White Paper

An excursion into the planning of room acoustics in offices – A comfort factor in focus

Tailor-made solutions for indoor climate

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An excursion into the planning of room acoustics in offices
– A comfort factor in focus

Noise is the nuisance most complained about in office workspaces – in particular in open-plan offices. These should enable both verbal communication and undisturbed concentration on the tasks in hand. The objective of room acoustic planning is the creation of good acoustic conditions for every workplace. Architectural trends are making this more difficult, e.g. through the use of external walls with large acoustically hard glazed areas. Open-plan offices also present problems with regard to adequate acoustic separation.

The White Paper addresses the following questions:

- What factors need to be taken into account for good room acoustics in offices?
- What considerations are important in lecture and conference rooms?
- Where in the room are sound absorbers installed and how do these work?
- What are the benefits of sound absorbent ceilings?
- How are sound absorbers designated and how is this information to be interpreted?

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Introduction

While thermal comfort is always taken into account in building standards today, too little attention is often paid to acoustic comfort – despite the fact that it plays an important role in a comprehensive approach to indoor climate. In many cases, retroactive measures have to be taken to improve the acoustics at a later stage, when the room is already in use.

This White Paper demonstrates what criteria need to be met for good room acoustics in offices and what measures are required for this. This includes a discussion of the important role of sound absorbent surfaces on the ceiling.

Contents

Criteria for good room acoustics

To achieve good room acoustics in offices, the following basic criteria need to be observed[1]:

- Low reverberation
  The reverberation time is used as a measure of the reverberation of a room. Low reverberation means a short reverberation time. This is achieved with sufficiently sound absorbent surfaces in the room. It is quieter inside a room with lower reverberation than in a room with high reverberation, if all the other conditions are the same (same level of external noise and/or internal noise sources). The reverberation also affects the sound propagation in the room.

- Low sound propagation
  As a general rule, it is important to aim for low sound propagation in an office. Low reverberation is necessary for this. In particular, (unwanted) sound propagation between workstations should be taken into account (more about this on the following pages).

- Low background noise level
  To achieve a low background noise level requires sufficient sound insulation, both externally and between neighbouring rooms, and the noise emissions of office equipment must also be considered. This comes under the category of architectural acoustics. Noise sources from office equipment in the room itself such as printers etc. must also be considered. As mentioned in the section at the top, the background noise level is also reduced by low reverberation.

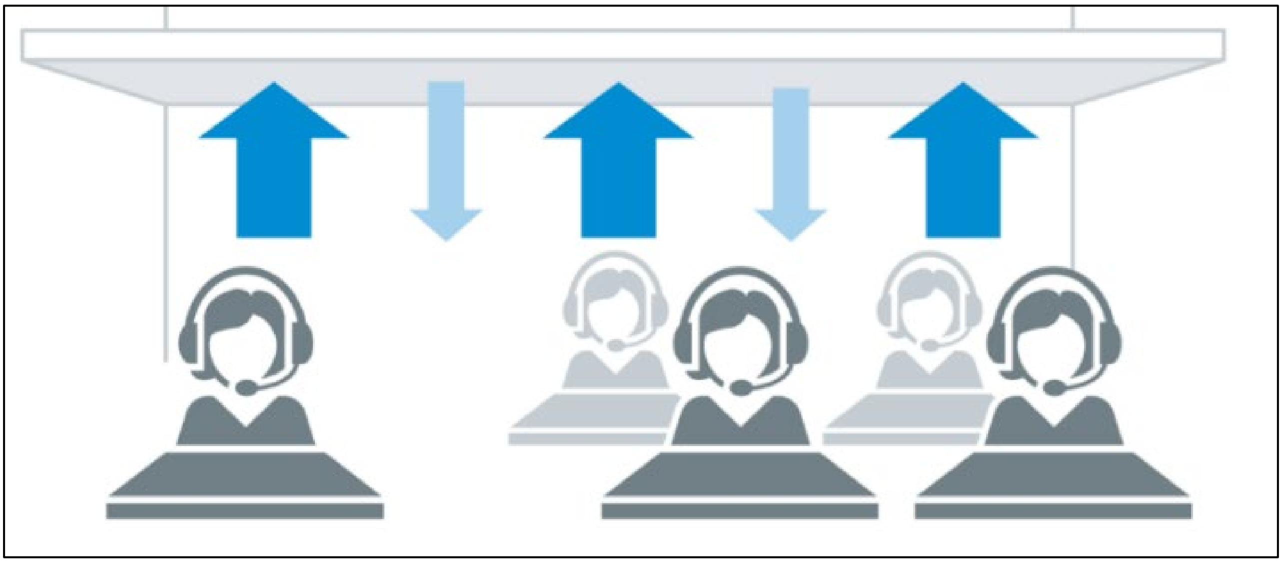


Fig. 0: Influence of sound reflection within a room

[1] For precise consideration: The standard VDI 2569, which deals specifically with the acoustic design of offices, subdivides them into single offices and small and large multi-person offices. It also specifies thresholds for parameters for the above mentioned criteria, in order to comply with three different room acoustics classes.

Sound propagation in offices

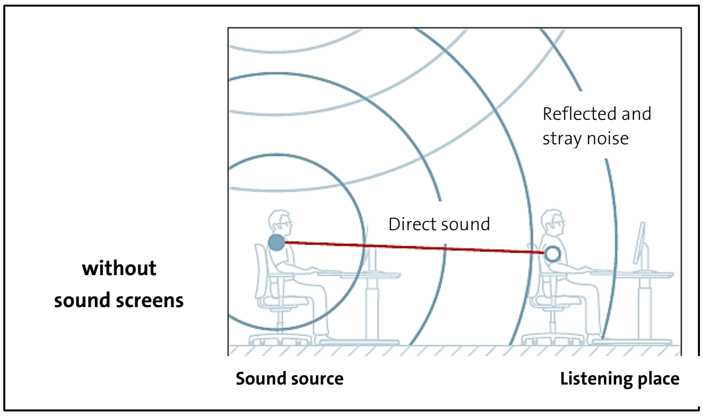


Fig. 1: Sound propagation in a multi-person office without sound screen (IBA)

Without sound screens

Figure 1 represents the sound propagation between neighbouring workstations in a multi-person office. Besides direct sound, sound reflection and acoustic scatter primarily occur on the ceiling.

Sound reflection and acoustic scatter can also occur on nearby walls, the façade or the floor. Sound propagation via the floor or walls is generally more limited than on the ceiling due to the office fittings.

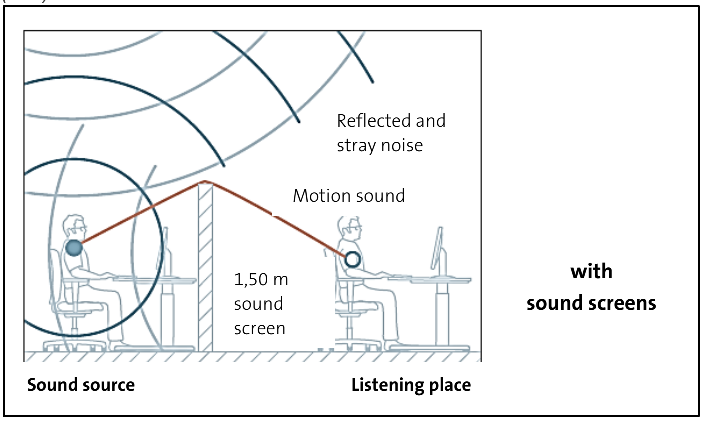


Fig. 2: Sound propagation in a multi-person office with sound screen (IBA)

With sound screens

Figure 2 shows the sound propagation with the same configuration, but with a sound screen.

Besides special partitions, it is also possible to use cupboards or desk attachments, for example, as sound screens.

The sound screen suppresses direct sound. A diffracted sound now occurs at the upper end of the sound screen, but the sound pressure of this is much lower than that of direct sound.

Special case: lecture and conference rooms

Lecture and conference rooms must be planned differently from office rooms. Unlike office rooms, the aim here is for good acoustic quality over larger distances. Much higher reverberation should therefore be opted for than in an office.

In a **lecture room**, it must be possible to clearly understand the person giving the lecture at all locations in the room. There should therefore be sound reflecting surfaces above the lecturer and the audience. Possible positioning of the reflecting surface on the ceiling is indicated in colour in Figure 3. Sound absorbent elements should, if anything, be installed further back in the room and on the rear wall.

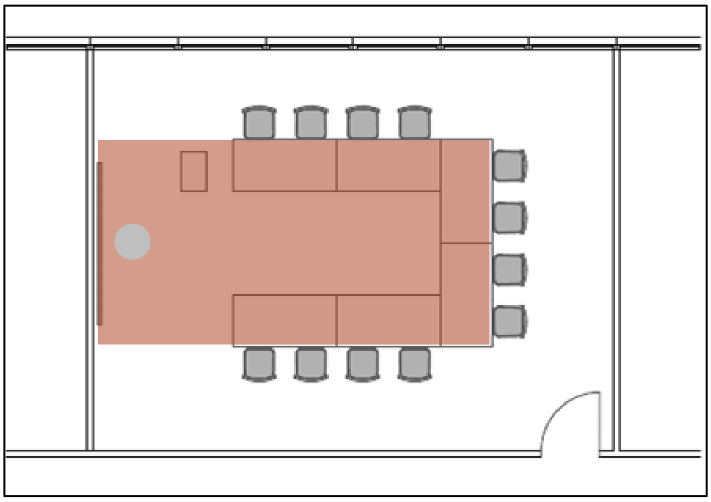


Fig. 3: Example of a lecture room with defined position of the lecturer and the audience, with the reflecting surface indicated (adapted illustration from the IBA)

A **meeting room** with a large table surrounded by chairs should have a sound reflecting ceiling above the table, so that the person speaking can be clearly understood by everyone else at the table. Possible positioning of the reflecting surface on the ceiling is indicated in colour in Figure 4. Sound absorbing elements should be installed further out on the ceiling in all directions.

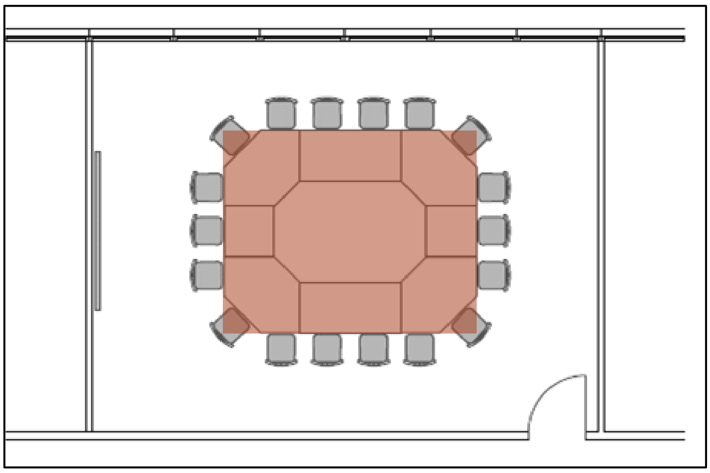


Fig. 4: Example of a meeting room with large table surrounded by chairs, with the reflecting surface indicated (adapted illustration from the IBA)

Permanently installed absorbers on the ceiling

Sound screens, partitions, desk attachments or similar can be flexibly integrated as part of the office fittings, depending on the usage scenario. The behaviour is different with permanently installed sound absorbers. For these, careful planning is recommended.

Due to the sound propagation in the office (Fig. 1 and 2), sound absorbers on the ceiling should definitely be considered, particularly above the workstations or other noise sources.

There is usually sufficient free space available on the ceiling for sound absorbers. It is also possible to install thicker insulation layers here, ideally with optimum spacing from the ceiling (more about this on the following pages). A radiant ceiling system, a top view of which is shown in Figure 5, then not only ensures thermal comfort and good ventilation, but also plays and important role in the acoustic concept of the room.

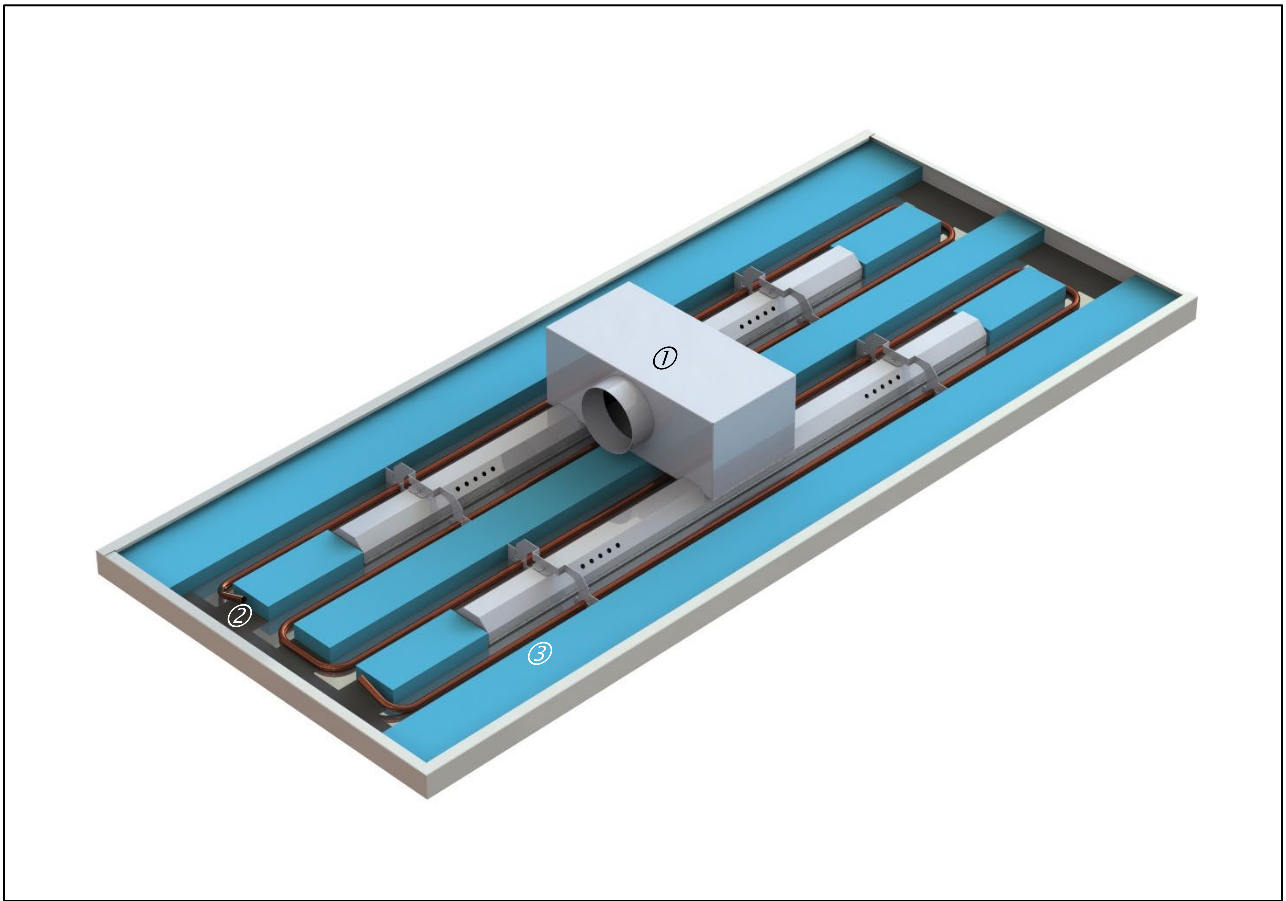


Fig. 5: Radiant ceiling system with supply air element ①, fleece ② glued onto the ceiling panel and mineral wool strips in black PE film ③ (blue used instead of black in the illustration for clarity)

Spacing from the ceiling as an influencing factor

If the space between the absorber and the ceiling (drop height) is well chosen, sound absorption is significantly improved. A porous absorber, such as mineral wool, installed directly on an acoustically hard surface (e.g. concrete ceiling) absorbs sounds primarily in the high frequency range, and possibly also mid frequencies, with customary installation thicknesses.

Figure 6 shows the sound absorption coefficient curve for mineral fibre panels with insulation thicknesses of 15 or 40 mm without any spacing, and those with spacing of 300 mm from an acoustically hard surface.

In Figure 6, it is also apparent that from a spacing of 0 to 300 mm, there is a significant improvement in the lower frequency range with both insulation thicknesses. This is because reflected sound waves create a "pressure stasis" at a distance of one quarter of the wavelength (in acoustics, this is known as an area of maximum sound velocity). Installing insulation in this area results in high absorption (Fig. 7).

At a distance of 300 mm, a quarter of the wavelength is equivalent to a frequency of around 280 Hz and therefore an improvement in absorption in the low frequency range.

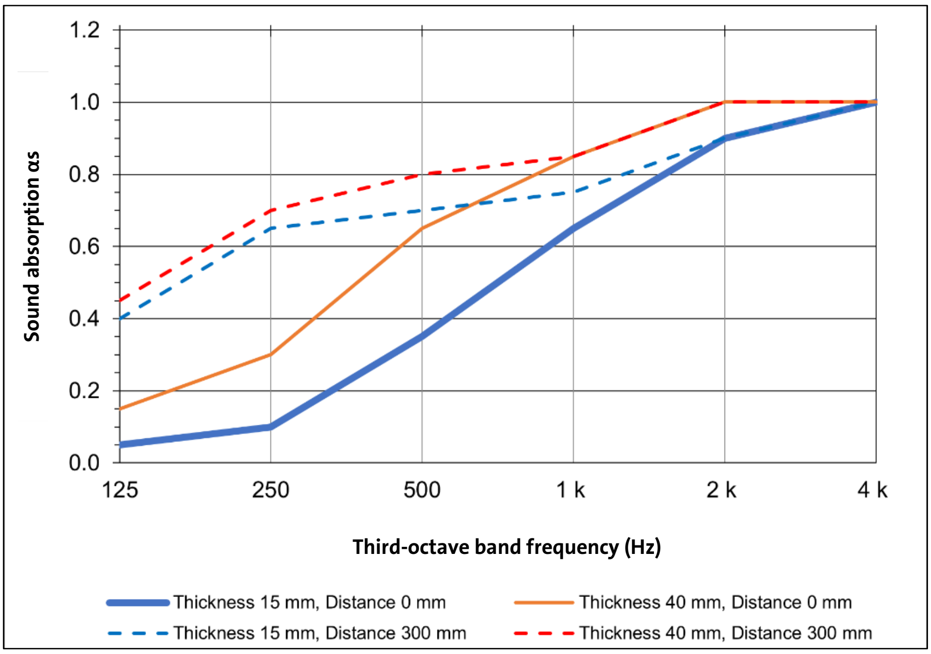


Fig. 6: Values from Fasold/Veres, Table 4.3

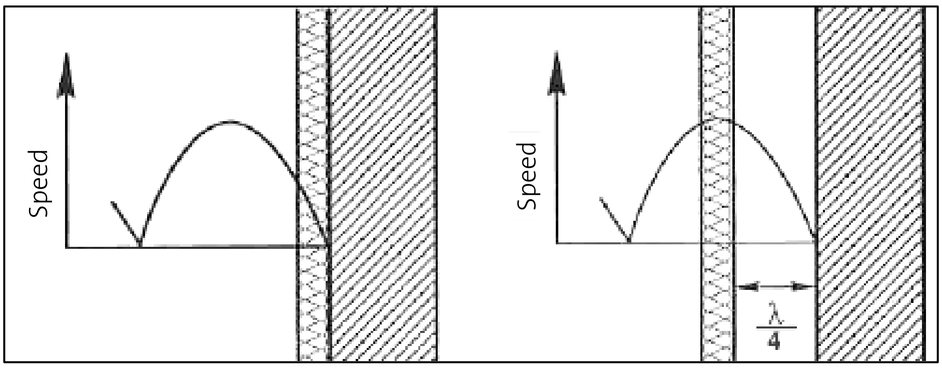


Fig. 7: Increase in the effectiveness of a porous absorber due to arrangement in the velocity maximum (Fasold/Veres)

Ceilings with perforations or holes as an influencing factor

In the case of ceilings with perforations or holes, a further effect can be utilised. Known as perforated panel absorbers, these can achieve high levels of absorption. The holes in the panel function as the mass (called the hole mass, which depends on the free cross-section, the hole shape and the hole size), and the air in the hollow cavity between the panel and the concrete ceiling acts as a spring.

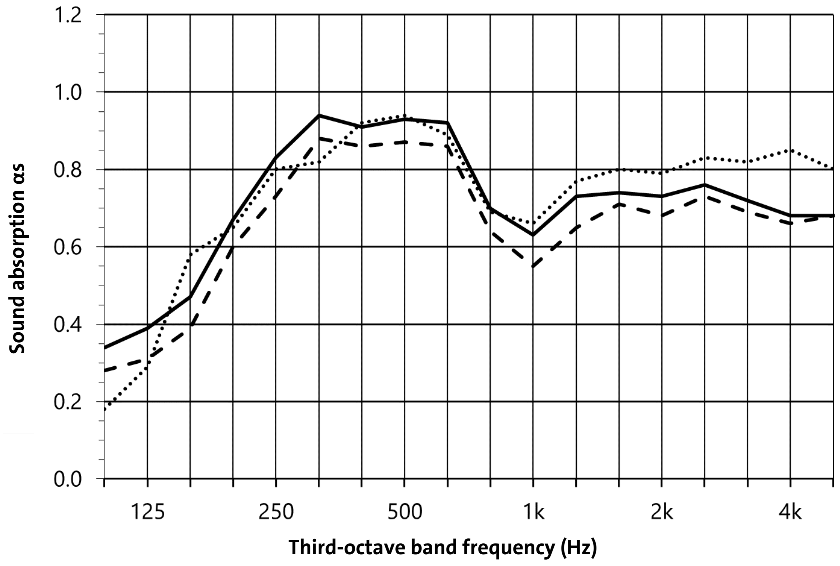
A radiant, perforated metal ceiling with acoustic fleece can achieve impressive sound absorption values. Figure 8 shows measurements for installations with different perforations and α_w values ranging from 0.70 to 0.80.

Sound absorption coefficient of three metal ceiling installations without activation

Installation 1: radiant metal ceiling made from steel, with acoustic fleece, perforation with round holes (RG) 1.5 with hole percentage 11 %, drop height 200 mm, without activation

Installation 2: same as Installation 1, but with perforation with round holes (RG) 1.5 with hole percentage 22 %

Installation 3: same as Installation 1, but with perforation with round holes (RG) 2.5 with hole percentage 16 %



Installation 1: perforation 1.5 – 11 %
Evaluation according to EN ISO 11654 (1997) α_w: **0.75** **(L)**
α_p: 250 Hz: 0.80   500 Hz: 0.90   1000 Hz: 0.70   2000 Hz: 0.75   4000 Hz: 0.70

Installation 2: perforation 1.5 – 22 %
Evaluation according to EN ISO 11654 (1997) α_w: **0.70** **(L)**
α_p: 250 Hz: 0.75   500 Hz: 0.85   1000 Hz: 0.60   2000 Hz: 0.70   4000 Hz: 0.70

Installation 3: perforation 2.5 – 16 %
Evaluation according to EN ISO 11654 (1997) α_w: **0.80**
α_p: 250 Hz: 0.75   500 Hz: 0.90   1000 Hz: 0.75   2000 Hz: 0.80   4000 Hz: 0.80

Fig. 8: Radiant metal ceiling with fleece and with different perforations (data from Fural product documentation)

Activated ceiling panels as an influencing factor

If the metal panels are activated with cooling coils, this leads to a slight reduction in the absorption values, as a portion of the ceiling panels is covered.

Additional insulation e.g. mineral wool can, on the other hand, significantly increase absorption (Figure 9).

Sound absorption coefficient of two radiant ceiling installations (with activation)

Installation 4: same as Installation 1, but activated with cooling coil

Installation 5: same as Installation 1, but activated with cooling coil, with additional mineral wool 20 mm

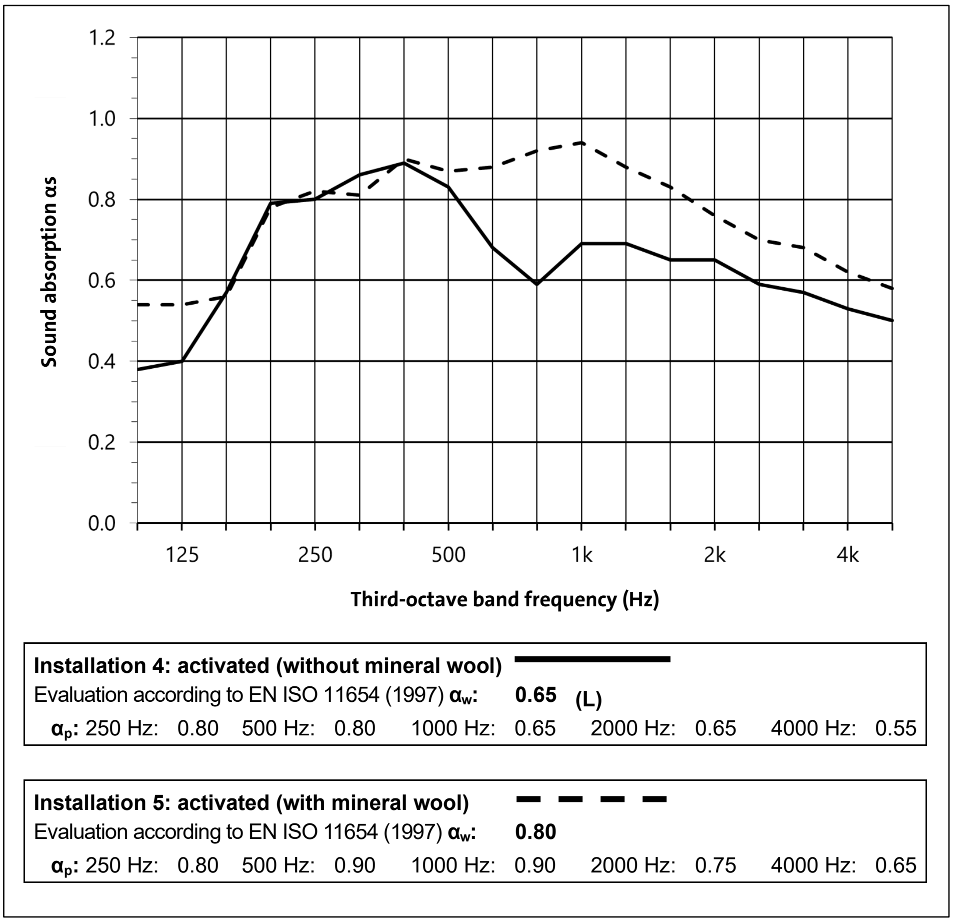


Fig. 9: Metal radiant ceiling with fleece (Installation 4) and with additional mineral wool (Installation 5)

Drop height as an influencing factor

If the hollow cavity between the panels and the concrete ceiling is also necessary for the perforated panel absorber effect, the drop height (and therefore the height of the hollow cavity) is not of primary significance within a certain range. For metal ceilings with the perforations listed in Figure 8, very similar α_w values are achieved with drop heights ranging from 100 to 400 mm, with the α_w values mostly highest at a drop height of around 200 mm. At a drop height of 100 mm, absorption is lower in the low frequency range, while at 400 mm drop height, it is lower in the mid frequency range.

Vertical arrangement as an influencing factor

Vertically arranged absorbers on the ceiling (known as baffles) can derive little benefit from the perforated panel absorber effect and velocity maximum effect described and therefore achieve much lower levels of absorption. However, this can be compensated for by installing a larger number of baffles.

Fig. 10: Baffles constitute a suitable shape for ceiling absorbers. The image shows heating/cooling baffles with an additional layer of sound absorption material (acoustic fleece and mineral wool mats).

Permanently installed absorbers not located on the ceiling

Absorbers positioned on the **wall** in offices are used, if anything, to supplement ceiling absorbers. Wall absorbers can be important for preventing echoes if two acoustically hard room surfaces are facing one another, e.g. the façade and a "bare" internal wall. Where there are existing ceiling absorbers, special wall absorbers are mostly not needed, since the customary office fittings with shelves and cupboards are largely sufficient.

On the **floor,** carpets can help to optimise room acoustics. Due to their thin nature, carpets are particularly effective in the high frequency range, and only slightly effective at best in the mid frequency range.

Fig. 11: Acoustic panels for the wall are available in many different designs

Designation of sound absorbers

The sound absorption coefficient α is the crucial index for flat absorbers. It describes the extent to which incident sound is absorbed. For a surface with ideal absorption, which absorbs 100 % of the incident sound, α = 1, and for a fully reflecting surface, α = 0. Real absorbers have values between 0 and 1.
The sound absorption coefficient is frequency dependent and is measured according to EN ISO 354 for 18 third octave bands with mid frequencies of 100 to 5000 Hz. The sound absorption coefficients for the third octave bands are called α_s values.

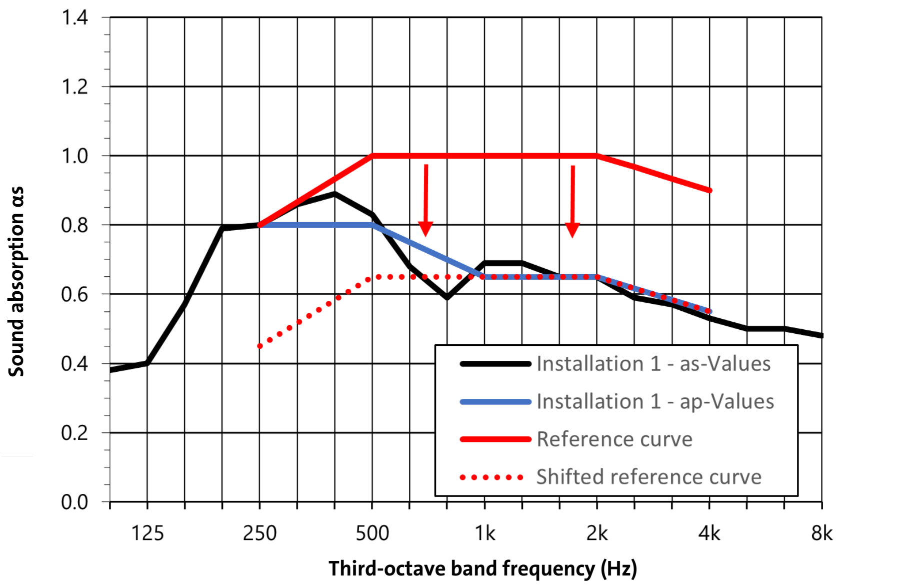
α_w value (single value index)

The α_w value is suitable for rough comparison of different absorbers. To calculate the α_w value, the 15 α_s values with mid frequencies of 200 to 5000 Hz are combined into a single value. To do this, the α_s values are firstly averaged out into octave band values α_p, i.e. three α_s values produce one α_p value in each case. The α_p values are defined in increments of 0.05 and have a maximum value of 1. The α_p values are then compared with the reference curve. The α_w value is the value of the reference curve at 500 Hz, which has been shifted according to certain criteria. The α_w value is also defined in increments of 0.05.

If the absorber is significantly better than the reference curve in certain ranges, shape indicators are assigned. If this deviation occurs at low frequencies, the indicator L is assigned. This is the case for the absorber in Figure 12. The indicators M or H are assigned for deviations in the mid or high frequency range (for a precise calculation of the α_w value, refer to the standard EN ISO 11654.)

NRC value (single value index)

In the English-speaking world, the NRC value (noise reduction coefficient) as per ASTM (American Society for Testing and Materials) C423 is primarily accepted as the single value index. The NRC value is comparatively easy to calculate: the α_s values of the third octave bands with the mid frequencies 250, 500, 1000 and 2000 Hz are arithmetically averaged and rounded off to 0.05.



Installation 4: activated (without mineral wool)
Evaluation according to EN ISO 11654 (1997) α_w: **0.65 (L)**
α_p: 250 Hz: 0.80 500 Hz: 0.80 1000 Hz: 0.65 2000 Hz: 0.65 4000 Hz: 0.55

Fig. 12: Installation 4 of Figure 9 with reference curve for calculation of the α_w value

Conclusion

Room acoustics are an important element of any examination of indoor climate. Various solutions are available in order to achieve optimum acoustic comfort. However, these are only helpful and effective if they take into account prevailing conditions, intended uses and scientific principles. It is particularly worthwhile to include the ceiling in the room acoustics concept. It should be ideally installed for sound absorption from a technical point of view, offer plenty of space and be capable of making a significant contribution to good room acoustics.

As a provider of radiant ceiling systems specialising in indoor climate, Barcol-Air regards room acoustics as a significant comfort factor. Corresponding parameters for the different radiant ceiling systems are therefore available from certified test institutes for room acoustic planning.

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– (Fural): Fural Metalldecken, Prüfwerte Schallabsorption, 10/2016 (https://www.fural.com/de/news/150)

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