Knowledge Guide

Sound absorption – free-hanging units vs. full ceiling

Ecophon®
SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

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1. Standards

For most of our products, the sound absorbing properties are evaluated by two standards: ISO 354 and ISO 11654. ISO 354 is the basic method where the absorption is measured in a reverberation room. This standard describes methods for measuring plane absorbers like our ceilings as well as methods for specifying the absorption of single objects like our SOLO panels. The standard also describes how to measure on baffles.

ISO 11654 gives further information on how to simplify the absorption data measured by ISO 354. The methods are intended for absorbent ceilings and not single objects like free-hanging units. ISO 11654 shows how to transform the third octave band absorption coefficients given by ISO 354 into octave bands and a “practical absorption coefficient” α_p. On the basis of the practical absorption coefficients, a weighted absorption coefficient α_w can be calculated. The single value index α_w is calculated through comparison of the practical absorption coefficients with a reference curve. Based on the α_w value, the absorbers can be classified into classes from A to E were A corresponds to products with an α_w larger or equal to 0.90.

The outcomes of the standards are

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

2. Room method for measuring sound absorption

The basis for measuring sound absorption is Sabine's[1] formula, which was discovered at the beginning of the 20th century. It gives a relation between reverberation time in seconds, the room volume in cubic metres and the equivalent absorption area in square metres. To distinguish the unit for the equivalent absorption area from the area of a surface, it is given the extension sabin (small caps, no e), in honour of the inventor. The meaning of reverberation time and equivalent absorption area will be discussed below.

The Sabine equation is given by

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1 Wallace Clement Sabine (June 13, 1868 – January 10, 1919) American physicist who founded the field of architectural acoustics.

T=0,16V/A (1)

Where T is the reverberation time in seconds (s), V is the room volume in cubic metres (m^3) and A is the equivalent absorption area in square metre sabin (m^2 sabin). The reverberation time is defined as the time it takes for the sound pressure level to decrease 60 dB after the sound source has been shut off. Normally the reverberation time is measured and evaluated for different frequencies. Often the reverberation time is given for the octave bands 125 to 4000 Hz.

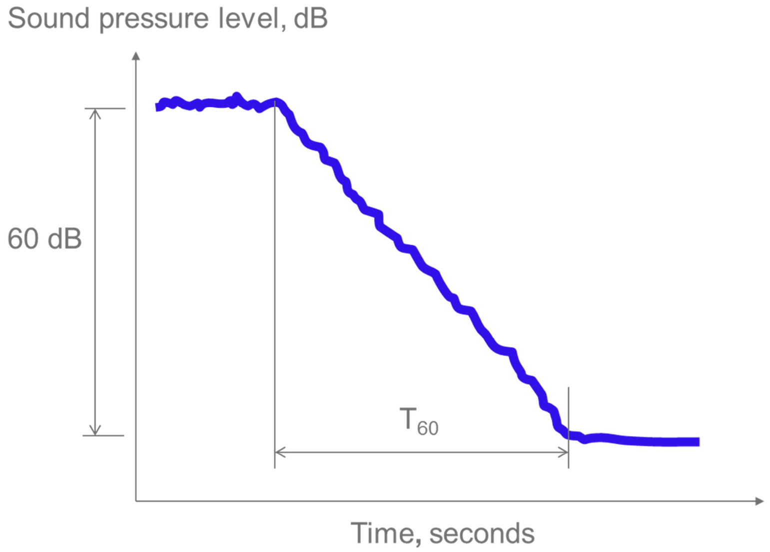
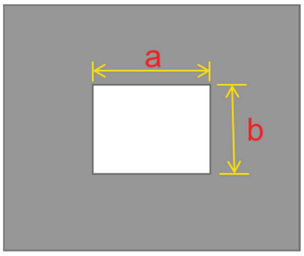


Figure 1. Definition of reverberation time

For a plane absorber, the equivalent absorption area is given by the absorption coefficient times the area of the plane absorber, i.e. A=α·S where α is the absorption coefficient and S is the area of the plane absorber. If the absorption coefficient is 1.0, the equivalent absorption area is equal to the area of the plane absorber. Sometimes the equivalent absorption area is called “open window” area. The reason for this is that a plane absorber with an area S and an absorption coefficient of α will absorb the same amount of sound energy as an open window with the area A=α·S. It is assumed that an open window has an absorption coefficient of 1.0.

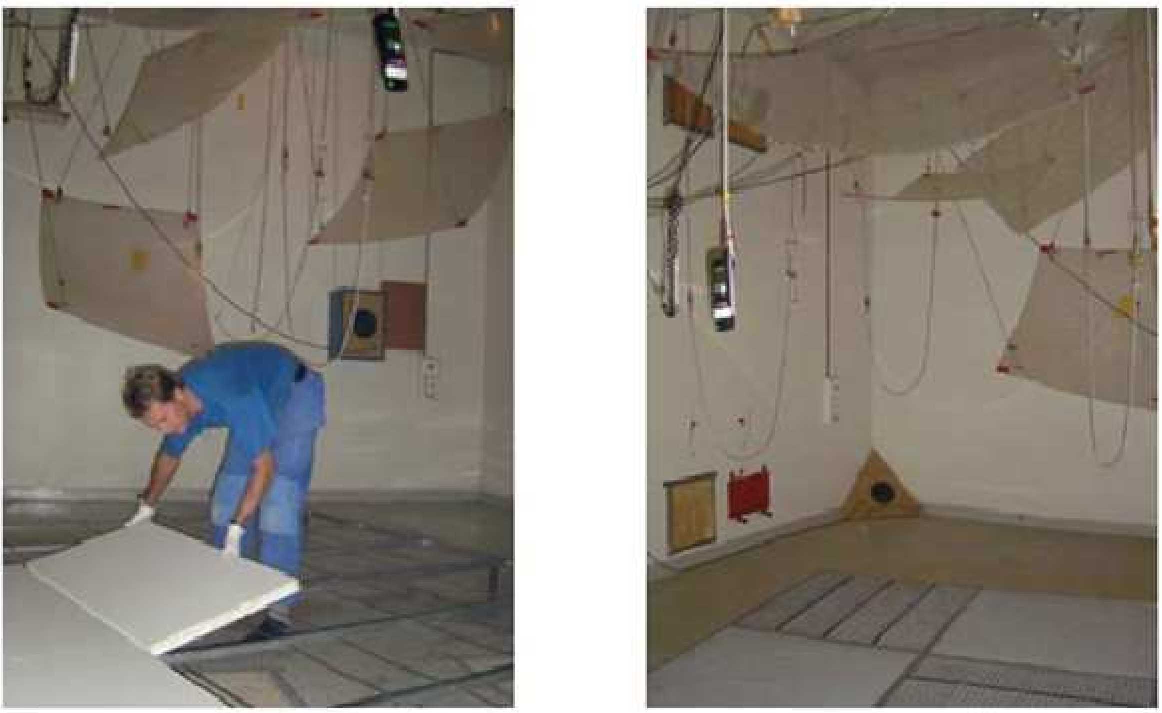
Example: An absorbing wall panel with the area 2.7 x 1.2=3.24 m2 has an absorption coefficient of 0.70 at 250 Hz. The equivalent absorption area at 250 Hz is then A =.70 x 3.24=2.27 m2 sabin. Using the open window allegory, this means that an open window (α=1.0) with an area of 2.27 m2 absorbs the same amount of sound energy as the wall panel with an area of 3.24 m2 and an absorption coefficient of 0.70.



“Open window”
A=S=a x b

Figure 2. The equivalent absorption area for an open window (α=1.0) is equal to the area of the window.

The Sabine formula assumes that the sound field in the room is diffuse. A diffuse sound field means, roughly speaking, that the same amount of sound energy is propagating in all directions. To create this condition, you normally need a room with highly reflecting walls and many sound diffusing objects. A reverberation room, see figure 3, is constructed for creating a diffuse sound field. These types of rooms are used for measuring the absorbing efficiency of different types of absorbers.



If the absorber has a well-defined surface which is exposed to sound, like for instance our ceiling absorbers, an absorption coefficient can be calculated given by the equivalent absorption area divided by the area of the panel surface that is exposed to sound. The absorption coefficient is given by

$\alpha = A_{abs}/S$

S is the area of the absorbing sample.

If the absorber is small or does not have a well-defined surface that is exposed to sound, it is not relevant or possible to calculate the absorption coefficient. However, we can still use the equivalent absorption area for quantifying the absorbing efficiency. This is a very useful and important property of the Sabine equation meaning that even for non-planar objects like furniture, people etc., the absorbing efficiency can be quantified by the equivalent absorption area.

Normally, when measuring the absorption coefficient of an absorbent ceiling, this is performed at a certain construction height. When measuring at different overall depths of system (o.d.s.), the panels are surrounded with a frame with a height equal to the o.d.s., see figure 4. The o.d.s. is defined as the distance between the floor and the upper side of the panel that is exposed to sound. Using the frame, only one side of the panel is directly exposed to sound. For normal sized reverberation rooms (V≈200 m3), the test sample should have an area between 10 m^2 and 12 m^2.

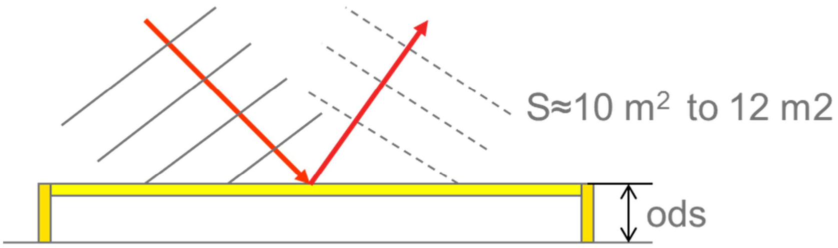


Figure 4. Mounting condition for measurements of absorption coefficients in a reverberation room.

When measuring on smaller units that are more or less exposed to sound all over, like for instance our Solo products, it is not appropriate to use an absorption coefficient since there is no well-defined surface exposed to sound. Depending on the distance between the floor and the panel, more or less of the rear part of the panel are exposed to sound, see figure 5. Those types of absorbers are sometimes referred to as volume absorbers. However, using the Sabine equation we don't need to define the surface area; instead we use the equivalent absorption area to quantify the absorbing efficiency.

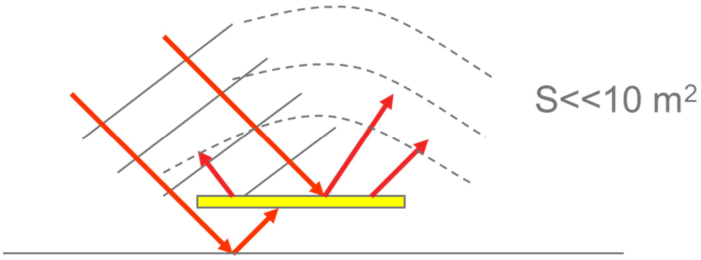


Figure 5. Equivalent absorption area is used to quantify the absorption of volume absorbers.

When measuring the equivalent absorption area for free-hanging units in a reverberation room, it is normally necessary to measure on several samples at the same time. This is due to the requirements in ISO 354 stating that the equivalent absorption area in the room must be larger than 1 m^2 sabin but less than 12 m^2 sabin. Normally, it is the low absorbing efficiency at low frequencies that determines the number of samples. Another constraint is that the samples must be located at least 2 m apart.

Sometimes it could be difficult to fulfil both demands. As an example, if the equivalent absorption area, A_{tot}, is measured for three samples, the equivalent absorption area per sample is given by $A_{sample}=A_{tot}/3$.

3. Sound absorbing free-hanging units

The use of free-hanging units provides flexibility and a multitude of acoustical solutions to acoustical design. Free-hanging units can be an efficient way to add absorption into a room. Free-hanging units have the benefit that the sound is distributed around the panels, and thus a larger area of the absorber is exposed to the sound field.

In large, noisy environments such as open-plan areas, restaurants, shopping centres etc., free-hanging units can be installed close to working areas or other locations where acoustical treatment is needed in order to achieve suitable conditions for communication, concentration or recovery. Free-hanging units contribute to creating specific, localised sound environments inside large premises, such as for instance reception and information counters or refreshment areas within larger, noisy spaces.

In premises where, for some reason, an overall ceiling cannot be used, e.g. where temperature is regulated via concrete slabs (thermally activated building systems, TABS) or where there are large areas of glass, absorbent islands is one way of creating good acoustic environments. The free-hanging units can be designed as horizontally suspended units or as baffles.

Absorbing free-hanging units can also be used in environments where absorbing ceilings do not provide sufficient absorption. By supplementing with suspended horizontal absorbers or baffles, the acoustic environment can be improved with a reduction of the sound level and a diminishing of sound propagation in the room.

The subjective effects of using free-hanging absorbing units include:

Increased speech and listening comfort

Reduced stress and stress-related symptoms

Less vocal effort

Easier to concentrate

Around a free-hanging unit, the acoustical effect is manifested as:

Reduced sound propagation

Noise reduction in the vicinity of free-hanging units

Increased directional hearing

Increased speech clarity

Shorter reverberation time

In open-plan spaces, free-hanging units can be used as a complement to wall-to-wall acoustical ceilings. Installing free-hanging units above workplaces will, in addition to the effects listed above, reduce sound propagation across large distances and contribute to increased privacy between working groups.

Note: **From an acoustical point of view, a complete wall-to-wall ceiling is generally a more efficient solution than free-hanging units. This is especially emphasized at low frequencies. The absorption of sound at low frequencies is very important in educational premises.**

4. Acoustic design with free-hanging units

Room Acoustic Comfort (RAC) is a concept developed by Ecophon. It is an approach for room acoustic design that aims to optimise the outcome of the activities performed by the people in a room.

The quality of the sound environment depends on subjective experience and should include the use of the following acoustic qualities:

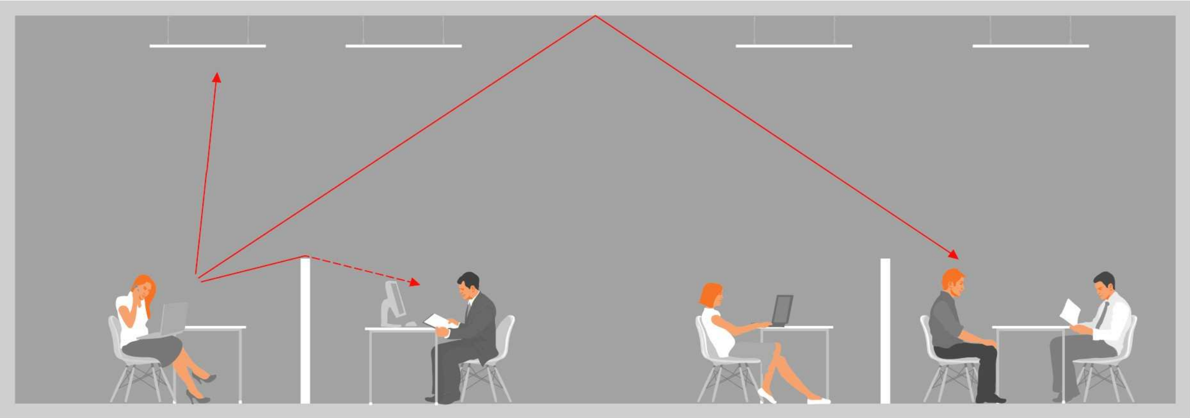
- Auditory strength
- Speech clarity
- Sound propagation (spatial decay)
- Reverberance

The RAC concept supports different phases in a building project and can be used to understand how people are influenced by the sound environment, specify the relevant room acoustic descriptors and choose the right acoustic solution for each room type. For further information, see the RAC content on **www.ecophon.com**.

Below are a few rules of thumb and comments related to acoustic design with Ecophon Solo.

- In cases where free-hanging units are used as solitary islands above workplaces, the absorbers should be installed as close to the workplace as possible, thus shielding from diffuse background noise as much as possible. The free-hanging units should cover the working area, preferably with a slight overlap.
- When using free-hanging units as a complement to a wall-to-wall acoustical ceiling, it is often better to split the free-hanging units into smaller patches and distribute them over the total ceiling area than concentrate the units to a certain part of the ceiling. Division into smaller patches such as Ecophon Solo will contribute to a more diffuse sound field, which is generally perceived as a positive acoustic quality.
- If a workplace is located near reflecting walls, the recommendation is to use wall absorbers as a complement to the Ecophon Solo free-hanging units.
- Free-hanging units close to a workplace increase the ability to localise sound sources in the vicinity of the workplace. This will increase the sensation of control and create a less stress-inducing environment.

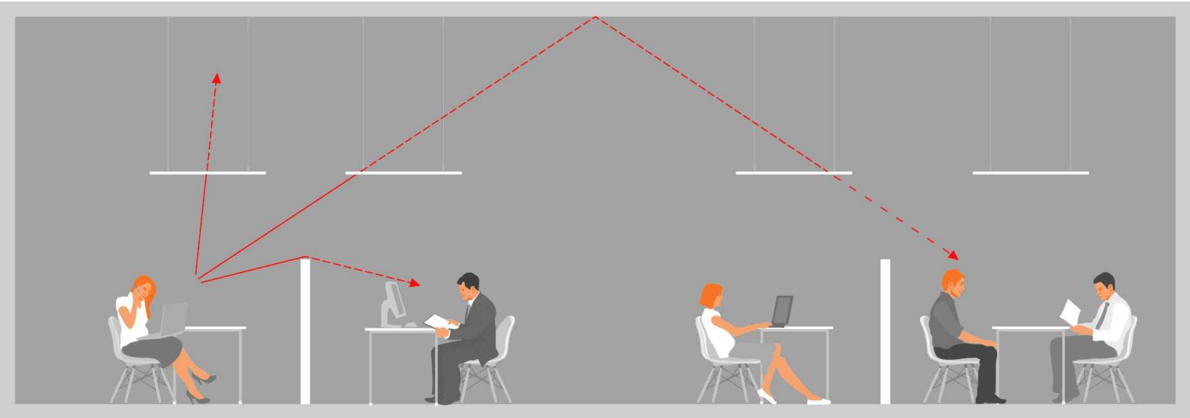
High installation



The installation of free-hanging units can significantly improve the acoustic conditions in reverberant rooms. The improvement depends on the number of units as well as on the placement of the panels.

If the free-hanging units are mounted in an array (cluster), the absorption area for each free-hanging unit will depend on the distance between the units. Putting the panels very close to each other will somewhat decrease the absorption area per unit. At distances of approximately 500 mm or more between the units in an array, the absorption area per unit will correspond to a single unit and there will be no reducing effect due to the array mounting

Low installation



Ecophon Solo to solve acoustic challenges:

The use of Ecophon Solo free-hanging units can solve or support situations

- that do not allow for a complete wall-to-wall ceiling installation
- where absorption from the existing ceilings is insufficient.

Examples of this include:

1. The use of thermally activated building systems (TABS)

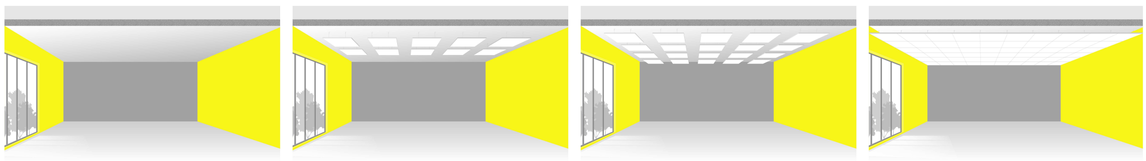
2. Prevention of sound propagation in open-plan spaces

3. Locally improved acoustics, e.g. in reception areas

4. Atriums with large glass areas

To illustrate the effect of Ecophon Solo's different covering ranges, the effect on different room acoustic parameters has been calculated. The calculations are based on the assumption of a diffuse sound field in the room. This means that to reach the values in the table below, a sufficient amount of sound spreading furniture or other equipment in the room is necessary. Most ordinary rooms do not contain enough sound diffusing interior details to establish a diffuse sound field. The values in the table should therefore be regarded as a rough guide. Observe that the values in the table refer to an average of the mid frequencies 500 and 1000 Hz.

A wall-to-wall ceiling is advantageous, especially with regard to absorption at low frequencies. Ecophon Wall Panels are recommended as a complement to free-hanging units.



Empty room | 30% coverage | 60% coverage | Full ceiling

Ceiling	No ceiling Exposed structure	Ecophon Solo 30% coverage of ceiling area	Ecophon Solo 60% coverage of ceiling area	Full ceiling Master A/alpha
		41 pieces 1200 x 1200 or 20 pieces 1200 x 2400	83 pieces 1200x1200 or 41 pieces 1200 x 2400	
Reverberation time	3.0 s	0.9 s	0.6 s	0.5 s
Speech Clarity (Definition)	21%	54%	68%	75%
Noise reduction in room	ref	- 5 dB	- 6 dB	- 8 dB

The table shows the effect of different covering with Ecophon Solo products compared to a full ceiling. The values in the table refer to an average of the mid frequencies 500 Hz and 1000 Hz. The volume of the room is height x width x length = 4m x 10m x 20m. Note that depending on room type and the activity taking place in the room, some parameters will be of more importance than others.

5. Free-hanging units versus full ceiling

A wall-to-wall ceiling is normally more beneficial than free-hanging units when it comes to acoustical efficiency. This is especially true when it comes to absorption at low frequencies. This is shown in the figure below for a typical classroom with a ceiling area of 57 m^2. A full ceiling with Ecophon Master A with a mounting height (o.d.s.) of 200 mm is compared with Ecophon Solo (size 1200 mm x 2400 mm) and a mounting height of 400 mm covering 60 per cent of the ceiling area.

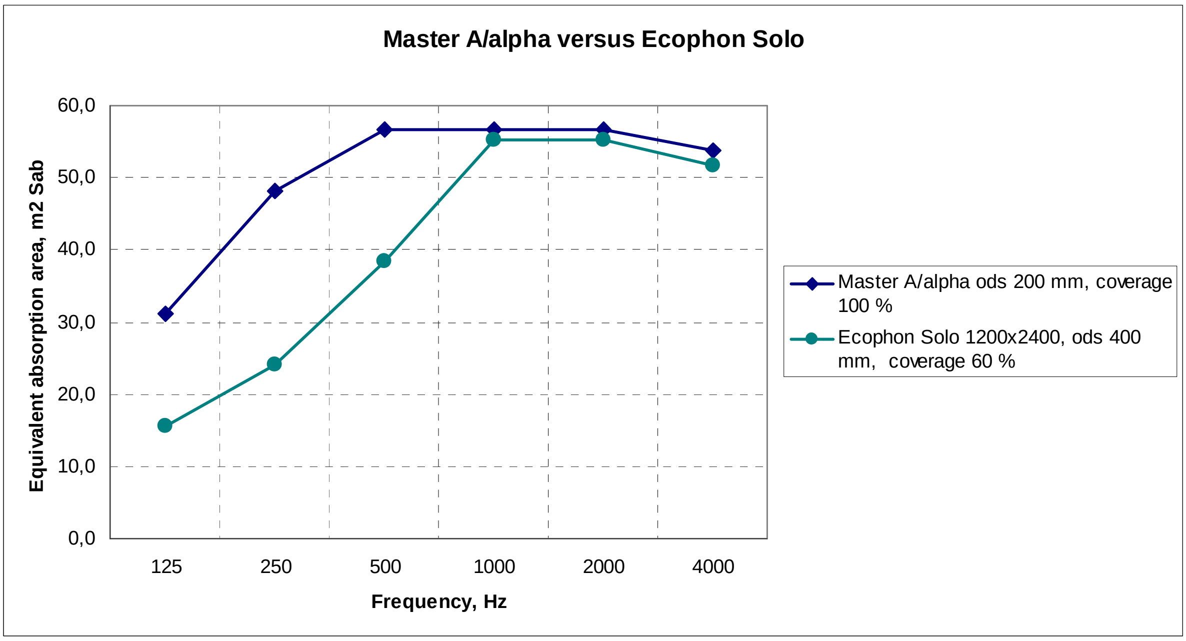


Figure 6. Solo versus full ceiling

6. Sound absorption and different shape of Ecophon Solo

The procedure used for the acoustic characterization of Ecophon Solo and similar free-hanging units differs from the one used for planar acoustic ceilings. The practical absorption coefficient commonly used for wall-to-wall ceilings is not appropriate for characterization of the absorbing efficiency of free-hanging units. The main reasons for this are:

- All surfaces of an Ecophon Solo unit are more or less exposed to sound. Since it is difficult to determine to what degree different surfaces are exposed to sound, it is not evident how to define the exposed area. To calculate a practical absorption coefficient, it is necessary to be able to determine the area exposed to sound. This is easy for a planar absorbent ceiling since only one side is exposed to sound incidence.

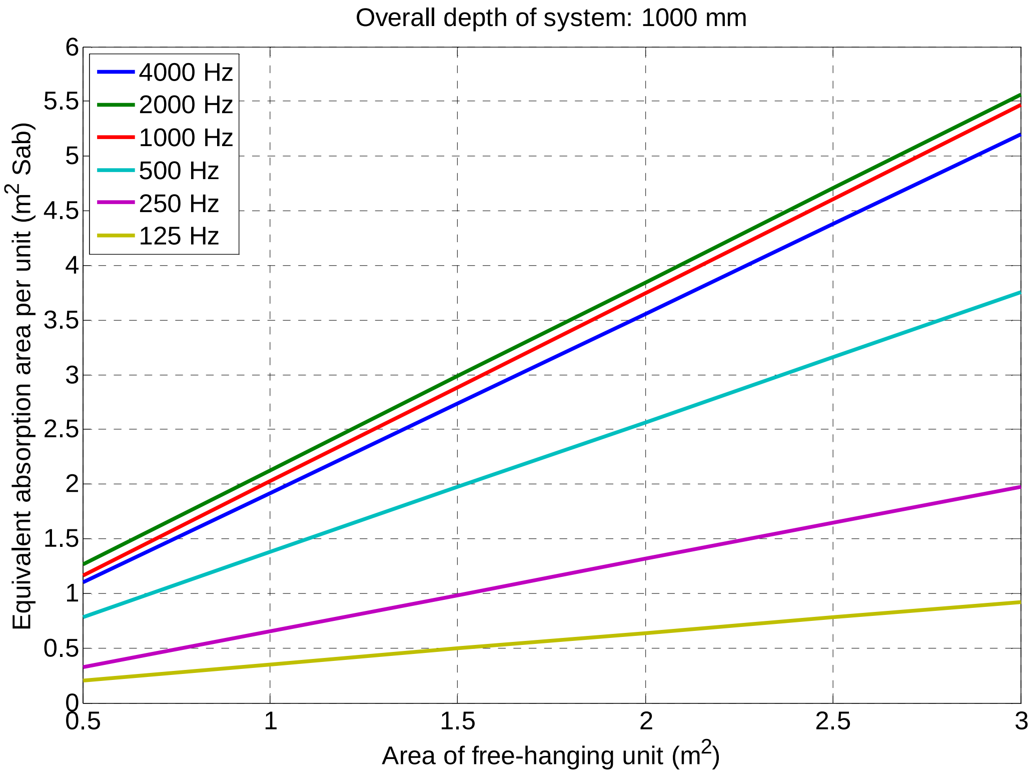
- The Ecophon Solo units exist for a large range of sizes and shapes. Normally the sizes of free-hanging units are small compared to acoustic ceilings, and this causes diffraction ("bending of sound waves"), a phenomenon that makes the use of a practical absorption coefficient inappropriate. The absorbing efficiency of the free-hanging unit will depend on the area and to some degree of the shape of the tiles. This is not the case for planar absorbent ceilings, which are specified by the absorption coefficient that are assumed independent of the ceiling area.

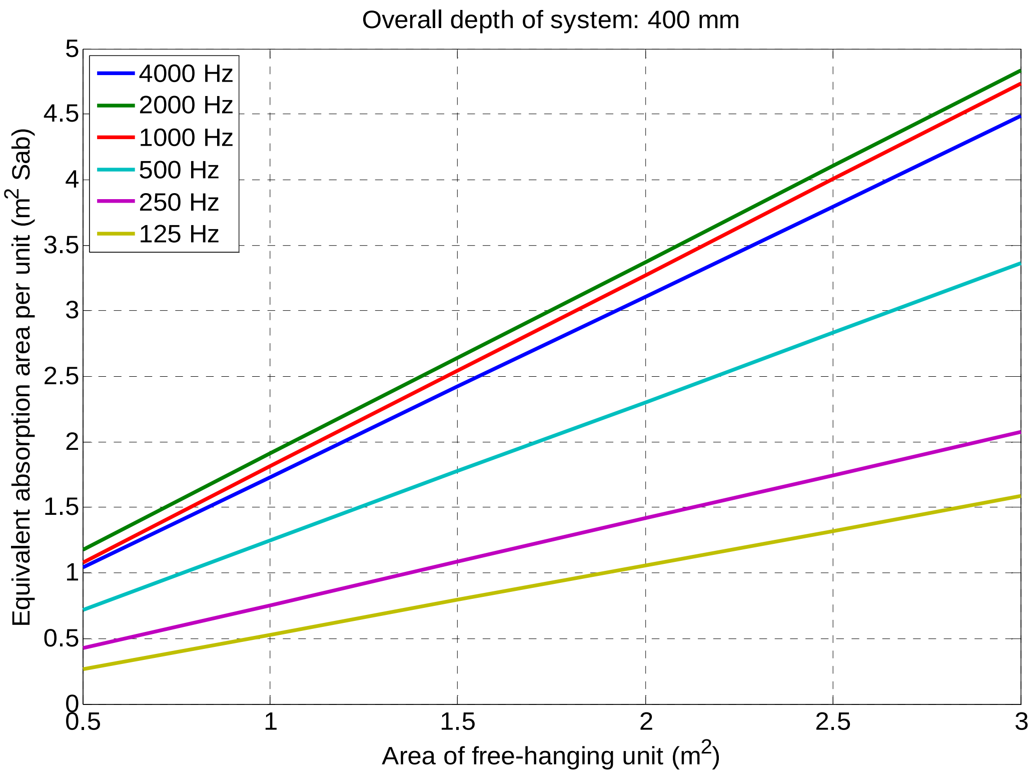
According to ISO 354, the absorbing efficiency of discrete objects like Ecophon Solo is characterized by the equivalent absorption area denoted A. The unit is m^2 sabin.

Normally, the equivalent absorption area for free-hanging units is given for octave bands from 125 Hz to 4000 Hz.

Some general statements regarding acoustic behaviour can be determined for Ecophon's range of free-hanging products. The absorption area of an Ecophon Solo unit depends on the distance between the ceiling and the unit. Increasing the distance between the ceiling and the Ecophon Solo unit will normally increase the absorption area at medium and high frequencies, i.e. between 500 Hz and 4000 Hz. At a certain distance, approximately 1 metre, there is no additional effect of increased distance and the maximum absorption area is reached.

Besides the distance from the ceiling, the absorption area is mainly dependent on the size of the free-hanging unit. The shape is generally of minor importance. The diagrams below show an estimated relation between the panel area and the equivalent absorption area for different mounting heights.


Overall depth of system: 1000 mm
Equivalent absorption area per unit (m2 Sab)
Area of free-hanging unit (m2)
4000 Hz
2000 Hz
1000 Hz
500 Hz
250 Hz
125 Hz
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
0.5
1
1.5
2
2.5
3


Overall depth of system: 400 mm
Equivalent absorption area per unit (m2 Sab)
Area of free-hanging unit (m2)
4000 Hz
2000 Hz
1000 Hz
500 Hz
250 Hz
125 Hz
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0.5
1
1.5
2
2.5
3

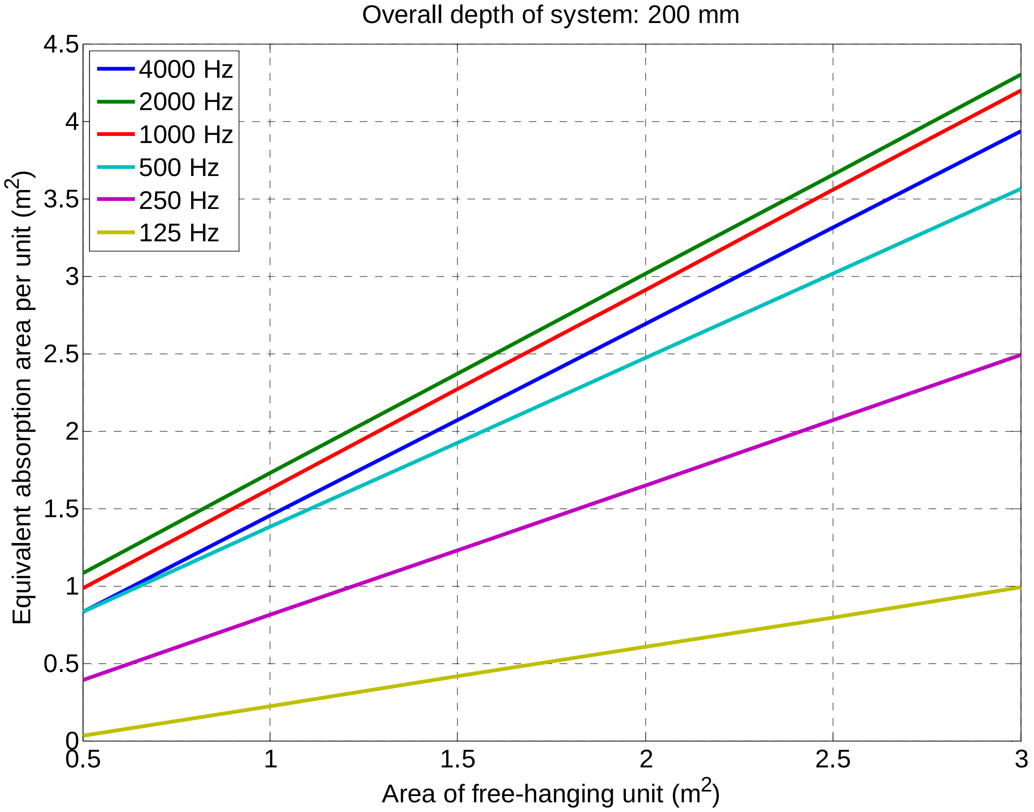


Figure 7. Equivalent absorption area as a function of panel area and for different system depths.

Example 1:

Estimate the equivalent absorption area per unit for an Ecophon Solo panel with an area of 2 m^2 and an overall depth of 1 metre.

The top figure gives the following result:

Frequency	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
A, m^2 Sab	0.6	1.3	2.6	3.8	3.9	3.6

7. Simplified approach for acoustic design with Ecophon Solo

To simplify the acoustical design with Ecophon Solo products, the equivalent absorption area per unit for the regular shapes in the Ecophon offer has been calculated. The equivalent absorption areas per unit in octave bands are given in table 1.

Table 1.

Product	Size (mm)	O.d.s. (mm)	Area (m^2)	Equivalent absorption area per unit (m^2 sabin)					
				125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Ecophon Solo™ Square	800 x 800	200	0.64	0	0.5	0.9	1.2	1.2	1
		400		0.1	0.5	0.8	1.3	1.3	1.2
		1000		0.3	0.4	0.9	1.4	1.4	1.3
	1200 x 1200	200	1.44	0.5	1.1	1.9	2.2	2.2	1.9
		400		0.6	1	1.8	2.5	2.5	2.4
		1000		0.5	0.9	1.9	2.8	2.8	2.6
Ecophon Solo™ Rectangle	2400 x 1200	200	2.88	0.9	2.4	3.4	4	4.1	3.8
		400		1.3	2	3.2	4.6	4.6	4.3
		1000		0.9	1.9	3.6	5.3	5.3	5
Ecophon Solo™ Circle	ø 800	200	0.50	0.0	0.4	0.8	1.0	1.0	0.8
		400		0.1	0.4	0.7	1.1	1.1	1.0
		1000		0.2	0.3	0.8	1.2	1.2	1.1
	ø 1200	200	1.13	0.3	1	1.6	1.9	1.9	1.6
		400		0.4	0.9	1.4	2.1	2.1	1.9
		1000		0.3	0.8	1.5	2.3	2.3	2.1
Ecophon Solo™ Circle XL	ø 1600	200	2.01	1.1	1.8	2.5	3.0	3.0	2.8
		400		0.9	1.5	2.3	3.3	3.4	3.4
		1000		0.6	1.5	2.5	3.8	3.9	3.8
Ecophon Solo™ Ellipse	2400 x 1000	200	1.89	0.6	1.6	2.4	2.8	2.8	2.6
		400		0.8	1.3	2.2	3.2	3.2	3.0
		1000		0.6	1.2	2.4	3.6	3.6	3.4
Ecophon Solo™ Octagon	1200 x 1200	200	1.19	0.3	1.0	1.6	1.9	1.9	1.7
		400		0.4	0.9	1.5	2.1	2.1	2.0
		1000		0.4	0.8	1.6	2.4	2.4	2.2
Ecophon Solo™ Heptagon	1168 x 1198	200	1.03	0.2	0.8	1.4	1.7	1.7	1.5
		400		0.3	0.8	1.3	1.9	1.9	1.8
		1000		0.4	0.7	1.4	2.1	2.1	2.0
Ecophon Solo™ Hexagon	1040 x 1200	200	0.94	0.2	0.8	1.3	1.6	1.6	1.4
		400		0.3	0.7	1.2	1.8	1.8	1.6
		1000		0.3	0.6	1.3	2.0	2.0	1.8
Ecophon Solo™ Pentagon	1139 x 1198	200	0.94	0.2	0.8	1.3	1.6	1.6	1.4
		400		0.3	0.7	1.2	1.8	1.8	1.7
		1000		0.3	0.6	1.3	2.0	2.0	1.8
Ecophon Solo™	1039 x 1200	200	0.62	0.1	0.5	1.0	1.2	1.2	1.0

Triangle	400	0.1	0.5	0.9	1.3	1.3	1.2
	1000	0.2	0.4	0.9	1.4	1.4	1.3

The following examples show how the data in table 1 can be used for estimating the number of Solo panels needed to fulfil a certain required reverberation time or amount of equivalent absorption area.

Example 2:

The required reverberation time in an open-plan offices is an average of 0.5 s for octave band frequencies 500 and 1000 Hz. The volume of the empty office is 2.7m x 7.5m x 17.7m=358 m^3 and the ceiling area is 133 m^2. The reverberation time for the mid frequencies 500 and 1000 Hz is 2 s in the empty office.

Since the ceiling is part of the thermal system (TABS) in the building, it is not permitted to completely cover the ceiling with an absorbent suspended ceiling. Instead a solution with Solo Square (1200 x 1200) with a mounting height (o.d.s.) of 200 mm must be used.

Question: How many Solo Square (1200x1200) panels are needed to fulfil the requirements for reverberation time?

Solution: The equivalent absorption area needed to reach the reverberation time of 0.5 s is given by Sabine's formula A=0.16V/T. With the volume V= 358 m^2 and the reverberation time T= 0.5 s, we get

A=0.16*358/0.5=115 m^2 sabin. The equivalent absorption area of the empty room is A_0=0.16*358/2=29 m^2 sabin. Thus, there is a lack of 115-29=86 m^2 sabin.

From table 1, we calculate the average equivalent absorption area for the octave bands 500 and 1000 Hz for Solo Square (1200x1200). The result for an o.d.s. of 200 mm is 2.1 m^2 sabin per unit.

The number of Solo Square panels required to add 86 m^2 sabin to the room is 86/2.1=41 panels. This corresponds to a coverage range of 41x1.44/133=44%.

Example 3:

Ecophon recommends a 60 per cent coverage with Solos in connection with TABS. Compared to a full wall-to-wall ceiling, Solo products are less efficient at low frequencies. A coverage range of 60 per cent is recommended, and the need of wall panels or screens should be considered.

Question: What reverberation time can we expect using 60 per cent Solo Square (1200x1200)?

Solution: 60 per cent of the ceiling area corresponds to 80 m^2. The amount of Solo Square panels needed to cover 60 per cent of the ceiling is 80/1.44=56. The equivalent absorption area for the panels is 56x2.1=118 m^2 sabin. The total equivalent absorption area in the room is 29+118=147 m^2 sabin, where 29 m^2 refers to an empty room. The corresponding reverberation time is 0.16x358/147=0.39 s.

Example 4:

Sometimes the requirements of absorption in open-plan offices is given as A=1.1 x floor area at frequencies 500 to 4000 Hz.

Question: How many Solo Square (1200x1200) panels with are needed to fulfil the requirements and what will the coverage range be?

Solution: The required amount of absorption is 1.1x133=146 m^2 sabin. The average equivalent absorption area per unit over the frequencies 500 to 4000 Hz is 2.1 according to table 1. The number of panels needed is 146/2.1=70 and the coverage range is 70x1.44/133=76%. The coverage range is larger than what Ecophon recommends in accordance with TABS. It is therefore advisable to reduce the number of panels to a 60 per cent coverage range and add extra absorption using wall panels and/or absorbing screens.

Note 1: Calculation with Sabine formula assumes that of the rooms contain a large number of sound diffusing objects. In practice, and especially in open-plan offices, there are normally quite large deviations between measured and calculated reverberation times according to the Sabine formula.

8. Specifying the absorption for Master Matrix

Master Matrix can appear in different shapes and configurations, see figure 8. If used as a full coverage ceiling or as small free-hanging units, this is no problem. In such cases, we stick to our normal convention and use the absorption coefficient for full ceiling and the equivalent absorption area per unit for the free-hanging units. However, the question arises how to handle all intermediate cases where Master Matrix is applied in large clusters.

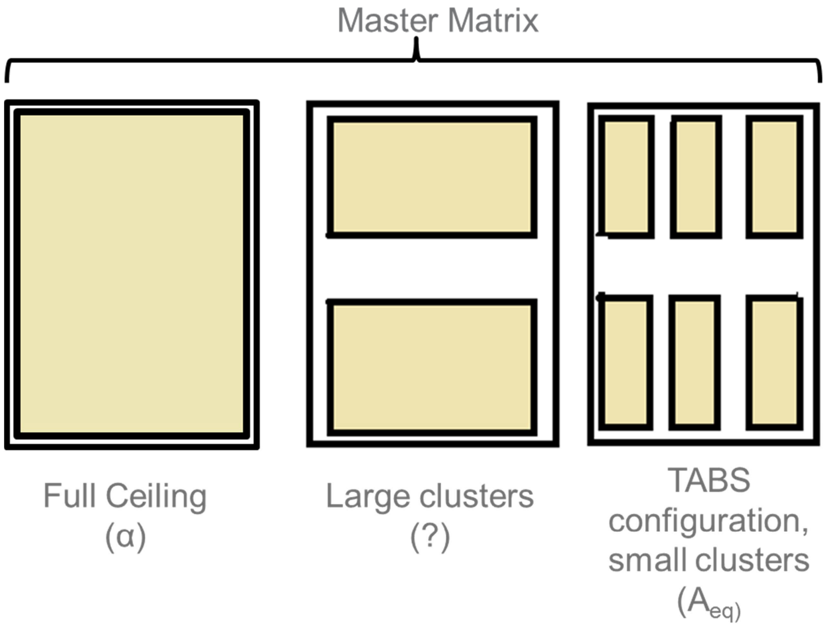


Figure 8. Master Matrix in different configurations

When measuring the absorption coefficient for an absorbent ceiling according to ISO 354, a sample of approximately 10 m^2 is tested. Thus, it is assumed that a sample of 10 m^2 represents the full ceiling. Samples much smaller than 10 m^2 generally need to be considered as single objects, and the absorption is characterized by the equivalent absorption area.

In this respect, it is reasonable to consider 10 m^2 as a limit separating large and small clusters. For units of less than 10 m^2 that are supposed to be mounted as solitaires with quite low coverage range, the acoustic data are expressed as equivalent absorption area. For clusters larger than 10 m^2, the acoustic data are expressed in the same way as for a full ceiling, i.e. as a practical absorption coefficient with a corresponding single value of α_w and classification rating (A to E).

This rule of thumb is illustrated in figure 9.

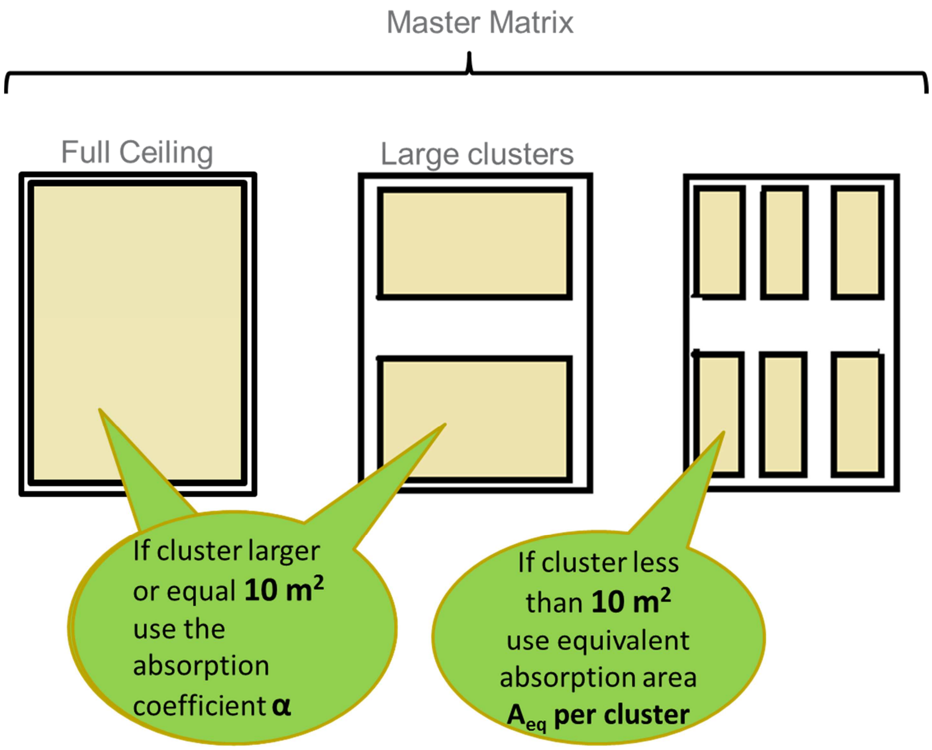


Figure 9. Rule of thumb for when to use absorption coefficient and equivalent absorption area.

Note 2. For Master Matrix in small clusters (<10 m^2), we use the equivalent absorption area per unit in the same way as for our Solo products. The same guidelines concerning the effect of distance between units and overall depth of system that apply for Ecophon Solo products will also apply for Master Matrix in small cluster configurations. Further, the effect of different shapes is estimated in the same way as for Solo products, see chapter 6.

9. The effect of different coverage range

The minimum distance between the panels in a master Matrix cluster is 40 mm. However, it is possible to increase this distance, and this will affect the coverage ratio. When Master matrix is used as a full ceiling or in a large cluster, the effect of different coverage ratios will influence the absorption coefficient.

The configurations in figure 10 correspond to different coverage ratios. The effect on the absorption coefficient is shown in figure 11. It is clear from figure 10 that the effect of coverage ratios in the range 80 to 100 per cent has a minor influence on the absorption coefficient.

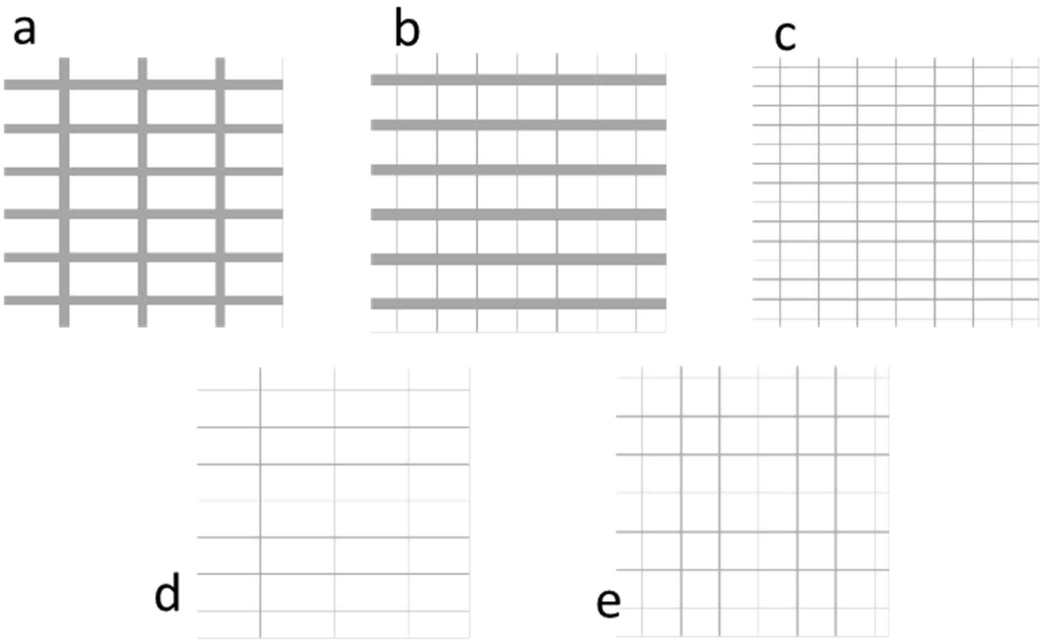


Figure10. Configurations with different coverage ratios. a) panel size: 1200 x 2400, width between panels 340 mm, coverage ratio 81% b) panel size: 1000 x 1160, width between panels 40 mm and 350 mm, coverage ratio 83% c) panel size: 560 x 1160, width between panels 40 mm, coverage ratio 93% d) panel size: 1200 x 2400, width between panels 40 mm, coverage ratio 97% e) panel size: 1200 x 1200, width between panels 40 mm, coverage ratio 96%.

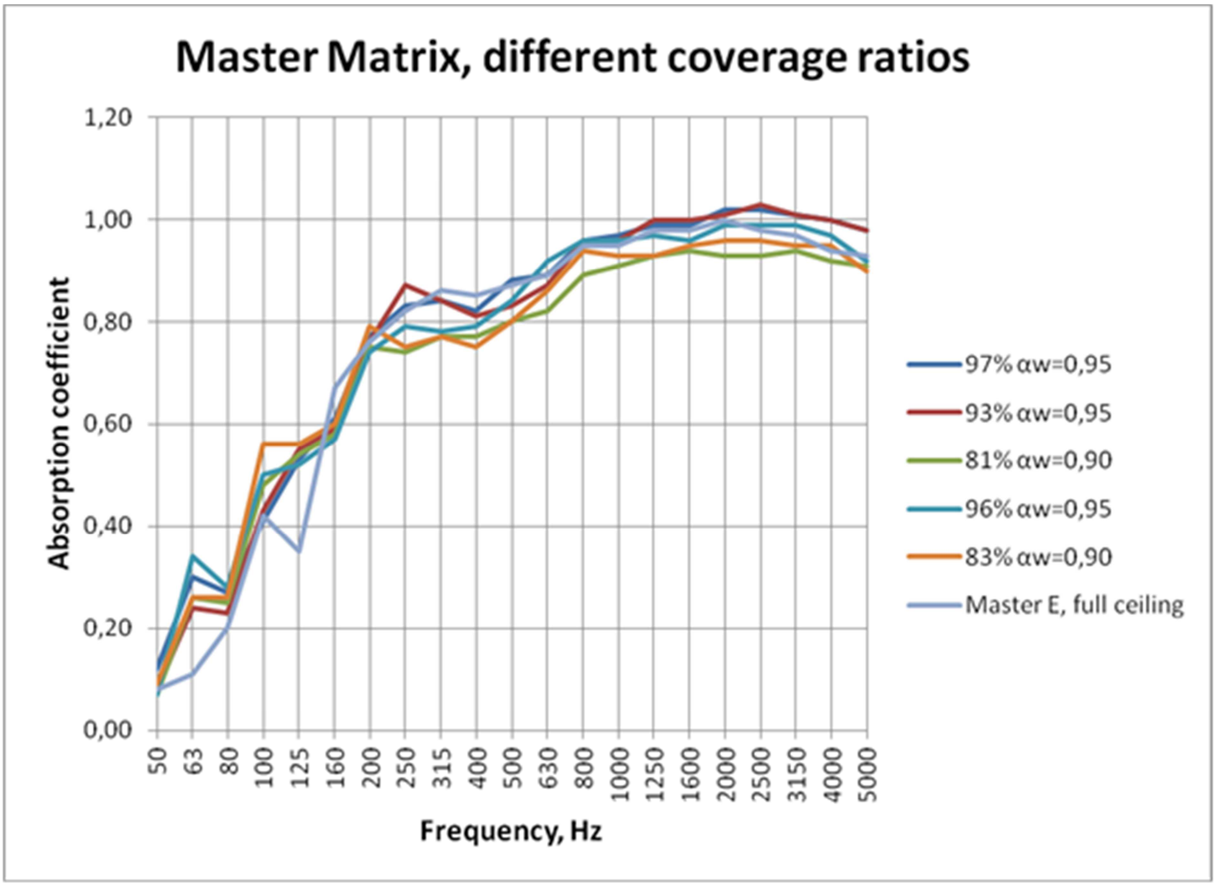


Figure 11. Master Matrix for different coverage ratios according to figure 10. For comparison, Master E full ceiling is included.

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Ecophon dates back to 1958, when the first sound absorbers from glass wool were produced in Sweden to improve the acoustic working environment. Today the company is a global supplier of acoustic systems that contribute to good room acoustics and a healthy indoor environment with the focus on offices, education, health care and industrial manufacturing premises. Ecophon is part of the Saint-Gobain Group and has sales units and distributors in many countries.

Ecophon's efforts are guided by a vision of earning global leadership in acoustic ceiling and wall absorber systems by providing superior end user value. Ecophon maintains an ongoing dialogue with government agencies, working environment organisations and research institutes, and is involved in formulating national standards in the field of room acoustics where Ecophon contributes to a better working environment wherever people work and communicate.

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