MEASUREMENTS OF SURFACE PROPERTIES IN A RECORDING STUDIO

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1 INTRODUCTION

The calculation accuracy of room acoustical simulation programs is strongly dependent on the correct assignment of the surface properties. These are the absorption and the scattering coefficient which have to be entered by the operator as single values for each octave band. Although on the Internet tables for absorption data are available today for the most common materials for acoustic treatment [1], scattering coefficients still have to be estimated, because no generally valid data exist. Neither are the absorption data in the tables sufficient for all practical cases and but rather have to be adjusted or checked by in-situ measurements. For the 3rd Round Robin on Room Acoustical Computer Simulation, the participants had to be supplied with such data for the room under test, i.e. the recording studio of the PTB. In order to get reliable data for the non-standard surfaces of, for example, a wooden absorbing wall, measurements have been carried out which will be reported on here.

2 THE STUDIO

The recording studio of the PTB has a volume of approx. 400 m³, the ground area is 78.43 m², the height of the ceiling frame is 4.85 m, and the maximum height in the diffusor area is 5.08 m. To avoid fluttering echoes, one of the side walls (east wall) was subdivided and inclined inwards by 9° about a vertical folding line. On the south wall, 42 wooden panels of different depth (rectangular cross-sectional area: 0.94 m², height: 0.715 m, width: 1.317 m) are arranged in a 6 x 7 grid. These panels have several acoustical functions: On the one hand, they serve as sound diffusors for higher frequencies, and on the other the different 6 mm plywood front covers are matched by differently coupled and damped cavities so that in the frequency range up to 300 Hz they act as low frequency absorbers. The offset in depth between the individual panels was selected such that with respect to deep frequencies the whole wall acts as a slightly folded wall with a maximum distance of 0.7 m from the solid wall behind. As a result, the formation of standing waves between this and the opposite wall is reduced.

Figure 1: Recording studio of the PTB with wooden wall and scattering ceiling.

The west wall is a plastered solid wall with a window on one side. To vary the decay time of the room, a curtain has been arranged which can cover the wall completely. When open, the two unequal parts are drawn to the sides; due to the greater density, they then have a higher absorption coefficient. Curtains of the same material are also used for the north wall: When closed, they cover a horizontal stripe of the wall of the height of the three windows.

The floor of the studio is parqueted. The ceiling consists of two parts with different acoustical characteristics: In the middle there are 20 similar diffusor panels with a smooth surface which are each composed of a tetrahedron with one smaller face and two faces of equal size; their heights are 0.4 m. The diffusors are surrounded by flat absorber areas consisting of commercial absorbers; the distance from the floor is 4.85 m.

3 ABSORPTION MEASUREMENTS

3.1 Wooden wall

3.1.1 Reverberation chamber

By its relatively large surface, the wooden wall, which consists of resonance absorbers, substantially determines the acoustical characteristics of the studio. This is true in particular for the deep frequency range below 300 Hz for which these vibratory panels were designed.

To obtain more accurate data for the absorption, the wooden panels were subjected to a measurement according to DIN EN ISO 354[2] in the reverberation room of the PTB which is 237 m³ in volume. As the length of this room with 8.24 m is somewhat smaller than that of the absorber walls, the first vertical row had to be excluded from the measurement. This row was selected because it anyway contains the flattest panels only two of which show resonant characteristics at all

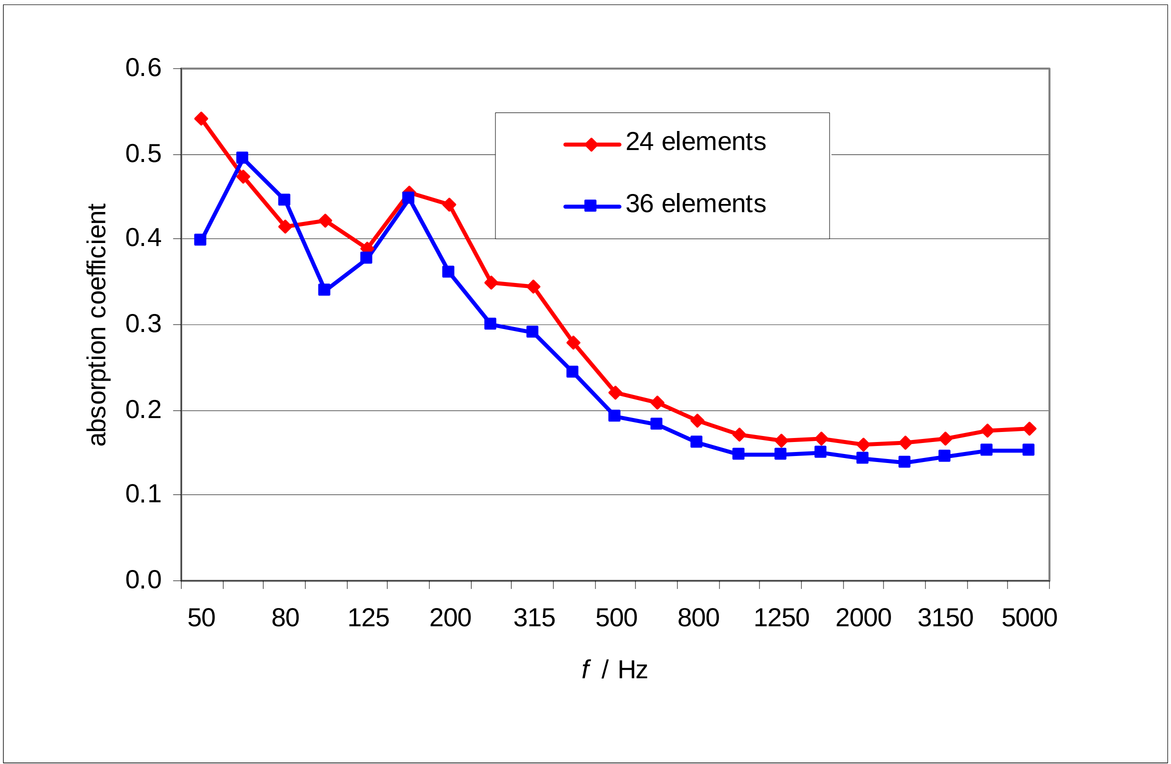

Figure 2: Measurement values for the absorption of the wooden wall in the reverberation room with 24 and 36 panels

(rectangular box, depth 0.1 m). The volume of all 42 absorber panels is 10.90 m³ and that of the 36 panels measured in the reverberation room 10.72 m³. In addition, another measurement with 24 panels was carried out (absorber volume 9.97 m³) removing also the second row. It thus was possible to estimate to what extent a partial measurement was representative of the entire wall. Due to somewhat deeper panels of the removed row, however, the difference in volume of the 36 panels is 0.75 m³, i.e. the measurement error due to the fact that panels 37 to 42 have been ignored is smaller than the difference between these two measurements.

It is to be noted that the test area of 10 m² to 12 m² required by the standard could not be complied with and that the prerequisite for the validity of the measurements thus was not fully provided. The results are represented in Figure 2 in third-octave areas; they are the mean values from 12 different measurement positions of loudspeaker and microphone.

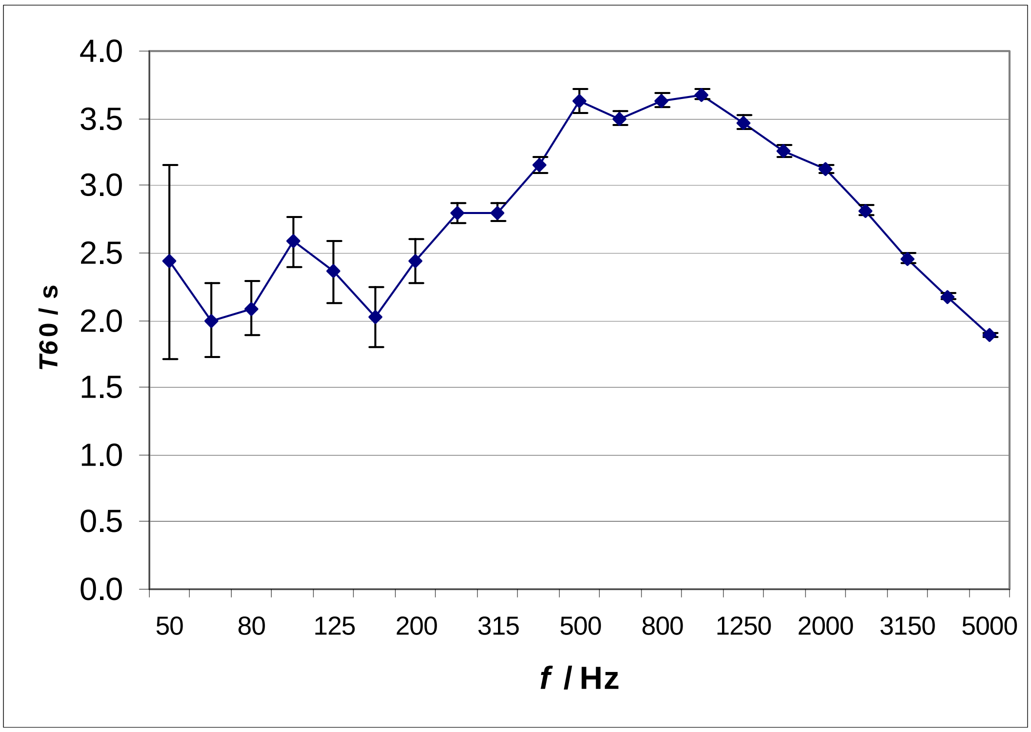

Figure 3: Mean values and standard deviations of the decay time from the measurements of the wooden wall in the reverberation room

The measurement accuracy in the reverberation room is documented in Figure 3 showing the mean value of the decay time with the associated standard deviations. The relatively great local dependence of the decay time at 50 Hz is to be attributed to the standing waves which at deep frequencies are unavoidable, so values between 1.54 s and 3.58 s were measured. At 125 Hz the standard deviations are still 0.23 s, which is due to measurement values between 1.91 s and 2.96 s.

3.1.2 In-situ measurement

It was intended to check as an alternative whether the decay time measurements with and without wooden wall allow conclusions to be drawn for its absorption characteristics in situ. Previous measurements carried out on the shell in 1976 had already confirmed that the wooden wall noticeably reduces the decay time in the 125 Hz and 250 Hz octaves:

Application of the well-known Sabine formula allows the associated absorption data to be approximately determined from the differences between the reciprocal decay times[3]:

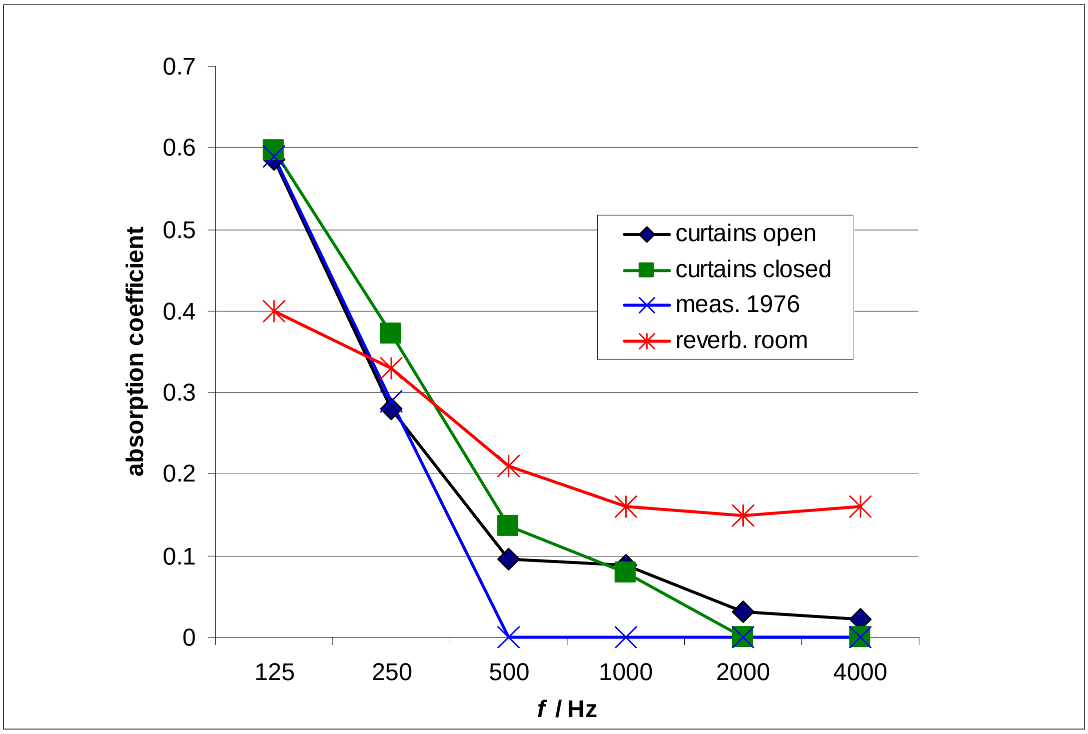

Figure 4: Absorption coefficient of the wooden wall in octave bands, measured under different conditions

$\alpha_x = 0.163 * V/A_x(1/T_x - 1/T_0)$

where V – volume of the empty room in m³ (400 m³), A_x – wall surface covered by the wooden panels in m² (39.5 m²), T_0 – decay time of the room without wooden panels in s, T_x – decay time with wooden wall in s. It turned out that already from 400 Hz the difference between the two measured decay times lies within the interval of the measurement accuracy and that the absorption coefficient of the wooden wall thus is equal to that of the free wall area.

To obtain further measurement data, the decay times were also measured in the studio without wooden wall and without the absorbers under current conditions (new air-conditioning unit, curtains).

The support structure which consists of a 30 mm thick chipboard screwed flush with the wall and serves to fasten the wooden panels had, however, to be retained. The resulting absorption is negligible as against that of the curtain and the acoustic panels on the ceiling, so a comparison of the different decay times only furnishes information about the absorption properties of the wooden boxes, i.e. the comparison measurement in the studio relates to the wall with chipboard and not to the plastered and varnished wall as in the reverberation room. This would also explain the very small influence at frequencies above 315 Hz. Here the decay times with and without wooden wall can be regarded as equal within the scope of the measurement accuracy. A comparison with the reference measurements of 1976 during which only the plastered wall (and not the wooden support structure) was present shows, however, that the influence of this support structure can be neglected and that the effect of the wooden wall is actually limited to the frequency range below 400 Hz.

The difference between the absorption coefficients as determined by these completely different methods, i.e. between reverberation room and in in-situ measurements, in Figure 4 shows the difficulties in the determination of absorption coefficients, which has a decisive effect on the quality of room acoustical computations: For the 125 Hz octave the reverberation room measurement shows noticeably smaller values, whereas the absorption above 250 Hz is clearly greater than zero (15 to 21 percent). Strictly speaking, it would even be necessary for an exact room acoustical simulation to know also the dependence of the absorption coefficient on the angle of incidence and to take it into account in the calculation. For the Round Robin the octave mean values determined by the standardized reverberation room procedure was ultimately used as a basis:

f / Hz	125	250	500	1000	2000	4000
wooden absorber	0.40	0.33	0.21	0.16	0.15	0.16

Table 1: Absorption coefficient of the wooden wall as given for Round Robin III

3.2 Curtains

For the variation of the acoustical conditions, curtains were provided for the west wall of the studio and in front of the windows. Due to their great length of 5 m, a measurement in the reverberation room was not possible, so the absorption values had to be estimated for the Round Robin exclusively from tabular values[1] and decay time measurements in the studio. Figure 5 shows the

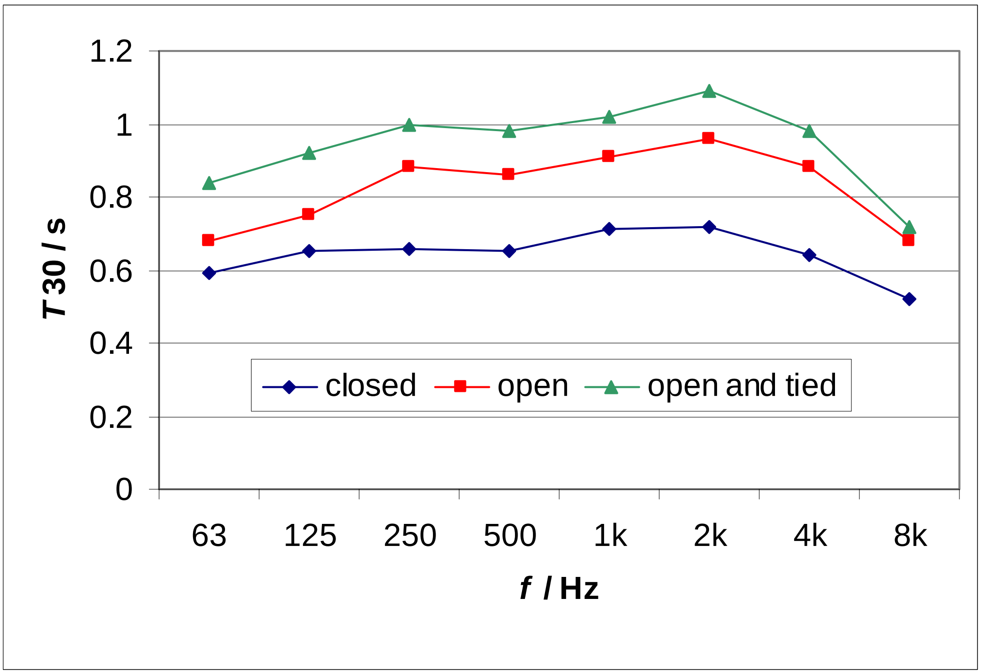

Figure 5: Decay times measured in different states of the curtains

measured decay times for three conditions: all curtains closed, i.e. covering the windows and the wall; curtains open: the normal state when curtains are redrawn; curtains open and tied: the curtains were tied closely with a rope in order to reduce their absorption area to a minimum value. The increase in decay time in this case is significant and shows the range of variation according to how the curtains are redrawn.

The absorption data given in Table 2 are much higher for the open curtain, as when opened the fabric is pushed to cover a smaller area and thus lies more densely.

f / Hz	125	250	500	1000	2000	4000
curtain (closed)	0.15	0.30	0.35	0.40	0.50	0.55
curtain (open)	0.30	0.45	0.60	0.70	0.70	0.70

Table 2. Absorption values for the curtain as provided to the participants of Round Robin III.

4 MEASUREMENTS OF THE SCATTERING COEFFICIENT USING MODELS

To make realistic values for the scattering characteristics of the large diffusor areas (wooden wall and ceiling) available, models were fabricated and measured at the Institut für Technische Akustik of the RWTH Aachen by the Vorländer and Mommertz method[4]. Details of the measurements are published by Avelar[5]. The values determined are valid for the simulation of the two areas as a single component for phase 2 of the Round Robin. Part of the measurements yielded values greater than one, which per definitionem is unrealistic, since the scattering coefficient gives the ratio of diffusely scattered sound energy to the entire reflected energy. These inaccuracies are due to the very sensitive model measurement method in which the sample form on the one hand and the air absorption and standing waves in the model reverberation room on the other limit the accuracy of measurement[4]. Therefore a maximum value of 0.95 was chosen for the room acoustical simulation; as regards its effect in ray tracing, this value is almost equivalent to a value of 1 and allows for the fact that some programs do not accept the value 1.0.

f / Hz	125	250	500	1000	2000	4000
wooden absorber	0.50	0.90	0.95	0.95	0.95	0.95
ceiling	0.13	0.56	0.95	0.95	0.95	0.95

Table 3: Global scattering coefficient for wooden absorber and ceiling for room acoustical simulation

5 CONCLUSION

It is evident that the absorption coefficients are strongly dependent on the measurement method used. When applying these data it should be borne in mind, how these values have been obtained. Measuring test samples of large areas in the reverberation room disturbs the required equal sound energy distribution of the sound field close to the sample and in addition standing waves in the reverberation room cannot be completely avoided at low frequencies. Measurements carried out under the final arrangement conditions can supply strongly different values which may be more realistic especially for room simulation purposes. The examples given here are results obtained by a global method which seems to be more appropriate for getting global results than the local methods using in-situ reflectometry[6].

6 REFERENCES

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