Mecanum

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ACOUSTICAL TEST REPORT

REPORT #:	**XXXXXXXX-XXX**
FOR:	**Client name**
TEST:	Biot characterization of sound absorbing materials
STANDARD:	ASTM E1050-12 / ASTM E2611-09
ON:	Material identification
DATE:	YYYY/MM/DD
BY:	Project manager
VERIFIED BY:	Quality control manager

DESCRIPTION OF THE SPECIMENS

Material Type:	fibrous material with thin geotextile on one side
Material sample and size provided by client:	3 samples of 30 cm x 30cm
Reference material thickness:	7.9 mm
Type of cutting for test specimens:	Die cutter
Test specimens used for this report:	☒ Small (S), 4 x (29-mm diameter) ☒ Medium (M), 4 x (44.44-mm diameter) ☒ Large (L), 3 x (100-mm diameter) ☐ Oberst beam (O), 3 x (249.7 mm (L) × 14.9 mm (W) × 8 mm (T)
Visual inspection:	No defects are observed in the specimens. Both faces seem to be identical.
Remark #1:	Notation of specimen is Xij, where X relates to the size of specimen S(small), M(medium), L(large) or O(rectangular Oberst beam), letter i is the specimen number, and letter j is the material sample number. For instance, specimen #1 of medium (M) diameter taken from material sample 1 reads M11. In this report, only use the letter I will be used.
Remark #2:	The material has a geotextile layer on one side (Figure 3).

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Figure 1 – Sample provided by the client.

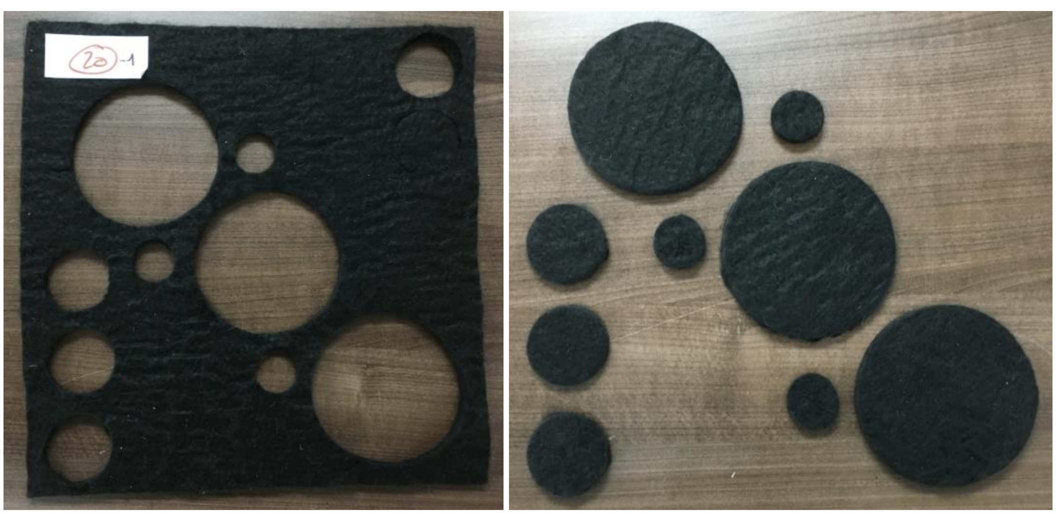

Figure 2 – Circular specimens obtained by mechanical circular cutting.

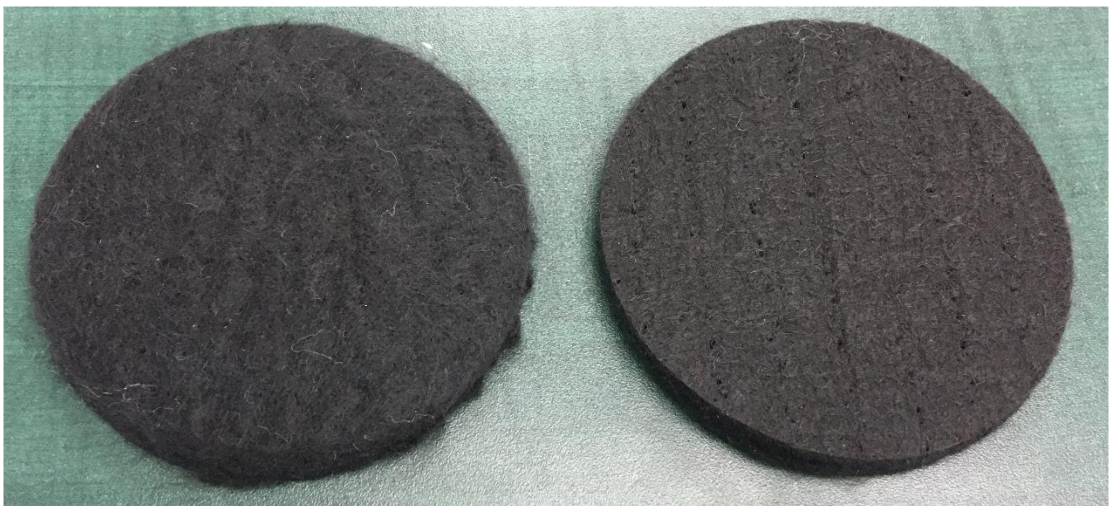

Figure 3 – Fibrous side (left) and geotextile side (right) of the material.

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CHARACTERIZATION RESULTS

Description of material properties: See References and Links
Description of characterization methods: See References and Links

Remark #1: The material properties characterized are those used by the Johnson-Champoux-Allard-Biot (JCA-Biot) model.

Remark #2: Sound absorption measurements are made with the fibrous side oriented to the sound waves.

Remark #3: Mechanical parameters are obtained with a static compression of 1.7 %.

Remark #4: Discrepancy between experimental and simulated data for mechanical resonance in transmission loss graph comes from the mounting condition in the impedance. Petroleum jelly was used to seal the material the tube and simulation does not consider this part.

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Table I – Characterized Equivalent Fluid Parameters and Elastic Parameters for Acoustic Models [8].

	Material properties	Specimens tested	Mean value	Standard deviation	Test method
h	Thickness (mm)	L11 L12 L13 M11 M12 M13 S11 S12 S13	XXX	XXX	Caliper
ρ	Bulk density (kg/m^3)[a]	L11 L12 L13 M11 M12 M13 S11 S12 S13	XXX	XXX	Porosity/density meter [3]
ϕ	Open porosity (-)[a]	L11 L12 L13 M11 M12 M13 S11 S12 S13	XXX	XXX	Porosity/density meter [3]
σ	Airflow resistivity at 0.5 mm/s (Ns/m^4)[b]	L11 L12 L13	XXX	XXX	Airflow Resistivity meter [4]
α_∞	Tortuosity (-)	L11 L12 L13	XXX	XXX	Tortuosity meter [8.b]
Λ	Viscous characteristic length (µm)	M11 M12 M13	XXX	XXX	Foam-X [6]
Λ'	Thermal characteristic length (µm)	M11 M12 M13	XXX	XXX	Foam-X [6]
E	Young's modulus (kPa)	S11 S12 S13 M11 M12 M13	XXX	XXX	QMA-X [5]
ν	Poisson's ratio	S11 S12 S13 M11 M12 M13	XXX	XXX	QMA-X [5] and Fiber Assumption [8.b]
η	Loss factor (%)	S11 S12 S13 M11 M12 M13	XXX	XXX	QMA-X [5]

[a] Measurements with a balance readability of 0.01g and micrometer readability of 0.01 mm
[b] Equivalence: 1 Ns/m^4 = 1 MKS rayls/m

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44.44 MM DIAMETER - NORMAL INCIDENCE ACOUSTICAL TUBE MEASUREMENTS AND VALIDATION

Name of test method: Impedance / transmission tube method
Standard: ASTM E1050-12 and E2611-09 [7]
System: 44.44 mm Mecanum impedance/transmission tube suite

Excel file containing tube results: **XXXXXXXXX-XXX**
Tested specimens: M11, M12, and M13

Description of Excel result file (see Figure 4):
- Results for specimen Xij is in Sheet Xij
- Room conditions during test are T0, P0, HR
- Air properties during test are Z0 and rho
- Backing conditions are hard wall or air cavity.
- Thickness of specimen is Thick.

Mounting conditions: Petroleum jelly was used to avoid peripheral leak.

Method used: 3 microphones and two-load method [7]

Graphical results: See Figure 5

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
1	%Sample	L11																
2	%T0	21.3	°C	- temperature														
3	%P0	100100	Pa	- static pressure														
4	%HR	30	%	- relative humidity														
5	%Z0	406.975	Pa*s/m	- characteristic impedance of air														
6	%rho0	1.181241	kg/m3	- density of air														
7	%Cav1	49.8	mm	- depth of air cavity backing in the case of air cavity backing														
8	%Cav2	101.2	mm	- depth of air cavity backing in the case of air cavity backing														
9	%Thick.	101.4	mm	- thickness of sample														
10	%hw stands for hard wall backing (but not glue on hard backing)																	
11	%f	nsac0	Re(R0)	Im(R0)	Re(Zs0/Z0	Im(Zs0/Z0	nsac1	Re(R1)	Im(R1)	Re(Zs1/Z0	Im(Zs1/Z0	nsac2	Re(R2)	Im(R2)	Re(Zs2/Z0	Im(Zs2/Z0	nstl	Re(
12	68.75	0.092246	0.87053	-0.38721	0.553386	-4.64577	0.169677	0.793926	-0.44722	0.699785	-3.68885	0.288681	0.705734	-0.4618	0.962748	-3.08019	6.188739	1.
13	70.3125	0.105286	0.863173	-0.38684	0.625332	-4.59519	0.178238	0.786801	-0.45023	0.718238	-3.62853	0.291455	0.700234	-0.46714	0.946048	-3.0326	6.223083	1.
14	71.875	0.138118	0.846554	-0.38109	0.818357	-4.51596	0.185529	0.779564	-0.4547	0.726591	-3.56148	0.306601	0.689569	-0.46679	0.975621	-2.97072	6.272476	1.

Figure 4 – Example of a typical measurement Excel file. For details, see Table II.

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Table II – Description of the column header abbreviations in a typical Excel file

Column	Header	Description
A	f	frequency (Hz)
B	nsac_hw	normal incidence sound absorption on hard wall
C	Re(R_hw)	real part of reflection coefficient on hard wall
D	Im(R_hw)	imaginary part of reflection coefficient on hard wall
E	Re(Zs_hw/Z0)	real part of normalized surface impedance on hard wall
F	Im(Zs_hw/Z0)	imaginary part of normalized surface impedance on hard wall
G	nsac_cav1	normal incidence sound absorption on the first air cavity
H	Re(R_cav1)	real part of reflection coefficient on the first air cavity
I	Im(R_cav1)	imaginary part of reflection coefficient on the first air cavity
J	Re(Zs_cav1/Z0)	real part of normalized surface impedance on the first air cavity
K	Im(Zs_cav1/Z0)	imaginary part of normalized surface impedance on the first air cavity
L	nsac_cav2	normal incidence sound absorption on the second air cavity
M	Re(R_cav2)	real part of reflection coefficient on the second air cavity
N	Im(R_cav2)	imaginary part of reflection coefficient on the second air cavity
O	Re(Zs_cav2/Z0)	real part of normalized surface impedance on the second air cavity
P	Im(Zs_cav2/Z0)	imaginary part of normalized surface impedance on the second air cavity
Q	Nstl	normal incidence sound transmission loss
R	Re(T11) *	real part of coefficient 11 of the four-pole transfer matrix (with i ,j = 1, 2, 3, 4)
S	Im(T11) *	imaginary part of coefficient 11 of the four-pole transfer matrix (with i ,j = 1, 2, 3, 4)
T	Re(T12) *	real part of coefficient 12 of the four-pole transfer matrix (with i ,j = 1, 2, 3, 4)
U	Im(T12) *	imaginary part of coefficient 12 of the four-pole transfer matrix (with i ,j = 1, 2, 3, 4)
V	Re(T21) *	real part of coefficient 21 of the four-pole transfer matrix (with i ,j = 1, 2, 3, 4)
W	Im(T21) *	imaginary part of coefficient 21 of the four-pole transfer matrix (with i ,j = 1, 2, 3, 4)
X	Re(T22) *	real part of coefficient 22 of the four-pole transfer matrix (with i ,j = 1, 2, 3, 4)
Y	Im(T22) *	imaginary part of coefficient 22 of the four-pole transfer matrix (with i ,j = 1, 2, 3, 4)

* For more details on transfer matrix see ASTM E2611 [7.b] and refs. 8.b and 7.c

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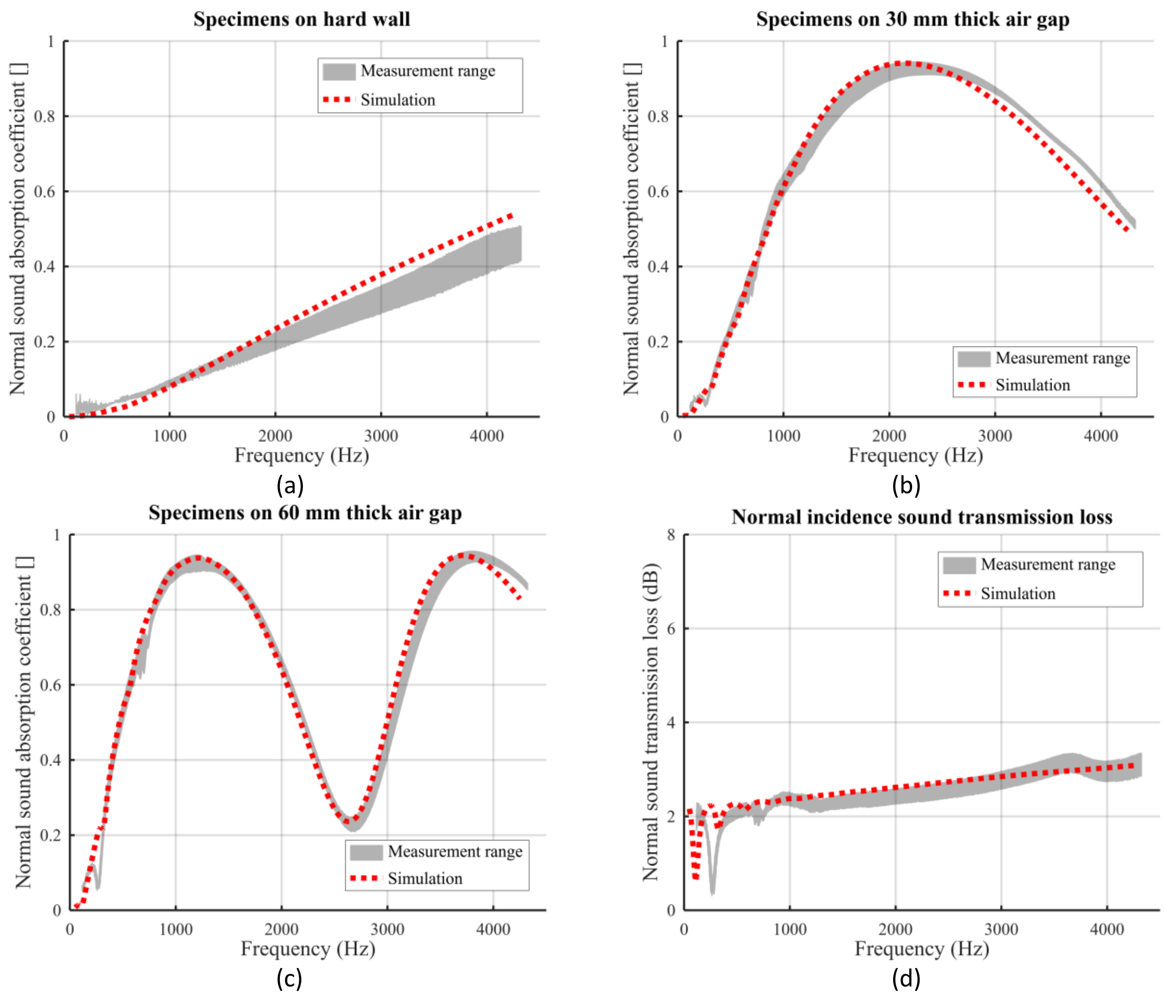

Figure 5 – Normal incidence sound absorption coefficient on hard wall backing (a), on 30-mm thick air layer (b), on 60-mm air layer (c) and sound transmission loss (d) of three specimens tested in medium 44.44-mm diameter tube. Red lines are simulations with JCA-Biot model on cylindrical specimens using characterized material properties and axisymmetric finite element method. Grey areas correspond to the measurements envelopes.

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REFERENCES AND LINKS

1. Description of the characterized material properties: http://www.mecanum.com/en/services/material-characterisation/.
2. Description of characterization equipment: http://www.mecanum.com/en/products/.
3. Porosity and density measurement method:
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4. Resistivity measurement method:
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   d. R. Panneton, X. Olny, “Acoustical determination of the parameters governing viscous dissipation in porous media,” J. Acoust. Soc. Am. 119, 2027-40 (2006). PDF Link.

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7. Acoustical tube measurements:

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   b. ASTM E2611: Standard Test Method for Measurement of Normal Incidence Sound Transmission of Acoustical Materials Based on the Transfer Matrix Method (American Society for Testing and Materials, New York, 2009).

   c. Y. Salissous, R. Panneton and O. Doutres, "Complement to standard method for measuring normal incidence sound transmission loss with three microphones" J. Acoust. Soc. Am. 131, EL216-EL222 (2012). PDF Link.

8. Acoustical models for porous materials:

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   b. J.F . Allard and N. Atalla, Propagation of Sound in Porous Media: Modelling Sound Absorbing Materials (2nd edition, Wiley, 2009). PDF Link.

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10. Tortuosity measurement method

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