POLITECNICO DI MILANO

Application: Airborne Acoustic Isolation

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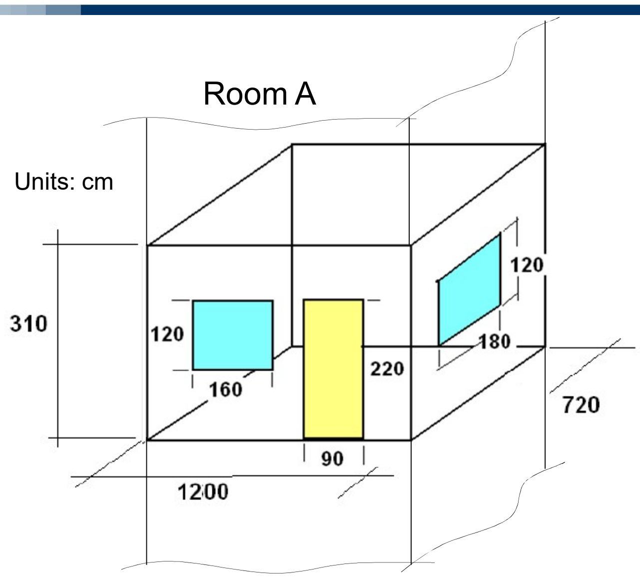
Acoustic Airborne Isolation : text

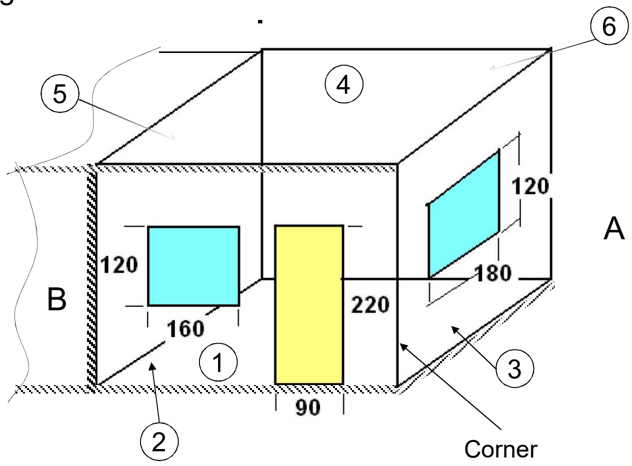
1. Calculate the sound reduction index of each components
2. Verify the passive acoustic requirements of buildings
   1. Calculate the apparent sound reduction index between rooms A and B from the transmission loss of each components
   2. Calculate the weighted standardized level difference of the façade for room A

Geometric characteristics



2. Transmission loss (sound reduction index) of each components

Calculate the sound reduction index of each components finalized to airborne noise between rooms A and B and façade weighted standardized level difference room A

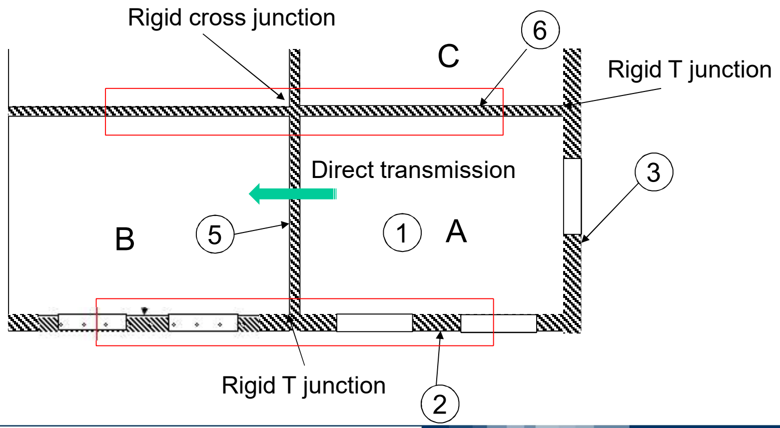


Top section

Plan from the top

Flanking transmission elements

1 - floor
3 – façade
5 – internal wall
6 – internal wall

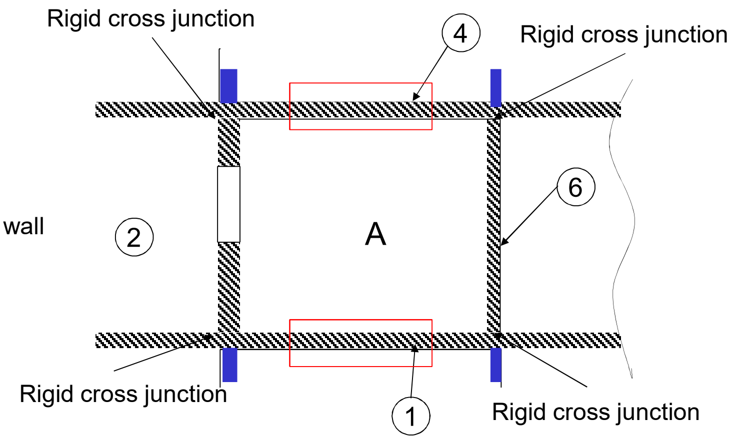


Side section

Side section

Flanking transmission elements

1 - floor
2 – façade
4 – ceiling
6 – internal wall



Composite Transmission Loss

The transmission loss of a partition consisting of **separated components** arranged in parallel is defined as:

$$R_m = 10 \cdot \log_{10}\left(\frac{1}{\tau_m}\right) = 10 \cdot \log_{10}\left(\frac{\sum_{i=1}^{N} S_i}{\sum_{i=1}^{N} S_i\,\tau_i}\right) = 10 \cdot \log_{10}\left(\frac{\sum_{i=1}^{N} S_i}{\sum_{i=1}^{N} S_i\,10^{\frac{-R_i}{10}}}\right)$$

where

S_i is the area of the surface of the i-th component

τ_i is the coefficient of transmission the i-th component arranged **in parallel**

R_i is the simple transmission loss of the i-th component arranged **in parallel**

Transmission loss of walls

Design the Facade Walls

R'w=?

100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150

Design the windows

R'w=?

100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150

Sound Reduction Index/ Single Wall / Brick(UNIVERSITA FERRARA):

$R_w = 18{,}1 \log_{10}(m') + 2{,}9$ **[experimental relation 2]**

Walls made of solid or hollow brick, plastered.

Requirement: mass per unit area: $80 \leq m' \leq 500$ kg/m^2

- Areic mass: ?

Floor/ceiling transmission loss

- Choose an other material from the table

Construction	Mass kg/m²	Sound reduction index (dB) in octave bands (Hz)							R_w (C; C_{tr})
		63	125	250	500	1 k	2 k	4 k	
120 mm concrete	276	35	34	36	46	54	62	69	49 (-2; -6)
260 mm concrete	598	43	42	51	59	67	74	75	61 (-1; -7)
110 mm Ca-Si blocks	193	34	34	33	39	49	58	65	44 (-1; -4)
240 mm Ca-Si blocks	420	38	38	46	54	62	68	68	56 (-1; -6)
120 mm lightweight conc.	156	33	36	34	35	44	53	56	42 (-1; -3)
300 mm lightweight conc.	390	37	37	42	51	58	58	58	54 (-2; -6)
100 mm autocl.aer. conc.	65	26	30	31	27	32	41	45	32 (0; -1)
200 mm autocl.aer. conc.	130	30	30	29	34	43	46	46	39 (-1; -3)

Door transmission loss

To estimate the sound insulation of the door (multi-layer: steel frame with steel- 5 cm rock wool – steel composite panel), proceed as follows

- calculate the transmission loss at normal incidence of the steel plate as:

$$R_n = 20 \cdot \log_{10}\left(m^* \cdot f\right) - 42{,}5 \quad [\mathrm{dB}]$$

- calculate the transmission loss at diffuse incidence of the steel plate as:

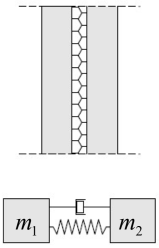
$$R_d = R_n - 10 \cdot \log_{10}\left(0{,}23 \cdot R_n\right) \quad [\mathrm{dB}]$$

- calculate the door total transmission loss (in series) with the formula in the next slide for a system consisting wall-absorbing material-wall

	DOOR	
	Steel	
ρ	0.002	m
th	7 500	kg/m³
m'	15	kg/m²
	Rock wool	
ρ	0.05	m
th	70	kg/m³
m'	3.5	kg/m²

Double-wall with the space filled with absorbing material

Estimation of sound insulation for double wall with an absorbent material inside the cavity (case b), when R_1 e R_2 are separately CALCOLATED for diffuse incidence :



b)

$$R \cong 20\log_{10}\left[(m_1 + m_2)\cdot f\right] - 47 \qquad f < \frac{2}{3} f_0$$

$$R \cong 10 \qquad 2 f_0/3 \le f \le f_0$$

$$R \cong R_1 + R_2 + 20\log_{10}(d \cdot f) - 29 \qquad f_0 < f < f_1$$

$$R \cong R_1 + R_2 + 6 \qquad f > f_1$$

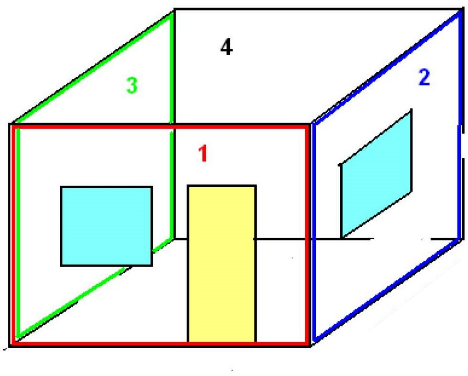
$$f_0 = 60 \cdot \sqrt{\frac{1}{d}\left(\frac{1}{m_1} + \frac{1}{m_2}\right)} \qquad f_1 = \frac{c}{2\,d} = \frac{343}{2\,d}$$

where
d = cavity thickness [m]

Warnock ACC, Fasold W. Sound insulation: airborne and impact. Encyclopedia of acoustics, New York: Wiley-Interscience, 1997. Vol. 3: pp. 1129-61.

Terms of adaptation and weighted sound reduction indexs

- Calculate the terms of adaptation C and C_{tr} for each for each wall



- Calculate the weighted sound reduction index for all components

Airborne Sound Insulation Indices – ISO 717
X_w a 500 Hz

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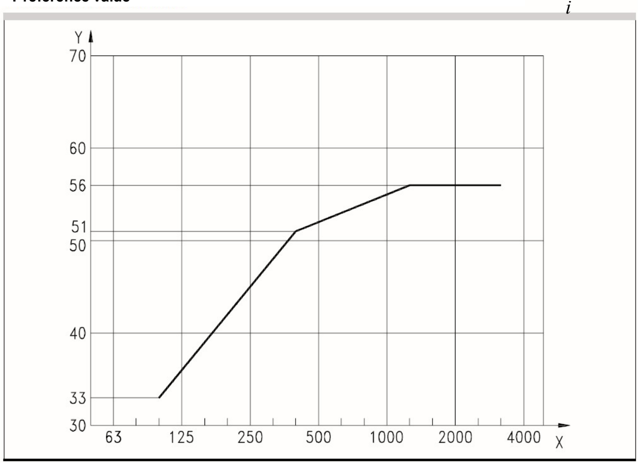
Curve of reference values for airborne sound, one-third-octave bands
Key
X frequency in Hz
Y reference value



va

$$\Delta Y = \sum_i \max\left[0; Y_{ref} - Y_{meas}\right]_i < 32$$

sum of unfavourable deviations is as large as possible, but not more than 32,0 dB, measurement in one-third-octave bands

The same procedure applies to all of the characteristic Airborne Sound Insulation Indices

Airborne Sound Insulation Indices – ISO 717
X_w at 500 Hz: spectra adaptation terms

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Spectra adaptation terms, C_j, in decibel, shall be calculated with the specific sound spectra *j* from the following equation:

$$C_j = X_{Aj} - X_w$$

where:

j is the subscript for the sound spectra N° 1 e 2;

X_w is the Insulation Index calculated from R, D_n or D_{nT} values;

X_{Aj}

$$X_{Aj} = -10 \cdot \log_{10} \sum_i 10^{\frac{L_{ij} - X_i}{10}} \quad [dB]$$

where:

- *i* is the subscript for the one-third-octave bands 100 Hz to 3150 Hz or the octave bands 125 Hz to 2000 Hz;
- L_{ij} are the levels of the sound level spectra to calculate the adaptation terms at the frequency i for the spectrum j;
- X_i is the transmission loss R_i, or apparent transmission loss, or the normalized level difference $D_{n,i}$, or standardized level difference $D_{nT,i}$, at the measuring frequency i, given to one decimal place.

Calculate the quantity, X_{Aj}, with sufficient accuracy and round the result to an integer.2) The resulting spectrum adaptation term is an integer by definition and shall be identified in accordance with the spectrum used, as follows:

C when calculated with spectrum No. 1 (A-weighted pink noise);

C_{tr} when calculated with spectrum No. 2 (A-weighted urban traffic noise).

Sound level spectra to calculate the adaptation terms

Sound level spectra to calculate the spectrum adaptation terms for one-third octave band values

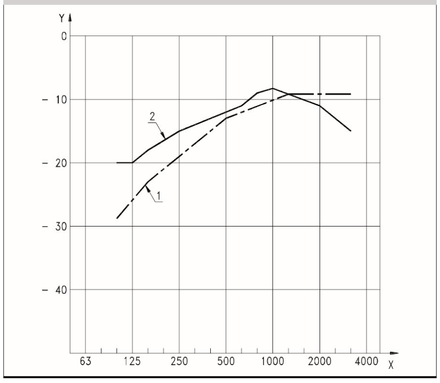
Key

1 spectrum No. 1 to calculate C

2 spectrum No. 2 to calculate C_{tr}

X Frequency in HZ

Y L_{ij} in dB



Sound level spectra to calculate the spectrum adaptation terms for octave band values

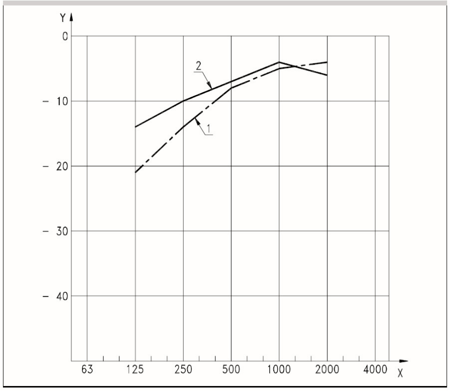
Key

1 spectrum No. 1 to calculate C

2 spectrum No. 2 to calculate C_{tr}

X Frequency in HZ

Y L_{ij} in dB



Frequency reference values and sound spectra in one-third-octave bands and octave bands reference values to calculate the spectrum adaptation terms C e C_{tr}.

Frequency	Reference Values[dB]	
Hz	one-third-octave band	octave band
100	33	
125	36	36
160	39	
200	42	
250	45	45
315	48	
400	51	
500	52	52
630	53	
800	54	
1 000	55	55
1 250	56	
1 600	56	
2 000	56	56
2 500	56	
3 150	56	

Frequency	Sound Level, L_{ij}, [dB]			
	spectrum N° 1 to calculate C		spectrum N° 2 to calculate C_{tr}	
Hz	one-third-octave band	octave band	one-third-octave band	octave band
100	-29		-20	
125	-26	-21	-20	-14
160	-23		-18	
200	-21		-16	
250	-19	-14	-15	-10
315	-17		-14	
400	-15		-13	
500	-13	-8	-12	-7
630	-12		-11	
800	-11		-9	
1 000	-10	-5	-8	-4
1 250	-9		-9	
1 600	-9		-10	
2 000	-9	-4	-11	-6
2 500	-9		-13	
3 150	-9		-15	

Relevant spectrum adaptation term

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Table A.1 — Relevant spectrum adaptation term for different types of noise source

Type of noise source	Relevant spectrum adaptation term
Living activities (talking, music, radio, TV) Children playing Railway traffic at medium and high speed[a] Highway road traffic at >80 km/h[a] Jet aircraft, short distance Factories emitting mainly medium- and high-frequency noise	C (spectrum No. 1)
Urban road traffic Railway traffic at low speeds[a] Aircraft, propeller driven Jet aircraft, large distance Disco music Factories emitting mainly low and medium frequency noise	C_{tr} (spectrum No. 2)
[a] In several European countries, calculation models for highway road traffic noise and railway noise exist, which define octave band levels; these could be used for comparison with spectra Nos. 1 and 2.	

3. Verify the passive acoustic requirements of buildings

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The required indices are:

- R'_w : **Weighted Apparent Sound Reduction Index**, which is:
  - R′(500 Hz) apparent transmission loss that is obtained at 500 Hz from the reference curve after repositioning to respect the unfavourable deviations limitation
- $D_{2m,n,T,w}$ **Facade Weighted Standardized Level Difference Index**, which is :
  - $D_{2m,n,T}$(500 Hz) Facade Weighted Standardized Level Difference that is obtained at 500 Hz from the reference curve after repositioning to respect the unfavourable deviations limitation

R'_w - Airborne sound insulation between rooms

Calculation sequence:

- determine the weighted sound reduction index of the elements: $R_{s,w}$. $R_{F,w}$. $R_{f,w}$;
- determine the vibration reduction index for each junction and path: K_{Ff}; K_{Fd}; K_{Df};
- determine the total weighted sound reduction index improvement for the separating element: $\Delta R_{Dd,w}$;
- determine the total weighted sound reduction index improvement for each flanking path: $\Delta R_{Ff,w}$; $\Delta R_{Fd,w}$; $\Delta R_{Df,w}$;
- calculate $R_{Dd,w}$ the weighted sound reduction index for direct transmission as:

$$R_{Dd,w} = R_{s,w} + \Delta R_{Dd,w}$$

R'_w - Airborne sound insulation between rooms

- calculate $R_{Ff,w}$ with

$$R_{Ff,w} = \frac{R_{F,w} + R_{f,w}}{2} + \Delta R_{Ff,w} + K_{Ff} + 10\log_{10}\left(\frac{S_s}{I_0 I_f}\right)$$

- calculate $R_{Df,w}$ with

$$R_{Df,w} = \frac{R_{s,w} + R_{f,w}}{2} + \Delta R_{Df,w} + K_{Df} + 10\log_{10}\left(\frac{S_s}{I_0 I_f}\right)$$

- calculate $R_{Fd,w}$ with

$$R_{Fd,w} = \frac{R_{F,w} + R_{s,w}}{2} + \Delta R_{Fd,w} + K_{Fd} + 10\log_{10}\left(\frac{S_s}{I_0 I_f}\right)$$

- calculate R'_w with

$$R'_w = -10 \cdot \log_{10}\left[10^{\frac{-R_{Dd,w}}{10}} + \sum_{F=f=1}^{N} 10^{\frac{-R_{Ff,w}}{10}} + \sum_{f=1}^{N} 10^{\frac{-R_{Df,w}}{10}} + \sum_{F=1}^{N} 10^{\frac{-R_{Fd,w}}{10}}\right]$$

Weighted Standardized level difference of a façade $D_{2m,nT,w}$

Calculation sequence:

- determine the weighted sound reduction index of each façade elements: $R_{w,i}$;
- determine the weighted small element normalized level difference for each i-elements: $D_{ne,w,i}$;
- calculate R'_{w} the weighted sound reduction index for the façade as:

$$R'_{w} = -10\log_{10}\left[\sum_{i=1}^{N}\frac{S_i}{S}10^{\frac{-R_{W,i}}{10}} + \sum_{i=1}^{N}\frac{A_0}{S}10^{\frac{-D_{ne,w,i}}{10}}\right] - K$$

- determine the weighted level difference due to facade shape, $\Delta L_{fs,w}$

Weighted Standardized level difference of a façade $D_{2m,nT,w}$

- calculate the Weighted Standardized level difference of a facade as:

$$D_{2m,nT,w} = R'_{w} + \Delta L_{fs,w} + 10\log_{10}\left[\frac{V}{6T_0 S}\right]$$