Thermally activated concrete slabs and suspended ceilings

H.Peperkamp, M.Vercammen

Peutz bv Mook, The Netherlands, Email: h.peperkamp@mook.peutz.nl

Abstract

Thermally activated concrete slabs offer an interesting possibility to control the indoor climate. When applying this system, a thermal as well as acoustic comfortable indoor climate can be realised. To control the sound pressure levels present, sufficient sound absorbing material has to be applied. This sound absorbing material is, regarding the free surface that is available, often placed as a suspended ceiling. However, a proper sound absorbing material is in many cases also thermally insulating, which negatively affects the thermally activated concrete slabs. The search for the optimum leads to sound absorbing free-hanging ceilings or so called baffles.

Aim of the current research is to quantify to which extend different suspended ceiling configurations reduce the thermal capacity of the thermally activated concrete slabs, and to relate this to the sound absorption.

Introduction

Because of the favourable energy aspects, thermally activated concrete slabs are applied more and more. When using this system the climate in rooms can be controlled with low temperature heating and high temperature cooling. As a result of using the mass of the building construction, a stable thermal indoor climate is obtained.

Usually however, sound absorbing suspended ceilings are applied to reduce sound pressure levels (a larger ceiling area results in higher sound absorption). These ceilings will have a considerable effect on the cooling capacity of the concrete slabs: more coverage of the concrete results in a lower thermal capacity. When applying this system, both the thermal as well as the acoustic comfort should be considered to find an optimum for each specific situation.

As a compromise sound absorbing free-hanging ceilings can be applied. We will first discuss the influence of these ceiling types on sound absorption, then on cooling capacity.

Absorption of open ceilings

Two acoustical effects of free-hanging ceiling elements occur, compared to fully and closed suspended ceilings.

The first effect is that parts of the ceiling will not be covered anymore, 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. In practice, no problems have been found in case of open strips with a width of less than 0,5 m.

The second effect 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 configuration of the ceiling elements on the sound absorption, a series of measurements have been performed on a mineral wool ceiling with a thickness of 25 mm. Figure 1 shows the measurement results according to ISO 354, with the ceiling mounted at 200 mm above the floor of the reverberation room. The number of elements (sized 0.6 x 1.8 m^2) is varied between 1 and 10, in different configurations, and the absorption factor is shown as a function of the ceiling material area.

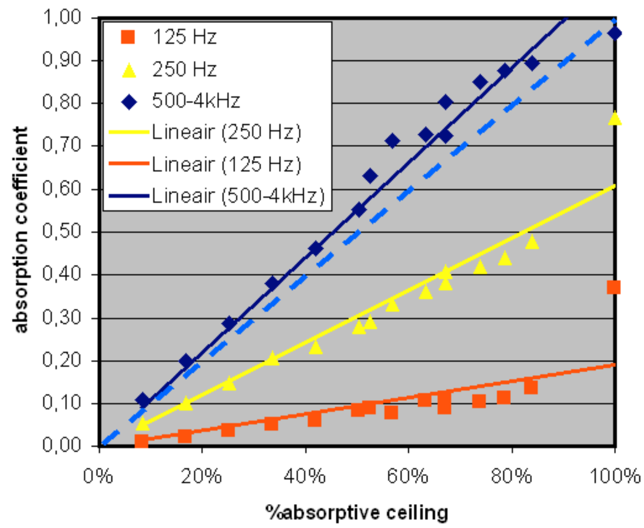

Figure 1: Sound absorption of 25 mm mineral wool ceiling tiles, mounted at 200 mm, for different ceiling elements configurations, expressed in area covered.

The results for the 125 Hz and the 250 Hz octave bands are presented separately. These show a sudden drop in the sound absorption from a closed (100%) to a free-hanging ceiling (<90%), visible in the right hand side of the graph. This drop depends 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.

In case of an open ceiling, the absorption is almost linear to the area of the material for these low frequencies. The absorption is almost linearly dependent of the area of the material for these low frequencies.

In figure 1 the average absorption of the 500 Hz to 4 kHz bands is shown. Here we see that reducing the absorptive area from 100 to 80% will hardly reduce the sound absorption. This is an important aspect, 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 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 1 is not perfect. A better correlation [1] can be obtained if we consider the open area between suspended ceiling and floor:

$$A_t = S_{ceiling} \cdot \alpha_s + S_{edge} \cdot \alpha_{edge} \qquad [\text{m}^2] \qquad (1)$$

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 2).

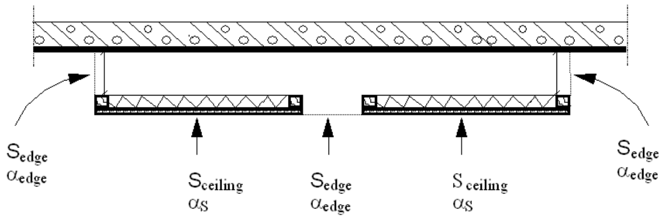

Figure 2: Indication of the open edge area.

Cooling capacity with suspended ceilings

To determine the influence of the free hanging ceiling on the thermal capacity of the activated concrete slab, a mock-up has been constructed in a climatic chamber. In this room the cooling of the concrete ceiling was controlled in order to obtain a constant value of the surface temperature. The room temperature was kept constant by using heating elements conform NEN EN 14240 which transfer heat by both radiation and convection. These elements simulate the heat transfer of persons and office equipment in the room.

Figure 3: One of the investigated ceiling configurations in the climatic chamber consisting of 40 mm mineral wool.

Several suspended ceiling configurations have been tested, consisting of 40 mm mineral wool. Each ceiling configuration contained six open lighting fixtures. The height of the gap between the concrete ceiling and the suspended ceiling, as well as the percentage suspended ceiling surface compared to the surface of the concrete ceiling has been varied.

The influence of the suspended ceiling on the cooling capacity of the concrete slab is given in figure 4. Here, 100% capacity represents the capacity of the situation without suspended ceiling.

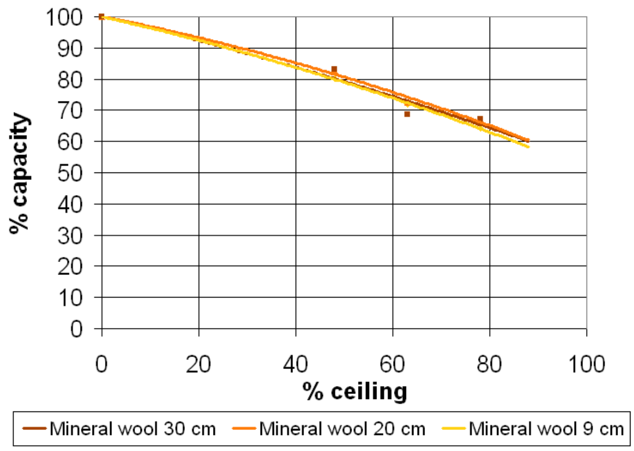

Figure 4: Thermal capacity of 40 mm mineral wool ceiling tiles mounted at different heights and metal baffles, both for different sizes of the ceiling elements.

The graph in figure 4 shows that, as expected, the thermal capacity of the concrete reduces with increasing ceiling area. If half of the concrete is covered with a suspended ceiling of 40 mm mineral wool, the thermal capacity reduces with approximately 20%.

Based on heat transfer by free convection (no forced airflow along the concrete) and radiation and based on the measured surface temperatures, the radiation is approximately 60% and the convection approximately 40% of the cooling capacity. In first assumption, the radiation part of the cooling capacity reduces directly proportional with the covered percentage concrete ceiling. This implies that with half of the concrete covered with a suspended ceiling, the radiation part of the thermal capacity reduces from 60% to 30% of the initial cooling capacity. However, the measured total reduction of the cooling capacity in this situation is approximately 20% (figure 4). Based on this fact and assuming that the convection does not increase when applying a suspended ceiling, it is concluded that the reduction of the radiation part of the cooling capacity is less than direct proportional with the covered percentage concrete.

The height of the cavity between the suspended ceiling and the concrete does seem to affect the reduction of cooling capacity by only a few percent.

Combining absorption and cooling capacity

Furthermore, the sound absorption of the specific mineral wool ceiling configurations investigated in the climatic chamber has been measured in the reverberation room according to ISO 354, using the same cavity heights.

In figure 5 both the thermal and the acoustic results are presented for different coverage percentages with a cavity of 200 mm.

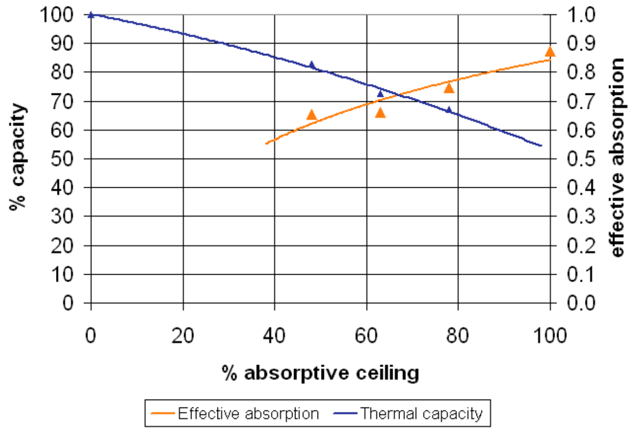

Figure 5: Thermal capacity of 40 mm mineral wool ceiling tiles mounted at 200 mm and effective absorption averaged over octave band from 500 Hz – 4kHz of the same ceiling.

In practice, for a single office an effective sound absorption of 0.65 is required. This means in this case (applying a ceiling type as in figure 5) a percentage absorptive ceiling of 50% which reduces the thermal capacity with 20 to 25%. If a higher thermal capacity of the concrete is required, additional sound absorption has to be applied on vertical surfaces.

For landscaped offices a larger absorption coefficient is required: 0.8 or higher. This implies a suspended ceiling of 85% of the floor area or larger. For the tested ceiling configuration the reduction of the thermal capacity, when applying a suspended ceiling that covers the concrete with 85%, is approximately 40%. To gain more benefit from the activated concrete slabs other solutions should be reviewed. With metal baffles, for example, more sound absorption for the higher frequencies can be achieved with the same percentage coverage.

Conclusions

With activated concrete slabs, a good thermal as well as acoustic comfort can be realised when applying open suspended ceilings. At higher frequencies (500 Hz – 4 kHz) the absorption of the edge surface contributes to the total absorption of the ceiling panels. The reduction of the radiation part of the thermal capacity is less than the coverage percentage of the concrete due to the suspended ceiling.

Depending on the type of ceiling material and configuration, an optimum for the thermal capacity and sound absorption can be obtained. This optimum depends on the room types, on the amount of sound absorption, and on the cooling capacity that is required.

References

[1] Vercammen and Scheers, Absorption of open ceilings, 19th International Congress on Acoustics, Madrid (2007)