Sound Insulation

J. NEGREIRA, D. BARD

DIVISION OF ENGINEERING ACOUSTICS, LUND UNIVERSITY

Outline

Introduction

Airborne Sound Insulation

Impact Sound Insulation

ISO methods

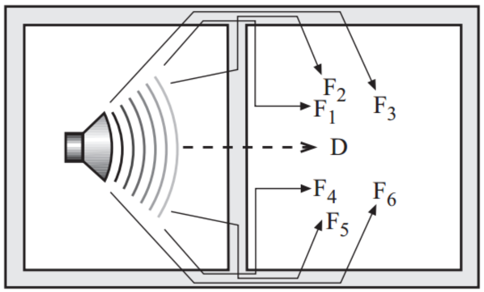
Analytical models for calculation of R_w in single and double-leaf walls

Conclusions

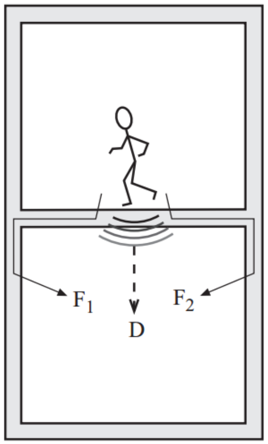
LUND UNIVERSITY

Introduction (I)

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



(a) Airborne sound transmission.



(b) Impact sound.

LUND UNIVERSITY

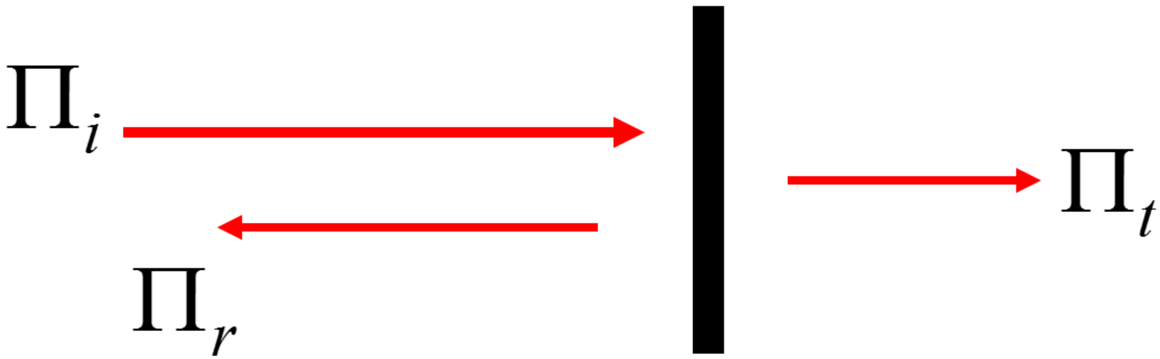
Introduction (II)

Π_i Incident wave power

Π_r Reflected wave power

Π_t Transmitted wave power

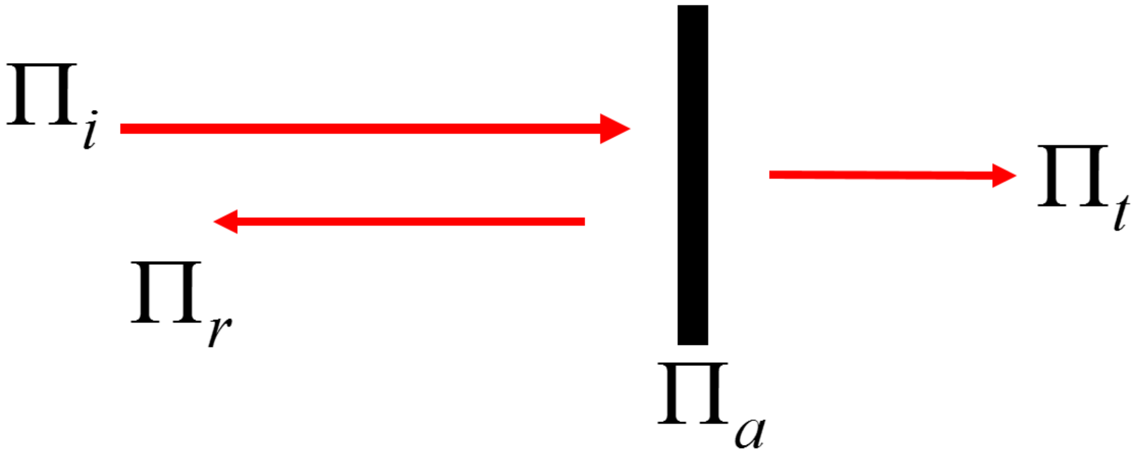
Π_a Power reduction due to absorption



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

LUND UNIVERSITY

Introduction (III)



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

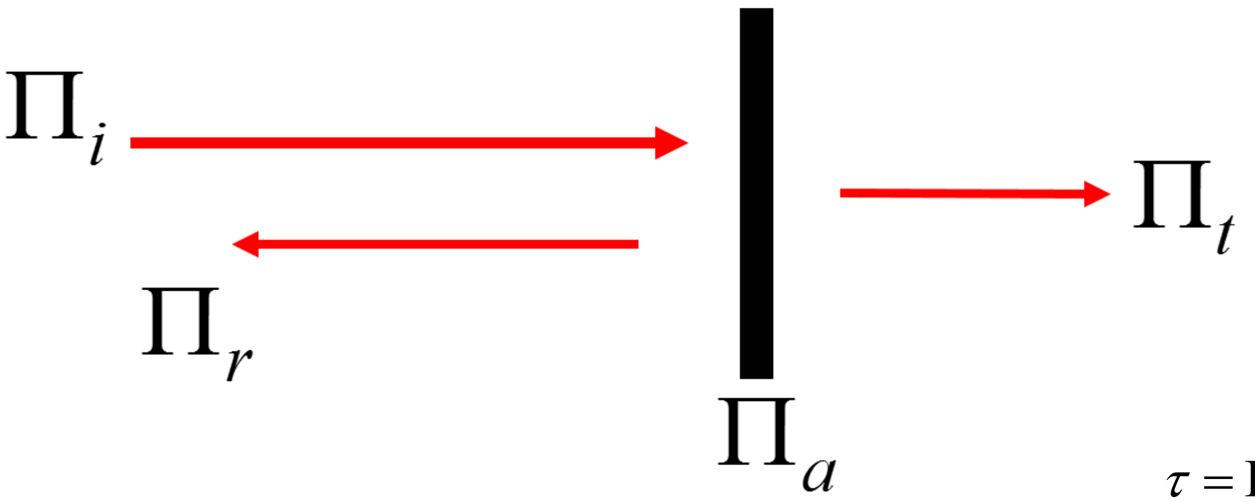
Absorption coefficient: $\alpha = \Pi_a / \Pi_i$ [-]

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

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

LUND UNIVERSITY

Introduction (IV)



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

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

LUND UNIVERSITY

Outline

Introduction

Airborne Sound Insulation

Impact Sound Insulation

ISO methods

Analytical models for calculation of R_w in single and double-leaf walls

Conclusions

LUND UNIVERSITY

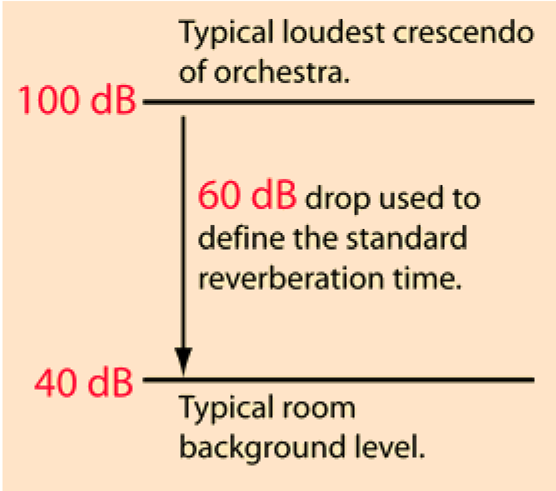
References

- ISO 140, Acoustics – Measurement of sound insulation in buildings and of building elements – Part 3: Laboratory measurements of airborne sound insulation of building elements (1995).
- ISO 140, Acoustics – Measurement of sound insulation in buildings and of building elements – Part 4: Field measurements of airborne sound insulation between rooms (1998).
- ISO 140, Acoustics – Measurement of sound insulation in buildings and of building elements – Part 5: Field measurements of airborne sound insulation of facade – elements and facades (1998).
- ISO 140, Acoustics – Measurement of sound insulation in buildings and of building elements – Part 10: Laboratory measurements of airborne sound insulation of small building elements (1991)
- ISO 717, Acoustics - Rating of sound insulation in buildings and of buildings elements – Part 1: Airborne sound insulation (1996).

LUND UNIVERSITY

DEF: Reverberation time

- Reverberation time
  - 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)



$$T_{60} = 0.16 \frac{V}{A_{eff}} = 0.16 \frac{V}{\sum_i \alpha_i S_i}$$

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

LUND UNIVERSITY

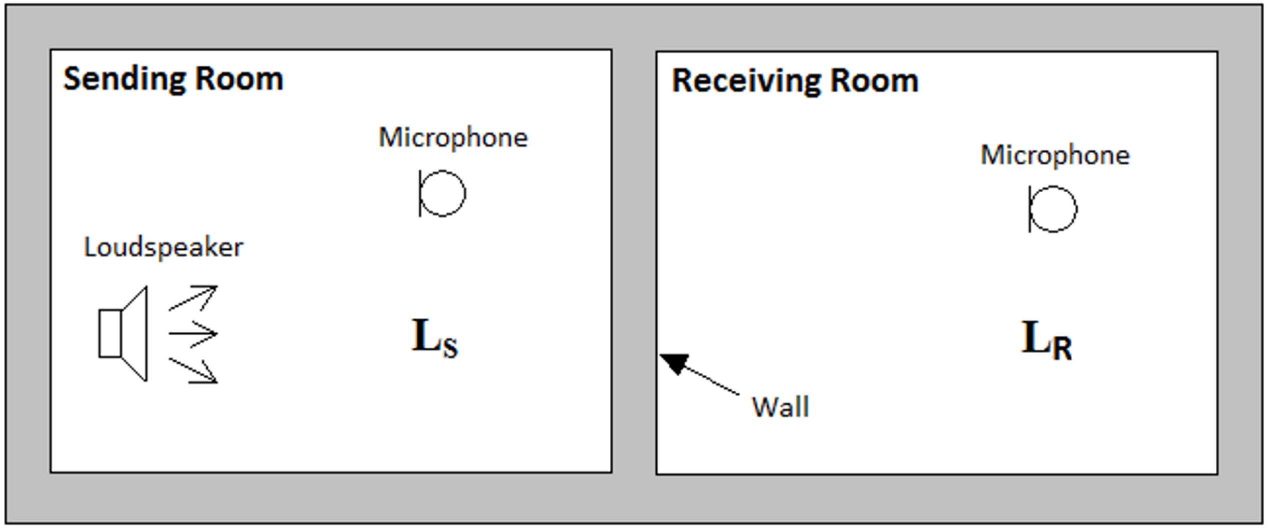
Nomenclature

- R'_w : apparent sound reduction index (*in-situ* measurement)
- R_w : sound reduction index (laboratory measurement)
- $C_{50\text{-}3150}$: spectrum adaptation term
- C_{tr}: spectrum adaptation term due to traffic noise
- D'_n , $D'_{n,T}$, D'_w etc. sound level differences (see standards)

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

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

Measurement sound reduction index (I)



L_S : SPL in the sending room [dB]

L_R : SPL in the receiving room [dB]

S : wall area [m^2]

A : Absorption area in receiving room [m^2]

Wall's reduction index [dB]

(= transmission loss):

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

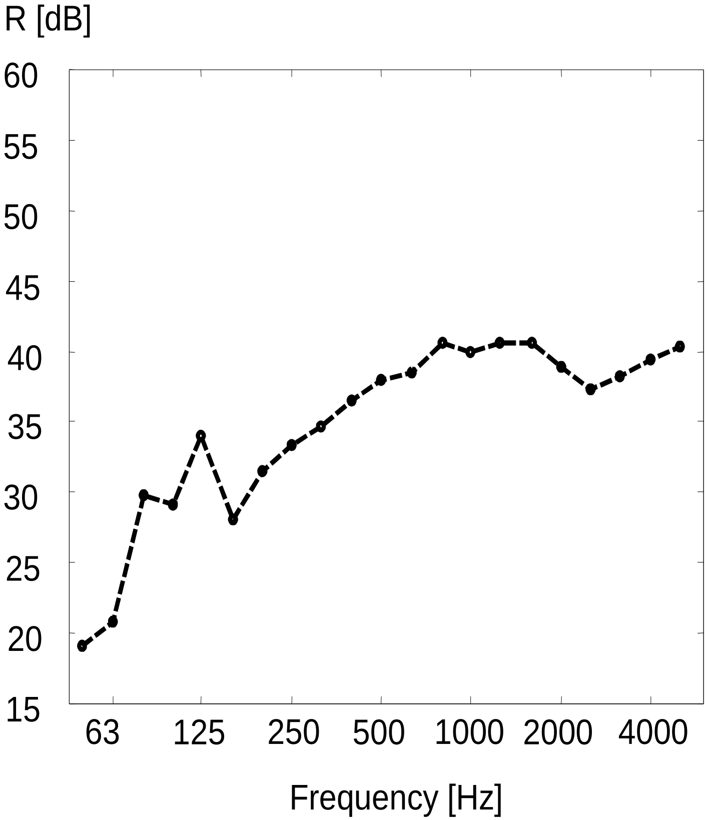
NOTE: Loudspeaker and microphone positions are defined in the corresponding ISO standard.

LUND UNIVERSITY

Measurement sound reduction index (II)

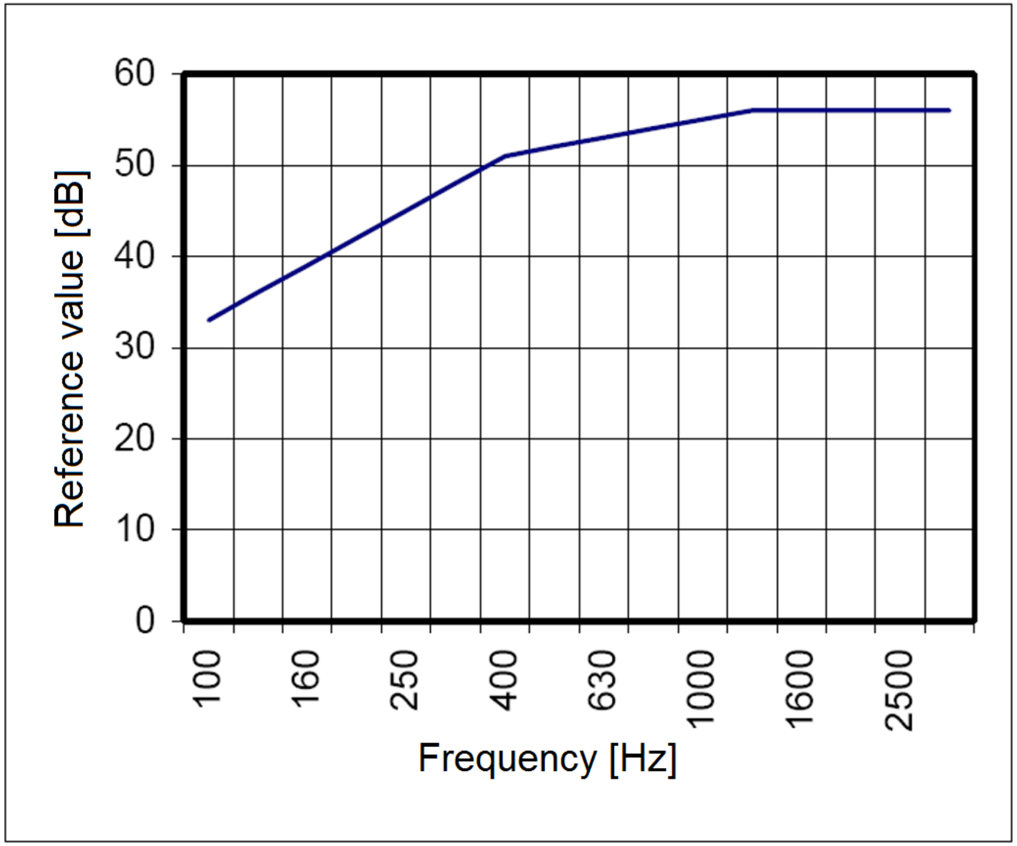
- Example of measured curve:
  - High values ⇒ Better insulation ⇒ *"Quieter"*

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



ISO Evaluation of sound reduction index (I)

- Reference curve (ISO 717-1)



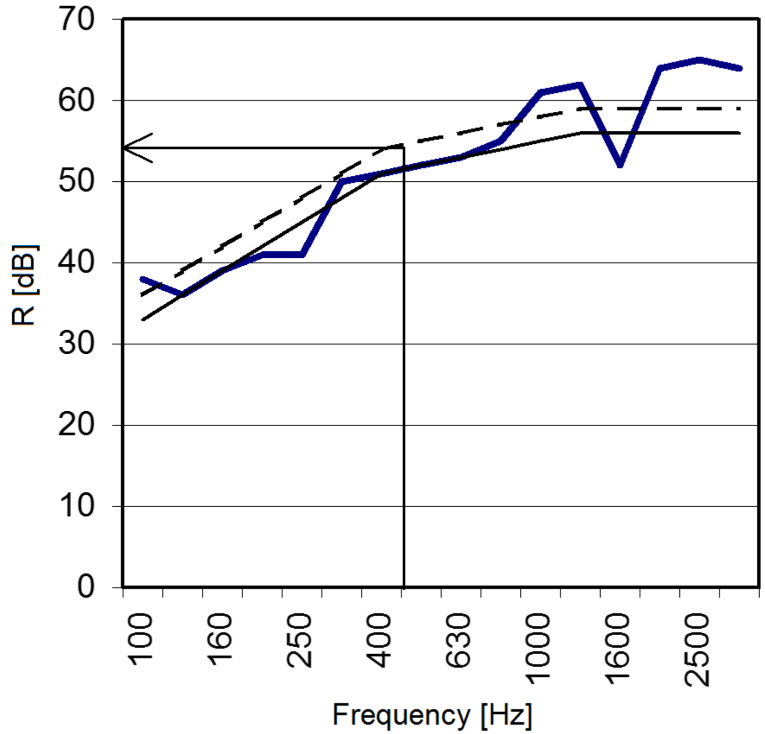
Frequency [Hz]	Ref. value [dB]
100	33
125	36
160	39
200	42
250	45
315	48
400	51
500	52
630	53
800	54
1000	55
1250	56
1600	56
2000	56
2500	56
3150	56

ISO Evaluation of sound reduction index (II)

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

"[…] 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.*

LUND UNIVERSITY

Airborne sound insulation – example

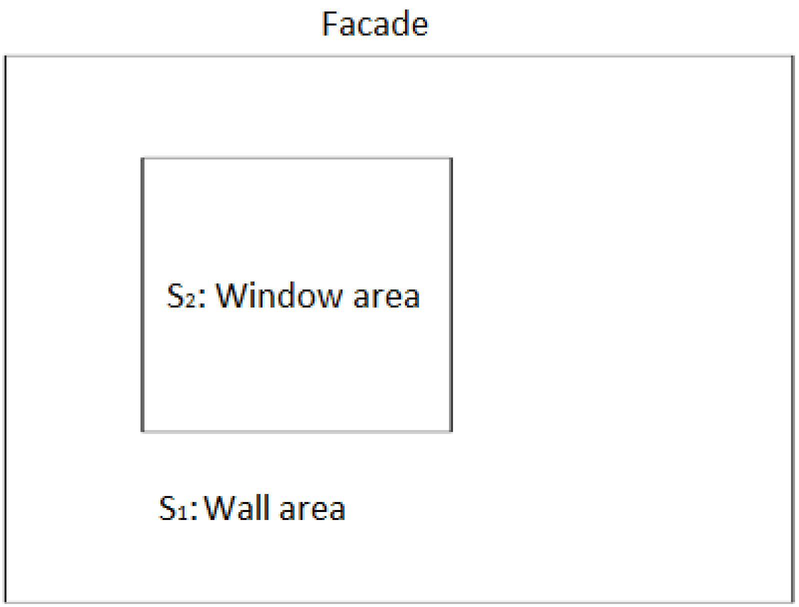
Upplevd störning vid olika luftljudsisolering

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.

LUND UNIVERSITY

DEF: Combined reduction index



R_1, R_2 … individual reduction indexes

S: total area, i.e. $S = S_1 + S_2 + \ldots$

Combined reduction index

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

DEF: Leakages

- Power of the opening (leakage)

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

- The reduction index of the wall then becomes

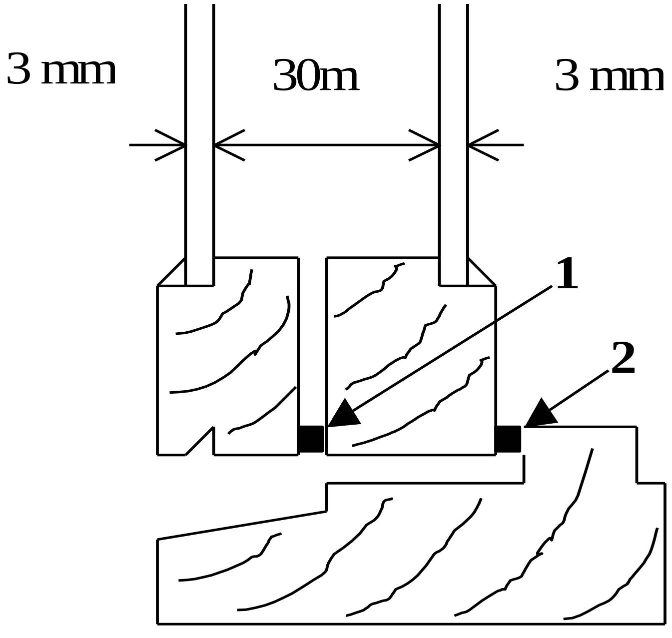
$$R = -10 \cdot \log\left(\frac{\Pi_l + \Pi_t}{\Pi_i}\right) = -10 \cdot \log\left(\frac{\Pi_t}{\Pi_i} + \frac{S_l}{S}\right) \Rightarrow$$

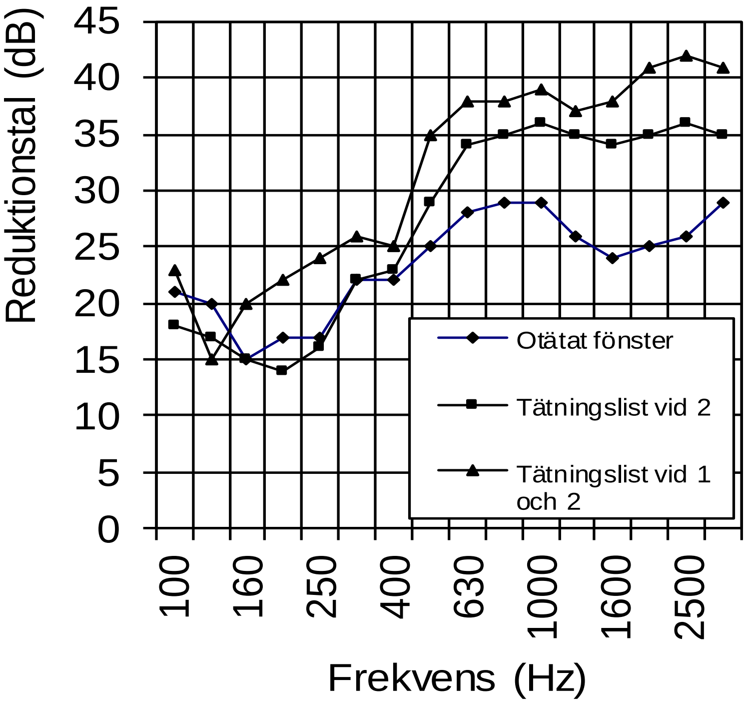
$$R_{withLeakage} = -10 \cdot \log\left(10^{-R/10} + \frac{S_l}{S}\right)$$

LUND UNIVERSITY

Example: influence of leakages

Sealing of windows is of crucial importance





Exercises

1.- A 9 m^2 facade has a sound reduction index of 60 dB and has installed a 1,0 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 60 dB? 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?

LUND UNIVERSITY

Outline

Introduction

Airborne Sound Insulation

Impact Sound Insulation

ISO methods

Analytical models for calculation of R_w in single and double-leaf walls

Conclusions

LUND UNIVERSITY

References

- ISO 140, Acoustics – Measurement of sound insulation in buildings and of building elements – Part 6: Laboratory measurements of impact sound insulation of floors (1998).
- ISO 140, Acoustics – Measurement of sound insulation in buildings and of building elements – Part 7: Field measurements of impact sound insulation of building elements (1998).
- ISO 717, Acoustics - Rating of sound insulation in buildings and of buildings elements – Part 2: Impact sound insulation (1996).

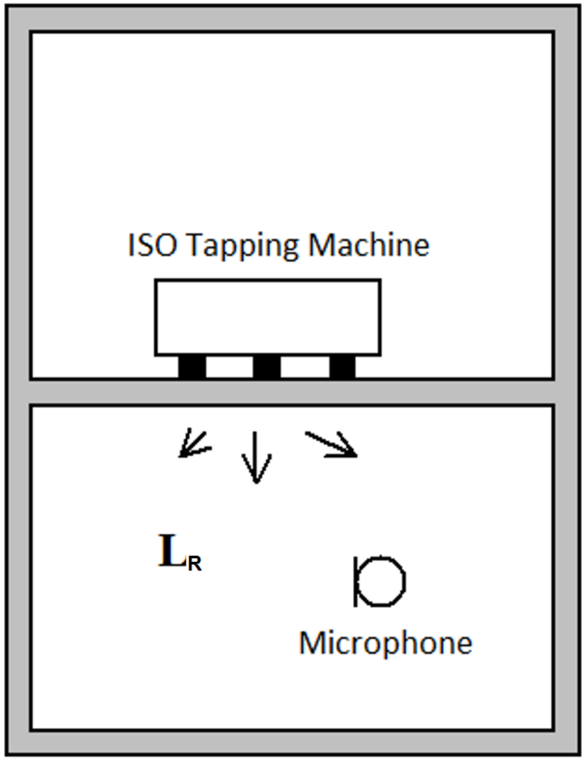
Nomenclature

- $L'_{n,w}$: weighed normalised impact sound level, (*in-situ*)
- $L_{n,w}$: weighed normalised impact sound level (laboratory)
- $C_{l,50\text{-}2500}$: spectrum adaptation term

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

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

Measurement impact sound insulation (I)



Impact sound level:

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

L_n : normalised impact sound level [dB]

L_R : SPL in the receiving room [dB]

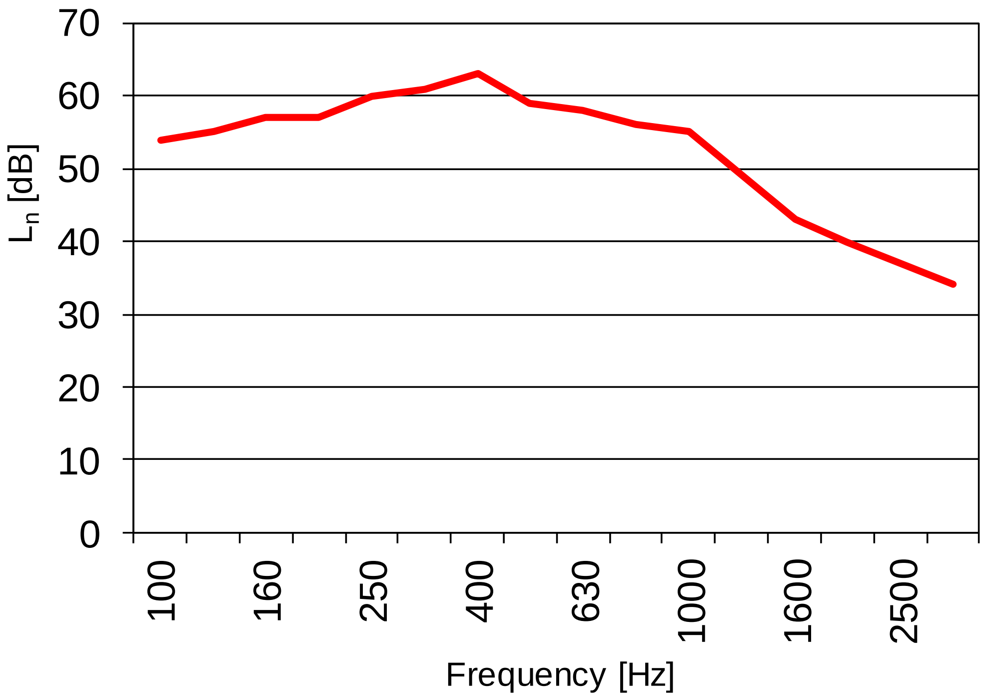
A : Absorption area in the receiving room

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

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

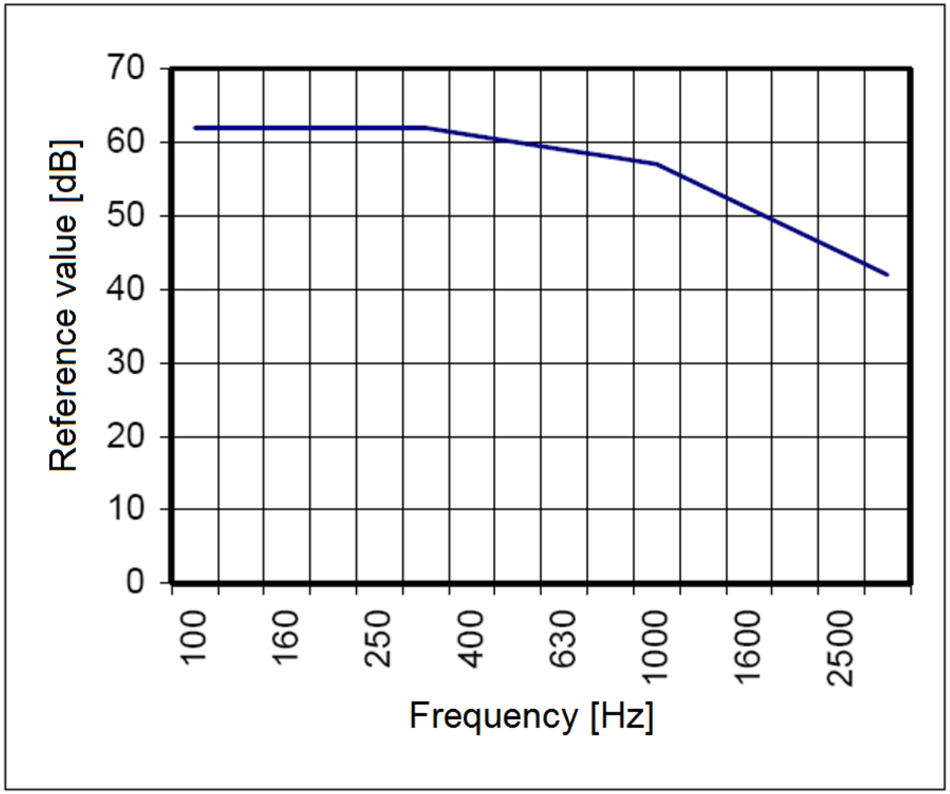
Measurement impact sound insulation (II)

- 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

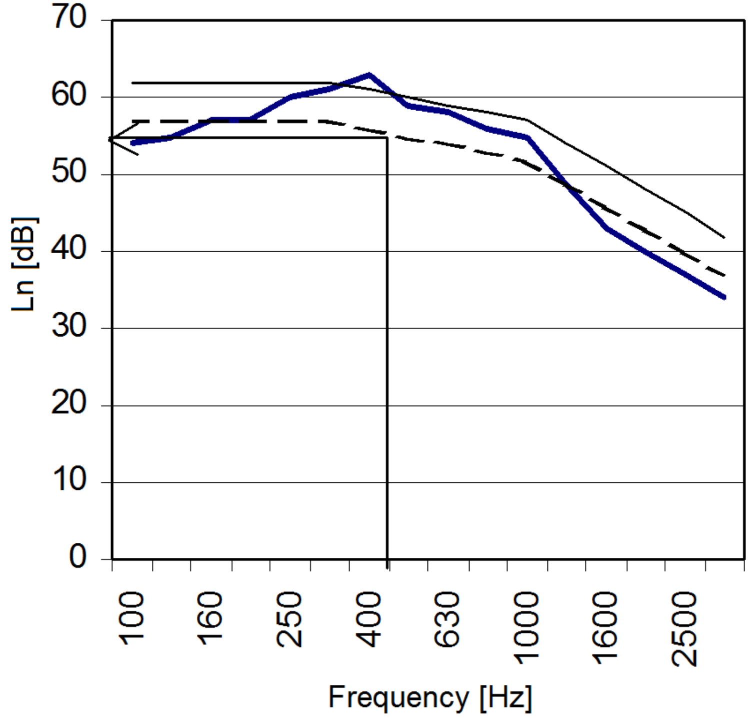
LUND UNIVERSITY

ISO Evaluation of impact sound insulation (II)

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

"[…] an unfavourable deviation at a particular frequency occurs when the result of measurements <u>exceed</u> 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.*

Sound classes (Sweden)

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

LUND UNIVERSITY

BBR and SS 25267:2004

Ljudkrav för bostäder	A [dB]	B [dB]	C [dB]	(D) [dB]
Luftljudsisolering	61	57	53	49
Stegljudsnivå	48	52	56	60
Installationsbuller	22/27	26/31	30/35	30/35
Trafikbuller	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*

LUND UNIVERSITY

Example from SS 25267:2004 – Sound class C

Tabell C1 – Lägsta tillåtna luftljudsisolering respektive högsta tillåtna stegljudsnivå och ljudtrycksnivå från installationer

Utrymme	Lägsta luftljudsisolering (dB)			Högsta steg-ljudsnivå (dB)		Högsta ljud-trycksnivå från installationer (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_{pA}	L_{pAFmax}
Från utrymme utanför bostad till utrymme i bostad	–	–	53	56	56	–	–
— dock från utrymme för närings- och servi-ceverksamhet samt gemensam-hetsgarage till bostad	–	–	57	52	52	–	–
— dock från utrymme inom särskilda boende-former för äldre till bostad inom särskilda boendeformer för äldre	–	53 57 [d]	–	62	62	–	–
— dock från loftgång och trapphus/korridor eller gemensam balkong/altan/ terrass till bostad	45 [a] 40 [b] 50 [c]	–	53	62	62	–	–
— dock från hygienrum och förråd till bostad	–	53	–	56 [f]	–	–	–
I utrymme för sömn, vila och daglig samvaro	–	–	–	–	–	30 [e]	35
I övriga utrymmen	–	–	–	–	–	35	40

LUND UNIVERSITY

Outline

Introduction

Airborne Sound Insulation

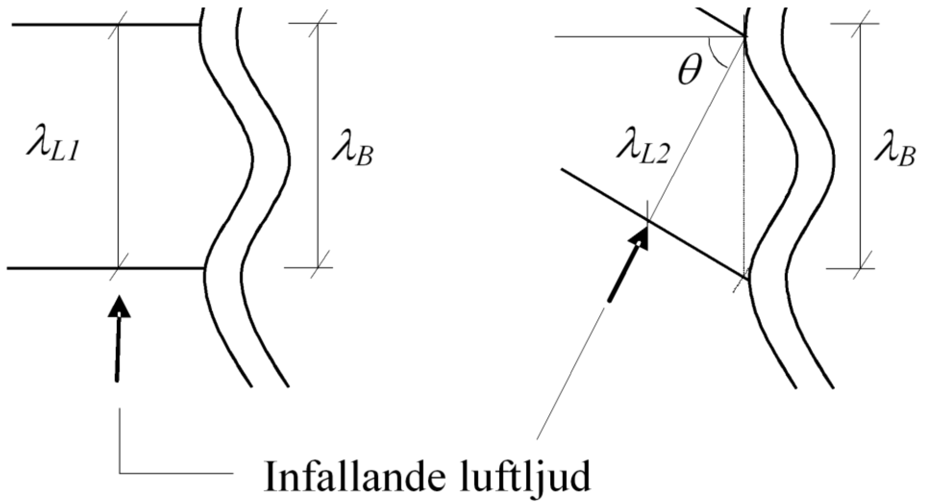
Impact Sound Insulation

ISO methods

Analytical models for calculation of R_w in single and double-leaf walls

Conclusions

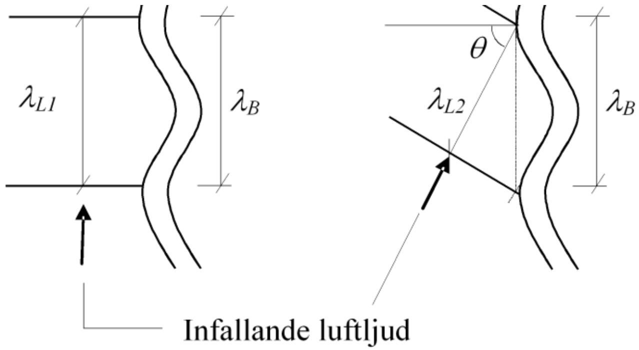
DEF: Coincidence – critical frequency (I)



- The wavelength of a bending wave λ_B is dependent on frequency, bending stiffness and mass density
- When the wavelength of sound in air coincides with the structural wavelength → Coincidence phenomena
  - Radiation efficiency becomes very high
  - Poor insulation

LUND UNIVERSITY

DEF: Coincidence – critical frequency (II)



- Bending wave velocity in a plate

$$c_B = \sqrt{2\pi f}\sqrt[4]{\frac{B}{m''}}$$

- If $f = f_c$ thus $c_B = c_o$ = 340 m/s (f_c = critical frequency)

$$f_c = \frac{c_0^2}{2\pi}\sqrt{\frac{m''}{B}}$$

- Or expressed as a function of the coincidence number

$$f_c = \frac{K}{h}$$

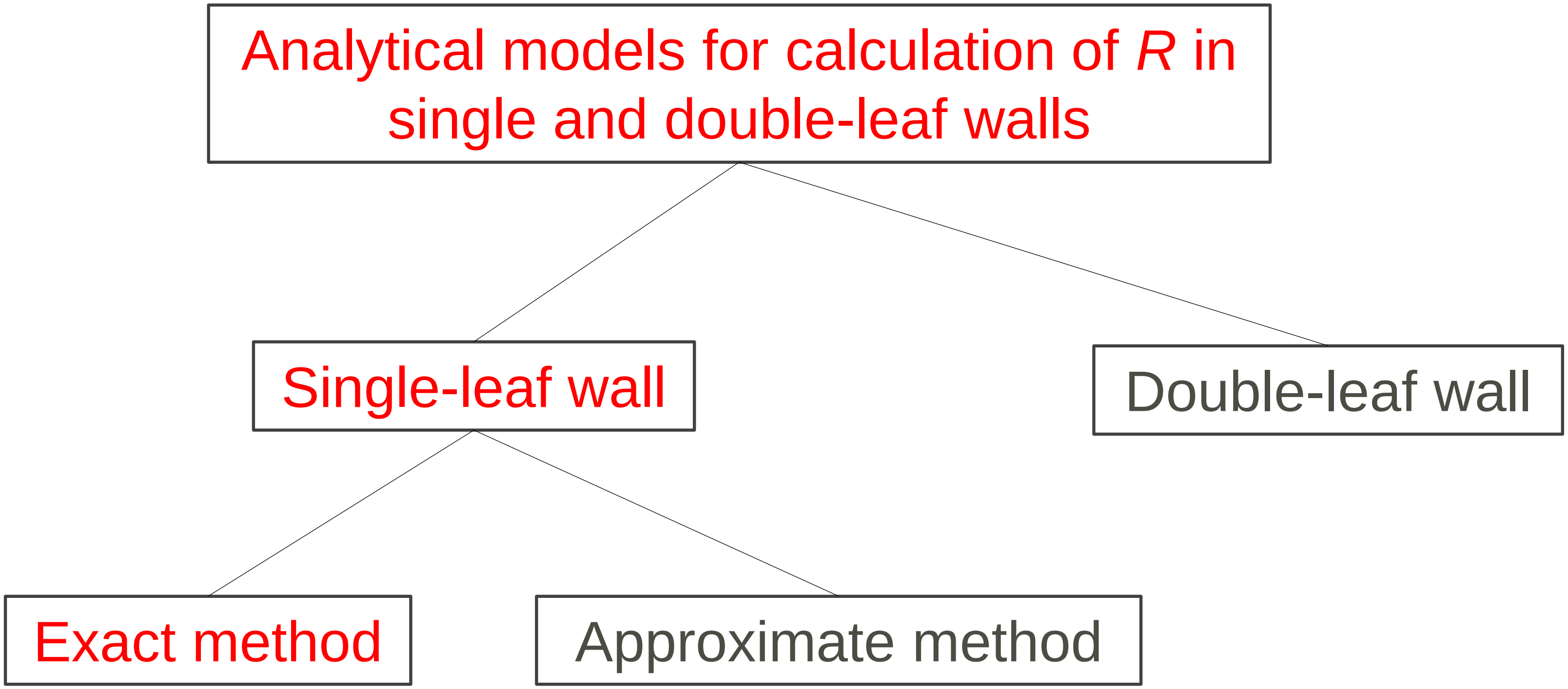
NOTE: The condition for coincidence is that $\lambda_B = \lambda \sin(\varphi)$. Therefore, if the incidence angle φ decreases, the coincidence frequency f_c increases according to $f_c(\varphi) = f_c/\sin^2(\varphi)$. The lowest frequency at which coincidence occur (critical frequency) occurs at the incidence angle φ=90º.

LUND UNIVERSITY

Critical frequency for common materials

Material	Coincidence number	Thickness [m]	f_c [Hz]
Concrete	18	160	110
Light concrete	38	70	540
Gypsum	32	10	3200
Steel	12-13	1	12000
Glass	18	3	6000

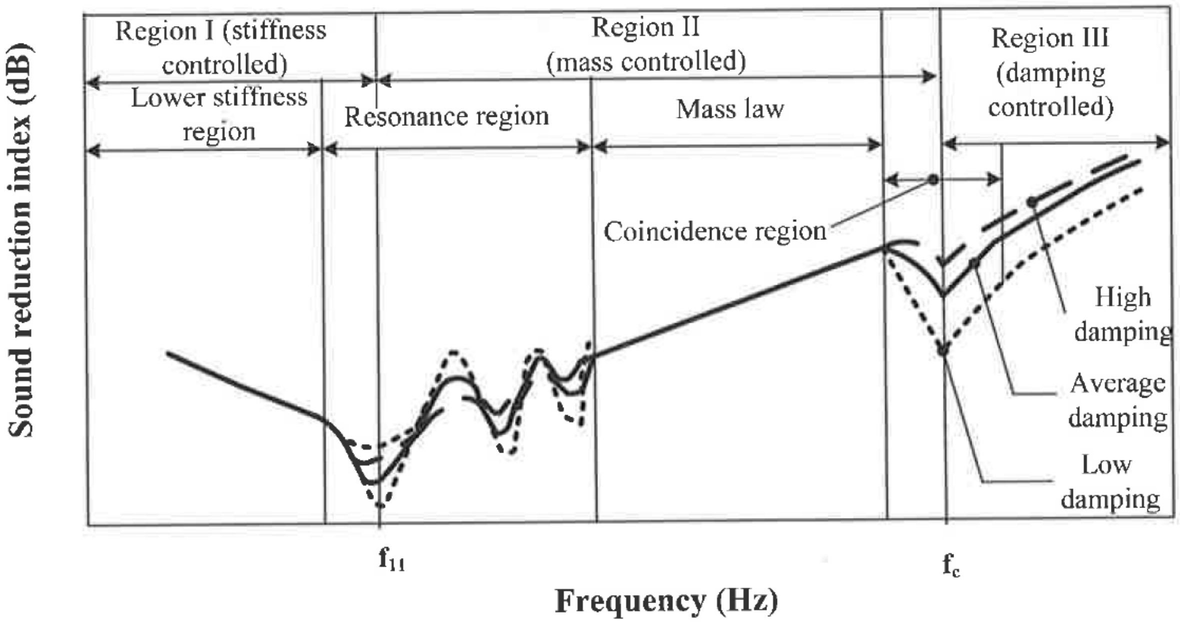
Outline



LUND UNIVERSITY

Sound reduction index of single-leaf partitions (I)

- **Exact Method**
  - Region I: Stiffness-controlled region ($f < f_{11}$)
  - Region II: Mass-controlled region ($f_{11} < f < f_c$)
  - Region III: Damping-controlled region ($f_c < f$)



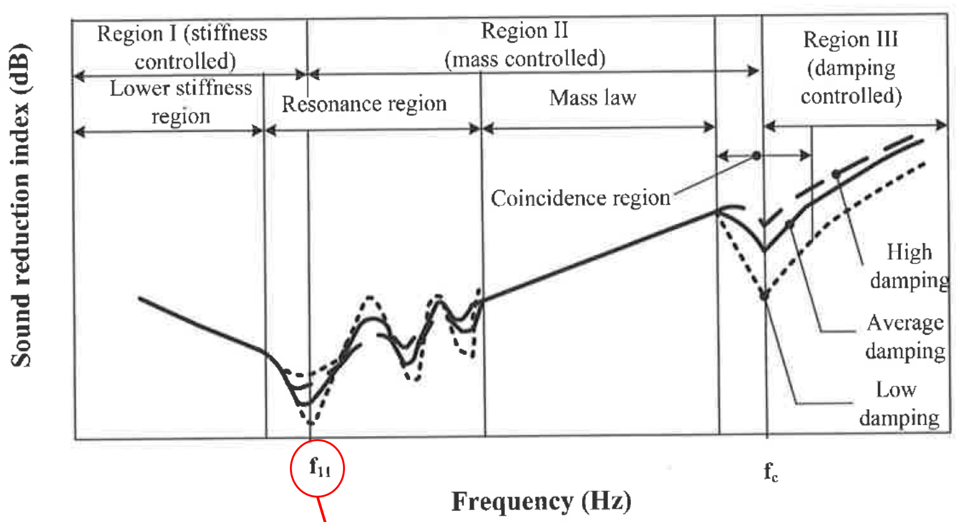
Sound reduction index of single-leaf partitions (II)

- Region I: Stiffness-controlled region ($f < f_{11}$)
  - Panel vibrates as a whole (considered thin)

$$R = 10\log\left(\frac{1}{K_S^2}\right) - 10\log\left(\ln\left(1 + K_S^{-2}\right)\right)$$

$$K_S = 4\pi f \rho_F c_F C_s$$

$$C_s = \frac{768(1-\upsilon^2)}{\pi^8 E h^3 \left(\frac{1}{a^2} + \frac{1}{b^2}\right)^2}$$



$$f_{11} = \frac{\pi}{4\sqrt{3}} c_{Lplate} h \left(\frac{1}{a^2} + \frac{1}{b^2}\right)$$

For a simply supported plate

C_S: Mechanical compliance for a rectangular plate
E: Young's modulus of the material the wall is made of
h: wall thickness
a, b: plate dimensions
υ: Poisson's ratio of the wall
ρ_F : Density of the surrounding fluid (F), i.e. air
c_F wave propagation speed in the fluid (F), i.e. air
c_{Lplate} wave propagation speed in the plate (longitudinal wave)

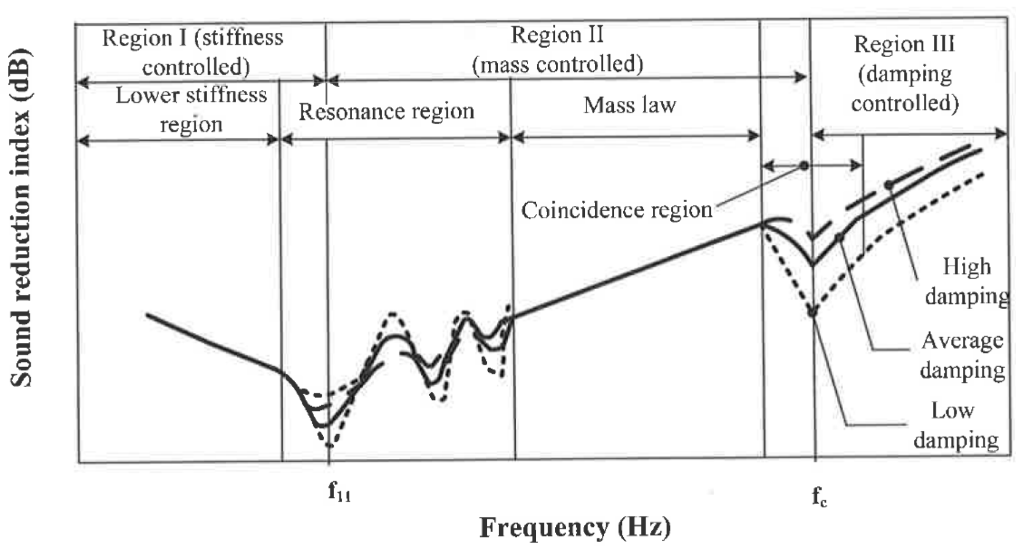
Sound reduction index of single-leaf partitions (III)

- Region II: Mass-controlled region ($f_{11} < f < f_c$)
  - Transmission loss independent of stiffness (controlled by mass inertia)
  - Some energy transmitted and part reflected at panel surface

$$R = 10\log\left(1+\left(\frac{\pi f m''}{\rho_F c_F}\right)^2\right) - 5dB$$

Mass law >>1

m''= ρh is the surface mass of the panel



NOTE: Although the above equation is valid for frequencies up to f_c, it yields only accurate results for f ≤ 0.5f_c . The mathematical expresion around f_c is mathematically cumbersome and rarely used, its being the reason why approximate methods were developed.

LUND UNIVERSITY

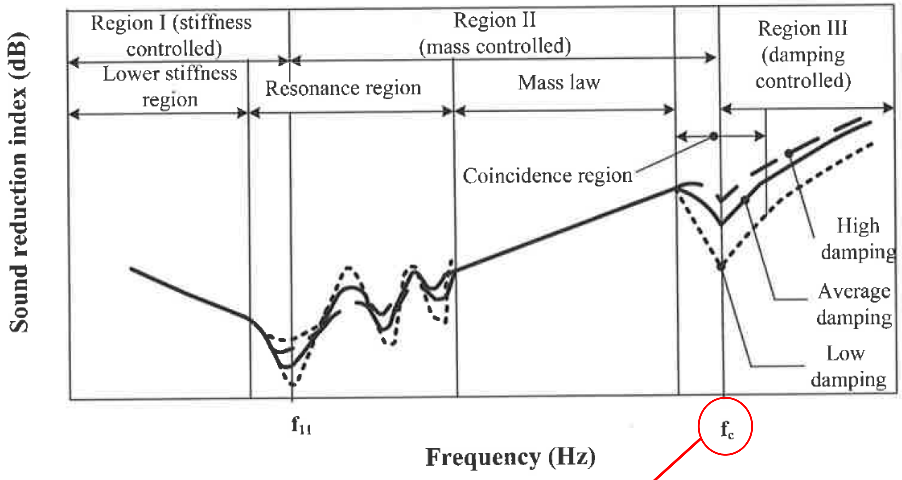
Sound reduction index of single-leaf partitions (IV)

- Region III: Damping-controlled region (f_c< f)
  - Curve “dip” controlled by internal material damping
  - Important for design (low insulation)

$$R = R(f_c) + 10\log(\eta) + 33.22\log\left(\frac{f}{f_c}\right) - 5.7dB$$

$$R(f_c) = 10\log\left(1 + \left(\frac{\pi f_c m''}{\rho_F c_F}\right)^2\right)$$

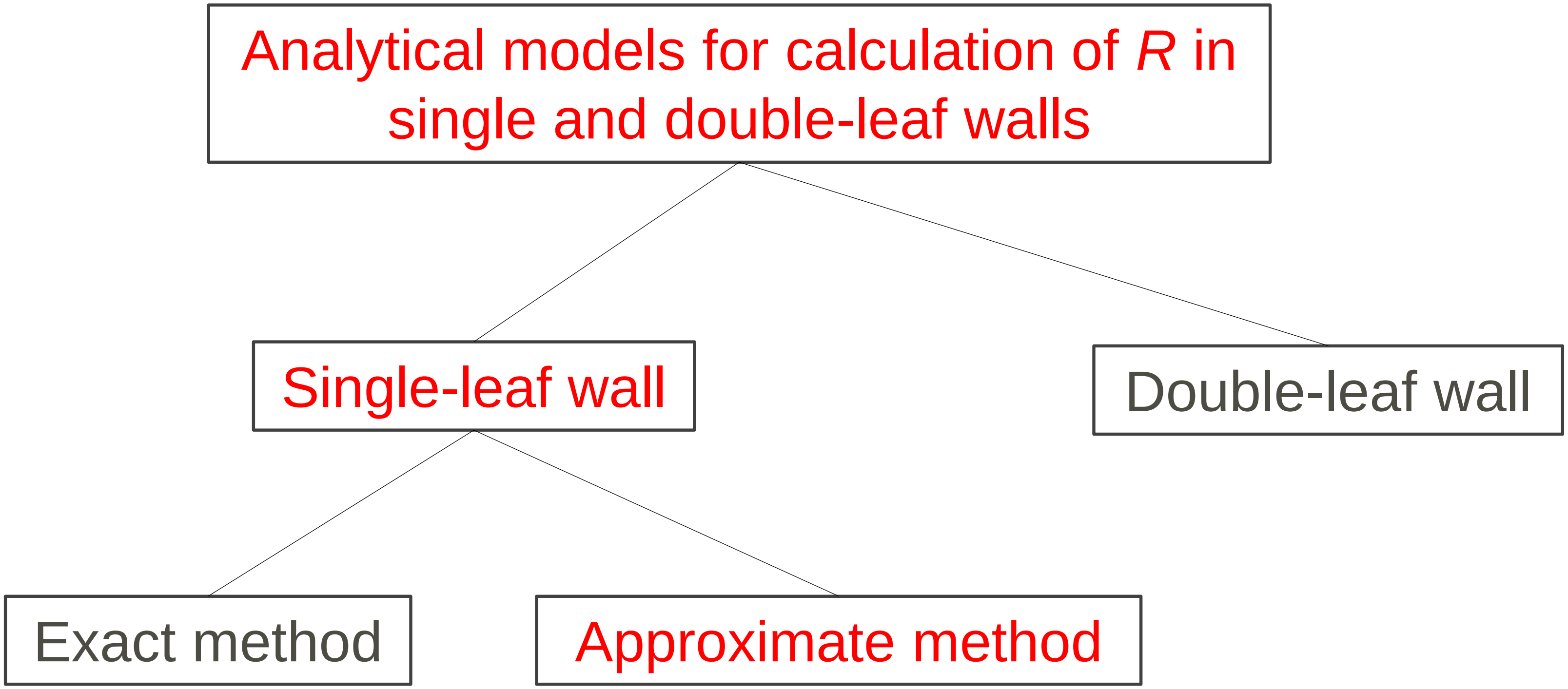
η is the total loss factor or damping of the panel



$$f_c = \frac{c_F^2\sqrt{3}}{\pi h c_{Lplate}}$$

LUND UNIVERSITY

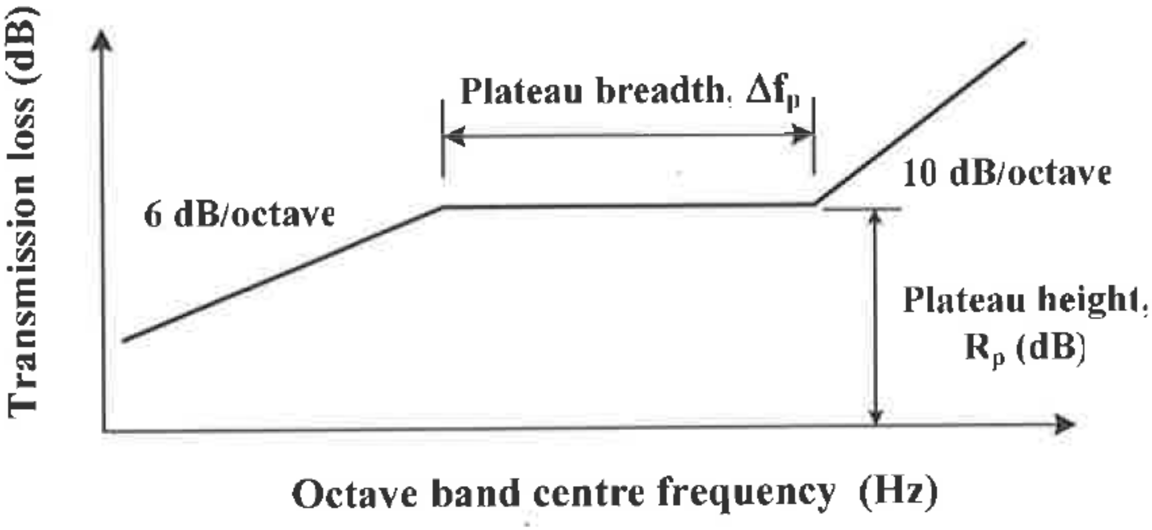
Outline



LUND UNIVERSITY

Sound reduction index of single-leaf partitions (I)

- **Approximate method**
  - Region I: Mass-controlled region ($f < f_1$)
  - Region II: “Plateau” ($f_1 < f < f_2$)
  - Region III: Stiffness-controlled region ($f_2 < f$)

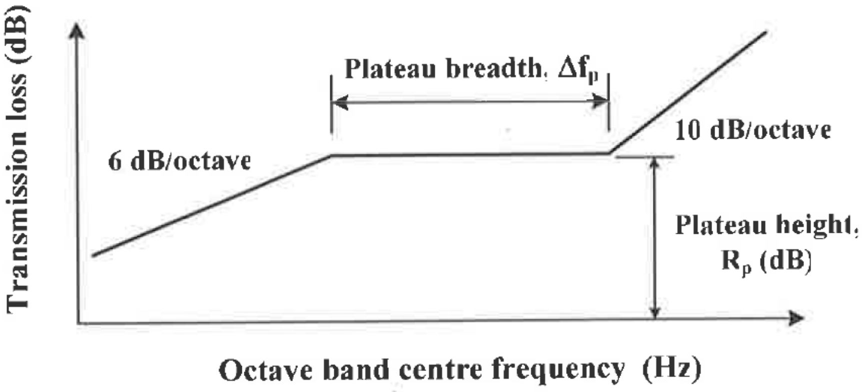


Hyphotesis: Infinite panel and diffuse field excitation

Sound reduction index of single-leaf partitions (II)

- Region I: Mass-controlled region ($f < f_1$)
  - Transmission independent of panel stiffness

$$R_n = 20\log(m'') + 20\log(f) - 20\log\left(\frac{\rho_F c_F}{\pi}\right) - 5dB$$



Sound reduction index of single-leaf partitions (III)

- Region II: "Plateau" ($f_1 < f < f_2$)
  - Governed by internal damping
  - Height of the plateau depends on material
  - f_1 *and* f_2 are the lower and upper limits of the plateau
    - » Calculated with expresions of adjoining regions

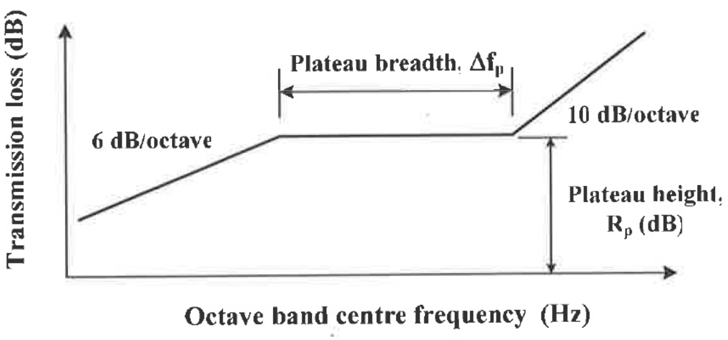


Table 4.2 Values of the plateau height (R_P) and plateau width (Δf_P) for the approximate method of calculation of the transmission loss for panels (partially after Watters, 1959).

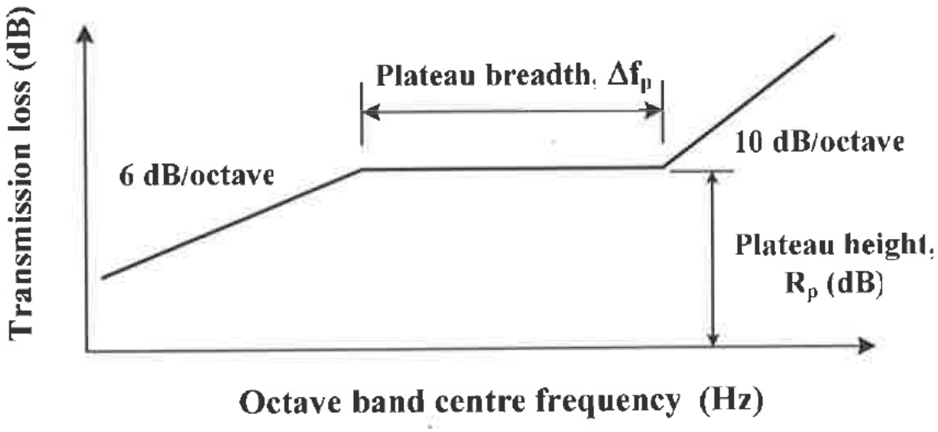
Material	Specific surface density (kg/m² per cm)	Plateau height, R_P (dB)	$\Delta f_P = f_2 - f_1$ (octave)	Plateau breadth, frequency ratio, f_2/f_1
Aluminum	26.6	29	3.5	11*
Brick	21	37	2.2	4.5
Concrete, dense	22.8	38	2.2	4.5
Glass	24.7	27	3.3	10
Lead	112	56	2.0	4
Masonry block				
Cinder**	11.4	30	2.7	6.5
Dense		32	3.0	8
Plywood, fir	5.7	19	2.7	6.5
Plaster, sand	17.1	30	3.0	8
Steel	76	40	3.5	11*

* These materials have, in general, very low damping. The numbers are for a typical panel in place
** Hollow block. The values are determined for 6-in (150 mm) plastered block.

Sound reduction index of single-leaf partitions (IV)

- Region III: Mass-controlled region ($f_2 < f$)
  - Governed by stiffness of the panel

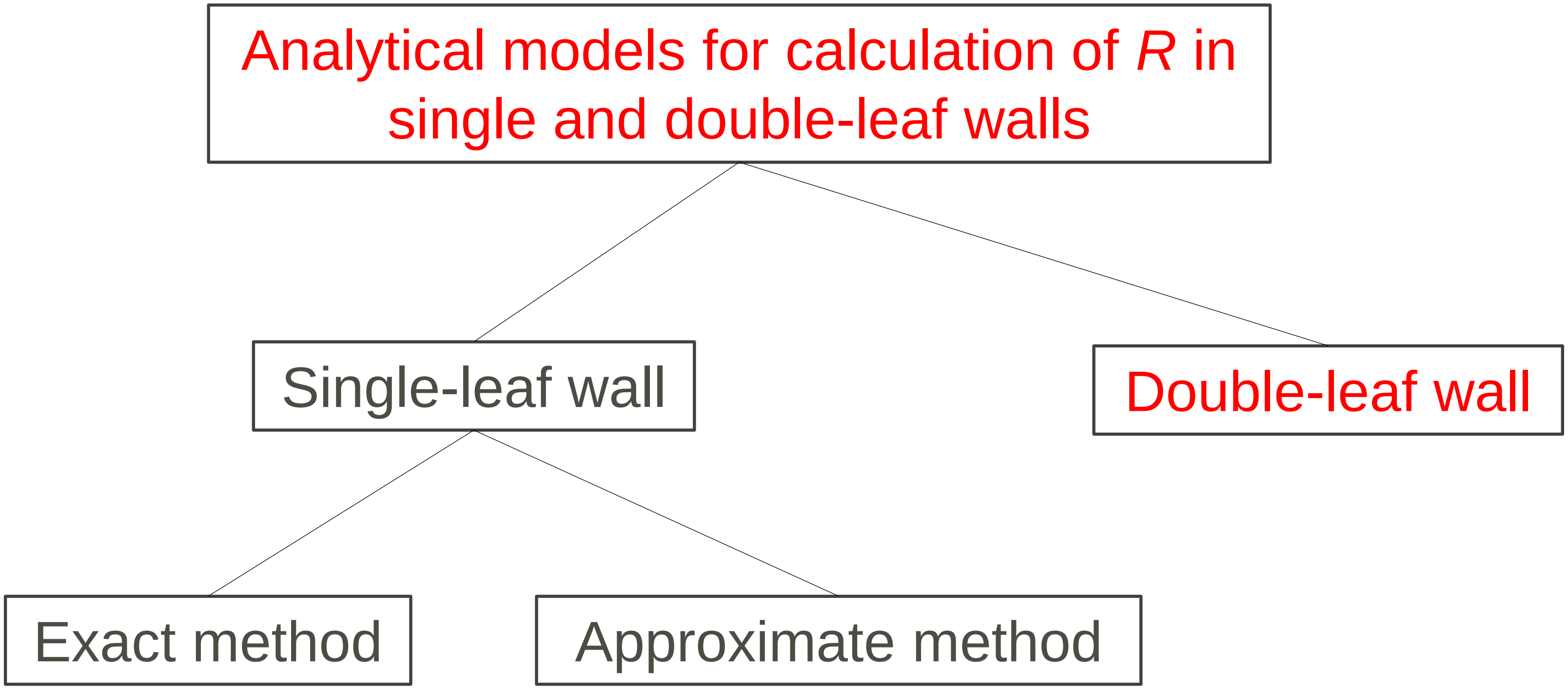
$$R_n = R(f_2) + 33.22\log\left(\frac{f}{f_2}\right)$$



NOTE: The slope of the expression (10 dB/octave) should just be used only for the 2 octaves above f_2. For the following octaves, one should use a slope equal to 6 dB/octave, i.e. "$20\log(f/f_{2oct})$" instead of "$33.22\log(f/f_2)$", where f_{2oct} is the frequency where the 3rd octave above f_2 start.

LUND UNIVERSITY

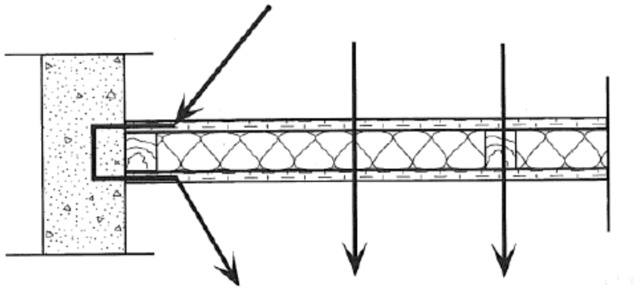
Outline



LUND UNIVERSITY

Introduction

- Double-leaf wall literature → rather extensive
  - Theoretical analysis, less developed due to complexity

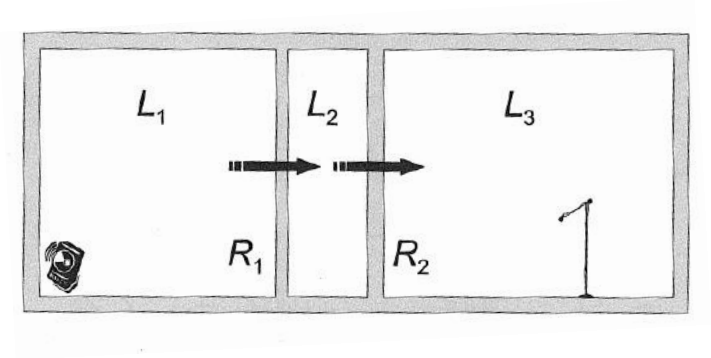


  - Analyses often carried out using FEM, SEA.

- Several theoretical derivations of sound transmission
  - Double-leaf wall without mechanical coupling
  - Double walls with structural connections
  - …

LUND UNIVERSITY

Sound reduction index of double-leaf walls



$$R_1 = L_1 - L_2 + 10\log\left(\frac{S}{A_2}\right)$$
$$R_2 = L_2 - L_3 + 10\log\left(\frac{S}{A_3}\right)$$
$$\Rightarrow R_{DoubleWall} = L_1 - L_3 + 10\log\left(\frac{S}{A_3}\right) \Rightarrow$$

$$\Rightarrow R_{DoubleWall} = R_1 + R_2 + 10\log\left(\frac{A_2}{S}\right)$$

- Approximate empirical model for a double leaf wall without structural connections, with cavity filled with porous absorber (Sharp 1978)

$$R = \begin{cases} R_M & ; f < f_0 \\ R_1 + R_2 + 20\log(f \cdot d) - 29dB & ; f_0 < f < f_d \\ R_1 + R_2 + 6dB & ; f > f_d \end{cases}$$

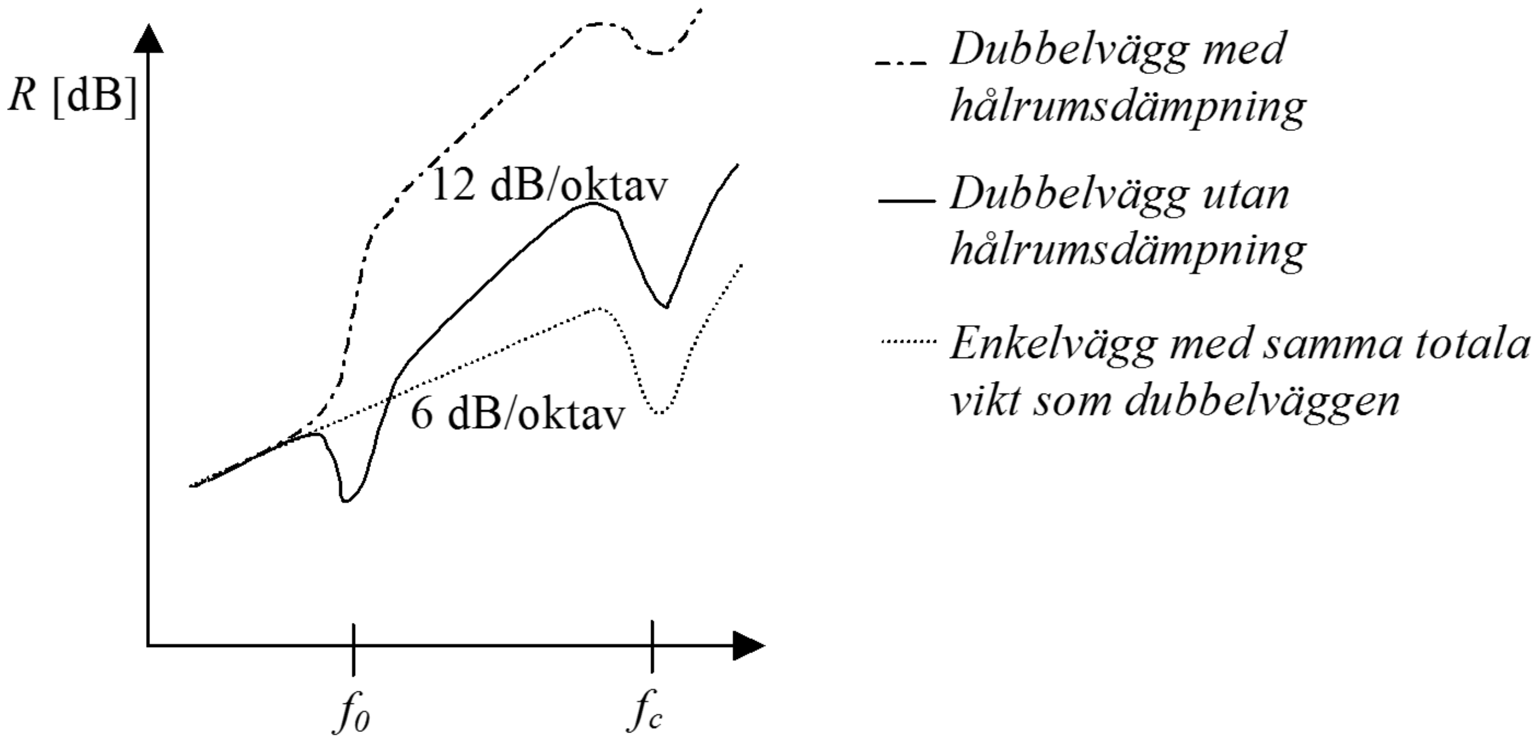
$$f_0 = \frac{c}{2\pi}\sqrt{\frac{\rho_F}{d}\left(\frac{1}{m_1''} + \frac{1}{m_2''}\right)}$$

$$f_d = \frac{55}{d}$$

R_M denotes the mass law with $M=m_1+m_2$
R_1 and R_2 denote the individual sound reduction index for each leaf
d: distance between the two leaves i.e. (cavity thickness)
NOTE: Diffuse field assumed in both rooms

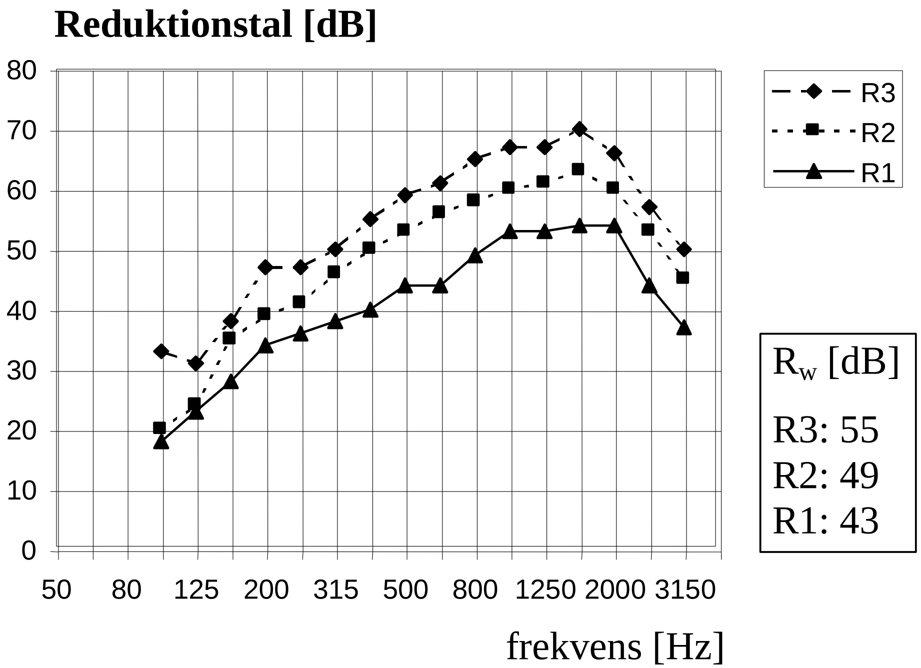
Examples (I)

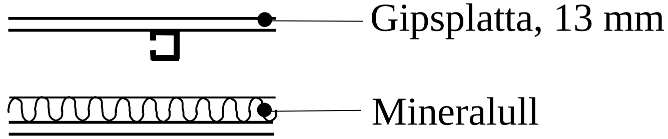
- Improvement in the sound reduction index of a double-leaf wall respect to a single wall, and also when including insulation in the cavity.



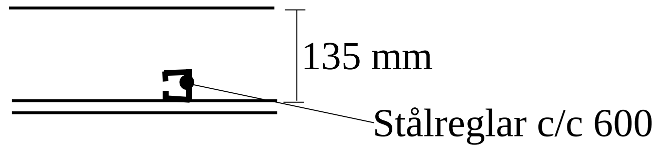
Examples (II)

- Variation in the sound reduction index of a double-leaf wall when varying parameters in the cavity (inclusion of insulation and its thickness).





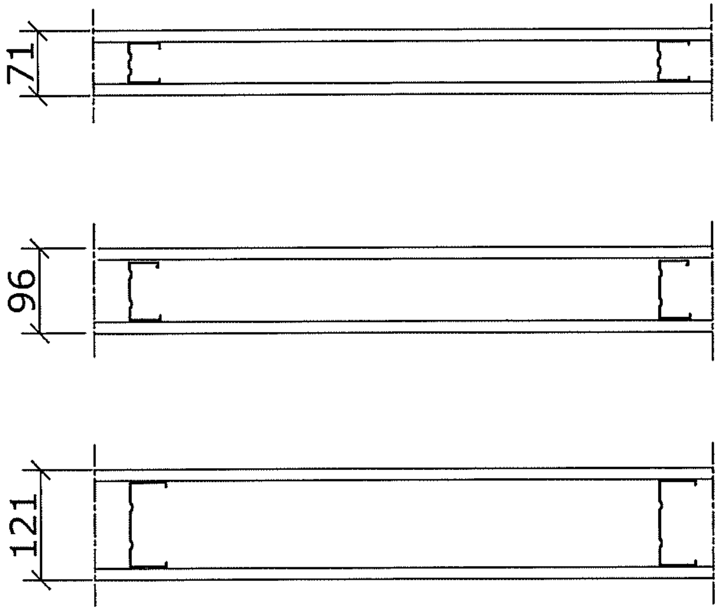
R3 = 140 mm mineralull
R2 = 30 mm mineralull



R1= tomt hålrum

LUND UNIVERSITY

Examples (III)

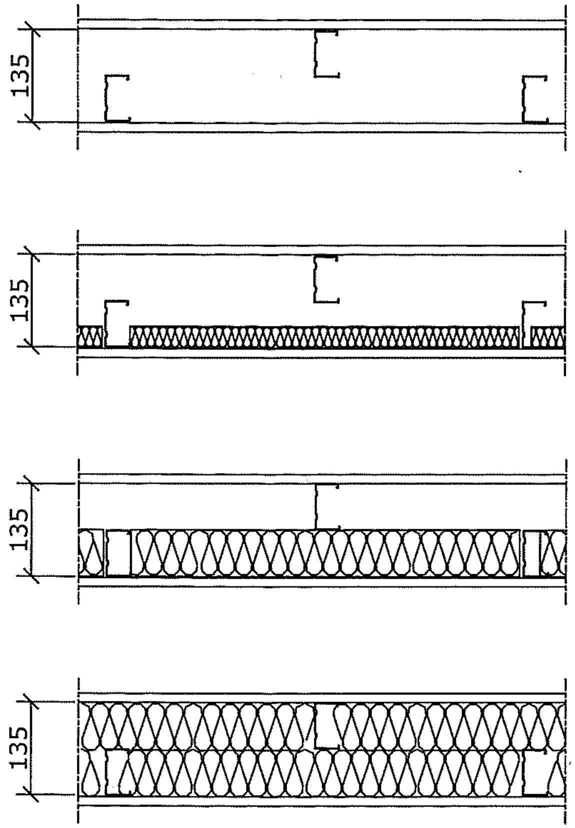


	$R_{w\ lab}$
13 mm gips 45 mm regel 13 mm gips	33 dB
13 mm gips 70 mm regel 13 mm gips	36 dB
13 mm gips 95 mm regel 13 mm gips	37 dB

Figur 4:24. Exempel på inverkan på det vägda reduktionstalet av avståndet mellan dubbelväggarna. Laboratoriemätresultat.

LUND UNIVERSITY

Examples (IV)

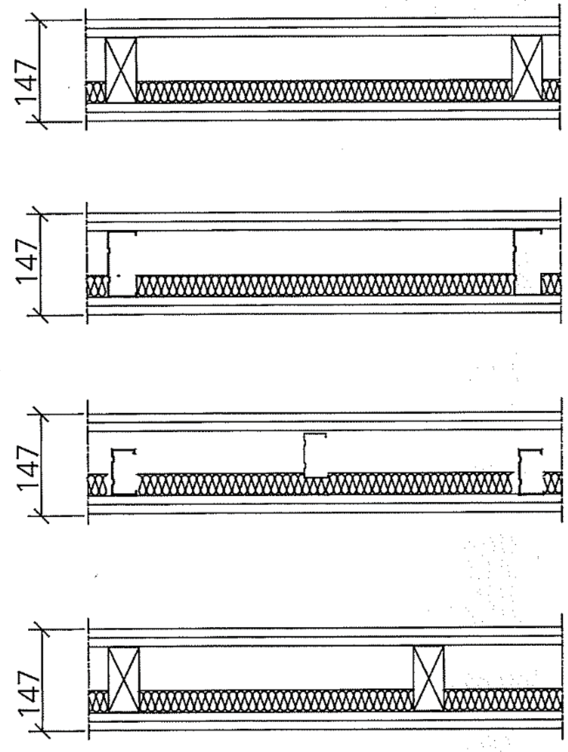


Construction	R_w dB
13 mm gips utan absorbent Stålreglar c 600 mm 13 mm gips	41
13 mm gips 30 mm mineralull Stålreglar c 600 mm 13 mm gips	49
13 mm gips 70 mm mineralull Stålreglar c 600 mm 13 mm gips	50
13 mm gips 2x70 mm mineralull Stålreglar c 600 mm 13 mm gips	54

Figur 4:25. Exempel på inverkan på det vägda reduktionstalet av absorbent i spalten på dubbelvägg med separata reglar. Laboratoriemätresultat.

LUND UNIVERSITY

Examples (V)



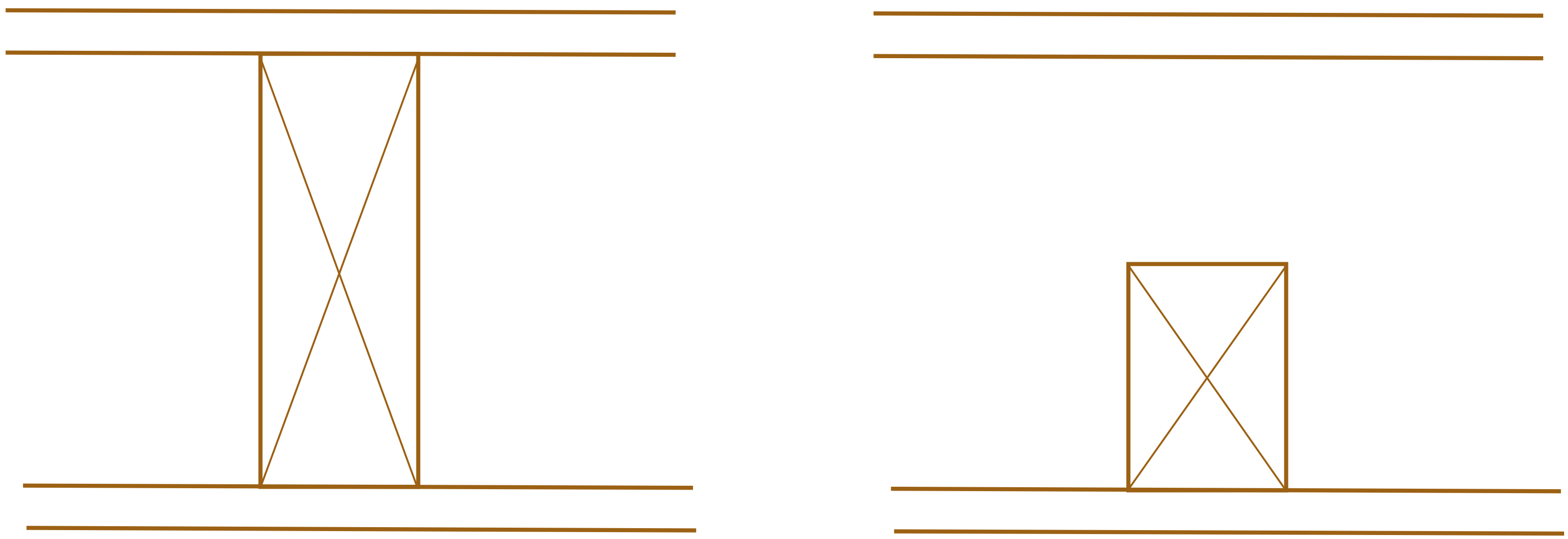
Construction	$R_{w\,lab}$
2x13 mm gips 95 mm träregel, c 600 30 mm mineralull 2x13 mm gips	48
2x13 mm gips 95 mm stålregel, c 600 30 mm mineralull 2x13 mm gips	52
2x13 mm gips 70 mm skilda stålreglar, c 600 30 mm mineralull 2x13 mm gips	55
2x13 mm gips 95 mm träregel, c 450 30 mm mineralull 2x13 mm gips	42

Figur 4:26. Exempel på inverkan på det vägda reduktionstalet av olika förbindningar, reglar, i en dubbelvägg. Laboratoriemätresultat.

LUND UNIVERSITY

Examples (VI)

"Rule of thumb": decoupled structures perform much better
→ acoustic bridges eliminated



Outline

Introduction

Airborne Sound Insulation

Impact Sound Insulation

ISO methods

Analytical models for calculation of R_w in single and double-leaf walls

Conclusions

LUND UNIVERSITY

Conclusions

- ISO procedures (acoustic insulation)
  - Airborne sound insulation
  - Impact sound insulation
- Analytical calculation methods of reduction sound index
  - Single-leaf wall
    - » Exact method
    - » Approximate method
  - Double-leaf wall

NOTE: Check out the acoustic glossary

Thank you for your attention!

juan.negreira@construction.lth.se

LUND UNIVERSITY