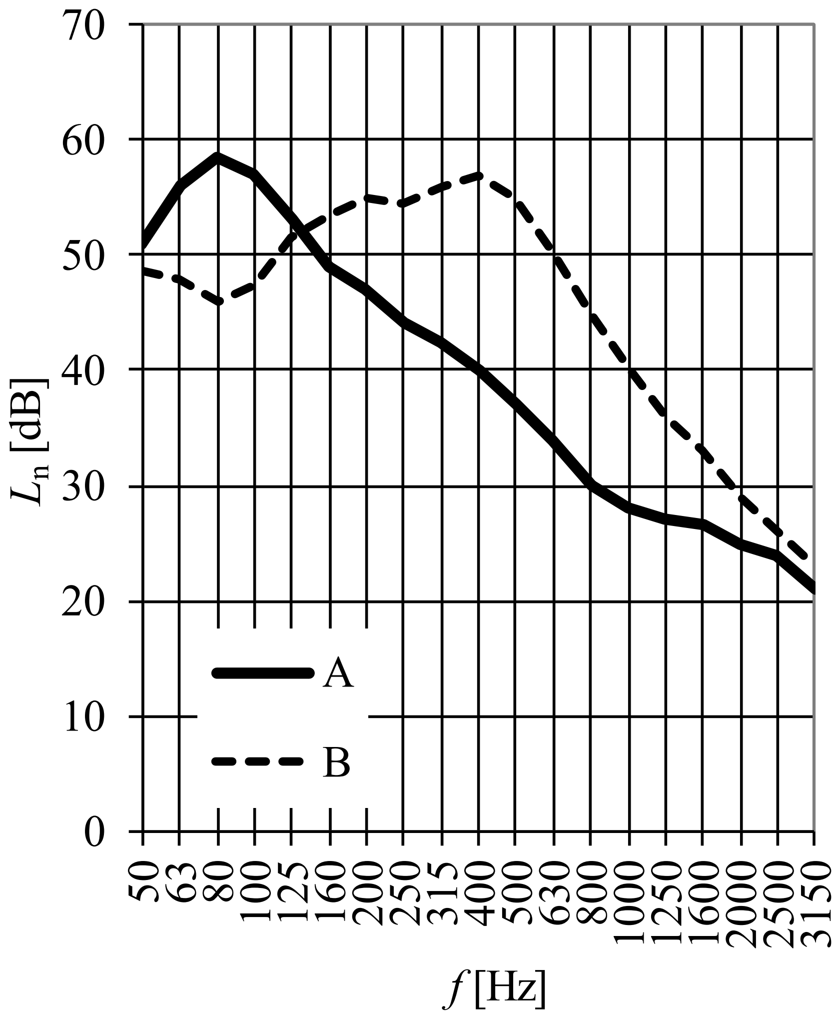
$S=\Sigma[10^{L_{n,i}/10}]=$ 2125782

$L_{n,sum}=10*\log_{10}(S)$ 63

$\boldsymbol{C_{I,50\text{-}2500}=L_{n,sum} - 15 - L_{n,w}=}$ **6**

Spectrum adaptation term $C_{I,50\text{-}2500}$

- A and B represent two typical floor constructions
- They are and also sound acoustically very different due to different resonance frequency f_0 and related decrement in impact SPL



	A	B
$L'_{n,w}$	42 dB	49 dB
$C_{I,50\text{-}2500}$	6 dB	0 dB
$L'_{n,w}+C_{I,50\text{-}2500}$	48 dB	49 dB
f_0	80 Hz	400 Hz

A

steel reinforced concrete 300 mm
wool 30 mm
gypsum 15 mm
gypsum 15 mm
flexible foam Parkolag
wood parquet 14 mm

B

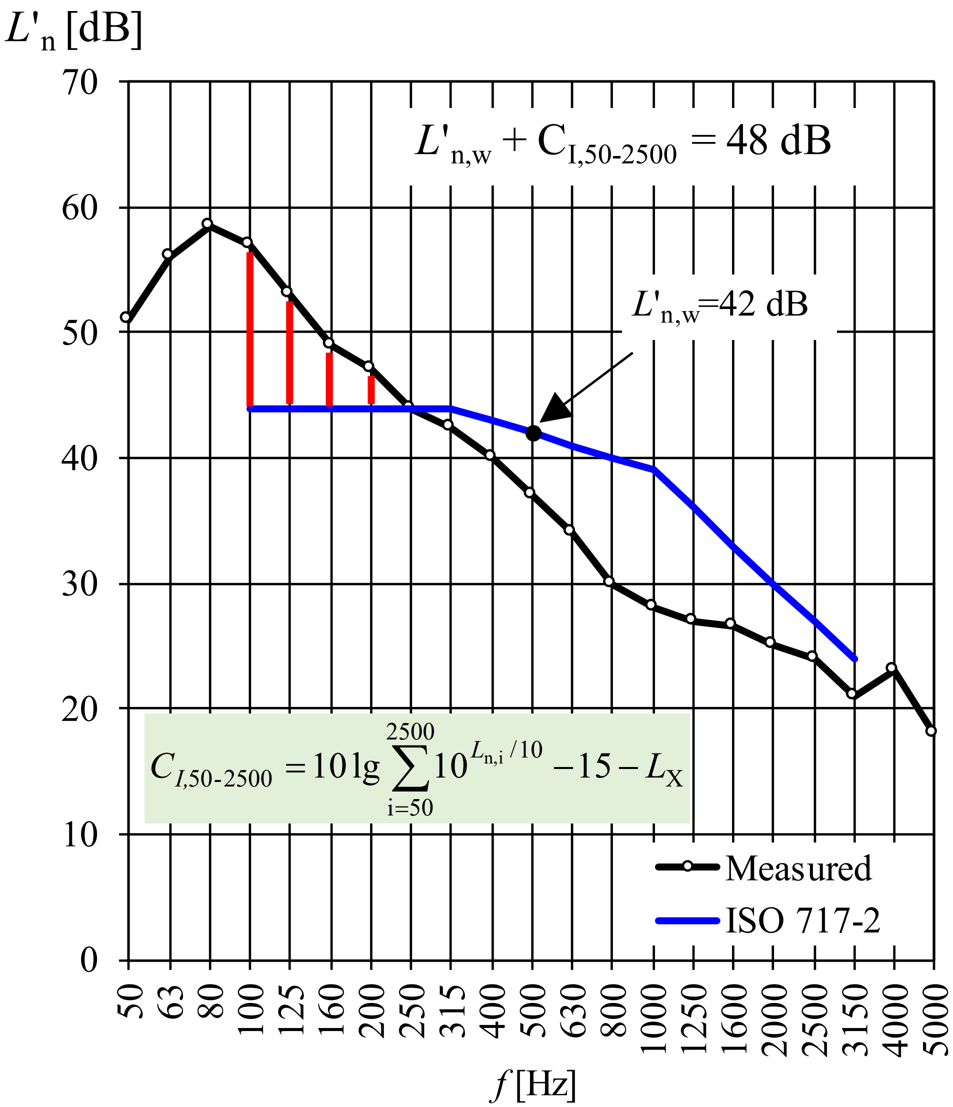
steel reinforced concrete 300 mm
flexible foam Parkolag
wood parquet 14 mm

RIL 243-1-2007

A

Frequency [Hz]	Measured [dB]	ISO 717-2 [dB]	Unfavorable deviation [dB]	$10^{L_{n,i}/10}$
50	51.0			125893
63	56.0			398107
80	58.5			707946
100	57.0	44	13.0	501187
125	53.0	44	9.0	199526
160	49.0	44	5.0	79433
200	47.0	44	3.0	50119
250	44.0	44	0.0	25119
315	42.5	44	0.0	17783
400	40.0	43	0.0	10000
500	37.0	**42**	0.0	5012
630	34.0	41	0.0	2512
800	30.0	40	0.0	1000
1000	28.0	39	0.0	631
1250	27.0	36	0.0	501
1600	26.5	33	0.0	447
2000	25.0	30	0.0	316
2500	24.0	27	0.0	251
3150	21.0	24	0.0	
4000	23.0			
5000	18.0			
SUM			30.0	2125782

$L_{n,w}$	**42**
$C_{I,50\text{-}2500}$	**6**



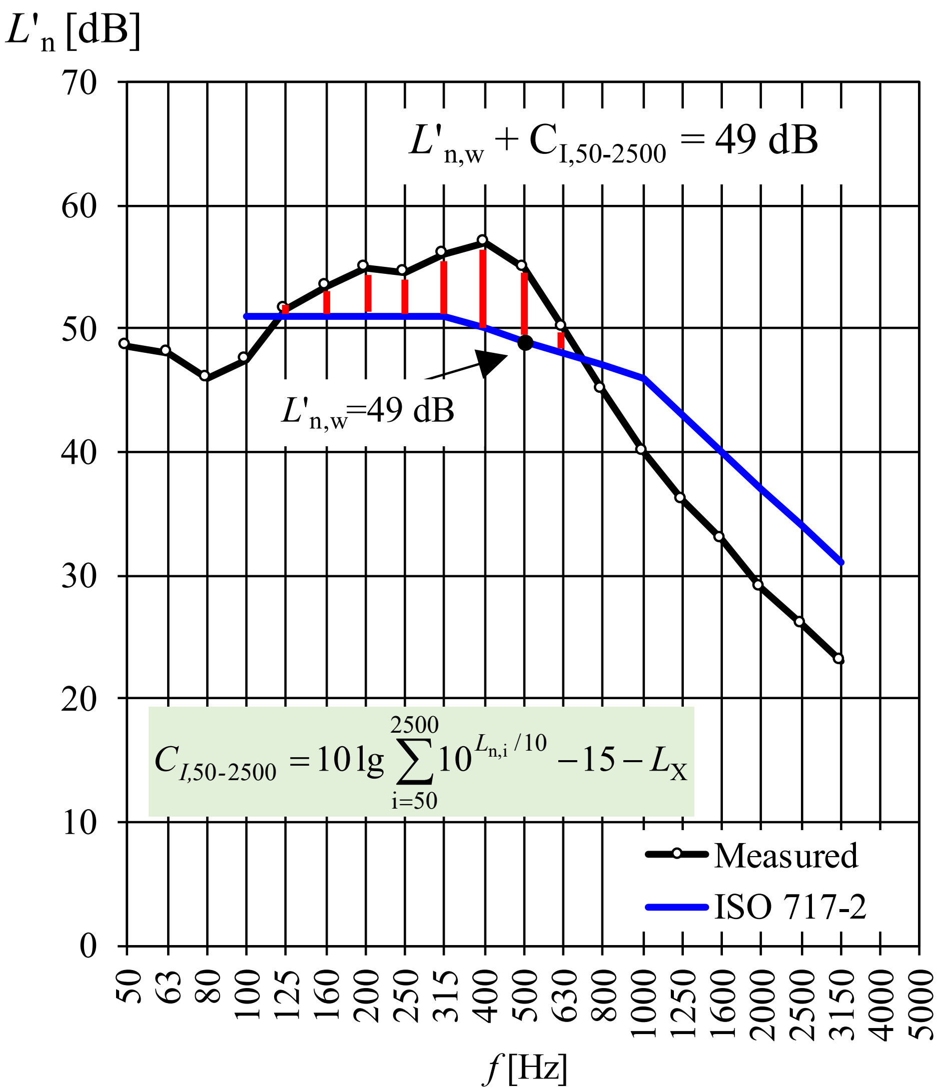
$$C_{I,50\text{-}2500} = 10\lg\sum_{i=50}^{2500} 10^{L_{n,i}/10} - 15 - L_X$$

ISO 717-2

B

Frequency [Hz]	Measured [dB]	ISO 717-2 [dB]	Unfavorable deviation [dB]	$10^{L_{n,i}/10}$
50	48.5			70795
63	48.0			63096
80	46.0			39811
100	47.5	51	0.0	56234
125	51.5	51	0.5	141254
160	53.5	51	2.5	223872
200	55.0	51	4.0	316228
250	54.5	51	3.5	281838
315	56.0	51	5.0	398107
400	57.0	50	7.0	501187
500	55.0	**49**	6.0	316228
630	50.0	48	2.0	100000
800	45.0	47	0.0	31623
1000	40.0	46	0.0	10000
1250	36.0	43	0.0	3981
1600	33.0	40	0.0	1995
2000	29.0	37	0.0	794
2500	26.0	34	0.0	398
3150	23.0	31	0.0	
4000				
5000				
SUM			30.5	2557441

***L* n,w**	**49**
***C* I,50-2500**	**0**



ISO 717-2

Tapping machine

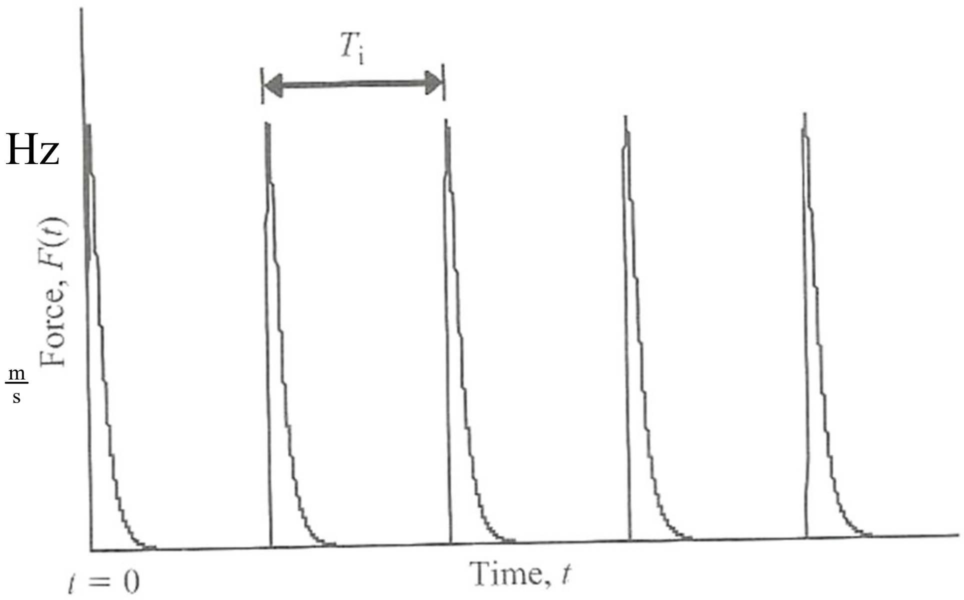
- Force consists of impacts that occur with frequency f_i = 10 Hz and period T_i = 0.1 s from drop height (h=0.04 m) of a hammer (m_h=0.5 kg).
- Kinetic energy equals with potential energy: $$\frac{m_h v^2}{2} = m_h g h$$
- Velocity at the impact, v_0 [m/s] becomes $$v_0 = \sqrt{2gh} = 0.886\,\tfrac{\text{m}}{\text{s}}$$
- The magnitude of the peak force of one drop is

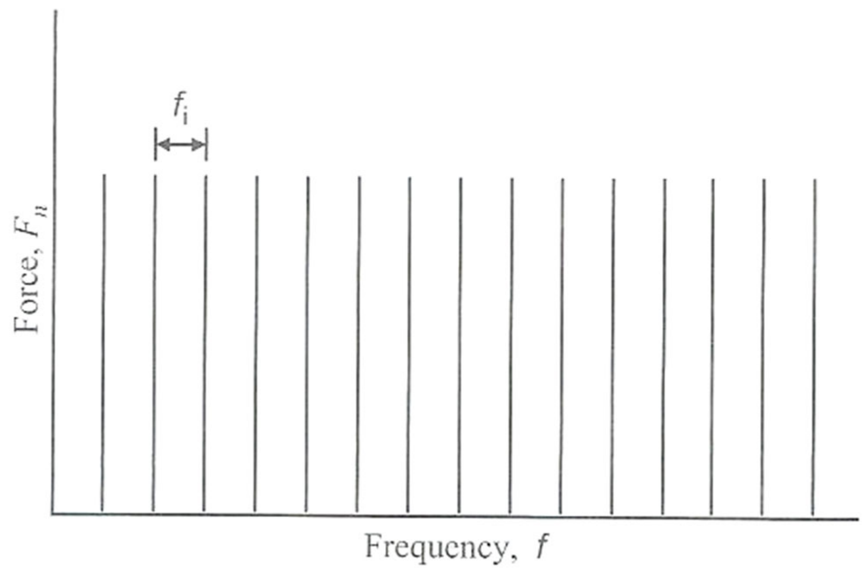
$$\left|F_n\right| = \frac{2}{T_i} m_h v_0 = 2 f_i m_h \sqrt{2gh}$$

- The force spectrum is a line spectrum with division f_i.
- For a bandwidth Δf [Hz], number of lines is $\Delta f / f_i$
- Mean square force within the frequency band is

$$F_{rms}^2 = \frac{\left|F_n\right|^2 \Delta f}{2 f_i} = 3.9 \Delta f$$

  - Δf=0.23$\cdot f_m$ for 1/3-octave band of middle frequency f_m
  - Δf=0.707$\cdot f_m$ for 1/1-octave band of middle frequency f_m
- The force is constant per each Δf up to appr.
  - 200 Hz: lightweight floors
  - 3000 Hz: heavyweight load-bearing floors





L_n of bare heavyweight slab

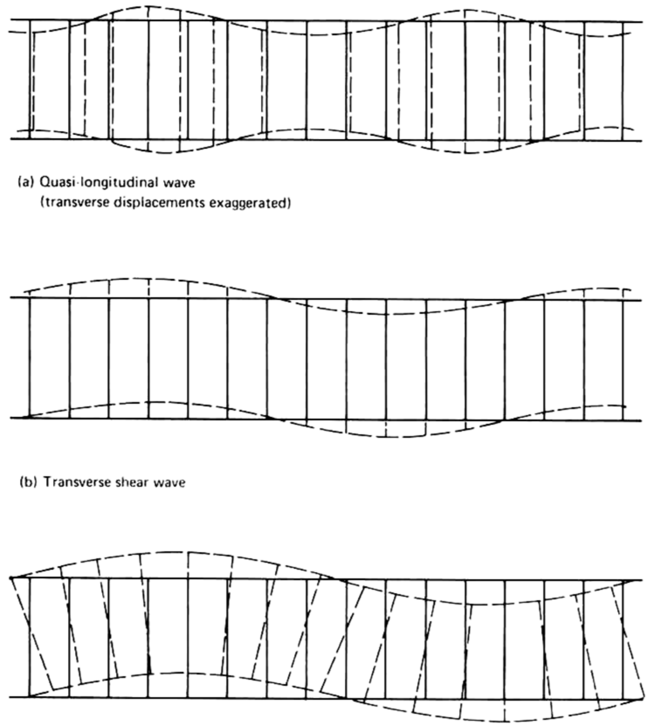
- The normalized SPL caused by tapping machine (assumed to be a point source) on a homogeneous heavy slab (e.g., concrete or CLT) can be predicted in two frequency ranges by two approximative equations.
  - m' [kg/m^2] is the surface mass of the floor
  - η is the total loss factor of the construction (frequency dependent)
  - f_c [Hz] is the critical frequency of the material
  - f_s [Hz] is the frequency where the speed of shear and bending waves are equal (see ”4 Airborne sound insulation”)
  - B [N/m] is the bending stiffness per unit width
  - c_s [m/s] is the speed of shear waves
- The values concern third-octave bands.

$$f_c = \frac{c_0^2}{2\pi}\sqrt{\frac{12\left(1-\mu^2\right)m'}{Eh^3}}$$

$$f_s = \frac{c_s^2}{2\pi}\sqrt{\frac{m'}{B}}$$

$$B = \frac{Eh^3}{12\left(1-\mu^2\right)}$$

$$c_s = \sqrt{\frac{Gh}{m'}} = \sqrt{\frac{E}{\rho_p 2(1+\mu)}}$$



(a) Quasi-longitudinal wave (transverse displacements exaggerated)

(b) Transverse shear wave

(c) Flexural (bending) wave

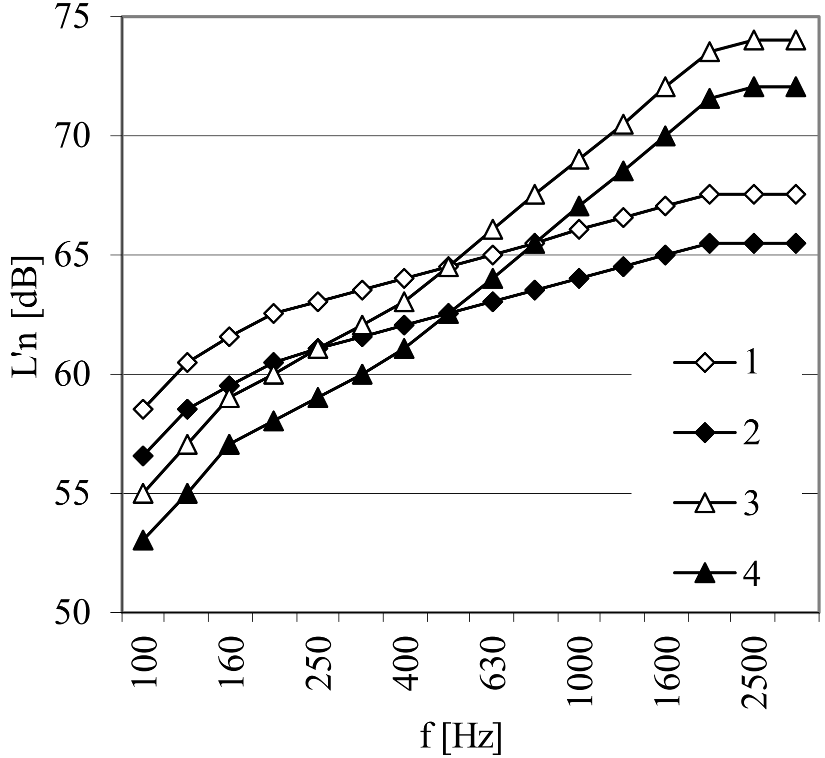
$$L_n \cong 82 - 10\log_{10}\left(m'^2\frac{\eta}{f_c}\right), \qquad f_c < f < \tfrac{1}{2}f_s$$

$$L_n \cong 82 - 10\log_{10}\left(m'^2\frac{\eta}{f_c}\right) + 10\log_{10}\left(\frac{2f}{f_s}\right), \qquad f > \tfrac{1}{2}f_s$$

Rindel (2006) DTU

Examples of L'_n for bare concrete slabs (tapping machine)

	1	2	3	4
	Steel-reinforced concrete 200 mm	Steel-reinforced concrete 240 mm	Hollow-core concrete 380 kg/m2	Hollow-core concrete 500 kg/m2
100	58.5	56.5	55.0	53.0
125	60.5	58.5	57.0	55.0
160	61.5	59.5	59.0	57.0
200	62.5	60.5	60.0	58.0
250	63.0	61.0	61.0	59.0
315	63.5	61.5	62.0	60.0
400	64.0	62.0	63.0	61.0
500	64.5	62.5	64.5	62.5
630	65.0	63.0	66.0	64.0
800	65.5	63.5	67.5	65.5
1000	66.0	64.0	69.0	67.0
1250	66.5	64.5	70.5	68.5
1600	67.0	65.0	72.0	70.0
2000	67.5	65.5	73.5	71.5
2500	67.5	65.5	74.0	72.0
3150	67.5	65.5	74.0	72.0
L'eq,0,w	71.0	69.0	72.0	70.0

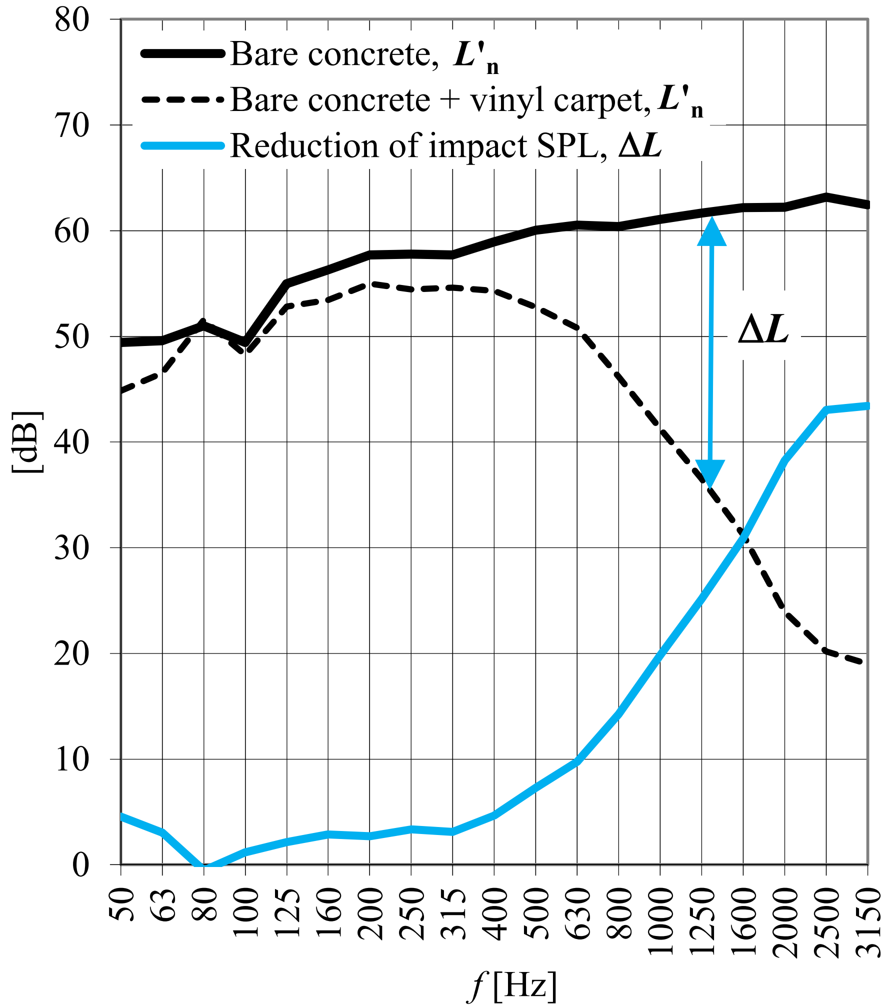


Reduction of impact SPL, ΔL and ΔL_w

- Reduction of impact SPL, ΔL, is determined in laboratory conditions according to ISO 10140-3 [dB]:

$$\Delta L = L_{n,0} - L_n$$

  - $L_{n,0}$ [dB] is the impact SPL of standard floor without floor covering
  - L_n [dB] is the impact SPL of covered floor
- Standard concrete floors:
  - steel-reinforced concrete: 140 ± 20 mm
  - wooden floor: three options C1-C3
- Impact SPL reduces with the surface mass of the concrete floor but the ΔL curve of a floor covering (or a floating floor) is applicable to any thickness.
- Performance of floor coverings or floating floors is usually reported by a single-number quantity ΔL_w. It is determined from the weighted normalized impact sound pressure levels by $\mathbf{\Delta L_w} = L_{n,w,0} - L_{n,w}$



ISO 10140-3-2010

ΔL of light floor coverings

- Flexible covering reduces the force of the tapping machine towards the floor.
- Hammer's mass, flexibility of the covering and the mass of the floor under the covering cause a mass-spring-mass system.
- The resonance frequency f_0 is:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{S_h E_t}{m_h h_t}}$$

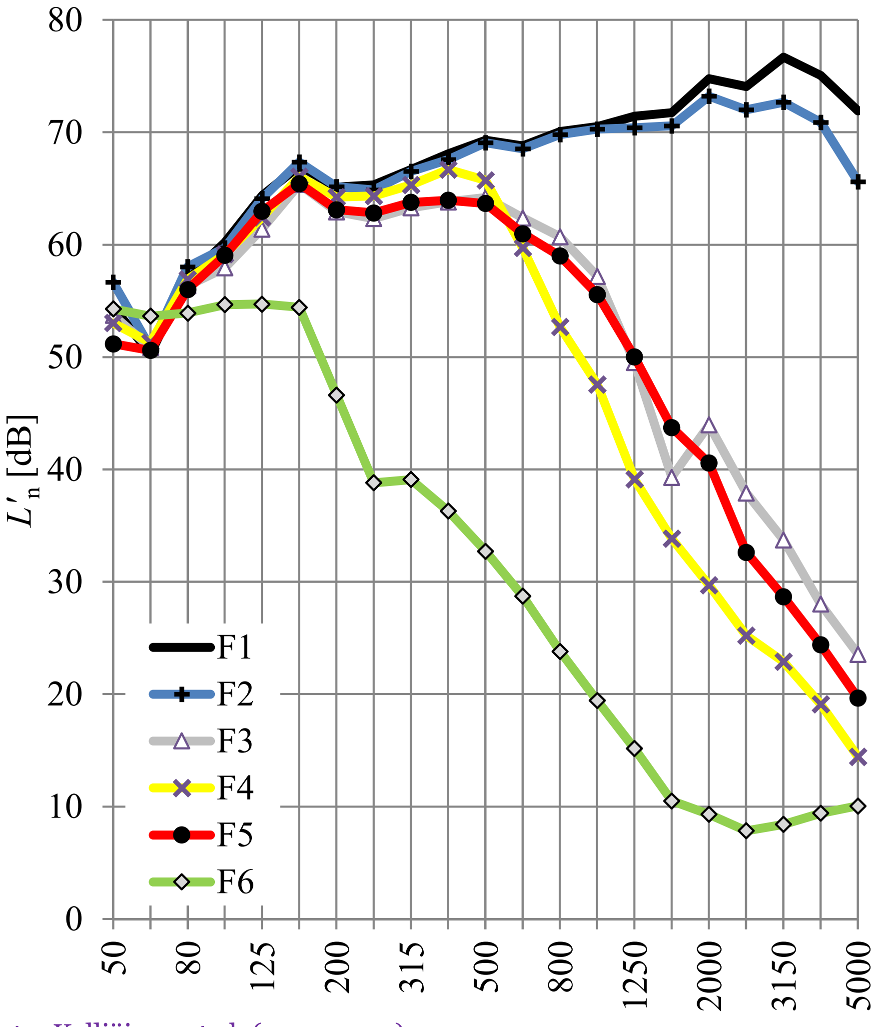
  - S_h [m^2] is the area of the hammer
  - E_t [Pa] is the Young's modulus of the covering
  - m_h [kg] is the mass of the hammer
  - h_t [m] is the thickness of covering
- For standardized tapping machine:
  - $m_h = 0.500$ kg
  - $S_h = 700$ mm^2

- **Note: the actual resonance frequency in the dwelling depends on the stimulus' mass and area**
  - heavy impact (large force) causes lower resonances than light impact
- Floor covering does not influence the impact SPL below the resonance frequency ($f<f_0$).
- Theoretical ΔL obtained by a flexible floor covering is

$$\Delta L \cong \begin{cases} 0, & f < f_0 \\ 40\lg\frac{f}{f_0} & f > f_0 \end{cases}$$

Rindel (2006) DTU

ΔL and ΔL_w values



Data: Kylliäinen et al. (2015, 2017)
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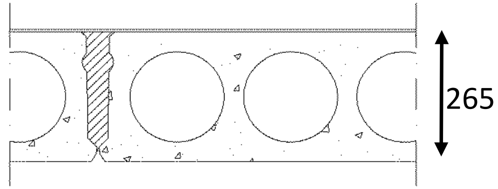
F1

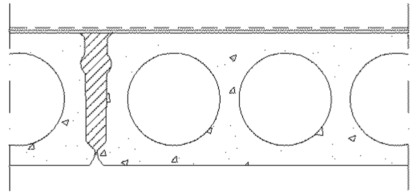
Bare floor

Hollow concrete slab 265 mm



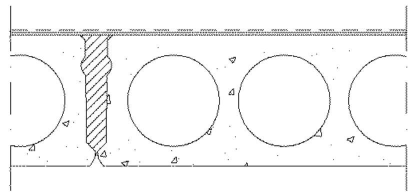
F2

F1 + hard vinyl carpet for public spaces *Estrad* (s'=3400 MN/m^3), ΔL_w=2 dB



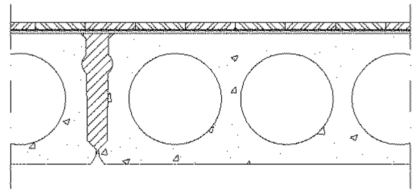
F3

F1 + soft vinyl carpet for domestic spaces *Upostep* (s'=2800 MN/m^3), ΔL_w=21 dB



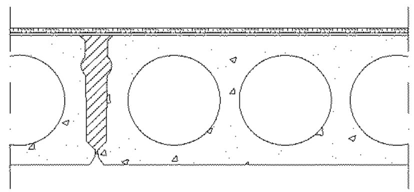
F4

F1 + soft underlayment *Tuplex* (s'=68 MN/m^3) + birch parquet, ΔL_w=20 dB



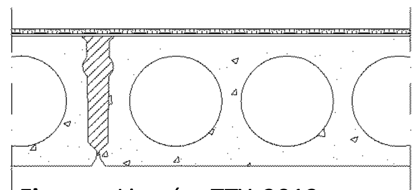
F5

F1 + hard textile carpet for public spaces *Epoca Compact* (s'=226 MN/m^3), ΔL_w=21 dB



F6

F1 + soft textile carpet for domestic spaces *Milliken* (s'=80 MN/m^3), ΔL_w=29 dB



Figures: Lietzén, TTY, 2012

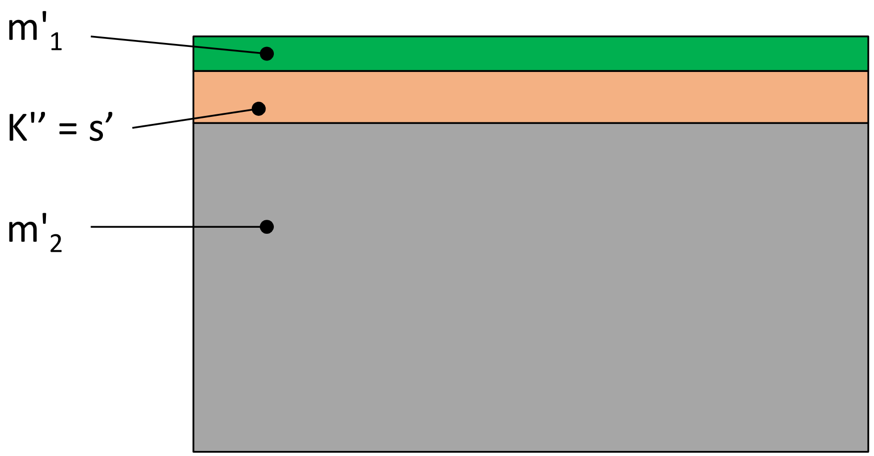
Floating floor – resonance frequency

- Floating floor is a construction where a floating slab m’$_1$ and the load bearing slab m’$_2$ are separated by a resilient layer having dynamic stiffness per unit area of s’
- Resonance frequency f_0 [Hz] is determined by:

$$f_0 = \frac{1}{2\pi}\sqrt{K''\frac{m'_1+m'_2}{m'_1\, m'_2}}$$

  - m'_1 [kg/m^2] surface mass of the floating layer
  - K'' [**N**/m^3] dynamic stiffness per unit area of the resilient layer
  - m'_2 [kg/m^2] surface mass of the load-bearing floor
- The manufacturers declare the properties of the flexible layer by ***s'*** [**MN**/m^3] so that the calculation of f_0 is done according to

$$f_0 = 159\sqrt{\frac{s'}{m'_1}}$$



$$f_0 = \frac{1}{2\pi}\sqrt{K''\frac{m'_1+m'_2}{m'_1\, m'_2}} \xrightarrow{m'_2 >> m'_1} \frac{1}{2\pi}\sqrt{K''\frac{1}{m'_1}}$$

$$159 = \frac{1}{2\pi}\sqrt{1.000.000}$$

Floating floor examples

Heavy floating slab (60-300 kg/m2)

- A ”real” floating floor refers usually constructions with a low mass-air-mass resonance frequency, $20<f_0<100$ Hz.
- Screed or concrete is used

Semi-heavy floating slab

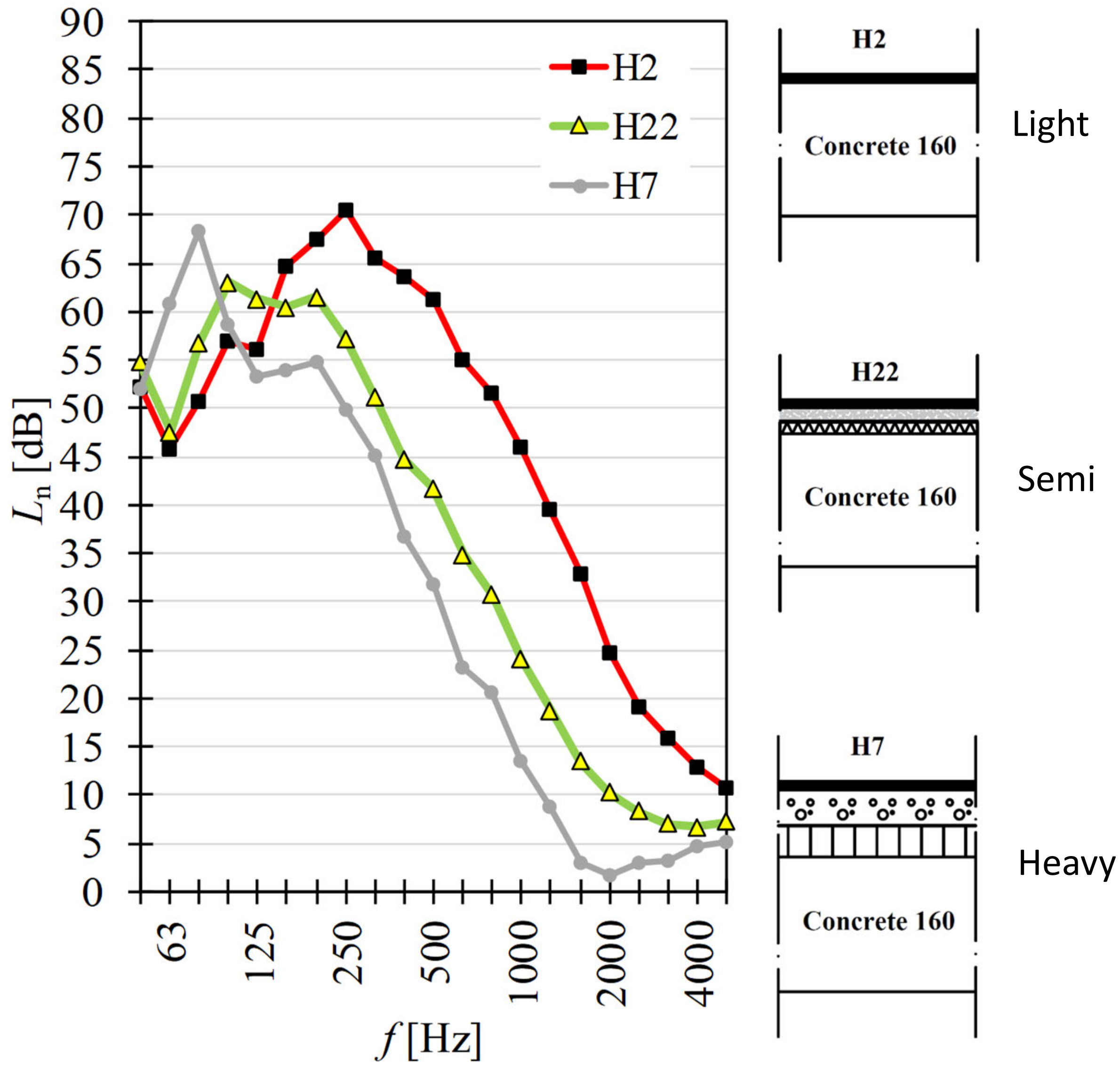
- Dry boards are used (10-60 kg/m^2)
- $50<f_0<200$ Hz.

Light floating floor

- Parquet with soft underlayment
- Resonance frequency is high, f_0 >300 Hz.
- If a light floating floors is installed on a heavy floating floor, two resonance frequencies are obtained. The higher is usually inaudible

The benefit (ΔL) of floating floor:

- Below $\frac{1}{2}f_0$: nothing.
- $\frac{1}{2}f_0$:-$1\frac{1}{2}f_0$: disadvantage by 0… 15 dB
- Within $2f_0$ and f_d: -12 dB/octave
- Above f_d: -6 dB/octave



Hongisto et al., **Data in Brief**, 2023

Determination of *K*''

- Specimen size 20x20 cm
- Thickness d [m] according to the product
- Load plate 8 kg over the specimen
- Load plate is shakened and the system's resonance frequency f_r [Hz] is determined with FFT analysis
- Dynamic stiffness per unit area K'' [N/m^3] is

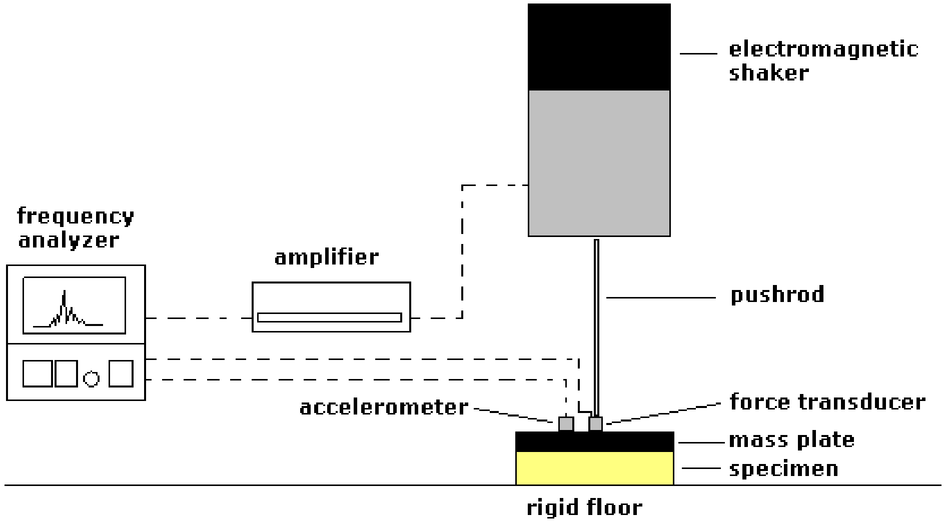
$$K'' = \frac{4\pi^2 m_t f_r^2}{A}$$

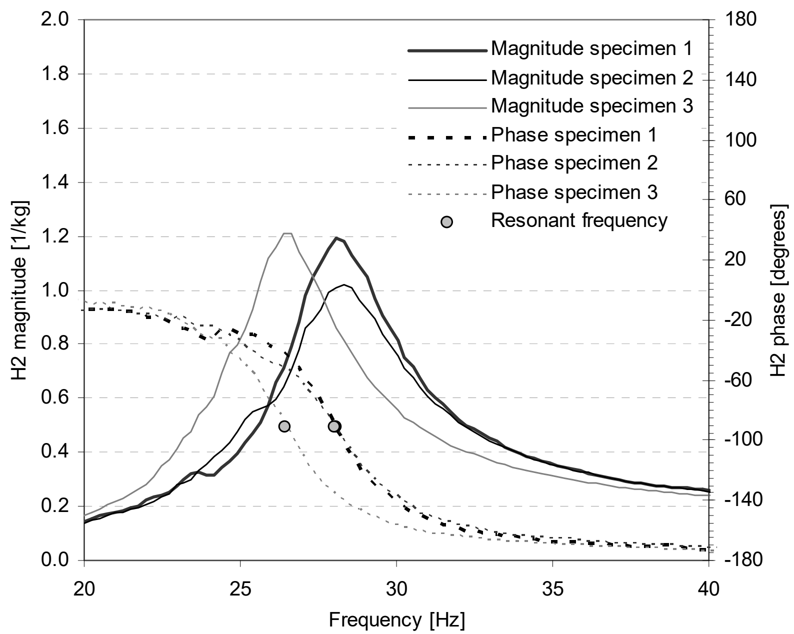
  - $m_t = 8$ kg.
  - $A = 0.04\ m^2$
- Final reported K'' depends on the properties of both the skeletal frame determined above, K_f'' and air within the pores, K_a'':

$$K'' = K_f'' + K_a''$$

$$K_a'' = \frac{p_0}{d\left(1 - \frac{\rho_m}{\rho_f}\right)}$$

  - p_0=101300 Pa
  - ρ_m [kg/m^3] is the density of material
  - ρ_f [kg/m^3] is the density of skeletal frame
- K_a'' is meaningful if r<100 kPa/m^2 in lateral direction





Examples of *s'* values for some materials

Product	Thickness [mm]	Density [kg/m3]	s' [MN/m3]
Isover RKL-31 wool	50	45	3
Isover FLO-50 wool	50	92	12
EPS - weber.floor 4900 Comfort grooved board 50 mm	50		12
EPS - weber.floor 4900 Comfort grooved board 35 mm	35		13
Isover VKL-13 wool	13	115	16
EPS - weber.floor Comfort Lite 30 mm	30		16
Tuplex felt used under parquet	2.1	77	68
Textile floor Milliken (soft, residential rooms)	8.2	470	80
Textile floor Epoca Compact (hard, public rooms)	3.8	550	230
Vinyl floor Upostep (soft, residential rooms)	2.4	703	2900
Vinyl floor Estrad (hard, public spaces)	2.2	1420	3400

Floating floor - Calculation of ΔL

Schiavi (2018, Appl Acoust)

Floating slab is globally reacting, i.e., resonating:

- The floating slab radiates sound efficiently on the entire area and interacts with the resilient material in the whole floor area although the stimulus is on one point.
- Slab is resonant, when $f > f_c$, where f_c is the critical coincidence frequency of the floating slab.
- Cement-based floating slabs usually have $f_c < 300$ Hz and thus they are resonant in a large frequency range.

$$\Delta L = -15 \cdot \log_{10}\left(\sqrt{\frac{1+\eta_m\left(\frac{f}{f_0}\right)^2}{\eta_m\left(\frac{f}{f_0}\right)^2+\left[1-\left(\frac{f}{f_0}\right)^2\right]^2}}\right)$$

$$f_0 = \frac{1}{2\pi}\sqrt{K''\frac{m'_1+m'_2}{m'_1\, m'_2}}$$

Floating slab is locally reacting i.e. non-resonant

- Floating slab interacts with the elastic material only locally close to the stimulus point (within half bending wavelenght). Outside this area acoustic short-cirquit prevents efficient radiation of sound.
- Slab is non-resonant, when $f < f_c$. Building boards usually have $f_c > 1000\ldots3000$ Hz where they behave as non-resonant slabs.
- η_m is the loss factor of resilient layer. Typical values 0.05-0.30.

$$\Delta L = -20 \cdot \log_{10}\left(\sqrt{\frac{1+\eta_m\left(\frac{f}{f_0}\right)^2}{\eta_m\left(\frac{f}{f_0}\right)^2+\left[1-\left(\frac{f}{f_0}\right)^2\right]^2}}\right)$$

6.1

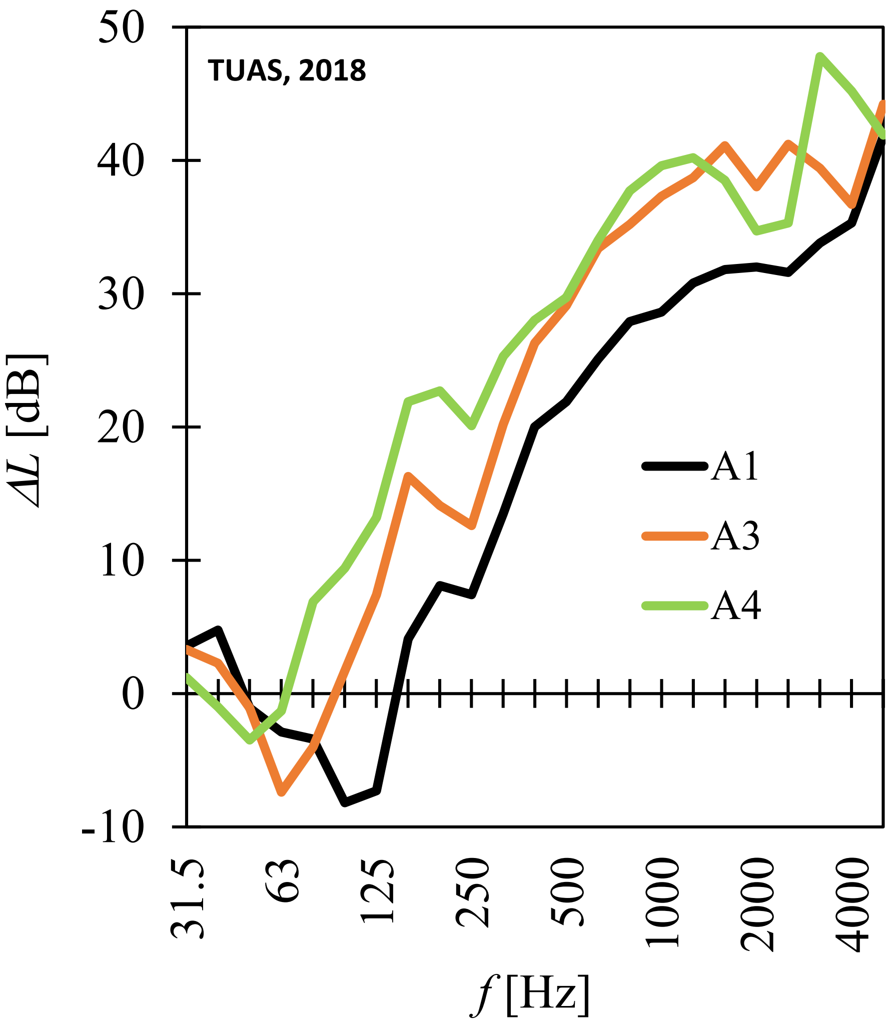
Dynamic stiffness per unit area of a flexible wool is 10 MN/m3.
Calculate the resonance frequency, if the wool is installed on top of concrete floor (450 kg/m2) and the following floating floor is installed on top of it:

a) 22 mm chipboard
b) two layers of 22 mm chipboard
c) 60 mm cast concrete

$$f_0 = 159\sqrt{\frac{s'}{m'_1}}$$

Heavy floating floors

- Three heavy floating floors were tested in laboratory conditions.
- Increment of screed mass from 30 mm (A1) to 80 mm (A2) increased ΔL_w by 9 dB
- Increment of EPS thickness by 20 mm and screed thickness further by 20 mm increased ΔL_w by 5 dB (A4)



A1 - ΔL_w = 19 dB
30 mm screed
35 mm EPS
160 mm concrete
f_0=100 Hz

A3 - ΔL_w = 28 dB
80 mm screed
35 mm EPS
160 mm concrete
f_0=63 Hz

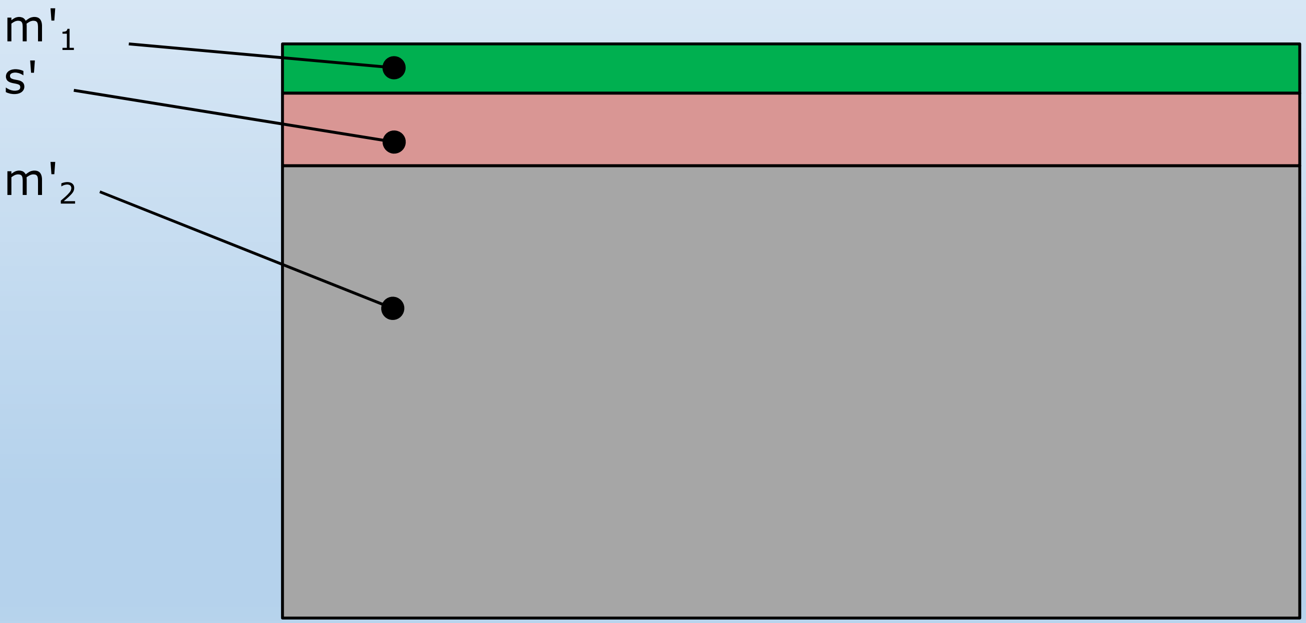
A4 - ΔL_w = 33 dB
100 mm screed
55 mm EPS
160 mm concrete
f_0=50 Hz

Hongisto et al. Build. Environ, 2020

6.2

Floating floor consists of 265 mm hollow concrete slab, 20 mm flexible layer (s'=20 MPa/m3) and and pumpable screed 60 mm (r=1700 kg/m3).
The flexible material is homogeneous and it can be produced at any thickness.
What should be the thickness to achieve f0=50 Hz?

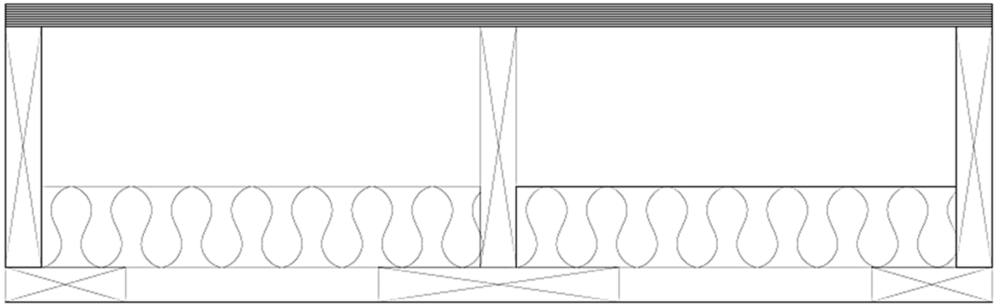
$$f_0 = 159\sqrt{\frac{s'}{m'_1}}$$



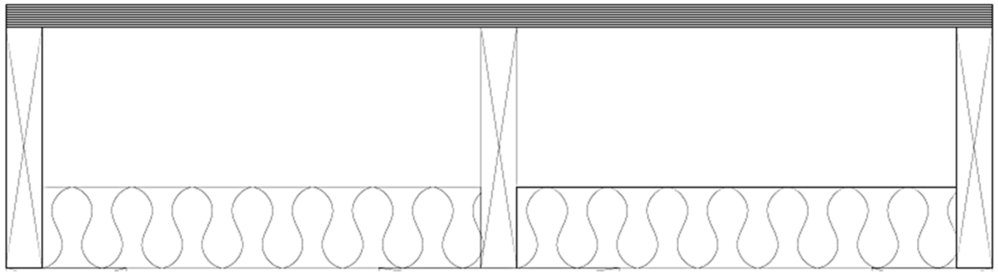
Timber floors

- Timber is increasingly favored in apartment buildings
- Typical timber load-bearing slabs
  - Rib slab
  - Hollow box slab
  - CLT slab
  - LVL slab
- Timber density is 600 kg/m^3 and concrete density is 2200 kg/m^3: the achievement of regulated ISPL with timber slabs requires usually more than additional layer, which is resiliently mounted to the slab
  - Resilient ceiling (see figure 4+5)
  - Floating floor (see figure 7+8)
  - Installation floor (not in the figure)
  - Absorption material in cavity

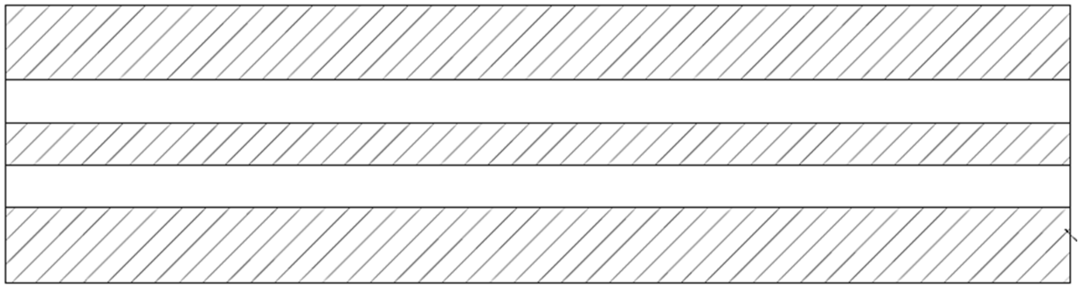
Avokotelolaatta 370 mm (Box slab)



Ripalaatta 320 mm (Rib slab)



CLT 260 mm



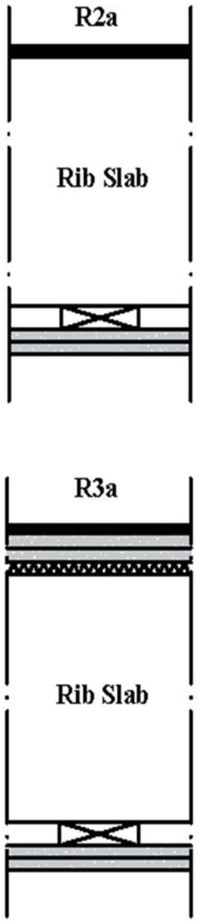
Cross laminated timber slab 260 mm
Cross-section

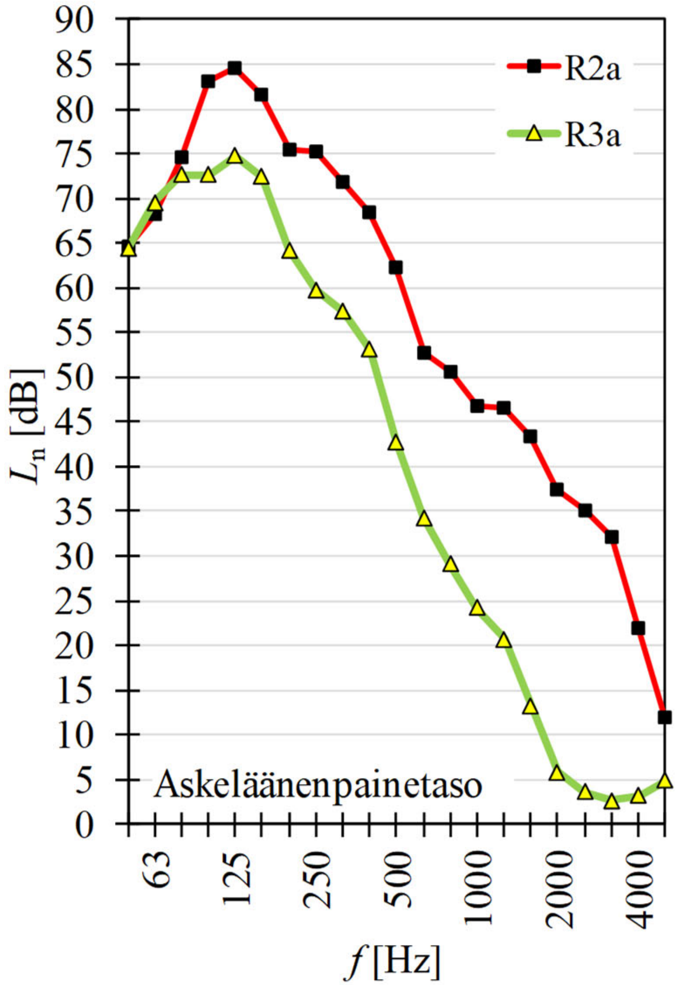
Open box timber slab 370 mm, installed on test opening

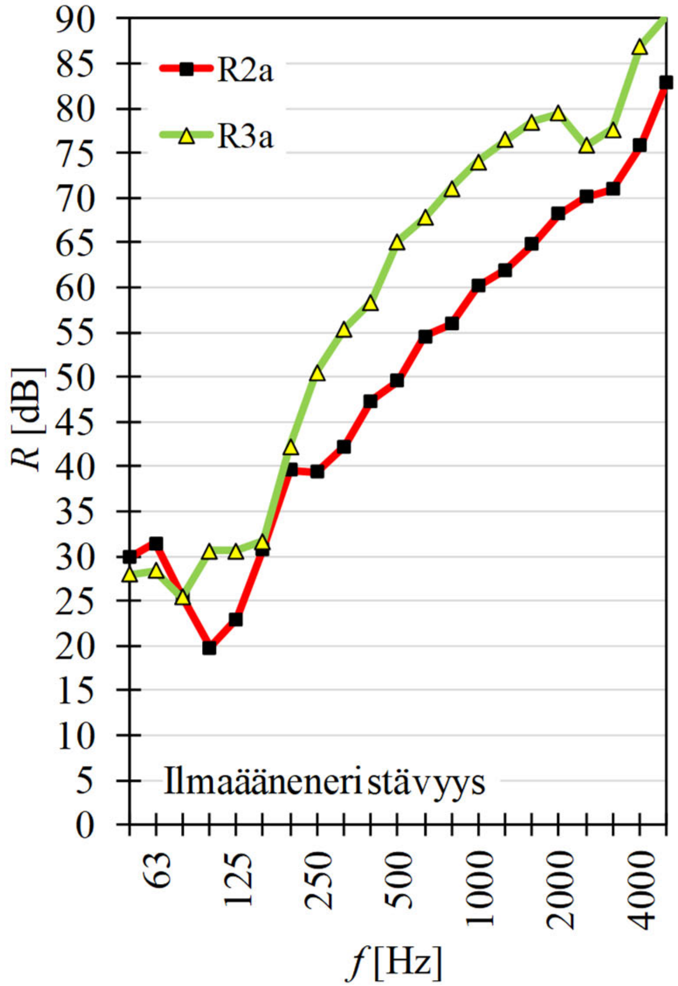
Kelluvan pintalaatan vaikutus avokotelopuulaatalla

The effect of floating floor slab with open box timber slab

Hongisto et al., **Data in Brief**, 2023







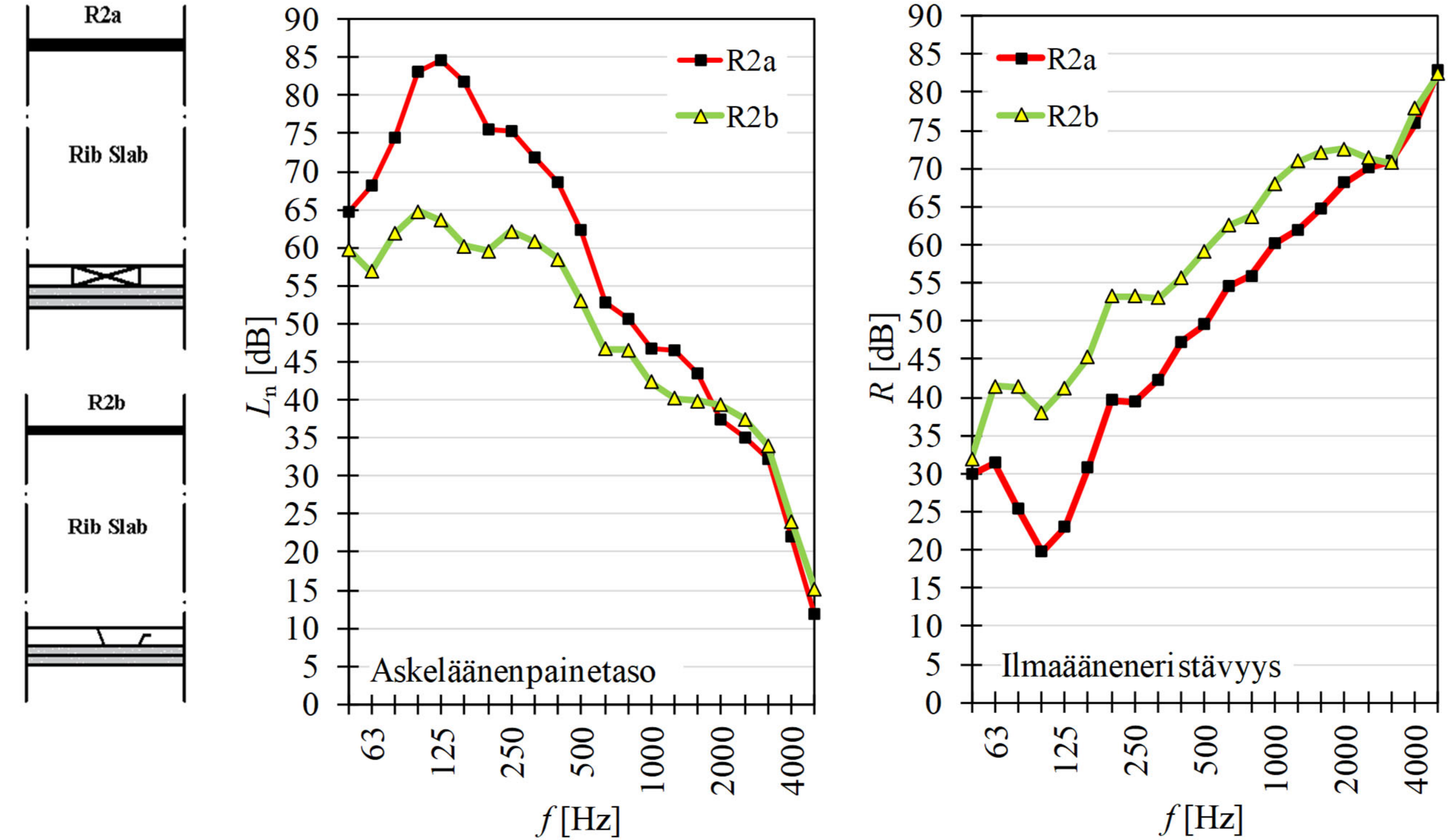
Kelluva rakenne	Float
13 mm villa 24 MN/m2	13 mm wool
2 x kipsi = 31 kg/m2	Two gypsum boards

	$L_{n,w}$	$L_{n,w}+C_{I,50\text{-}2500}$	R_w
R2a	72	73	49
R3a	61	65	56

Joustavan alakaton vaikutus avokotelopuulaatalla

The effect of resiliently suspended ceiling with open box timber slab

Hongisto et al., **Data in Brief**, 2023



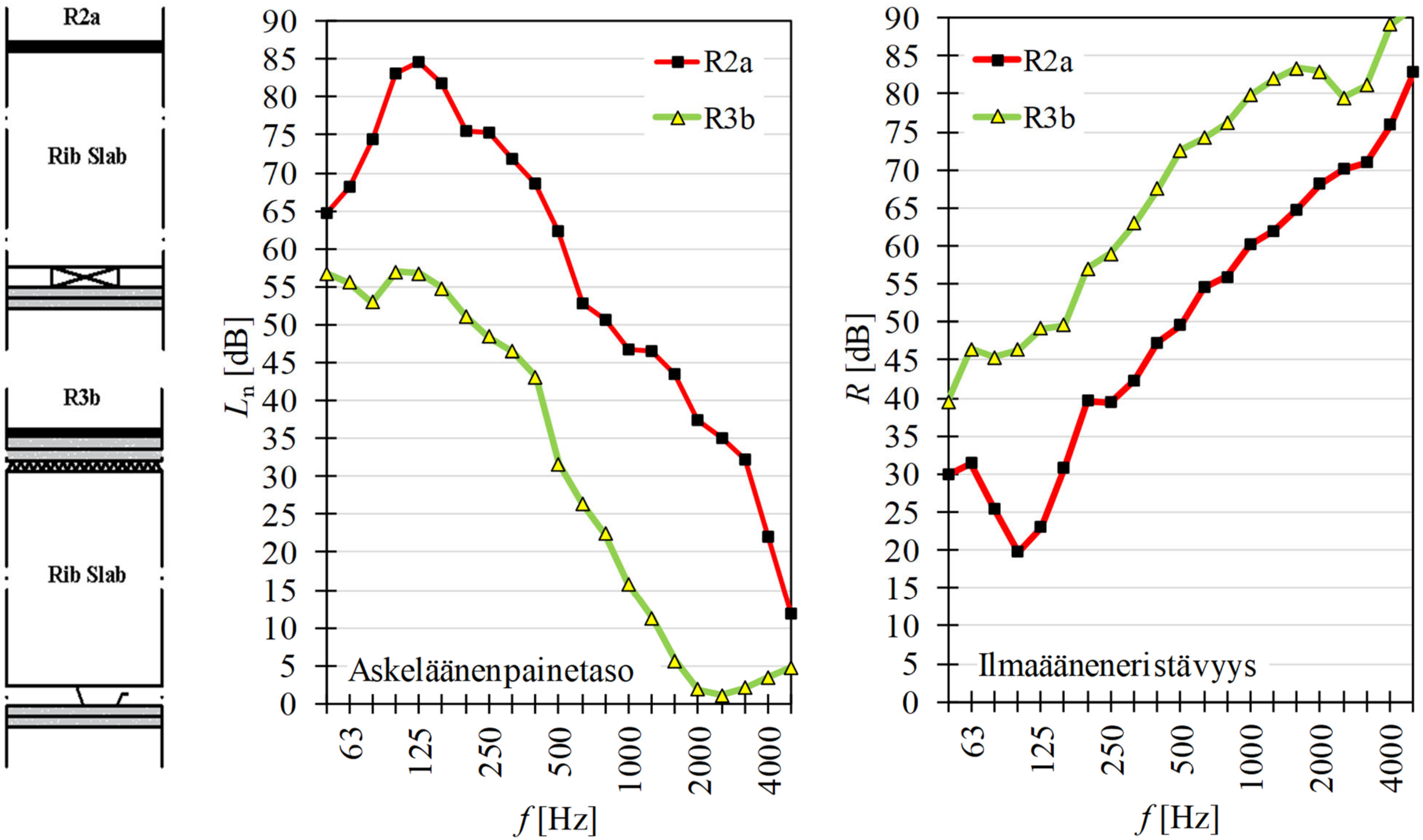
Alakatto:
R2b: AP25 jousiranka k400
R2a: lautakoolaus

Suspended ceiling:
R2b: resilient steel bar
R2a: timber lath

	$L_{n,w}$	$L_{n,w}+C_{I,50\text{-}2500}$	R_w
R2a	72	73	49
R2b	55	56	62

Joustavan alakaton ja kelluvan laatan yhtäaikainen vaikutus avokotelopuulaatalla

The simultaneous effect of resiliently suspended ceiling and floating floor slab with open box timber slab



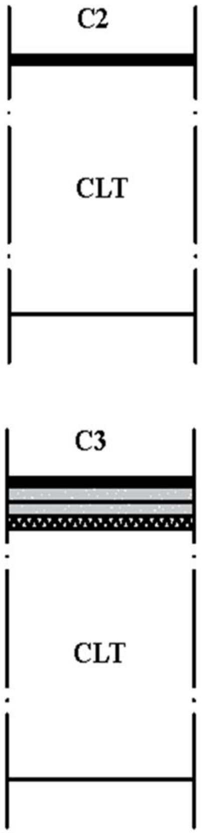
	$L_{n,w}$	$L_{n,w}+C_{I,50\text{-}2500}$	R_w
R2a	72	73	49
R3b	46	49	70

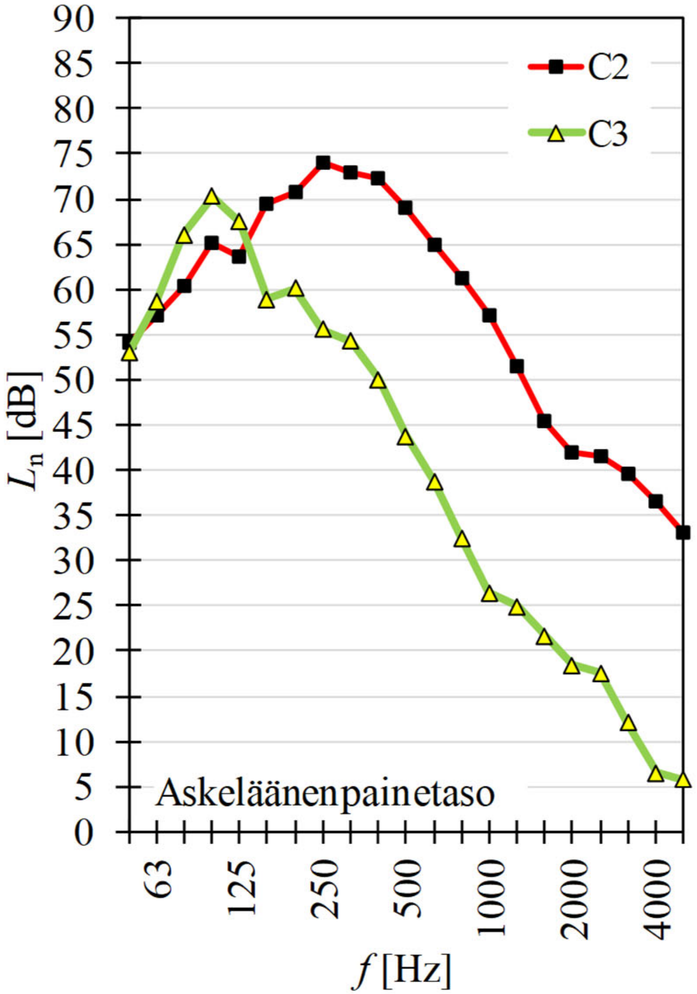
Hongisto et al., **Data in Brief**, 2023

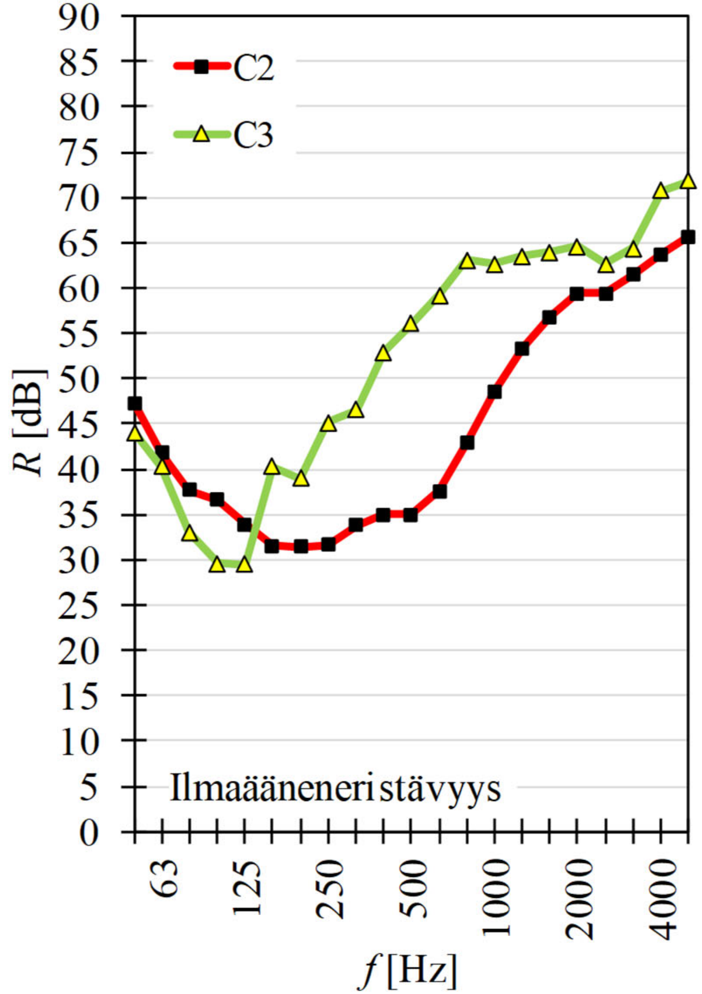
Kelluvan pintalaatan vaikutus massiivipuulaatalla

Hongisto et al., **Data in Brief**, 2023

The effect of floating floor slab with cross-laminated timber (CLT) slab







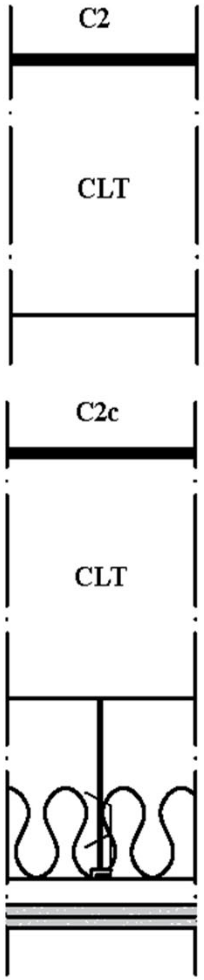
Kelluva pintalaatta	Floating floor
13 mm villa 24 MN/m2	13 mm wool
2 x kipsi = 31 kg/m2	Two gypsum boards

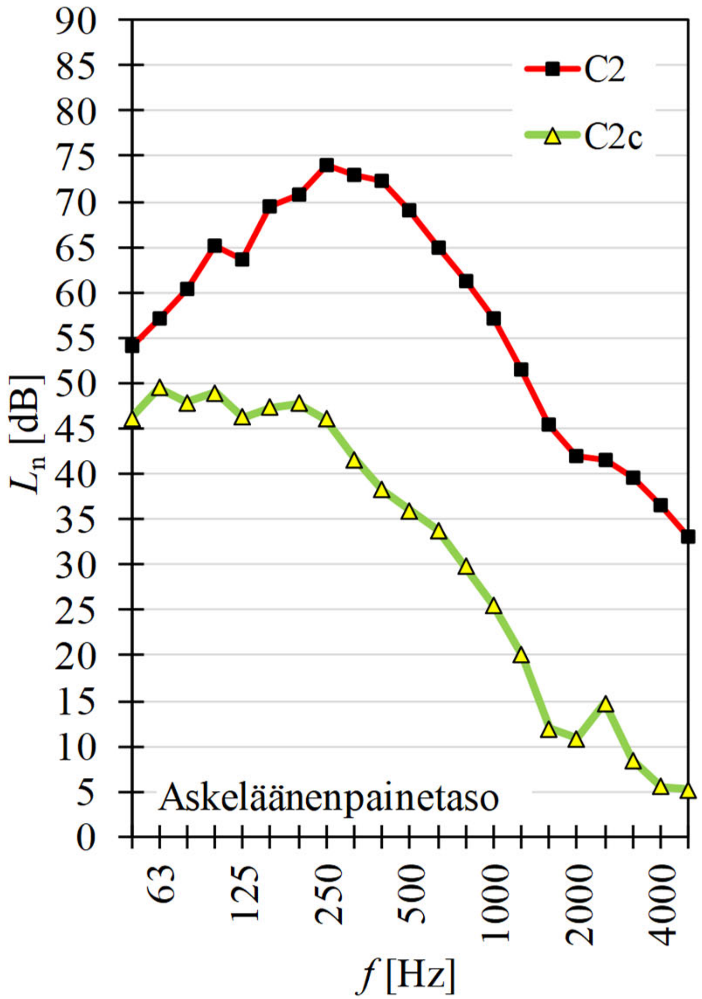
	$L_{n,w}$	$L_{n,w}+C_{I,50\text{-}2500}$	R_w
C2	65	65	42
C3	55	59	54

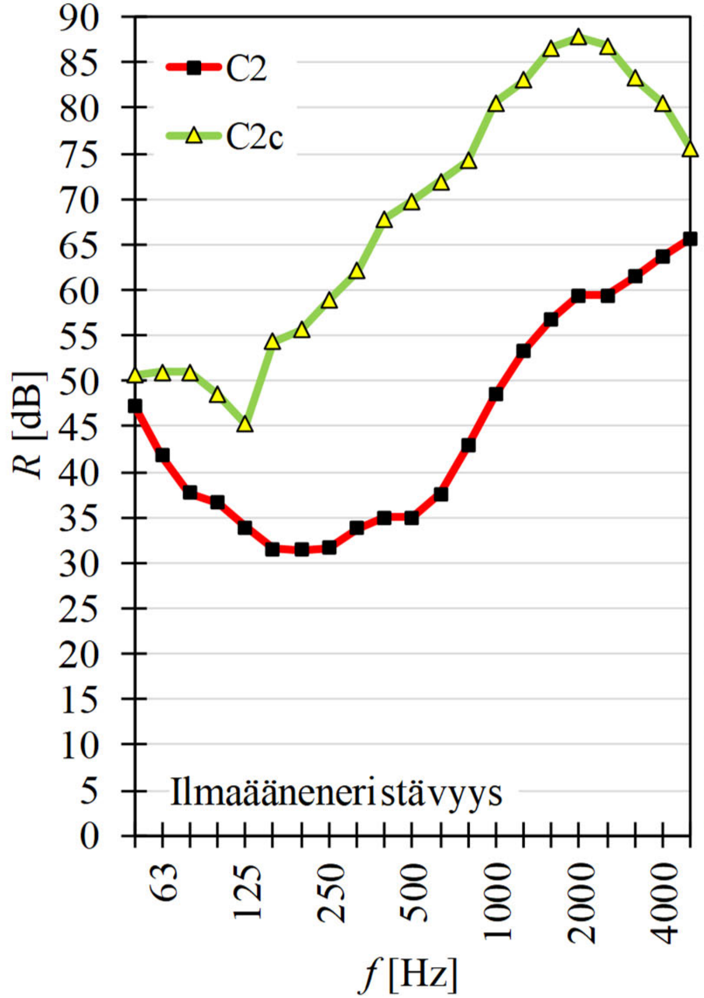
Joustavan alakaton vaikutus massiivipuulaatalla

The effect of resilient suspended ceiling with CLT slab

Hongisto et al., **Data in Brief**, 2023







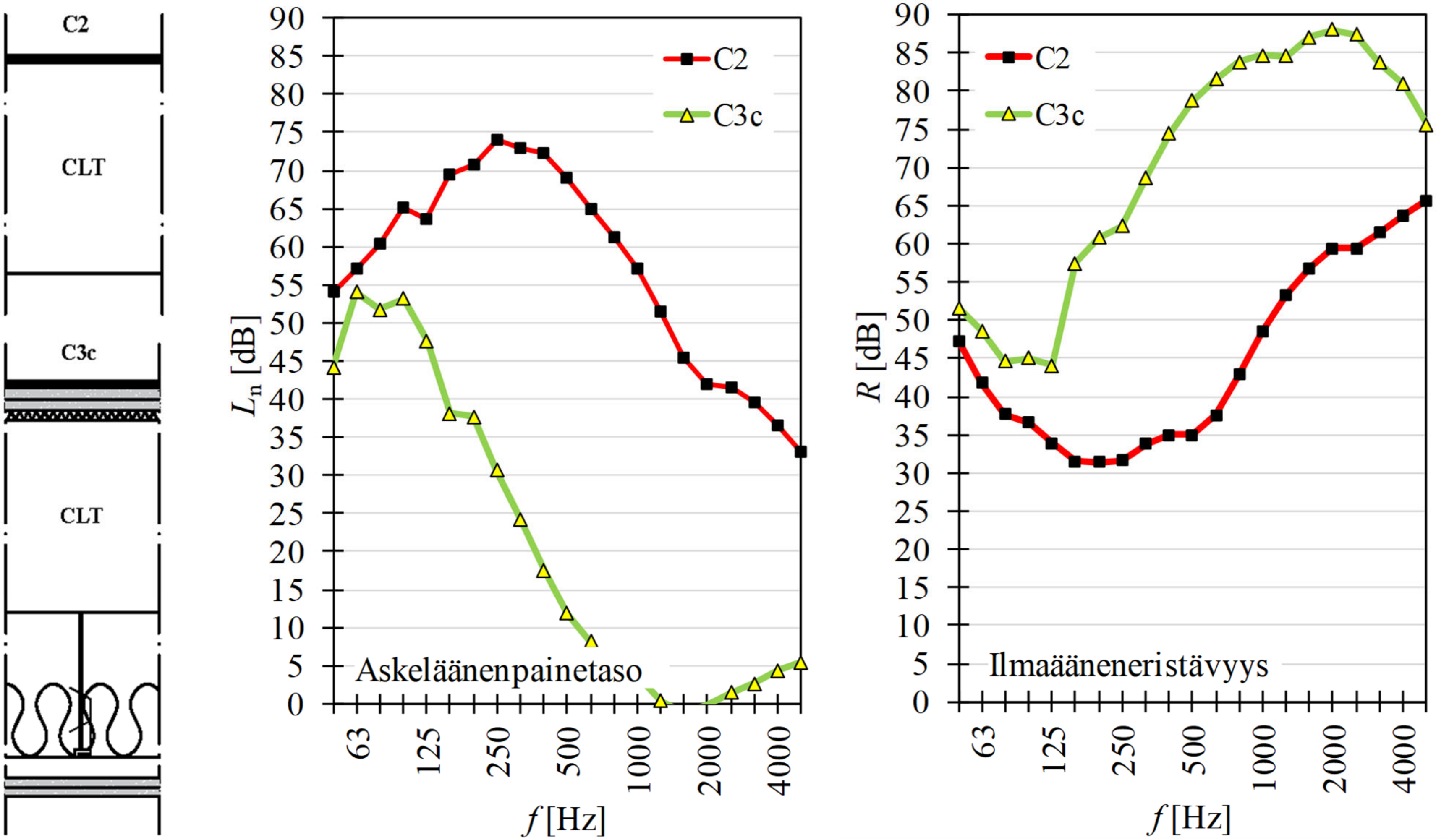
Alakatto:
270 mm ripustuslanka + villa 100 mm
2 x kipsi

Suspended ceiling:
270 mm steel rod + wool100 mm
Two gypsum boards

	$L_{n,w}$	$L_{n,w}+C_{I,50\text{-}2500}$	R_w
C2	65	65	42
C2c	39	42	70

Joustavan alakaton ja kelluvan laatan yhtäaikainen vaikutus massiivipuulaatalla Hongisto et al., **Data in Brief**, 2023

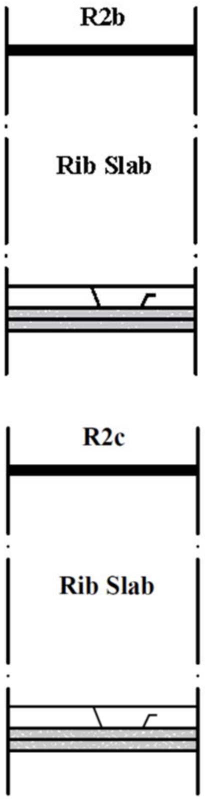
The simultaneous effect of resiliently suspended ceiling and floating floor slab with CLT slab

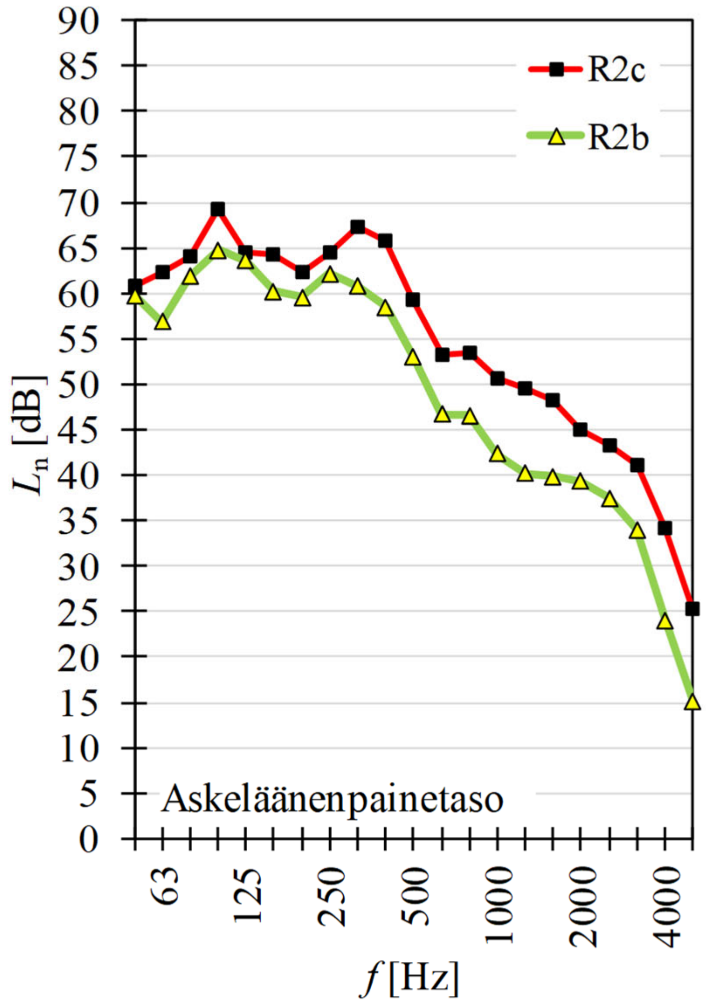


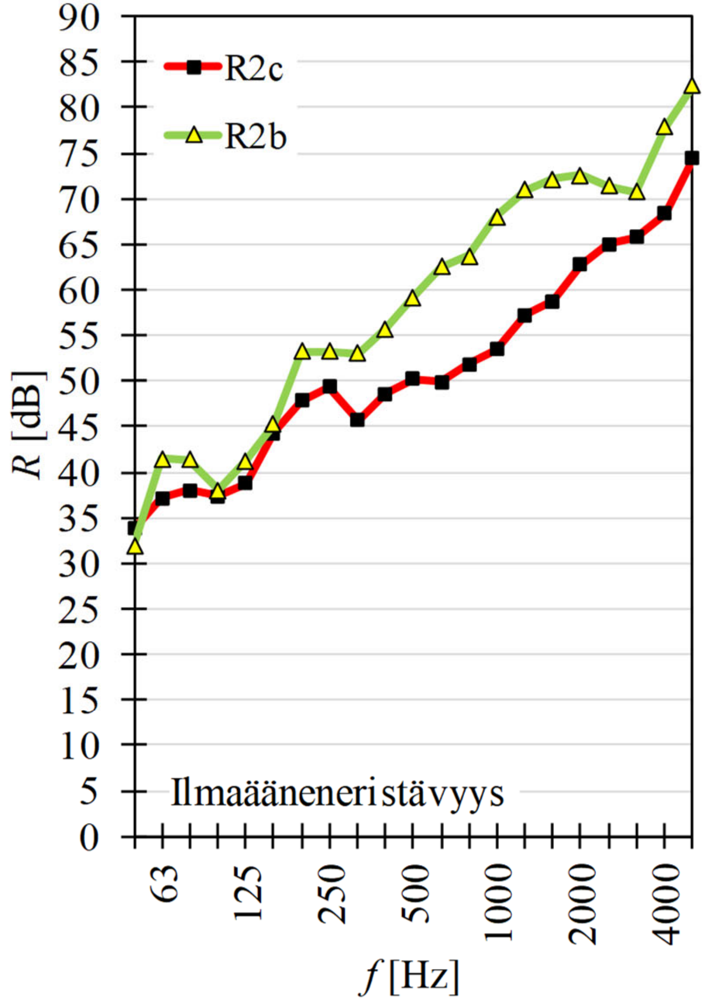
	$L_{n,w}$	$L_{n,w}+C_{I,50-2500}$	R_w
C2	65	65	42
C3c	35	44	73

Kaviteetin 100 mm villaeristeen vaikutus avokotelopuulaatalla, joustavalla alakatolla Hongisto et al., **Data in Brief**, 2023

The effect of 100 mm cavity absorbent with open box timber slab, with resiliently suspended ceiling







Avokotelolaatan kaviteetti:
R2b: 100 mm villa
R2c: Ei villaa

Cavity of the open box slab:
R2b: 100 mm wool
R2c: No wool

	$L_{n,w}$	$L_{n,w}+C_{I,50-2500}$	R_w
R2b	55	56	62
R2c	60	60	54

Kannen lisämassan vaikutus avokotelopuulaatalla

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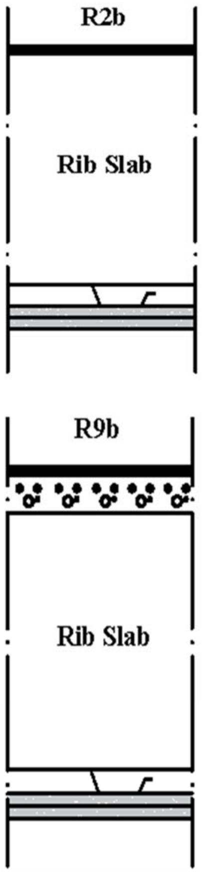
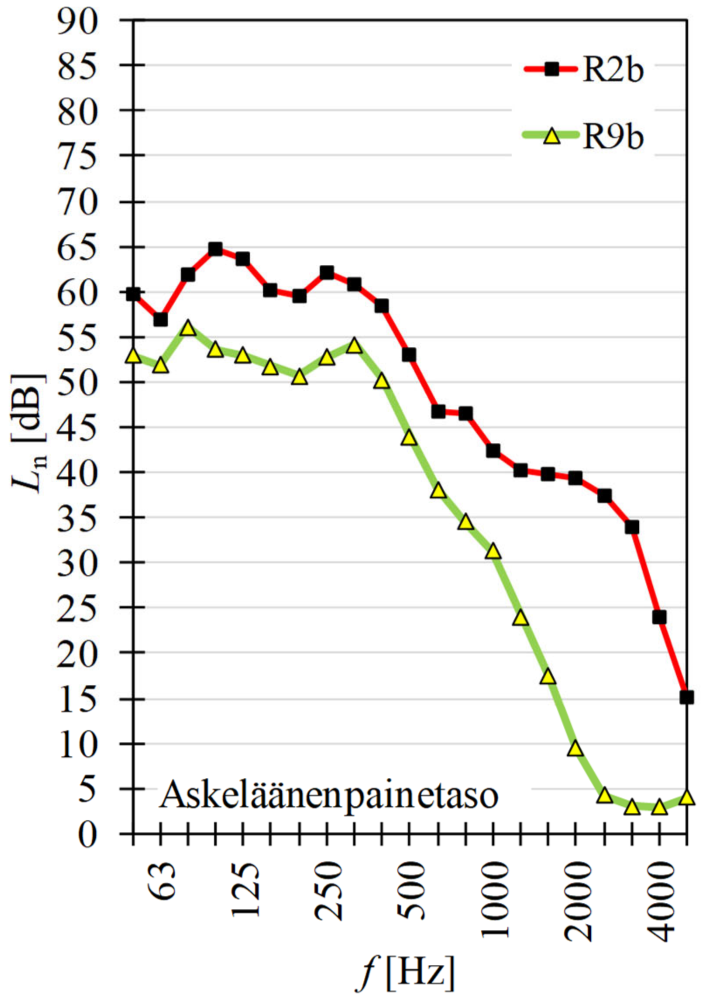
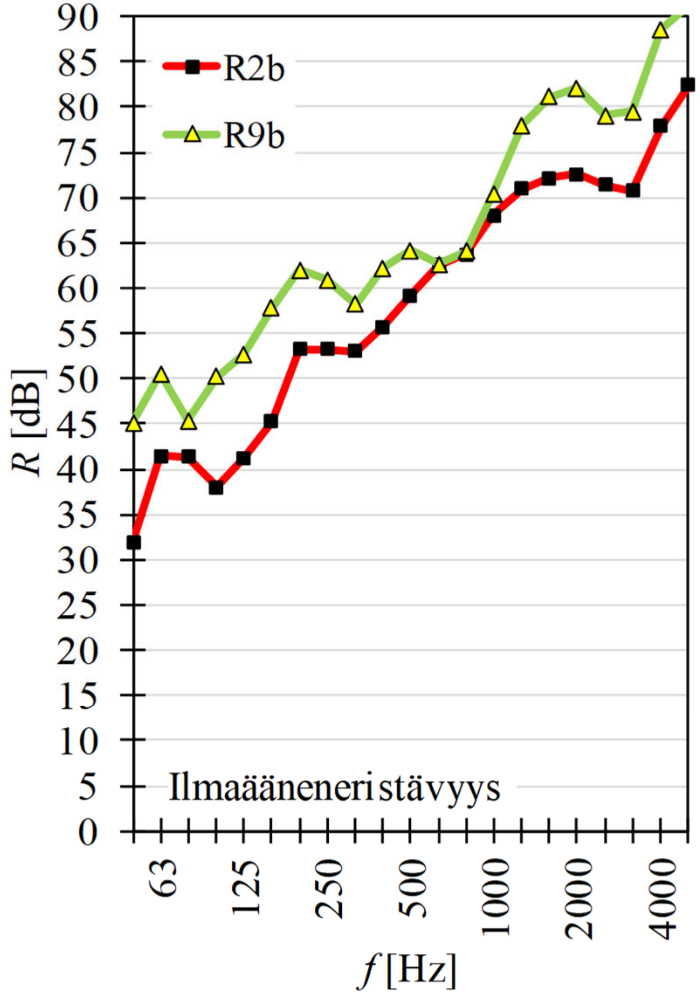
The effect of additional top mass with open box timber slab, with resiliently suspended ceiling







Lisämassa:
40 mm tasoite 72 kg/m2

Additional mass:
40 mm screed 72 kg/m2

	$L_{n,w}$	$L_{n,w}+C_{I,50\text{-}2500}$	R_w
R2b	55	56	62
R9b	46	48	68

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