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Acoustics in Open-Plan Offices with Thermo Active Ceilings - a Case Study

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In open-plan offices various sources like telephones, speech, computers and other technical equipment contribute to an overall noise level, which challenge the demands for a quiet work space. A basic requirement for an open-plan office to function is that the acoustic environment is appropriate. Often this is secured by enabling sound absorbing material covering most of the ceiling area supplemented by sound absorption on selected walls. In buildings with thermo active decks it is not possible to utilize all of the ceiling area for sound absorption since a portion of the area must be kept open for cooled air to propagate downwards. This paper is a case study of the new COWI open-plan office in Aalborg showing the compromises made between acoustics and thermo activity.

1 Introduction

Thermo active building decks are one of the construction methods used to make a building more sustainable and to reduce its environmental impact over its entire lifetime while optimizing its economic viability. Thermo active decks work by having embedded pipes in a concrete ceiling. The method utilizes concretes mass and ability to equalize room temperature by absorbing and emitting heat and cooled air. Thermo active decks are most efficient when the concrete is completely exposed for air to propagate freely downwards into the open plan offices. This is not in good agreement with traditional regulation of room acoustics since the entire ceiling area should typically be covered in sound absorbing material.

This paper is a case study dealing with the compromises made to enable acceptable room acoustics without obstructing the thermo activity. Focus is aimed at fulfilling basic acoustic requirements of the Danish Working Environment Authority (At.1.16). The required amount of sound absorption in office areas larger than 300 m^3 must be at least 0.9 times the floor area of the room.

2 Method

In the engineering process of the building the sound absorbing capabilities of the combined suspended acoustic ceiling and the open perforated segments was calculated.

Based on a study work concerning thermo active ceilings and acoustic requirements the result of the negotiated compromise is shown in Table 1

Table 1 Portion of ceiling area in 343 m^2 open office for thermo activity, light fixtures, ventilation fans and sound absorbing material

Ceiling	Concrete	Light fixtures and fans	Acoustics
Area [%]	26 %	7 %	67 %
Area [m^2]	89 m^2	24 m^2	230 m^2

The effective open air area for thermo activity is 17 % since 67 % perforated metal sheets are used in the air openings.

The sound absorption coefficients of the combined ceiling area have been calculated. With a suspended ceiling leaving 0.30 meters of cavity above the acoustic bats it is estimated that 84 % of the sound is reflected against the suspended ceiling, taking advantage of the acoustic bats, rather than being reflected by the concrete surface. Therefore, the absorption coefficients of the acoustic material have been weighted in the proportion 84 % to achieve the overall characteristics of the ceiling.

Sound absorption of all relevant surfaces of the open plan office has been taken into account calculating the total amount of sound absorption and relating it to the basic requirements. In the selected representative room (B-103) walls are concrete (138 m^2), floors are 3 mm vinyl (316 m^2) and glass is used for separating meeting room and windows (50 m^2).

Subsequent measurements of the reverberation time after finishing the building have been made. For the measurements made there is only acoustic absorption in the ceiling hence no regulation on the walls.

3 Calculation Results

As mentioned the required amount of sound absorption in office areas larger than 300 m^3 must be at least 0.9 times the floor area of the room. This is equivalent to a reverberation time of 0.53 seconds calculated as the average from 125 Hz to 2 kHz with a maximum deviation in any frequency band of 0.15 seconds.

The calculated reverberation time of the example room B-103 is 0.56 seconds taking into account 22 office working places.

Table 2 Calculated reverberation time [s] and additional equivalent absorption area [m^2] needed in open plan office B-103

Room	Floor area [m^2]	Room volume [m^3]	T20 [s] $Mean_{125\text{-}4000Hz}$	Additional absorption [m^2]
B-103	343	1029	0.56	25

To fulfil requirements regarding sound absorption calculations show that adding approximately 25 m^2 of sound absorption on the wall surfaces, equivalent to 17 % of the wall area excluding window area, is sufficient.

4 Measurement Results

Construction of the office buildings was finished and ready for use February 2012. Subsequently the reverberation time of selected offices has been measured. At the time of the measurements rooms were facilitated with furniture but no other distinct sound absorption that the portion of the ceiling area.

The reverberation time, T_{20}, was measured using the method of DS/EN ISO 3382 [1]. The equipment used was an impulse source together with a Brüel and Kjær hand held analyzer type 2250. A sound file was recorded and postprocessed using dBBati32 to evalute the decay curves and calculate the reverberation time.

Table 3 shows the measured reverberation times of rooms B-103, B-200, B-302 and A-310.

Table 3 The reverberation time T_{20} as an arithmetic mean between 125 Hz and 4000 Hz.

Room	Floor area [m2]	T20 [s] Mean$_{125\text{-}4000Hz}$
B-103	343	0.50
B-200 part 1	199	0.53
B-302 part 1	240	0.57
B-302 part 2	131	0.54
A-310 part 1	141	0.56

Figure 1 shows the measured reverberation times in 1/1 octave bands from 125 Hz to 4000 Hz. There is a significant amount of low and mid frequency absorption whereas the reverberation times at 2 kHz and 4 kHz are somewhat high. The measurements are affected by flutter echoes this is especially the case for the rooms B-302 part 1.

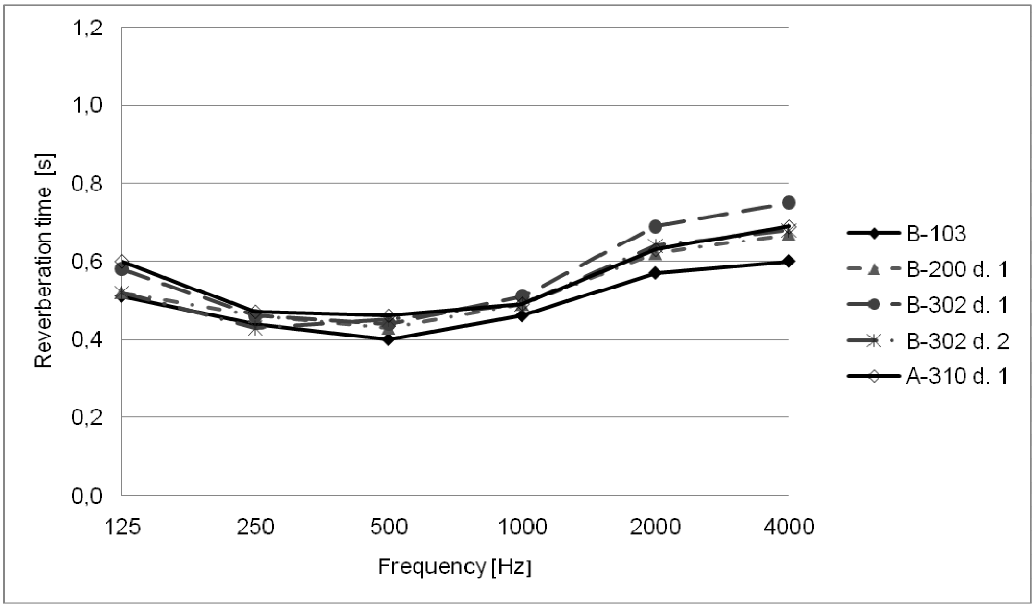

Figure 1 Measured reverberation times as a function of the frequency in full octave bands.

Table 4 shows the calculated missing absorption area to fulfil the At.1.16 requirement.

Table 4 Missing absorption area for the different rooms when considering minimum requirement At.1.16. Maximum allowed deviation in any frequency band from the required average is not included.

	Additional equivalent absorption area [m^2]					
Room	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
B-103	7	0	0	0	25	32
B-200 part 1	10	0	0	0	37	48
B-302 part 1	36	0	0	11	65	77
B-302 part 2	6	0	0	0	27	32
A-310 part 1	25	0	0	2	30	38

5 Analysis and Discussion

The reverberation time for the measured rooms all show the same convex shape as a function of frequency as seen in Figure 1. The low values at the mid and low frequencies are due to the suspended ceiling. A sufficient amount of absorption is not present at the higher frequencies. The measurements emphasize the fact that it is important to place acoustic absorption on room walls. This is even more important for thermo active decks where some of the concrete ceiling has to be exposed in order for the cooling/heating to work properly.

During the measurements it was found that the results in some positions are affected by flutter echo between large and parallel wall surfaces. Therefore selection of suitable wall areas for sound absorption might reduce the reverberation significant and more rapidly than expected, meaning smaller demands on missing absorption areas.

6 Conclusion

A comparison of the calculated reverberation time and the measured reverberation time in room B-103 shows good agreement. Both results indicate that additionally 25 m^2 of sound absorption is needed in the open plan office to fulfil minimum At A.1.16 requirements.

In room B-103 the missing 25 m^2 sound absorption area is equivalent to 17 % of the concrete wall area.

The requirements regarding sound absorption in the open plan offices can realistically be fulfilled even though effectively 17 % of the ceiling is dedicated the thermo activity, 67 % for the acoustics and the rest for lighting fixtures and active ventilation.

But to achieve an acceptable acoustic environment future open plan office projects should take into account that some portion of the wall areas needs to be utilized absorption wise.

After completing the amount of sound absorbing material and fulfilling the requirements next investigations should be to do interviews among the people using the offices daily. This is seen in the perspective that open plan areas can be used for different purposes and noise sources may vary depending on this. In a calm office environment the minimum sound absorption requirements of At A1.16 may be sufficient whereas the acoustic challenge in a call centre environment, or similar noisy environment, with many phones ringing and people speaking may raise a potential problem achieving acceptable acoustics in combination with thermo active decks.

References

[1] ISO-3382, Acoustics - *Measurement of the reverberation time of rooms with reference to other acoustical parameters.* International Organization of Standardization (ISO), 2. Edition, 1997.