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DELTA Test Report

TEST Reg. no. 100

Measurement of Acoustic Properties of light weight concrete SL-Deck

Performed for Abeo A/S

DANAK 100/1820
Project no.: I100486
Page 1 of 25

30 June 2014

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Title
Measurement of Acoustic Properties of light weight concrete SL-Deck

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DANAK 100/1820	I100486	LOD/DH/ilk	May-June 2014

Client
Abeo A/S
Finsensvej 37F
DK-2000 Frederiksberg
Denmark

Client ref.
Morten S. Rasmussen

Summary

Laboratory measurement of sound reduction index has been carried out per one-third octave according to the test method of EN ISO 10140-2:2013 for a light-weight concrete deck with and without wooden flooring.

Test results evaluated according to EN ISO 717-1:2013:

R_w (C; C_{tr}) = 57 (-1; -6) dB for the bare concrete deck

R_w (C; C_{tr}) = 58 (-2; -7) dB for the concrete deck with a wooden flooring

Laboratory measurements of the reduction of impact sound pressure level per one-third octave were carried out according to the test method of EN ISO 10140-3:2010 for a light-weight concrete deck with and without wooden flooring.

Test result evaluated according to EN ISO 717-2:2013:

$L_{n,w}$ = 77 dB for the bare concrete deck. Spectrum adaptation term: C_I = -14 dB

$L_{n,w}$ = 47 dB for the concrete deck with a wooden flooring. Spectrum adaptation term: C_I = 1dB.

The test results per one-third octave are shown in tabular form and graphically on the Graph Sheets. Descriptions of test rooms, test method, and evaluation method are found in the Appendix.

The test results per one-third octave and per octave are shown in tabular form and graphically on the graph sheets together with the weighted sound absorption coefficient α_w and the absorption class according to EN ISO 11654:1997.

Remarks

The test results apply only to the objects tested.

DELTA, 30 June 2014

Leif Ødegaard
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Contents

1. Introduction

At the request of Abeo A/S building acoustic laboratory measurements were carried out on the light weight concrete deck type SL-Deck. The measurement comprises of the following:

- Measurement of the impact sound pressure level
- Measurement of airborne sound insulation
- Measurement of the sound absorption properties
- Structural reverberation time (Loss factor measurements)

2. Description of the Deck based on the Client's Specifications

The design of the SL-Deck is based on Abeo's technology, Super-Light Structures, which is based on a combination of ordinary concrete and lightweight concrete. The SL-Deck consists of arch shaped blocks made of light-aggregate concrete (700 kg/m^3). These are covered with a completely traditional concrete (2400 kg/m^3).

The under surface of light-aggregate concrete gives an area with improved sound absorbing properties than traditional concrete.

In the gaps between the light-aggregate blocks, reinforcement is put across the deck which in combination with the pre-stressing that runs lengthwise gives a grid like reinforcement structure.

Figure 1
Construction of SL-Deck.

3. Mounting in the Laboratory

The two test elements (approx. 10 m²) were mounted in a 2.99 m × 3.37 m test opening between two reverberant rooms. The two elements are casted together with concrete after mounting in the test opening. The gap between the test specimens and the mounting frame in the test opening was partly filled with mineral wool and sealed with approx. 50 mm concrete on the top.

The floor consists of two elements each of dimensions (lengths x width x height) 2968 x 1658 x 220 mm. The weight of the slab is 350 kg/m^2 corresponding to a total weight of 3450 kg for the test elements. The under surface of light aggregate concrete covers an area of 7.33 m^2 of the test elements.

The mounting of the test specimens was carried out by DELTA.

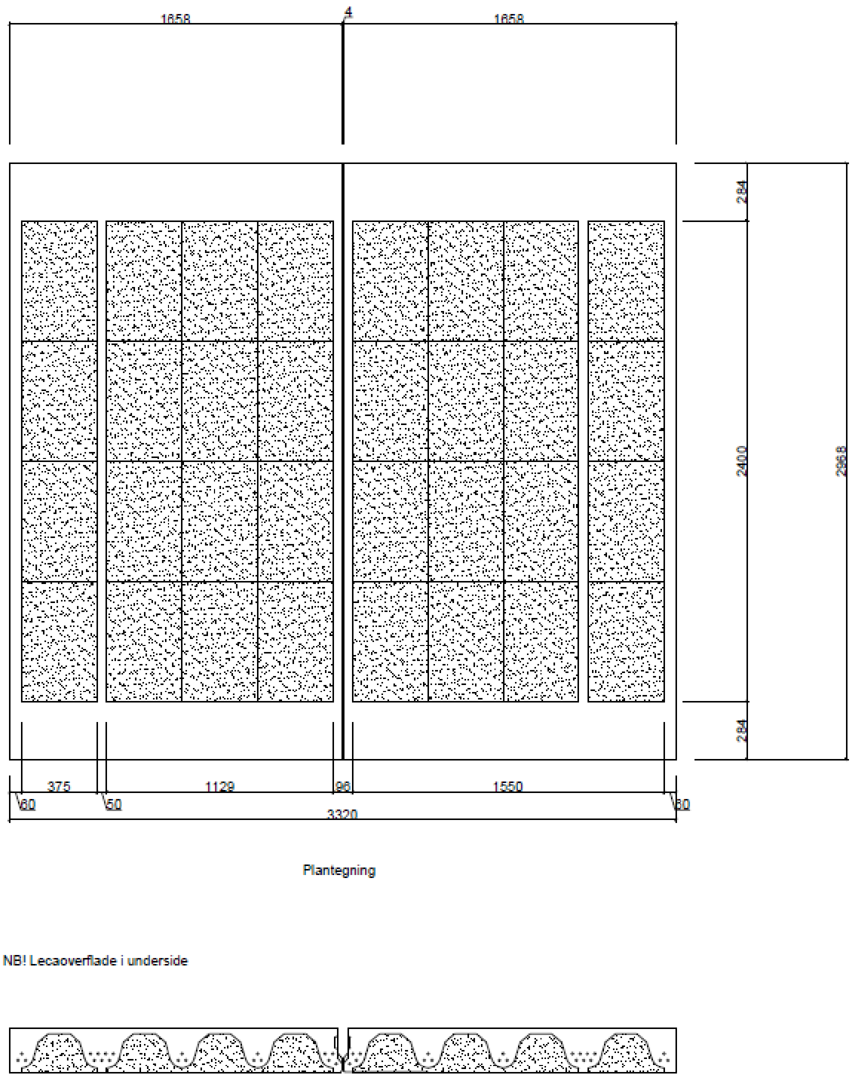


Figure 2
Construction of the test floor.

3.1 Test with a wooden flooring

The flooring system tested with the SL-Deck consists of the following:

22 mm wooden parquet mounted on 40 x 39 mm Kerto wooden joists spaced 600 mm. The joists are supported by wedges of type Knudsen Combi Max per approx. 550 mm. The support system includes Knudsen Combi sound reducers consisting of 5 mm plate of plastic and 5 mm Regupol E48.

The total height of the construction is 162 mm. The edge of the wooden flooring was lined by a wooden frame mounted at the edge of the test opening. The floor was kept clear from the lining frame. The gap was sealed with tape.

The mounting of the test flooring was carried out by Knudsen Kilen A/S.

4. Test Methods

The impact sound pressure level and the sound reduction measurements were carried out according to the test method of EN ISO 10140:2010 - All parts: "Acoustics - Laboratory measurement of sound insulation of building elements".

The measurements were performed in Rooms 004 and 904, Building 355 at the Technical University of Denmark. A brief description of the test rooms and test methods is found in Appendix 1 and Appendix 2 .

The sound absorption measurements were carried out according to the test method of EN ISO 354:2003: "Measurement of Sound Absorption in a Reverberation Room". Due to the application details of the heavy test specimen the mounting specified in the standard Annex B could not be used. Consequently, the absorption measurements were performed in room 904, Building 355 at the Technical University of Denmark with the test specimens mounted in the test openings between the two rooms. A brief description of the test rooms and test procedures is found in Appendix 3.

The measurement of the structural reverberation time is made as stated in section 4.7 in EN ISO10140:4:2010. However, it is chosen that the results for these measurements are reported outside the accreditation sections.

4.1 Impact sound pressure level

The normalized impact sound pressure level of the concrete slab was measured with and without a wooden floor covering.

The measurements were performed using a standardized tapping machine. The sound pressure level in the receiving room was measured using one-third octave band filters.

4.2 Sound reduction index

The measurement of sound reduction index was carried out using two loudspeaker positions in the source room (the lower room with the test specimen has the most absorbing surface). One receiver position was placed in in the receiver room. Rotating microphones were used in all positions. The sound pressure level in the source and in the receiving room was measured using one-third octave band filters.

4.3 Sound absorption

The sound absorption coefficient was calculated from the reverberation times measured in the room with the test specimen mounted in the test opening and with the standard floor (140 mm concrete slab) mounted in the test opening. Due to the special mounting conditions of the heavy test specimen in a mounting frame the tested area was only 9 m^2.

5. Instrumentation

The following instruments were used for the tests:

Instrument	Type	A&V No.
Sound Level Frequency Analyser	B&K 2270	1498L
Tapping Machine	Norsonic	04L023
Measuring Microphone (004)	B&K 4144	731L
Measuring Microphone(904)	B&K 4144	853L
Microphone Preamplifier(004)	B&K 2619	853L
Microphone Preamplifier(904)	B&K 2619	857L
Measuring Microphone	B&K 4144	859L
Microphone Power Supply(004)	B&K 5935	1392L
Microphone Power Supply	B&K 2807	722L
Sensor for Temperature and Humidity	Elpro Ecolog TH1	1216L
Sound Level Calibrator	B&K 4231	1158L

Table 1
Instrumentation used for the measurement.

5.1 Measuring conditions

The measuring conditions in the upper room during measurement of the impact sound pressure level and the sound reduction index were as stated in Table 2.

Test Specimen	Date of test	Temperature °C	Relative humidity %
Without floor covering	12 May 2014	19.4	47
With the wooden floor covering	14 May 2014	19.3	47

Table 2
Measuring conditions for the impact sound pressure level and the sound reduction index.

The measurement conditions during absorption measurements for the SL-Deck were as stated in Table 3.

Test Specimen	Date of test	Temperature °C	Relative humidity %
Standard Concrete deck	8 April 2014	15.5	61
With the wooden floor covering	6 May 2014	16.2	60

Table 3
Measurement conditions for sound absorption.

6. Test Results

6.1 Impact sound pressure levels

Impact sound pressure level is determined to according to EN ISO 10140-3:2010. The single-number quantity $L_{n,w}$ and the corresponding spectrum adaptation term is determined according to EN ISO 717-2:2013.

The wooden flooring was loaded approximately 24 hours and during by approx. 25 kg/m² during the measurements.

The tapping machine was placed in six positions on the floor under test.

Description of the evaluation methods is found in the Appendix 2.

The results of the measurements are given in Table 4.

Test Specimen	$L_{n,w}$	Spectrum adaptation term: C_I
Without floor covering	77 dB	-14 dB
With the wooden floor covering	47 dB	1 dB

Table 4
Results of the impact sound pressure level for the SL-Deck.

The test result, L_n, per one-third octave from 100 Hz to 5000 Hz is shown in tabular form and graphically on Graph Sheet 1 with floor covering and without the floor covering.

6.2 Sound Reduction Index

The sound reduction insulation is determined to according to EN ISO 10140-2:2010. The single-number quantity R_w and the corresponding spectrum adaptation terms are determined according to EN ISO 717-1:2013.

The results of the measurements are given in Table 5.

Test Specimen	R_w	Spectrum adaptation term: (C; C_{tr})
Without floor covering	57 dB	(-1,-6) dB
With the wooden floor covering	58 dB	(-2,-7) dB

Table 5
Results of the sound reduction index measurements for the SL-Deck.

The sound reduction index, R, per one-third octave from 100 Hz to 5000 Hz is shown in tabular form and graphically on Graph Sheet 2.

Description of the evaluation method is found in the Appendix 2.

6.3 Sound Absorption

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 was initially measured with a standard concrete deck mounted in the test opening. After dismounted the standard deck and after mounting the SL-Deck the reverberation time T_2 was measured. The way of the applied mounting method departs from the specified mountings in the standard Annex B (see Section 4.3).

The reverberation time T_1 per third octave of the room without test the standard deck and the reverberation time T_2 per third octave of the room with SL-Deck (averaged values) are stated in Table 6.

The test result α_s per one-third octave from 100 Hz to 5000 Hz is shown in tabular form and graphically on Graph Sheet 3.

The calculated, practical sound absorption coefficient α_p per octave from 125 Hz to 4000 Hz is shown on Graph Sheet 4 together with the weighted sound absorption coefficient α_w as well as the absorption class. These values are calculated in accordance with EN ISO 11654:1997.

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 0.01 at 4000 Hz, 0.02 at 5000 Hz, and 0 at all other frequencies.

Frequency f [Hz]	Reverberation Time T_1 [sec.]	Reverberation Time T_2 [sec.]
100	8.1	7.4
125	7.4	5.7
160	7.2	5.0
200	7.2	5.0
250	6.8	4.6
315	7.8	4.9
400	7.2	5.0
500	6.9	4.8
630	7.1	4.7
800	6.7	4.4
1000	6.4	4.1
1250	5.7	4.0
1600	5.3	3.6
2000	4.5	3.2
2500	4.1	2.9
3150	3.3	2.5
4000	2.7	2.2
5000	2.2	1.8

Table 6. *The reverberation time T1 per third octave of the room without test the standard deck and the reverberation time T2 per third octave of the room with SL-Deck.*

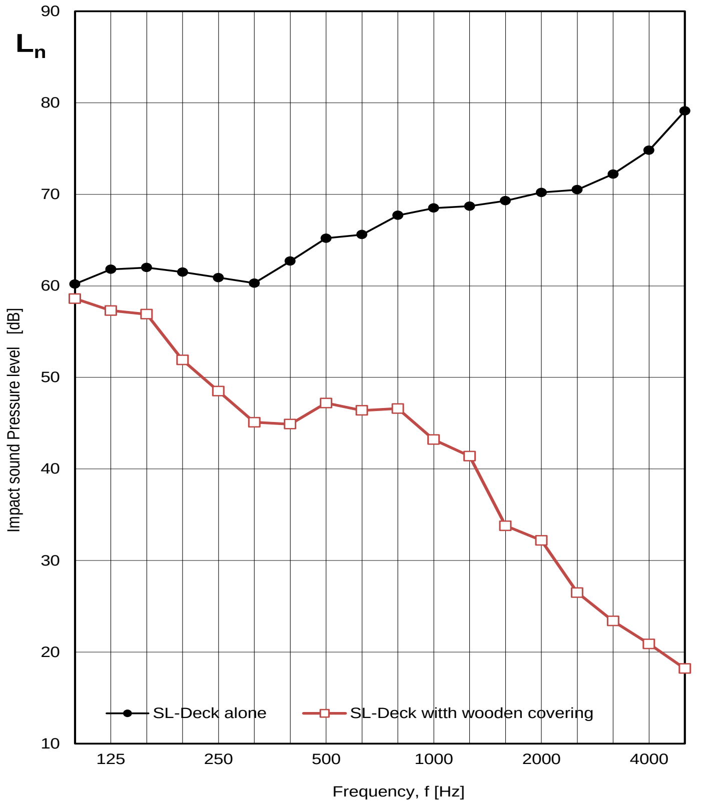
Laboratory Measurement of Impact Sound Pressure Level according to EN ISO 10140:2010 - All parts

Client: Abeo A/S, Finsensvej 37F, 2000 Frederiksberg, Denmark
Date of test: 12 and 14 May 2014

Test specimen: SL-Deck with and without wooden flooring

Test specimen mounted by: DELTA and Knudsen Kilen A/S
Receiving room volume: 243 m^3

Frequency f [Hz]	L_n in dB SL-Deck	L_n in dB SL-Deck with covering
100	60.2	58.6
125	61.8	57.3
160	62	56.9
200	61.5	51.9
250	60.9	48.5
315	60.3	45.1
400	62.7	44.9
500	65.2	47.2
630	65.6	46.4
800	67.7	46.6
1000	68.5	43.2
1250	68.7	41.4
1600	69.3	33.8
2000	70.2	32.2
2500	70.5	26.5
3150	72.2	23.4
4000	74.8	20.9
5000	79.1	18.2



Weighed Impact Sound Level index according EN ISO 717-2:2013

$L_{n,w}$ = 77 dB without flooring and $L_{n,w}$ = 47dB with wooden flooring

DELTA, 30 June 2014

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TEST Reg. no. 100

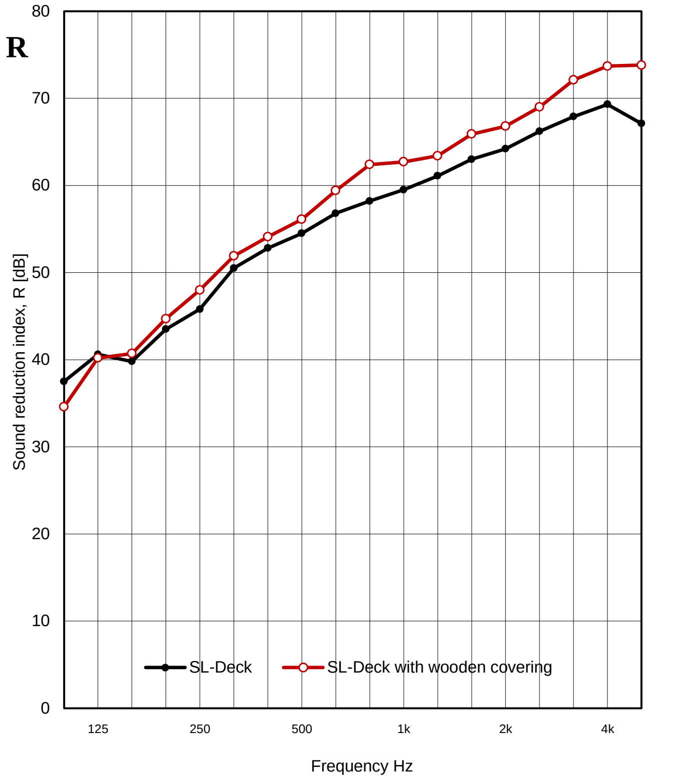
Laboratory Measurement of Sound Reduction Index according to EN ISO 140-2:2010 - All parts

Client: Abeo A/S,Finsensvej 37F, 2000 Frederiksberg, Denmark
Dates of test: 12 and 14 May 2014

Test specimen: SL-Deck with and without wooden flooring

Test specimen mounted by: DELTA
Receiving room volume: 230 m³

Frequency f [Hz]	R in dB SL-Deck	R in dB SL-Deck with covering
100	37.5	34.6
125	40.6	40.2
160	39.8	40.7
200	43.5	44.7
250	45.8	48.0
315	50.5	51.9
400	52.8	54.1
500	54.5	56.1
630	56.8	59.4
800	58.2	62.4
1000	59.5	62.7
1250	61.1	63.4
1600	63.0	65.9
2000	64.2	66.8
2500	66.2	69.0
3150	67.9	72.1
4000	69.3	73.7
5000	67.1	73.8



Weighed Sound reduction index R_w according EN ISO 717-1:2013

$R_{,w}$ = 57 dB without flooring and R_w = 58 dB with wooden flooring

DELTA, 30 June 2014

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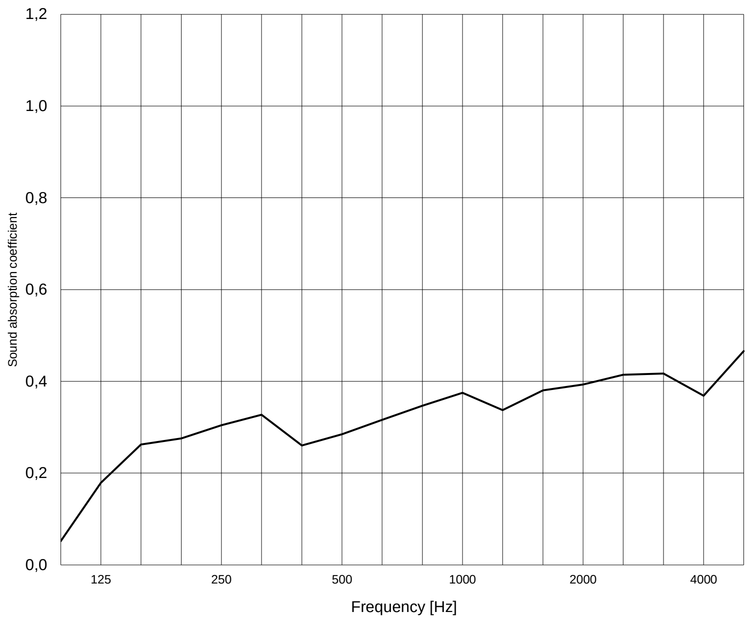
Laboratory Measurement of Sound Absorption Coefficient according to EN ISO 354:2003

Client: Abeo A/S, Finsensvej 37F, 2000 Frederiksberg, Denmark
Date of test: 8 April and 6 May 2014

Test specimen: SL-Deck

Test area: 9 m²
Room volume: 243 m³
Room surface: 240 m²

Frequency f [Hz]	α_s
100	0.05
125	0.18
160	0.26
200	0.28
250	0.30
315	0.33
400	0.26
500	0.28
630	0.32
800	0.35
1000	0.37
1250	0.34
1600	0.38
2000	0.39
2500	0.41
3150	0.42
4000	0.37
5000	0.47



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Graph Sheet 4

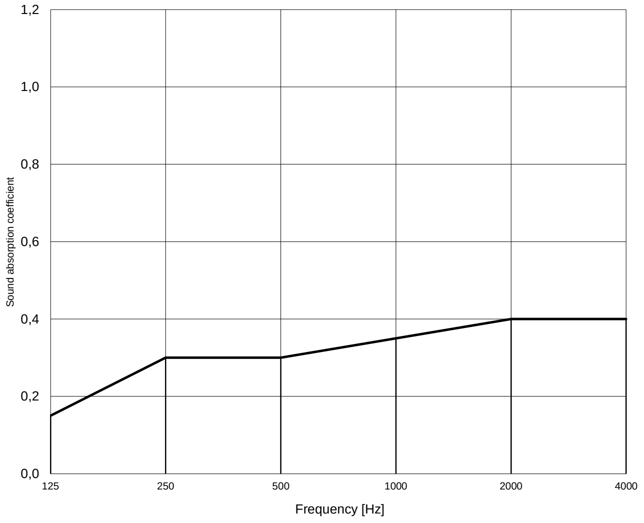
Laboratory Measurement of Sound Absorption Coefficient according to EN ISO 354:2003

Client: Abeo A/S, Finsensvej 37F, 2000 Frederiksberg, Denmark
Date of test: 8 April and 6 May 2014

Test specimen: SL-Deck

Test area: 9 m²
Room volume: 243 m³
Room surface: 240 m²

Frequency f [Hz]	α_p
125	0.15
250	0.30
500	0.30
1000	0.35
2000	0.40
4000	0.40



Practical sound absorption coefficient, weighted sound absorption coefficient, and absorption class according to EN ISO 11654:1997:

α_w 0,35 Absorption class: D

DELTA, 30 June 2014

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7. Measurement Uncertainty

According to EN ISO 140-2:1992 precision of laboratory measurements expressed as the reproducibility of single-number quantities R_w and $L_{n,w}$ will normally be in the range of 1 dB to 3 dB.

Measurement uncertainty (90 % confidence interval) estimated from a Nordic intercomparison (Nordtest Project No. 1023-92) for the practical absorption coefficient α_p per octave:

Frequency [Hz]	Uncertainty
125	±0.15
250	±0.10
500	±0.05
1000	±0.10
2000	±0.10
4000	±0.10

8. Evaluation and Interpretations

The following sections are not a part of the accreditation.

8.1 Structural reverberation time

The structural reverberation time has been measured using vibrator excitations. The vibrator applied is a B&K type 4809. The response of the deck is measured with an accelerometer B&K type 4381 in connection with charge amplifier type B&K 2635.

The exciter is fed with a MLS signal (Maximum Length Sequence) and the structural reverberation time has been determined using a frequency analyser Norsonic type RTA 840-2. The integrated impulse response method has been used with backward integration of the squared impulse response. The vibration signal used for input for the impulse response function has been as a velocity signal. The number of measuring positions has been 4 for each exciter positions. The exciter has been placed in 3 positions. The measuring positions are randomly distributer over the test element. In Figure 3 is shown the test set-up for the structural reverberation measurements.

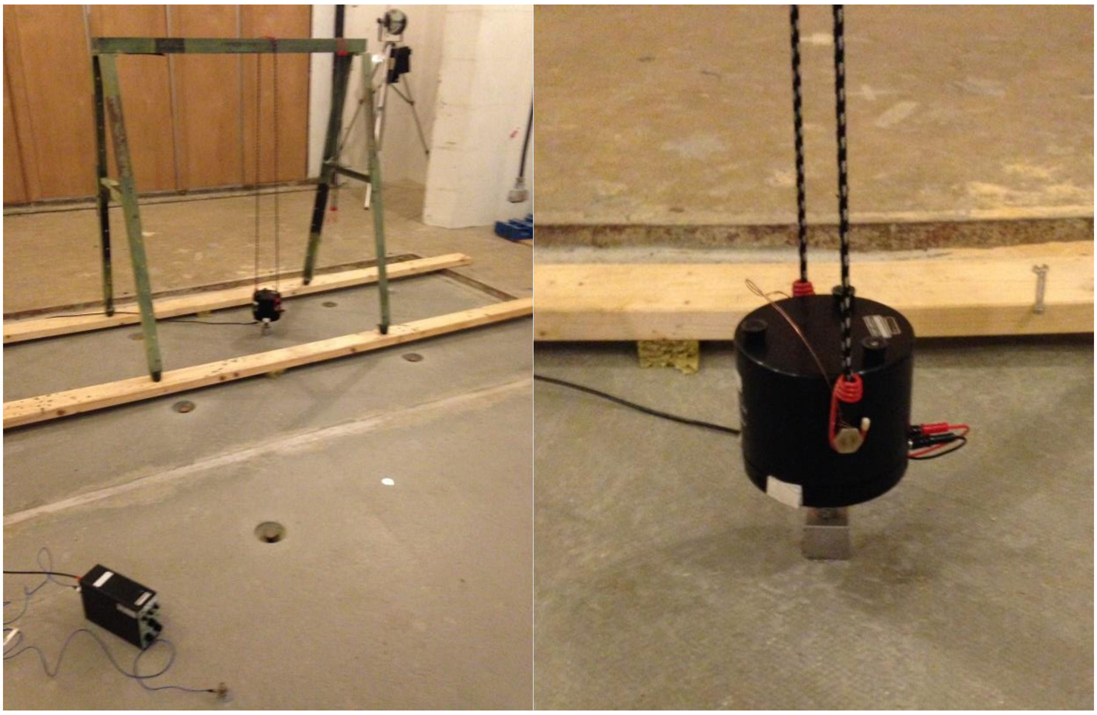


Figure 3
Mounting of exciter on test deck for the structural reverberation time.

The relation between the total loss factor η_{total} and the structural reverberation time T_S of the element is:

$$\eta_{total} = \frac{2,2}{f\ Ts}$$

where f is the frequency.

The results of the measurement of the structural reverberation time are given in Table 7.

Frequency f [Hz]	**Reverbera-tion Time T_S [sec.]**	**Total loss factor**
100	0.336	0.065
125	0.282	0.062
160	0.349	0.039
200	0.289	0.038
250	0.211	0.042
315	0.227	0.031
400	0.137	0.040
500	0.121	0.036
630	0.126	0.028
800	0.105	0.026
1000	0.098	0.022
1250	0.092	0.019
1600	0.073	0.019
2000	0.063	0.017
2500	0.054	0.016
3150	0.056	0.012
4000	0.051	0.011
5000	0.057	0.008

Table 7
Results of the structural reverberation time measurements.

8.2 Impact sound reduction for wooden flooring

Laboratory measurements of the reduction of impact sound pressure level for flooring systems are normally carried out according to the test method of EN ISO 10140:2010 part 1, 3 and 4 with the system installed on a 140 mm concrete floor. However, in this case the flooring system is not tested on the standard deck but on a light-weight concrete deck construction.

The reduction of the impact sound pressure level ΔL of the flooring system has in this case been calculated as the difference of the impact sound pressure level with and without the flooring system installed on the test concrete deck.

The test result, impact sound reduction relative to bare SL-deck ΔL, per one-third octave from 100 Hz to 5000 Hz is shown in tabular form and graphically in Figure 4.

Frekvens f [Hz]	**ΔL dB**
100	1,6
125	4,5
160	5,1
200	9,6
250	12,4
315	15,2
400	17,8
500	18,0
630	19,2
800	21,1
1000	25,3
1250	27,3
1600	35,5
2000	38,0
2500	44,0
3150	48,8
4000	53,9
5000	60,9

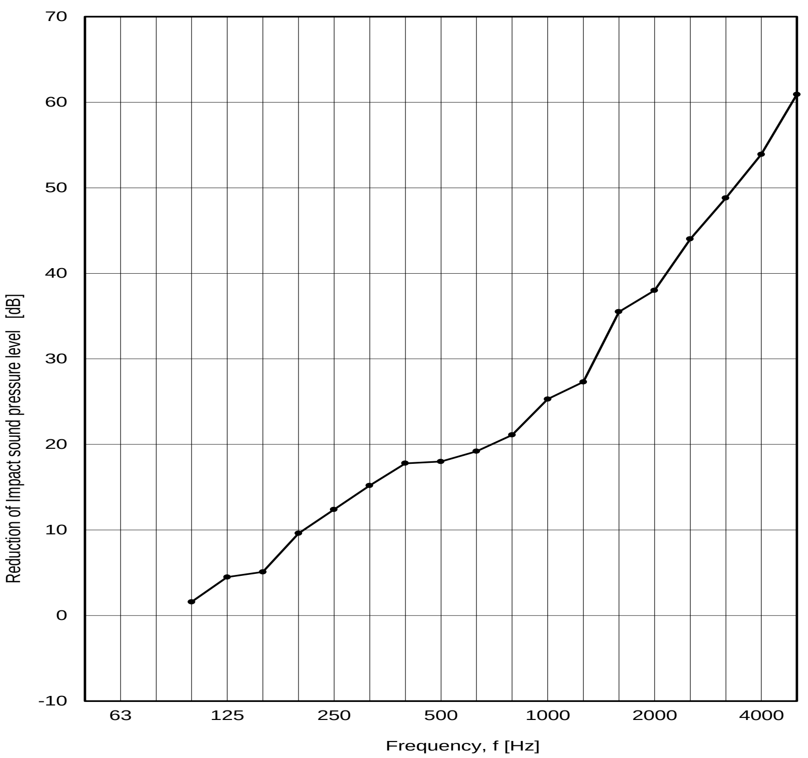


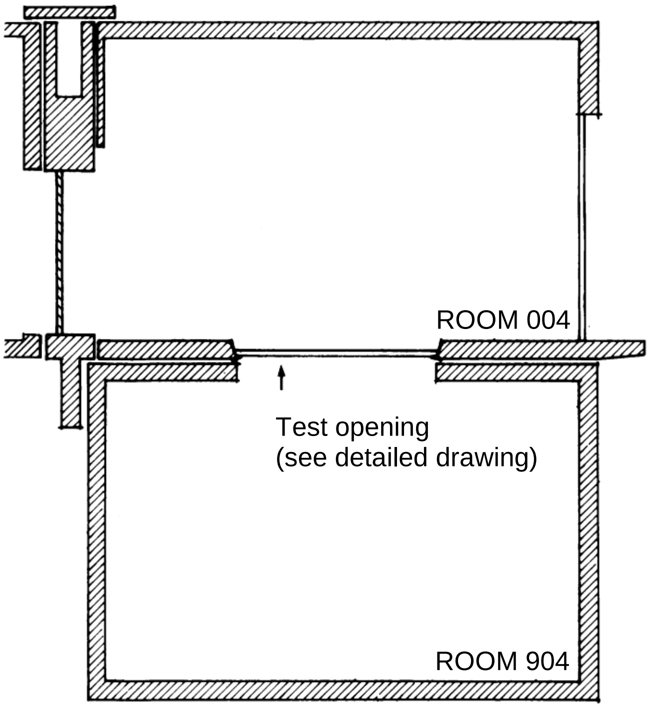
Figure 4
Impact sound reduction relative to bare SL-deck ΔL, per one-third octave from 100 Hz to 5000 Hz.

8.2.1 Measurement uncertainty

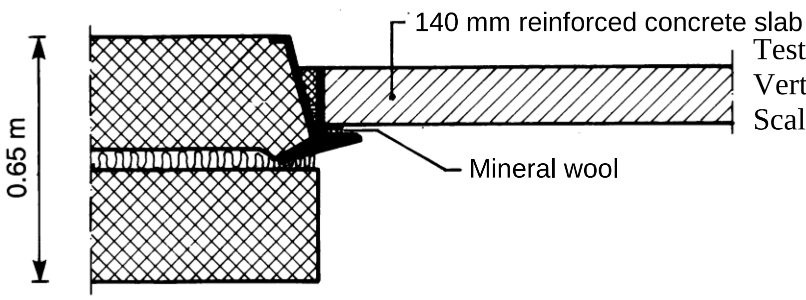
According to DS/ISO 140-2:1992 precision of laboratory measurements expressed as the reproducibility of single-number quantities, including ΔL_w, will normally be in the range of 1 dB to 3 dB.

Description of Test Rooms

The measurements are performed in two reverberant rooms (004 and 009), one placed on top of the other. The length, width and height of the rooms are 7.85 m, 6.25 m and 4.95 m, respectively. The test opening between the rooms is 2.99 m × 3.37 m and has a depth of 0.65 m. In the upper room (004) sound diffusing elements of concrete and of damped steel plate are situated on two of the walls and on the ceiling. The volume of the room is approx. 230 m³. In the lower room (904), the volume of which is approx. 245 m³, 20 sheets of 10 mm acrylic (dimensions 0.90 m × 1.2 m) are used as sound diffusing elements.



Test rooms.
Vertical section.
Scale 1:125.



Test opening with standard floor.
Vertical section.
Scale 1:20.

Test Method – Impact sound pressure level

The normalized impact sound pressure level is defined as the sound pressure level in the receiving room when the floor under test is excited by the standardized tapping machine increased by a correction to a reference equivalent absorption area (10 m²) of the receiving room.

The measurements of the normalized impact sound pressure level are performed using a standardized tapping machine provided with steel hammers and meeting the requirements of EN ISO 10140-5:2010 Annex E. The tapping machine is adjusted in such a way that the falling height of the hammers on an even surface corresponds to a free fall from a height of 40 mm.

The tapping machine is placed in six positions on the floor under test, and the sound pressure level in the receiving room is measured using a moving microphone with a sweep radius of approx. 1.25 m and with an inclined plane of the traverse. The measurement is carried out using a real-time frequency analyzer with one-third octave band filters. The averaging time is 32 seconds corresponding to two traverses of the moving microphone. The total electrical and acoustic background noise level in the receiving room is measured. The sound pressure level in the receiving room is corrected for background noise, if affected. If the sound pressure level in the receiving room is less than 6 dB above the background noise level, this will be stated in the report together with an indication of the validity of the test results.

The equivalent absorption area of the receiving room is determined by means of Sabine's formula by measuring the reverberation time of the room in three microphone positions with two decays in each. The measurement of the reverberation time is performed with pink noise emitted by a loudspeaker system placed in a corner of the receiving room. The one-third octave filtered microphone signal is registered during the decay and evaluated in the range approx. 5 dB to approx. 25 dB below the steady-state level.

The normalized impact sound pressure level is determined within frequency bandwidths of one-third octave at the following standardized center frequencies: 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, 3150, 4000, and 5000 Hz.

$$L_n = L_M + 10 \log_{10} \cdot \frac{A_M}{A_O} \quad \text{and} \quad A_M = \frac{0.163 \cdot V_M}{T_M}$$

where L_n = Normalized impact sound pressure level with a reference equivalent absorption area of 10 m² [dB re 20 µPa]

L_M = Sound pressure level in the receiving room when the floor under test is excited by the standardized tapping machine [dB re 20 µPa]

A_M = Equivalent sound absorption area in receiving room [m²]

A_0 = Reference equivalent sound absorption area (10 m²)

V_M = Volume of receiving room [m³]

T_M = Reverberation time in receiving room [s]

Evaluation Method- Impact sound

To evaluate the normalized impact sound pressure level of a floor the single-number quantity $L_{n,w}$ is used. The value is determined according to EN ISO 717-2:2013.

When determining the evaluation value, $L_{n,w}$, the measured results of the normalized impact sound pressure level per one-third octave from 100 Hz to 3150 Hz are compared with a reference curve, which has a constant value from 100 Hz to 315 Hz, while it falls by 1 dB per one-third octave from 315 Hz to 1000 Hz, and by 3 dB per one-third octave from 1000 Hz to 3150 Hz. The values of the reference curve at the one-third octave centre frequencies are integers. An unfavourable deviation occurs at a certain frequency when the test result exceeds the value of the reference curve. The reference curve is shifted in steps of 1 dB until the sum of unfavourable deviations is as large as possible, but not more than 32.0 dB.

The $L_{n,w}$-value is determined from the shifted reference curve as the value in dB at 500 Hz.

As an additional evaluation method based on a summation of the unweighted linear impact sound level the spectrum adaptation terms C_I for the normalized impact sound pressure level is defined in EN ISO 717-2:2013, Annex A.

Test Method – Sound Reduction Index

The sound reduction index, R, is defined as the ratio in decibel between the sound power incident on the test specimen and the transmitted sound power radiated from the other side of the test specimen.

When measuring the sound reduction index, R, according to EN ISO 10140-2:2010 and EN ISO 10140-4:2010 the test specimen is placed between a source room and a receiving room meeting the requirements of EN ISO 10140-5:2010, and the sound reduction index is determined by means of the formula below presupposing diffuse sound fields in the rooms.

The measurement was carried out with a broadband noise signal emitted by a loudspeaker in the source room. The loudspeaker is fed through an equalizer and a power amplifier. Two loudspeaker positions established according to the qualification method in EN ISO 10140-5:2010 are used in the source room.

The sound pressure levels of the source room and the receiving room were averaged for each loudspeaker position within a period of 32 seconds corresponding to two revolutions of a rotation microphone system with sloping path and a radius of approx. 1.25 m. The sound pressure level is measured using a real-time frequency analyser with one-third octave band filters. The total electrical and acoustic background noise level in the receiving room is measured. The sound pressure level in the receiving room is corrected for background noise, if affected.

The equivalent absorption area of the receiving room was determined by means of Sabine's formula by measuring the reverberation time of the room in tree microphone positions with two decays in each. The measurement of the reverberation time was performed with a broadband noise signal emitted by a loudspeaker system placed in a corner of the receiving room. The one-third octave filtered microphone signal was registered during the decay and evaluated in the range approx. 5 dB to approx. 25 dB below the steady-state level.

The sound reduction index was determined within frequency bandwidths of one-third octave at the following standardized centre frequencies: 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, 3150, 4000, and 5000 Hz.

$$R = L_1 - L_2 + 10 \log_{10} \frac{S}{A} \text{ and } A = \frac{0.16 \cdot V}{T} \text{ [dB]}$$

where R = Sound reduction index of test specimen [dB]

L_1 = Sound pressure level in source room [dB/20 µPa]

L_2 = Sound pressure level in receiving room [dB/20 µPa]

S = Area of test specimen [m²]

A = Equivalent sound absorption area in receiving room [m²]

V = Volume of receiving room [m³]

T = Reverberation time in receiving room [s]

Evaluation Method – Sound Reduction Index

To evaluate the airborne sound insulation of the test specimen, the weighted sound reduction index, R_w, is used. The value is determined according to EN ISO 717-1:2013.

When determining the evaluation value, R_w, the measured results of the sound reduction index, R, per one-third octave from 100 Hz to 3150 Hz are compared with a reference curve. The reference curve is shifted in steps of 1 dB towards the measured curve until the sum of unfavourable deviations is as large as possible, but not more than 32.0 dB. An unfavourable deviation at a particular frequency occurs when the test result is less than the value of the reference curve.

The evaluation value, R_w, is determined from the shifted reference curve as the value in dB at 500 Hz.

Additionally, the spectrum adaptation terms, C and C_{tr}, for A-weighted pink noise and A-weighted urban traffic noise are calculated. These adaptation terms are stated in the report in brackets after the R_w-value.

Description of Reverberation Room

The measurements are performed in a reverberation room (Room 904, Building 355 at the Technical University of Denmark) with walls, ceiling, and floor of 300 mm in situ cast concrete. The length, width and height of the rooms are 7.85 m, 6.25 m and 4.95 m. In the room (904), the volume of which is approx. 245 m^3, 20 sheets of 10 mm acrylic (dimensions 0.90 m × 1.2 m) are used as sound diffusing elements. The total surface area is approximately 240 m^3.

Test Procedure

Measurement of sound absorption according to EN ISO 354:2003 is carried out in a reverberation room. The reverberation time is measured with and without the test specimen, and the sound absorption 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 three 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 equivalent sound absorption area per object A_{obj} is calculated using the following formula:

$$A_{obj} = \frac{55.3 \cdot V}{c \cdot n} \cdot \left(\frac{1}{T_2} - \frac{1}{T_1} \right) - \frac{4V}{n} \cdot (m_2 - m_1)$$

where V = Volume of the empty reverberation room [m^3]

c = Velocity of sound in air [m/s]

n = Number of test objects

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 T_1 (m^{-1})

m_2 = Attenuation coefficients due to air absorption during measurement of T_2 (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.