PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Pattern and orientation of diffusers in rooms with an absorbent ceiling

Emma ARVIDSSON[1]; Erling NILSSON[2]; Delphine BARD[3] Ola KARLSSON[4]

[1,3] Lund University, Sweden

[2,4] Saint-Gobain Ecophon, Sweden

ABSTRACT

Lately have the demands on good room acoustics in public ordinary rooms increased. Traditionally has only reverberation time been considered in this type of rooms but complementary parameters as sound strength and speech clarity are more commonly used today. This trend naturally implies higher demands on the acoustic treatment.

Typical for public ordinary rooms is to use an absorbent ceiling. One way to further improve the acoustic properties is to complement the ceiling treatment with diffusers. To investigate the effect of combining these two types of acoustic treatments have measurements been carried out combing different setups of diffusers in a reverberant room with an absorbent ceiling. The impact on reverberation time, speech clarity and sound strength has been studied.

In this paper we present how diffusers can be used in order to improve the acoustic properties in a public ordinary room with an absorbent ceiling and how the pattern and orientation of diffusers can be used to adjust different acoustic parameters.

Keywords: Absorbent ceiling, Diffusers, Speech clarity

1. INTRODUCTION

Contribution of early reflections is of importance in rooms for speech. In acoustic design of performance spaces as auditoria and theaters has parameters considering the early reflections been included for many years. Several researchers recommends higher effort on considering these parameters also in rooms for speech [1] [2] [3].

The traditional acoustic treatment for public ordinary rooms, such as classrooms and offices, is an absorbent ceiling. Nilsson has showed how furniture contributes to a more diffuse sound field and by that improving the acoustic parameters reverberation time and speech clarity [4]. Choi has made a study, in 1/10 scale, on the combination of absorbers and diffusers, showing that the combination of these two different types of acoustic treatments were the most preferable for reverberation time, speech clarity and sound strength [5].

An advantage by treating the acoustics also with diffusers in these type of rooms is that the sound energy is conserved in the room [6]. By choosing the right design and pattern of the diffusers could certain frequencies be treated and room acoustic parameters be improved. The use of diffusers could also open up for more esthetical freedom for interior designers.

This paper presents the results from an investigating using adaptive diffusers specially designed for rooms with absorptive ceilings. It is investigated how the amount, orientation and pattern of

1 Emma.arvidsson@construction.lth.se
2 Erling.nilsson@ecophon.se
3 Delphine.bard@construction@lth.se
4 Ola.karlsson@ecophon.se

diffusers effects the equivalent scattered absorption area (Asc). Further is the relation between Asc and the room acoustic parameters reverberation time, speech clarity and sound strength investigated.

2. METHOD

2.1 Room configuration and measurement method

Measurements have been carried out in a reverberation chamber. A highly absorptive ceiling, α_p of 1, for the frequency range 500 Hz to 4000 Hz, was installed at height 2,70 m. The area of the chamber was 3,6 x 4,00 m2.

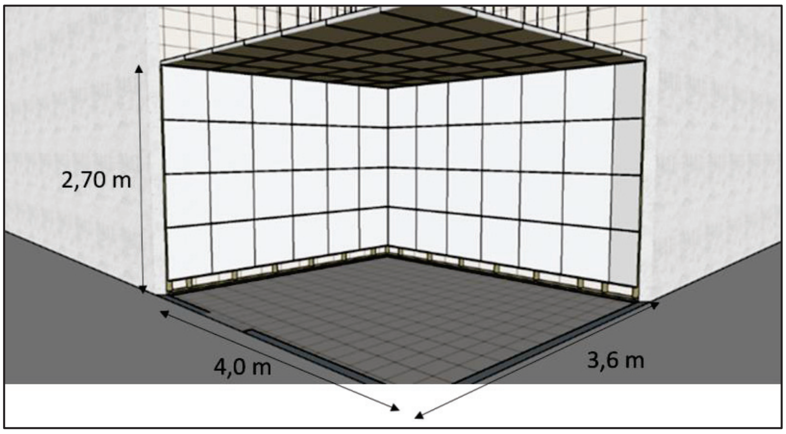

Figure 1 Sketch of reverberation chamber used for the measurements.

Reverberation time [7] and speech clarity [8] has been evaluated from the impulse response measured from an omni directional sound source. A constant sound power source was used to evaluate the sound strength [8].

2.2 Diffuser design

The design of the diffusers used in the study is showed in Figure 2. The frequencies of interest in this case were 2000 Hz and 4000 Hz. The results for reverberation time, speech clarity and sound strength were thereby evaluated for these frequencies.

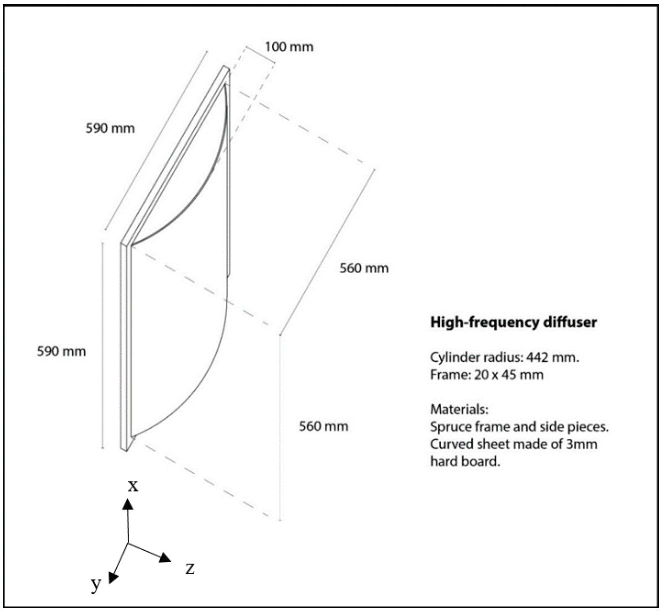

Figure 2 Sketch of diffuser used in the test.

2.3 Equivalent scattering absorption area (Asc)

A Statistical Energy Analysis (SEA) model [9] developed for characterization of the energy decay in rooms with absorbent ceiling treatment has been applied in the analysis. In these type of rooms can the sound field be subdivided into a grazing and non-grazing part where the grazing field comprises waves propagating almost parallel to the ceiling.

To quantify the scattering effect of furniture or other sound diffusing objects a parameter called equivalent scattering absorption area (Asc) is introduced. In an SEA terminology the Asc is interpreted as a coupling loss factor describing the energy transfer between the grazing and non-grazing sound field. The Asc is given by

$$A_{sc} = \pi\omega V/c * \eta_{ng,g} \tag{1}$$

where

V is the room volume,
ω the radian frequency and
c the speed of sound.

Assuming that the subdivision into a grazing and non-grazing part still is justified after introducing the sound diffusing objects the A_{sc} is approximately given by

$$A_{sc} = 0{,}127V * \left(1/T_{20,with} - 1/T_{20,without}\right) \tag{2}$$

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

Equation (2) is a two-dimensional equivalent to Sabine formula.

2.4 Diffuser configurations

17 configurations were evaluated. These configurations include different directions of diffusers, different amount of diffusers and diffusers installed in different patterns. Description of all configurations can be find in Table 1 and are visualized in Figure 3 (configurations with both vertically and horizontally oriented diffusers) and Figure 4 (configurations that were evaluated for only vertically oriented diffusers).

Table 1 Description of the configurations.

Configuration	Number of diffusers	Orientation	Pattern
1	12	Vertical	Vertical rows
2	12	Horizontal	Vertical rows
3	24	Vertical	Vertical rows
4	24	Horizontal	Vertical rows
5	24	Vertical	One full wall
6	24	Horizontal	One full wall
7	48	Vertical	Two full walls
8	48	Horizontal	Two full walls
9	12	Vertical	Chess
10	12	Horizontal	Chess
11	24	Vertical	Chess
12	24	Horizontal	Chess
13	20	Vertical	Chess
14	10	Vertical	Chess
15	2	Vertical	Chess
16	24	Vertical	Horizontal rows
17	8	Vertical	Horizontal rows

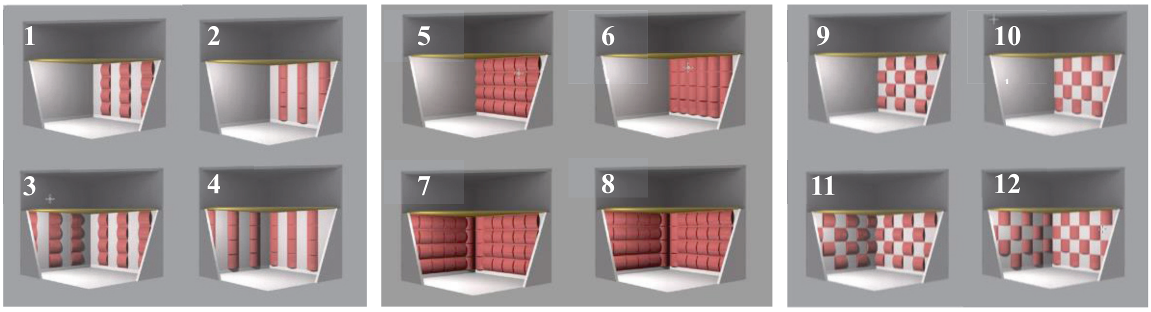

Figure 3 Configurations with vertically and horizontally oriented diffusers.

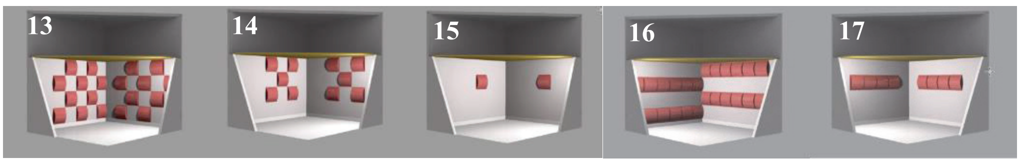

Figure 4 Configurations with vertically oriented diffusers.

The effect on the acoustic parameters reverberation time, speech clarity and sound strength was related to the number of diffusers and to Asc, calculated according to Eq. (2) in order to investigate the impact of different diffuser directions and the installation pattern.

3. RESULT

The equivalent scattered absorption area (Asc) was calculated according to Eq (2). The Asc values increase with the number of diffusers but the result shows also that same amount of diffusers can give different Asc depending of the pattern of which the diffusers are positioned. This is seen for both vertically and horizontally oriented diffusers. It should be observed that the same number of diffusers gives significantly higher Asc values for vertically oriented diffusers compared to horizontally oriented diffusers. Asc related to the number of diffusers is shown in Figure 5 and Figure 6. Figure 5 presents the values for vertically oriented diffusers and Figure 6 presents the results for the horizontally oriented diffusers.

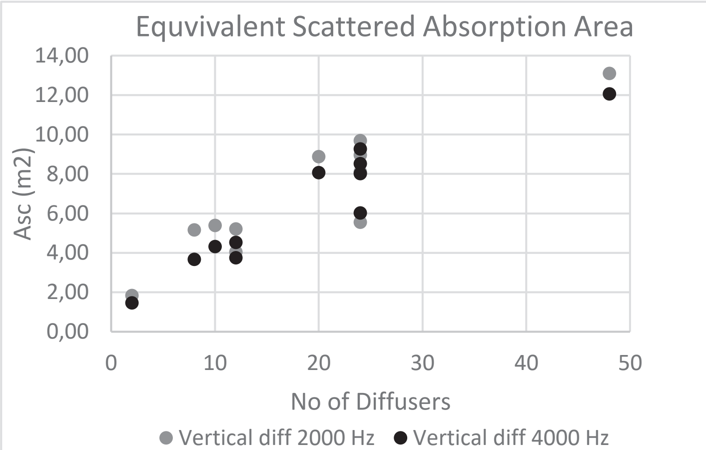

Figure 5 Equivalent scattered absorption area, vertically oriented diffusers, depending on the number of diffusers.

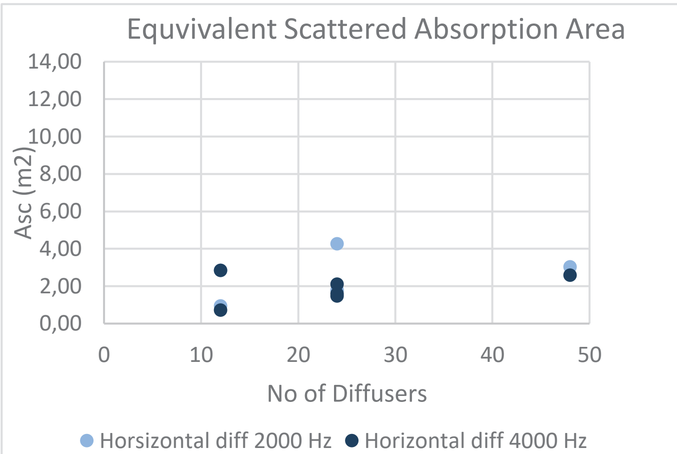

Figure 6 Equivalent scattered absorption area, horizontally oriented diffusers, depending on the number of diffusers.

The relation between Asc and the acoustic parameters reverberation time and speech clarity has been evaluated. This evaluation indicates that similar behavior are achieved in T20 and C50 when relating these parameters to Asc even if the pattern or orientation of the diffusers differs. The results of T20 and C50 related to Asc is presented in Figure 7 and Figure 8. The graphs to the left are the results for vertically oriented diffusers and the figures to the right presents the results for horizontally oriented diffusers. It is important to observe the different scale on the x-axis and that the number of diffusers to reach a certain Asc value differs between the left and right figures.

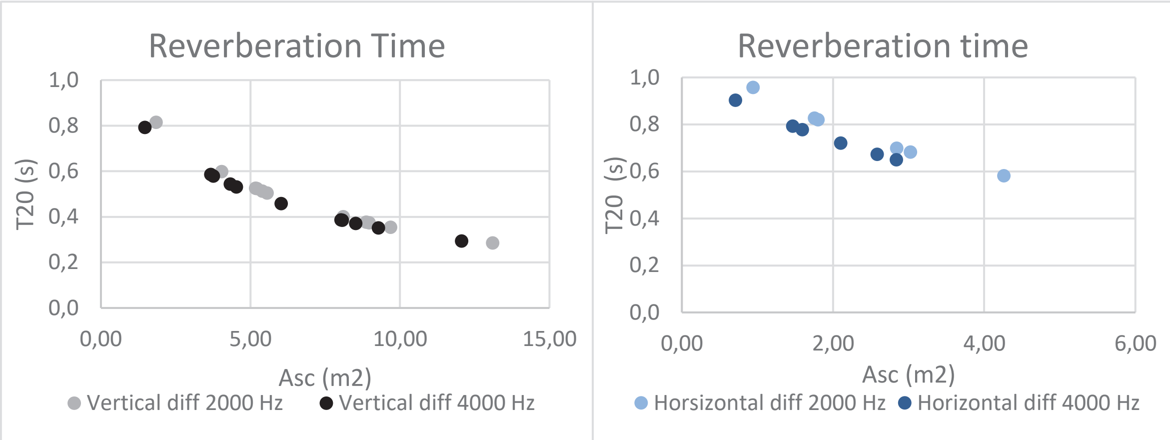

Figure 7 Reverberation time depending on Asc for vertically, to the left, and horizontally, to the right, oriented diffusers.

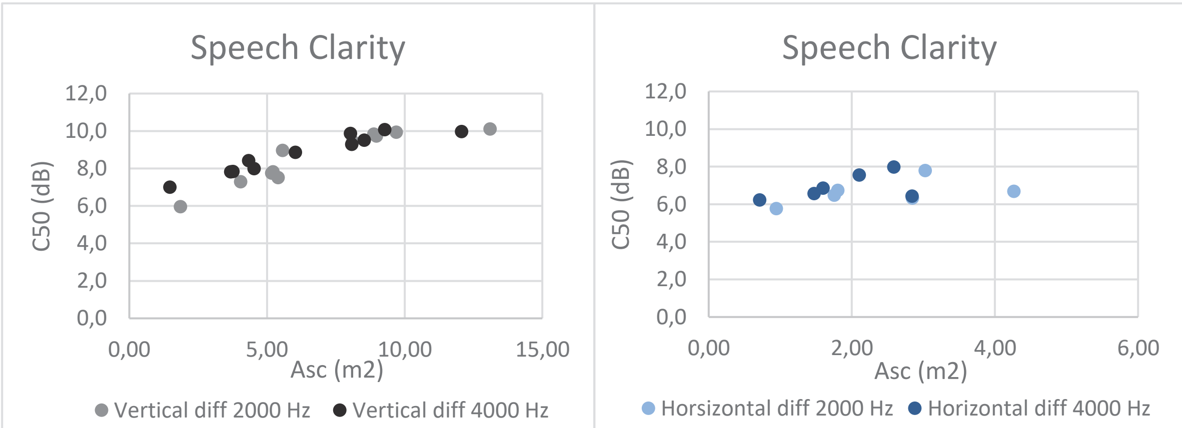

Figure 8 Speech clarity depending on Asc for vertically, to the left, and horizontally, to the right, oriented diffusers.

The acoustic parameter sound strength (G) was also evaluated in relation to Asc. The results show that just a small effect on G is achieved by using diffusers. Further is no obvious trend seen in the relation between G and Asc, as for T20 and C50. The result of G related to Asc is shown in Figure 9. This figure includes both vertically oriented diffusers and horizontally oriented diffusers.

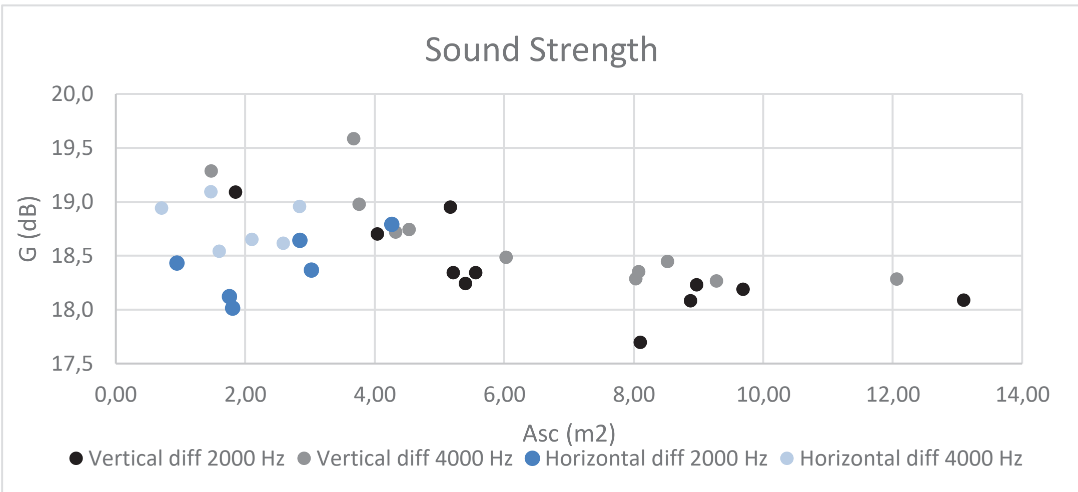

Figure 9 Sound strength related to Asc for vertically and horizontally oriented diffusers.

4. DISCUSSION

The results show that the orientation, in terms of vertically and horizontally, of the diffusers as well as the pattern of how these are installed influences the equivalent scattered absorption area (Asc). Vertically oriented diffusers gave significantly higher Asc than horizontally oriented diffusers when same amount of diffusers were compared. This can be explained by the direction of which the sound waves are reflected. The vertically oriented diffusers contribute with a higher extent to the diffuse sound field by disturbing the grazing field. Further will the vertically oriented diffusers direct the sound to the absorbent ceiling.

Concerning the patterns was it found that Asc, for configurations with same amount of diffusers but with different patterns, was higher for the chess pattern compared with vertical row pattern. Further gave diffusers organized in horizontal rows higher values than the chess pattern. This was valid for both 2000 Hz and 4000 Hz and can to some extent be explained by how the diffusers are exposed related to the sound field. The design, in terms of the construction of edges etc may have an influence.

A correlation can be seen between the Asc values and the acoustic parameters reverberation time and speech clarity, in both 2000 Hz and 4000 Hz. Similar values are found for vertically oriented diffusers and horizontally oriented diffusers when relating it to Asc values. Comparing Asc values seems to be a good indicator for the effect on the acoustic parameters reverberation time and speech clarity. More research is needed on how to estimate the effect of a diffuser depending on the pattern. The relation between the pattern, Asc, C50 and T20 may also be investigated in different room dimensions with more realistic conditions.

Concerning sound strength, just a small change was seen when using diffusers. Since strength, opposite reverberation time and speech clarity, is related to the steady state condition it is closer determined by the diffuse field assumption. Thereby is strength more influenced by the total absorption in the room and less by the scattering. Combining diffusers and absorbent treatment is thereby of interest to investigate further in order to improve the acoustics in public ordinary rooms.

5. CONCLUSION

The direction, amount and pattern of diffusers will have an impact on the efficiency of the diffuser. Further is the design of the diffuser important, in terms of the frequencies in which the diffuser should operate but also regarding choices of how it is accomplished.

The Asc value seems to be an appropriate method for quantifying the effect of the diffusers when comparing the values to the room acoustic parameters reverberation time and speech clarity. Sound strength will be more dependent on the amount of absorption.

This study has been based on measurement in a reverberant chamber, it will be of importance to investigate the influence of diffusers in combination with an absorbent ceiling in a real sized room.

6. REFERENCES

[1] J. Bradley, H. Sato och M. Picard, ”On the importnace of early refelctions for speech in rooms,” *The journal of Acoustical Society of America,* 2003.

[2] E. Nilsson och C. Svensson, ”Room Acosutic Evaluation of Different Room Types,” *BNAM,* 2008.

[3] C. Campbell, E. Nilsson och C. Svensson, ”The same reverebration time in two identical rooms does not necessarily mean the same levels of speech clarity and sound levels when we look at impact of different ceiling and wall absorbers,” *IBPC,* 2015.

[4] E. Nilsson, ”Input Data For Acoustical Design Calculations,” ICSV, 2017.

[5] Y.-J. Choi, ”An Optimum Combination of Absorptive and Diffusing Treatments for Classroom Acosutic Design,” *BUILDING ACOUSTICS · Volume 21 · Number 2 · 2014 ,* p. Pages 175–180, 2014.

[6] T. J. Cox och P. D'Antonio, Acoustic Absorbers and Diffusers, CRC Press, Third Edition, 2017.

[7] EN ISO 3382-2: Acoustics - Measurements of room acosutic parameters- Part 2: Reverberation time in ordinary rooms, 2008.

[8] EN ISO 3382-1: Acoustics - Measurement of room acoustic parameters - Part 1: Performance spaces, 2009.

[9] E. Nilsson, ”Decay Processes in Rooms with Non-Diffuse Sound Fields Part II: Effect of Irregularities,” *Building Acosutics,* vol. 11, pp. 133-134, 2004.