Uncertainty of sound absorption measurement in reverberation rooms: practical absorption coefficient and single number value according to EN 1793-1

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Introduction

The quality of life in rooms is largely influenced by an appropriate acoustic design. This design is based on input data which is among others the sound absorption of the furniture and the room surfaces. It is usually measured in reverberation rooms according to ISO 354 [1]. Therefore, sound absorption is a major parameter for the marketing of products, and its uncertainty is required for a fair comparison between products. This led to the idea to develop a separate ISO-standard [2] which should contain uncertainty estimates based on round robin results. The uncertainty estimates are derived in [3] which is extended by this contribution to cover also the practical absorption coefficient according to ISO 11654 [4] and the single number value calculated according to EN 1793-1 [5].

Principle

The basic idea for estimating the uncertainty is to analyse sound absorption coefficients of the same material which were measured according to ISO 354 [1]. Such data is available from published round robin results and from internal round robin reports. An overview on the used data can be found in [3]. This data base includes also measurement results which were obtained according to ASTM C423 [6]. The uncertainties of the ASTM C423 – results turned out to match the uncertainties of the ISO 354 – results. It was then possible to estimate the uncertainty of the measured sound absorption coefficient α by the standard deviation of reproducibility σ_R. This is described by

$$u(\alpha) \approx \sigma_R \approx m\,\alpha + n \qquad (1)$$

where the slope m and offset n are determined by a linear fit of the round robin data. The analysis was performed for the sound absorption coefficient in one-third octave bands α_s and for the weighted sound absorption coefficient α_w [3].

Practical absorption coefficient

Figures 1 – 5 show the standard deviation of reproducibility σ_R for the practical absorption coefficient for different octave bands as a function of the practical absorption coefficient α_p. Whereas σ_R increases for larger α_p at 250 Hz (figure 1) it declines slightly for the higher octave bands (figures 2 - 5). This is due to the effect of rounding and limiting the α_p – values artificially to a maximum of 1.00. The same effect was already observed for α_w [3]. Since the slope is very small at all frequencies above 250 Hz it seems to be appropriate to estimate the corresponding uncertainties by a constant value. The same is proposed for α_w in [3]. The proposed values for m and n are given in table 1.

Table 1: m and n for the practical absorption coefficient

	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
m	0,059	0,000	0,000	0,000	0,000
n	0,016	0,040	0,040	0,040	0,050

Also, the standard deviation of repeatability is given in figures 1 to 5. It is significantly smaller than the standard deviation of reproducibility. It is to be noted that the number of data points is identical for all graphs. Due to the limitation, many data points fall above one another and appear to be one single point in the graphs. The estimate from [3]

$$\sigma_r \approx 0.6\,\sigma_R \qquad (2)$$

which was found to be appropriate for α_s and α_w is also a good estimate for the practical absorption coefficient α_p for all octave bands.

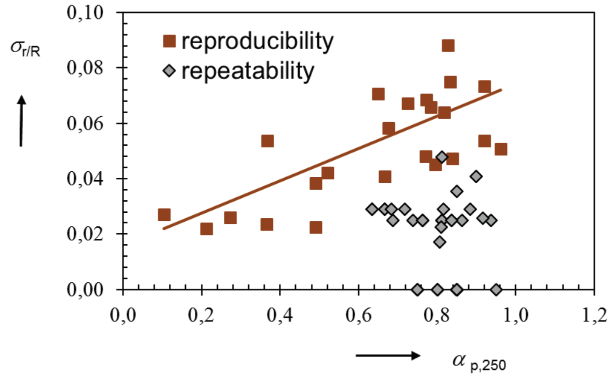

Figure 1: Reproducibility and repeatability standard deviation for the practical absorption coefficient at 250 Hz and linear best fit for reproducibility standard deviation

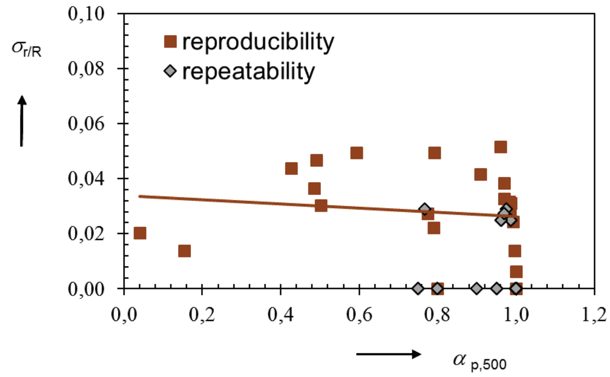

Figure 2: Reproducibility and repeatability standard deviation for the practical absorption coefficient at 500 Hz and linear best fit for reproducibility standard deviation

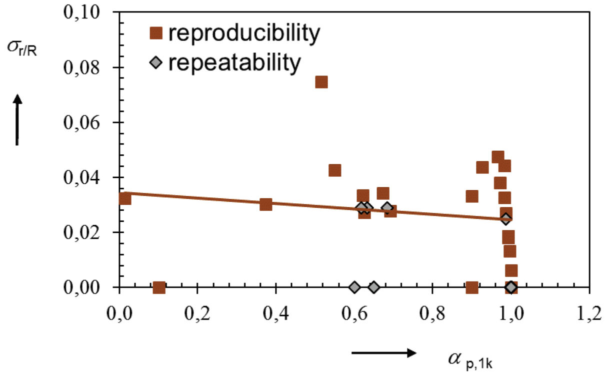

Figure 3: Reproducibility and repeatability standard deviation for the practical absorption coefficient at 1 kHz and linear best fit for reproducibility standard deviation

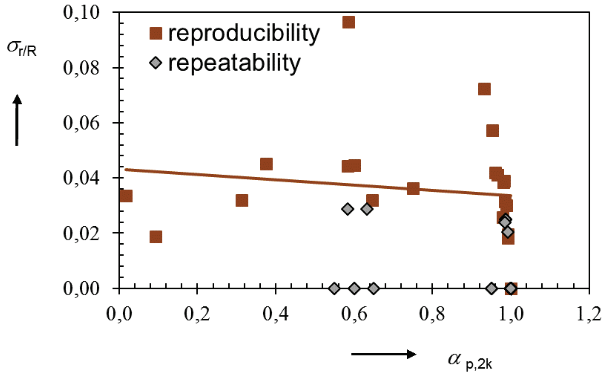

Figure 4: Reproducibility and repeatability standard deviation for the practical absorption coefficient at 2 kHz and linear best fit for reproducibility standard deviation

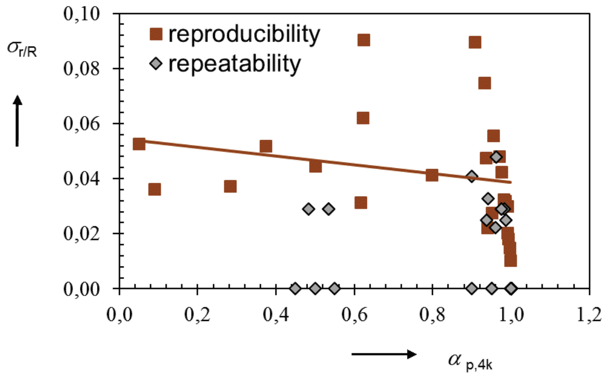

Figure 5: Reproducibility and repeatability standard deviation for the practical absorption coefficient at 4 kHz and linear best fit for reproducibility standard deviation

Single number value according to EN 1793-1

The same analysis was applied to the single number value according to EN 1793-1. It is calculated by

$$DL_a = -10 \lg \left| 1 - \frac{\sum_{i=1}^{18} \alpha_{\mathrm{NRD},i} \, 10^{0.1 \, L_i/dB}}{\sum_{i=1}^{18} \, 10^{0.1 \, L_i/dB}} \right| \, dB \qquad (3)$$

where L_i are the levels of the normalised traffic noise spectrum in the one-third octave band i [7] and the sound absorption coefficient α_{NRD} is calculated from the α_s measured according to ISO 354.

$$\alpha_{\mathrm{NRD},i} = \begin{cases} \alpha_{s,i} & \text{for } \alpha_{s,i} < 0.99 \\ 0.99 & \text{for } \alpha_{s,i} \geq 0.99 \end{cases} \qquad (4)$$

This calculation was performed for the round robin data from [3], and the standard deviations of reproducibility and repeatability were calculated (figures 6 and 7). It turns out that these values increase linearly with increasing DL_a -values which can be approximated by

$$\sigma_R \approx 0.1 \, DL_a \qquad (5)$$

and

$$\sigma_r \approx 0.02 \, DL_a \qquad (6)$$

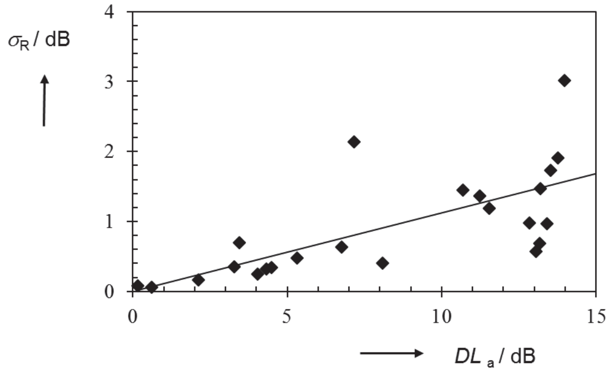

Figure 6: Standard deviation of reproducibility for DL_a according to EN 1793-1 and linear best fit

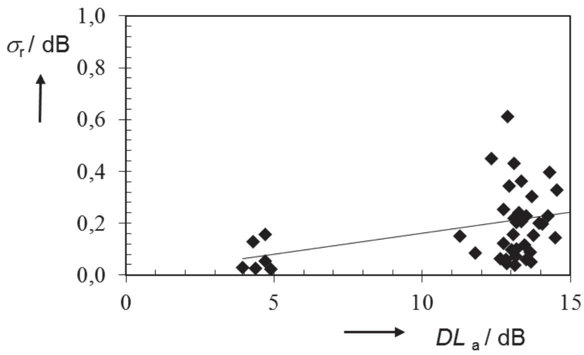

Figure 7: Standard deviation of repeatability for DL_a according to EN 1793-1 and linear best fit

Conclusion

The uncertainty of the practical absorption coefficient and of the single number value according to EN 1793-1 was estimated on the base of round robin results. These estimates provide realistic uncertainties which may be used for comparing products or for a comparison with specifications.

Literature

[1] ISO 354:2003 Acoustics -- Measurement of sound absorption in a reverberation room
[2] ISO/CD 12999-2 Determination and application of measurement uncertainties in building acoustics -- Part 2: Sound absorption
[3] Wittstock, V.: Determination of measurement uncertainties in building acoustics by interlaboratory tests Part 2: Sound absorption measured in reverberation rooms. Acta Acustica united with Acustica: 104 (2018), 999 - 1008.
[4] ISO 11654:1997 Acoustics -- Sound absorbers for use in buildings -- Rating of sound absorption
[5] EN 1793-1:2017 Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 1: Intrinsic characteristics of sound absorption under diffuse sound field conditions
[6] ASTM C423 - 09a Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method
[7] EN 1793-3: 1997 Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 3: Normalised traffic noise spectrum