Communication Room Acoustics in Passive Cooled Buildings

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Introduction

In up to date buildings passive cooling, i.e. without active cooling devices just through the building's optimized thermal behaviour, is a standard method to achieve thermal comfort during summer. An essential feature for passive cooling is the thermal storage capability of the building. In most cases main thermal storage elements are concrete ceilings with good thermal contact to the room's interior, both convective and radiative. This prohibits any thermally isolating cover on the ceiling, as acoustic absorbers.

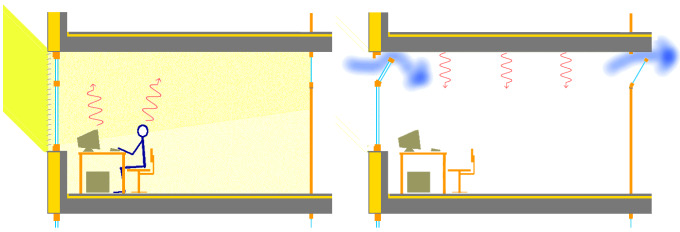

Figure 1: The basic concept of passive cooling - an office room shown as an example. During day (left) the room is heated by several sources: the sun, electric light, computers and other equipment, and the occupants. Part of this heat is stored into the massive concrete ceiling. During night (right) the room is vented by cool night air and the heat is unloaded from the ceiling. For good cooling effect the storage element (the ceiling) must show a large surface to the room at good thermal conductiyity and high storage capacity. This prohibits acoustic absorbers covering the ceiling.

Communication Room Solutions

In this study [1] communication room solutions meeting the passive cooling requirements have been investigated using acoustics simulation software [2]. Reverb Times and several other measures for speech transition quality (e.g. center times) show that the reflective concrete ceiling is an advantage for communication (such effects can be expected after publications of Kuttruff [3] and other authors).

Compatible solutions (massive, reflective ceiling)		Incompatible solution
a) all absorbers at the walls	b) absorbers at walls and on ground	c) absorbers at ceiling and on ground

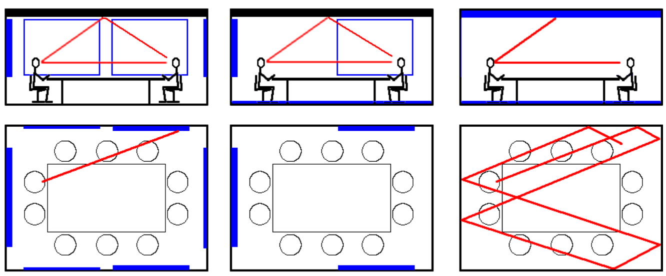

Figure 2: Room acoustical solutions for passive cooling, and one incompatible solution, shown for a small conference room.

A comparison of different absorber positions (walls, floor, ceiling) shows that absorbers mounted at walls will lead to a better acoustic quality than other absorber positions at equal equivalent absorber surface. Thus passive cooling and good acoustic quality for communication can be achieved at the same time. An important issue is that flat low frequency absorbers are required for mounting at walls.

In fig. 3 simulation results of three versions of a conference room are displayed. Reverb times as well as other quality measures show distinct effects of absorber position. Center times came out as one of the most sensitive measures.

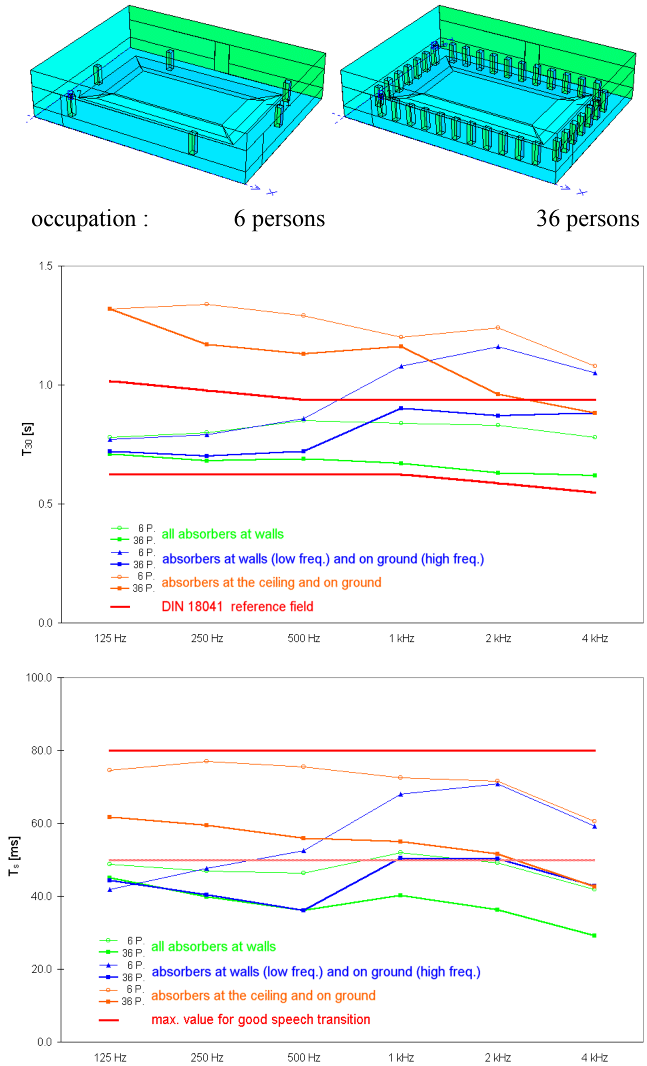

Figure 3: Effects of absorber position are studied by simulation of a conference room (10m x 14m x 3m) occupied by 6 or 36 persons. 3 versions, corresponding to a), b) and c) of fig.2, are compared, all with equal equivalent absorber surface. Results indicate that absorbers are most effective to reduce reverb times (mid graph) and center times (lower graph), when positioned at the walls.

Auralization as a Tool for Communication Room Planning

In addition it has been tested, whether the absorber position effects can be discriminated on auralized samples. Five versions of the conference room were compared :

1. the acoustically untreated room, no absorbers
2. carpet on ground, no other absorbers
3. low frequency absorbers at walls, carpet on ground, (b) in fig.2
4. absorbers at the ceiling and on ground, (c) in fig. 2
5. low and high frequency absorbers at walls, (a) in fig.2

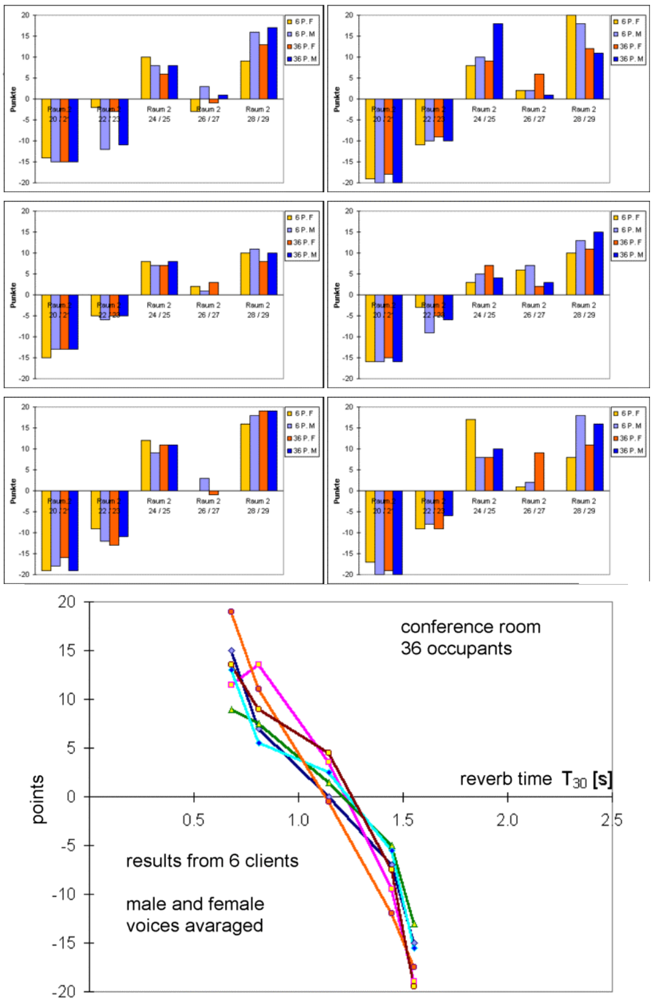

Figure 4: Auralization test results from 6 test candidates In a blind test they compared each room version to each other, only knowing they were hearing ‘different rooms’. Comparisons were done with low (6 P.) and high (36 P.) occupation, and with male and female voice. In every single comparison the following ‘double question’ was asked :
”which of the two rooms is the better for communication ?”
”how easy is it to decide about this pair, 5 (very easy) to 0 (impossible) ?”
The points were added to the better room and subtracted from the worse room every time. Summing up all points gives a ranking of all rooms in the test (upper graph). These point sums correlate well with mean reverb times (lower graph) and with other quality measures, e.g. center times.
At beginning it is essential to instruct the candidates, that the best communication room is not always the same as the ‘best sounding room’.

Summary of Results

Room acoustical solutions for communication rooms have been studied, where the ceiling must not be covered by absorbers in order to be compatible with passive cooling.

Adequate solutions with absorbers at walls and on ground are shown. Flat low frequency absorbers at the walls are required. High frequency absorption may be achieved by an appropiate carpet on ground or by wall absorbers.

Simulation results indicate that the efficiency of absorbers depends significantly on their positions. Absorbers at walls show better effect than absorbers of equal equivalent absorber area at the ceiling or on ground.

Auralized samples have been tested for their usefulness to evaluate room acoustical quality. Tests show that persons without acoustical education are able to classify rooms corresponding to acoustic quality measures as reverb times or center times, when samples are compared in pairs and appropriate questions are answered.

Limitations

Results suffer from several limitations due to the method of simulation and due to input data. A major limit arises from the assumption of ‘geometrical optics’ as a base of the simulation method. So room eigenfrequencies are not modelled, and, as the room height is in the order of the wavelenght at the lower frequency bands (λ = 2.7 m at 125 Hz), low frequency results have to be considered as estimates.

Another limitation is due to missing scattering coefficients for almost any surface construction or material. So estimated values were applied. A sensitivity analysis showed some influence of scattering coefficients on the absorber position effects. Effects reduce slightly with higher scattering coefficients, but do not even vanish at 50%.

Future Work

To overcome uncertaincies of present results experimental verification is necessary. Combined experimental and simulation work has just begun, where built example rooms will be investigated from both ‘sides’ under identical conditions including sound sources and binaural measurements.

Acknowledgements

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References

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