Acoustics in wooden buildings – Field Measurements in Multi-Storey Buildings

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Project Report No. 2

Field Measurements in Multi-Storey Buildings

WoodWisdom-Net: AcuWood – Acoustics in Wooden Buildings

Development of advanced measurement and rating procedures for sound insulation in wooden buildings as basis for product optimisation

Research project 033R056

Term of project

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Contents

Acknowledgements

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1 Introduction

Wooden multi storey family houses are increasingly build in Europe. Driving forces are better sustainability, a development towards industrialisation of building elements and related to it, cost reduction in the construction sector. In the past years, legislation has enabled wooden multi storey houses in many countries, including Germany. The main problems of fire protection issues have been solved. However, noise and vibration disturbances experienced by residents tends to increase, even if the building code requirements are fulfilled. Therefore, sound and vibration issues have become the new hindrance for multi storey wooden buildings.

The current acoustic requirements in multi storey family houses are based on experience in heavy weight multi storey buildings, as wooden buildings have not been possible previously. The perceived acoustic quality in lightweight buildings is different, compared to heavyweight structures. In particular, low frequency sound transmission of airborne and especially impact sound sources lead to complaints in wooden buildings, and might become very evident and disturbing in lightweight structures [1].

The currently used rating systems for airborne and impact sound transmission in buildings were developed in the 1950's and aimed to rate the building constructions of this time. In the 1990's the introduction of spectrum adaption terms in ISO 717 [2, 3] changed the rating system and included (in parts) low frequencies down to 50 Hz. With the introduction of wooden multi-storey houses with acoustic requirements on the separating elements (floors and walls), it was obvious that the current rating systems did not prevent increased annoyance of living noise, especially impact noise, in wooden buildings.

In this project, the aim was to find better technical descriptors of impact noise sources by correlation to subjective ratings of impact noise sources in Buildings. Besides wooden constructions, a concrete floor was also investigated to include the behaviour of common floor design in this study.

1.1 Aim of the project

As problems of noise and vibration disturbances in wooden buildings have been recognised, the aim of this project is to develop sound and impact noise criteria that better correspond to human perception in heavy weight and lightweight buildings. The criteria should not only focus on wooden buildings, but also include traditional heavy weight buildings, for example made of brick, concrete etc.

The disagreement between the acoustic requirements in national standards and the subjective noise perception of the occupants is a general problem, which applies to wooden and lightweight buildings all over Europe [1, 4, 5].

Although it has been tried to solve the problems by adding spectrum adaption terms to the conventional single-number quantities of the weighted sound reduction index R_w [2, 6] and the weighted impact sound pressure level $L_{n,w}$ [3, 7], the problems are still not solved [8].The main problem in noise protection in wooden buildings are the impact sound insulation of wooden (lightweight) floors and – to a smaller degree – the airborne sound insulation of the exterior building elements like walls and roofs. Even though there are numerous investigations on propagation and human reception of impact and airborne sound in wooden buildings, a uniform and consistent approach for adapted rating criteria and requirements is not available yet [9–13].

1.2 Aim of the report

This report documents the conducted measurements in multi-storey multi-family houses in Switzerland. It includes all important information on the constructions of the floors and the room situations in the buildings. It lists the basic measured values for documentation. Each of the objects was documented in a single report (in German), which is available at Lignum (LIGNUM – Holzwirtschaft Schweiz | Economie suisse du bois | Economia svizzera del legno | Mühlebachstrasse 8 | 8008 Zürich).

2 Measurements

In the AcuWood project, measurements and recordings of the sounds were conducted, as different single number values of measurements were to be correlated with subjective ratings from listening tests. In the receiving room all signals were recorded, and third octave band measurement values were calculated from the recordings. Therefore, measurements and recordings are termed "measurements" in the following. Additionally to the recordings of microphones, reported here, calibrated recordings of a dummy head were also conducted in parallel in the receiving room. These recordings were used for the listening tests.

2.1 Sources

All field measurements were performed using the following standardized and non-standardized impact noise sources.

2.1.1 Tapping machine

The utilised tapping machines are standardized impact noise sources for building acoustics measurements according to DIN EN ISO 10140-5 [14] Annex E. The used tapping machine is listed in section 2.6. According to the standards DIN EN ISO 10140-4 [15] and DIN EN ISO 140-4 [16], measurements were performed with four positions of the tapping machine on the floor, the measurements had a duration of 60s. A photograph of the tapping machine is shown in figure 1.

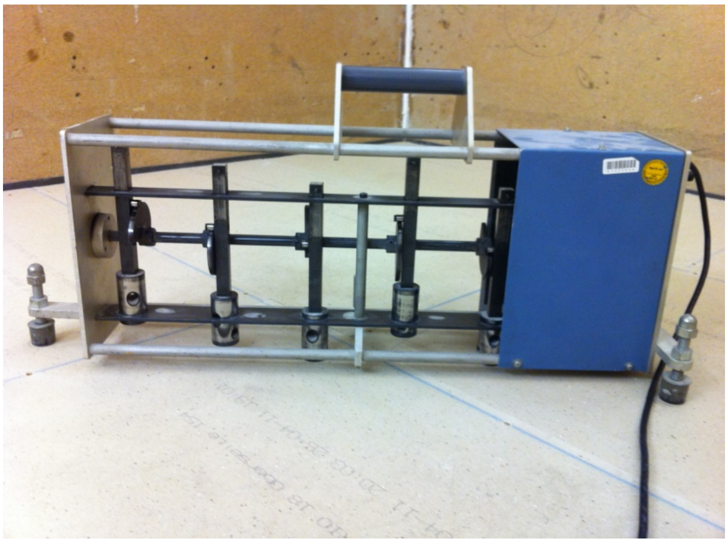


Figure 1:Photograph of the utilised tapping machine.

2.1.2 Modified tapping machine

As modified tapping machine, the above mentioned tapping machine was placed on elastic pads with 12.5 mm thickness, and the hammers were falling onto an elastic interlayer of the same thickness. The material below the hammers was Getzner Sylomer (yellow), according to DIN EN ISO 10140-5 [14] Annex F1, method b. Again, the same four positions were used as for the tapping machine, and the measurement duration was again 60s. A photograph of the modified tapping machine is shown in figure 2.

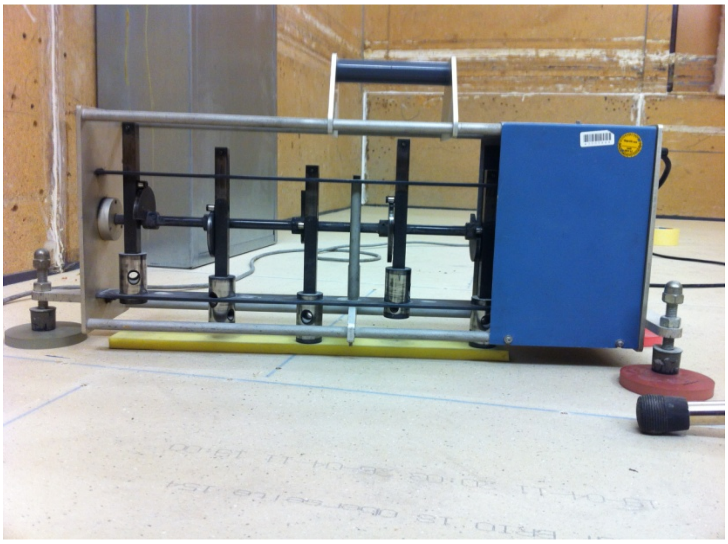


Figure 2:Photograph of the modified tapping machine.

2.1.3 Japanese rubber ball

The Japanese rubber ball is a standardized source, developed in Japan for impact noise generation and measurement. It is described in DIN EN ISO 10140-5 [14] Annex F2. For the measurements, the Japanese rubber ball of the Fachhochschule Stuttgart – University of Applied Sciences was employed. The friendly relinquishment of the ball is gratefully acknowledged. The rubber ball was dropped from a height of 1 m and caught after each drop. The height was set approximately by the operator. Tests showed that the repeatability of the ball drops was very high, giving a standard deviation of the ball drops at the same position in general below 1 dB. The measurements were performed on the same four positions as the tapping and modified tapping machine positions. The ball drop was repeated 10 times on each floor position, giving a total of 40 measurements, which were arithmetically averaged. The signals on the different microphone positions were energetically averaged. Each ball drop was recorded within a time period between 3 and 10 s, and the $L_{,F,max}$ value was taken in third octave band as measured value, analysed with third octave band filters by the acoustic software Artemis by Head Acoustics. A photograph of the Japanese rubber ball is shown in figure 3.

Figure 3:Photograph of the Japanese rubber ball.

2.1.4 Real sources: walking persons

As real sources, walking persons were also measured in the field. Here, the same male person with similar footwear was employed during the measurements. The footwear was normal male shoes with leather sole and socks. A female walker was not employed..

On each floor, the walking person was walking in a circle across the four above mentioned excitation positions. The speed of walking was close to two steps per second, the measurement was done for a time of 60 s. (In some of the field measurements, the background levels were disturbing. As the signals were recorded, times of high background noise in the recordings were not included in the generation of third octave band levels and also not included in the listening test signals. Therefore, in those cases the averaging was shorter than 60 s). A photograph of one walking person is shown in figure 4.

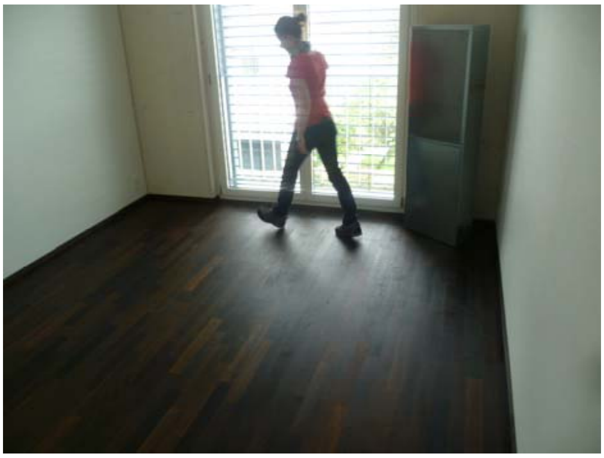


Figure 4:Photograph of a walking person.

2.1.5 Real sources: drawing of chair across the floor

As another real source, a standard four leg chair was used. To generate normal chair moving sounds on the floor, it was drawn by a rope for a distance of about 1 m across the floor. The speed was about 20 cm/s, so the signals were about 5 seconds long. The signal was recorded for 10 s. The drawing of the chair was performed on the similar four positions as the operation of the tapping and modified tapping machine and the ball. The drawing of the chair was repeated 10 times on each position, giving in total 40 signals. The signals were averaged arithmetically. The averaged signals of the different microphone positions were energetically averaged. In the case of carpet as floor covering, the procedure of the measurements was the same. On carpet, the source acted differently, as the main excitation mechanism was the slip-stick-effect of the feet of the chair on the floor. On carpet, a stick-slip-effect did not occur, and the chair gave a very different excitation of the floor itself. This should always be kept in mind when analysing the measurement results of the drawing of the chair. A photograph of the drawing of the chair is shown in figure 5.

Figure 5:Photograph of the drawing of the chair.

2.2 Sound pressure level

2.2.1 Tapping machine, modified tapping machine, walking persons, drawing of chair

The sound pressure levels in the receiving room of the different sources are calculated by energetic averaging of all microphone positions. The sound pressure level is calculated by:

$$L = 10\log\frac{1}{n}\sum_{n} 10^{(L_i/10)} \quad (1)$$

with:

L = energetic averaged sound pressure level dB

L_i = sound pressure level of each microphone in the same room dB

2.2.2 Japanese rubber ball

As the Japanese rubber ball is an impulse sound source, the max values of the signals with time weighting fast (τ = 125 ms) was used. The averaged sound pressure level of the ball is calculated by:

$$L_{F,\max} = 10\log\frac{1}{n}\sum_{n} 10^{(L_{i,F,\max}/10)} \quad (2)$$

with:

$L_{F,max}$ = energetic averaged maximum sound pressure level in dB

$L_{i,F,max}$ = sound pressure level of each microphone in the same room in dB

2.3 A-weighted sound pressure level

To compare the different impact sound sources on the basis of a single number value, the A-weighted standardized sound pressure level $L_{n,T,A}$ was calculated from the measurements.

2.3.1 Tapping machine, modified tapping machine, walking persons, drawing of chair

For all sources, the sound pressure level L in the receiving room (Equation 1) was standardized to a reverberation time of 0.5 s and A-weighted, giving:

$$L_{n,T,A} = 10\log\sum_{n} 10^{\left(\left(L_{n,T,i}+L_{A,i}\right)/10\right)} \tag{3}$$

with:

$L_{n,T,A}$ = the A-weighted standardized sound pressure level in dB

$L_{A,i}$ = the A-weighting values for the third octave bands i in dB

$L_{n,T,i}$ = the standardized sound pressure level for the third octave bands i in dB, given by

$$L_{n,T} = L + 10\log\left(\frac{T}{T_0}\right) \tag{4}$$

where:

L = sound pressure level in the receiving room (Equation 1) in dB

T = measured reverberation time in the receiving room in s

T_0 = reference reverberation time of 0.5 s

2.3.2 Japanese rubber ball

For the ball, the maximum sound pressure level L in the receiving room (Equation 2) was standardized to a reverberation time of 0.5 s and A-weighted, giving:

$$L_{F,\max,n,T,A} = 10\log \sum_{n} 10^{\left(\left(L_{F,\max,n,T,i} + L_{A,i}\right)/10\right)} \tag{5}$$

with:

$L_{F,max,n,T,A}$ = the A-weighted standardized maximum sound pressure level in dB

$L_{A,i}$ = the A-weighting values for the third octave bands i in dB

$L_{F,max,n,T,i}$ = the standardized maximum sound pressure level for the third octave bands i in dB, given by

$$L_{F,\max,n,T} = L_{F,\max} + 10\log\left(\frac{T}{T_0}\right) \tag{6}$$

where:

$L_{F,max}$ = maximum sound pressure level in the receiving room (Equation2) in dB

T = measured reverberation time in the receiving room in s

T_0 = reference reverberation time of 0.5 s

2.4 Sound reduction index

All measurements in the field were conducted on the basis of DIN EN ISO 140-4 [16]. The weighted sound reduction index R'_w, the weighted standardized sound pressure level difference $D'_{nT,w}$ and the spectrum adaption terms were calculated according to DIN EN ISO 717-1:2006 [6]. In all field measurements, flanking transmission was included. All the measurements were performed with stationary microphones. The signal was pink noise. Further details are given at the description of the specific measurements. The sound reduction index in the field was calculated by:

$$R' = L_1 - L_2 + 10\log\left(\frac{S}{A}\right) \tag{7}$$

with:

R′ = sound reduction index in dB, including flanking transmission

L_1 = Sound pressure level in the sending room in dB

L_2 = Sound pressure level in the receiving room in dB

S = Area of the separating element in m²

A = equivalent sound absorption area in m²

The standardised sound pressure level difference in the field was calculated by:

$$D'_{nT} = L_1 - L_2 + 10\log\left(\frac{T}{T_0}\right) \tag{8}$$

with

T = measured reverberation time in the receiving room in s

T_0 = reference reverberation time of 0.5 s

2.5 Impact sound pressure level of the tapping machine

All measurements in the field were conducted on the basis of DIN EN ISO 140-7 [17]. The weighted normalized impact sound pressure level $L'_{n,w}$, the weighted standardized impact sound pressure level $L'_{nT,w}$ and the spectrum adaption terms were calculated according to DIN EN ISO 717-2:2006 [7]. In all field measurements, flanking transmission was included. All the measurements were performed with stationary microphones. Further details are given at the description of the specific measurements. The normalized impact sound pressure level was calculated by:

$$L'_n = L_2 + 10\log\left(\frac{A}{A_0}\right) \tag{9}$$

with:

L'_n = normalized impact sound pressure level in dB, including flanking transmission

L_2 = sound pressure level in the receiving room in dB

A = equivalent sound absorption area in m²

A_0 = reference sound absorption area of 10 m²

The standardized impact sound pressure level was calculated by:

$$L'_{n,T} = L_2 + 10\log\left(\frac{T}{T_0}\right) \tag{10}$$

with:

$L'_{n,T}$ = standardized impact sound pressure level in dB, including flanking transmission

L_2 = sound pressure level in the receiving room in dB

T = measured reverberation time in s

T_0 = reference reverberation time of 0.5 s

A correction for the airborne sound transmission to the impact noise measurements was applied for L'_n and L'_{nT}. This correction was small (≤ 0,1 dB)

As the focus of the investigation were real living situations, the analysis of the signals within the AcuWood-Project was based on standardized impact sound levels with reference to 0.5 s.

2.6 Equipment used

For the measurements of the sound reduction index and the reverberation time following equipment was used:

- Real Time Analyser Norsonic type 840 S.-No.: 18736
- Power Amplifier Norsonic 235, S.-No. 22595
- Dodecahedron loudspeaker Norsonic type 229, , S.-No. 22568
- Preamplifier Norsonic 1201, S.-No. 22062 and S.-No.22063
- Mikrophones B&K type 4165, S.-No. 1158476 and S.-No 1330519
- Calibrator Bruel & Kjaer 4230 S.-No. 1472576

For the recording of the calibrated signals, the following equipment was used:

- Head Acoustics Frontend SQLab III, S.-No.: 35020102
- Dummy head Head Acoustics type HDM I.Q. S.-No.: 13001362
- Microphones G.R.A.S. type 46 AE, S.-No.: 88711, 88712, 88713, 88717, 88719, 88720, 88727, 88730

- Tapping machine Norsonic type 211 , Sr.-No. 706

2.7 Listening tests and questionnaires

With the recorded signals of the dummy head in the receiving rooms, listening tests were performed. The listening tests are a main and crucial part of the of the AcuWood study. The listening tests performed are described in AcuWood-report No. 3. Additional questionnaires were conducted within the project in Germany and Switzerland, also described in AcuWood report No. 3.

3 Field measurements in multi-storey multi-family houses

Additionally to the laboratory measurements and measurements in single family houses with wooden floors in Germany, reported in AcuWood-report No. 1, measurements in multi-storey multi-family houses were conducted in Switzerland. In Germany, multi-storey multifamily houses are not available in such a great number and are still rather of prototype character. In Switzerland; in the past years many wooden multi-storey multifamily houses have been build and in this time "standard" constructions of the floors have been developed. In the AcuWood project it has been tried to measure in buildings, which cover the most common "standard" floor constructions which are being built in Switzerland today. The choice of the buildings measured, the organisation of the measurements and the support at the building sites was covered by Lignum.

3.1 House A

House A was a newly build 6 – family house on two floors and an attic floor, with two flats on each floor. The building was a wooden building with a hollow box floor with ballast. The attic floor had large room height, so the measurements were conducted between first floor and ground floor of flat 1. Both floor plans of flat 1 on the first floor and flat 1 on the ground floor were identical. The measurement included flanking transmission.

Measurements were conducted between two room pairs, room 1 and room 2 of both flats. The sending room were situated on the first floor, the receiving rooms on the ground floor. The volume of the sending room 1 and receiving room 1 was 31.4 m³, the floor area of room situation 1 was 12.1 m². The volume of the sending room 2 and receiving room 2 was 45.2 m³, The floor area of room situation 2 was 17.4 m².

3.1.1 Description of the floor construction

The separating floor is described from top to bottom:

	floor covering parquet
55 mm	calcium-sulphate floating floor type "Fliessestrich C30-F6"

polyethylene foil

30 mm impact sound insulation „Isover PS 81", dynamic stiffness s´= 6 MN/m³

30 mm insulation mineral wool " Isover LURO 814", dynamic stiffness s´≤ 9 MN/m³ / installations

15 mm gypsum fibre board

254 mm wooden box floor of

27 mm wooden three-layer board

200 mm wooden beam structure with 200 mm mineral wool filling "Flumrock Dämmplatte 1", λ=0.036 W/mK

27 mm wooden three-layer board

The construction of the floor is given in figure 6.

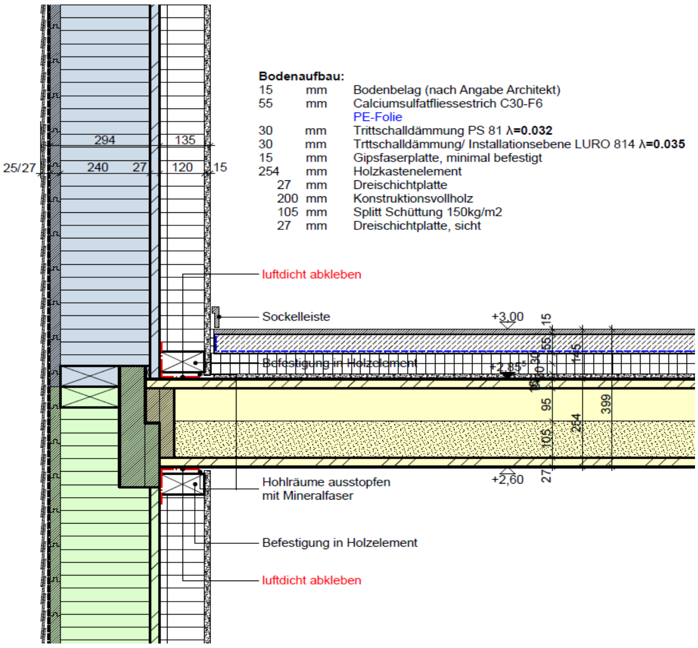


Figure 6: Floor construction of house A (Source: Manufacturer of house A, in German).

3.1.2 Description of the measurement conditions

In the Building A, the measurements were conducted similar to the laboratory measurements, described in AcuWood report 1 [18]. The same measurement equipment was used, given in Section 2.6. In table 1 the basic measurement conditions in house A are described:

Table 1: Description of the measurement conditions in house A.

House A	Description
Sending Room 1	First floor, flat 1, room 1, V = 31.4 m^3
Receiving Room 1	Ground floor, flat 1, , room 1, V = 31.4 m^3
Common separating floor area 1	12.1 m^2
Sending Room 2	First floor, flat 1, room 2, V = 45.2 m^3
Receiving Room 2	Ground floor, flat 1, , room 2, V = 45.2 m^3
Common separating floor area 2	17.4 m^2
Air temperature during measurement	20°C
Room conditions	unfurnished, each receiving room equipped with 2 sound absorbers
Floor surface	Parquet
Measurement airborne sound insulation	On the basis of DIN EN ISO 140-4 with following deviations: • Reduced number of microphone positions in the sending room The measurements were conducted with stationary microphones. Number of loudspeaker positions: 2 Number of independent microphone measurements: sending room 4, receiving room 12 Calculation of weighted sound reduction index and spectrum adaption terms according to DIN EN ISO 717-1: 2006.
Measurement impact noise	According to DIN EN ISO 140-7 . The measurements were conducted with stationary microphones. Number of tapping machine positions: 4. Number of independent microphone measurements: sending room 8, receiving room 24. Calculation of weighted normalized impact sound level and spectrum adaption terms according to DIN EN ISO 717-2: 2006
Additional measurements	• Modified Tapping machine similar as tapping machine • Japanese rubber ball, excitation on same 4 positions then tapping machine; number of ball drops on each

	position: 10; number of microphone positions in receiving room: 6. • Walking of persons as described in section 2.1.4, no female walker, male walker with shoes and socks: Moritz, number of independent microphone measurements 6; measurement duration 60 s. • Moving of chair: as described in section 2.1.5 on similar 4 positions then tapping machine; number of repeated drawing of chair at each position: 10; number of independent microphone positions in receiving room: 6.

3.1.3 Measurement results of house A

The measurement results of the weighted sound reduction index for room situation 1 are:

R'_w (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\,50\text{-}5000}$) = 65.6 (-1.5; -3.6; -10.2; -24.1) dB.

The measurement results of the weighted standardized level difference for room situation 1 are:

$D'_{nT,w}$ (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\,50\text{-}5000}$) = 64.8 (-1.3; -3.5; -10.0; -23.9) dB.

The results of the weighted normalized impact noise level for room situation 1 are:

$L'_{n,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 51.0 (-4.5; 7.7) dB.

The results of the weighted standardized impact noise level for room situation 1 are:

$L'_{nT,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 51.0 (-4.5; 7.7) dB.

The graph of the standardized level difference is given in figure AA1, the graph of the standardized impact sound level is given in figure AA2 in annex A.

The measurement results of the weighted sound reduction index for room situation 2 are:

R'_w (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\,50\text{-}5000}$) = 65.0 (-1.7; -4.9; -12.7; -26.7) dB.

The measurement results of the weighted standardized level difference for room situation 2 are:

$D'_{nT,w}$ (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\,50\text{-}5000}$) = 64.2 (-1.5; -4.7; -12.5; -26.5) dB.

The results of the weighted normalized impact noise level for room situation 2 are:

$L'_{n,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 52.8 (-4.8; 2.9) dB.

The results of the weighted standardized impact noise level for room situation 2 are:

$L'_{nT,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 51.2 (-4.8; 2.9) dB.

The graph of the standardized level difference is given in figure A3, the graph of the standardized impact sound level is given in figure A4 in annex A.

The values of the levels of the additional measurements are given in annex A.

3.2 House B

House B was a newly build three story tall wooden building with a wood-concrete-composite floor. The building has a concrete basement floor with a concrete ceiling, a ground floor and a first floor, separated by the wood-concrete-composite floor construction. The building has different-sized flats, the measurements were conducted between two flats in first floor and ground floor with similar floor plan. The roof is a visible shed roof, so the volumes of the rooms on the first floor are higher than on the ground floor. The flats had an open spaced living area with attached kitchen. Therefore the measurements of the floors were conducted between two bedrooms in the same flats. The room volumes of the first room combination were for the sending room 34.7 m³ and for the receiving room 30.5 m³, the separating floor had an area of 12.5 m². The room volumes of the second room combination were for the sending room 38.0 m³ and for the receiving room 37.2 m³, the separating floor had an area of 15.2 m².

3.2.1 Description of the floor construction

The separating floor is described from top to bottom:

	floor covering parquet	
80 mm	cement floating floor, m‘ = 160 kg/m²	
	Polyethylene foil	
17 mm	impact sound insulation mineral wool “Isover PS 81 20/17,” dynamic stiffness s´< 9 MN/m³	
20 mm	thermal insulation “Swisspor EPS 20”	
220 mm	concrete-wood-compound floor with	
	100/120 mm	concrete with reinforcement and
	120/100 mm	glued laminated timber, visible, m´= 324.5 kg/m²

The construction of the floor is given in figure 7 .

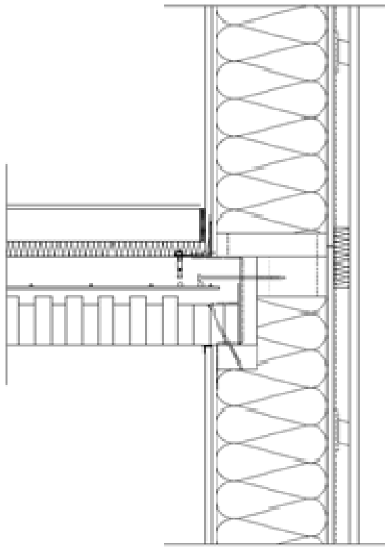


Figure 7: Floor construction of house B (Source: Manufacturer of house B).

3.2.2 Description of the measurement conditions

In the Building B, the measurements were conducted similar to the laboratory measurements and with the same measurement equipment. In table 2 the basic measurement conditions in house B are described:

Table 2: Description of the measurement conditions in house B.

House A	Description
Sending Room 1	First floor, flat 26.201, room 8, V = 34.7 m³
Receiving Room 1	Ground floor, flat 26.101, , room 8, V = 30.5 m³
Common separating floor area 1	12.5 m²
Sending Room 2	First floor, flat 26.201, room 6, V = 38.0 m³
Receiving Room 2	Ground floor, flat 26.101, room 6, V = 37.2 m³
Common separating floor area 2	15.2 m²

Air temperature during measurement	20°C
Room conditions	unfurnished, each receiving room equipped with 2 sound absorbers
Floor surface	Parquet
Measurement airborne sound insulation	According to DIN EN ISO 140-4. The measurements were conducted with stationary microphones. Number of loudspeaker positions: 2. Number of independent microphone measurements: sending room: 12; receiving room :12. Measurement duration: 60s. Calculation of weighted sound reduction index and spectrum adaption terms according to DIN EN ISO 717-1: 2006.
Measurement impact noise	According to DIN EN ISO 140-7 . The measurements were conducted with stationary microphones. Number of tapping machine positions: 4. Number of independent microphone measurements: sending room 8, receiving room 24. Calculation of weighted normalized impact sound level and spectrum adaption terms according to DIN EN ISO 717-2: 2006
Additional measurements	• Modified Tapping machine similar as tapping machine • Japanese rubber ball: excitation on same 4 positions then tapping machine; number of ball drops on each position: 10; number of microphone positions in receiving room: 6. • Walking of persons as described in section 2.1.4; male walker with shoes and socks: Moritz. Number of independent microphone measurements: 6; measurement duration 60 s. • Moving of chair: as described in section 2.1.5 on similar 4 positions then tapping machine; number of repeated drawing of chair at each position: 10; number of independent microphone positions in receiving room: 6.

3.2.3 Measurement results of house B

The measurement results of the weighted sound reduction index for room situation 1 are:

R'_w (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\,50\text{-}5000}$) = 63.4 (-1.6; -4.8; -1.1; -8.2) dB.

The measurement results of the weighted standardized level difference for room situation 1 are:

$D'_{nT,w}$ (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\,50\text{-}5000}$) = 62.3 (-1.7; -4.9; -1.2; -8.3) dB.

The results of the weighted normalized impact noise level for room situation 1 are:

$L'_{n,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 44.3 (-3.0; 2.4) dB.

The results of the weighted standardized impact noise level for room situation 1 are:

$L'_{nT,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 44.4 (-3.0; 2.4) dB.

The graph of the sound reduction index is given in figure B1, the graph of the normalized impact sound level is given in figure B2 in annex B. The values of the levels of the additional measurements are given in annex B.

The measurement results of the weighted sound reduction index for room situation 2 are:

R'_w (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\ 50\text{-}5000}$) = 62.4 (-1.7; -5.5; -1.8; -10.9) dB.

The measurement results of the weighted standardized level difference for room situation 2 are:

$D'_{nT,w}$ (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\ 50\text{-}5000}$) = 61.3 (-1.8; -5.5; -1.8; -11.0) dB.

The results of the weighted normalized impact noise level for room situation 2 are:

$L'_{n,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 43.7 (-2.7; 4.6) dB.

The results of the weighted standardized impact noise level for room situation 2 are:

$L'_{nT,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 43.0 (-2.8; 4.5) dB.

The graph of the sound reduction index is given in figure B3, the graph of the normalized impact sound level is given in figure B4 in annex B. The values of the levels of the additional measurements are given in annex B.

3.3 House C

House C was a newly build four storey wooden house with three flats. The floors and walls were made of massive timber (Brettstapel), with additional ballast on the floors. The wooden construction was erected on a concrete ground floor, which included basement rooms and garages. First and second floor included two flats with similar floor plan, the third floor was the attic flat with smaller ground floor, but a roof balcony. The roof of the building was a platform roof. On one side to the building, on a separate concrete construction, balconies on each floor were added. There was no structural connection between the wooden construction and the balconies.

The living rooms of both flats was not practical for measurements, as they were open to the accessing entrance hall. The measurements were conducted between the second and first floor, measuring the massive timber floor construction of two bedroom combinations.

The measured floor separated bedrooms on the second floor and the first floor. The volume of the sending and receiving room of the first room combination was 31.5 m³, Both rooms had a common separating floor area of 12.9 m². The volume of the sending and receiving room of the second room combination was 33.1 m³, Both rooms had a common separating floor area of 13.6 m².

3.3.1 Description of the floor construction

The separating floor of house C is described from top to bottom:

10 mm floor covering parquet

85 mm Cement floating floor, unit area mass m´ = 180 kg/m²

Polyethylene foil

40 mm Thermal insulation "Roll-EPS20 +EPS 30", dynamic stiffness s´> 30 MN/m³

50 mm Ballast of cement floor plates, m´= 120 kg/m², fixed by cold bitumen

15 mm OSB plates

180 mm Massive timber (Brettstapel) "Bresta"

The construction of the floor is given in figure 8

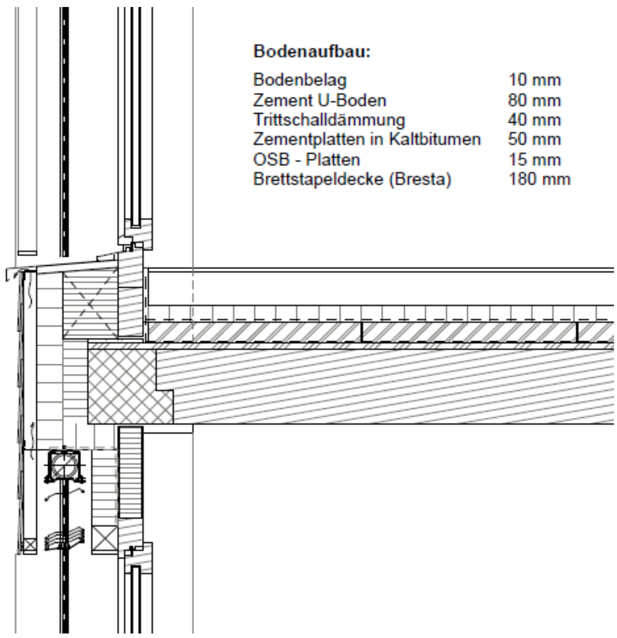


Figure 8: Floor construction of house C (Source: Manufacturer of house C, in German).

3.3.2 Description of the measurement conditions

In Building C, the measurements were conducted similar to the laboratory measurements and with the same measurement equipment. In table 3 the basic measurement conditions in house C are described:

Table 3: Description of the measurement conditions in house C.

House C	Description
Sending Room room 1	Room 2, second floor, V = 31.5 m^3
Receiving Room 1	Room 2, first floor, V = 31.5 m^3
Common separating floor area 1	12.9 m^2
Sending Room room 2	Room 3, second floor, V = 33.1 m^3
Receiving Room 2	Room 3, first floor, V = 33.1 m^3
Common separating floor area 2	13.6 m^2
Air temperature during measurement	20°C
Room conditions	Unfurnished with additional two sound absorbers in the sending rooms on second floor, furnished on first floor
Floor surface	Parquet
Measurement airborne sound insulation	According to DIN EN ISO 140-4. The measurements were conducted with stationary microphones. Number of loudspeaker positions: 2. Number of independent microphone measurements: sending room: 12; receiving room :12. Measurement duration: 60s. Calculation of weighted sound reduction index and spectrum adaption terms according to DIN EN ISO 717-1: 2006.

Measurement impact noise	According to DIN EN ISO 140-7 . The measurements were conducted with stationary microphones. Number of tapping machine positions: 4. Number of independent microphone measurements: receiving room 24. Calculation of weighted normalized impact sound level and spectrum adaption terms according to DIN EN ISO 717-2: 2006
Additional measurements	• Modified Tapping machine similar as tapping machine • Japanese rubber ball: excitation on same 4 positions then tapping machine; number of ball drops on each position: 10; number of microphone positions in receiving room: 6. • Walking of persons as described in section 2.1.4; male walker with shoes and socks: Moritz. Number of independent microphone measurements: 6; measurement duration 60 s. • Moving of chair: as described in section 2.1.5 on similar 4 positions then tapping machine; number of repeated drawing of chair at each position: 10; number of independent microphone positions in receiving room: 6.

3.3.3 Measurement results of house C

The measurement results of the weighted sound reduction index for room situation 1 are:

R'_w (C; C_{tr}; $C_{50-5000}$; $C_{tr,\,50-5000}$) = 60.8 (-1.6; -4.8; -2.1; -11.6) dB.

The measurement results of the weighted standardized level difference for room situation 1 are:

$D'_{nT,w}$ (C; C_{tr}; $C_{50-5000}$; $C_{tr,\,50-5000}$) = 59.7 (-1.7; -4.9; -2.2; -11.7) dB.

The results of the weighted normalized impact noise level for room situation 1 are:

$L'_{n,w}$ ($C_{I,100-2500}$; $C_{I,50-2500}$) = 52.1 (1.0; 3.7) dB.

The results of the weighted standardized impact noise level for room situation 1 are:

$L'_{nT,w}$ ($C_{I,100-2500}$; $C_{I,50-2500}$) = 52.1 (1.0; 3.7) dB.

The graph of the standardised level difference is given in figure CC1, the graph of the standardized impact sound level is given in figure CC2 in annex C. The values of the levels of the additional measurements are given in annex C.

The measurement results of the weighted sound reduction index for room situation 2 are:

R'_w (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\,50\text{-}5000}$) = 60.7 (-0.7; -3.6; -0.6; -8.7) dB.

The measurement results of the weighted standardized level difference for room situation 2 are:

$D'_{nT,w}$ (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\,50\text{-}5000}$) = 59.7 (-0.8; -3.7; -0.7; -8.8) dB.

The results of the weighted normalized impact noise level for room situation 2 are:

$L'_{n,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 52.9 (0.4; 2.1) dB.

The results of the weighted standardized impact noise level for room situation 2 are:

$L'_{nT,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 52.7 (0.4; 2.1) dB.

The graph of the standardised level difference is given in figure C3, the graph of the standardized impact sound level is given in figure C4 in annex C. The values of the levels of the additional measurements are given in annex C.

3.4 House D

House D was newly build wooden building complex of two fife storey buildings with 155 flats. The construction was made of wood, the floors are ribbed wooden floors of glued laminated timber with ballast. The measurements were conducted of the floor between two flats with similar floor plan on 4th and 3rd floor. As the living rooms of the flats were open to the hall way, the measurement were conducted between two different sized bedroom pairs.

The volume of the sending and receiving room of the first room combination was 35.5 m³, Both rooms had a common separating floor area of 14.4 m². The volume of the sending and receiving room of the second room combination was 45.0 m³, Both rooms had a common separating floor area of 18.2 m².

The floor construction of room combination 1 was homogeneous, for the room combination 2, the floor was not homogeneous, but consisted of two parts, as the room stretched over two differently constructed floor parts. The floor constructions are described below.

3.4.1 Description of the floor construction

The main separating floor of both room combinations of the outer field in house D is described from top to bottom:

	floor covering parquet
60 mm	Anhydride floating floor, unit area mass m´ = 115 kg/m²
2 x 20 mm	Impact sound insulation "Brumma Isoroll PE 20/17", dynamic stiffness s´< 9 MN/m³

30 mm   Ballast chipping (flint), m´ = 45 kg/m²

Foil against water

27 mm   wood-based three-layer-board, m´ = 12.2 kg/m²

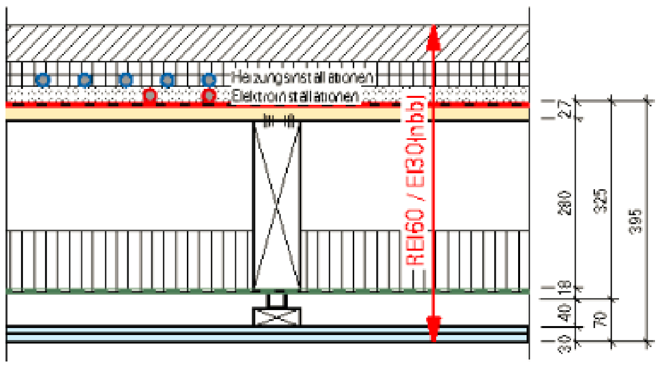
280 mm   wooden ribbed floor of glued laminated timber, e=625 mm, m´ = 20.2 kg/m² with

100 mm   mineral wool filling “Flumroc Type 1”, m´ = 3.2 kg/m²

45 mm   suspended ceiling with metal construction and spring shackle and 40 mm mineral wool filling “Rigips Isoresist Piano Plus “ near the walls, with 400 mm width

2 15 mm   Gypsum boards m´= 2 x 13.2 kg/m²

The construction of the floor of the outer filed is given in figure 9.



Statik:	tragend
Brandschutz:	REI60/EI30nbb
Bemerkung:	Minergie-P-ECO

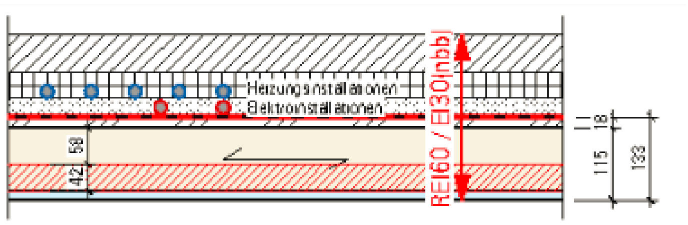
Aufbau Aussenfeld (Rippendecke):		
- Bodenbelag Anhydrid geschliffen		
- Anhydritestrich	60mm	
- Trittschalldämmung	2x20mm	BKZ 6q.3
- Sandschüttung in Waben	30mm	
- Löschwasserfolie		
- Rippendecke verleimt, bestehend aus:		
Dreischichtplatte, Stösse		
Luftdicht ausgebildet	27 mm	BKZ 4.3
Rippen C24, a=650mm	80/280 mm	BKZ 4.3
- Mineralwolle	100 mm	BKZ 6q.3
- Flies für Befestigung der Dämmung		
- Federbügel mit Lattung gem Architekt	ca. 58 mm	BKZ 4.3
- Gipfaserplatte	2 x 12.5 mm	BKZ 6q.3

Figure 9: Floor construction of the outer field of house D (Source: Manufacturer of house D, in German).

The floor of the outer field stretches over the entire floor of room combination 1 and over 14.23 m² of the floor of room combination 2. The rest of the floor of room combination 2 of 3,97 m² is constructed by the inner field floor, described in the following:

	floor covering parquet
60 mm	Anhydride floating floor, unit area mass m´ = 115 kg/m²
2 x 20 mm	Impact sound insulation "Brumma Isoroll PE 20/17", dynamic stiffness s´< 9 MN/m³
30 mm	Ballast chipping (flint), m´ = 45 kg/m²
	Foil against water
27 mm	wood-based three-layer-board, m´ = 12.2 kg/m²
100 mm	massive glue laminated timber, m´ = 45.0 kg/m² with
15 mm	gypsum fibre board m´ = 17.2 kg/m²
202 mm	suspended ceiling with metal construction and spring shackle and 40 mm mineral wool filling "Rigips Isoresist Piano Plus " near the walls, with 400 mm width
2 15 mm	Gypsum boards m´= 2 x 13.2 kg/m²

The construction of the floor of the inner filed is given in figure 10.



SUSPENDED CEILING

Statik:	tragend
Brandschutz:	REI60/EI30nbb
Bemerkung:	Minergie-P-ECO

Aufbau Innenfelder (Brettschichtholz):		
- Bodenbelag Anhydrid geschliffen		
- Anhydritestrich	*60mm*	
- Trittschalldämmung	*2x20mm*	*BKZ 6q.3*
- Sandschüttung in Waben	*30mm*	
- Löschwasserfolie		
- OSB-3- OSB-3 (formaldehydfrei,vernagelt mit BSH		
Stösse Luftdicht ausgebildet	18 mm	BKZ 4.3
- Brettschichtholz	100 mm	BKZ 4.3
- Gipsfaserplatte FERMACELL oder gleichwertig	15 mm	BKZ 6q.3

Figure 10: Floor construction of the inner field of house D, which covers a small part of the floor of room combination 2 in house D (Source: Manufacturer of house D, in German).

3.4.2 Description of the measurement conditions

In house D, the measurements were conducted similar to the laboratory measurements and with the same measurement equipment. In table 4 the basic measurement conditions in house D are described:

Table 4: Description of the measurement conditions in house D.

House D	Description
Sending Room 1	Room 2, 4th floor, V = 35.5 m³
Receiving Room 1	Room 2, 3rd floor, V = 35.5 m³
Common separating floor area 1	14.4 m²
Sending Room 2	Room 1, 4th floor, V = 45.0 m³
Receiving Room 2	Room 1, 3rd floor, V = 45.0 m³
Common separating floor area 2	18.2 m²
Air temperature during measurement	20°C

Room conditions	Unfurnished with additional two sound absorbers in the receiving rooms on 3rd floor
Floor surface	Parquet
Measurement airborne sound insulation	According to DIN EN ISO 140-4. The measurements were conducted with stationary microphones. Number of loudspeaker positions: 2. Number of independent microphone measurements: sending room: 12; receiving room :12. Measurement duration: 60s. Calculation of weighted sound reduction index and spectrum adaption terms according to DIN EN ISO 717-1: 2006.
Measurement impact noise	According to DIN EN ISO 140-7 . The measurements were conducted with stationary microphones. Number of tapping machine positions: 4. Number of independent microphone measurements: receiving room 24. Calculation of weighted normalized impact sound level and spectrum adaption terms according to DIN EN ISO 717-2: 2006
Additional measurements	• Modified Tapping machine similar as tapping machine • Japanese rubber ball: excitation on same 4 positions then tapping machine; number of ball drops on each position: 10; number of microphone positions in receiving room: 6. • Walking of persons as described in section 2.1.4; male walker with shoes and socks: Moritz. Number of independent microphone measurements: 6; measurement duration 60 s. • Moving of chair: as described in section 2.1.5 on similar 4 positions then tapping machine; number of repeated drawing of chair at each position: 10; number of independent microphone positions in receiving room: 6.

3.4.3 Measurement results of house D

The measurement results of the weighted sound reduction index for room situation 1 are:

R'_w (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\,50\text{-}5000}$) = 77.6 (-1.5; -6.6; -8.9; -22.4) dB.

The measurement results of the weighted standardized level difference for room situation 1 are:

$D'_{nT,w}$ (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\,50\text{-}5000}$) = 76.6 (-1.5; -6.6; -8.9; -22.5) dB.

The results of the weighted normalized impact noise level for room situation 1 are:

$L'_{n,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 38.9 (1.5; 12.3) dB.

The results of the weighted standardized impact noise level for room situation 1 are:

$L'_{nT,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 38.4 (1.5; 12.3) dB.

The graph of the sound reduction index is given in figure DD1, the graph of the normalized impact sound level is given in figure DD2 in annex D. The values of the levels of the additional measurements are given in annex D.

The measurement results of the weighted sound reduction index for room situation 2 are:

R'_w (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\,50\text{-}5000}$) = 78.2 (-1.9; -7.3; -7.4; -20.8) dB.

The measurement results of the weighted standardized level difference for room situation 2 are:

$D'_{nT,w}$ (C; C_{tr}; $C_{50\text{-}5000}$; $C_{tr,\,50\text{-}5000}$) = 77.2 (-2.0; -7.3; -7.4; -20.8) dB.

The results of the weighted normalized impact noise level for room situation 2 are:

$L'_{n,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 36.7 (2.2; 13.6) dB.

The results of the weighted standardized impact noise level for room situation 2 are:

$L'_{nT,w}$ ($C_{I,100\text{-}2500}$; $C_{I,50\text{-}2500}$) = 35.1 (2.2; 13.6) dB.

The graph of the sound reduction index is given in figure D3, the graph of the normalized impact sound level is given in figure D4 in annex D. The values of the levels of the additional measurements are given in annex D.

4 Conclusions

In this report, the basic information of the field measurements in multi-storey and multi-family houses in Switzerland within the AcuWood project are reported The conducted measurements in the laboratories of the IBP and in German single family houses in the field are described in AcuWood project report No. 1. The conducted listening tests are described in AcuWood Project report No.3. Results from the correlation analysis of objective and subjective ratings are described in AcuWood project report No. 4 and in Späh [19], results of the questionnaire survey are described in Liebl [20].

5 Literature

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Appendix A: Basic data of the measurements in house A

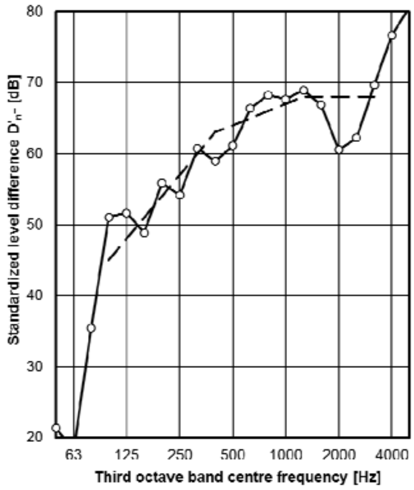

Figure A1: Measured standardized level difference in house A in room situation 1
(-o- measurement, – – reference curve)

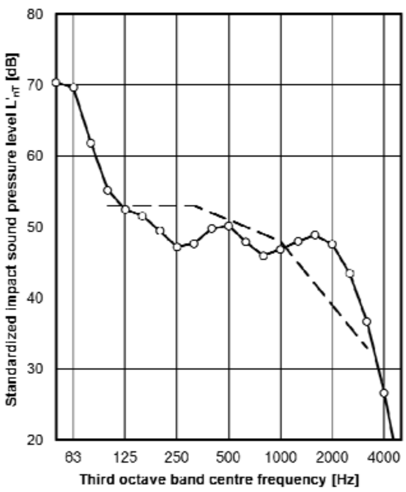

Figure A2: Measured standardized impact sound pressure level of house A in room situation 1
(-o- measurement, – – reference curve)

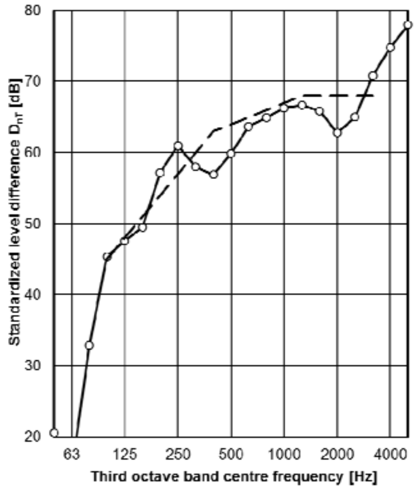

Figure A3: Measured standardized level difference in house A in room situation 2
(-O- measurement, – – reference curve)

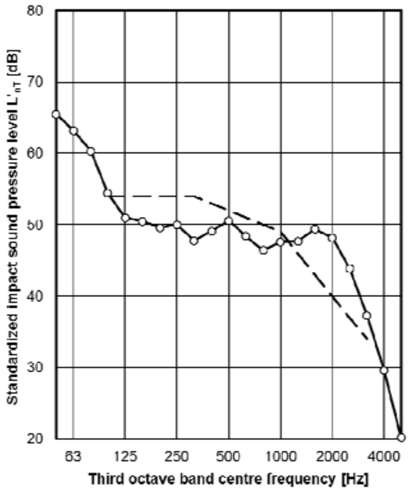

Figure A4: Measured standardized impact sound pressure level of house A in room situation 2
(-O- measurement, – – reference curve)

In the following tables, the basic data of the measurements is listed.

- The reverberation time in the receiving room. The reverberation time was measured with the conventional method of stationary pink noise, turned off to measure the reverberation time. The measured reverberation times were above the given values for the minimum reverberation time to be measured with Norsonic [21].

- The measured sound pressure levels of the airborne sound transmission measurement. The excitation was performed by an dodecahedron loudspeaker at two positions in the sending room, the signal was pink noise. The measurements were conducted by stationary microphones, the measurement duration was 60 seconds. The different microphone measurements were averaged energetically in the sending and receiving room.

- The recorded signals of the different impact sources in the receiving room. The third-octave band value were calculated by the filter function with filters of 6th degree Head Acoustics Artemis. For the max value of the ball drop, the third octave max function of Artemis was used, with time constant fast (125 ms).

Table A1: Reverberation time of the receiving room, house A

Frequency [Hz]	Reverberation time [s] receiving room 1	Reverberation time [s] receiving room 2
20	0.67	0.97
25	1.04	2.08
31.5	0.91	1.36
40	0.86	1.13
50	0.84	0.59
63	0.90	1.06
80	0.89	1.12
100	0.87	1.31
125	0.87	1.32
160	0.78	1.16
200	0.87	1.33
250	1.29	1.53
315	1.42	1.73
400	1.41	1.67
500	1.31	1.80
630	1.39	1.73
800	1.40	1.66
1000	1.32	1.67
1250	1.35	1.66
1600	1.27	1.59
2000	1.13	1.45
2500	1.16	1.39
3150	1.23	1.47
4000	1.20	1.44
5000	1.14	1.31
L-netw	1.26	1.62
A-netw	1.32	1.65

Table A2: Averaged third octave band levels of the airborne sound insulation measurement of sending and receiving room for the room situation 1, house A.

Frequency [Hz]	Sound pressure level L_1 [dB] sending room	Sound pressure level L_2 [dB] receiving room
20	64.7	34.5
25	68.6	36.9
31.5	72.2	37.3
40	78.7	56.8
50	84.9	65.8
63	86.5	70.7
80	93.4	60.3
100	102.6	53.9
125	107.3	58.0
160	107.8	60.8
200	108.5	55.0
250	106.5	56.5
315	101.0	44.7
400	102.0	47.5
500	100.2	43.2
630	100.6	38.7
800	100.4	36.5
1000	99.1	35.6
1250	100.3	35.6
1600	99.0	36.1
2000	96.8	39.7
2500	96.9	38.3
3150	94.4	28.6
4000	94.2	21.2
5000	91.4	14.8

Table A3: Averaged third octave band levels of the sources standard and modified tapping machine, the chair and the Japanese rubber ball for the room situation 1, house A.

Frequency [Hz]	Standard tapping machine level L [dB]	Modified tapping machine level L [dB]	Chair level L [dB]	Japanese rubber Ball $L_{F,max}$ [dB]
20	72.6	69.9	53.8	85.4
25	60.7	60.8	64.1	80.8
31.5	61.2	58.6	56.7	79.2
40	72.5	63.6	54.2	86.2
50	72.7	61.9	64.1	85.3
63	72.5	59.2	66.0	74.9
80	64.4	50.0	58.2	64.0
100	57.6	37.4	49.2	55.4
125	54.9	35.4	45.4	52.2
160	53.6	32.0	42.5	49.4
200	51.9	29.6	40.4	45.7
250	51.3	24.6	38.7	40.7
315	52.2	17.8	41.1	38.8
400	54.3	20.0	38.5	36.8
500	54.4	18.6	35.1	32.8
630	52.3	13.1	30.5	27.6
800	50.5	11.6	22.3	22.2
1000	51.1	12.4	18.9	20.1
1250	52.3	14.3	14.8	18.5
1600	52.9	15.7	10.4	17.0
2000	51.2	23.2	7.7	15.2
2500	47.2	18.6	5.6	11.9
3150	40.6	16.0	5.6	9.0
4000	30.5	12.1	5.3	7.1
5000	18.3	7.4	5.2	6.3

Table A4: Averaged third octave band levels of the walkers and the background noise in the receiving room for the room situation 1, house A.

Frequency [Hz]	Male walker hard footwear level L[dB]	Male walker socks level L [dB]	Background noise L [dB]
20	52.3	58.3	25.7
25	46.3	49.0	29.7
31.5	42.0	50.3	33.3
40	44.2	55.5	38.4
50	43.1	55.6	37.3
63	42.9	53.1	35.1
80	34.5	35.6	23.3
100	28.9	25.6	21.1
125	27.4	22.0	23.3
160	24.1	16.9	19.0
200	20.7	14.6	14.9
250	15.5	13.2	9.4
315	13.7	11.5	11.2
400	9.6	7.6	5.5
500	4.8	3.5	3.9
630	2.7	2.4	1.6
800	2.7	2.8	1.8
1000	2.2	2.1	2.1
1250	2.2	2.4	1.9
1600	2.4	2.3	2.2
2000	4.1	3.3	2.9
2500	4.2	3.8	3.5
3150	4.4	4.2	4.1
4000	4.6	4.5	4.5
5000	4.9	4.8	4.8

Table A5: Averaged third octave band levels of the airborne sound insulation measurement of sending and receiving room for the room situation 2, house A.

Frequency [Hz]	Sound pressure level L_1 [dB] sending room	Sound pressure level L_2 [dB] receiving room
20	59.8	41.4
25	64.3	40.4
31.5	71.4	43.3
40	83.7	59.5
50	79.9	60.0
63	80.4	68.2
80	85.0	55.6
100	93.9	52.7
125	103.7	60.3
160	104.6	58.7
200	107.6	54.7
250	108.7	52.6
315	104.4	51.9
400	101.5	49.8
500	101.4	47.0
630	101.1	42.8
800	99.2	39.5
1000	98.6	37.5
1250	100.3	38.8
1600	98.3	37.4
2000	95.6	37.4
2500	96.6	36.1
3150	93.7	27.6
4000	93.1	22.9
5000	90.1	16.6

Table A6: Averaged third octave band levels of the sources standard and modified tapping machine, the chair and the Japanese rubber ball for the room situation 2, house A.

Frequency [Hz]	Standard tapping machine level L [dB]	Modified tapping machine level L [dB]	Chair level L [dB]	Japanese rubber Ball $L_{F,max}$ [dB]
20	64.5	64.8	49.4	78.6
25	61.0	57.3	69.1	77.3
31.5	60.5	57.0	60.7	78.0
40	72.5	62.8	53.1	83.2
50	66.3	57.1	57.4	80.4
63	66.8	58.1	59.7	67.2
80	63.8	47.9	54.6	60.5
100	58.6	38.4	49.9	56.3
125	55.2	36.8	45.8	49.1
160	54.2	31.1	42.2	47.1
200	53.8	31.7	41.9	47.5
250	54.8	28.6	41.8	44.3
315	53.3	20.9	41.9	38.5
400	54.5	22.3	38.2	34.4
500	56.2	21.3	36.1	32.5
630	53.8	17.2	31.7	27.9
800	51.6	16.1	23.5	21.1
1000	52.8	18.4	19.4	19.4
1250	52.9	18.1	14.5	16.7
1600	54.4	17.4	10.5	16.0
2000	52.9	20.8	7.3	13.7
2500	48.4	17.0	5.6	9.9
3150	42.0	16.3	5.6	7.3
4000	34.2	13.9	5.1	6.2
5000	24.4	8.7	5.0	6.1

Table A7: Averaged third octave band levels of the walkers and the background noise in the receiving room for the room situation 2, house A.

Frequency [Hz]	Male walker hard footwear level L[dB]	Male walker socks level L [dB]	Background noise L [dB]
20	50.9	56.6	25.7
25	49.8	55.0	29.7
31.5	44.8	54.3	33.3
40	46.1	59.9	38.4
50	42.8	56.8	37.3
63	38.1	51.9	35.1
80	32.0	39.8	23.3
100	29.1	32.4	21.1
125	28.5	26.6	23.3
160	23.5	15.9	19.0
200	21.1	14.6	14.9
250	16.1	9.0	9.4
315	12.1	8.3	11.2
400	8.1	5.1	5.5
500	5.3	3.0	3.9
630	2.7	1.4	1.6
800	2.0	1.3	1.8
1000	1.7	1.4	2.1
1250	1.6	1.7	1.9
1600	2.1	2.0	2.2
2000	2.9	2.6	2.9
2500	3.6	3.2	3.5
3150	4.1	3.8	4.1
4000	4.6	4.3	4.5
5000	4.9	4.6	4.8

Appendix B: Basic data of the measurements in house B

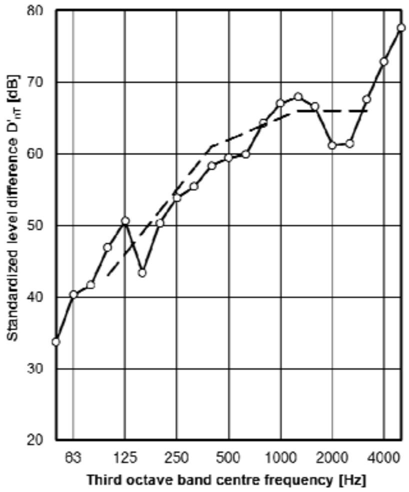

Figure B1: Measured standardized level difference in house B in room situation 1
(-O- measurement, – – reference curve)

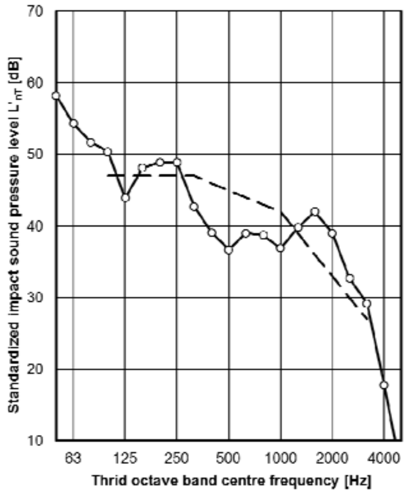

Figure B2: Measured standardized impact sound pressure level in house B in room situation 1
(-O- measurement, – – reference curve)

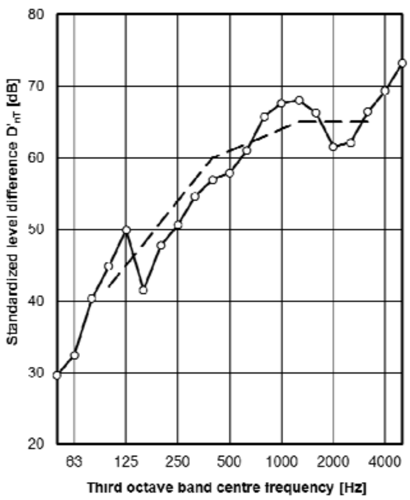

Figure B3: Measured standardized level difference in house B in room situation 2
(-O- measurement, – – reference curve)

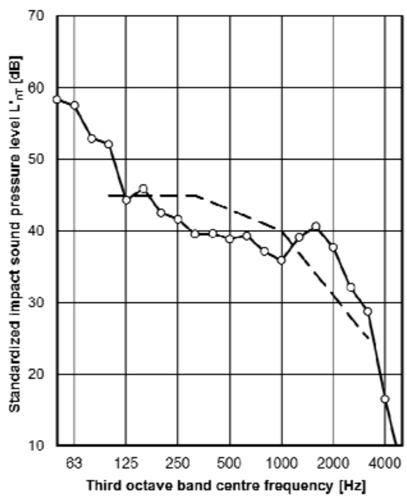

Figure B4: Measured standardized impact sound pressure level in house B in room situation 2
(-O- measurement, – – reference curve)

In the following tables, the basic data of the measurements is listed.

- The reverberation time in the receiving rooms. The reverberation time was measured with the conventional method of stationary pink noise, turned off to measure the reverberation time. The measured reverberation times were above the given values for the minimum reverberation time to be measured with Norsonic 840 [21].

- The measured sound pressure levels of the airborne sound transmission measurement. The excitation was performed by an dodecahedron loudspeaker at two positions in the sending room, the signal was pink noise. The measurements were conducted by stationary microphones, the measurement duration was 60 seconds. The different microphone measurements were averaged energetically in the sending and receiving room.

- The recorded signals of the different impact sources in the receiving room. The third-octave band value were calculated by the filter function with filters of 6th degree Head Acoustics Artemis. For the max value of the ball drop, the third octave max function of Artemis was used, with time constant fast (125 ms).

Table B1: Reverberation time of the receiving rooms of room situation 1 and room situation 2, house B

Frequency [Hz]	Reverberation time [s] receiving room room situation 1	Reverberation time [s] receiving room room situation 2
20	1.36	1.41
25	1.01	0.99
31.5	0.77	0.82
40	0.60	0.83
50	0.86	0.82
63	0.71	0.84
80	0.56	0.73
100	0.45	0.43
125	0.82	0.91
160	0.96	1.29
200	0.99	1.35
250	1.29	1.35
315	1.55	1.58
400	1.44	1.47
500	1.55	1.41
630	1.38	1.33
800	1.34	1.37
1000	1.17	1.34
1250	1.07	1.24
1600	0.99	1.13
2000	1.00	1.09
2500	1.01	1.11
3150	1.06	1.18
4000	1.01	1.11
5000	0.93	1.03
L-netw	1.31	1.44
A-netw	1.27	1.34

TableB2:Averaged third octave band levels of the airborne sound insulation measurement of sending and receiving room, room situation 1, house B.

Frequency [Hz]	Sound pressure level L_1 [dB] sending room	Sound pressure level L_2 [dB] receiving room
20	65.2	33.1
25	68.2	34.3
31.5	71.4	29.8
40	78.4	41.9
50	88.2	56.9
63	86.1	47.3
80	85.8	44.7
100	97.7	50.3
125	103.5	55.0
160	105.0	64.4
200	105.2	57.9
250	107.1	57.3
315	103.9	53.3
400	103.1	49.4
500	102.9	48.4
630	101.3	45.7
800	99.0	38.9
1000	98.5	35.1
1250	100.3	35.6
1600	99.1	35.4
2000	96.8	38.6
2500	97.2	38.7
3150	94.4	30.0
4000	94.1	24.2
5000	90.7	16.1

Table B3: Averaged third octave band levels of the sources standard and modified tapping machine, the chair and the Japanese rubber ball, room situation 1, house B.

Frequency [Hz]	Standard tapping machine level L [dB]	Modified tapping machine level L [dB]	Chair level L [dB]	Japanese rubber Ball $L_{F,max}$ [dB]
20	63.0	63.5	61.7	79.8
25	60.4	63.1	66.9	78.6
31.5	55.8	50.4	50.6	71.5
40	57.2	47.1	44.7	70.1
50	60.6	48.8	54.3	73.3
63	55.9	42.2	50.9	63.5
80	52.2	35.4	46.5	54.4
100	49.9	26.8	42.3	52.0
125	46.1	27.2	39.0	45.0
160	50.9	25.4	41.2	47.0
200	51.9	28.0	41.5	43.7
250	53.0	25.5	43.9	40.2
315	47.6	17.3	40.1	34.0
400	43.7	17.9	34.2	29.3
500	41.6	17.4	27.7	24.2
630	43.4	14.0	24.4	24.7
800	43.0	10.0	18.3	25.0
1000	40.6	8.9	12.3	21.6
1250	43.1	10.9	7.9	25.0
1600	45.0	11.5	5.8	28.8
2000	42.0	17.4	4.6	23.0
2500	35.8	15.2	4.0	13.6
3150	32.5	15.3	4.4	10.0
4000	20.9	11.8	4.8	7.5
5000	9.7	7.0	5.2	6.6

Table B4: Averaged third octave band levels of the walkers and the background noise in the receiving room, room situation 1,house B.

Frequency [Hz]	Male walker hard footwear level L[dB]	Male walker socks level L [dB]	Background noise L [dB]
20	51.7	55.8	19.2
25	51.7	54.4	19.7
31.5	37.5	45.1	15.7
40	35.7	44.5	16.0
50	37.2	48.2	25.6
63	31.0	40.1	19.0
80	23.0	29.7	14.5
100	23.9	23.4	21.6
125	17.7	14.8	11.9
160	16.8	12.0	9.7
200	17.2	10.5	9.1
250	19.2	6.7	5.5
315	12.4	4.4	3.5
400	6.8	1.8	1.5
500	2.2	0.0	0.0
630	1.0	0.5	0.5
800	2.1	2.2	2.3
1000	1.2	1.6	1.9
1250	1.8	2.3	2.2
1600	2.3	2.4	2.4
2000	2.9	2.9	3.0
2500	3.6	3.6	3.7
3150	4.2	4.1	4.2
4000	4.8	4.7	4.8
5000	5.2	5.1	5.2

TableB5:Averaged third octave band levels of the airborne sound insulation measurement of sending and receiving room, room situation 2, house B.

Frequency [Hz]	Sound pressure level L_1 [dB] sending room	Sound pressure level L_2 [dB] receiving room
20	66.0	40.0
25	70.1	32.6
31.5	78.5	52.1
40	83.1	58.7
50	85.7	58.2
63	91.2	61.1
80	90.6	52.0
100	94.8	49.3
125	102.5	55.1
160	105.7	68.2
200	106.0	62.5
250	104.0	57.7
315	103.5	53.8
400	103.1	50.8
500	102.7	49.3
630	100.6	43.9
800	98.9	37.6
1000	98.5	35.2
1250	100.3	36.2
1600	99.2	36.4
2000	96.9	38.8
2500	97.2	38.5
3150	94.3	31.6
4000	94.0	28.1
5000	90.7	20.6

Table B6: Averaged third octave band levels of the sources standard and modified tapping machine, the chair and the Japanese rubber ball, room situation 2, house B.

Frequency [Hz]	Standard tapping machine level L [dB]	Modified tapping machine level L [dB]	Chair level L [dB]	Japanese rubber Ball $L_{F,max}$ [dB]
20	70.8	66.0	54.9	80.6
25	52.3	52.1	54.2	70.2
31.5	67.5	57.8	57.8	81.3
40	65.6	57.4	54.9	79.5
50	60.5	47.9	51.2	70.9
63	59.8	46.8	51.4	63.1
80	54.6	40.2	47.2	54.8
100	51.5	31.5	42.8	55.1
125	47.0	29.7	38.5	46.0
160	50.0	25.0	40.8	47.1
200	46.9	22.1	39.0	39.1
250	45.9	21.6	37.3	35.8
315	44.6	16.3	36.3	30.8
400	44.3	21.2	31.8	28.5
500	43.4	19.2	26.4	24.2
630	43.6	13.5	21.6	19.2
800	41.5	10.0	14.9	14.6
1000	40.2	9.4	10.5	12.8
1250	43.0	11.6	6.6	11.5
1600	44.2	13.2	5.1	10.7
2000	41.1	18.8	4.7	8.3
2500	35.6	15.9	4.0	7.2
3150	32.5	17.0	4.4	7.4
4000	20.2	15.0	4.8	7.2
5000	10.9	9.3	5.2	6.7

Table B7: Averaged third octave band levels of the walkers and the background noise in the receiving room, room situation 2,house B.

Frequency [Hz]	Male walker hard footwear level L[dB]	Male walker socks level L [dB]	Background noise L [dB]
20	58.8	61.8	19.2
25	45.3	46.8	19.7
31.5	48.5	56.2	15.7
40	48.3	56.4	16.0
50	41.4	49.8	25.6
63	37.4	45.5	19.0
80	29.1	33.5	14.5
100	23.7	26.7	21.6
125	19.9	22.7	11.9
160	19.8	11.6	9.7
200	19.0	11.8	9.1
250	16.9	11.9	5.5
315	13.7	9.3	3.5
400	10.1	6.9	1.5
500	5.8	4.1	0.0
630	4.4	3.9	0.5
800	3.7	4.5	2.3
1000	2.4	3.4	1.9
1250	2.2	2.8	2.2
1600	2.4	2.4	2.4
2000	2.9	2.9	3.0
2500	3.6	3.5	3.7
3150	4.2	4.1	4.2
4000	4.8	4.7	4.8
5000	5.2	5.1	5.2

Appendix C: Basic data of the measurements in house C

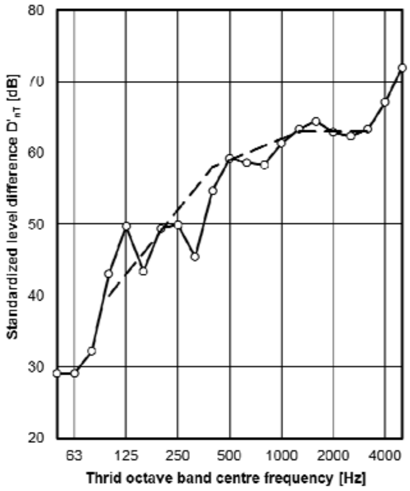

Figure C1: Measured standardized level difference of room situation 1 in house C
(-O- measurement, — — reference curve)

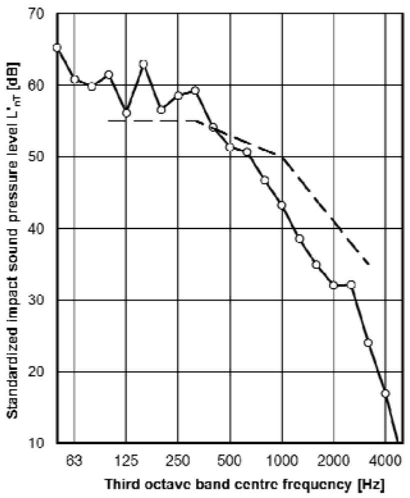

Figure C2: Measured standardized impact sound pressure level of room situation 1 in house C
(-O- measurement, — — reference curve)

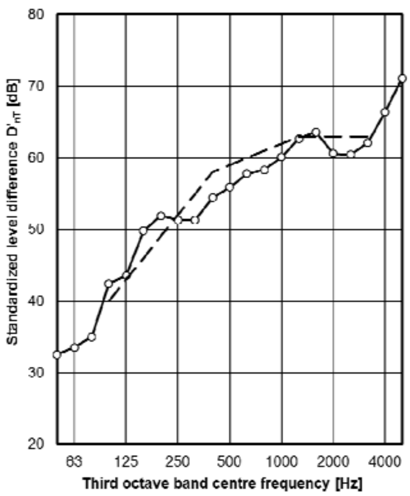

Figure C3: Measured standardized level difference of room situation 2 in house C
(-O- measurement, – – reference curve)

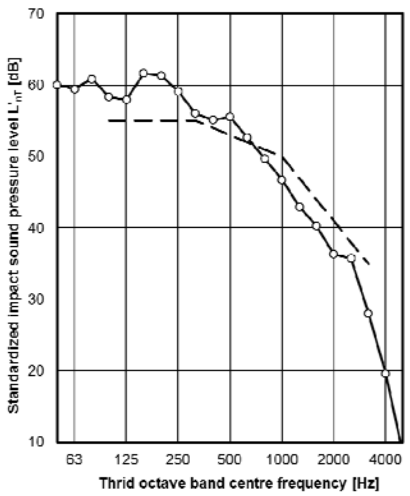

Figure C4: Measured standardized impact sound pressure level of room situation 2 in house C
(-O- measurement, – – reference curve)

In the following tables, the basic data of the measurements is listed. It is gained by averaging

- The reverberation time in the receiving room. The reverberation time was measured with the conventional method of stationary pink noise, turned off to measure the reverberation time. The measured reverberation times were above the given values for the minimum reverberation time to be measured with Norsonic 840 [21].

- The measured sound pressure levels of the airborne sound transmission measurement. The excitation was performed by an dodecahedron loudspeaker at one position in the sending room, the signal was pink noise. The measurements were conducted by stationary microphones, the measurement duration was 60 seconds. The different microphone measurements were averaged energetically in the sending and receiving room.

- The recorded signals of the different impact sources in the receiving room. The third-octave band value were calculated by the filter function with filters of 6th degree Head Acoustics Artemis. For the max value of the ball drop, the third octave max function of Artemis was used, with time constant fast (125 ms).

Table C1: Reverberation time of the receiving room, house C

Frequency [Hz]	Reverberation time [s] receiving room room situation 1	Reverberation time [s] receiving room room situation 2
20	1.41	1.50
25	1.81	1.32
31.5	1.16	1.10
40	0.95	1.09
50	0.68	0.88
63	0.61	0.47
80	0.55	0.48
100	0.57	0.45
125	0.73	0.63
160	0.49	0.60
200	0.56	0.58
250	0.48	0.51
315	0.53	0.52
400	0.56	0.58
500	0.58	0.52
630	0.61	0.56
800	0.62	0.55
1000	0.58	0.53
1250	0.67	0.58
1600	0.70	0.59
2000	0.63	0.56
2500	0.59	0.51
3150	0.58	0.52
4000	0.59	0.53
5000	0.64	0.55
L-netw	0.6	0.58
A-netw	0.625	0.55

Table C2:Averaged third octave band levels of the airborne sound insulation measurement of sending and receiving room, room situation 1, house C.

Frequency [Hz]	Sound pressure level L_1 [dB] sending room	Sound pressure level L_2 [dB] receiving room
20	59.5	29.3
25	64.5	35.2
31.5	70.8	41.9
40	80.7	55.9
50	85.7	57.9
63	90.2	62.0
80	85.7	53.9
100	92.9	50.5
125	103.2	55.1
160	108.9	65.4
200	106.7	57.7
250	104.0	53.9
315	102.3	57.1
400	102.5	48.3
500	102.7	44.1
630	100.7	42.9
800	98.9	41.4
1000	98.8	38.2
1250	100.6	38.6
1600	99.6	36.7
2000	97.6	35.6
2500	97.7	36.1
3150	94.5	31.8
4000	94.2	27.8
5000	91.3	20.4

Table C3: Averaged third octave band levels of the sources standard and modified tapping machine, the chair and the Japanese rubber ball, room situation 1,house C.

Frequency [Hz]	Standard tapping machine level L [dB]	Modified tapping machine level L [dB]	Chair level L [dB]	Japanese rubber Ball $L_{F,max}$ [dB]
20	69.3	63.4	65.4	82.7
25	59.1	57.0	60.3	75.6
31.5	63.5	58.0	57.3	78.5
40	69.0	55.9	56.6	82.1
50	66.6	54.1	57.6	79.6
63	61.8	48.4	55.8	68.6
80	60.3	41.5	55.1	58.9
100	62.1	36.9	54.4	60.3
125	57.8	36.5	50.9	51.9
160	62.9	38.2	53.2	57.4
200	57.0	34.0	48.7	50.1
250	58.4	30.1	49.1	44.8
315	59.5	23.1	50.4	45.7
400	54.7	17.6	43.7	37.8
500	52.0	15.6	37.5	32.3
630	51.5	13.1	34.3	27.6
800	47.6	11.7	26.0	20.5
1000	43.9	10.9	19.5	16.3
1250	39.8	13.0	10.9	12.0
1600	36.4	12.7	8.4	9.0
2000	33.0	15.5	7.0	9.1
2500	32.9	13.8	4.9	8.1
3150	24.7	16.3	5.0	7.6
4000	17.9	14.1	5.1	7.6
5000	9.8	8.8	5.3	6.8

Table C4: Averaged third octave band levels of the walkers and the background noise in the receiving room, room situation 1, house C.

Frequency [Hz]	Male walker hard footwear level L[dB]	Male walker socks level L [dB]	Background noise L [dB]
20	56.5	60.1	34.8
25	47.5	50.2	23.2
31.5	47.2	53.8	18.4
40	45.4	53.5	18.5
50	42.6	52.4	25.7
63	33.6	40.9	28.7
80	28.9	33.2	25.0
100	27.5	26.4	20.8
125	24.7	20.7	19.7
160	26.2	16.7	18.5
200	24.9	21.4	16.8
250	21.8	14.4	22.0
315	21.0	11.6	15.1
400	16.3	5.9	8.7
500	9.7	4.1	3.8
630	6.5	4.9	2.7
800	2.4	2.7	4.7
1000	1.2	1.2	2.0
1250	1.9	2.1	1.1
1600	2.3	2.3	2.0
2000	3.0	3.0	2.4
2500	3.6	3.7	3.1
3150	4.3	4.4	3.7
4000	4.9	4.9	4.4
5000	5.3	5.2	4.9

Table C5: Averaged third octave band levels of the airborne sound insulation measurement of sending and receiving room, room situation 2, house C.

Frequency [Hz]	Sound pressure level L_1 [dB] sending room	Sound pressure level L_2 [dB] receiving room
20	58.3	30.4
25	63.6	34.4
31.5	71.7	41.9
40	85.5	60.4
50	88.9	58.9
63	91.3	57.5
80	89.4	54.1
100	92.5	49.6
125	100.4	57.9
160	109.2	60.2
200	107.2	55.9
250	105.2	54.0
315	102.6	51.4
400	102.3	48.5
500	101.7	46.0
630	100.0	42.7
800	99.3	41.5
1000	98.0	38.2
1250	100.5	38.4
1600	99.6	36.6
2000	97.0	36.9
2500	97.4	37.0
3150	94.5	32.6
4000	94.2	28.0
5000	91.1	20.3

Table C6: Averaged third octave band levels of the sources standard and modified tapping machine, the chair and the Japanese rubber ball, room situation 2,house C.

Frequency [Hz]	Standard tapping machine level L [dB]	Modified tapping machine level L [dB]	Chair level L [dB]	Japanese rubber Ball $L_{F,max}$ [dB]
20	66.6	61.4	61.5	81.7
25	57.8	53.2	56.2	72.4
31.5	61.8	54.7	54.4	77.4
40	70.9	58.7	58.2	84.7
50	62.5	48.7	54.2	74.7
63	59.2	46.7	53.7	65.7
80	60.6	42.3	55.8	60.1
100	57.9	34.2	51.9	58.5
125	59.0	36.3	52.3	54.7
160	62.4	36.0	53.6	57.9
200	62.0	34.1	51.6	53.9
250	59.3	31.3	49.7	47.5
315	56.2	20.6	48.4	41.8
400	55.8	18.9	45.1	39.3
500	55.7	18.3	41.1	35.2
630	53.2	13.6	35.7	29.0
800	50.2	11.7	27.6	22.4
1000	47.0	10.9	21.0	17.3
1250	43.6	13.1	12.7	13.6
1600	41.0	12.6	9.0	14.9
2000	36.8	16.1	7.9	14.2
2500	35.9	14.6	5.2	12.4
3150	28.3	17.0	5.2	15.7
4000	19.9	14.0	5.3	15.2
5000	10.3	8.5	5.4	12.3

Table C7: Averaged third octave band levels of the walkers and the background noise in the receiving room, room situation 2, house C.

Frequency [Hz]	Male walker hard footwear level L[dB]	Male walker socks level L [dB]	Background noise L [dB]
20	58.1	61.3	35.2
25	48.2	45.5	25.5
31.5	46.9	48.7	22.5
40	52.1	54.1	32.7
50	42.1	44.6	30.6
63	35.3	37.6	24.3
80	31.8	30.9	19.3
100	27.1	21.5	24.6
125	26.9	16.8	16.2
160	28.4	13.6	15.0
200	29.0	16.2	14.7
250	25.7	15.7	20.4
315	21.9	12.5	14.6
400	18.8	6.5	13.1
500	14.2	1.9	9.6
630	12.5	2.8	6.5
800	7.4	2.5	8.3
1000	3.3	1.5	4.4
1250	2.7	1.6	1.4
1600	2.7	2.2	1.8
2000	3.0	2.9	2.4
2500	3.7	3.6	3.0
3150	4.6	4.3	3.6
4000	5.1	5.0	4.3
5000	5.3	5.3	5.0

Appendix D: Basic data of the measurements in house D

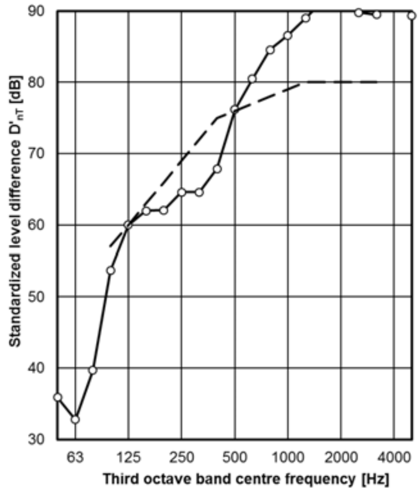

Figure D1: Measured standardized level difference of room situation 1 in house D
(-O- measurement, – – reference curve)

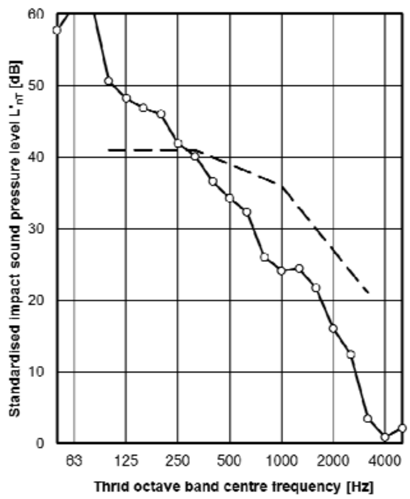

Figure D2: Measured standardized impact sound pressure level of room situation 1 in house C
(-O- measurement, – – reference curve)

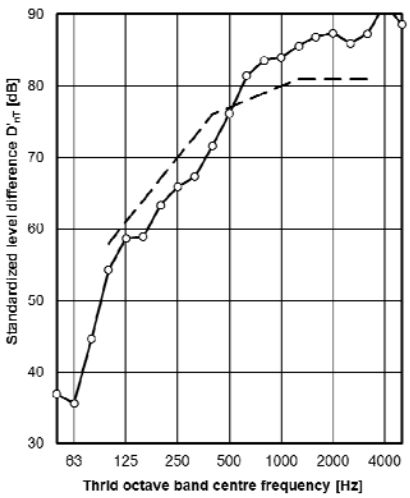

Figure D3: Measured standardized level difference of room situation 2 in house D
(-○- measurement, – – reference curve)

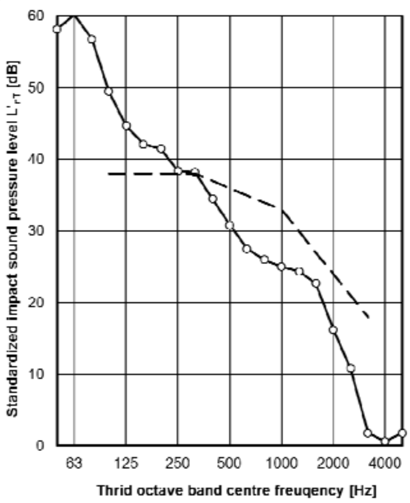

Figure D4: Measured standardized impact sound pressure level of room situation 2 in house C
(-○- measurement, – – reference curve)

In the following tables, the basic data of the measurements is listed.

- The reverberation time in the receiving rooms. The reverberation times were measured with the conventional method of stationary pink noise, turned off to measure the reverberation time. The measured reverberation times were above the given values for the minimum reverberation time to be measured with Norsonic 840 [21].

- The measured sound pressure levels of the airborne sound transmission measurement. The excitation was performed by an dodecahedron loudspeaker at two positions in the sending room, the signal was pink noise. The measurements were conducted by stationary microphones, the measurement duration was 60 seconds. The different microphone measurements were averaged energetically in the sending and receiving room.

- The recorded signals of the different impact sources in the receiving room. The third-octave band value were calculated by the filter function with filters of 6th degree Head Acoustics Artemis. For the max value of the ball drop, the third octave max function of Artemis was used, with time constant fast (125 ms).

Table D1: Reverberation time of the receiving room, house D

Frequency [Hz]	Reverberation time [s] receiving room room situation 1	Reverberation time [s] receiving room room situation 2
20	1.61	1.51
25	1.16	1.42
31.5	1.10	1.03
40	0.77	0.87
50	0.61	0.65
63	0.67	0.64
80	0.72	0.82
100	0.67	1.11
125	0.69	0.90
160	0.96	1.04
200	0.98	1.12
250	1.12	1.17
315	1.20	1.29
400	1.14	1.32
500	1.17	1.34
630	1.20	1.37
800	1.17	1.27
1000	1.16	1.22
1250	1.24	1.23
1600	1.25	1.24
2000	1.24	1.36
2500	1.25	1.27
3150	1.23	1.29
4000	1.22	1.29
5000	1.04	1.13
L-netw	1.13	1.25
A-netw	1.21	1.29

Table D2:Averaged third octave band levels of the airborne sound insulation measurement of sending and receiving room, room situation 1,house D.

Frequency [Hz]	Sound pressure level L_1 [dB] sending room	Sound pressure level L_2 [dB] receiving room
20	66.4	37.3
25	70.5	40.0
31.5	79.8	55.2
40	81.4	57.1
50	77.9	42.9
63	89.8	58.3
80	89.5	51.5
100	93.9	41.5
125	101.8	43.2
160	107.9	48.7
200	103.5	44.4
250	104.5	43.5
315	104.7	43.9
400	103.8	39.5
500	102.5	30.0
630	100.4	23.7
800	99.0	18.1
1000	97.8	15.2
1250	99.9	15.2
1600	99.1	12.1
2000	96.8	10.9
2500	97.0	11.9
3150	94.6	10.3
4000	94.0	6.3
5000	90.4	5.5

Table D3: Averaged third octave band levels of the sources standard and modified tapping machine, the chair and the Japanese rubber ball, room situation 1,house D.

Frequency [Hz]	Standard tapping machine level L [dB]	Modified tapping machine level L [dB]	Chair level L [dB]	Japanese rubber Ball $L_{F,max}$ [dB]
20	67.8	66.6	62.1	82.0
25	67.4	63.8	74.8	83.3
31.5	70.0	64.1	70.7	85.1
40	69.8	58.4	58.0	81.8
50	58.6	46.4	53.1	68.0
63	62.6	46.9	56.2	64.0
80	63.2	42.2	56.3	60.2
100	51.9	29.3	46.2	51.0
125	49.7	29.2	41.8	44.9
160	49.6	27.0	38.5	44.5
200	48.9	25.2	37.2	41.0
250	45.5	22.5	31.8	35.1
315	44.0	18.5	27.3	30.6
400	40.5	13.2	20.5	27.8
500	38.0	10.5	13.9	25.0
630	36.2	8.3	10.6	23.0
800	29.8	5.7	7.3	19.8
1000	27.7	4.1	4.7	23.3
1250	28.3	3.9	4.5	22.1
1600	25.6	3.9	3.8	21.3
2000	19.8	4.1	4.0	21.5
2500	16.2	4.6	4.4	23.8
3150	8.3	5.6	5.1	24.5
4000	5.2	5.3	5.2	25.4
5000	5.3	5.5	5.4	25.0

Table D4: Averaged third octave band levels of the walkers and the background noise in the receiving room, room situation 1,house D.

Frequency [Hz]	Male walker hard footwear level L[dB]	Male walker socks level L [dB]	Background noise L [dB]
20	59.6	63.9	26.0
25	57.3	58.1	24.2
31.5	55.9	61.4	24.6
40	50.9	57.5	24.4
50	38.8	43.2	21.7
63	37.9	42.3	27.5
80	33.7	35.6	21.7
100	30.1	28.1	19.7
125	27.8	25.9	20.1
160	28.3	25.9	21.7
200	24.3	23.0	16.6
250	24.1	22.9	15.4
315	19.0	17.8	11.5
400	14.9	14.4	9.1
500	10.3	9.4	5.5
630	9.6	9.0	4.3
800	7.6	7.2	2.7
1000	4.1	4.3	2.6
1250	4.2	4.4	2.6
1600	3.6	3.5	2.8
2000	3.7	3.5	3.2
2500	4.2	4.0	3.9
3150	5.0	4.7	4.6
4000	5.1	4.9	4.9
5000	5.3	5.2	5.2

Table D5: Averaged third octave band levels of the airborne sound insulation measurement of sending and receiving room, room situation 2, house D.

Frequency [Hz]	Sound pressure level L_1 [dB] Sending Room	Sound pressure level L_2 [dB] Receiving Room
20	68.3	36.9
25	75.7	54.9
31.5	75.6	49.6
40	72.4	40.6
50	79.1	43.4
63	88.0	53.4
80	88.7	46.2
100	91.5	40.7
125	102.2	46.1
160	106.5	50.8
200	106.0	46.2
250	105.4	43.2
315	103.5	40.3
400	102.0	34.7
500	101.6	29.7
630	100.3	23.3
800	98.7	19.1
1000	97.5	17.5
1250	99.1	17.6
1600	98.2	15.5
2000	96.4	13.8
2500	96.4	14.8
3150	93.7	11.5
4000	93.1	7.0
5000	89.4	5.6

Table D6: Averaged third octave band levels of the sources standard and modified tapping machine, the chair and the Japanese rubber ball, room situation 2,house D.

Frequency [Hz]	Standard tapping machine level L [dB]	Modified tapping machine level L [dB]	Chair level L [dB]	Japanese rubber Ball $L_{F,max}$ [dB]
20	66.3	65.4	64.4	81.1
25	72.7	68.2	79.1	89.5
31.5	70.5	63.4	68.7	85.5
40	64.8	52.7	52.6	75.2
50	59.3	47.0	56.8	68.6
63	61.3	48.9	56.8	64.3
80	58.9	40.0	53.9	56.3
100	53.0	31.6	46.5	51.5
125	47.2	28.7	41.5	44.6
160	45.3	27.1	37.1	42.9
200	45.0	23.6	34.8	38.1
250	42.1	20.5	30.5	33.6
315	42.4	15.4	26.7	30.7
400	38.9	12.5	19.5	26.2
500	35.2	8.2	13.6	23.3
630	31.9	6.2	8.6	22.9
800	30.1	4.8	5.6	21.1
1000	28.8	3.7	4.1	18.6
1250	28.2	3.6	3.7	16.6
1600	26.5	3.4	3.5	12.7
2000	20.3	4.0	4.1	12.5
2500	14.8	4.5	4.4	11.0
3150	7.1	5.3	4.8	9.6
4000	5.2	5.1	5.1	9.0
5000	5.4	5.3	5.3	8.3

Table D7: Averaged third octave band levels of the walkers and the background noise in the receiving room, room situation 2,house D.

Frequency [Hz]	Male walker hard footwear level L[dB]	Male walker socks level L [dB]	Background noise L [dB]
20	57.0	63.0	26.0
25	60.2	62.3	24.2
31.5	54.3	59.6	24.6
40	44.4	52.1	24.4
50	34.1	43.4	21.7
63	33.3	42.1	27.5
80	28.4	31.7	21.7
100	24.0	23.8	19.7
125	23.2	20.1	20.1
160	24.7	22.7	21.7
200	19.5	18.0	16.6
250	18.6	17.0	15.4
315	15.9	15.2	11.5
400	11.2	9.6	9.1
500	6.5	5.9	5.5
630	4.9	4.8	4.3
800	3.0	3.0	2.7
1000	2.9	3.1	2.6
1250	2.8	2.9	2.6
1600	3.1	3.0	2.8
2000	3.7	3.7	3.2
2500	4.2	4.0	3.9
3150	4.9	4.6	4.6
4000	5.1	4.9	4.9
5000	5.3	5.2	5.2

AcuWood –
Acoustics in wooden buildings

AcuWood is a project within the WoodWisdom-Net Research programme and running 2010-2013. It is performed in cooperation with research and industry partners from Germany, Sweden and Switzerland and coordinated by SP Wood Technology.

The main objectives are to find objective criteria for acoustic quality that is independent of the type of building system, to increase the knowledge base for future development and to increase the competitiveness of lightweight structures. The project is run in close contact with international R&D and standardization.

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SP Report 2014:15