# Airborne and structure-borne properties for floor constructions

## July 2013

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| Report no. | 13.3731 rev.1 |
| Project ref. | 12.450282 |
| Client ref. | Sika Italia S.p.A<br>Via L. Einaudi 6<br>I 20068 Peschiera Borromeo (MI)<br><br>Italy<br><br>Attn.: Carsten Brutus Jørgensen |

Lloyd's Register ODS
ENGINEERING DYNAMICS

Lloyd's Register
LIFE MATTERS

# Revision

| Version | Date | Comments |
|---|---|---|
| 1 | 17 July 2013 | First version |
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# Contents

# Executive Summary

In terms of noise abatement control in the accommodation area of the ship, the floor is usually one of the most important contributors to the overall noise level. The noise contribution from the floor consists either of airborne noise transmission through the floor or of structure-borne noise contribution radiated from the floor. Consequently, when using a special floor construction for noise control purposes, the floor construction must have the ability to reduce:

- the transmission of airborne sound
- the transmission of structure-borne sound through the floor construction and to minimize sound radiation into the adjoining rooms
- the transmission of impact noise due to walking on the deck to the room underneath

In order to manage the noise control abatement, it is important for the shipyards, the ship owners and the ship designers to obtain detailed information about the noise reducing properties for constructions used in ships.

This report describes the results of measurements of the airborne sound insulation, of the impact sound insulation and of the structure-borne sound insulation for four different floor constructions for ships developed and manufactured Sikafloor© Marine.

The following types of floor constructions have been investigated:

- a floor construction with a steel plate constrained viscoelastic layer
- a floor construction with a compound constrained viscoelastic layer
- a floating floor construction with a compound constrained viscoelastic layer and a compound on top of the rockwool
- a floating floor construction with a compound constrained viscoelastic layer and constrained layer damped steel plates on top of the rockwool

In order to evaluate the gained improvement of the sound insulation properties caused by the various floors, the airborne and structure-borne insulation properties from a reference deck consisting of an 8 mm stiffened steel deck have been determined.

# 1 Introduction

## 1.1 Standards

The airborne sound insulation, the impact sound insulation and the structure-borne sound insulation were all measured according to the following standards and methods:

1) ISO 10140: 2010, Acoustics – Laboratory measurements of sound insulation of building elements.

   Part 1: Application rules for specific products
   Part 2: Measurement of airborne sound insulation
   Part 3: Measurement of impact sound insulation
   Part 4: Measurement procedures and requirements
   Part 5: Requirements for test facilities and equipment

2) EN ISO 717:2013, Acoustics - Rating of sound insulation in buildings and of building elements.

   Part 1: Airborne sound insulation in buildings and interior building elements.
   Part 2: Impact sound insulation.

3) Method developed by Lloyd's Register ODS for measuring structure-borne sound insulation of ship floors.

## 1.2 Test Facilities

The measurements were carried out in two reverberant rooms at the Acoustics Laboratory, Technical University of Denmark, Lyngby. The test facilities are shown in Figure 1.

The two reverberant rooms have the following dimensions: length 7.85 m, width 6.25 m and height 4.95 m. In the upper room, sound diffusing elements of concrete and steel were placed on the side-walls and the ceiling. With the diffusing elements mounted as described, the volume of the upper room was 230 m3.

In the lower room, a number of 10 mm thick acrylic plates of 90 cm x 120 cm and a number of absorbers were placed adjusting the reverberation time to between 2.5 and 10.0 seconds. The volume of the lower room was 245 m3. The rooms are built on two separate foundations and are made of concrete with a wall thickness of 30 cm between the lower room and the upper room. There is an opening of 2.99 m x 3.37 m in the ceiling of the lower room and in the floor of the upper room, see Figure 1.

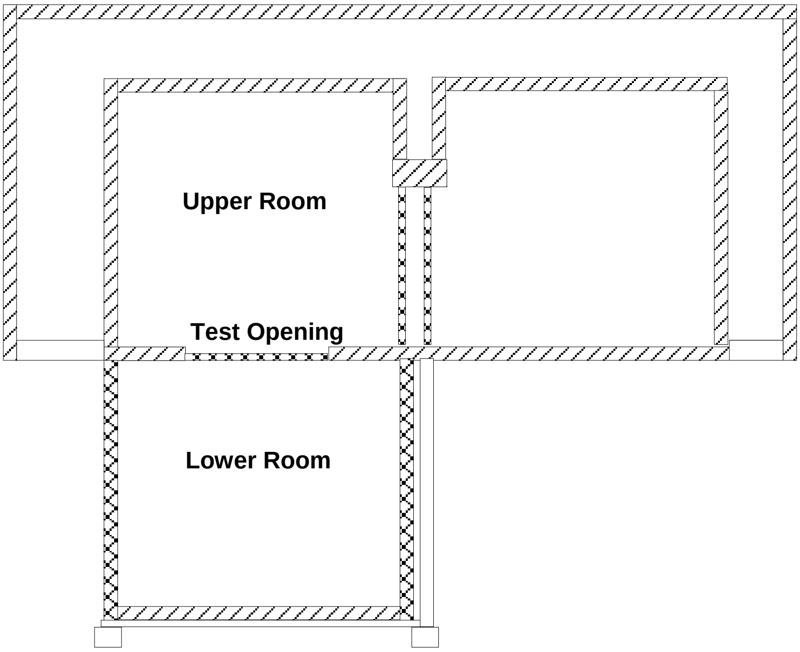



**Figure 1 Sketch showing the measurement rooms at the Technical University of Denmark.**

Excitation of the deck with airborne noise and impact noise was carried out with loudspeakers and a tapping machine as stated in ISO 10140, parts 1-5.

Excitation of the deck with structure-borne noise was performed by means of a vibration exciter coupled to a steel plate, which was mounted perpendicularly to and below the steel deck positioned in the opening. By means of this arrangement, a reverberant vibrational field was established both in the steel plate coupled to the exciter and in the steel deck simulating the real conditions occurring in a ship structure. A sketch of the arrangement is shown in Figure 2.

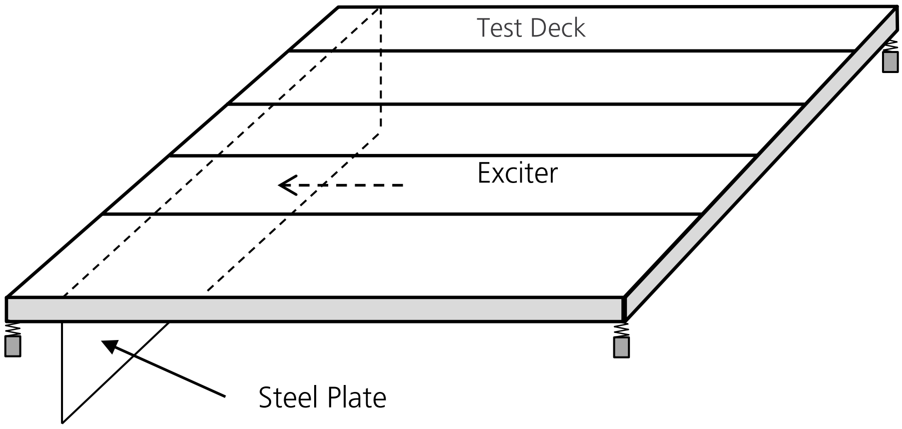



**Figure 2 Sketch showing the arrangement consisting of the 8 mm test deck, the elastic mounting of the deck and the 6 mm steel plate coupled to the test deck. The arrow indicates the position of the electro-dynamic exciter.**

## 1.3 Measurement Methods

The measuring instruments comply with the standard ISO 10140 "Laboratory measurements of sound insulation of building elements; Part 5 Requirements for test facilities and equipment.

The measurement method satisfied the standard ISO 10140 "Laboratory measurements of sound insulation of building elements; Part 2 Measurement of airborne sound insulation and Part 3 Measurement of impact sound insulation.

During the airborne and structure-borne sound measurements, the excitation was performed by means of broadband white noise in the frequency range 25 - 10000 Hz.

The response, i.e. the sound pressure level in the receiving room for the airborne and impact sound insulation measurements or the velocity level on the floor for the structure-borne sound measurements, was measured in 1/3-octave filter bands with centre frequencies from 50 Hz to 5000 Hz.

Measurements at the 1/3-octave filter bands of 50, 63, 80, 4000 and 5000 Hz are not required according to ISO 10140. However, based on experiments from previous measurements in ships, it seems, reasonable to include these frequency ranges.

Due to the volume of the test rooms, some uncertainty occurs for the measurements at the 1/3-octave filter bands of 50, 63 and 80 Hz. In Section 2, the measurement results from these frequency bands are therefore presented for information only.

### 1.3.1 Airborne Sound Insulation

The airborne sound insulation is normally specified by the sound reduction index, R, which is defined as:

$$R = L_1 - L_2 + 10\log\left(S/A\right) \quad dB$$

Where

- L1 is the average sound pressure level in the source room.
- L2 is the average sound pressure level in the receiving room.
- S is the area of the test floor, which was 10 m2.
- A is the equivalent absorption area in m2 in the receiving room, defined according to ISO 10140-4.

In order improve the accuracy of the measurements both the upper and the lower room was used as the source room. The reported values is the averaged values of both directions.

The average sound pressure levels L1 and L2 were measured by means of a rotating microphone in the source room and in the receiving room. The sweep radius of the microphone was 1.5 metre, and the traversing time was 64 seconds. This time was equal to the averaging time of the recording instrument.

From the measured values of R, the weighted sound reduction index, Rw was calculated. The calculation followed the procedure as outlined in EN ISO 717-1:2013.

The spectrum adaptation term C has been calculated as outlined in EN ISO 717-1:2013, where the spectrum adaptation term C is defined as:

$$C = X_{A,1} - R_W$$

where $X_{A,1}$ characterise the difference between the A-weighted sound levels in the source room and in the receiving room for pink noise excitation in the source room.

The spectrum adaptation term C (100 Hz – 3.15 kHz) has been calculated in the frequency range from 100 Hz – 3.15 kHz.

Generally, C is approximately –1. However, when a dip occurs in the sound insulation curve in a single frequency band, the C value will be less than –1.

When comparing constructions, it may be appropriate to consider both C and Rw. By setting up requirements, the sum of Rw and C may be applied.

### 1.3.2 Impact Sound Insulation

The normalized impact sound pressure level, Ln, is defined as the impact sound pressure level, Li, increased by a correction term given in decibels. It is ten times the common logarithm of the ratio between the measured equivalent absorption area A of the receiving room and the reference equivalent absorption area $A_0$, i.e.

$$L_n = L_i + 10\ log\left(\frac{A}{A_0}\right)\ dB$$

Where

$A_0 = 10\ m^2$

The average sound pressure level Li was measured by means of a rotating microphone in the lower room. The sweep radius of the microphone was 1.5 metre, and the traversing time was 64 seconds. This time was equal to the averaging time of the recording instrument.

Two measurement series were performed. The normalized impact sound pressure level in the lower room Ln,0 was measured in the absence of the floor covering, i.e. in this case the normalized impact sound pressure level was measured with the tapping machine placed on the steel deck. Subsequently, the normalized sound pressure level Ln was measured having applied the floor covering.

For each measurement series, the weighted normalized impact sound pressure level Ln,w was calculated as stated in En ISO 717-2:2013.

The weighted impact sound improvement index, $dL_m$, is useful when comparing the measured impact sound pressure level of the floating floor with the impact sound pressure level of the reference steel deck. This quantity can be calculated according to the following procedure.

$$dL_m = L_{n,r,steel\,deck,w} - L_{n,r,w}$$

Where

- Ln,r,steel deck,w is the calculated weighted normalized impact sound pressure level of the reference steel deck.
- Ln,r,w is the calculated weighted normalized impact sound pressure level of the steel deck with the flooring.
- $dL_m$ is the improvement of the weighted normalized impact sound pressure level obtained by the flooring.
-

Furthermore, the spectrum adaptation term CI value in decibels has been calculated as outlined in EN ISO 717-2:2013 to take account of the unweighted impact sound levels representing the characteristics of typical walking noise spectra. The spectrum adaptation term CI has been calculated in the frequency range from 100 -2500 Hz.

The spectrum adaptation term CI is calculated by the following equation:

$$C_I = L_{n,sum} - 15 - L_{n,W}$$

where Ln,sum is added by energy basis in the frequency range.

Generally, the CI value for constructions without covers or with less cover will range from –15 dB to 0 dB. For constructions with dominating low frequency peaks, the CI will be positive.

### 1.3.3 Structure-borne Sound Insulation

For the measurement of structure-borne sound insulation, no international standard exists. Consequently, the test has been carried out by means of a method previously developed Lloyd’s Register ODS used for similar constructions.

Vibrational power was supplied to the steel deck by means of the arrangement described in Figure 2. The supply of constant vibrational force was monitored during the measurement period by means of a force transducer mounted between the vertical steel plate and the vibration exciter.

The response was measured as the velocity level, Lv in dB re $10^{-9}$ m/s in 30 different positions on each surface, i.e. on the steel deck and on the floor.

The measurement results were averaged with respect to the following equation

$$L_v = 10\log\left(\frac{1}{10}\sum_{i=1}^{i=30} 10^{\frac{L_{v,1}}{10}}\right)$$

where

- Lv is the average velocity level in dB re $10^{-9}$ m/s.
- Lv,i is the velocity level measured in dB re $10^{-9}$ m/s in the i'th position.

From the average value of the velocity level measured on each surface, the transmission loss and insertion loss were calculated as

$$TL_v = L_{v,deck} - L_{v,floor}$$

$$IL_v = L_{v,0} - L_{v,floor}$$

$$IL_p = L_{p,0} - L_p$$

where

- TLv is the transmission loss in velocity level.
- ILv is the insertion loss in velocity level.
- ILp is the insertion loss in sound pressure level.
- Lv,deck is the velocity level in dB re $10^{-9}$ m/s measured on the steel deck after application of the floor covering.
- Lv,floor is the velocity level in dB re $10^{-9}$ m/s measured on the surface of the floor material.
- Lv,0 is the velocity level in dB re $10^{-9}$ m/s measured on the steel deck before application of the floor covering.
- Lp,0 is the averaged sound pressure level in dB re 20 µPa in the upper room before application of the covering floor.
- Lp is the averaged sound pressure level in dB re 20 µPa in the upper room after application of the covering floor.

The measured transmission loss TLv in dB for the floor constructions describes the difference between the velocity level on the steel deck after installation of the floor construction and the velocity level measured on top of the floor covering. Thus, the transmission loss expresses the reduction in the velocity level from the steel deck to the floor covering.

The measured insertion loss ILv in dB describes the difference between the velocity level measured on the bare steel deck before installation of the floor construction and the velocity level measured on top of the applied floor construction. The insertion loss ILv describes the improvement of the vibration level on the floor achieved by using the floor covering.

The measured insertion loss ILp in dB regarding radiated structure-borne sound to the room describes the difference between the measured radiated sound pressure level in the receiving room before installation of the floor covering and the measured radiated sound pressure level after applying the floor covering. The insertion loss ILp thus expresses the improvement of the sound level in the room above the deck achieved by using the floor covering.

### 1.3.4 Radiation Efficiency

The radiation efficiency is a characteristic frequency dependent number that describes the level of the radiated sound power from a vibrating surface.

Normally, the radiation efficiency is specified as a logarithmic quantity named the radiation index, 10log $\sigma$. If the radiation index is determined from sound power measurements in a reverberant room, it can be calculated from

$$10\log\sigma = L_p - L_v + 10\log(A/S) + 10\log\left(1+\frac{F\cdot\lambda}{8\cdot V}\right) + 28dB$$

Where

- Lp is the averaged sound pressure level in dB re 20 µPa in the receiving room.
- Lv is the averaged velocity level in dB re $10^{-9}$ m/s measured on the surface of the covering floor.
- A is the equivalent absorption area in $m^2$ in the receiving room.
- S is the area of test floor, which was 10 $m^2$.
- F is the total area in $m^2$ of the surface in the receiving room, which is 300 m2.
- $\lambda$ is the wavelength in m of the centre frequency of the 1/3-octave filter band in question.
- V is the volume in $m^3$ of the receiving room, which is 230 $m^3$.

The averaged sound pressure level Lp was measured by means of a rotating microphone in the receiving room. The sweep radius of the microphone was 1.5 metres, and the traversing time was 64 seconds. This time was equal to the averaging time of the recording instrument. The response measured as the sound pressure level Lp in dB re 20 µPa was measured during each test in four different positions in the receiving room.

During each test, the response expressed as the velocity level Lv in dB re $10^{-9}$ m/s was measured in 30 different positions on each floor covering.

The radiation index describes the ability of a vibrating floor to radiate sound. A high radiation index combined with a high velocity level on the floor covering causes high noise levels in the rooms above the deck covering.

# 2 Measurement Results

The results of the measurements of the airborne sound insulation, the impact sound insulation and the structure-borne sound insulation for the investigated floor construction are shown in Sections 2.1 to 2.4.

The results are expressed as 1/3-octave values in the frequency ranges 63 Hz to 5000 Hz and, when appropriate, as a single-number quantity calculated according to the ISO standards.

The results of the measurement in the frequency range below 100 Hz are given for information only, as the dimensions of the two reverberant rooms are too small for precise measurement in this frequency range.

Furthermore, the results of the measurements on the bare steel deck are indicated with blue on each diagram for the airborne sound and the impact sound measurements. The difference between the curves for the test deck and the curve for the steel deck indicates the improvement in the sound reduction and the impact sound insulation caused by the applied floor construction.

## 2.1 Sikafloor® Marine VES 515

The vibration damped floor construction Sikafloor® Marine VES 515 is a floor construction with constrained layer viscoelastic damping. It consists of 2 mm Sikaflex 515 viscoelasic material constrained by steel plates of 1.5 mm thickness.

The structure of the vibration damping floor covering is shown in Figure 3.

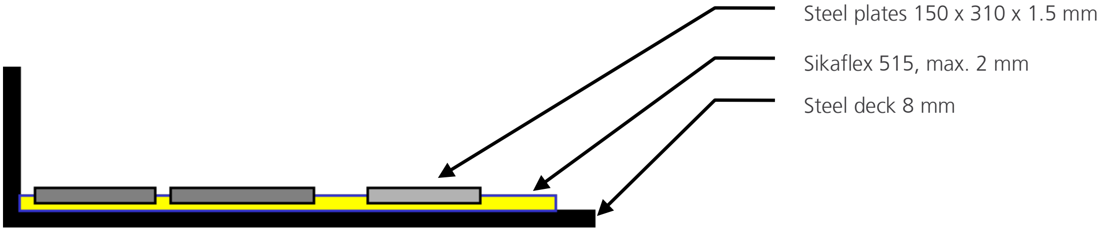



**Figure 3 Structure of the vibration damping construction Sikafloor® Marine VES 515**

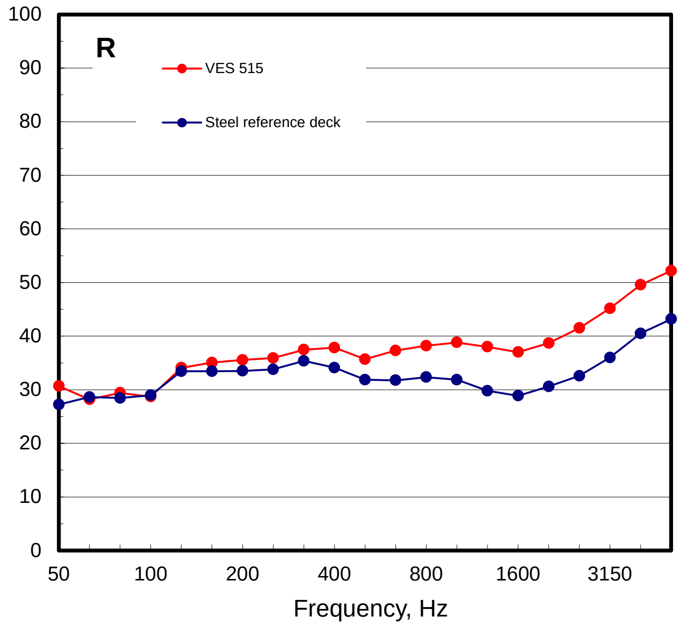
The measured Sound Reduction Index R per 1/3-octave frequency band is shown in figure 4.

The measured Normalized Impact Sound Pressure Level Ln per 1/3-octave frequency band is shown in figure 5.

The measured Insertion Loss ILv regarding structure-borne sound is shown in figure 6. And the measured Transmission Loss TLv is shown in figure 8.

The measured Insertion Loss ILp regarding radiated sound to the receiving room is shown in figure 7.

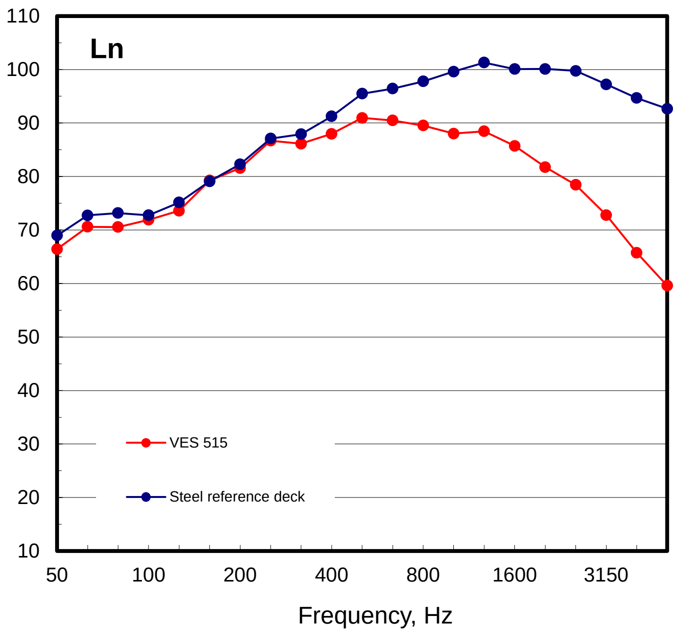
The Radiation efficiency is shown in figure 9.




| Hz | dB |
|---|---|
| 50 | 30.7 |
| 63 | 28.2 |
| 80 | 29.4 |
| 100 | 28.7 |
| 125 | 34.1 |
| 160 | 35.1 |
| 200 | 35.6 |
| 250 | 35.9 |
| 315 | 37.5 |
| 400 | 37.8 |
| 500 | 35.7 |
| 630 | 37.3 |
| 800 | 38.2 |
| 1000 | 38.8 |
| 1250 | 38.0 |
| 1600 | 37.0 |
| 2000 | 38.7 |
| 2500 | 41.5 |
| 3150 | 45.2 |
| 4000 | 49.5 |
| 5000 | 52.2 |

| | |
|---|---|
| Rw | 39 |
| C | -1 |

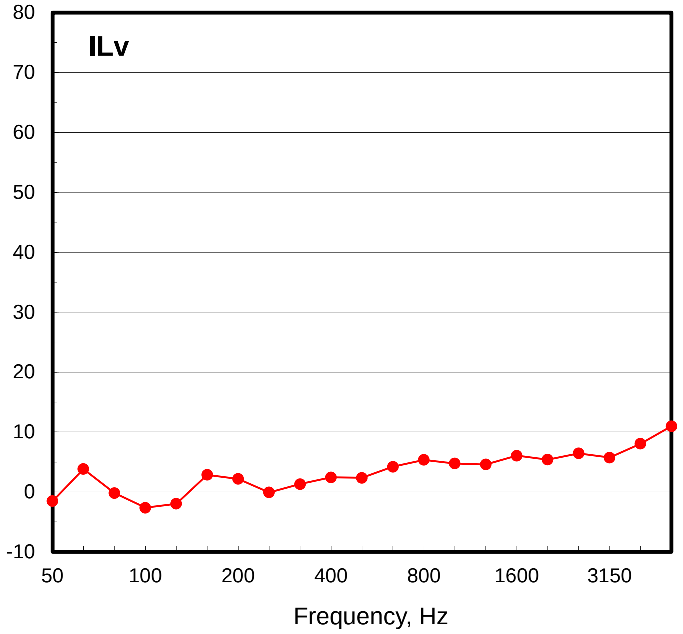
**Figure 4 Sound Reduction Index R for the vibration damped construction VES 515, expressed in dB per 1/3-octave frequency band. For comparison, the results of the measurements on the bare steel deck are also shown.**




| Hz | dB |
|---|---|
| 50 | 66.4 |
| 63 | 70.6 |
| 80 | 70.6 |
| 100 | 71.9 |
| 125 | 73.6 |
| 160 | 79.3 |
| 200 | 81.6 |
| 250 | 86.7 |
| 315 | 86.1 |
| 400 | 88.0 |
| 500 | 91.0 |
| 630 | 90.5 |
| 800 | 89.5 |
| 1000 | 88.0 |
| 1250 | 88.5 |
| 1600 | 85.7 |
| 2000 | 81.8 |
| 2500 | 78.5 |
| 3150 | 72.8 |
| 4000 | 65.8 |
| 5000 | 59.6 |

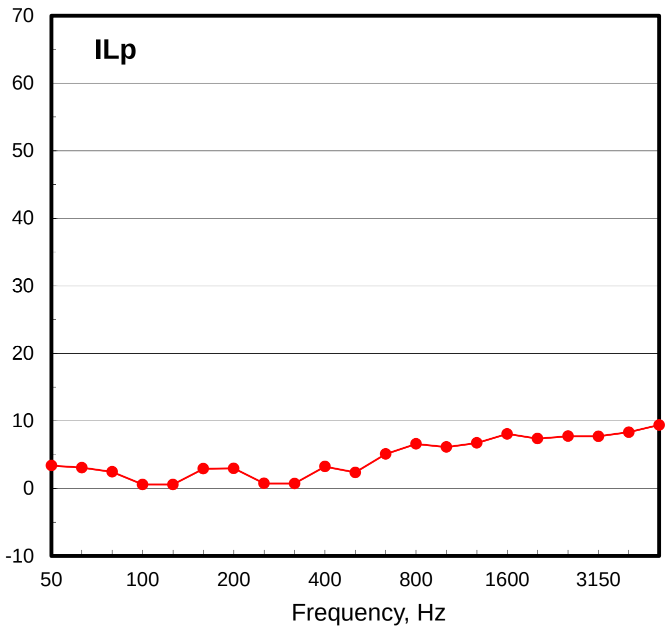
| | |
|---|---|
| Ln,w | 89 |
| CI | -6 |
| dLm | 17 |

**Figure 5 Measured Normalized Impact Sound Pressure Level Ln, for the vibration damped construction VES 515, expressed in dB re 20 µPa per 1/3-octave frequency band. For comparison, the results of the measurements on the bare steel deck are also shown.**



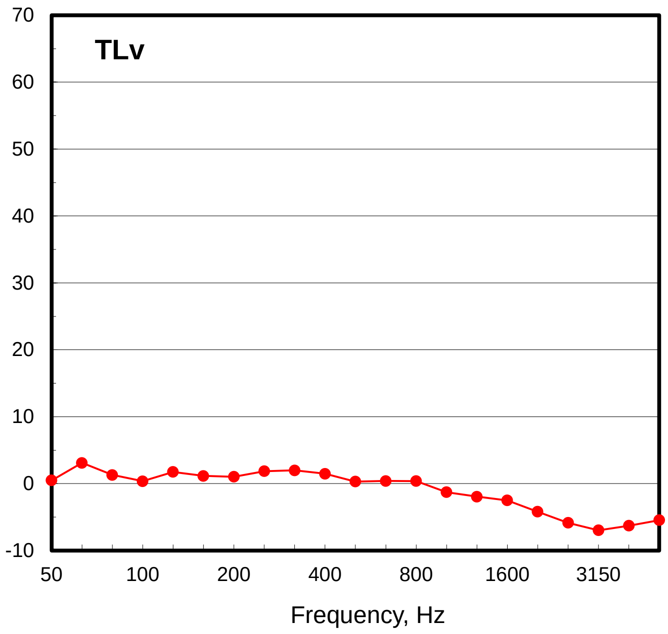

| Hz | dB |
|---|---|
| 50 | -1.5 |
| 63 | 3.8 |
| 80 | -0.2 |
| 100 | -2.6 |
| 125 | -2.0 |
| 160 | 2.9 |
| 200 | 2.2 |
| 250 | -0.1 |
| 315 | 1.3 |
| 400 | 2.4 |
| 500 | 2.4 |
| 630 | 4.2 |
| 800 | 5.4 |
| 1000 | 4.8 |
| 1250 | 4.6 |
| 1600 | 6.1 |
| 2000 | 5.4 |
| 2500 | 6.4 |
| 3150 | 5.7 |
| 4000 | 8.1 |
| 5000 | 11.0 |

**Figure 6 Measured Insertion Loss ILv for the vibration damped VES 515, expressed in dB per 1/3-octave frequency band. The insertion loss ILv refers to the mean velocity level difference in dB.**



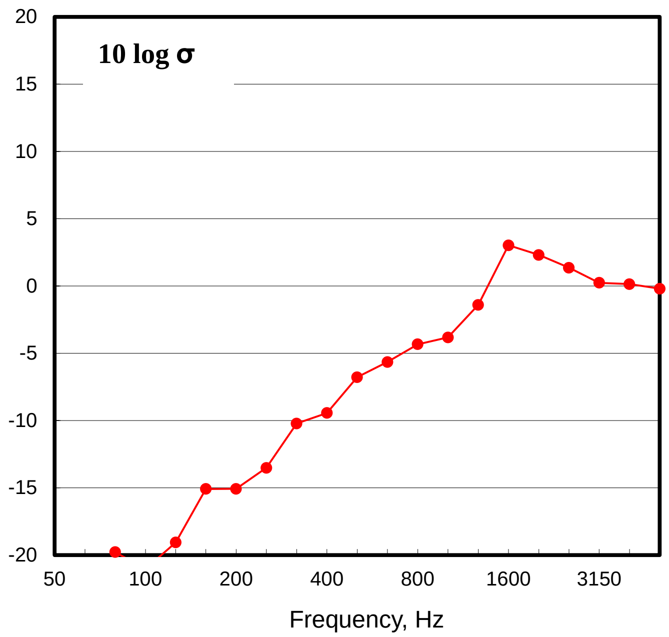

| Hz | dB |
|---|---|
| 50 | 3.4 |
| 63 | 3.1 |
| 80 | 2.5 |
| 100 | 0.6 |
| 125 | 0.6 |
| 160 | 2.9 |
| 200 | 3.0 |
| 250 | 0.7 |
| 315 | 0.7 |
| 400 | 3.2 |
| 500 | 2.4 |
| 630 | 5.1 |
| 800 | 6.6 |
| 1000 | 6.1 |
| 1250 | 6.7 |
| 1600 | 8.1 |
| 2000 | 7.4 |
| 2500 | 7.7 |
| 3150 | 7.7 |
| 4000 | 8.3 |
| 5000 | 9.4 |

**Figure 7 Measured Insertion Loss ILp for the vibration damped construction VES 515 expressed in dB per 1/3-octave frequency band. The insertion loss ILp refers to the radiated mean sound pressure level difference in dB in the receiving room above the floor.**




| Hz | dB |
|---|---|
| 50 | 0.5 |
| 63 | 3.1 |
| 80 | 1.3 |
| 100 | 0.4 |
| 125 | 1.7 |
| 160 | 1.2 |
| 200 | 1.0 |
| 250 | 1.9 |
| 315 | 2.0 |
| 400 | 1.5 |
| 500 | 0.3 |
| 630 | 0.4 |
| 800 | 0.4 |
| 1000 | -1.3 |
| 1250 | -1.9 |
| 1600 | -2.5 |
| 2000 | -4.2 |
| 2500 | -5.8 |
| 3150 | -7.0 |
| 4000 | -6.3 |
| 5000 | -5.5 |

**Figure 8 Measured Transmission Loss TLv for the vibration damped construction VES 515 expressed in dB per 1/3-octave frequency band.**




| Hz | dB |
|---|---|
| 50 | |
| 63 | |
| 80 | -19.8 |
| 100 | -21.0 |
| 125 | -19.1 |
| 160 | -15.1 |
| 200 | -15.1 |
| 250 | -13.5 |
| 315 | -10.2 |
| 400 | -9.4 |
| 500 | -6.8 |
| 630 | -5.6 |
| 800 | -4.3 |
| 1000 | -3.8 |
| 1250 | -1.4 |
| 1600 | 3.0 |
| 2000 | 2.3 |
| 2500 | 1.4 |
| 3150 | 0.2 |
| 4000 | 0.1 |
| 5000 | -0.2 |

**Figure 9 Measured radiation efficiency for the vibration damped construction VES 515, expressed in dB per 1/3-octave frequency band.**

## 2.2 Sikafloor® Marine VEM 18

The vibration damped floor construction Sikafloor® Marine VEM 18 is a floor construction with constrained layer viscoelastic damping. It consists of 2 mm VEM viscoelasic material constrained by a SFM compound of 12 mm thickness.

The structure of the vibration damping floor covering is shown in figure 10.

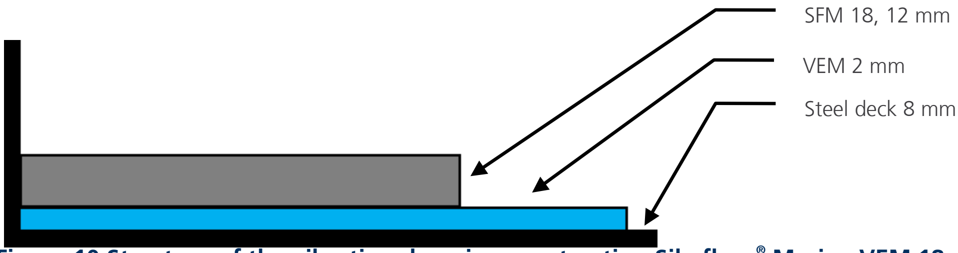



**Figure 10 Structure of the vibration damping construction Sikafloor® Marine VEM 18.**

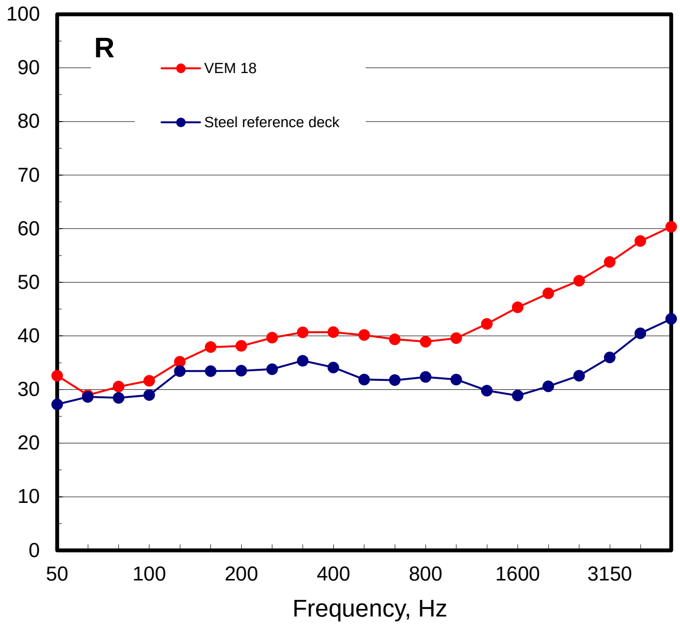
The measured Sound Reduction Index R per 1/3-octave frequency band is shown in Figure 11.

The measured Normalized Impact Sound Pressure Level Ln per 1/3-octave frequency band is shown in figure 12.

The measured Insertion Loss ILv regarding structure-borne sound is shown in figure 13. And the measured Transmission Loss TLv is shown in figure 15.

The measured Insertion Loss ILp regarding radiated sound to the receiving room is shown in figure 14.

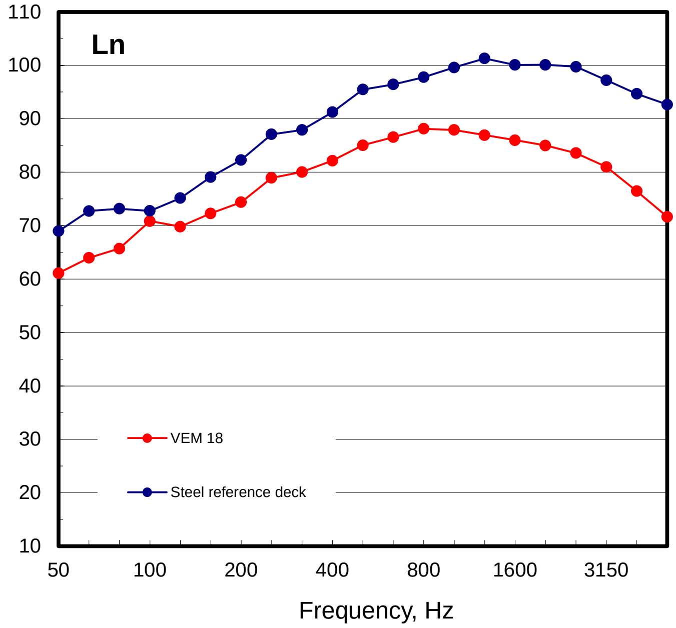
The Radiation efficiency is shown in figure 16.




| Hz | dB |
|---|---|
| 50 | 32.6 |
| 63 | 28.9 |
| 80 | 30.5 |
| 100 | 31.6 |
| 125 | 35.2 |
| 160 | 37.9 |
| 200 | 38.1 |
| 250 | 39.7 |
| 315 | 40.7 |
| 400 | 40.7 |
| 500 | 40.2 |
| 630 | 39.4 |
| 800 | 38.9 |
| 1000 | 39.6 |
| 1250 | 42.2 |
| 1600 | 45.3 |
| 2000 | 47.9 |
| 2500 | 50.3 |
| 3150 | 53.8 |
| 4000 | 57.7 |
| 5000 | 60.4 |

| | |
|---|---|
| Rw | 43 |
| C | -1 |

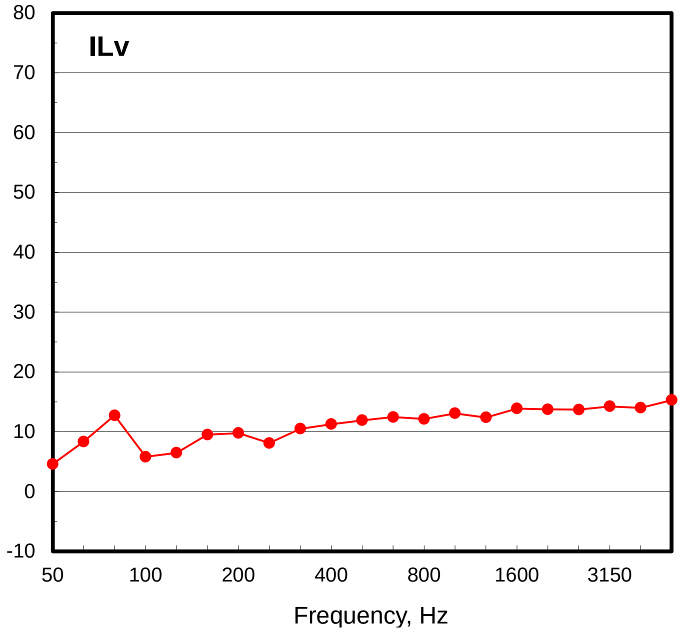
**Figure 11 Sound Reduction Index R for the vibration damped construction VEM 18, expressed in dB per 1/3-octave frequency band. For comparison, the results of the measurements on the bare steel deck are also shown.**




| Hz | dB |
|---|---|
| 50 | 61.1 |
| 63 | 64.0 |
| 80 | 65.7 |
| 100 | 70.8 |
| 125 | 69.8 |
| 160 | 72.3 |
| 200 | 74.4 |
| 250 | 78.9 |
| 315 | 80.0 |
| 400 | 82.2 |
| 500 | 85.0 |
| 630 | 86.6 |
| 800 | 88.1 |
| 1000 | 87.9 |
| 1250 | 87.0 |
| 1600 | 86.0 |
| 2000 | 85.0 |
| 2500 | 83.6 |
| 3150 | 81.0 |
| 4000 | 76.5 |
| 5000 | 71.7 |

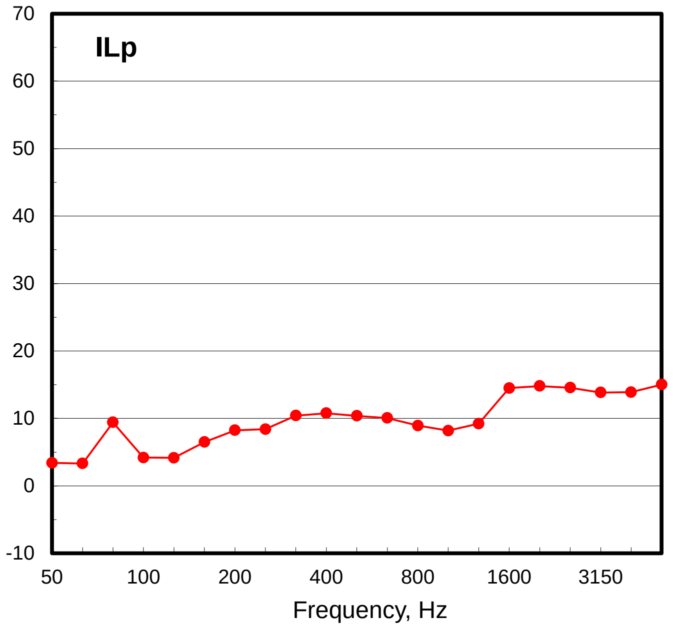
| | |
|---|---|
| Ln,w | 91 |
| CI | -10 |
| dLm | 15 |

**Figure 12 Measured Normalized Impact Sound Pressure Level Ln, for the vibration damped construction VEM 18, expressed in dB re 20 μPa per 1/3-octave frequency band. For comparison, the results of the measurements on the bare steel deck are also shown.**



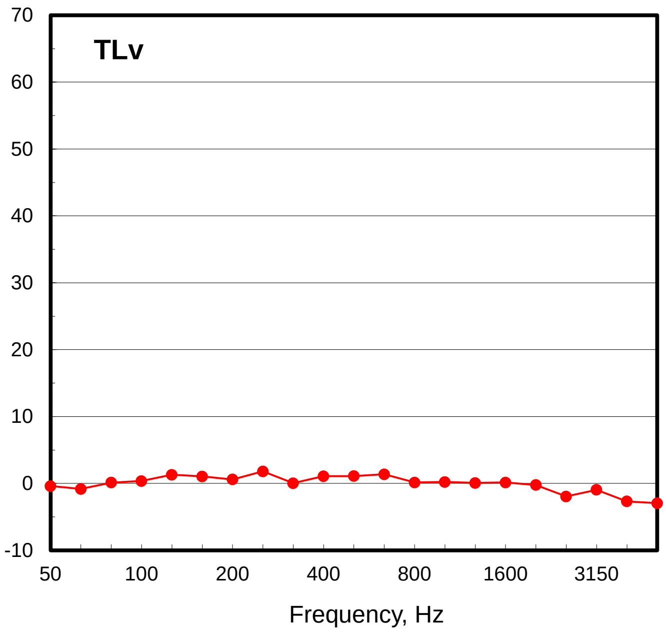

| Hz | dB |
|---|---|
| 50 | 4.6 |
| 63 | 8.3 |
| 80 | 12.7 |
| 100 | 5.8 |
| 125 | 6.5 |
| 160 | 9.5 |
| 200 | 9.8 |
| 250 | 8.1 |
| 315 | 10.5 |
| 400 | 11.3 |
| 500 | 11.9 |
| 630 | 12.4 |
| 800 | 12.1 |
| 1000 | 13.1 |
| 1250 | 12.4 |
| 1600 | 13.9 |
| 2000 | 13.7 |
| 2500 | 13.7 |
| 3150 | 14.2 |
| 4000 | 14.0 |
| 5000 | 15.3 |

**Figure 13 Measured Insertion Loss ILv for the vibration damped VEM 18, expressed in dB per 1/3-octave frequency band. The insertion loss ILv refers to the mean velocity level difference in dB.**



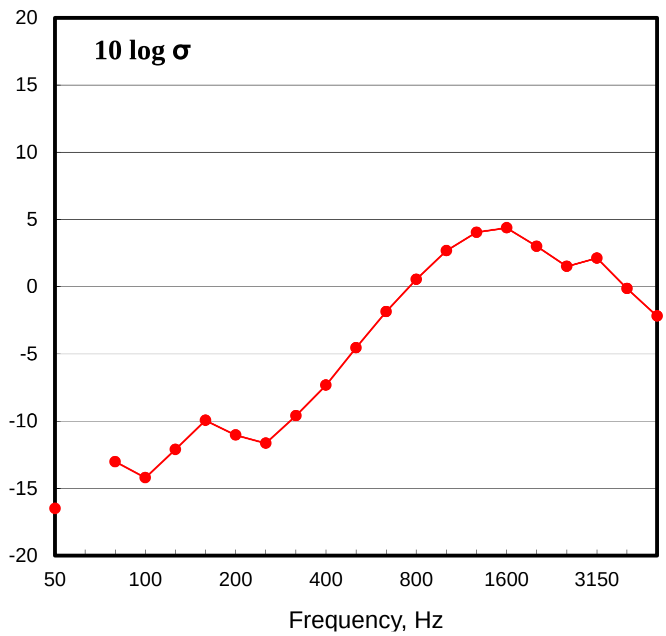

| Hz | dB |
|---|---|
| 50 | 3.4 |
| 63 | 3.3 |
| 80 | 9.4 |
| 100 | 4.2 |
| 125 | 4.2 |
| 160 | 6.5 |
| 200 | 8.2 |
| 250 | 8.4 |
| 315 | 10.4 |
| 400 | 10.8 |
| 500 | 10.4 |
| 630 | 10.1 |
| 800 | 8.9 |
| 1000 | 8.2 |
| 1250 | 9.2 |
| 1600 | 14.5 |
| 2000 | 14.8 |
| 2500 | 14.5 |
| 3150 | 13.8 |
| 4000 | 13.9 |
| 5000 | 15.0 |

**Figure 14 Measured Insertion Loss ILp for the vibration damped construction VEM 18, expressed in dB per 1/3-octave frequency band. The insertion loss ILp refers to the radiated mean sound pressure level difference in dB in the receiving room above the floor.**




| Hz | dB |
|---|---|
| 50 | -0.4 |
| 63 | -0.8 |
| 80 | 0.1 |
| 100 | 0.4 |
| 125 | 1.3 |
| 160 | 1.1 |
| 200 | 0.6 |
| 250 | 1.8 |
| 315 | 0.0 |
| 400 | 1.1 |
| 500 | 1.1 |
| 630 | 1.4 |
| 800 | 0.1 |
| 1000 | 0.2 |
| 1250 | 0.1 |
| 1600 | 0.2 |
| 2000 | -0.2 |
| 2500 | -1.9 |
| 3150 | -0.9 |
| 4000 | -2.7 |
| 5000 | -3.0 |

**Figure 15 Measured Transmission Loss TLv for the vibration damped construction VEM 18, expressed in dB per 1/3-octave frequency band.**




| Hz | dB |
|---|---|
| 50 | -16.5 |
| 63 | |
| 80 | -13.0 |
| 100 | -14.2 |
| 125 | -12.1 |
| 160 | -9.9 |
| 200 | -11.0 |
| 250 | -11.6 |
| 315 | -9.6 |
| 400 | -7.3 |
| 500 | -4.5 |
| 630 | -1.9 |
| 800 | 0.5 |
| 1000 | 2.7 |
| 1250 | 4.0 |
| 1600 | 4.4 |
| 2000 | 3.0 |
| 2500 | 1.5 |
| 3150 | 2.1 |
| 4000 | -0.1 |
| 5000 | -2.2 |

**Figure 16 Measured radiation efficiency for the vibration damped construction VEM 18, expressed in dB per 1/3-octave frequency band.**

## 2.3 Sikafloor® Marine VEM 18 + Litosilo N

The floating floor construction Sikafloor® Marine VEM 18 + Litosilo N consists of a constrained layer VEM damping of the steel deck with a 12 mm SFM 18 compound as the constraining layer. A 25 mm thick Litosilo N compound is on top of the rocwool.

The structure of the floating floor covering is shown in Figure 17.

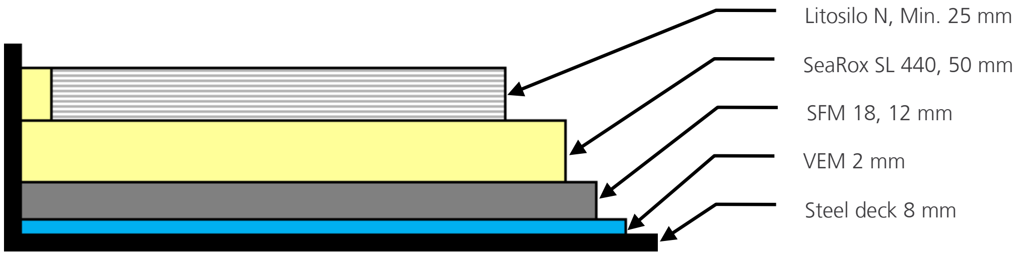


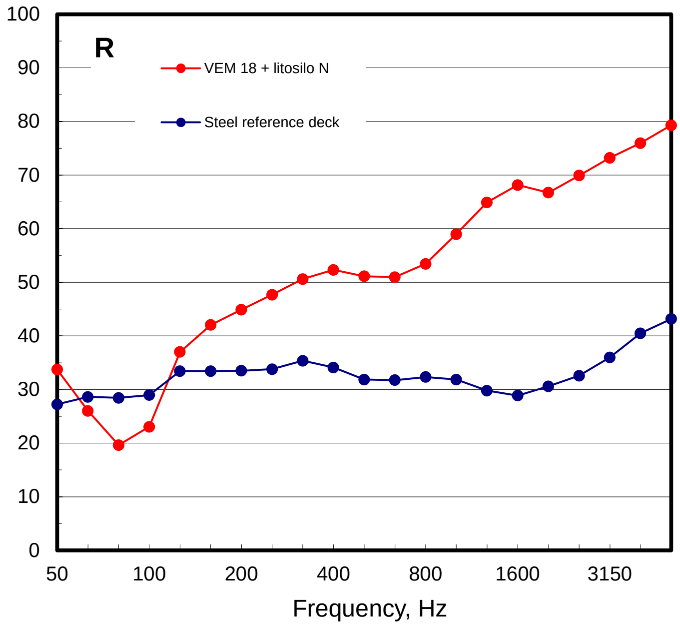

**Figure 17 Structure of the floating floor Sikafloor® Marine VEM 18 + Litosilo N**

The measured Sound Reduction Index R per 1/3-octave frequency band is shown in figure 18.

The measured Normalized Impact Sound Pressure Level Ln per 1/3-octave frequency band is shown in figure 16.

The measured Insertion Loss ILv regarding structure-borne sound is shown in figure 20. And the measured Transmission Loss TLv is shown in figure 22.
The measured Insertion Loss ILp regarding radiated sound to the receiving room is shown in figure 21.

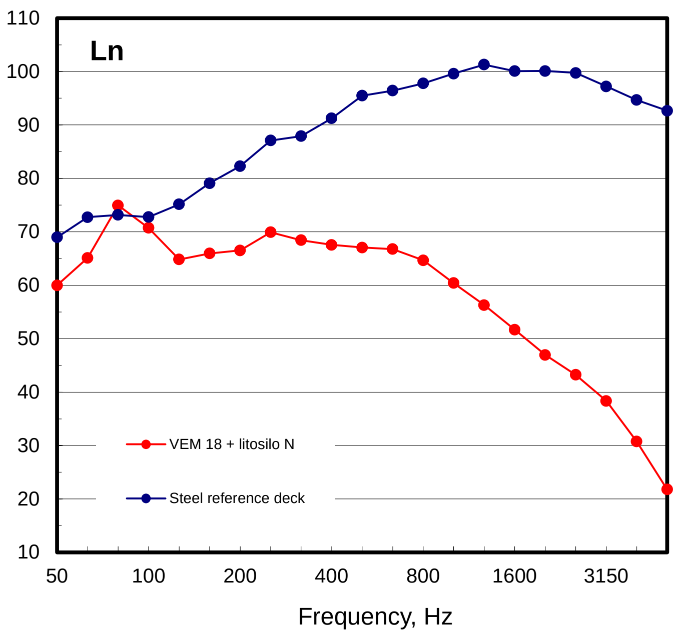
The Radiation efficiency is shown in figure 23.




| Hz | dB |
|---|---|
| 50 | 33.7 |
| 63 | 26.0 |
| 80 | 19.6 |
| 100 | 23.1 |
| 125 | 37.0 |
| 160 | 42.0 |
| 200 | 44.9 |
| 250 | 47.7 |
| 315 | 50.6 |
| 400 | 52.3 |
| 500 | 51.1 |
| 630 | 51.0 |
| 800 | 53.4 |
| 1000 | 59.0 |
| 1250 | 64.9 |
| 1600 | 68.1 |
| 2000 | 66.7 |
| 2500 | 69.9 |
| 3150 | 73.2 |
| 4000 | 76.0 |
| 5000 | 79.3 |

| | |
|---|---|
| Rw | 55 |
| C | -5 |

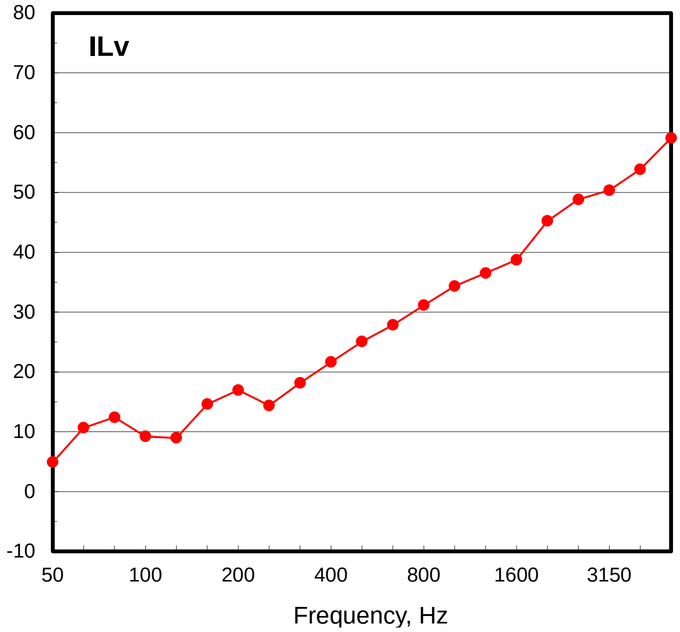
**Figure 18 Sound Reduction Index R for the floating floor construction VEM 18 + Litosilo N, expressed in dB per 1/3-octave frequency band. For comparison, the results of the measurements on the bare steel deck are also shown.**




| Hz | dB |
|---|---|
| 50 | 60.0 |
| 63 | 65.1 |
| 80 | 75.0 |
| 100 | 70.7 |
| 125 | 64.8 |
| 160 | 66.0 |
| 200 | 66.5 |
| 250 | 69.9 |
| 315 | 68.4 |
| 400 | 67.6 |
| 500 | 67.1 |
| 630 | 66.8 |
| 800 | 64.7 |
| 1000 | 60.4 |
| 1250 | 56.3 |
| 1600 | 51.7 |
| 2000 | 47.0 |
| 2500 | 43.2 |
| 3150 | 38.4 |
| 4000 | 30.8 |
| 5000 | 21.8 |

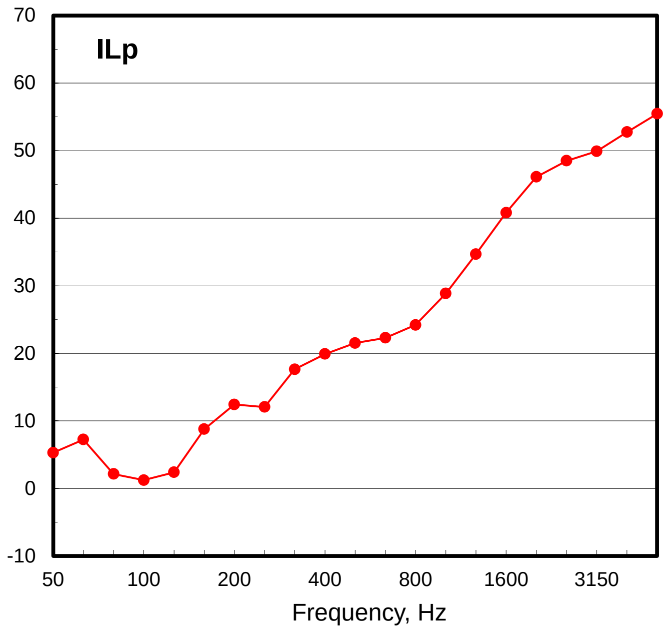
| | |
|---|---|
| Ln,w | 64 |
| CI | -1 |
| dLm | 42 |

**Figure 19 Measured Normalized Impact Sound Pressure Level Ln, for the floating floor construction VEM 18 + Litosilo N, expressed in dB re 20 μPa per 1/3-octave frequency band. For comparison, the results of the measurements on the bare steel deck are also shown.**



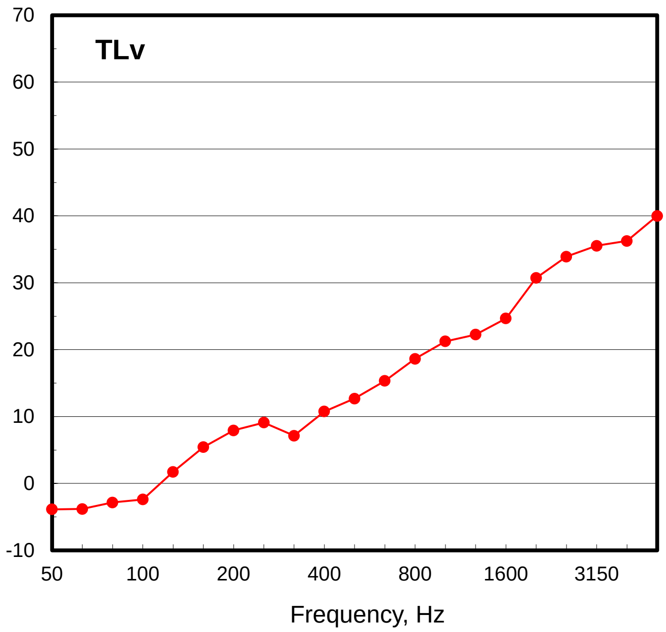

| Hz | dB |
|---|---|
| 50 | 4.9 |
| 63 | 10.7 |
| 80 | 12.4 |
| 100 | 9.2 |
| 125 | 9.0 |
| 160 | 14.6 |
| 200 | 17.0 |
| 250 | 14.4 |
| 315 | 18.2 |
| 400 | 21.6 |
| 500 | 25.1 |
| 630 | 27.9 |
| 800 | 31.1 |
| 1000 | 34.3 |
| 1250 | 36.5 |
| 1600 | 38.7 |
| 2000 | 45.2 |
| 2500 | 48.8 |
| 3150 | 50.4 |
| 4000 | 53.9 |
| 5000 | 59.1 |

**Figure 20 Measured Insertion Loss ILv for the floating floor construction VEM 18 + Litosilo N, expressed in dB per 1/3-octave frequency band. The insertion loss ILv refers to the mean velocity level difference in dB.**



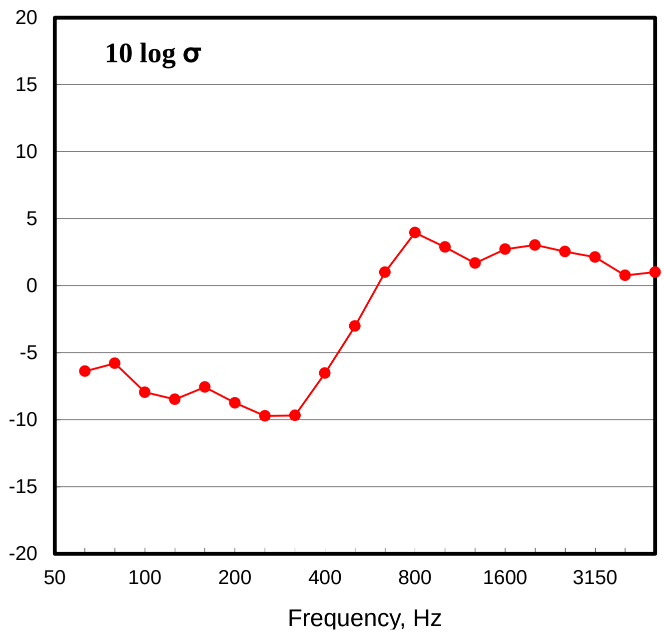

| Hz | dB |
|---|---|
| 50 | 5.3 |
| 63 | 7.2 |
| 80 | 2.1 |
| 100 | 1.2 |
| 125 | 2.4 |
| 160 | 8.8 |
| 200 | 12.4 |
| 250 | 12.0 |
| 315 | 17.6 |
| 400 | 19.9 |
| 500 | 21.5 |
| 630 | 22.3 |
| 800 | 24.2 |
| 1000 | 28.9 |
| 1250 | 34.7 |
| 1600 | 40.8 |
| 2000 | 46.1 |
| 2500 | 48.5 |
| 3150 | 49.9 |
| 4000 | 52.7 |
| 5000 | 55.4 |

**Figure 21 Measured Insertion Loss ILp for the floating floor construction VEM 18 + Litosilo N, expressed in dB per 1/3-octave frequency band. The insertion loss ILp refers to the radiated mean sound pressure level difference in dB in the receiving room above the floor.**




| Hz | dB |
|---|---|
| 50 | -3.9 |
| 63 | -3.8 |
| 80 | -2.8 |
| 100 | -2.4 |
| 125 | 1.7 |
| 160 | 5.4 |
| 200 | 7.9 |
| 250 | 9.1 |
| 315 | 7.1 |
| 400 | 10.8 |
| 500 | 12.7 |
| 630 | 15.3 |
| 800 | 18.6 |
| 1000 | 21.3 |
| 1250 | 22.3 |
| 1600 | 24.7 |
| 2000 | 30.7 |
| 2500 | 33.9 |
| 3150 | 35.5 |
| 4000 | 36.3 |
| 5000 | 40.0 |

**Figure 22 Measured Transmission Loss TLv for the floating floor construction VEM 18 + Litosilo N, expressed in dB per 1/3-octave frequency band.**




| Hz | dB |
|---|---|
| 50 | |
| 63 | -6.4 |
| 80 | -5.8 |
| 100 | -7.9 |
| 125 | -8.5 |
| 160 | -7.6 |
| 200 | -8.7 |
| 250 | -9.7 |
| 315 | -9.7 |
| 400 | -6.5 |
| 500 | -3.0 |
| 630 | 1.0 |
| 800 | 4.0 |
| 1000 | 2.9 |
| 1250 | 1.7 |
| 1600 | 2.7 |
| 2000 | 3.0 |
| 2500 | 2.5 |
| 3150 | 2.1 |
| 4000 | 0.8 |
| 5000 | 1.0 |

**Figure 23 Measured radiation efficiency for the floating floor construction VEM 18 + Litosilo N, expressed in dB per 1/3-octave frequency band.**

## 2.4 Sikafloor® Marine VEM 18 + Litosilo Steel

The floating floor construction Sikafloor® Marine VEM 18 + Litosilo Steel consists of a constrained layer VEM damping of the steel deck with a 12 mm SFM 18 compound as the constraining layer. Constrained layer viscoelastic damped steel plates of 1.5 mm and 3 mm thickness is on top of the rocwool. The damping material is 1 mm Sikaflex 298i.

The structure of the floating floor covering is shown in figure 24.

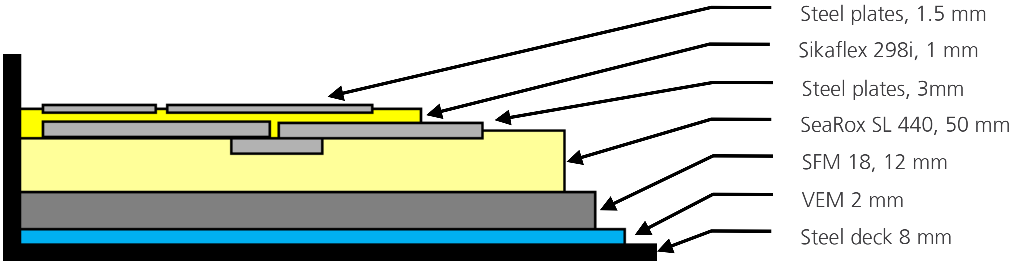



**Figure 24 Structure of the floating floor construction VEM 18 + Litosilo Steel.**

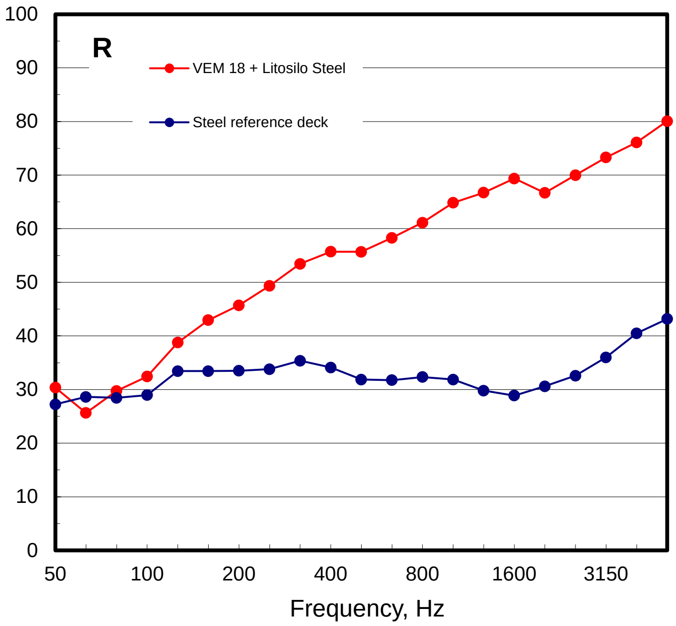
The measured Sound Reduction Index R per 1/3-octave frequency band is shown in figure 25.

The measured Normalized Impact Sound Pressure Level Ln per 1/3-octave frequency band is shown in figure 26.

The measured Insertion Loss ILv regarding structure-borne sound is shown in figure 27. And the measured Transmission Loss TLv is shown in figure 29.

The measured Insertion Loss ILp regarding radiated sound to the receiving room is shown in figure 28.

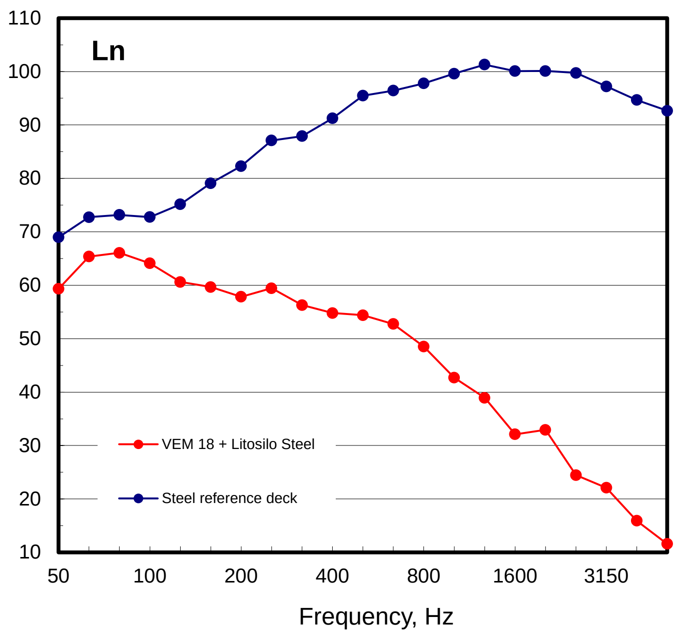
The Radiation efficiency is shown in figure 30.




| Hz | dB |
|---|---|
| 50 | 30.4 |
| 63 | 25.6 |
| 80 | 29.8 |
| 100 | 32.4 |
| 125 | 38.8 |
| 160 | 42.9 |
| 200 | 45.7 |
| 250 | 49.3 |
| 315 | 53.4 |
| 400 | 55.7 |
| 500 | 55.7 |
| 630 | 58.3 |
| 800 | 61.1 |
| 1000 | 64.8 |
| 1250 | 66.7 |
| 1600 | 69.4 |
| 2000 | 66.7 |
| 2500 | 70.0 |
| 3150 | 73.3 |
| 4000 | 76.1 |
| 5000 | 80.1 |

| | |
|---|---|
| Rw | 59 |
| C | -3 |

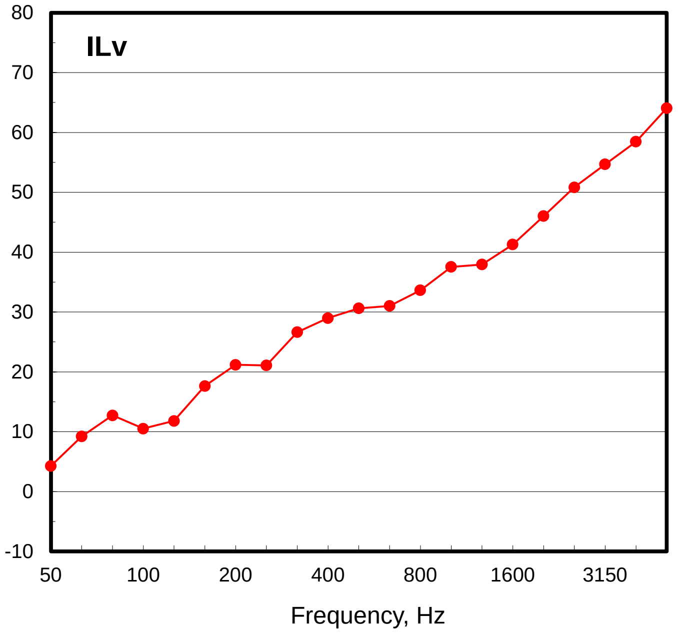
**Figure 25 Sound Reduction Index R for the floating floor construction VEM 18 + Litosilo Steel, expressed in dB per 1/3-octave frequency band. For comparison, the results of the measurements on the bare steel deck are also shown.**




| Hz | dB |
|---|---|
| 50 | 59.3 |
| 63 | 65.4 |
| 80 | 66.1 |
| 100 | 64.1 |
| 125 | 60.6 |
| 160 | 59.7 |
| 200 | 57.8 |
| 250 | 59.4 |
| 315 | 56.3 |
| 400 | 54.8 |
| 500 | 54.4 |
| 630 | 52.8 |
| 800 | 48.5 |
| 1000 | 42.7 |
| 1250 | 38.9 |
| 1600 | 32.1 |
| 2000 | 32.9 |
| 2500 | 24.5 |
| 3150 | 22.1 |
| 4000 | 15.9 |
| 5000 | 11.6 |

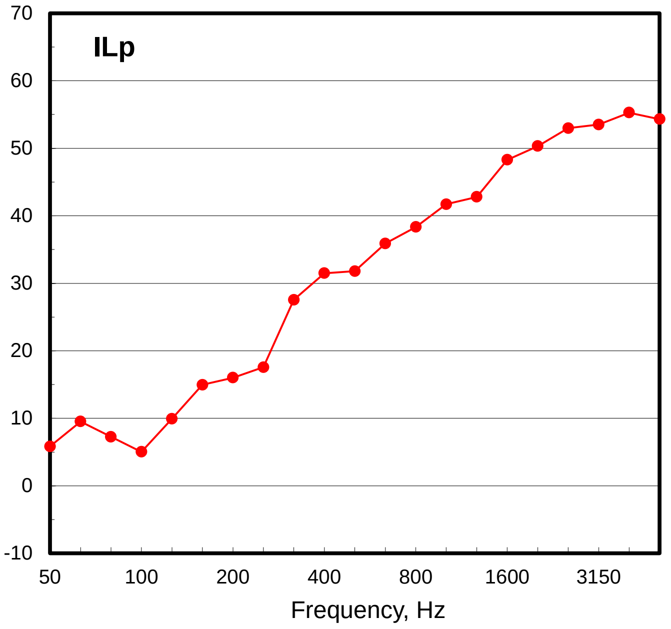
| | |
|---|---|
| Ln,w | 53 |
| CI | 1 |
| dLm | 53 |

**Figure 26 Measured Normalized Impact Sound Pressure Level Ln, for the floating floor construction VEM 18 + Litosilo Steel, expressed in dB re 20 µPa per 1/3-octave frequency band. For comparison, the results of the measurements on the bare steel deck are also shown.**



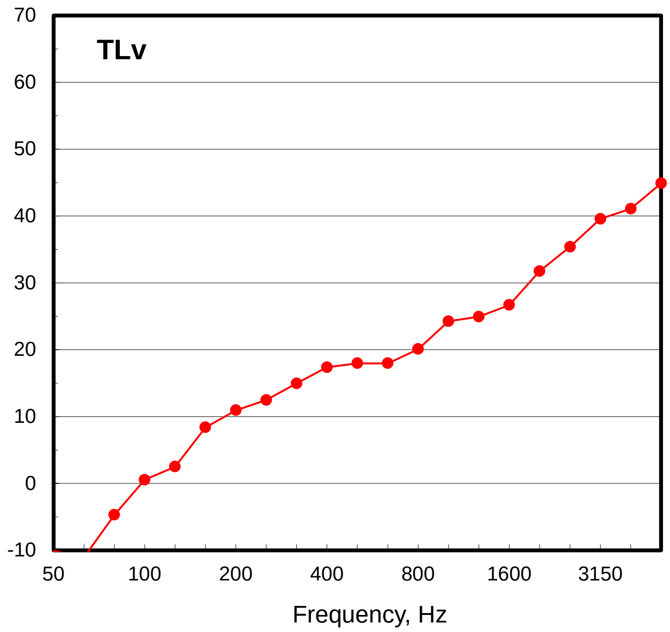

| Hz | dB |
|---|---|
| 50 | 4.3 |
| 63 | 9.2 |
| 80 | 12.7 |
| 100 | 10.5 |
| 125 | 11.8 |
| 160 | 17.6 |
| 200 | 21.2 |
| 250 | 21.1 |
| 315 | 26.6 |
| 400 | 29.0 |
| 500 | 30.6 |
| 630 | 31.0 |
| 800 | 33.6 |
| 1000 | 37.5 |
| 1250 | 37.9 |
| 1600 | 41.3 |
| 2000 | 46.0 |
| 2500 | 50.8 |
| 3150 | 54.7 |
| 4000 | 58.5 |
| 5000 | 64.1 |

**Figure 27 Measured Insertion Loss ILv for the floating floor construction VEM 18 + Litosilo Steel, expressed in dB per 1/3-octave frequency band. The insertion loss ILv refers to the mean velocity level difference in dB.**



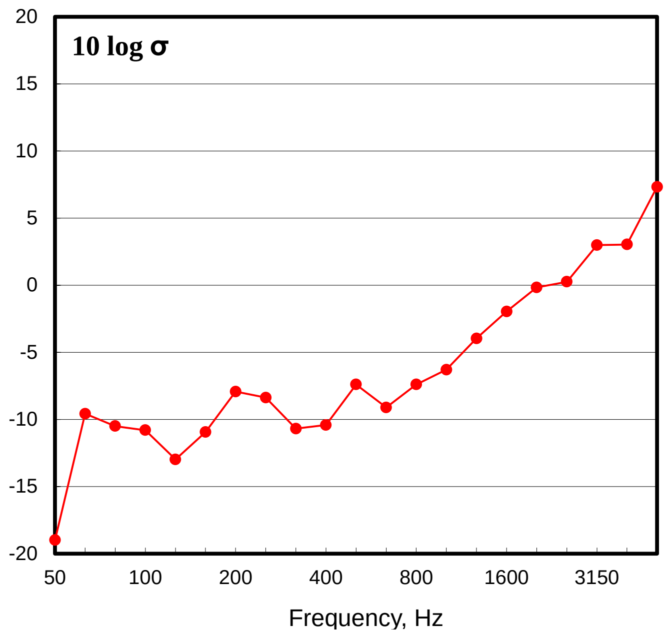

| Hz | dB |
|---|---|
| 50 | 5.8 |
| 63 | 9.5 |
| 80 | 7.3 |
| 100 | 5.0 |
| 125 | 9.9 |
| 160 | 15.0 |
| 200 | 16.0 |
| 250 | 17.6 |
| 315 | 27.5 |
| 400 | 31.5 |
| 500 | 31.8 |
| 630 | 35.9 |
| 800 | 38.3 |
| 1000 | 41.7 |
| 1250 | 42.8 |
| 1600 | 48.3 |
| 2000 | 50.3 |
| 2500 | 53.0 |
| 3150 | 53.5 |
| 4000 | 55.3 |
| 5000 | 54.3 |

**Figure 28 Measured Insertion Loss ILp for the floating floor construction VEM 18 + Litosilo Steel, expressed in dB per 1/3-octave frequency band. The insertion loss ILp refers to the radiated mean sound pressure level difference in dB in the receiving room above the floor.**




| Hz | dB |
|---|---|
| 50 | -10.1 |
| 63 | -11.0 |
| 80 | -4.7 |
| 100 | 0.5 |
| 125 | 2.5 |
| 160 | 8.4 |
| 200 | 10.9 |
| 250 | 12.5 |
| 315 | 15.0 |
| 400 | 17.4 |
| 500 | 18.0 |
| 630 | 18.0 |
| 800 | 20.1 |
| 1000 | 24.3 |
| 1250 | 24.9 |
| 1600 | 26.7 |
| 2000 | 31.8 |
| 2500 | 35.4 |
| 3150 | 39.6 |
| 4000 | 41.1 |
| 5000 | 44.9 |

**Figure 29 Measured Transmission Loss TLv for the floating floor construction VEM 18 + Litosilo Steel, expressed in dB per 1/3-octave frequency band.**




| Hz | dB |
|---|---|
| 50 | -19.0 |
| 63 | -9.6 |
| 80 | -10.5 |
| 100 | -10.8 |
| 125 | -13.0 |
| 160 | -10.9 |
| 200 | -7.9 |
| 250 | -8.4 |
| 315 | -10.7 |
| 400 | -10.4 |
| 500 | -7.4 |
| 630 | -9.1 |
| 800 | -7.4 |
| 1000 | -6.3 |
| 1250 | -4.0 |
| 1600 | -2.0 |
| 2000 | -0.2 |
| 2500 | 0.3 |
| 3150 | 3.0 |
| 4000 | 3.0 |
| 5000 | 7.3 |

**Figure 30 Measured radiation efficiency for the floating floor construction VEM 18 + Litosilo Steel, expressed in dB per 1/3-octave frequency band.**

# 3 Conclusions

The measured weighted sound reduction index Rw and the spectrum adaptation term C are stated in Table 1 for each floor construction. The single number quantities have been derived from the 1/3-octave frequency band values as stipulated in EN ISO 717:2013, "Acoustics - Rating of Sound Insulation in Building and of Building Elements, Part 1 and Part 2.

| Test # | Test Deck | Rw | $C_{(100\text{-}3.15k)}$ |
|---|---|---|---|
| 1 | Sikafloor® Marine VES 515 | 39 | -1 |
| 2 | Sikafloor® Marine VEM 18 | 43 | -1 |
| 4 | Sikafloor® Marine VEM 18 + Litosilo N | 55 | -5 |
| 3 | Sikafloor® Marine VEM 18 + Litosilo Steel | 59 | -3 |

**Table 1 Results of the measurements of the airborne sound insulation stated as single number quantities, expressed in dB.**

The weighted normalized impact sound pressure level Ln,w and the spectrum adaptation term CI are stated in Table 2 for each floor construction. The $dL_m$ is calculated as described in section 1.3.2.

| Test # | Test Deck | $L_{n,w}$ | $dL_m$ | $CI_{(100\text{-}2.5K)}$ |
|---|---|---|---|---|
| 1 | Sikafloor® Marine VES 515 | 89 | 17 | -6 |
| 2 | Sikafloor® Marine VEM 18 | 91 | 15 | -10 |
| 4 | Sikafloor® Marine VEM 18 + Litosilo N | 64 | 42 | -1 |
| 3 | Sikafloor® Marine VEM 18 + Litosilo Steel | 53 | 53 | 1 |

**Table 2 Results of measurements of the impact sound insulation properties, stated as single number quantities, expressed in dB.**

| Test # | Test Deck | Mass, $kg/m^2$ |
|---|---|---|
| 1 | Sikafloor® Marine VES 515 | 17 |
| 2 | Sikafloor® Marine VEM 18 | 24.2 |
| 4 | Sikafloor® Marine VEM 18 + Litosilo N | 64.2 |
| 3 | Sikafloor® Marine VEM 18 + Litosilo Steel | 71.3 |

**Table 3 Mass of the floor constructions, excluding the steel deck.**

The Sikafloor® Marine VEM 18 + Litosilo Steel have the best properties both with regard to the weighted sound transmission loss and with regard to the weighted normalized impact sound pressure level.The Sikafloor® Marine VEM 18 + Litosilo N has a4 dB lower weighted sound transmission loss and a 11dB higher weighted normalized impact sound pressure level. The Sikafloor® Marine VES 515 and the Sikafloor® Marine VEM 18 are comparable with respect to weighted normalized impact sound pressure level with the VEM 18 having a 4 dB higher weighted sound transmission loss.

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