Saimaa University of Applied Sciences
Technology, Lappeenranta
Double Degree Programme in Civil and Construction Engineering

Olga Burmistrova

METHODS FOR MEASURING THE SOUND INSULATION OF FACADES

Bachelor’s Thesis 2012

Contents

ABSTRACT
Olga Burmistrova
Methods for measuring the sound insulation of facades
Saimaa University of Applied Sciences, Lappeenranta
Degree Programme in Civil and Construction Engineering
Bachelor's Thesis 2012
Instructors: Mr. Timo Lehtoviita, Mr. Lauri Pellinen

The main goals of this study were to describe different methods for measuring airborne sound insulation of facades, to practice some of these methods and make field measurements and to analyze the results of measurements according to standard requirements.

The first part of this thesis is about methods which are described in the European standard EN ISO 140-5: "Field measurements of airborne sound insulation of facade elements and facades". This standard shows various methods for measuring sound insulation of a whole facade (global methods) and facade elements, such as a window (element methods).

The second part is about measuring equipment which was used during field measurements: a loudspeaker, real-time sound analyzers and a calibrator. Features and possibilities of this equipment are described.

The third part describes field measurements. These measurements are practical applying of the Global loudspeaker method. Measurements have been done in two different places. The first place is the concrete laboratory of Saimaa University of Applied Sciences and the second place is testing building.

On the basis of these measurement results test reports were made. In these reports the results are presented graphically and as standardized level difference D1s,2m,n,w. This value for the concrete laboratory facade is 22 dB and for the testing building facade in the second case is 29 dB.

Keywords: sound insulation, measurement equipment, field measurements

1 INTRODUCTION

Facades serve as the outer skin of buildings and so have to fulfill the demand of static strength and insulation. However, if facades are planned in a suitable way, they can also act as a barrier for incident sound fields. Due to the fact that nowadays noise exposure in daily life is considered as one of the main environmental pollutions, low sound emissions into buildings have gained increasing importance over the past years. For the construction of large public buildings such as hotels, hospitals or conference centers, which are often situated near airports, major roads, and railway lines, the acoustic shielding of ambient noise is very important and in many cases difficult to handle with classic passive methods (Forum Acusticum 2005, Noise Insulation applying Active Elements onto Facades, p.869).

On the one hand, facade elements should be constructed to be as light as possible. This helps to reduce the overall weight and reduces the cost. On the other hand, heavy and stiff elements can provide better acoustic shielding (Forum Acusticum 2005, Noise Insulation applying Active Elements onto Facades, p.869).

This thesis work focuses on description how to evaluate sound insulation of facades and how to apply these methods in practice, not on sound insulation facade requirements. However, action plans according to the Environmental Noise Directive will be implemented during the coming years, implying that traffic noise intruding from the outside could be considerably reduced. The primary goal is to reduce outdoor noise levels by reducing emissions from vehicles and to increase facade sound insulation, where necessary, to obtain satisfactory indoor conditions. The activities are described in several publications such as “Research for a Quieter Europe in 2020”. This is a strategy paper about a research for a quieter Europe (related to environmental noise only). A new WHO guideline “Night noise guidelines for Europe” reviews the health effects of sleep disturbance and presents limit values of night noise exposure (Improving the Quality of Suburban Building Stock, p.4)

2 DESCRIPTION OF DIFFERENT FIELD MEASUREMENTS

The standard which was used is ISO 140-5:1998 Acoustics. Measurement of sound insulation in buildings and of building elements. Part 5: Field measurements of airborne sound insulation of facade elements and facades.

2.1 Field measurements of airborne sound insulation of facade elements and facades

For the measurement of the airborne sound insulation of facade elements and the whole facade there are two series of methods: element methods and global methods. The element methods aim to estimate the sound reduction index of a facade element, for example a window. The most accurate element method uses a loudspeaker as an artificial sound source. Other, less accurate, element methods use available traffic noise. The global methods, on the other hand, aim to estimate the outdoor/indoor sound level difference under actual traffic conditions. The most accurate global methods use the actual traffic as sound source. In addition, a loudspeaker may be used as an artificial sound source (ISO 140-5:1998, chapter 1: Scope).

The element road traffic method will serve the same purposes as the element loudspeaker method. It is particularly useful when, for different practical reasons, the element loudspeaker method cannot be used. These two methods will often yield slightly different results. The road traffic method tends to result in lower values of the sound reduction index than the loudspeaker method.

The global road traffic method yields the real reduction of a facade in a given place relative to a position 2 m in front of the facade. This method is the preferred method when the aim of the measurement is to evaluate the performance of a whole facade, including all flanking paths, in a specified position relative to nearly roads. The result cannot be compared with that of laboratory measurements.

The global loudspeaker method yields the sound reduction of a facade relative to a position 2 m in front of the facade. This method is particularly useful for different practical reasons when the real noise source cannot be used. The result cannot be compared with that of laboratory measurements (ISO 140-5:1998, chapter 1: Scope).

An overview of the methods is given in table 1

Table 1. Overview of the different measurement methods

No	Method	Result	Field of application
Element			
1	Element loudspeaker	R'_{45}	Preferred method to estimate the apparent sound reduction index of façade element
2	Element road traffic	$R'_{tr,s}$	Alternative to method No.1 when road traffic noise of sufficient level is available
3	Element railway traffic	$R'_{tr,s}$	Alternative to method No.1 when railway traffic noise of sufficient level is available
4	Element air traffic	$R'_{at,s}$	Alternative to method No.1 when air traffic noise of sufficient level is available
Global			
5	Global loudspeaker	$D_{1s,2m,nT}$ $D_{1s,2m,n}$	Alternative to method Nos. 6, 7 and 8
6	Global road traffic	$D_{tr,2m,nT}$ $D_{tr,2m,n}$	Preferred method to estimate sound insulation of a façade exposed to road traffic noise
7	Global railway traffic	$D_{rt,2m,nT}$ $D_{rt,2m,n}$	Preferred method to estimate sound insulation of a façade exposed to railway traffic noise
8	Global air traffic	$D_{at,2m,nT}$ $D_{at,2m,n}$	Preferred method to estimate sound insulation of a façade exposed to air traffic noise

(ISO 140-5:1998, chapter 1: Scope).

2.2 Definitions

The average sound pressure level on a test surface, $L_{1,s}$: Ten times the logarithm to the base 10 of the ratio of the surface and time average of the sound pressure squared to the square of the reference sound pressure, the surface average being taken over the entire test surface including reflecting effects from the test specimen and facade; dB (ISO 140-5:1998, chapter 3: Definitions):

$$L_{1,S} = 10\lg(10^{L_1/10} + 10^{L_2/10} + \cdots + 10^{L_n/10}) - 10\lg(n)\ dB \qquad (1)$$

Where L_1, L_2, …, L_n are the sound pressure levels in positions 1, 2, …, n.

The average sound pressure level in a room, L_2: Ten times the logarithm to the base 10 of the ratio of the surface and time average of the sound pressure squared to the square of the reference sound pressure, the space average being taken over the entire room with the exception of those parts where the direct radiation of a sound source or the near field of the boundaries (wall, window, etc.) is of significance; dB:

$$L_2 = 10\ \lg(10^{L_{2,1}/10} + 10^{L_{2,2}/10} + \cdots + 10^{L_{2,n}/10}) - 10\lg(n)\ dB \qquad (2)$$

Where $L_{2,1}$, $L_{2,2}$, …, $L_{2,n}$ are the sound pressure levels in positions 1, 2, …, n.

Equivalent continuous sound pressure level, L_{eq}: Value of the sound pressure level of a continuous steady sound that, within the measurement time interval, has the same mean square sound pressure as the sound under consideration, the level of which varies with time; dB (ISO 140-5:1998,chapter 3: Definitions).

Sound reduction index, R: Ten times the logarithm to the base 10 of the ratio of the sound power W_1 incident on the test specimen to the sound power W_2 transmitted through the specimen:

$$R = 10\,\lg \cdot \frac{W_1}{W_2}\ dB \qquad (3)$$

Apparent sound reduction index, R': Ten times the logarithm to the base 10 of the ratio of the sound power W_1 which is incident on the test specimen to the total sound power transmitted into the receiving room, if, in addition to the sound power W_2 radiated by the specimen, sound power W_3 radiated by flanking elements or by other components is significant:

$$R' = 10\,\lg \cdot \frac{W_1}{W_2+W_3}\ dB \qquad (4)$$

Apparent sound reduction index, R'_{45}: Measure of the airborne sound insulation of a building element when the sound source is a loudspeaker and when the angle of sound incidence is 45. The angle of sound incidence is the angle between the loudspeaker axis directed toward the center of the specimen and the normal to the surface of the facade. The apparent sound reduction index is then calculated from equation:

$$R'_{45} = L_{1,S} - L_2 + 10\,\lg \cdot \frac{S}{A}\,dB - 1{,}5\ dB \qquad (5)$$

Where

$L_{1,S}$ is the average sound pressure level on the surface of the test specimen

L_2 is the average sound pressure level in the receiving room

S is the area of the test specimen

A is the equivalent sound absorption area in the receiving room

Apparent sound reduction index, $R'_{tr,s}$: Measure of the airborne sound insulation of a building element when the sound source is traffic noise and the outside microphone position is on the test surface. The apparent sound reduction index is then calculated from equation:

$$R'_{tr,s} = L_{eq,1,S} - L_{eq,2} + 10\lg \cdot \frac{S}{A} dB - 3\ dB \quad (6)$$

Where

$L_{eq,1,s}$ is the average value of the equivalent continuous sound pressure level on the surface of the test specimen including reflecting effects from the test specimen and facade

$L_{eq,2}$ is the average value of the equivalent continuous sound pressure level in the receiving room

S is the area of the test specimen

A is the equivalent sound absorption area in the receiving room

Level difference, D_{2m}: Difference, in decibels, between the outdoor sound pressure level 2 m in front of the façade, $L_{1,2m}$, and the space and time averaged sound pressure level, L_2, in the receiving room:

$$D_{2m} = L_{1,2m} - L_2 \quad (7)$$

Standardized level difference, $D_{2m,nT}$: Level difference, in decibels, corresponding to a reference value of the reverberation time in the receiving room:

$$D_{2m,nT} = D_{2m} + 10\lg \cdot \frac{T}{T_0} dB \quad (8)$$

Where T_0 = 0.5 s.

Normalized level difference, $D_{2m,n}$: Level difference, in decibels, corresponding to the reference absorption area in the receiving room:

$$D_{2m,n} = D_{2m} + 10\lg \cdot \frac{A}{A_0} dB \quad (9)$$

Where A_0 = 10 m^2 (ISO 140-5:1998, chapter 3: Definitions).

2.3 Measurement with loudspeaker noise

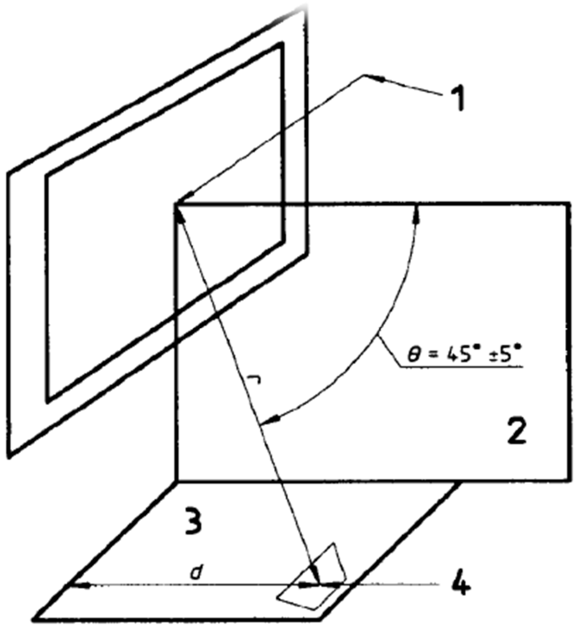
Two methods, the element and the global loudspeaker method, are described.

The element loudspeaker method will yield an estimate of the apparent sound reduction index which, under specified circumstances, can be compared with the sound reduction index for the corresponding facade elements obtained in laboratories.

The global loudspeaker method will quantify the airborne sound insulation of a whole facade or even a whole building in a specified situation. This result cannot be compared with laboratory measurements (ISO 140-5:1998, chapter 5, 5.1: General)

2.3.1 Principle

The loudspeaker is placed in one or more positions outside the building at a distance *d* from the facade, with the angle of sound incidence equal to (45±5)° (see figure 2.1).



1. Normal to the facade
2. Vertical plane
3. Horizontal plane
4. Loudspeaker

Figure 2.1. Geometry of the loudspeaker method

The average sound pressure level is determined either directly on the test specimen (the element method) or 2 m in front of the facade (the global method), as well as in the receiving room. The apparent sound reduction index $R'_{45°}$ or the level difference $D_{1S,2m}$ is calculated (ISO 140-5:1998, chapter 5, 5.2: Principle).

2.3.2 Generation of sound field

The sound field generated shall be steady and have a continuous spectrum in the frequency range considered. If the measurements are made in one-third-octave bands, frequency bands with center frequencies from at least 100 Hz to 3150 Hz, preferably from 50 Hz to 5000 Hz, shall be used. If the measurements are made in octave bands, frequency bands with center frequencies from at least 125 Hz to 2000 Hz, preferably from 63 Hz to 4000 Hz, shall be used. In addition, the differences between the sound power levels in the one-third-octave bands belonging to an octave band shall not be greater than 6 dB in the 125 Hz octave band, 5 dB in the 250 Hz band, and 4 dB in bands of the higher center frequencies (ISO 140-5:1998, chapter 5, 5.3: generation of sound field).

2.3.3 Position of the loudspeaker

Choose the position of the loudspeaker and the distance *d* to the façade so that the variation of the sound pressure level on the test specimen is minimized. This implies that the sound source is preferably placed on the ground. Alternatively, place the sound source as high above the ground as is possible in practice.

The distance *r* from the sound source to the center of the test specimen shall be at least 5 m ($d > 3{,}5\ m$) for the element loudspeaker method, and at least 7 m ($d > 5\ m$) for the global loudspeaker method. The angle of the sound incidence shall be (45±5)° (see figure 1).

2.3.4 Measurements in the receiving room

Obtain the average sound pressure level in the receiving room by using a single microphone moved from position to position, or by an array of fixed microphone positions shall be averaged on an energy basis for all sound source positions. In addition, determine the background noise level L_b.

2.3.4.1 Microphone positions

As a minimum, five microphone positions shall be used in each room to obtain the average sound pressure level of each sound field. These positions shall be distributed within the maximum permitted space throughout each room, spaced uniformly.

The following separating distances are the minimum values and should be exceeded where possible:

- 0,7 m between microphone positions;
- 0,5 m between any microphone position and room boundaries or objects in the room;
- 1,0 m between any microphone position and the sound source.

When using a moving microphone, the sweep radius shall be at least 0,7 m. The plane of the traverse shall be inclined in order to cover a large portion of the permitted room space and shall not lie in any plane within 10° of a room surface. The duration of a traverse period shall be not less than 15 s (ISO 140-5:1998, chapter 5, 5.5.3: Microphone position).

2.3.4.2 Corrections for background noise

Measure background noise levels to ensure that the observations in the receiving room are not affected by extraneous sound, such as noise from the outside the test room, electrical noise in the receiving system, or electrical cross-talk between the source and receiving systems.

The background level should be at least 6 dB (and preferably more than 10 dB) below the level of the signal and background noise combined. If the difference in levels is smaller than 10 dB but greater than 6 dB, calculate corrections to the signal level according to equation:

$$L = 10\,\lg(10^{L_{sb}/10} - 10^{L_b/10})\ dB \tag{10}$$

Where

L is the adjusted signal level, in decibels;

L_{sb} is the level of signal and background noise combined, in decibels;

L_b is the background noise level, in decibels.

(ISO 140-5:1998, chapter 5, 5.5.3: Corrections for background noise)

2.3.4.3 Measurement of reverberation time and evaluation of the equivalent sound absorption area

The correction term in equation $D_{2m,nT} = D_{2m} + 10 \lg \cdot \frac{T}{T_0} dB$ containing the equivalent sound absorption area is evaluated from the reverberation time measured in accordance with ISO 354 and determined using Sabine's formula:

$$A = \frac{0,16V}{T} \qquad (11)$$

Where

A is the equivalent absorption area, in square metres;

V is the receiving room volume, in cubic metres;

T is the reverberation time in the receiving room, in seconds.

Begin the evaluation of the reverberation time from the decay curve about 0,1 s after the sound source has been switched off, or from a sound pressure level a few decibels lower than that at the beginning of the decay. Use a range neither less than 20 dB nor so large that the observed decay cannot be approximated by a straight line. The bottom of this range shall be at least 10 dB above the background noise level.

The minimum number of decay measurements required for each frequency band is six. At least one loudspeaker position and three microphone positions with two readings in each case shall be used (ISO 140-5:1998, chapter 5, 5.5.4).

2.3.5 Element loudspeaker method

If the purpose of the measurement is to obtain results as comparable as possible to those of laboratory measurements, carry out the following steps:

a. verify that the facade element under test is in accordance with the specified construction and is properly mounted according to the manufacturer's instructions;

b. estimate the sound reduction index of the facade to ensure that the sound transmission through the wall surrounding the test specimen does not contribute significantly to the sound pressure level in the receiving room.

2.3.5.1 Measurements on the outer surface of the facade element

Determine the average sound pressure level $L_{1,S}$ on the test surface. Carry out the measurements either with the microphone fastened directly on the actual test specimen with its axis parallel to the plane of the façade and directed upwards or downwards, or with its axis pointing in the direction normal to the test specimen. The distance from the test specimen to the center of the microphone membrane shall be 10 mm or shorter, depending on the diameter of the microphone, if the axis of the microphone is parallel to the test surface, and 3 mm or shorter if the axis is normal to the test surface. If fastened, the microphone shall be fastened to the test specimen with a strong, adhesive tape. Equip the microphone with a hemispherical windscreen (see figure 2.2).

(ISO 140-5:1998, chapter 5, 5.6.2)

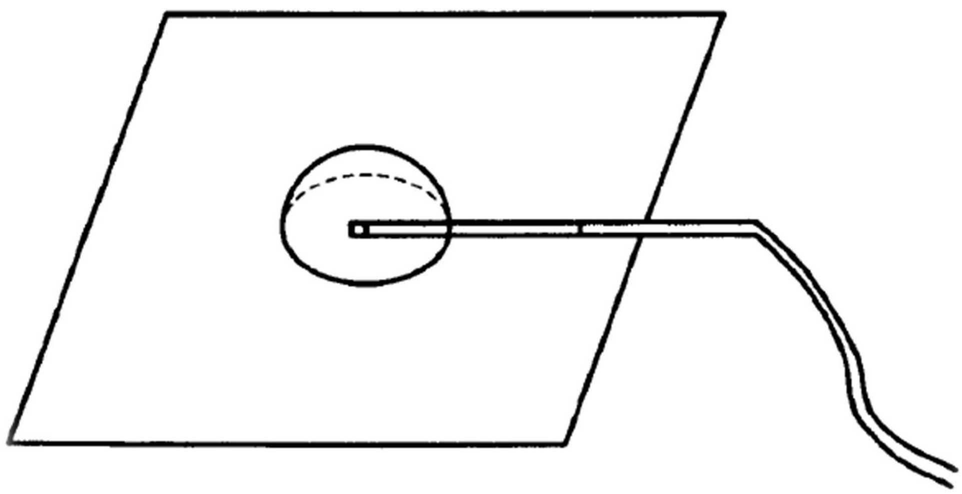


Figure 2.2. Flush-mounted microphone

Choose between three and ten measurement positions depending on the difference in the sound pressure levels between the positions. Distribute the measurement positions evenly but asymmetrically on the measurement surface. It is recommended to begin with three measurement positions *(n-3).* If the difference in the sound pressure level between two positions in one frequency is more than *n,* increase the number of measurement positions up to ten. If the test specimen is mounted in a recess of the facade, always choose ten measurement positions. If the difference in the sound pressure levels between the measurement positions is more than 10 dB, this shall be stated in the measurement report.

As an alternative to several fixed positions, a scanning microphone is allowed provided that the distance to the facade element can be kept constant and provided that the background noise is kept at least 10 dB below the signal level (ISO 140-5:1998, chapter 5, 5.6.2).

Average the *n* positions as given by equation (1):

$$L_{1,S} = 10\lg(10^{L_1/10} + 10^{L_2/10} + \cdots + 10^{L_n/10}) - 10\lg(n)\ dB$$

Where L_1, L_2, …, L_n are the sound pressure levels in positions 1, 2, …, n.

2.3.6 Global loudspeaker method

If measurements are done in front of the facade, place the microphone on the outside of the facade, in the middle. The distance shall be:

a. (2,0 ± 0,2) m from the plane of the facade, or
b. 1,0 m from a balustrade or other similar protrusion.

The height of the microphone shall be 1,5 m above the floor of the receiving room.

If a building has large rooms or facades comprising more than one outside wall, it is normally not possible to measure with one source position only. In those cases, use several source positions. The number of positions is given by the directional characteristics of the loudspeaker and the area of the facade (ISO 140-5:1998, chapter 5, 5.7.3).

2.3.7 Calculation of measurement results

If several source positions have been used, calculate the level difference for each position and average them according to equation:

$$D_{1S,2m} = -10\ lg\left(\frac{1}{n}\sum 10^{-D_i/10}\right)\ dB \tag{13}$$

Where

n is the number of source positions;

D_i is the level difference for each source-receiver combination

2.4 Measurements with road traffic

Two methods, the element and the global road traffic method, are described. The element road traffic method will yield an estimate of the apparent sound reduction index which, under specified circumstances, can be compared with the corresponding sound reduction index obtained in laboratories. The global road traffic method will quantify the airborne sound insulation of a whole façade or even a whole building in a specified situation. This result cannot be compared with the sound reduction index obtained in a laboratory.

The work principle of these methods is, if the sound is incident on the test specimen from different directions and with varying intensity (e.g. traffic noise in busy streets), the sound reduction index or the level difference is obtained from the equivalent sound pressure levels measured as a function of frequency on both sides of the test specimen (ISO 140-5:1998, chapter 6).

2.4.1 Test requirements

During the measurements the background noise in the receiving room shall be at least 10 dB below the measured equivalent sound pressure level. Use the existing traffic noise incident on the test specimen for sound generation. The measurement time shall include at least 50 passing vehicles.

On account of possible fluctuations in traffic noise, measure the equivalent sound pressure levels simultaneously on opposite sides of the specimen. Avoid quiet periods, i.e. periods when the traffic noise does not exceed the background noise by more than 10 dB.

2.4.2 Element road traffic method

If the purpose of the measurement is to compare the results with laboratory measurements or to obtain results which are representative of a facade element, follow, if possible, the procedure of element loudspeaker method. If, for practical reasons, that procedure is not applicable, the element road traffic method is an alternative. However, in all cases, the test requirements given in element loudspeaker method shall be complied with.

2.4.2.1 Generation of the sound field

The measurement situation shall fulfill the following requirements.

a) The traffic shall flow approximately along a straight line within an angle of sight within $\pm 60^\circ$ from the facade; within this angle, deviations from a straight line are allowed within $\pm 15^\circ$ with the tangent to the traffic line at the intersection of the traffic line and the normal from the facade on the traffic line (see figure 2.3).

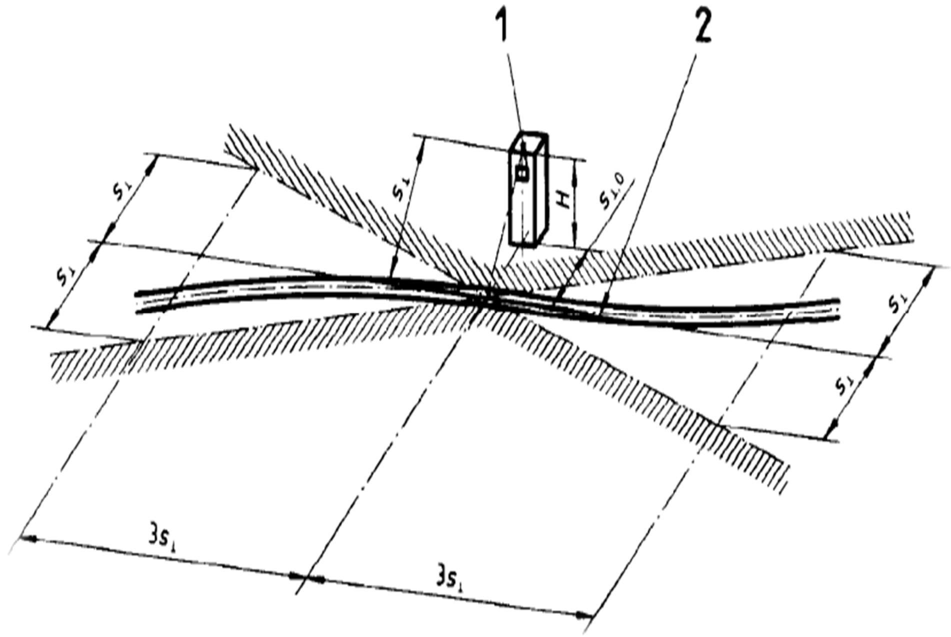


Figure 2.3. Conditions at long straight traffic lines

1- receiving point

2- traffic line

$S_{\perp}$ - is the distance between the receiving point and the traffic line

$S_{\perp,0}$ – is the horizontal distance between the receiving point and the traffic line

H - is the height difference between the receiving point and the traffic line

b) The angle of elevation, observed from the point of least distance between the facade and the line of traffic, shall be less than 40° ;

c) Free view of the whole facade shall be possible from the whole width of the traffic flow;

d) The minimum horizontal distance between the traffic line and the facade shall be at least three times the width of the facade to be tested, or 25 m, whichever is the largest (ISO 140-5:1998, chapter 6, 6.5.2).

2.4.2.2 Measurement of the equivalent sound pressure levels

Place the microphone on the outside of the test specimen as given in figure 2. If the facade is flat without large recesses or balconies, use three microphone positions asymmetrically distributed over the measurement surface. If the facade has large recesses or balconies, use five microphone positions. Denote the measured sound pressure level $L_{1,eq,s}$.

Carry out the measurements in the receiving room as given in 2.4. If discrete microphone positions are used, it is permitted to use one position for each microphone position on the outside.

2.4.3 Global road traffic method

In this method there are no special requirements or restrictions other than given in 3.1 and 3.2.1.

2.4.3.1 Measurement of the equivalent continuous sound pressure levels

Place the microphone on the outside of the facade, in the middle. The distance shall be:

a) (2,0 ± 0,2) m from the plane of the facade or

b) 1,0 m from a balustrade or other similar protrusion.

The height of the microphone shall be 1,5 m above the floor of the receiving room. If the main part of the facade is an oblique construction such as a roof, choose the position not nearer to the roof than the projected part of the vertical part of the facade. If the room considered has more than one outside wall, position the microphone in front of each of the facades. Denote the measured sound pressure level $L_{1,eq,2m}$.

2.4.3.2 Reverberation time

Proceed as given in 2.4.3.

2.4.3.3 Calculation of measurement result

If several microphone positions on the source side have been used, calculate the level difference for each position and average according to equation:

$$D_{tr,2m} = -10\lg\left(\frac{1}{n}\sum 10^{-D_i/10}\right)\ dB \tag{14}$$

Where

n is the number of microphone positions on the source side;

D_i is the level difference for each source-receiver combination.

2.5 Equipment

The microphone shall have a maximum diameter of 13 mm.

The sound pressure level measurement equipment shall meet the requirements of a class 0 or 1 instrument according to IEC 60651 or IEC 60804. The measurement chain shall be calibrated by using a class 1 or better acoustical calibrator according to IEC 60942.

The one-third-octave band filters and, if relevant, the octave band filters shall meet the requirements of IEC 61260.

The reverberation time measurement equipment shall meet the requirements of ISO 354.

2.5.1 Loudspeaker

The directivity of the loudspeaker in a free field shall be such that the local differences in the sound pressure level in each frequency band of interest are less than 5 dB, measured on an imaginary surface of the same size and orientation as the test specimen.

3 MEASUREMENT EQUIPMENT

Measurement equipment has to determine the average noise level directly or indirectly. It should meet the requirements of standard SFS 2877/IEC 651, preferably in precision class 1, but at least class 2. An integrating sound level meter should meet the requirements of standard IEC 804.

3.1 Real time sound analyzer Nor118

A sound level meter is an instrument designed to respond to sound in approximately the same way as the human ear and to give objective, reproducible measurements of sound pressure level. There are many different sound measuring systems available. Although different in detail, each system consists of a microphone, a processing section and a read-out unit. The microphone converts the sound signal to an equivalent electrical signal. The most suitable type of microphone for sound level meters is the condenser microphone, which combines precision with stability and reliability. The electrical signal produced by the microphone is quite small and so it is amplified by a preamplifier before being processed. Several different types of processing may be performed on the signal. It is relatively simple to build an electronic circuit whose sensitivity varies with frequency in the same way as the human ear, thus simulating the equal loudness contours ("Measuring sound", Bruel & Kjer brochure, p.10).

The real time sound analyzer Nor 118 (figure 3.1.) is a sound level meter with built-in real time analyzer capabilities. Parallel octave filters are standard, but the impressive list of optional extensions include sound power calculations, third octave filters and statistics in every frequency band, multispectrum and reverberation time measurements.

Figure 3.1. Real time sound analyzer Nor118
(Instruction manual Nor118, Chapter 1)

3.1.1 The functions available

The functions available with Nor118 include the following

- SPL The Instantaneous Sound Pressure Level. It is the deviation from the local ambient pressure caused by a sound wave at a given location and given instant in time.
- L_{max} The Maximum Sound Pressure Level
- L_{min} The Minimum Sound Pressure Level
- L_{eq} The Integrated Equivalent SPL. It is the constant noise level that would result in the same total sound energy being produced over a given period.
- L_E The sound Exposure Level. It is a Leq normalized to 1 second. It can be used to compare the energy of noise events which have different time durations.

- L_{peak} The Sound Maximum Peak Level. It is the maximum value reached by the sound pressure
  (Instruction manual Nor118, Chapter 1, p.3)

3.1.2 Level vs. time

The electronic level recorder concept is available in two versions – basic and enhanced. While the basic version logs the equivalent level, the maximum level and the peak level, the enhanced version is capable of logging any combination of functions available with the Norsonic. In addition it allows source coding.

3.1.3 Frequency analysis

When fitted with the frequency analysis extensions Norsonic can do real time frequency analysis:

- in octaves (8 Hz to 16 kHz)
- in third-octaves (6.3 Hz to 20 kHz)

3.1.4 Reverberation time

A typical Norsonic application has the ability to calculate the reverberation time in octaves and third-octaves. Units without filters will calculate the broadband values (a- and c- or z-weighted values).

The reverberation time algorithm is based on the integrated impulse response method, hence, impulses are required as excitation signals.

3.1.5 Sound power

Sound power levels may be calculated from sound pressure level measurements using almost any sound level meter. However, the methods described in ISO 3746 involve a tedious calculation procedure before it was ended up with the single figure is needed to be able characterize measurement object. Just specify the measurement surface type (hemisphere or parallelepiped), its dimensions and the location of the measurement object (on the floor, against a hard reflecting wall or in a corner) apply the correction factors and start the measurement. The sound power will then be calculated and displayed in tabulated form (Instruction manual Nor118, Chapter 1, p.4).

3.2 Real time sound analyzer Nor140

The principle of working this analyzer is the same as Nor118. This analyzer is shown in figure 3.2.

Figure 3.2. Real time sound analyzer Nor140
(Instruction manual Nor140, Chapter 1)

3.3 Dodecahedron Loudspeaker Nor276

Nor276 is a high power loudspeaker with omnidirectional characteristics. Nor276 is shown in figure 3.3.

Figure 3.3. Dodecahedron Loudspeaker Nor276

A multitude of applications within the field of building acoustics requires the use of isotropic sound fields.

3.3.1 Features of Nor276

This loudspeaker has the following features:

- Conforms to ISO 140-3 Annex C standard for airborne laboratory insulation
- Conforms to ISO 3382-2 Annex A 3.1 standard for reverberation time
- Conforms to DIN 52210
- Powerful - 120 dB Lw

3.3.2 Sound power level vs. frequency

Typical sound power level vs. frequency of the Dodecahedron Loudspeaker Nor276 when used with the pink noise source and equalizer is shown in the figure 3.4.

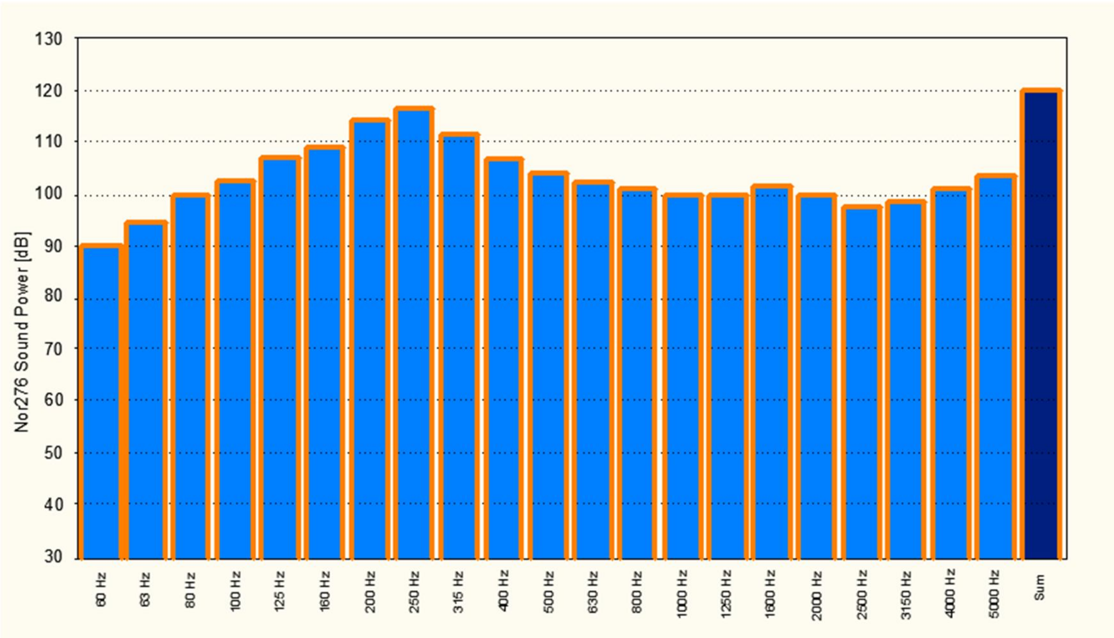


Figure 3.4. Typical sound power level vs. frequency

3.3.3 Sound power

Sound power in different directions for Nor276 is shown in figure 3.5. The measurement is done in a horizontal plane through the center of the loudspeaker. The graph shows the response for a sinusoidal signal at 100 Hz, 315 Hz, 1 kHz and 3,15 kHz.

("Noise Excitation Equipment for building Acoustics Measurements www.norsonic.com/uploads/kundefiler/Downloads/pdnoiseexcited5rev2eng0510_web.pdf)

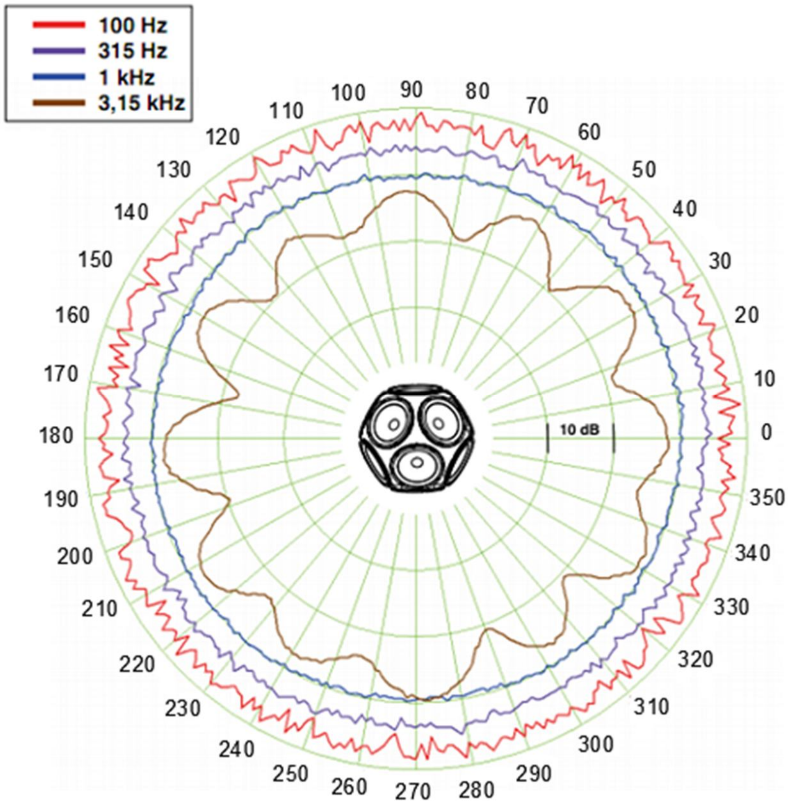


Figure 3.5. Sound power in different directions for Nor276

3.3.4 Maximum and minimum directivity indices

A multitude of applications within the field of building acoustics requires the use of isotropic sound fields. The loudspeaker Nor276 has been designed to comply with these requirements and satisfies:

- ISO 140-3 Annex C (Laboratory measurements);
- ISO 140-4 Annex A (Field measurements);
- ISO 3382-2 Annex A (Reverberation Time measurements).

(“Noise Excitation Equipment for building Acoustics Measurements www.norsonic.com/uploads/kundefiler/Downloads/pdnoiseexcited5 rev2eng0510_web.pdf)

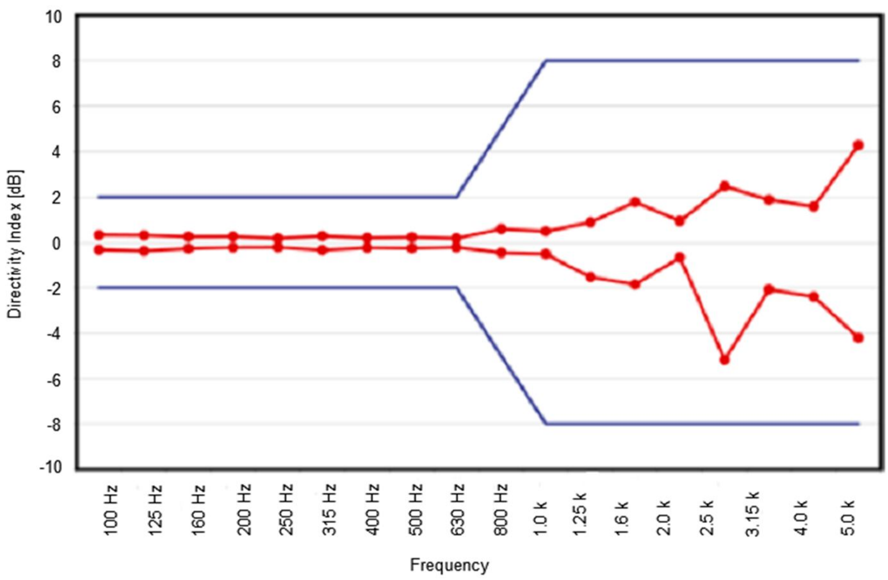


Figure 3.6. Maximum and minimum directivity indices in different directions according to the requirements in ISO 140-3 and ISO140-4 compared to the tolerance limits.

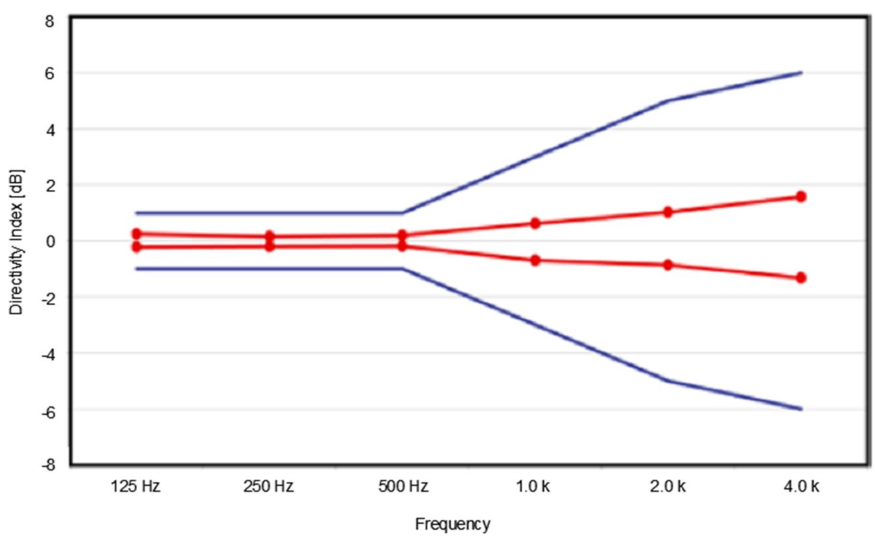


Figure 3.7. Maximum and minimum directivity indices in different directions according to the requirements in ISO 3382-1 compared to the tolerance limits.

3.4 Sound calibrator

Sound level meters should be calibrated in order to provide precise and accurate results. This is best done by placing a portable acoustic calibrator, such as a sound level calibrator or a pistonphone, directly over the microphone. These calibrators provide a precisely defined sound pressure level to which the sound level meter can be adjusted. It is good measurement practice to calibrate sound level meters immediately before and after each measurement session. If recordings are to be made of noise measurements, then the calibration signal should also be recorded to provide a reference level on playback ("Measuring sound", Bruel & Kjer brochure, p.13).

To calibrate a sound measuring instrument a sound calibrator was used which was produced by "Norsonic". A sound calibrator is designed to produce a known sound pressure level when used correctly together with the measuring microphone of the sound measuring instrument.

Sound Calibrator Nor-1251 (see figure 3.8) is a small, battery operated sound source for the calibration of microphones and sound measuring instruments.

Figure 3.8. Sound Calibrator Nor-1251 (Nor 1251 manual)

The microphone is placed in an acoustic coupler where the calibrator produces a regulated sinusoidal sound pressure signal. The calibrator is supplied with an output of 114dB SPL @ 1000Hz.

Due to the principle of operation, the calibration level is virtually independent of ambient conditions like temperature, atmospheric pressure and humidity within the specified range of operation. The calibrator complies with IEC60942 Class1 and has been designed to serve one-inch and smaller microphones and sound level meters equipped with such microphones (Nor 1251 manual, p.8).

4 FIELD MEASUREMENTS

4.1 Introduction

The present report gives a discussion of a suitable measurement method to be used for the determination of the airborne sound insulation of building facades in the frequency range 50-5000 Hz and presents the measurement result.

4.2 Aim

The aim is to specify a method for measurements of airborne sound insulation of building facades and investigate the sound insulation at frequency range from 50 Hz to 5000 Hz.

It has been chosen to express the sound insulation as the outdoor/indoor sound level difference of the whole building facade instead of using the weighted sound reduction index R'_w of facade elements, for example windows.

4.3 Measurement process

The international standard EN ISO 140-5:1998 [1] for field measurements of airborne sound insulation of facade elements and facades is intended for use in the frequency range from 50 to 5000 Hz. The standard deals with different measurement methods which are using loudspeaker noise or traffic noise as sound source.

The Global loudspeaker method was used to evaluate the airborne sound insulation of facade. The loudspeaker methods define a loudspeaker position outside the building with the angle of sound incidence equal to $45° \pm 5°$. The outdoor sound pressure level is determined at the distance 2 m in front of the façade. The indoor level is measured at five positions distributed throughout the room and spaced uniformly. The minimum separating distance between any microphone position and room boundaries is 1,0 m.

4.4 Field measurements in concrete laboratory

4.4.1 Description of the house

The first field measurements have been done in the concrete laboratory of the Saimaa University of Applied Sciences.

Figure 4.1. Concrete laboratory facade

Location: Saimaa University of Applied Sciences, Lappeenranta

Type of house: Public building

Facade: Brick

Doors: Wood

Room dimensions: Approx. volume is 200 m^3

4.4.1.1 Outside measurements

This measurement determined the outdoor sound pressure level.

The loudspeaker is placed outside the building with the angle of sound incidence equal to $45° \pm 5°$ and such that the real traffic noise impact is simulated the best possible way. Exact position of loudspeaker is shown in figure 4.2.

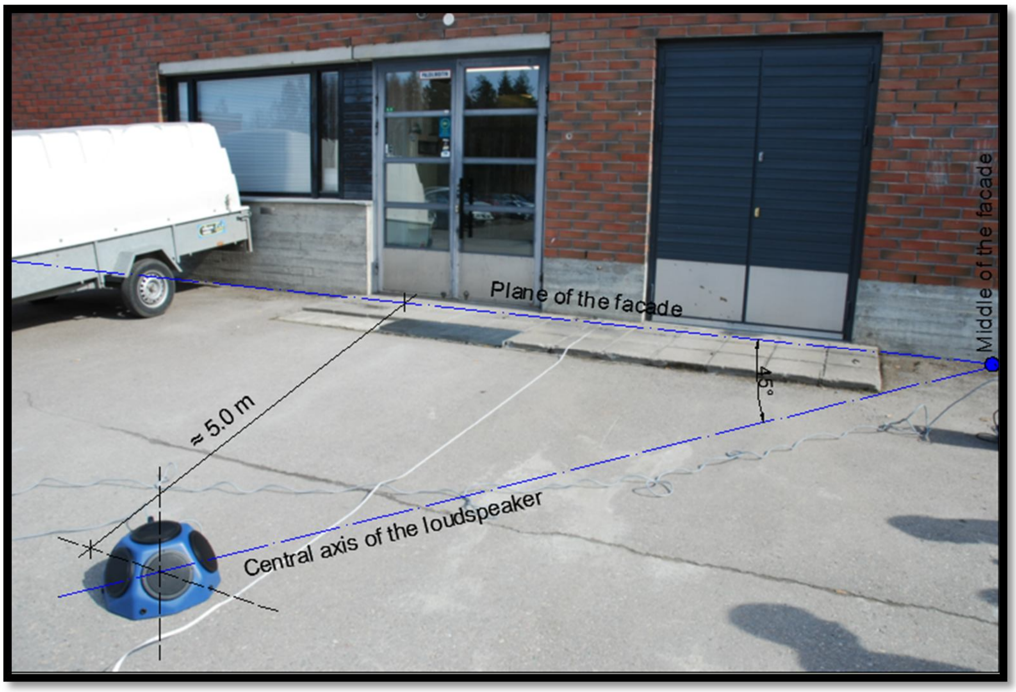


Figure 4.2. Loudspeaker position

In this case only one loudspeaker position was used and the outdoor sound pressure level has been measured at 2 m in front of the facade plane.

Figure 4.3. Distance between the plane of facade and microphone position

The hight of microphone position is 1.5 m.

Figure 4.4. Microphone position above the ground

4.4.1.2 Inside measurements

This measurement determined:

- average sound pressure level
- background noise
- reverberation time

In the receiving room five microphone positions were used to obtain the average sound pressure level. The minimum separating distance between any microphone position and room boundaries is 1.0 m.

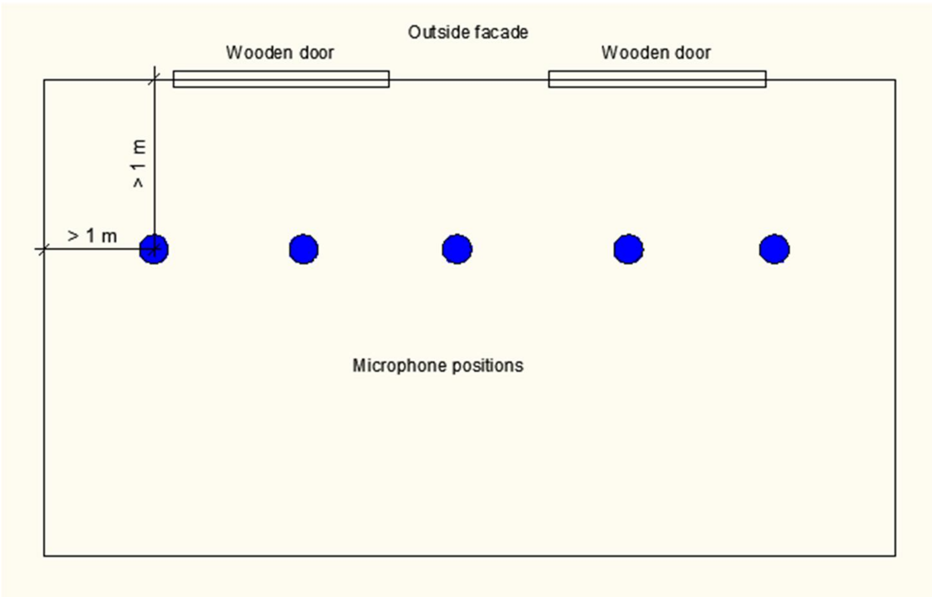


Figure 4.5. Microphone positions in the receiving room during sound pressure level measurements

In each microphone position sound pressure level was determined. The duration of each measurement is 30 seconds.

Background noise was measured in two points by using two microphones at the same time. The duration of each measurement is 30 seconds.

Figure 4.6. Microphone positions in the receiving room during background noise measurements

Reverberation time was measured in two positions of the microphone. The duration of each measurement is 40 seconds.

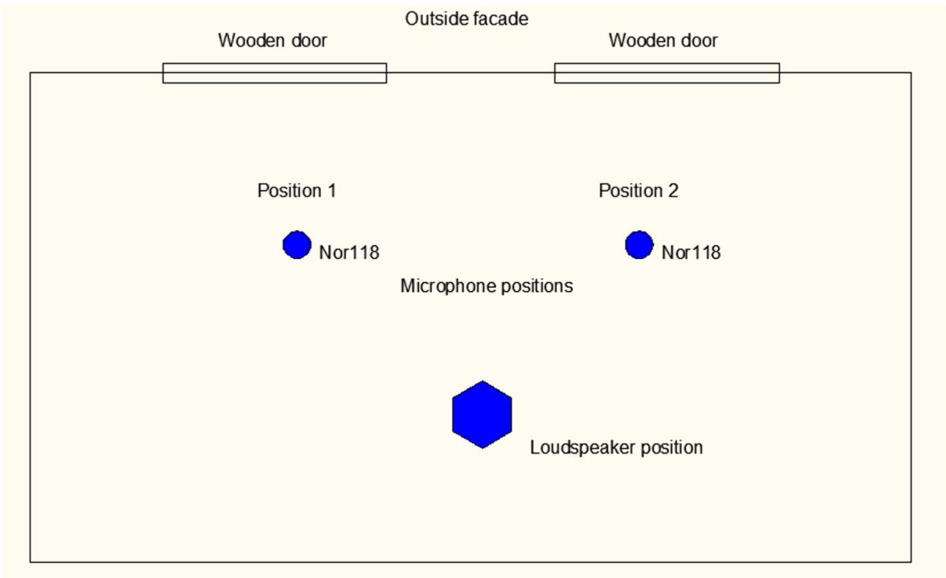
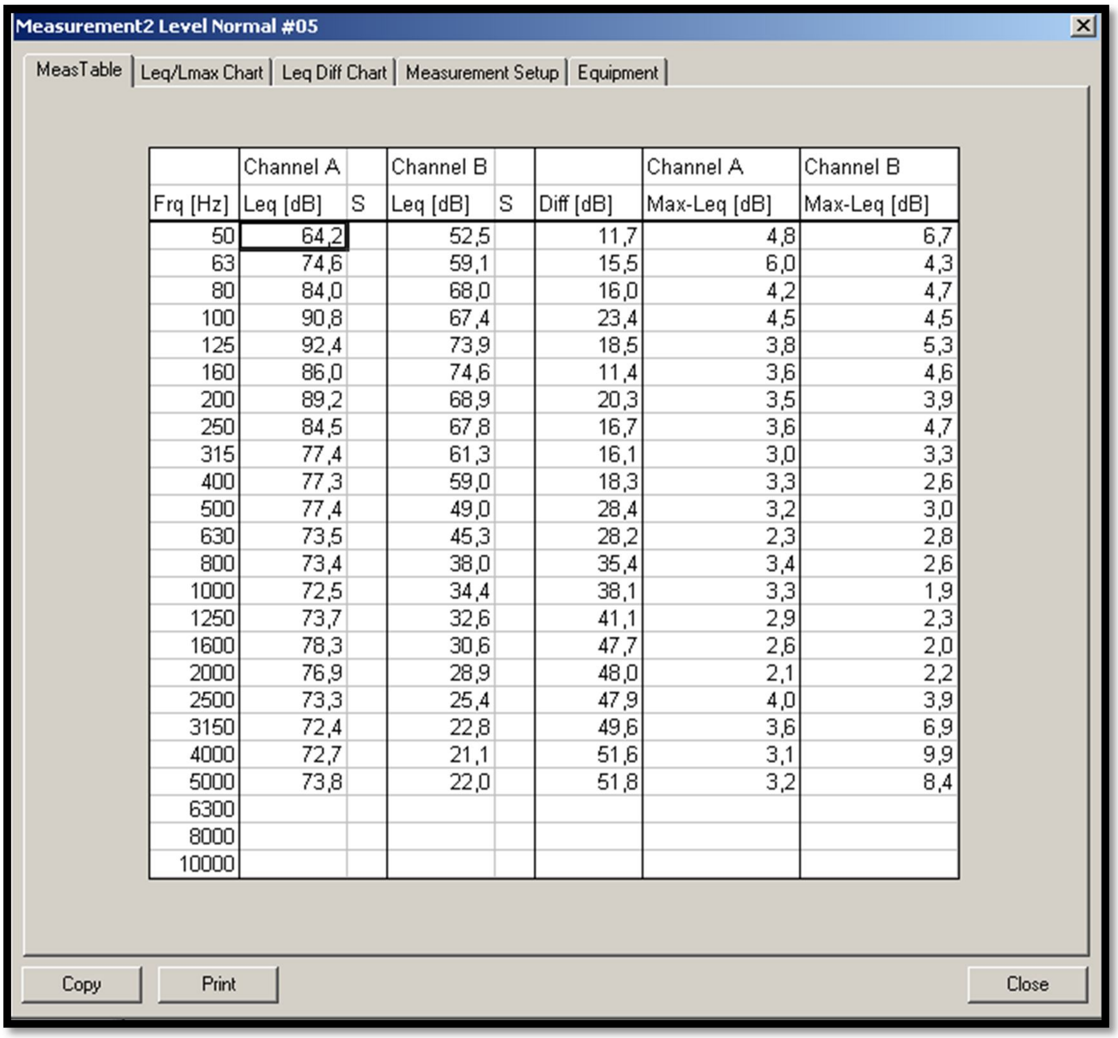


Figure 4.7. Microphone positions in the receiving room during reverberation time measurements

4.5 Results

All results were analyze using the computer program “NorBuild”. According to the standard, the standardized level difference $D_{1s,2m,nT}$ was calculated which evaluates the airborne sound insulation of the facade.

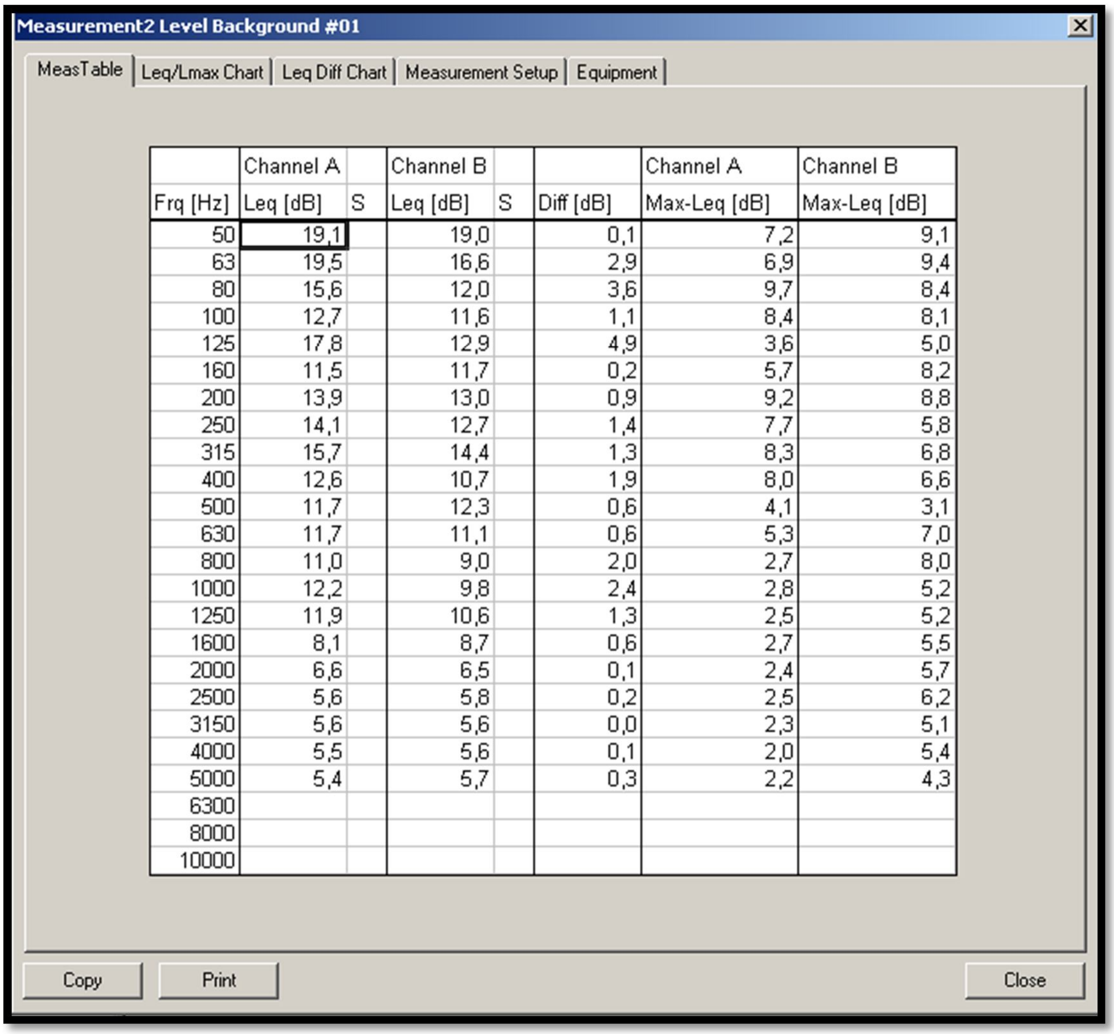
Tables with sound pressure level, background noise and reverberation time measured values are shown in figures 4.8, 4.9 and 4.10.



	Channel A		Channel B			Channel A	Channel B
Frq [Hz]	Leq [dB]	S	Leq [dB]	S	Diff [dB]	Max-Leq [dB]	Max-Leq [dB]
50	64,2		52,5		11,7	4,8	6,7
63	74,6		59,1		15,5	6,0	4,3
80	84,0		68,0		16,0	4,2	4,7
100	90,8		67,4		23,4	4,5	4,5
125	92,4		73,9		18,5	3,8	5,3
160	86,0		74,6		11,4	3,6	4,6
200	89,2		68,9		20,3	3,5	3,9
250	84,5		67,8		16,7	3,6	4,7
315	77,4		61,3		16,1	3,0	3,3
400	77,3		59,0		18,3	3,3	2,6
500	77,4		49,0		28,4	3,2	3,0
630	73,5		45,3		28,2	2,3	2,8
800	73,4		38,0		35,4	3,4	2,6
1000	72,5		34,4		38,1	3,3	1,9
1250	73,7		32,6		41,1	2,9	2,3
1600	78,3		30,6		47,7	2,6	2,0
2000	76,9		28,9		48,0	2,1	2,2
2500	73,3		25,4		47,9	4,0	3,9
3150	72,4		22,8		49,6	3,6	6,9
4000	72,7		21,1		51,6	3,1	9,9
5000	73,8		22,0		51,8	3,2	8,4
6300							
8000							
10000							

Figure 4.8. Table with sound level measurement results in position 1

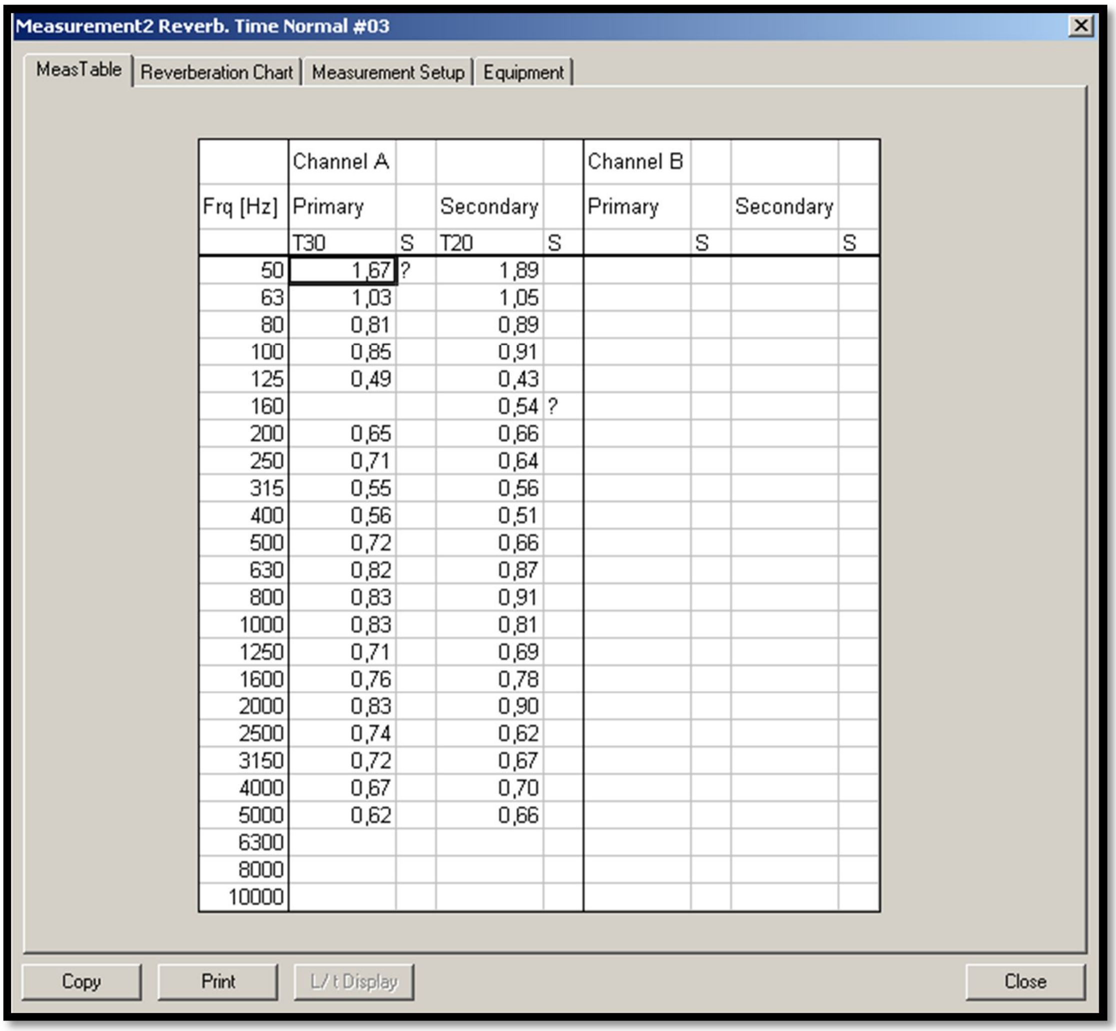
The numeric table of all activated channels (Leq) and their difference is shown. Additionally the difference of the Max value and the Leq is shown, too.



	Channel A		Channel B			Channel A	Channel B
Frq [Hz]	Leq [dB]	S	Leq [dB]	S	Diff [dB]	Max-Leq [dB]	Max-Leq [dB]
50	19,1		19,0		0,1	7,2	9,1
63	19,5		16,6		2,9	6,9	9,4
80	15,6		12,0		3,6	9,7	8,4
100	12,7		11,6		1,1	8,4	8,1
125	17,8		12,9		4,9	3,6	5,0
160	11,5		11,7		0,2	5,7	8,2
200	13,9		13,0		0,9	9,2	8,8
250	14,1		12,7		1,4	7,7	5,8
315	15,7		14,4		1,3	8,3	6,8
400	12,6		10,7		1,9	8,0	6,6
500	11,7		12,3		0,6	4,1	3,1
630	11,7		11,1		0,6	5,3	7,0
800	11,0		9,0		2,0	2,7	8,0
1000	12,2		9,8		2,4	2,8	5,2
1250	11,9		10,6		1,3	2,5	5,2
1600	8,1		8,7		0,6	2,7	5,5
2000	6,6		6,5		0,1	2,4	5,7
2500	5,6		5,8		0,2	2,5	6,2
3150	5,6		5,6		0,0	2,3	5,1
4000	5,5		5,6		0,1	2,0	5,4
5000	5,4		5,7		0,3	2,2	4,3
6300							
8000							
10000							

Figure 4.9. Table with background noise level measurement results in position 1

The numeric table of all activated channels (Leq) and their difference is shown. Additionally the difference of the Max value and the Leq is shown, too.



	Channel A				Channel B			
Frq [Hz]	Primary		Secondary		Primary		Secondary	
	T30	S	T20	S		S		S
50	1,67	?	1,89					
63	1,03		1,05					
80	0,81		0,89					
100	0,85		0,91					
125	0,49		0,43					
160			0,54	?				
200	0,65		0,66					
250	0,71		0,64					
315	0,55		0,56					
400	0,56		0,51					
500	0,72		0,66					
630	0,82		0,87					
800	0,83		0,91					
1000	0,83		0,81					
1250	0,71		0,69					
1600	0,76		0,78					
2000	0,83		0,90					
2500	0,74		0,62					
3150	0,72		0,67					
4000	0,67		0,70					
5000	0,62		0,66					
6300								
8000								
10000								

Figure 4.10. Table with reverberation time measurement results in position 1

Toggles between T30 and T20 as the main parameter (primary) for the decay curve.

The numeric table shows the T20 and T30 of all activated channels.

The test report from “NorBuild” computer program is shown in figure 4.11.

Normalized level difference according to ISO 140-5

Field measurements of airborne sound insulation of façade elements and façades

Client: Saimaa University of Applied Sciences

Date of test: 16.4.2012

Description:

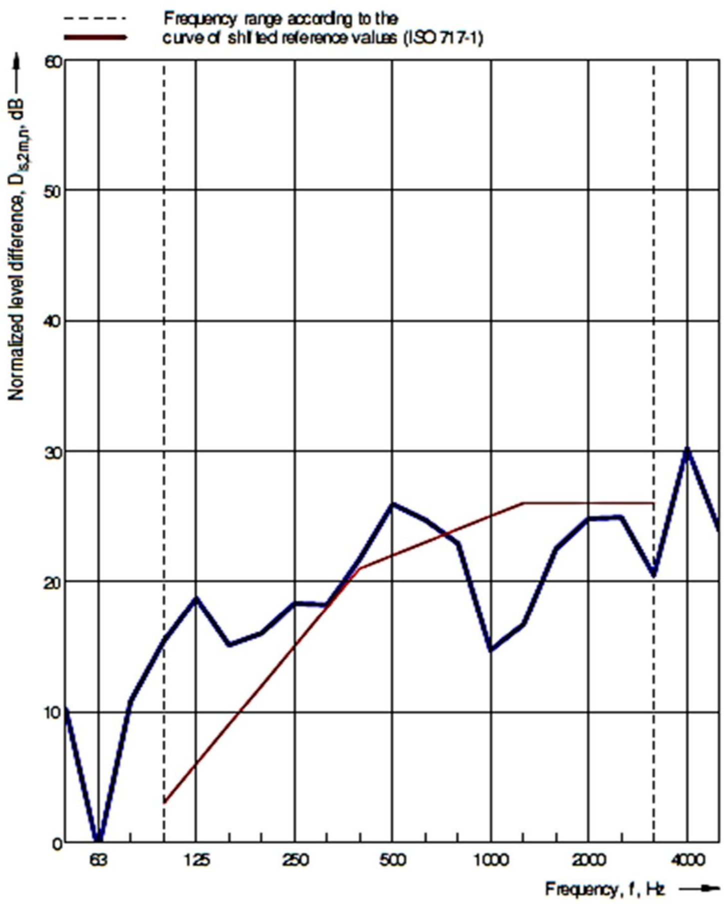
Object: Concrete laboratory

Source room volume: m³

Receiving room volume: 200,0 m³

Frequency f [Hz]	$D_{ls,2m,n}$ 1/3 octave [dB]
50	10,2 [1]
63	-0,6
80	10,8
100	15,4
125	18,7
160	15,1
200	16,0
250	18,3
315	18,2
400	21,7
500	25,9
630	24,7
800	22,9
1 000	14,7
1 250	16,7
1 600	22,5
2 000	24,8
2 500	24,9
3 150	20,5
4 000	30,2 [1]
5 000	23,9 [1]

[1] Background noise too high



Rating according to ISO 717-1

$D_{ls,2m,n,w}(C;C_{tr})$ = 22 (-2;-3) dB

Evaluation based on field measurement results obtained in one-third-octave bands by an engineering

$C_{50-3150}$ = -2 dB $C_{50-5000}$ = -2 dB $C_{100-5000}$ = -2 dB

$C_{tr,50-3150}$ = -5 dB $C_{tr,50-5000}$ = -5 dB $C_{tr,100-5000}$ = -3 dB

Company:

No. of test report:

Date: 16.04.2012 Signature:

Figure 4.11. The test report from “NorBuild” computer program

The result is $D_{1s,2m,n,w}$ (C;C_{tr}) = 22(-2;-3)

Where

C and C_{tr} are the spectrum adaptation terms. The spectrum adaptation terms C and C_{tr} correct the single-number ratings with respect to two different sound pressure level spectra, referring to an indoor (term C) and a traffic noise spectrum (term C_{tr}).
The spectrum adaption terms for enlarged frequency range $C_{100\text{-}5000}$, $C_{tr,100\text{-}5000}$, $C_{50\text{-}5000}$, $C_{tr,50\text{-}5000}$, $C_{50\text{-}3150}$, $C_{tr,50\text{-}3150.}$ (Handbook of noise and vibration control, Chapter 107, p. 1283, 1285)

4.6 Field measurements in test building (case 2)

4.6.1 Description of the house

The second field measurements have been done in a test building. This building is a garage which was built by using new wall and roof structures technology.

Figure 4.12. Testing building

Type of house: Garage

Facade: Wood

Windows: Windows with one layer insulating glass units

Room dimensions: Approx. volume is 196 m3

4.6.1.1 Outside measurements

This measurement determined the outdoor sound pressure level.

The method which was used is the same as in the first measurements. The loudspeaker is placed (figure 4.13.) outside the building on the ground with the angle of sound incidence equal to $45° \pm 5°$.

Figure 4.13. Loudspeaker position

In this case also only one loudspeaker position was used and the outdoor sound pressure level has been measured at 2 m in front of the facade plane.

The height of the microphone position is 1.5 m.

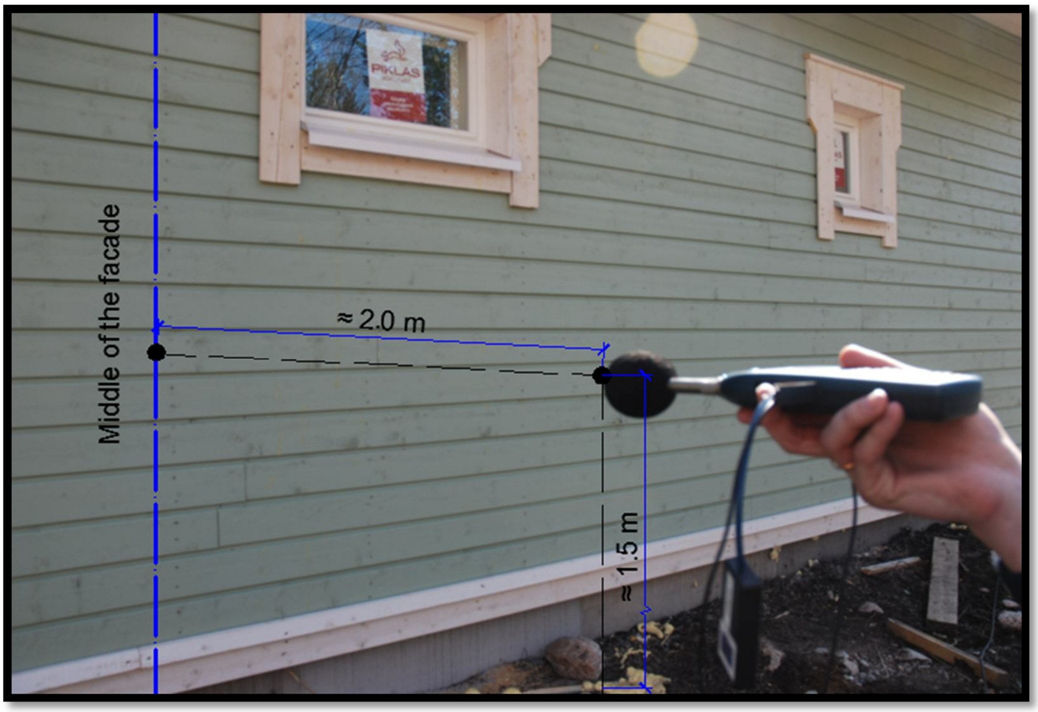


Figure 4.14. Microphone position

4.6.1.2 Inside measurements

This measurement determined:

- average sound pressure level
- background noise
- reverberation time

Because of a difficult situation inside the building other arrangement of microphones was applied. The scheme was not like in the first measurements in the concrete laboratory.

Sound pressure level was determined in five positions of the microphone. These positions are shown in the figure 4.16.

The duration of each measurement is 30 seconds.

Figure 4.15. Situation inside the test building

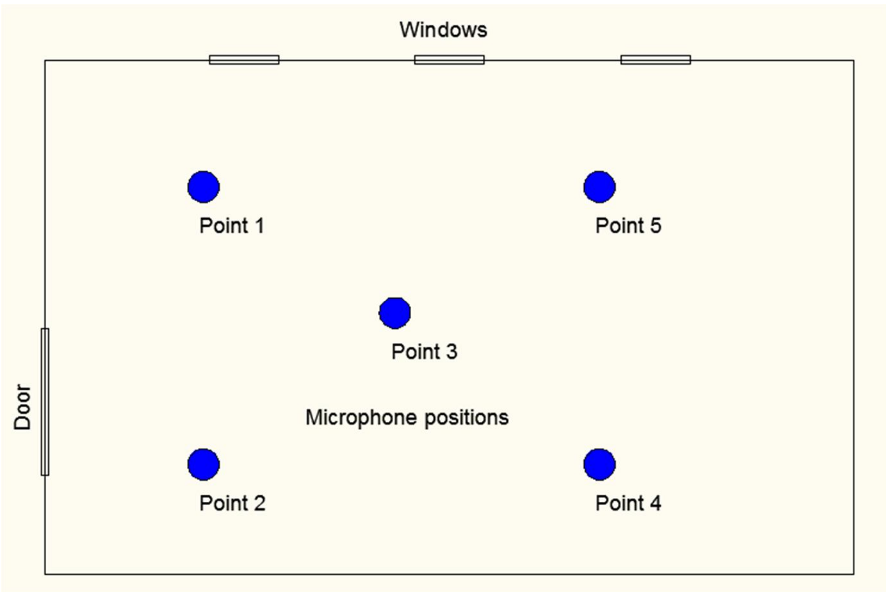


Figure 4.16. Microphone positions in the receiving room during sound pressure level measurements

Background noise was measured in two points by using two microphones at the same time. The duration of each measurement is 30 seconds.

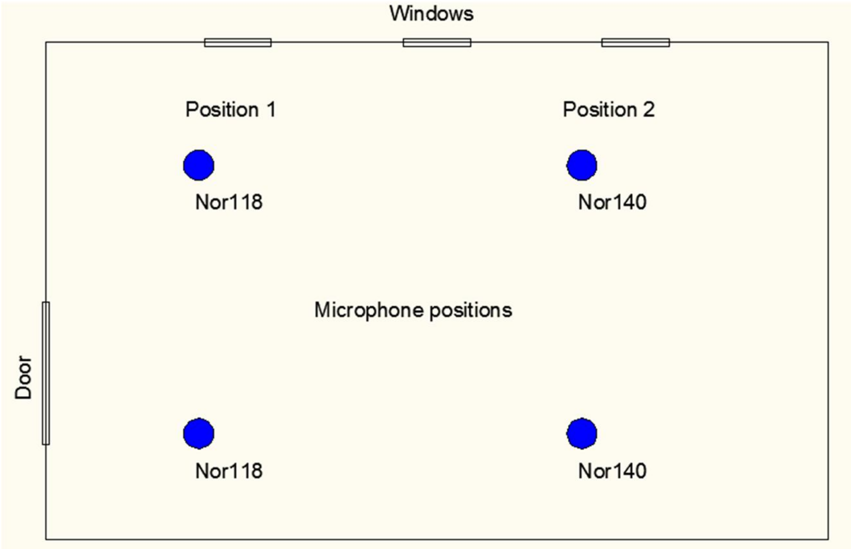


Figure 4.17. Microphone positions in the receiving room during background noise measurements

Reverberation time was measured in two positions of the microphone. The duration of each measurement is 40 seconds.

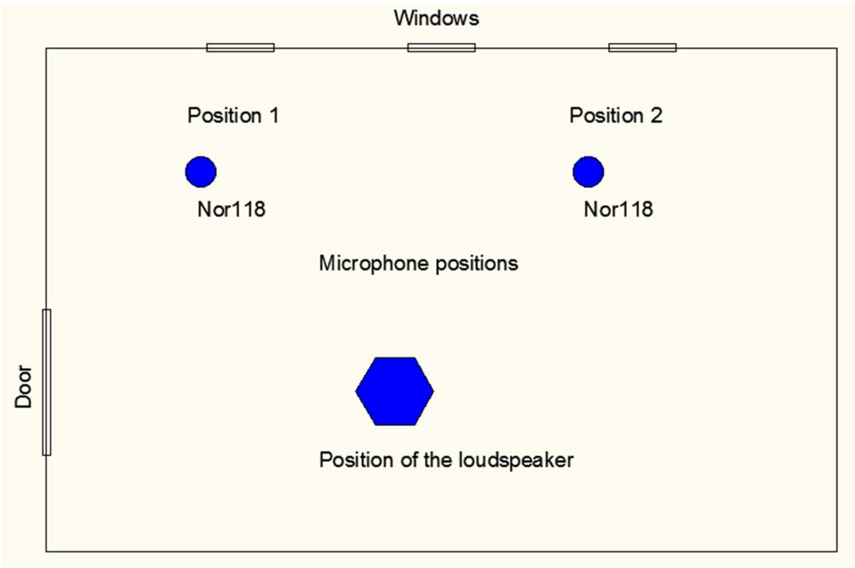


Figure 4.18. Microphone positions in the receiving room during reverberation time measurements

4.7 Results

All results were analyzed using the computer program “NorBuilt”. According to the standard, the standardized level difference $D_{ls,2m,nT}$ was calculated which evaluates the airborne sound insulation of the facade.

Tables with sound pressure level, background noise and reverberation time measured values are shown in figures 4.19, 4.20 and 4.21.

Measurement2 Level Normal #05

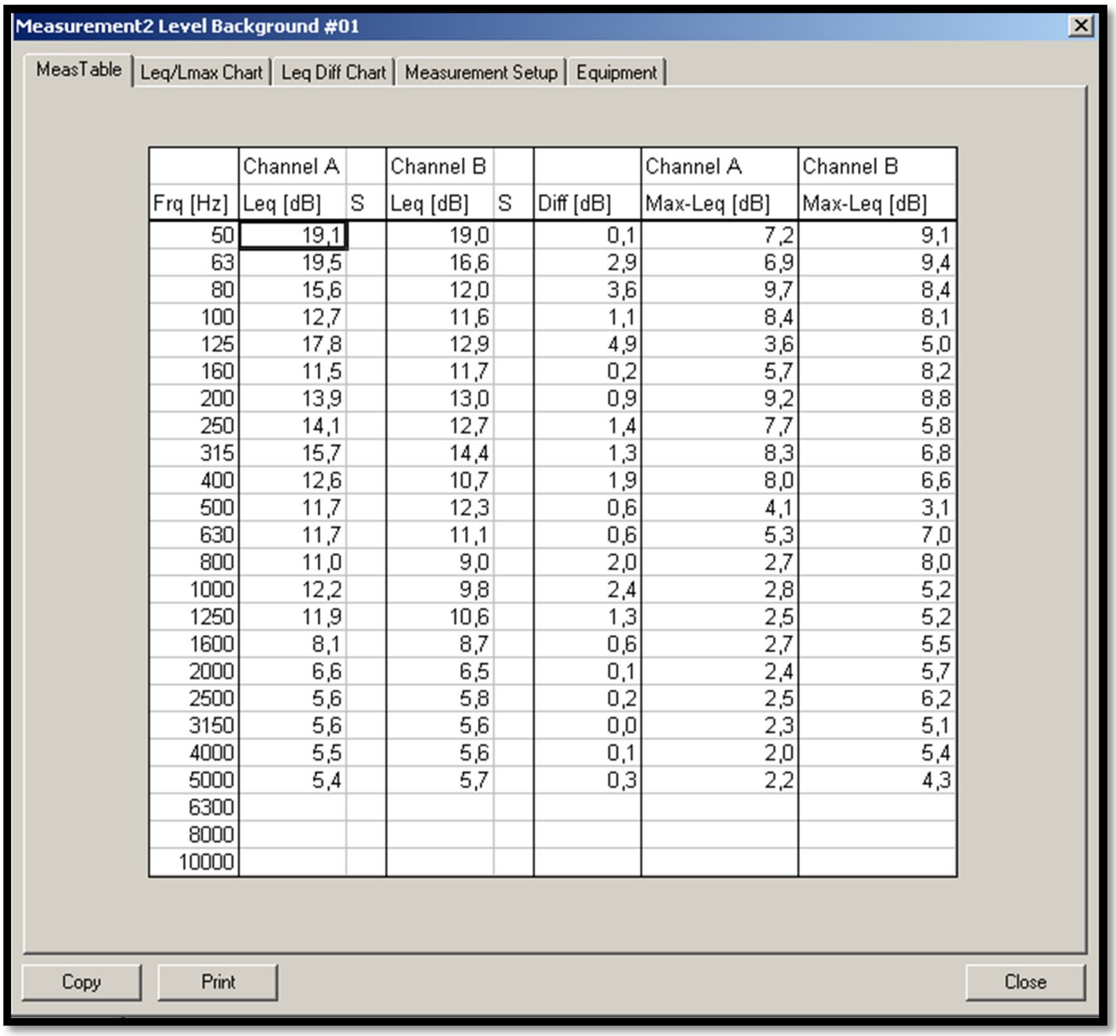
MeasTable | Leq/Lmax Chart | Leq Diff Chart | Measurement Setup | Equipment

	Channel A		Channel B			Channel A	Channel B
Frq [Hz]	Leq [dB]	S	Leq [dB]	S	Diff [dB]	Max-Leq [dB]	Max-Leq [dB]
50	64,2		52,5		11,7	4,8	6,7
63	74,6		59,1		15,5	6,0	4,3
80	84,0		68,0		16,0	4,2	4,7
100	90,8		67,4		23,4	4,5	4,5
125	92,4		73,9		18,5	3,8	5,3
160	86,0		74,6		11,4	3,6	4,6
200	89,2		68,9		20,3	3,5	3,9
250	84,5		67,8		16,7	3,6	4,7
315	77,4		61,3		16,1	3,0	3,3
400	77,3		59,0		18,3	3,3	2,6
500	77,4		49,0		28,4	3,2	3,0
630	73,5		45,3		28,2	2,3	2,8
800	73,4		38,0		35,4	3,4	2,6
1000	72,5		34,4		38,1	3,3	1,9
1250	73,7		32,6		41,1	2,9	2,3
1600	78,3		30,6		47,7	2,6	2,0
2000	76,9		28,9		48,0	2,1	2,2
2500	73,3		25,4		47,9	4,0	3,9
3150	72,4		22,8		49,6	3,6	6,9
4000	72,7		21,1		51,6	3,1	9,9
5000	73,8		22,0		51,8	3,2	8,4
6300							
8000							
10000							

Copy Print Close

Figure 4.19. Table with sound level measurement results in position 1

The numeric table of all activated channels (Leq) and their difference is shown. Additionally the difference of the Max value and the Leq is shown, too.



	Channel A		Channel B			Channel A	Channel B
Frq [Hz]	Leq [dB]	S	Leq [dB]	S	Diff [dB]	Max-Leq [dB]	Max-Leq [dB]
50	19,1		19,0		0,1	7,2	9,1
63	19,5		16,6		2,9	6,9	9,4
80	15,6		12,0		3,6	9,7	8,4
100	12,7		11,6		1,1	8,4	8,1
125	17,8		12,9		4,9	3,6	5,0
160	11,5		11,7		0,2	5,7	8,2
200	13,9		13,0		0,9	9,2	8,8
250	14,1		12,7		1,4	7,7	5,8
315	15,7		14,4		1,3	8,3	6,8
400	12,6		10,7		1,9	8,0	6,6
500	11,7		12,3		0,6	4,1	3,1
630	11,7		11,1		0,6	5,3	7,0
800	11,0		9,0		2,0	2,7	8,0
1000	12,2		9,8		2,4	2,8	5,2
1250	11,9		10,6		1,3	2,5	5,2
1600	8,1		8,7		0,6	2,7	5,5
2000	6,6		6,5		0,1	2,4	5,7
2500	5,6		5,8		0,2	2,5	6,2
3150	5,6		5,6		0,0	2,3	5,1
4000	5,5		5,6		0,1	2,0	5,4
5000	5,4		5,7		0,3	2,2	4,3
6300							
8000							
10000							

Figure 4.20. Table with background noise level measurement results in position 1

The numeric table of all activated channels (Leq) and their difference is shown. Additionally the difference of the Max value and the Leq is shown, too.

Measurement2 Reverb. Time Normal #03

MeasTable | Reverberation Chart | Measurement Setup | Equipment

	Channel A				Channel B			
Frq [Hz]	Primary		Secondary		Primary		Secondary	
	T30	S	T20	S		S		S
50	1,67	?	1,89					
63	1,03		1,05					
80	0,81		0,89					
100	0,85		0,91					
125	0,49		0,43					
160			0,54	?				
200	0,65		0,66					
250	0,71		0,64					
315	0,55		0,56					
400	0,56		0,51					
500	0,72		0,66					
630	0,82		0,87					
800	0,83		0,91					
1000	0,83		0,81					
1250	0,71		0,69					
1600	0,76		0,78					
2000	0,83		0,90					
2500	0,74		0,62					
3150	0,72		0,67					
4000	0,67		0,70					
5000	0,62		0,66					
6300								
8000								
10000								

Copy | Print | L/t Display | Close

Figure 4.21. Table with reverberation time measurement results in position 1

Toggles between T30 and T20 as the main parameter (primary) for the decay curve.

The numeric table shows the T20 and T30 of all activated channels.

The test report from “NorBuild” computer program is shown in figure 4.22.

Standardized level difference according to ISO 140-5

Field measurements of airborne sound insulation of façade elements and façades

Client: Date of test:

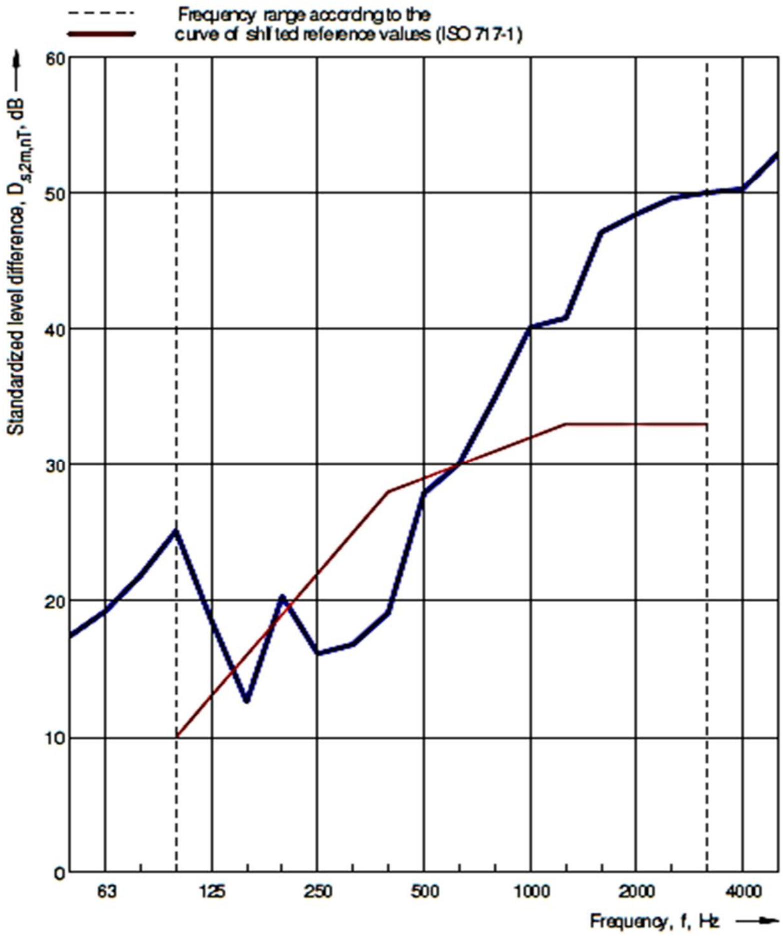
Description:

Object:

Source room volume: m³

Receiving room volume: 196,0 m³

Frequency f [Hz]	$D_{ls,2m,nT}$ 1/3 octave [dB]
50	17,4
63	19,2
80	21,8
100	25,1
125	18,6
160	12,6
200	20,3
250	16,1
315	16,8
400	19,1
500	27,9
630	30,1
800	34,9
1 000	40,1
1 250	40,8
1 600	47,1
2 000	48,4
2 500	49,6
3 150	50,0
4 000	50,3
5 000	52,9



Rating according to ISO 717-1

$D_{ls,2m,nT,w}(C;C_{tr})$ = 29 (-1;-5) dB

Evaluation based on field measurement results obtained in one-third-octave bands by an engineering

$C_{50\text{-}3150}$ = -1 dB $C_{50\text{-}5000}$ = 0 dB $C_{100\text{-}5000}$ = 0 dB

$C_{tr,50\text{-}3150}$ = -5 dB $C_{tr,50\text{-}5000}$ = -5 dB $C_{tr,100\text{-}5000}$ = -5 dB

Company:

No. of test report:

Date: 09.05.2012 Signature:

Figure 4.22. Test report from "NorBuild" computer program

The result is $D_{1s,2m,n,w}$ $(C;C_{tr})$ = 29(-1;-5)

Where

C and C_{tr} are the spectrum adaptation terms. The spectrum adaptation terms C and C_{tr} correct the single-number ratings with respect to two different sound pressure level spectra, referring to an indoor (term C) and a traffic noise spectrum (term C_{tr}).

The spectrum adaption terms for enlarged frequency range $C_{100\text{-}5000}$, $C_{tr,100\text{-}5000}$, $C_{50\text{-}5000}$, $C_{tr,50\text{-}5000}$, $C_{50\text{-}3150}$, $C_{tr,50\text{-}3150}$ (Handbook of noise and vibration control, Chapter 107, p. 1283, 1285).

5 CONCLUSIONS

This thesis work was focused on measurements of airborne sound insulation of the facade. Many different ways for this purpose was shown in Table 1 and described in the beginning. In cases with the concrete laboratory facade and the test building facade it was impossible to apply the global road traffic method because the real noise source could not be used.

A measurement method for sound insulation of building facades in the frequency range from 50 Hz to 5000 Hz with respect to noise from loudspeaker which simulated road traffic noise has been specified.

The method is based on the ISO 140-5 method for the normal building acoustics frequency range. The specified measurement method was used for measurements of the outdoor/indoor level difference for the building facades in different types of houses, representing possible buildings situated in areas near roads.

Tables with measured values in Saimaa University case and the second test case are attached. On the basis of these measurement results test reports were made. In these reports the results are presented graphically and as standardized level difference $D_{1s,2m,n,w}$. This value for the concrete laboratory facade is 22 dB and for the test building facade is 29 dB.

Unfortunately, descriptors applied limits related to traffic noise are not always defined in ISO 717. The needed facade sound insulation depends on the outdoor noise level and maximum indoor level. The outdoor noise levels are calculated based on the traffic data and conditions. Often, the traffic noise levels are available from authorities. The levels vary with positions. The housing blocks behind facing the busy road are less exposed to traffic noise, and thus requirements could be less strict.

FIGURES

TABLES

REFERENCES

“Handbook of noise and vibration control”, Chapter 107, p. 1283, 1285

“Improving the Quality of Suburban Building Stock”, p.4
http://vbn.aau.dk/files/43741580/SoundClassesEuropeRenovatedHousing_TU0701_UniversityMalta_May2010BiR.pdf
(Accessed on 30 May 2012)

Instruction manual Nor118

Instruction manual Nor-1251

ISO 140-5 : 1998 “Field measurements of airborne sound insulation of façade elements and facades”

“Measuring sound”, Bruel & Kjer brochure, p.10
www2.tech.purdue.edu
(Accessed on 5 April 2012)

“Noise Excitation Equipment for building Acoustics Measurements”
www.norsonic.com/uploads/kundefiler/Downloads/pdnoiseexcited5rev2eng0510_web.pdf (Accessed on 19 March 2012)

“Noise insulation applying Active elements onto facades”, Forum Acusticum 2005, p.869
webistem.com
(Accessed on 5 April 2012)

TABLE WITH SOUND LEVEL MEASUREMENT RESULTS IN POSITION 1 (CONCRETE LABORATORY)

Measurement2 Level Normal #05

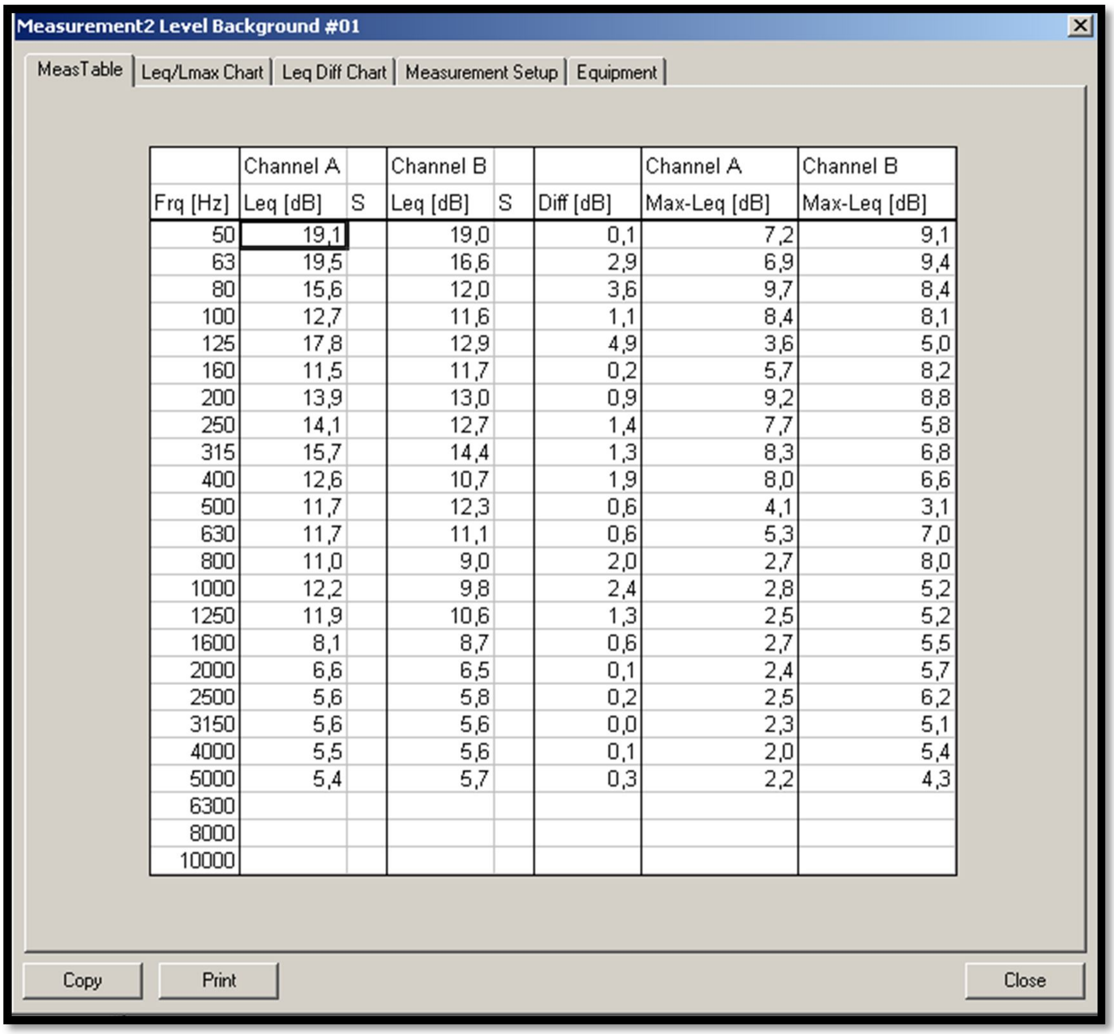
MeasTable | Leq/Lmax Chart | Leq Diff Chart | Measurement Setup | Equipment

Frq [Hz]	Channel A Leq [dB]	S	Channel B Leq [dB]	S	Diff [dB]	Channel A Max-Leq [dB]	Channel B Max-Leq [dB]
50	64,2		52,5		11,7	4,8	6,7
63	74,6		59,1		15,5	6,0	4,3
80	84,0		68,0		16,0	4,2	4,7
100	90,8		67,4		23,4	4,5	4,5
125	92,4		73,9		18,5	3,8	5,3
160	86,0		74,6		11,4	3,6	4,6
200	89,2		68,9		20,3	3,5	3,9
250	84,5		67,8		16,7	3,6	4,7
315	77,4		61,3		16,1	3,0	3,3
400	77,3		59,0		18,3	3,3	2,6
500	77,4		49,0		28,4	3,2	3,0
630	73,5		45,3		28,2	2,3	2,8
800	73,4		38,0		35,4	3,4	2,6
1000	72,5		34,4		38,1	3,3	1,9
1250	73,7		32,6		41,1	2,9	2,3
1600	78,3		30,6		47,7	2,6	2,0
2000	76,9		28,9		48,0	2,1	2,2
2500	73,3		25,4		47,9	4,0	3,9
3150	72,4		22,8		49,6	3,6	6,9
4000	72,7		21,1		51,6	3,1	9,9
5000	73,8		22,0		51,8	3,2	8,4
6300							
8000							
10000							

Copy | Print | Close

The numeric table of all activated channels (Leq) and their difference is shown. Additionally the difference of the Max value and the Leq is shown, too.

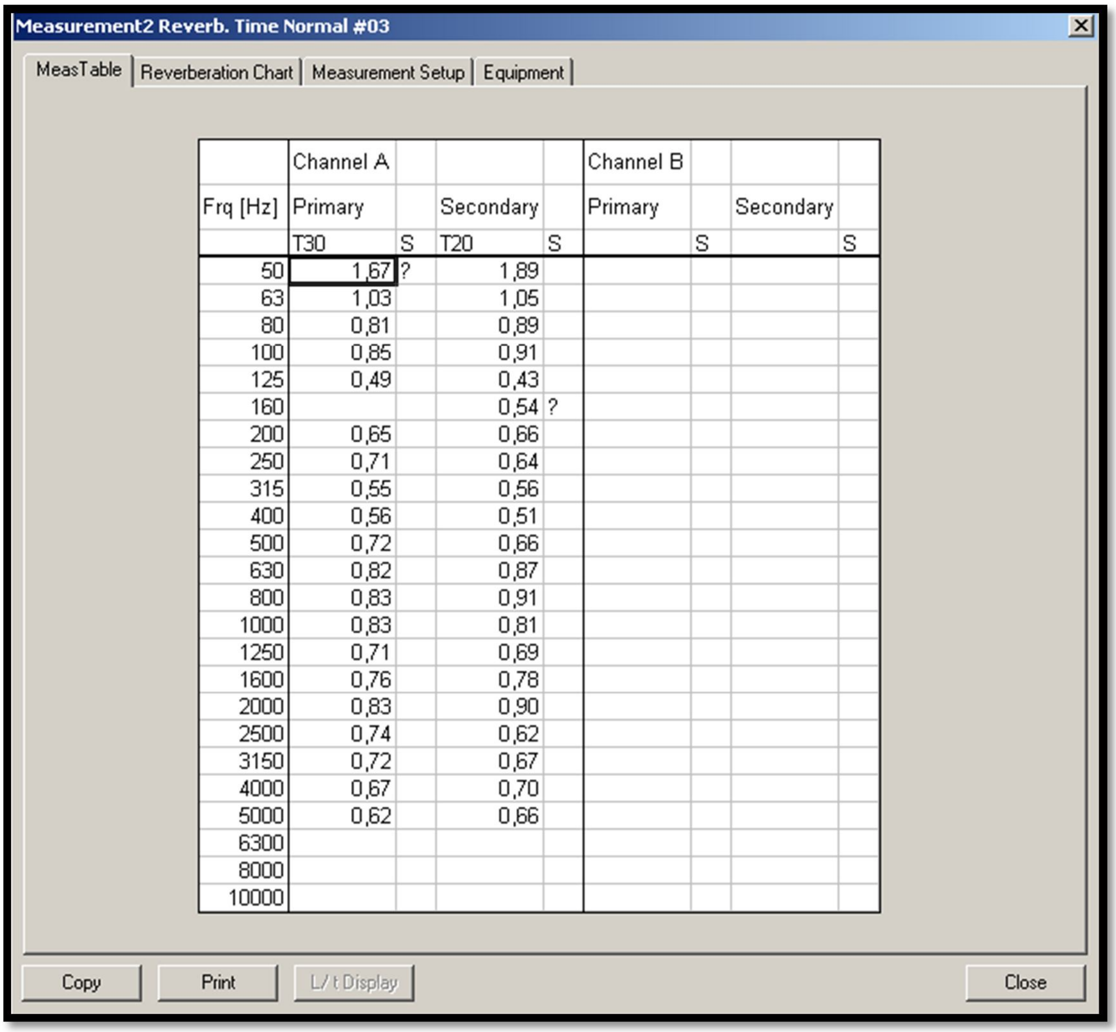
TABLE WITH BACKGROUND NOISE LEVEL MEASUREMENT RESULTS IN POSITION 1 (CONCRETE LABORATORY)



	Channel A		Channel B			Channel A	Channel B
Frq [Hz]	Leq [dB]	S	Leq [dB]	S	Diff [dB]	Max-Leq [dB]	Max-Leq [dB]
50	19,1		19,0		0,1	7,2	9,1
63	19,5		16,6		2,9	6,9	9,4
80	15,6		12,0		3,6	9,7	8,4
100	12,7		11,6		1,1	8,4	8,1
125	17,8		12,9		4,9	3,6	5,0
160	11,5		11,7		0,2	5,7	8,2
200	13,9		13,0		0,9	9,2	8,8
250	14,1		12,7		1,4	7,7	5,8
315	15,7		14,4		1,3	8,3	6,8
400	12,6		10,7		1,9	8,0	6,6
500	11,7		12,3		0,6	4,1	3,1
630	11,7		11,1		0,6	5,3	7,0
800	11,0		9,0		2,0	2,7	8,0
1000	12,2		9,8		2,4	2,8	5,2
1250	11,9		10,6		1,3	2,5	5,2
1600	8,1		8,7		0,6	2,7	5,5
2000	6,6		6,5		0,1	2,4	5,7
2500	5,6		5,8		0,2	2,5	6,2
3150	5,6		5,6		0,0	2,3	5,1
4000	5,5		5,6		0,1	2,0	5,4
5000	5,4		5,7		0,3	2,2	4,3
6300							
8000							
10000							

The numeric table of all activated channels (Leq) and their difference is shown. Additionally the difference of the Max value and the Leq is shown, too.

TABLE WITH REVERBERATION TIME MEASUREMENT RESULTS IN POSITION 1 (CONCRETE LABORATORY)



Frq [Hz]	Channel A Primary T30	S	Secondary T20	S	Channel B Primary	S	Secondary	S
50	1,67	?	1,89					
63	1,03		1,05					
80	0,81		0,89					
100	0,85		0,91					
125	0,49		0,43					
160			0,54	?				
200	0,65		0,66					
250	0,71		0,64					
315	0,55		0,56					
400	0,56		0,51					
500	0,72		0,66					
630	0,82		0,87					
800	0,83		0,91					
1000	0,83		0,81					
1250	0,71		0,69					
1600	0,76		0,78					
2000	0,83		0,90					
2500	0,74		0,62					
3150	0,72		0,67					
4000	0,67		0,70					
5000	0,62		0,66					
6300								
8000								
10000								

Toggles between T30 and T20 as the main parameter (primary) for the decay curve.

The numeric table shows the T20 and T30 of all activated channels. Problematic reverberation values are marked with a '?'.

TEST REPORT FROM "NORBUILD" COMPUTER PROGRAM (CONCRETE LABORATORY)

Normalized level difference according to ISO 140-5

Field measurements of airborne sound insulation of façade elements and façades

Client: Saimaa University of Applied Sciences

Date of test: 16.4.2012

Description:

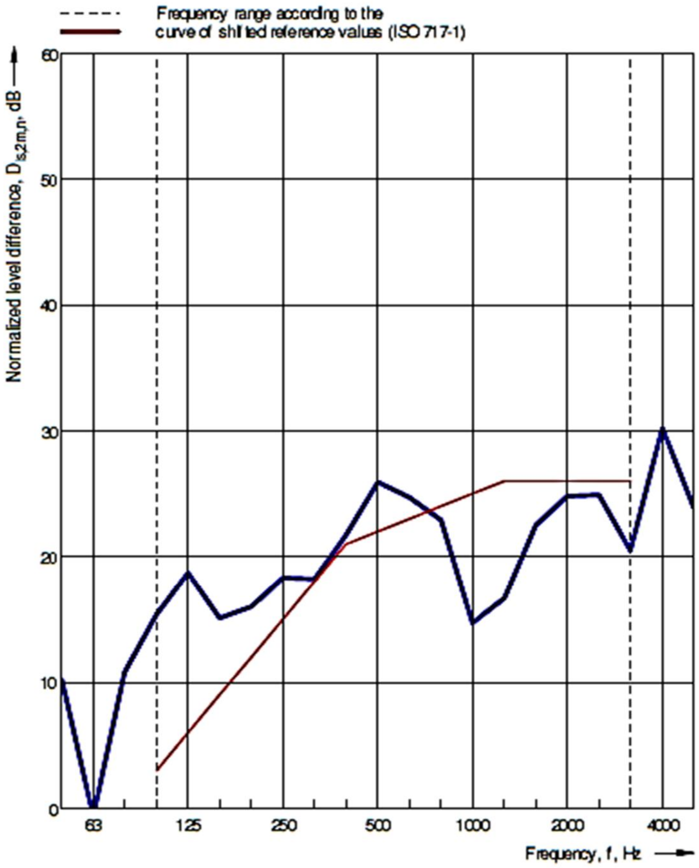
Object: Concrete laboratory

Source room volume: m³

Receiving room volume: 200,0 m³

Frequency f [Hz]	$D_{ls,2m,n}$ 1/3 octave [dB]
50	10,2 [1]
63	-0,6
80	10,8
100	15,4
125	18,7
160	15,1
200	16,0
250	18,3
315	18,2
400	21,7
500	25,9
630	24,7
800	22,9
1 000	14,7
1 250	16,7
1 600	22,5
2 000	24,8
2 500	24,9
3 150	20,5
4 000	30,2 [1]
5 000	23,9 [1]

[1] Background noise too high



Rating according to ISO 717-1

$D_{ls,2m\,n,w}(C;C_{tr})$ = 22 (-2;-3) dB

Evaluation based on field measurement results obtained in one-third-octave bands by an engineering

$C_{50-3150}$ = -2 dB | $C_{50-5000}$ = -2 dB | $C_{100-5000}$ = -2 dB

$C_{tr,50-3150}$ = -5 dB | $C_{tr,50-5000}$ = -5 dB | $C_{tr,100-5000}$ = -3 dB

Company:

No. of test report:

Date: 16.04.2012

Signature:

TABLE WITH SOUND LEVEL MEASUREMENT RESULTS IN POSITION 1 (TEST BUILDING, CASE 2)

Measurement2 Level Normal #05

MeasTable | Leq/Lmax Chart | Leq Diff Chart | Measurement Setup | Equipment

	Channel A		Channel B			Channel A	Channel B
Frq [Hz]	Leq [dB]	S	Leq [dB]	S	Diff [dB]	Max-Leq [dB]	Max-Leq [dB]
50	64,2		52,5		11,7	4,8	6,7
63	74,6		59,1		15,5	6,0	4,3
80	84,0		68,0		16,0	4,2	4,7
100	90,8		67,4		23,4	4,5	4,5
125	92,4		73,9		18,5	3,8	5,3
160	86,0		74,6		11,4	3,6	4,6
200	89,2		68,9		20,3	3,5	3,9
250	84,5		67,8		16,7	3,6	4,7
315	77,4		61,3		16,1	3,0	3,3
400	77,3		59,0		18,3	3,3	2,6
500	77,4		49,0		28,4	3,2	3,0
630	73,5		45,3		28,2	2,3	2,8
800	73,4		38,0		35,4	3,4	2,6
1000	72,5		34,4		38,1	3,3	1,9
1250	73,7		32,6		41,1	2,9	2,3
1600	78,3		30,6		47,7	2,6	2,0
2000	76,9		28,9		48,0	2,1	2,2
2500	73,3		25,4		47,9	4,0	3,9
3150	72,4		22,8		49,6	3,6	6,9
4000	72,7		21,1		51,6	3,1	9,9
5000	73,8		22,0		51,8	3,2	8,4
6300							
8000							
10000							

Copy | Print | Close

The numeric table of all activated channels (Leq) and their difference is shown. Additionally the difference of the Max value and the Leq is shown, too.

TABLE WITH BACKGROUND NOISE LEVEL MEASUREMENT RESULTS IN POSITION 1 (TEST BUILDING, CASE 2)

Measurement2 Level Background #01

MeasTable | Leq/Lmax Chart | Leq Diff Chart | Measurement Setup | Equipment

	Channel A		Channel B			Channel A	Channel B
Frq [Hz]	Leq [dB]	S	Leq [dB]	S	Diff [dB]	Max-Leq [dB]	Max-Leq [dB]
50	19,1		19,0		0,1	7,2	9,1
63	19,5		16,6		2,9	6,9	9,4
80	15,6		12,0		3,6	9,7	8,4
100	12,7		11,6		1,1	8,4	8,1
125	17,8		12,9		4,9	3,6	5,0
160	11,5		11,7		0,2	5,7	8,2
200	13,9		13,0		0,9	9,2	8,8
250	14,1		12,7		1,4	7,7	5,8
315	15,7		14,4		1,3	8,3	6,8
400	12,6		10,7		1,9	8,0	6,6
500	11,7		12,3		0,6	4,1	3,1
630	11,7		11,1		0,6	5,3	7,0
800	11,0		9,0		2,0	2,7	8,0
1000	12,2		9,8		2,4	2,8	5,2
1250	11,9		10,6		1,3	2,5	5,2
1600	8,1		8,7		0,6	2,7	5,5
2000	6,6		6,5		0,1	2,4	5,7
2500	5,6		5,8		0,2	2,5	6,2
3150	5,6		5,6		0,0	2,3	5,1
4000	5,5		5,6		0,1	2,0	5,4
5000	5,4		5,7		0,3	2,2	4,3
6300							
8000							
10000							

Copy | Print | Close

The numeric table of all activated channels (Leq) and their difference is shown. Additionally the difference of the Max value and the Leq is shown, too.

TABLE WITH REVERBERATION TIME MEASUREMENT RESULTS IN POSITION 1 (TEST BUILDING, CASE 2)

Measurement2 Reverb. Time Normal #03

MeasTable | Reverberation Chart | Measurement Setup | Equipment

	Channel A				Channel B			
Frq [Hz]	Primary		Secondary		Primary		Secondary	
	T30	S	T20	S		S		S
50	1,67	?	1,89					
63	1,03		1,05					
80	0,81		0,89					
100	0,85		0,91					
125	0,49		0,43					
160			0,54	?				
200	0,65		0,66					
250	0,71		0,64					
315	0,55		0,56					
400	0,56		0,51					
500	0,72		0,66					
630	0,82		0,87					
800	0,83		0,91					
1000	0,83		0,81					
1250	0,71		0,69					
1600	0,76		0,78					
2000	0,83		0,90					
2500	0,74		0,62					
3150	0,72		0,67					
4000	0,67		0,70					
5000	0,62		0,66					
6300								
8000								
10000								

Copy | Print | L/t Display | Close

Toggles between T30 and T20 as the main parameter (primary) for the decay curve.

The numeric table shows the T20 and T30 of all activated channels.

TEST REPORT FROM “NORBUILD” COMPUTER PROGRAM

Standardized level difference according to ISO 140-5

Field measurements of airborne sound insulation of façade elements and façades

Client:

Date of test:

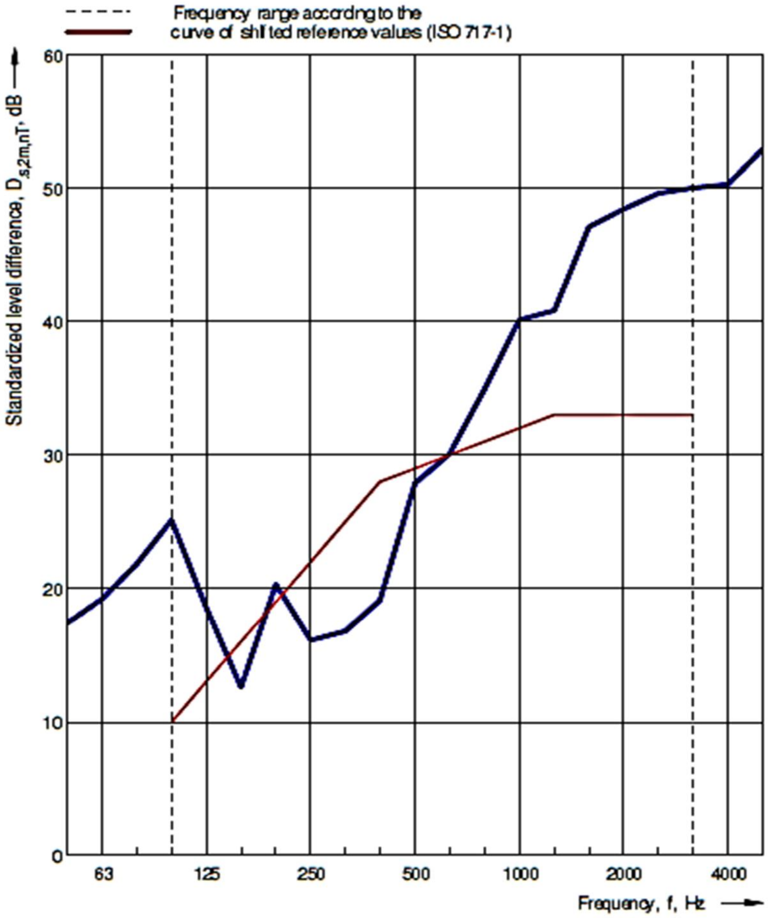
Description:

Object:

Source room volume: m³

Receiving room volume: 196,0 m³

Frequency f [Hz]	$D_{ls,2m,nT}$ 1/3 octave [dB]
50	17,4
63	19,2
80	21,8
100	25,1
125	18,6
160	12,6
200	20,3
250	16,1
315	16,8
400	19,1
500	27,9
630	30,1
800	34,9
1 000	40,1
1 250	40,8
1 600	47,1
2 000	48,4
2 500	49,6
3 150	50,0
4 000	50,3
5 000	52,9



Rating according to ISO 717-1

$D_{ls,2m,nT,w}(C;C_{tr})$ = 29 (-1;-5) dB

$C_{50-3150}$ = -1 dB | $C_{50-5000}$ = 0 dB | $C_{100-5000}$ = 0 dB

$C_{tr,50-3150}$ = -5 dB | $C_{tr,50-5000}$ = -5 dB | $C_{tr,100-5000}$ = -5 dB

Evaluation based on field measurement results obtained
in one-third-octave bands by an engineering

Company:

No. of test report:

Date: 09.05.2012

Signature: