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REPORT

Measurement of sound absorption

client	Ursa Slovenija d.o.o.
measurement procedure	ISO 354:2003
test specimen	Ursa FP Basic d=100
mounting	Type A
report number	AL-RP-0005-10-2022-EN
total number of pages	10
date	13. 10. 2022
facility	Acoustic Laboratory InnoRenew CoE Livade 6a, SI-6310 Izola/Isola, Slovenia
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1 STANDARDS

The measurements are conducted in accordance to:

- ISO 354:2003 Acoustics – Measurement of sound absorption in a reverberation room (accepted within EU as European Norm EN ISO 354:2003)
- EN ISO 11654:1997 Acoustics – Sound absorbers for use in buildings – Rating of sound absorption

2 TEST SPECIMEN

The tested samples have been delivered to the InnoRenew CoE acoustic laboratory by Ursa Slovenija d.o.o.. The specimen consists of 15 rectangular sound-absorbing mineral wool panels with dimensions (width x length x thickness) 60 cm x 120 cm x 10 cm.

The insulation boards are arranged in a rectangular grid of 3 x 5 and form the test specimen with a length of 3.61 m, a width of 3.05 m and an area of $S = 11.01 \text{ m}^2$. The arrangement meets the ISO 354:2003 requirement for plain absorbers (10-12 m^2) for which the sound absorption coefficients are measured.

3 MOUNTING

The specimen is placed directly on the floor of the reverberation room. The sides of the specimen are enclosed and tightly sealed by 30 mm thick plywood laths. The mounting corresponds the Type A mounting as defined in Annex B of the ISO 354:2003.

The mounting of the test specimen during the measurement is shown on Figure 1.



Figure 1: Mounting of the test specimen during the measurement.

4 MEASUREMENT PRINCIPLE

The tests are conducted in accordance with the requirements of ISO 354:2003 in the reverberation room of InnoRenew Acoustic laboratory (Livade 6a, SI-6310 Izola/Isola, Slovenia). Details about the reverberation room are provided in Appendix B of the measurement report.

The basic measurement performed is of reverberation time, T , under two conditions:

- when the reverberation room is empty (T_1),
- when the reverberation room includes the test specimen (T_2).

The introduction of test specimens generally introduces additional absorption into the room and therefore reduces the reverberation time. The reverberation time difference is the quantity that relates to the sound absorbing properties of the test specimen.

From the measured reverberation time in the empty room the equivalent sound absorption A_1 is

calculated in 1/3-octave bands as

$$A_1 = \frac{55.3 V}{c T_1} - 4 V m_1 \quad [\text{m}^2] \quad (1)$$

in which:

- V [m^3] is the volume of the reverberation room
- T_1 [s] is reverberation time in the empty reverberation room
- m_1 [m^{-1}] are attenuation coefficients determined by

$$m_1 = \frac{\alpha}{10 \log e} \quad [\text{m}^{-1}] \quad (2)$$

with α being the attenuation coefficients according to ISO 9613-1.

- c [m/s] is the propagation speed of sound in air, determined by

$$c = 331 + 0.6 t \quad [\text{m/s}] \quad (3)$$

with t being the temperature in °C (valid for values in range 15 - 30 °C).

The equivalent sound absorption A_2 of the room with the test specimen is calculated in an analogue way. The index 2 is used to denote the corresponding reverberation time and sound propagation speed.

The equivalent sound absorption A of the test specimen is determined as the difference of absorption areas

$$A = A_2 - A_1. \quad (4)$$

If the test specimen surface area S is between 10 and 12 m^2 we can determine the sound absorption coefficients as

$$\alpha = \frac{A}{S}. \quad (5)$$

5 MEASUREMENT EQUIPMENT

The measurement is performed using the following equipment:

- 6 phase matched microphones: Brüel & Kjær Type 4958
frequency range: 10 Hz–20 kHz (± 3 dB), dynamic range: 28-140 dB, inherent noise < 28dBA
- input data acquisition modul: Brüel & Kjær LAN-XI Type 3053-B-120-R, UA-2107-12
12 input channels, frequency range: 0-25.6 kHz, bit-depth: 24 bit
- audio signal generator: NTI, Minirator MR-PRO
flatness ± 0.2 dB (10 Hz-20 kHz), excitation signal: 20 Hz-20 kHz exponential sine sweep
- sound source: NTI DS3 dodecahedron omnidirectional loudspeaker, NTI PA3 power amplifier



accordance with the ISO 16283 and ISO 3382 standards, SPL=120.5 dB

- data acquisition software: Brüel & Kjær BK Connect
- python post-processing

6 MEASUREMENT PROCEDURE

The integrated impulse response method is used to determine reverberation time. The impulse response is measured in 6 microphone positions and in 2 loudspeaker positions. In total, 12 measurement microphone-loudspeaker combinations are used.

Exponential sine sweeps in the frequency range from 20 Hz to 20 kHz are used as excitation signals. The duration of the sweeps is 10 s followed by 10 s sections of silence. Three repetitions in each measurement positions are recorded and the impulse response determined from the averaged frequency response.

Reverberation time is determined by fitting the inverse integrated impulse response in the 20 dB dynamic range (-5 dB to -25 dB). The analysis is carried out in standardized 1/3-octave bands from 100 to 5000 Hz. Octave band α values are calculated as the arithmetic average values from corresponding 1/3-octave values.

7 ATMOSPHERIC CONDITIONS

The atmospheric conditions during the measurements are given in Table 1.

empty room		room with absorber	
Temperature	Relative humidity	Temperature	Relative humidity
22°C	68%	22°C	68%

Table 1: Atmospheric conditions during the measurements.

8 RESULTS

The measured sound absorption coefficients α_S in 1/3-octave bands and calculated 1/1-octave bands values are given in table 2. 1/3-octave bands values are plotted on Figure 2.

Frequency [Hz]	α_S	
	1/3-octave	1/1-octave
50	0.02	
63	0.02	0.03
80	0.05	
100	0.37	
125	0.62	0.58
160	0.74	
200	0.82	
250	0.85	0.84
320	0.85	
400	0.89	
500	0.97	0.93
630	0.94	
800	0.90	
1000	0.90	0.89
1250	0.89	
1600	0.86	
2000	0.87	0.87
2500	0.88	
3200	0.87	
4000	0.87	0.88
5000	0.89	

Table 2: Measured sound absorption coefficients α_S .

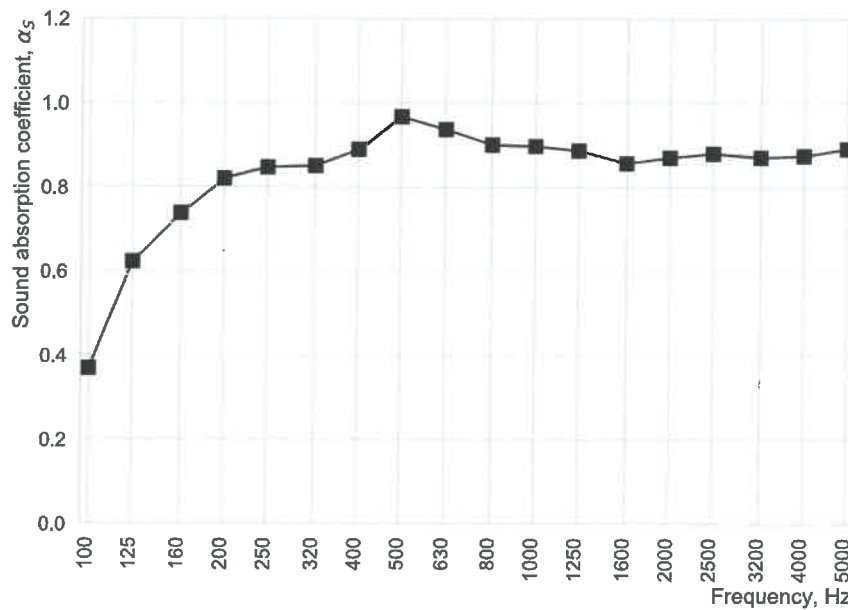


Figure 2: Measured sound absorption coefficients α_S measured in 1/3-octave bands.

Practical sound absorption coefficients α_P (rounded to 0.05 multiples) are given in Table 3 for each 1/1-octave band. The values are plotted on Figure 3 together with the ISO 11654 reference curve.

Frequency [Hz]	α_P
63	0.05
125	0.60
250	0.85
500	0.95
1000	0.90
2000	0.85
4000	0.90

Table 3: Practical sound absorption coefficients α_P .

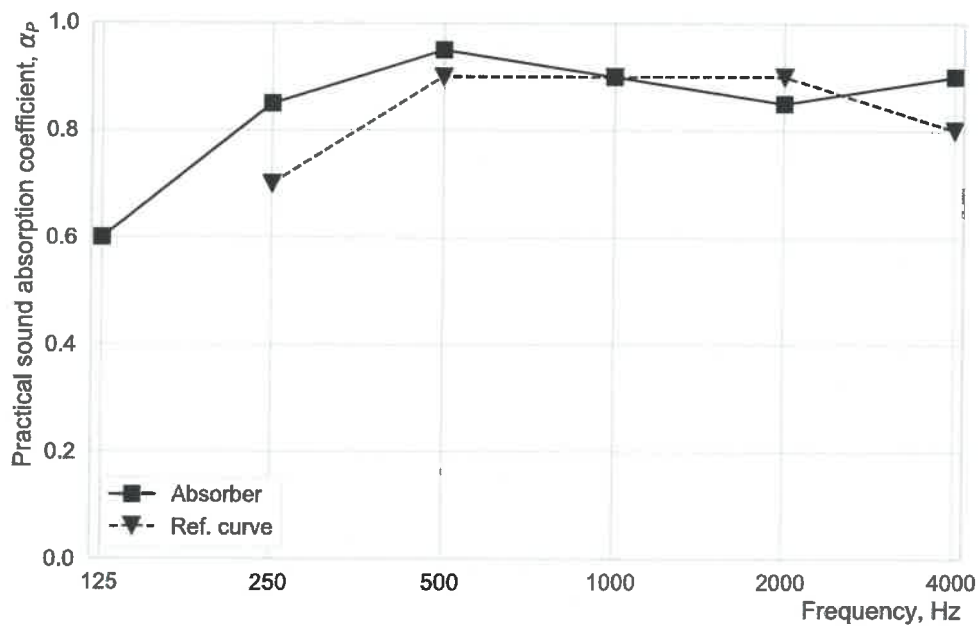


Figure 3: Practical sound absorption coefficients α_P in 1/1-octave bands with the corresponding reference curve.

According to ISO 11654:

- the weighted sound absorption coefficient is $\alpha_w = 0.9$.
- classification: class A.

The measured values hold exclusively for the tested specimen.

APPENDIX A: RESULTS SUMMARY

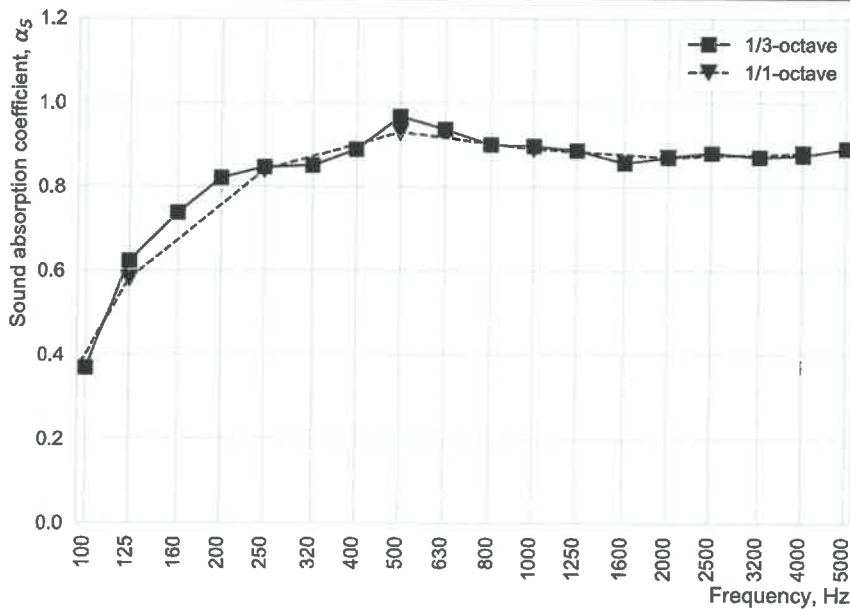
MEASUREMENT OF SOUND ABSORPTION IN A REVERBERATION ROOM ACCORDING TO ISO 354:2003

facility	Acoustic laboratory
address	InnoRenew CoE Livade 6a, SI-6310 Izola/Isola Slovenia
date	13. 10. 2022
client	Ursa Slovenija d.o.o.
specimen	Ursa FP Basic d=100
surface area	11.01 m ²
mounting	Type A
room volume	283.65 m ³
at. conditions	22°C, RH=68%
method	int. imp. response
positions	12
rating	ISO 11654
α_w	0.9
classification	class A



The specimen consists of 15 rectangular sound-absorbing mineral wool panels with dimensions (width x length x thickness) 60 cm x 120 cm x 10 cm.

1/3-octave [Hz]	50	63	80	100	125	160	200	250	320	400	500
α_S	0.02	0.02	0.05	0.37	0.62	0.74	0.82	0.85	0.85	0.89	0.97
1/3-octave [Hz]	630	800	1000	1250	1600	2000	2500	3200	4000	5000	
α_S	0.94	0.90	0.90	0.89	0.86	0.87	0.88	0.87	0.87	0.89	
1/1-octave [Hz]	63	125	250	500	1000	2000	4000				
α_S	0.03	0.58	0.84	0.93	0.89	0.87	0.88				



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APPENDIX B: FACILITY

REVERBERATION ROOM

laboratory	Acoustic laboratory InnoRenew CoE
address	Livade 6a, SI-6310, Izola/Isola, Slovenia
room volume	283.65 m ³
total area (walls, floor and ceiling)	11.01 m ²
diffusion	Uneven walls and ceiling function as diffusers.

EMPTY ROOM MEASUREMENT

date	13. 10. 2022
air temperature	22°C
air relative humidity	68%
measurement method	integrated impulse response
measurement positions (microphone-loudspeaker combinations)	12

REVERBERATION TIME

1/3-octave [Hz]	50	63	80	100	125	160	200	250	320	400	500
T_1 [s]	14.20	14.42	15.54	14.73	14.81	14.70	14.28	14.01	13.76	13.49	12.76
1/3-octave [Hz]	630	800	1000	1250	1600	2000	2500	3200	4000	5000	
T_1 [s]	12.31	11.68	11.63	10.89	10	8.91	7.76	6.24	4.81	3.52	

PLAN:

