TEST REPORT

Laboratory measurement of sound absorption of Acupanels Upcycled Turf Panels – Type C-45 mounting – ASTM

Performed for Acupanels International ApS

Project no.: 122-30179

DANAK no. 100/2783

Hørsholm, 12 October 2022

TEST Reg. nr. 100

Acoustics, Noise and Vibrations

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OVERVIEW

Title	Laboratory measurement of sound absorption of Acupanels Upcycled Turf Panels - Type C-45 mounting – ASTM
Project no.	122-30179
DANAK no.	100/2783
Test period	8 September 2022
Client	Acupanels International ApS Industrivej 12 7490 Aulum Denmark E-mail: hello@acupanels.dk Tel.: +45 8877 8370
Contact person	Tom Nielsen E-mail: tn@acupanels.dk
Test method	Test method and evaluation: ASTM C423-22 Specimen mounting: ASTM E795-16 Uncertainty: EN ISO 12999-2:2020
Summary	Laboratory measurements of sound absorption coefficients were carried out in a reverberation room according to the test method of ASTM C423-22. Product: Acupanels Upcycled Turf Panels Mounting: Type C-45 The test results per one-third octave are shown in tabular form and graphically on Graph Sheet 1. Descriptions of reverberation room and test procedure are found in Appendix 4.
Revisions	Initial version
Test site	DTU, Akademivej, Bygning 355, 2800 Kongens Lyngby, Denmark

Our ref. LISL/RSHS/ilk

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1 Introduction

At the request of Acupanels International ApS, measurements of sound absorption coefficients in a reverberation room have been carried out for Acupanels Upcycled Turf Panel product.

2 Description of the test specimen based on the client's specifications

Acupanels Upcycled Turf Panel is a felt panel covered with MDF lamellas that are coated in veneer. The felt is made from upcycled turf.

Product:	Acupanels Upcycled Turf Panel
Lamellas:	27 x 10 mm MDF lamellas covered with veneer, 40 mm spacing, cc 13 mm
Felt:	7 mm felt from upcycled turf, density 150 kg/m^3
Thickness:	7 mm of felt / 17 mm felt with lamellas
Weight:	~6.55 kg/m²
Insulation:	45 mm mineral wool, density 16.0 kg/m^3, placed between 45 x 45 mm wood furring strips of 600 mm spacing
Construction height:	62 mm
Module size:	different sizes

3 Mounting in the laboratory

The panels were placed as a plane on a concrete floor in a frame with the size 2.40 m × 2.74 m on top of a 45 mm mineral wool layer. The mineral wool was placed between 45 x 45 mm wood furring strips of 600 mm spacing.

Mounting depth: 62 mm (Type C-45 mounting).

Both the mineral wool layer and the edges of the test specimen were enclosed by a wooden frame.

All joints between the test specimen and the frame as well as between the frame and the concrete floor were sealed with tape. The usage of tape between the test specimen and the frame differs from mounting practices specified in ASTM E795-16.

The test sample was placed so that no part of them was closer than 1 m to any edge of the boundary of the room other than the floor.

The photo and drawing of the test specimen in the laboratory can be seen in Appendix 3.

4 Test method

The measurements were carried out according to the test method of ASTM C423-22: "Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method" and ASTM E795-16 "Standard Practices for Mounting Test Specimens During Sound Absorption Tests".

The test specimen was put together of 4 Upcycled Turf Panels of size 2400 x 600 mm and 1 Upcycled Turf Panel of size 2400 x 335 mm to form a test area of 6.56 m^2 (2.40 x 2.74 m).

The sound absorption coefficient was calculated from the reverberation times measured with and without the test specimen. The measurements were performed in Room 005, Building 355 at the Technical University of Denmark. Brief descriptions of the reverberation room and test procedure are found in Appendix 4.

5 Measurement conditions

The reverberation time was recorded in 6 microphone positions, each placed in the range 1.55 m to 2.85 m above the floor. The number of sound source positions was two.
The reverberation time T_1 per third octave of the room without test specimen and the reverberation time T_2 per third octave of the room with test specimen:

Frequency f [Hz]	Reverberation time T_1 [s]	Reverberation time T_2 [s]
100	6.21	5.20
125	7.41	5.23
160	7.83	5.05
200	7.14	3.89
250	6.93	3.58
315	7.03	3.31
400	6.60	2.80
500	6.02	2.81
630	5.98	2.90
800	5.62	2.83
1000	4.98	2.69
1250	4.74	2.67
1600	4.41	2.61
2000	3.95	2.54
2500	3.65	2.34
3150	3.00	2.05
4000	2.51	1.80
5000	2.15	1.63

Temperature, relative humidity and atmospheric pressure in the reverberation room during measurements:

Room without test specimen: 21.5 °C, 59.6 % RH, 1.00 atm. Date of test: 08 September 2022

Room with test specimen: 21.6 °C, 60.1 % RH, 1.00 atm. Date of test: 08 September 2022

The correction of the absorption coefficient due to differences in temperature and relative humidity during measurements of T_1 (the reverberation time of the empty room) and T_2 (the reverberation time of the room with test specimen) was 0 at all frequencies.

6 Test results

The test results – the sound absorption coefficient α per one-third octave from 100 Hz to 5000 Hz are shown in tabular form and graphically on Graph Sheet 1.

The calculated sound absorption coefficient α per octave from 125 Hz to 4000 Hz is shown in tabular form and graphically on Graph Sheet 2, together with the sound absorption average SAA and noise reduction coefficient NRC. These numbers are calculated according to ASTM C423-22.

7 Measurement uncertainty

The measurement uncertainty for the sound absorption coefficient α per object per one-third octave is calculated according to EN ISO 12999-2:2020. The expanded uncertainty U given as a two-sided 95 % confidence interval (k=2) based on the reproducibility is as follows:

Frequency f [Hz]	U (k = 2, two sided)
100	±0.10
125	±0.14
160	±0.14
200	±0.16
250	±0.16
315	±0.16
400	±0.16
500	±0.14
630	±0.12
800	±0.10
1000	±0.10
1250	±0.10
1600	±0.10
2000	±0.10
2500	±0.10
3150	±0.12
4000	±0.14
5000	±0.16

The uncertainty U (two-sided 95 % confidence interval, k=2) based on reproducibility of the practical sound absorption coefficient α per octave is

Frequency [Hz]	U (k=2)
250	±0.12
500	±0.08
1000	±0.08
2000	±0.08
4000	±0.10

Uncertainty based on reproducibility based on the sound absorption average SAA and noise reduction coefficient NRC is **±0.07.**

Appendix 1 Graph Sheets

Laboratory measurement of sound absorption according to ASTM C423-22

Client: Acupanels International ApS, Industrivej 12, 7490 Aulum, Denmark

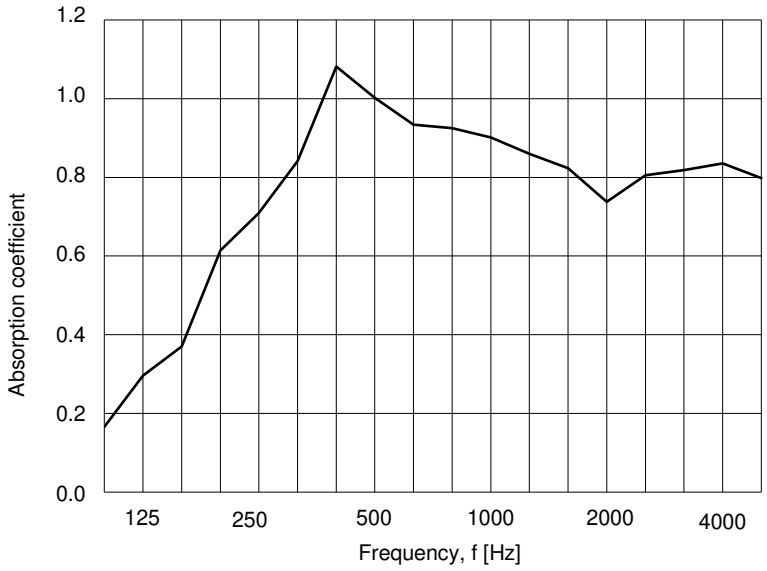
Date of test: 8 September 2022

Test specimen: Product: Acupanels Upcycled Turf Panel
Thickness: 17 mm

Construction height: 62 mm (Type C-45 mounting)

Test area: 6.6 m²
Room volume: 215 m³
Room surface: 305 m²

Frequency f [Hz]	α
100	0.17
125	0.30
160	0.37
200	0.61
250	0.71
315	0.84
400	1.08
500	1.00
630	0.93
800	0.92
1000	0.90
1250	0.86
1600	0.82
2000	0.74
2500	0.81
3150	0.82
4000	0.84
5000	0.80



FORCE Technology, 12 October 2022

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Laboratory measurement of sound absorption according to ASTM C423-22

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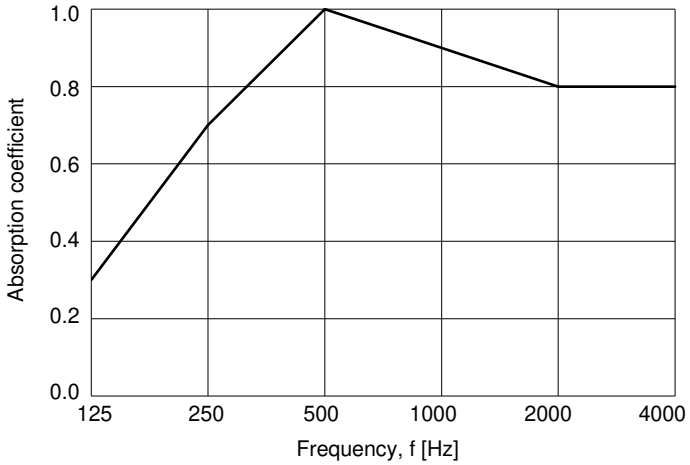
Thickness: 17 mm

Construction height: 62 mm (Type C-45 mounting)

Test area: 6.6 m²
Room volume: 215 m³
Room surface: 305 m²

Frequency f [Hz]	α
125	0.30
250	0.70
500	1.00
1000	0.90
2000	0.80
4000	0.80



Sound absorption average and noise reduction coefficient according to ASTM C423-22:

SAA = 0.85 NRC = 0.85

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Appendix 2 List of instruments

No.	Equipment	Producer	Model	Calibration Latest	Calibration Next
1498L	Sound Level Meter/ Analyzer	Brüel & Kjær	2270	2021-09-02	2023-09-02
1256L	Measuring microphone	Brüel & Kjær	4144	2022-02-25	2024-02-25
0716L	Measuring microphone	Brüel & Kjær	4144	2022-06-20	2023-06-20
853L	Microphone preamplifier	Brüel & Kjær	2619	2022-02-25	2024-02-25
1395L	Microphone preamplifier	Brüel & Kjær	2619	2022-07-08	2024-07-08
1040L	Microphone power supply	Brüel & Kjær	5935	2022-07-12	2024-07-12
1654L	Sensor for tempera-ture and humidity	Rotronic Instruments	BL-1D-SET	2021-05-18	2023-01-01
1158L	Acoustic calibrator	Brüel & Kjær	4231	2022-06-07	2022-12-07

Appendix 3 Photo and drawing

Figure 1 *Acupanels Upcycled Turf Panels mounted in the laboratory (type C-45 mounting).*

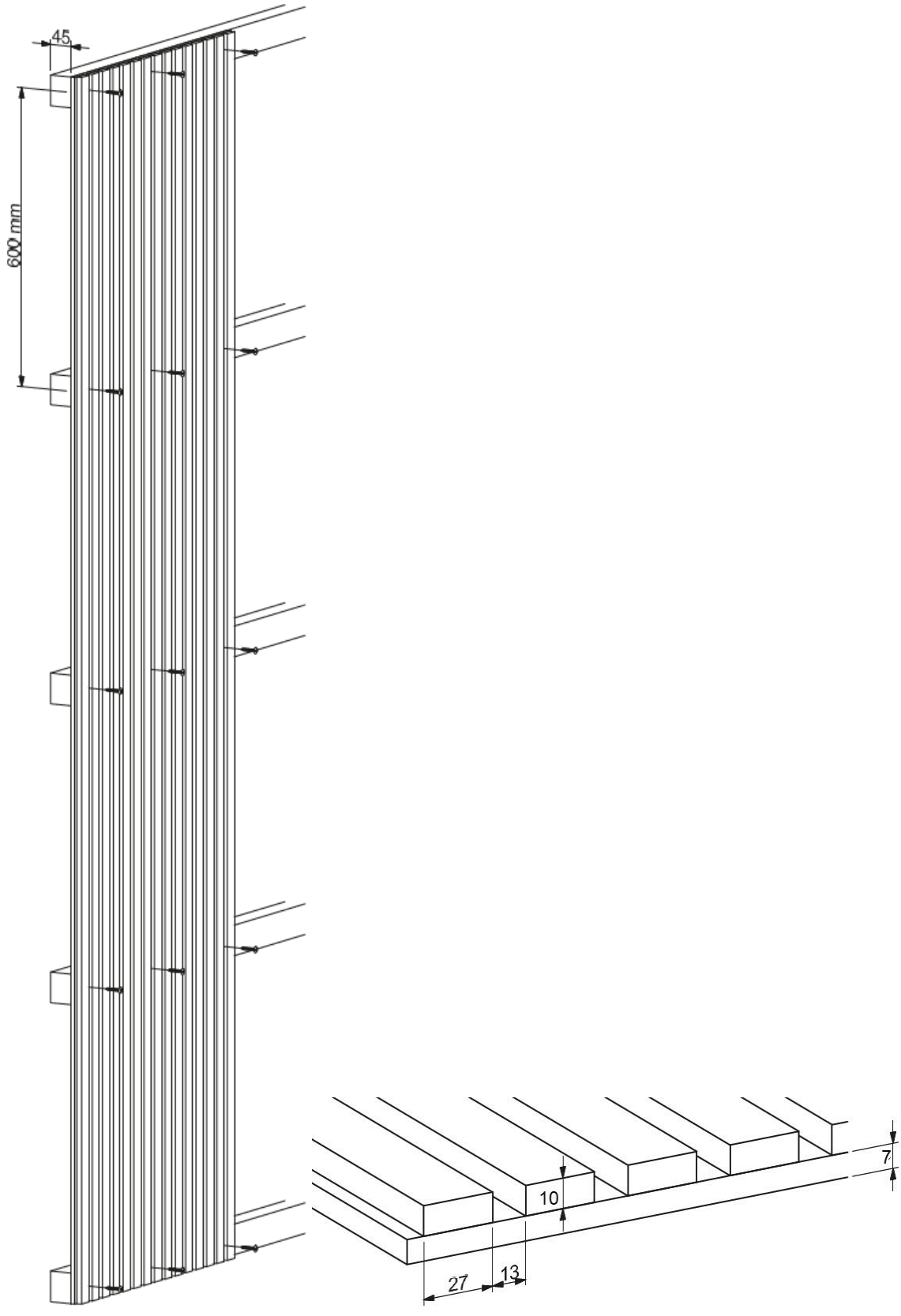

Figure 2 *Drawing of Acupanels Upcycled Turf Panels.*

Appendix 4 Description of reverberation room and test procedure

Reverberation room

The measurements are performed in a reverberation room (Room 005, Building 355 at the Technical University of Denmark) with walls, ceiling, and floor of 300 mm in situ cast concrete. Length, width, and height of the room are 7.85 m, 6.25 m, and 4.95 m, respectively. The volume of the room is approx. 215 m³, and the total surface area is approx. 305 m². Sound diffusion elements of concrete, of damped steel plate, and of acrylic sheets are placed in the room.

Test procedure

Measurement of sound absorption according to ASTM C423-22 is carried out in a reverberation room. The reverberation time is measured with and without the test specimen, and the sound absorption coefficient is evaluated using Sabine's formula.

The test signal used is broad band pink noise emitted successively by two loudspeakers located in two opposite corners of the room. The reverberation time is measured in six microphone positions for each loudspeaker. For each microphone/loudspeaker position ten repeated excitations are used. One-third octave filters (100-5000 Hz) are included in the receiving equipment.

The reverberation time is evaluated from the averaged slope of the decay curve over a range from 5 dB to 25 dB below the steady state level.

The sound absorption coefficient α is calculated using the following formula:

$$\alpha = \frac{55{,}3 \cdot V}{S} \cdot \left(\frac{1}{c_2 \cdot T_2} - \frac{1}{c_1 \cdot T_1} \right) - \frac{4V}{S} \cdot (m_2 - m_1)$$

Where

- α = Sound absorption coefficient
- V = Volume of the empty reverberation room [m³]
- S = Area of the test specimen
- c_1 = Velocity of sound in air [m/s] without test specimen
- c_2 = Velocity of sound in air [m/s] with test specimen
- T_1 = Reverberation time of the empty reverberation room [s]
- T_2 = Reverberation time of the reverberation room after the test specimen has been introduced [s]
- m_1 = Attenuation coefficients due to air absorption during measurement of T1 (m^{-1})
- m_2 = Attenuation coefficients due to air absorption during measurement of T2 (m^{-1})

The attenuation coefficient of sound in air varies with relative humidity, temperature, and frequency. During a series of measurements of reverberation times T_1 and T_2, the relative humidity and the temperature are held as constant as possible. A correction term as given in the formula above is applied. The correction is based on data from ISO 9613-1:1993.