19th INTERNATIONAL CONGRESS ON ACOUSTICS
MADRID, 2-7 SEPTEMBER 2007

ABSORPTION OF OPEN CEILINGS

PACS: 43.55.Dt

Vercammen, Martijn[1], Scheers, Theo[2]
[1] Peutz bv, P.O. Box 66, NL-6585 ZH MOOK, Netherlands; m.vercammen@mook.peutz.nl
[2] Peutz bv, P.O. Box 66, NL-6585 ZH MOOK, Netherlands; t.scheers@mook.peutz.nl

ABSTRACT

Thermally activated concrete slabs offer an interesting possibility to control the climate in rooms. In order to reduce the sound pressure level, enough sound absorbing material has to be applied. This sound absorbing material will usually, considering the available surfaces, be realised as a suspended ceiling.
However, a proper sound absorbing material is often also thermal isolating which is disadvantageous regarding thermally activated concrete slabs. Searching for an agreement leads to sound absorbing free-hanging ceilings or so called baffles.

In the paper the absorption of free-hanging suspended ceilings will be discussed.

INTRODUCTION

By the use of thermally activated concrete slabs the climate in rooms can be controlled. Usually however sound absorbing suspended ceilings are applied to reduce sound pressure levels. These ceilings will have an considerable effect on cooling capacity of the concrete slabs. When making use of this system, one should both consider thermal and acoustical comfort.
A compromise is to apply sound absorbing free-hanging ceilings. We will first discuss the influence of these types of ceiling on sound absorption, then on cooling capacity.

ABSORPTION OF CLOSED AND OPEN CEILINGS

There are two acoustical effects of free-hanging ceiling elements, compared to full and closed suspended ceilings.
The first effect is that parts of the ceiling will not be covered any more, and locally reflections will appear at the concrete slab above the ceiling. Of course this effect depends on the width of the open area and the location of source and receiver. From practical experience one can say that no problems have been found in case of open strips with a width of no more than 0,5 m. For a width of over 1 m one can notice the additional reflection.
The second part we will focus on here is the influence of the reduced ceiling surface on the total absorption. The reduction of surface will inevitably lead to a reduction of sound absorption.
To show the influence of the size of the ceiling elements on the sound absorption a serie of measurements have been done on a mineral wool ceiling with a thickness of 25 mm.

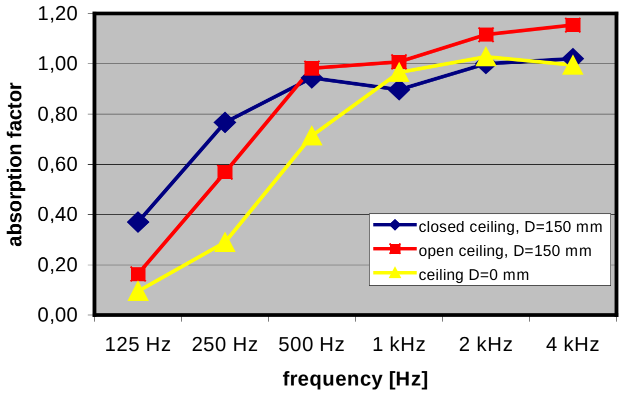

Figure 1. Sound absorption of 25 mm mineral wool ceiling tiles in three different settings.

Figure 1 shows 3 results, the “closed ceiling” is the result of a standard measurement and mounting procedure according to ISO 354. The ceiling is mounted upside down with a mounting height of 200 mm. The sides are “closed” with a plywood slab.
The sound absorption is very much dependent on the mounting height. In case the ceiling tiles are directly put on the floor, the sound absorption at high frequencies remains the same but at the low frequencies the absorption drops. Of course this depends on material thickness in relation to wavelength. At $\frac{1}{4}\lambda$ the particle velocity will be maximum and so will be the absorption.
The results with the open ceiling show that at the low frequencies there is a significant drop in sound absorption. There is a short-circuit of air between the front and the back side of the ceiling tiles and the particle velocity drops.
On the other hand, for the higher frequencies we see an increase in sound absorption. Where the side slabs have been removed an additional area for high frequency absorption is created.

ABSORPTION OF OPEN CEILING ELEMENTS

Figure 2 shows the results of the 25 mm mineral wool ceiling mounted at 200 mm above the floor of the reverberation room. The number of elements (size 0,6x1,8 m^2) is varied between 1 and 10, in different configurations, and the absorption factor is shown as a function of the area of ceiling material.

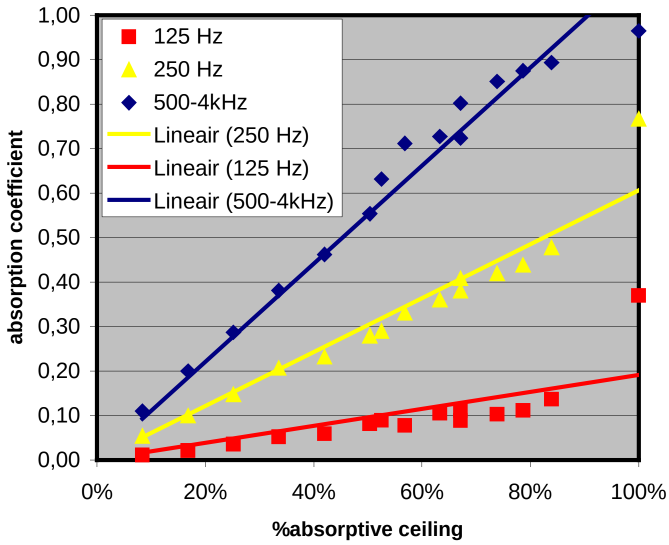

Figure 2. Sound absorption of 25 mm mineral wool ceiling tiles, mounted at 200 mm, for different size of the ceiling elements.

The results for the 125 Hz and the 250 Hz octave bands are shown separately. They show the sudden drop in sound absorption from a closed (100%) to a free-hanging ceiling (<90%). This drop is dependent on the material: for mineral wool with considerable thickness, the drop will be less. For low thickness material (e.g. felt on a perforated metal sheet) the drop will be more pronounced.

Dealing with an open ceiling, the absorption is almost linear to the area of the material for these low frequencies. The absorption at these frequencies does not seem to depend on the size of the ceiling elements nor on the mounting height. There is no indication of a strong “edge” or “area” effect as found for absorption material directly mounted on the floor.

In figure 2 the average absorption of the 500 to 4 kHz bands is shown. Here we see that reducing the absorptive area from 100 to 80% will hardly reduce the sound absorption. And that is good news since most of the energy of speech is in these octave bands. The open areas will also absorb energy since the sound waves will enter the open area between suspended ceiling and the floor, where the absorptive backside of the ceiling will remove the sound energy. Although there still is a relation between absorption and the area of the material, the correlation in figure 2 is not perfect. A better correlation can be obtained if we consider the open area between suspended ceiling en floor:

$$A = S_{ceiling} \cdot \alpha_S + S_{edge} \cdot \alpha_{edge} \qquad (1)$$

Where α_S is the absorption of the closed ceiling in the standard mounting, S_{edge} is the open area at the sides and α_{edge} is the assumed effective sound absorption of the open edge area (see also figure 5)

Figure 3 shows the relation between measured absorption area A and calculated absorption according to (1), with α_{edge} = 0,6.

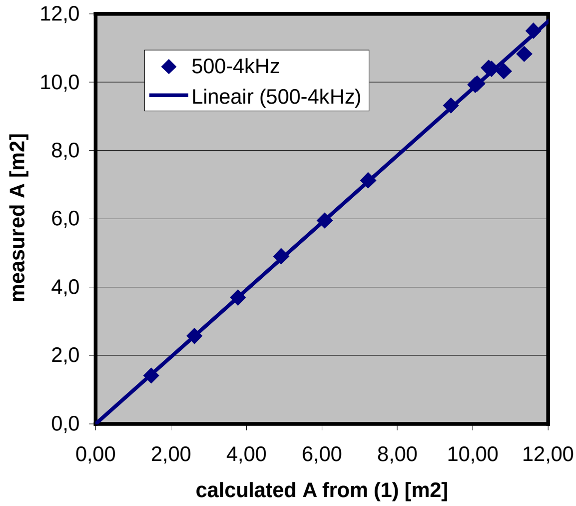

Figure 3. Measured versus calculated absorption, averaged over octave band from 500 to 4 kHz, for different configurations of a mineral wool ceiling d=25 mm mounted at a height of 200 mm. For the calculation $\alpha_{edge} = 0{,}6$ is assumed

Using formula (1) the effective absorption of the edge can be calculated from a measurement of the open (free-hanging) ceiling and the closed ceiling:

$$\alpha_{edge} = \frac{A_{open} - A_{closed}}{S_{edge}} \qquad (2)$$

Figure 4 shows the α_{edge} of the same mineral wool ceiling, as one element (3x3,6 m^2), mounted on different heights. The results show that, apart from the low mounting height (unstable calculation) for this ceiling the α_{edge} =0,45 to 0,6, independent of mounting height.

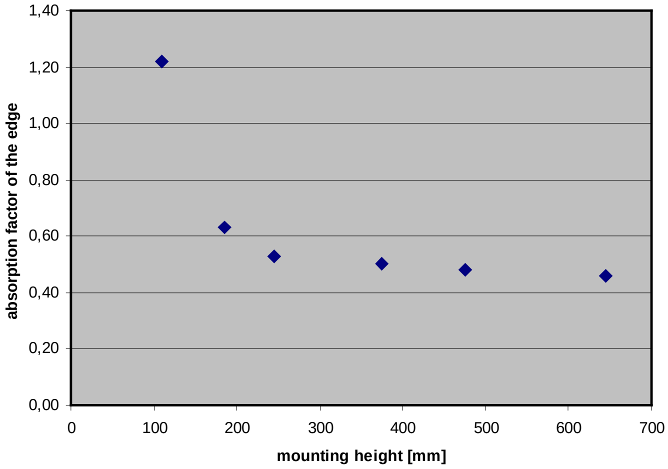

Figure 4. Calculated α_{edge} (average 500-4kHz) from the measured absorption with the open and closed ceiling according to (2). Measured with 25 mm mineral wool tiles with an area of 10,8 m^2.

The calculation of the S_{edge} has to be clarified. In case the distance of ceiling elements is more than double the height, twice the height (of the opening) is taken, otherwise the distance between the ceiling elements (see figure 5).

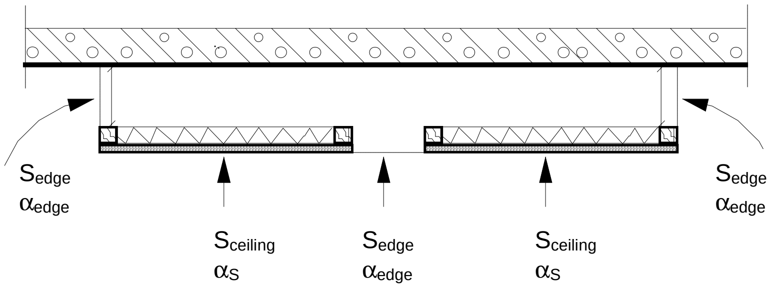

Figure 5. Indication of the additional absorption area for the high frequencies.

`

The absorption of the edge will dependent on the absorption of the backside of the ceiling tiles. From the results from figure 3 and 4 we might conclude that for mineral wool tiles the α_{edge} = 0,45 to 0,6. However if we do the same measurement for other mineral wool products (see figure 6) we find other values for α_{edge}, mostly between 0,6 and 1,1. There is a tendency that for small ratio of the edge surface to the total surface the absorption of the edge is higher.

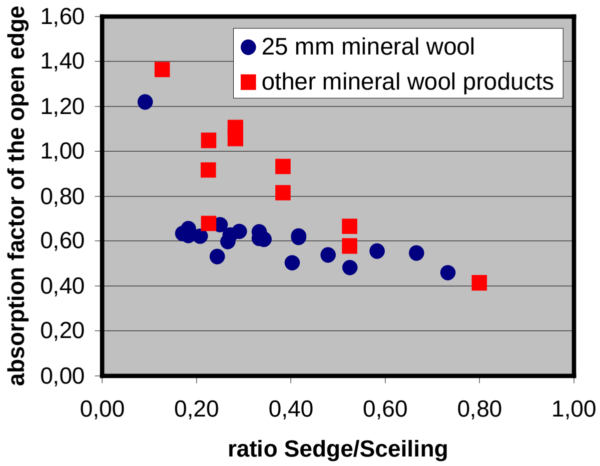

Figure 6. Calculated α_{edge} (average 500-4kHz) from the measured absorption with the open and closed ceiling according to (2) as a function of the edge area divided by the area of ceiling material. Measured with 25 mm mineral wool tiles in several configurations and with a number of other mineral wool products.

CONCLUSION

From the measurements performed with different configurations ceiling elements we may conclude that for the low frequencies (125, 250 Hz) absorption of open ceilings is considerably lower than the absorption of closed ceilings. The absorption at low frequencies depends (only) on the area of the material.

For higher frequencies (500-4kHz) there is an increase in absorption depending on the edge surface and the absorption of the backside of the panels. The influence of the open ceiling on the absorption can be estimated from figure 2. The absorption at higher frequencies can be estimated reasonably accurate by including the edge absorption in the total absorption (1).