recording

Rumsakustik

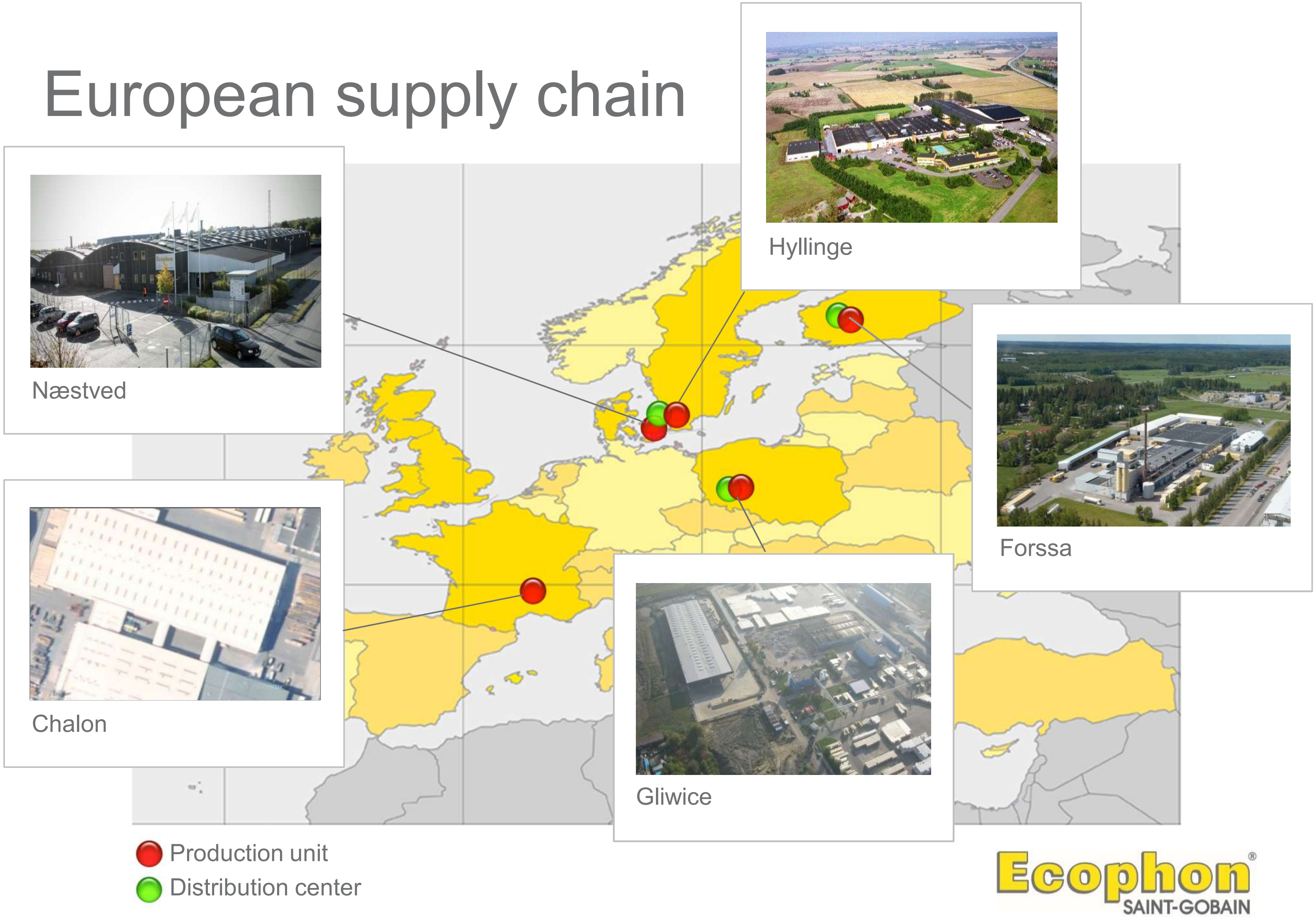
Erling Nilsson, Akustiker
ECOPHON Saint-Gobain

Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Community school no 15, Gdynia, Poland. Architect: Adam Drochomiercki. Photo: Szymon Polanski.
System: Ecophon Master A/alpha

Ecophon

European supply chain



Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Saint-Gobain

- One of the world’s 100 leading industry groups
- Focusing on habitat and construction
- Established in 1665
- Present in 64 countries
- 190 000 employees
- ~ €40 billion in sales

Spegelsalen i Versailles

Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Four market segments

Education

Modern Office

Healthcare

Clean Industry

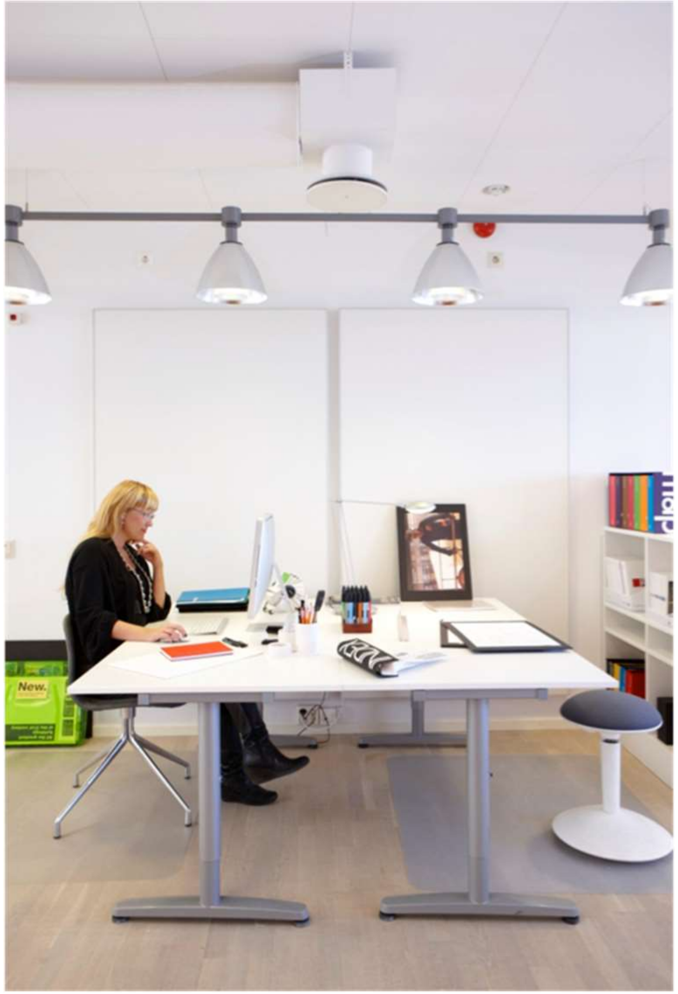
- Long experience of how sound affects people
- Specialised knowledge about segment specific activities
- Systems developed for specific needs

Ecophon® SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

Benefits of good acoustics

- Increased wellbeing and satisfaction
- Less tiredness
- Easier to concentrate
- Fewer errors
- Less stress hormones
- Easier to communicate
- More positive energy
- Increased creativity



Innehåll

- Något om Ecophon
- Rumsakustik i praktiken
- Betydelsen av god akustik
- Rumsakustik och ljudabsorption

Fö 2020-05-13, 13-15
Öv 2020-05-14, 10-12

- "Activity based acoustic design"
- Rumsakustiska mått
- Effekt av akustikreglering i klassrum
- Öppna kontorslandskap
- Beräkning av rumsakustiska mått

Fö 2020-05-18, 10-12
Öv 2020-05-18, 13-15

Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Room Acoustic design in practise



Schools:

Positive effects of a good sound environment in educational premises include:

- Reduced vocal strain and voice disorders for teachers
- Improved concentration
- Reduced tiredness, fatigue and stress levels
- Easier to hear and be heard with improved speech clarity
- Optimised environment for multi-communicational activities such as group work
- Improved student behaviour and reduced burden on school and classroom management

Ecophon® SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

Healthcare:

Better sound environment contributes to:

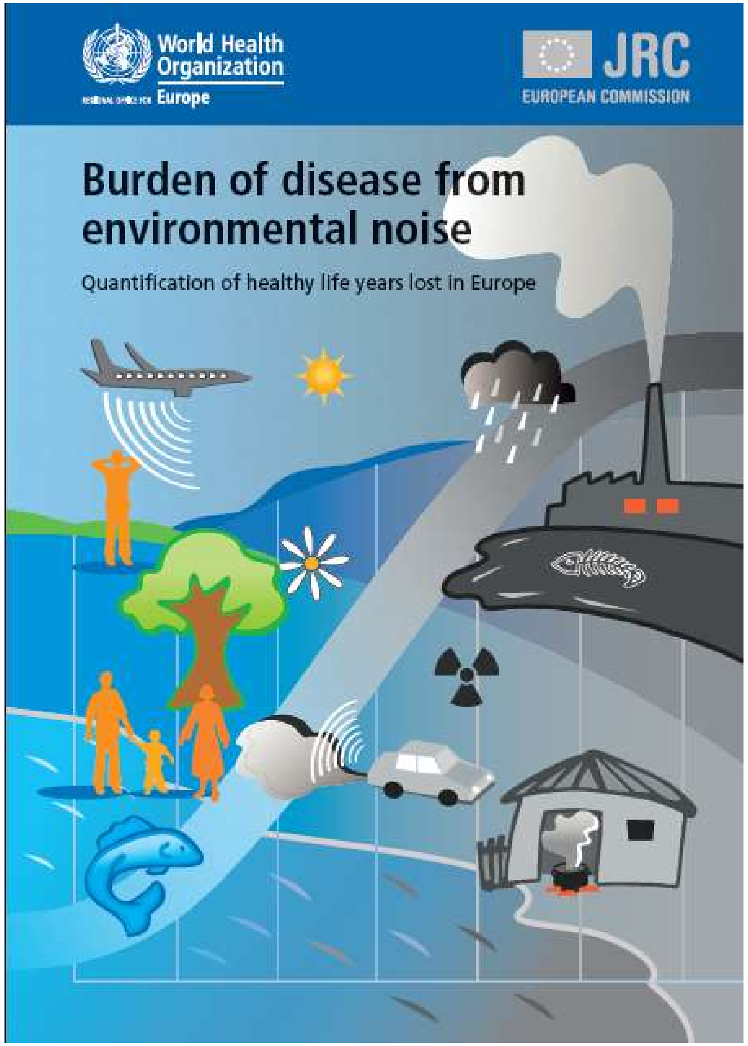
- Lowering of blood pressure
- Improving quality of sleep
- Reducing intake of pain medication
- Reducing the number of re-admissions
- Improving the wellbeing of staff and increasing perceived performance

Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Open-plan offices:

- In a modern flexible OPO, the creation of a functional work station is a complex process in which acoustic planning is only one part of a series of considerations having to be addressed. The open-plan office should support both communication and concentrated work. Thus, for an OPO to be an efficient and comfortable place of work there are several other requirements than acoustic treatment that have to be fulfilled.

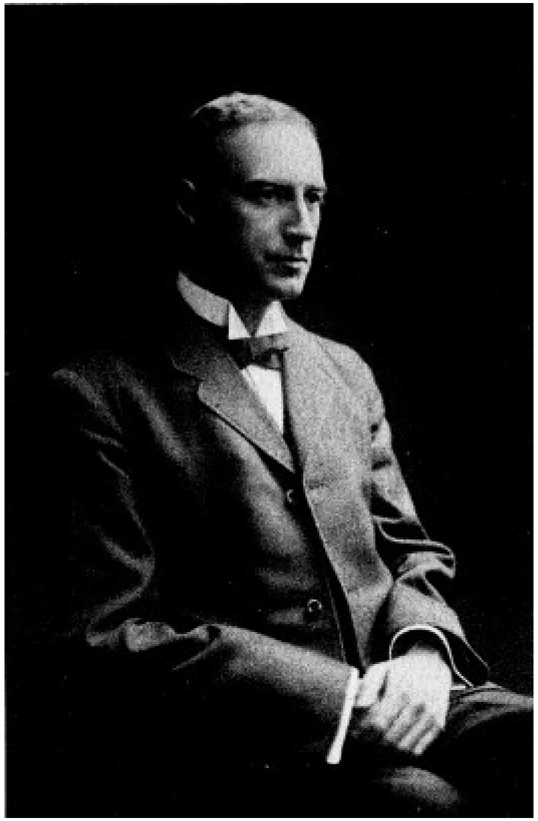
WHO report



Public health experts agree that environmental risks constitute 24% of the burden of disease. Widespread exposure to environmental noise from road, rail, airports and industrial sites contributes to this burden. One in three individuals is annoyed during the daytime and one in five has disturbed sleep at night because of traffic noise. Epidemiological evidence indicates that those chronically exposed to high levels of environmental noise have an increased risk of cardiovascular diseases such as myocardial infarction. Thus, noise pollution is considered not only an environmental nuisance but also a threat to public health.

Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

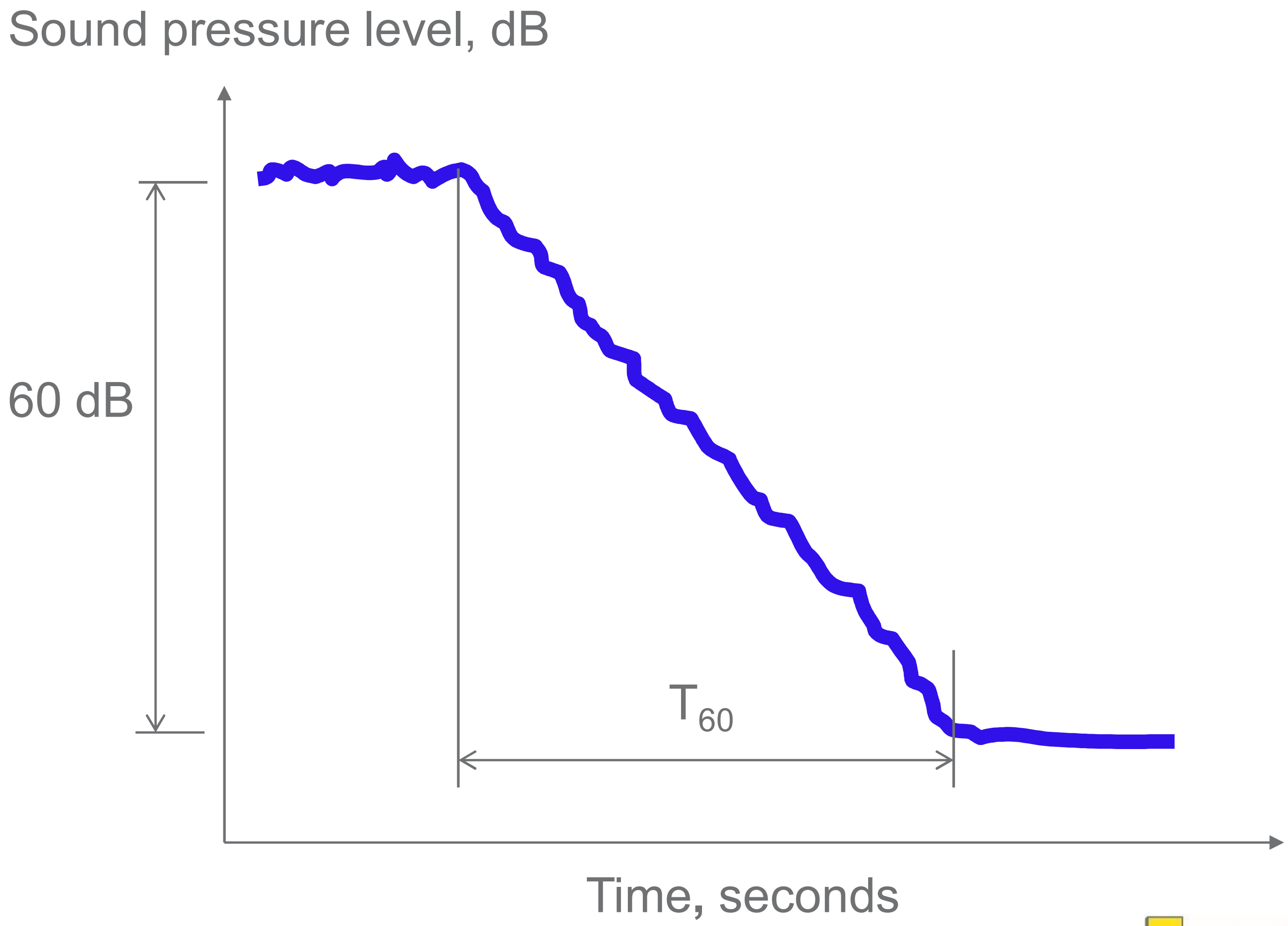
Architectural acoustics



Wallace Clement Sabine
(June 13, 1868 – January 10, 1919)

American physicist who founded the field of architectural acoustics

Definition: Reverberation time



His formula

$$T = 0.16\left(\frac{V}{A}\right) \quad \text{or} \quad A = 0.16\left(\frac{V}{T}\right)$$

where

T=the reverberation time (s)
V=the room volume (m^3)
A=the total equivalent absorption area (m^2 sabin)

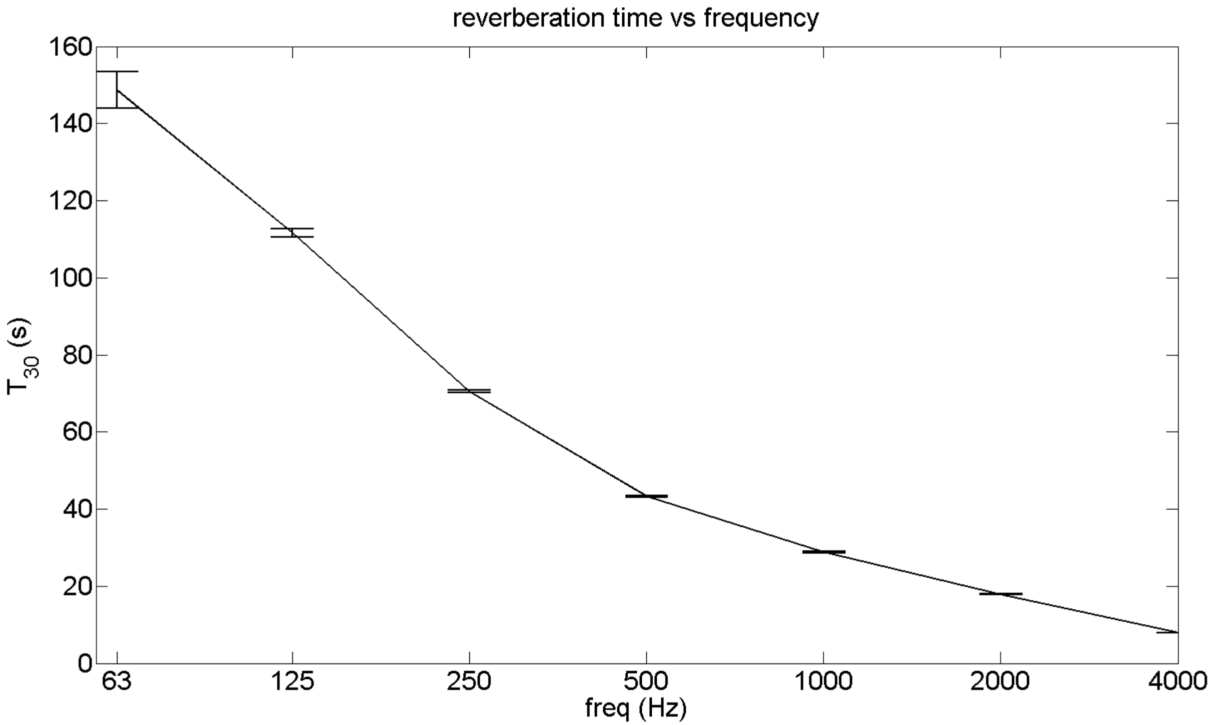
The equivalent absorption area A for a surface with area S m^2 is equal to α x S where α is the absorption coefficient for the surface

The oil-storage complex at Inchindown, near Invergordon in Scotland, was built during the Second World War

The broadband reverberation time, which considers all frequencies simultaneously, was 75 seconds – the figure certified as a world record by Guinness.

https://soundcloud.com/tags/sonic%20wonderland

The oil-storage complex at Inchindown



Ecophon SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

Standards and regulations

Ecophon® SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

Acoustic design with Sabine formula

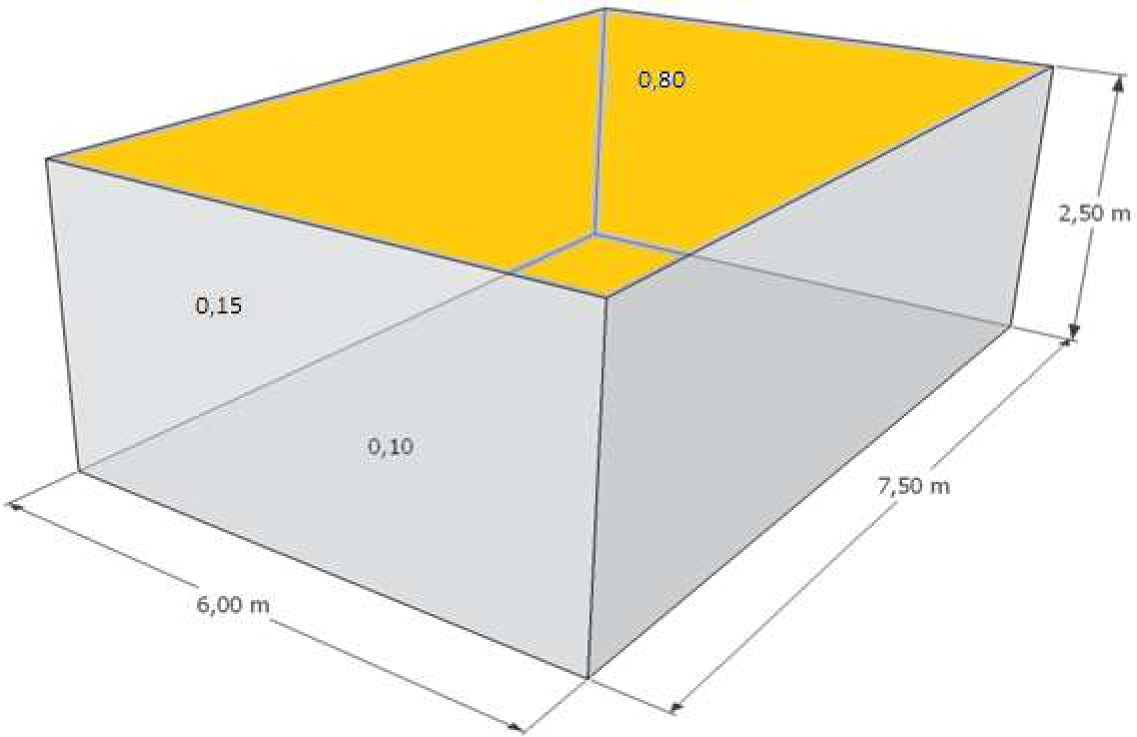
Example: The reverberation time in a room with a volume of 200 m^3 is 2,5 s at 1000 Hz.
Target value for the reverberation time is 0,40 s at 1000 Hz

- A(before treatment)=0,161xV/T= 0,161x200/2,5=12,9 m^2 sabin
- A(needed to fulfil 0,40 s)= 0,161xV/T=0,161x200/0,40=80,5 m^2 sabin
- A(to be added to fulfil 0,40 s)=A(needed)-A(before)=80,5-12,9=67,6 m^2 sabin

If e.g. the absorption coefficient for a ceiling absorber is 0,90 at 1000 Hz we will need S= A/α=67,6/0,90=75 m^2

Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Sabine formula: How it works in theory



Absorption coefficients (500 Hz):

Walls=0,15
Ceiling=0,80
Floor=0,10

Absorption data from EN 12354-6

Table B.1 — Typical values for the absorption coefficient

Material	**Sound absorption coefficient α_s in octave bands, centre frequency in Hz**					
	125	250	500	1 000	2 000	4 000
concrete, plastered brick	0,01	0,01	0,01	0,02	0,02	0,03
brickwork, unplastered	0,02	0,02	0,03	0,04	0,05	0,07
hard floor coverings (e.g. PVC, parquet) on heavy floor	0,02	0,03	0,04	0,05	0,05	0,06
soft floor covering on heavy floor; ≤ 5 mm	0,02	0,03	0,06	0,15	0,30	0,40
soft floor covering on heavy floor; ≥ 10 mm	0,04	0,08	0,15	0,30	0,45	0,55
wooden floor, parquet on battens	0,12	0,10	0,06	0,05	0,05	0,06
windows, glass facade	0,12	0,08	0,05	0,04	0,03	0,02
doors (wood)	0,14	0,10	0,08	0,08	0,08	0,08
net curtain; 0 mm - 200 mm in front of hard surface[1]	0,05	0,04	0,03	0,02	0,02	0,02
curtain, < 0,2 kg/m^2; 0 mm – 200 mm in front of hard surface; typical minimum [1]	0,05	0,06	0,09	0,12	0,18	0,22
curtain, woven material ≈ 0,4 kg/m^2; folded or ruffled > 1:3, 0-200 mm in front of hard surface; typical maximum	0,10	0,40	0,70	0,90	0,95	1,00
large openings (smallest dimension > 1 m)	1,00	1,00	1,00	1,00	1,00	1,00
air grid, 50 % open area	0,30	0,50	0,50	0,50	0,50	0,50
NOTE These data are based on publications used in Austria, Denmark and the Netherlands.						
[1] in front of a window the values of the combination can increase to the values for such a window alone.						

Ecophon SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

Absorption data from EN 12354-6

Table C.1 — Typical values for the equivalent absorption area for some common objects

Object	Equivalent absorption area A_{obj} in octave bands, centre frequency in Hz					
	125	250	500	1 000	2 000	4 000
single chair, wood	0,02	0,02	0,03	0,04	0,04	0,04
single chair, upholstered	0,10	0,20	0,25	0,30	0,35	0,35
single person in a group, sitting or standing, 1 per 6 m^2 area; typical minimum	0,05	0,10	0,20	0,35	0,50	0,65
single person in a group, sitting, 1 per 6 m^2 area; typical maximum	0,12	0,45	0,80	0,90	0,95	1,00
single person in a group, standing, 1 per 6 m^2 area; typical maximum	0,12	0,45	0,80	1,20	1,30	1,40

NOTE These data are based on publications used in Austria, Denmark and the Netherlands.

Table C.2 — Typical vales for the sound absorption coefficient for some common specified arrays of objects

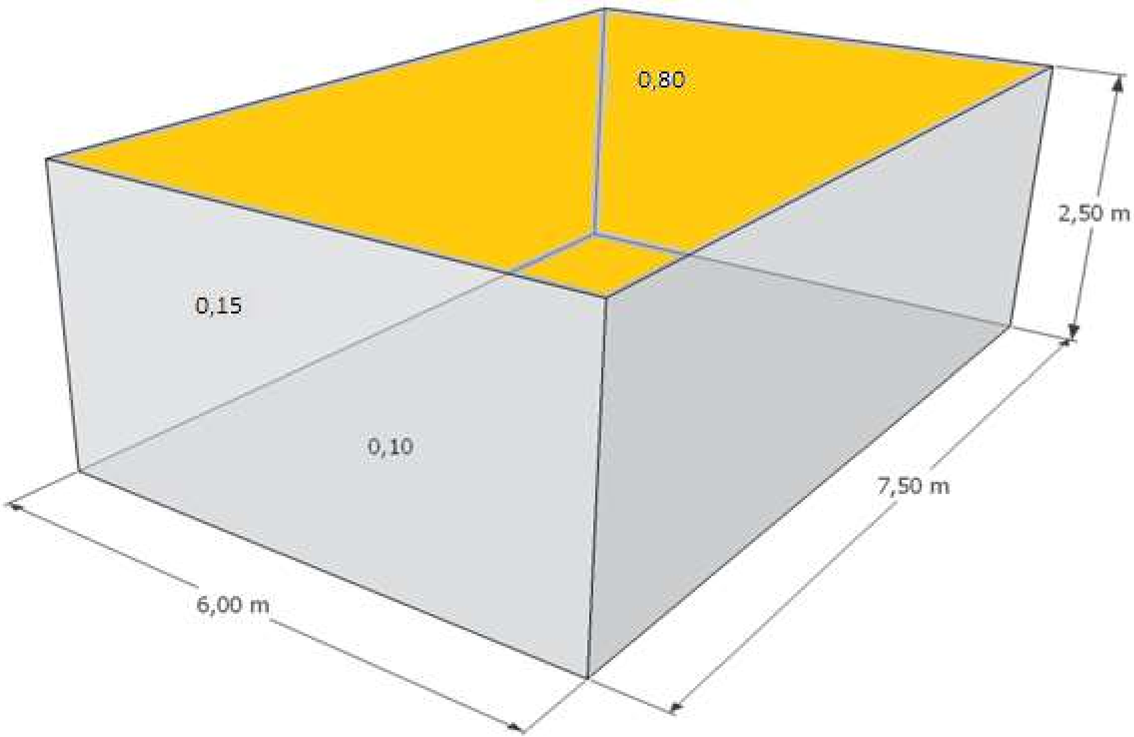
Array of objects	Sound absorption coefficient α_s in octave bands, centre frequency in Hz					
	125	250	500	1 000	2 000	4 000
chairs in a row at 0,9m – 1,2m; wood/plastic	0,06	0,08	0,10	0,12	0,14	0,16
chairs in a row at 0,9m – 1,2m; upholstered; typical minimum	0,10	0,20	0,30	0,40	0,50	0,50
chairs in a row at 0,9m – 1,2m; upholstered; typical maximum	0,50	0,70	0,80	0,90	1,0	1,0
persons sitting in a row at 0,9m – 1,2m (audience); typical minimum	0,20	0,40	0,50	0,60	0,70	0,70
persons sitting in a row at 0,9m – 1,2m (audience); typical maximum	0,60	0,70	0,80	0,90	0,90	0,90
children in a hard furnished class room, 1 per m^2 area	0,10	0,20	0,25	0,35	0,40	0,40

NOTE These data are based on publications used in Austria, Denmark and the Netherlands.

Ecophon® SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

Sabine formula: How it works in theory



Absorption coefficients (500 Hz):

Walls=0,15
Ceiling=0,80
Floor=0,10

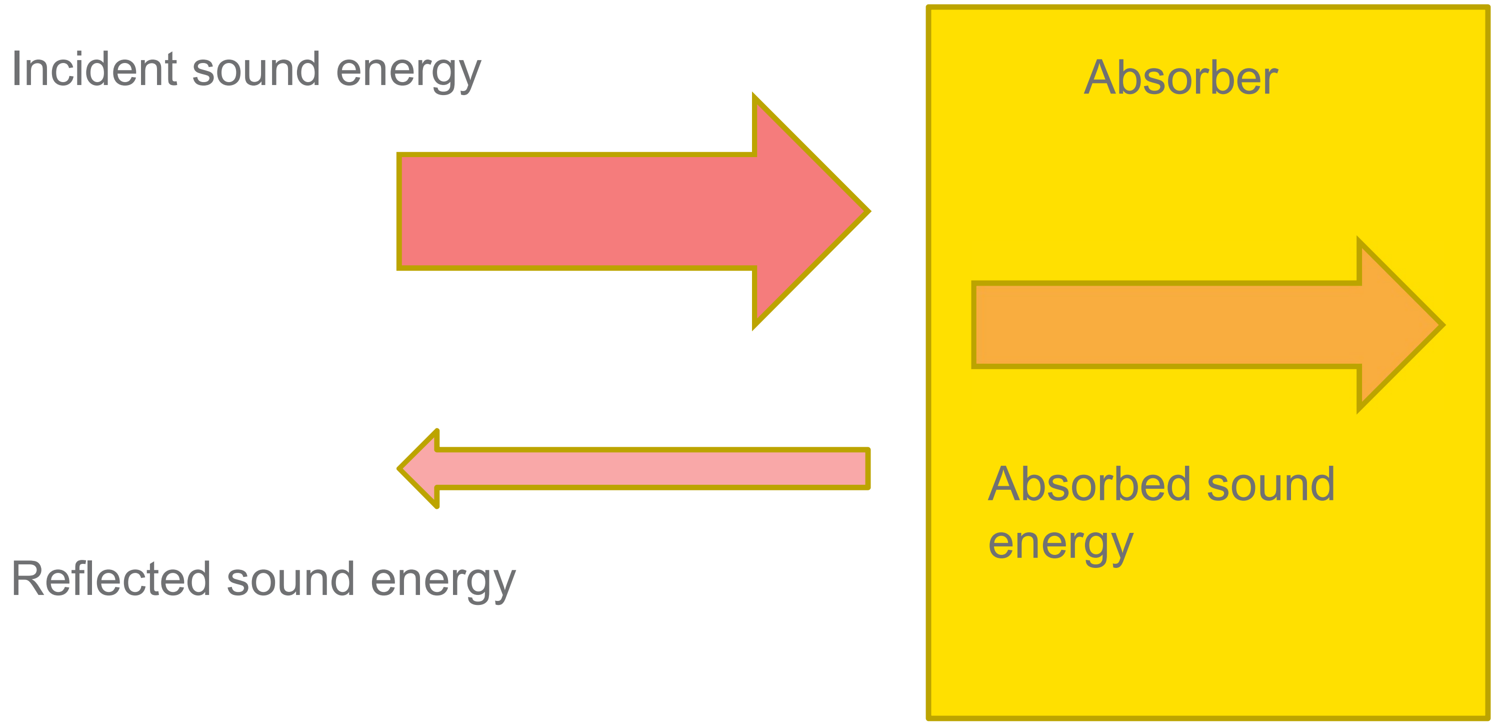
$A=\sum \alpha_i \times S_i$ = 0,10x6x7,5+2x0,15x7,5x2,5+2x0,15x6x2,5+0,80x6x7,5=51 m^2 sabin

T_{60}=0,161x(V/A)=0,161x112,5/51≈0,36 s

Ecophon SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

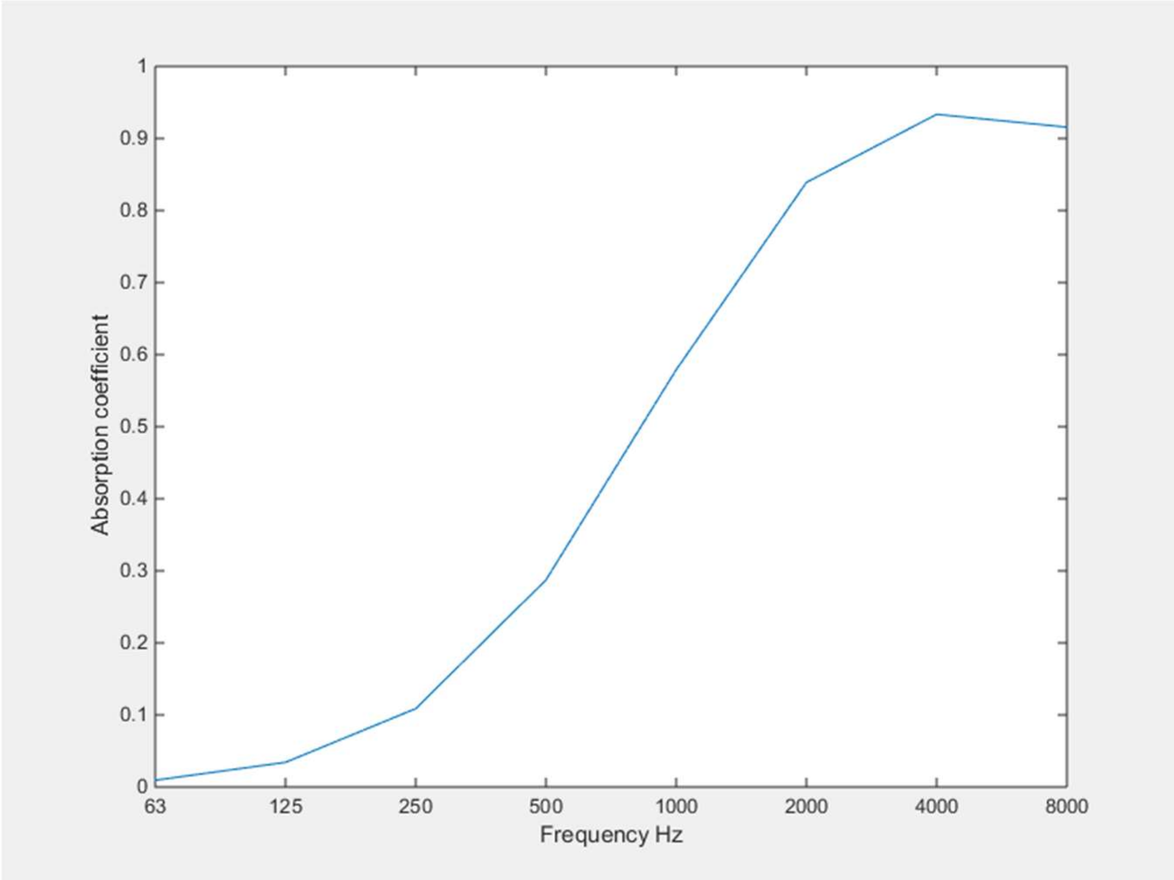
Absorption coefficient at normal incidence



$$Absorption\ coefficient\ \alpha = \frac{Absorbed\ sound\ energy}{Incident\ sound\ energy}$$

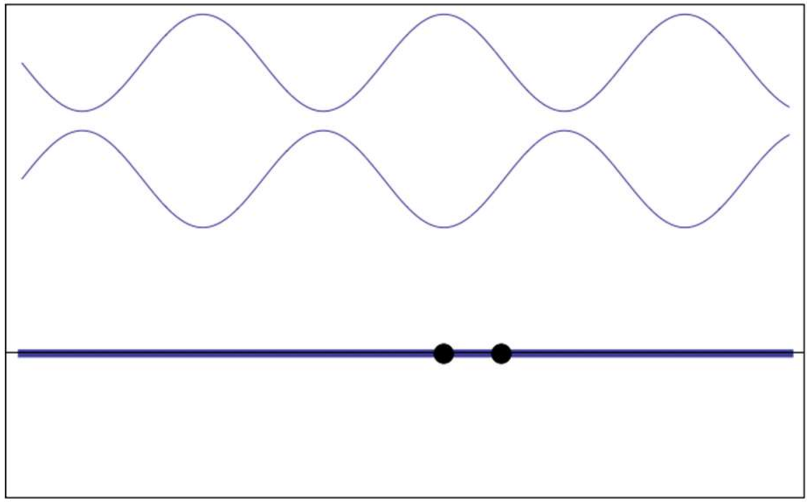
Ecophon® SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Absorption coefficient as a function of frequency



20 mm glass wool absorber directly mounted in front of a hard surface (concrete)

Standing wave



wave 1 going right

wave 2 going left

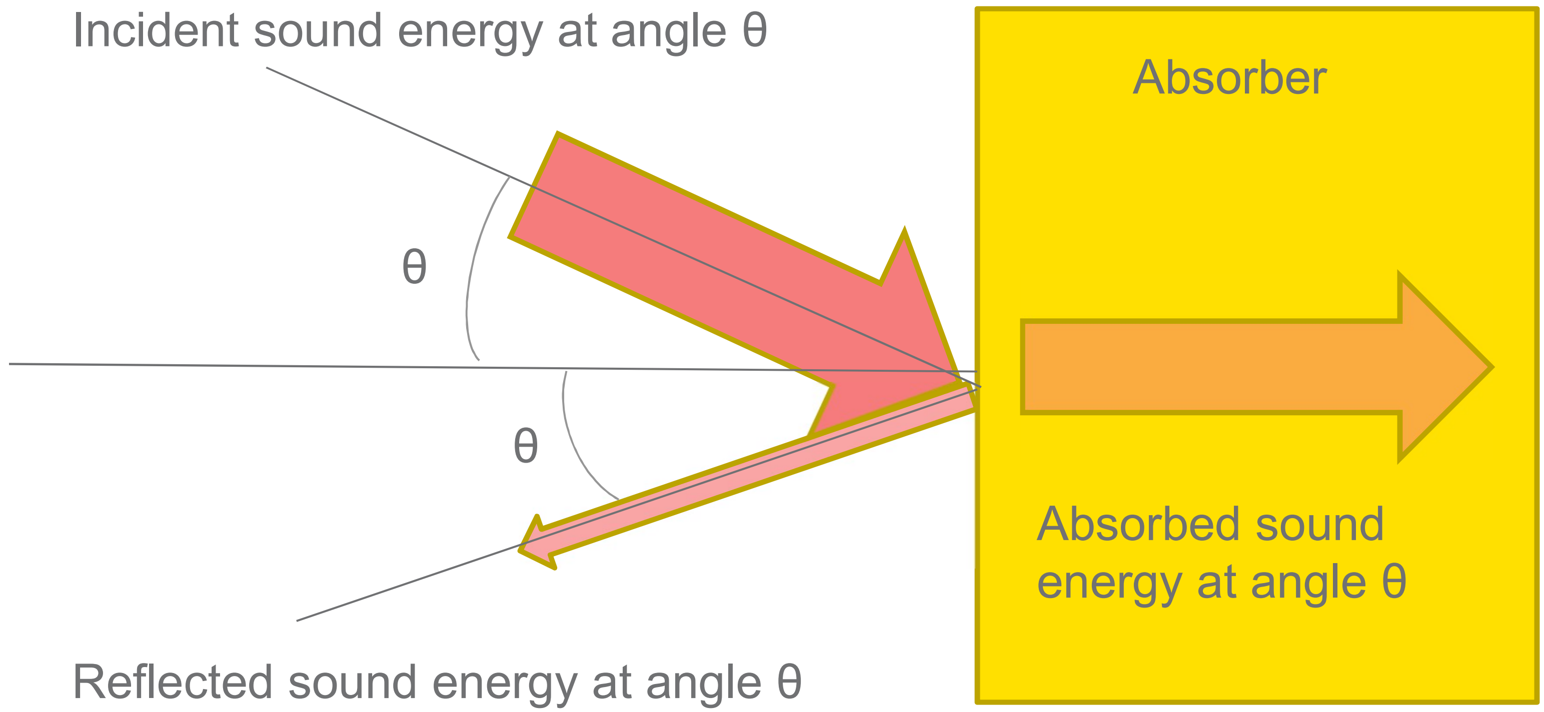
wave 1 + wave 2

Impedance tube (Kundt's tube)

$$F = 10^{(L_{max} - L_{min})/20}$$

$$\alpha = \frac{4F}{(1+F)^2}$$

Absorption coefficient

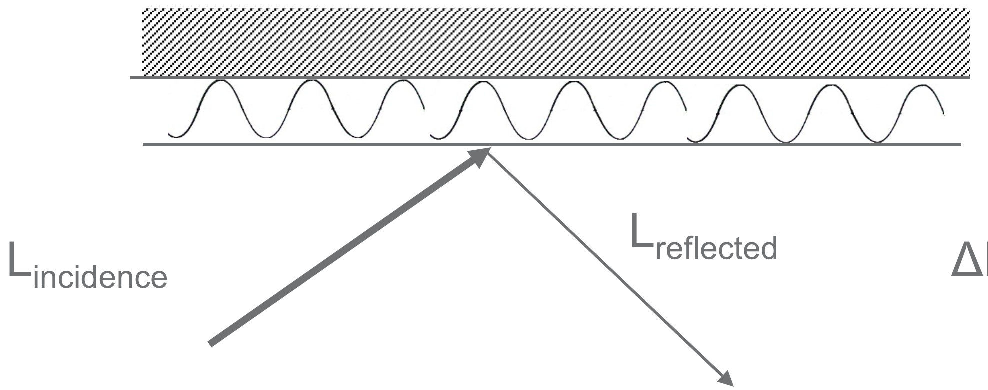


$$Absorption\ coefficient\ \alpha(\theta) = \frac{Absorbed\ sound\ energy\ at\ angle\ \theta}{Incident\ sound\ energy\ at\ angle\ \theta}$$

Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Reflected sound

$$\Delta L = 10 \cdot \log(1 - \alpha)$$

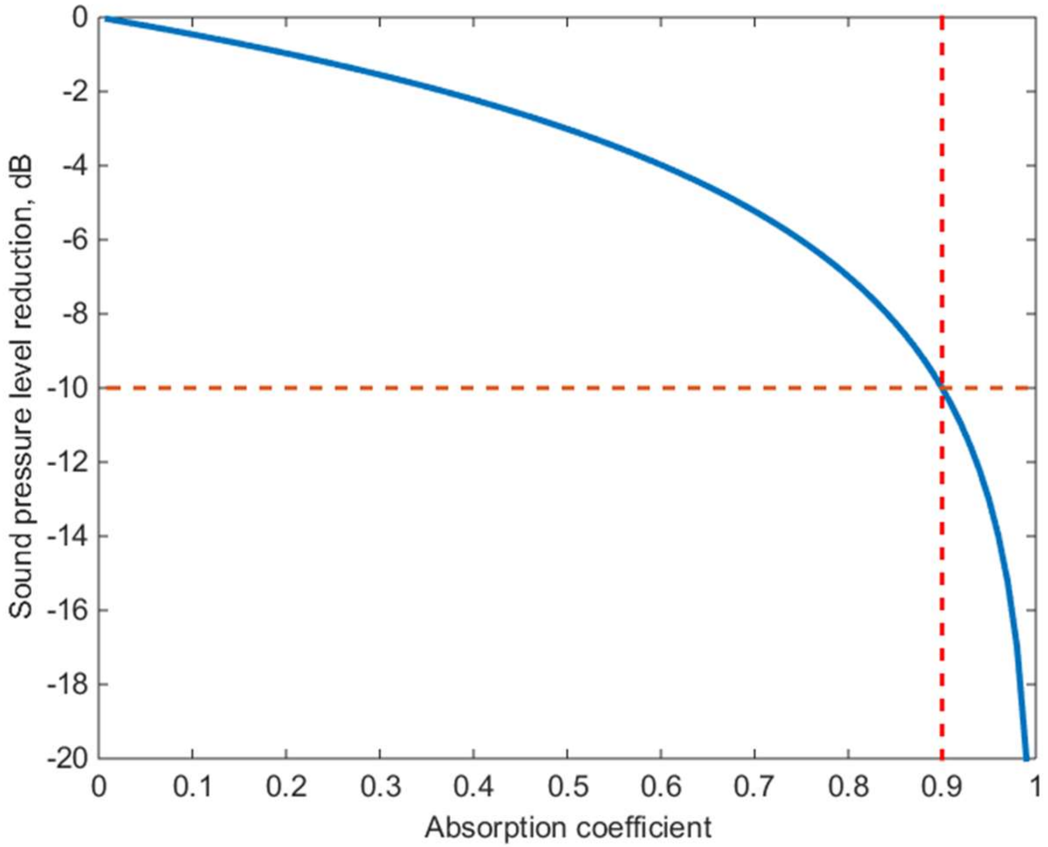


$\Delta L = L_{incidence} - L_{reflected}$ (dB)

Absorption coefficient	The reflected sound is reduced by
0,30 – 0,55 (class D)	1-4 dB
0,60 – 0,75 (class C)	4-7 dB
0,80 – 0,85 (class B)	7-10 dB
0,90 – 0,99 (class A)	10-20 dB

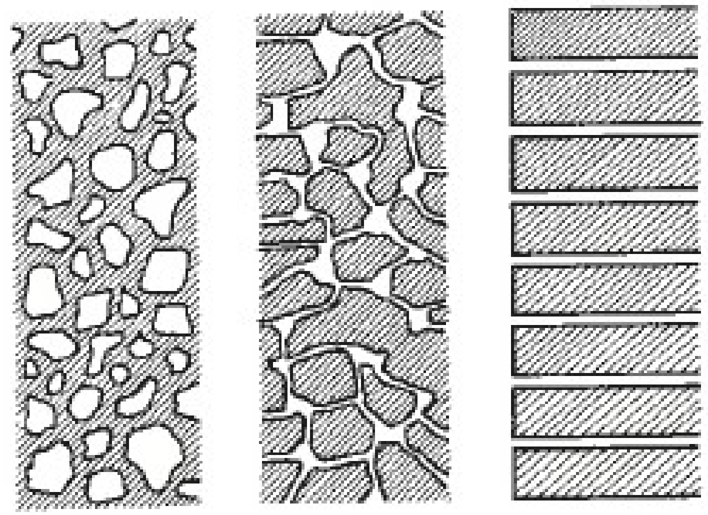
Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Level reduction of sound reflection



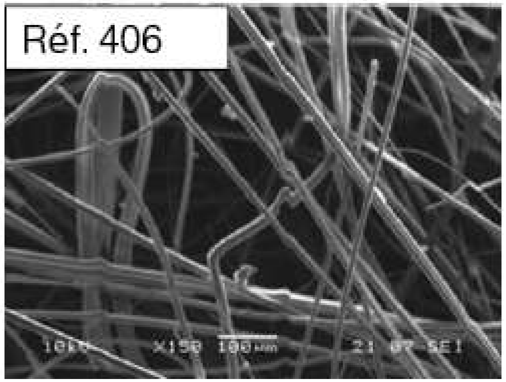
Glass wool

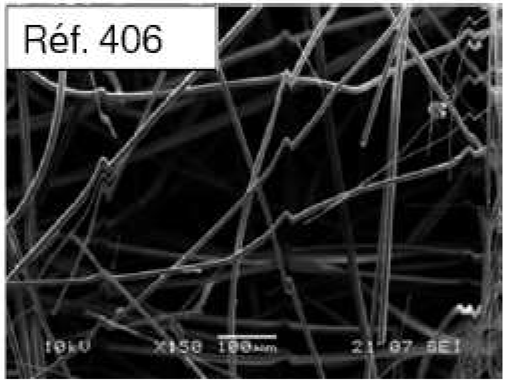
Open and closed structures

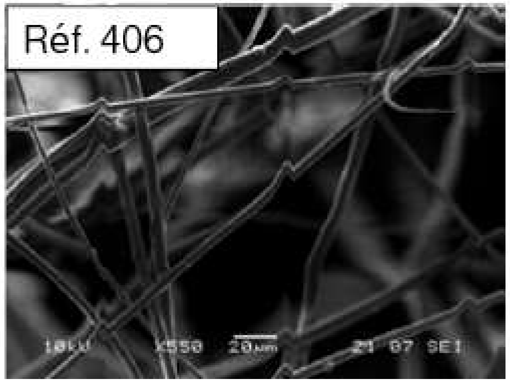


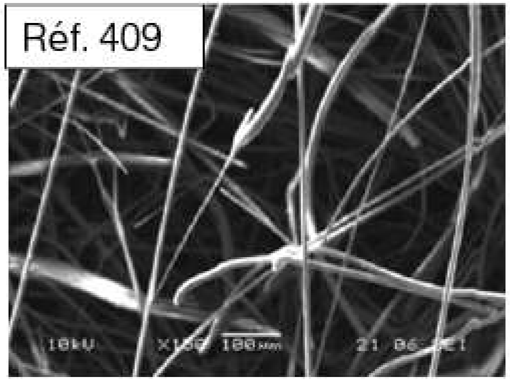
Closed cell Open cell Simple model of porous absorber

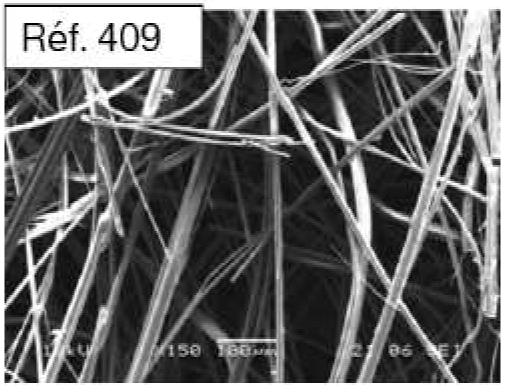
Microscopic structure

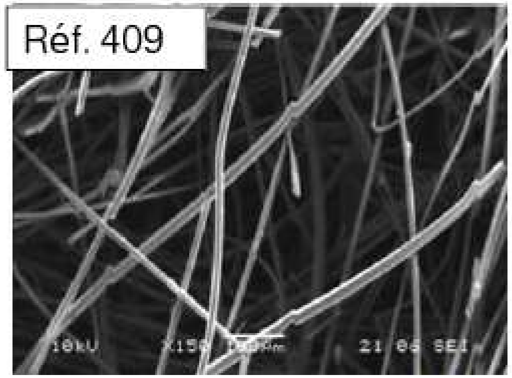












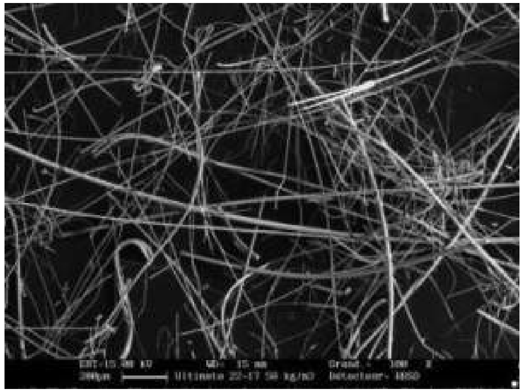
Acoustical behavior of porous materials

Porous materials
- Solid phase
- Fluid phase

→ Porous materials are used to dissipate energy:

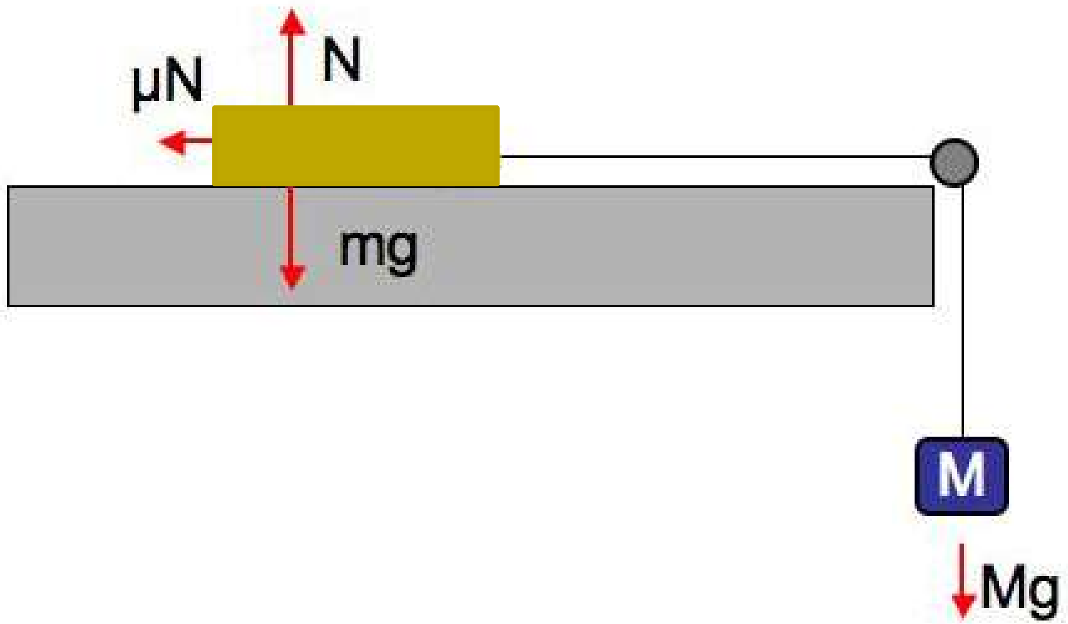
Acoustic energy is being transferred into heat

General properties:
- -Characteristic pore size between μm and mm
- -Open porosity

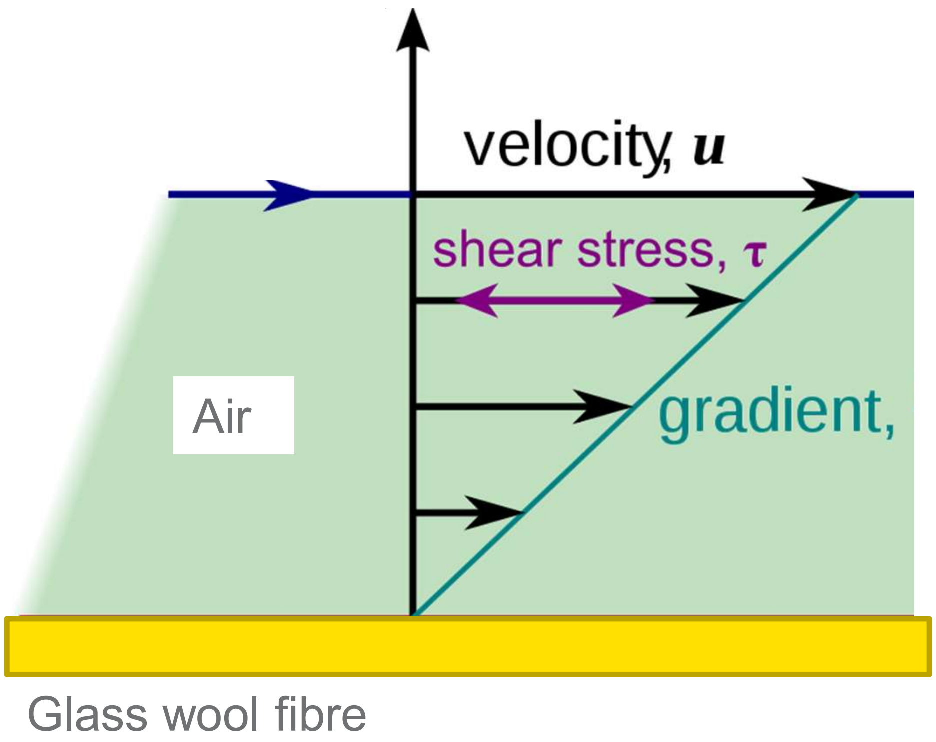


Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

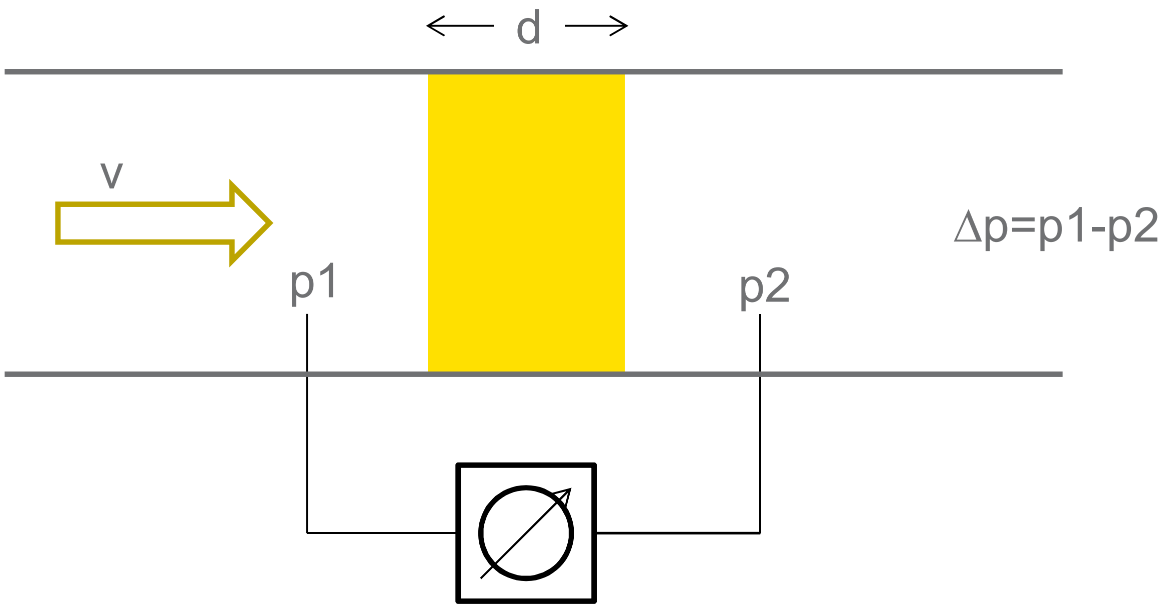
Friction



Viscosity: energy converted into heat (friction losses)

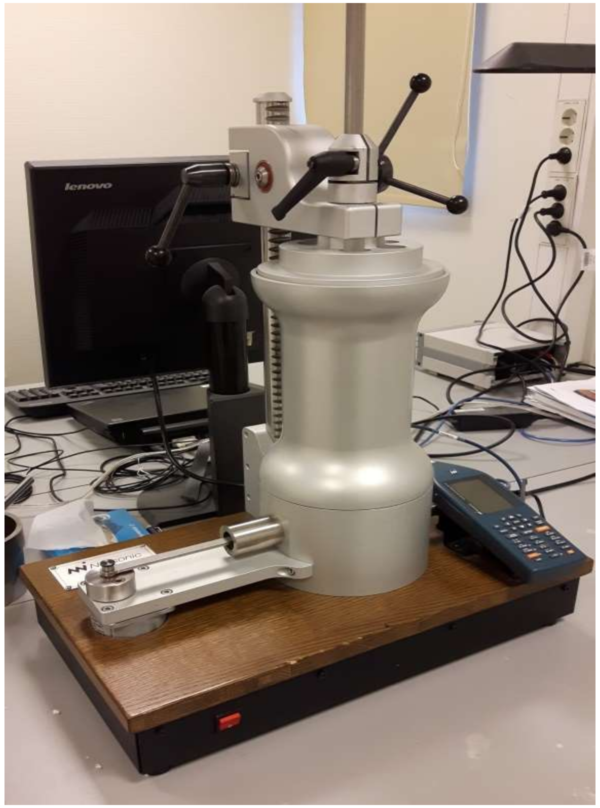


Measurement of air flow resistivity (ISO 9053)



$$Flow\ resistivity\ r = \frac{\Delta p}{v \cdot d} \quad \left(\frac{Pa \cdot s}{m^2}\right)$$

Air flow resistance equipment



Acoustical behavior of porous materials

- Physical phenomenon:
  - Viscous and thermal exchanges
    - When acoustical wave is propagating in the porous materials, frictional losses and heat exchanges between solid and fluid phases occur.
  - Structural damping
    - Energy dissipation by deformation of the structure

Models for characterizing porous material

- Delany and Bazley's model (1970)
- Miki's model (1990)
- Komatsu's model (2008)

Models for characterizing porous material

- Delany and Bazley's model (1970)
- Miki's model (1990)

Characteristic impedance

Airflow resistivity

$$Z_c = \rho_0 c_0 \left[1 + 0.070 \left(\frac{f}{\sigma}\right)^{-0.632} - j0.107 \left(\frac{f}{\sigma}\right)^{-0.632} \right]$$

- Komatsu's model (2008)

Acoustical behavior of porous materials

Sound propagation in poro-elastic media
(Biot-Jonhson-Champoux- Allard model)

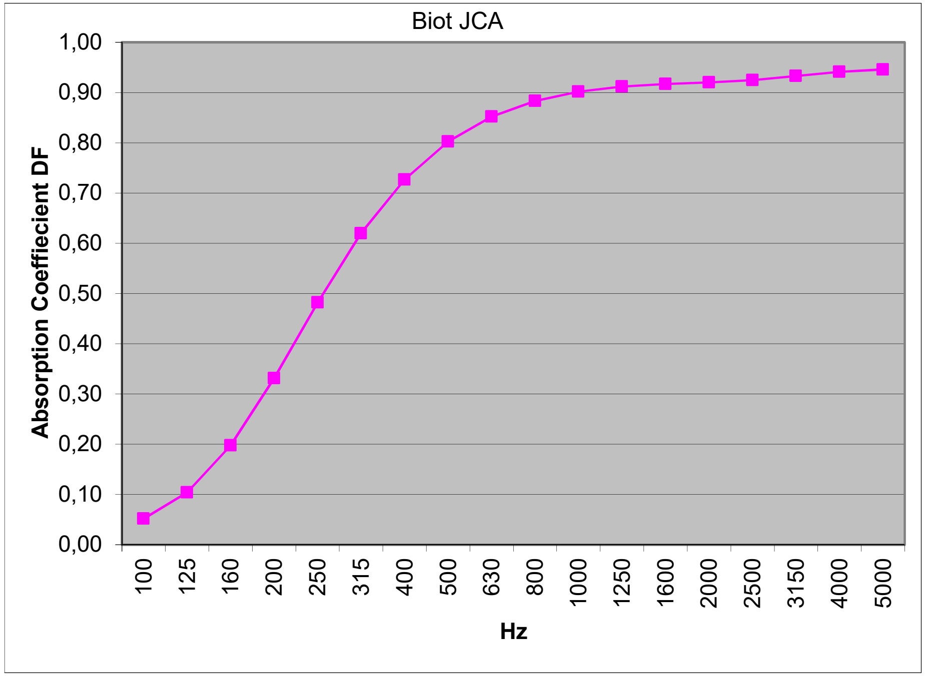
• Fluid density	ρ_f
• Flow resistivity	σ
• Open porosity	ϕ
• Tortuosity	α_∞
• Viscous characteristic length	Λ
• Thermal characteristic length	Λ'
• Solid density	ρ_s
• Young's modulus	E
• Shear modulus	N

Ecophon® SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Parametric Study: materials properties and sound absorption

– Properties of Glass wool

Properties	Glass wool
Thickness (mm)	50
σ, airflow resistivity (Pa s/m²)	35000
Φ, Porosity	0.96
α_∞, Tortuosity	1.02
Λ, Viscous Characteristic Length (μm)	52
Λ', Thermal Characteristic Length (μm)	61
ρ, Density (kg/m³)	40
E, Young Modulus (Pa)	4000
η, Loss factor	0.31
N, Poisson Ratio	0



Acoustical behavior of porous materials

- Perspectives
  - Modify the microstructure of the materials
    - Length of the fibers
    - Diameter of the fibers
    - Space between fibers
    - Arrangement of the fibers
    - …..

Flow resistivity as a function of density

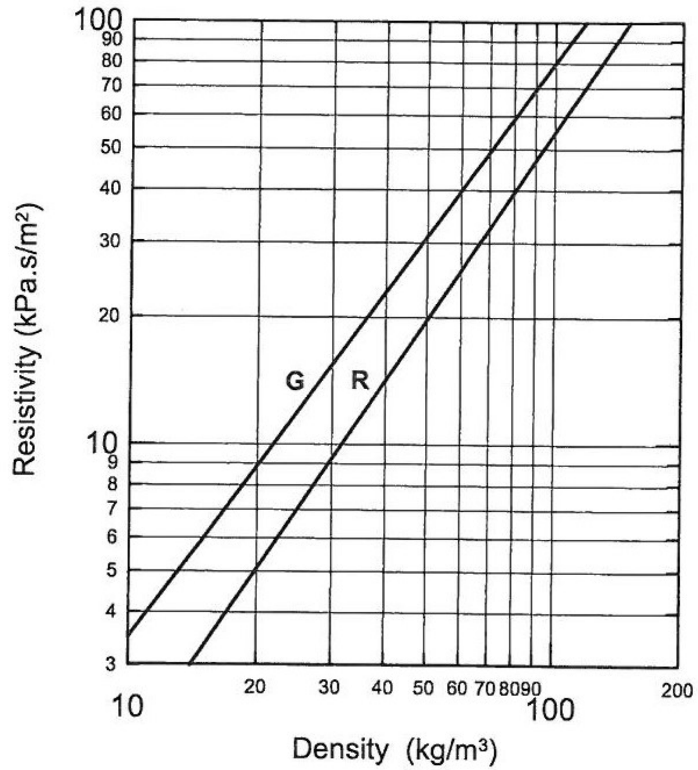
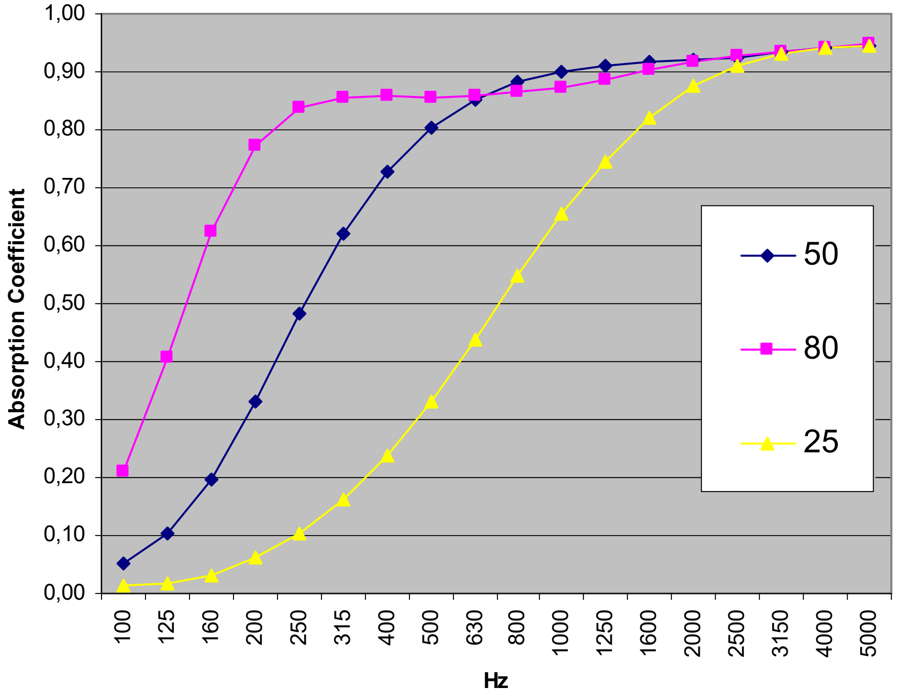


Figure 5.33 Typical data for airflow resistivity of mineral wool, glass wool (G) and rock wool (R) as a function of density.

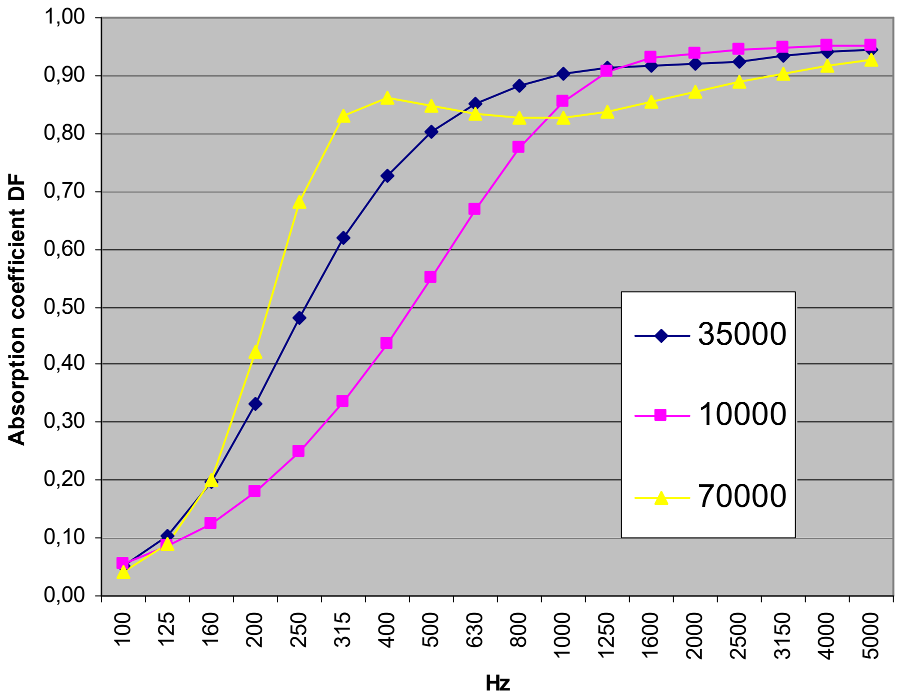
Parametric Study: materials properties and sound absorption

- Parametric Study
  - Influence of the thickness of the porous material
    - 50mm, 25mm and 80mm



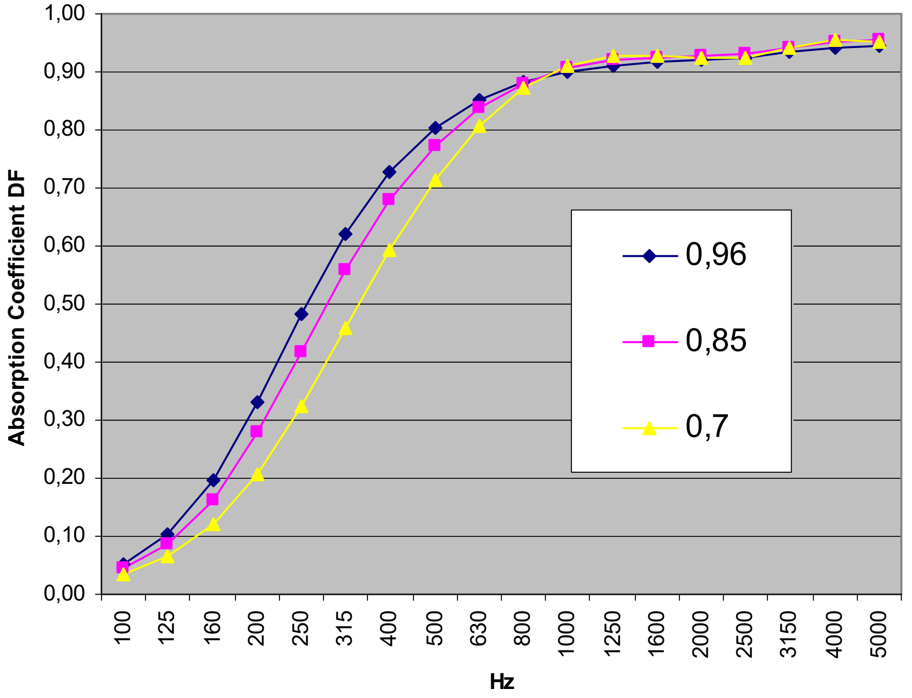
Parametric Study: materials properties and sound absorption

- Parametric Study
  - Influence of the flow resistivity
    - 35000N.s.m^{-4}, 10000N.s.m^{-4} and 70000N.s.m^{-4}



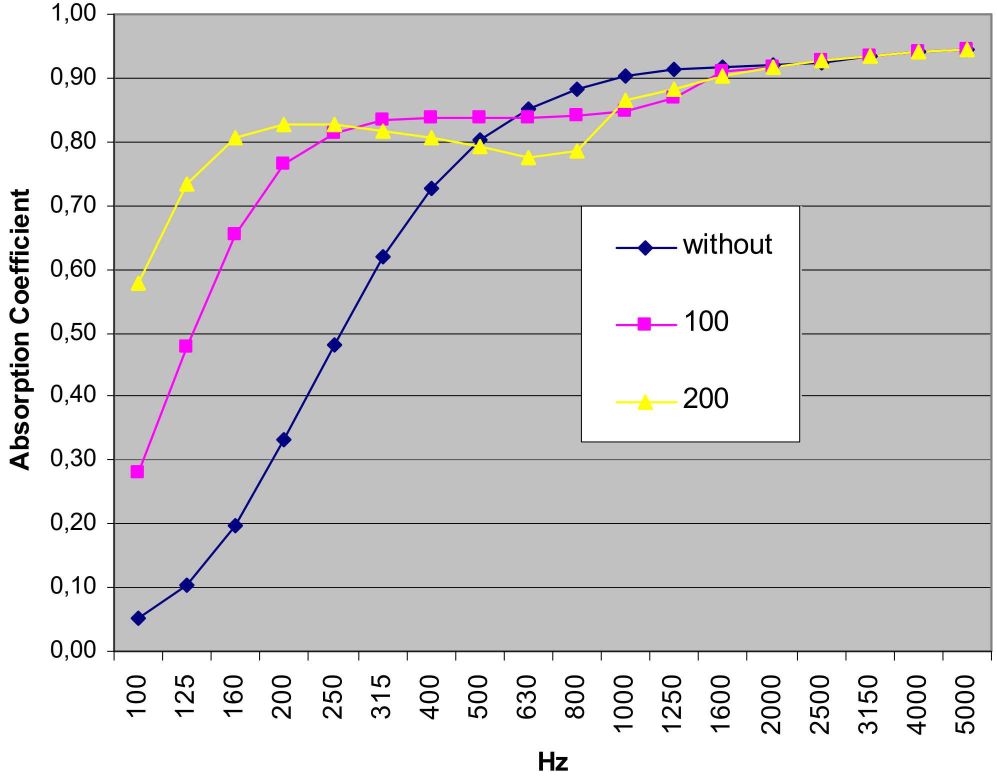
Parametric Study: materials properties and sound absorption

- Parametric Study
  - Influence of the porosity
    - 0.96, 0.85 and 0.7



Parametric Study: materials properties and sound absorption

- Parametric Study
  - Influence of air cavity
    - 100mm and 200mm



Absorbers

1. Porous absorbers

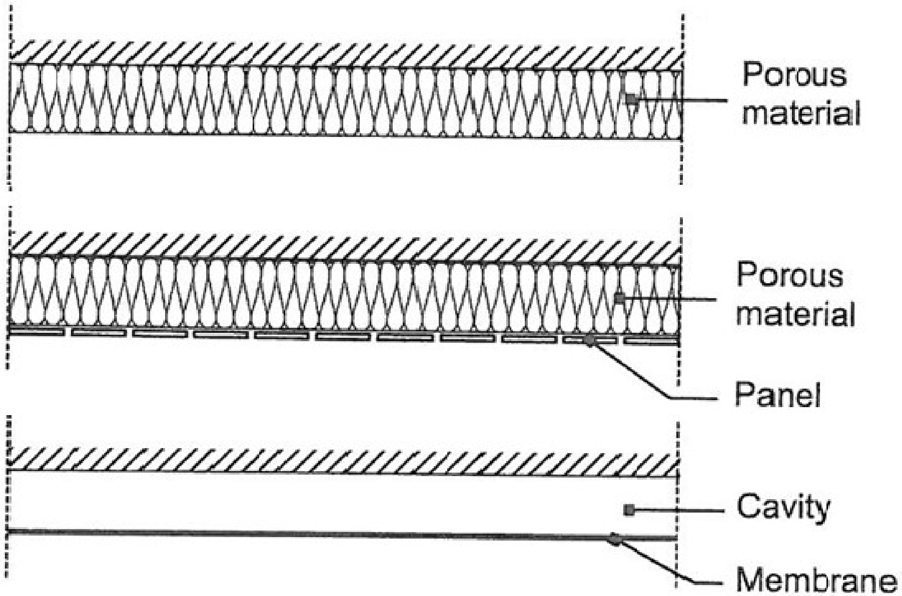
(mineral wool products, porous fibreboard products, foam plastic, fabric, felt etc)

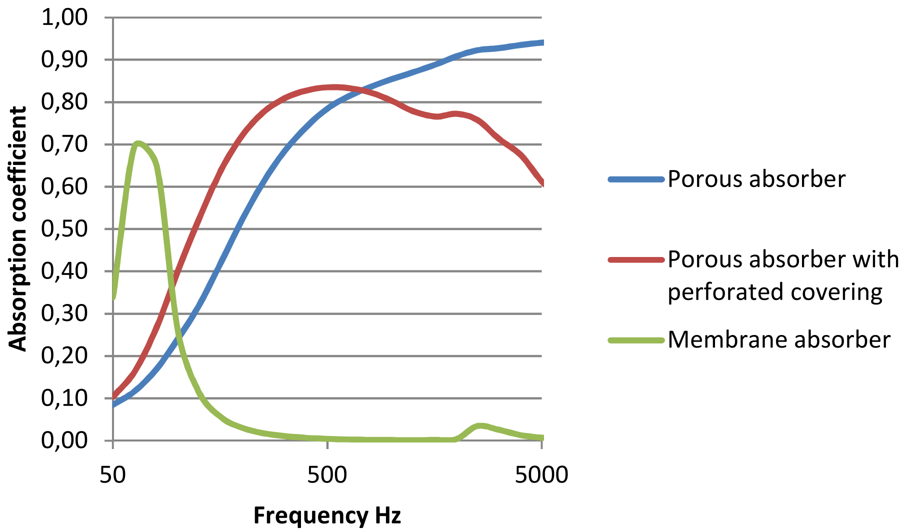
2. Resonance absorbers

a) Cavity absorbers (Helmholtz absorbers)

b) Membrane absorbers

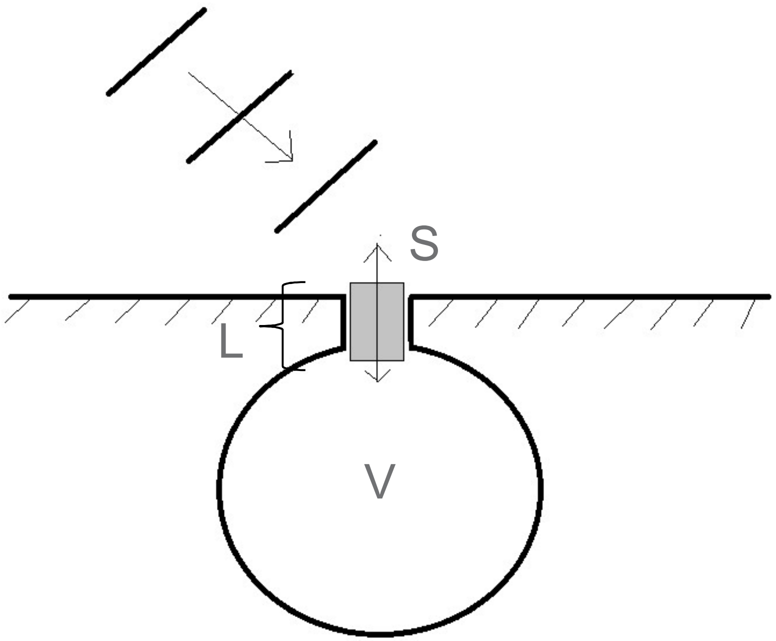
Different types of absorbers





Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Helmholtz resonator



Resonance frequency (Hz)

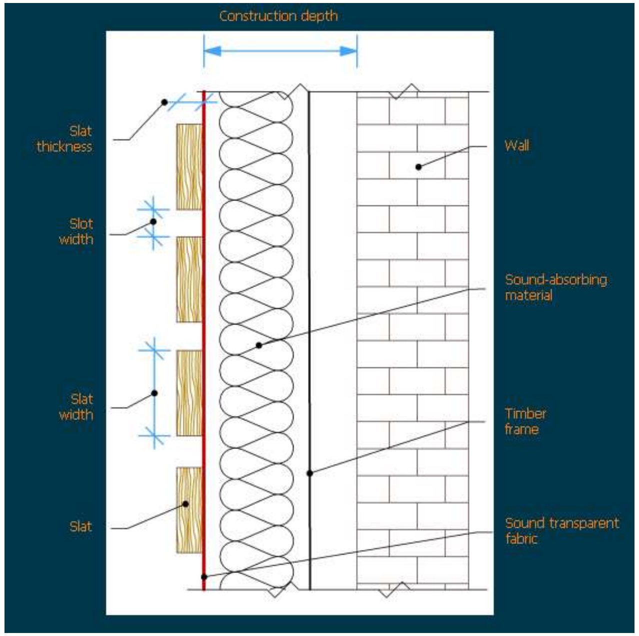
$$f_r = 55 \cdot \sqrt{\frac{S}{L \cdot V}}$$

S= the cross sectional area of the neck
L=approx. the length of the neck
V= the volume of the cavity

Example: “an empty bottle of wine”, $S=2{,}54\text{x}10^{-4}\ m^2$,
$L= 0{,}08\ m$, $V= 0{,}75 \times 10^{-3}\ m^3$
$f_r = 113$ Hz

Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Slotted absorber



$$f_0 = \frac{c}{2\pi}\sqrt{\frac{r}{d \cdot 1.2 \cdot D \cdot (r + w)}}$$

w - slat width,
r - slot width,
d - slat thickness,
D - frame depth,
c - speed of sound in the air.

Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Standards

ISO 354:2003 Acoustics – Measurements of sound absorption in a reverberation room

- Plane absorbers
- Discrete sound absorbers
- Baffles

ISO 11654:1997 Acoustics – Sound absorbers for use in buildings – Rating of sound absorption

- Practical absorption coefficient α_p
- Weighted sound absorption coefficient α_w
- Sound absorption classes A to E

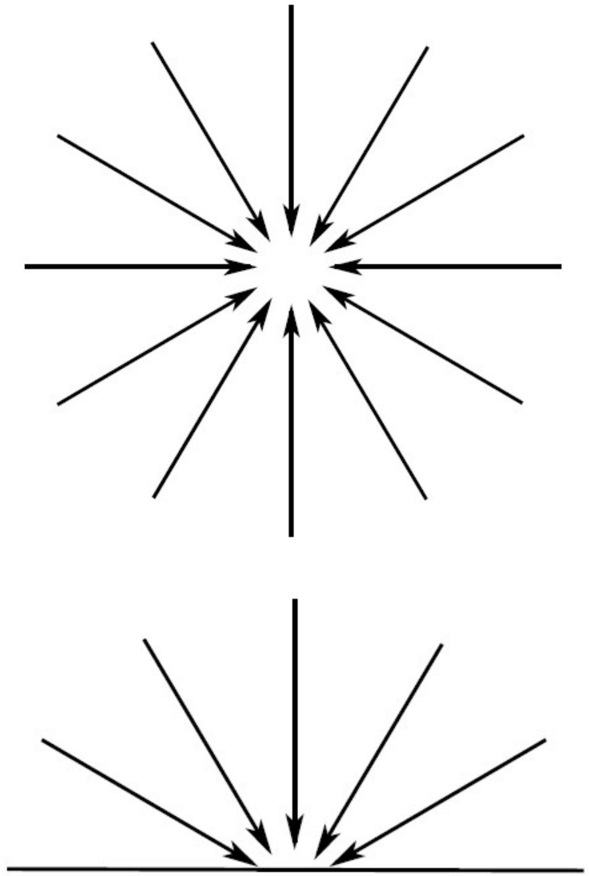
US standard: ASTM C423, “Sound absorption and sound absorption coefficients by the reverberation room method”

- Recommended room volume: 200 m^3 (ISO 354 recommends 200 m^3)
- Recommended test area: 6,69 m^2 (ISO 354 recommends 10 to 12 m^2)
- Typical ods.: 400 mm (ISO 354: typical ods. 200 mm)

Absorption coefficients (single number):

- **Sound absorption average, SAA**: average of the sound absorption coefficients for the twelve one-third octave bands from 200 Hz to 2500 Hz.
- **Noise reduction coefficients, NRC**: average for the sound absorption coefficients for 250, 500, 1000, and 2000 Hz rounded to the nearest multiple of 0.05.

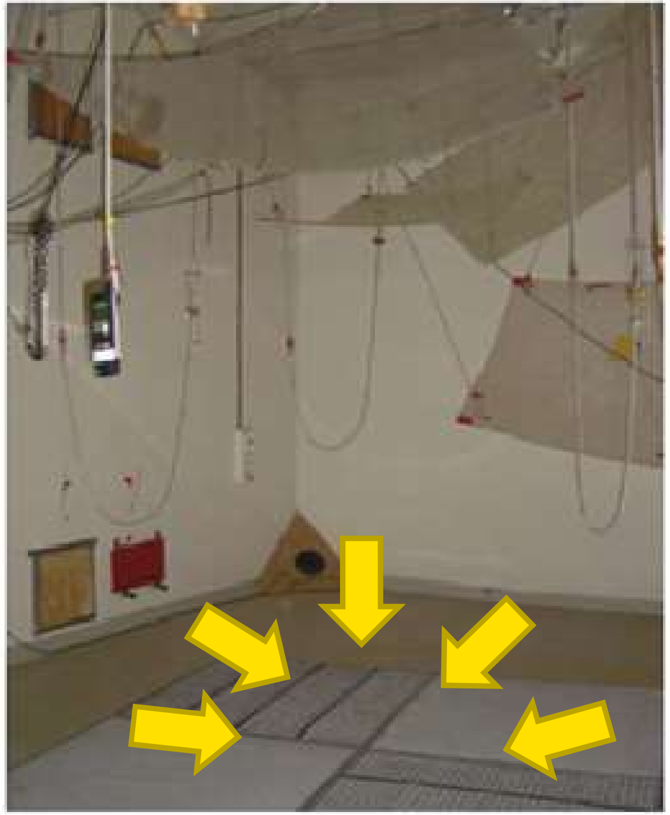
Diffuse sound field



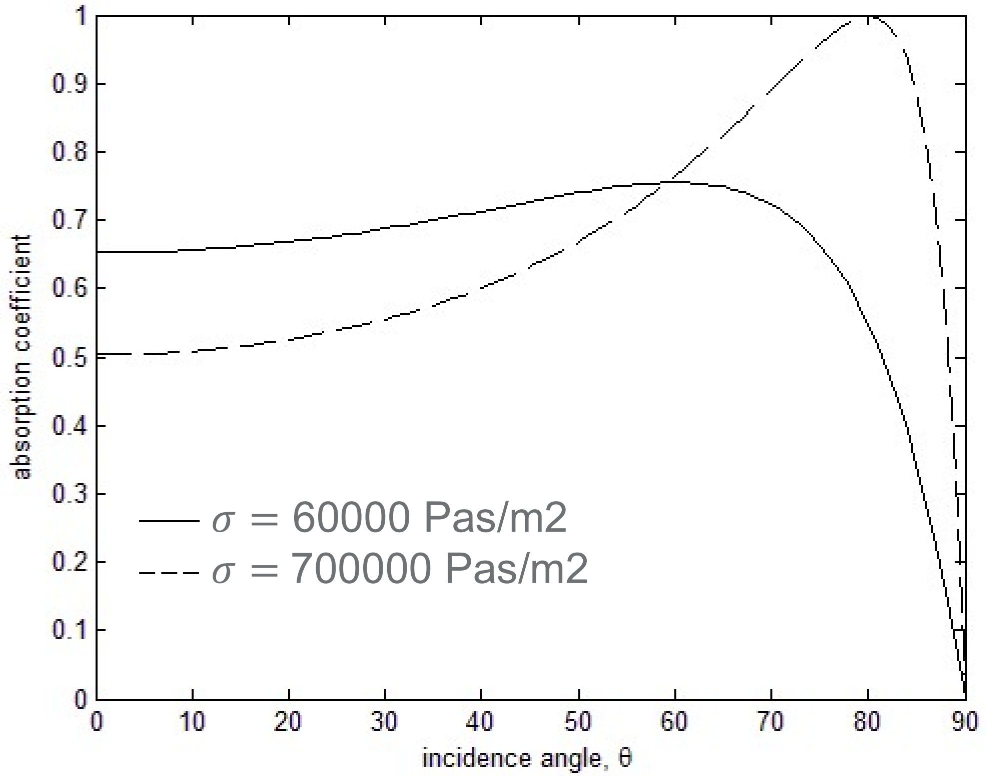
Echo chamber of the Dresden University of Technology

On the use of practical absorption coefficients

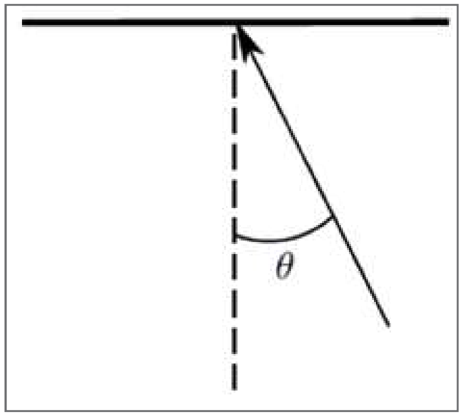
On the use of practical absorption coefficients



Angle dependent absorption coefficient

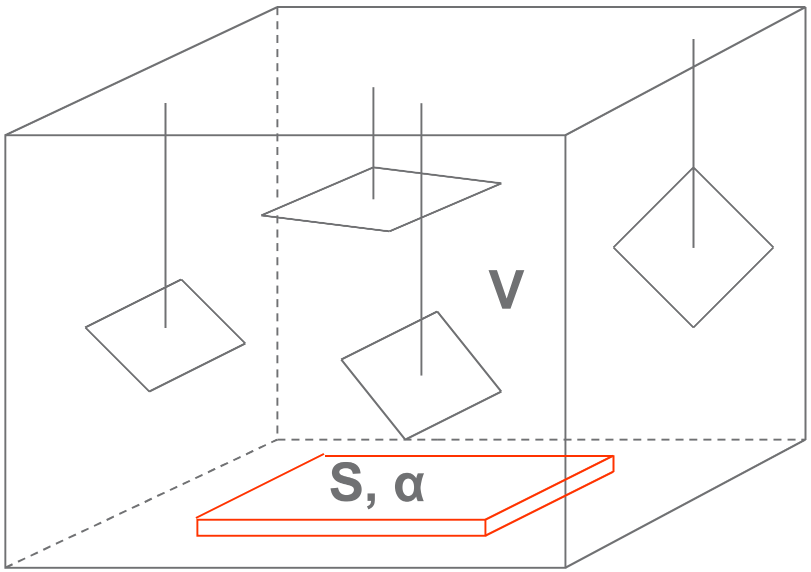


$\sigma = 60000$ Pas/m2
$\sigma = 700000$ Pas/m2



Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Measurement of absorption coefficients according to EN ISO 354



$$\Delta A = A_{with} - A_{without} = \frac{0.16 \cdot V}{T_{with}} - \frac{0.16 \cdot V}{T_{without}}$$

A=equivalent absorption area, m^2 sabine

V= room volyme, m^3

T= reverberation time, s

absorption coefficient

α = ΔA/S

Ecophon SAINT-GOBAIN

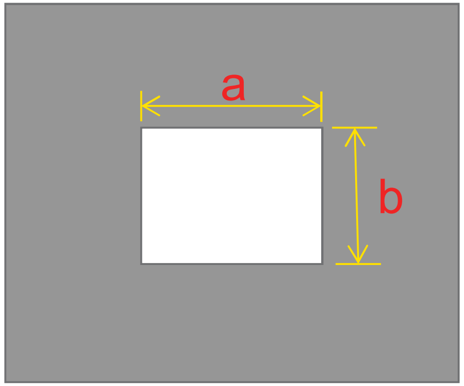
A SOUND EFFECT ON PEOPLE

Equivalent absorption area A (m^2 sabin)

$$T = 0.16 \left(\frac{V}{A} \right)$$

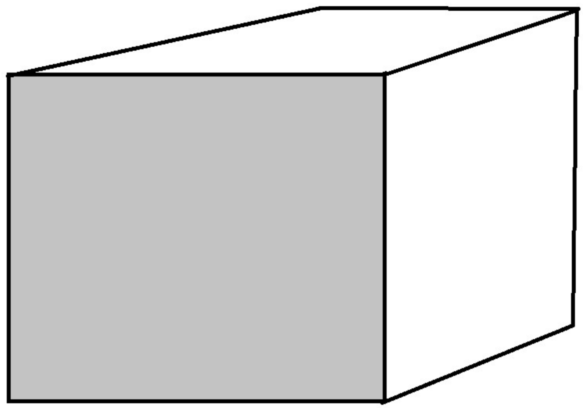
$$A = \alpha \cdot S$$

if α=1 then A=S

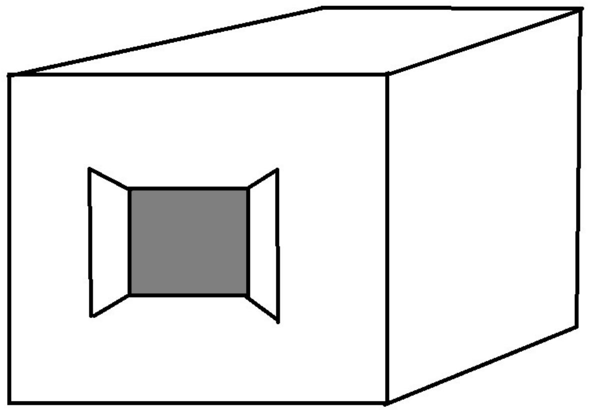


"Open window"
A=S=a x b

Example: Equivalent absorption area



Wall panel
α=0.3
S=10 m^2
A=0.3 x 10=3 m^2 sabin



Open window
α=1.0
S=3 m^2
A=1.0 x 3=3 m^2 sabin

The open window with an area of 3 m^2 absorbs the same amount of sound power as the wall panel with an alpha of 0.3 and an area of 10 m^2

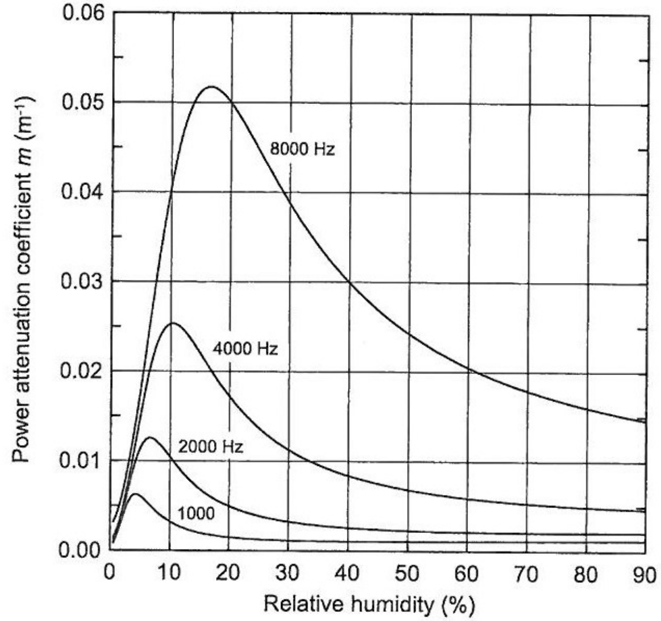
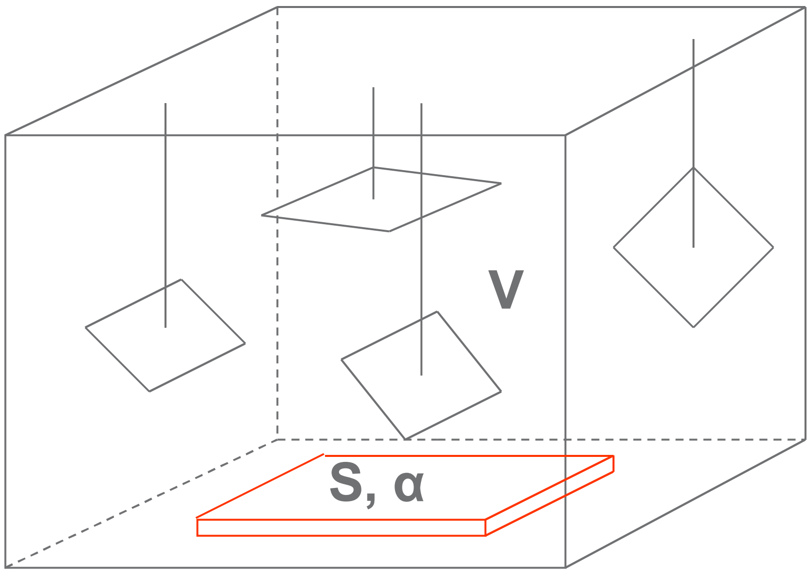
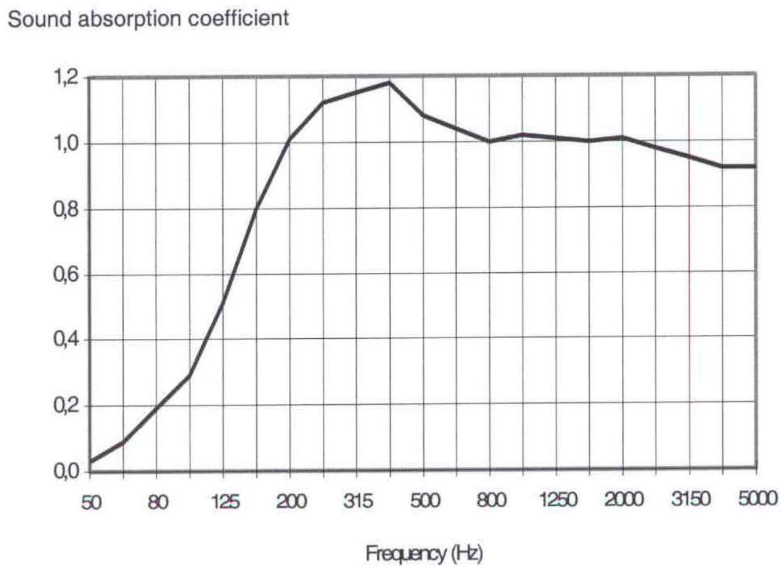


Figure 4.8 Power attenuation coefficient *m* for atmospheric absorption at 20° Celsius. Calculated from ISO 9613–1.

Measurement of sound absorption in reverberation room (ISO 354)



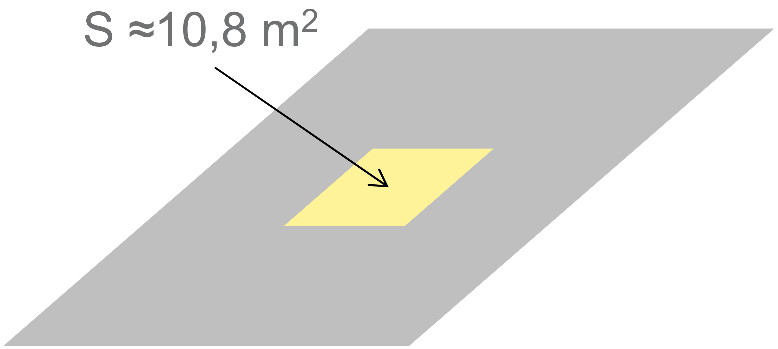
$$\alpha = \frac{0{,}16V}{S}\left(\frac{1}{T_{with}} - \frac{1}{T_{without}}\right)$$

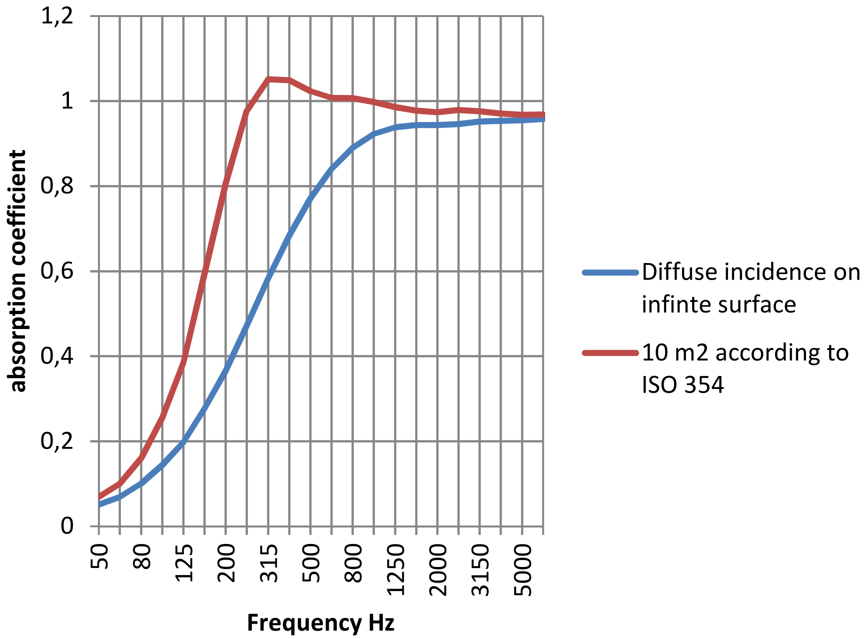


Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

The area effect

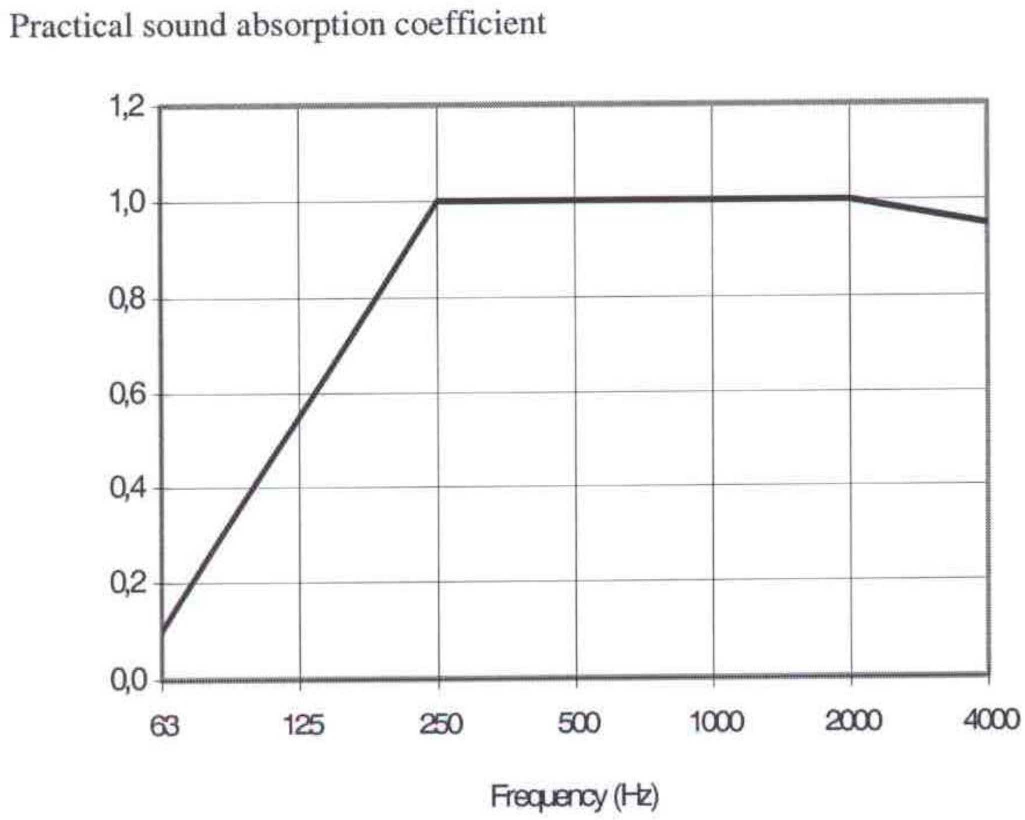
- Sabine coefficient vs. random incidence





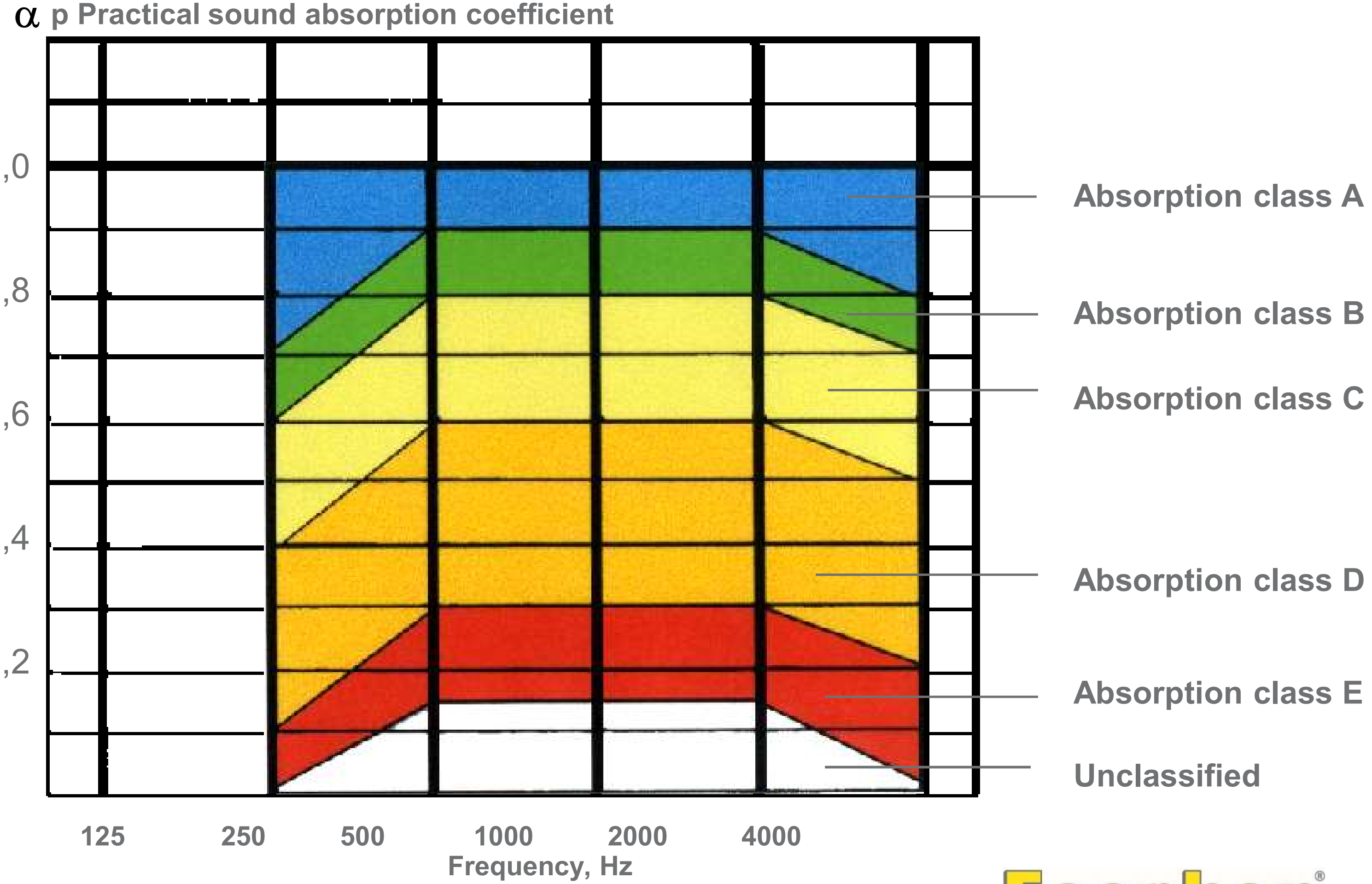
Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Practical sound absorption coefficient according to ISO 11654



Frequency (Hz)	α_p
63	0,10
125	0,55
250	1,00
500	1,00
1000	1,00
2000	1,00
4000	0,95

Classification of sound absorbers EN-ISO 11654



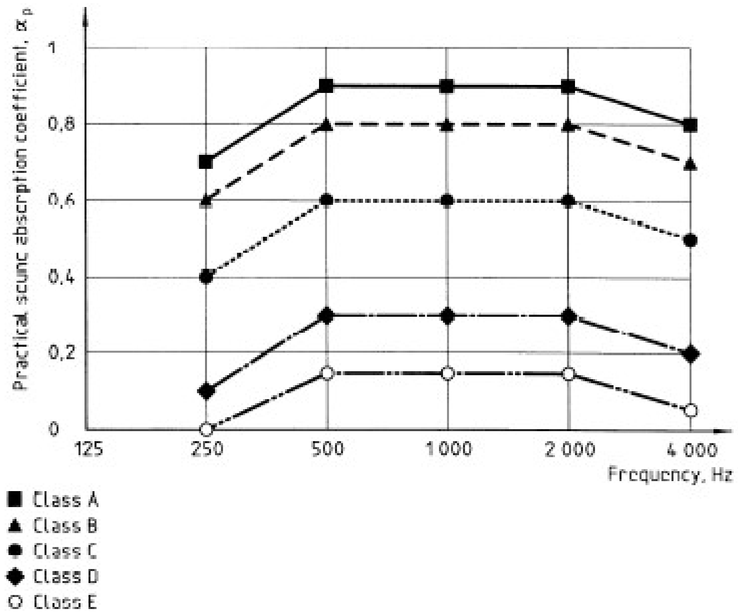
Ecophon SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

Weighted sound absorption coefficient according to ISO 11654

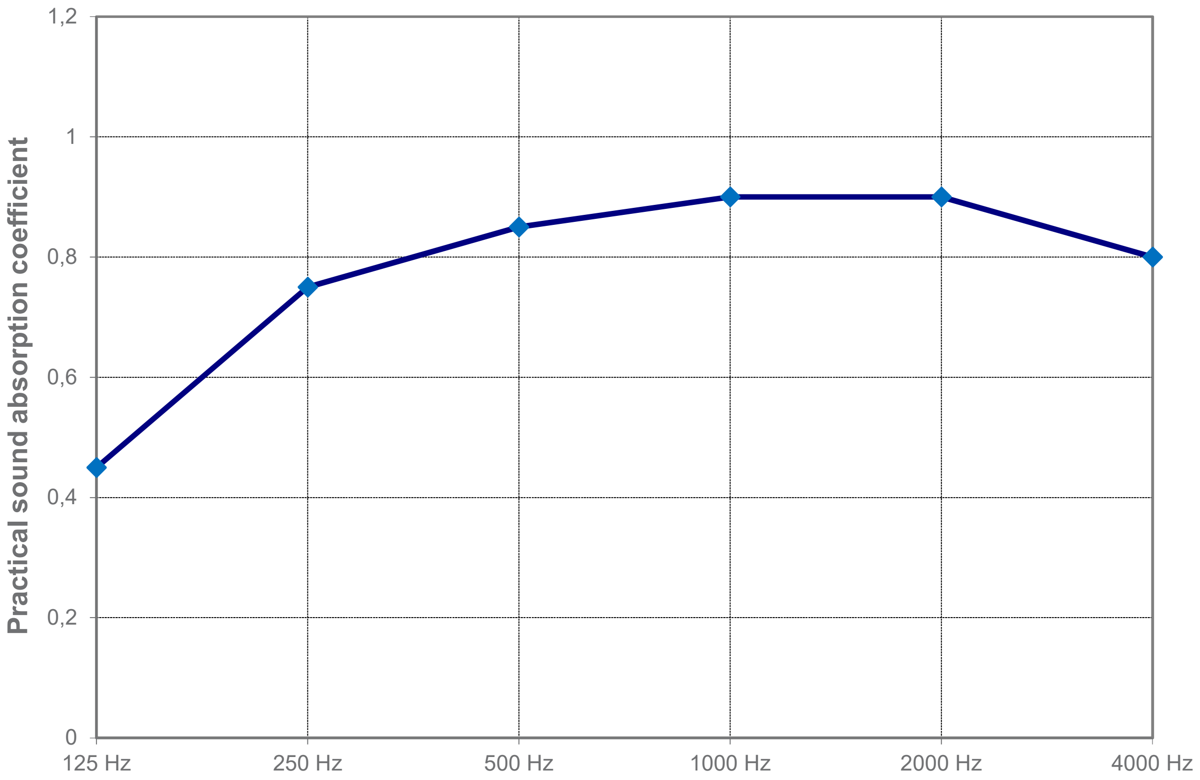
Table B.1 — Sound absorption classes

Sound absorption class	α_w
A	0,90; 0,95; 1,00
B	0,80; 0,85
C	0,60; 0,65; 0,70; 0,75
D	0,30; 0,35; 0,40; 0,45; 0,50; 0,55
E	0,25; 0,20; 0,15
Not classified	0,10; 0,05; 0,00



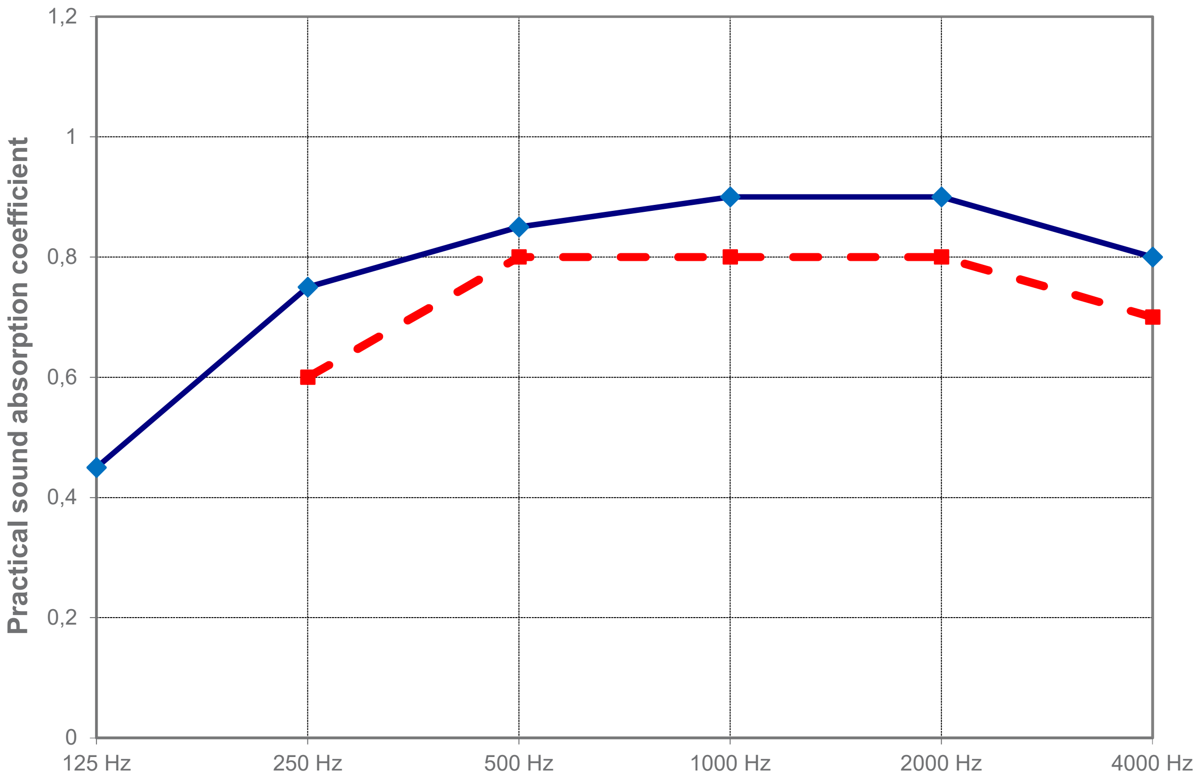
Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Practical absorption coefficient and classification

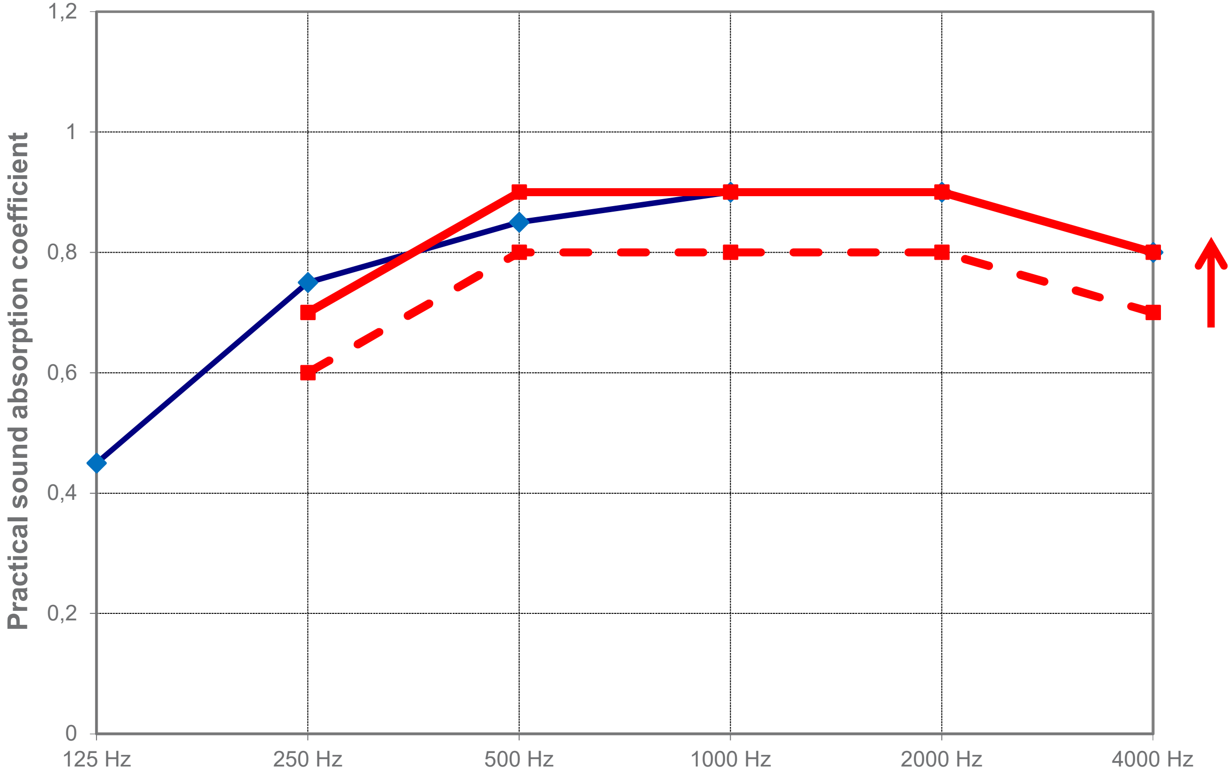


Ecophon®
SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Practical absorption coefficient and classification



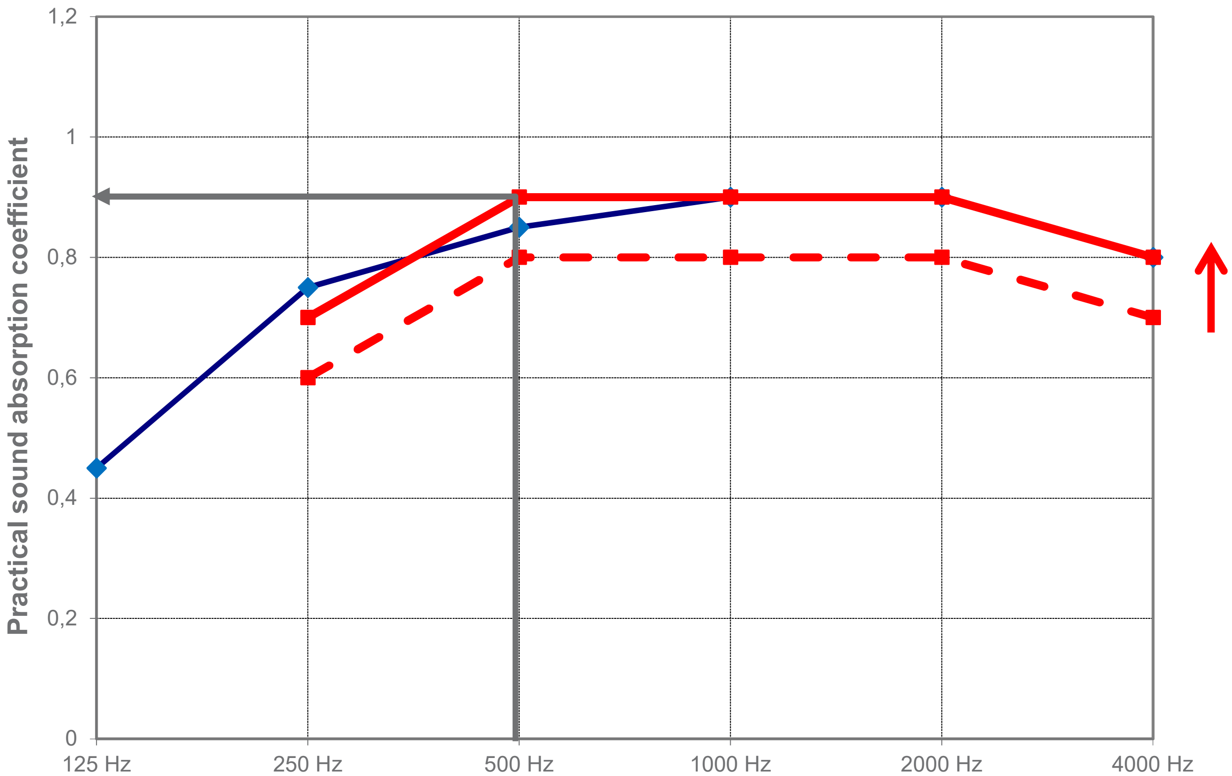
Practical absorption coefficient and classification



Practical absorption coefficient and classification

Weighted absorption coefficient, α_w

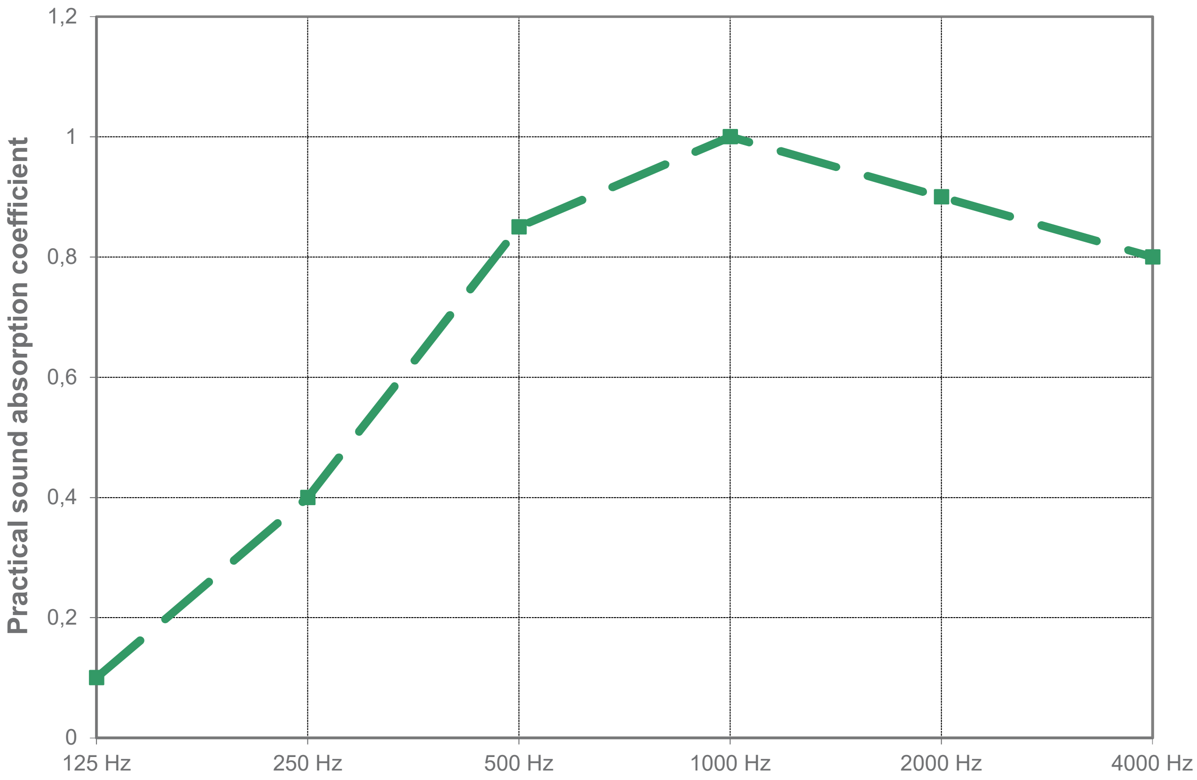
α_w = 0,9, class A



Ecophon SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

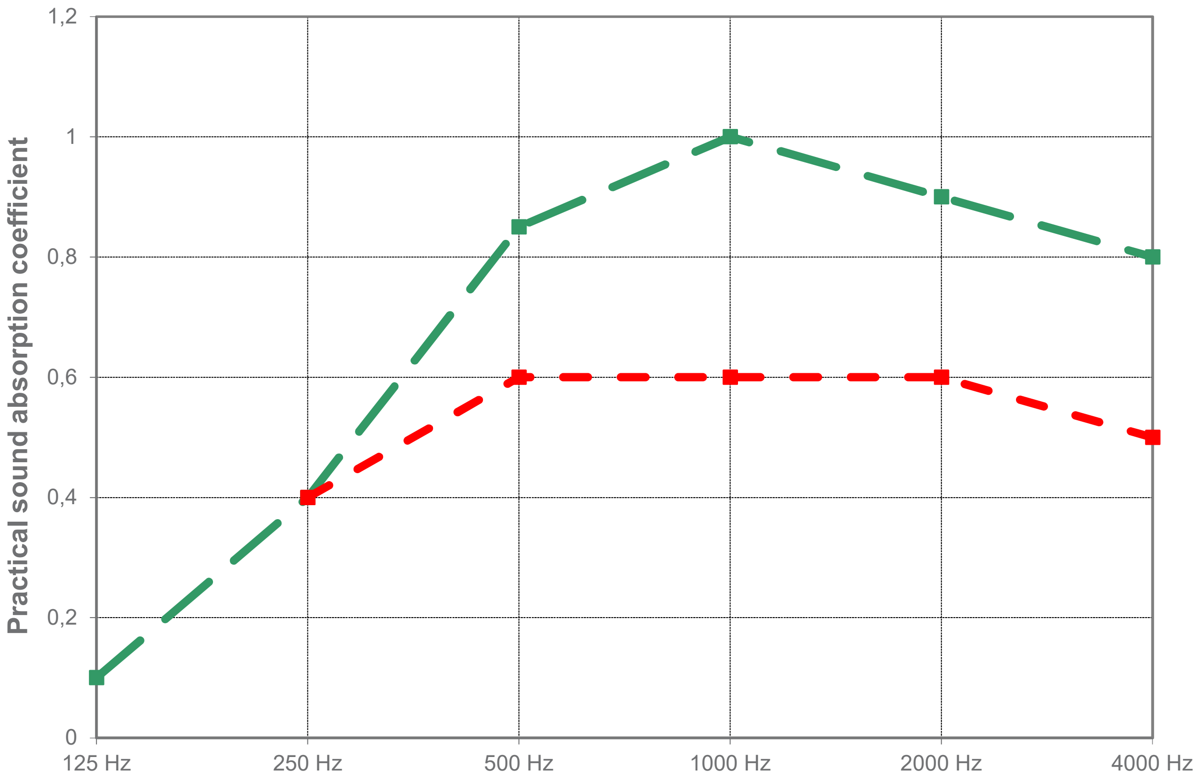
Practical absorption coefficient and classification



Ecophon® SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

Practical absorption coefficient and classification

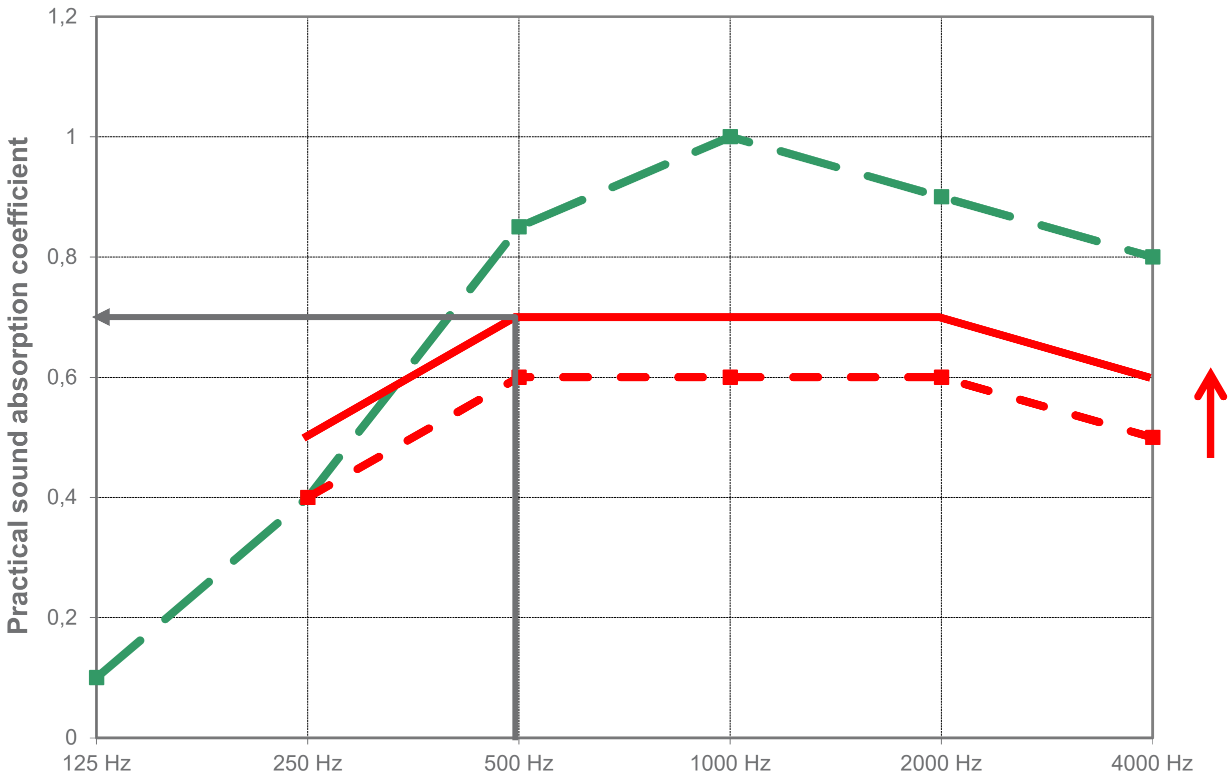


Ecophon®
SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Practical absorption coefficient and classification

Weighted absorption coefficient, α_w

α_w = 0,7, class C



Ecophon SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

Use of practical absorption coefficients

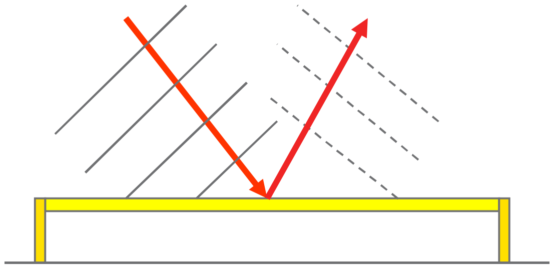
- Comparison of products
- Sabine calculations
- Simulation software (Odeon, Catt, etc.)

Ecophon®
SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

FHU - Acoustic specification

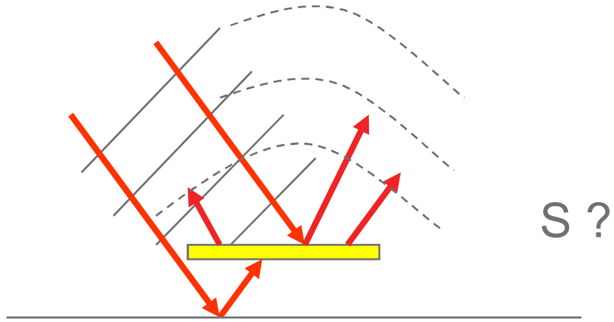
Absorbent ceiling



Absorption factor (ISO 354)

$$\alpha = \frac{A}{S}$$

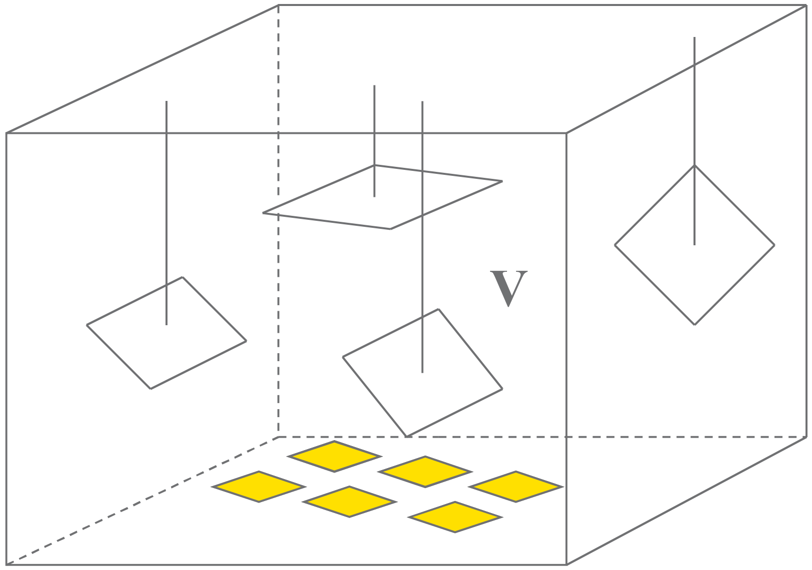
FHU – free hanging unit



Equivalent absorption area (ISO 354)

A (m^2)

Free hanging units “Solo”

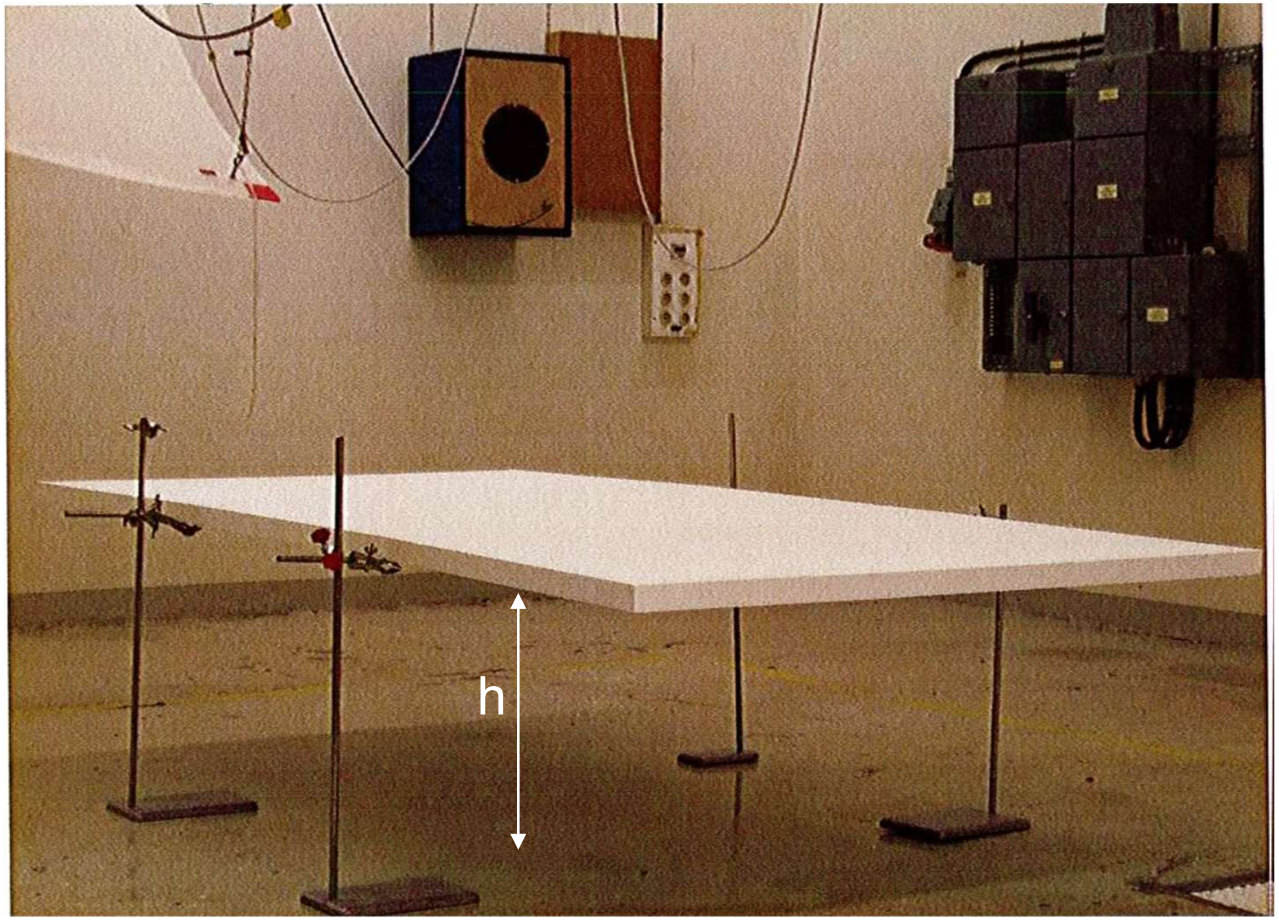


Reverberation chamber

$$A = 0.16V\left(\frac{1}{T_{with}} - \frac{1}{T_{without}}\right)$$

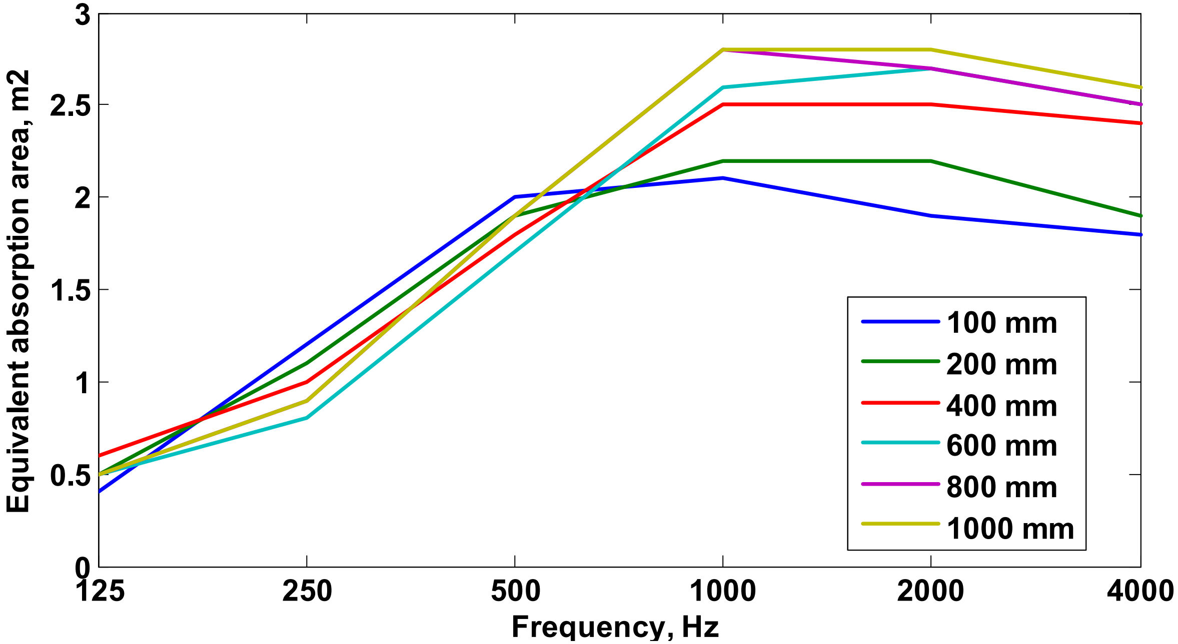
$$A_{FHU} = A/6$$

Master Solo S (2400x1200)



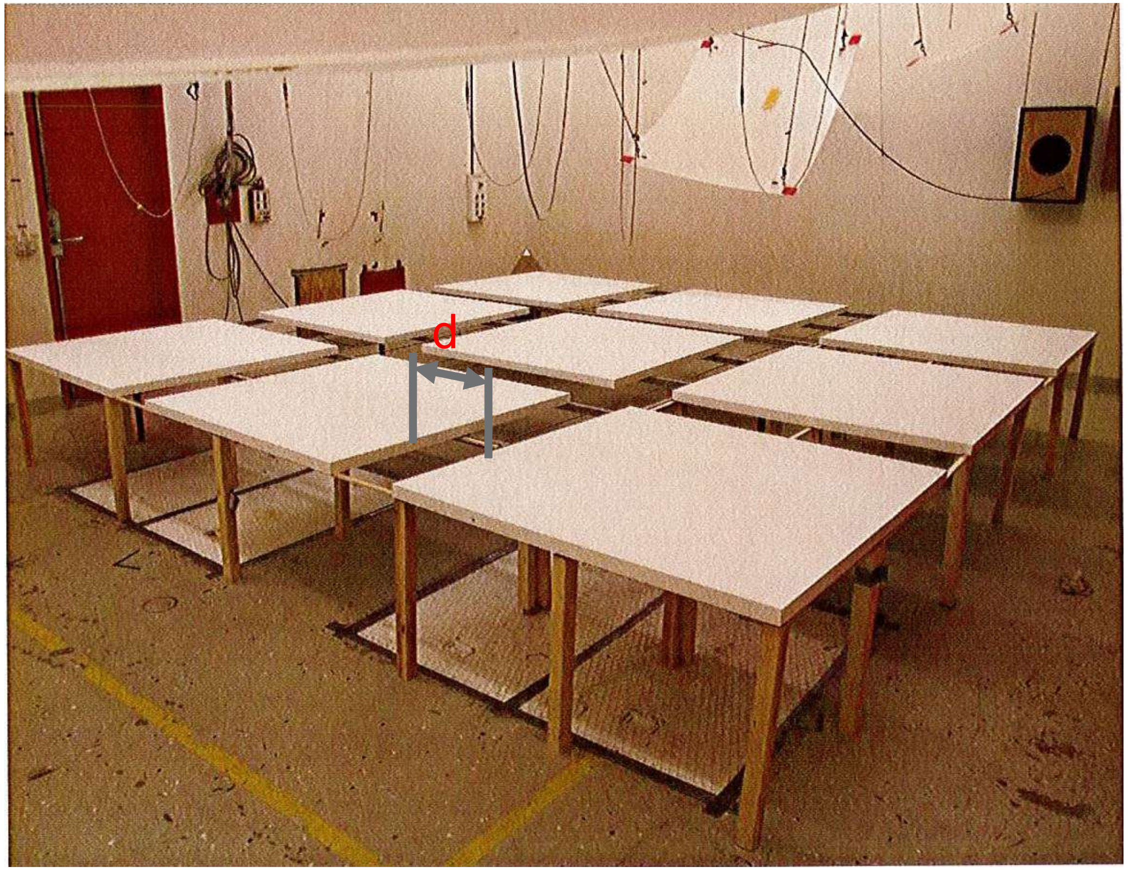
Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Master Solo S (1200x1200), single unit for various o.d.s.

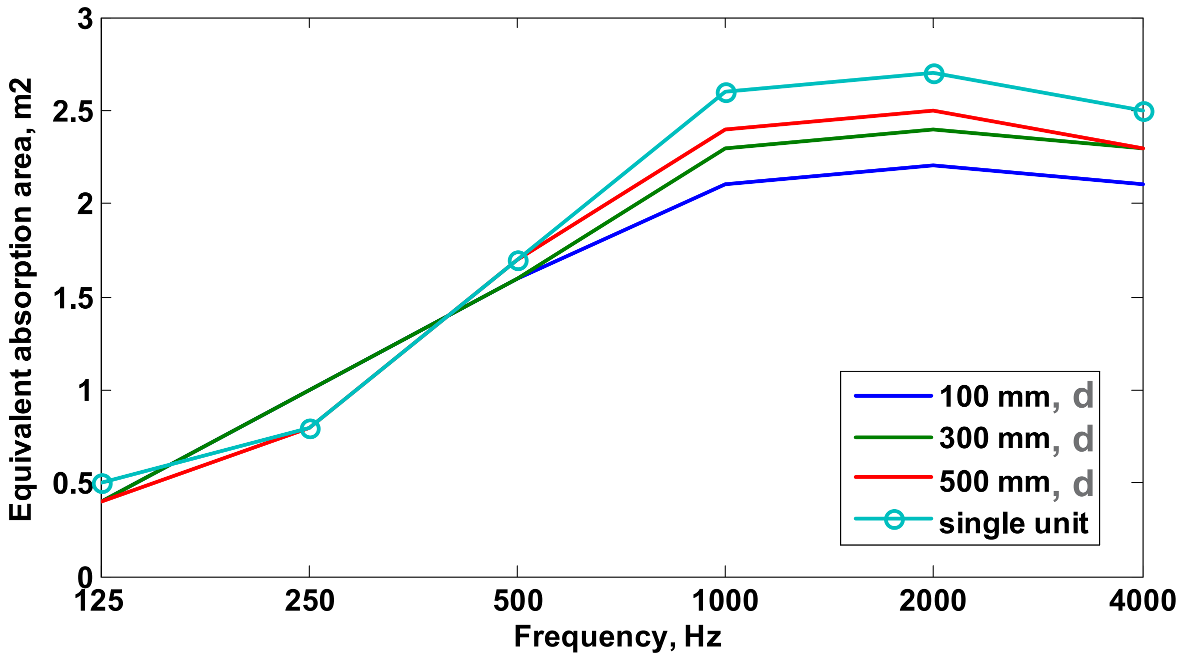


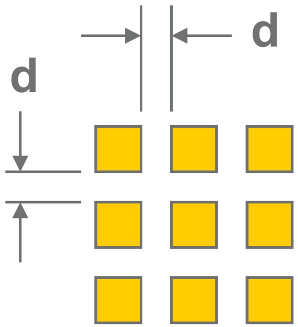
Ecophon SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Array of Master Solo S (1200x1200)



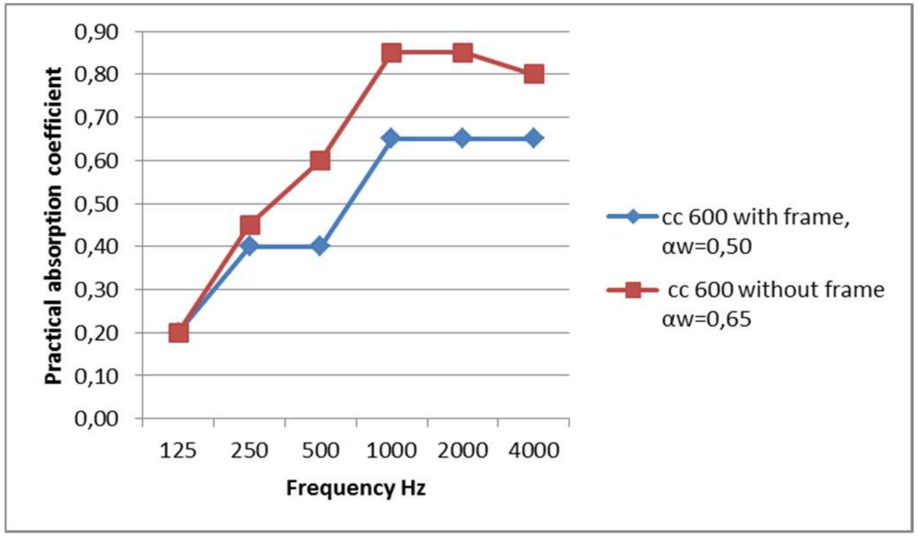
Master Solo S, array with 9 panels 1200 x 1200, 600 mm o.d.s., for various distances d





Solo Baffle: Laboratory measurements (see knowledge guide Solo™ Baffle - Acoustics

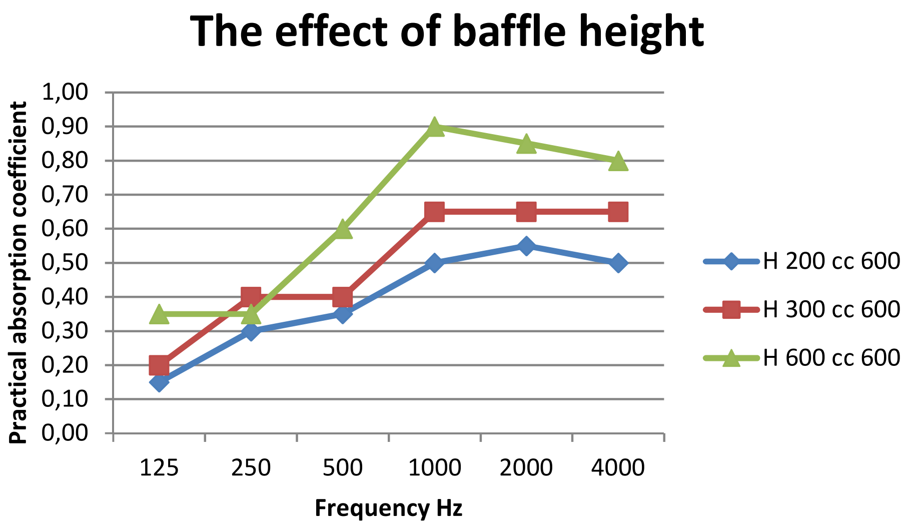
Laboratory measurements of baffles



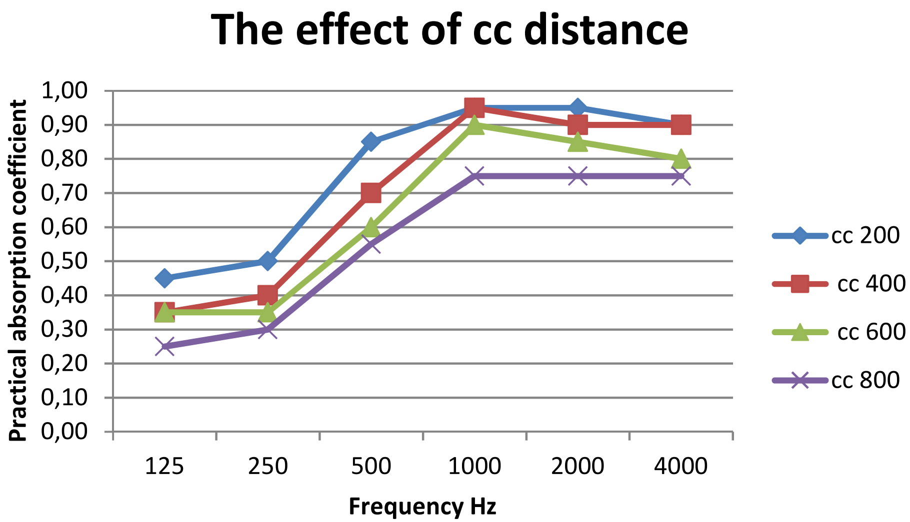
Ecophon SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

The effect of baffle height and the distance between baffles



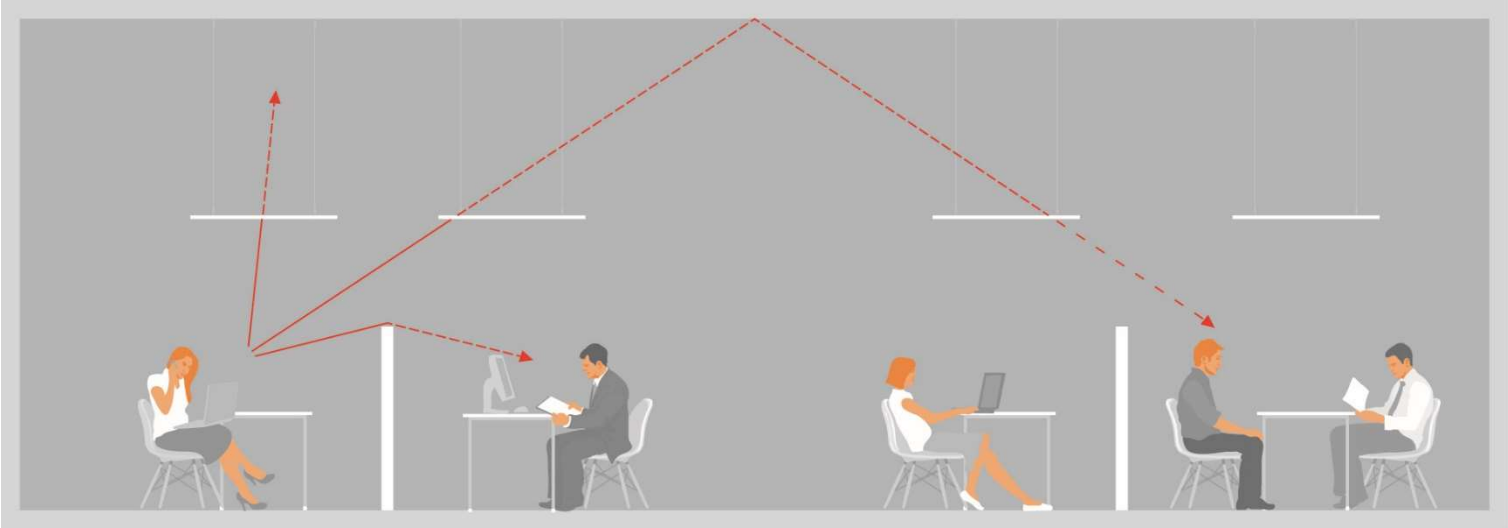
Practical absorption coefficient for Solo Baffle with heights 200, 300 and 600 mm at cc distance 600 mm



Practical absorption coefficient for Solo Baffle 1200 x 600 x 40 at cc distances 200, 400, 600 and 800 mm

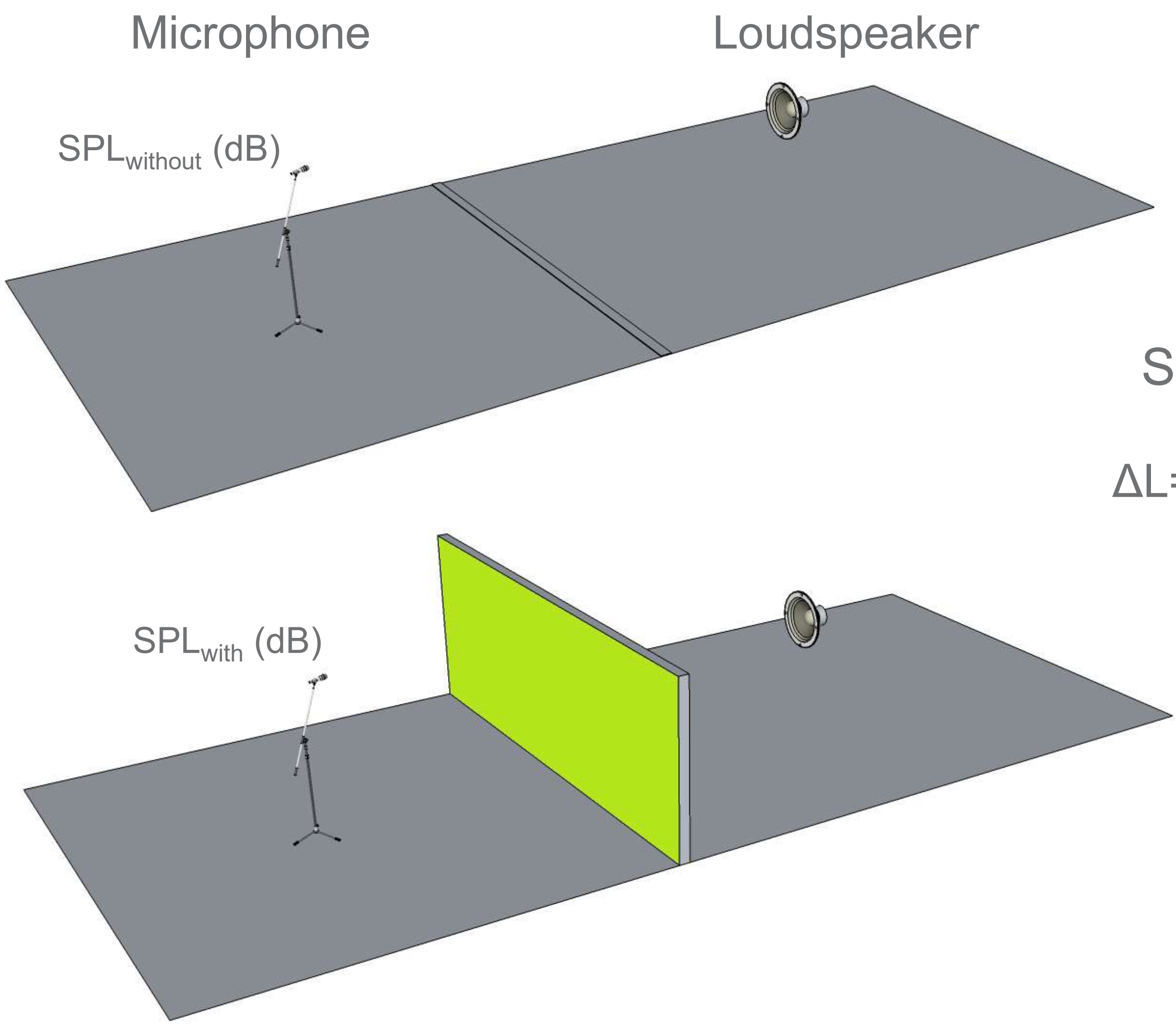
Ecophon® SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

Speech privacy between workplaces in an open plan office



Screens in an open-plan office

Screen attenuation (ISO 10053:1991)



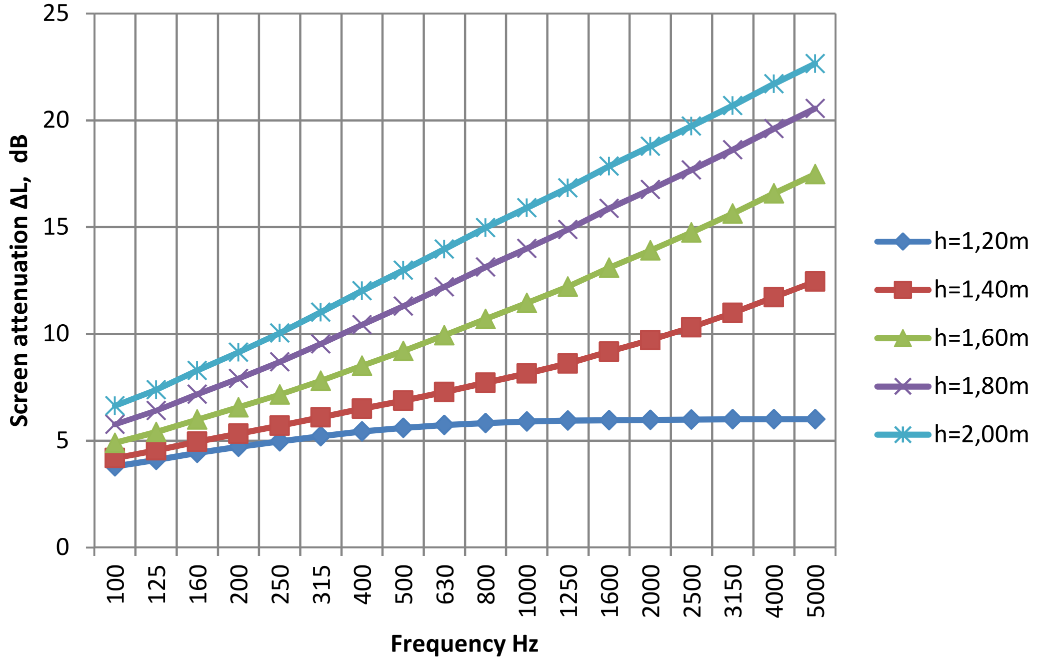
Screen attenuation ΔL

$$\Delta L = SPL_{without} - SPL_{with} \text{ (dB)}$$

Ecophon SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

Screen attenuation and it's dependence of screen height. Calculated values for outdoor conditions



Ecophon® SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE