Dipl.-Ing. Stefan Mock[1], Tobias Karl Müller[1], Dipl-Ing. Gerd Meurer[2]
[1] Koblenz University of Applied Sciences, Koblenz, [2] WEM Wandheizung GmbH, Koblenz, D

# Sound insulation in residential construction in connection with locally and naturally available earth building materials

As part of the process of product optimization, and in the course of the development of a new standard for clay boards and panels (DIN 1894X), we conducted several tests in cooperation with the company WEM GmbH to establish building physics material parameters. In addition to the physical parameters of bulk density, thermal conductivity and sorption characteristics, the sound reduction index was one of the values to be determined. Since a standard test chamber according to DIN EN ISO 10140 requires considerable space and expenses, we developed a mobile test chamber as part of a university research project.

Compared to the standard test chamber, the sound test chamber we developed was scaled down by a factor of 5. The exterior walls were constructed using a fully-insulated timber frame structure, as opposed to the recommended plastered masonry wall. The mobile test facility therefore offers substantial space and cost savings. In addition, thanks to the fact that the individual segments of the test facility are removable, a high degree of flexibility is provided and the test facility can be easily moved and adjusted to different test set-ups.

## Physical principles

The following section explains the physical principles and parameters of the test facility.

### Sound reduction index *R* ([1]: p.12 ff.)

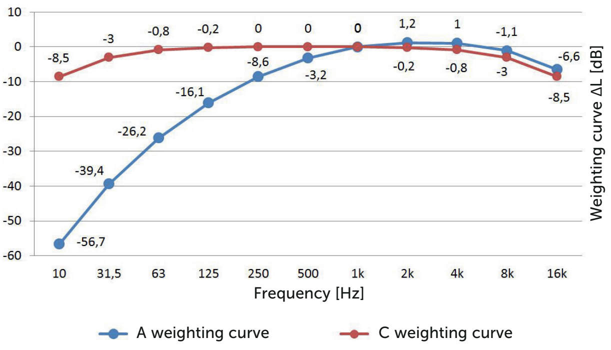
The sound reduction index *R* describes the ratio between the incident sound energy and the emitted energy to the back side of a building element. It is measured in [dB].

There is a difference between the sound reduction index *R* in test chambers where sound is only transmitted through the building element which is being tested (no flanking transmission) and the apparent sound reduction index *R'* which also takes sound transmission through flanks and other secondary paths into consideration. Both sound reduction indices are highly dependent on the frequency range. This is the reason why sound level differences in test chamber tests are determined in a frequency range of 100 to 5000 Hz in thirds and shown in a diagram as a function of the frequency *f* (current changes (July 2016) to DIN 4109 have not been applied).

Compared to the purely physical measurements, various frequency ranges are perceived by the human ear to different extents.

The relevant weighting curves *A* and *C* aim to mimic the listening habit and evaluate sound levels; bearing in mind that low sounds are perceived as being quieter than high sounds at the same sound level. Internationally, the weighting curve *A* is generally used for measuring the strength of a sound. The obtained value is given as the weighted sound level $L_A$ in dB(A). It roughly expresses the disturbing effect perceived by the human ear. The "weighting curve" therefore serves to correct the measured levels of a sound.

Fig. 1 A and C weighting curves ([2], p. 31)



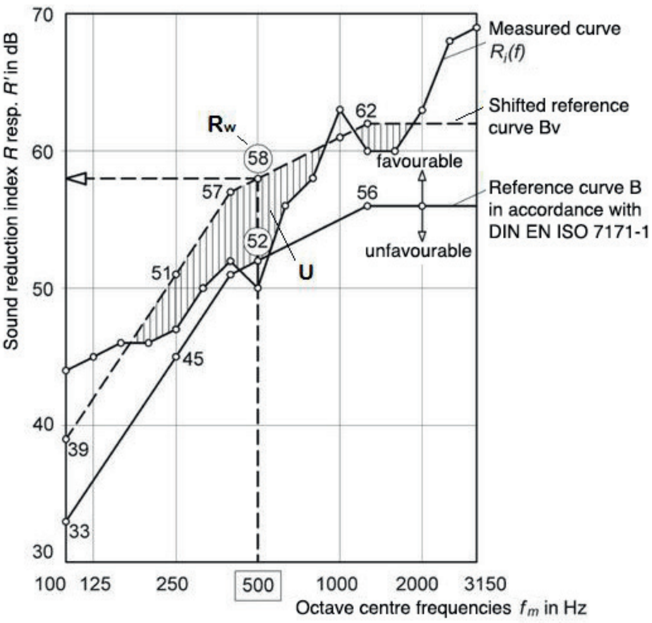


Fig. 2 Definition of the weighted sound reduction index $R_W$ ([1]: p.15)

### Weighted sound reduction index $R_W$ ([1]: p.15)

Good sound insulation properties of wall structures in low frequency ranges do **not** offset bad sound insulation properties in high frequency ranges. With the help of a reference curve *B* (not to be confused with the above correction curves), which represents the stylized curve progression of the sound insulation of a 24 cm-thick brick wall, the measuring curve $R_i^{(f)}$ is used to form the weighting curve $B_V$. Here, only the measurements of the 16 thirds between 100 and 3150 Hz are taken into consideration. The reference curve *B* (Abb. 2) (Fig. 2) is then shifted towards low insulation values until the sum of the lower deviations between the shifted reference curve $B_V$ and the measuring curve $R_i^{(f)}$ is a maximum of 32 dB. The value (in decibels) which was obtained using the reference curve $B_V$, at 500 Hz, is the single value designation of the weighted sound reduction index $R_W$ of a building element.

### Sound insulation behavior of single-leaf solid building elements ([3]: p.13)

The sound insulation behavior of single-leaf building elements can be easily described with the help of the so-called Berger's Mass Law which states that sound insulation increases with the surface density $m'$ [$\mathrm{kg/m^2}$] and the frequency of the sound. This means that the heavier the single-leaf building element and the higher the frequency of the sound to be insulated against the better the attainable sound insulation. At a frequency below approx. 200 Hz, the building elements are referred to as stiff (e.g. sand-lime brick walls), above approx. 1600 Hz as flexible.

### Sound insulation behavior of facings on solid building elements

Another acoustically favorable combination is a wall with a so-called facing. This is a double-leaf wall structure with one stiff and one flexible leaf. With regard to attaining a resonant frequency which is as low as possible (desirable: $f_R < 80$ Hz) the optimal distance between the wall leaves is between 40 and 80 mm. It is also important to consider that a direct attachment of the facing to the stiff wall produces a sound bridge because of structure-borne sound transmission. This would cancel out the sound insulation benefits of a facing. The facing should therefore be attached to a freestanding, usually wooden or metal framework.

Table 1 Improvement factors $\Delta R_{ij,w}$ of wall facing structures according to Weber [9]

| **Structure** | **$\Delta R_{ij,w}$** |
|---|---|
| Freestanding gypsum board facing, consisting of:<br>175 mm solid sand-lime brick ($m' = 335\ \mathrm{kg/m^2}$),<br>50 mm freestanding metal stud framing,<br>40 mm loosely filled mineral wool in between,<br>12.5 mm gypsum board | 10.5 dB |
| Gypsum board sandwich panel, consisting of:<br>175 mm solid sand-lime brick ($m' = 335\ \mathrm{kg/m^2}$),<br>50 mm expanded rigid polystyrene EPS ($s' = 4\ \mathrm{MN/m^3}$),<br>12.5 mm gypsum board | 7.0 dB |
| Gypsum board sandwich panel, consisting of:<br>175 mm solid sand-lime brick ($m' = 335\ \mathrm{kg/m^2}$),<br>20 mm mineral wool ($s' = 10\ \mathrm{MN/m^3}$);<br>12.5 mm gypsum board | – 0.4 dB |

## Typical improvement factors for wall facings

### The effect of standing waves on room characteristics

The measurement accuracy of a test room can be influenced by strong standing waves which particularly occur close to reflecting walls. These waves develop especially when the incident wave and the reflected wave have the same frequency and amplitude and their phases overlap. [101]

Measurements in the mobile sound test chamber have shown that the specific geometry of the room promotes standing waves in the low-frequency range (<250 Hz). If exceedingly strong standing waves cause high fluctuations of the sound pressure level in a room, diffusers can be used to establish a homogeneous sound field ([4]: p.8). Diffusers create a defined unevenness in the wall surface and therefore reflect sound in as many directions as possible.

Depending on the frequency range of the incident noise, sound absorbers might be used as well. They are designed to reduce the reflecting sound on building elements.

There are two general types of absorbers: resonating absorbers and porous absorbers. Porous absorbers have many small cavities which allow the sound energy to dissipate. ([5]: p.185).

Resonating absorbers represent a spring-mass system and can be further divided into panel resonators and perforated panel resonators (Helmholtz resonators).

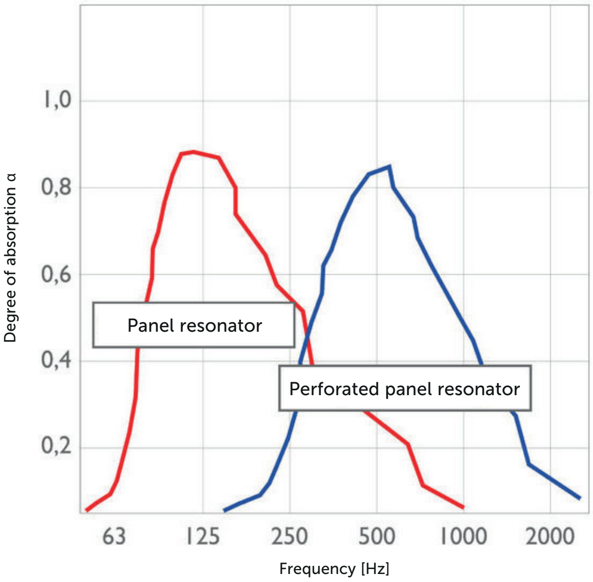


Fig. 5 Frequency-dependent comparison of absorbers (manufacturer specifications [102])

Perforated panel resonators typically have their resonance peak at higher frequencies than panel resonators. In contrast to porous resonators, resonating absorbers can also absorb low frequencies well.

Due to their construction, the exterior walls of the test chamber can be regarded as panel resonators and therefore contribute to an easy absorption of low frequencies.

### Spectrum adaptation terms

Through the introduction of the so-called spectrum adaptation terms $C$ and $C_{tr}$ in DIN EN ISO 717-1 , the characteristics of different real-life sound spectra can be taken into consideration. The application of the spectrum adaptation terms depends on the type of sound source and is shown in Table 2.

Adaptation terms are added to the single value of the sound insulation measurement as a separate number (e.g.: $R_w$ ($C$; $C_{tr}$) = 55 (-2; -4) dB). Building elements

Fig. 3 Panel resonator [102]

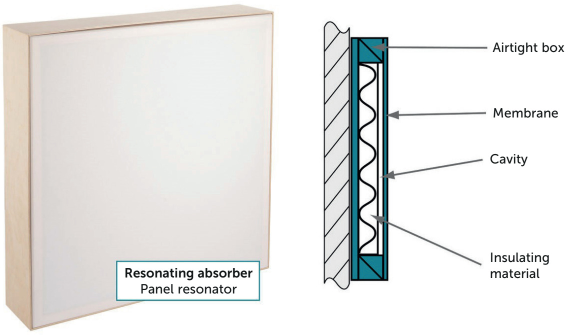
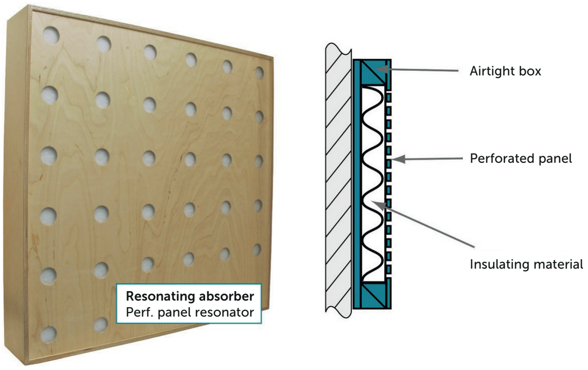


Fig. 4 Perforated panel resonator [102]



| **Type of sound source** | **Corresponding spectrum adaptation term** |
|---|---|
| e.g.: domestic activities (conversation, music, TV), children playing | C (spectrum 1) |
| e.g.: urban traffic, disco music, propeller plane, rail traffic at a great distance | $C_{tr}$ (spectrum 2) |

Table 2 Excerpt of spectrum adaptation terms for various types of sound sources ([7]: p.15)

with particular deficiencies in regard to these specific noises therefore receive high negative $C$- and $C_{tr}$ values in addition to $R_w$.

During our first tests it could be determined that standing waves occur in the low-frequency range (<250 [Hz]). The available spectrum adaptation terms are therefore only for information purposes and might have to be modified. This requires an optimization of the room characteristics in the course of further research and tests.

For test chamber measurements, defined sound sources are used to create noise spectra. The term *white noise* refers to an acoustic signal where all audible frequencies are represented with random, constantly changing sound pressure levels which, on average, however, are of the same level. The sound energy of the different frequency bands is the same (e.g. there is as much energy in the 100 – 200 Hz range as there is in the 2000 – 2100 Hz range).

With *pink noise* on the other hand, the sound energy density decreases with the frequency. The sound pressure level of an octave decreases by approx. 3 dB compared to the previous octave (frequency-dependent amplitude).

For this reason, *white noise* sounds brighter than *pink noise*.

For the tests, digitally generated and readily reproducible *white noise* was used.

### Description of the mobile sound test chamber

The sound test chamber we have developed consists of a source and a receiving room which have been built using timber-frame construction from individually fabricated modules. The rooms can be accessed through airtight fire doors. Two prefabricated reinforced concrete walls ($d$ = 18 cm, $\rho$ = ca. 2.400 kg/m$^3$) separate the rooms from each other. The minimum distance of 50 [mm] between the walls has been filled with mineral wool and sealed with diffusion-resistant tape. The reinforced concrete walls have "special small" test openings for the test building elements. The openings have been constructed using facing concrete on the insides of the rooms to ensure a reflective surface is achieved ( [4]: p.12). The individual timber-frame modules consist of solid structural timber (spruce) and have been covered with a single layer of 18 mm OSB boards on the exterior and a double layer of 15 mm OSB boards on the interior. In order to avoid interfering joint patterns, which could have a negative impact on the air tightness of the test chambers, the OSB boards were installed using a tongue and groove system and sealed. The cavities of the timber-frame modules have been completely filled with insulation.

The wall, floor and ceiling modules are connected with the help of straps in the form of tensioning belts and ratchets. The connections are acoustically decoupled using cellular rubber sealing tape (elastomeric bearings). The sound test chamber can be supplied with electricity via exterior electrical outlets..

In order to prevent interference of the sound field, people are not allowed to be inside the source or receiving room during tests. For this reason, sealed ducts have been installed in the exterior walls of both rooms which can be used to run loudspeaker and microphone cables into the interior. All interior connections between the building elements have been sealed with diffusion-resistant tape to increase the air tightness of the test rooms..

### Deviations of the mobile sound test facility from the requirements for standard test facilities

Table 2 shows deviations from the requirements for test facilities defined in the DIN standard which are due to the fact that the sound test facility needs to

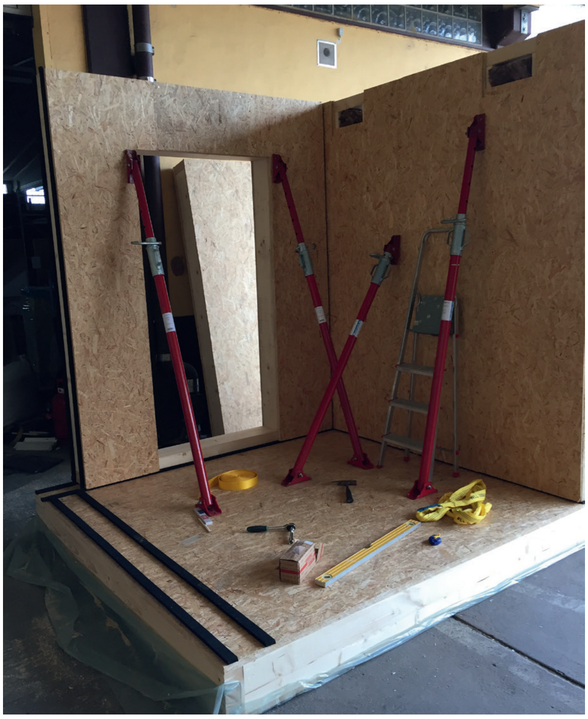


Fig. 6 Overview of construction

be able to be dismantled. The page numbers and paragraphs shown in brackets refer to the relevant sections of the requirements defined in DIN EN ISO 10140-5:2014 [4].

According to the requirements placed on test rooms and test facilities in DIN EN ISO 10140-5, the sound energy in test rooms which is transmitted indirectly (via secondary paths) – as opposed to the sound energy transmitted by the tested building element – should be negligible. “In order to achieve this in the test rooms, sufficient structure-borne sound insulation between source room and receiving room must be ensured.”

Fig. 8 Schematic diagram of the inner dimensions of the rooms

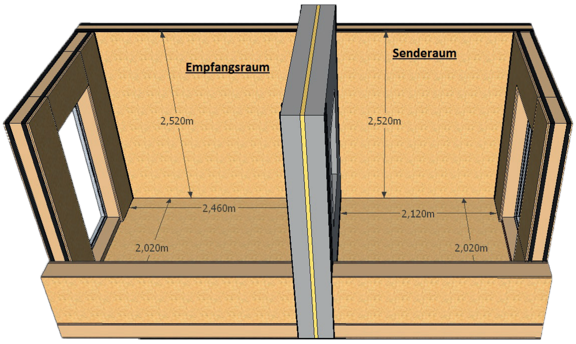


Fig. 7 Interior view of sound test facility

All connections have been sealed with compriband and sealing tape for acoustic decoupling of all building elements. This way, flanking transmission can be largely eliminated. During installation into test openings, the test building elements were placed on sealing tape. A further description of secondary paths is therefore not necessary.

### Measuring airborne sound insulation

Within the framework of these empirically designed measurements, test series were selected which allow a direct comparison between each other as well as to the chosen standard reference building element. In addition, practice-relevant building elements were selected.

Fig. 9 Mobile sound test facility

| **Requirements according to DIN EN ISO 10140-5** | **Mobile sound test facility** |
|---|---|
| Volume of test chambers > 50 m$^3$<br>(p.8 paragraph 3.2.1) | Volume of source room: approx. 11 m$^3$<br>Volume of receiving room: approx. 13 m$^3$ |
| The source room should be the larger space<br>(p.15 paragraph 5.1) | Both rooms are of approx. the same size |
| Dimensions of the specific small test opening<br>(p.12 paragraph 3.3.3)<br>w = 1250 mm ± 50 mm<br>h = 1500 mm ± 50 mm | Dimensions of the specific test opening:<br>Gross dimensions<br>w = 1020 mm<br>h = 1220 mm<br>Net dimensions<br>w = 1000 mm<br>h = 1200 mm |
| Stepped recesses on the sides and the top of the test opening<br>(p.12ff. paragraph 3.3.3) | No stepping of the recesses on the sides and the top of the test opening |
| The walls of the testing facility should be homogeneous and solid structures, e.g. made of heavy-weight concrete or brick masonry | The walls are made of individual timber frame modules |
| Reverberation time should be between 1 and 2 seconds<br>(p.9 paragraph 3.2.3) | Reverberation time is 0.5–1.1 seconds |
| Minimum distances of the microphone positions:<br>(DIN EN ISO 10140-4 p.8 paragraph 4.2.2)<br>0.7 m between a microphone position and the room boundaries<br>1.0 m between a microphone position and the test building element<br>1.0 m between a microphone position and the sound source | Due to the geometry of the space, it is not possible to adhere to the minimum distances of the microphone positions. The following values serve as substitutes.<br>0.5 m between a microphone position and the room boundaries<br>0.8–1.0 m between a microphone position and the test building element<br>0.8–1.0 m between a microphone position and the sound source |

Table 3 Deviations: Mobile sound test facility vs. requirements for standard test facilities

For our tests, the test elements described below were installed into "specific small" test openings between the test rooms and examined.

In order to be able to compare the test results with each other and to gain an understanding and insights into correlations, the different facing structures and other building elements were tested for three different basic walls (sand-lime masonry wall, Holz100 glued laminated timber, timber-frame construction with thermal insulation):

The following section describes the basic building elements and the test elements.

### Conducting the tests

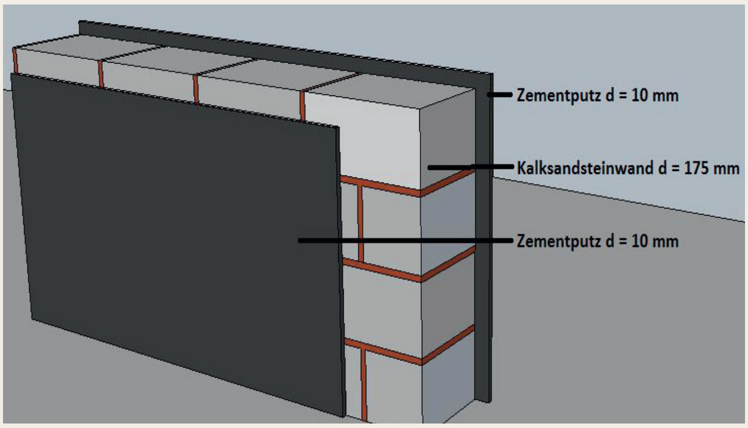
According to the recommendations in DIN EN ISO 10140-3-5 ( [4]: p.15), noise excitation took place in the source room using white noise via the stationary building acoustics dodecahedron speaker with a power amplifier. Using the dodecahedron speaker created a uniform and diffuse distribution of the sound energy. The measurement of the sound pressure level was carried out in real time on multiple channels on the emitting side, and using ½" measuring microphones (class 1) at four fixed microphone positions.

The energetic average sound pressure level in the source room and the receiving room was calculated using the equation 1.1:

$$L = 10\lg\frac{l}{n}\sum_{j=1}^{n}10^{\frac{L_j}{10}} \qquad (1.1)$$

Here, $L_1$, $L_2$, ..., $L_n$ are the sound pressure levels in $n$ positions in the room.

Fig. 10 Sand-lime basic element



**1 – Sand-lime masonry wall**

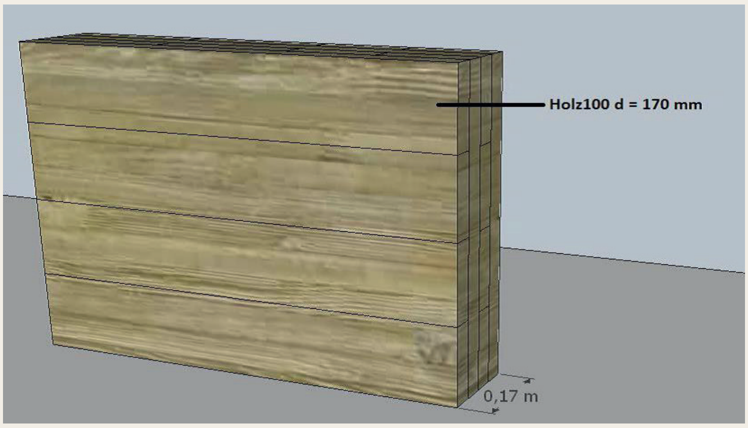
bulk density class 2.0 using standard mortar, d = 175 mm
$\rho_W = 1900\ \mathrm{kg/m^3}$, 10 mm cement plaster on both sides
$m'_P = 18\ \mathrm{kg/m^2}$ ([6]:10.63)

Calculation of the surface density of the basic element:

| | | | |
|---|---|---|---|
| Mass of the masonry | $0.175\ \mathrm{m} \times 1900\ \mathrm{kg/m^3}$ | = 332.5 | $\mathrm{kg/m^2}$ |
| Cement plaster | $2 \times 18\ \mathrm{kg/m^2}$ | = 36.0 | $\mathrm{kg/m^2}$ |
| | $m'$ | = 368.5 | $\mathrm{kg/m^2}$ |

The wall meets the requirements of DIN EN ISO 10140:5 ( [4]: p.21) as a standard basic element with a surface density of 350 ± 50 $\mathrm{kg/m^2}$ which is recommended for the use of wall facings. It was installed into the opening of the reinforced concrete wall of the receiving room using EPDM cellular rubber strips, and plastered on both sides in order to increase air tightness.

Fig. 11 Holz100 basic element



**2 – Holz100 – glued laminated timber basic element**

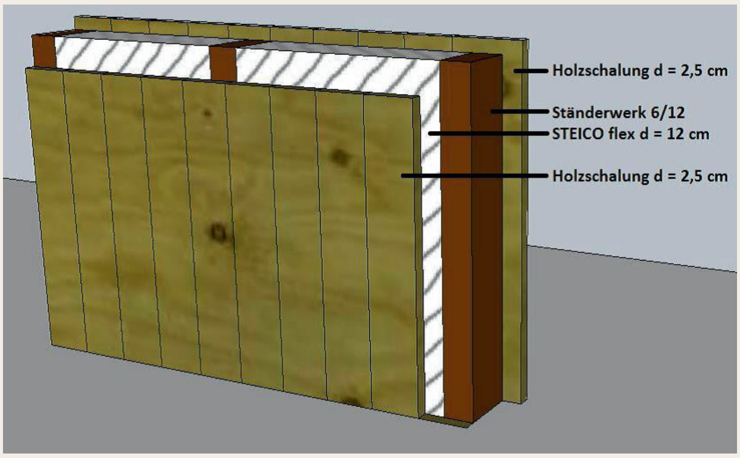
d = 170 mm, b = 1000 mm, h = 1200 mm, $\rho \approx 450\ \mathrm{kg/m^3}$

Calculation of the surface density of the basic element:

$m' = 0.17\ \mathrm{m} \times 450\ \mathrm{kg/m^3} = 76.5\ \mathrm{kg/m^2}$

The basic element consists of several layers of KVH solid structural timber made of spruce and fir. Using thin compriband on the bottom and EPDM insulation on the remaining sides it was acoustically decoupled from the reinforced concrete wall. In addition, acrylic seams were attached to the edges of the building element and then sealed on all sides using an airtight adhesive tape. On the receiving side, a distance of 3.5 cm to the reinforced concrete wall was kept in order to ensure a flush closure for the installation of the wall facing.

Fig. 12 Timber frame basic element



### 3 – Timber frame construction with thermal insulation

d = 170 mm, b = 1000 mm, h = 1200 mm

Calculation of the surface density of the basic element:

| | | |
|---|---|---|
| Timber formwork | $0.025\ m \times 500\ kg/m^3$ | $= 12.5\ kg/m^2$ |
| Timber frame | $0.06 \times 0.12 \times 500\ kg/m^3/0.625$ | $= 5.76\ kg/m^2$ |
| STEICOflex | $0.565 \times 0.12 \times 50\ kg/m^3/0.625$ | $= 5.424\ kg/m^2$ |
| Timber formwork | $0.025\ m \times 500\ kg/m^3$ | $= 12.5\ kg/m^2$ |
| | m‘ | $= 36.18\ kg/m^2$ |

The timber frame basic element was installed in the same manner as the previously mentioned Holz100 basic element. In addition, acrylic seams were attached to the edges of the building element and then sealed on all sides using an airtight adhesive tape. The distance to the reinforced concrete edge on the receiving side was also 3.5 cm.

Before each test series the measuring microphones were calibrated. In addition, a measurement of the level of background noise was carried out to ensure that the measured values in the receiving room were not affected.

The level of background noise needs to be at least 6 dB below the level of the combination of signal and background noise in each frequency band ( [7] p.9).

For differences in level between 6 and 15 dB, the corrections of the signal level are calculated using the equation 1.2.

$$L_{2,k} = 10 \lg\left(10^{\frac{L_2}{10}} - 10^{\frac{L_b}{10}}\right) \qquad (1.2)$$

with $L_{2,k}$ the corrected signal level in the receiving room, in dB

$L_2$ the level of the combination of signal and background noise, in dB

$L_b$ the background noise level, in dB

The sound reduction index *R* between the test chambers of the test facility was determined using the following equation ([8]: p.7):

$$R = L_1 - L_{2,k} + 10lg * \frac{S}{A}$$

with $L_1$ energetic average sound pressure level in the source room, in dB

$L_{2,k}$ energetic average sound pressure level in the receiving room (corrected), in dB

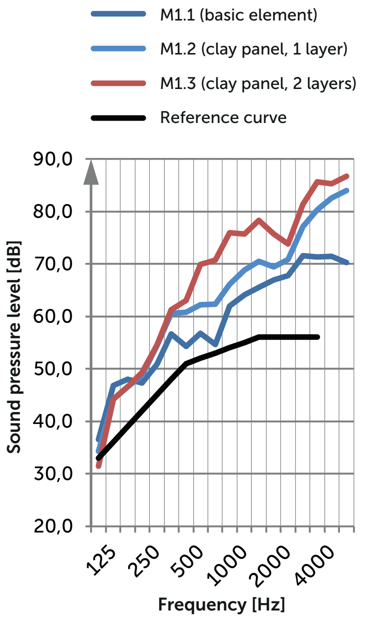
S the surface of the free partition wall, including the tested building element, in $m^2$

A the equivalent sound absorption area in the receiving room, determined using the measured reverberation time *T*, in $m^2$

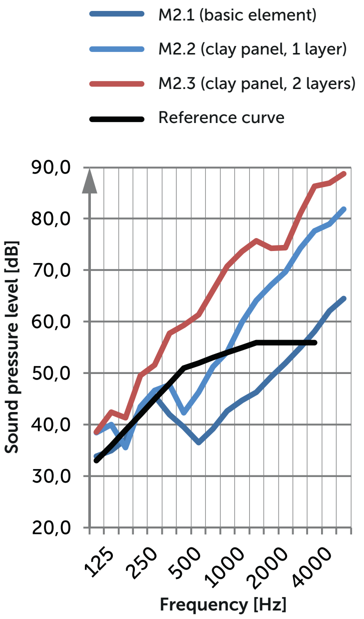
### Results – Solid building element without wall facing

The application of a clay panel and a thin layer of earth plaster significantly increases the sound insulation values of the measured curves M2.2 and M3.2. The reason for the improved sound insulation primarily lies in the increase of the surface density of the walls. The Holz100 basic element shows the effect of a stiff basic wall in connection with a facing.

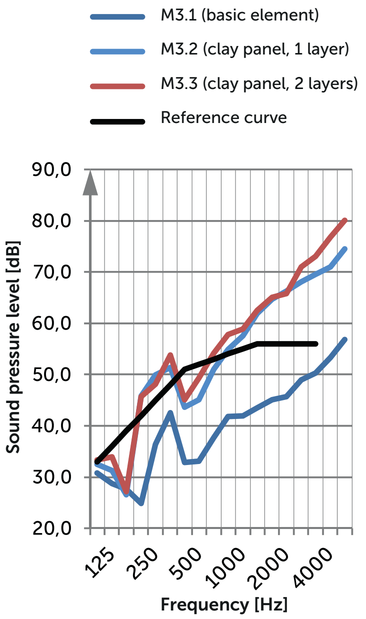
**Lime-sand basic element with clay panels**



**holz100 basic element with clay panels**



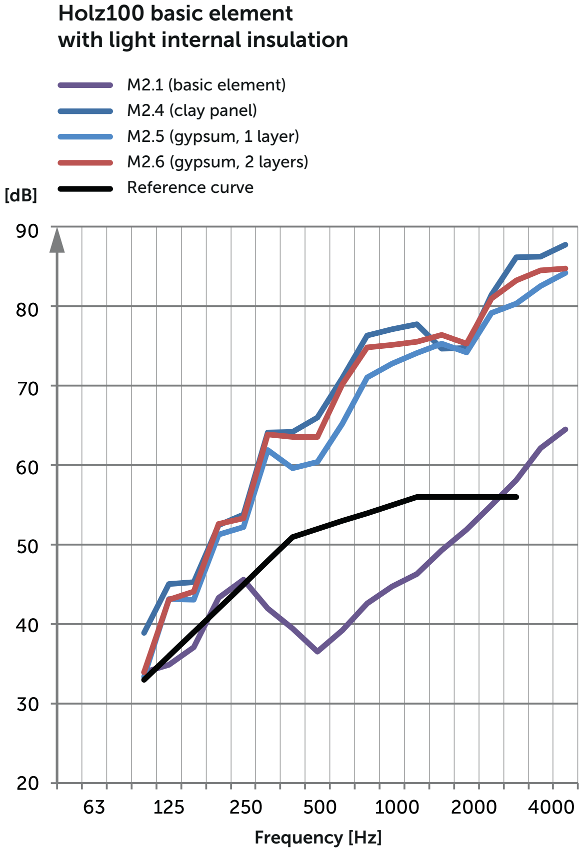
**timber-frame basic element with clay panels**



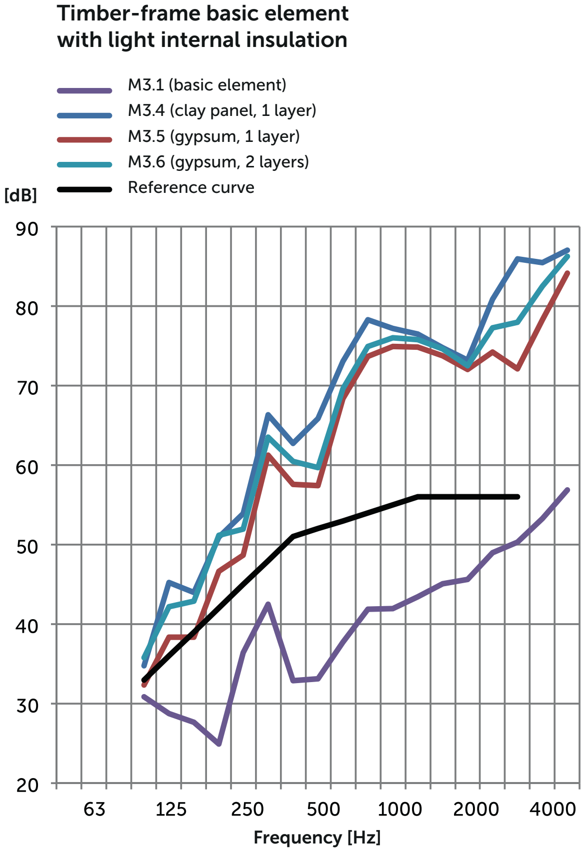
| | | **Facing structure in mm** | |
|---|---|---|---|
| | **Measurement No.** | **25 clay panel** | **50 clay panel** |
| | $R_{w,res}$ \| $R_{w,test}$ | 8 earth plaster | 16 earth plaster |
| | ($C$ ; $C_{tr}$) | | |
| | $\Delta R_{w,direct}$ | m′= +45 kg/m$^2$ | m′= +90 kg/m$^2$ |
| **Sand-lime basic element** | **M1.1** | **M1.2** | **M1.3** |
| 10 mm cement plaster | 61.1 \| **55.0 dB** | 63.8 \| **57.8 dB** | 64.5 \| **58.5 dB** |
| 175 mm sand-lime brick, ρ=1900 kg/m$^3$ | (-2 ; -7) | (-4 ; -11) | (-6 ; -14) |
| 10 mm cement plaster, m′=365.5 kg/m$^2$ | | 2.8 dB | 3.5 dB |
| **Holz100 basic element** | **M2.1** | **M2.2** | **M2.3** |
| 170 mm solid structural timber | 45.4 \| **39.3 dB** | 53.9 \| **47.8 dB** | 63.0 \| **56.9 dB** |
| m′=76.5 kg/m$^2$ | (-1 ; -3) | (-1 ; -4) | (-2 ; -6) |
| | | 8.5 dB | 17.6 dB |
| **Timber-frame construction** | **M3.1** | **M3.2** | **M3.3** |
| 25 mm timber sheathing | 41.4 \| **35.0 dB** | 51.7 \| **45.6 dB** | 53.8 \| **47.7 dB** |
| timber frame 6/12, STEICOflex 120 mm | (-2 ; -5) | (-4 ; -9) | (-5 ; -10) |
| 25 mm timber sheathing, m′=36.2 kg/m$^2$ | | 10.6 dB | 12.7 dB |

### Results – Solid building element with 80 [mm] interior insulation

Compared to their basic construction, the measured curves M2.4 and M3.4 show a significantly higher degree of sound insulation. After exchanging the clay panel with two gypsum boards, the weighted sound reduction index of measurements M2.6 and M3.7 decreased by approx. 2 dB which can be explained by the lower surface density of approx. 25 kg/m².



**Holz100 basic element with light internal insulation**



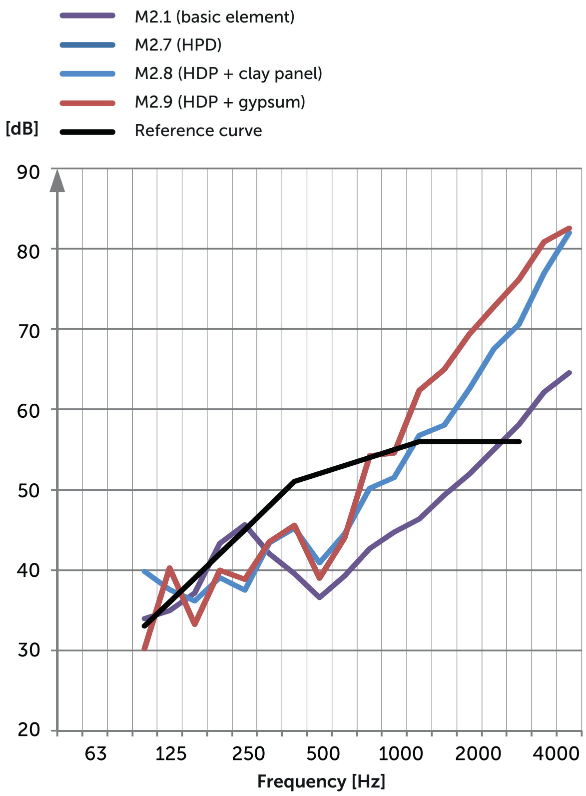
**Timber-frame basic element with light internal insulation**

| | | **Facing structure in mm** | | |
|---|---|---|---|---|
| | **Measurement No.** | **80 int. insulation** | **80 int. insulation** | **80 int. insulation** |
| | $R_{w,res}$ \| $R_{w,test}$ | 25 clay panel | 12,5 gypsum board | 25 gypsum board |
| | ($C$ ; $C_{tr}$) | 8 earth plaster | | |
| | $\Delta R_{w,direct}$ | m′= +50 kg/m² | m′= +15 kg/m² | m′= +25 kg/m² |
| **Holz100 basic element** | **M2.1** | **M2.4** | **M2.5** | **M2.6** |
| 170 mm solid structural timber | 45.4 \| **39.3 dB** | 66.2 \| **60.2 dB** | 63.0 \| **56.9 dB** | 64.6 \| **58.6 dB** |
| m′=76.5 kg/m² | (-1 ; -3) | (-3 ; -9) | (-4 ; -11) | (-5 ; -12) |
| | | 20.9 dB | 17.6 dB | 19.3 dB |
| **Timber-frame construction** | **M3.1** | **M3.4** | **M3.6** | **M3.7** |
| 25 mm timber sheathing | 41.4 \| **35.0 dB** | 64.9 \| **58.9 dB** | 59,6 \| **53,5 dB** | 63.1 \| **57.0 dB** |
| timber frame 6/12, STEICOflex 120 mm | (-2 ; -5) | (-4 ; -12) | (-3 ; -10) | (-3 ; -10) |
| 25 mm timber sheathing, m′=36.2 kg/m² | | 23.9 dB | 18.5 dB | 22.0 dB |

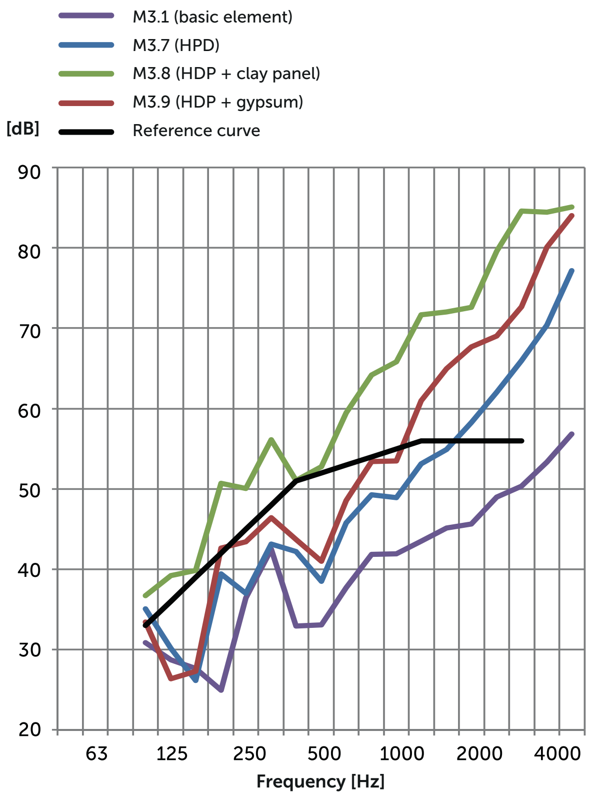
### Results – Solid building element with 140 [mm] interior insulation

The sound insulation values of the curves M2.8 and M2.9 show a significantly higher measured value at the midband frequency 100 Hz compared to the other curves. A review of the values showed that the sound levels in the source room were higher than normal for both measurements. Using the light-weight interior insulation with a clay panel achieved the highest degree of sound insulation. The difference between the two timber elements with plastered clay panels (M2.4 and M3.4) and double gypsum board (M2.6 and M3.7) was + 1.6 dB and +1.9 dB respectively.

**Holz100 basic element**
**with wood fibre insulation (HDP)**



**Timber-frame basic element**
**with wood fibre insulation (HDP)**



**Facing structure in mm**

| | **Measurement No.** | **140 wood fibre** | **140 wood fibre** | **140 wood fibre** |
|---|---|---|---|---|
| | $R_{w,res}$ \| $R_{w,test}$ | | 25 clay panel | 12.5 gypsum board |
| | (C ; $C_{tr}$) | | 8 earth plaster | |
| | $\Delta R_{w,direct}$ | m'= +22.4 kg/m$^2$ | m'= +67.4 kg/m$^2$ | m'= +32.4 kg/m$^2$ |
| **Holz100 basic element** | **M2.1** | **M2.7** | **M2.8** | **M2.9** |
| 170 mm solid structural timber | 45.4 \| **39.3 dB** | 49.9 \| **43.8 dB** | 55.5 \| **49.4 dB** | 49.9 \| **43.8 dB** |
| m'=76.5 kg/m$^2$ | (-1 ; -3) | (-2 ; -5) | (-2 ; -6) | (-2 ; -6) |
| | | 4.5 dB | 10.1 dB | 4.5 dB |
| **Timber-frame construction** | **M3.1** | **M3.8** | **M3.9** | **M3.10** |
| 25 mm timber sheathing | 41.4 \| **35.0 dB** | 47.5 \| **41.4 dB** | 59.4 \| **53.3 dB** | 49.5 \| **43.4 dB** |
| timber frame 6/12, STEICOflex 120 mm | (-2 ; -5) | (-3 ; -7) | (-2 ; -8) | (-3 ; -8) |
| 25 mm timber sheathing, m'=36.2 kg/m$^2$ | | 6.4 dB | 18.3 dB | 8.4 dB |

For wall structures with exterior insulation, the timber-frame construction element with a clay panel displayed the best degree of sound insulation (M3.9). In contrast, the degree of improvement of sound insulation by attaching the gypsum board was considerably lower.

### Summary and outlook

This report presents the first preliminary results of a larger series of measurements and tests. A larger number of test results will reduce uncertainties and allow for a more exact determination of safety factors.

As expected, it could be proven that the specific increase in mass achieved by attaching the clay panels offers a significant advantage compared to lighter-weight systems. This can be explained by "Berger's Mass Law". The well-known advantages of wall facings in terms of sound insulation could be confirmed with the tests as well. This means that it is beneficial to combine the good sound insulation characteristics of clay panels with energy-efficient interior insulation.

This report could not expand on the sound insulation characteristics of the absorption coefficients (room acoustics) nor the frequency-dependent effect of surface finishes (e.g. paints, wallpaper, coatings). Future plans include determining the absolute absorption coefficient and identifying the direct effects of clay panels on room acoustics as well as developing impact sound measurements according to DIN EN 16205:2013 with tests in the sound test chamber. Furthermore, problems in the low-frequency range will be addressed through the appropriate use of sound absorbers and reflectors, and the test series will be continued.

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