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Acoustics (VTAF01)
– Building Acoustics (Sound Insulation)

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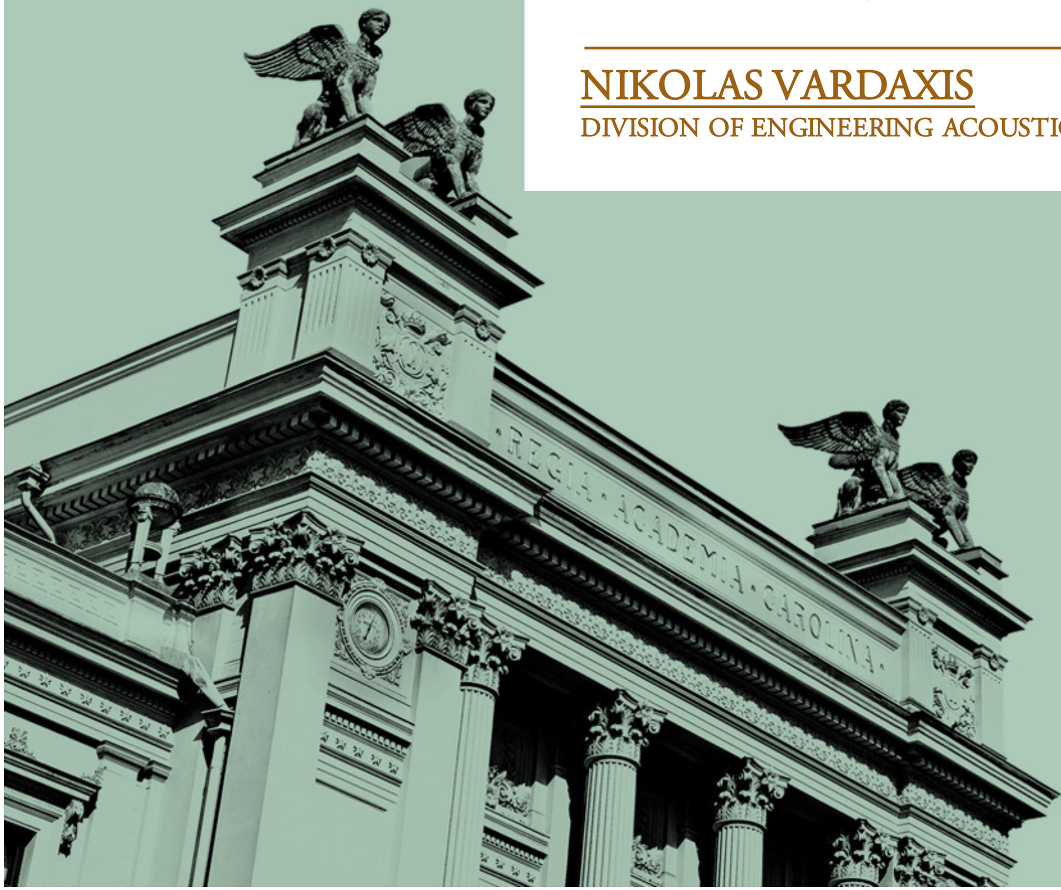


RECAP from previous lectures

- Time & frequency domains
- Narrow band & Octaves & 1/3-octave
- Sound pressure level (SPL / L_p)

$$L_p = 10\log\left(\frac{\tilde{p}^2}{p_{ref}^2}\right) = 20\log\left(\frac{\tilde{p}}{p_{ref}}\right)$$

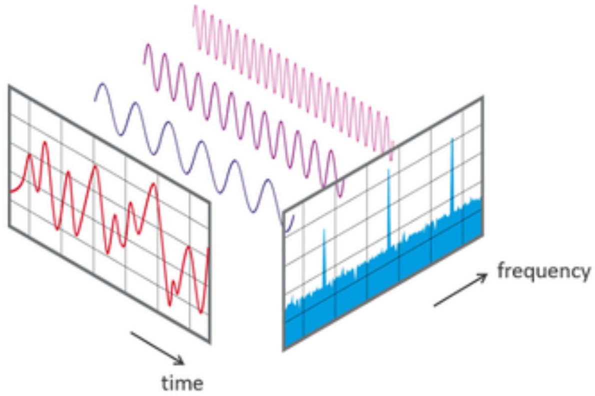
  – Hand held (measurements)

- Sound intensity level (SIL / L_I)

$$L_I = 10\log\left(\frac{I}{I_0}\right)$$

  – Plane/cylindrical/spherical prop.

- Sound power level (source property)

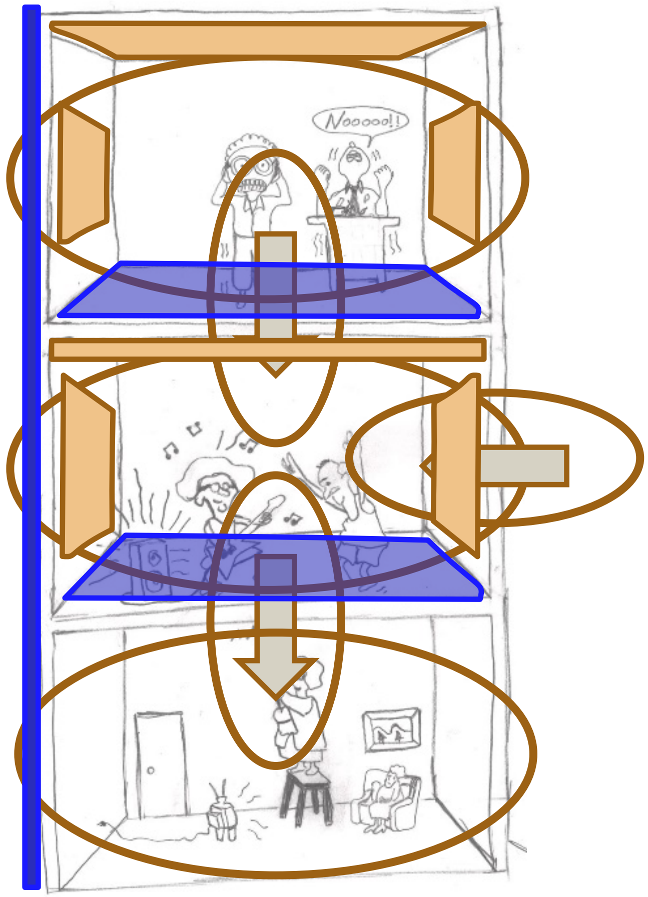


ISO 266 Standard Frequencies for Acoustic Measurements		
ISO Band numbers	Octave band center frequency	One-third octave band center frequencies
1	1.25 Hz	
2, 3, 4	2 Hz	1.6 Hz, **2 Hz**, 2.5 Hz
5, 6, 7	4 Hz	3.15 Hz, **4 Hz**, 5 Hz
8, 9, 10	8 Hz	6.3 Hz, **8 Hz**, 10 Hz
11, 12, 13	16 Hz	12.5 Hz, **16 Hz**, 20 Hz
14, 15, 16	31.5 Hz	25 Hz, **31.5 Hz**, 40 Hz
17, 18, 19	63 Hz	50 Hz, **63 Hz**, 80 Hz
20, 21, 22	125 Hz	100 Hz, **125 Hz**, 160 Hz
23, 24, 25	250 Hz	200 Hz, **250 Hz**, 315 Hz
26, 27, 28	500 Hz	400 Hz, **500 Hz**, 630 Hz
29, 30, 31	1000 Hz	800 Hz, **1000 Hz**, 1250 Hz
32, 33, 34	2000 Hz	1600 Hz, **2000 Hz**, 2500 Hz
35, 36, 37	4000 Hz	3150 Hz, **4000 Hz**, 5000 Hz
38, 39, 40	8000 Hz	6300 Hz, **8000 Hz**, 10000 Hz
41, 42, 43	16000 Hz	12500 Hz, **16000 Hz**, 20000 Hz

Isolate & Conditioning

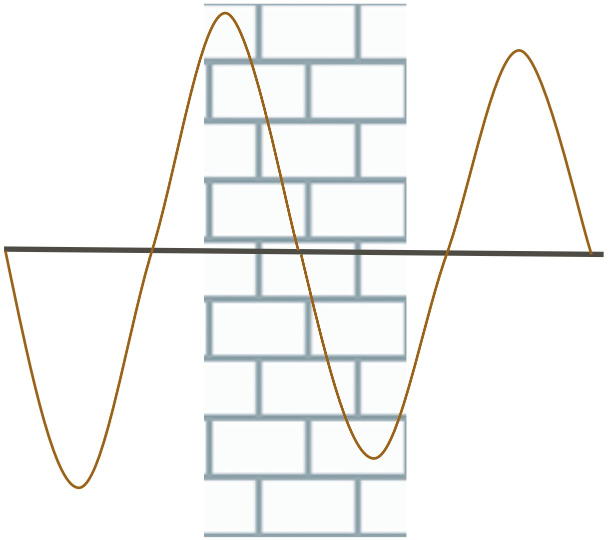
- Isolation → Building acoustics
  - Prevent transmission
    - » Improve "envelopes"

- Conditioning → Room acoustics
  - Improve comfort
    - » Room treatment

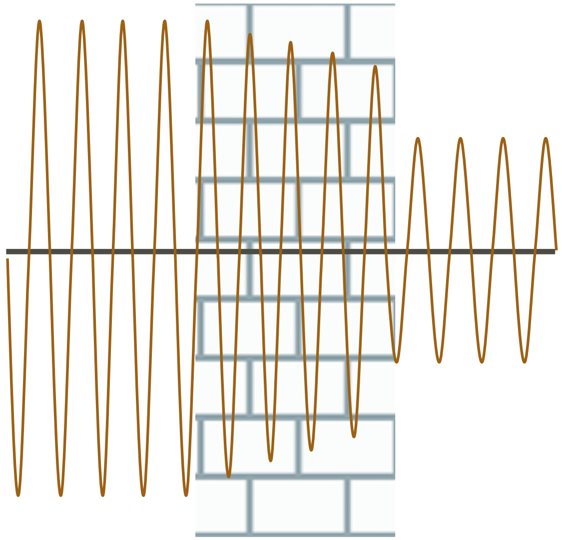


High & Low Frequencies

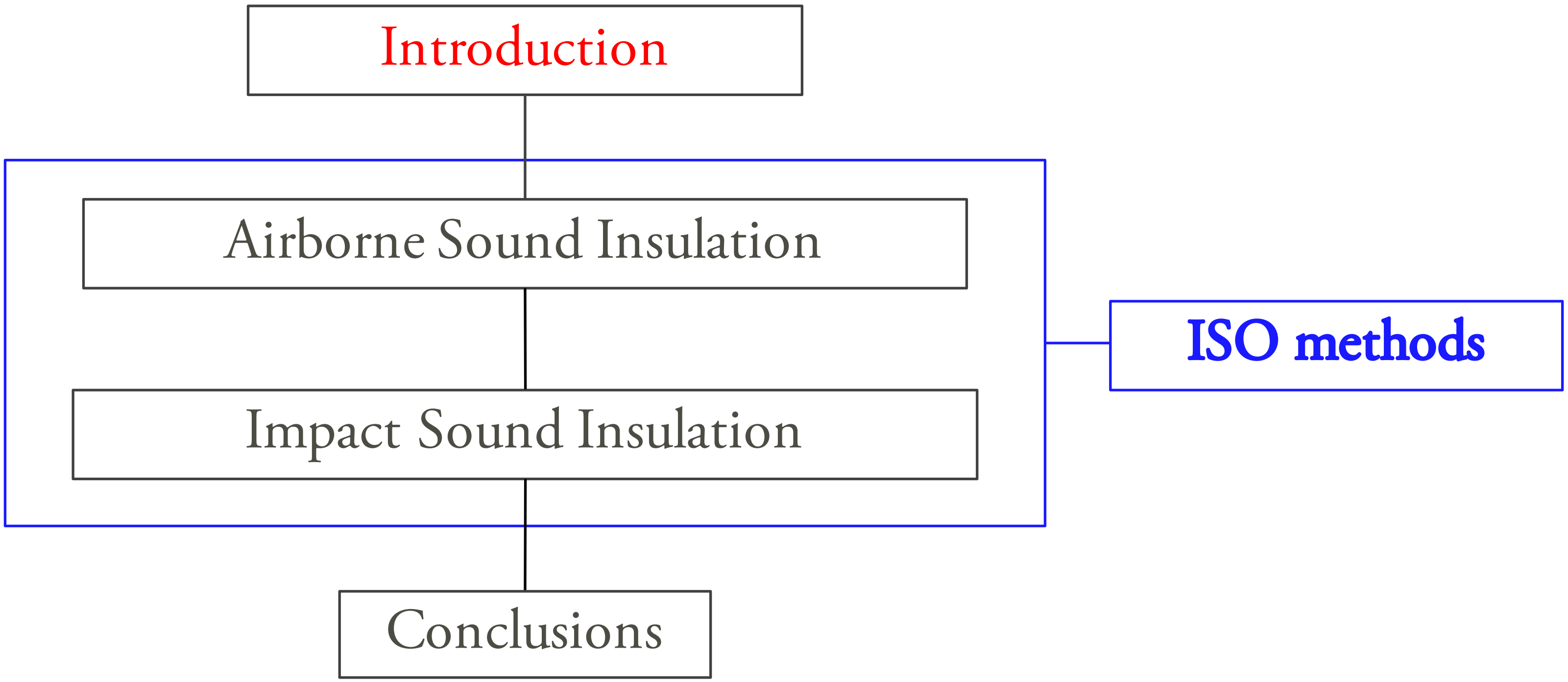
- Low frequency: long "stride" (wavelength)



- High frequency: short "stride" (wavelength)

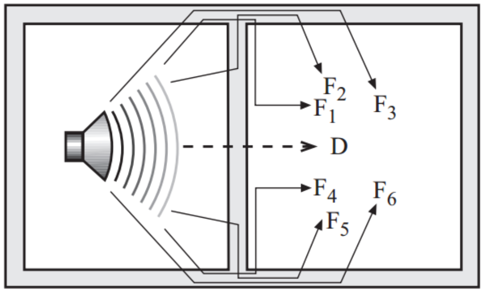


Outline

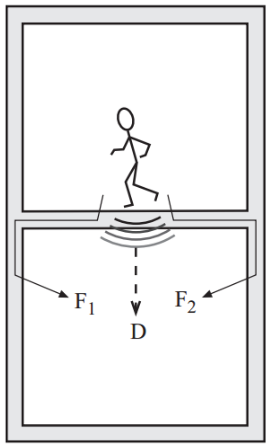

Introduction
Airborne Sound Insulation
Impact Sound Insulation
Conclusions
ISO methods

Introduction (I)

- Sound transmission
  - Airborne
  - Structure-borne
- Transmission paths
  - Direct transmission (D)
  - Flanking paths (F_i)



(a) Airborne sound transmission.



(b) Impact sound.

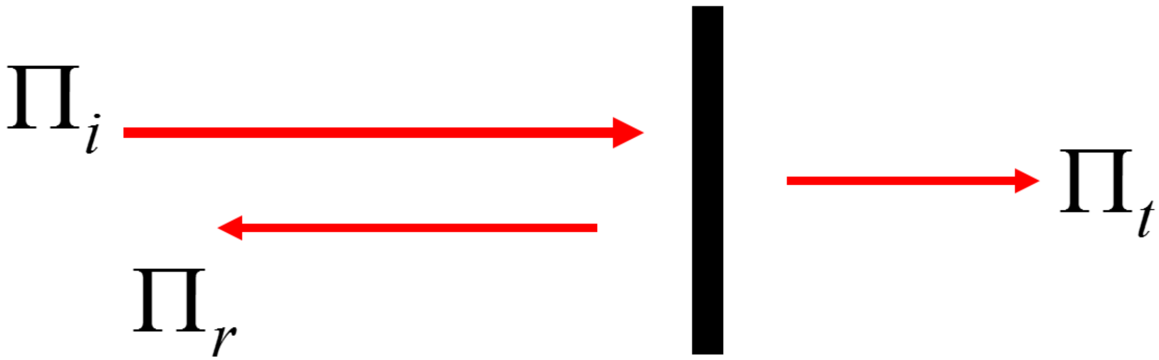
Introduction (II)

Π_i Incident wave power

Π_r Reflected wave power

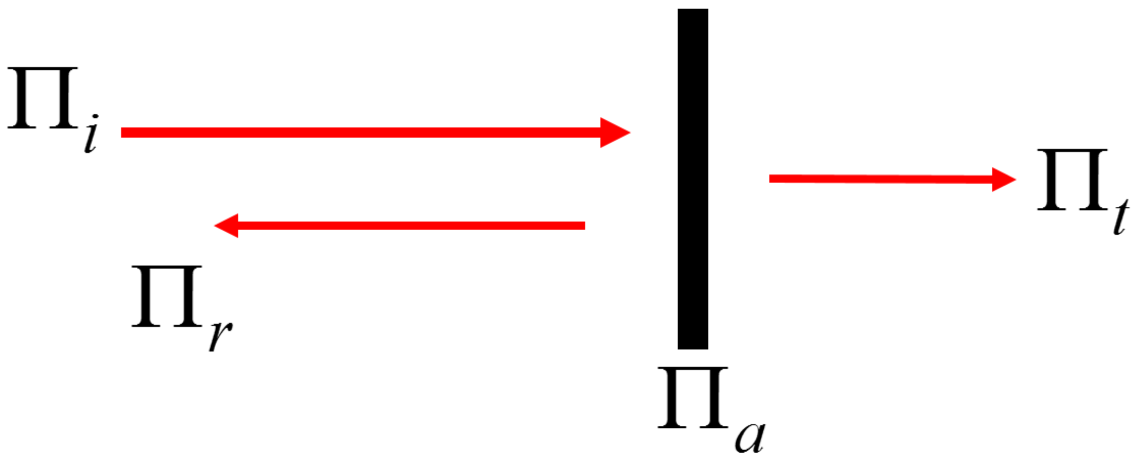
Π_t Transmitted wave power

Π_a Power reduction due to absorption



$$\Pi_i = \Pi_r + \Pi_t + \Pi_a$$

Introduction (III)



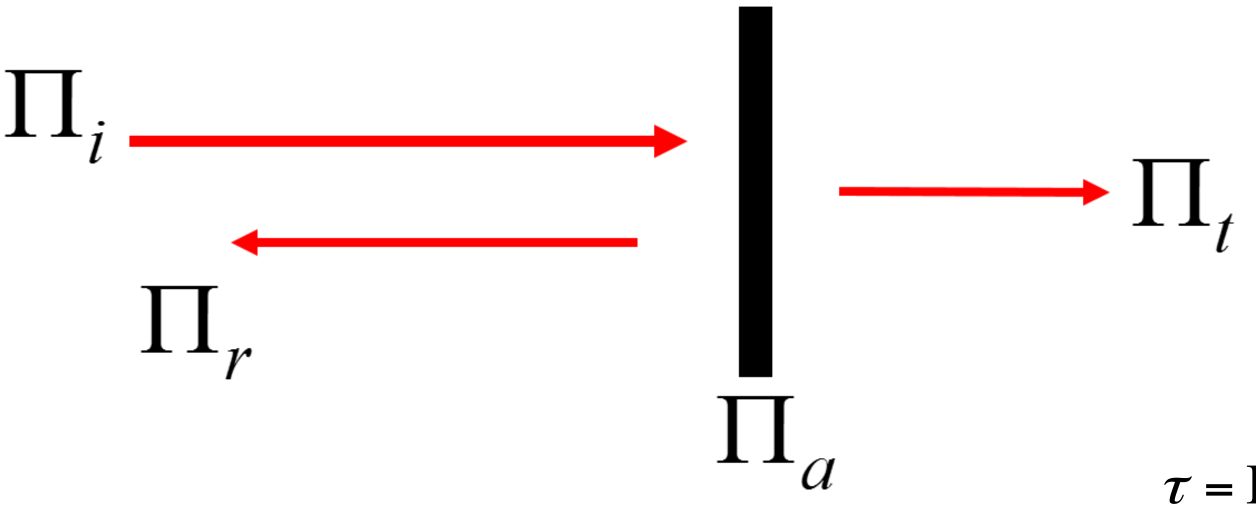
Transmission coefficient: $\tau = \Pi_t / \Pi_i$ [-]

Absorption coefficient: $\alpha = \Pi_a / \Pi_i$ [-]

Reflection coefficient: $\rho = \Pi_r / \Pi_i$ [-]

$$\tau + \rho + \alpha = 1$$

Introduction (IV)

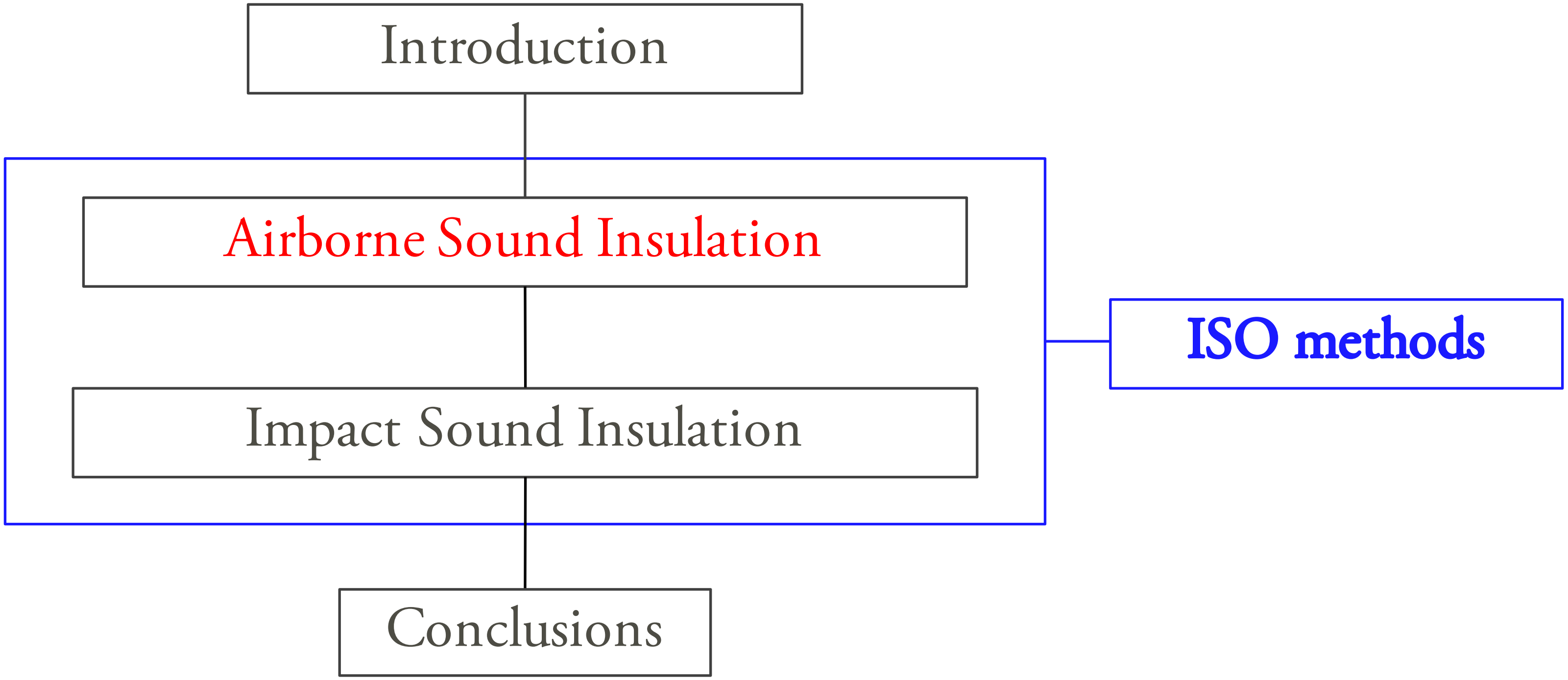


$$\tau = \Pi_t / \Pi_i$$

Reduction index:

$$R \equiv 10 \cdot \log\left(\frac{\Pi_i}{\Pi_t}\right) = 10 \cdot \log\left(\frac{1}{\tau}\right) \quad \text{[dB]}$$

Outline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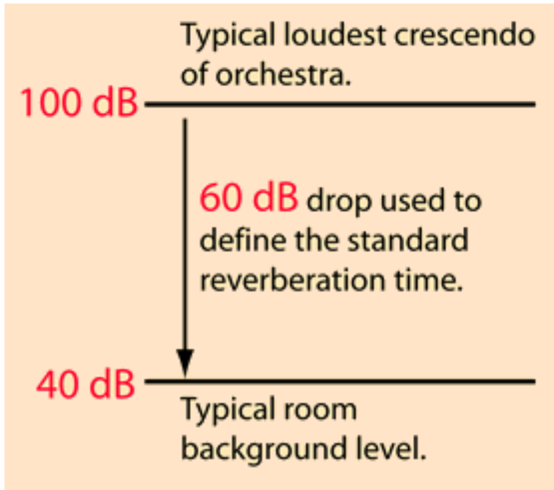
DEF: Reverberation time

- <u>Reverberation time</u>
  - Time for sound to decrease 60 dB from initial level
    - » "Clarity vs. Intensity" compromise
  - Not necessarily coincident with listener feeling
  - Why 60 dB?
  - Values dependent on ussage
    - » Ex: general auditorium: 1.5 - 2.5 sec.
  - Calculation (Sabine's law)



$$RT(f) = T_{60}(f) = 0.16\frac{V}{A_{eff}(f)} = 0.16\frac{V}{\sum_i \alpha_i(f)S_i}$$

V: room volume / A_{eff}: effective absorption area / α_i: individual absorption coefficients / S_i: surface of each element with α_i

T_{20} / T_{30} ?

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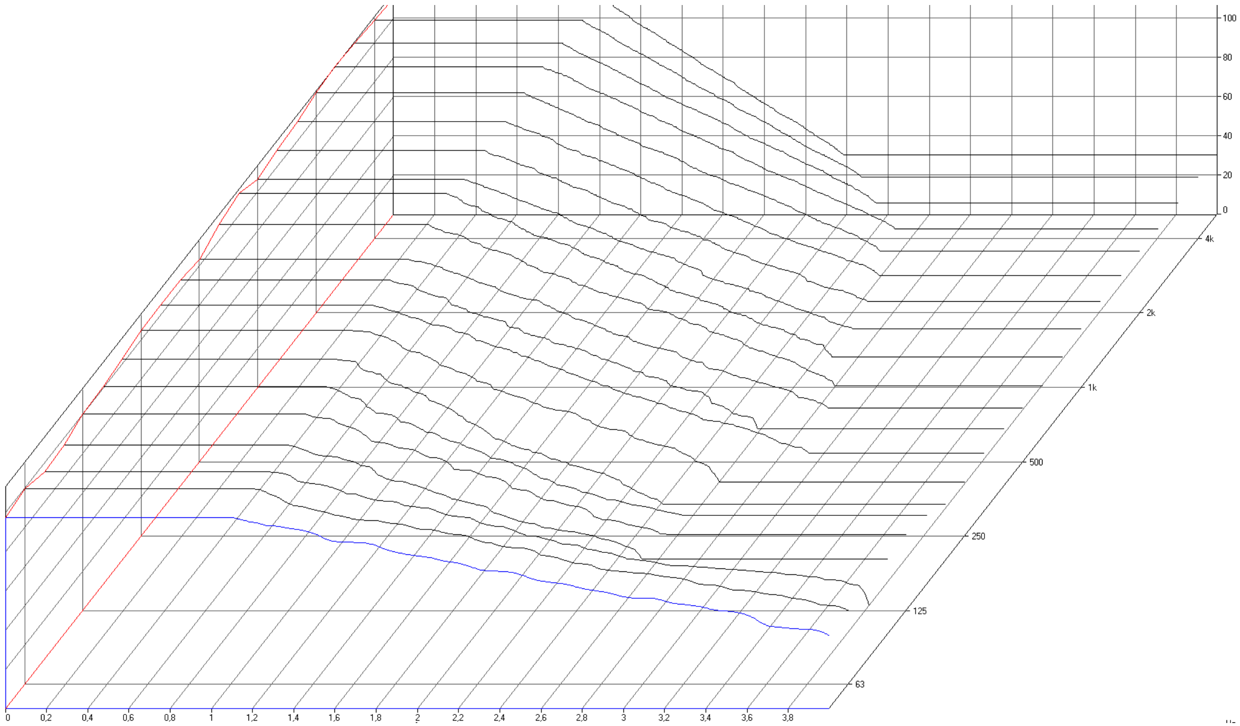
Reverberation time – Frequency dependence



Nomenclature

- $R(f)$: sound reduction index (laboratory)
- R_w : weighted sound reduction index (laboratory)
- $R'(f)$: apparent sound reduction index (*in-situ*)
- R'_w : weighted apparent sound reduction index (*in-situ*)
- $D_{nT}(f)$: standardised level difference (*in-situ*)
- $D_{nT,w}$: weighted standardised level difference (*in-situ*)
- $C_{50\text{-}3150}$: spectrum adaptation term
- C_{tr}: spectrum adaptation term due to traffic noise

Lab measurements

In-situ (mainly used to compare with lab results)

In-situ (better correlated with human perception than R´)

Statement of results: $R'_w\,(C_{50\text{-}3150}\,;\,C_{tr})$ / $R_w\,(C_{50\text{-}3150}\,;\,C_{tr})$ / $D_{nT,w}\,(C_{50\text{-}3150}\,;\,C_{tr})$

"Rule of thumb": Difference between lab and *in-situ* ~4 dB!

NOTE: There are more single-number indicators, but they are not included here to not make it even more complicated (see ISO 717-1:2013)
NOTE2: "to normalise" means "to scale" with a reference area of 10 m^2, whereas when "standardising" a reference T_{60} of 0.5 s is used
NOTE3: In the course, for the sake of simplicity, D_{nT} will not be used, we will stick to R and R'.
NOTE4: a prime (') next to R/R_w is used to distinguish between in-situ and lab measurements respectively.

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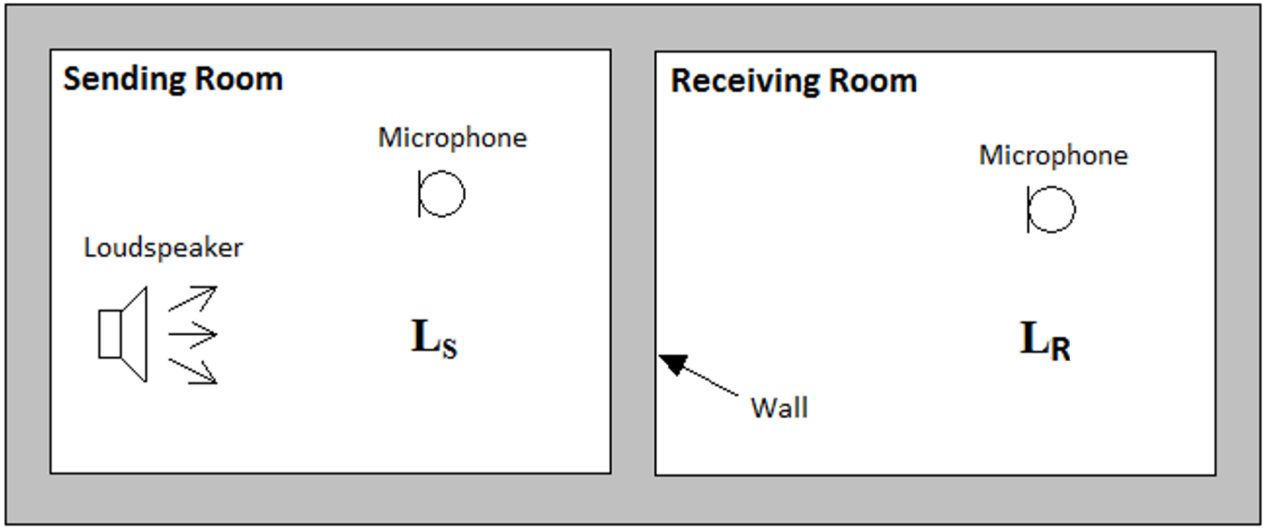
Measurement sound reduction index (I)



Wall's reduction index [dB]

(= transmission loss):

$$R(f) = L_S(f) - L_R(f) + 10\log\left(\frac{S}{A(f)}\right)$$

$L_S(f)$: SPL in the sending room [dB]

$L_R(f)$: SPL in the receiving room [dB]

S : wall area [m^2]

$A(f)$: Absorption area in receiving room [m^2]

In practice, A(f) is calculated by measuring $T_{60}(f)$

NOTE: Loudspeaker and microphone positions are defined in the corresponding ISO standard.

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Measurement sound reduction index (II)

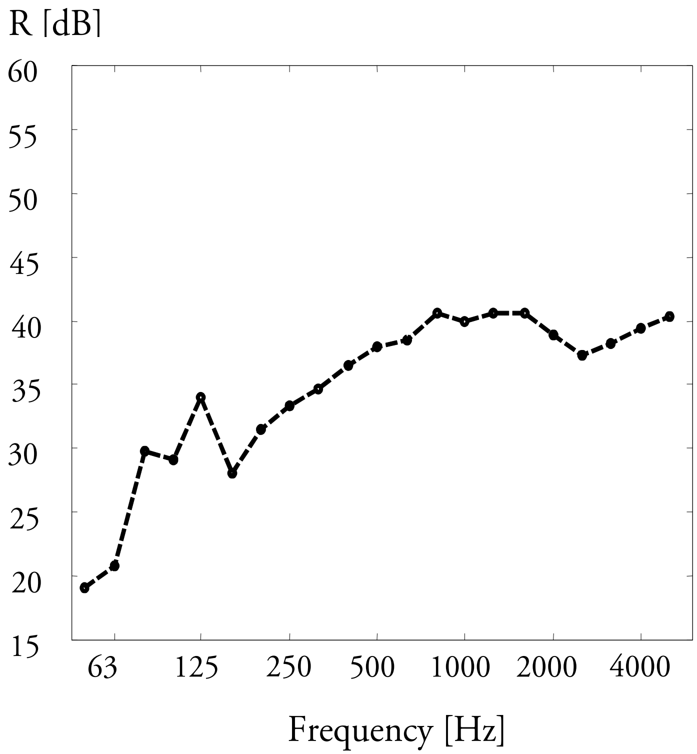
- <u>Example</u> of (lab) measured curve:
  - High values ⇒ Better insulation ⇒ *"Quieter"*

$$R(f) = L_S(f) - L_R(f) + 10\log\left(\frac{S}{A(f)}\right)$$

<u>NOTE:</u> For in-situ measurements, the curve would be $R'(f)$ instead, since it would account for flanking tranmission. In Sweden nowadays $D_{nT}(f)$ and $D_{nT,w}$ are used instead of $R'(f)$ for in-situ measurements, to correlate better with human perception. In this course, however, we will stick to $R(f)$ and $R'(f)$ *and thus* R_w *and* R'_w.

$$D_{nT}(f) = \boxed{L_S(f) - L_R(f)} + 10\log\left(\frac{T_{60}(f)}{0.5}\right)$$

$D_n(f)$: level difference



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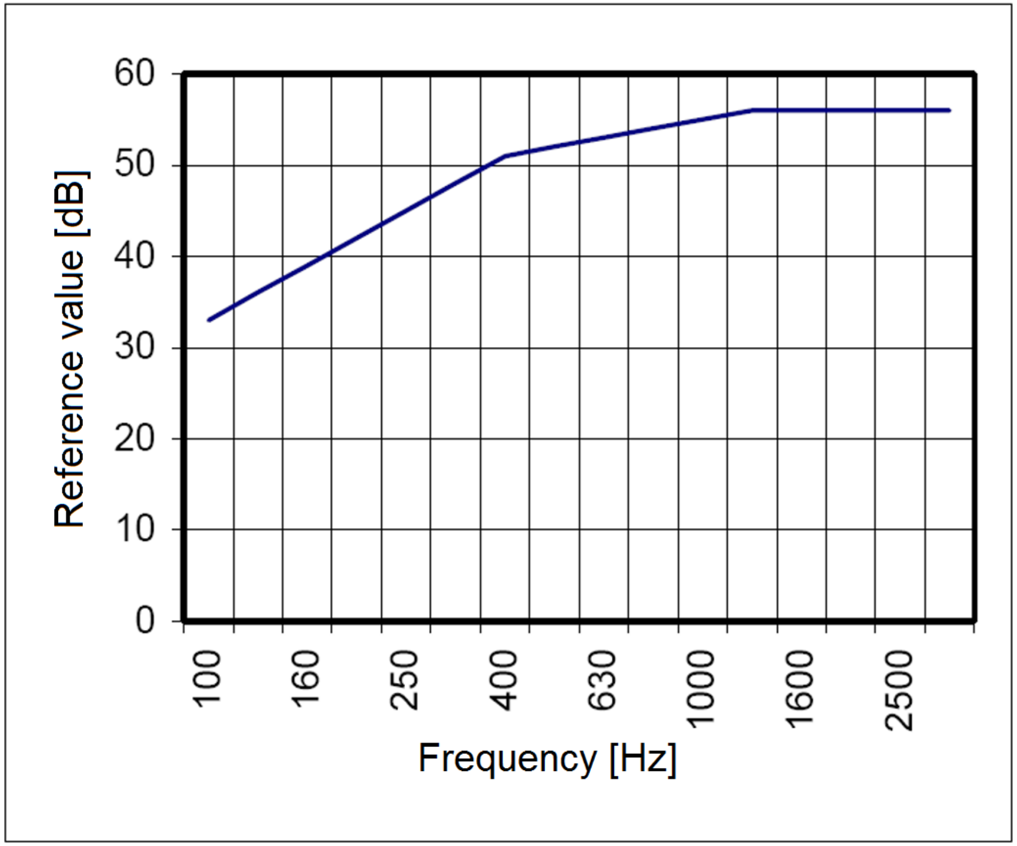
ISO Evaluation of sound reduction index (I)

- Reference curve (ISO 717-1)



Frequency [Hz]	Ref. value [dB]
100	33
125	36
160	39
200	42
250	45
315	48
400	51
500	52
630	53
800	54
1000	55
1250	56
1600	56
2000	56
2500	56
3150	56

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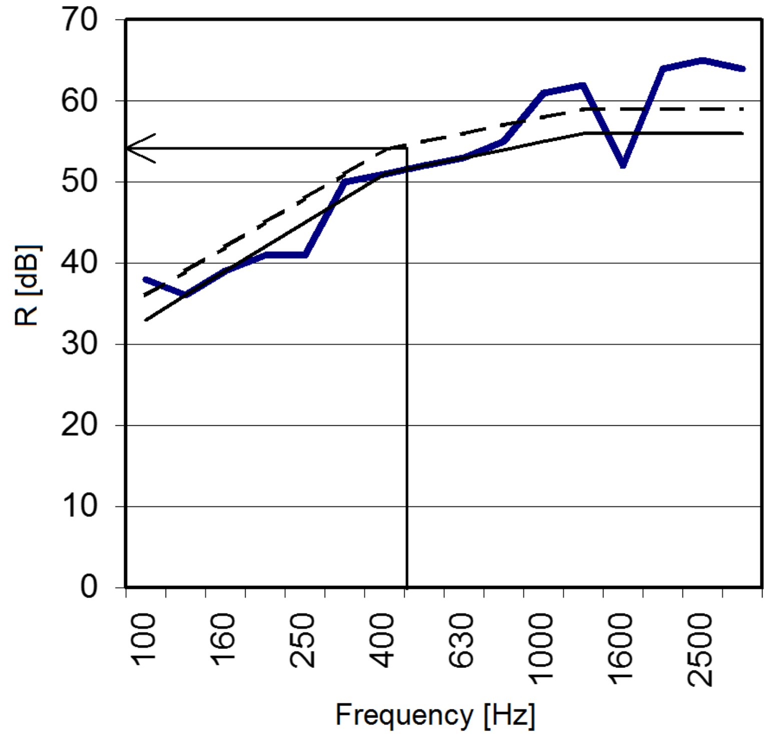
ISO Evaluation of sound reduction index (II)

"[…] the reference curve is shifted in steps of 1dB towards the measured one, until the sum of the unfavourable deviations is as large as possible, but not more than 32dB"*

"[…] an unfavourable deviation at a particular frequency occurs when the result of measurements ***is less*** *than the reference value"*

"[…] the value, in dB, of the reference curve has at 500 Hz, after shifting in accordance with this procedure, is R_w"



**for measurements in 16 one-third-octave band. If measurements are performed in 5 octave bands, the sum should not exceed 10 dB.*

Spectrum adaptation terms

- Defined in ISO 717-1: take into account different source spectra
  - C_{tr}: A-weighted urban traffic noise spectrum
  - $C_{50\text{-}3150}$: frequency adaptation term

Table B.1 — Sound level spectra to calculate the adaptation terms for enlarged frequency range

Frequency	Sound levels, L_{ij}, dB					
Hz	Spectrum No.1 to calculate				Spectrum No.2 to calculate C_{tr} for any frequency range	
	$C_{50-3150}$		$C_{50-5000}$ and $C_{100-5000}$			
	One-third octave	Octave	One-third octave	Octave	One-third octave	Octave
50 63 80	−40 −36 −33	−31	−41 −37 −34	−32	−25 −23 −21	−18
100 125 160	−29 −26 −23	−21	−30 −27 −24	−22	−20 −20 −18	−14
200 250 315	−21 −19 −17	−14	−22 −20 −18	−15	−16 −15 −14	−10
400 500 630	−15 −13 −12	−8	−16 −14 −13	−9	−13 −12 −11	−7
800 1 000 1 250	−11 −10 −9	−5	−12 −11 −10	−6	−9 −8 −9	−4
1 600 2 000 2 500	−9 −9 −9	−4	−10 −10 −10	−5	−10 −11 −13	−6
3 150 4 000 5 000	−9		−10 −10 −10	−5	−15 −16 −18	−11

NOTE All levels are A weighted and the overall spectrum level is normalized to 0 dB.

<u>NOTE:</u> large negative values indicate poor airborne insulation at low frequencies

$$C_{tr} = -10\log\left(\sum_i 10^{(Li-Ri)/10}\right) - R_w$$

$$C_{50-3150} = -10\log\left(\sum_{i=1}^{19} 10^{(Li-Ri)/10}\right) - R_w$$

<u>Statement of results:</u>

- $R'_w\ (C_{50\text{-}3150}\ ;\ C_{tr})$
- $R_w\ (C_{50\text{-}3150}\ ;\ C_{tr})$

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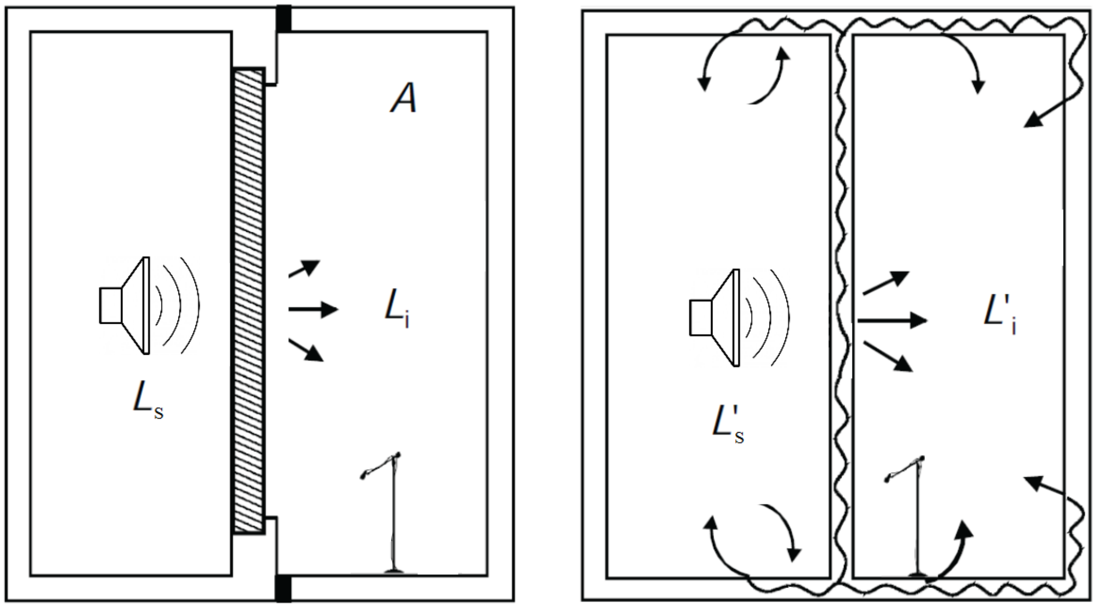
Remember…

… Laboratory vs. Field situation (flanking transmission comes into play)



[REF] Vigran(2008)

ISO 717-1:2013
ISO 10140-2:2010

R_w

ISO 717-1:2013
ISO 16283-1:2014

R'_w

SS-EN12354-1:2000
Prediction of R'_w from the individual acoustic performances (R_w) of the elements involved in the junction, as sum of individual contributions

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Airborne sound insulation – example

Upplevd störning vid olika luftljudsisolering

Vägt reduktionstal i byggnad, R'_w	*Normalt samtal*	*Högröstat*	*Skrik samtal*	*TV, radio, musikanläggning (måttlig nivå)*	*Musik från större musikanläggning i hemmet*
40 dB	Kan uppfattas	Uppfattas	Hörs	Hörs	Hörs
44 dB	Kan höras	Kan uppfattas	Hörs	Hörs	Hörs
48 dB	Hörs inte	Kan höras	Kan höras	Hörs	Hörs
52 dB	Hörs inte	Kan höras	Kan höras	Kan höras	Hörs
56 dB	Hörs inte	Hörs inte	Kan höras	Kan höras	Hörs
60 dB	Hörs inte	Hörs inte	Hörs inte	Hörs inte	Kan höras

Figur 2:12. Exempel på hur störningar av olika aktiviteter kan upplevas beroende på aktuell luftljudsisolering. Störningskänsligheten liksom störningens karaktär kan dock variera utanför siffrorna i tabellen.

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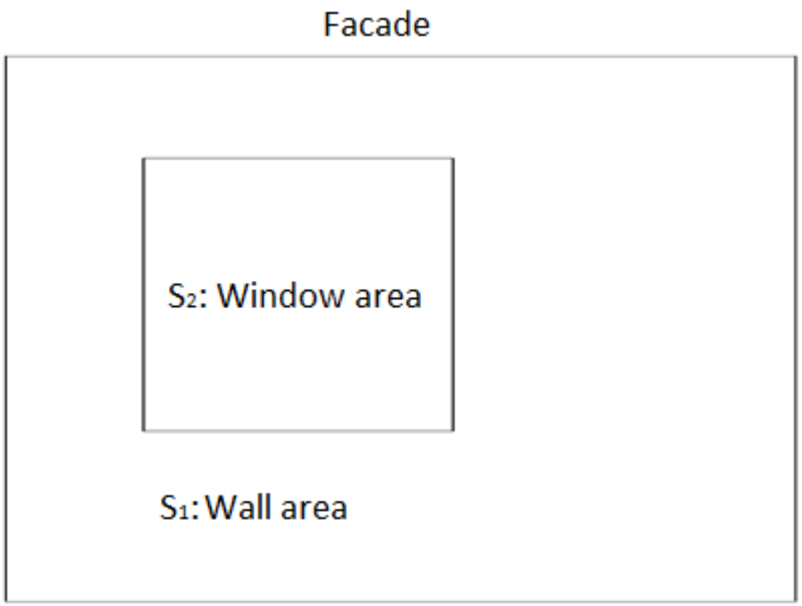
DEF: Combined reduction index



R_1, R_2 … individual reduction indeces
S: total area, i.e. $S = S_1 + S_2 + \dots$

Combined reduction index:

$$R = -10\log\left(\frac{1}{S}(S_1 10^{-R_1/10} + S_2 10^{-R_2/10} + \dots)\right)$$

Leakages

- Power of the opening (leakage)

$$\Pi_l = \Pi_i \cdot \frac{S_l}{S}$$

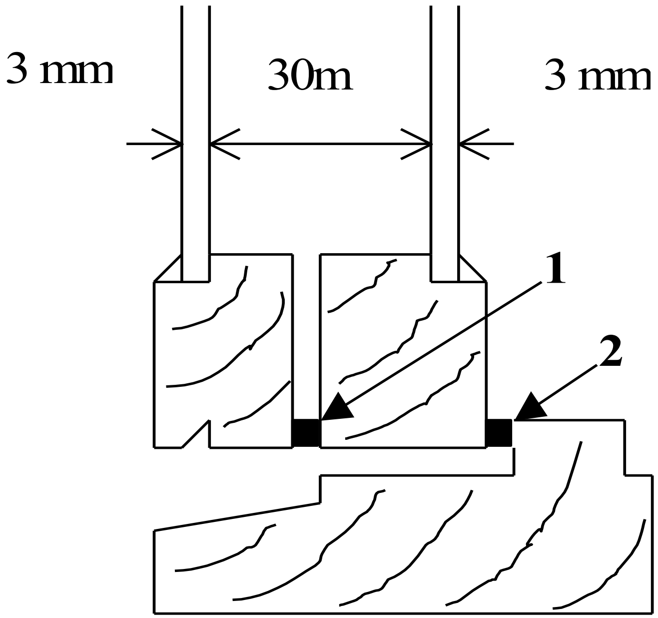
- The reduction index of the wall then becomes

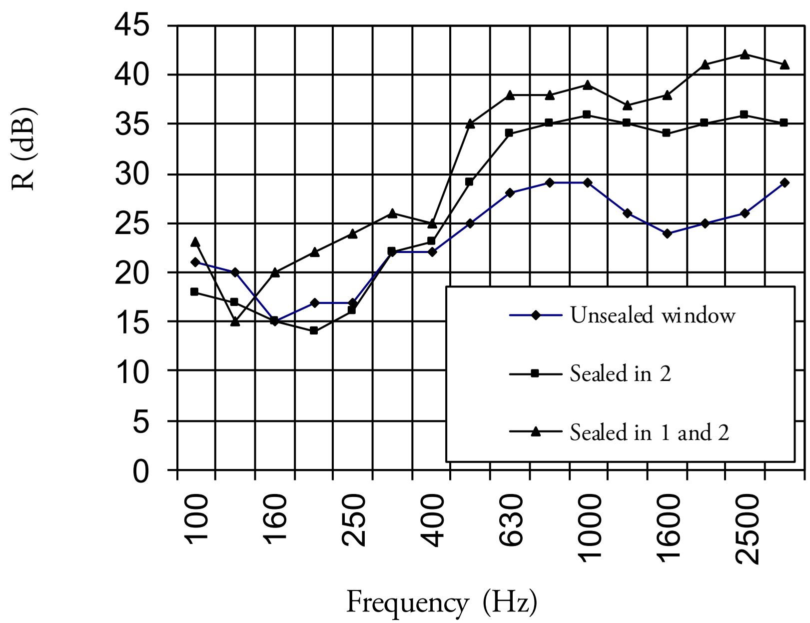
$$R = -10 \cdot \log\left(\frac{\Pi_l + \Pi_t}{\Pi_i}\right) = -10 \cdot \log\left(\frac{\Pi_t}{\Pi_i} + \frac{S_l}{S}\right) \Rightarrow$$

$$R_{withLeakage} = -10 \cdot \log\left(10^{-R/10} + \frac{S_l}{S}\right)$$

Example: influence of leakages

Sealing of windows is of crucial importance





NOTE: Example of leakage detection

Exercises

1.- A 9 m^2 facade has a sound reduction index of 60 dB and has installed a 1 m^2 double window whose reduction index is 30 dB.

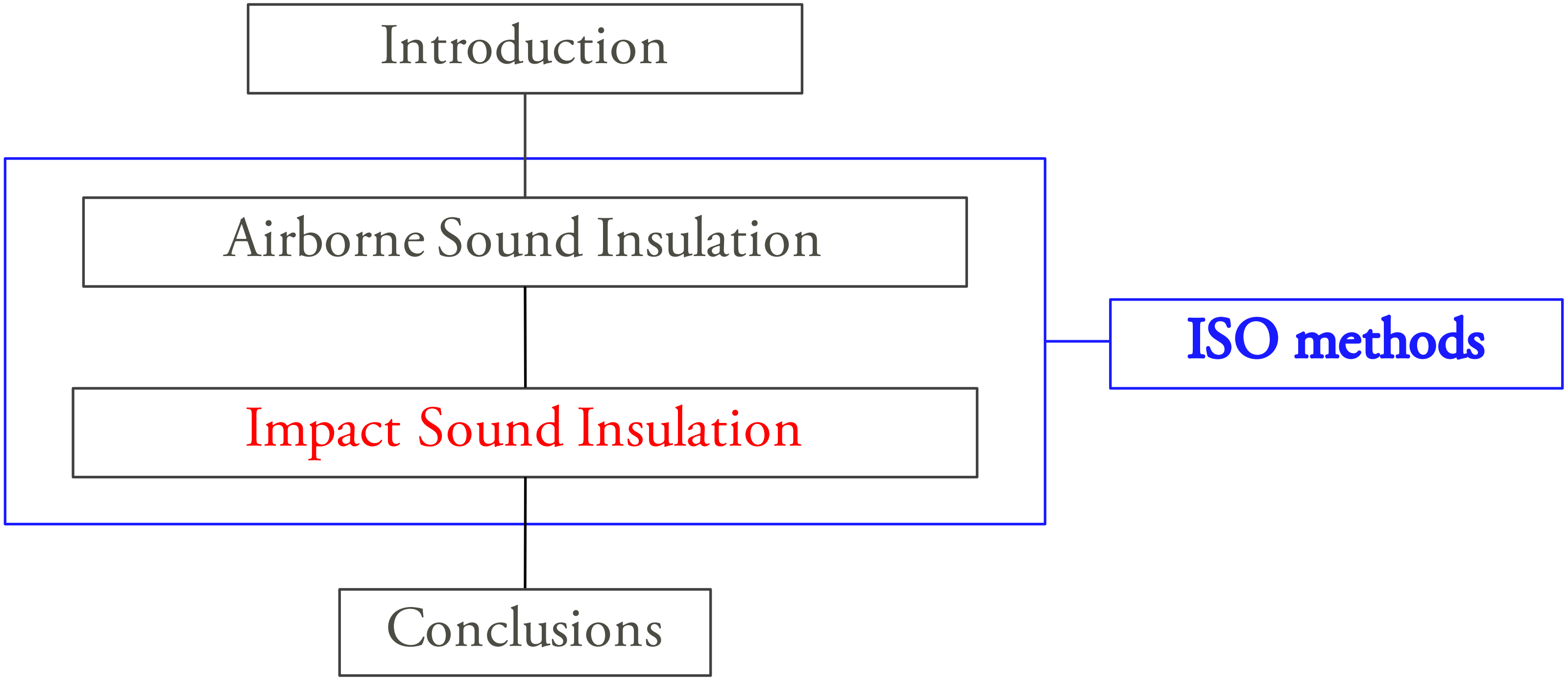
a) What does it mean that the material of the wall has a reduction index of 60dB? How much energy does the material let through?

b) Calculate the combined sound reduction index of the facade

2.- What is the influence of a crack in a wall whose dimensions are 1 mm in width and 1 m in length in a wall of 2.40 m height and 4 m length? The sound reduction index of the wall without leakage is 50 dB.

How much the combined sound reduction index would be if the sound reduction index of the wall would increase up to 60 dB?

Outline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Nomenclature

- $L_n(f)$: normalised impact sound level (*laboratory*)
- $L_{n,w}$: weighted normalised impact sound level (laboratory)
- $L'_n(f)$: apparent normalised impact sound level (*in-situ*)
- $L'_{n,w}$: weighted normalised impact sound level (in-situ)
- $L'_{nT}(f)$: apparent standardised impact sound level (*in-situ*)
- $L'_{nT,w}$: weighted normalised impact sound level (*in-situ*)
- $C_{I,50\text{-}2500}$: spectrum adaptation term

Lab measurements

In-situ (mainly used to compare with lab results)

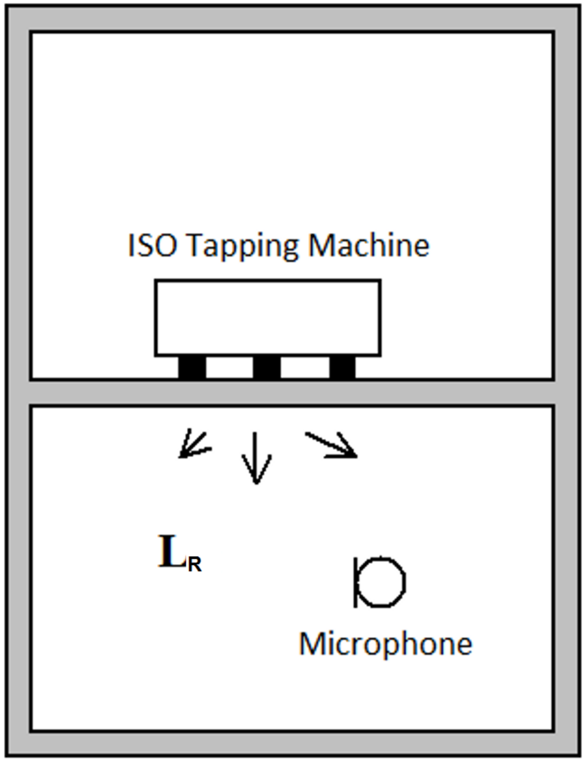
In-situ (better subjective correlation than L'_n)

Statement of results: $L'_{nT,w}(C_{I,50\text{-}2500})$ / $L'_{n,w}(C_{I,50\text{-}2500})$ / $L_{n,w}(C_{I,50\text{-}2500})$

”Rule of thumb”: Difference between lab and *in-situ* ~4 dB!

NOTE: There are more single-number indicators, but they are not included here to not make it even more complicated (see ISO 717-2:2013)
NOTE2: ”to normalise” means ”to scale” with a reference area of 10 m^2, whereas when ”standardising” a reference T_{60} of 0.5 s is used
NOTE3: L_{nT} provides a straightforward link to the subjective impression of impact sound insulation and is used as indicator in Sweden for field measurements. In the course, however, and to facilitate comparisons, we will stick to L_n and L'_n
NOTE4: a prime (’) next to an *L* indicator is used to distinguish between in-situ and lab measurements respectively

Measurement impact sound insulation (I)



Impact sound level:

$$L_n(f) = L_R(f) + 10\log\left(\frac{A(f)}{10}\right)$$

$L_n(f)$: normalised impact sound level [dB]

$L_R(f)$: SPL in the receiving room [dB]

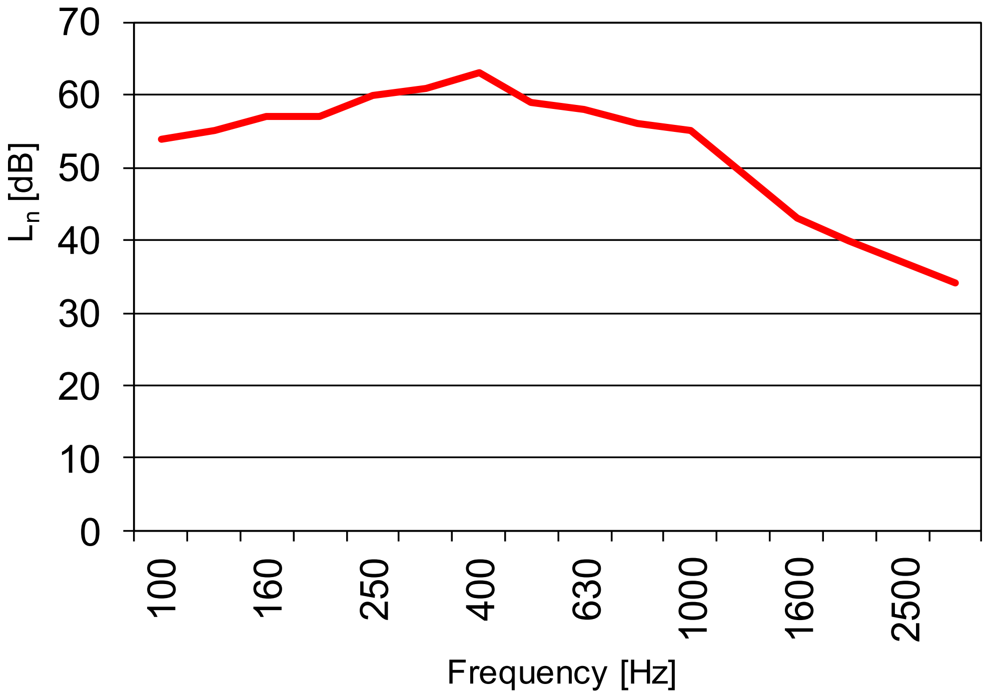
$A(f)$: absorption area in the receiving room

NOTE: Tapping machine and microphone positions are defined in the pertinent ISO standard.

- <u>ISO Tapping Machine</u>
  - Standardised: 1 hit per 0.1 s
  - 5 steel cylinders which alternatively hit the floor

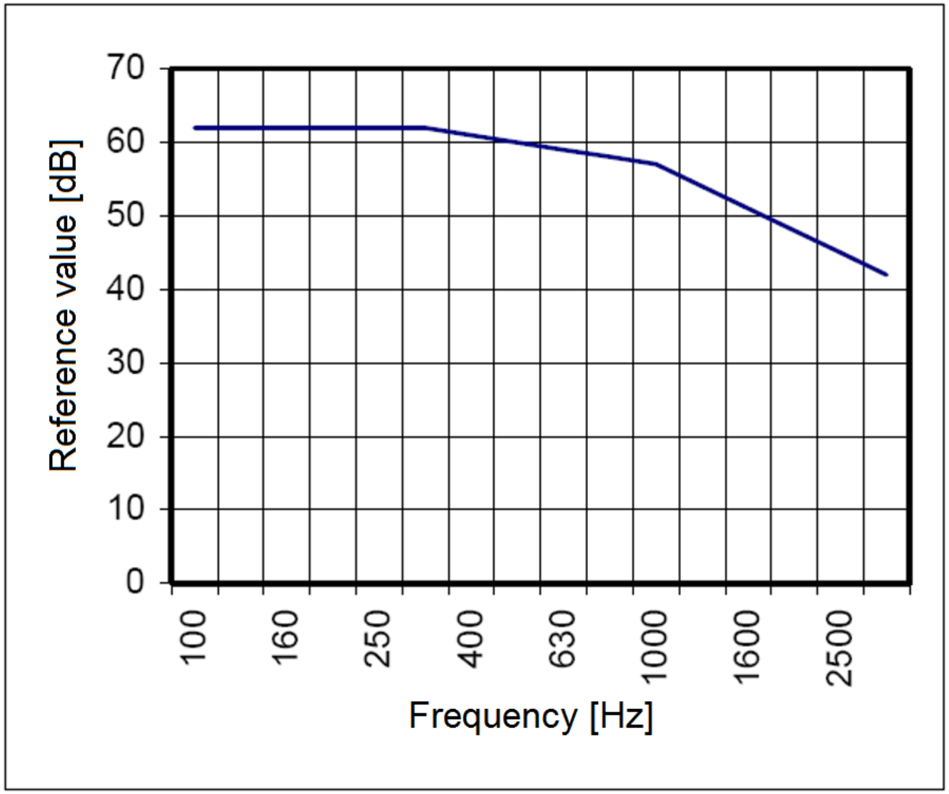
Measurement impact sound insulation (II)

- Example of measured curve:
  - High values ⇒ Higher sound transmission ⇒ ”Noisier”



ISO Evaluation of impact sound insulation (I)

- Reference curve (ISO 717-2)



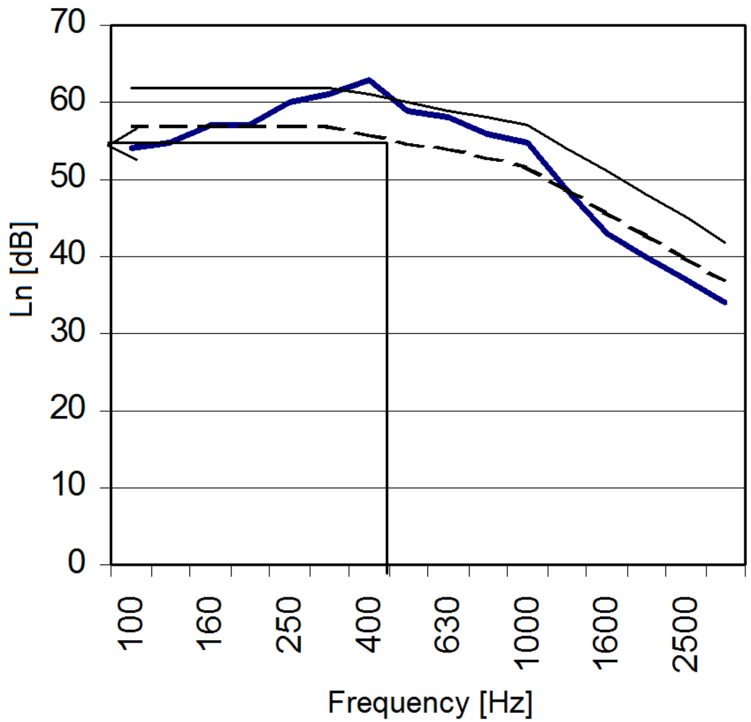
Frequency [Hz]	Ref. value [dB]
100	62
125	62
160	62
200	62
250	62
315	62
400	61
500	60
630	59
800	58
1000	57
1250	54
1600	51
2000	48
2500	45
3150	42

ISO Evaluation of impact sound insulation (II)

“[…] the reference curve is shifted in steps of 1dB towards the measured one, until the sum of the unfavourable deviations is as large as possible, but not more than 32dB”*

“[…] an unfavourable deviation at a particular frequency occurs when the result of measurements exceed the reference value”

“[…] the value, in dB, of the reference curve has at 500 Hz, after shifting in accordance with this procedure, is $L_{n,w}$”



**for measurements in 16 one-third-octave band. If measurements are performed in 5 octave bands, the sum should not exceed 10 dB.*

Spectrum adaptation term

- Defined in ISO 717-2
  - $C_{I,50\text{-}2500}$: improves correlation with subjective response at low frequencies

$$C_{l,50-2500} = 10\log\left(\sum_{50}^{2500} 10^{Ln,i(f)/10}\right) - 15 - L_{n,w}$$

<u>Statement of results:</u>

- $L'_{nT,w}\,(C_{l,50\text{-}2500})$
- $L'_{n,w}\,(C_{l,50\text{-}2500})$
- $L_{n,w}\,(C_{l,50\text{-}2500})$

<u>NOTE:</u> large positive values indicate poor impact insulation at low frequencies

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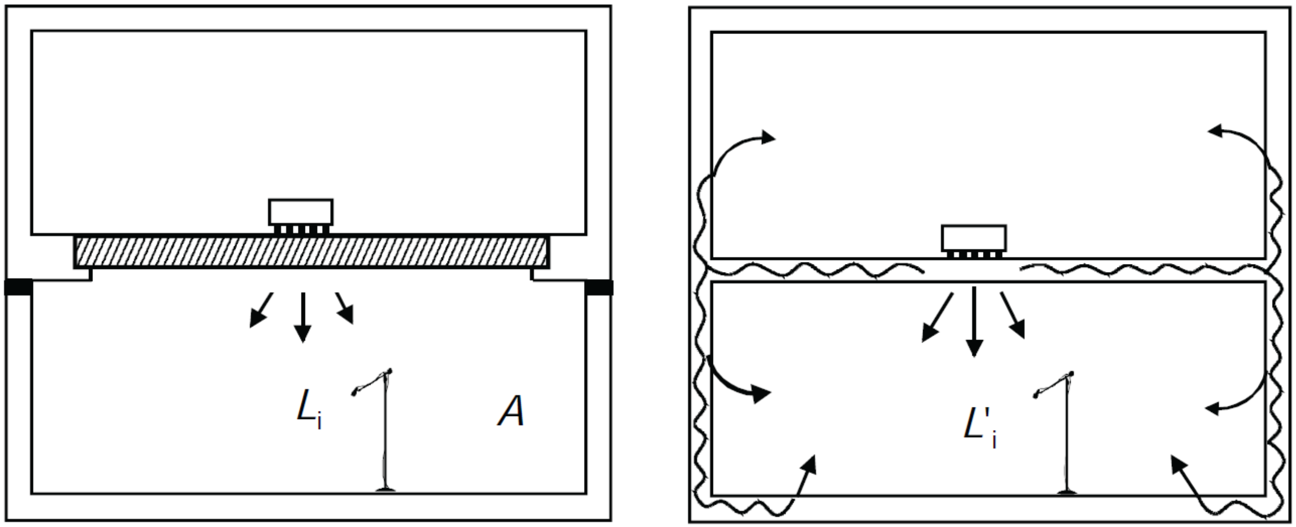
Remember…

… Laboratory vs. Field situation (flanking transmission comes into play)



[REF] Vigran(2008)

ISO 717-2:2013
ISO 10140-3:2010
$L_{n,w}$

ISO 717-2:2013
ISO 16283-2:2014
$L'_{n,w}$

SS-EN12354-2:2000
Prediction of $L'_{n,w}$ from individual acoustic performances ($L_{n,w}$)

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Sound classes (Sweden)

- **Ljudklass A:** the soundclass corresponds to very good acoustic conditions
- **Ljudklass B:** it comprises slightly better acoustic conditions than soundclass BBR. Certain individuals can still, in some cases, be disturbed. This sound class is the minimum if good living environment is requested
- **Ljudklass BBR:** this is the minimum requirements in Swedish buildings
- **Ljudklass D:** corresponds to noise conditions that are intended to be applied when sound class C cannot be achieved, e.g. in connection with some refurbishment works

BBR and SS 25267:2004

Requirements dwellings	A [dB]	B [dB]	BBR [dB]	(D) [dB]
Airborne sound insul.	61	57	53	49
Impact sound insul.	48	52	56	60
Installation noise	22/27	26/31	30/35	30/35
Traffic noise	22/37	26/41	30/45	34/49

**Installation and traffic noise have not been addressed in this lecture. For more information about how to measure and evaluate, see the correspondent ISO standards*

Example from SS 25267:2004 – Sound class A

Tabell A1 – Lägsta tillåtna luftljudsisolering respektive högsta tillåtna stegljudsnivå och ljudtrycksnivå från installationer

Utrymme	Lägsta luftljudsisolering (dB)			Högsta steg-ljudsnivå (dB)		Högsta ljudtrycks-nivå från installa-tioner (dB)	
	$R'_{w,10m^2}$	R'_w	$R'_w + C_{50\text{-}3150}$	$L'_{n,w}$	$L'_{n,w} + C_{I,50\text{-}2500}$	L_{pAeq}	L_{pAFmax}
Från utrymme utanför bostad till bostad	–	–	61	48	48	–	–
— dock från utrymme för närings- och serviceverksamhet samt gemensamhets-garage till bostad	–	–	65	44	44	–	–
— dock från utrymme inom särskilda boende-former för äldre till bostad inom särskilda boendeformer för äldre	–	61 65 [d]	–	54	54	–	–
— dock från loftgång och trapphus/korridor eller gemensam balkong/altan/ terrass till bostad	55 [a] 50 [b] 60 [c]	–	61	54	54	–	–
— dock från hygienrum och förråd till bostad	–	61	–	48 [f]	–	–	–
Inom bostad med fler än 2 rum till minst ett rum	44 [g]	–	–	64	–	–	–
I utrymme för sömn, vila och daglig samvaro	–	–	–	–	–	22 [e]	27
I övriga utrymmen	–	–	–	–	–	31	36

NOTE: Nowadays, there is a newer version of the standard, i.e. SS 25267:2015, which uses $D_{nT,w}$ and $L'_{nT,w}$ as single number indicators for field measurements. However and as previously stated, in the course we will stick to R'_w and $L_{n,w}$ to be able to compare in-situ and laboratory measurements in a more straightforward way.

The problem: lack of harmonisation (I)

Table 2
Overview of ISO 717 descriptors for evaluation of sound insulation in buildings.

ISO 717:1996 descriptors for evaluation of field sound insulation	Airborne sound insulation between rooms (ISO 717-1)[b]	Airborne sound insulation of facades[a] (ISO 717-1)[b]		Impact sound insulation between rooms (ISO 717-2)[b]
Basic descriptors (single-number quantities)	R'_w $\boldsymbol{D_{n,w}}$ $\boldsymbol{D_{nT,w}}$	R'_w $\boldsymbol{D_{n,w}}$ $\boldsymbol{D_{nT,w}}$		$L'_{n,w}$ $L'_{nT,w}$
Spectrum adaptation terms (listed according to intended main applications)	***None*** $\boldsymbol{C}$ $\boldsymbol{C_{50-3150}}$ $\boldsymbol{C_{100-5000}}$ $\boldsymbol{C_{50-5000}}$	***None*** $\boldsymbol{C}$ $\boldsymbol{C_{50-3150}}$ $\boldsymbol{C_{100-5000}}$ $\boldsymbol{C_{50-5000}}$	 $\boldsymbol{C_{tr}}$ $\boldsymbol{C_{tr,50-3150}}$ $\boldsymbol{C_{tr,100-5000}}$ $\boldsymbol{C_{tr,50-5000}}$	***None*** $\boldsymbol{C_I}$ $\boldsymbol{C_{I,50-2500}}$
Total number of descriptors	$3 \times 5 = 15$	$3 \times 9 = 27$		$2 \times 3 = 6$

[a] For facades, the complete indices for $R'_w, D_{n,w}, D_{nT,w}$ are found in ISO 717.
[b] For simplicity, only 1/3 octave quantities and C-terms are included in the table, although some countries allow 1/1 octave measurements for field check.

[REF] Rasmussen(2010)

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The problem: lack of harmonisation (II)

Table 2
Airborne sound insulation between dwellings – Main requirements in 24 European countries.[a,b]

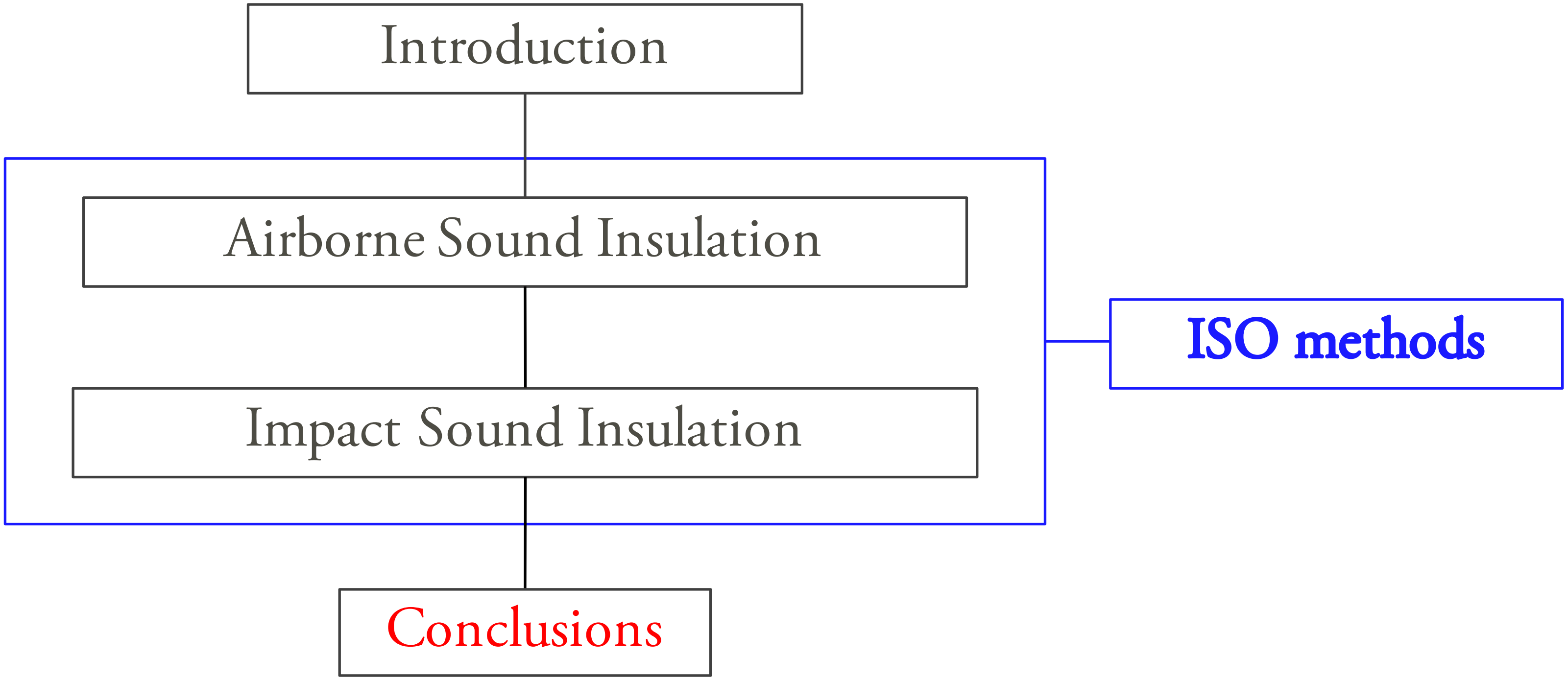
Country	Descriptor[c]	Multi-storey housing Req. (dB)	Row housing Req. (dB)
Austria	$D_{nT,w}$	⩾55	⩾60
Belgium	$D_{nT,w}$	⩾54	⩾58
Czech Rep.	R'_w	⩾52	⩾57
Denmark	R'_w	⩾55	⩾55
Estonia	R'_w	⩾55	⩾55
Finland	R'_w	⩾55	⩾55
France	$D_{nT,w} + C$	⩾53	⩾53
Germany[i]	R'_w	⩾53[g]	⩾57
Hungary	$R'_w + C$	⩾51	⩾56
Iceland	R'_w [e]	⩾52[h]	⩾55
Ireland	$D_{nT,w}$	⩾53[g]	⩾53
Italy	R'_w	⩾50	⩾50
Latvia	R'_w	⩾54	⩾54
Lithuania	$D_{nT,w}$ or R'_w	⩾55	⩾55
Netherlands	$I_{lu;k}$ [d]	⩾0	⩾0
Norway	R'_w [f]	⩾55[f]	⩾55[f]
Poland	$R'_w + C$	⩾50[g]	⩾52[h]
Portugal[i]	$D_{n,w}$	⩾50	⩾50
Slovakia	R'_w	⩾52	⩾52
Slovenia	R'_w	⩾52	⩾52
Spain	$D_{nT,w} + C_{100-5000}$	⩾50	⩾50
Sweden	$R'_w + C_{50-3150}$	⩾53	⩾53
Switzerland	$D_{nT,w} + C$	⩾52[j]	⩾55
UK[k]	$D_{nT,w} + C_{tr}$	⩾45	⩾45

Table 3
Impact sound insulation between dwellings – Main requirements in 24 European countries.[a,b]

Country	Descriptor[c]	Multi-storey housing Req. (dB)	Row housing Req. (dB)
Austria	$L'_{nT,w}$	⩽48	⩽43
Belgium	$L'_{nT,w}$	⩽58[g]	⩽50
Czech Rep.	$L'_{n,w}$	⩽58	⩽53
Denmark	$L'_{n,w}$	⩽53	⩽53
Estonia	$L'_{n,w}$	⩽53	⩽53
Finland	$L'_{n,w}$ [f]	⩽53[f]	⩽53[f]
France	$L'_{nT,w}$	⩽58	⩽58
Germany[j]	$L'_{n,w}$	⩽53	⩽48
Hungary	$L'_{n,w}$	⩽55	⩽45
Iceland	$L'_{n,w}$ [e]	⩽58[h]	⩽53
Ireland	$L'_{nT,w}$	⩽62	None
Italy	$L'_{n,w}$	⩽63	⩽63
Latvia	$L'_{n,w}$	⩽54	⩽54
Lithuania	$L'_{n,w}$	⩽53	⩽53
Netherlands	I_{co} [d]	⩾ +5	⩾ +5
Norway	$L'_{n,w}$ [f]	⩽53[f]	⩽53[f]
Poland	$L'_{n,w}$	⩽58	⩽53
Portugal[j]	$L'_{n,w}$	⩽60	⩽60
Slovakia	$L'_{n,w}$	⩽58	⩽58
Slovenia	$L'_{n,w}$	⩽58	⩽58
Spain	$L'_{nT,w}$	⩽65	⩽65
Sweden	$L'_{n,w} + C_{I,50-2500}$	⩽56[i]	⩽56[i]
Switzerland	$L'_{nT,w} + C_I$	⩽53[k]	⩽50
UK[l]	$L'_{nT,w}$	⩽62	None

[REF] Rasmussen(2010)

Outline


Introduction
Airborne Sound Insulation
Impact Sound Insulation
Conclusions
ISO methods

Conclusions

- ISO procedures (sound insulation)
  - Airborne sound insulation
  - Impact sound insulation

NOTE: Check out the acoustic glossary

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References (I)

ISO 10140 series:

- ISO (2010), ISO 10140-1: Acoustics – Laboratory measurement of sound insulation of building elements – Part 1: Application rules for specific products, International Organization for Standardization, Geneva, Switzerland.

- ISO (2010), ISO 10140-2: Acoustics – Laboratory measurement of sound insulation of building elements – Part 2: Measurement of airborne sound insulation, International Organization for Standardization, Geneva, Switzerland.

- ISO (2010), ISO 10140-3: Acoustics – Laboratory measurement of sound insulation of building elements – Part 3: Measurement of impact sound insulation, International Organization for Standardization, Geneva, Switzerland.

- ISO (2010), ISO 10140-4: Acoustics – Laboratory measurement of sound insulation of building elements – Part 4: Measurement procedures and requirements, International Organization for Standardization, Geneva, Switzerland.

- ISO (2010), ISO 10140-5: Acoustics – Laboratory measurement of sound insulation of building elements – Part 5: Requirements for test facilities and equipment, International Organization for Standardization, Geneva, Switzerland.

References (II)

ISO 717 series:

- ISO (2013), ISO 717-1: Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation, International Organization for Standardization, Geneva, Switzerland.
- ISO (2013), ISO 717-2: Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Impact sound insulation, International Organization for Standardization, Geneva, Switzerland.

ISO 16283 series:

- ISO (2014), ISO 16283-1: Acoustics – Field measurement of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation, International Organization for Standardization, Geneva, Switzerland.
- ISO (2014), ISO 16283-2: Acoustics – Field measurement of sound insulation in buildings and of building elements – Part 2: Impact sound insulation, International Organization for Standardization, Geneva, Switzerland.
- ISO (2014), ISO 16283-3: Acoustics – Field measurement of sound insulation in buildings and of building elements – Part 3: Façade sound insulation, International Organization for Standardization, Geneva, Switzerland.

Thank you for your attention!

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