Acoustic design

with wall acoustic solutions

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Ecophon SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

Introduction

A suspended ceiling is by far the most common acoustical treatment in a room. In most cases this is also a sufficient solution to create a good acoustical environment. However, situations occur where a suspended ceiling on its own is not enough to fulfil the acoustic demands. There can be various reasons for this, such as:

- Technical – if, for example, the room temperature is regulated via the concrete slab (thermally activated building systems, TABS) it is not possible to use a full coverage suspended ceiling since this will influence the efficiency of the slab. In this case added wall panels could be necessary to fulfil acoustic requirements.

- Aesthetic – if, for example, the ceiling has details of architectural importance that shouldn't be hidden, sound absorbing wall panels could be a solution to secure good acoustic conditions.

- Acoustic – in premises where there is a need for higher acoustic performance due to special activities, sound absorbing wall panels in combination with a full coverage suspended ceiling are often necessary to meet the acoustic requirements.

  For instance:
  Educational premises: Higher acoustic demands are motivated when more noise is generated due to the educational style (e.g. teaching in groups), the pupils are younger, the presence of hearing-impaired children.

  Open-plan offices: To prevent sound propagation over longer distances.

  Industrial spaces and sports halls: In spaces with high ceilings the addition of sound absorbing wall panels has a positive effect on reverberation time, sound strength as well as speech intelligibility.

  Healthcare premises: To create calm and stress-free environments that benefit patient recovery, staff wellbeing and working performance, the acoustic performance is an essential factor.

Room Acoustic Comfort™

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

The human perception of sound, the physical properties of the room and the activity for which the room is planned are all factors that influence our judgement of the acoustical quality of the room and how suitable it is for the planned activities. The interaction between these factors has to be considered in the acoustical design process. As a consequence, several acoustic criteria are needed for relevant characterisation of room acoustic conditions. Those criteria reflect different acoustic properties of the sound field in a room.
For ordinary rooms there are at least four properties that are of importance. Those properties are

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

The properties and their corresponding criteria are given in table 1.
Depending on the physical properties of the room and the planned activity, some criteria will be of more importance than others. For instance, in a room where the understanding of spoken words is essential, the criteria related to speech clarity are most important, while in rooms with noisy activities, criteria related to noise reduction, such as sound strength, are most important.

Table 1. Room acoustic parameters

Acoustic quality	Acoustic criteria (parameter)	Unit	Definition
Auditory strength	Sound Strength, G	dB	ISO 3382-1
Speech clarity*	Speech Clarity, C_{50}	dB	ISO 3382-1
Sound propagation (spatial decay)	DL_2, DL_f	dB	ISO 14257
Reverberance	Reverberation time T_{20}	s	ISO 3382-1

* Speech clarity could also be expressed as a percentage. The measure is then called Definition or Deutlichkeit and denoted by D.
Definition is related to speech clarity by $D = 1/(1+10^{-C_{50}/10})$

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

Figure 1. Room Acoustic Comfort™, acoustic design approach considering the interaction between the people, the activity and the room.

Sound fields in rooms with suspended acoustic ceiling

If a sound source such as a loudspeaker is continuously emitting noise into a room, the sound field becomes quite diffuse after a very short time, even if there is a suspended ceiling present. In simplified terms, a diffuse sound field means that sounds waves are travelling in all directions with equal probability and intensity. When the sound pressure level in the room is stabilised and a constant sound pressure level is reached the condition is called steady state. The sound pressure level at this stage is determined by the total absorption in the room. Normally, the suspended ceiling is the main absorbing surface in the room and the contribution from the ceiling to the total absorption is given by the ceiling area times the absorption coefficients. The steady state condition is illustrated in figure 2.

The reverberation time is measured by shutting off the sound source and measuring the time for the sound pressure level to decline by 60 dB. As the sound energy decays, the diffusivity of the sound field will not be maintained. During the decay the sound waves that hit the most absorbent surface, in this case the ceiling, will disappear first, while sound waves that hit hard surfaces that reflect sounds, in this case the surrounding walls, will persist for longer. In fact, in many rooms with suspended ceilings the reverberation time is very much determined by these persistent sound waves travelling almost parallel to the ceiling. These waves are sometimes referred to as grazing waves since they hit the ceiling at a very grazing angle of incidence. By increasing the amount of furniture and sound scattering objects in the room the sound field becomes more diffuse during the decay. This also implies that in rooms with suspended ceilings the reverberation time is very much dependent on furniture and equipment in the rooms. The grazing sound field is illustrated in figure 3.

Figure 2. Sound field at steady state in a room with suspended ceiling and sound scattering objects.

Figure 3. Sound field during sound decay in a room with suspended ceiling

Referring to the discussion above, a summary:

- Sound pressure levels in rooms with suspended ceilings and due to ongoing noise sources are determined by the total absorption in the room.
- The reverberation time not only depends on the ceiling absorption but also to a large extent on the absorption of the surrounding walls and the amount of furniture.

The effect of wall panels on room acoustic parameters

- In cases where the area of wall panels only constitutes a small amount of the total absorption, the acoustical effect of the wall panels is to increase the speech clarity and reduce the reverberation time but only slightly affect the sound level. This is normally the case in the presence of a highly absorbing suspended ceiling
- Wall panels are an efficient solution to prevent disturbing echoes e.g. between parallel reflecting walls (flutter echo) or to diminish reflections from distant walls, such as the rear wall in a lecture room, which can interfere with speech.
- Generally it is preferable to position the wall panels as close to the sound sources as possible. However, in classrooms it is recommended to keep a distance of about one metre between the wall panel and the position of the student's head. If you sit too close to a wall panel the sound environment can create a sensation of unbalance.
- In rooms with high ceilings, such as sports halls and industrial spaces, wall panels are an efficient complement to a suspended ceiling. The wall panels should preferably be located as close to the sound sources as possible, but to avoid accidental mechanical impact it is recommended that they are placed a certain distance above the floor. As a first choice the wall panels should be mounted on two adjacent walls. The wall panels will contribute to higher speech intelligibility and lower reverberation time. If the area of wall panels is of the same order as the suspended ceiling the wall panels will also significantly contribute to lowering the sound level.

Recommended area of wall panels

- In rooms for educational purposes of the most effective wall panel area is in the range of 10 to 25% of the floor area, depending on whether the acoustical demands require one or two walls to be treated with wall panels.
- In open-plan offices, wall panels along the workplaces at the height of a seated person will help to prevent sound from propagating over longer distances and create a calmer environment.
- In smaller room, such as a dining room or meeting room, even a small area of wall panels in the range of 8 to 13% of the floor area will significantly increase the speech clarity and reduce the reverberation time.
- In industrial spaces and sports halls it is recommended to use as much of the available wall area as possible, since the main goal generally is to reduce the sound levels.

Field cases

Dining/meeting room at a hospital in Landskrona, Sweden.

The room is used as a dining and meeting room for the staff of the medical emergency department at Landskrona Hospital. The volume of the room is 69 m^3 with a floor area of 25 m^2. Both ceiling and walls consist of plasterboard without any acoustical treatment. The room before refurbishment is shown in figure 4.

Figure 4. Dining and meeting room at Landskrona Hospital before refurbishment.

The staff complained about the acoustic conditions and some comments are given below:

- *It echoes a lot.*
- *If you sit in the middle of the room you can't participate in any conversation at all.*
- *I just take shorts breaks and avoid having lunch together with others.*
- *Sometimes you have to ask people to repeat what they said.*
- *There is an incredible din that prevents you from talking, even with the person sitting next to you, when there are a lot of people here.*
- *I leave the room as fast as possible.*

An acoustic refurbishment of the room was carried out. The ceiling was covered with a 40 mm thick porous absorber (Ecophon Master B) mounted directly on the plasterboard. On one of the side walls a 40 mm thick wall panel (Ecophon Wall Panel C/Texona) was mounted. The size of the wall panel was 2700 x 1200 mm. The wall panel area corresponds to 13% of the floor area. The room after refurbishment is shown in figures 5 and 6.

Figure 5. Ceiling absorber: Ecophon Master B

Figure 6. Wall panel: Ecophon Wall Panel C/Texona

The practical absorption coefficients for Ecophon Master B ceiling absorber and Ecophon Wall Panel C/Texona are identical. The absorption graph is shown in figure 7.

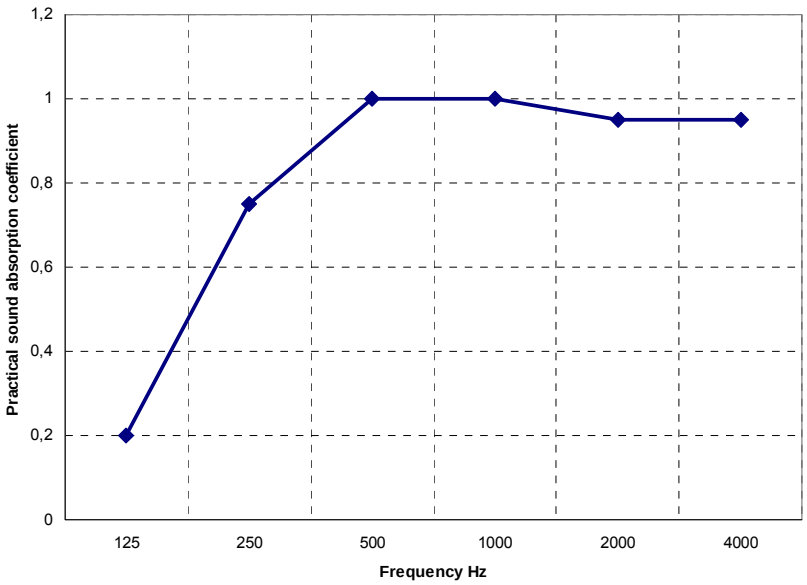

Figure 7. Practical sound absorption coefficients for the absorbers used in the premises at Landskrona Hospital.

Room acoustic measurements were performed in three steps:

1. before acoustic treatment
2. for the room with ceiling treatment only and
3. for the ceiling treatment in combination with the wall panel

This made it possible to evaluate the effect of the ceiling absorber and the wall panel separately. The results are presented in table 2.

Table 2. Result of measurements at Landskrona Hospital			
Parameter	**Before acoustic treatment**	**Only acoustic ceiling**	**Acoustic ceiling and wall panel**
	Average 500 and 1000 Hz	Average 500 and 1000 Hz	Average 500 and 1000 Hz
T20 [s]	0.76	0.37	0.27
∆L [dB]*	-	-8	-8
C50 [dB]	1.8	8.6	12.0
D [%]	60	88	94
RASTI **	0.66	0.82	0.87

* * ∆L is the reduction of sound levels in the room compared to the untreated room.
**Room Acoustic Speech Transmission Index according to IEC 60268-16

Comments on the results:

The ceiling absorbers will dramatically reduce reverberation time and sound levels and increase speech clarity. Adding the wall panel will further reduce reverberation time and increase speech clarity but will not further reduce the sound level in the room. The reason for this behaviour is that the reduction of sound levels in the room is mainly related to the total amount of absorption in the room. Since the wall panel in this case only constitutes a small part of the total absorption (the wall panel area is 13% of the floor area) there is no influence on the sound level. Reverberation time and speech clarity are more dependent on the location of the absorbers. These parameters are influenced by the "lateral sound field" i.e. the sound waves hitting the walls. Those sound waves will be affected by the wall panel and as a consequence the reverberation time will decrease and the speech clarity will increase.

Some comments from the staff after the refurbishment are given below:

- *Much more subdued environment. I feel more relaxed in the room.*
- *It's easier to talk to each other.*
- *There's less din when a lot of people are in the same room.*
- *There are less echoes in the room.*
- *A lot of people can talk simultaneously in different parts of the room without a problem.*

A food factory in Landskrona, Sweden

The next field case is the food producer Oatly's factory in Landskrona. The factory building is acoustically untreated and is perceived as a noisy work environment by the staff. The source of the noise is the mechanical production line. To reduce the overall noise levels in the industrial premises it was decided to install a full coverage suspended ceiling in combination with wall panels on accessible parts of the walls. The ceiling absorber was Hygiene Performance 20 mm and the wall absorber was Hygiene Performance 40 mm. The ceiling surface was 250 m^2 and the wall surface that was covered with wall panels was about 150 m^2. The wall panels were mounted partly on three walls. The acoustic treatment is shown in figure 8.

Figure 8. Acoustic treatment of ceiling and walls in Oatly's factory.

To reduce the noise levels at especially exposed locations, wall panels were also mounted as close to the noise sources as possible. Such a location was the "corridor" between the machinery and wall as shown in figure 9. The panels were mounted at head height.

Figure 9. Hygiene Advance Protection C3 on the wall close to noisy machinery.

The results from the room acoustic measurements are presented in table 3.

Table 3. Measurement results before and after refurbishment at Oatly.

	The values refer to an average for the octave band 500 and 1000 Hz	
	Before treatment	After treatment
T20 [s]	2.4	0.62
ΔL [dB]	-	5
C_{50} [dB]	-2.9	3.7
D [%]	34	70
RASTI	0.47	0.70

* * ΔL is the reduction of sound levels in the room compared to the untreated room.
**Room Acoustic Speech Transmission Index according to IEC 60268-16

Comments on the results:

After treatment the overall noise levels in the factory have decreased by 5 dB. Based on a diffuse field calculation, the contribution from the wall panels is 2 dB. Before treatment the noise levels were in the region of 81 to 84 dB(A). After treatment the noise level has decreased to below 80 dB(A). Close to the machinery the noise level is still above 80 dB due to the dominating direct field, which is not affected by the acoustic treatment. The reverberation time has decreased and speech clarity has increased, indicating a significant improvement in the ability to hear speech in the factory.

Some comments from the staff after the refurbishment are given below:

- *It's easier to hear what is being said.*
- *Easier to hear where the sound is coming from.*
- *It's nice not having to wear ear protection.*
- *I'm not so tired when I get home, and I sleep better*

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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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