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Diffusers in public ordinary rooms

Arvidsson, Emma[1]
Bard, Delphine[2]
Lund University
John Ericssons väg 1
223 63 LUND
SWEDEN

Nilsson, Erling[3]
Karlsson, Ola[4]
Saint-Gobain Ecophon AB
Yttervägen 1
265 75 HYLLINGE
SWEDEN

ABSTRACT

Traditionally, the room acoustic properties in an ordinary public room are defined by only one parameter, the reverberation time. However, research has showed that additional room acoustic parameters as sound strength and speech clarity are necessary to consider in order to achieve good acoustic conditions.

In a room with acoustical ceiling treatment the effects of furniture and interiors on the room acoustic parameters are significant. In addition, by using diffusers with directional properties it is possible to individually control the room acoustic parameters.

Room acoustical measurements have been carried out in a reverberation chamber with suspended absorbing ceiling and directional diffusing objects. The effect of different diffuser configurations has been examined regarding reverberation time, speech clarity and sound strength.

The evaluation shows that the orientation and the amount of the diffusing elements have a significant influence on the room acoustic parameters and can be used to fine-tune the acoustical conditions in public ordinary rooms with an existing acoustic ceiling treatment.

This paper presents a study showing how diffusers can be used to contribute to an improved sound environment in public ordinary rooms with an acoustic ceiling.

Keywords: Diffusers, Speech clarity, Reverberation time
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[1] emma.arvidsson@ecophon.se
[2] delphine.bard@construction.lth.se
[3] erling.nilsson@ecophon.se
[4] ola.karlsson@ecophon.se

1. INTRODUCTION

The importance of considering several room acoustic parameters beside reverberation time also in public ordinary rooms, and not only performance spaces, has been raised by several researchers.

Nilsson and Svensson **[1]** have described different room acoustic parameters to be used depending on room types; the reverberation room, a room with an acoustic ceiling and an open space. It is shown how reverberation time is relevant to be used in a reverberant room but additional parameters are needed in rooms with acoustic ceilings since the first reflections will not be encountered when measuring the reverberation time. Further are propagation measures needed to describe the acoustics in open plan environments.

Campbell, Nilsson and Svensson **[2]** have shown two identical rooms with the same reverberation time having different values in sound strength and speech clarity. This indicates that the reverberation time does not give a complete description of the acoustics in a room and other parameters than reverberation time should be considered also in public ordinary rooms to give a more complete description of the acoustic characteristics of the room. Further was a difference in speech clarity as well as in sound strength found in the different rooms which can explain the different acoustic experience of the two rooms.

Bradley, Sato and Picard **[3]** have studied the importance of early reflections for speech and recommends to focus on maximizing the early reflections to contribute to the direct sound. It is recommended to control the reverberation time in order to not make it too long but at the same time being aware of keeping enough sound energy in the room.

Diffusers have been used for many years in performance spaces in order to create good sound environments both for the artists and the audience. Diffusers can be used to reduce echoes keeping the sound energy. Using absorbers will reduce echoes but also decrease the sound energy levels. Another advantage with diffusers is using it as a tool to increase the early reflections and direct the sound in preferred directions **[4]**. To use the acoustic technology behind this effect is of interest also in public ordinary rooms in order to improve the acoustic environment without risking too low sound energy values.

2. METHOD

Test has been made in a reverberant room with dimensions 3,60 x 4,00 x 4,05 m. A suspended highly absorptive ceiling was installed at a height 2,70 m from the floor. The average practical absorption factor for the ceiling is 1.0 for the frequency range 500 Hz to 4000 Hz.

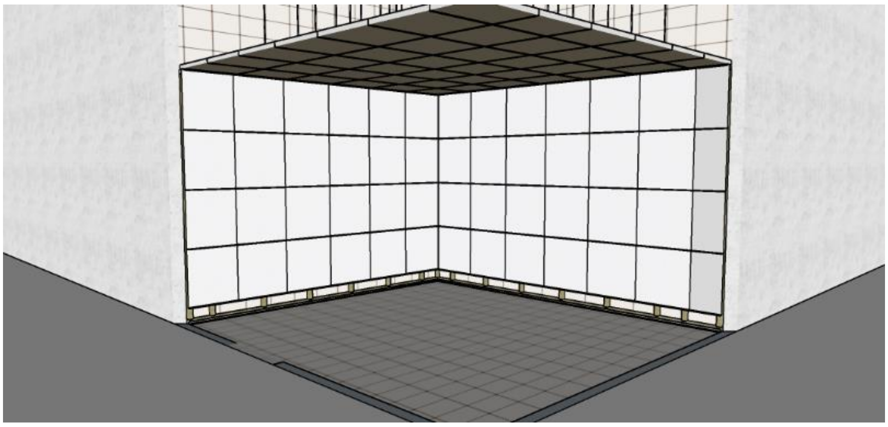

Figure 1 Sketch of reverberant chamber with absorbent ceiling used for the measurements.

Due to the dimensions of the diffusers were the main diffusing effects for the octave bands 2000 Hz and 4000 Hz. The dimensions of the diffuser can be seen in figure below.

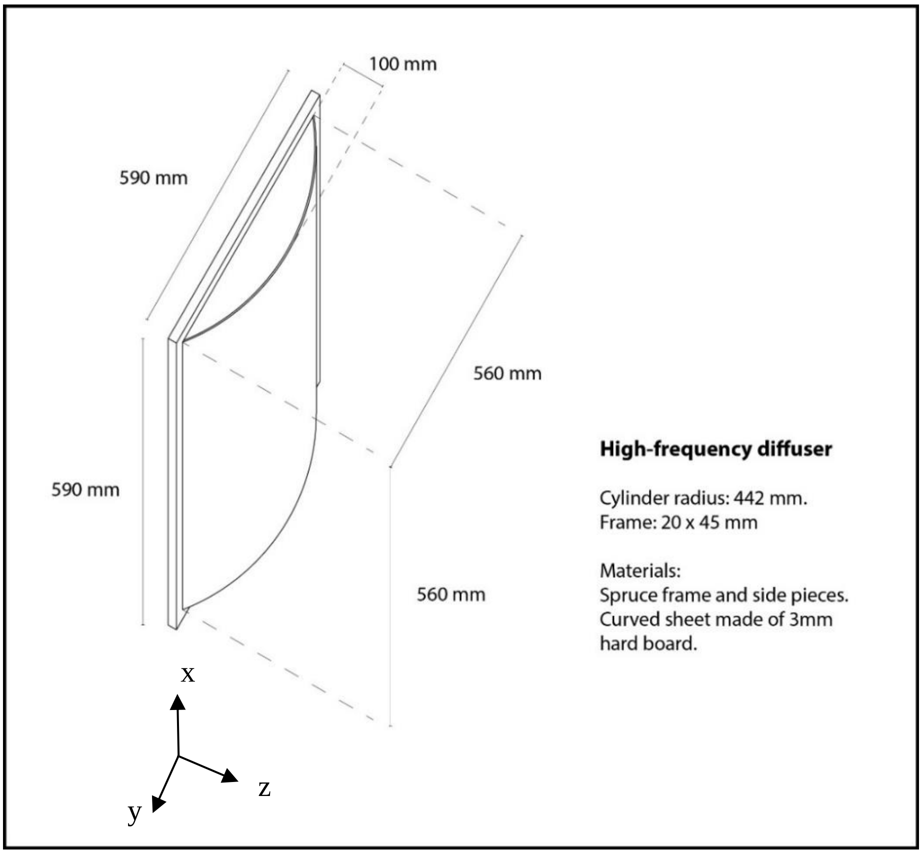

Figure 2 Sketch of diffusers used in the study.

The diffusers have been tested in two different directions defined as vertically and horizontally oriented diffusers. Vertically oriented diffusers direct the sound vertically and horizontally diffusers direct the sound horizontally. The diffusor in Figure 2 is mounted in the horizontal orientation referring to the room configuration. The floor is at x=0 and the suspended ceiling at x=H where H is the height to the suspended ceiling i.e. 2,7 m. Turning the diffusor 90 degrees around the z-axis corresponds to the vertical direction. The two orientations are shown in Figure 3.

Configurations with diffusers oriented in vertical rows, from three rows up to twelve rows, for vertically respectively horizontally oriented diffusers as seen in the sketches below.

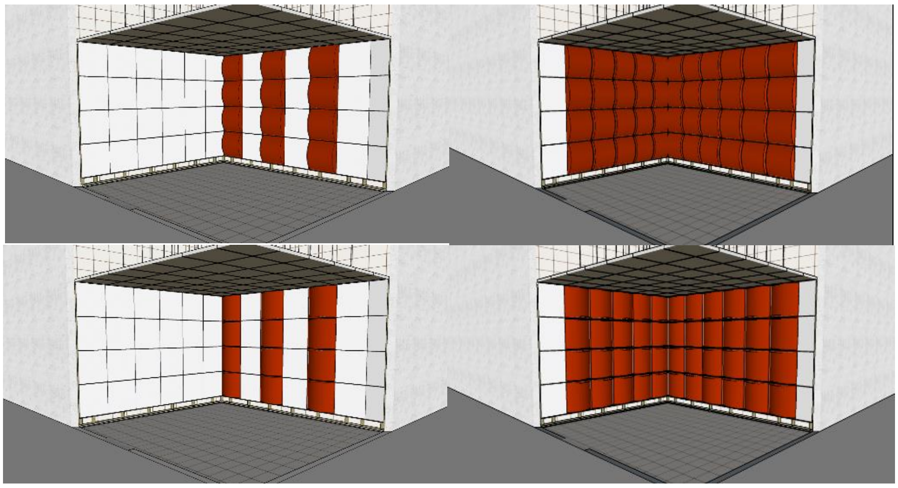

Figure 3 Diffusers in vertical rows, vertically oriented diffusers as in the left figures and horizontally oriented diffusers as in the right figures

Reverberation time, speech clarity and sound strength were measured for the different configurations. An omnidirectional sound source was used for the measurement of reverberation time and speech clarity for which the impulse response was evaluated. Sound strength was evaluated using constant sound power source (a fan).

The influence of the amount of diffusers were quantified in terms of an equivalent scattering absorption area Asc. The equivalent scattering absorption area was calculated according to.

$$\boldsymbol{A_{sc} = 0,127V * \left(\frac{1}{T_{20,with}} - \frac{1}{T_{20,without}}\right)} \qquad \textbf{(1)}$$

Where
$\boldsymbol{V}$ is the volume,
$\boldsymbol{T_{20,with}}$ is the reverberation time with diffusers and
$\boldsymbol{T_{20,without}}$ is the reverberation time without diffusers

The estimation of Asc according to Eq. 1 is based on a model outlined in **[5]**. The basic idea is that the sound field in rooms with absorbent ceilings can be subdivided into a grazing and non-grazing part where the grazing part refer to sound waves propagating almost parallel to the ceiling. The scattering part of Asc is related to the energy transfer from the grazing to the non-grazing part. Asc is measured in a room with highly absorptive ceiling with and without diffusers, assuming a two-dimensional diffuse sound field.

3. RESULTS

3.1 Equivalent scattering absorption area

The graphs below show the equivalent scattering absorption area Asc according to Eq. 1 for the octave bands 2000 Hz and 4000 Hz. The upper curves show the vertical orientation of the diffusers and the lower ones the horizontal oriented diffusers.

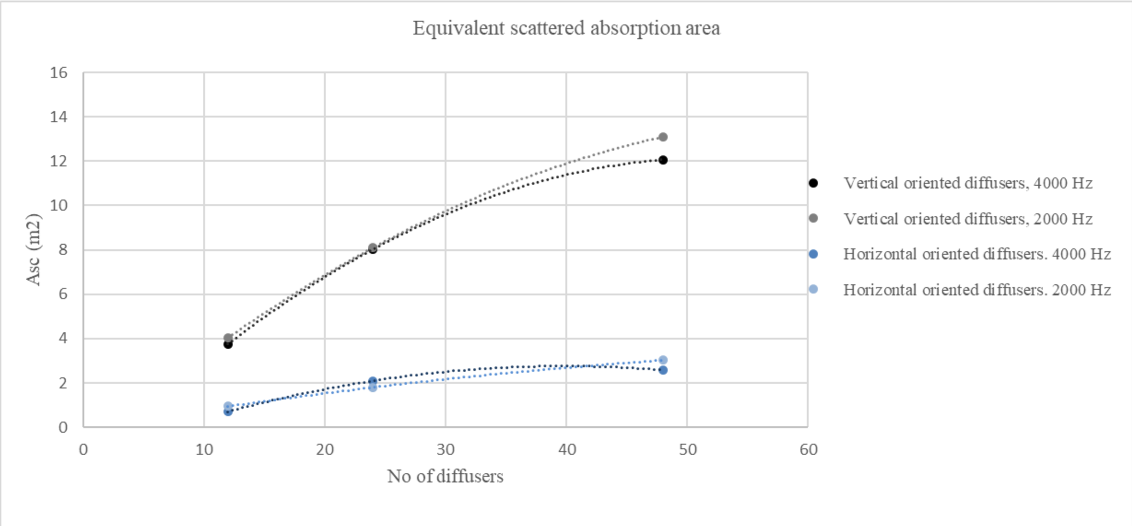

Figure 4 Equivalent scattered absorption area, 2000 Hz and 4000 Hz for vertical and horizontal oriented diffusers.

The Asc for the vertical oriented diffusers is significantly larger than for the horizontally oriented. The effect is similar for 2000 Hz and 4000 Hz. The relative increase o Asc as function of the number of diffusers are similar for the orientations. Vertically oriented diffusers gave about four times bigger values.

3.2 Room acoustic parameters

The effect of the diffusers was evaluated for the acoustic parameters reverberation time, speech clarity and sound strength for the octave bands 2000 Hz and 4000 Hz for the two diffuser orientations.

The diagrams below show the difference achieved in reverberation time **[6]** compared with measurement on configuration only including absorbent ceiling and no diffusers. In the figures are the effects of orientation is shown.

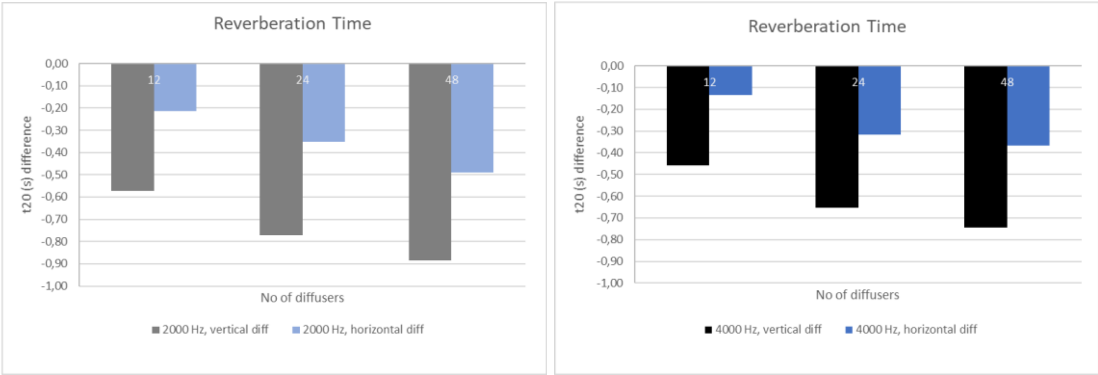

Figure 5 Reverberation time. Grey collars represents the vertical oriented diffusers; blue collars represent vertically oriented diffusers.

A significant improvement in reverberation time can be seen by using the diffusers, for both octave bands. It should be observed that the vertically oriented diffusers give significantly higher improvement than the horizontally oriented diffusers even though these gave a difference larger than Just Noticeable Difference, JND, **[7]** already at the lowest amount of diffusers.

The figures below show the difference in speech clarity, C50, **[7]** comparison is made with measurement on configuration only including absorbent ceiling, i.e. no diffusers.

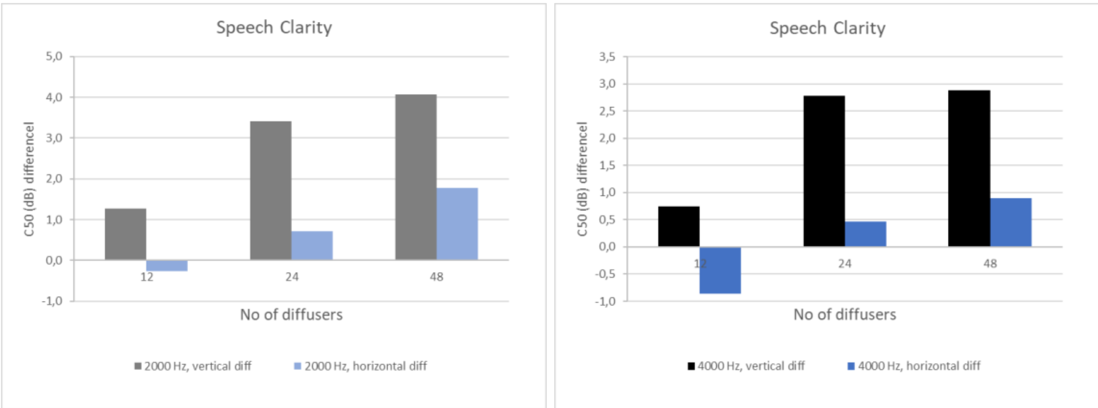

Figure 6 Grey collars represents the vertical oriented diffusers, blue collars represents vertically oriented diffusers.

The speech clarity was improved using diffusers with vertical orientation, showing results of improvement in the range of JND or higher already at the lowest amount of diffusers. Duplication of the diffusers in this orientation gave an increase of about 3 dB which is a significant improvement. Important to notice is that more diffusers than 24 gives only a small increase in speech clarity compared to the double amount of diffusers.

The figures below show the difference in sound strength, G, **[7]**. Comparison is made with measurement on configuration only including absorbent ceiling, i.e. no diffusers.

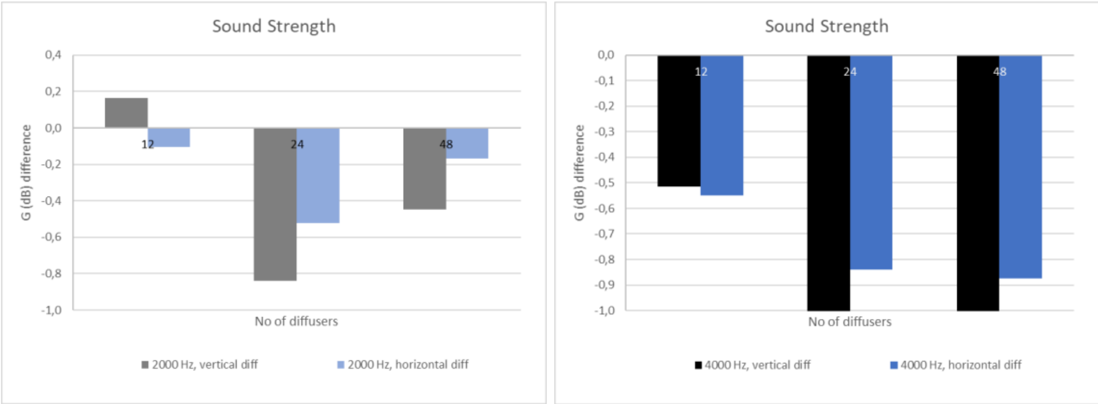

Figure 7 Grey collars represents the vertical oriented diffusers, blue collars represents vertically oriented diffusers.

The diffusers, both vertical and horizontal orientations, gave no or small influence on sound strength for the frequencies 2000 Hz and 4000 Hz. This parameter is measured under steady state conditions and will be more dependent on the amount of absorption. This is visualised in figure below where sound strength has been measured for different amount of absorption. The results represent the average values from 500 Hz to 4000 Hz.

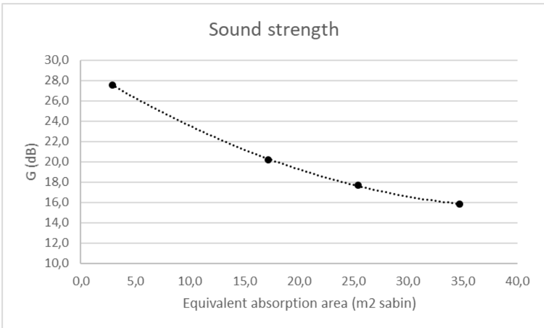

Figure 8 Sound strength related to amount of absorption.

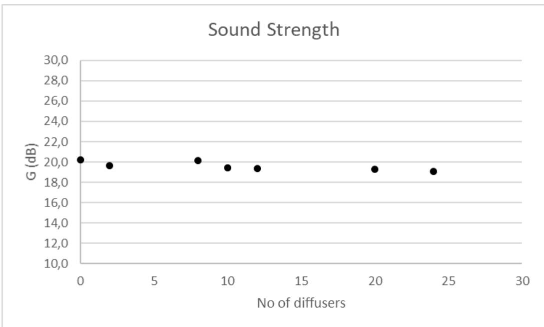

Figure 9 Sound strength related to amount of diffusers.

DISCUSSION AND CONCLUDING REMARKS

Several researchers have shown that speech clarity, reverberation time and sound strength are important to consider in rooms for speech. The results from this study shows that diffusers in combination with an absorbent ceiling can be an efficient way to improve speech clarity and reverberation time. Sound strength will be less effected by the use of diffusers and is more dependent on the amount of absorption.

In order to use the diffusers efficiently is it important to consider the directions of which the diffuser will operate. Diffusers which direct the sound vertically contributed more to the diffuse sound field, compared with horizontally oriented diffusers.

The results from the measurements indicates a threshold in number of diffusers where additional diffusers not gave any differences on the room acoustic parameters. At the same number of diffusers could a change in the behaviour for the relation between the number of diffusers and the equivalent scattering absorption area be seen.

This study has shown that diffusers can play an important role in improvements of the room acoustics in public ordinary rooms with acoustic ceilings. However, more knowledge is needed on how to use them efficiently in order to fine-tune the acoustics in these type of rooms. In the coming steps of this study will the effect of different pattern of diffusers be investigated for further understanding of the relation between diffuser design, the quantification in terms of equivalent scattering absorption area and the room acoustic parameters.

ACKNOWLEDGEMENT

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