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Optimising the Acoustic Design for Multi-Purpose Rooms used for a Variety of Speech Communication Activities

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ABSTRACT

The sound environment for a room designed for speech communication can be influenced by many factors. In a newly completed multi-purpose lecture room, we wanted to see the effects of the different design elements during the process including; utilising predictive modelling, the surface materials in terms of absorption performance, discussion, amount and placement as well as other design details influencing the overall sound environment. We have followed this project though the build and fit out process making acoustic measurements at different stages. Typically, a room of this type might have acoustic criteria for sound insulation and reverberation time. However, this can be somewhat limited when we compare the theoretical acoustic predictive modelling versus how the occupants might actually perceive the room in real life situations. We have measured additional room acoustic parameters such as speech clarity and the difference in sound levels. We will identify the acoustic differences as the room is built up with ceiling, wall and floor finishes, in addition to the design elements and furniture. Finally, we will discuss design configurations which can make a room fit for multi-purpose speech based activities.

Keywords: Reverberation Time; Speech Clarity; Sound Strength Sound Pressure Levels; Speech Communication

1. INTRODUCTION

The acoustic characteristics of a room can be calculated, measured and many room acoustic standards have been set around one common parameter – Reverberation Time (RT). Over the years, RT has been widely understood and referenced as the most practical measure to evaluate the quality of acoustics in a classroom.

In recent decades it has also become increasingly common for the acceptable reverberation time values to be lowered (shortened) and indeed in many cases, the previous recommended lower limits have been removed. Looking at the relevant and similar types of rooms also used for similar speech communication intensive activities; monologue lectures, dialogue in the form of group work and discussions in pairs. According to Rasmussen(1) in the Nordic countries the trend has clearly indicated that a shorter RT is assumed to be better. However, even when a speech communication intensive room like a classroom, meets the required short objective RT values, it does necessarily mean the given classroom will be subjectively perceived as having good speech intelligibility or low sound levels by the users when the room is occupied which cast doubt on whether the room is fit for purpose.

Measuring the RT means that we mostly consider the decay of the late reflections and we miss the overall room response to a given sound and in particular the early reflections (Bradley(2)) which are very significant when it comes to the clarity of speech and how it will be perceived as found in listening tests performed by Nilsson(3,7) also Marshall(4).

The shortcomings of the classical diffused field theory(5,6) become quite clear in rooms with non-uniform distribution of absorption treatment. This has paved the necessity for introducing more

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parameters as well as taking into account the scattering effect of furniture and interior fittings has been investigated.

2. BACKGROUND

2.1 Variety of speech communication activities

Increasingly, there is a requirement for multi-purpose speech communication rooms which can hold a variety of different speech communication intensive activities. These activities might include; monologue lectures, watching knowledge films or streaming lectures and more diverse speech communication activities encouraging dialogue which include workshops, group work and discussions in pairs.

2.2 Characterising the room acoustic conditions for speech communication

On this basis and from the increasing knowledge about how to characterise the acoustical conditions in these types of rooms used for multi-purpose speech communication activities can to an extent be compared to modern classrooms has increased in recent years. Several investigations have highlighted the necessity of including more acoustic parameters (Nilsson(7), Bradley(8)) for a relevant characterisation of the acoustic environment. Parameters related to the noise levels and to speech intelligibility have shown to be an important and necessary complement to the RT (Campbell(9)).

2.3 The relevant room acoustic parameters

In Bradley's paper(8), the use of the room acoustic parameters C_{50} and Strength are examined both experimentally and theoretically. In Barron(10), Nilsson(7), a model is presented for calculating C_{50}. There was particular focus on explaining the non-diffuse sound field in rooms with ceiling treatment and how this influences these parameters. In national standards and regulations for classrooms designed for similarly intensive and varied speech communication e.g. UK, Germany, (Nordic countries see Rasmussen(1)) there is still a clear dominance of RT as the parameter for characterizing the acoustic quality. In view of this, it is clear that the practice of only defining a single number evaluation of RT potentially restricts development of optimal acoustic conditions to make these rooms fit for purpose. (5)

3. OUTLINE OBJECTIVE

3.1 Objective measurements which correspond to subjective perceptions

In this study we wanted to look into objective measurement data which we understood to have a significant correspondence to the subjective perceptions of the room for the users. Today, the main parameter in acoustic design, standards and regulations of ordinary room types is the RT. Nevertheless, it is well known that the RT alone is not sufficient for a relevant characterization of the acoustical conditions in rooms. The purpose of this modest room acoustic investigation is to show the potential benefit of including additional parameters alongside RT whilst measuring different acoustic configurations. Optimal acoustic conditions should be specified by a balance of objectively measureable parameters related to speech clarity, sound strength and reverberation time.

3.2 Objective room acoustic parameters

A key objective in this study is to establish the conditions for optimal room acoustics as manifested in the room acoustic parameters; Speech Clarity C_{50} (dB), sound pressure levels (measured with a constant sound power source) and reverberation time, T20 (s). C_{50} evaluates the effect of the room's response to given sounds and the balance of the early reflections in relation to the late reflections. The parameters are defined in the standards ISO 3382-1 and 2(11,12). In general, this additional parameter C_{50}, outlined in ISO 3382-1(11), were intended for large performance spaces rather than for speech in smaller rooms, however, they have been found to be good indicators regarding the room acoustic quality as well as RT (4,5,6,7,8,9). It has also already been identified that in typical classrooms that C_{50} values can be different even when the RT is the same, Nilsson(5).

4. ROOM DESCRIPTION

4.1 Room dimensions

The size of the rectangular room we used are length x width x height = 12.35m x 6.05m x 2.64m. 74.4m^2 overall floor area 74.4m^2 and 197m^3 volume.

4.2 Room surface finishes

The room surfaces before the acoustic treatment on the ceiling and the additional wall absorption, were 1000mm average overall depth of system in the ceiling void, sloped soffit.

Room acoustic treatment, a fully covering suspended ceiling 20mm “Absorption Class A” glass wool absorber panels. 40mm “Absorption Class A” wall absorbers in accordance with ISO 11654. (wall coverage 7.8m2).

Walls are a typical lightweight drywall construction with partition cavity insulation. One long glass wall installed with around a 5degree outward tilt – so wider at the top.

Carpet Egetaepper 8mm heavy commercial, Alpha w 0.2 tufted cut pile with a woven textile back.

Figure 1 – Multi-purpose (Orion) room in use during a workshop session.

5. METHODOLOGY

5.1 Acoustic intervention study

The main part of this study was to measure and analyse data from the room before and during the three acoustic intervention stages to understand the influence of additional surface materials on the floor, walls and ceiling.

5.2 Impulse response measurements

The acoustic measurements were done using an impulse response in order to evaluate the following room acoustic descriptors; T20 and C50 in accordance with ISO 3382-1[(11)] and we measured the sound levels Leq in dB. Analysis of the room acoustic parameters measurement data is gathered across 125-4000Hz frequency band. In addition, the sound pressure levels (Leq) in dB were measured with a constant sound power source.

5.3 Acoustic configurations

The Ecophon Orion multi-purpose room acoustic measurements:

Configuration No. 1 – room with fully covering ceiling absorption.
Configuration No. 2 – same as “No. 1” plus fully covering carpet on the floor.
Configuration No. 3 – same as “No. 2” plus the furniture (tables & chairs).

Configuration No. 4 – same as number "No. 3" plus 7.8m2 of wall absorbers over 3 walls.

Figure 2 – Config. 1. Base conditions with a fully covering suspended ceiling.

Figure 3 – Config 2. Now with the carpet installed.

Figure 4 – Config. 3. Now with furniture in place.

Figure 5 – Config. 4. Now with the additional 7.2m2 of wall absorbers distributed over three walls

Figure 6 – Config. 4. Six vertical wall absorbers at the front on the left wall as shown in Figure 5.

Figure 7 – Config. 4. Two circular wall absorbers on the right wall towards the middle of the room.

Figure 8 – Config. 4. Nine circular wall absorbers on the back wall.

6. ACOUSTIC MEASUREMENT RESULTS

We measured the base conditions in the room (Confg.1) followed by three further alterations giving a total of four separate configurations outlined below. Below is a summary of the values achieved with the configurations 1-4 for T20, C_{50} and SPL:

Configuration No. 1 – room with fully covering ceiling absorption.
Configuration No. 2 – same as "No. 1" plus fully covering carpet on the floor.
Configuration No. 3 – same as "No. 2" plus the furniture (tables & chairs).
Configuration No. 4 – same as number "No. 3" plus 7.8m2 of wall absorbers over 3 walls.

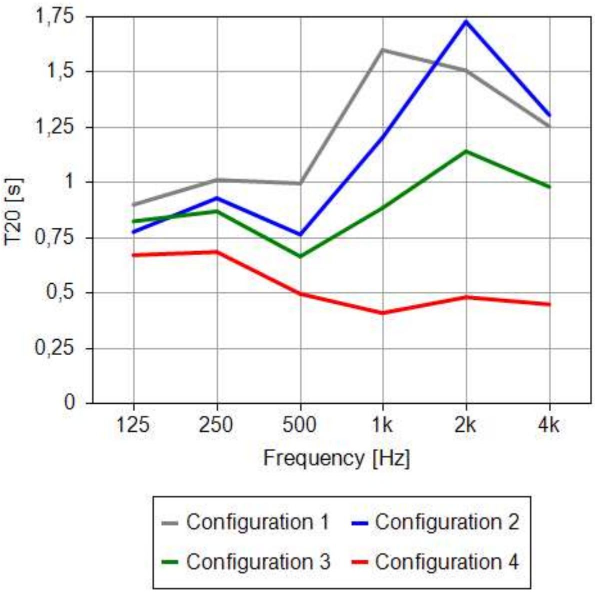

Figure 9 – T20 results for all room configurations.

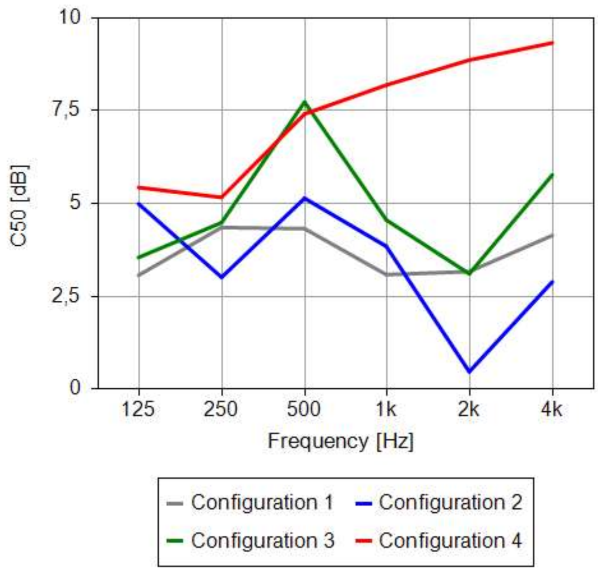

Figure 10 – C_{50} results for all room configurations.

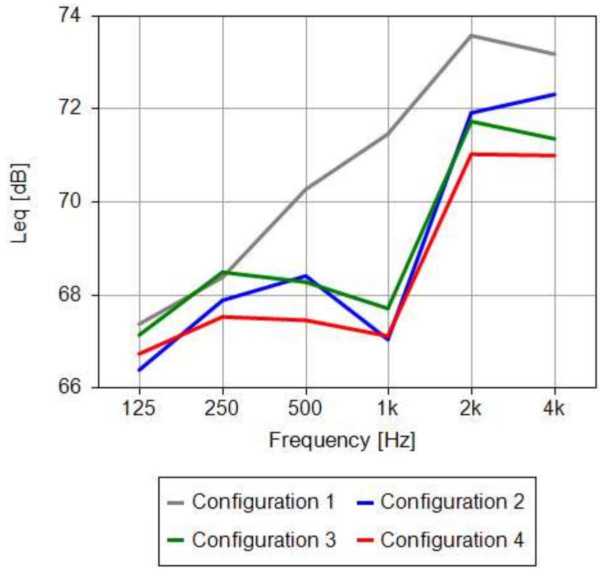

Figure 11 – Sound pressure levels for all room configurations

7. DISCUSSION AND CONCLUSION

The effect of different acoustical treatment in a multi-purpose room has been studied. Measurements of reverberation time, speech clarity and sound pressure level have been performed. The sound pressure levels were measured with a constant sound power source. The acoustical treatment has been performed in four stages, starting with a suspended absorbent ceiling in the non-furnished room. Next stage was to add a sound absorbent carpet, then inserting furniture and finally adding wall panels. During each step room acoustic measurements have been carried out. The results are presented in figures 9 to 11. Some interesting conclusions can be drawn. Inserting the suspended ceiling creates a non-diffuse sound environment which gives long reverberation times in the high frequency region. This is due to the grazing sound field occurring between the walls and which is to a less extent influenced by the ceiling absorber. However, even if the reverberation times are long the (steady state) sound pressure levels have been significantly lowered. Adding the absorbent carpet even further emphasises the grazing sound field and in fact gives even longer reverberation times at the higher frequencies, but this in combination with and due to the decrease of the (steady state) sound pressure levels. Inserting furniture will add some sound scattering which mainly shortens the reverberation times and increases the speech clarity. The sound pressure levels are hardly at all affected by the furniture. The furniture consists of non-absorbent tables and lightly upholstered chairs. Thus, the main effect of furniture is to increase the diffusion in the room which affect the reverberation times and the speech clarity however there is only a minor effect on the sound pressure level. An efficient way to reduce the effect of the grazing sound field is to add wall panels. This gives a clear improvement of reverberation times as well as speech clarity, even though the amount of wall absorption coverage was quite small.

It's clear from the measurement results that to understand the effect of different acoustical treatment under non-diffuse conditions it's important to analyse several room acoustic parameters. For example, if only reverberation time were considered and assuming diffuse conditions, the increased reverberation times at higher frequencies when adding the carpet would have led to the conclusion that the sound pressure level has increased, which would be wrong. Furthermore, the large effect of wall panels on reverberation times and speech clarity values is another effect that would have be hidden if we assume diffuse field conditions.

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