The assessment of sound absorption coefficient of seats in reverberation room

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In this paper the problem of assessment of absorptive seats and audience is discussed. In literature there is sound absorption coefficient as well as equivalent sound absorption area per object. This parameters sometimes are not determined configurations or necessity of shielding. There is no information which value is given: the equivalent sound absorption area per unit or per object. It may influence estimating of reverberation time in room, which is presented in this paper.

In previous EN 20354 standard (ISO 354: 1985) shielding of the edges of the sample of the tested chairs by 1 meter high non – absorptive panels was assumed. The last version of standard from 2003 don’t assumed shielding. There is not given explicitly which quantity characterizing sound absorbing should be determined for chairs, for discrete sound absorbers. Also the correct value: the sound absorption coefficient (equivalent sound – absorption area per unit) or equivalent sound absorption area per object, is not specified.

The results of the sound absorption of soft seats in different configurations are presented, made in reverberant chamber in Building Research Institute. Also the influence of species of arrangement of seats in reverberant chamber (configuration, density) and influence of boundary effect are analysed, that mean the influence of shielding of the edges of the sample of the tested chairs with non – absorptive 1 meters high barrier regarded to 1 m² of area.

1 Introduction

The sound absorption of seats and audience is the most important factor in the assessment of the reverberation time of the concert halls and auditoriums. Occupied or unoccupied chairs are the major absorption in the large halls. Up to now the most important parameter describing the acoustic performance of the concert halls is the reverberation time (RT). In accordance with Davies, Orlowski and Lam [9] the difference limen for the reverberation time for the complex sound sources (orchestra music) amounts 5% at midfrequencies. Therefore it is indispensable to predict precisely the reverberation time of the halls as well as there is need to predict with great accuracy the sound absorption coefficient of the chairs.

Many studies on the sound absorption coefficient of occupied and unoccupied chairs have been carried out. They have a lot of advantages and disadvantages. The sound absorption coefficient might be determined from measurements carried out in a reverberation chamber with a small sample of chairs or measurement made in real halls.

In 1960 Beranek proposed the method of averaged data of the sound absorption [6]. He tried to characterize an average absorption coefficient of the occupied and unoccupied seating. It was measured from the test carried out in many halls. During his measurements he showed great accuracy in assessment of reverberation time of halls by using in calculations the sound absorption coefficient of the seats based on equivalent sound absorption area. Then, in 1998 Beranek carried out more measurements and he classified occupied seats into three categories depending on the degree of upholstering of seats – COH method [8].

Another method for assessment of the sound absorption coefficient of chairs carried out in actual concert halls is the ΔA method. There is determination of the sound absorption coefficient per person based on the measurements carried out in a number of halls and averaged. This is very simply and comfortable method for designers of the acoustics of the concert halls because there is no necessity to determine the audience area from architectural drawings [8].

All these methods mentioned above require carrying out difficult measurements The results obtained on the basis of them vary and might create some errors caused by the differences of diffusions among different halls and auditoriums. In order to normalize measurements of the seat absorption coefficient they are carried out in a reverberation chamber. The sound absorption coefficient obtained by this kind of measurements can minimize financial expenditures but it may create other mistakes in assessment of the reverberation time of the halls.

The ISO 354:2003 standard concerning the assessment of sound absorption coefficient establishes the measurements of the small sample of chairs covering the area of 10 – 12 m² placed in the centre of the reverberation chamber, 1m or more away from any wall and diffuser. The previous version of the ISO 354:1987 standard recommended shielding of the sample by the non – absorptive wooden frame.

Kath and Kuhl proposed changes in ISO 354 standard. They recommended the measurements of the sample placed in a 90 – degree corner of the reverberation
chamber in order to minimize the edge effect. Each part of the sample (top, side and front) received the sound absorption coefficient. The $\lambda/8$ – wide strips were added to two sides of the sample placed near the walls of the reverberation chamber to compensate additional absorption. But still diffraction effects might be present and influence the sound absorption coefficient. [8]

Method proposed by Bradley [5] is a changed ISO method. It stipulate the measurements of a sample of chairs with different ratios of perimeter to area of the sample (P/A). He applied to his measurements the equation:

$$\alpha = \beta \left( \frac{P}{A} \right) + \alpha_{\infty}$$  \hspace{1cm} (1)

where $\alpha$ is the sound absorption coefficient of a finite sample, $\beta$ is the regression constant and $\alpha_{\infty}$ is the sound absorption coefficient of an infinite sample. The result are extrapolated to smaller values of the ratio P/A, which characterize the large seating areas in concert halls or auditoriums. The main disadvantage of this method is that it requires making measurements of few (5 – 6) different sized arrays of a one seat type.

To eliminate the edge effect caused by the implementation of a barrier during measurements Kawakami with Sakai [1] proposed using deep – well approach in parallel with “Power – law Decay” (PLD) approach. They maintain that it eliminate both the edge effect and a differences of diffusion between reverberation room and real concert hall.

A lot of different methods of assessment of the sound absorption coefficient were proposed by various authors. Many of them were described above but still the only one official method to measure the sound absorption coefficient of the seat is the ISO method. This method do not require large expenditures of measurements in real halls. Therefore this method was used to measurements of the sound absorption coefficient of the unoccupied chairs in this paper. The differences and insignificancies in both ISO 354:1985 standard and 2003 caused the author to carry out measurements.

The aim of this paper was to point differences between test arrangements and its influence on the calculations of the reverberation time in halls.

2 Reverberation chamber measurements

The series of tests of measuring the sound absorption coefficient of one type of chairs were carried out in the reverberation chamber of the Acoustic Department of the Building Research Institute in Warsaw. The amount of 24 chairs were measured in various groups with the row – to – row spacing of 1 m. That is the back of one chair was 1 m behind the same point on the chair in the next row. Figure 1 describes the type of the measured chair.

$$\alpha = \beta \left( \frac{P}{A} \right) + \alpha_{\infty}$$

Hence the largest sample of measured chairs was four rows with six chair of the area 12 m$^2$ that is 3×4 m. The Figure 2 presents the maximum sample of tested chairs in the shielding.

The tests were performed in a 200 – m$^3$ reverberation chamber with a total surface of partitions limited the chamber of 203 m$^2$. In the chamber there is kept the constant temperature of 19ºC and humidity of 54%.

Measurements were carried out in accordance with ISO 354:2003 standard. Measurements were made in the 1/3–octave bands. During measurements there were used 12 – mm – thick wooden barrier as a shielding. Different densities of the chairs were measured:

- 2 objects per m$^2$ (24 chairs per 12 m$^2$)
- 1.5 objects per m$^2$ (18 chairs per 12 m$^2$)
- 1 object per m$^2$ (12 chairs per 12 m$^2$)

In the next sections the influence of the density and shielding on the results of the sound absorption coefficient and on the reverberation time is analysed.
3 Comparison of the results

3.1 The edge effect

In the ISO 354:1985 standard the edge effect is eliminated by the barrier surrounding the specimen mounted in the reverberation chamber. The high or barrier should be up to 1 m (for discrete absorbers like chairs). In the ISO 354:2003 standard this shielding is not mentioned, especially in case of chairs. The measurement with and without barrier were carried out.

![Figure 3: The effect of shielding](image)

The Figure 3 presents the results of these measurements for sample of 24 chairs on the area 12m². Lines and points represents results of $\alpha_S$ and $\alpha_P$ respectively.

As it is shown in the Figure 3 the differences are in the range of high frequencies. The differences between shielded and unshielded specimen are smaller than presented by other authors, i.e. Bradley [5]. It can be caused by the kind of the chairs used to measurements. Seats used by Bradley were more absorptive theatre chairs.

3.2 The effect of different density of the chairs

Measuring procedure of the sound absorption coefficient of the seats in the ISO 354:2003 standard stipulate that chairs are treated as discrete absorbers. In spite of that chairs used in real hall have fairly large area and they should be treated as plane absorber, some of the authors give results for chairs as the equivalent sound absorption area per object ($A_{obj}$) [1]. Other prefer the value of the sound absorption coefficient ($\alpha_S$) [6]. The ISO 354:2003 standard is unclear in this area.

![Figure 4: The effect of different units and densities of the measurement chairs](image)

As it is shown the differences between the results of the equivalent sound absorption per object of the same chairs are smaller then between the sound absorption coefficient. One might create smaller errors by determination of the $A_{obj}$ instead of $\alpha_S$. Another regularity is that the sound absorption coefficient is growing with increasing its density. It might cause the errors in the calculated reverberation time what is shown in the next section.

In the previous paper [7] it is also shown that sound absorption coefficient is independent on the configuration of the chairs.

3.3 The effect of differences of the $\alpha_S$ or $A_{obj}$ on calculated reverberation time

The differences between results of the same chairs but with different densities can implement mistakes in calculations of the reverberation time in concert halls. On the basis of the measurements carried out in reverberation chamber the calculations for real halls
It is shown that the implementation of the results of the same chairs but of different density the results of RT might implement differences even to 2 seconds. Figure 5 presents the results of the calculated RT of the concert halls with the area of the chairs of 200 m². In the upper picture there are compared results obtained by the equation (2) with different units of the sound absorption:

\[ T = \frac{0.163 V}{S \ln(1 - \alpha_m)} \text{[sec]} \]  

(2)

where \( V \) is volume of the hall, \( S \) is the area surrounded the hall and \( \alpha_m \) is the medium sound absorption coefficient of the materials used in the hall. Lower picture is comparing results of RT with the sound absorption coefficient of chairs of different density obtained by calculations with the same equation (2).

4 Summary

Reverberation chamber measurements of the sound absorption coefficient or the equivalent sound absorption area per object made in accordance with the standard ISO 354:2003 might create a lot of inaccuracies and errors. Then a lot of mistakes might be created during calculation procedure of the reverberation time of a real concert halls. The results of the sound absorption coefficient given by many authors are also defined variously. It can cause many subsequent errors during designing calculations therefore there is necessity of clear unification.

The results presented in this paper will be checked with another, more and less absorptive chairs. The measurements of occupied seated will be also carried out. The results will be verified by measurements made in real halls.

References


